Guidance on Integrated Urban Hydrometeorological, Climate and Environment Services

Volume II: Demonstration Cities

2021 edition

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
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EDITORIAL NOTE

METEOTERM, the WMO terminology database, may be consulted at https://public.wmo.int/en/meteoterm.

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Chair, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 81 17
Email: publications@wmo.int

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Lead authors: Gerald Mills, Luisa Tan Molina, Heinke Schluenzen, James Voogt, Valéry Masson, Brian Golding, Chao Ren, Chandana Mitra, Shiguang Miao, Felix Vogel, Jens Hesselbjerg Christensen, Alexander Baklanov, Oksana Tarasova and Paul Joe.

Editors: Sue Grimmond and Ranjeet Sokhi.

Contributors: Jorge Amorim, Miriam Andrioli, Elena Akentyeva, Gufran Beig, Estelle de Coning, Bert Jan Davidse, Petra Fuchs, Lars Gidhagen, Pablo Hernandez, Anahit Hovsepyan, Liisa Jalkanen, Christer Johansson, David Johnston, Ari Karppinen, Dimitri Kiktev, Jhoon Kim, Peter Kreft, John Lebadie, Tsz-Cheung Lee, Sylvie Leroyer, Dev Niyogi, Chris Noble, Moon-Soo Park, Rayk Rinke, Matthias Roth, Magnus Sannebro, Ezekiel Sebago, Rachid Sebarri, Joy Shumake-Gillemot, A. [Sena] Sopaheluwakan, Megha Srestha, Jianguo Tan, Marie-Claire ten Veldhuis, Patrick Willems, Chui Wah Yap and Ester Yung.

EXECUTIVE SUMMARY

The *Guidance for Integrated Urban Hydrometeorological, Climate and Environment Services, Volume I: Concept and Methodology* outlined the need for Integrated Urban Hydrometeorological, Climate and Environmental Services (hereafter referred to as Integrated Urban Services) to support management and planning in cities. This *Guidance for Integrated Urban Hydrometeorological, Climate and Environment Services, Volume II: Demonstration Cities* presents an overview of the demand for Integrated Urban Services in WMO Members and provides examples of current Integrated Urban Services designed to meet a range of urban environmental challenges in a variety of administrative settings.

For this volume, a survey was conducted among WMO Members in 2018 to judge the level of service provision in each area, the extent to which users and providers collaborate and the status of urban services currently provided. The common hazards that require Integrated Urban Services are identified as heavy rainfall, flooding, windstorms, tropical storms, heatwaves, thunderstorms and air pollution. Meteorological services to support the needs of integrated services were reported to be more mature than the services related to hydrology and air quality. Although the responses largely reflect the perspective of National Meteorological and Hydrological Services (NMHSs), they indicate a certain level of availability of the specific urban services and reflect a demand for more integrated approach to provision of the urban services.

This Guidance also uses information gathered from 27 demonstration cities to provide examples of types of Integrated Urban Services and their placement within distinct administrative frameworks. The details from these demonstration cities are abstracted to map the level of integration across the services providers (cross-service integration) and between service providers and service users (cross-sectoral integration). The demonstration city summaries support the Member survey results in terms of the relative development of weather versus hydrological and air quality services. Examples of current Integrated Urban Services are dominated by applications for weather hazards linked with disaster management and health. According to the degree of integration, demonstration cities fall into two main categories: one provides basic data, and the other delivers city-specific tailored services to a range of users for managing and mitigating risk from hazards.

This Guidance contains a set of recommendations and lessons learned for WMO Members in general and for urban stakeholders in particular.

Evidence from the demonstration cities indicates that:

- Good practices in Integrated Urban Services can be found within a variety of risk governance structures, but their best reflections are often found in tightly integrated organizations embedded within city-state governments.
- With a few exceptions, urban requirements for weather and climate services are met by city authorities using national services provided by NMHSs. However, examples show the benefits of tailoring this information to specific urban requirements.
- Cities have specific needs that are different from rural and national requirements. Examples show that better results can be achieved where communities, city authorities and service providers work together in partnership to define the needs and implement the services.
- Most Integrated Urban Services are developed to meet a particular need; however, once created, they could be expanded to meet other requirements benefiting from information and data sharing and coordinated responses.
- Most countries have a variety of governmental and private sector organizations involved in delivering urban services, with hydrological services and air quality services typically provided by a combination of organizations other than weather services. Service delivery is often separate from monitoring and prediction activities. The examples from demonstration cities indicate benefits of cooperation between monitoring/forecasting organizations and those that deliver services. Open sharing of core (for example, weather) and ancillary (for example, land-cover) data is essential for delivery of Integrated Urban Services.

- Few weather services routinely engage social, economic and behavioural scientists in the design or delivery of their services. This type of engagement of multidisciplinary teams is more common in the provision of climate services with clear benefits.
- A growing number of countries and cities are providing online service portals, bringing together urban and/or national services across multiple hazard areas from a variety of sources (typically governmental) to simplify delivery and provide easy access. This trend has several benefits such as providing information and advice rapidly, and providing links to supporting agencies.

In addition to general recommendations, the following additional points should be taken into consideration by urban stakeholders when considering implementation of Integrated Urban Services:

- Recognizing the complexity of Integrated Urban Services, cities are recommended to initially consider development and implementation of less-complex elements of Integrated Urban Services. This Guidance presents examples of Integrated Urban Services of different levels of complexity and completeness, and at different levels of co-production among partners.
- Experience shows that implementation of Integrated Urban Services is facilitated if cities' institutions are engaged in the collection of in situ observations, the establishment of an Integrated Urban Services system or in the experimental quantification of the potential benefits of an Integrated Urban Service within their domain of responsibility. This allows improvement of local knowledge (on the hazard/impacts) and use of appropriate Integrated Urban Services by urban stakeholders and end users.
- Local governments should give full recognition to the "early warning" role of Integrated Urban Services and organize related government departments to establish disaster prevention and mitigation plans.

1. INTRODUCTION

1.1 Issues encountered in cities

More than half of the world's population now live in urban areas. Nearly 68% of the human race are predicted to be urban dwellers by 2050 (https://population.un.org/wup/). The rapid urbanization in the past half century has brought new migrants into urban areas and has also converted natural landscapes into urban settings. Urban dwellers are the primary users of energy and resources, and they contribute in a significant way to increasing atmospheric greenhouse gas (GHG) emissions and air pollution. Such human activities have consequent impacts on human health and the environment. The frequency, intensity and length of extreme weather events (such as flooding, storms, heatwaves and tropical cyclones) have increased, and are likely to increase further in the twenty-first century, due to climate change (IPCC, 2013). Most (90%) disasters affecting urban areas are of a hydrometeorological nature (United Nations Human Settlement Programme, 2016). Cities consume over two thirds of the world's energy and account for more than 70% of global CO_2 emissions (https://www.c40.org/why_cities#:~:text=Cities%20consume%20over%20two%2Dthirds,levels%20and%20powerful%20coastal%20storms). Thus, cities have an impact on climate change, and vice versa. These two aspects need to be considered together. Furthermore, a single extreme event can lead to a cascading or domino effect that generates new hazards and leads to a broad breakdown of a city's infrastructure. Figure 1 gives an example. The cascading effects of a typhoon weather event with heavy rainfall lead to hydrological flooding, inundation and coastal erosion, and strong winds lead to damaging waves, among others. These phenomena lead to the activation of emergency services for search and rescue, power outages, fires and even damage to nuclear power plants. Post event impacts include disease outbreaks, nuclear waste dispersion, urban fabric changes and even displaced people. Integrated Urban Services are required to provide consistent short-term emergency and long-term planning applications, efficiently and effectively. There is a critical need to consider the problem in a holistic manner when addressing disaster risk reduction and climate change for urban areas (Grimmond et al., 2014; Baklanov et al., 2018).

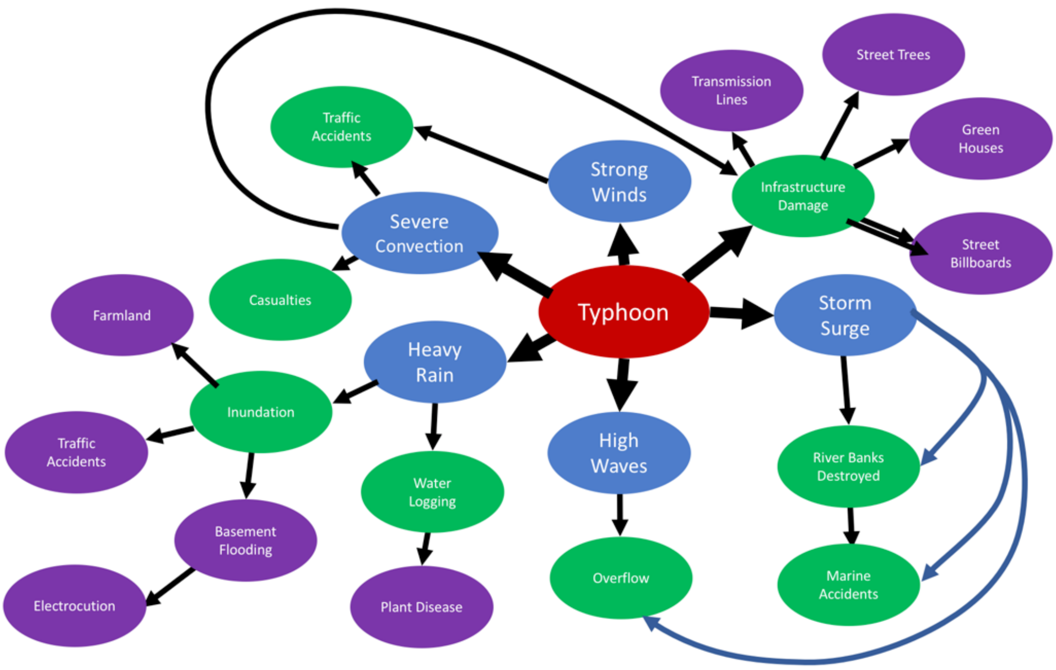

Figure 1. An example of the domino effect

Source: Paul Joe

1.2 WMO engagement in the urban agenda

The New Urban Agenda was adopted at the United Nations Conference on Housing and Sustainable Urban Development in October 2016 (United Nations Human Settlement Programme, 2016; United Nations, 2017). Of the 17 United Nations Sustainable Development Goals (SDGs), SDG 11 focuses on urban resilience, climate and environment sustainability, and disaster risk management (Figure 2). In response, WMO proposes a cross-cutting urban focus initiative through Integrated Urban Hydrometeorological, Climate and Environmental Services (hereafter referred to as Integrated Urban Services) for urban resilience and sustainable development. The main goal is to develop urban multi-hazard early warning systems, an Integrated Urban GHG Information System (IG^{3}IS-urban) and climate services, with a focus on impact-based forecasts and risk-based warnings. Integrated Urban Services is an emerging multi-disciplinary field, where requirements for such services are not clearly articulated, and research and development is needed for refinement of the concept. Integrated Urban Services support resilient and sustainable cities through multi-hazard early warning, and through services to support emergency services and planning for the long-term impacts of disasters. Sustainability is supported through long-term urban planning for climate change and support of adaptation and mitigation strategies.

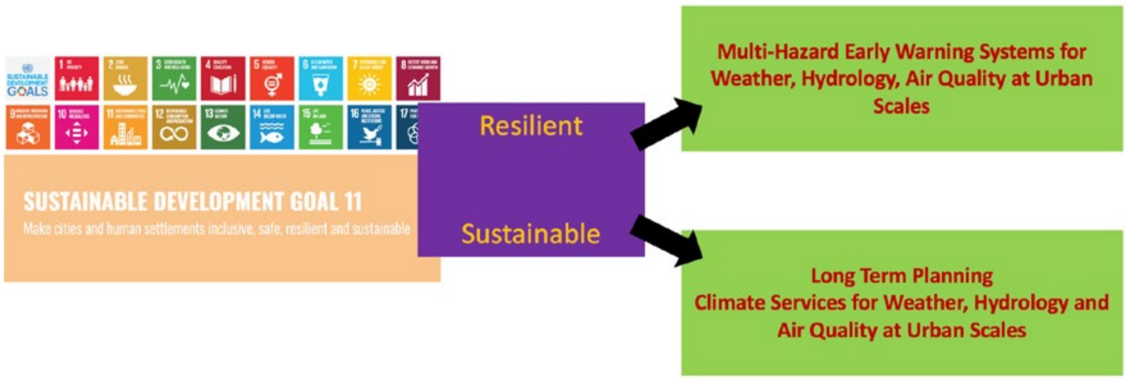

Figure 2. The Integrated Urban Services concept supports SDG 11

Source: Paul Joe

WMO has recognized the increasing demands of Members for dedicated urban services that can improve resilience to: environmental, weather-, climate- and water-related hazards; increased frequency and severity of weather, water and climate extremes; and impacts brought about by climate variability and change. It has taken a number of related decisions as described in the *Guidance on Integrated Urban Hydrometeorological, Climate and Environmental Services, Volume I: Concept and Methodology* (WMO, 2019*a*). The guidance is related to Decision 7 of the seventieth session of the WMO Executive Council (WMO, 2018*a*).

Box 1 briefly presents the objectives and the concept of the Integrated Urban Services methodology, while Volume I gives a full description (WMO, 2019*a*). Box 2 defines Integrated Urban Services, Box 3 outlines different approaches to integration, Box 4 summarizes benefits of Integrated Urban Services and Box 5 outlines climate mitigation efforts in cities.

Box 1. Integrated Urban Services: concept and methodology

Integrated Urban Services include a combination of dense observation networks, high-resolution forecasts on different timescales to support multi-hazard early warning systems and long-term planning, and user interfaces for services delivery and feedback. The services should meet the special needs of cities, as expressed by urban stakeholders and assist cities in setting and implementing mitigation and adaptation strategies that will enable them to build resilient, thriving sustainable cities that promote the New Urban Agenda of the United Nations.

Integrated Urban Services focus on improving and integrating the following main services and subsystems:

– Weather (especially high-impact weather prediction at the urban scale)

– Climate (urban climate, climate extremes, sector-specific climate indices, climate projections, climate risk management and adaptation, and drivers of climate change)

– Hydrology and water-related hazards (flash river floods, heavy precipitation, river water stages, inundation areas, storm tides, sea-level rise and urban hydrology)

– Air quality (such as urban air quality and larger-scale hazards affecting cities: long-range transport, dust storms, wildfire smog, anticyclonic and blocking driven air pollution episodes)

Integrated Urban Services should consider seamless provision of services across all timescales. They should cover historical records and monitor current conditions to long-term timescales. The applied approaches are nowcasting (for very short-term multi-hazard early warnings such as thunderstorms, flash floods and dispersion), short-term and medium-range forecasting for larger-scale phenomena (typhoons and extratropical storms) and sub-seasonal to seasonal and climate change forecasting. The spatial scales cover urban and sub-urban ones. The applications range from environmental and climate risk management, adaptation to climate change, mitigation strategy assessments and urban planning to decision-making mechanisms and effective communication routes.

Source: Adapted from WMO (2019*a*)

Box 2. Integrated Urban services: attributes

In the traditional sense, and in the context of city management (mayors and other city agencies), urban services refer to services such as transportation, housing, water management, waste and wastewater management and snow clearance. Urban services are generally the mandate of, and therefore delivered in partnership with, city authorities (such as mayors, emergency services, health authorities and civil protection). Social scientists, economists, regulatory agencies and policymakers may also play a role in the delivery of urban services.

In this Guidance, Integrated Urban Services refer to the provision by a WMO Member of weather, climate, hydrology and air quality infrastructure (data, observations and predictions) that may be used to support traditional and new urban services. These services may be provided directly by National Meteorological and Hydrometeorological Service (NMHS) operations, in cooperation with or indirectly through stakeholders or partners in public and private agencies.

Integrated Urban Services are inherently high resolution. High-resolution local area meteorological observations and modelling are two foundational elements of urban and sub-urban scale services (for example, city block scale), although large-scale phenomena (for example, tropical cyclones or biomass burning events) also affect cities. The spatial resolutions of typical operational weather models (in the definition of Frelich and Sharman, 2008) for local, regional and global predictions are ~2.5 km, 10 km and 30 km, respectively. The spatial extent of big cities varies from 15 km to 100 km; hence, it is poorly resolved by the regional and global models. High-resolution urban models (250 m and 1 000 m) are being developed in research mode and demonstrated in various projects (for example, see Figure 3 on Toronto and Annex 2; Joe et al., 2018). High-resolution weather models (~1 km) are used with climate change scenarios for long-term urban planning applications (see Annex 2 on Stockholm; Amorim et al., 2018). However, these models are highly dependent on the application, articulated requirements, and local and regional factors. The urban domain is defined by local governments, and may include nearby cities, the area and roads in between, rural watersheds or catchments and the location of industries in order to capture their impact. Urban planners may include surrounding areas, as planning in major metropolitan areas will affect housing, transportation and recreation in those areas.

Figure 3. Example of intra-urban Integrated Urban Services warning services for the Toronto Pan and Parapan American Games in Canada in 2015. The domain of the image is about 100 km × 100 km. Integrated Urban Services (weather, air quality and heat stress warnings) were provided to ensure public safety and security for venues (dots) with simultaneous events and large crowds. Normal public warning areas are shown (coloured blocks). The Integrated Urban Services venue warnings were provided to games organizers, emergency services and health authorities only. These were given special training and support for interpretation of the tailored venue warnings as they may appear to contradict public warnings.

Source: Paul Joe

Box 3. Integration of services

Integrated services means the end user receives an appropriate product that takes into consideration two or more of weather, climate, hydrological and air quality domains. Integration can mean several things: organizational integration, single access point for services or data, merging monitoring networks, coupled modelling, creating products from distinct systems or providing expertise at the service level (WMO, 2019*a*).

These services may be delivered through different programmes or agencies within a WMO Member. Individual parts of integrated services may be delivered by different agencies. Mandate and collaboration are the core jurisdictional and governance issues to resolve for effective urban service delivery.

Impact-based forecasts (WMO, 2015) describe the impact of a hazard, or multi-hazards, on an individual or a community at risk. They consider the hazard, the vulnerability and the exposure. For example, a hazard-based forecast could be “Severe thunderstorms are expected today with wind gusts exceeding 60 mph” (mph is miles per hour, and is equal to 96.5 km per hour), whereas an impact-based forecast would be “Extensive traffic delays in Kensington may occur due to the risk of large trees downing power lines and blocking roads as a result of severe thunderstorms”.

Successful impact-based forecasting requires collaboration (integration) among the meteorological forecasting community and other communities or institutions who have the additional necessary expertise, resources and knowledge (such as demographic data, crowdsourcing techniques, geographical information systems, and third-party data integration and usage) to deliver impact services that NMHSs cannot do on their own. From the perspective of service users, this would include communities most vulnerable to disasters contributing to the information system.

Box 4. Benefits of Integrated Urban Services: useful, usable, used

There are many benefits of Integrated Urban Services, but key ones include providing:

- Resiliency through multi-hazard early warning systems
- Sustainability through urban long-term planning
- Capability and capacity through cross-cutting services
- Efficiency through infrastructure multifunctionality
- Consistency (hence, effectiveness and efficiency) through integration
- Effective service through partnerships/risk communication

Box 5. Climate mitigation efforts in cities

Cities are a critical part of the endeavour to limit global GHG emissions to achieve goals set out in the 2015 Paris Agreement. Many city authorities have responded to this challenge; to date, 9 378 cities have registered their climate actions on the Global Climate Action platform NAZCA of United Nations Climate Change (http://climateaction.unfccc.int/). Furthermore, over 4 000 studies related to urban climate mitigation projects have been published (Lamb et al., 2019). The demonstration cities included in this Guidance (Annex 2) have planned over 500 mitigation activities to decrease their net emissions and over 100 adaptation actions (Carbon Disclosure Project, http://www.cdp.net/). City stakeholders need science-based information for their decision-making. In addition to the different existing inventory approaches and datasets (for example, Nangini et al., 2019), atmospheric observations can also play an important role.

WMO activities to support urban mitigation activities through the Integrated Global Greenhouse Gas Information System (IG^{3}IS): IG^{3}IS was established to promote the use of atmospheric observations in combination with modelling tools and socioeconomic data to help provide relevant information to stakeholders to cost-efficiently and rapidly implement mitigation actions, as well as to track their success (WMO, 2019*b*). Local city authorities often cannot rely on their own resources to establish complex atmospheric monitoring and modelling activities, but many of the skills required to fill these gaps usually reside in national institutions, especially NMHSs. Therefore, one of the key goals of WMO IG^{3}IS is bringing the stakeholder community and their challenges to the solution providers from NMHSs, academia and research institutions. WMO IG^{3}IS has started to establish good practices for urban GHG modelling and monitoring. It has also endorsed multiple urban GHG projects that will demonstrate the usefulness of this integrated approach for evidence-based decision-making and for tracking the progress related to GHG emission reduction targets.

Implications for Integrated Urban Services: Providing guidance on Integrated Urban Services helps to disseminate the WMO IG^{3}IS good practices for climate (mitigation)-related services. It also ensures WMO activities at the urban scale will be consistent and services can be delivered efficiently. Many NMHSs can play a key role in assuring science-based information is provided to local authorities by defining performance standards, for example, for atmospheric data to be used when creating these new urban climate services that are often delivered by a diverse set of actors, including the private sector. Urban-scale studies focusing on mitigation tracking, for example the WMO IG^{3}IS demonstration projects, also leverage existing infrastructure (for example, weather data as input in atmospheric transport models). Future improvement of weather forecast models, for example when used in addressing urban weather or air quality issues, can also immediately feed into improved forecasting or analysis of urban GHGs when the services are integrated. Furthermore, integrating different urban services can highlight the additional benefits of many mitigation measures such as improved air quality, which has better health outcomes associated with it. Many of the cities (Annex 2) have not yet included their climate mitigation activities explicitly, but this Guidance should be seen as a step towards an inclusion of the medium- to long-term climate mitigation challenges in the current framework centred around short-term hazards.

1.3 Scope and purpose of this Guidance

This Guidance documents and shares good practices and successful cases of implementation of Integrated Urban Services among WMO Members. Its objectives are to:

- Show good practices from selected demonstration cities
- Articulate common attributes of the integrated services in different demonstration cities
- Make recommendations on Integrated Urban Services for WMO Members and city authorities
- Define the main gaps in the availability of Integrated Urban Services and develop recommendations for their upscaling

1.4 Development process of this Guidance

To capture the cross-cutting aspects of urban services and of governance and mandates, contributions were solicited from a variety of experts and representatives through a broad consultation process. Experts were identified by the WMO Technical Commissions and WMO Secretariat urban focal points. A broad range of urban experts and WMO Members were surveyed. The Global Atmosphere Watch Urban Research Meteorology and Environment (GURME) Scientific Advisory Group (SAG) was appointed to lead the preparation of this second volume, with contributions from relevant Technical Commissions. The writing team included representatives of NMHSs, academia, urban councils, the WMO Secretariat, scientific organizations and other United Nations agencies.

Information on Integrated Urban Services was collected through the four complementary tools shown in Table 1. Annex 1 describes the tools themselves.

Table 1. Tools used to gather information on Integrated Urban Services

Tool	*Issued by*	*Target respondents*	*Comment*	*Number of responses*
Reflections survey	GURME SAG	Urban experts	Urban project leaders, experts and researchers in government and academia were asked to share their experiences in an open-ended survey about specific cities (outputs from WMO, 2019*a*). Respondents were given limited time, and asked for their immediate reactions to the survey. The intent was to gather information quickly from urban experts, who acted in their personal capacity.	21
Urban focal point survey	GURME SAG	Members urban focal points	A subset of the reflections survey was sent directly to the urban focal points of WMO Members for their immediate reactions about specific cities. The intent was to gather additional information.	11
Member survey	WMO Secretary-General	WMO Members	A formal WMO survey was sent to WMO Members. Unlike the two surveys above, this survey was designed for categorical responses, their urban services and not specific to a particular city. Chapter 2 provides analysis of this survey as a context for the demonstration cities.	87
Demonstration city summaries			The authors of this Guidance worked with respondents in different cities to collect the reflections related to implementation of Integrated Urban Services and to produce a structured summary of these services for specific demonstration cities. These inputs form the core material for this Volume II. See Chapter 3 and annexes for more details.	27

2. OVERVIEW AND ANALYSIS OF THE MEMBER SURVEY

2.1 Introduction

A survey enquiring about urban weather, climate, hydrological and air quality services was sent to the permanent representatives of all WMO Members in 2018. Its purpose was to establish a baseline of WMO Member urban services for use in evaluating their development in future surveys. As such, the results represent a preliminary assessment of the current status of these services and the impediments to enhancing these. Here, the survey is used to set the context for subsequent chapters, which explore the types of services available in demonstration cities.

Eighty-seven Members completed the survey. Most respondents were NMHSs, and the responses therefore reflect the NMHS perspective. The survey measured the level of service provision in each area, the extent to which users and providers collaborate, and the status of urban services currently provided. In addition to contact information, there were 49 questions focusing on six areas (number of questions in parentheses):

(a) Main hazards in urban areas (1)
(b) Current activities in urban services (16)
(c) Other urban services in the country (2)
(d) User connections and partnerships (13)
(e) Capacity development and training (11)
(f) International collaboration (6)

As an overview of Member responses, each response was categorized by region and income level using the World Bank income categories (Table 2). Of the 87 respondents, about a third were from the Europe and Central Asia region. While the largest number (33 responses or 38%) of respondents were from high-income countries, lower and upper middle-income countries were well represented, and nine respondents were from low-income countries located mostly in sub-Saharan Africa. These data may be of some relevance in interpreting and using the demonstration city information presented in the following chapters.

Table 2. Survey respondents by region and World Bank income level (% values in grey represent the percentage of responses in each geographical region per income category). As an example, for sub-Saharan Africa, the total number of responses was 17, out of which 47% were from low-income Members, 41% from lower middle-income Members and the remaining 12% from upper middle-income Members.

Region	*Low income*	*Lower middle income*	*Upper middle income*	*High income*	*Total number of respondents*
Sub-Saharan Africa	47%	41%	12%	0%	17
Latin America and the Caribbean	0%	13%	63%	25%	16
Europe and Central Asia	0%	10%	21%	69%	29
South Asia	25%	75%	0%	0%	4
East Asia and Pacific	0%	42%	25%	42%	12
North America	0%	0%	0%	100%	2
Middle East and North Africa	0%	17%	50%	33%	6
Total number of respondents	9	21	24	33	87

2.2 Geophysical characteristics and hazards in urban areas

Members were asked to place their urban areas in geographical (coastal, inland, mountainous, desert and river/delta) and climatological (polar, mid-latitude and tropical) contexts. In addition, each Member was asked to identify the main urban hazards of relevance they face. Table 3 shows a cross-tabulation of these geographical, climatological and hazard dimensions.

The most common urban topographic settings were inland, coastal, mountain and riverine/delta, in that order, and a few in polar latitudes (2) or in desert environments (17). Six main urban hazards were identified (marked in bold in Table 3): heavy rainfall, flooding (pluvial and fluvial), windstorms, heatwaves, air pollution and thunderstorms.

There were some links among the types of hazard and geographic parameters:

- Heavy rainfall, flooding, thunderstorms and air pollution were common hazards across all responses
- Heat and cold waves, windstorms and snow/ice were more commonly identified as mid-latitude urban hazards, while tropical storms were emphasized as urban hazards in tropical urban areas

Table 3. Geophysical and climatological characteristics and hazards of urban areas mentioned in survey responses. Values are numbers of responses for a particular hazard (listed in the first column), except column 3, which gives the responses as a percentage out of a total of 87 respondents. Bold numbers in the second ("Number of respondents") and third ("Percentage") columns indicate the most commonly identified hazards. Columns with grey shading provide the number of responses according to the "geographical" context of the urban areas, and the last three columns show the number of responses according to the "climatological" context of the urban areas. The last row marked "Total" corresponds to the total number of responses reported in urban areas according to the specific geographical and climatological categorizations indicated in the headings of the table. As an example, 98% of the responses were for urban areas that suffered heavy rainfall; 66 respondents reported on urban areas that were classified as "inland" and 31 responses were for urban areas that could be classified as "tropical".

Hazard type	*Number of respondents*	*Percentage*	*Coastal*	*Inland*	*Mountain*	*Desert*	*Riverine*	*Polar*	*Tropical*	*Mid-latitudes*
Heavy rainfall	**85**	**98%**	**65**	**66**	**49**	**17**	**41**	**2**	**31**	**32**
Flooding	**75**	**86%**	**60**	**58**	**44**	**13**	**38**	**2**	**29**	**26**
Water scarcity	41	47%	30	31	28	11	21	0	18	17
Fog	46	53%	30	37	28	14	23	1	16	22
Tropical storms	29	33%	27	23	19	7	17	0	21	9
Coastal inundation	38	44%	38	31	25	9	23	2	17	15
Windstorms	**60**	**69%**	**43**	**47**	**37**	**16**	**30**	**0**	**19**	**29**
Heatwaves	**57**	**66%**	**39**	**46**	**32**	**14**	**31**	**1**	**17**	**32**
Cold waves	38	44%	23	32	24	11	23	1	12	24
Snow	33	38%	22	26	20	7	20	2	6	23
Ice	23	26%	15	17	13	3	15	1	4	16
Sandstorms	22	25%	16	19	16	15	13	0	8	10
Air pollution	**54**	**62%**	**38**	**40**	**30**	**12**	**28**	**2**	**21**	**25**
Thunderstorms	**70**	**80%**	**54**	**54**	**41**	**15**	**35**	**1**	**28**	**30**
Volcanic ash	11	13%	11	8	9	2	5	0	8	3
Other	23	26%	21	18	16	6	15	0	15	7
Total	87	100%	66	66	49	17	42	2	31	34

Table 4. Survey respondent services and level of development

	Weather		*Climate*		*Hydrological*		*Air quality*	
	Number of responses	*Percentage*	*Number of responses*	*Percentage*	*Number of responses*	*Percentage*	*Number of responses*	*Percentage*
Level of development								
Fully operational	69	79%	48	55%	41	47%	31	36%
Partly operational/moving to operations	13	15%	29	33%	30	35%	21	24%
Research/planning	7	8%	10	12%	13	15%	28	32%
By hazard								
Heavy rainfall	67	77%	48	55%	40	46%	31	36%
Flooding	58	67%	42	48%	36	41%	26	30%
Tropical storms	25	29%	20	23%	17	20%	8	9%
Coastal inundation	30	34%	22	25%	19	22%	13	15%
Windstorms	49	56%	33	38%	28	32%	23	26%
Heatwaves	45	52%	30	34%	27	31%	24	28%
Air pollution	44	51%	30	34%	27	31%	22	25%
Thunderstorm	57	66%	40	46%	34	39%	25	29%

2.3 Services and level of development

Most Members indicated their urban meteorological services were fully operational (79%); however, 8% were still at the research/planning stage (Table 4). Fewer respondents described their climate services as being fully operational. Hydrological and air quality services were more diverse, with the latter being the least developed. Fewer Members had fully operational climate (55%), hydrological (47%) and air quality (36%) services. In the case of air quality, 32% indicated such services were just at the research/planning stage. When the fully operational services are cross-tabulated with the common hazards identified, some of the gaps in the operational status are clear. For example, Members concerned about tropical storms had the fewest fully operational systems in all categories. By comparison, meteorological support for heavy rainfall, flooding and thunderstorms was present in services, but hydrological support was relatively weak.

2.4 Service provision

Nearly all Member respondents indicated services were provided to official bodies and the public (Table 5). Additional targeted customer services for water management, energy supply and transportation were closely linked to many of the hazards identified. Fewer than half of the respondents indicated they had an integrated platform to provide these services.

Table 5. Number and percentage of respondents indicating the provision of Member services to different recipients. For example, 75% of respondents indicated they provided services to the transportation sector.

Recipients	*Number of respondents*	*Percentage*
General services to the public	84	96%
Services to authorities (city, state, national)	85	97%
Other customers		
Water management	72	83%
Energy supply	65	75%
Transportation	65	75%
Health sector	55	63%
Infrastructure design	54	62%
Tourism sector	52	60%
Road traffic	52	60%
Special events	51	59%
City planning	51	59%
Food safety	42	48%
Industry	40	46%
Other	17	20%
Respondents with systems that include Integrated Urban Services	**39**	**45%**

2.5 Use of impact-based forecasting for urban areas

Fewer than half of Members (45%) provided impact-based forecasts for urban areas (Table 6). Out of those who did not provide such services, nearly 83% were planning for them. The majority of respondents did not use alert systems to communicate hazards/impacts and relied mostly on conventional media (television, radio, Internet and email). An analysis of the medium and the type of hazard did not reveal any differences in approach.

Table 6. Use of impact-based forecasting for urban areas by respondents. The last two columns show the number and percentage of respondents who provided impact-based forecasts for urban areas.

Forecasting and alerts	*Number of respondents*	*Percentage*
Does your service use impact-based forecasting for urban areas?	39	45%
If "no", do you plan for such services?	40	83%
Weather alerts and warnings	85	98%
Flood/drought alerts	73	84%
Medium of communication		
Newspaper	60	69%
Television	76	87%
Radio	75	86%
Telephone (including SMS (short message service) alerts)	62	71%
Web portal	74	85%
Email	70	80%
Digital display	29	33%
Social media	58	67%
Other	33	38%

2.6 Users of the services and user engagement

Member responses indicated that local governments, and disaster and water management units were the most engaged communities in development of urban products and services. The energy, transport and health sectors were less involved, and the general public had little involvement.

When hazard type is cross-tabulated against service user (Table 7), some relationships become clear. For example, tropical storm hazard is linked to multiple sectors, while local government and disaster and water management units are associated with development of dedicated services for heavy rainfall and flooding. The transport sector is linked to services related to air quality and excess water.

Table 7. Involvement of users of impact-based forecasting for urban areas in the development of urban services

	Local government	*Disaster management*	*Water management sector*	*Energy sector*	*Industry sector*	*Transportation sector*	*Road traffic sector*	*Food safety sector*	*Health sector*	*Tourism sector*	*General public*
Number of respondents	51	52	47	37	15	40	26	21	35	15	19
Percentage	58%	59%	53%	42%	17%	46%	30%	24%	40%	17%	22%
Hazard											
Heavy rainfall	52%	52%	46%	38%	14%	40%	26%	22%	36%	16%	20%
Flooding	44%	45%	43%	35%	13%	36%	22%	21%	35%	14%	20%
Tropical storms	19%	18%	20%	14%	5%	12%	8%	7%	14%	10%	8%
Coastal inundation	22%	25%	24%	17%	6%	18%	10%	9%	19%	9%	8%
Windstorms	34%	35%	31%	27%	11%	28%	20%	18%	23%	11%	13%
Heatwaves	33%	35%	29%	27%	13%	27%	19%	16%	25%	10%	13%
Air pollution	35%	35%	33%	28%	11%	28%	21%	17%	24%	11%	17%
Thunderstorms	41%	42%	36%	31%	13%	33%	21%	18%	29%	14%	17%

2.7 Partnerships and capacity-building

Some questions in the survey were related to partnerships and the range and frequency of interactions with the partners (Table 8). About half of the respondents had formed partnerships to create and provide urban services. Social scientists had not generally been part of the process of development of urban services. Most Members had regular meetings with partners (72%); about half had conducted training workshops and a third had attended WMO training. Many respondents (72%) were interested in helping other Members to develop urban services through twinning, and 83% would like to develop their urban services through twinning.

Table 8. Partnerships and capacity-building

Partnerships and training	*Number of respondents answering "Yes"*	*Percentage*
Has your service formed partnerships in the provision of urban services?	50	57%
Do you carry out regular surveys, such as for further development or for obtaining information on the benefits of your services, with your partners or relevant national/regional/local authorities?	50	57%
Have you established regular meetings with your partners or relevant national/regional/local authorities?	63	72%
Does your service work with economists on urban services?	8	9%
Does your service work with social scientists/authorities on urban services?	25	28%
Does your service measure the economic and/or social benefits of urban services?	15	17%
Does an authority have responsibility for measuring the economic and/or social benefits of urban services?	14	16%
Has your service or another national/municipal authority organized capacity development activities, including training, on urban services that your staff have attended?	43	49%
Have your staff attended any WMO organized capacity development activities, including training, related to developing urban products and services and associated infrastructures?	31	35%
How does your service develop capacity and guide stakeholders, authorities and users in the interpretation and use of urban products and services?		
Do you organize training for them?	43	49%
Do you have regular meetings with them?	49	56%
Do you provide them with written guides or operative procedures?	37	42%
Does your service conduct periodic exercises to ensure proficiency?	48	55%
Is your service collaborating with international partners on urban activities?	33	37%
Would your service be interested in providing twinning to a country/city in need of developing urban services?	63	72%
Would your service be interested in developing your urban services by twinning with a country/city already having expertise in urban services?	73	83%

2.8 General outcomes of the survey

The survey of weather, climate, hydrological and air quality services was completed by 87 WMO Members. While this is a sizeable proportion of the population of 187 Member States and six Member Territories, it may not be representative of service provision for a couple of reasons. First, most respondents were drawn from NMHSs, who may have incomplete knowledge of the range of urban services available in a Member. Second, the completed survey responses may overrepresent those Members with an interest in providing urban services. Nevertheless, these data provide a first look at the provision of urban services by WMO Members and a baseline overview of the urban services provided and the nature of integration across services and with users. General outcomes of the survey included:

– Common urban hazards were heavy rainfall, flooding, windstorms, tropical storms, heatwaves, thunderstorms and air pollution.
– Meteorological operations were well developed, while hydrological and air quality operations were significantly less well developed. Improving the operational status of hydrological and air quality services to match meteorological services is needed to meet the common hazards identified.
– Many WMO Members indicated they had already developed relationships between urban services providers and users. This allowed for creation and provision of services that meet user requirements and of communication systems that connect hazard impact to users. Such practices can be used to identify and engage with urban users and assist service providers in meeting their distinct needs.
– About half of WMO Member survey respondents had created some type of urban services (including training), and of those that had not, most plan to do so. Many respondents indicated they wished to learn from other WMO Members on how to develop these services.

3. INTEGRATED URBAN SERVICES: DEMONSTRATION CITY SUMMARIES

3.1 Introduction

This chapter reviews selected demonstration cities with existing Integrated Urban Services in weather, environment (hydrological and air quality) and climate for common elements (Table 9). Recognizing there is great variation in the implementation of the concept of Integrated Urban Services, it is considered useful to identify which core elements represent necessary attributes of the Integrated Urban Services and how those elements connect with the methodology developed by WMO. The input was solicited from city-specific experts, urban focal points and selected Members. Annex 2 presents response summaries for each demonstration city as provided (without editorial or special information processing).

Table 9. Selected demonstration cities

City	*Country*	*Climate zone*
Antwerp	Belgium	Temperate
Auckland	New Zealand	Subtropics (marine)
Beijing	China	Temperate
Casablanca	Morocco	Subtropics (dry summer)
Dallas–Fort Worth Metroplex	United States of America	Subtropics
Frankfurt am Main	Germany	Temperate
Hamburg	Germany	Temperate
Helsinki	Finland	Temperate
Hong Kong	China	Subtropics
Johannesburg	South Africa	Subtropics
London	United Kingdom of Great Britain and Northern Ireland	Temperate
Mexico City	Mexico	Tropics
Moscow	Russian Federation	Temperate
New Delhi	India	Subtropics
New York City (NYC)	United States	Temperate
Rotterdam	Netherlands	Temperate

City	*Country*	*Climate zone*
Saint Petersburg	Russian Federation	Temperate
Santiago	Chile	Subtropics (semi-arid)
Seattle	United States	Temperate
Seoul Metropolitan Area	Republic of Korea	Temperate
Shanghai	China	Subtropics
Singapore	Republic of Singapore	Tropics
Stockholm	Sweden	Temperate
Stuttgart	Germany	Temperate
Toronto	Canada	Temperate
Toulouse and Paris	France	Temperate
Wellington	New Zealand	Temperate (marine)

3.2 Demonstration city summary information

A common template was created and distributed to city representatives, to ensure compatible information was provided by different cities. The request for information was organized into three major categories corresponding to general information, needs for integrated services and services integration.

Section A: General information

– Socioeconomic condition (city size, isolated or agglomeration and economic condition (for example, contribution to gross domestic product)), level of infrastructure (for example, transport and communication, environmental management, monitoring and response mechanisms)
– Climate zone, weather classification and geographical position (inland, coastal, mountains, desert and so forth)
– Governance structure (decision-making): legal framework, autonomous or metropolitan/regional, responsibility pathway for addressing urban hazards and policymaking powers (local, regional and national)

Section B: Needs for the integrated services

– Most common hazards in cities and associated environmental risks (for example, hydrological hazards, elevated air pollution episodes and vulnerability to other regional hazards)
– Description of existing Integrated Urban Services for meeting hazard challenges, or hazard-specific services, and capability of monitoring, predicting and forecasting hazards
– Providers of the urban services (dedicated Members, academia, consultancies, advisers and so forth)
– Users of the Integrated Urban Services (government, environmental agencies, economic sectors, public and so forth) – local, regional and national
– Requirements for the services: short term (disaster risk reduction) or long term/strategic (urban and national planning), scientific and technical expertise, and capabilities (for example, observational, computing and training)

Section C: Services integration

– Short term: multi-hazard early warning and forecasting systems
– Long term: urban planning for sustainable development, climate change mitigation and adaptation
– Components integrated (and how):

- At the level of observational infrastructure
- At the level of modelling tools
- At the level of the services/information delivery and communication

3.3 Comparison of demonstration city summaries with the Member survey

As some of the information gathered in the demonstration city summaries and the Member survey (Chapter 2) is similar, the overall results can be compared. However, differences in survey questions should be kept in mind. The city summaries: (a) are city specific (rather than an expression of national urban services' needs), (b) represent only a selection of all cities and (c) contain much greater detail on existing Integrated Urban Services. In the following, results are presented as percentages based on the number of survey respondents ($N = 87$ Members) and the number of city summaries ($N = 27$ cities, Table 9).

In the Member survey, heavy rainfall was the most frequently reported among 15 hazards (98% of responses). "Other" non-specific hazards were reported by 26% of the Member respondents. The variety of hazards addressed by the city summaries was broader, with 20 hazards explicitly identified (Figure 4). At the same time, there was a substantial difference in terms of frequency of hazard mentions. For example, 98% of the Member survey respondents reported heavy rainfall as a hazard yet only 67% of the city summaries reported the same. This difference may represent a lower concern with this hazard by the selected demonstration cities as the related services may already be routinely provided and no longer a priority, or the individual cities may have different focuses. On the other hand, the Member survey also has limitations as it often represents the view of NMHSs, which have monitoring and forecasting meteorological hazards among their major responsibilities. The city survey indicates a higher priority is placed on providing information on the impact of heavy rainfall, namely flash floods or riverine flooding, rather than the meteorological event itself. Flooding was identified most frequently as a hazard in the city summaries (78%). The Member survey and the city summaries indicated air pollution as a high priority hazard (63%) and generally agreed on the importance of heatwaves and cold waves (63% and 48%, respectively). Demonstration city summaries indicated high demand for climate change information (26%), while this demand was not explicitly mentioned in the Member survey and was probably included in the "Other" services category although it was not directly mentioned. Demonstration city summaries clearly recognize the risks of climate change. Mexico City indicated "vector-borne diseases, social and spatial inequality and high vulnerability related to climate change", Hamburg, Rotterdam and Stockholm mentioned "sea level rise" and Auckland mentioned "coastal erosion". These, and others, are likely to change in the future and have significant impacts on cities as the climate changes. These changes are particularly important for heritage cities (Box 6).

Box 6. United Nations Educational, Scientific and Cultural Organization World Heritage Sites

Climate change is already having a considerable impact on some of the world's most spectacular built and natural World Heritage Sites. The effects of climate change relevant to cities include sea-level rise and increased frequency and severity of flooding, increased temperature, desertification and coastal erosion. In China, the Peking Man World Heritage Site at Zhoukoudian in Beijing was damaged by floods caused by the heaviest rainfall in six decades. The ancient city of Fenghuang in Hunan Province was surrounded by rushing water for 12 h in 2012 (Yung and Chan, 2015). Natural ecosystems, like the unique Great Barrier Reef (Australia) or the Wadden Sea (Denmark, Germany and the Netherlands) are threatened by increasing water temperatures and sea-level rise. Thus, immediate actions are needed to protect the outstanding universal values, integrity and authenticity of the World Heritage sites from the adverse impacts of climate change. Air pollution and acid precipitation could destroy cultural sites such as the Acropolis in Athens or the Sphinxes in Egypt.

The World Heritage Committee convened a working group of experts, in collaboration with the World Heritage Convention's Advisory Bodies, interested States parties and petitioners, to prepare a report on predicting and managing the effects of climate change on world heritage (UNESCO, 2007*a*), case studies on climate change and world heritage (UNESCO, 2007*b*) and a policy document on the impacts of climate change on world heritage properties (UNESCO, 2008). The World Heritage Convention is gradually evolving into a competent body to monitor the impacts of climate change on heritage sites and to suggest pertinent practical measures to safeguard them (UNESCO, 2008).

The WMO expert network contains Members with skills and capabilities related to meteorology and heritage conservation that can support the World Heritage Committee. Experts from different disciplines and sectors working together can identify heritage sites and hazards they are prone to. Integrated Urban Services implemented in the heritage cities can provide microclimate data and high-resolution modelling for more effective monitoring. Multidisciplinary analyses can be used to draw the effective protection, mitigation and adaptation measures for the heritage sites.

Another hazard mentioned in city summaries is wildfires (30% of respondents). They also affect visibility and air quality, and endanger property and human health. Addressing this issue requires meteorological (wind and precipitation) and hydrological (ground conditions and water availability for firefighting) information to develop action plans. Furthermore, collaboration with climate services will assist in developing fire prevention plans for various climate change scenarios or projections.

Many of the demonstration city summaries indicate the need to address hazards that lie outside the Integrated Urban Services concept adopted here. For instance, 30% of respondents required information on earthquakes. Additional collaboration and partnerships are needed to deliver such services (see an example of a hazard matrix at http://www.naturalhazardspartnership.org.uk/products/hazard-matrix/).

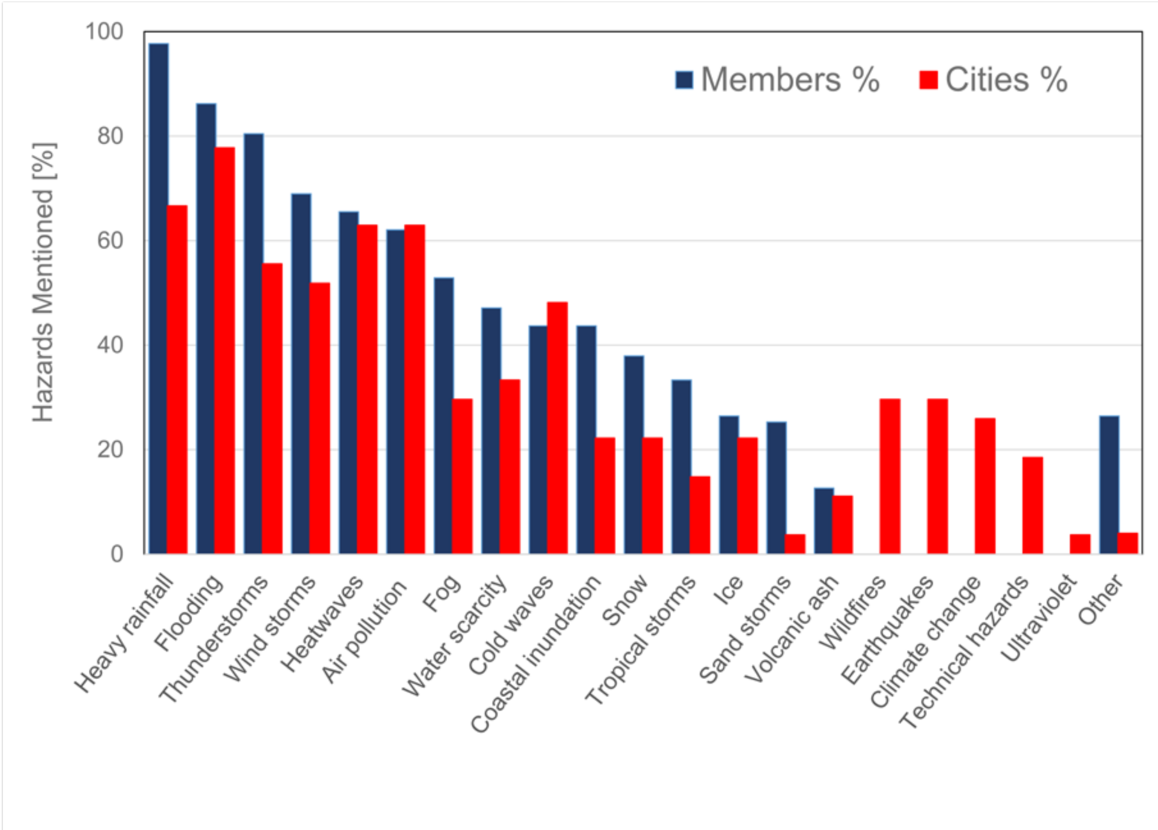

Figure 4. Frequency of specific hazards mentioned by Members in the survey (blue, Chapter 2, sample size = 87) and by demonstration cities in the summary (red, Chapter 3, sample size = 27)

Source: Heinke Schluenzen, University of Hamburg

4. OVERVIEW OF INTEGRATED URBAN SERVICES

4.1 Introduction

While urban services can cover a wide range of areas, here the focus on weather, climate, hydrological and air quality services and integration across two or more of these is considered as realization of Integrated Urban Services. In general, Integrated Urban Services include communications with urban sectors (such as energy management and planning) for which these services are developed. The demonstration city summaries provide multiple examples of the implementation of Integrated Urban Services developed to address different hazards, situated in a variety of institutional, political and legal contexts, with varying levels of complexity. A classification framework for Integrated Urban Services is presented below. It describes the interactions needed to develop Integrated Urban Services from the outset. This framework allows classification of the attributes of Integrated Urban Services with demonstration cities used as exemplars.

4.2 Integrated Urban Services classification framework

Qualitative analyses are intended to provide information on integration of urban services (see Box 7 for explanation of the approach used), specifically for the areas where:

- Data are exchanged among specific services in different areas (cross-service integration)
- Diverse urban sectors are engaged (cross-sector integration)

4.2.1 *Cross-service integration*

Integrated Urban Services are based on the exchange of appropriate data among four specific area services under consideration here (weather, climate, hydrological and air quality). Table 10 shows examples of such data exchanges. Note the information in the cells is not meant to be exhaustive but shows necessary and beneficial data flows among services. Practically, data collection and hosting may be accomplished within one or more organizations, which requires removal of the institutional barriers for data exchange. For example, often meteorological and air quality data are gathered by different organizations within the same jurisdiction. Similarly, some services may collect data on the same variable for different purposes; thus, meteorological and hydrological services may both have raingauge networks that operate independently. Development of the shared networks (for observations and data exchange) is an important step in development of Integrated Urban Services.

Table 10. Service integration: examples of data flow among domains of urban services that would be needed to produce integrated services. Integration among services is based on the flow of data from one service to one other. Each row shows the data generated by each type of service that is of value to the other service (column); the diagonal columns are empty as the data generated are of obvious value to the service that generated it.

Services	*Weather*	*Hydrological*	*Climate*	*Air quality*
Weather		Precipitation, tides and weather forecasting	Long-term datasets (for example, temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, short-wave radiation and atmospheric pressure)	Drives day-to-day variability in air pollutant transport and concentration
Hydrological	Evaluation data, initial data for improving forecasting, moisture content, land type and use, groundwater levels; surface temperatures of water bodies		Short-term data adding to long-term trends on water resources, soil moisture, precipitation, snowmelt, groundwater, river flows, droughts, flooding, run-off, river levels and sea level	Land use, irrigation, fertilizers and ammonia emissions

Services	*Weather*	*Hydrological*	*Climate*	*Air quality*
Climate	Radiation, changes to weather patterns (for example precipitation, wind, surface radiation, droughts, cold spells and heatwaves); urban heat island and changes in urban design; changes in vegetation cover	Climate-driven long-term changes in sea level, land use, river flows, precipitation, groundwater levels, water quality and availability, flooding frequency and urban planning/design		Changes in meteorological parameters (for example, wind, mixing height and radiation); future air quality (for example, particulate matter, nitrogen oxides and ozone), changes in air pollution emissions (for example, biogenic emissions and pollen) and pollen season; land-use patterns, changes in frequency of high air pollution events, needed for management and adaptability; new composition relations
Air quality	Visibility, local radiation balance, cloud seeding and synoptic circulation regime multi-hazards (for example, air pollution episodes and hot and cold spells)	Deposition of air pollutants on marine and other water bodies; deposition to soils (soil and groundwater pollution)	Effects of short-lived climate pollutants on radiation balance and climate; surface nitrification to assess ecosystem effects; determination of how urban green areas are resistant to pollution	

4.2.2 ***Cross-sector integration***

Table 11 presents examples of potential Integrated Urban Services for various user types. One important measure of integration is the level of utilization of the Integrated Urban Services by different economic sectors and user engagement in services co-design, including investments in personnel and infrastructure to support these services. The table outlines the types of information that might be needed to support short- to long-term sectoral solutions, which entail cross-sector integration.

Table 11. Sectoral users of Integrated Urban Services. Potential users (customers) are categorized into sectors and the types of information that need contributions from different service types.

Integrated Urban Services	*Health*	*Disaster management*	*Water management*	*Energy management*	*Industry*	*Transport management*
	Municipal urban planning					
Partners	Health services/ hospitals	Municipal services including civil defence	Civil bodies, water supply/management and industry	Energy production and infrastructure bodies	Industries	Roads/rail/airport/ harbour authorities and corresponding users (for example, airlines) and industries
Information	Health-specific information to responsible bodies; general information for public (diverse channels)	Rapid and timely warning systems to enable appropriate responses by officials and the public (television and social media)	Information relevant to short-, medium- and long-term excess/ deficient water/snow resources, drinking water amount and quality; data to establish risk statistics and standards	Information relevant to short-, medium- and long-term decisions affecting energy demand, supply (blackout) and production	Directed information to relevant authorities that might include reports and detailed analyses; tailored services for relevant industries	Directed information to relevant authorities that might include reports and detailed analyses
Weather	Temperature, heat stress, wind and storm advice, and ultraviolet radiation	Timely information that allows for rapid decision-making on meteorological hazards such as windstorms	Precipitation distribution from short-term events to multi-year series for supporting decision-making	Energy demand (heat/cold wave) events, energy production (solar/wind) and distribution (infrastructure maintenance)	Design codes for building infrastructure storm tide events	Disruptive weather events such as snow, ice, fog and high wind
Hydrological	Water quality and disease transmission	Rainfall, flooding, surface run-off and drainage	Water resources for settlements and winter snowpacks	Water resources for hydroelectric systems; disruptive events such as flooding	Design codes for drainage infrastructure	Disruptive hydrological events

Integrated Urban Services	*Health*	*Disaster management*	*Water management*	*Energy management*	*Industry*	*Transport management*
Climate	Changes in urban climate, heat stress, drought and cold days, heatwaves, changes in diseases, changes in seasonality, deterioration in water and air quality, security, water availability and pollen season	Long-term changes to extreme weather and hydrological events, including heatwaves and intense precipitation events	Long-term systemic changes of climate, sea level and groundwater level	Heating and cooling degree days; supporting information on renewable energy and limiting urban fossil fuel consumption	Codes for building infrastructure and settlements that may include urban design and planning	Long-term changes to infrastructure to regulate GHG emissions through technology, design and behaviour
Air quality	Population exposure to air pollutants, increased mortality and adverse health outcomes	High pollution episodes linked to emissions within the city and transport from events outside the city such as forest fires	Atmospheric deposition into water bodies and acid precipitation	Emission controls on pollution sources through regulations, fuel management and measurement	Emission controls and source attribution	Emission changes ("go green") and control

Many applications may not be covered by the examples collected for this Guidance, such as small-scale wind studies for building construction. These studies are often performed by private companies.

Box 7. Cross-service and cross-sector integration

This Guidance defines two types of partners in the design and delivery of Integrated Urban Services.

Cross-services integration includes partners that provide different elements or components of the Integrated Urban Services (defined here as weather, climate, hydrological and air quality services). Integration of these partners is underpinned by the exchange, combination and merging (coupling) of scientific knowledge and information. In expanded definitions of Integrated Urban Services, other providers of the integrated services elements with a focus on biodiversity or environmental law, for example, could be incorporated.

Cross-sectoral integration includes partners that provide information critical for the development of the Integrated Urban Services by service providers, various urban customers (such as economists, sociologists, regulators and policymakers) and city authorities. The level of integration is dependent on the degree of shared investment in the design and management of the Integrated Urban Services.

The largest benefits of Integrated Urban Services can be reaped from the implementation of cross-service and cross-sector integration.

4.3 Assessing levels of integration

The sophistication of an Integrated Urban Service is assessed by the degree of cross-service and cross-sector integration. This assessment is applied to the demonstration city summary information to classify each according to the maturity of an Integrated Urban Service.

Cross-service integration is evaluated based on the information flow among the four services (Table 10). As an example, hydrological services depend on inputs of weather data, primarily precipitation measurements and perhaps predictions. A high level of integration would be indicated if there is a partnership between the weather and hydrology agencies where the weather agency provides a tailored, dedicated fast transfer of data to the hydrological service. Absence of integration is indicated if the hydrological service must obtain data from elsewhere or on its own. The diagonal elements in Table 10 represent the level of integration of each service itself. A city with multiple watercourses, each in the responsibility of a separate hydrological service agency, would be poorly integrated in comparison with a city in which one agency provides a single and consistent service.

Two questions are posed to assess demonstration city Integrated Urban Services in cross-service integration (Table 12):

(a) What is the nature of a service (diagonal-shaded cells)?
(b) How is a service combined with another service (off-diagonal cells)?

Table 12. Questions to assess the level of cross-service integration among and within services based on data flow from one service to another and the internal collaboration (diagonal-shaded cells, Table 10) within a service (services do not have to be provided by one institution only)

Services	*Weather*	*Hydrological*	*Climate*	*Air quality*
Weather	What is the nature of the weather service – how is it integrated?	How does the hydrological service obtain weather data – how closely are they coupled?	How does the climate service obtain weather data – how closely are they coupled?	How does the air quality service obtain weather data – how closely are they coupled?

Services	*Weather*	*Hydrological*	*Climate*	*Air quality*
Hydrological	How does the weather service obtain hydrological data – how closely are they coupled?	What is the nature of the hydrological service (coastal/ fluvial/ pluvial flood and drought) – how is it integrated?	How does the climate service obtain hydrological data – how closely are they coupled?	Does the air quality service obtain hydrological data – how closely are they coupled?
Climate	Does the weather service obtain climate data – how closely are they coupled?	Does the hydrological service obtain climate data – how closely are they coupled?	What is the nature of the climate service – how is it integrated (covers weather, hydrological and air quality)?	Does the air quality service obtain climate data – how closely are they coupled?
Air quality	Does the weather service obtain air quality data – how closely are they coupled?	Does the hydrological service obtain air quality data – how closely are they coupled?	Does the climate service obtain air quality data – how closely are they coupled?	What is the nature of the air quality service – how is it integrated?

Cross-sector integration is evaluated based on the urban impacts that an Integrated Urban Service is designed to address (for example, health, disaster management, water management, energy, other industry and transport; see Table 11). For instance, transport is affected by weather (for example, wind, icy roads and poor visibility), hydrology (for example, sea conditions for shipping) and air quality (for example, emissions regulations for vehicle engine regulations). Higher levels of integration are demonstrated by partnerships with representatives of relevant sectors. For instance, an Integrated Urban Service providing information on exceedance thresholds, where significant impacts may be expected, that are defined by the international, national or municipal agencies responsible for air quality policy, standards and their regulation. A low level of integration is where for example air quality agencies use only the online generic public weather forecasts. The highest level of integration is where the services work with sectors to co-produce and co-maintain Integrated Urban Services.

The questions below are posed to assess demonstration city Integrated Urban Services in cross-sector integration (Table 13):

(a) Which partners should be involved? What partners are willing to be involved?
(b) Is the needed partner willing to provide the information? How can specific information of the Integrated Urban Services be properly used and combined? What legal aspects are to be considered? Can co-production of the urban services be achieved and a win–win situation be created?
(c) What type and form of weather, hydrological, climate and air quality information are needed by health services?

A fully Integrated Urban Service is demonstrated where the component services collaborate (through knowledge-sharing based on information flows) and these are linked formally to urban-user needs through a process of co-design.

Table 13. Questions to assess impact of Integrated Urban Services in various sectors

Areas to assess integration	*Health*	*Disaster management*	*Water management*	*Energy*	*Industry*	*Transport*
Partners	Which partners should be involved? What partners are willing to be involved?					
Information	Is the needed partner willing to provide the information? How can specific information of the Integrated Urban Services be properly used and combined? What legal aspects are to be considered? Can co-production be achieved and a win–win situation be created?					
Weather/hydrological/ climate/air quality service(s)	What type and form of weather/ hydrological/ climate/air quality information is needed by the health services?	What type and form of weather/ hydrological/ climate/air quality information is needed by the emergency disaster management services?	What type and form of weather/ hydrological/ climate/air quality information is needed by the water supply and drainage sector?	What type and form of weather/ hydrological/ climate/air quality information is needed by the energy sector?	What type and form of weather/ hydrological/ climate/ air quality information is needed by industry?	What type and form of weather/ hydrological/ climate/air quality information is needed by transport services?

4.4 Evaluating Integrated Urban Services in demonstration cities

The following section applies the principles discussed above to map demonstration cities in terms of levels of integration. This qualitative analysis uses information provided in the demonstration city summaries (Annex 2). Keep in mind that the summary template used to gather information was limited in scope, and so this exercise should be seen as indicative of the range and complexity of the Integrated Urban Services already in place. It will also become clear there is a variety of approaches to provide the same Integrated Urban Services. For example, some of the demonstration cities are part of a national system of service provision where Integrated Urban Services must be designed to suit city needs, while others are "city states", where the distinction between general and urban services is moot.

Integrated Urban Services in the demonstration cities are at different stages of maturity and completeness. Challenges, issues and new solutions arise at each stage of development of Integrated Urban Services. Therefore, services already completed and also those in development should be looked at when designing or planning a new service. This will be useful in the early stages of Integrated Urban Services planning.

4.4.1 *Cross-service analysis*

Integrated Urban Services should provide a service that brings more value than just the juxtaposition of data from several sources, by a greater level of integration or combination of services. For example, using a website where meteorological and air quality data are available for use fulfils the lowest level of integration, but co-analysis of the meteorological and air quality data would provide added value (consistency, accuracy and efficiency), such as improved indicators and forecasts, and is a higher level.

To integrate services, useful data must exist and be available, at least among the partners involved in the construction of the Integrated Urban Services. For example, providing rainfall data from the weather service may allow the hydrological service to improve and produce precise flooding information. Thus, to provide the service, free and open data exchange within and among WMO Members and service provider partners is strongly recommended.

Ultimately, the Integrated Urban Services have to be delivered in a useful form; otherwise, they will not be used. This can happen in several ways, depending on the requirements of the end user and of the Integrated Urban Services. For example, they could be delivered to public or emergency services (through alerts and warnings via the Internet, television and smartphones), to newspapers or through city documents (as urban planning legal documents) or even to ftp (file transfer protocol) sites for use by other institutions. These will be highly tailored products and are considered the highest level of integration.

The overall picture of cross-service integration extracted from the summaries (Figure 5) shows the links among the weather service and the other services are by far the strongest, followed by those of climate and other services. Considering service pairs, weather/hydrological are strongly integrated while weather/climate and weather/air quality are slightly less. Hydrological/air quality integration is understandably weak. Climate/hydrological is strong, and climate/air quality is less so. Air quality services have the weakest overall integration (except with weather), and were most likely to be part of a research project.

4.4.2 *Cross-sector analysis*

The lowest level of integration occurs where the services design and implement an Integrated Urban Service with no significant engagement of urban sectors or city authorities. This is typically the case for services provided by NMHSs at the national level, where forecasts and warnings/alerts are provided for institutions and the public without regard to location. The NMHSs may, for example, provide some general guidance for city inhabitants in case of extreme events (for example, to avoid vehicle travel because of risks of tree falls, icy roads or river flooding), and may even have completed some minimal cross-sector engagement such as to identify needs. However, city authorities have had no substantial engagement with the design and evaluation of the Integrated Urban Services.

Higher-level integration that produces specific, city-tailored Integrated Urban Services needs city authorities (or acting agencies) to be involved in the creation and implementation process, through financial or in-kind (expertise, time and/or provision of fine-scale urban data) investments. This also requires specific investment from NMHSs. This co-production will tailor service provision to the specific needs of individual cities. For example, for urban planning and climate plans, city authorities may simply use observed data from the nearest synoptic weather

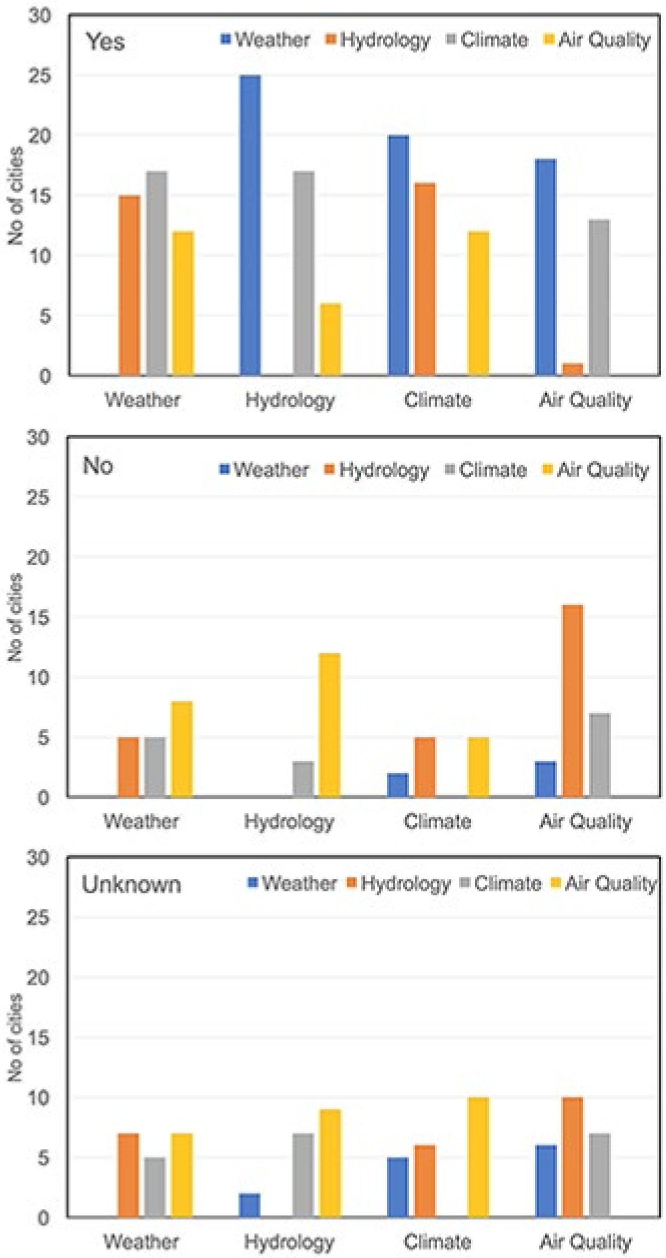

Figure 5. Numbers of demonstration cities with information exchange among different components (labelled "Yes", top), with no exchange (labelled "No", middle) or where provision of the service is unclear (labelled "Unknown", bottom). Total number of demonstration cities = 27.

Source: Heinke Schluenzen, University of Hamburg station (often the airport) to specify building codes. This would be a base-level Integrated Urban Service. However, a more complex Integrated Urban Service, co-designed and co-constructed with city authorities (for example, through contributing monitoring stations), might include fine-scale urban and intra-urban meteorological data to include local urban climate. A temperature monitoring network within a city may provide information on the spatial nature of the urban heat island.

A higher level of partnership would involve Integrated Urban Service providers, city authorities and researchers (for example, social scientists), who would define improved ways to identify and transfer or translate the urban climate information, such as urban climate maps, for application to urban planning. Other high cross-sector partnerships include: (a) involving health expertise in specifying observation requirements and defining thresholds for hazardous air quality or temperature alerts (heatwaves and cold waves) and (b) involving air quality expertise as well as legal, technical and socioeconomic expertise to alter the urban structure, land use, traffic and zoning by-laws. Air pollutants and the urban structure have a complex relationship in terms of emissions. Improving fine-scale knowledge of emissions, air pollutants and particle concentration information in cities may lead to better predictions and therefore more-effective health warnings.

The overall picture of cross-sector integration extracted from the summaries (Figure 6) shows the weather service was involved in the greatest number of Integrated Urban Services in the demonstration cities and was highest for air quality. Disaster management (and reduction) was a sector needing all services. Weather for health, water management and transport, hydrology for water management, and air quality for health were noted in the demonstration cities. Energy applications were least developed; energy, industry and transport applications were less common than health, disaster reduction and water management ones. The lowest frequency service/sector pair was air quality for water management.

4.5 Overview of Integrated Urban Services in demonstration cities

The authors of this Guidance used the principles and analysis discussed above to place Integrated Urban Services examples for the demonstration cities within a schematic consisting of four quadrants (Figure 7). The vertical axis represents the degree of cross-service integration and the horizontal axis the degree of cross-sector integration. The symbols represent three types of Integrated Urban Services that deal with daily operations (for example, weather forecasts), emergencies (short term, hazard events) and planning issues (long term, climate events). A city that has several Integrated Urban Services can appear on this diagram in several places.

Moving from left to right is a measure of the level of integration among service providers and urban partners (cross-sectors). On the left, services are provided but there is no substantive engagement with the urban partners and city authorities in particular. On the right, the Integrated Urban Services are a product of ongoing collaboration with city authorities and are likely to engage socioeconomic scientists, regulatory agencies and policymakers.

Moving from top to bottom indicates the level of integration among the four services. At the top, the Integrated Urban Services provide limited information (often just data) generated by linking two or more services. Towards the bottom, enhanced collaboration among the services supported by data sharing supports the development of highly tailored products at urban scales using numerical and/or statistical models. Not all services need to be integrated in a particular city; they will depend on the requirements for the Integrated Urban Services. As examples, Mexico City and Stuttgart were judged to have a high level of cross-service integration.

The top-left quadrant represents Integrated Urban Services that have limited cross-sector and cross-service integration. These Integrated Urban Services provide information that links few services and has undergone limited processing to support city-specific needs (Figure 8). The top-right quadrant is distinguished by the level of integration with urban partners to meet their needs; this includes engagement to develop the Integrated Urban Service and link the information provided with decision-making. The lower-left quadrant represents the development of sophisticated systems that join the knowledge and products of individual services to create enhanced products such as climate projections and (multi-)hazard forecasts for individual cities. The lower-right quadrant represents the highest level of integration along both axes, that is, sophisticated products developed in collaboration with urban partners.

It should be noted that as an Integrated Urban Service matures over time, it will shift to the right and towards the bottom within this schematic. Naturally, the Integrated Urban Service will depend on the capacity, capability, maturity and resources of NMHSs, city authorities and other urban sectors. For the initial stage of the Integrated Urban Services, the services provided currently by NMHSs may be sufficient to cover the initial needs of a city. In the case of

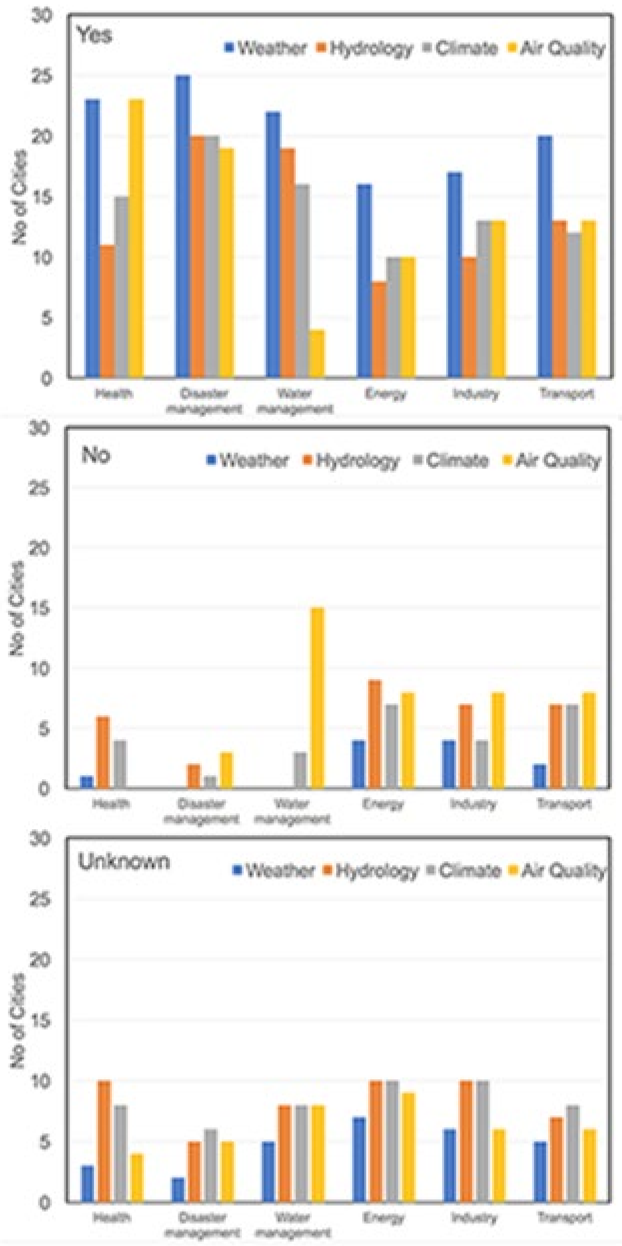

Figure 6. Sectors that used weather, hydrological, climate or air quality services based on demonstration city summaries. "Yes" indicates it was clearly stated in the summaries that the sectors used the services, "No" indicates they did not and "Unknown" indicates where it was not clear. Total number of demonstration cities = 27.

Source: Heinke Schluenzen, University of Hamburg more mature Integrated Urban Services, the city authorities and others will have contributed resources that may affect the design, construction, production and implementation of Integrated Urban Services.

The location of a city on Figure 7 represents the judgement of the expert team that wrote this Guidance based on the evidence in the city summary data (Annex 2).

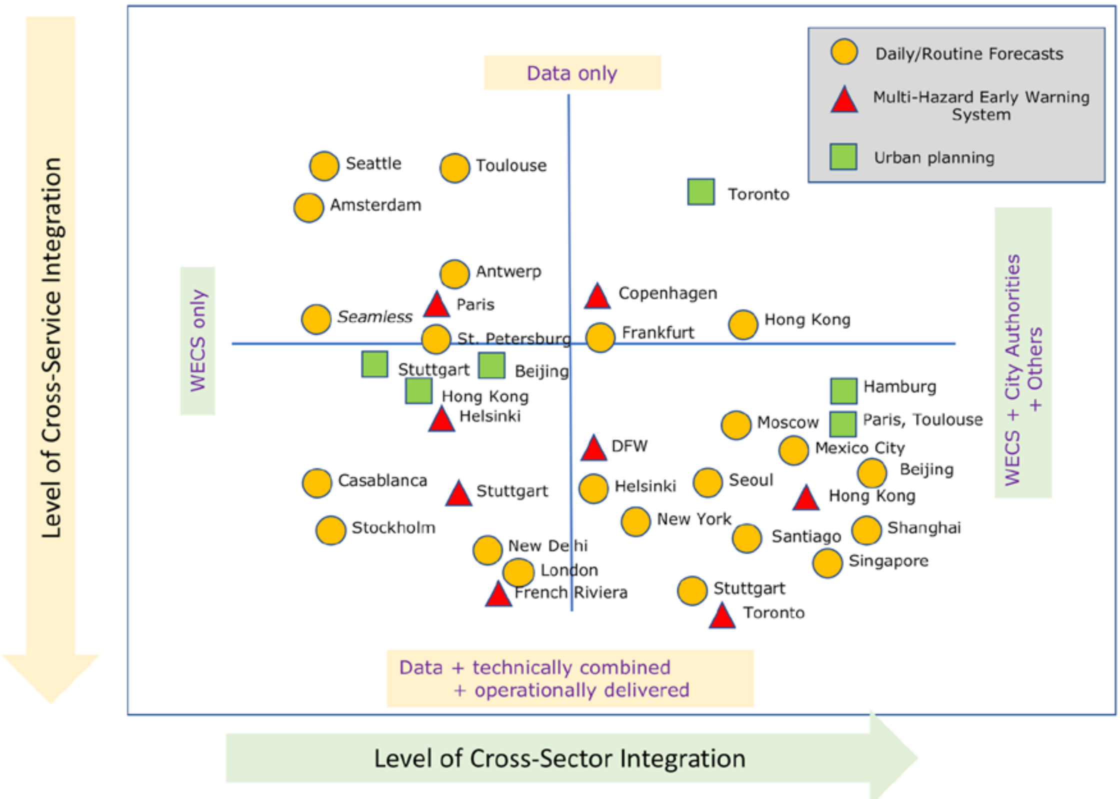

Figure 7. Assessment of the degree of urban services integration in demonstration cities. Data are plotted versus the degree of multiservice integration with degree of multisector integration. Symbols represent the general application of Integrated Urban Services; a demonstration city may be plotted more than once to represent the different status of a specific urban service component. WECS refers to weather, environment and climate services.

Source: Valéry Masson, National Centre for Meteorological Research

Figure 8 provides an interpretation of the cross-service and cross-sector integration and Table 14 provides a legend of the symbols in Figure 7.

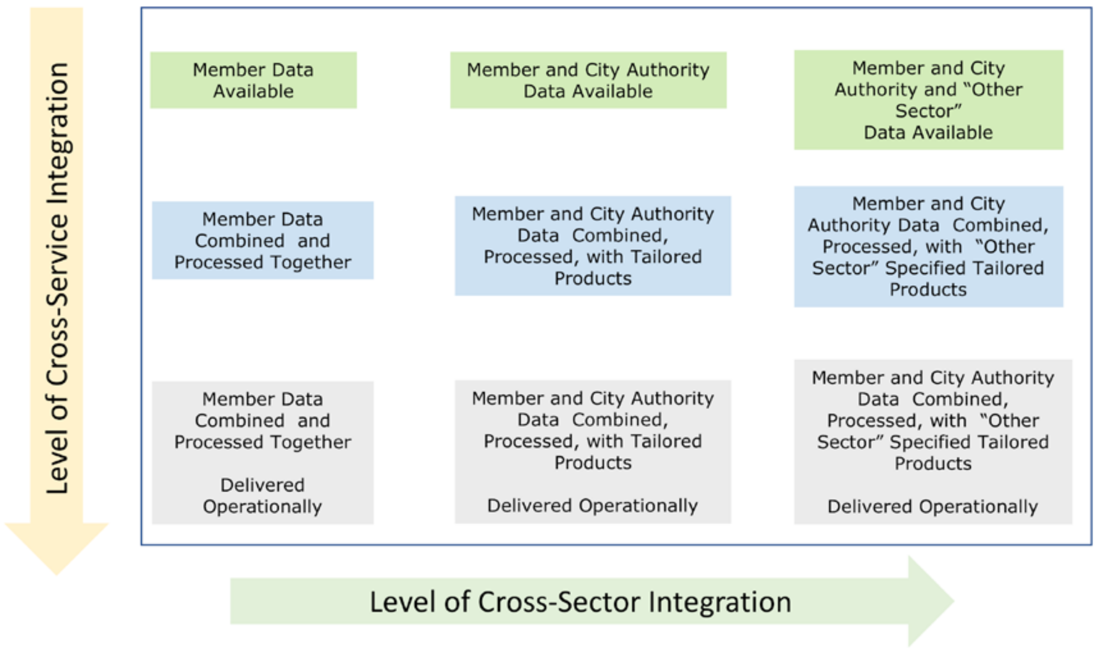

Figure 8. Explanation for the degree of cross-service with degree of cross-sector Integrated Urban Services classification ("Member" refers to national-scale data or services)

Source: Paul Joe

Table 14. Cross-service and cross-sector integration level legend for Figure 7

Symbol in Figure 7	*City*	*Area where integration is established*
●	Amsterdam	Air quality data on website
●	Antwerp	Flood control plan
●	Beijing	Many sectors, weather, climate, hydrology and air quality services with users
■	Beijing	Urban ventilation corridor and urban climate map for urban planning
●	Casablanca	Weather forecast and climatological information for urban planning
▲	Copenhagen	Climate and extreme weather
▲	Dallas–Fort Worth (DFW)	Severe storms hazard; uses data generated by the National Weather Service, city agencies and third parties for severe storm hazards
●	Frankfurt	Weather services, across all services

Symbol in Figure 7	*City*	*Area where integration is established*
▲	French Riviera	Flood emergency local forecasts and assistance to emergency services
■	Hamburg	Multisectoral and multidisciplinary climate adaptation and mitigation strategy including adopted urban planning
●	Helsinki	Weather and air quality forecasts and warnings
▲	Helsinki	Forecast of dispersion (for security issues)
▲	Hong Kong, China	Typhoon and storm surges for emergencies
■	Hong Kong, China	Typhoon and storm surges for daily operations
●	Hong Kong, China	Long-term urban planning
●	London	Thames barrier flood service
●	Mexico City	Multi-hazard management in command centre, comprehensive air quality and climate action plans, and personal health index
●	Moscow	Comprehensive Integrated Urban Services for weather, air quality and hydrology provided to the Russian Government; urban monitoring network and urban modelling is in development
●	New Delhi	Air quality warning to city management and traffic control
●	New York	Integration in city office to make climate change projections
▲	Paris	Road watering for cooling in case of heatwaves
●	Saint Petersburg	Operational Integrated Urban Services; ongoing development related to freshwater availability and urban planning
●	Santiago	Comprehensive air quality management and climate action plans, including daily forecasts of meteorology and air quality; green tax on new cars, power plants and industries
●	Seattle	Diffusion of meteorological and air quality data on website

Symbol in Figure 7	*City*	*Area where integration is established*
●	*Seamless*	*This point is provided for reference, it demonstrates where seamless tools for weather, climate and environment that could be implemented within NMHSs would lie on this diagram (reflects cross-services integration)*
●	Seoul	Integration of observations, model and user-specific services
●	Stockholm	Copernicus project C3S UrbanSis on air quality, weather and climate
●	Stuttgart	Heat warning system; the German weather service forecast is used and modified with web-based and email messaging
●	Shanghai	Weather link to air quality and air quality link to health
●	Singapore	Four services produced with city authorities with ongoing development
●	Toulouse	Dense open-data urban meteorological stations network
▲	Stuttgart	Heat warning system
■	Stuttgart	Urban development outline plan
■	Paris, Toulouse	Multidisciplinary evaluation of adaptation strategies and planning
▲	Toronto	Air quality, weather, health forecasting for emergency services and Pan American games organizers
■	Toronto	GHGs, air quality modelling and monitoring with information for local stakeholders

5. EXAMPLES OF DEMONSTRATION CITY GOOD PRACTICES

This chapter reviews the demonstration city summaries for good practices against the framework detailed in Chapter 4. The examples presented below are also put in the context of the recommendations made in Volume I (WMO, 2019*a*).

5.1 Do not wait for disaster

Integrated Urban Services are developed to assist decision makers and end users; it is important not to wait for a disaster to occur. Examples of well-functioning Integrated Urban Services that can be used as templates for development are presented in the following sections.

5.1.1 *Pollution forecasts and emission restrictions in Santiago*

In Chile, the providers of urban services in Santiago are mainly government services (ministries). The Ministry of Environment and the Chilean Meteorological Service are together responsible for providing daily forecasts of meteorology and air quality. Air quality forecasting tools are included in the decision-making process and are required for predicting pollution episodes to reduce exposure to harmful levels of pollutants. A system forecasting fine particulate matter ($PM_{2.5}$) 3 days in advance has been implemented and has enabled local governments to make contingency-based emission restrictions. As a consequence, there were 36 pre-emergencies and emergencies for $PM_{2.5}$ in 2013 before the system was implemented, but only 2 in 2017 (Annex 2). Forecasts and meteorological bulletins are published daily by the Chilean Meteorological Service through a website, television (news) and social media (for example, Facebook, Instagram and Twitter).

5.1.2 *Integrated severe weather, air quality and health warning systems in Toronto and Stuttgart*

In Canada, Toronto hosted the high-profile Pan and Parapan American Games in 2015. Many events occurred simultaneously, at many venues, and with large crowds who may be exposed to heavy precipitation/flooding, lightning, strong winds including tornadoes, hail, heat stress and poor air quality. Toronto is situated near a lake; the lake breeze can have a significant impact on thunderstorm initiation, heat stress and air quality. Previous experience of events with large crowds (such as the Olympic Games, papal visits and music festivals) established the requirement for high spatial and temporal precision and accuracy, and multi-hazard nowcasts including public warnings for severe weather, air quality and heat stress (health) warnings at specific venues. An urban network of black globe thermometers (used to calculate heat stress) was deployed. The venue-specific warnings, in addition to the normal public warnings (targeted for much bigger areas), were disseminated to event organizers, emergency planners, police (multiple levels), and civil and health authorities. Specialized briefings, tailored products and protected websites were created. Specific training was developed, and dedicated forecasters provided interpretations as required.

In Germany, Stuttgart introduced the "Feinstaubalarm" (a fine dust alarm system for particulate matter with a diameter greater than 10 μm (PM_{10})) in 2016. This alarm system informs citizens during periods with poor air pollution dispersion conditions (October to April each year) that high PM_{10} concentrations are expected. The alert triggers actions for citizens, for example, voluntarily switching to alternative transportation or prohibiting use of wood stoves during the high PM_{10} alert period. A law was introduced managing the non-essential use of "comfort fireplaces" or wood stoves. The city government introduced the law in agreement with national and European law, but it is specific to Stuttgart. The PM_{10} alarm is disseminated via email, websites, Facebook, Twitter, radio stations, newspapers and several display panels in the city.

5.1.3 *Integrated city services for disaster prevention in New York City*

In the United States, NYC government, stakeholders and end users plan together to prepare for disasters. NYC city planners are responsible for the regulations, laws, plans and policies, and the NYC emergency management looks after mitigation and preparedness strategies for hazards and disasters. Different providers such as Volunteers of America, the Center for Urban Community Services, Samaritan Village, Project Renewal and others work together at a time of crisis (https://www1.nyc.gov/site/dhs/shelter/providers/providers.page). Academic institutions such as the State University of New York and Columbia University work together to mitigate climate change risks and hazards. Different programmes and initiatives such as Notify New York City, New York City Severe Weather, Know Your Zone and Partners in Preparedness have developed adaptation analyses and regulations. For example, Community Risk and Resiliency Act are in place to understand and provide services at times of hazards (https://www1.nyc.gov/site/em/index.page; https://www.dec.ny.gov/energy/100236.html). NYC has a presence on many social media channels. This facilitates real-time, two-way communication between city authorities and the public.

5.1.4 *Integrated services for public health, water and energy with infrastructure design for disaster risk reduction in Hong Kong, China*

In Hong Kong, China, the Hong Kong Observatory (HKO; the meteorological authority in the city) has successfully cultivated close partnerships with various stakeholders to enhance its weather and climate services over the years. In alignment with the priority areas of the WMO Global Framework for Climate Services (WMO, 2018*b*), the big data concept has been used in recent years (Shun and Chan, 2017), in particular in areas related to disaster risk reduction, energy, water and health.

In collaboration with other government departments, tertiary institutions and social enterprises, HKO has been studying the impact of weather on public health in Hong Kong, China. Some examples include:

- HKO has worked with the Chinese University Hong Kong to develop the Hong Kong heat index for use in a hot and humid subtropical climate (Lee et al., 2016) and to study the health impacts of extreme hot weather events (Lau and Ren, 2018; Wang et al., 2018). In-house heat stress monitoring systems automatically measure the dry bulb, natural wet bulb and globe temperatures required to compute the Hong Kong heat index.
- HKO has also collaborated with microbiologists at the Chinese University Hong Kong to study the seasonal variations of influenza to prevent seasonal peaks and to understand how weather and climate condition affect the spread of disease (Chan et al., 2009).
- HKO works closely with the Senior Citizen Home Safety Association to study how weather and climate affect the health of senior citizens (Mok and Leung, 2009; Wong et al., 2015) and to enhance care services for the elderly in Hong Kong, China, through the utilization of weather and climate information (Lee and Leung, 2016; HKO, 2018).

To support water resource management in Hong Kong, China, HKO has been providing monthly forecasts of yield in reservoirs to the Water Supplies Department since 2010. Verifications showed the yield forecast was generally better than climatology, demonstrating the benefits of climate prediction for managing water resources (Lam and Lee, 2012).

After the occurrence of severe acute respiratory syndrome in 2003, a series of application-based urban climate-related governmental consultancy projects were launched, and design measures formulated and implemented into local planning and development (Figure 9) (Ng, 2009; Ren et al., 2011). HKO has been providing technical support and weather records in these consultancy projects. Other application-based projects in mainland China and overseas have adopted the knowledge of the impact of high-density urban morphology on local climatic conditions and design-related outcomes from Hong Kong, China (Ren et al., 2018).

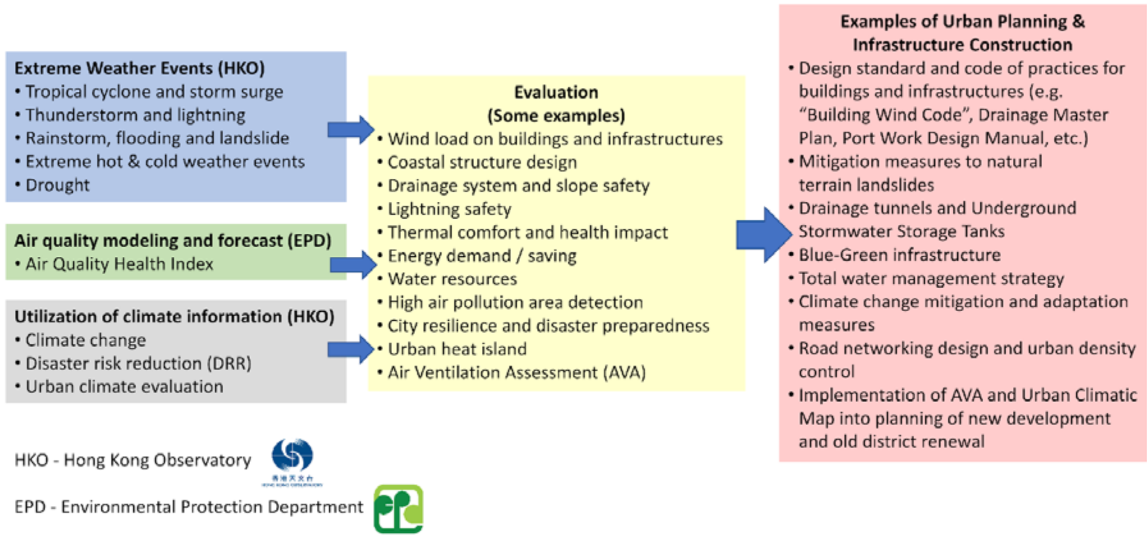

Figure 9. Examples of integrated weather, climate and environmental services in urban planning and infrastructure in Hong Kong, China

Source: WMO (2019*a*)

With a view to promoting energy efficiency and conservation, HKO and Power Hong Kong Limited have collaborated to provide a 9 day energy forecast from the HKO 9 day weather forecast. The energy forecast allows property managers to efficiently plan energy saving measures to reduce electricity consumption and peak loading under hot weather situations (Cheung et al., 2016).

Over the years, HKO has worked closely with different engineering departments and professional bodies to establish, and regularly review, the engineering design standards and codes of practices appropriate to local conditions for protecting the city and the public against various weather hazards and natural disasters. Some examples include the Code of Practice on Wind Effects, estimation of extreme rainfall return periods and probable maximum precipitation, and anticipated highest sea level incorporated in the Port Works Design Manual.

5.1.5 *Beat the heat!! Ahmedabad, India – a United Nations Educational, Scientific and Cultural Organization heritage city*

Ahmedabad (a city in western India with a population of over 7 million population), along with national and international organizations, has developed an efficient and effective heat action plan (HAP; Natural Resources Defense Council, 2019) since 2011. The three key strategies were to: (a) build public awareness and community outreach on the risks of heatwaves and practices to prevent heat-related diseases, (b) initiate an early warning system to alert residents and (c) train medical professionals to recognize and respond to heat-related diseases.

Heat predictions are made 5–7 days in advance and utilize the early warning system to alert the governmental agencies, the Met Centre, health officials and hospitals, emergency responders, local community groups and media outlets of forecasted extreme temperatures. In addition to these actions, several preventive measures were also implemented, including raising public awareness, improving community outreach, training health officials, and providing access to potable drinking water and cooling spaces during extreme heat days. The plan mainly focuses on those individuals who are most at risk during heatwaves, such as slum communities, outdoor workers, the elderly and children. The preventive measures include few simple but vital measures like learning about early signs of heat exhaustion, limiting heavy work during extreme heat, drinking plenty of water, staying out of the sun, wearing light clothing, checking on neighbours and informing fellow community members about how to keep cool and protect themselves from heat.

The Ahmedabad HAP was the first one in South Asia, showcasing a unique example of an Integrated Urban Services approach. With the leadership of the National Disaster Management Authority and the Indian Meteorological Department, as well as partners such as the Natural Resources Defence Council and the Indian Institute of Public Health Gandhinagar, HAP has now been implemented in 11 Indian states and 30 Indian cities.

5.1.6 *Leadership by WMO Members*

WMO Members are encouraged to contribute to the development and promotion of Integrated Urban Services in their Member countries (WMO, 2019*a*).

In China, since 2007, the Shanghai Meteorological Service has successfully conducted several WMO programmes including the Shanghai Multi-Hazard Early Warning System (MHEWS), the Shanghai GURME project and the Shanghai Typhoon Land Falling Forecast Demonstration Project under the support of the China Meteorological Administration. The research projects have effectively promoted the development of modern meteorological practice and played an important role in crisis and risk management. WMO convened the MHEWS and Megacity Implementation Plan expert meetings in Shanghai in August 2013.

The Shanghai Integrated Urban Weather and Climate Service Demonstration Project aims to develop seamless multi-timescale weather forecast capabilities by introducing advanced technology and weather/climate disaster management theory. Using numerical models, the project will develop an impact-based forecasting and warning system, improve urban climate services, interact with users of information services and help the city to manage risks caused by climate change. The project is an extension of Shanghai MHEWS as well as a demonstration of how the Global Framework for Climate Services can be applied to urban areas. At the research frontier of disaster prediction and reduction, the Integrated Urban Weather and Climate Service Demonstration Project represents the international community's joint efforts to adapt to climate change.

5.2 Governance of Integrated Urban Services

NMHSs should work with their partners and governmental institutions on national and city scales to ensure that legal and institutional frameworks that clearly define partners mandates, roles and responsibilities to enable, create and maintain Integrated Urban Services are in place (WMO, 2019*a*).

5.2.1 *State-wide regulations helping cities*

The United Kingdom Civil Contingencies Act 2004 provides a governance framework for dealing with all types of threats to the public in the United Kingdom. It applies to all levels, from the national to city to business to individual, providing a scalable model that could be copied elsewhere. It was enacted in the wake of perceived weaknesses in the emergency response to several major disasters around the year 2000, including floods, an animal disease epidemic and rioting. It defines an "emergency", as a human or natural threat that threatens serious damage to human welfare. It superseded the previous concept of civil defence against military threats that arose following the Second World War.

The act also broadens the scope of those involved beyond local government and the emergency services to include utilities and infrastructure authorities. It lays down requirements for risk assessment and contingency plans, and defines who has responsibility and who has authority.

The act mandates use of a gold–silver–bronze command structure. Two types of emergency responders are defined. Category 1 – the core group of responders – consists of local authorities, police, fire, ambulance and coastguard services, health services, the Environment Agency, the Scottish Environment Protection Agency and Natural Resources Wales. Category 2 largely comprises infrastructure operators: electricity, gas, water and telecommunications providers; railway, highways, airports and harbour companies; and the Health and Safety Executive and voluntary agencies. In an emergency, each responder has its own command structure but contributes to a multiagency structure, hosted and chaired by the police. The gold commander provides remote strategic oversight. The silver commander manages its implementation; the bronze commander formulates and implements actions locally. The multiagency silver commander is typically located in a command vehicle at or near the scene.

Supporting legislation requires category 1 responders to have regard to the Met Office's duty to warn the public, and provide information and advice, if an emergency is likely to occur or has taken place. This duty includes issuing warnings such as for severe weather and pollution episodes, together with tidal alerts.

5.2.2 *Regulations at different levels – from State to local*

In Mexico, civil protection is supported by different levels of legislation, including:

(a) Constitution: Article 123 covers the security and health of workers in facilities.
(b) State law: the General Act for Civil Protection defines the general terms of each state law on civil protection and the regulation of each state on civil protection. As Mexico City is also the capital of the nation, it can never become a state; however, Mexico City has the same level of autonomy comparable to that of a state. The following institutions are responsible for addressing urban hazards and the policymaking process:
    (i) National Water Commission: provides national plans and mandates for flood management.
    (ii) National Meteorological Service: provides meteorological information at national and local levels, and manages the climatological database.
    (iii) National Centre for Disaster Prevention: in charge of risk management and disaster prevention in Mexico to reduce population exposure to meteorological, hydrological, geological and chemical hazards such as volcanic eruptions, flooding, tropical storms, earthquakes and chemical releases.
    (iv) Secretariat of Environment of Mexico City: responsible for climate action plans and air quality management programmes, including air quality and meteorological forecasts to alert the public about critical pollution levels and prevent exposure to harmful pollutants; it also announces contingency actions when measured pollutant levels are above a critical threshold.
    (v) Megalopolis Environmental Commission: covers Mexico City and five surrounding states (Hidalgo, Mexico, Morelos, Puebla and Tlaxcala) in central Mexico. The commission plans and executes policies, and handles air quality monitoring, emissions standards and smog-check issues in this region.
(c) The urban services for Mexico City are provided by the city government through the different agencies that report to the mayor and the public. The centre for Command, Control, Computers, Communications and Citizen Contact integrates the urban services to provide rapid responses to emergencies in the city. Agencies send information to the centre, which reports directly to the mayor.

5.2.3 *Regulations for a city in a state*

In China, the Shanghai People's Congress issued the Shanghai Implementation Regulation of the Meteorological Law of the People's Republic of China on 1 October 2006, and the Shanghai Municipal Government issued the Measures for the Defense of Meteorological Disasters in Shanghai on 1 March 2017. These clarified the mandate of Shanghai Meteorological Service in disaster risk reduction and weather/climate/environment services. Weather departments are required to provide services through multiagency cooperation, and to receive support and feedback from different sectors such as water, traffic and transportation, environment and emergency response.

5.2.4 *Regulations for a city state*

In Singapore, the Meteorological Service Singapore is a division of the National Environment Agency, which is a statutory board under the Ministry of the Environment and Water Resources. This ministry also oversees the Public Utilities Board (the national water agency) and the Singapore Food Agency. Synergistic issues of climate/weather, water, air quality and food security come under the remit of this single ministry, thus enabling a holistic approach to policymaking.

The National Environment Agency Act empowers the National Environment Agency, through the Meteorological Service Singapore, to: provide meteorological services for users, including government agencies, aviation and shipping communities and the public; maintain reliable climatological records of Singapore; and provide advice on meteorological matters.

Singapore is a low-lying island vulnerable to the impacts of climate change. The Government of Singapore is actively attempting to address the challenges of climate change. To reduce carbon emissions, a carbon tax was introduced in 2019, which targets large industrial facilities. Under the Carbon Pricing Act, taxable facilities have to engage a third-party verifier to verify their annual emissions report.

Cross-sector coordination, necessary for the delivery of Integrated Urban Services, is enabled through a “whole-of-government” approach adopted by Singapore government agencies. This approach allows the establishment of institutional frameworks to better manage and coordinate cross-cutting issues such as transboundary haze and climate change. For example, an Inter-Ministerial Committee on Climate Change was set up to enhance whole-of-government coordination on climate change policies, such as long-term adaptation planning in areas of coastal protection, water resources, public health, biodiversity and network infrastructure.

5.3 Involve multiple stakeholders

> NMHSs should engage with relevant stakeholders (for example, agencies, universities, the public, other Members, city governments and the private sector), right from the beginning to ensure clear articulation of the value of Integrated Urban Services, to obtain user feedback and to co-design of future services (WMO, 2019*a*).

Many cases have shown the benefit of Integrated Urban Services for cities. The French cities of Paris and Toulouse decided to continue the co-development of operational Integrated Urban Services after initial research projects. Toulouse decided to install an observation network for urban climate. Paris City Council commissioned a first research study in 2008 on adaptation strategies for heatwaves (present and future). Numerical modelling explored the influence of building colour, vegetation and road watering in inner Paris and gathered evidence of the impact, efficiency and optimization of road watering during heatwaves. It found potential impacts of more than 1 °C on the thermal comfort index.

A national programme was initiated to understand the limiting factors for implementation of Integrated Urban Services and to determine which French cities would benefit from them. A collaboration among MeteoFrance, the French federation of urban planning agencies (with 51 agencies) and social scientists was formed. A survey found the urban planning agencies do not have: (a) access to the same data, (b) the same expertise in climate and local meteorology and (c) the same political environment. Another general conclusion was that it is not sufficient to have evidence from elsewhere, but there is a need to replicate the experience and develop experimental evidence locally. Experiences in other cities has helped to reach the first stage in the planning, development and use of an Integrated Urban Service.

A good way to initiate the use and co-production of Integrated Urban Services with cities is to establish a common source of information such as urban data (from the national mapping service) and meteorological data (which has the advantage of crossing administrative boundaries). During project MApUCE, urban parameters were computed for 50 French agglomerations and were distributed freely as open data (MApUCE, 2019). This access to new data, designed for urban climate studies, favours the co-production of an Integrated Urban Service locally. Higher-resolution data can be used, as local authorities recognize the need.

Actions with French national stakeholders and institutions that support the needs of local ones have bolstered the diffusion of Integrated Urban Services needs to city and agglomeration scale.

5.4 How research helps

NMHSs should work closely with relevant partners to conduct further research, particularly multidisciplinary cross-cutting studies, to develop Integrated Urban Services capabilities (WMO, 2019*a*).

5.4.1 *National programmes*

Interdisciplinarity is essential for Integrated Urban Services, due to the complexity of cities. In France, several research projects in Paris and other cities had the objective of improving Integrated Urban Services capabilities for urban planning and adaptation of cities to climate change. Implementation of these projects required collaboration of scientists from various disciplines: meteorology, hydrology, architecture, geography, sociology, economics, acoustics and environmental law. In addition, the participation of urban planning agencies and city administrations was a key to success. Engaging such interdisciplinary teams of researchers takes years, because of different languages and expertise; however, once formed, it allows for the integration of several interconnected pieces of the urban system. This poses an important implication for Members, as urban characteristics such as city growth, human behaviour and architecture are pertinent to developing urban modelling tools to evaluate interactions among the urban heat island and heat/air quality and waste heat release. It is also pertinent to study the impact of climate change and city growth on population exposure depending on different density and urban vegetation strategies.

Modelling tools are an efficient way to explore different concepts in some fields. Field studies help to explore and build a common interdisciplinary culture (for example, combining microclimate, noise pollution and social perception studies) around a common urban area. Such interdisciplinary research sometimes leads to pure disciplinary advances, which are necessary to unlock questions asked by other disciplines.

These research findings are now applied in operational Integrated Urban Services. For example, construction requirements of the villages for the Summer Olympics in Paris 2024 were specified using: (a) local weather characteristics, (b) present and future climate conditions, (c) classical climate zones, (d) small-scale patterns of the city and (e) the urban heat index. Interdisciplinary research, while long and demanding to put in place, is necessary for urban climate services studies. It is also rich and scientifically profitable, from the point of view of encouraging cross-fertilization of different disciplines.

5.4.2 *City programmes for urban services*

In China, the city of Beijing launched the Study of Urban Impacts on Rainfall and Fog/Haze Project in 2014 to investigate urban, terrain, convection and aerosol interactions to improve weather and air quality forecast accuracy. Comprehensive multiscale observations and modelling enabled an international team of scientists to study, understand and better predict urban effects on heavy summer convective precipitation and winter fine-particle pollutant episodes in the Greater Beijing Metro Area. The Rapid-refresh Multi-scale Analysis and Prediction System was developed and included five offline, one-way nested components: the Nowcasting Model, the Short Term Model, the Urban Model, the Integration Model and the Chemistry Model. The system runs operationally at the Institute of Urban Meteorology, starting with global forecasts and terminating with weather and air quality forecasts for use by health, energy, hydrology, climate change, air quality, planning and emergency response managers.

5.5 Open access data policy

WMO Members are encouraged to facilitate wider accessibility of data by influencing ownership issues and providing technical support to enable Integrated Urban Services (WMO, 2019*a*).

5.5.1 *City-wide measurements*

In France, as part of an urban planning collaboration, the city of Toulouse decided to build a monitoring network for urban climate. This could be expanded to air quality measurements in the near future. This meteorological network is composed of 60 semi-professional stations and is included in the smart city policy (Figure 10). The objective of this network is to better observe the environmental conditions of the area and to allow the production of Integrated Urban Services. It may facilitate improvement of fine-scale urban weather forecasts, building heating system pilots, adaptation of the buildings and neighbourhood design and so forth. Critically, this network will soon provide open access data, to promote the production of such Integrated Urban Services.

Interest in freely and open access data, from cities and from NMHSs can motivate open access of the data from private companies (for example, the Netatmo personal stations network; https://www.netatmo.com/en-ca). All countries and national and subnational actors are encouraged to make their data freely available for production of Integrated Urban Services.

Figure 10. Example of urban monitoring using compact stations in Toulouse

Source: Valéry Masson, National Centre for Meteorological Research

5.5.2 ***City-wide data***

In the United States, Dallas–Fort Worth provides open access data and information at the local government level as well as data from the National Oceanic and Atmospheric Administration, the National Weather Service, the United States Geologic Survey and the Environmental Protection Agency. Several platforms that integrate and can be used for data sharing inform end users of the benefits of integrated systems. An example of the data from the urban radar network is shown in Figure 11. One such platform is the North Central Texas Council of Governments, a voluntary association of, by and for local governments, established to assist in regional planning.

The Texas Commission on Environmental Quality, the environmental agency for the state of Texas, provides another platform for data sharing. It manages a network of air monitoring sites across the metroplex in accordance with national Environmental Protection Agency regulations. The status of regional air quality is compiled annually in the North Central Texas Council of Government's *Air Quality Handbook*. These annual reports are available to all agencies and end users, and support is provided to analyse and interpret the presented data.

Figure 11. The Urban Radar Network (Dallas–Fort Worth) provides high-resolution, accurate low-level wind and heavy rain information for a variety of users. Information is communicated to and from users via mobile technology. NWS WFO refers to the National Weather Service Weather Forecast Office.

Source: Brenda Phillips, University of Massachusetts

In Germany, the city of Hamburg introduced an open access data policy that covers measurements (for example, used for air quality indicators or warnings) and all consultancy reports on assessments of environment or air quality, planning approaches or climate. This allows for large involvement of citizens as well as ensuring knowledge exchange between the administration and researchers. Knowledge exchange is supported by the round table KlimaCampus Hamburg, where researchers and administrators regularly sit together and discuss latest research results, emerging regulatory problems, future research approaches and possible solutions.

5.6 Showcasing Integrated Urban Services

WMO Members are encouraged to initiate demonstration projects to promote and advance development and implementation of Integrated Urban Services (WMO, 2019*a*).

5.6.1 *Example of Stuttgart*

The German city of Stuttgart (600 000 population in Stuttgart and 2.6 million in the region) has a long history of addressing urban climate and air quality (https://www.stadtklima-stuttgart.de/index.php?luft_rueckblick_1698) because of its specific geographic setting in a river valley between vineyards and thick woodland. The city is spread over several hills (549 m above sea level) and valleys, with steep slopes surrounding the city centre (207 m above sea level) on three sides. This affects surface radiation, air temperature, wind and air pollutant concentrations. Low air exchange and frequent inversions hinder dispersion of pollutants. In 1689, with 13 000 inhabitants, the upper council of the time feared that new buildings could hinder the transport of fresh air to the city, thus making it unhealthy. Consequently, a number of first measures were suggested. To this day, Stuttgart still takes measures to improve knowledge of air quality and urban climate. Responsibility for each measure and the legal basis are openly communicated on a web page (https://www.stadtklima-stuttgart.de/index.php?luft_luftreinhaltung_massnahmentabelle). All measurements are also available.

The Stuttgart example has inspired several cities worldwide, which plan to establish Integrated Urban Services.

5.6.2 *Example of Toronto*

In Canada, the Integrated Urban Services project for Toronto has been showcased through articles published in the *WMO Bulletin* (WMO, 2016), the *Bulletin of the American Meteorological Society* (Joe et al., 2018) and an Environment and Climate Change Canada report (Environment and Climate Change Canada, 2016). These publications are broadly used within and outside the meteorological community. In particular, lessons learned through retrospective examination of the project are valuable for development of Integrated Urban Services. Together, these publications and lessons learned provide evidence that the Toronto project has been communicated to a broad and relevant audience. Appearance in the published literature provides a legacy of information that can be accessed by anyone: the *Bulletin of the American Meteorological Society* (after a short embargo) and the *WMO Bulletin* are freely available online, and the government report is available online. The scope of the available material provides an example of good practice. In particular, *The Toronto 2015 Pan and Parapan American Games Experience: An Environment and Climate Change Canada Perspective* (Environment and Climate Change Canada, 2016) provides substantial details on the outcomes and lessons learned from the implementation of Integrated Urban Services. It provides a synthesis and guidance for the improvement of meteorological services in Canada. It also provides details on the initiation, planning, execution and outcomes of the Integrated Urban Services and thus can serve as a template for other cities who may embark on similar projects.

6. BRIDGING THE GAPS IN IMPLEMENTATION OF WARNING SYSTEMS

6.1 Gaps

This section uses the “value chain for provision of weather-related warning” concept (Zhang et al, 2019) to establish the gaps in implementation of the warning system (Figure 12). The starting point is the decision that needs to be made and then progress is made through the different levels of information that contribute towards enabling the decision to be the right one. Not all levels will be needed for all decisions.

6.1.1 *Decision-making*

The value of an urban service for weather-related hazards and climate change risks lies in the decisions that could be made differently if a service could possibly have been provided.

Some cities have identified a problem, often from a failure due to a disaster. Solution of the problem may require one or more decisions to be made in a specific city environment. Consistency of decision-making is important, whether for long-term planning or for rapid response to a disaster. Integrated Urban Services can contribute significantly to achieving consistency, leading to more efficient, sustainable and resilient cities.

Further work is required in the following areas to:

(a) Classify the weather-related decisions that city managers and residents would like to be able to make, in response to weather- and climate-related hazards, and the information needed to make them, including minimum required levels of precision, accuracy and reliability. Such decisions might relate to land-use planning, drainage and energy provision, stockpiling of equipment, rostering of staff, evacuation, search and rescue, and so forth.
(b) Understand how urban dynamics (such as population and traffic density, roads, buildings (for example, commercial and residential), land and resource use, and policies) influence weather/climate/water/environmental conditions, which can amplify the state of these to become hazardous to society and human well-being (for example, air quality, water quality and quantity, ecosystems, urban heat island effect and disease transmission).
(c) Identify a subset of these requirements that could be met, in principle, bearing in mind uncertainty associated with rapid and random variability in the surface and near-surface environment.
(d) Set limits to the lead time for which such information could be provided and the growth of that uncertainty with lead time due to non-linear interactions.
(e) Partition the decisions that city managers would like to be able to make into those for which information could be provided (in principle) and those that it will not be possible to meet.
(f) Establish conditions where integration of services will bring particular benefit by minimizing the risk from multiple hazards to the urban area and under which relevant information can be provided and exchanged, such as organizational governance, infrastructure, observation accuracy, model configuration and resolution.
(g) Understand and communicate the range and critical limit values of hazard-related variables and indices based on an integrated framework operating for urban services with respect to human health and environmental protection.
(h) Establish the reusability of information prepared to support real-time risk reduction decisions for use in long-term planning within an integrated framework for urban services set in the national context.
(i) Develop integrated decision support systems to efficiently present to technical experts and the public, relevant, often uncertain and conflicting information, to support warning decision-making at appropriate timescales. These systems should take into consideration the timing of impacts (now, imminent or decades), governance, societal impacts, consequences and action statements. Understanding the impact of an event on human response and behaviour is part of the decision-making process.

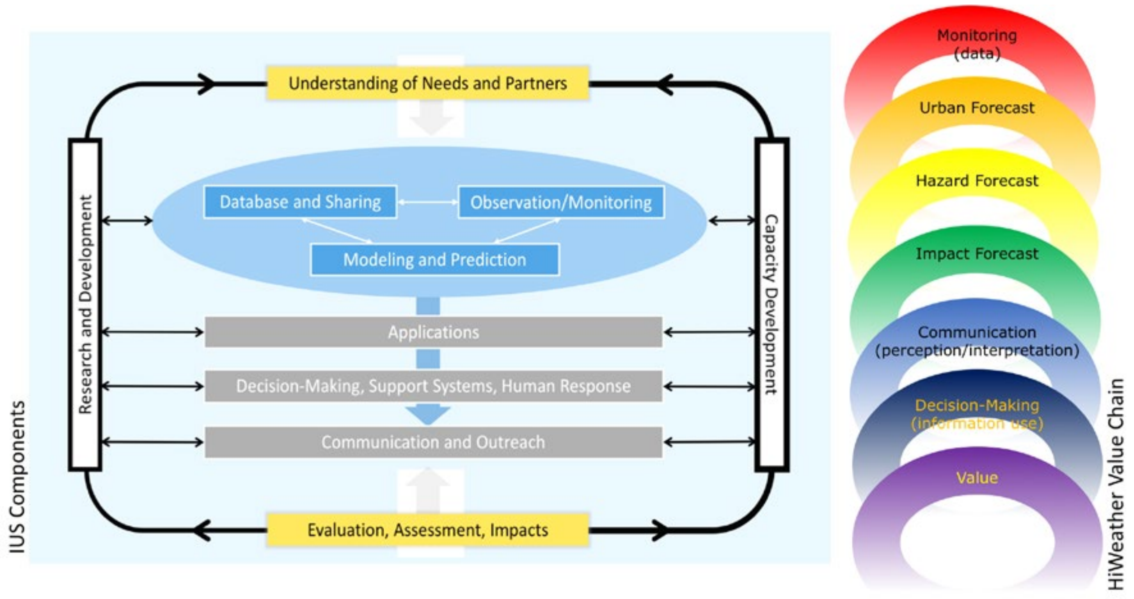

Figure 12. (Left) Integrated Urban Services (IUS) components (from Volume I) and (right) the HiWeather value chain representing information flow from decisions that need to be made, tracing backward through the different levels of contributing information and forward to assess the value of the decision made

Source: Adapted from WMO (2019*a*)

6.1.2 *Communicating information to decision makers (including the public)*

The decision maker needs to receive and understand the required information at the required time and location, for a useful decision to be made. This is particularly important when multiple services are operating within an integrated framework to ensure the efficient use of information that may reflect different hazards and urban and national departments.

Examples in this Guidance fall largely into two types: communication of information to experts, in which care is taken to design a system by which the specific needs of the recipient are met, and "open" communication, in which website design or other media determines how well communication will occur. Consistent communication of information in an integrated system helps to facilitate effective access and use by decision makers.

Further work is required in the following areas to:

(a) Identify the portfolio of communication channels needed to reach the whole population at risk, given the characteristics of the nature of the hazard(s), multiagency response, population affected (including gender, language and cultural diversity) and those with special needs.

(b) Identify the most effective means of preparing people to take protective action in the case of single or multiple hazards, including through education (school and adult), awareness-raising events, exercises and pre-warnings. Bear in mind research suggesting the reason people do not respond is that they do not know what to do; identify means to help people identify responses depending on the nature of the hazard and emergency and be prepared to take them. For those unable to respond themselves, identify procedures to ensure they receive help.

(c) Establish standards for the use of language and graphics to represent information, including the need to use appropriate idioms that may span a combination of different hazard disciplines when communicating in multiple languages, reflecting the importance of context, and appropriate use of symbols as an alternative to or reinforcement of words.

(d) Identify practices that build and destroy trust and belief of the information received, including identification of the source, sharing of information on skill and track record, and compatibility with prior knowledge (including indigenous knowledge, community memory, religious belief and age).
(e) Use language that communicates a useful perception of risk, incorporating the likelihood of the event and the severity of the likely impact, to expert users and to the general public, in emergency response and future planning situations.
(f) Promote good practices in working with decision makers to design integrated systems that promote effective use of information provided, for example, enabling merging of environmental data with the decision-maker's system status data and/or drilling down into detail to clarify specific detail.
(g) Design standards for open delivery platforms using an array of appropriate communication techniques that facilitate wide receipt and comprehension of information within an integrated framework.

6.1.3 *Producing information on expected socioeconomic impacts related to hazards*

Increasing evidence is accumulating about the benefits to decision-making of providing integrated information on the geophysical, chemical, biochemical and socioeconomic impacts of hazards on all timescales. However, a common issue among examples in this Guidance is the challenge of obtaining data to support the provision of such impact information, especially in the case of multi-hazard situations, either because the data are not gathered, because they are difficult to access or because they are confidential (for example, health data or proprietary business data).

Further work is required in the following areas to:

(a) Develop cost-effective methods for observing the impacts of weather and climate change or for extracting such impact information from related data.
(b) Set standards for exposure and vulnerability data used in impact assessment.
(c) Establish the scope and standards of impact assessment required to inform disaster response and planning, including air quality, health, energy and water.
(d) Develop methods for assessing multiple, cascading, compound and indirect impacts.
(e) Develop methods for dealing with weather- and climate-related impacts resulting indirectly from geological, technical or security hazards.
(f) Develop methods for dealing with slowly responding impacts, particularly in health, including vector-borne diseases related to climate change.

6.1.4 *Producing information on weather-related hazards*

Observation of the current state of the environment and its projection forward using dynamical and/or statistical models is central to the hazard information production process. Short-term information is conditioned on the currently observed state, using initial value approaches, including nowcasting, numerical weather prediction and machine learning. Long-term climate change information is conditioned on specification of the changing boundary conditions of factors such as atmospheric composition and land use, using analysis of past observations and future climate modelling. In both cases, dealing with the relevant environmental processes requires appropriate levels of coupling of models to represent the different environmental domains (such as a city within national and regional domains). In both cases, statistical post-processing may be required to represent the statistical distribution of unresolved variability. Examples in this Guidance emphasize benefits of integrating and linking models, particularly weather/hydrology and weather/air quality, and also of using modelling for short-term application to feed into long-term applications.

Further work is required in the following areas to:

(a) Define the observation requirements for the urban predictions needed to support the desired services under single- and multi-hazard situations. These will include observations of and within the urban fabric (urban canopy layer) that most directly connect to the relevant impacts, observations around and above the urban canopy that will drive the prediction models (roughness sublayer, constant flux layer and through the boundary layer), observations that can be used to evaluate and tune the models, and observations that enable processes to be described and understood.

(b) Define and establish infrastructure to support integrated observational and prediction information that will arise from coupled response systems such as weather/hydrology and weather/air quality, with links to health and socioeconomic impacts. Such infrastructure should take account of different users, the knowledge base and technical requirements.

(c) Define the characteristics of the urban environment, and their spatial and temporal resolutions, which need to be known to achieve required levels of precision and skill in the predicted hazards. These include building structure (for example, height, density and materials), surface (for example, materials, drainage and vegetation) and anthropogenic effects (for example, heat, pollutant emissions and concentrations). Some characteristics change slowly in time, while others change quickly. The fast-changing characteristics need to be specified in predictions and projections. Metadata need to be updated at appropriate time intervals.

(d) Distinguish the variables and their spatial and temporal scales that need to be predicted/projected dynamically from those that can be adequately inferred or downscaled. Identify appropriate strategies for incorporating the inferred variables in datasets.

(e) Solve the problem of initializing dynamical atmospheric models consistently at weather system scale, at convection scale and potentially at boundary-layer eddy scale, and of specifying initial and process perturbations that enable ensemble prediction of the distribution of uncertainty.

(f) Develop appropriate coupling strategies for different space scales and timescales that represent the significant sensitivities and that enable consistent prediction of hazards in separate and integrated environmental domains, while minimizing the complexity of the technical solution.

(g) Develop methods for incorporating a wider range of processes associated with important single and multi-hazards into weather and climate change modelling frameworks, including air and water quality, ecosystem response, disease occurrence, sediment transport, wildfires and dust storms, appropriately for short- and/or long-term applications.

6.1.5 ***Optimizing and evaluating the production and delivery chain***

The value in urban services lies in the benefits of the decisions taken at the end of the chain. Investment should be informed by the relative costs and benefits of improving each component of the chain, as well as the benefits of integrating the components along the chain. It is currently difficult to carry out such analysis due to the lack of information about how each component contributes to the overall value and to the lack of understanding of how to attribute value to contributors. Typical weather service verification can quantify the accuracy or skill of weather forecasts. Surveys and reviews provide snapshots of end value, typically of a whole service. Examples in this Guidance provide such measures of the end benefit of specific interventions. This needs to be done in a routine and consistent way if end-to-end optimization is to become possible, particularly where integration is shown to be beneficial.

Further work is required in the following areas to:

(a) Set standards for routine evaluation of urban services, including data collection, analysis and distribution, decision-specific and user-oriented process evaluation, and impact evaluation of socioeconomic benefits and costs of the integrated system.

(b) Establish methods for modelling the value chain to enable routine assessment of the contributions of different components and their integration where appropriate.

(c) Organize intercomparison of end-to-end evaluation using different production chains to enable analysis of the sensitivity of the end value to production differences.

6.2 Ways forward

Arising from the gaps identified above, the following key areas are suggested for promoting collaborative work, integration and partnership development and dialogue with actors managing urban services:

(a) Promote the capturing and sharing of observations of environmental and human impact and response information of all kinds, including from unconventional data sources. Standards for sharing of metadata will be important to facilitate sharing of (potentially) low-quality data. Much work is being done, especially in academia, but it needs to be better shared through tailored pilot projects that also examine the benefits of integration, dedicated workshops, conferences and publications.
(b) Progress research on the need for better modelling capabilities for urban areas, encompassing the scales needed, the degree of detail in the representation of the urban fabric, and the degree of coupling required among different environmental domains. Intercomparison experiments and forecast testbeds could provide powerful opportunities for taking such work forward. This could be undertaken in the context of an opportunistic event, such as the forthcoming Olympic Games in Paris, and explore where integration will prove to be beneficial for addressing urban hazards.
(c) Reinforce activities that bring together toolboxes of impact-prediction models, especially in an integrated framework, and extend currently limited number of projects to a wider range of countries and applications focusing on an identified set of requirements for urban hazard and risk awareness services.
(d) Enhance and improve coordination of communication efforts utilizing expertise from behavioural psychology and other similar disciplines that have the skills and methods to define good practices in communication of information from different disciplines. Promotion of a community of practice in this area is a high priority. A methodology for comparing different approaches in real life could be tested alongside a forecast experiment such as that suggested above for the Paris Olympic Games.
(e) Take forward the successful modelling and analysis components to bring them into the integrated chain for Integrated Urban Services. Such an approach could yield substantial gains in effectiveness and efficiency.

7. RECOMMENDATIONS

7.1 Recommendations arising from demonstration city analysis

The assessment of the demonstration city experiences through the information sources described above gives rise to some recommendations. These are additional to, and complement, the recommendations in Volume I (WMO, 2019*a*), which are still key:

(a) Implementers of Integrated Urban Services should start from a discussion with urban users (such as city officials, urban planners, traffic storm and water engineers), to understand their needs. The implementers need to perform a gap analysis to examine how existing services can be modified or updated to meet the new needs identified, identify what data the city has (for example, land use and land cover) that can be usefully employed to improve operational services, and communicate warnings and information effectively.
(b) Integrated Urban Services can be initiated through a single service when co-produced with a city for a particular hazard – starting simple makes sense! The experience of the demonstration cities shows this is most likely to occur in the weather service sector, but cities are encouraged to begin with the hazard of greatest importance. The experience of developing Integrated Urban Services in a particular sector provides an important template for further expansion to other services and with greater integration.
(c) The examples show services can be integrated at a technical level through data sharing at appropriate time and space scales. Ideally, this information flow should be integrated directly into the provision of that service, where required. This integration is an important

step, but has a particular relevance for the provision of urban services because of the concentration of people and infrastructure and the added impact of the urban effect on weather, climate, hydrology and air quality.

(d) Data to support urban services do exist in many cases. Providing technical integration in the form of observational analyses, dedicated geographic information system layers or modelling is key to creating additional value. This provides additional value relative to the separate use of such data.

(e) Implementations of Integrated Urban Services in support of a specific event should provide an efficient means for developing capabilities in NMHSs, and for identification of relevant partners and establishment of efficient collaboration with them. The experience gained can then be used to develop a longer-term plan for the Integrated Urban Services.

(f) For cities with experience in Integrated Urban Services, the goal is to improve the integration of these services through incorporation of a greater range of partners with experience in substantially different areas. These partners should assist with bringing a completely different type of service that provides an important feedback to NMHSs to advance their part in the services.

(g) WMO Members should support the showcasing and demonstration of Integrated Urban Services through joint workshops, publications and outreach. Workshops might most usefully target cities at the initiation level or support interactions among cities where Integrated Urban Services are implemented to help them expand their capabilities.

7.2 Targeted guidance and recommendations for stakeholders

7.2.1 *Recommendations for WMO Members*

Integrated Urban Services have demonstrated benefits for Members, as has been articulated in this Guidance. As such services are in different states of maturity, the following recommendations are made to assist members with full implementation:

(a) Members should improve data-sharing pathways among services and with user sectors. This technical improvement will facilitate the ability to provide Integrated Urban Services in partnership with cities where these services are most needed.

(b) Members should facilitate development of partnerships between NMHSs and specific urban users, and ensure dialogue with regard to progress in implementation of Integrated Urban Services, and also the costs, impacts and benefits.

(c) Members should establish a two-way information transfer between service providers and users. This will support users with relevant information and allow service providers to improve their services.

(d) Members should be prepared to support development of urban-scale observation networks to address specific hazards, so these developments are conducted in a manner consistent with existing services.

(e) Members should look for "initiation opportunities", such as major events, that may provide a source of additional support needed to begin an Integrated Urban Service or to expand and/or further develop an existing one.

(f) Members should support knowledge exchange, for example through training workshops, between service providers and cities to enable the upscaling of Integrated Urban Services in more cities in their country.

(g) Members should develop and regularly update a list of urban experts that can be drawn upon, particularly considering experts in demonstration cities for further guidance and expertise sharing.

7.2.2 *Recommendations for city authorities*

City authorities seeking implementation of Integrated Urban Services are recommended to implement the following recommendations:

(a) City authorities should look for demonstration city analogues. This Guidance provides a range of examples of how demonstration cities implement Integrated Urban Services.

These can be used to identify cities with needs, hazards, governance structures and Member services that are similar in nature and which can be used as a template for Integrated Urban Services development.

(b) City authorities should engage with NMHSs on the provisions for Integrated Urban Services. They should identify a point of contact and determine existing data sources on which Integrated Urban Services can be built.

(c) City authorities should start simple and then advance services by either integration across services or adding more sectors that can benefit from the services.

(d) City authorities should have a specific target for improved urban services within a sector.

(e) City authorities should be prepared to invest time/human resources and funds. Money may be needed to advance infrastructure; time is needed to understand the current availability of resources and to identify partners.

(f) City authorities should engage with researchers (for example, the academic community) from the onset to evaluate and help develop Integrated Urban Services. The demonstration city summaries provide ideas of project-based work that may be relevant for the community.

ANNEX 1. SURVEYS[1]

A1.1 **Members Survey**

(issued in October 2018, used for Volumes II and III)

Contact information

Q1. Please choose your country or territory

Q2. Contact information (Mandatory - Free-text up to 256 characters for each textbox): name of service; name of person; position/title; address; email.

Q3. Additional contact information

Information on main hazards in the urban areas

Q4. What are the main hazards the urban areas face in your country (please tick as many boxes as required)? If needed, use the "Other" box for free-text to specify the hazards in more detail, such as the type of flooding: heavy rainfall; flooding; water scarcity; fog; tropical storms; coastal inundation; windstorms; heatwaves; cold waves; snow; air pollution (including smoke and haze); thunderstorms.

Information on your activities in urban services

Q5a. Is your Service providing, or planning to provide, any urban services in the areas listed below in b?

Q6b. In which area (meteorological, climatological, hydrological, air quality) and at which stage of development (planning stage … fully operational) are the services? Please tick as many boxes as apply as you may have services at different stages of development.

- Meteorological (including severe weather) fully operational
- Climatological (including seasonal forecasts) fully operational
- Hydrological (including water resources management support and flooding)
- Fully operational
- Air quality or other related parameters (such as UV Index) Fully operational

Q7c. In your country, what are the main geophysical characteristics of the urban areas for which you provide, or plan to provide, urban services? (please tick as many boxes as required): coastal; inland; mountainous; riverine or delta; polar; mid-latitudes; tropical.

Q8d. In which cities and urbanized areas are you providing, or planning to provide, your services? (free-text)

Q9e. Do these services include: general services to the public? yes/no

Q10f. Do these services include: services to the authorities? yes/no

Q11g. Do these services include: Targeted services to specific customers (please tick as many boxes as required): city planning; infrastructure design; energy supply; water management; industry; transportation; road traffic; health sector; tourism sector; special events.

[1] This annex is reproduced as provided, and has not been edited.

Q12a. Does your system include an integrated platform for these services? Yes/no

Q13b. If your answer to the preceding question was "Yes", what components does your platform include? (free-text)

Q14c. If your answer to the preceding question was "No", is there any integration in the system of your Service between any of the different components for giving urban services? (free-text)

Information on your activities in urban services

Q15a. Does your Service use impact-based forecasting for urban areas? Yes/no

Q16b. If your answer to the preceding question was "No", do you have plans to use impact-based forecasting for urban areas? Yes/no

Q17a. Weather alerts and warnings? Yes/no

Q18b. Flood/drought alerts? Yes/no

Q19 By which methods does your Service disseminate and communicate your urban products and services? Telephone (including SMS alerts); web portal; email; digital display; social media.

Q20 Please write below any possible comments on this section D (free-text).

Information on other urban services in your country

Q21a. Do you know of any institutes other than yours that provide urban services? Yes/no

Q22b. If your answer to the preceding question was "Yes", please provide information on those institutes below, for example the name of the Institute, their area of work, and/or products and services provided (free-text).

User connections and partnerships

Q23a. Are any groups of service users involved in (developing) your urban products and services? Yes/no

Q24b. If your answer to the preceding question was "Yes", who? (please tick as many boxes as required): Local government and/or authorities; water management sector; road traffic sector.

Q25a. Has your Service formed partnerships in the provision of urban services? Yes/no

Q26b. If Yes, with whom? (free-text up to 500 characters).

Q27c. Do you carry out regular surveys, such as for further development or for obtaining information on the benefits of your services, with your partners or relevant national/regional/local authorities? Yes/no

Q28d. Have you established regular meetings with your partners or relevant national/regional/local authorities? Yes/no

Q29e. What kind of arrangements and/or agreements (such as for example Memorandum of Understanding) have you established with them? (free-text up to 500 characters).

Q30a. Does your service work with economists on urban services? Yes/no

Q31b. Does your service work with social scientists/authorities on urban services? Yes/no

Q32a. Does your service measure the economic and/or social benefits of urban services? Yes/no

Q33b. Does an authority have responsibility for measuring the economic and/or social benefits of urban services? Yes/no/don’t know

Q34c. If your answer to the preceding question was “Yes”, which authority? (free-text).

Q35 Please write below any possible comments on this section (free-text).

Capacity development and training

Q36a. Has your Service or another national/municipal authority organized capacity development activities, including training, on urban services that your staff has attended? Yes/no

Q37b. If your answer to the preceding question was “Yes”, please fill in below: regularly, irregularly.

Q38c. Which subjects (free-text)

Q39a. Have your staff attended any WMO organized capacity development activities, including training, related to developing urban products and services and associated infrastructures? Yes/no

Q40b. If your answer to the preceding question was “Yes”, please provide below more information, such as examples (free-text).

Q41 How does your service develop capacity and guide stakeholders, authorities and users in the interpretation and use of urban products and services? a. Do you organize training for them? Yes/no

Q42b. Do you have regular meetings with them? Yes/no

Q43c. Do you provide them with written Guides or Operative Procedures? Yes/no

Q44d. Other (free-text)

Q45 Does your Service conduct periodic exercises to ensure proficiency? These can be joint activities or exercises between a number of agencies and/or individuals to try out and practice activities and processes which might be taken up in the event of an hazardous occurrence. Yes/no

Q46 Please write below any possible comments on this section.

International collaboration

Q47a. Is your Service collaborating with international partners on urban activities? Yes/no

Q48b. If so, please mention the most relevant (free-text)

Q49a. Would your Service be interested in providing twinning to a country/city in need of developing urban services? Yes/no

Q50b. Would your Service be interested in developing your urban services by twinning with a country/city already having expertise in urban services? Yes/no

Q51 Please write below any possible comments on section H (free-text)

Q52 Please provide below any possible suggestions regarding the provision and the development of functional urban services (Free-text)

A1.2 **Reflections Survey**

(issued December 2017, for Volume I)

A1.2.1 ***Introduction***

A survey was created to solicit information on the current status of integrated urban services to inform and shape the Guidance. The survey is attached below and was designed to be open ended.

As the schedule to prepare the Guidance was very short, a two-week response deadline was set.

The responders were explicitly asked to provide their immediate thoughts and impressions and not necessarily be comprehensive in order to facilitate a quick but broad response.

Twenty-six specific demonstration cities were identified by experts and the response rate was over 80% (21 responses). The surveys were sent to urban experts that included academics, city managers, researchers and not necessarily National Meteorological and Hydrometeorological Services.

A1.2.2 ***Terminology***

The terminology has been altered from the time of the survey. The term Integrated Urban Hydrometeorological, Climate and Environmental Services (Integrated Urban Services or IUS for short) is the current terminology instead of Integrated Urban Weather, Environment and Climate Services.

A1.2.3 ***The survey template***

1. Specific background on Integrated Urban Services:

   Two Key Concepts

   Integrated Services – The services that are being considered are related to weather, water, air quality and climate. The over-arching premise is that their integration is "the way to go". The crux of the Guidance is to articulate the objectives (what, what services), articulate the benefits (why), articulate how and to whom.

   Urban - Are there specific urban services? Who are the clients? What are their requirements? How does urban services impact operations – different than global/regional, what are the characteristics of urban observation systems, their spatial/timescale of reporting, spatial scale of services and how are urban services delivered?

2. Objectives/context of your city's Integrated Urban Services

   - What are your city's objectives/goals?
   - Did it include all the services: weather, water, air quality and climate? Did it include others? Sandstorms, wildfires?

- What were the spatial and temporal scales of the urban services?
- How did your iServices project originate? (World events like Olympics, Expo or other).
- This may be found in your overview documents or project website. It is fine to refer to that material.
- Are there references that you can provide?

3. Urban Services

- What are the "urban" services provided?
- How are these services integrated?
- How and who are they delivered? (We are interested in the "Last Mile", delivery to the end user)
- Are there references that you can provide?

4. Urban Techniques

- What did you have to do to provide "urban" services?
- Observations (mesonet, update in temporal sampling, spatial distribution, new technologies, data sharing, define standards).
- Modelling (high resolution (how high), data assimilation, meteorological and air quality parameterizations, hydrological model).
- If high resolution modelling was implemented, did the numerical weather or environment prediction systems have a specific urban component? Yes/no.
- Implementation (part of national, regional or local infrastructure), service changes (urban central office, distributed sectorial offices)
- Communications (direct, generic, push, pull)?
- We appreciate that this can be detailed but short bullets are sufficient.
- How was the urban environment characterized in the model?
- Were unconventional observations used (e.g. crowdsource)
- Are there references that you can provide?

5. Integration Techniques

- Where was "integration done" – at the technical level or at the services level? Please describe.
- Are there references that you can provide?

6. Institutional Integration

- Which agencies/institutions did you work with to deliver the Integrated Services?
- To whom did you deliver the services – directly (specific agency/institution) or indirectly (via public message or other)? Did you work with them to design the service/product/message (tailored to their thresholds or requirements)?
- Are there references that you can provide?

7. Key Performance Indicators Evaluation/Impacts/Societal Benefits

- How is success defined? Is there a key success indicator for your specific city?
- Are there references that you can provide?

8. Best Practices

- What was done right?
- What was the role of research?
- How did the technology process from research to operations happen?
- Are there references that you can provide?

9. Challenges/Lessons Learned

- What would you do differently? Where should more thought be given? What was more difficult than originally thought?
- What issues need science, technology, research, social science, public health development? What would you give more effort to?
- How has science (includes social and political) contributed to Integrated Urban Services?
- Are there references that you can provide?

10. Technology Transfer

- GURME has a focus to promote and exploit scientific advances that are cross-cutting and require an integrative approach. See GURME website.
- How did science (e.g. air pollution, climate change, disaster risk reduction) drive, impact policy, create an enabling environment or create requirements (e.g. climate change) for an Integrated Urban Services programme.
- How did operational requirements/expectations drive the science agenda?
- Are there references that you can provide?

A1.2.4 ***The Respondents***

The following is a list of the cities that responded to the Reflections Survey (A1.2). Note that in most cases, the contacts solicited the inputs from many others.

City	*Country*	*Contributor and affiliation*
Amsterdam	Netherlands	Gert- Jan Steeneveld, Wageningen University
Beijing	China	Shiguang Miao, Institute of Urban Meteorology
Copenhagen	Denmark	Jens H Christensen and Eigil Kass, Danish Meteorological Institute
Dallas-Fort Worth	United States of America	Brenda Phillips, University of Massachusetts
Helsinki	Finland	Dr Ari Karppinen, Finnish Meteorological Institute Prof. Ttuukka Petaja, University of Helsinki Leena Järvi, University of Helsinki
Hong Kong	China	Chao Ren, The University of Hong Kong, Tsz-Cheung Lee, Hong Kong Observatory Kenneth Kai Ming Leung, Environmental Protection Department
Jakarta	Indonesia	A. (Sena) Sopaheluwakan
Johannesburg	South Africa	Kobus Pienaar, North-West University
London	United Kingdom	Damian Wilson, MetOffice
Mexico City	Mexico	Luisa Tan Molina, Molina Center for Energy and the Environment (lead) Tanya Müller, Former Secretary of the Environment Mexico City (contributor)
Moscow	Russian Federation	Evgenia Semutnikova, Elena Tarasova, Roshydromet
Paris	France	Valèry Masson, Météo-France
Santiago	Chile	Pablo Hernandez, Ministerio del Medio Ambiente Pablo Saide, University of California, Los Angeles
São Paolo	Brazil	Lais Fajersztajn, University of São Paolo Mariana Matera Veras, University of São Paolo
Seattle	United States	John Labadie, Consultant
Seoul	Republic of Korea	Jae-Cheol Nam; Korea Meteorological Administration
Shanghai	China	Jianguo TAN, Shanghai Meteorological Bureau
Singapore	Republic of Singapore	Raizan Rahmat, YAP Chui Wah; Meteorological Service Singapore
St Petersburg	Russian Federation	Elena Akentyeva, Main Geophysical Observatory

City	*Country*	*Contributor and affiliation*
Stockholm	Sweden	Lars Gidhagen and Jorge H. Amorim, Swedish Meteorological and Hydrological Institute
Stuttgart	Germany	Jasmin Hoefgaertner, Rayk Rinke, Ranier Kapp Office for Environmental Protection Municipality of Stuttgart
Toronto	Canada	Sylvie Leroyer, Environment and Climate Change Canada

A1.3 **Urban Focal Point Survey**

(Issued January 2018, for Volume I)

A1.3.1 ***Introduction***

In collaboration with Public Weather Services, a survey was sent to selected National Meteorological and Hydrological Services regarding the urban services or their plans for the provision of urban services. It was an open-ended survey. The survey is attached below. Due to the short schedule, a two-week response was requested. Eighteen surveys were received.

A1.3.2 ***The Survey template***

What system(s) are you currently using to forecast weather and/or environmental conditions (hydrology, flooding, air quality, heat) for urban centers? What are you using in the climate and urban planning context?

What is/are the spatial resolution of the system(s)? Is it sufficient for your particular context?

Is your organization developing an integrated forecasting system at the urban scale for operational use?

- What level of integration does your system includes between the following: weather, water, air quality and climate? Did it include others? Sandstorms, wildfires, volcanic ash, pollen…?

- How did your system originate? (World events like Olympics, Expo, other)

- How far are you planning to expand the services? How are the user needs evaluated and included in the development?

- How is this work coordinated/collaborated with city governments/administrations and other stakeholders/end users?

If not, what are the main reasons? (cost of development, cost of computing, mandate, lack of demonstration of capacity, responsibility of other agency, training, guidance, …)

What should the IUS Guidance document address in priority to support your organization?

A1.3.3 ***Respondents***

The following responses were received.

NMHS	*Name*
Argentina	Celeste Saulo
Canada	Veronique Bouchet

NMHS	*Name*
Congo	Jean Louis Ebengo B. Mpotokole
Denmark	Knud-Jacob Simonsen
French	Cyrille Honore
Germany	Karolin Eichler
Italy	Col. Paolo Capizzi
Japan	Kenji Oshio
Kenya	Ayub Shaka
Malaysia	Zaidi B. Zainal Abidin
Morocco	Said El Khatri
Mexico	Ricardo Prieto González
Netherlands	Hans Roozekrans
New Zealand	Chris Noble
Nigeria	Mosunmola Idumu
Russian Federation	Marina Makarova
Sweden	Karro Ilmar
United States of America	Elliott Jacks

ANNEX 2. DEMONSTRATION CITY SUMMARIES[1]

A2.1 Contributors

City	*Contributors*
Antwerp	Patrick Willems
Auckland	David Johnston, Peter Kreft, Chris Noble
Beijing	Shiguang Miao
Casablanca	Rachid Sebarri
Dallas-Fort Worth Metroplex	Chandana Mitra
Delhi	Gufran Beig
Frankfurt am Main	Petra Fuchs
French cities (Paris, Toulouse)	Valery Masson
Hamburg	Heinke Schluenzen, Bert Jan Davidse
Helsinki	Ari Karppinen
Hong Kong, China	Chao Ren, Tsz-Cheung Lee
Johannesburg	Ezekiel Sebago
London (England)	Brian Golding
Mexico City	Luisa Molina, Tanya Mueller
Moscow	Dmitri Kiktev
New York City	Chandana Mitra
Rotterdam	Marie-Claire tenVeldhuis
Saint Petersburg	Elena Akentyeva
Santiago	Pablo Hernandez
Seattle	Chandana Mitra
Seoul Metropolitan Area	Moon-Soo Park, Jhoon Kim
Singapore	Matthias Roth, Chui Wah Yap
Shanghai	Jianguo Tan
Stockholm	Jorge Amorim, Christer Johansson, Magnus Sannebro
Stuttgart	Rayk Rinke
Toronto	Felix Vogel, Sylvie Leroyer
Wellington	David Johnston, Peter Kreft, Chris Noble

A2.2 Caveats

The demonstration city surveys are provided as they were written, respecting the contributions of the authors. Only formatting of section headers was done.

A2.3 ANTWERP

Prepared by Patrick Willems

Section A: General information

The city of Antwerp is the second largest city in Belgium after Brussels. It lies in the Dutch (Flemish) speaking part of Belgium. It is the capital of the province of Antwerp and has a total

[1] This annex is reproduced as provided, and has not been edited.

population of more than half a million people. With 60% of all European consumers located within a 500 km radius, the port of Antwerp plays a significant part in Belgium's economy serving as Europe's second biggest port, handling 214 million tonnes of freight in 2016. As Belgium's most important logistical centre, Antwerp generated a total GDP of USD67 billion in 2016, accounting for 14% of the country's total GDP.

The climate is sub-oceanic, humid and rainy, influenced by the Atlantic Ocean: winters are cold but not freezing, while summers are quite cool. The average temperature is 3.5 °C in January, and 18 °C in July. Precipitation is relatively abundant, about 850 mm per year, but above all it is common and distributed throughout the year. The rainiest seasons are summer and autumn; the least rainy season is spring. Rainfall often occurs in the form of short showers or drizzle.

The city of Antwerp is situated on the Scheldt River, about 88 km from the North Sea. The Scheldt, together with the Meuse and the Rhine, forms the biggest estuary in western Europe. The city is located at a vulnerable spot along the Scheldt: where the river downstream from Antwerp has the shape of a funnel, it narrows up significantly near the city. Although the Scheldt represents a large potential threat, Antwerp has not been flooded by it recently. The city is, however, regularly (almost on an annual basis) affected by pluvial floods and less frequency by floods along rivers that cross the city and that are downstream connected to the Scheldt.

Four governance levels have an influence on the policymaking: the Federal government of Belgium, the regional government of Flanders, the City Council of Antwerp, that plays an important role in the management of the different types of hazards and that is strongly supported by the city administrations, and the councils of the nine city districts. In terms of risk governance, there are three sub-arrangements, which each focus on a specific part of the policy domain. A first is the urban spatial and water management arrangement, which includes pre-dominantly spatial planners at municipal and regional level. The flood defence arrangement consists of water managers at several governmental levels, which are in charge of the maintenance of a specific river. The central cornerstone of this sub-arrangement is the Sigma Plan, which provides protection measures against flooding along the Scheldt river. The flood preparation arrangement is formed by emergency planners of the city and the federal level. It aims to reduce the damage caused by flooding through the development of actions plans.

Section B. Needs for the integrated services

The main hazards in the city are River Scheldt flooding (tidal influence), Pluvial flooding, Droughts, Heat stress and Air pollution.

Studies have been conducted to assess the hazards and risks related to river Scheldt flooding (by Flanders' Ministry of Public Works; risk maps are available; revised Sigma Plan is being implemented), heat stress (by research institute VITO for the city authorities), river and pluvial flooding (by KU Leuven university for the city authorities and i.c.w. the sewer system managing company Water-link for the pluvial flooding).

The Sigma Plan, revised in 2005, involves many flood control areas installed along the Scheldt and more upstream rivers, combined with nature management, and increasing dyke crest levels and walls along the urban areas. The goal of that plan is to protect cities within the Scheldt basin against a river flood with a return period of 4000 years.

Also for the flood management along the other rivers, a move has been made from an exclusive focus on flood defence to a discourse on 'making space for water'. This discourse shift was triggered by the floods of 1998 and by new regulation of the Flemish government, in particular by the instrument of the so-called "water test" (no new building permits in high flood risk areas and mitigation measures such as water storage and infiltration to be taken on public and private domains when new building projects involve additional pavement, loss of water storage or new rain water drainage network).

A real-time flood forecasting system has been developed (at Flanders Hydraulics for the Scheldt and at Flemish Environment Agency for the other rivers).

To study air pollution, recently a crowdsource based measurement campaign has been held. This has drawn strong public attention. The city has taken measures by installing a low emission zone in the city centre. This means that old cars with high concentrations of fine dust emissions can no longer enter the city centre.

Section C: Services integration

Drought related risks are currently being studied by the city authorities. To cope with the pluvial and drought related risks, a water plan is being developed, looking at the interactions between the sewer and river systems and spatial planning (considering blue-green solutions). Strong attention goes to green roofs and there are also pilot projects on green walls in specific streets (living labs), collective rainwater reservoirs, rainwater treatment, and so forth. The EU-H2020 project BRIGAID even tested in Antwerp a so-called "smart greenroof", at which the water storage is controlled in real-time based on weather forecasts.

A raingauge network is being installed and river and groundwater levels are being measured but at a limited number of locations. There are plans to install X-band radars to measure the rainfall over the city with high resolution and to set up a pluvial flood forecasting system.

There is a need for more coordination of the different flood risk management strategies. Today, all strategies are present but they work rather independently from one another, which in some cases leads to ineffectiveness and inefficiency. Coordinating flood risk governance in Antwerp is complicated since it involves a large number of actors. In recent years, however, steps have been taken to reduce the fragmentation level and to strengthen informal coordination networks. The City's planned development of a climate adaptation strategy might lead to a further intensification of the coordination between the different actors involved.

A2.4 **AUCKLAND**

Prepared by David Johnston/Peter Kreft

Section A: General information

Socioeconomic

Auckland, in the North Island of New Zealand, is by far the largest urban area of the country. The city is expected to continue growing faster rate than the rest of the country. The core of Auckland City is the Auckland central business district, a major financial and commercial centre, surrounded by many suburbs. The city is the major financial centre of New Zealand.

Population and area

The Auckland urban area is comprised of one city with a population of over 1.7 million people (one-third of New Zealand's population) and an area of 1 102.9 km^2.

Geography and climate

Auckland City lies between the Hauraki Gulf of the Pacific Ocean to the east, the low Hunua Ranges to the south-east, the Manukau Harbour to the south-west, and the Waitakere Ranges and smaller ranges to the west and north-west. The populated areas are a combination of gently rolling hills and flat land, generally a few tens of metres (or less) above sea level. The Auckland Volcanic Field is an area of about 360 km^2 centred on Auckland city; within this field are over 50 separate volcanoes. Many of the volcanoes have been quarried or become public parks.

Auckland's existing volcanoes are unlikely to become active again, but the Auckland Volcanic Field itself is young and still active. Auckland has a subtropical oceanic climate, with warm humid summers and mild damp winters.

Governance

The Auckland Council is the local government council for the region. The governing body consists of a mayor and 20 councillors, elected from 13 wards. Besides providing many of the services required by its community, Auckland Council provides environmental and emergency management, flood protection and land management, provision of regional parks, public transport planning and funding, and metropolitan water supply.

Section B: Needs for the integrated services

Hazards (https://www.aucklandcouncil.govt.nz/building-and-consents/Pages/natural-hazards.aspx)

- Tsunami
- Earthquake
- Coastal erosion
- Wildfire
- Volcanic eruption
- Storms (both subtropical and local)
- Landslips
- Flash flooding
- Storm surge
- Air and swimming water quality.

Providers

Seismological information is provided by the Institute for Geological and Nuclear Sciences (GNS Science), a government science department.

Tsunami Watches and Warnings are provided by New Zealand's Ministry of Civil Defence & Emergency Management (MCDEM), with support from GNS.

Fire information is provided by Fire and Emergency New Zealand (FENZ), with support from the National Institute for Water and Atmospheric Research (NIWA), a government science department.

Weather observing and forecasting is conducted by the Meteorological Service of New Zealand Limited (MetService), New Zealand's National Meteorological Service. MetService provides Outlooks, Watches and Warnings of both broad-scale and local-scale (convective) severe weather.

Flood warnings and forecasts of air and swimming water quality are provided by Auckland Council (that is, local government), with support from MetService.

Users

General public, government departments, local government (including disaster management, water supply and stormwater management), energy providers, national and local roading authorities, port authority and shipping companies, airport authority and airlines, industry, media.

Requirements

Forecasting of rainfall-induced landslips and their consequences (e.g. road closures, evacuations).

Longer lead times on forecasts of urban flooding during periods of convective rainfall

Longer lead times and greater accuracy of forecasts of flow in river and stream catchments, and urban waterways, of all sizes.

Inclusion of likely impacts in forecasts and warnings of geophysical hazards.

Forecasts of coastal inundation (storm surge and tsunami) of greater specificity and longer lead time.

Forecasts of windstorms and their impacts (e.g. power outages) of greater specificity and longer lead time.

Section C: Services integration

Responsibility for the provision of information about natural hazards and their impacts is widely distributed. While there is good collaboration among the providers of hazard information, there is no "single source of truth" on either hazards or their impacts. Further, it is common for managers of weather-related risks to use weather information from multiple sources in their decision-making.

A2.5 BEIJING

Prepared by Shiguang Miao

Section A: General information

Socioeconomic

- Total area of about 16 411 km^2
- Urban area of about 1 401 km^2
- About 21.7 million people (2017)
- 16 municipal districts
- Core city of Jing-Jin-Ji city agglomeration
- GDP of about 2.8 Trillion RMB
- Modern and highly urbanized metropolitan
- Superb infrastructure (e.g. advanced land and air transport and communication systems, reliable water and power supplies, etc.)

Climate zone

- Northern temperate semi-humid continental climate with summer and winter monsoons
- Inland city with mountainous topography

Governance structure

- Beijing is a municipality directly under the central government of China

Section B. Needs for the integrated services

Most common hazards

- Heavy rain, thunderstorms, heatwaves, cold surges, fog, air pollution, water scarcity, landslide

Description of existing integrated urban services

- Meteorological service
- Climate service
- Environmental meteorological service (Haze)
- Air quality service

Providers of the urban services

- Beijing Meteorological Service (BMS) – weather and climate monitoring/forecast/warning
- Beijing Municipal Ecological Environment Bureau (BMEEB) – air quality monitoring/forecast and water quality monitoring

Users of the integrated urban services

- Government departments
- General public
- Transportation sectors (land and air)
- Energy sector
- Water management
- Industry sector
- Health sector
- Tourism sector
- Insurance sector
- Disaster risk management

Requirements for the services

Short term (DRR)

- In situ weather observations (rainfall, temperatures, relative humidity, pressure, wind speed/direction, visibility, solar radiation, evaporation, etc.)
- Regular upper-air soundings and the high-resolution remote sensing images including radars, satellite, and lightning location, etc.
- Wide range of weather forecasts covering multi-timescales.
- Warnings and advisories for various weather hazards (e.g. thunderstorm, heavy rain, landslide, flooding, cold and very hot weather, etc.)
- Tailor-made meteorological services for energy departments as well as other weather-sensitive users.
- Air pollution monitoring and forecast.

Long term (urban planning)

- Climatological monitoring and information
- Seasonal predictions

- Climate data and expert advices for different sectors (e.g. infrastructure and building designs, urban planning, air ventilation assessment, public health, water resource management, public utilities (energy), research communities, etc.)

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

Long term: urban planning for sustainable development, climate change mitigation and adaptation

Components integrated (and how)

Short term:

(1) At the level of observational infrastructure

Weather

In total over 400 automatic weather stations (AWS) providing a wide range of meteorological measurements (e.g. rainfall, temperatures, relative humidity, pressure, winds, visibility, solar radiation, and evaporation, etc.)

1 S-band and 6 X-band weather radars, 7 wind profilers, 7 microwave radiometers, 7 cloud radars, 10 ceilometers, satellite reception systems and a lightning location network

One regular upper-air soundings station, twice per day at 0000 and 1200 UTC

Air and water quality

- BMEEB

(2) At the level of modelling tools

Weather

State-of-the-art numerical weather prediction (NWP) products from major global models (e.g. ECMWF, NCEP, JMA, etc.)

Rapid-refresh Multi-scale Analysis and Prediction System (RMAPS) includes five off-line, one-way nested components, each with its own horizontal grid spacing (Δx). The system starts with ECMWF Global forecasts (at 3 h intervals) and terminates with hourly weather and air quality forecasts. Relationships between these internal operational components are described below:

- Nowcasting (NOW) Model (Δx of 5 and 2.5 km): uses input from the Variational Doppler Radar Analysis System (VDRAS) for 6 h real-time forecasts, with ingested data from seven S-band weather radar and all AWS sites.

- Short Term (ST) Model ($\Delta x = 9$ and 3 km): uses WRF Data Assimilation (WRFDA), and either the WRF Noah (for rural grid points) or SLUCM (for urban grid points) land-surface modules for operational 72 h forecasts, for which regional and local data are assimilated.

- Urban Model (Δx =1 km): for urban weather forecasts with the multi-level BEP + Building Energy Model (BEM) urban PBL modules for 24 h real time (but not yet operational) forecasts and research studies, where BEM, BEP, and their urban LU/LC input data are used and where its AWS data are assimilated.

- Integration (IN) Model: combines observations into the NOW, ST, and Urban model forecasts for objective 12 h forecasts, where its input (QPE) are radar data and are calibrated by AWS raingauge observations.

- CHEM Model (Δx = 9 km and 3 km): for 96 h chemical forecasts from the WRF-Chem model.

(3) At the level of the services/information delivery, communication

Weather

By integrating comprehensive weather observations and numerical weather prediction products, BMS provides a wide range of forecasts covering multi-timescales (e.g. nowcasting, 3-day forecast, 10-day forecast) and different spatial resolutions in Beijing, including territory wide, district, and specific sites.

Warnings and special advisors are issued whenever Beijing is threatened by severe weather conditions such as rainstorms, thunderstorms, very hot or cold weather.

Various weather information, forecast and warnings of BMS are timely disseminated to the general public, government departments and other specialized users through different channels, including media (TV, radio and newspaper), webpages, mobile platforms and social media.

Online information service and location specific weather services are available from BMS's website and Tianqitong app for urban dwellers to access various first-hand weather information anywhere and anytime.

BMS launched its Micro-blog page and WeChat platform to enhance communication with the public through social media in July 2013.

Pre-flood season seminars, training courses, briefings and visits are conducted for relevant government departments and weather sensitive stakeholders to promote their awareness of, and community preparedness for natural disasters.

Air and water quality

- BMEEB

Long term

(1) At the level of observational infrastructure

- Continuous observations of essential surface meteorological observations for over 100 years at 54511 meteorological station (such as temperatures, rainfall, pressure and relative humidity).
- Regular upper air soundings at 54511 since 1950s.
- High temporal and spatial resolution meteorological observations from AWS networks since 2000s.

(2) At the level of modelling tools

- BMS adopts an ensemble approach to formulate its seasonal forecast for Beijing, taking into consideration available products from major climate prediction centres and the Regional Climate Model (RCM) operated in CMA.

(3) At the level of the services/information delivery, communication

- The meteorological observations collected in Beijing are compiled and published regularly for monitoring the monthly, seasonal, and annual climate status in Beijing. Long term variations of various meteorological elements and indices, such as temperature, rainfall, and extreme weather events, are also conducted to assess the climate change in Beijing due to global warming and local urbanizations.
- Seasonal forecasts of average temperature and total rainfall and annual outlook of rainfall in broad terms are prepared.
- Establish close partnerships with various stakeholders in the city to enhance its weather and climate services. For examples:

    - Providing monthly forecast of yield collected in Beijing reservoirs to support water resource management.
    - Joining hands with energy sector to enhance energy consumption forecast to reduce the electricity consumption and peak loading under hot weather situation.
    - Providing meteorological service and expert advice for Urban Planning Department and other professional bodies to establish guidelines to assess and regulate the impact of potential city, community and building developments on urban climate and atmospheric environment.
    - Working closely with different engineering departments and professional bodies to establish and regular review the engineering design standards and codes of practices appropriate to local conditions for protecting the city and public safety against various weather hazards and natural disasters.

A2.6 **CASABLANCA**

Prepared by Rachid Sebbari

Section A: General information

Socioeconomic

Total area of about 1117 km^2; population of about 4.27 million (2014 census). Casablanca is a coastal city located in the north-western Morocco and bordered by the Atlantic Ocean to the north and northwest. The Grand-Casablanca, which includes Casablanca and Mohammedia cities, is the economic heart of the Moroccan economy. It generates 19% of national GDP, owns 40% of industrial establishments, attracts 48% of investments and has 30% of the banking network. Please refer to the following URL for economic conditions and more: https://www.hcp.ma/reg-casablanca/. Modern and highly urbanized metropolitan. Superb infrastructure (e.g. advanced land, sea and air transport and communication systems, reliable water and power supplies, etc.).

Geographical

Casablanca is a coastal city and has a Mediterranean climate influenced by the Ocean (Köppen climate classification Csa). Because of its proximity to the Atlantic Ocean, climate of the region of Casablanca-Settat undergoes the maritime influence and is of oceanic type. It is mild, moderate and rainy in winter and humid and temperate in summer. Casablanca is located in the Chawiya Plain with the Bouskoura forest as the only natural attraction in the city and the closest permanent river is Oum-Rabia, 70 km to the south-east.

Governance

The Wilaya of Grand-Casablanca consisted of two prefectures and two provinces. It is a part of the Administrative Region called Casablanca-Settat. Please refer to the link below for more details: http://casablanca.ma/.

Section B. Needs for the integrated services

Hazards

Heavy rain, thunderstorms, flooding, extreme winds, heatwaves, cold surges, water scarcity, fog, air pollution.

Users

General public, Government departments, Energy sector, Water management, Industry sector (building), Transportation sectors (land, sea and air), Health sector, Tourism sector, Insurance sector, Disaster risk management

Providers

National Meteorological Service – weather and climate monitoring/forecast/warning; air quality monitoring/forecast (http://www.marocmeteo.ma/). Basin Management Agency of Bouregreg and Chaouia (http://www.abhbc.com/index.php).

Requirements

Short term (DRR)

- In situ weather observations (rainfall, temperatures, relative humidity, pressure, wind, solar radiation, evaporation, etc.) and air pollution measurements (Ozone, Nitrogen dioxide, particulate matter, Sulphur dioxide, Carbon monoxide, etc.)
- Regular upper-air soundings and the high-resolution remote sensing images including radars, satellite, and lightning location, etc.
- High resolution weather forecasts for different timescales.
- Marine forecasts for short term.
- Air pollution monitoring and high-resolution forecast.
- Warnings and advisories for various weather hazards.
- Tailor-made meteorological services for aviation (Mohamed V airport) and marine communities as well as other weather-sensitive users such as Water and Power Authority (Lydec).

Long term (urban planning)

- Climatological information and Climate data and expert advices (e.g. such as Normals, Intensity-frequency-duration of extreme rainfall events, etc.) for different sectors (e.g. infrastructure and building designs, urban planning, public health, water resource management, public utilities (energy), research communities, etc.)
- Climate projections of temperature, rainfall, mean sea level based on IPCC climate model data.

Section C: Services integration

Components integrated (and how):

(1) At the level of observational infrastructure

Weather

Over the administrative region where Casablanca is located, there are six manned stations (4 located in Grand-Casablanca) and 12 automatic weather stations (4 located in Grand-Casablanca) providing a wide range of meteorological measurements (e.g. rainfall, temperatures, relative humidity, pressure, winds, visibility, solar radiation, etc.)

1 Doppler weather radar, satellite reception systems receiving data from different meteorological satellites and a lightning location network.

Daily upper-air measurement using radiosonde.

Two radars of high frequency for the measurement of ocean wave height, length and period and also surface ocean current.

Air quality

13 air quality monitoring stations of EPD for regularly monitoring O_3, NOx, SO_2, CO, PM_{10}, Methane, COV.

1 air quality mobile station.

Climate

Continuous observations of essential surface meteorological observations since 1911 for the main Casablanca station (such as temperatures, rainfall, pressure etc.).

(2) At the level of modelling tools

Weather

State-of-the-art numerical weather prediction (NWP) products from ALADIN/Al Bachir Model with 7.5 km resolution (forecasts up to 72 h) and AROME Model with 2.5 km resolution (forecasts up to 48 h), ECMWF (forecasts up to 15 days) and Météo-France (forecasts up to 96 h) major global models.

A fog nowcasting system is operated for Mohamed V (GMMN) international airport. It makes use of the single column detailed physics COBEL-ISBA model and conventional and mast measurements.

WAVEWATCH3 marine model with 0.25° resolution is used to produce wave height, length and period forecasts up to 72 h and also wind speed and direction forecast.

ALJAZR model for tidal predictions.

Forecasting accidental marine pollution drift is performed by MOTHY model with forecasts up to 72 h.

Air quality

Regional air quality model named "Casablanca-Air" and since 2014 is providing 48 hours forecasts of air quality on daily basis for major atmospheric pollutant (including NO_2, SO_2, O_3 and PM_{10}) with a resolution of 200 metres. The system used is ADMS-Urban (Atmospheric Dispersion Modelling System).

The MOCAGE (MOdèle de Chimie Atmosphérique à Grande Echelle) runs daily for one day and produces NO_2, SO_2, O_3, PM_{10}, $PM_{2.5}$ and CO forecasts. Its simulations are carried out on two nested domains: the globe at 1° of horizontal resolution and Morocco at 0.2°.

DMN uses also air quality products of the Copernicus Atmosphere Monitoring Service (CAMS) to follow air quality (NO_2, SO_2, O_3, PM_{10}, $PM_{2.5}$ and CO).

AERMOD model is used at DMN since 2012 for research purposes related to pollutants transport and dispersion modelling with the main objective of forecasting continuous or accidental dispersion of emitted pollutants.

Climate

DMN uses ALADIN Climat model to produce high resolution and dynamical downscaling of climate projections up to 2100.

Climate projections of temperature, wet bulb temperature, rainfall, mean sea level, extreme events return period are computed based on IPCC climate model data using appropriate downscaling methods; dynamical or statistical.

(3) At the level of the services/information delivery

Weather

By integrating comprehensive weather observations and numerical weather prediction products, DMN provides a wide range of forecasts covering different timescales (up to 15-days forecasts) and different spatial resolutions in Morocco, including territory wide, district or regional level, and specific sites.

Three hourly (up to 72 h) and hourly (up to 48 h) meteographs for rainfall, temperature, humidity, wind speed and direction are provided for Casablanca.

Warnings and special advisors are issued whenever Casablanca is threatened by severe weather conditions particularly thunderstorms, rainfall exceeding specified threshold, hot or cold spells, abrupt changes in temperature, heavy swell, strong wind, extreme tidal.

Various weather information, forecast and warnings from DMN are timely disseminated to the general public, government departments and other specialized users through different channels, including media (TV, radio and newspaper) and webpages.

Regular visits are conducted for relevant government departments and weather sensitive stakeholders to promote their awareness of, and community preparedness for, natural disasters.

DMN provides weather information for Mohamed V International Airport in support of international aviation navigation.

DMN provides marine meteorological information and forecasts to serve international shipping on Atlantic coastal waters.

Air quality

Air Quality information including the Air Quality Index are released to the public via a website and through regular weekly and monthly bulletins (http://www.marocmeteo.ma/aircasa/public/).

Climate

The meteorological observations collected by DMN are compiled and published internally for monitoring the monthly, seasonal, and annual climate status in Morocco and at the administrative regional level.

Studies of long-term variations of various meteorological elements and indices, such as temperature, rainfall, sea level, and extreme weather events, are also conducted to assess the climate change in Casablanca due to global warming and local urbanizations and shared with many institutions.

Climate data and products of Casablanca are accessible by contacting the DMN with the possibility of access through the Extranet of DMN by signing a memorandum of agreement.

Seasonal forecasts of average temperature and total rainfall are prepared and made available online for users' reference and also published through the North Africa Regional Climate Centre.

DMN established close partnerships with various stakeholders in the city to enhance its weather and climate services for the priority areas of WMO GFCS on energy, water, health, and disaster risk reduction.

A2.7 DALLAS-FORT WORTH METROPLEX

Prepared by Chananda Mitra

Section A: General information

Population and area

Dallas-Fort Worth-Arlington, Texas Metropolitan Statistical Area is known as Dallas-Fort Worth Metroplex or simply DFW.

- DFW population in 2017 was about 7.4 million encompassing 12 800 square miles.
- DFW is made up of 13 counties. The City of Dallas is the most populous city with 1.34 million inhabitants, followed by Fort Worth with 874 168.
- Real GDP was over US$511 billion in 2016 making DFW the 11th largest economy in the world.

Infrastructure

DFW International Airport is the largest airport in Texas and one of the busiest airports in the USA.

This region has thousands of lane-miles of freeways and interstates.

The Dallas Area Rapid Transit (DART), Trinity Metro and Denton County Transportation Authority offer extensive public transportation options expanding across the Metroplex.

Climate zone and geographical position

The DFW region is situated about 250 miles north of the Gulf of Mexico, at an elevation of between 500-800 feet.

According to the National Weather Service, the region's climate is humid subtropical with hot summers. It is also continental, which is characterized by a wide annual temperature range (average 37 °F in January to 98 °F in August). Precipitation varies considerably, which ranges from less than 20 to more than 50 inches (https://www.weather.gov/fwd/dnarrative).

Governance structure (decision-making)

Legal Framework: Although DFW is considered as single Metroplex, its governance is separate as evidenced by separate authority for each city in the area. Each city (Dallas, Fort Wort, Arlington, etc.) has separate same type governance. Council-City Manager system prevails where city council appoints a manager to monitor and coordinate all activities. The council also appoints city secretary, city attorney, city auditor, municipal court judges and citizens who serve on city boards and commissions.

Responsible institutions for addressing urban hazards, policymaking powers:

Federal Emergency Management Agency (FEMA): The mission of FEMA is to reduce the loss of life and property and protect institutions from all hazards by leading and supporting the nation in a comprehensive, risk-based emergency management programme of mitigation, preparedness, response, and recovery. Texas is part of FEMA region VI.

Floodplain Management: Floodplain management for the DFW region is overseen at a local, regional, and state level. Each city has its own Stormwater Management department within its own local government. On a regional level, the Trinity River Authority promotes conservation, reclamation, protection and development of the natural resources of the river basin for the benefit of the public. Multiple water districts support clean water and flood protection measures such as the Tarrant Regional Water District and the North Texas Municipal Water District. The National Oceanic and Atmospheric Agency's West Gulf River Forecast Center monitors river levels and produces river forecasts and products.

National Weather Service (NWS): The NWS provides weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy. The Fort Worth/Dallas Weather Forecast Office (FWD WFO) provides regional forecast and weather warning products to the general public and regional partners such as emergency managers, media, energy and transportation officials, airports, hospitals, schools and universities. NWS disseminates weather warning products via the Emergency Alert System, Wireless Emergency Alerts, NOAA Weather Radio, Integrated Public Alert and Warning System. FWD WFO incorporates data from various meteorological networks such as agricultural stations, US Geological Services rain and flood gauges, military, airports, universities, and multiple radar networks including (NEXRAD, Terminal Doppler Weather Radar (TDWR) and the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA).

North Central Texas Council of Governments: This is a voluntary association of, by and for local governments, established to assist in regional planning. Programmes include transportation planning, environment and development, aging and disability resources, emergency preparedness, demographic research, regional training, criminal justice, and police resources.

Texas Commission on Environmental Quality: This is the environmental agency for the state of Texas. It manages a network of air monitoring sites across the Metroplex in accordance to national Environmental Protection Agency (EPA) regulations. The status of regional air quality is compiled annually by the North Central Texas Council of Government's Air Quality Handbook. Individual cities making up the DFW Metroplex are responsible for monitoring air quality for their respective jurisdiction. For example, the City of Dallas Air Pollution Control Programme provides data to TCEQ, and monitors for the presence of criteria pollutants, including ozone, identified by the EPA as detrimental to public health.

United States Geological Service (USGS): serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect quality of life.

Section B. Needs for the integrated services

Most common technical hazards

- Transportation accidents
- Utility (water or energy interruption)
- Fuel pipeline accidents
- Terrorism
- Dam and levee failure
- Biological

Most common natural hazards

- Flooding (riverine and flash flood)
- Severe Thunderstorms (high winds, hail, lightning)
- Tornadoes: DFW is the largest metropolitan area in "Tornado Alley" (a zone that stretches from northern Texas through Oklahoma and into Nebraska where the strongest tornadoes occur most frequent). Rapid movement of air is enhanced due to flat terrains, while high humidity of the Gulf Stream further induces instability in the atmosphere. Tornado hazards need significant consideration for this region due to the evidence of devastating impacts from previous tornado occurrences
- Winter storms (snowstorms, blizzards, cold waves, and ice storms)
- Drought
- Extreme heat and associated health impacts
- Wildfire
- Seismic: Due to the position in relatively stable geologic platform with no active fault systems, DFW experiences only minor seismic activity due to oil and gas extraction and injection activities. However, the Meers Fault System of Southwestern Oklahoma and the Reelfoot Rift Region of Southern Missouri pose some risk in terms of high magnitude seismic events. (FEMA 1997 Multi-Hazard Identification and Risk Assessment. Seismic Hazards, Chapter 16).
- Expansive soils hazards pose a risk in Blackland Prairie areas (Dallas, Ellis, Collin, Kaufman, Rockwall counties etc.) (https://www.nrc.gov/docs/ML0929/ML092990302.pdf http://www.dallascounty.org/Assets/uploads/docs/hsem/2015_12_01_Dallas_County_HazMAP_APA_Copy.pdf).

Providers of the urban services

Individual city governments are mainly responsible bodies for providing urban services

Government agencies such as NOAA, USGS, EPA, etc. Government organizations provide important services in terms of land use/ cover change information, weather/climate data etc.

Users of integrated urban services

- Government agencies (environment, energy, water management, transportation, health, tourism, disaster risk management)
- Industries (energy, health, airports, insurance sector)
- General public
- Media

Requirements for the services

Requirements for short term DRR (Disaster Risk Reduction) are rainfall, temperature, precipitation, humidity, wind speed, solar radiation, evaporation rate, remote sensing images such as Landsat, SPOT, MODIS, QuickBird, wide range of weather forecasting, warnings for weather hazards, air quality etc.

For long term urban planning we need climatological data and seasonal predictions. Climatologic data for urban design, building design initiatives, public utilities, water resources management, etc.

Section C: Services integration

National Weather Service (of NOAA) provides a huge range of weather/climate related data such as temperature, precipitation, snowfall, wind data, sky cover data, relative humidity, sunrise/sunset etc. FEMA (maintained by U.S. Department of Homeland Security) is behind the "National Response Framework (NRF)." NRF provides guidelines for all response partners to deliver a unified national response to disasters and other emergencies. Local agencies (of U.S. Emergency Management System, comprised with local, state, federal E.M. agencies) and Non-Governmental Organizations (such as the Red Cross) work at weather warning stage like increasing awareness, providing presentations, etc. (https://www.wmo.int/pages/prog/drr/projects/Thematic/MHEWS/GoodPractices/USA/UnitedStates.pdf)

Urban Area Security Initiative (UASI) provides financial assistance to address the unique planning, equipment, training, and exercise needs of high-threat, high-density urban areas, and to assist them in building and enhanced and sustainable capacity to prevent, respond to, and recover from threats or acts of terrorism. This initiative is organized in DFW through the North Central Texas Council of Governments (NCTCOG).

Observational infrastructure

- NEXRAD S-Band radar (NWS)
- TDWR C-Band Radar (Federal Aviation Administration)
- CASA X-Band Radar (Collaborative Adaptive Sensing of the Atmosphere (CASA) Dallas-Fort Worth Urban Testbed)
- ASOS/AWOS surface data (NWS National Mesonet Program distributed via NOAA Meteorological Assimilation Data Ingest System (MADIS)
- SODAR wind profilers (WeatherFlow)
- Surface-based radiometers (Radiometrics)
- Aircraft data (MDCRS and TAMDAR)
- High-frequency pressure and GPS-Met data (CASA installed weather stations)
- Citizen and private weather service surface observations (CWOP and Earth Networks)
- Commercial systems (GST MoPED and Understory)
- Stream gauge networks (USGS)
- Raingauge networks (Local municipalities, CoCoRaHS)

- The NCTCOG has worked to create a regional flood warning software tool called OneRain, Inc. with the goal to enable communities to see storms as they track across the region and the impacts they are having in neighbouring communities, allowing for better preparedness and collaboration.

Services/information delivery and communication

NWS disseminates official weather warning products via the Emergency Alert System, Wireless Emergency Alerts, NOAA Weather Radio, Integrated Public Alert and Warning System. Alerts and warnings are disseminated by the media, emergency management and public officials via social media (Facebook, Twitter) as well as emergency notification systems and traditional methods such as TV, radio and newspapers. These have been effective mediums for disseminating information at pre, during and post hazards/disaster stages for making the public aware about possible impacts.

A2.8 DELHI (INDIA)

Prepared by Gufran Beig (https://safar.tropmet.res.in/)

Section A: General information

Population and area

Delhi National Capital Territory (NCT): 20M inhabitants occupying 1484 km^2 area. The NCT comprises of nine districts, 27 tehsils, 59 census towns, 300 villages, and three statutory towns, the Municipal Corporation of Delhi– 1 397.3 km^2, the New Delhi Municipal Council– 42.7 km^2 and the Delhi Cantonment Board– 43 km^2.

Infrastructure

Delhi City Atmospheric Monitoring System has a wide geographic coverage and good data collection capacity. It has monitoring of weather parameters, climate parameters, hydrology and air quality parameters. The emission inventory of Delhi and surrounding fringe areas was first developed in 2010 by SAFAR (System of Air Quality and Weather Forecasting and Research). Emission Inventory has recently been upgraded for 2018. Emission inventory is available for eight parameters- NOx, CO, $PM_{2.5}$, PM_{10}, SO_2, BC, OC and HCs. Transport infrastructure includes public transportation infrastructure (urban buses, Metro train service), motorized transport (bike sharing programme). The city has good communication infrastructure.

Climate zone and geographical position

Delhi is located at 23.38 °N and 77.13 °E in the Northern part of India and bounded by Haryana State on the Northwest and South, Rajasthan state on the Southwest and Uttar Pradesh state on the east. The metropolis city is demarcated into three parts, with the Gangetic plains forming the major part, the Yamuna flood plain and the Delhi ridge. Delhi lies in the landlocked Northern Plains of the Indian Subcontinent. Its climate is greatly influenced by its proximity to the Himalayas and the Thar Desert, causing it to experience both weather extremes. Delhi has five distinct seasons, viz. Summer, Rainy, Autumn, Winter and Spring. But there are three major seasons - Monsoon (Rainy): July, August, September; Hot, Pleasant during rains; v High to very high humidity; Heavy precipitation. Summer starts in early April and peaks in May, with average temperatures near 32 °C although occasional heatwaves can result in highs close to 45 °C (114 °F). Winter starts in late November or early December and peaks in January, with average temperatures around 12–13 °C (54–55 °F). Although winters are generally mild, Delhi's proximity to the Himalayas results in cold waves leading to lower apparent temperature due to wind chill. Delhi is notorious for its heavy fogs during the winter season. In December, reduced visibility leads to disruption of road, air and rail traffic.

Governance structure

As a first-level administrative division, the National Capital Territory of Delhi has its own Legislative Assembly, Lieutenant Governor, council of ministers and Chief Minister. Members of the legislative assembly are directly elected from territorial constituencies in the NCT. The Municipal corporation handles civic administration for the city as part of the Panchayati Raj Act. The Government of India and the Government of National Capital Territory of Delhi jointly administer New Delhi, where both bodies are located.

Responsible Institutions for addressing urban hazards, policymaking powers

India Meteorology Department (IMD) is a national weather services agency and plans and mandate meteorological information at national and local levels; manages the climatological database. It shares information in newsletters or special advisories through news bulletins, phone or internet to specific users, common public and Govt. ministries.

National

Disaster Management Authority of India (NDMA) is in charge of risk management and disaster prevention to reduce population exposure to meteorological, hydrological, geological and chemical hazards such as volcanic eruptions, flooding, tropical storms, earthquakes, and chemical releases, among others. Central Pollution Control Board (CPCB) and Ministry of Environment and Forest and Climate Change (MOEFCC) handles air quality monitoring, emissions standards to deal with air pollution and climate change aspects and implement the control measures. Delhi state Environmental Secretariat manages Delhi's environment. SAFAR (System of Air Quality and Weather Forecasting and Research is India's first metro air quality forecasting system and also a pilot project of GURME, WMO is implemented and operationalized by Indian Institute of Tropical Meteorology, Pune under the Indian Ministry of Earth Sciences. The SAFAR is responsible for Air Quality Monitoring, forecasting and issues air quality and meteorological forecast to alert the public about critical pollution levels in terms of Air Quality Index (AQI) and prevent exposure to harmful pollutants (https://safar.tropmet.res.in/) using giant LED display boards, IVRS services, MobileApp (SAFAR-Air).

SAFAR –Products

(1) Air quality: Colour-coded Index based Current & 3-days forecast with health advisories.
(2) Harmful Radiation: Severity of UV radiation (UVI) with associated skin advisories.
(3) Weather: Current & 3 days advance forecast, sea, tide and severe weather.
(4) Extreme Events: Alert for extreme pollution and weather events.
(5) Emission Scenario: Accounting location-wise sources of air pollution.

Section B. Needs for the integrated services

Most common hazards in the city and associated with environmental risks. Delhi is highly affected by extreme pollution events caused due to cold winter in a land lock city Delhi, stubble burning in the neighbouring states, long-range transport from Indo-Gangetic Plane region and duststorm in summer from Gulf region and neighbouring province Rajasthan Desert.

Extreme weather events leading to floods and landslides. Health impacts caused by heatwaves and dehydration, handles/ air quality monitoring, emissions standards, handles air quality monitoring, emissions standards earthquake, social and spatial inequality & high vulnerability to climate change, vector-borne diseases related to climate change and other pollution.

Existing integrated urban services for meeting hazard challenges

Ministry of Earth Sciences, Govt of India operationalized the first Air Quality Forecasting Services SAFAR for Indian Megacities, indigenously designed and developed by Indian Institute of Tropical Meteorology, Pune. SAFAR is a seamless early warning system enriching local people with 3 days advance information on air quality, related health advisory, weather, harmful radiations, extreme event and environmental awareness to deal with their adverse impacts and hence protect citizens by early preparedness and interventions.

The MOEF&CC has formed a monitoring committee to formulate short and long-term measures to solve air pollution of Delhi NCR. The GRAP, Graded Response Action Plan is one such plans to combat air pollution of Delhi NCR. GRAP laid down a stratified action which is required when the concentration of pollution reaches a certain level. This is the first ever plan of its kind that designates short, medium and long-term measures for all key sources of pollution and will help the Delhi NCR region to make a sustained improvement in air quality.

The job of ensuring implementation of the action plan will be EPCA's, which will delegate the responsibility to the concerned departments. The government has also established the Earth Quack Seismology Services, Agrometeorological advisories for farmers by IMD. Risk alerts system by NDMA, etc.

Requirements for the services

Short term

Environmental monitoring and forecast: provide timely information to different sectors of Delhi population about weather, water, air quality, climate, wildfires, volcanic hazards. Improve the performance of air quality forecasting systems SAFAR using updated IITM emission inventories, satellite data assimilation, dust module and updated environmental data. A new initiative on the line with SAHAS (SAFAR-Air Health Alert System) envisages an action based management system where advance Air Quality information, precautions, advisory in terms of ALERTS go hand in hand with ACTION on the ground with people's participation to protect Human health. SAHAS also engineers awareness drive by educating Public, Medicos and Executives to pave the path to develop mitigation strategies. The programme will benefit policymakers for sustainable action plan, researchers and educationist, and general public by creating awareness and early preparedness from air pollution and weather extremes. It is also leading to better understanding of linkages among emissions, weather, pollution and climate.

Long term

Invest in infrastructure and personnel for the monitoring network due to changes in the sources of emissions and pollutants and the expansion of urban areas to the periphery and many other metropolitan cities. Enhance measurement of vertical profiles of meteorological parameters using balloon, aircraft and satellite monitoring. In-depth analysis of the increase in atmospheric temperature on the air quality in the NCT and the impact of meteorology on air pollution. Reinforce epidemiological surveillance and implement an integrated regional land use-transportation-air quality management system involving close cooperation of the relevant authorities (environment, transportation, urban development, and public works) with public participation. Expand model coverage and air quality forecasting to include the megalopolis region. Expand and strengthen capacity-building for technicians and scientists.

Section C: Services integration

Short term

There is an urgent need to integrate weather services of IMD, air quality forecasting services of SAFAR, Climate services of MoEFCC and IITM, Seismic and Tsunami warning system services of INCOIS of MoES, air quality monitoring and expansion of services of CPCB and Delhi government.

Long term

Delhi City need to be under Smart City Mission launched by the Central Government. This must integrate following 5 pillars: (i) Foster regional coordination; (ii) Promote water resilience as new paradigm to manage water in the Mexico Basin; (iii) Plan for urban and regional resilience; (iv) Improve mobility through an integrated safe and sustainable system; and (v) Develop innovation and adaptive capacity.

Indian government has started a nationwide programme namely, NCAP (National Clean Air Programme) with a specific target to reduce pollution levels by at least 30% in a limited time frame. Government has taken actions to mitigate emissions of greenhouse gases and short-lived climate pollutants by integrating air quality and climate action plans in the design of environmental policy to realize potential synergistic benefits, such as emission control standards for vehicles, energy efficiency programmes for public and private buildings, improve collection and disposal of solid waste with more efficient solutions including potentially using landfill gas recovery to supply clean energy.

(1) Observational infrastructure

- Extensive and robust air quality monitoring (data with high time and coverage resolution)
- Updated emissions inventory (criteria and toxics pollutants, GHGs)
- Health standards and air quality risk index
- Vehicular Inspection and maintenance programme
- Industry regulation and surveillance
- Open data with high access and transparency and integrated app.

(2) Modelling tools

Research has play an important role in designing, implementing and improving many of the urban services; Delhi City has a long history of collaboration with research institutions, both national and international. Recent field measurement campaigns under the Indo-UK (MoES-NERC) programme "Air Pollution in Indian Mega city (APHH) have provided comprehensive data sets for updating and improving tour understanding on air quality of Delhi, the chemistry, dispersion and transport processes of the pollutants emitted to the Delhi NCR atmosphere and their regional transport, transformation and impacts. The information is being used for modelling studies. Air quality modelling and forecasting services are the result of collaborations with national and international research institutions. Forecasting of air quality conditions on short timescales in SAFAR, support the city government with information to take effective actions through mitigation to exposure to high concentrations of pollutants and lay the groundwork for developing policies to reduce emissions for air quality improvement and other co-benefits (e.g. climate, food security, etc.).

(3) Services/information delivery, communication

SAFAR has taken a lead in developing various communication strategies to disseminate information to the public, including real-time report of ambient air quality data and forecasting, which are available to the public via website and mobile application (SAFAR-Air), and are used by the news media in weather forecast to alert the public of high pollution episodes and severe weather events. This need to be expanded under NCAP national wide and in other hazard related programmes in climate services.

A2.9 FRANKFURT AM MAIN

Prepared by Petra Fuchs

Section A: General information

Socioeconomic condition

- City size: appr. 750 000 inhabitants, fifths largest city of Germany
- Area: 248 m²
- Forms a conurbation with the neighbouring city of Offenbach am Main, and its urban area has a population of 2.3 million and is the centre of the larger Rhine-Main Metropolitan Region, which has a population of 5.5 million
- Contribution to GDP: According to a ranking list (2001) produced by the University of Liverpool, Frankfurt is the richest city in Europe by GDP per capital
- High level of infrastructure (e.g. airport, public transport)
- Environmental management established (organized by environmental agency), monitoring of air quality, consideration of urban climate conditions in the planning process.

Geographic conditions

Frankfurt is located in the mid-latitudes at the river Main and has a temperate-oceanic climate (Köppen) with an average annual temperature of 10.6 °C , with monthly mean temperatures ranging from 1.6 °C in January to 20.0 °C in July, annual precipitation: 629 mm (169 rainy days), 1662 sunshine hours (35% possible sunshine).

Governance structure

Federalism in Germany is made of the states of Germany and the federal government. The central government, the states, and the German municipalities have different tasks and partially competing regions of responsibilities ruled by a complex system of checks and balances. Frankfurt is a municipality with autonomy in decision-making, which is also applicable for responsibility pathway for addressing urban hazard.

Section B. Needs for the integrated services

Most common hazards in the city and associated environmental risks

- Heatwaves
- Air quality
- Extreme events (e.g. heavy rainfall, storm)
- Flooding

Description of existing integrated urban services

- Observation and monitoring of weather and climate conditions
- Weather forecasts
- Weather warning system (downscaled to urban districts)
- Heat health warning system

- Pollen forecast
- Urban climate models and online information systems for assessing the impact of climate change
- Continuous monitoring of urban climate and air quality.

Providers of the urban services

- Members (DWD)
- City of Frankfurt
- Federal state Hesse

Users of the integrated urban services

- Municipalities
- Environmental agency
- Disaster control
- Infrastructure sector
- Energy sector
- Health service
- General public
- Planning offices
- Media

Requirements for the services

- Precise forecasts and warning systems in high temporal and spatial resolution (high hardware requirements) especially for temperature, wind, precipitation, thunderstorm, air quality
- Forecasts from nowcasting to long term
- Monthly, seasonal and decadal climate prediction
- Development of applications based on climate projection
- Data provision in common formats
- Integration of socioeconomic information
- Development of common terminology for better understanding.

Section C: Services integration

At the level of observational infrastructure

- Observation network in WMO standard, data provided with high quality
- Operation of a ground based network of weather radar systems
- Implementation of network of urban climate stations
- Mobile measurements
- Use of remote sensing data
- Monitoring of radio activity

At the level of modelling tools

- Development and operation of complex NWP models for global and regional weather prediction, as well as special applications like sea state and the environmental tasks (e.g. dispersion of radioactive particles, volcanic ash and mineral dust)
- Nowcasting applications based on spatially and temporally high resolved observations with rapid update cycle
- Automatic warning guidance on nowcast and very short-term scale

- Development of urban climate models
- Downscaling of regional climate models to urban scale
- Information tools for climate adaptation.

At the level of the services/information delivery, communication

- Downscaling of complex scientific information to easily understandable information
- Integration of weather and climate information.

A2.10 FRENCH CITIES (PARIS, TOULOUSE)

Prepared by Valery Masson

Section A: General information

Socioeconomic condition

High socioeconomic level. Cities can be ancient, with historical city center several centuries old, and difficulties to modify these for understandable cultural and architectural reasons. Cities growth is limited compared to other parts of the world.

Climate zone

Temperate oceanic climate. Inland, coastal and mountain cities.

Governance structure

Decision-making is mostly done, for big agglomerations, at agglomeration level (municipalities grouped together). Paris is a specific case, with some higher-level coordination (regional, Paris itself is both a city and an administrative department) that is added (not replacing municipalities).

Section B. Needs for the integrated services

Main hazards in the city and urban area

Given the variability in geography and climate in France, cities focus on several and different hazards on adaptation strategies in urban planning. In general, coastal cities are more concerned by sea level rise and, especially around the Mediterranean Sea, on flash flood events, that are recurrent in Autumn. Inland cities however, are more focused on heatwaves and river flooding. For these cities, the expected climate change especially points to the risk of future increases in the frequency and intensity of heatwaves. This is why, even if this is not the only hazard, adaptation to heatwaves and mitigation of Urban Heat Islands has become a priority for many French cities, such as Paris, Lyon, Toulouse, Lille, and Rennes, even though these cities are under contrasting summer climates (much warmer in Toulouse than Rennes or Lille).

Description of existing integrated urban services

- See below

Providers of the urban services

Providers of the presented UCS on adaptation of cities to climate change are mostly academia. Members provides information on meteorological hazards, emergencies and climate change. Consultancies certainly also provide some dedicated UCS, but often more on CO2 and Greenhouse Gas emissions reductions or local adaptation strategies in local building operations.

Users of the integrated urban services

Mostly, all, depending on the UCS. For adaptation strategies to climate change UCS, local and regional collectivities, and national environmental agencies (for diffusion to other collectivities).

Requirements for the services

Always need of a dedicated people (internally or externally) that is motivated and knows of the climatic issues and understand the need for the UCS. This greatly helps diffusion and appropriation.

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

Emergencies (heatwave, heavy rain, thunderstorms, flooding) are fully operational from systems that cover the whole territory, not only the cities. Some dedicated behavior indications to follow in case of emergency are provided. There is institutional contact and organization with all emergency and security institutes for the operations.

Urban meteorological services are mostly in the commercial domain. Therefore, cities do indicate by public procurement what they want. Cities may want something more or less elaborated, for: security, transportation systems, public works, water resources, energy, etc. Some cities have their own observation systems, and share it with their meteorological operator. In some cases, this is done by the meteorological operator (definition, installation, maintenance).

Other IUS were developed in collaboration between the local authorities, Météo-France and the Predict Services company, to provide for some urban areas on the French Mediterranean Coast impact-based forecast and hydrometeorological monitoring. This IUS aims to help to manage the crisis and activate appropriate response plans. Diagnostics of vulnerability of the city is done beforehand, and a safety plan is co-constructed. There are local meteorological forecasters giving tailored information to the city administrations during heavy rain and flooding crises, and that helps the mayor to take good decision in relation with the communal safety plan.

Long term

Proposition and evaluation of adaptation strategies to climate change demand a quantification of the combined UHI and heatwave impacts, in terms of exposure of people, sanitary issues, and the development of interdisciplinary urban climate services (UCS).

Because questions of mitigation of and adaptation to climate change are driven by very long-term horizons, a common tool to address these is numerical modelling. However, a city is a very complex system, with its, own evolution, influencing strongly the local meteorology (e.g. a growing city is likely to lead to a larger UHI). Studying future urban climate require UCS to consider the interactions between city and climate changes, including city evolution models (that include socioeconomics and architectural aspects) and state-of-the-art urbanized atmospheric models.

Using modelling approaches, UCS should be delivered on the urban agglomerations at the city-scale (both processes and impacts cover the entire agglomeration), with a spatially fine-scale (typically 200m). This allows assessment at the neighbourhood scale, which is considered by French urban planners as the pertinent scale for the study of energy transition policies concerning urban planning related to buildings energy consumption.

Components integrated (and how)

(1) At the level of observational infrastructure:

- A crucial point for city administrations is to anchor the state-of-the-art knowledge, coming from researchers or experiences in other cities, into their own city. This is preliminary to concrete action and realization of an adaptation strategy.

- Experimental studies are then considered necessary for cities to reach this objective. Two examples are used to illustrate this need. In Toulouse, the city administration decided to build a city-owned real-time urban network of meteorological stations (60, semi-professional), with the aim of finely mapping the urban heat island and other meteorological parameters within the agglomeration. In order to reach a spatial resolution fine enough for communities, meteorological information needs to be combined with urban features. Further urban climate services issued from these data will be built. While most urban meteorological networks are deployed and owned by research centers, this was the initiative of the municipality. The municipality will gather the data to allow for future conception and production of UCS, internally or externally. One such UCS, that is relevant for long-term planning, is the diagnosis of the current state of the city, in term of urban climate.

- The city of Paris launched an experimental study focused on the estimation of the impact of the watering of sidewalks and roads during summer days. This experiment was performed after previous numerical studies evaluating adaptation scenarios on Paris (based on white roof and street watering), in order to gain both experimental evidence and a first assessment of feasibility. A meteorological station was installed on a sidewalk, and several heat flux measurements were performed within the sidewalk and the road. Watering time intervals by water trucks were optimized, and daytime cooling of 0.8 °C on air temperature, and 1.5 °C on UTCI comfort index were observed. Such experimental implementation also eases the knowledge exchange with the stakeholders.

(2) At the level of modelling tools

- One example UCS covered the evaluation of the meteorological impacts of an urban renewal operation (Marseille, at 100 m resolution), including the impact of a park and use of sea-cooled air conditioning system. Quantification of impacts on city and population (UHI, comfort, energy consumption, water needs) and effects of adaptation strategies on these, were performed over Paris and Toulouse. The wide range of impacts but also the large scope of the adaptation scenarios (limited only by the imagination of people) require the use of, and sometimes the development of, many specific parameterizations within the numerical modelling system.

- Many scenarios are based on the application urban vegetation in various configurations (e.g. ground vegetation, street trees, vegetated walls and green roofs). Impacts on hydrology are now included in the model and will allow study of the combined UHI-hydrology impacts on Paris and its suburbs. The model developments also permitted testing of implementing alternative urban energy systems such as solar panels. Air conditioning can increase night-time temperatures in more densely built parts of Paris by more than 1 °C, so a Building Energy Module is also a desirable component of the modelling system to evaluate anthropogenic heat fluxes to the atmosphere. Energetic human behaviour has been including in TEB thanks to a collaboration with sociologists. The modelling system then permits testing the impacts of not only changes to the character of the urban structure (insulation), but also eventually, societal change, such as aging of the population, who may demand greater use of building cooling during summertime. This emphasizes the interdisciplinary interactions that are needed to study the urban system and build UCS.

(3) At the level of the services/information delivery, communication

- In order to be pertinent, such UCS need to be co-constructed between several actors, including city administrations. Such UCS co-construction can typically emerge from research projects, as national level (e.g. MApUCE project, https://www.umr-cnrm.fr/ville.climat/spip.php?rubrique120) or European level (URCLIM project, http://www.urclim.eu/). This has been initiated by direct collaboration with urban planning agencies in research projects with local communities (through meetings, co-funded PhD thesis), and by the inclusion of sociologists and researchers in urban law in the research projects, in order to facilitate knowledge transfer and the proposition of modification of the legal documents to better consider energy and micro-climatic issues in the making of the city.

- In the collaboration between several actors, especially institutional and academic ones, one field where co-construction is particularly important is during scenario development. During the conception of UCS, urban scenarios are built at both the services and technical levels: they are built in a cooperative way with the stakeholders, and then translated into input variables for the models. This allows definition of practical tools for UCS, but also to exchange knowledge between sectors and between planners and academics.

A2.11 **HAMBURG**

Prepared by Heinke Schluenzen (Contact person: Bart Jan Davidse, email: bartjan.davidse@bue.hamburg.de*)*

Section A: General information

Socioeconomic and governance

Hamburg is the second largest city in Germany, and growing with currently 1 83 million inhabitants (compared to 1 793 million in 1970). The city Hamburg is part of a bigger metropolitan area of which it builds the centre (total population 5 36 million). Hamburg covers an area of 755 km² with 8% water surface and 25% being agriculturally used and 7% forest areas (Statistisches Bundesamt, Wiesbaden 2016). The Free and Hanseatic City of Hamburg is both a municipality and a city state within the Federal Republic of Germany.

The city has been growing in its economic performance (GDP from 15 984 million Euros, 1970, to 117.572 million Euros, 2017) (https://de.statista.com/statistik/daten/studie/5014/umfrage/entwicklung-des-bruttoinlandsprodukts-von-hamburg-seit-1970/). The economy is made up of one-third by trade, transport, tourism, information and communication (31.9%) and another third by finance, housing, company services (32.1%), the rest consists of public services and education (17.9%), production (14.8%), construction industry (2.4%), agriculture and forestry (0.1%) (Data: Shares of the sectors of total gross value creation in the city of Hamburg in 2017. Source: https://www.hamburg.de/contentblob/1005676/9c5c492e6dde8c4bd758cb0ccecc0c92/data/statistisches-jahrbuch-hamburg.pdf, S. 197). The harbour is a major economic driver. Hamburg over proportionally contributes to the national gross domestic product (3.6% in year 2017 with 2.2% of Germany's population). Hamburg has the highest GDP per person and income per person compared to the other federated states of Germany.

Geographic setting

Hamburg is located in the north-west of Germany (53°33′N, 10°0′E). The city has an outside territory, the island Neuwerk and its surroundings, which are part of the transboundary World

Heritage site Wadden Sea, the largest uninterrupted system of intertidal sand and mudflats worldwide (since 2010). In addition, the Speicherstadt and Kontorhausviertel, with traditional buildings close to the water, are UNESCO world heritage and to be protected cultural sites.

Hamburg's area is characterized by a relatively flat topography, with the highest elevations of 116 m above sea level located in the south-west of the city and lowest site 0.8 m below sea level close to the river Elbe. The tidal river Elbe is running through the city, constituting a close link to the North Sea (distance 100 km) and thus of major importance for the harbour of the city. The regular high tide is about 2.1 m above average water level. About once a year storm tides of more than 5 m occur, but extreme tides have occurred as well (1962, 5.7 m above sea level; 1973, 5.33 m above sea level; 1976, 6.4 m above sea level; 1990 and 1994, 6.02 above sea level; 1995, 6.02 above sea level; 1999, 5.95 m above sea level; 2007 and 2013, 6.09 m above sea level). Therefore, around 100 km dykes alongside the Elbe and several backwaters protect the citizens. The UNESCO world heritage site Speicherstadt is located outside of the regular flood protection and thus depends on individual flood protection measures on the buildings itself.

Hamburg's overall climate is mild with a maritime influence. The average annual air temperature is 9.4 °C (period 1981-2010) with an increase of about 1.4 °C from 1881 to 2013 (Meinke et al., 2018) (https://www.springer.com/de/book/9783662553787). There are in the 1981-2010 climate average 16.4 (4.5) days per year with maximum temperatures below 0 °C (above 30 °C) and 70 (0.8) days per year with minimum temperatures below 0 °C (above 20 °C) (Meinke et al., 2018). Precipitation is around 790 mm per year with an increase of average values, consisting of a tendency for larger increases in winter and smaller ones in summer. Heavy precipitation events become more frequent and snow amounts decrease. Wind speed average is 4 m s^{-1}; 10% of the days have average wind speeds of 7 m s^{-1} and more (Schlünzen et al., 2010).

The city's geographical location, the topographical characteristics and its maritime climate have a positive impact on urban climate and avoid building of an in the average very intense urban heat island and reduce air quality problems. Nonetheless, urban heat values are in the climate and summer average 3 °C (1.5 °C) in the summer (winter) months, based on differences in minimum temperatures. Due to ships and their emissions, the airport in the city, industrial production, commuting movements of around 350 000 people (coming from outside of city borders), emissions and pollutant concentrations are still high in some places within the city and close to the harbour.

Section B: Needs for integrated services

Main hazards

Climate change induced sea level rise, river level rise, storm tides, heatwaves, cold waves, heavy rain events, draughts, groundwater level increase, longer pollen season, air pollution, noise pollution.

With its close distance to the sea, Hamburg is especially vulnerable to climate change. Sea level rise and more frequently occurring storm tides are hazards for about 109 000 households (around 250 000 people). A higher variability of growing conditions and a longer vegetation period with expected draughts in summer create the urgency to ensure water provision for agriculture and urban green. Additionally, heavy rainfalls occur more frequently and higher the risks of inland flooding.

The city of Hamburg faces the challenge to prepare well regarding increasing climate change effects for the safety of its people and simultaneously meet the needs of its growing population and businesses economically which are met with enormous building activities. In part, these needs seem to be opposed, for example increasing rainwater infiltration in soil is inhibited by further sealing of ground/soil and therefore raises the risk of inland floods. In spite of the air quality enhancement through the marine air, Hamburg is highly exposed to emissions of ships, the airport, industrial production, trade and commuting traffic. In summer, heatwaves are a threat to the health of its population.

Hamburg suffers regularly from inland floods after heavy rainfalls, causing negative impacts on transport infrastructure, the ecology of water bodies and economic impacts due to flooded stores and cellars.

Actions taken

Flood warning system

Storm tides of up to 4.5 m above sea level (NHN) are announced by the federal office of maritime traffic and hydrography (Bundesamt für Seeschifffahrt und Hydrographie, BSH), higher storm tides are announced and updated by the Hamburg Service for Storm Tide Warning (Sturmflutwarndienst WADI) of the Hamburg Port Authority (HPA) every half an hour. The Hafenstab (HASTA) as part of the Katastrophenschutz (disaster warning service; under the HPA) takes measures to protect the population, infrastructure etc. Reacting to water levels published by the Central Disaster Response Unit (Zentraler Katastrophendienststab, ZKD) police, fire service, and aid organizations are activated to take the required measures of protection. Information about an upcoming storm tide is spread (depending on height of water level rising) by gun salutes six hours before a flood (+3.5 m NHN); sound vans in city districts (+4.5 m NHN); radio and television warnings (+5 m NHN); sirens (+7.3 m NHN). In any case, information about upcoming storm tides can be obtained by calling the services (numbers are found online and in information brochures) or checking water levels online (https://www2.bsh.de/aktdat/wvd/lf/StPauli_lf.htm). HPA offers a free service for warnings via sms or email for self-registered persons (Flutwarn Hafen).

General information on storm tides threatening Hamburg, recommended individual behaviour practices and help services can be found in brochures, online, or be acquired by telephone calls. The flood warning system is crucial for the implementation of the individual flood protection measures on the buildings of the Speicherstadt. These measures are only installed in case of a real flood risk.

Katwarn is a German-wide online warning system through which public authorities, police, fire service etc. inform the public via smartphone-app or email/sms about various bigger hazards like fires, windstorms, diffusing toxic substances and others. It includes storm tides for Hamburg. Warnwetter is a weather information and warning system by the German Meteorological Service (DWD) for informing disaster control (Katastrophenschutz) and the broader public about natural hazards and dangerous weather conditions. The Smartphone-App “NINA” combines these two services and offers action recommendations for precaution additionally to the warnings.

In cases of extreme heat the city’s agency for health and consumer protection informs, based on information provided by the DWD, the management of nursing homes in order to take precautionary actions for safeguarding the residents.

Air quality measuring net (Luftmeßnetz)

Several monitoring stations record the air quality within Hamburg at urban hotspots, the urban background and in the more rural parts. The values of five air pollutants (nitrogen dioxide, sulphur dioxide, ozone, carbon monoxide and fine dust) are measured and published every hour, graded singularly and combined as one general indicator (air quality index). This way potential health risks for the population are tracked and the public informed. The air quality plan (dated July 2017) defines measures to meet the EU-standard of air quality (esp. for nitrogen dioxide) as soon as possible. Measures include: Extension of bike routes and public transport (underground and suburban railway), new climate-neutral busses, new charging stations for electro-mobility, restriction of Diesel-cars for certain streets, cooperation with car producers for more electro-cars at existing car sharing offers; shore power and liquefied natural gas to reduce the nitrogen oxide emitted by harbours.

Climate plan Hamburg

In its climate plan, Hamburg has set out climate mitigation and adaptation strategies for various sectors. In order to decelerate global warming, and consequently contributing to the protection of UNESCO values like, ecologically, the Wadden Sea, and culturally, the buildings of Hamburg's Speicherstadt and Kontorhausviertel, Hamburg has set various measures to reduce carbon emissions. Overall long-term goals are a carbon reduction of 50 percent until 2030, and of 80 percent until 2050 compared to 1990. More short term, CO_2-emissions shall be reduced by 2 mio.to until 2020 compared to 2012.

Mitigation measures are amongst others: Fostering low emission mobility (expansion of extended bike routes, creation of public charging stations for electric cars, partnerships with firms to inform and promote conversion to electro-mobility). The repurchase of the district heat and gas network enables the municipality to influence the energy supply of Hamburg towards renewability, as part of the nationwide Energy Transition. The public administration aims to be CO_2-neutral in their agencies in 2030 through higher energy savings, efficiency and conversion to renewable energy sources (CO_2 compensation of flights of business trips, the prioritization of transport by train for business trips (run by renewable energy), conversion of the car fleets of public agencies to electric cars).

Adaptation is part of the climate plan with an emphasis on new rainwater and flood management approaches. The RISA-process, contained in the climate plan, aims for a new sustainable rainwater management system, aiming at retaining rainwater on properties instead of instantly draining it through the sewage system. Thus, the rainwater can naturally seep into the soil, providing a close to natural system and supporting evapotranspiration. RISA is established by a broad cooperation network of water related agents in Hamburg. In this context, a green roof strategy has been implemented, to support rainwater retention on rooftops and reducing the amount of 100% sealed surfaces.

Monitoring

In the context of the climate plan, a monitoring system is being developed, to monitor the effects of climate change and the implementation of adaptation measures. Climate change IMPACT indicators have been developed for five fields (continuously extended) to track climate change and its according impacts within the city. Furthermore, response indicators are being developed to monitor the climate change adaptation measures within the city. Current IMPACT indicators are related to inland flood prevention, coastal flood prevention, urban and landscape planning, agriculture and health. Special attention is given to the potential spreading of the tiger mosquito (Aedes albopictus). The institute for hygiene and environment in Hamburg conducts monitoring investigations for the discovery of tiger mosquitos since 2009 (until now, none were found).

Existing cooperation

Northern German Climate Monitor (Norddeutscher Klimamonitor): collects and presents information of climate and climate changes in the different regions of northern Germany. It is an information product for the public by a cooperation of the Norddeutsches Klimabüro of Helmholtz-Zentrum Geesthacht (HZG) and Regional Climate Bureau Hamburg of the German Meteorological Service (DWD). The Klima Campus Hamburg is a round table of Hamburg based national and local authorities and several research institutions including Hamburgs universities and focuses in climate related topics. To give a few examples, the Climate Service Center Germany GERICS, the DWD, the federal hydrological service BSH as well as the Center of Earth System Sciences and Sustainability of Universität Hamburg sit at the round table jointly with representatives from different agencies (e.g. Hamburgs agency for Environment and Energy). Several services have been and are coproduced by administration and research institutions.

Providers of urban services

Municipality (office for environmental protection), technical authorities (German meteorological service DWD, federal hydrological service BSH, environmental agencies).

Users of urban services

General public, municipality, technical authorities, ministries (of the federal state and nation), health sectors, companies, industry and transportation sectors, press agencies.

Requirements

Observation data (for warning systems, and model validation)

- Meteorological measurements, including high-resolution precipitation measurements (provided by DWD and Universität Hamburg)
- Water levels in Hamburg rivers, specifically the tidal river Elbe
- Air pollutant concentrations
- Climate indicators
- Weather and water level forecast.

Section C. Services integration

Short and long term

In several fields (see above) short term and long term integrated services or strategies exist. The aim is to enhance the combination of the above-mentioned services to increase the effectiveness of measures. Flood warning systems and traffic monitoring could for instance be combined to optimize traffic flow during flood events with according closures of important streets. Furthermore, a combination of weather services and rainwater retention systems can increase the capacity to deal with heavy rainfall. If heavy rainfall is likely, retention systems can be emptied just before the event, without decreasing the availability of water in case of droughts and heatwaves. The data of the Climate Monitor and the monitoring of the climate change effects can be used to optimize urban planning regarding climate change adaptation. Furthermore, a digitalised register of the entire urban rain water system within the city is currently under construction, this system will improve the capability to deal with heavy rainfall in the early stages of urban planning. In addition, research in the Universität Hamburg cluster of excellence CLICCS (Climate, Climatic Change, and Society) will address the needed complexities of urban planning/management systems to assess water induced stresses. There also ground water levels will be considered.

A2.12 **HELSINKI**

Prepared by Ari Karppinen

Section A: General information

Socioeconomic

Helsinki is the capital city and most populous municipality of Finland. Located on the shore of the Gulf of Finland, it is the seat of the region of Uusimaa in southern Finland, and has a population of 648 650. The city's urban area has a population of 1 268 296 making it by far the most populous urban area in Finland as well as the country's most important center for politics, education, finance, culture, and research. Helsinki is located 80 kilometres (50 mi) north of Tallinn, Estonia, 400 km (250 mi) east of Stockholm, Sweden, and 390 km (240 mi) west of Saint Petersburg, Russian Federation. It has close historical ties with these three cities.

Together with the cities of Espoo, Vantaa, and Kauniainen, and surrounding commuter towns, Helsinki forms the Greater Helsinki metropolitan area, which has a population of nearly 1.5 million. Often considered to be Finland's only metropolis, it is the world's northernmost metro area with over one million people as well as the northernmost capital of an EU member state. After Stockholm and Oslo, Helsinki is the third largest city in the Nordic countries. The city is served by the international Helsinki Airport, located in the neighbouring city of Vantaa, with frequent service to many destinations in Europe and Asia.

Geographical

Called the "Daughter of the Baltic", Helsinki is on the tip of a peninsula and on 315 islands. The inner city is located on a southern peninsula, Helsinginniemi ("Helsinki's peninsula"), which is rarely referred to by its actual name, Vironniemi ("Estonia's peninsula"). Population density in certain parts of Helsinki's inner city area is comparatively higher, reaching 16 494 inhabitants per square kilometre (42.720/sq mi) in the district of Kallio, but as a whole Helsinki's population density of 3.050 per square kilometre (7.900/sq mi) ranks the city as rather sparsely populated in comparison to other European capital cities. Outside of the inner city, much of Helsinki consists of postwar suburbs separated by patches of forest. A narrow, 10 kilometres (6.2 mi) long Helsinki Central Park, stretching from the inner city to Helsinki's northern border, is an important recreational area for residents. The Helsinki urban area is an officially recognized urban area in Finland, defined by its population density. The area stretches throughout 11 municipalities, and is the largest such area in Finland, with a land area of 66.931 square kilometres (25.842 sq mi) and approximately 1.2 million inhabitants.

Governance

As is the case with all Finnish municipalities, Helsinki's city council is the main decision-making organ in local politics, dealing with issues such as urban planning, schools, health care, and public transport. The council is chosen in the nationally-held municipal elections, which are held every four years.

Section B. Needs for the integrated services

Hazards

The most common disasters and hazards in the city are flooding, extreme winter conditions, traffic and slipping injuries, strong wind and thunderstorm impacts and fires.

Existing

Preparedness for such risks is part of advance operational and resource planning. This is aimed at securing the provision of services and limiting the damage caused by the situation. The goal is to secure the organization's operational capability in all conditions (https://www.hel.fi/static/kanslia/Julkaisut/2018/hybridiraportti_eng_020818_netti.pdf).

Users

The users of these services vary from General public, Government departments, Energy sector, Water management, Industry sector (building), Transportation sectors (land, sea and air), Health sector, Tourism sector, Insurance sector, Disaster risk management, etc.

Providers

Finnish Meteorological Institution is the responsible organization for providing the cities all the relevant information related to climate, weather and air quality related risk and hazards.

The municipal central administration defines the general guidelines for preparedness and continuity management in the municipality, issues joint guidelines for planning to be applied by each sector in their own plans, and maintains overall preparedness in the municipality. The City of Helsinki has prepared operational models for various disruptions, such as those caused by extreme weather and other unexpected circumstances. The City maintains a tight network of cooperation with Government authorities in safety and security matters. Continuity management and other planning that reinforce preparedness are the responsibility of the Helsinki Mayor, and the routine management of the operations is carried out by the City Executive Office.

Housing companies, enterprises and institutions are required by the Rescue Act to be prepared for emergencies and draw up an emergency plan for a building or other site to secure the safety of people. The emergency plan should specify potential emergencies, provide instructions on how to prevent them and name the persons in charge. It should also specify the actions to be taken in emergencies. The Finnish Government has defined (Government Bill on Rescue) the sites that need an emergency plan. These sites include workplaces that accommodate more than 50 people at a time and residential buildings with more than three dwellings. The owner or manager of a property is responsible for producing a preparedness plan for the property. The Rescue Department provides information on how to produce a preparedness plan.

Section C: Services integration

Short term

Multi-hazard early warning and forecasting systems are all operated/integrates by FMI – and the final products and services are tailored to meet exactly the user/city needs.

Long term

Urban planning for sustainable development, climate change mitigation and adaptation. Both FMI, Universities, some other institutes and cities themselves have their own activities related to long-term planning- but already now, especially FMI has a very close cooperation with the Helsinki area in assessing the climate and air quality related risk.

Components integrated (and how)

For operative weather measurements, fully integrated (FMI responsibly).

For operative air quality, partially integrated: Helsinki Metropolitan Area Council carries the main responsibility for this, and operates the official monitoring network (~10 stations); the responsibility of supporting measurements built during several research project (~40 stations), is divided between several operators (Companies, University, FMI. HSY); but the results are already integrated through FMI-EnFUser model.

All existing operative modelling tools (weather, AQ) are integrated/developed/provided by FMI, while information delivery and communication is a shared responsibility of several operators the cities, Helsinki Area Metropolitan council, FMI and University provide all some services of their own. Still the official responsibility of communication is quite clearly defined: FMI is the responsible organization for weather-related communications/info in the area while HSY is the responsible organization for AQ related info/communication.

A2.13 HONG KONG, CHINA

Prepared by Chao Ren/TC Lee

Section A: General information

Socioeconomic

Total area of about 1106 km2 and about 7.4 million people (2017). Hong Kong is a coastal city situated at the southeastern coast of China and over the eastern part of the Pearl River Delta (PRD). HK is a modern and highly urbanized metropolitan with superb infrastructure (e.g. advanced land, sea and air transport and communication systems, reliable water and power supplies, etc.) (https://www.yearbook.gov.hk/2017/en/pdf/E03.pdf).

Geographical

Sub-tropical climate with tropical and mid-latitude weather systems together with summer and winter monsoons. Coastal city with mountainous topography. Steep slopes over 20 percent of the total land area, most of the urban activities are concentrated on built-up areas which take up about 24 percent of land.

Governance

Hong Kong is an autonomous Special Administrative Region of the People's Republic of China, except in defence and foreign affairs (https://www.gov.hk/en/about/govdirectory/govstructure.htm).

Section B. Needs for the integrated services

Hazards

Heavy rain, Thunderstorms, Tropical Cyclones, Coastal inundation/Flooding, Landslides Heatwaves, Cold surges, Water scarcity, Fog, Air pollution.

Users

General public, Government departments, Energy sector, Water management, Industry sector (building), Transportation sectors (land, sea and air), Health sector, Tourism sector, Insurance sector Disaster risk management, Mass Media.

Providers

Hong Kong Observatory (HKO) –meteorological authority in Hong Kong, China; weather and climate monitoring, weather forecasting and warnings of severe weather.

Environmental Protection Department (EPD) – air quality monitoring/forecast/advisories.

Civil Engineering and Development Department (CEDD) – raingauge network, landslip risk, coastal and port engineering.

Drainage Services Department (DSD) – raingauge network, stormwater drainage services and flood prevention.

Other government departments/bureaus on urban planning, emergency rescue and disaster risk reduction (e.g. Security Bureau, Fire Services Department, Planning Department, etc.)

Requirements

Short term (DRR)

In situ weather observations (rainfall, temperatures, relative humidity, pressure, wind speed/direction, tidal information, visibility, solar radiation, evaporation, etc.)

Regular upper-air soundings and the high-resolution remote sensing images including radars, satellite, and lightning location, etc.

A wide range of weather forecasts covering multi-timescales.

Timely and effective warnings and advisories for various weather hazards (e.g. tropical cyclone, thunderstorm, heavy rain, landslide, flooding, cold and very hot weather, etc.)

Tailor-made meteorological services for aviation and marine communities as well as other weather-sensitive users

Air pollution monitoring and forecast

Long term (urban planning)

Climatological monitoring and information services as well as seasonal predictions for different sectors (e.g. infrastructure and building designs, urban planning, air ventilation assessment, public health, water resource management, public utilities (energy), research communities, etc.)

Climate projections of various elements in Hong Kong based on IPCC climate model data.

Research development and public education.

Section C: Services integration

Components integrated (and how)

(1) At the level of observational infrastructure

Weather

Over 200 automatic weather stations (HKO, CEDD, DSD) providing a wide range of meteorological measurements (e.g. rainfall, temperatures, relative humidity, pressure, winds, tidal information, visibility, solar radiation, and evaporation, etc.).

Regular upper air soundings and a full range of remote sensing observations (including Doppler weather radars, wind profilers, microwave radiometers, Doppler LIDARS, SODARs, satellite reception systems, and a lightning location network).

Automatic tide gauge network for tidal predictions, real-time monitoring of storm surges and tsunamis.

Developed in-house a set of heat stress monitoring system which automatically measures the dry bulb, natural wet bulb, and globe temperatures in Hong Kong for computing the Hong Kong Heat Index which caters for the climate and environment of Hong Kong.

Community Weather Information Network (Co-WIN) http://cowin.cse.cuhk.edu.hk/

Air quality: 16 air quality monitoring stations of EPD for regularly monitoring O_3, NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$

Climate

- Continuous observations of essential surface meteorological observations for over 130 years at HKO headquarters.
- Regular upper air soundings at HKO's King's Park Meteorological Station since 1950s.
- Tide gauges for monitoring water levels since 1950s.
- Automatic weather station networks since mid-1980s.
- Raster based Urban Climatic Map data for urban planning and air ventilation assessment.

(2) At the level of modelling tools

Weather

State-of-the-art numerical weather prediction (NWP) products from major global models (e.g. ECMWF, NCEP, JMA, etc.)

HKO's Aviation Model which is a WRF-based system providing hourly-updated, detailed short-term meteorological forecasts for the PRD region down to the urban scale

In-house developed rainstorm nowcasting system called SWIRLS (Short-range Warnings of Intense Rainstorm of Localized Systems) to support rainstorm related high-impact weather services for public and special users.

Air quality: Regional air quality model "Pollutants in the Atmosphere and their Transport over Hong Kong (PATH)" and air quality forecasting system based on WRF model and the Community Multiscale Air Quality (CMAQ) model. The operation of WRF is supported by the NWP results provided by HKO.

Climate

HKO adopts an ensemble approach to formulate its seasonal forecast for Hong Kong, taking into consideration available products from major climate prediction centres and the Global-Regional Climate Model (G-RCM) operated in-house.

Climate projections of various elements (e.g. temperature, wet bulb temperature, rainfall, mean sea level) in Hong Kong are computed based on IPCC climate model data.

(3) At the level of the services/information delivery

Weather

HKO provides a wide range of forecasts covering multi-timescales (e.g. nowcasting, 9-day forecasts, etc.) and different spatial resolutions in Hong Kong, including location-specific weather forecast for the next 9 days through the Automatic Regional Weather Forecast (ARWF) service and "Extended Outlook" featuring probabilistic forecast of maximum and minimum temperatures up to 14 days ahead and the tropical cyclone track probability forecast up to the following 9 days.

Warnings and special advisors are issued for various weather-related hazards such as tropical cyclones, rainstorms, thunderstorms, very hot or cold weather.

Various weather information, forecast and warnings of HKO are timely disseminated to the general public, government departments and other specialized users through different channels, including media (TV, radio and newspaper), Dial-a-Weather service, webpages, mobile platforms, social media and tailor-made information dissemination systems.

Online information service and location specific weather services (e.g. ARWF and nowcast products for rainfall and lightning) are available from HKO's "MyObservatory" mobile app and website for urban dwellers to access various first-hand weather information anywhere and anytime.

HKO launched its Facebook page and Instagram platform to enhance communication with the public through social media in March 2018. Facebook posts on weather information and various weather phenomena were released regularly to enhance public understanding of the weather.

Pre-wet season seminars, training courses, briefings and visits are conducted for relevant government departments and weather sensitive stakeholders to promote their awareness of, and community preparedness for, natural disasters.

HKO's Airport Meteorological Office, via web-based Aviation Meteorological Information Dissemination System (AMIDS), provides weather information for Hong Kong International Airport and the Hong Kong Flight Information Region (HKFIR) in support of international aviation navigation.

HKO provides marine meteorological information and forecasts to serve international shipping on the high seas, fishing in coastal waters and local water transport and recreation offshore.

Air quality

Air Quality information and the Air Quality Health Index (AQHI) are released to the public via various channels, including website, mobile app, computer desktop alert wizard and telephone hotline.

PATH provides 3-day air quality forecasts for internal reference and to support the AQHI forecast for next 24 hours.

Climate

The meteorological observations in Hong Kong are published regularly by HKO for monitoring the monthly, seasonal, and annual climate status in Hong Kong. Analysis of long term variations of various meteorological elements and indices are also conducted to assess the climate change in Hong Kong due to global warming and local urbanization.

HKO has set up the Climatological Information Services and Climate Change webpages to provide one-stop-shop online access to climate data/statistics of Hong Kong, the latest global and local climate change status, climate projections and educational resources on climate subjects.

Seasonal forecasts of average temperature and total rainfall and annual outlook of tropical cyclone activity and rainfall in broad terms are prepared and made available online for users' reference.

HKO has established close partnerships with various stakeholders in the city to enhance its weather and climate services by embracing the spirit of the Big Data concept, especially for urban-focused services concerning the priority areas of WMO Global Framework for Climate Services on energy, water, health, and disaster risk reduction.

For example:

- Working closely with different engineering departments and professional bodies to establish and regularly review the engineering design standards and codes of practices for protecting the city and public safety against various weather hazards and natural disasters.
- Collaborating with other government departments, tertiary institutions, and social enterprises to study the impact of weather on public health.
- Providing meteorological data and expert advice for Planning Department and its consultants as well as other professional bodies to establish guidelines to assess the impact of urban developments on air ventilation and micro-climate.
- Joining hands with energy sector to enhance energy saving and resilience of energy infrastructure.
- Providing monthly reservoir yield forecast to support water resource management.
- Coordinating Research Forums to interact with experts and researchers to apply research results for the benefits of the society.
- Collaborating with government departments and stakeholders to promote public awareness on climate change issues.

A2.14 **JOHANNESBURG**

Prepared by Ezekiel Sebago

Section A: General information

Socioeconomic

The City of Johannesburg (CoJ) is located in the Gauteng province in the north-eastern part of the Republic of South Africa, at 26.2041 °S, 28.0473 °E. It is the largest city in South Africa covering an area of 1645 square kilometres and the most populous with 8% of the national population (close to 5 million). The city's population has been growing over the last decade as it continues to attract people from other parts of the country and internationally, who are looking for better economic opportunities and quality of life. CoJ has some world class infrastructure in the fields of telecommunications, transportation, water, power, and with globally competitive health care and educational facilities. However, the city also has great contrasts – home to both wealthy and poor, residents and refugees, global corporations and emerging enterprises.

The main economic sectors found in the city are finance and business services, retail and wholesale trade, community and social services and the manufacturing sector. It contributes 40% to the provincial economy and almost 16% to the national economy.

Climate

Johannesburg is located on the high-veld plateau region of South Africa with an average elevation of around 1500 m above mean sea level. The climate of Johannesburg is classified as sub-tropical, with mild and mostly sunny winters (cold nights with occasional frost), and warm summers but with thunderstorms at times mostly in the afternoon and evening. Most of the rainfall is concentrated in the summer months.

Governance

The City of Johannesburg is made up of a legislative arm (the council); an executive arm (consisting of the executive mayor and the mayoral committee); and an administrative arm. The council focuses on legislative, oversight and participatory roles, delegating its executive function to the executive mayor and the mayoral committee. The council's principal role is as lawmaker, with the other key role to debate and discuss issues affecting the city. The city is sub-divided into 11 districts.

Section B. Needs for the integrated services

Most common hazards in the city are due to severe thunderstorms which are prevalent in the spring and summer seasons. Occasional heavy downpours from these storms often result in flash floods which result in most of the damage that occurs in CoJ, especially in informal settlements. Loss of life due to drownings have also been experienced. Road flooding has also resulted in many traffic accidents. Another common hazard from storms is hail (large in size or abundance of small, on occasions) which causes damage to housing and vehicles. Strong winds can also cause damage which could lead to disruption in the service delivery, especially power. Duststorms do occur and result in poor visibility, but are rare. Although heatwaves could occur during the summer, CoJ's elevation ensures that they are as common as surrounding areas with lower elevation.

Description of existing integrated urban services for meeting hazard challenges, or hazard-specific services, capability of monitoring, predicting and forecasting hazards.

The South African Weather Service (SAWS) has several automatic weather stations within the precincts of CoJ, the city administration has also installed automatic rainfall stations in identified areas. In addition, CoJ lies within a good coverage area for the S-Band weather radar situated in the neighbouring City of Tshwane. The METEOSAT Second Generation (MSG) satellite is in usage. For air quality, CoJ owns several monitoring stations across the city.

Providers of the urban services

SAWS is responsible of all weather-related hazards, including flash flooding. This is currently done on a thresh-hold basis, but a switch to impact-based is expected soon. There are plans to issue air quality forecasts in the future.

Users of the integrated urban services

The main users are the Disaster Management structures, from National, provincial and city. Other users are emergency responders, government departments, media and non-governmental relief organizations.

Requirements for the services

SAWS is busy procuring a forecaster workstation which will allow for efficient visualization of all meteorological parameters (observations and models).

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

An impact-based severe weather warning system to be implemented. This will be used in conjunction with existing systems like the flash flood guidance system.

Long term

(1) At the level of modelling tools

SAWS plans to run the local version of the Unified Model at a sub-km resolution. There are also plans to implement data assimilation from AWS, ARS and radar.

(2) At the level of the services/information delivery, communication

Air quality forecasts to be issued. Dynamic vulnerability data to be made available on a GIS platform to ensure improved impact-based weather warnings.

A2.15 LONDON (ENGLAND)

Prepared by Brian Golding

Section A: General information

Socioeconomic

The Greater London administrative area is a cosmopolitan urban area of 9M people covering an area of 1 600 sq km. Its GDP of $0.75 billion is almost 30% of the English GDP. The London economic area extends beyond this to much of south-east England in an extended agglomeration covering about 15 000 sq km with a total population of 18 million people. This area abuts the economic areas of other major cities which, together, take in almost 50% of the area of England and over 80% of its population of 53 million. London is well provided with infrastructure: power (integrated electricity and gas supply grids cover England), transport (served by five international airports, high speed rail links to all parts of England, high speed highways to all parts of England, port with connections to other UK ports, European and global ports), communications (wired grid covers England), water (supplied by reservoirs round the periphery of London) and drainage. Much of the infrastructure in central London is of 19th century construction.

Geographical

England is set in the middle latitudes, with a maritime climate on the eastern edge of the Atlantic Ocean. London is influenced by proximity of the Eurasian land mass to its east, but that influence is ameliorated by the North Sea. London is on the Estuary of a major river with numerous small tributaries, many of them confined in channels or pipes within the urban fabric. It is open to fluvial and coastal hazards. The terrain is rather flat, mostly flood plain, surrounded by gentle hills. The latter are largely of chalk and contain the main aquifer water sources.

Governance

The UK is a sovereign kingdom of four nations: England, Scotland, Wales and Northern Ireland. The UK government has authority for defence and foreign affairs. For internal affairs, the nations have varying levels of independent authority, with Scotland having most. There is no separate English national authority. Within England, the primary sub-division is into Counties/Unitary Authorities/Metropolitan Boroughs, of which London is a special case of the last. Within London are lower tier authorities: boroughs and parishes. Emergency management is the responsibility of the top tier of local authority. However, operational arrangements (police, fire & rescue, ambulance) do not always align with this administrative structure.

The Met Office is a UK government institution under the Department of Business, Energy and Industrial Strategy and funded by customer government departments and private industry.

The primary weather forecasting and warning capability is funded through the Public Weather Service, in which a variety of government customers are represented through the Public Weather Service Commissioning Group. Flood warnings (fluvial, coastal and surface water) for England are the responsibility of the Environment Agency which is an institute of and funded by the Department of Environment, Food and Rural Affairs (DEFRA). The Met Office and Environment Agency work closely together, especially through the joint Flood Forecasting Centre, based in the Met Office. Air quality and pollution forecasts and warnings are provided by the Met Office on behalf of DEFRA. Weather-related health forecasts are provided by the Met Office on behalf of Public Health England.

The civil contingencies act (2005) defines the responsibilities of emergency responders, including the emergency services and infrastructure operators. These include identifying weather-related risks and drawing up response plans. All responders are required to take note of weather warnings, which they receive through a dedicated web portal, Hazard Manager. Their use of the forecast and warning information is supported by Met Office Civil Contingency Advisors. The response to a disaster is layered at gold (strategic), silver (tactical), and bronze (operational) levels, involving all affected actors, but with the police providing the lead at each level.

Prior to 1987, severe weather warnings in the UK were focused on 18 urban areas. Since 1987, that concept has been dropped in favour of a national service that covers all populated areas. The affected area is indicated graphically on maps, with affected administrative areas listed in the text. The presence of an urban area influences the issue of a warning, since the warnings are impact-based and impacts tend to be larger in highly populated areas.

Section B. Needs for the integrated services

Hazards

Windstorm, flood (fluvial, surface & coastal), fog, snow/ice, thunderstorm, cold, heat, UV, air pollution.

Existing

National (UK) service by Met Office (separate urban services merged following 1987 storm disaster review) for storm, heavy precipitation, snow/ice/fog, separate customer-defined for heat, cold, AQ, pollen, UV, space weather.

London-specific Air pollution warning service delivered through the Mayor’s office (other cities also have local air pollution services).

Birmingham (and possibly other cities) have integrated travel information services, including weather-related hazard information.

National Flood warning service (England), with warnings for specific river reaches and coast sectors.

Providers

NMS, Environment Agency, Private Sector (consultants, media, insurance). Government departments, Infrastructure authorities and Businesses are responsible for obtaining their information to enable risk to be managed. Information may be obtained from free sources or paid-for services. In the latter case, the source may be the Met Office or a private provider. There are some large providers (e.g. Meteogroup), but many smaller, niche, providers.

Users

General public; Central Government departments; Local government; Energy; Water management; Transportation sectors (land, sea and air); Health; Insurance; Telecommunications; Military; Business; Education.

Requirements for the services

Short term (DRR)

- Observations of weather hazards: precipitation maps from radar, in situ observations of extreme wind, temperature, snow, ice, fog, lightning.
- Forecasts of weather hazards: precipitation, wind, temperature, snow, ice, fog, lightning.
- National Severe Weather Warning Service warnings of weather hazards classified by likelihood and impact: covers wind, rain, snow, ice, fog, thunderstorm.
- Flood guidance (joint with Environment Agency) warnings of flooding from coastal, fluvial, surface water and ground water sources by area classified by likelihood and impact.
- Bespoke forecasts/warnings for vulnerable sectors such as marine, aviation, rail, road, crane operators.
- Air quality forecast.
- UV forecast.
- Heatwave and Cold Wave health guidance.
- Pollen forecast.

Long term

The primary input to long term planning is the UK Climate Projections, which are updated every 10 years, and contain the spatial distribution of trends and probability distributions of key variables, both over the UK for internal planning, and more widely for strategic and business analysis.

Section C: Services integration

Short-term plans - Components integrated (and how)

(1) Observational

Met obs integrated; AQ separate; road met separate; hydrology separate.

- The Met Office observing network provides WMO standard meteorological observations at approximately 50 km spacing over lowland England. These observations represent the environment within which urban development modifies the surface weather characteristics.
- The Met Office and Environment Agency jointly operate a network of C-band dual-polarisation, Doppler radars that cover lowland England within a range of approximately 100km. Precipitation is also monitored with raingauges: of which a subset are available in real time, but the bulk are daily gauges read manually.

- Upper air conditions are predominantly inferred from assimilation of satellite data into models. However, substantial and increasing use is made of automatic aircraft observations. Monitoring of volcanic ash is carried out with a network of lidars and sun photometers.

- River flow and/or level and coastal tide levels are monitored by the Environment Agency. Data from these networks feed into the joint Met Office/Environment Agency Flood Forecast Centre.

- The Met Office manages a network of pollen gauges which feed information into the Met Office pollen warning system.

- There are several networks of air quality monitors in England, mostly operated by private companies for specific city authorities. The Environment Agency operate a baseline network of about 130 air composition measuring stations, of which 16 are within Greater London. These stations monitor a selection from PM_{10}, $PM_{2.5}$, NOx, SOx, O_3 and feed routine data into the Met Office for use in the national Air Quality forecasting system.

- Road weather is monitored using roadside observations operated by private companies, which are fed into prediction systems, some privately operated and some Met Office operated.

- Several industries make observations to inform their own operations. These include power transmission, rail transport, wind and solar power generation, nuclear power plants, chemical plants, agriculture. Many of these stations are reported through online hubs, including Weather Underground and Weather-on-the-Web (WoW). The latter is operated by the Met Office and the observations are used in the forecasting process.

(2) Modelling

Met & AQ & hydrology & surge integrated; river catchment hydrology separate

- The Met Office operates a unified weather prediction model (UM) for forecasting from minutes ahead at km-scale resolution up to long term climate change at 100s of km resolution. Km-scale forecasts for the UK are updated hourly using the latest observations.

- The UM has the capability for interactive coupling with ocean, land hydrology, ice and atmospheric chemistry models as required. Currently such coupling is used for seasonal and climate prediction but not for short range NWP, except for the AQUM regional coupled chemistry configuration used for UK air quality forecasting. Fluvial and Coastal flood prediction and pollution transport use stand-alone models driven by meteorological input from the UM. The STEPS nowcasting system is used to adjust NWP output to match observations at the start of the forecast.

(3) Services/information delivery, communication

- Warnings of the main weather hazards are communicated through a single standard warning system: the National Severe Weather Warning Service, which provides seamless warnings using a colour-coded probability/impact matrix up to the limit of hazard predictability – typically 5 days for windstorms and major fluvial floods, but much less for flash floods, snowstorms and fog. A web portal is used to communicate this information, together with supporting material, to emergency responders.

- A broader range of hazards, including space weather and geological hazards, are summarized in the Daily Hazard Assessment, prepared by the Met Office for government on behalf of all of the government natural hazard institutes.

- The joint Met Office/Environment Agency Flood Forecasting Centre produces a daily Flood Guidance Statement, using the same probability/impact matrix as the NSWWS, for all forms of flooding up to 5 days ahead.
- The hydrologically-related government institutes collaborate to produce a monthly hydrological summary and outlook providing the status of water resources and likelihood of floods and/or drought over the following season.
- The Met Office provides a monthly seasonal outlook to government from the available seasonal forecasting systems.
- The main service supporting government, utilities and commerce at climate timescales is the UK Climate Projections, updated every 10 years and produced by the Met Office, based on its own and CMIP climate runs, and drawing in partner information on hydrology, oceanography etc.

A2.16 **MEXICO CITY (Ciudad de México, https://www.cdmx.gob.mx/)**

Prepared by Luisa Tan Molina

Section A: General information

Socioeconomic

Mexico City Metropolitan Area (MCMA): 21.4 million inhabitants occupying 7 585 km^2, consists of:

- Mexico City: 8.8 million inhabitants in an area of 1 485 km^2
- 59 municipalities of the State of Mexico: 12.5 million inhabitants in an area of 6 000 km^2
- 1 municipality of the State of Hidalgo, 130 000 inhabitants in an area of 100 km^2

Mexico City Atmospheric Monitoring System has a wide geographic coverage and good data collection capacity; the emission inventory is very well developed and is now compliant with the BASIC+ certification issued by C40; the inventory is updated every two years and includes criteria and toxic pollutants, black carbon and greenhouse gases. Transport sector includes comprehensive public transportation infrastructure (urban buses, Bus Rapid Transit (Metrobus), subway (Metro), light rail) and non-motorized transport (bike sharing programme). The city has maintained an extensive communication infrastructure.

Geographical

The MCMA lies in an elevated basin at an altitude of 2 240 m above mean sea level and is surrounded on three sides by mountains and volcanoes, with an opening to the Mexican Plateau to the north and a mountain gap to the southeast. Subtropical highland climate: a cool dry season from November to February is followed by a warm dry season until May and a rainy season from June to October.

Governance structure

Civil protection is supported by different levels of Mexican legislation: (a) Constitution: article 123 covers security and health of worker in facilities, (b) State Law: General Act for Civil Protection defines the general terms of each state law on civil protection and the regulation of each state on civil protection. Because Mexico City is also the capital of the nation, it can never become a state; however, Mexico City has the same level of autonomy comparable to that of a state.

There are a number of institutions responsible for addressing urban hazards and have policymaking powers:

- National Water Commission (CONAGUA): national plans and mandate for flood management.
- National Meteorological Service (SMN): provides meteorological information at national and local levels; manages the climatological database. SMN shares information in newsletters or special advisories through fax, modem, phone or internet to specific users such as Interior Ministry, National Defence, Navy, Environmental Secretary, oil companies, electricity companies, Tourism Secretary, state governments, mass media, airports, hospitals, insurers, general public and the National Service of Civil Protection. SMN has begun collecting information from meteorological networks from other institutions, such as electricity companies, agricultural stations, the navy, and universities.
- National Centre for Disaster Prevention (CENAPRED): in charge of risk management and disaster prevention in Mexico to reduce population exposure to meteorological, hydrological, geological and chemical hazards such as volcanic eruptions, flooding, tropical storms, earthquakes, and chemical releases, among others.
- Secretariat of Environment (SEDEMA): manages Mexico City's Air Quality Monitoring System (SIMAT); issues air quality and meteorological forecast to alert the public about critical pollution levels and prevent exposure to harmful pollutants; announces contingency actions when measured pollutants levels are above critical threshold. URL: https://www.sedema.cdmx.gob.mx/
- Megalopolis Environmental Commission (CAMe): covers Mexico City and five surrounding states (Puebla, Tlaxcala, Morelos, Hidalgo and Mexico) in central Mexico. The commission plans and execute policies, handles air quality monitoring, emissions standards and smog-check issues in this region.

Section B. Needs for the integrated services

Hazards

- High pollution events due to high pressure systems and thermal inversion
- Extreme hydrometeorological events leading to floods and landslides
- Health impacts caused by heatwaves and dehydration
- Earthquake
- Volcanic eruptions
- Wildfires
- Social and spatial inequality & high vulnerability to climate change
- Vector-borne diseases related to climate change

Existing

The government has established the Center for Command, Control, Computation, Communications and Citizen Contact (C5) to monitor multi-hazard and respond within five minutes of an incident:

- Environmental Contingency Programme (air pollution)
- Air quality forecast system
- Hydrometeorological alert system

- Seismic system
- Volcanic alert
- Hydrometeorological Bulletin
- Risk Atlas
- Contingency task force for water scarcity

Providers

The urban services are provided by the city government through the different agencies that report to the Mayor and to the public.

- Center for Command, Control, Computation, Communications and Citizen Contact (C5) integrates most of the urban services to provide rapid response against emergencies in the city; agencies send information to C5 which reports directly to the Mayor.

- Secretariat of Environment is responsible for climate action plans and air quality management programmes. The General Director of air quality management is responsible for ambient air quality monitoring and forecasting, updating emissions inventory.

Users

Government agencies responsible for the environment, energy, water management, transportation, health, tourism, disaster risk management, National Service of Civil Protection; Industries, hospitals, airports, insurance sector General public and; Mass media.

Requirements

Short term

- Environmental monitoring and forecast: provide timely information to different sectors of Mexico City population about weather, water, air quality, climate, wildfires, volcanic hazards.

- Improve the performance of air quality forecasting systems using emission inventories and updated environmental data.

Long term

Invest in infrastructure and personnel for the monitoring network due to changes in the sources of emissions and pollutants and the expansion of urban areas to the periphery.

Enhance measurement of vertical profiles of meteorological parameters.

In-depth analysis of the increase in atmospheric temperature on the air quality in the MCMA and the impact of meteorology on air pollution.

Improve data collection in the health system in Mexico, including better temporal and spatial resolution, diagnostics and historical exposure data, reinforce epidemiological surveillance.

Develop and implement an integrated regional land use-transportation-air quality management system involving close cooperation of the relevant authorities (environment, transportation, urban development, and public works) with public participation.

Expand model coverage and air quality forecasting to include the megalopolis region.

Expand and strengthen capacity-building for technicians and scientists.

Section C: Services integration

Short term

Mexico City government has established the Center for Command, Control, Computation, Communications and Citizen Contact (C5) to monitor multi-hazard with rapid respond.

Long term

Mexico City government launched the Resilience Strategy on 2016 to build resilience in specific areas at the community level and includes the following 5 pillars: (i) Foster regional coordination; (ii) Promote water resilience as new paradigm to manage water in the Mexico Basin; (iii) Plan for urban and regional resilience; (iv) Improve mobility through an integrated safe and sustainable system; (v) Develop innovation and adaptive capacity.

Mexico City government has taken actions to mitigate emissions of greenhouse gases and short-lived climate pollutants by integrating air quality and climate action plans in the design of environmental policy to realize potential synergistic benefits, such as emission control standards for vehicles, energy efficiency programmes for public and private buildings, improve collection and disposal of solid waste with more efficient solutions including potentially using landfill gas recovery to supply clean energy.

(1) observational

- Extensive and robust air quality monitoring (data with high time and coverage resolution)
- Updated emissions inventory (criteria and toxics pollutants, GHGs)
- Health standards and air quality risk index
- Vehicular Inspection and maintenance programme
- Industry regulation and surveillance
- Open data with high access and transparency and integrated app.

(2) modelling

- Research has play an important role in designing, implementing and improving many of the urban services; Mexico City has a long history of collaboration with research institutions, both national and international.

- Recent field measurement campaigns have provided comprehensive datasets for updating and improving the emissions inventory, the chemistry, dispersion and transport processes of the pollutants emitted to the MCMA atmosphere and their regional transport, transformation and impacts. The information is being used for modelling studies.

- Air quality modelling and forecasting services are the result of collaborations with national and international research institutions.

- Forecasting of air quality conditions on short timescales, support the city government with information to take effective actions through mitigation to exposure to high concentrations of pollutants and lay the groundwork for developing policies to reduce emissions for air quality improvement and other co-benefits (e.g. climate, food security, etc.)

(3) services/information delivery, communication

- Mexico City government has deployed various communication strategies to disseminate information to the public, including real-time report of ambient air quality data and forecasting, which are available to the public via website and mobile application, and are used by the news media in weather forecast to alert the public of high pollution episodes and severe weather events, as well as provide hydrometeorological notices and risks atlas.

A2.17 **MOSCOW**

Prepared by Dmitri Kiktev

Section A: General information

Socioeconomic

Moscow is a major political, economic, cultural, and scientific center of Russia with a population of more than 12.5 million people. Moscow has one of the biggest municipal economies in Europe. It accounts for more than one-fifth of Russia's gross domestic product (GDP). The city is a busy transport node. Moscow is served by four international airports and nine railway terminals.

Geographical

Moscow is the northernmost and coldest megacity on the planet. The city is situated in a plane area on the banks of the Moskva River and stretches for 40 km from west to east, and for 52 km from north to south. By its territorial expansion southwest in July, 2012, the area of the capital more than doubled, going from 1 091 to 2 511 square kilometres.

The region’s climate is humid continental. High weather variability and variety of natural hazards are typical for the area of the Moscow city.

Governance

The Mayor of Moscow is the leading official in the executive, leading the Government of Moscow, which is the highest organ of executive power. All local city laws must be approved by the Moscow City Council (Duma). The Government of Moscow is the highest executive body of state authority of Moscow.

Moscow Department for Environmental Management and Protection is an executive authority and has the rights of special empowered authority for environment protection, atmosphere air protection, fauna and its habitat protection, biological diversity saving, state ecological expertise.

Responsibility pathway for addressing urban hazards: the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) is responsible for general purpose weather forecasts and warnings; a special municipal meteorological office is responsible for specialized urban meteorological forecasts and services.

Section B. Needs for the integrated services

Hazards

The list of most common hazards in the city includes windstorms, heavy precipitation, icing, visibility reductions (fog, blizzards), thunderstorms, air pollution, forest fires, pollen.

Existing services

A Unified System of Environmental Monitoring was developed and implemented for Moscow megapolis basing on automated monitoring methods for priority indicators of the state of natural environment and meteorological characteristics. The system is a high-tech integration platform exploiting modern geoinformation technologies for large data sets of meteorological parameters, concentrations of air pollutants, industrial emissions, residents' complaints etc. A special citywide information resource, Unified City Database for Environmental Monitoring is developed for the city authorities and decision-makers. An information-analytical center was established for 24/7 operational monitoring of the environmental situation in Moscow megapolis, timely detection of environmental issues, warnings and organization of rapid response to environmental incidents.

Providers

Services are provided by the respective federal and municipal entities (Federal State Budgetary Institution (FSBI) "Hydrometcenter of Russia" and Central Regional Administration of Roshydromet, Autonomous Non-Profit Organization "Hydrometeorological Bureau of Moscow and the Moscow Region" (along with Roshydromet Moscow is served by its own municipal meteorological office), State Environmental Budgetary Institution (SEPI) «Mosecomonitoring» under umbrella of the Department of Environmental Management and Protection of the city of Moscow.

Users

General public, local government, disaster risk management, transportation sectors (land and air), energy sector, housing and communal services, health sector, tourism sector, insurance sector, etc.

Requirements for the services

Ensuring the hydrometeorological and ecological security of the city population and economy.

Improvement of reliability, diversity and outreach of environmental information services.

Optimization of city services maintenance and development of the smart city infrastructure.

Timely assessment and prediction of the flooded areas taking into account the dynamics of hydrometeorological processes.

Realization and development of monitoring of atmospheric air condition, water objects, hydrometeorological characteristics in the city of Moscow, assessment of the state and dynamics of natural environments, determination of the main sources of pollution.

Operational forecasting of atmospheric air pollution, taking into account forecasts of the meteorological situation with differentiation across the city.

Development of technologies for assessing the effectiveness of urban activities for reducing air and water pollution, taking into account weather and climate factors.

Short term (DRR)

- Dense in situ weather observations and air pollution measurements.
- High-resolution remote sensing (radars, satellite, profilers, lightning detectors, etc.)
- High resolution weather forecasts with differentiation across the city.
- Air pollution monitoring and high-resolution forecasting with differentiation across the city.
- Tracing of the main sources of the environmental pollution.
- Warnings and advisories for various weather hazards with differentiation across the city.
- Tailored meteorological services for various weather-sensitive users (for transportation, energy sector etc.).

Long term (urban planning)

Stage-by-stage development of seamless environmental forecasting system and its integration into the city decision-making support systems.

Section C: Services integration

Components integrated

(1) At the level of observational infrastructure

According to the approved city Roadmap for development of weather monitoring, forecasting and warning services for the Moscow city, a network of gradient meteorological observations (automatic meteorological stations at 3 levels w.r.t. to the ground at 120 towers of mobile communication) and 42 surface automatic meteorological stations is to be established in Moscow region in the nearest 3 years. It should be integrated with observational in situ and remote sensing network of Roshydromet, Universities and private providers.

(2) At the level of modelling tools

In the nearest 2-3 years a limited area numerical weather prediction system COSMO/ICON with a sub-kilometre grid spacing and assimilation of high-resolution network observations is to be operational for the Moscow region for the purposes of deterministic weather forecasting. Limited area ensemble prediction system is to be developed for probabilistic forecasting of natural hazards in the Moscow megapolis. Chemical transport model COSMO/ICON-ART and CHIMERE systems are to be used for the air quality forecasting.

Further development of forecasting tools for forecast ranges from nowcasting to climate projections.

(3) At the level of services/information delivery, communication

Development of interfaces and information gateway between the Moscow city bodies, Roshydromet, Universities and private information providers, development of “tailored” applications for various categories of users, promotion of Common Alerting Protocol (CAP).

A2.18 **NEW YORK CITY**

Prepared by Chananda Mitra/Dev Niyogi

Section A: General information

New York City (NYC) is often considered emblematic of a complex, heterogeneous, and vibrant urban locale. NYC is on the north-eastern coast of the United States, along the Hudson River. The city covers an area of 303 square km and is home to 8.6 million people (Census 2017). It is one of the most urbanized cities in the face of the Earth and has highly modernized infrastructure (e.g. transportation, communication, reliable water and power supplies). The metro region has a broader population of over 20 million and houses around 1 million buildings (https://datausa.io/profile/geo/new-york-northern-new-jersey-long-island-ny-nj-pa-metro-area/).

Geographically, New York city has 5 boroughs, 59 community districts and number of neighbourhoods (https://www1.nyc.gov/site/planning/data-maps/city-neighborhoods.page). Each borough has extensive stretches of shoreline, and all except the Bronx are islands unto themselves (Manhattan and Staten Island) or part of one (Brooklyn and Queens are part of Long Island). The water bodies border and contain are as diverse as the urban landscape: canals, creeks, ponds, inlets, straits, rivers, estuaries, bays, a sound, and an ocean. It is classified to have warm humid subtropical climate.

Politically, the City government, which is led by a Mayor and a Council of 51 members, employs more than 300 000 civil servants – including public safety, sanitation, transportation, professionals, artists- enabling safety, well-being, vibrancy, and opportunities in the City. The city governance is done through elected Mayor, borough Presidents, City Council Members, Public Advocates, and Comptroller (https://www1.nyc.gov/nyc-resources/about-the-city-of-new-york.page).

Section B. Needs for the integrated services

New York as a coastal city has hazards such as erosion, and coastal storms, thunderstorms, flooding, winter storms, droughts and technological/anthropogenic infrastructure failures (earthquakes, cyber threats).

The City through its Emergency Management has developed a hazard mitigation programme. Additionally, there is a concerted effort related to climate resiliency assessment and planning. A full hazard mitigation plan is available with detailed guidance related to different hazards to be tackled including ways of detection, early warning, actions during emergencies and post disaster phase (https://www1.nyc.gov/site/em/ready/hazard-mitigation.page).

The users of these services vary from the general public, government departments, energy sector, water management, industry sector, transportation sectors (land, sea and air), health sector, tourism, insurance sector, disaster risk management, etc. The NYC Department of City Planning looks after all the regulations, laws, plans and policies and NYC emergency management regulates the mitigation and preparedness strategies at times of hazards. Different providers including volunteer services and organizations work together at the time of crisis in the city of New York (https://www1.nyc.gov/site/dhs/shelter/providers/providers.page). For more details refer: Academic institutions such as City College/City University of New York, Columbia University, New York University also work together to mitigate the risks of climate change and hazards in the city. Different programmes and initiatives such as OneNYC plan, Notify NYC, NYC Severe Weather, Know Your Zone, Partners in Preparedness, etc. with adaptation analysis and act such as New York's ClimAID Analysis and Community Risk and Resiliency Act (CRRA) are in place to understand and provide service for hazard response and long-term climate resiliency (https://www1.nyc.gov/site/em/index.page, https://www.dec.ny.gov/energy/100236.html, https://onenyc.cityofnewyork.us/).

Short-term services (https://www1.nyc.gov/site/em/ready/hazard-mitigation.page) and long-term services include plans for different hazard mitigation, seasonal predictions, Climate data and expert advices for different sectors (e.g. infrastructure and building designs, urban planning, air ventilation assessment, public health, water resource management, public utilities (energy), research communities, etc.) and Climate projections of temperature, temperature, rainfall, mean sea level in New York based on IPCC climate model data, and the city's climate resiliency plan. NYC has its own mitigation plans where the planning effort was led by New York City Emergency Management and the Department of City Planning in close collaboration with the Mayor's Office of Recovery and Resiliency. What resulted was a comprehensive approach to risk reduction (https://www1.nyc.gov/site/orr/challenges/nyc-panel-on-climate-change.page).

Section C: Services integration

To assess risk and identify appropriate management strategies, the planners pursued a rigorous process of analysis and research, drawing from the historical record, the latest scientific and technical information, various city plans and reports, and consultation with many parties. The Department of City Planning is responsible for the City's long-term planning, including land-use and environmental review; preparation of plans and policies; and providing technical assistance and information to government agencies, public officials, and community boards. The New York City Panel on Climate Change (NPCC), a body of leading climate and social scientists and risk management experts, was convened by the City in 2008 to produce climate projections for New York City and inform City government's decision-making and the public. They also work on the latest climate models, observations about climate trends, and new information about greenhouse gas emissions. The City uses its Zoning Resolution and Construction Codes to control the built environment and create a safer, healthier, more resilient city. Zoning is developed and written by the Department of City Planning and enforced by Department of Buildings. There are programmes such as Notify NYC alerts for emergency activity in all five boroughs, NYC Emergency Management's Advanced Warning System to alert individuals with special needs to hazardous weather, utility or transportation disruptions, public health emergencies, and incidents requiring evacuation, Wireless Emergency Alerts for governmental officials to send geographically targeted emergency alerts to enabled mobile devices on the AT&T, Sprint, T-Mobile, and Verizon wireless networks, Ready New York to encourage New Yorkers to prepare for a variety of emergencies. Also, New York City now has a presence on many social media channels. It facilitates real-time, two-way communication between the City and the public. These programmes and initiatives are part of short-term communication strategies which include these:

- Sending emergency alerts prior to severe winter weather events, taking care to target populations with special needs, ensuring that communication is multi-lingual, and reaching out to populations who are homeless.

- Sending weather notifications to property owners, contractors, and developers, advising them of measures they can quickly take to prepare for a winter storm, such as clearing gutters and removing snow or ice from roofs.

- For major storms or prolonged periods of extreme cold, coordinating with multiple City agencies to communicate a consistent message about weather conditions and steps New Yorkers can take to prepare. Severe weather events may require mayoral press conferences.

- Communicating via as many media as possible: social media, press releases, notifications to elected officials, and alert systems. For social media platforms, providing real-time updates as conditions worsen or improve. Whereas long-term strategies aim for these objectives:

    - Help the public learn how to prepare for severe winter weather events.

    - Help homeowners learn how to maintain buildings to reduce heat loss, roof leaks, and roof collapses.

    - Help households understand the potentially lethal dangers of carbon monoxide poisoning that can be caused by gas appliances in their homes.

A2.19 **ROTTERDAM**

Prepared by Marie-Claire ten Veldhuis

Section A: General information

Socioeconomic

Rotterdam is 325.8 km^2 and has a population of approximately 620 000 people, agglomeration. Part of Randstad positive contribution to GDP (15%). Rotterdam is a harbour city at the west coast of Europe, with one of the biggest harbours of the world.

It also has a very strong national connectivity especially Rotterdam – Amsterdam is a very good connection. This great connectivity is a result of the four big highways surrounding the city.

Rotterdam has a pro-active approach to climate adaptation, with a lot of innovative projects going on.

Climate

Rotterdam has a very moderate climate. Oceanic climate (very near to the North Sea, coastal) it also has a big river running through the middle of the city (The Maas). Urban heat islands are a serious issue because of the high urbanization rate.

Rotterdam has a very flat environment mostly below sea level (this is because the city is built on reclaimed land).

Governance

Rotterdam's decision-making structure:

The Municipal Executive Committee and the City Council jointly govern the city and make up the City Government. The City Council sets out general policy and passes bills. The Executive Committee is the executive body which submits bills, implements policy and does day-to-day decision-making. Long-term climate adaptation plans will go through the City Council, but if there's an emergency hazard, the Executive Committee will make the decision.

Rotterdam belongs to the Kingdom of the Netherlands and at national level the Dutch government does the decision-making.

Section B. Needs for the integrated services

Most common hazards

Because of the large harbour in Rotterdam air pollution is a serious issue as a result of diesel powered ships passing through Rotterdam.

For Rotterdam, the most dangerous environmental risk is fluvial and coastal flooding because it lies below sea level. If we take sea level rise into account this is the biggest risk.

Pluvial flooding could also do a lot of damage to both cities, but it is highly unlikely to cause dangerous situations for the citizens. Nevertheless, urban pluvial flooding should be treated seriously. Over the years, the accumulation of relatively small local events has resulted in substantial aggregate damages (Ten Veldhuis, 2009).

Existing integrated urban services

Rotterdam relies on the hazard forecasting by the KNMI. Which is done with a lot of different tools like radar and satellite data. This is an organization funded by the Dutch government and is available for every city in the Netherlands.

Providers of the urban services

KNMI, Aeolis (for precise, detailed and specific meteorological information), Consultancies, for example Royal HaskoningDHV (which provides advice at for instance flood risk management), Universities: UVA, TU Delft, Erasmus Rotterdam.

Users of the integrated urban services

- General public
- Government (local)
- The Port of Rotterdam
- Transportation sectors
- The general public transportation network (Train, tram, metro, bus)
- Airport of Rotterdam
- Insurance sector
- Disaster risk management

Requirements for the services

Short term (DDR)

- In situ weather observations (rainfall, temperature, humidity, air pressure, tidal information (Maas), etc.

- Air quality monitoring to measure pollution
- Warning systems in case of extreme weather events
- Special meteorological services for the port of Rotterdam

Long term (urban planning)

- Big database of all the collected weather data
- Climate data experts to advise the city council (with urban planning, infrastructure, air quality, water management)
- Accurate sea level data (for coastal flooding protection)
- Seasonal predictions (to warn the public in case of extreme drought or wet periods, and what they can do to anticipate in these scenarios)

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

Long term: urban planning for sustainable development, climate change mitigation and adaptation.

Components integrated (and how)

(1) At the level of observational infrastructure

Short term (Weather/Air quality/Tidal measurements)

- In the Netherlands are 30 continuously monitored weather stations (They measure: Temperature, wind direction and strength, relative humidity, precipitation, solar radiation and air pressure)
- Seismologic monitoring
- Two identical 5.6 GHz Doppler weather radars (One in the Bilt and the other one in Den Helder)
- Tidal gauges of the Maas
- Air quality monitoring by the RIVM (Rijksinstituut voor Volksgezondheid en Milieu) and the Rijksuniversiteit Groningen. (Measuring fine dust $PM_{2.5}$, PM_{10}, NO_2, NO, CO, CO_2, O_3, BC, SO_2, H_2S and Ultra Fine Particles UFP).

Long term (Climate prediction)

KNMI DataCenter (KDC) has observations for over 300 years (temperatures, precipitation, etc.)

In Europe, there is an observational institution European Climate Assessment & Dataset which receives data from 63 different countries in Europe and has more than 50 000 different series of data. These series are in 12 different categories: Maximum Temperature (TX), Minimum temperature (TN), Mean temperature (TG), Sunshine (SS), Snow depth (SD), Precipitation amount (RR), Sea level pressure (PP), Humidity (HU), Wind gust (FX), Wind speed (FG), Wind direction (DD), Cloud cover (CC).

The ECA&D also works together with the WMO for region VI (Europe and the Middle East).

(2) At the level of modelling tools

Short term

ECMWF, Global model from the European Weather Centre in Reading (United Kingdom). Forecasts up to 14 days on a 9 by 9 km grid (around 600 squares in The Netherlands).

HARMONIE Model for The Netherlands and a bit of the surroundings. Is used since 2012 for forecasts up to 2 days on a 2.5 by 2.5 km grid (around 10 000 squares for The Netherlands

CRIME, Cloud Representation, Improvement and Evaluation in the HARMONIE model.

Long term

The department Research and Development of Weather and Climate models investigates and develops research tools for weather and air quality prediction applications and climate models. RDWK participates in some international projects and is the Focal Point of the Netherlands to the IPCC.

RDWK consists of about 45 research professionals (including PhD and technical support staff). We have a strong international network, and most activities are executed in collaboration with partners in e.g. HIRLAM/Harmonie, EC-Earth, ECMWF and universities.

RDWK is structured in 3 clusters: Mesoscale modelling develops tools for regional numerical weather prediction (NWP) and climate analyses; Large scale modelling focuses on global climate and atmospheric chemistry; Postprocessing and Analysis develops statistical analyses, applications and climate services (https://www.knmi.nl/research/weather-climate-models).

(3) At the level of the services/information delivery, communication

Short term

Weather prediction is a very common thing which is provided to the public through a lot of different communication types such as television (more national approach), newspapers, radio, internet webpages and even social media platforms.

Weather alarms and warnings are special advice provided by the KNMI on a national scale, but they can be given for certain regions in The Netherlands. You can select your region by province. There can be alarms for different types of weather issues such as heavy rainfall, gusts of wind, snowy conditions and slipperiness, heatwaves, whirlwinds, fog (especially for traffic information), thunderstorms and extremely low temperatures (https://www.knmi.nl/nederland-nu/weer/waarschuwingen/utrecht).

For air quality, there is an internet website where all the data of The Netherlands is stored together for the different types of particle in the air. You can find actual data on the site http://www.luchtmeetnet.nl/.

Long term

Almost all data from ECA&D is open access, and can be downloaded from their websites. There are organizations who use this data to do climate predictions, which are communication by the government through news stations to the public.

The KNMI website is a place where long term climate information is being provided to the public with a lot of 'simple' explanations so the common public can understand.

Instances such as WMO Global Framework for Climate Services on energy water, health and disaster risk reduction is more focused on the big data concept, so they try to get as much data as possible from all over the world to do climate predictions as precise as possible. WMO lets engineers and professionals from different departments work together to process this data.

A2.20 **SAINT PETERSBURG**

Prepared by Elena Akentyeva

Section A: General information

Socioeconomics

Saint Petersburg is the second largest city in the Russian Federation after Moscow. It's situated in North-western Federal District of Russia, on the Neva River, at the head of the Gulf of Finland on the Baltic Sea.

As a federal subject Saint Petersburg contains, besides Saint Petersburg proper, a number of towns, 21 municipal settlements, as well as rural localities. The total territory of the federal subject comprises 1 439 km2. The area of Saint Petersburg city proper is 605.8 km^2. The federal subject's population is 5 281 579 or 3.6% of the total population of Russia (2017). Saint Petersburg is the important industrial, scientific and cultural centre of Russia. It takes the 2nd place on economy scales among all subjects of the Russian Federation, conceding only to Moscow and contributes 5.4% of Russian GDP (2016). Its specialization includes oil and gas trade, shipbuilding yards, aerospace industry, technology, including radio, electronics, software, and computers, machine building, heavy machinery and transport, mining, instrument manufacture, chemicals, pharmaceuticals, and medical equipment, publishing and printing, food and catering, wholesale and retail, textile and apparel industries, and many other businesses.

Climate

Saint Petersburg experiences a humid continental climate of the cool summer subtype (Köppen: Dfb), due to the distinct moderating influence of the Baltic Sea cyclones. Summers are typically cool, humid and quite short, while winters are long and cold but with frequent warm spells. The average winter minimum is about -9 °C, and the record low temperature is -35.9 °C recorded in 1883. Solid frozen ground is a normal part of winter there. The Neva River within the city limits usually freezes up in November-December (recent years in January), while break-up occurs in April. On average, there are 123 days with snow cover (stable from December to March), which reaches the average of 24 cm by February. The frost-free period in the city lasts on average for about 135 days. There is some temperature variation within the city limits, and the city itself experiences a climate slightly warmer than its suburbs. The highest temperatures of July and August, 37.1 °C, were reached in 2010. Weather conditions are, however, quite variable all over the year. Average annual precipitation varies across the city, being about 600–750 mm per year on average and reaching maximum in late summer and in the north (daily maximum is 89 mm).

Though this number is not high by itself, soil moisture is almost always excessive because of low evapotranspiration due to the cool climate. Relative humidity of air is also high (78% on average), and overcast is common throughout the year (165 days a year on average).

Governance

The political life of Saint Petersburg is regulated by the Charter of Saint Petersburg adopted by the city legislature in 1998. The superior executive body is the Saint Petersburg City Administration, led by the city governor. Saint Petersburg has a single-chamber legislature, the Saint Petersburg Legislative Assembly, which is the city's regional parliament. Committee on Natural Resource Management and Ecology is an executive authority that pursues a policy of environmental conservation, and coordinates activities of other executive branches of the Saint Petersburg government in this area (https://www.gov.spb.ru/gov/otrasl/ecology/).

Section B. Needs for the integrated services

Hazards

High wind and wind-driven floods, heavy rain, snowfall, hail, snowstorm, ice and snow loads, strong fog, severe cold, intense heat, and fire hazards. Hydrological risks are connected with surges, backwater from jams, ice dams, storms, and coast erosion. Ecological risks can be caused by elevated air pollution under conditions of atmospheric inversion, surface- and sea water contamination, soil and ground water pollution.

Existing

Main integrated urban services for meeting hazard challenges are the North-West Territorial Administration for Hydrometeorological and Environmental Monitoring and Hydrometeorological Centre of St. Petersburg. They are the branches of Federal Service for Hydrometeorology and Environmental Monitoring of Russia (Roshydromet, http://www.meteo.nw.ru/). Meteorological observation network in the region of Saint Petersburg includes 3 basic meteorological stations, 7 automatic stations, 35 precipitation gauges, and 27 air monitoring stations. Hydrological observation network consists of 15 stations and 22 hydrologic sections on 15 water bodies.

Providers

Hydrometeorological service provides information on climate and hydrology, forward-looking information including forecasting hazards, and tailored hydrometeorological and environmental information for agriculture, energy, transport, building construction, housing and public utilities in Saint Petersburg. This service checks calibration of hydrometeorological instruments, and carries out licensing activities in the area of hydrometeorology and ecology. Private companies who have license agreement with Roshydromet can also provide hydrometeorological services. There are several research institutes of Roshydromet in Saint Petersburg that explore urban climate pattern, impact of changing climate conditions on economy sectors, human health and environment, create hydrological, weather- and climate models. They carry out scientific and technical expertise for all Russian territory. For example, Voeikov Main Geophysical Observatory (MGO) is the oldest institute of Roshydromet. Its areas of research cover structuring of observational network, air pollution analysis and modelling, climate services for economy and social sphere, analyses of past and current climate, creation and development of hydrodynamic atmospheric climate models of different classes, statistical interpretation of model calculations and the use of model estimates in applied research, including analysis of the impact of climate change on sectors such as the economy, transport, construction, energy, and social sphere, climate related risk assessment as well as elaboration of adaptation strategies taking into account economic appraisal (http://voeikovmgo.ru).

Users

The Committee on Natural Resource Management and Ecology of Saint Petersburg, Emergencies Ministry (regional and national), regional water services companies, design and construction companies, energy providers, Leningrad nuclear power plant, traffic committee, Russian Railways, airport Pulkovo, river – and seaport.

Requirements

Since 2010, Roshydromet has organized the annual training on "Climate services for economic and social sectors in the context of climate variability and change" at the MGO. Participants of the training are exposed to the different types of tailored climate products, methods of calculation and data formats for the different user groups in the context of the current and future climate. Intended audience: climatologists and meteorologists from Russian Meteorological and Hydrological Services and other organizations that deal with the climate services for the various economic and social sectors. MGO gives similar training on methods of observation over meteorological indexes and air pollution. Training on hydrological observations and forecast is given by the State Hydrological institute (http://www.hydrology.ru/).

Section C: Services integration

Short term

North-West Territorial Administration for Hydrometeorological and Environmental Monitoring and Hydrometeorological Centre of St. Petersburg realize multi-hazard early warning and real-time forecast of dangerous events for Saint Petersburg administration, Emergencies Ministry, mass media, and other interested organizations.

Long term

Committee on Natural Resource Management and Ecology, research institutes of Roshydromet, and Institute of urban development work out long-term urban planning.

In 2016-2017 Climate strategy of Saint Petersburg was created. It was based on urban area development plan, and results of regional climate modelling. The main goal of this strategy is the adaptation of urban infrastructure to current and future climate change as well as climate change mitigation. When developing Climate strategy, the results of international research projects were taken into account.

For example, the objective of the Russian-Finnish project RAINMAN was to develop feasible and innovative solutions to ensure good state of freshwater resources within changing climate and intensified land use and to integrate selected solutions into city development guidelines and plans. The members of this project were meteorological and hydrological services, regional water services companies, State Hydrological institute, MGO, https://www.researchgate.net/project/RAINMAN-Integrated-Heavy-Rain-Risk-Management).

A2.21 **SANTIAGO**

Prepared by Pablo Hernandez

Section A: General information

Socioeconomic

The city of Santiago (33.5 °S; 70.5 °W) is the capital of Chile. It has 5.2 million inhabitants and an area of 641 km^2. This city is located in Metropolitan region (the region has a total of 7.1 million inhabitant and 15 403 km^2 of surface). It's modern and urbanized, and the 16.8% of the energy matrix is based on renewable energy. Chile is a country with the economy centralized in Santiago.

Geographical

Geographically Santiago is surrounded by the Cordillera de la Costa (west), Cordillera de Los Andres (east) and with mountain ranges, Angostura de Paine (south) and Cordón de Chacabuco (North). The geography discourages the ventilation of the basin, because the Cordillera de la Costa is opposed to the propagation generated by the sea.

Its climate is warm temperate with winter rains that reach 300 mm per year, with a prolonged dry season.

Governance

Chile has a presidential republic system (http://www.ceacgr.cl/CEA/pdf/Organigrama-de-la-administracion-del-Estado.pdf).

Section B: Needs for the integrated services

Hazards: Droughts, earthquake, air pollution, wildfire, landslides and floods.

Providers

The providers of urban services are mainly public services (ministries). The Ministry of the Environment (MMA) together with the Chilean Meteorological Service (DMC) are in charge of providing daily forecasts of air quality and providing real-time information on the current state of the atmosphere (meteorology and air quality. This information must be always displayed (air quality (https://sinca.mma.gob.cl/), weather (http://www.meteochile.gob.cl/PortalDMC-web/index.xhtml)). The Meteorological Service provides daily meteorological forecasts for 5 ~ 7 days, seasonal bulletins (3 months) and long-term annual information (climate change 2030 to 2060). In addition, it also provides emergency bulletins for volcanic ash, wildfires and floods. There is also the National Seismological Center (CSN) of the University of Chile and the National Emergency Office of the Ministry of the Interior (ONEMI), which is responsible for announcing alerts during an emergency.

Users

The general public, public sector (ministries, sub-departments), private sector (industries, companies).

Requirements

In terms of requirements, whether short or long term, everyone needs observed data. For meteorology, observed data is required to be used in modelling with data assimilation and input data from global models (such as GFS) is required to start the model. For air quality, it is the same but without data assimilation. Also, to carry out modelling and forecasting, it requires machines dedicated to High Performance Computing (HPC) and people who can manage them. These machines are found in universities and some public services.

Section C: Services integration

Observational infrastructure

In Santiago, there are 11 air quality monitoring stations that measures in real-time concentrations of CO, SO_2, NO, NO_2, NOX, O_3, PM_{10} and $PM_{2.5}$ that also measure meteorological variables of relative humidity (%), ambient temperature, Wind direction and wind speed. These stations are provided by the Ministry of the Environment. In addition, the Chilean Meteorological Service has a network dedicated to measuring meteorological variables, such as: Temperature 2 m, Temperature 10m, wind direction, wind speed, humidity, pressure at sea level and water fall.

Modelling tools

For meteorological and air quality forecasts, the model used is WRF-Chem (Weather Research and Forecasting with Chemistry), which is used in operational mode for forecasting particulate material (PM_{10} and $PM_{2.5}$) with national coverage. Also, they use MOS statistical models (Model Output Statistics) and other models based on linear regressions. On average, the forecast horizon is 3 days. For weather forecasts, the WRF model is also used, as well as information extracted directly from global models (GFS). On average, the forecast shows for the next 5-7 days.

For climate, experimental data is used that allows modelling from periods of 2030 to 2060 with WRF for studies and research. Software such as CPT (Climate Predictability Tool) is also used to make seasonal forecasts.

Services/information delivery, communication:

Meteorology

Forecasts and meteorological bulletins are published daily by the Chilean Meteorological Service through the website and television (news). In addition, these products are announced through social networks (Facebook, twitter, Instagram, etc.).

Air quality

Air quality forecasts are published daily by the Ministry of the Environment through the website, Email, television (news). In addition, these products are announced through social networks (Facebook, twitter, Instagram, etc.).

Climate

The Chilean Meteorological Office publishes monthly and annual newsletters on the website. They also publish information for agricultural, aeronautical and maritime purposes.

A2.22 **SEATTLE**

Prepared by Chandana Mitra/John Lebadie

Section A: General information

Population and area

Seattle city: 730 400 inhabitants occupying 83 mi^2, consists of:

- 7 City/District Council
- PUMA (Public Use Microdata Area, http://www.seattle.gov/opcd/population-and-demographics/about-seattle - landuse)

Infrastructure

The density of the city is 11.6/acre. 5 003 acre parks and 8.9 acres open spaces per 1 000 people. Percent of the population that lives with ¼ mile of a city-owned open space: 85%. Percent of the city in single-family zoning (excluding parks and rights-of-way): 54%. Net new housing units added since 2004: 29 330. Square feet of non-residential space built between 1995 and 2005: Over 25 million.

Nearly all of Seattle's population, 97.5%, lives within ¼ mile of a transit stop with some level of service. Ranks 7th of the 25 largest U.S. cities in transit service with a Transit Score of 59 (Walk Score).

Land use distribution

Seattle's land area remains mostly single-family in nature, but most residential development capacity, 93.5 percent, is in the multifamily zoning types with 73 percent in designated growth areas (http://www.seattle.gov/Images/Departments/OPCD/Demographics/AboutSeattle/Existing Land Use Full Size.png).

Residential construction permits: Seattle is experiencing high volumes of residential permits with historic highs of residential units in the permit pipeline for 2012 (http://www.seattle.gov/Images/Departments/OPCD/Demographics/AboutSeattle/Unit Count Line Graph.png).

Climate zone and geographical position

The Seattle has 29 NWS station (Seattle Tacoma Airport station lies in an altitude of 427 m above mean sea level, https://www.wrh.noaa.gov/mesowest/mwmap.php?wfo=sew&map=sew&list=1&sort=name&limit=1). The Seattle municipal area is 91.5685 square miles. This includes 88.4997 square miles of land area and 3.0688 square miles of water area. This figure was compiled by the Seattle Engineering Department and is included in the department's official history, Public Works in Seattle. The area includes all water areas between the north and south city limits from the Pierhead Line on Puget Sound to the Pierhead Line on Lake Washington. Annexed water areas outside these lines are not included.

Seattle is situated on a series of hills in a lowland area on Puget Sound's eastern shore between the Olympic Mountains to the west and the Cascade Mountains to the east. Westerly air currents from the ocean and the shielding effects of the Cascade range produce a mild and moderately moist climate, with warm winters and cool summers. Extremes in temperature are rare and of short duration, and the daily fluctuation is slight. While Seattle is known for its pronounced rainy season and frequent cloudy weather, the average annual rainfall is actually less than that of many other cities in the United States, including New York and Atlanta (http://www.city-data.com/us-cities/The-West/Seattle-Geography-and-Climate.html).

Seattle's climate is temperate, with cool summers and mild winters. To the west, the Olympic Mountains provide protection from the heavy winter rains that frequently inundate the Pacific coast of Washington, while the tall Cascades to the east shield the city from mid-continental extremes of heat and cold. Average high temperatures in July seldom exceed the mid-70s F (about 24 °C), while average highs in January are in the upper 40s F (about 8 °C). The temperature drops below freezing for about 10 to 15 days annually. Owing to the confluence of humid continental and oceanic weather systems, the sky is often overcast. However, the city receives an average of only 37 inches (940 mm) of precipitation each year. The summer sky is usually at least partly clear, but overall there are fewer than 60 completely sunny days annually (https://www.britannica.com/place/Seattle-Washington).

Average Temperatures: January, 40.8 °F; August, 66.1 °F; annual average, 52.4 °F.

Average Annual Precipitation: 36.6 inches.

Governance structure (decision-making)

Legal Framework: The mayor-council form is the oldest form of government found in Washington cities and was the only option available to most cities from statehood in 1889 until 1910 when the commission form was first introduced (https://www.seattle.gov/cityclerk/agendas-and-legislative-resources/seattles-form-of-government).

This form consists of an elected mayor (elected at-large) who serves as the city's chief administrative officer and a council (elected either at-large or from districts) which is responsible for formulating and adopting city policies. The mayor-council form is characterized by a separation of executive and legislative powers and a system of checks and balances patterned after traditional national and state governments. In all but the largest cities, elected city and town mayors and council members serve on a part-time basis leaving most of the day-to-day operations to various full and part-time administrative personnel (http://mrsc.org/getdoc/88bd80e7-61ce-49ba-a848-0b2c070c3ef9/Trends-in-Forms-of-Government-in-Washington-Cities.aspx).

Seattle is designated as a first-class Charter City under RCW 35.01.010, operating under a Mayor-Council form of government.

The Seattle City Charter embodies the fundamental principles of the City, defines the City's powers and duties, and guarantees certain rights to the people. The City Charter also sets forth the powers and duties of the City Council.

City Departments and Offices are established by the Seattle Municipal Code, Title 3 and the City Charter (https://www.seattle.gov/cityclerk/agendas-and-legislative-resources/seattles-form-of-government).

Responsible Institutions for addressing urban hazards, policymaking powers:

- The Seattle Department of Finance and Administrative Services (FAS): FAS is responsible for Facilities and Emergency Response Programme (Fire Facilities and Emergency Response Levy), Facility Assessments and Pre-Disaster Mitigation Planning and Seismic Risk Assessment.

- Office of Sustainability and Environment: The Office of Sustainability and Environment delivers cutting-edge policies and effective programmes to address Seattle's environmental challenges while creating vibrant communities and building shared prosperity. OSE collaborates with City departments, business partners, non-profit and community-based organizations, and learning institutions to develop and implement initiatives in the following areas: climate protection, buildings and energy, urban forestry, green stormwater infrastructure, and food policy. They have the authority to make Seattle Climate Action Plan and Citywide Climate Change Preparedness Strategy.

- Public Health – Seattle & King County: Public Health – Seattle & King County provides public health services for the City, including services for children and youth, persons with chronic disease, and communicable diseases; immunization services; environmental health services; public health emergency preparedness; emergency medical services; violence and injury prevention services; a medical examiner; nutrition support services; and tobacco prevention programmes.

- Department of Planning and Development: The Department of Planning and Development provide rapid assessment of damaged buildings following earthquakes. The Department of Planning and Development manages the City's National Flood Insurance Program (NFIP). Conduct public outreach with the intent of providing expert advice for property owners to manage landslide-prone areas.

- Seattle Fire Department: The Fire Marshal's Office (FMO) administers the SFD fire prevention programme to provide a reasonable level of life safety and property protection from the hazards of fires, explosions, and dangerous conditions, including releases of hazardous materials for Seattle's residents, workers, and visitors.

- Office of Emergency Management: The Seattle Office of Emergency Management (OEM) is responsible for managing and coordinating the City's resources and responsibilities in dealing with all aspects of emergencies. Its basic mission is devoted to citywide disaster preparedness, response, recovery, and mitigation. It places a strong emphasis on individual and community preparedness and provides a key liaison function between the city and its state and federal emergency management counterparts.

- Seattle city Light: The Dam Safety Programme of Seattle city light involves the coordination, monitoring, and oversight of activities for six major dams to reduce the risk and impacts from dam failure due to natural and man-made hazards.

- Seattle Public Utilities: Seattle Public Utilities (SPU) is comprised of three major direct-service providing utilities: water, drainage and wastewater, and solid waste. The water utility provides more than 1.3 million customers in King County with a reliable water supply; the drainage and wastewater utility collects and disposes of sewage and storm water; and the solid waste utility collects and disposes of recycling, yard waste, and residential and commercial garbage. All three utilities strive to operate in a cost-effective, innovative, and environmentally responsible manner. SPU also houses the engineering services line of business, which serves both City departments and outside agencies, providing efficient, customer oriented engineering services that assist clients with replacing, improving, and expanding facilities with the least possible disruption to the community (http://www.seattle.gov/Documents/Departments/Emergency/PlansOEM/HazardMitigation/Seattle 2015 - 2021 HMP Final.pdf).

Section B. Needs for the integrated services

Hazards

Unlike other parts of the country, Seattle doesn't have any regular catastrophic events to deal with on a yearly basis. They don't have tornadoes. They don't have hurricanes. They get a lot of rain and can sometimes get high winds during storms, but these don't usually result in disaster-level damages (although, fallen trees are no joke if you live under any tall fir trees).

But make no mistake—Seattle is not immune to major disasters. Quite the contrary, this region has the potential for major and massive natural disasters to strike, so major in fact that the entire region could even be destroyed if the worst-case scenario were to happen (think huge Cascadia Subduction Zone earthquake followed by an equally destructive 9.0 earthquake). From earthquakes to tsunamis, no matter how remote the chances are, it's best to understand what could happen and how to be prepared (https://www.tripsavvy.com/seattle-natural-disasters-2965046).

A Washington State Department of Health study examined incidents occurring in 1992. According to the report there were 118 events in King County, about 10.2% involving transportation and 89.8% occurring at fixed facilities. Twenty-six incidents caused a total of 66 injuries, most commonly involving acids and volatile organic compounds. Additionally, 29 incidents resulted in the evacuation of nearly 1 400 people. The report indicates that 44 incidents in King County occurred within one quarter mile of residential areas, indicating some risk to people not directly involved with the released chemicals.47. A recent Washington State Hazard Identification and Vulnerability Analysis cited an average of 960 emergency spills occurring annually in King County. Significant events in King County detailed by the study include: the release of 2 500 gallons of fuel from Olympic Pipeline at their Renton pumping station, the release of hydrofluoric and nitric acids from Boeing's Auburn plant, numerous drug lab events, metal finishing company fires at Boeing and Universal Manufacturing, a spill at UPS in Redmond, numerous releases of ammonia from cold storage facilities and the release of a small amount of chorine from a public water company. Response teams have narrowly averted some potentially large releases (https://www.kingcounty.gov/safety/prepare/EmergencyManagementProfessionals/Plans/~/media/safety/prepare/documents/HIVA/Hazmat.ashx).

Existing integrated urban services

The government has established the Center for Command, Control, Computation, Communications and Citizen Contact (C5) to monitor multi-hazard and respond within five minutes of an incident:

- Environmental Contingency Programme (air pollution)
- Air quality forecast system
- Hydrometeorological alert system
- Seismic system
- Volcanic alert
- Hydrometeorological Bulletin
- Risk Atlas
- Contingency task force for water scarcity

Providers of the urban services

It has been stated in the paragraph under "Responsible Institutions for addressing urban hazards, policymaking powers" (http://www.seattle.gov/Documents/Departments/Emergency/PlansOEM/HazardMitigation/Seattle 2015 - 2021 HMP Final.pdf).

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

Long term: urban planning for sustainable development, climate change mitigation and adaptation.

A2.23 SEOUL METROPOLITAN AREA

Prepared by Moon-Soo Park via Jhoon Kim (jkim2@yonsei.ac.kr)

Section A: General information

Socioeconomic

The Seoul Metropolitan Area (SMA) is located on central part of the Korean Peninsula. It was ranked to include the fifth largest built-up urban area by population in 2018 (Demographia, 2018). The SMA consists of three administrative provinces: Seoul Special City (Seoul City), Incheon Metropolitan City (Incheon City), and Gyeonggi Province. Seoul City, the capital city of South Korea, is surrounded by Gyeonggi Province (to the north, south, and east) and Incheon City (to the west). Incheon City is located between Seoul City and the Yellow Sea. The Gyeonggi Province surrounds Seoul City and Incheon City. The SMA covers an area of 11 799 km^2 and is home to 25.8 million people (http://kosis.kr). Seoul City has an area of 605 km^2 and the highest population density of 16 142 km^{-2}, while Gyeonggi Province has the highest population of 13.1 million people, but the largest area of 10 184 km^2, thus the lowest population density of 1 285 km^{-2}. The SMA's gross regional product was 698 billion USD, generating 49.5% of the country's total GDP. The SMA has ranked as the fourth largest urban economy in the world.

Geographical

The SMA has very complex geography, topography, and land cover. The Gyeonggi Bay is in the Yellow Sea in the west of the SMA, and has a very irregular coastline. The western part of the SMA comprises relatively low-lying farmland or urban areas, while the eastern part contains high-altitude mountain ranges, some of which are higher than 1 000 m. Most mountains are covered with forest. The Han River flows from east to west, and divides the SMA and Seoul City. Seoul City is surrounded by several high mountains: Bukhan Mt. and Dobong Mt. in the northern part, Surak Mt. and Bulam Mt. in the north-eastern part, and Gwanak Mt. and Cheonggye Mt. in the southern part. There is a small mountain (Nam Mt.) in the center of Seoul City. The SMA's climate is classified as temperate with four distinct seasons: hot and humid summers due to the North Pacific high-pressure system, and cold and dry winters due to the Siberian high-pressure system (Jung et al., 2002).

Governance

Seoul City is comprised of 25 districts, Incheon City is comprised of 8 districts and 2 Guns, while Gyeonggi Province is comprised of 28 Cities and 2 Guns. Each City is led by a mayor, while Gyeonggi Province is led by a governor. Mayors and Governors as well as heads of district are elected by provincial election. KMA (Korea Meteorological Administration) and ME (Ministry of Environment) are responsible for meteorology and air quality related service, respectively. The Seoul Metropolitan Office of Meteorology (SMOM) and the Metropolitan Air Quality Management Office (MAMO), a subsidiary organization of KMA and ME, are responsible for the meteorology-related and air quality-related services in SMA, respectively. NIMS (National Institute of Meteorological Sciences) and NIER (National Institute of Environmental Research) are responsible for research-based or technical support for KMA and ME, respectively.

Section B. Needs for the integrated services

Hazards

Recently, the SMA has experienced severe Asian dust/haze/smog events frequently in every winter and spring, blackouts of more than 1.6 million houses due to failure in electric power demand prediction after extremely hot weather in autumn, massive damage from shallow landslides due to heavy rainfall in 2011, several inundations by flash floods, traffic accidents as a result of road ice, and deaths due to annual heat/cold waves. Especially, visibility reduction and health effects by long-range-transported or domestic air pollutants became one of the nationwide concerns. To meet the needs to decrease PM concentration and to reduce damages by fine dust, a special law on fighting find dust pollution has been established to be obligated to take emergency dust reduction measures under high PM2.5 concentration in 2019.

Existing

There are many meteorological and air quality stations in the SMA: 7 ASOSs (Automatic Synoptic Observation System), 108 AWSs (Automatic Weather Station), 4 radars, 2 wind profilers, 2 microwave radiometers, and 2 rawinsonde stations operated by KMA; 201 air quality monitoring stations operated by ME and local administrations. The Weather Information Service Engine (WISE) project was launched in 2012 to deliver high-quality meteorological information customized for users' demands for the purpose of urban resilience and sustainability (Choi et al., 2013). Under the project, high-resolution urban observation system in the SMA (UMS-Seoul) has been installed in 2013-2017 (Park et al., 2017). It includes 14 surface energy balance systems, 7 surface-based remote sensing instruments (7 microwave radiometers, 6 wind lidars, 2 ceilometers, and 2 aerosol lidars), and applied meteorological observation instruments (6 road-weather, agro-meteorology). The user-specific weather information services such as flash flood, road weather, agro-meteorology, urban micro-climate, energy-use, released hazardous materials diffusion, and urban ecology were developed.

Users

The users for these services cover all kinds of sectors: governmental departments, transportation sectors, water management, energy sectors, health sectors, disaster risk management sectors, general public, etc. policymakers make their own guidance for each hazard and deliver it to the relevant general public.

Providers

Meteorological information is provided by KMA, while air quality information is provided by ME and NIER (National Institute of Environmental Research). The WISE project had installed UMS-Seoul observation platform, and had developed user-specific services in the SMA. After the project was completed in 2017, the services were transferred to KMA and NIMS (National Institute of Meteorological Sciences) since 2018. UMS-Seoul, as an observation platform, was maintained by HUFS (Hankuk University of Foreign Studies) and KMI (Korean Meteorological Institute) in 2018, and was transferred to NIMS in 2019. As a result, observed data and services will be provided by NIMS and KMA in collaboration with HUFS since 2019.

Section C: Services integration

The SMA is to integrate not only observed meteorological (operated by KMA) & air quality (operated by ME) data, meteorological and applied model outputs, and user-specific services. These services will help to prevent possible damages from extreme disaster in advance, to give the best timely guidance to citizens during an unexpected disaster, and to optimize the efficiency of urban planning and reconstruction.

Short term: The SMA is to:

- Integrate all kinds of observation data: UMS-Seoul (operated by NIMS), 108 AWSs and 7 ASOSs and other remote sensing instruments (operated by KMA), air quality (SO_2, NOx, CO, O_3, PM_{10}, $PM_{2.5}$) (operated by ME), road weather information (road surface temperature and status, water depth) (operated by NIMS).

- Construct real-time data acquisition, quality check, and display system in near future.

- Share the data with relevant users: NIER (ME) for the purpose of severe fine dust, The Seoul Institute (SI) and Seoul Institute of Technology (SIT) for the purpose of urban planning and thermal adaptation, SMOM for urban meteorology, researchers in universities and research institutes for urban resilience and sustainability.

- Transfer WISE-developed services (e.g. flash flood, road weather, urban climate, dispersion) to other SMART Cities (e.g. Busan (LCT) and Sejong).

Long term: The SMA is to:

- Improve the Seoul Urban Meteorological Model by applying the input variables (building height, plane area density, frontal area density, surface roughness length, zero-plane displacement length, albedo, thermal capacity and diffusivity, etc.), assimilating observed data, and improving the urban boundary-layer processes (e.g. urban canopy, boundary-layer turbulence, surface scheme, etc.).

- Develop the high-resolution and high-quality reanalysis data with the use of available observation data obtained from UMS-Seoul, KMA, and satellites.

- Improve the spatial and temporal resolution, accuracy and quality of services continuously.

A2.24 SINGAPORE

Prepared by Matthias Roth/Chui Wah YAP

Section A: General information

Singapore is an island city state nestled in the centre of the Southeast Asia region. A large part of its 724 square kilometres of land area is densely built-up. The island is relatively flat, and much of the island lies 15 m above sea level with about 30% less than 5m above sea level. The highest point is 163 m above sea level.

Singapore is highly urbanized with a population of 5.6 million people (as at June 2018). The population is served by a highly modernized infrastructure that includes an inter-connected bus and rail network, world class air and maritime ports, extensive communication networks, reliable energy and water supply. According to Mercer's 19th annual Quality of Living survey in 2017, Singapore was ranked first for city infrastructure.

Climate of Singapore

Singapore has a tropical climate that is relatively uniform throughout the year with little variation in seasonal weather. The main features of Singapore's climate are uniform temperature, high humidity and abundant rainfall throughout the year due to maritime influence and the island's close proximity to the Equator. Daily variations in these elements are typically diurnal in nature, driven by solar heating.

Singapore experiences two main monsoon seasons each year – the Northeast Monsoon which typically lasts from December to March and the Southwest Monsoon from June to September. The Northeast Monsoon season is wetter and accounts for about half of the annual rainfall while the Southwest Monsoon season is relatively drier and accounts for about a third. The monsoon seasons are separated by inter-monsoonal periods (April to May and October to November), during which the winds are generally light and variable in direction, sea breeze induced thunderstorms are common.

Governance structure

The Government of Singapore is modelled after the Westminster system, with 3 separate branches: the Legislature, the Executive and the Judiciary. The Executive branch administers the law and comprises the Cabinet led by the Prime Minister, who is the Head of Government.

The Meteorological Service Singapore (MSS) is a division of the National Environment Agency (NEA), which is a statutory board under the Ministry of the Environment and Water Resources (MEWR), along with the Public Utilities Board (PUB – the national water agency) and the Singapore Food Agency. MEWR's mission is to ensure a clean, sustainable environment, and supply of water and safe food for Singapore. Synergistic issues of climate/weather, water, air quality and food security come under the remit of a single ministry (MEWR), enabling a holistic approach to policy-making.

The National Environment Agency Act, empowers the NEA, through MSS, to provide meteorological services for users, including government agencies, aviation and shipping communities and the public; conduct meteorological observations and maintain reliable climatological records of Singapore; and furnish advice on meteorological matters.

As a low-lying island state that is vulnerable to the impacts of climate change, the Government of Singapore is actively dealing with the challenges of climate change. To reduce carbon emissions, one of the key measures introduced is a carbon tax, which targets large industrial facilities. The Government consulted businesses extensively before introducing the carbon tax. Under the Carbon Pricing Act which came into effect in Jan 2019, taxable facilities have to engage a third part verifier to verify their annual emissions report.

Cross-sectoral coordination necessary for the delivery of integrated urban services is enabled through a "Whole-of-Government" (WOG) approach adopted by Singapore government agencies. MSS works closely with PUB on water resource management and drainage issues, the Pollution Control Department of NEA on air quality issues, and a wide cross-section of government agencies on climate change issues. Beyond that, MSS serves as a multi-hazard early warning centre to provide alerts and advisories to national response agencies for emergency preparedness.

Institutional frameworks are in place to better manage and coordinate cross-cutting issues. For example, there is an Inter-Ministerial Committee on Climate Change (IMCCC) to enhance WOG coordination on climate change policies. A Climate Resilience Working Group under the IMCCC guides adaptation planning by government agencies overseeing coastal protection, water resources and drainage, biodiversity and greenery, public health and food security, network infrastructure, and building structures. There is also an Inter-Agency Haze Task Force comprising over 20 government agencies that manages transboundary haze pollution that occasionally affects Singapore during the traditional dry season. The Task Force, led by the NEA, coordinates the respective agencies' response plans for mitigating the effects of haze on public health and various sectors of the economy.

Section B. Needs for integrated services

Main hazards

The most common weather hazard in Singapore is extremes in rainfall. On one end, intense rain from short-lived thunderstorms or prolonged rain (from monsoon surges during the Northeast Monsoon season) often trigger flash floods. Thunderstorms and lightning are the most common severe weather phenomenon in Singapore, with an annual average of 168 thunderstorm days. On the other end, prolonged dry weather can pose a problem for water resource management. Other weather-related hazards include strong wind gusts (from localized thunderstorms and squall lines), and warm temperatures leading to heat stress.

Occasionally, Singapore experiences windborne transboundary pollutants that can lead to deterioration of local air quality. A common air pollutant is transboundary smoke haze from land and vegetation fires in the surrounding region. Other potential pollutants include ash cloud from volcanic eruptions with potential to affect air quality and disrupt aviation operations in the region.

As a low-lying island city state, Singapore is susceptible to sea level rise due to climate change. Like other parts of the world, Singapore is expected to experience more frequent and intense weather events such as heavy rain, prolonged dry weather, and heat stress, due to the climate change.

Singapore may be affected by geohazards although such impacts are normally mild, for example, tremors due to strong earthquakes in the nearby region.

Existing services

Operational weather services to support safe and efficient operations of government sector and business, and for the public to better prepare for impact of severe weather

- Weather information: real-time information of rain locations, lightning, weather elements (rainfall, temperature, humidity, surface wind) from automated observation networks, and UV index.
- Forecast: nowcast (2-hr), forecast (24-hr, 4-day), and fortnightly weather outlook.
- Alerts and advisories: lightning risk, heavy rain, prolonged high temperatures, prolonged dry weather, strong winds (from squall lines), and monsoon surges.

Multi-hazard watch and warning services to enable public agencies to better plan and respond to hazards for disaster risk reduction and better prepare the public.

- Daily smoke haze advisory on outlook for haze situation and forecast air quality band.
- Advisories on potential air contamination by volcanic ash or radiological fallout.
- Multi-tier alert system for tsunami.
- Reports and assessments of major earthquakes, volcanic eruptions, and tropical cyclones in the region.

Climate services to support longer-term planning and building climate resilience.

- Climate projections: climate scenarios for Singapore up to 2100 and assessment of climate change effects to guide national climate adaptation planning.
- Sub-seasonal and seasonal predictions: forecast of climate variability and extreme weather conditions to support advance planning for climate-sensitive sectors including water resource, forestry and environment, agriculture and disaster management.
- Climate statistics & climate studies: provide climate data and climate assessment and review for the media and public, research community and academia, government agencies and businesses such as insurance and construction industry.

Requirements

Short term:

- City-scale forecasts of air quality (24-hour Pollutant Standards Index).
- Early warnings with improved accuracy and longer lead times of weather hazards such as heavy rain and high temperatures.
- Improved advisories on risk of lightning for outdoor sporting and labour activities.

- Heat stress information.

Long term:

- Observation networks to study the urban environment such as the Urban Heat Island (UHI) effect.

- Multi-year predictions to support medium-term planning in water resource management and food security.

- Long term climate projections for Singapore, updated in alignment to the latest IPCC Assessment Report.

Section C: Services integration

Observations

WEATHER: network of ~ 100 automatic weather stations, 5 manned weather synoptic stations, 1 upper air observatory, 1 wind profiler, satellite reception ground station, 2 Doppler weather radars, 2 LIDARs (upper winds and aerosol), network of lightning detection sensors, 5 Wet Bulb Globe Temperature (WBGT) stations, and 5 seismic monitoring stations comprising broadband sensors and accelerometers linking to a central processing system (operated by MSS).

Air quality: 22 air quality monitoring stations measuring PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3 (operated by Pollution Control Department (PCD) of NEA).

Water: 208 water level sensors for monitoring drainage system, 49 CCTVs (operated by PUB).

Modelling

Numerical Weather Prediction (NWP): development of convective-scale NWP with data assimilation and using an ensemble approach.

Nowcasting: various approaches combining the use of radar data and high-resolution NWP models are being tested.

Atmospheric dispersion modelling: operational model to forecast the transport of smoke haze, volcanic ash and radioactive contaminants from radiological fallout.

Air quality modelling: development of air quality prediction model with chemistry configuration.

Urban modelling: study the Urban Heat Island effect and impact of urbanization on key climate processes over Singapore.

Regional climate modelling: develop understanding of the changing climate in the region and generate long-term climate projections to support national resilience planning; high resolution climate model simulations with explicit convection are also conducted.

Integrated components

Data from MSS' weather observing network and PUB's water level sensors are integrated to provide warnings of heavy rain and water levels exceeding certain thresholds (in various locations island-wide) to the public and business sector. The information enables users to prepare for any potential occurrence of flash floods.

Singapore's air quality is occasionally affected by haze from land and vegetation fires in the nearby region or from local sources. Monitoring and assessment of the haze and air quality situation is carried out using data from the weather observing network and air quality monitoring stations. A daily forecast of the air quality (24-hr PSI) for the next 24 hours is done jointly by MSS and PCD/NEA for certain periods of the year.

The Urban Heat Island (UHI) effect coupled with global warming is a concern as it affects the thermal comfort of the population. Plans to make the outdoor environment cooler are being undertaken, and one such initiative is the Cooling Singapore project (www.coolingsingapore.sg). MSS is contributing its weather data and modelling expertise to the project, together with other government agencies overseeing urban planning, building construction, transport and biodiversity.

MSS is working with a panel of experts from the health and related sectors to develop a heat stress information service. The information is based on WBGT measurements.

Dengue is endemic in the tropical and sub-tropical regions of the world, including Singapore. MSS' weather observation data and seasonal prediction feed into the dengue prediction model run by the Environmental Health Institute.

Amongst various clean technologies, solar energy is the most promising renewable energy source for Singapore. The main challenges are Singapore's limited size, and intermittency of solar output which is dependent on weather conditions. MSS is contributing its data and expertise in a national solar forecasting programme which involves the participation of local research institutions.

The Government of Singapore has put in place a comprehensive Climate Action Plan mapping out various long-term adaptation and mitigation measures. MSS is responsible for the generation of long-term climate projections to guide long-term adaptation planning by government agencies overseeing coastal protection, water resources and drainage, biodiversity, public health, food security and network infrastructure. This entails extensive engagement between MSS and the agencies to ensure their needs and requirements are appropriately factored in the climate modelling. Further engagement is carried out to interpret the results and explain the uncertainties of the projections to agencies, so that they are properly applied in adaptation planning.

Services/information delivery, communication

Warnings of main weather hazards and geohazards are issued by a single authoritative source (MSS) to the public. Additional assessment and situation reports are communicated to the relevant government agencies to assist in their contingency planning and decision-making.

Service delivery to the public via the internet, mobile applications and social media, print and broadcast media, location-specific alert services via SMS or push notification, and to response agencies via direct line to operations rooms.

Water management

7-day outlook, monthly weather assessment, 3-month seasonal outlook, rainfall trends for Singapore and its reservoirs and catchments are provided to Singapore's national water agency (PUB) for better planning and water resource management. Weather consultation services as well as advisories of heavy rainfall that could lead to flash floods are also provided.

Air quality

During the haze season, MSS works closely with PCD/NEA to issue a daily Haze Situation Update. The advisory includes the forecast of air quality over Singapore and health advisory on whether to curtail outdoor activities. It is issued to the public, schools and government agencies. A dedicated haze website (www.haze.gov.sg) is set up as a one-stop site for all information relating to haze, such as the latest air quality, haze situation in the region, etc.

Weather extremes

Special advisories issued for very warm weather (heatwave), cool weather, prolonged dry weather, prolonged heavy rain to keep the public updated on developing weather conditions and for better preparedness.

Fortnightly outlook

A video presentation of the fortnightly outlook of the weather for Singapore is produced and updated twice a month online by MSS. MSS leverages on the video format to better engage the public and cater to a social media generation.

A2.25 SHANGHAI

Prepared by J. Tan

Section A: General Information

Socioeconomic

Shanghai is one of the most populated cities in China and had an area of 6 340.5 km^2 and a population greater than 24 million in 2018 (Shanghai Municipal Statistics Bureau, 2018), with more than 2.6 million automobiles, more than 32 000 tall buildings (>30 m tall), and over 1 200 skyscrapers (>100 m tall) in 2012. (Tan et al., 2015). Current population density in the city center of Shanghai exceed 15 000 people km^{-2}. Also, Shanghai is the economic, financial, shipping and trade center of China, generating 3 267.987 billion Yuan GDP ranked by the first city in China.

Geographical

Shanghai is a coastal city located at the middle of China's coastline and the mouth of Yangtze River and Hangzhou Bay, with water on two of its three sides. Shanghai is flat with mean elevation of 4 m above sea.

Governance

Shanghai is a direct-controlled municipality which is administratively equivalence to a province, including 17 districts.

Section B: Needs for the integrated services

Hazards

Shanghai experiences a subtropical monsoon climate with four distinct seasons. Winters are generally cold and dry, with only 1 or 2 days of snowfall in average, while summer are hot and humid, with two to three typhoons annually. Most common hazards in Shanghai and associated environment risks are typhoons, severe rain, heatwaves, thunder and lightning, fog, storm surges, and air pollution episodes. With its rapid urbanization and population growth, Shanghai has become more vulnerable to disasters. Shanghai has vast infrastructures—for example, transport networks, transmission lines, drainage networks, and underground spaces (e.g. metro lines, parking garages). These are all vulnerable to weather and climate events and can benefit from integrate service. Since 2010 World Expo in Shanghai, a multi-hazard early warning system has been put in use, but integrated weather, climate and environmental service are also needed. Owing to magnification effect and domino effect in the city, sometimes non-severe weather may bring serious problems because an increasing number of activities are more sensitive to weather and climate.

Providers

Shanghai Meteorological Service play the role in disaster watches and warnings, and Shanghai Emergency Warning Center (EWC) was officially established in 2013, through which all kinds of emergency warnings in Shanghai could be issued.

Users

Integrated services were directed towards four major end users, such as city government and relevant agencies, community, industrial sector or private enterprise, and individual citizen.

For example, flood control agencies need data on precipitation (rain, snow) distribution and runoff, as well as the water storage capability of urban pervious surfaces, drainage systems, and water-logged ground. Power plants, grid operators, and local utilities need high-resolution air temperature for assessing energy demand and resulting loads on the electric grid. Wind and solar radiation are also needed for renewable energy assessments. Urban planners and design departments need information on the UHI, vegetation stress index, urban air quality, and wind. Public health agencies want to know pollutant emissions and concentration, solar radiation, wind, humidity, and air temperature are needed at appropriate scales for street level, air quality, pollen, and predictions of heat stress. Transport agencies need data on strong winds (especially channeling wind), precipitation and its forms (i.e. rain, freezing rain, sheet, or snow), surface state (dry, wet, ice covered), and high-resolution spatial forecasts (e.g. roadway scale) for metros, highways, and seaports. Urban emergency response agencies need timely and accurate information on extreme weather, such as detailed street-level flood information, and high spatial- and temporal-resolution wind, temperature, and moisture data in and above the urban canopy.

Section C: Services integration

A WMO Demonstration Project, Shanghai Integrated Urban Weather and Climate Service, is being carried by Shanghai Meteorological Service. Through introducing advanced technology and weather/climate disaster management theories, the project is aimed at developing seamless multi-time-scale weather forecast supported by numerical models, developing impact-based forecasting and warning system, improving urban climate services, interacting with users by information services and helping the city to manage risks caused by climate change.

Integrated observation: To understand the interactions between the urban surface and atmospheric processes, improve the performance of urban weather, air quality, and climate models; and provide key information for city end users, Shanghai's Integrated Urban Meteorological Observation Network (SUIMON), a network of observation networks, has been established from different systems and instrumentation deployment types (See Tan et al., 2015). The ultimate goal of SUIMON is to provide integrate measurements of all the processes that influence Shanghai's regional environment and the city itself, including both physical and chemical characteristics of the boundary-layer and the free atmosphere, so linkages can be better understood.

Integrated forecast system: A seamless forecast system including nowcasting, short-term, mid-term, extended range and long-term forecast has been established to integrate of weather forecast and climate prediction, including high resolution regional NWP system up to 3 km horizontal resolution and high-resolution regional climate models and air quality models.

Integrated urban Service: Impact-based weather forecasting and risk warning system has been established to integrate the weather and risk management, including demand-oriented, user-interactive system of impact-based weather forecasting and risk warning system(urban flood, aviation, marine navigation, health, and transportation, etc.) based on high resolution numerical forecasting, a user-interactive urban climate service platform for improving the resilience of the city, and a public service quality management system, standardize the process of emergency warning for improving meteorological disaster prevention/reduction and public service.

A2.26 **STOCKHOLM**

Prepared by Jorge H. Amorim (SMHI), with contributions from Christer Johansson (Stockholm City) and Magnus Sannebro (Stockholm City)

Section A: General information

Socioeconomic

Stockholm is the financial center of Scandinavia with the largest gross regional product. With an official plan to build 140 000 new homes by 2030, it is also one of the five fastest growing metropolitan areas in Europe, with Stockholm Royal Seaport standing as one of the largest urban development areas in northern Europe. The proximity to expanding markets around the Baltic Sea makes Stockholm a very attractive city for investors. The Scandinavian countries, along with the Baltic Sea area, are increasingly viewed as one collective market by global companies. In 2013, Standard & Poor's Ratings Services affirmed its 'AAA' long-term and 'A-1+' short-term issuer credit ratings on the City of Stockholm.

Sweden's capital city Stockholm has an urban population of nearly 1 million inhabitants and 1.8 million inhabitants living within the Greater Stockholm. The city is growing fast and new housing is needed. The increasing share of the Swedish population living in dense urban environments will become more vulnerable to environmental and climate hazards, calling for innovative planning solutions for the city that converge housing and mobility needs with well-being and health. Intensive impervious sealing of surfaces and human densification are important drivers of the urban microclimate and how it will respond to climate change in the future.

Geographical

Stockholm has a maritime-influenced humid continental climate (Köppen Climate Classification Dfb), with warm summers and cold winters. Stockholm is located on Sweden's east coast, where the freshwater Lake Mälaren, Sweden's third largest lake, flows out into the Baltic Sea. The central parts of the city consist of fourteen islands that are continuous with the Stockholm archipelago.

Stockholm city is located at the border between the large lake Mälaren and the Baltic Sea, thus highly sensitive to future changes in river runoff as well as lake and sea levels. The underground subway, as well as the different existing and planned road traffic tunnels, are also highly vulnerable to extreme precipitation events. Another significant risk is failure in electricity supply, as well as IT- and tele communications. Expected climate change effects include higher rainfall intensities, with 25% rise in extreme rain events by the end of the century. Recent modelling results by SMHI suggest an even higher increase in rainfall intensity. As a result, the Stockholm area will experience a rise in both intense flash floods and "pluvial flooding" that may last for weeks or even months and cover large areas. This strains the sewer networks and built environment and poses a risk for the population.

Governance

Sweden has 290 municipalities of which Stockholm is the largest. The City Council is the supreme decision-making body of the City of Stockholm. The City provides Stockholm's inhabitants with a multitude of different municipal services. Most of the municipal activities in Stockholm are carried out in administrative or corporate form.

Stockholm has been working on climate change mitigation since the 1990s, and adaptation for at least a decade. The city is a real frontrunner, with well implemented climate action plans and pioneering policies to ensure it meets its ambitious environmental targets. The carbon dioxide emissions have been cut by 25% per citizen since 1990. Stockholm was the first city to receive the award European Green Capital by the EU Commission in 2010.

The Environment and Health Administration of the City of Stockholm (EHA) has as key priority to ensure that Stockholm remains a sustainable city, while offering an attractive and inspiring living and working environment. The climate action group coordinates implementation and monitors the results of all climate actions undertaken in the city. Their long-term aim is to become completely fossil-fuel free by 2040.

The City of Stockholm´s work with Climate Adaptation is process-based, and focuses on producing strategies for different climate risks. The first strategy deals with cloudburst protection, and is expected to be adopted by the City Council during 2019. Development of a new strategy is suggested for heat stress and health impacts of extreme temperatures. The Climate Adaptation work is organized as a coordination group where several administrations are included under the direction of the City Executive.

The Swedish Meteorological and Hydrological Institute (SMHI) is an expert agency under the Ministry of the Environment and Energy. It offers high quality products and services to professional clients and carries out R&D in the fields of meteorology, climate, hydrology and oceanography with a strong international cooperation. SMHI is the National Focal Point for the IPCC and has coordinated the Copernicus C3S proof-of-concept project Urban SIS (2015-2017), which provides high resolution data on climate, hydrology and air quality over the Stockholm region for present and future time windows.

SMHI is currently engaged in several initiatives together with the City of Stockholm aimed at understanding and quantifying the impact of heatwave events in Stockholm. One can mention the HazardSupport project, funded by the Swedish Civil Contingencies Agency (MSB), the Horizon2020 project CLARITY, funded by the EC, and the recently started project GreenWave, funded by the Swedish Research Council for Sustainable Development (FORMAS).

Section B. Needs for the integrated services

Hazards

Cloudburst and flooding, air pollution, heatwave, snow and ice. In the long-term: sea-level rise.

Existing

SMHI provides daily forecasts at the national level and issues multi-hazard early warnings. Climate scenario data is also produced and delivered by SMHI. Monitoring and modelled data is available to the public through SMHI´s Open Data API (https://opendata.smhi.se/).

As an example of an Integrated Urban Service, the Copernicus climate change services (C3S) project UrbanSIS delivered 1km resolution ECVs and impact indicators on climate, hydrology and air quality for 3 5-year time windows representing past, present and future climate conditions in Stockholm. This dataset is available for visualization and download (http://urbansis.climate.copernicus.eu/). New climate and urban planning scenarios for Stockholm are being simulated in the projects HazardSupport, CLARITY and GreenWave.

Supervision of air quality in Stockholm and neighbouring cities is carried out by SLB analysts, a Department at the Environment and Health Administration of the City of Stockholm. This includes extensive regulatory monitoring of regulated air pollutants as well as some key unregulated pollutants (black carbon and nanoparticles), short term forecast reported on the web and to newspapers and radio and also long-term prognoses of impacts of urban planning on air quality and health. SLB is the operator of the Eastern Sweden Air Quality Association with 60 member organizations including 50 other cities in Sweden.

Alarms of high air pollutant concentrations are reported to Naturvårdsverket (the Swedish Environmental Protection Agency), who informs the public. In the event of an accidental release of e.g. toxic chemicals it is firstly the fire brigade's responsibility.

The cloudburst model is the most strategic climate service tool that Stockholm holds at the moment. The results are available to both internal City of Stockholm users, as well as external users through the web data portal Stockholm Open Data (http://dataportalen.stockholm.se/dataportalen/). However, the functionality is much higher for internal users, with the possibility to do overlay-analyses with thematic maps.

Stockholm Vatten och Avfall (Stockholm Water Company) has also developed a web-based User Guide to the cloudburst model, aimed at developers and city planners within the City of Stockholm. This guide is only accessible to internal users, and is designed as a tool for cloudburst analyses of a specific area.

Stockholm Vatten och Avfall has developed a coupled flooding model for the river Bällstaån, in close cooperation with DHI. It is calibrated against actual rainfall and discharge data, and is used especially for urban development in the Bällstaån catchment.

General flood mapping is carried out by the Swedish Civil Contingencies Agency (MSB).

Regarding heatwaves and heat stress, a map of mean radiant temperature over the city is also accessible from the same web portal as mentioned above.

Providers

SMHI, City of Stockholm, SLB Analys, Stockholm Vatten och Avfall, the Swedish Civil Contingencies Agency, the Swedish Environmental Protection Agency, universities and research institutes, consultancy companies.

Users

Swedish authorities, multiple organizations, municipalities, consultant companies, private companies from different sectors and general public.

Requirements for the services

Short term (DRR)

- In situ weather observations
- Atmospheric remote sensing
- Air quality monitoring and short-term forecast

- Warning systems in case of extreme weather events

Long term/strategic (urban planning)

- Climatological analysis
- Seasonal predictions
- Climate projections

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

Long term: urban planning for sustainable development, climate change mitigation and adaptation.

Components integrated (and how)

- at the level of observational infrastructure
- at the level of modelling tools
- at the level of the services/information delivery, communication

A2.27 STUTTGART

Prepared by Rayk.Rinke@stuttgart.de

Section A: General information

Socioeconomic

Stuttgart is the capital of the state of Baden-Wuerttemberg located in southwestern Germany. As the sixth-largest city in Germany, Stuttgart has a population of about 600 000 and is the centre of a densely populated area, the Greater Stuttgart Region, with a population of 2.6 million. Stuttgart covers an area of 207 km^2 thereof 49 percent are settlements. It is one of the greenest cities in Germany. Greenery in the form of vineyards, forests, parks, etc. is prevalent throughout the city. In Stuttgart 39 percent of the surface area has been listed as protected green belt land or nature conservation area. Despite this greenery populated, industrial and commercial areas are densely built-up. The population density is about 5410 person/km^2.

Geographical

Stuttgart's area is characterized by a complex topographic situation with local distinctions.

The city's geographical location and the topographical characteristics have a negative impact on urban climate and cause an intense urban heat island and air quality problems. The city is located in a river valley nested between vineyards and thick woodland. Stuttgart's center is situated close by, but not on the River Neckar. The city area is spread across a variety of hills and valleys. Steep hill slopes surround the city center on three sides. The elevation ranges from 207 m to 549 m asl. The complex terrain has a significant influence on all climatic elements like radiation, air temperature, wind and air pollutant concentrations, resulting in large climatic distinctions within the city area. Stuttgart's overall climate is mild with an average annual air temperature of about 10 °C in the Stuttgart basin (city center) and about 8 °C in the more elevated outskirts situated about 400 m asl. Besides the Upper Rhine Valley, Greater Stuttgart is one of the warmest regions in Germany. A major element of Stuttgart's climate is the light wind, which causes a lack of adequate air exchange. The whole Neckar Valley is known for low wind speeds and very frequent lulls. This is the result of small air pressure differences common to Southern Germany and Stuttgart's sheltered position between the Black Forest, the Swabian Alb, the Schurwald and the Swabian-Franconian Forest. The sheltered position between the surrounding mountain ranges leads to a frequent development of local wind systems, especially at the slopes and in the valleys. In addition, cold air is produced over large green areas in the surrounding and the city area especially at the higher altitudes during the night-time and it generates cold air streams. Even if these winds have no high wind speeds, they play a significant role in the ventilation and local fresh or cold air supply for some city districts.

Governance

A mayor, seven deputy majors (different areas of responsibilities, financial, urban planning and environment, social, law and order, culture, education, administration) and a Council of 60 members lead by the city government. The majors are elected every eight years (the deputy majors are elected by the Council); the citizen elects the members of the Council every 5 years.

Section B: Needs for the integrated services

Hazards

Global climate change, heatwaves, episodic raise in air pollution, heavy rain events, thunderstorms (hail), noise pollution, high traffic amount and many hours of traffic jam.

Existing

A dense network of monitoring stations (meteorology and air quality). These measurements are used for warning systems.

The municipality has established (in cooperation with the German weather service and ministries of the state Baden-Württemberg) warning systems for:

- Heatwaves
- High air pollutant concentrations

In addition:

The state of Baden-Württemberg and the German weather service have established warning systems for several natural hazards (floods, thunderstorms, storms)

Users

General public, municipality, technical authorities, ministries (of the federal state and nation), health sectors, companies, industry and transportation sectors, press agencies.

Providers

Municipality (office for environmental protection), technical authorities (German weather service, environmental agencies).

Requirements

Observation data (for warning systems, and model validation)

- Air pollutants – especially VOCs and more particle parameters (numbers, UFP, substances – black carbon).
- Vertical profiles (air temperature, humidity, aerosol) – for us very important data related to mixing layer height.
- Wind – flows in street canyons for a better understanding of heat and air pollutant transport and local wind systems (cold air streams).

Weather forecast

- Forecast (urban scale) with consideration of the influence of cities on the atmospheric fields (triggering of rain events, urban heat island, air pollutants).
- Emission data with high temporal and spatial resolution for air quality forecasts.
- Better "translation" between atmospheric scientists and urban planners, citizens, politicians, industry.
- Better understanding of the effective measures for improving the urban climate and air quality taking into account the special conditions in specific cities.

Section C: Services integration

The section urban climatology at the office of environmental protection is a part of the municipality of Stuttgart. Colleagues in this section are experts with a scientific background in the sectors meteorology, urban climate, global climate change, air quality control and noise reduction. One important part of the sections work is the transfer of solutions for urban atmospheric problems from science to urban planning, public and political boards. Also part of the sections work is the development and the integration of strategies and action plans to solve problems related to the different sectors.

Short term

- Heat warning system Stuttgart:

Since 2005/2006 all federal state in Germany have implemented the heat health warning system of the German Meteorological Service (DWD).

On the local level Stuttgart has developed the HITWIS as the heat warning system including the parts of the urban climate, health care and social welfare. The HITWIS is in line with the official heat health warning system but with a strong focus on specific local needs. Within HITWIS it has been recommended to provide the public with an easily accessible mapping of drinking water dispensers and cooling zones in the city. The heat warning is disseminated via email and the city website.

- Feinstaubalarm:

In 2016 Stuttgart introduced the "Feinstaubalarm". This is an alert system to inform citizens from October to April during weather periods with worse dispersion conditions when the PM_{10} concentrations are expected to raise. With the Feinstaubalarm, the city and the state of Baden-Württemberg are appealing to all people in Stuttgart and commuters from the region to use their cars as little as possible in Stuttgart. The alarm will be triggered in the winter season between 15 October and 15 April when the German Meteorological Service (DWD) forecasts particular limitations in atmospheric airflow on at least two consecutive days or if current dust concentrations in the city exceed the European short-term limit value for PM_{10}. The criteria on which the proclamation of the alert are based on several meteorological forecasts like wind speed, rainfall and nightly ground inversion. Currently the switching on alternative mobility forms is voluntary but since woodstoves contributes also to a higher PM_{10} concentration, Stuttgart introduced a regulation that prohibits the use of woodstoves during the Feinstaubalarm period. With an improved local transport service and numerous benefits from the various mobility partners, switching to green means of transport during the Feinstaubalarm is both straightforward and appealing. With the Feinstaubalarm, everyone can check her or his environmental and mobility patterns. The alarm is disseminated via email, websites, twitter, Facebook, radio stations, newspapers and several display panels in the city. The Feinstaubalarm is part of the clean air action plan in Stuttgart.

Long term

- Local global climate protection programme (KLIKS):

Since 1995, the city of Stuttgart has a local global climate protection programme (KLIKS) that define measures for Stuttgart's contribution to protecting global climate. In 2007 a second version was worked out were additional measures are added based on ideas from politics and public. What is special with Stuttgart's Climate Protection Programme is that the traffic sector and the traditional energy sector are treated equally. With KLIKS strategies to protect the environment in the form of two scenarios (the first scenario with optimum targets, the second as a realistic and practical scheme) including concrete and Stuttgart specific measures to reduce carbon dioxide emissions were developed. These measures were valued on account of the reduction potential, the technical, economic and legal feasibility as well as the profitability and planning interval for their application. On the basis of this programme, Stuttgart's administration section has established a binding action programme, which is not only thought to address to the administration section itself. It is rather addressed to all companies, drivers, homeowners and many others, who are invited to apply the depicted measures wherever they can.

- Urban development outline plans:

Urban development outline plans (UDOPs) constitute a non-formalized level of spatial planning. The UDOPs proved to be a valuable and flexible tool to steer urban development within built-up areas. It is an essential function of UDOPs in Stuttgart to define the municipality's development and planning goals for those parts of the city that show tendencies of urban change. In practice, the planning intentions for public spaces and streets can be described more precisely than those for private building sites. In Stuttgart UDOPs are used to set up the urban planning strategy for a sustainable future development and restructuring of single city districts weighting all aspects of urban living, economy and nature, environment and climate protection. UDOPs in Stuttgart contain several measures to improve the local climatic situation and to reduce the negative impacts of the urban heat island effect.

- Clean air action plan:

Air pollutant measurements along highly polluted road sections in Stuttgart have revealed that the European limit values for the air pollutants particulate matter (PM_{10}) and nitrogen dioxide (NO_2), are exceeded. This is why a clean air action plan needed to be drawn up in Stuttgart. The measures defined therein foremost are to bring short-term improvement, but also measures which have a medium-term and long-term focus are be taken in order to control air pollution sustainable. The first clean air action plan was developed in 2005 (updates in 2010 and 2018). The clean air action plan contains over 40 measures for bettering air quality in the city area, including the improvement of the local public transport, the conversion of public vehicle fleets, infrastructural and road building measures, increased parking fees in the inner city as well as a ban on the combustion of solid fuels and garden waste.

- Observational infrastructure:

In total 11 long-term measurement stations (6 meteorology, 5 meteorology and air quality) including also one radio sounding and more than 15 short-term hotspot measurement stations (air quality) provide a wide range of observation data. The municipality, the German weather service, the University Hohenheim or the environmental agency of the state Baden-Württemberg operates the stations.

Most of the observation data are published in the internet.

- Modelling tools:

The micro-meteorological models ENVIMET, MISKAM and KLAM21 are used in Stuttgart to simulate the impact of urban structures on meteorological fields (temperature, wind, cold airflows, air pollutants, radiation flux densities, thermo-physiological assessment indices and heat). We use the simulation results to analyse the effectivity of urban planning strategies to improve local urban climate and air quality. The simulations are a basis for the development of clean air action plans and urban development outline plans.

- PROKASonline:

PROKASonline is a simplified screening model for the simulation of air pollutants caused by traffic emissions along roads. In Stuttgart, the model is currently used for the online (operational) simulation of PM10and NO2 concentrations based on real traffic data (traffic amount and composition and traffic flow) in the inner-city area. It's planned to extend the model domain to the whole city area. The hourly updates simulation results are published in the Internet for public information (http://www.stadtklima-stuttgart.de/).

- PALM-4U:

PALM-4U (Parallelized Large-Eddy Simulation Model for Atmospheric and Oceanic Flows) is a new extensive non-hydrostatic urban-scale model. The model is currently in development within the [UC]2 Urban Climate Under Change project founded by the BMBF. The city of Stuttgart is partner of the project. In future, we will use this new model for our work, to simulate the urban atmospheric conditions with more detail and a higher quality.

Services and information delivery

Climate Atlas Region of Stuttgart

Since planning-related statements refer to specific areas, the use of maps as an informational basis is recommended. Maps in this context are a very significant tool for the planner, and are a meaningful method of communicating information for politicians and the interested public. In the Climate Atlas produced by the Stuttgart Regional Federation for the territory of the federation and the bordering parts of the Middle Neckar Region the concerns of climate and air are incorporated into cartographic representations for land use planning.

The climate atlas consists of two parts. First the regional climatic situation and the role of urban climate and the atmosphere itself in municipal planning are described in words. Also the methods used for the creation of the maps are demonstrated. The second part of the climate atlas comprises cartographic representations in form of basic information-maps, result-maps and analysis-maps. The maps covering the Greater Stuttgart Region with about 3 654 sq km and containing to date spatial information of the urban climatic, bioclimatic and air pollutant concentrations in the Greater Stuttgart Region. The basic information-maps representing maps, which are relevant for quantifying and evaluating the urban climatic situation (e.g. altitude, land use, localization of measurement stations). In addition, cartographic representations of traffic noise are included in the basic information-map part.

In the result-map section of the climate atlas cartographic representations of surface temperatures, annual temperatures, areas for cold air production, amount of cold air production and cold airflows are included. In addition, the result-map part shows maps of wind speed and wind direction in respect to the local topographic situation. The spatial distribution of typical mean temperatures in special episodes, for example on hot days, summer days, days with frost, ice or closed snow cover are also presented in the result-maps. Beside the climatic-maps, also maps depicting the air pollution concentrations are include in the result-map part of the climate atlas.

The analysis-map part summarizes the most important climatic information of the result-maps and gives planning references. In addition, several contents of the result-maps are valuated and connected with each other for estimating to date and future bioclimatic exposure. Recreation areas and highly air-polluted areas with potential of human health risks are also included in the cartographic representation of the analysis-map part.

Information system: Urban Climate 21

The information system Urban Climate 21 provides multitude information to currently and future urban climate, bioclimatic exposure and air pollution in the Greater Region of Stuttgart for planning experts and interested public. The motivation for Urban Climate 21 is the planned redevelopment of a railway area (i.e. "STUTTGART 21") situated in the climatically sensitive city basin, which makes it necessary to provide relevant information on climate and air quality and to assimilate this information into the planning as early as possible. The used methods within the studies range from model calculations and simulations to experiments with a full-scale model in the wind tunnel and to measurements, drilling, mapping and nature observation in the plan area and its surroundings. The studies performed for the project and the analysis of already existing data provided a wealth of information, mainly in digital form. Besides climatic and environmental information. Altogether, the DVD-ROM "Urban climate21" contains 400 area and line datasets, more than 100 point datasets, 420 text files and 1000 photos and pictures. The DVDROM "Urban climate21" is a prominent source about the urban climate of Stuttgart.

Climate Booklet for Urban Development (available in German and English)

The Climate Booklet for Urban Development is a booklet created and updated by colleagues of our office that provides an insight in urban climatic processes. The booklet addresses urban planners and interested persons. Relevant physical and chemical processes are described as simple as possible to provide a basic understanding of the urban atmosphere and the interactions between urban structures (urban conditions) and the urban atmosphere. Urban planners in several German cities use the booklet. An online version is available https://www.staedtebauliche-klimafibel.de/.

Website www.stadtklima-stuttgart.de

The section urban climatology at the office of environmental protection has an own website (www.stadtklima-stuttgart.de), where information (publications, maps, about the work of the section and the urban climatic situation in Stuttgart are published. Also, basic information about urban climate, global climate change and the observation data from the measurement stations operated by the section are published at the website.

A2.28 **TORONTO**

Prepared by Felix Vogel/Sylvie Leroyer

Section A: General information

Socioeconomic

The Greater Toronto and Hamilton Area (GTHA) is the most populated place in Canada with circa 7 million inhabitants. The population density in the City of Toronto is over 4 300 inhabitants per km^2 and around 850 inhabitants per km^2 in the GTHA (Statistics Canada 2019). It is an important region of economic activity generating about ¼ of Canada's GDP and also hosts the second largest financial centre in North America. The GTHA continues to experience both population increase and urban sprawl. For example, between 2011 and 2016 the population increased by nearly 6% and 4.5% for the metropolitan area and City of Toronto respectively.

Geographical

Geographically the GTHA is located in Southern Ontario and stretches along the North-western shore of Lake Ontario (43.7 N 79.4 W, Toronto Midtown). It falls within the lake Simcoe-Rideau ecoregion, which has a mostly mild and moist climate (Crins et al., 2009).

The terrain is generally flat and the air shed is strongly influenced by the lake effect caused by Lake Ontario and the slope between the lakeshore and the hinterland (Mohsin et al., 2010).

Governance

The GTHA consists of 30 municipalities with very limited cross boundary agencies. Besides the role of the individual cities and municipal regions to manage activities at local scale the City of Toronto established 'The Atmospheric Fund' (TAF) as an agency to finance initiatives to combat climate change and improve air quality for the entire GTHA. Furthermore, the provincial government of Ontario and the Federal government have legislative influence.

Section B: Needs for the integrated services

Hazards

The region is characterized by the regular occurrence of complex hydrometeorological conditions with high-impact. These have led to recurrent infrastructure damage in the region due to isolated extreme rainfalls or strong winds and lightning, blizzard, problematic thermal stress conditions related to high levels of humidity in summer and cold weather in winter, occurrence of unhealthy air quality episodes, risks of high water levels along stream networks and coastal flooding in the springtime. An additional need for information beyond hazards relates to the plans of the City of Toronto and TAF to reduce greenhouse gas emissions levels by 80% emission in 2050 relative to 1990 levels.

Providers

The TO15 Environment Canada and Climate Change (ECCC) science project provided the opportunity to showcase the capacity of ECCC to implement advanced technical tools and to ensure to provide derived products to end users.

Users

Integrated services for this event were directed towards three major end users: the TO15 organization (regular briefings), the police, and public health organizations (partnership for the extended region surrounding Toronto). The ongoing continuous greenhouse gas monitoring is conducted to provide information to citizens and TAF.

Requirements

Communications between researchers and those involved in operations and services for the different sectors (weather, air quality, UV, nowcasting, emergency preparedness, marine, public health) and for different organizations (ECCC, Health Canada, public health regional and municipal organizations, some universities, and a network of provincial and municipal government partners). ECCC project objectives for the Games were: (1) to issue weather warnings (2) to forecast weather conditions (in particular at the sport venues sites), (3) to provide climatological information, (4) to support critical weather sensitive government services, and (5) to monitor atmospheric conditions (ECCC, 2016b). Underlying wider objectives were to provide legacy to the involved partners and the scientific community by developing: (1) monitoring strategies, (2) prediction models, (3) forecast methods, (4) data acquisition processes, and (5) distribution applications.

Section C: Services integration

Observational infrastructure

The observational network was designed to provide environmental conditions at the sport venues sites and to capture meteorological patterns specific to Toronto, such as lake-breeze front tracking (as they can lead to high-impact weather or modify local conditions rapidly, e.g. Mariani et al., 2018), heat stress conditions (monitored by globe temperature sensors, e.g. Herdt et al., 2018) or atmospheric pollution (e.g. using vehicle traverse sampling, Wren et al., 2018). It was composed of fixed networks for weather, lightning, air quality and UV monitoring, mobile measurements with equipped vehicles (Joe et al., 2018). 55 fixed weather stations were deployed at ground-level and rooftop locations using compact, inexpensive, and easily sited weather instrumentation together with high speed cell technology that increased bandwidth and memory capacity. Once installed, data from the mesonet network successfully reached users with 95% ‘up time’. The new high-resolution data acquisition system (60 observations per minute) for the weather mesonet was supported by existing operational network protocols to facilitate the use post-Games. Since the TO15 project four continuous greenhouse gas monitoring stations have been integrated and multiple field campaigns to identify CH_4 emission hotspots were conducted.

Modelling tools

The meteorological and air quality forecasting is based on the Global Environmental Multiscale (GEM) Model (Girard et al., 2014) with several configurations used as per the product target and forced with available operational forecasts (the Canadian regional NWP system with 10 km grid spacing, Fillion et al., 2010). The surface-atmosphere interactions are modelled with a tiling approach with ISBA as the land surface scheme. For the TO15, high-resolution forecasts were provided with a pan-Canadian system with 2.5 km grid spacing and updated four times a day (system that became operational afterwards, Milbrandt et al., 2016). The urban-scale forecasting was achieved down to 250 m grid spacing (Leroyer et al., 2018) using in addition the single layer urban canopy scheme TEB (Masson 2000), soil moisture, and temperature daily analysis (Carrera et al., 2015) and lake surface temperature and ice conditions hourly forecasts (Durnford et al., 2018). Operational regional air quality forecasts are provided with the GEM-MACH system (Modelling Air quality and CHemistry) with 10 km grid spacing. In addition high-resolution air quality forecasts for a large region surrounding Toronto were provided down to 2.5 km grid spacing (Stroud et al., 2011). Since the TO15 experiment, this system has been extended to the two most important anthropogenic greenhouse gases. i.e. CO_2 and CH_4 and includes TEB as well.

Services/information delivery, communication

During Pan American and Parapan American Games: Service integration included on site briefings provided by meteorologist team to the clients, a weather portal for sharing observations, forecasts and alerts to sporting federations and TO15 organization, push-type communication with a mobile application for integrated health ("EC Alert me"), and pull-type communication such as the weather and public health decision web-portal based on the Web-Mapping Services (WMS).

Legacy: After the TO15 experiment the development of a demonstration for applications relevant to greenhouse gas emission studies in the GTHA was started. ECCC and the University of Toronto have successfully built a high-resolution (2.5 x 2.5 km2) sector-specific emission inventory 'SOCE' (Southern Ontario Carbon Emission) for CO2 based on air quality emission maps for the TO15 domain (Pugliese et al., 2018). Furthermore, this inventory was benchmarked against other existing emission estimates by investigating their ability to predict atmospheric concentrations compared to ECCC's continuous CO2 observations.

A2.29 **WELLINGTON**

Prepared by David Johnston/Peter Kreft

Socioeconomic

Wellington is located at the south-western tip of the North Island of New Zealand and is the country's capital. The economy is primarily service-based, primarily around government, but also including finance and business services. It is the centre of New Zealand's film and special effects industries, and a hub for information technology and innovation.

Population and area

The Wellington urban area is comprised of four cities:

- Wellington City, on the peninsula between Cook Strait and Wellington Harbour; area 1 388 km^2, population 216 000
- Porirua City, on Porirua Harbour; area 182 km^2, population 57 000
- Lower Hutt City; area 377 km^2, population 106 000
- Upper Hutt City; area 540 km^2, population 44 000
- Geography and climate

The cities of Wellington and Porirua are on hills surrounding natural harbours. The cities of Lower Hutt and Upper Hutt are largely on the floor of a large river valley and are also surrounded by hills. Because of the area's situation at the southwestern tip of the North Island and its proximity to Cook Strait (the narrow channel between New Zealand's North and South Islands), it is reasonably windy and has a moderate maritime climate. The area is also subject to earthquakes and has three major fault lines running through it.

Governance

Each of the four cities has its own governance organization, a Council, which is led by an elected Mayor and Councillors. Each Council is responsible for providing many of the services required by its community. The Greater Wellington Region, which includes the cities of Wellington, Porirua, Lower Hutt and Upper Hutt, provides environmental and emergency management, flood protection and land management, provision of regional parks, public transport planning and funding, and metropolitan water supply.

Section B: Needs for the integrated services

Hazards

(https://wellington.govt.nz/about-wellington/emergency-management/hazards)

- Tsunami
- Earthquake
- Wildfire
- Windstorms
- Landslips
- River and flash floods.

Providers

Seismological information is provided by the Institute for Geological and Nuclear Sciences (GNS Science), a government science department.

Tsunami Watches and Warnings are provided by New Zealand's Ministry of Civil Defence & Emergency Management (MCDEM), with support from GNS.

Fire information is provided by Fire and Emergency New Zealand (FENZ), with support from the National Institute for Water and Atmospheric Research (NIWA), a government science department.

Weather observing and forecasting is conducted by the Meteorological Service of New Zealand Limited (MetService), New Zealand's National Meteorological Service. MetService provides Outlooks, Watches and Warnings of both broad-scale and local-scale (convective) severe weather.

Flood warnings are provided by Greater Wellington Regional Council (that is, local government), with support from MetService.

Users

General public, government departments, local government (including disaster management, water supply and stormwater management), energy providers, national and local roading authorities, port authority and shipping companies, airport authority and airlines, industry, media.

Requirements

Forecasting of rainfall-induced landslips and their consequences (e.g. road closures, evacuations).

Longer lead times on forecasts of urban flooding during periods of convective rainfall.

Longer lead times and greater accuracy of forecasts of flow in river and stream catchments of all sizes.

Inclusion of likely impacts in forecasts and warnings of geophysical hazards.

Forecasts of coastal inundation (storm surge and tsunami) of greater specificity and longer lead time.

Section C: Services integration

Responsibility for the provision of information about natural hazards and their impacts is widely distributed. While there is good collaboration among the providers of hazard information, there is no "single source of truth" on either hazards or their impacts. Further, it is common for managers of weather-related risks to use weather information from multiple sources in their decision-making.

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For more information, please contact:

World Meteorological Organization

7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland

Strategic Communications Office

Tel.: +41 (0) 22 730 87 40/83 14 – Fax: +41 (0) 22 730 80 27

Email: communications@wmo.int

public.wmo.int

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