Urban Climate News

Quarterly Newsletter of the IAUC

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Inside the Fall issue...

From the IAUC President

The current issue is primarily dedicated to ICUC-7 which took place in Yokohama (Japan) between 29 June – 3 July 2009. It contains a **Special Conference Report** written by our newsletter editor David Pearlmutter and many of the regular items are related to this conference. The **Feature** article, on urban warming and temperature trends in Japan, is contributed by Fumiaki Fujibe, one of the ICUC-7 plenary speakers, whereas the **Urban Project Reports** introduce research by conference award winners. A second set of conference-related reports will appear in the next newsletter at the end of December.

Next, I would like to thank all who have participated in the recent Board election by nominating candidates and voting. In particular I would like to express my gratitude to the 5 candidates who stood for the election. It is my great pleasure to announce that the two new Board members as of August 2009 are Jason Ching (Environmental Protection Agency, USA) and James Voogt (University of Western Ontario, Canada) (see details on p. 39). They will replace Sven Lindqvist (Göteborg University, Sweden) who will leave the Board and Manabu Kanda (Tokyo Institute of Technology) who will stay on as a non-voting member. On behalf of all IAUC members I would like to thank Sven and Manabu for their many contributions, in particular as past chairs of ICUC-6 and ICUC-7, respectively.

Please note the call for nominations for the **Luke Howard Award** (see p. 40). I strongly encourage you to nominate colleagues for IAUC's most prestigious honor by the deadline of 15 October 2009!

And finally I am very delighted to announce a couple of important recent developments which have greatly enhanced the visibility of IAUC and are signs of our growing significance. First, IAUC has been involved in a leading role in the working session on 'Climate and More Sustainable Cities' at the recent **World Climate Conference-3 (WCC-3)** in Geneva (Switzerland) (see report on p. 2). Second, IAUC has been invited to be represented at the First Global Meeting of the newly established International Forum of Meteorological Societies (IFMS) which will be held alongside the AMS 90th Annual Meeting in Atlanta, Georgia (USA) next January. It is a great honor to be recognized by this new umbrella organization alongside all national and some other international meteorological societies and IAUC will be suitably represented at this meeting. I think we can be proud of our progress and growing reputation, and I wish to thank all IAUC members who have helped to make this happen.

Matthias Roth

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IAUC outlines vision for sustainable cities at World Climate Conference (WCC-3)

August, 2009 — The Third **World Climate Conference** (WCC-3) organized by WMO took place in Geneva, Switzerland from August 31 to September 4, 2009. Past conferences (WCC-1 in 1979 and WCC-2 in 1990) have resulted in the establishment of the IPCC and UNFCCC, respectively; i.e. this is a major climate conference with far reaching outcomes. WCC-3 was organized to focus on how humankind can benefit from the enormous advances in climate prediction and information services to build resilience in adapting to climate variability and change. The WCC-3 main goal was to develop a global framework that will enhance the provision, exchange and application of climate prediction and information services and thereby will contribute to the UNFCCC COP15 to be held in Copenhagen, Denmark in December 2009.

The conference was attended by over 2,500 participants from all over the world. This included almost 100 ministers and heads of state and about 50 heads of UN agencies and other international institutions/organizations. During the Opening Ceremonies, the Conference was addressed by the President of the Swiss Confederation and the UN Secretary-General Mr. Ban Ki-Moon, as well as the president of the Global Humanitarian Forum, Mr. Kofi Annan.

The conference was divided into two segments. During the Expert Segment (first two days), scientists presented their research and shared findings and knowledge with the users of climate information. This was followed by the High Level Segment (last two days), which saw short presentations by many Heads of State, Ministers and Heads of International Organizations. The Expert Segment consisted of four Plenary Sessions and 12 Working Sessions, which presented the advances of climate prediction and information services along with their benefits for the management of climate related risks in key climate sensitive sectors such as agriculture and food security, water resources, energy, transport, cities and health.

The inclusion of urban climate themes into WCC-3 was originally suggested by the 'WMO Expert Team 4.4 on Urban Building Climatology' (which includes past and present IAUC Board members). Facilitated by the recent establishment of a Working Arrangement between WMO and IAUC, the latter has been asked to take a lead role in the preparation of materials and to actively participate in the Working Session 8 (WS-8) on **Climate and Sustainable Cities - Climate Information for Improved Planning and Management of Mega Cities**. IAUC has subsequently coordinated the preparation of two White Papers which contain the condensed deliberations of a large number of experts (many of whom are members of IAUC). These White Papers give the state of the modern

Participants of WCC-3 WS-8 (Climate and more sustainable cities) (from left to right): Zifa Wang (discussant; IAP Beijing), Matthias Roth (chair), Tim Oke (theme leader), Gerald Mills (speaker), Paola Deda (discussant; UNECE Geneva), Mathias Rotach (discussant; MeteoSwiss Zürich), Sue Grimmond (speaker), Yinka R. Adebayo (discussant; WMO Geneva), Michael Hebbert (discussant; University of Manchester). Additional photographs from the sessions on 2 September can be found at http://www.iisd.ca/ymb/climate/wcc3/2september.htm.

capabilities, and the outstanding needs, in understanding and modeling interactions between climate and cities, and the use of such understanding in the development of more sustainable cities.

The actual 90-minute session was chaired by **Matthias Roth** (National University of Singapore) and started off with presentations by the lead authors of the White Papers on Needs and Capabilities, respectively: **Gerald Mills** (University College Dublin) introduced the critical needs of the urban planning and design community to promote climate-sensitive urban development, and **Sue Grimmond** (King's College London) identified the emerging capabilities and noted the gaps in existing knowledge. The two presentations were followed by remarks from **Tim Oke** (University of British Columbia) in his capacity as the theme leader of WS-8. Tim summarized the recommendations and actionable items suggested in the White Papers. In the second part of the session, five experts representing a spectrum of cognate fields provided critical assessments and complementary perspectives on the White Papers and recommendations. The White Papers and additional information about the participants are available at: http://www.wcc3.org/sessions.php?session_list=WS-8.

The conference concluded with the adoption of the Summary Conclusions from the Expert Segment. The main conference outcome expressed through the High

Level Declaration states that Governments have agreed 'to establish a Global Framework for Climate Services to strengthen production, availability, delivery and application of science-based climate prediction and services'.

The full conference statement with all recommendations from the Expert Segment is available at the site: http://www.wmo.int/wcc3/page_en.php (Conference Statement – Full document). This document includes the recommendations adopted by WS-8 (see textbox) which constitute the most important outcome of this session together with the two White Papers mentioned above.

– Matthias Roth

Conference Statement

Summary of Expert Segment:
Recommendations from Working Session 8

3.7 Climate and more sustainable cities

51. Cities impact and are impacted by climate change in many ways and at many scales. Climate knowledge should be used more effectively to ensure more sustainable cities.

52. The scientific understanding of urban climates has advanced substantially over the past two decades including conceptualisation, field observations, analysis of processes and model building. However the field is young and much more research is needed to improve understanding to that acquired for other environments. At the same time there is growing demand for urban climate information in the design and management of more sustainable cities. Implications of global climate change for cities have not been adequately assessed to date. In general, few National Meteorological and Hydrological Services (NMHSs) have appropriate expertise in urban meteorology.

53. The experts of the session encourage WMO, through its NMHSs, to introduce urban–related climate services through establishing relations to the political and socio-economic stakeholders and urban developers. These service should include:

- **Improving urban climate observation networks.** Urban climate stations and networks should be greatly improved, including vertical information, in all countries. This should be done in line with WMO urban guidelines. International archives of urban climate, morphological and land cover data should be established; (3.7.a)
- **Climate research for hot cities.** Highest priority should be given to strengthening observational networks and establishing urban climate research programs for tropical cities where population growth is greatest and vulnerability to excess heat and inundation is highest; (3.7.b)
- **Urban climate modelling.** Improved numerical models should be developed to forecast weather, air quality and climate in cities. A focus should be to incorporate urban land surface schemes into global climate models, to down-scale regional climate predictions and projections to the urban scale and to assess their impact on urban health, safety and management; (3.7.c)
- **Education, training and knowledge transfer in urban climatology.** Much greater effort should be directed to increase understanding amongst climatologists, NMHSs and indeed urban stakeholders. (3.7.d)

Scientists investigate Urban Climate in Rotterdam and Arnhem

August, 2009 — Researchers from Wageningen University used the warm days in August to map out the urban climate in two Dutch cities. The research team drove two cargo bicycles with measurement equipment during various times of a 24 hours' day through Rotterdam and Arnhem. The results may indicate to which extent heat stress may become a problem for the inhabitants.

The measurements on 6 August in Rotterdam showed that during day time the city centre was two degrees warmer on average than Zestienhoven airport, which is located outside the city. A striking observation was that the city park De Twee Heuvelen was 2.4°C cooler than Zestienhoven. This means that the differences in the afternoon in the city can rise to 4.4°C. During the late evening (22-24 hours), the city centre was more than 5°C warmer than Zestienhoven. The route near the national Green Heart (Doenkade) turned out to be even cooler (2°C) than Zestienhoven. The difference in temperature between the city and countryside consequently amounted to more than 7°C during nocturnal hours.

In the late afternoon the "felt" air temperature – as perceived by the human body – was 28°C at Zestienhoven, the temperature at the city centre of Rotterdam (in the sun and out of the wind) would feel more than 6 degrees higher – so well above 30°C. Surprisingly, similar effects were measured in the much smaller city of Arnhem. *Source:* http://www.sciencedaily.com/releases /009/08/090827123520.htm

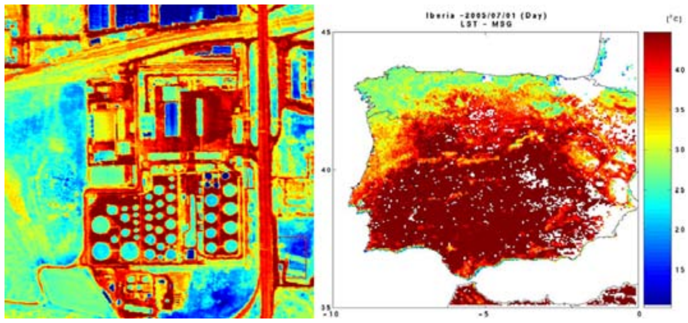
ESA launches Phase 2 of "UHI and Urban Thermography" project

July, 2009 — The Urban Heat Island and Urban Thermography (UHI) project, financed by ESA in the framework of the Data User Element program, has started the second stage of its 30-month pogram. Phase 2, scheduled to run through April 2011, will deal with all activities relevant to the implementation of a user-tailored information system that exploits Earth Observation (EO) technology for supporting local authorities in assessing, monitoring and forecasting heat waves and UHI impacts.

The project team is analyzing UHI trends in 10 European cities (Athens, Bari, Brussels, Budapest, Lisbon, London, Madrid, Paris, Seville, Thessaloniki) over the last 10 years, using a multi-sensor approach that includes satellite-based TIR sensors (SEVIRI, AVHRR, AATSR, MODIS, LANDSAT, ASTER) to analyze the spatial variability of the UHI in these metropolitan areas. One of the recently-publicized components of the project is the **Thermopolis 2009** study in Athens, Greece (http://www.sciencedaily.com/releases/2009/08/090827101217.htm).

Started in November 2008, the project's main objectives include: 1) the assimilation of satellite remote sensing observations and ground weather stations data into urban meteorological and climate models, to remediate the impact of the UHI and reduce the risk of heat waves; 2) study of the mission requirements for a high-resolution TIR (Thermal Infra Red) satellite sensor; and 3) study of how TIR observations from space can support the implementation of urban energy efficiency policies embracing typical issues from Southern Europe (i.e., energy for air conditioning demand) as well as from Northern Europe (i.e., energy for domestic heating).

In order to predict UHI spatial and temporal variability, Land Surface Temperatures derived from remote sensing observations are assimilated into urban climate models, and long-term (10-year) LST series are analyzed to identify historical trends of surface and air temperatures in the metropolitan and surrounding rural areas of the cities. From these data, bio-climatic indicators (e.g. thermal stress indices) are produced and LST retrievals are integrated within Numerical Weather Prediction (NWP) models to forecast the location and magnitude of urban heat islands, in particular during heat waves.



Remotely sensed temperature mapping: industrial structures in Madrid from DESIREX 2008 (left), and LSTs over the Iberian peninsula on a summer day (right).

The observed LST and air temperatures are also analyzed as a function of land use/land cover, surface albedo, surface emissivity, surface roughness and air quality. Thermographic maps support energy balance studies and aid in monitoring the impact of energy efficiency policies involving the installation of specific materials on roofs or pavements, planting vegetation, and improving the thermal efficiency of buildings. Project partners include EDISOFT S.A (Lisbon, Portugal), INDRA (Madrid, Spain), NOA-ISAR (Athens, Greece), VITO (Mol, Belgium), EUROSENSE (Wemmel, Belgium) and PLANETEK (Bari, Italy). For more information see: http://www.urbanheatisland.info/

Beijing air 'cleaner' since 2008 Olympic Games

August, 2009 — Beijing is enjoying the best air quality this decade because of measures taken during last year's Olympic Games, officials have said. They say there were 171 days of low pollution in the first seven months of this year, 22 more than in 2008.

One year after the games, independent experts agree that air quality in the Chinese capital has improved. But they say the city still has some way to go before it can be compared with the world's cleanest cities. And the clean-up came at a cost – so China will find it hard to spend similar amounts of money improving its other polluted cities. "All the major measures taken by the city were expensive and not easily replicated elsewhere," said Yang Ailun, of Greenpeace in China.

Beijing's notorious air pollution was a major concern for athletes, spectators and Olympic officials before the games (see **News**, Issue 29). Chinese officials did not want the biggest international event ever staged in communist China being overshadowed by pollution.

So the government initiated a series of clean-up programmes for the Olympics. According the United Nations Environment Programme (UNEP), China spent a total of $17bn on these schemes. Polluting factories were moved, private cars were banned from the roads and coal boilers were converted so they could use cleaner natural gas.

This massive spending spree worked, to an extent. Pollution was down by 36% in Beijing during the games last August compared to previous years, but it is clear that some of the gains made during the Games were not sustained when the athletes left. Measurements of particulate matter (PM_{10}) on August 7 showed a concentration of 158 μg/m^3, down from 191 one year earlier – but still well above the WHO air quality guideline level of 50 μg/m^3. *Source:* http://news.bbc.co.uk/2/hi/asia-pacific/8189921.stm

有難う御座いました！

"Arigatoo gozaimashita"

Thank You Very Much!

On behalf of all IAUC members, I would like to thank the Local Organizing Committee on their outstanding job organizing and hosting ICUC-7. The many students and secretarial staff helping out are also remembered for their enthusiasm and positive spirit.

Matthias Roth, IAUC President

The ICUC-7 Local Organizing Committee:

Manabu Kanda, Chair
(Tokyo Institute of Technology)
Yasunobu Ashie
(National Inst. for Land & Infrastructure Management)
Fumiaki Fujibe
(Meteorological Research Institute)
Toshiaki Ichinose
(National Institute for Environmental Studies)
Atsushi Inagaki
(Tokyo Institute of Technology)
Hiroaki Kondo
(National Inst. of Advanced Industrial Science & Tech)
Hiroyuki Kusaka (University of Tsukuba)
Akashi Mochida (Tohoku University)
Ryo Moriwaki (Ehime University)
Masakazu Moriyama (Kobe University)
Hirofumi Sugawara (National Defense Academy)

Striving for perfection: ICUC-7 organizers Ryo Moriwaki (left) and Manabu Kanda, Chair of the LOC and star of the 'surprising' Ninja Show (see page 13).

The ICUC-7 venue: Pacifico Yokohama-Pacific Convention Plaza, Yokohama, Japan.

ICUC-7 in Yokohama, Japan: A look back

By David Pearlmutter, Editor

Urban climatologists from around the world came together for the seventh time at the International Conference on Urban Climate (ICUC-7), held from June 29 to July 3, 2009 in Yokohama, Japan.

In defiance of both a world economic crisis and swine flu, the Japanese local organizing committee hosted a highly successful conference that drew some 350 participants from 36 separate countries (see Table, page 9).

Committee chairman **Manabu Kanda** kicked off the event by thanking the many organizations who lent their generous support, including EXPO '70 and the ESA, as well as the WMO – which also sponsored the new online Bibliography on Urban and Building Climatology. Both this bibliographic database and the newly launched Urban Flux Network were introduced at the opening session by IAUC President **Matthias Roth**.

Along with his opening remarks (see box at right), Roth highlighted the growth of IAUC as a world-wide organization, which now numbers some 1600 members from 80 countries. He also emphasized the importance of urban climatology for rapidly growing cities in the developing world, many of which are located in tropical or semi-tropical regions and face the compound challenge of urban heating and global climate change.

A ceremony was held in honor of three recent recipients of the Luke Howard Award: **Arieh Bitan** (2006), **Masatoshi Yoshino** (2007) and last year's winner **Bob Bornstein**. Accepting his award in a recorded message, Bornstein spoke of the urban boundary layer as a "battleground" for conflicting forces, and recalled how he has worked to unravel the "beautiful complexity" of urban climate.

Left to right: Manabu Kanda, Sue Grimmond, Masatoshi Yoshino, Arieh Bitan, Tim Oke and Matthias Roth.

ICUC-7 Opening Remarks by Matthias Roth
President of the IAUC

Distinguished guests, fellow members of IAUC, ladies and gentlemen:

My name is Matthias Roth. As President of the International Association for Urban Climate, I have the unique pleasure and honor to welcome you to ICUC-7, the Seventh International Conference on Urban Climate. ICUC is a series of conferences dedicated to the climate of cities which informally started in Brussels in 1968. The first conference with the name 'ICUC' was held in Kyoto (Japan) in 1989. I am extremely pleased to note that Yasuto Nakamura, the chair of that meeting can be here with us today. As many of you will remember the last ICUC was held three years ago in Göteborg (Sweden) with Sven Lindqvist as its Chair. I don't know if, when ICUC-7 was awarded to Yokohama three years ago, anybody realized that it would go back to Japan after exactly 20 years. This is of course also a testimony to the quality and vibrancy of urban climate research in Japan.

(continued on page 14)

Scientific themes

As was the case at ICUC-6 and earlier conferences, the main program at ICUC-7 was divided into two streams of parallel sessions, reflecting the balance of interests encompassed by urban climatology. One of these streams focused on the measurement and modeling of physical processes within the urban environment, and the other stream examined the relations between these processes and wider issues of design, planning and policy (see Table below for an overview of the oral presentations by theme and topic).

• In terms of physical science, a strong emphasis was placed on the numerical modeling of air flow over urban terrain, using advanced CFD and LES techniques. Of the four sessions devoted to this field of analysis, one was entirely focused on the effects of thermal stratification, mainly within urban canyons. The measurement of urban wind flow and turbulence was prominent as well, reflected in a total of 15 studies using a range of in-situ and scale model-based observation tools – from Doppler lidar to Particle Image Velocimetry.

Models of the urban atmosphere were presented in a number of sessions, highlighting the ongoing development and application of these models at a range of scales. The intensive interest surrounding mesoscale models was in evidence with a full session allocated to

studies involving the Town Energy Balance (TEB) scheme, and a presentation by past-IAUC president **Sue Grimmond** on the international urban energy balance model comparison, co-authored by 27 other researchers. Separate sessions were filled with studies examining particular urban exchange processes, addressing the fluxes of CO2 and other pollutants as well as the urban energy balance. Continuing a trend noted at ICUC-6, more and more studies dealt with urban air quality, and another area of expanded interest is the use of remote sensing and GIS tools for urban climate analysis.

• On the more applicative side, the familiar topic of

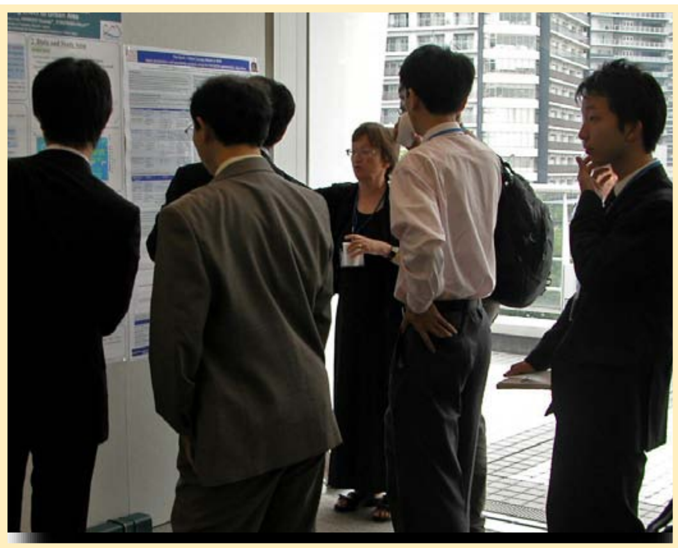
ICUC-7 oral presentations by theme and topic (number of sessions/papers)

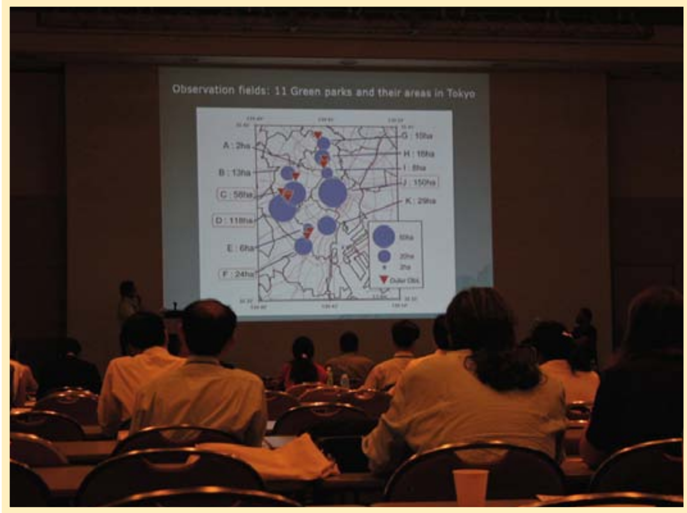
(A) Physical processes in urban areas		(B) Applied urban climatology	
Measurement of airflow	(3/15)	**Building climates**	(1/3)
Exchange processes:		**Climatic performance:**	
CO_2 exchange	(1/7)	Surfaces, water and greenspace	(1/6)
Energy and mass exchange	(1/7)	Urban parks and plants	(1/7)
CFD of flow & dispersion: general	(3/16)	**Design & planning:**	
Effects of stratification	(1/6)	Overview	(1/6)
Models of the urban atmosphere:		Climate maps and tools	(1/5)
Mesoscale models	(1/5)	Outdoor comfort, wind	(1/4)
TEB development and applications	(1/6)	**Urban environment forecasts**	(1/6)
Thermal & wind environment	(1/6)	**Climate change impacts**	(2/12)
Urban models at all scales	(2/14)	**Low-carbon cities**	(2/11)
Air pollution meteorology & modeling	(1/7)	**Impacts on precipitation**	(2/11)
Aerosols and photochemical pollutants	(1/8)	**Human biometeorology**	(2/15)
Remote sensing	(2/12)	**UHI analysis and mitigation**	(3/18)

urban heat islands was addressed by no fewer than 18 presenters – with nearly as many looking at the effects of urbanization on precipitation, and methods for urban forecasting. Presenters in one session looked especially at novel UHI mitigation strategies, based on various types of landscape elements. In fact the intentional use of water and vegetation for urban cooling is a theme that has expanded considerably, as seen in the considerable number of studies evaluating the climatic performance of parks and other types of green space. Another well-established, but growing area of interest is biometeorology, with researchers delving into the subtleties of human behavior and perception regarding climatic stress, as well as design strategies (such as greenery) for moderating it.

Urban design, though once considered peripheral to urban climatology, was a prominent theme in several sessions – one on building climates, and three others on various design and planning issues. One session provided a showcase for GIS-based mapping tools, some of which have seen real-world implementation as climatic atlases and municipal planning instruments. IAUC president-elect **Gerald Mills** discussed the recently completed WMO white paper on climate and sustainable cities, emphasizing new opportunities for the formulation of climate-based planning guidelines – as well as another "new" source of relevance for urban climatology, global climate change.

It is attention to this last issue – the role of cities as both sources and victims of global warming – that was notably lacking at ICUC-6, but notably abundant at ICUC-7. A dozen presentations looked at the impacts of climate change on urban systems, and nearly the same number discussed strategies for "low carbon cities" – making it clear that the relationship between urban energy consumption and climate has indeed become a two-way street.





Plenary Lectures

Along with its regular parallel sessions, the conference was punctuated by a series of stimulating plenary talks. The first of these was presented by **Fumiake Fujibe** of the Meteorological Research Institute in Tsukuba, Japan, who surveyed the history of climate monitoring in Japanese cities over the course of their tremendous growth. Tokyo's population has increased more than ten-fold since 1900 (triple the overall rate in Japan), and in that time has seen an increase of 3ºC in its mean temperature and over 6ºC in its minimum. Significant urban heat islands have been identified in other Japanese cities as well, and Fujibe described the detection of UHI signals even in sites that are only slightly urbanized (see **Feature**, page 15).

Greg Carmichael of the University of Iowa stressed in his plenary that the global air pollution community is "reaching down" to the urban scale, ever-more cognizant that the dominant source of atmospheric pollutants is the megacities of the world. He pointed out that these large urban centers, while embodying much of the problem, also embody much of the solution – since they are the main sources of wealth and power, and of capabilities for hammering out solutions to pressing environmental threats.

He placed special emphasis on "black carbon," which is the principal component of aerosols in urban areas – and which, unlike other aerosols that reflect incoming radiation, is highly absorptive and therefore acts like a greenhouse gas, second only to CO_2 in importance. But since its lifetime in the atmosphere is only 1-2 weeks, as opposed to 100+ years for CO_2, black carbon is inherently more manageable and thus represents an important opportunity for remediation of atmospheric warming. Using aircraft and satellites to detect urban plumes of various pollutants, the atmospheric "footprint" of megacities was shown by Carmichael not only to vary over time (as in the case of Beijing since the 2008 Olympics – see **News**, page 4), but to be global in reach – leading to modifications in atmospheric composition across oceans and continents (as reinforced by recent media reports).

The emission of anthropogenic heat and moisture in the urban environment was the focus of a plenary presentation by **David Sailor**, a researcher at Portland State University. Sailor examined the limitations in existing methods for quantifying anthropogenic heat in cities, whose production may be attributed to industry, buildings and transport. He pointed out that an inventory approach based on the mapping of building energy consumption due to thermal loads may underestimate the sensible heat actually removed by HVAC systems, and even more so the latent heat removed by evaporative cooling.

On the other hand a micrometeorological approach, in which anthropogenic heat is estimated as the residual in the surface energy budget, may be limited in accuracy because closure of the energy balance incorporates accumulated errors in the measurement of radiation, storage and turbulent fluxes. An alternative approach is based on building energy modeling, in which detailed building energy simulation results are integrated with an urban canopy meteorological model or with a GIS database that reflects the characteristics of different building prototypes. In this way, the city's anthropogenic heating may be more realistically disaggregated into local-source heat islands that have different diurnal and seasonal characteristics. While all three approaches have strengths and weaknesses, Sailor emphasized that the challenge remains of achieving accuracy and at the same time simplicity – since the ultimate goal is to allow for wide application in many cities based on data that are readily available.

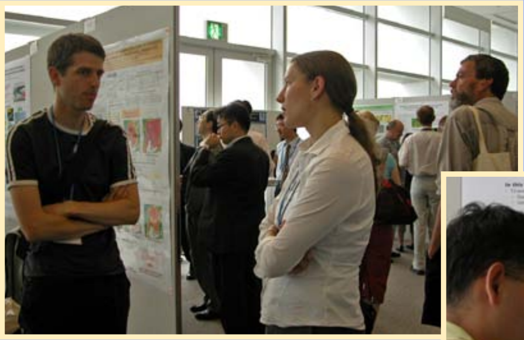
The closing plenary was given by **Yasunobu Ashie** of the Japanese Building Research Institute, on the application of a powerful supercomputer system – known as the "Earth Simulator" – to the development of UHI countermeasures for the Tokyo Bay area. With a population that is expected to exceed 26.5 million by the time of the Tokyo Olympics in 2016, this metropolis is the largest of all the world's "megastructures" – and its role in modifying the local climate is correspondingly immense.

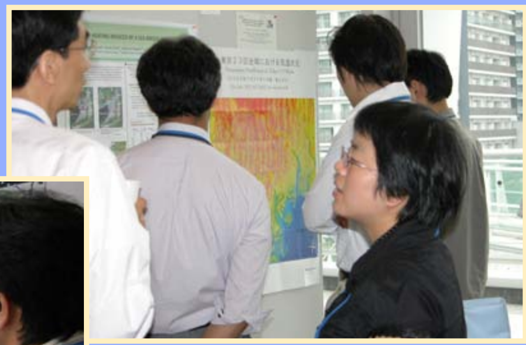
Using a high-resolution CFD model to simulate air flow and temperature fields over the entire 23 wards of Tokyo, Ashie illustrated how the "Tokyo Wall" of skyscrapers obstructs wind penetration and deprives much of the city of cooling that was once provided by the sea breeze. Considering that the results of this complex numerical simulation agreed well with field observations and wind tunnel experiments, it was proposed with some confidence that Tokyo's environmental problems be addressed with far-reaching measures – including the creation of a wind corridor through the coastal "wall" by permanently removing a number of existing high-rise buildings.

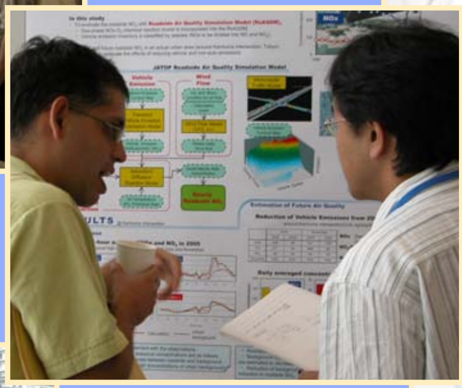
ICUC-7 registered participants by country

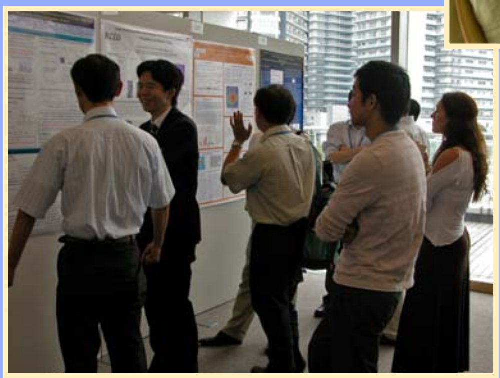
Japan	148	Singapore	4
Germany	24	Belgium	3
China	14	Italy	3
United States	13	Spain	3
Hong Kong	11	Australia	2
Canada	10	India	2
Republic of Korea	10	Iran	2
United Kingdom	10	Ireland	2
France	7	Mexico	2
Israel	7	New Zealand	2
Nigeria	7	Sweden	2
Hungary	6	Turkey	2
Taiwan	6	Czech Republic	1
Poland	5	Jordan	1
Russia	5	Luxembourg	1
Switzerland	5	Malaysia	1
Brazil	4	Nepal	1
Finland	4	Vietnam	1

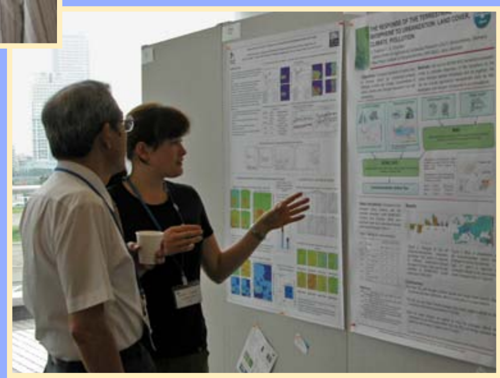
Following this fourth and final plenary talk, a challenge was laid out to the ICUC-7 conferees by IAUC's founding president, **Tim Oke**. While expressing confidence in the urban climate community's capability to produce tools and scientific knowledge at an advanced level, he questioned our ability thus far to convey such information to policy makers and see it translated into action: "We need to work with architects, planners and city officials, to translate 'watts and meters per second' into potential deaths – or wasted dollars or yen – that are the consequences of inaction in climatically improving cities."





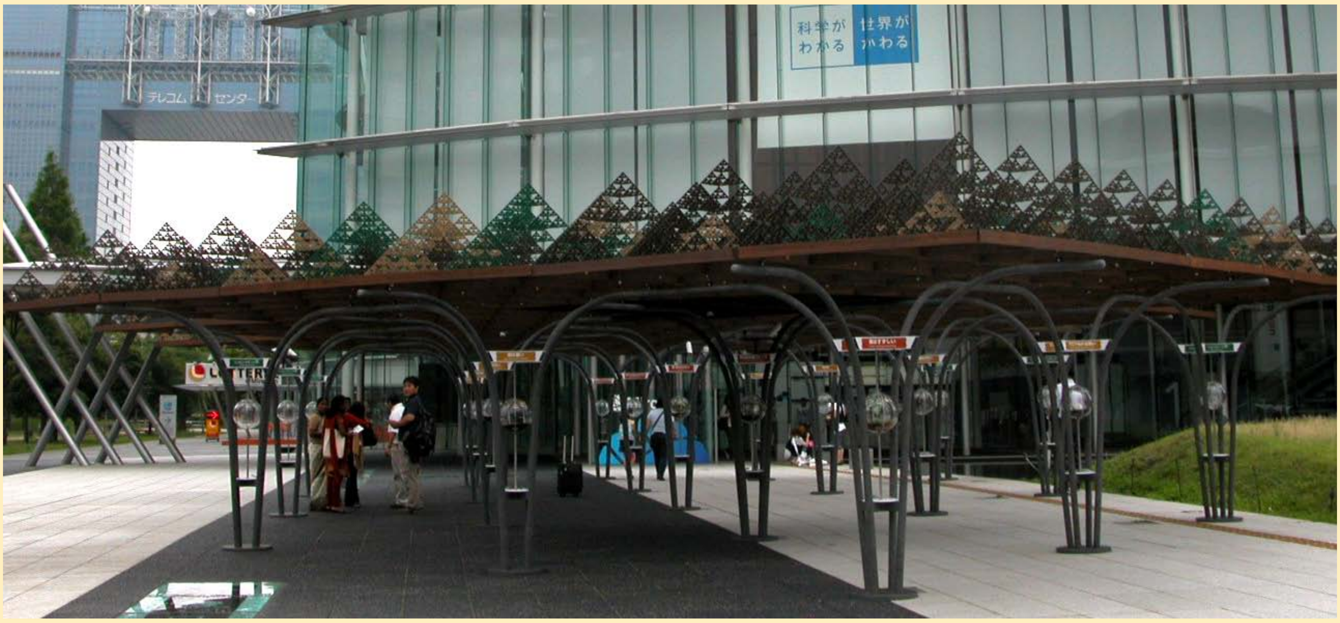






Poster sessions

Over the five days of the conference, 222 posters were exhibited – covering a spectrum of urban climate issues ranging from pollutant transport to human thermal perception.



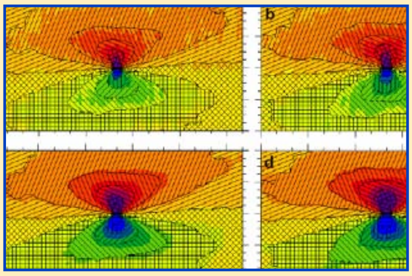
Technical tours: The ICUC-7 program included visits to the Taisei Corporation Technology Center, and to "Sierpinski's Forest" (above) – a demonstration of new technology for cooling urban surfaces with fractal-geometry overhead coverings. The project was presented by **Satoshi Sakai** of Kyoto University, who described how the shading device intercepts solar radiation and at the same time maintains a low surface temperature. The effect is attributed to efficient convective heat removal from the small-scale elements, which mimic the leaf structure of a shade tree – but do not require irrigation.

Student Awards

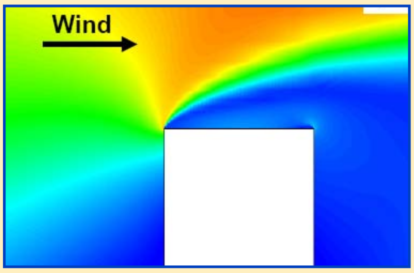
The awards committee was delighted to announce the 2009 winners of the student paper competition at the 7th International Conference for Urban Climate. The **Student Award** winners' work is featured in the **Urban Projects** section of this issue (see pp. 19-29)

Best Student paper (joint winners):

Marieta Cristina L. Castillo (Tokyo Institute of Technology), with Jin Zhang, Manabu Kanda, Marcus O. Letzel and Atsushi Inagaki, for the paper "Coherent structures of a neutrally stratified urban boundary layer using large-eddy simulation" (see p. 19)

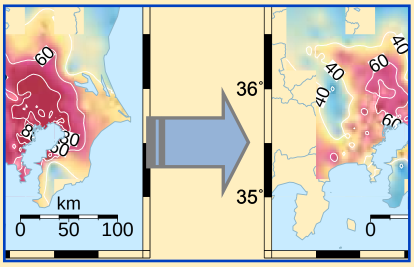


Thijs Defraeye (Katholieke Universiteit), with Bert Blocken and Jan Carmeliet, for the paper "Computational modelling of convective heat and moisture transfer at exterior building surfaces" (see p. 23)



Best Poster:

Sayuri Okubo (Tokyo Metropolitan University), with Hideo Takahashi, for the poster "Long-term and seasonal trend of SPM concentration and its spatial distribution in the Kanto region, Japan" (see p. 26)



ESA Awards

Also featured in the **Urban Projects** section (see pp. 30-35) is the work of two researchers who were selected by the awards committee as recipients of the **ESA awards** for remote sensing:

Best Oral presentation ($400 US):

Corinne Myrtha Frey et al., (University of Basel), for the paper "Comparison of in situ and remotely sensed radiation and heat fluxes of the megacity of Cairo, Egypt" (see p. 30)

Best Poster ($300 US):

Yasuaki Kambe (the University of Tokyo), with Yotsumi Yoshii, Kenshi Takahashi and Kenichi Tonokura, for the paper "Continuous monitoring of urban air quality with a pulsed DOAS technique" (see p. 33)

William P. Lowry Awards (The Lowry Award winners' work will be featured in the **Urban Projects** section of the next issue of *Urban Climate News*, in December 2009.)

The **William P. Lowry Graduate Student Prize** is a cash award of $200 US given to the author of the best paper in urban biometeorology/bioclimatology presented at ICUC-7 by a graduate student:

Sookuk Park (University of Victoria), with Stanton E. Tuller, for the paper "Modeling human radiation exchange in outdoor urban environments"

The **William P. Lowry Methodology Prize** is a cash award of $200 made to the author of the paper that incorporates the best conceptual or experimental methodology:

Iain D. Stewart (University of British Columbia), with Tim Oke, for the paper "Classifying urban climate field sites by 'local climate zones': The case of Nagano, Japan"

The **William P. Lowry African Student Travel Award** is a cash award of $300 US to help defray travel expenses to ICUC-7 for a graduate student traveling from the continent of Africa, and was awarded to:

Ifeoluwa Balogun (Department of Meteorology, Federal University of Technology, Akure, Nigeria)

A special Country Report on urban climate research in Nigeria will appear in the next issue (December 2009) of *Urban Climate News*.

Japan Prize winners

The **Japan Prizes** are valued at $1,000 US and honor researchers from developing countries who are judged to have given the best papers at ICUC-7. The prize winners' work will be featured in the **Urban Projects** section of the next issue (December 2009) of *Urban Climate News*.

Qinglin Meng & Lei Zhang (South China University of Technology)

"Near-ground air temperature calculation model based on heat transfer of vertical turbulent and horizontal air flow"

Nuri Serteser (Technical University of Istanbul, Turkey)
with Vildan Ok

"The Effects of Building Parameters on Wind Velocity and Air-Flow Type in the Urban Settlements"

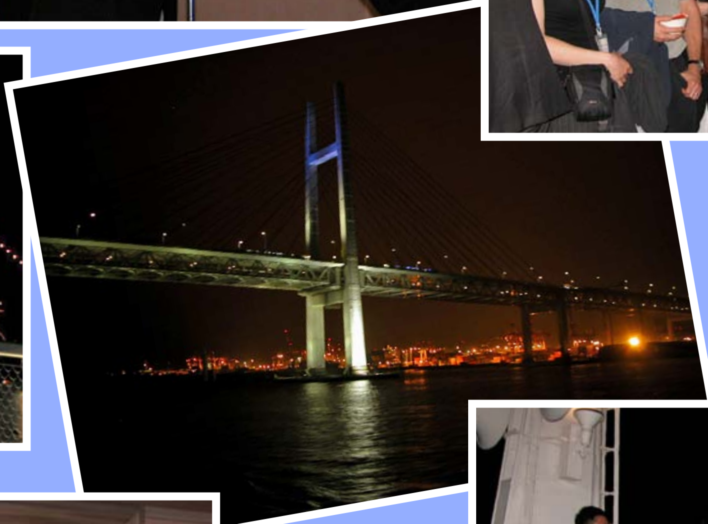
Alessandra R. Prata Shimomura (University of Sao Paulo)
with Leonardo Marques Monteiro & Anesia Barros Frota

"Physiological Equivalent Temperature index applied to wind tunnel erosion technique pictures for the assessment of pedestrian thermal comfort"

Origami, Ninjas and a cruise on Tokyo Bay

Japanese hospitality was in evidence throughout ICUC-7, with a social program full of surprises.

Monday evening's Ice Breaker featured a demonstration of traditional paper folding and Japanese music.



On Tuesday evening, ICUC boarded the "Royal Wing" for a dinner Bay Cruise.

At the banquet on Wednesday, **Manabu Kanda** made an unexpected cameo appearance in ICUC-7's breathtaking *Ninja Show*.

IAUC Board (from left): Jamie Voogt, Sofia Thorsson, Gerald Mills, Jenny Salmond, Matthias Roth, Sue Grimmond, Toshiaki Ichinose, Manabu Kanda, Rohinton Emmanuel, Petra Klein and Tim Oke

(Opening remarks, continued from page 6)

For many decades, Tokyo-Yokohama has now been the globe's largest urban agglomeration. Tokyo-Yokohama is also the home to many renowned institutions involved in cutting-edge urban climate research and this region is a leader in applying theoretical knowledge to urban planning in order mitigate unwanted effects. The selection of Yokohama as a host for ICUC-7 is therefore a natural one in many respects.

I would like to take this opportunity to acknowledge people and organizations, which have helped us to get here:

• The World Meteorological Organization has been an important partner since the first urban climate meetings conducted in the late 1960s. This time again, WMO is a co-sponsor and its financial support has been crucial to enable the attendance of four young scientists who otherwise would not have been able to be here. Many thanks to WMO for their continuing support. WMO is not directly represented here today, but Sue Grimmond, our immediate past president of IAUC, will say a few words on their behalf.

• The European Space Agency for the first time this year, has contributed generously to support the attendance of three scientists and fund two new student awards. I am very grateful to Benedict Doussett, who is on the IAUC board, for approaching ESA, and Volker Liebig, Director of the Earth Observation Systems at ESA, for making these funds available.

• Speaking of awards, I would like to acknowledge the continuing support provided by the Japan Prizes, which were initiated by Yasuto Nakamura and his Japanese friends, and the William P. Lowry Memorial awards made possible by the sons of Bill Lowry, Samuel and Porter Lowry.

• I would also like to mention in-kind support from a number of cognate organizations which are: PLEA (organization for Passive and Low Energy Architecture), IGU (International Geographical Union) Commission on Climatology, UGEC (Urbanisation and Global Environmental Change) Project and of course AMS, the American Meteorological Society. David Sailor, Chair of the AMS Board on the Urban Environment is here today.

• Next I would like to acknowledge the outstanding support received from the local organizing committee under the leadership of Manabu Kanda from Tokyo Institute of Technology, without which there would not be an ICUC-7. Helping Manabu Kanda with the many practical details and day-to-day issues was Ryo Moriwaki from Ehime University, who is also in charge of the social program. I would like to take this opportunity to express my deep appreciation to them for their sustained effort. Organizing such a conference is not an easy undertaking under the best of circumstances. Add a severe financial crisis limiting conference funds to potential participants, plus a worldwide flue pandemic on top, and you would have to agree with me that the LOC has done an outstanding job persevering under adverse and uncertain circumstances.

IAUC President Matthias Roth

• I would also like to acknowledge the essential contributions from the various local Japanese organizations, in particular the important and generous support from EXPO70. In addition, we are very grateful for the outstanding and indispensable help from the very motivated graduate students and administrators in Manabu Kanda's research lab at TIT. Here, in particular I would like to mention Mrs. Okamoto, who has worked untiringly for this conference. On behalf of the IAUC Board and the entire IAUC community, thank you very much! Domo arigatoo gozaimasu!

• The biggest Thank You of all, however, is for you, all of you who are now sitting here and have made the effort to attend this meeting, prepare presentations or simply come to listen to the program.

Ever increasing urban populations and the associated anthropogenic emissions of heat, pollutants, and other waste products which alter the local urban climate, together with the concentration of fast-growing cities in tropical or subtropical coastal locations exposed to the consequences of climate change, mean that urban climate research is relevant and will increase in importance as a key component to make cities more livable and sustainable to the benefit of their inhabitants.

In this respect, I am looking forward to good papers and stimulating scientific interactions. I hope you will all enjoy ICUC-7 and the great hospitality provided by the local organizing committee.

Thank you very much.

Urban warming in recent temperature trends in Japan

By Fumiaki Fujibe (ffujibe@mri-jma.go.jp)

Meteorological Research Institute, Tsukuba, Japan

While climate change monitoring requires the identification of trends in the background field that are free of urban bias, many of the stations that have a long measurement history are located in cities. The present article gives an overview of a study on urban warming in Japan, that was based on data from a dense network of stations (AMeDAS) over 29 years. The results indicate that urban bias in temperature trends is detectable not only in densely inhabited areas, but also at only slightly urbanized sites with 100-300 people per square kilometer.

1. Introduction

Urban warming can be a biasing factor in monitoring climate change, as many observation sites having a long history are located in cities (Karl *et al*., 1988; Jones *et al*., 1990). There has been some evidence of anomalous increases in urban temperature (Hansen *et al*., 2001; Choi *et al*., 2003; Hale *et al*., 2006; Ren *et al*., 2008; Lai and Cheng, 2009), although some researchers have emphasized the small magnitude of the urban contribution to observed temperature trends (Peterson, 2003; Li *et al*., 2004; Pepin and Seidel, 2005; Parker, 2006). From the viewpoint of global warming studies, it is of interest to quantify the contribution of urban warming in long-term temperature changes, not only in large cities but also at sites that are only slightly urbanized.

In Japan, urban warming is quite conspicuous in large cities (Fujibe, 1995; Kato, 1996), corresponding to rapid industrialization during the last century. Figure 1 shows a time series of daily mean temperature in Tokyo, where the observation site is located in the central business area of the city. The linear trend is 3.00°C/century, which is much larger than that at Hachijo Island (0.56°C/century), located 300 km south of Tokyo, and also that of the global mean land temperature provided by the Climatic Research Unit at the University of East Anglia (CRUTEM3v; http://www.cru.uea.ac.uk/cru/data/temperature/). Trends of 2-3°C/century are also found for other large cities in Japan (Fujibe, 1995; Kato, 1996; Japan Meteorological Agency, 2009). Moreover, a heat island can be observed even in a small settlement with population of a thousand or less (e.g., Sakakibara and Matsui, 2005).

Fujibe (2009, hereafter F09) analyzed temperature trends over the past few decades using data from the AMeDAS (Automated Meteorological Data Acquisition System) network, which has more than 500 available stations including many rural sites. In this article, an overview of these results is presented on the basis of an analysis using updated data.

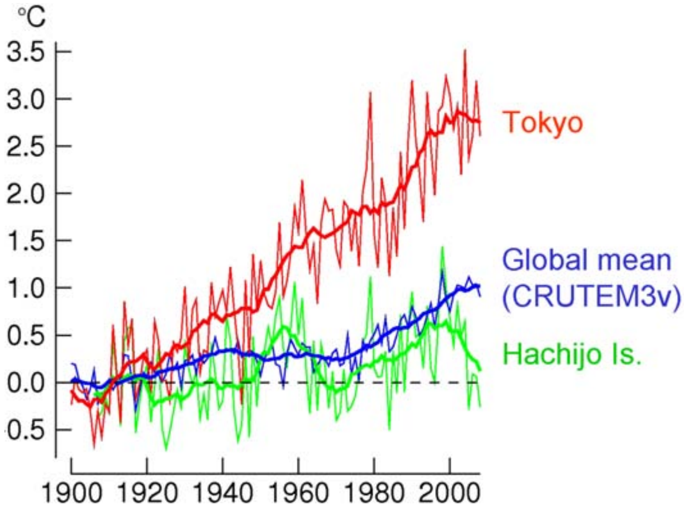


Figure 1. Time series of annual mean temperature (departure from the average for 1901-1920) at Tokyo and Hachijo Island, and the global mean land temperature (CRUTEM3v) for 1901-2008. Thin and thick lines indicate annual values and the eleven-year running average, respectively.

2. Data and procedure of analysis

The analysis was based on hourly temperature data from March 1979 to February 2008. These data are the same as those used in F09, although the period was extended by two years. Stations were selected on the conditions that (1) days having more than two missing values should be less than 3% in any of the twelve months, and (2) site changes should be less than a horizontal distance of 500m and altitude of 3m. In addition, some stations were removed from the analysis by evaluating the accuracy of spatial interpolation of rural temperature, as detailed in F09. The resulting number of stations is 546.

Data on population distribution was obtained from results of the 2000 census, on grids of 30″ in latitude and 45″ in longitude (about 1km x 1km), compiled by the Ministry of Internal Affairs and Communications of Ja-

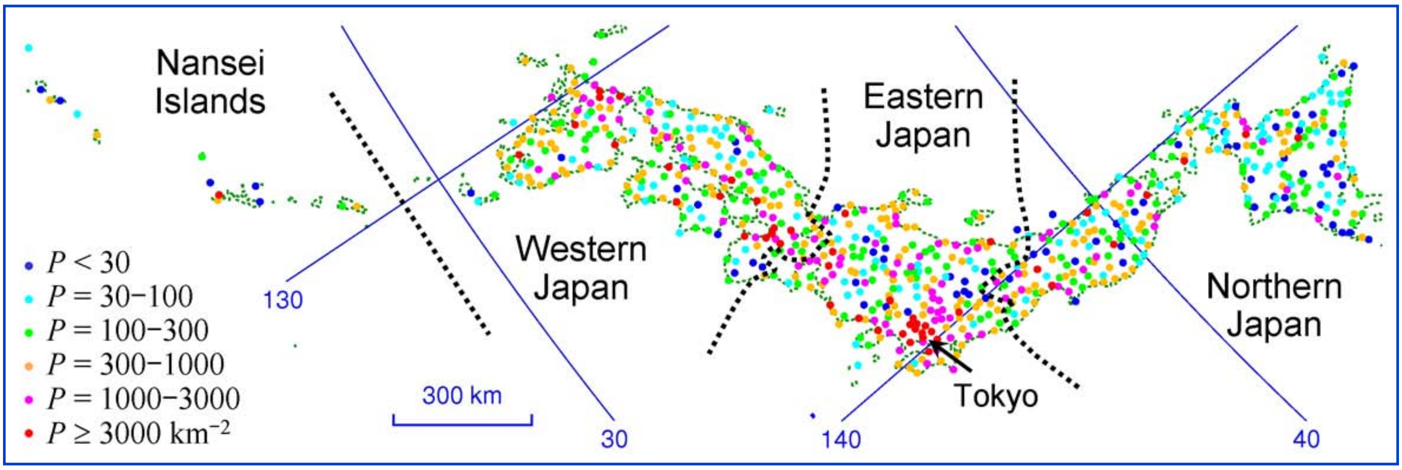


Figure 2. AMeDAS stations used for analysis.

pan and distributed by Orkney, Inc. The population density around a station *i* was calculated from a weighted average in the form:

$$P(i) = \frac{\Sigma_g exp\{-(\frac{r_{ig}}{R})^2\}P_0(g)}{\pi R^2}$$

where $P_0(g)$ is population on the grid g, r_{ig} is its distance from the station i, and R=3km. Figure 2 shows the distribution of stations categorized by P.

Stations with P<100km^{-2} were regarded as non-urban sites and were used as the reference to define the urban anomaly. Although some anomalous temperature trends were found even for stations with P=30-100km^{-2} (F09), they are treated as rural sites in the present analysis in order to achieve adequate spatial coverage of reference stations, allowing for the possibility of slight urban bias.

3. Results

Figure 3 shows the relation between P and the trends of daily mean temperature (T'). There is a trend of about 0.3^{o}C/decade even for stations with P<100km^{-2}, indicating the background climate change. On the other hand, there is a positive correlation of 0.403 between T' and P, indicating anomalous warming that is more rapid at stations with higher population density.

In order to evaluate the net urban trend, the departure of T' from its average over surrounding non-urban stations was obtained on the assumption that regional warming was locally uniform. The averaging was based on spatial interpolation using the least-squares condition:

$$\Sigma_j exp\{-(\frac{r_{ij}}{r_0})^2\}[T'(j)- \{a(i)x_{ij} +b(i)y_{ij} +T'_0(i)\}]^2 \longrightarrow min.$$

where x_{ij} and y_{ij} are eastward and northward distance from the target station i to the reference non-urban station j, $r_{ij}^2 = x_{ij}^2 + y_{ij}^2$, and r_0 is a given parameter controlling the spatial scale of interpolation. The value of r_0 was given to be 300km, although analyses based on r_0=150km and r_0=600km hardly alter the result. The urban contribution to T' was defined by $\delta T'(i) = T'(i) - T_0'(i)$. Figure 4 shows the

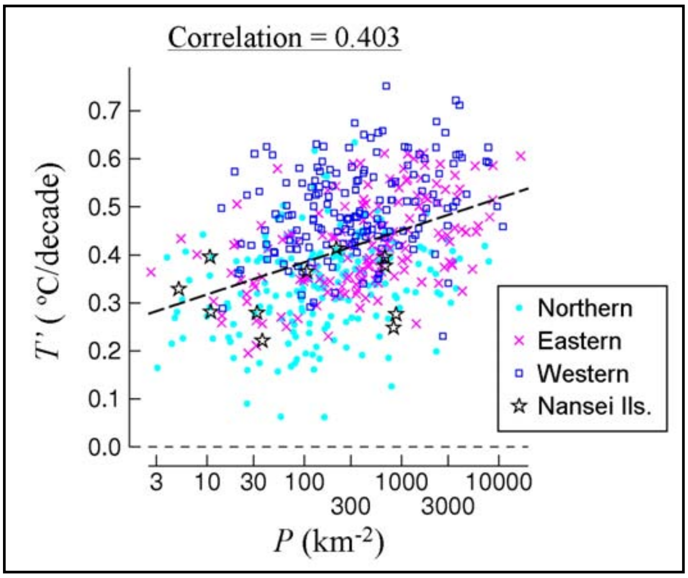


Figure 3. Plot of T' and log P at each station.

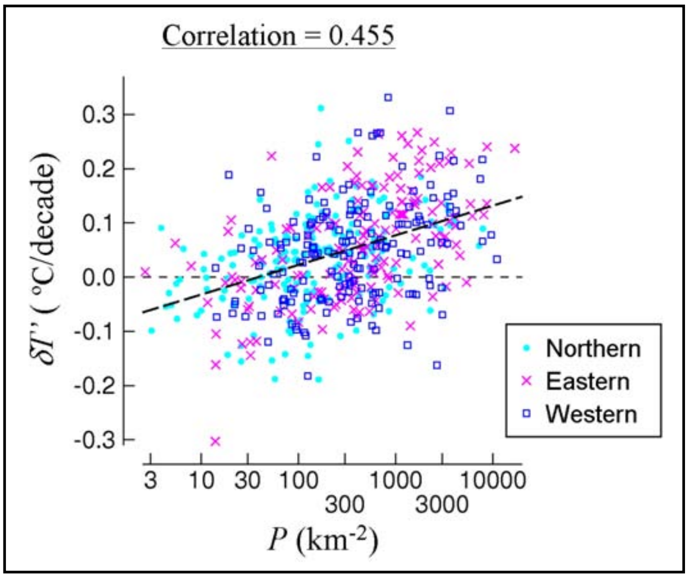


Figure 4. Same as Fig.3, but for $\delta T'$.

relation between $\delta T'$ and P. Although scatter among stations is considerably large, there is a correlation of 0.455, which is significant at the 1% level. Figure 5 shows the values of $\delta T'$ averaged for each category and region except the Nansei Islands. It can be seen that stations in densely inhabited areas ($P \geq 3000 km^{-2}$) have an anomalous trend of 0.12°C/decade, which is close to the value estimated for Chinese cities (Jones *et al*., 2008; Ren *et al*., 2008). Moreover, an anomalous trend of 0.03-0.05°C/decade is detected even for weakly inhabited stations with P=100-300km^{-2}.

Figure 6 shows the seasonal and time-of-day dependence of $\delta T'$. For stations in densely inhabited areas ($P \geq 1000 km^{-2}$), $\delta T'$ has a distinct diurnal variation with a minimum around noon and a broad maximum at night, in agreement with the general understanding that urban warming is more conspicuous in the nighttime than in the daytime. For stations with relatively sparse inhabitants (P=100-1000km^{-2}), $\delta T'$ has double peaks in the morning and evening. This may be different from the typical cycle of the urban heat island, but temperature changes of similar diurnal variation pattern have been found to prevail over the United States, resulting at least partially from urbanization influences (Knappenberger *et al*., 1996; Schwartzman *et al*., 1998). The diurnal variation patterns in $\delta T'$ are common to the four seasons with only a slight difference in peak time.

4. Summary

In an attempt to separate urban and background warming in Japan, temperature data at 546 AMeDAS stations for 29 years (March 1979 - February 2008) were analyzed by categorizing stations according to the population density of the surrounding few kilometers. There

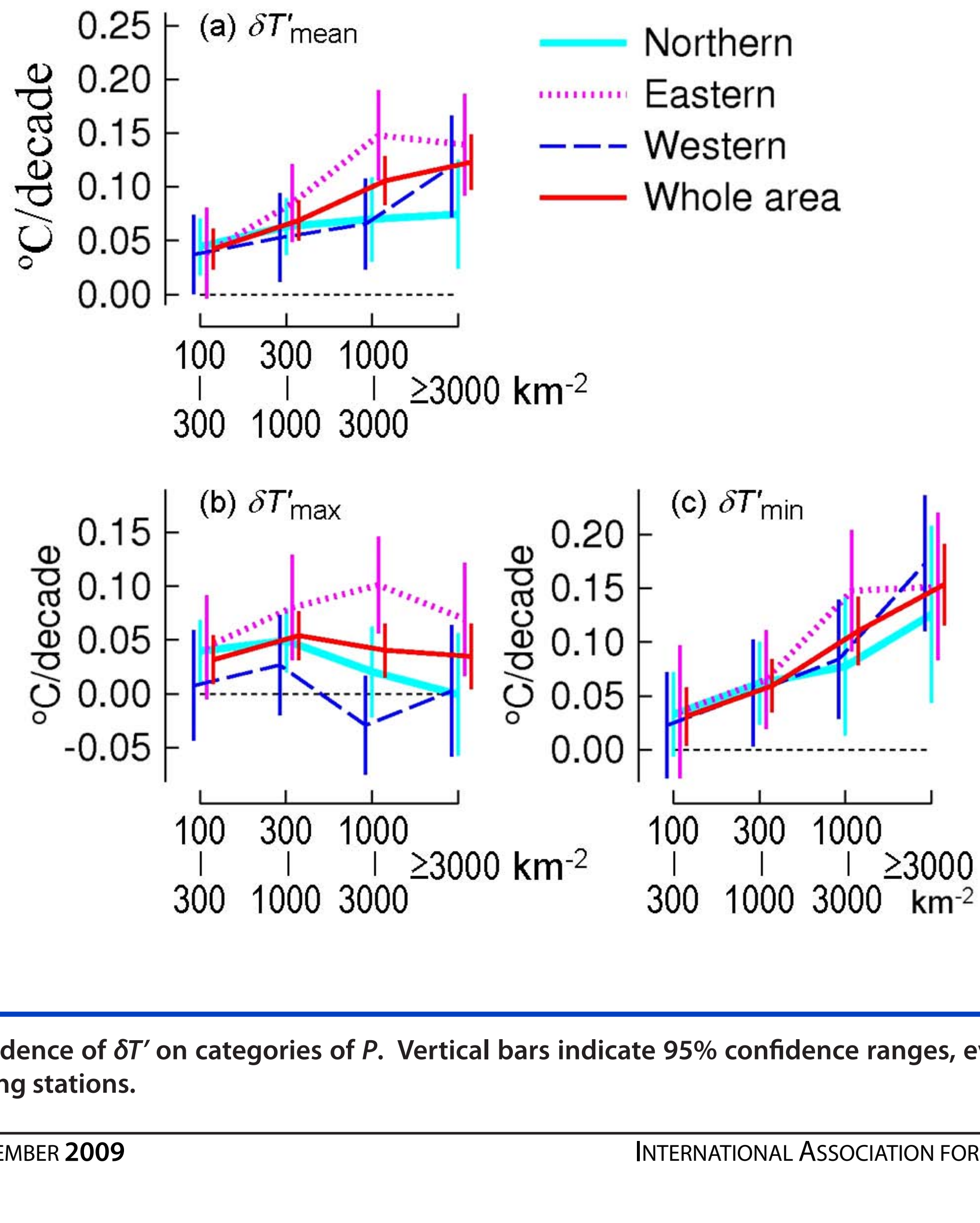


Figure 5. Dependence of $\delta T'$ on categories of P. Vertical bars indicate 95% confidence ranges, evaluated from the scatter among stations.

is a warming trend of 0.3-0.4°C/decade even for stations with low population density (<100km^{-2}), indicating that recent temperature increase is largely contributed by background climatic change. On the other hand, an anomalous warming trend is detected for stations with larger population density. Even for only weakly populated sites with population density of 100-300km^{-2}, there is an anomalous trend of 0.03-0.05°C/decade. This fact suggests that urban warming is detectable not only in large cities but also at slightly urbanized sites in Japan.

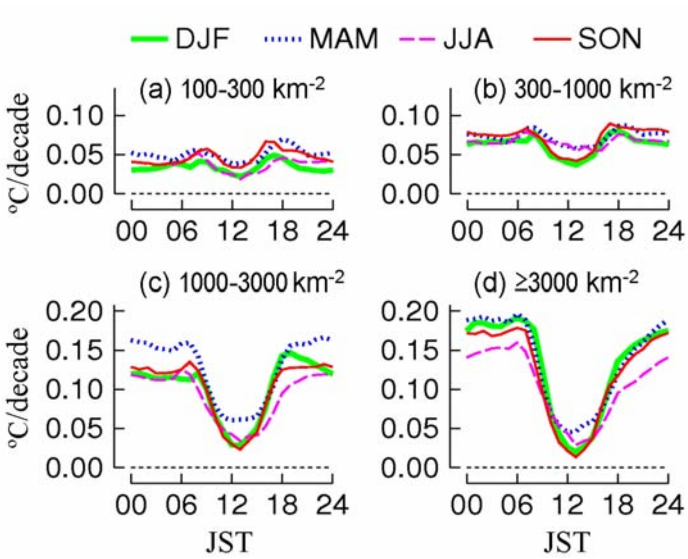


Figure 6. Time-of-day dependence of $\delta T'$ for each category of *P* and season.

Acknowledgments

This study was partly supported by Grant-in-Aid from the Japan Society for the Promotion of Science (No. 18340145).

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Coherent Structures of a Neutrally Stratified Urban Boundary Layer Using Large-Eddy Simulation

Introduction

Researchers over the years have attempted to make sense of turbulence with coherent structures and similarity theories. Coherent structures are responsible for the transport, production and dissipation of momentum, turbulent kinetic energy and scalars. There are a number of paradigms and structural signatures regarding the formation and interaction of these coherent structures. Here, we subscribe to Adrian *et al.*'s Hairpin Vortex Packet Model (Fig. 1). The most commonly used and visually identifiable of these are as follows: low momentum regions, or low speed streaks are induced by counter-rotating vortices; these counter-rotating vortices are the legs of hairpin vortices; spatially organized ejections (u'<0, w'>0) and sweeps (u'>0, w'<0) are associated with low-momentum regions. Ejections (Q2 events) are located at the convergence line between the low speed streaks and hairpin vortices, while sweeps (Q4 events) are outside these convergence lines. Monin-Obukhov's Similarity Theory states that any atmospheric statistic may be determined by elevation, and the stability parameters of surface shear and thermal buoyancy. In the urban boundary layer, the inner layer is where surface shear stress dominates and similarity exists. On the other hand, the outer layer is where turbulence is characterized by thermal convection and does not follow similarity. The overlap of these two layers is the logarithmic layer. Therefore, this is where maximum interaction between inner-outer motions occurs. It is curious that horizontal velocity fluctuations do not follow similarity theory. The conjecture is that the horizontal velocity fluctuation is composed of a similar component and a non-similar component, the first being an inner layer component, while the latter is an outer layer component. Hence, the study is about turbulence in the log-layer, considering both coherent structures and the issue of similarity.

Coherent structure signatures that are considered are as follows: low momentum regions are streamwise velocity fluctuations of less than negative 75% of the fluctuation mean; hairpin vortices are measured by horizontal swirling strength, which is a vortex identification scheme that captures the local swirling character without contamination from shear, and is multiplied by the sign of vertical vorticity. These signatures are paired with the decomposition of u' into inner and outer components. Thus, the objective of this study is to numerically quantify the statistical relationships among the coherent structure signatures, associated with inner and outer motions, in the log-layer of an urban boundary layer. With this objective, it is imperative to compute for the two-point correlation of streamwise velocity fluctuation, swirling strength, and the cross correlation of streamwise velocity fluctuation and swirling strength for the inner and outer motions, considering the conditions of low momentum regions and ejection-sweep events.

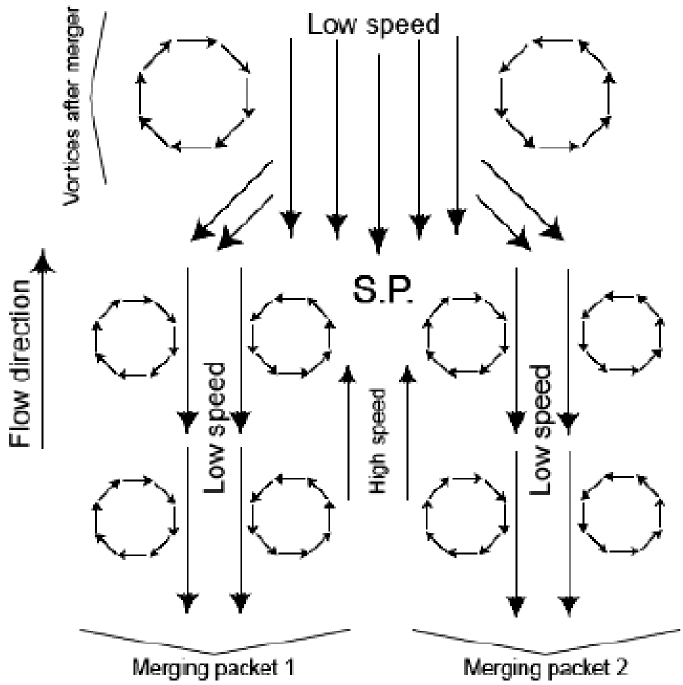

Figure 1. Horizontal slice of Adrian *et al.*'s Hairpin Vortex Packet Model (2000).

Numerical Procedure

A near-neutral boundary layer, consisting of an urban surface layer and a convective mixing layer, was simulated. This was attained by initially setting the streamwise wind (20 m/s), surface heat flux (0.1 Km/s) and potential temperature profiles, approximating an entrainment layer near the top of the domain (Fig. 2). To study the influence of both inner and outer motions on the turbulence in the log-layer, it is imperative that the domain is large enough to include both inner layer surface shear and outer layer convective mixing. A domain, consisting of a square array of cubic buildings, is 64h x 64h x 65h along the horizontal and vertical directions, where h is the building height of 40 m, and grid resolution is 2.5 m. The following are the boundary conditions for the 3-hour numerical simulation: cyclic along horizontal domains, non-slip for all surfaces, slip for the top boundary. A parallelized Large-Eddy Simulation model (PALM) for the urban boundary layer was used to calculate the non-hydrostatic, incompressible Boussinesq-approximated Navier Stokes Equations (Letzel et al. 2008).

Spatial filtering

In distinguishing between inner and outer turbulence, spatial decomposition is used. In the following equations for instantaneous streamwise fluctuation:

$$u' = u'_{outer} + u'_{inner} \quad (1)$$

$$u' = [u_m'] + u_m'' \quad (2)$$

the outer component (u'_{outer}) is the spatially averaged fluctuation ($[u_m']$), and the inner component (u'_{inner}) is the spatial fluctuation from this outer component (u_m''). In averaging, a square spatial filter is used which is bigger than the inner component but smaller than the outer. At the log-layer, inner motion is responsible for the local Reynolds stress. Thus, to determine the appropriate size for the square spatial filter, different sizes were tested by calculating the contribution of the filtered fluctuation to the original local Reynolds stress. For elevation 2h, which closely approximates the log-layer, the filter size was determined to be 10h (Fig.3). Two-point correlation, swirling strength and cross-correlations for the streamwise fluctuation are based on the unfiltered and filtered fields. Two conditions are considered for conditional averaging: the low momentum streaks, which are less than negative 75% of the fluctuation mean, and the Q2-Q4 events.

Results

- Filtering the streamwise fluctuation field

The unfiltered instantaneous streamwise velocity fluctuation field (Fig. 4a) has relatively larger structures, while the filtered field (Fig. 4b) is more horizontally homogeneous. Yet, there are still large structures in the filtered field, though they are relatively smaller than those in the unfiltered field. Since the filtered field represents inner motions, these large structures are created by the turbulence from the surface roughness, specifically, the cubic buildings.

- Two-point correlations

The spatial two-point correlations for the instantaneous streamwise velocity fluctuations in Fig. 5 are overlays of unconditional (hashed marks) and conditional averages (colored overlay), as well as representative of the original (Figs. 5a and 5c) and filtered fluctuation field (Figs. 5b and 5d) at the logarithmic layer. The general patterns of the two-point correlations of the streamwise velocity fluctuations are more or less the same. The filtered structure is 40 to 50% smaller than the original fluctuation field, while the low momentum regions are 10 to 20% smaller than the unconditional field. The ejection-sweep contours closely correspond to the unconditional contours.

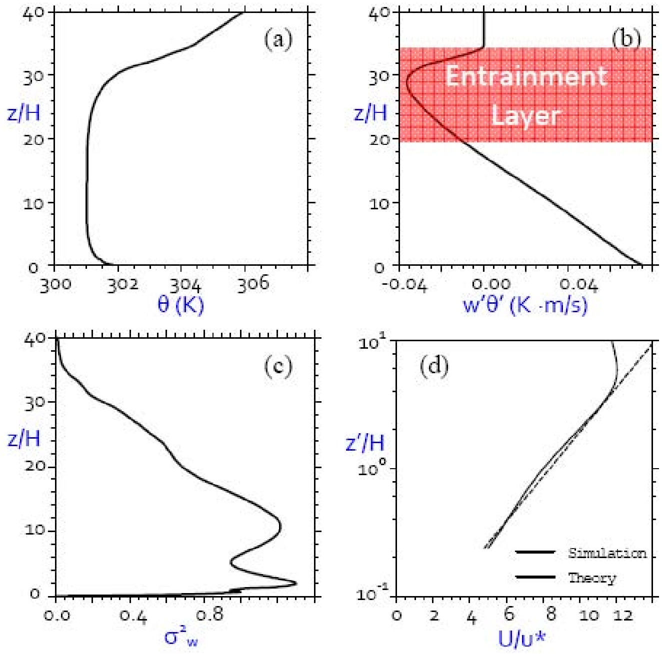

Figure 2. Horizontally averaged vertical profiles for simulated near-neutral urban boundary layer.

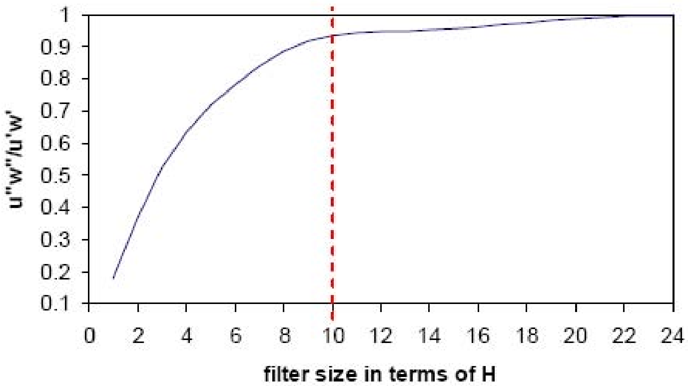

Figure 3. Spatial filter size test via contribution of filtered field to the original local Reynolds stress.

- Swirling strength

The two-point correlation for swirling strength for the unfiltered and filtered fluctuation fields are very close to each other (not shown here). They have a slight streamwise elongation that is consistent with the streamwise orientation of hairpin vortex packets in Adrian *et al.*'s model. The dominance of a single peak may be due to the constancy of the convection velocity of the vortices.

- Cross correlations

The spatial cross correlations between the streamwise velocity fluctuations and the corresponding swirling strength statistically quantify the relationships among the coherent structure signatures of inner and outer motions (Fig. 6). The general horizontal patterns are similar, especially for the unfiltered and filtered fields. This is the difference between the resulting two-point correlation

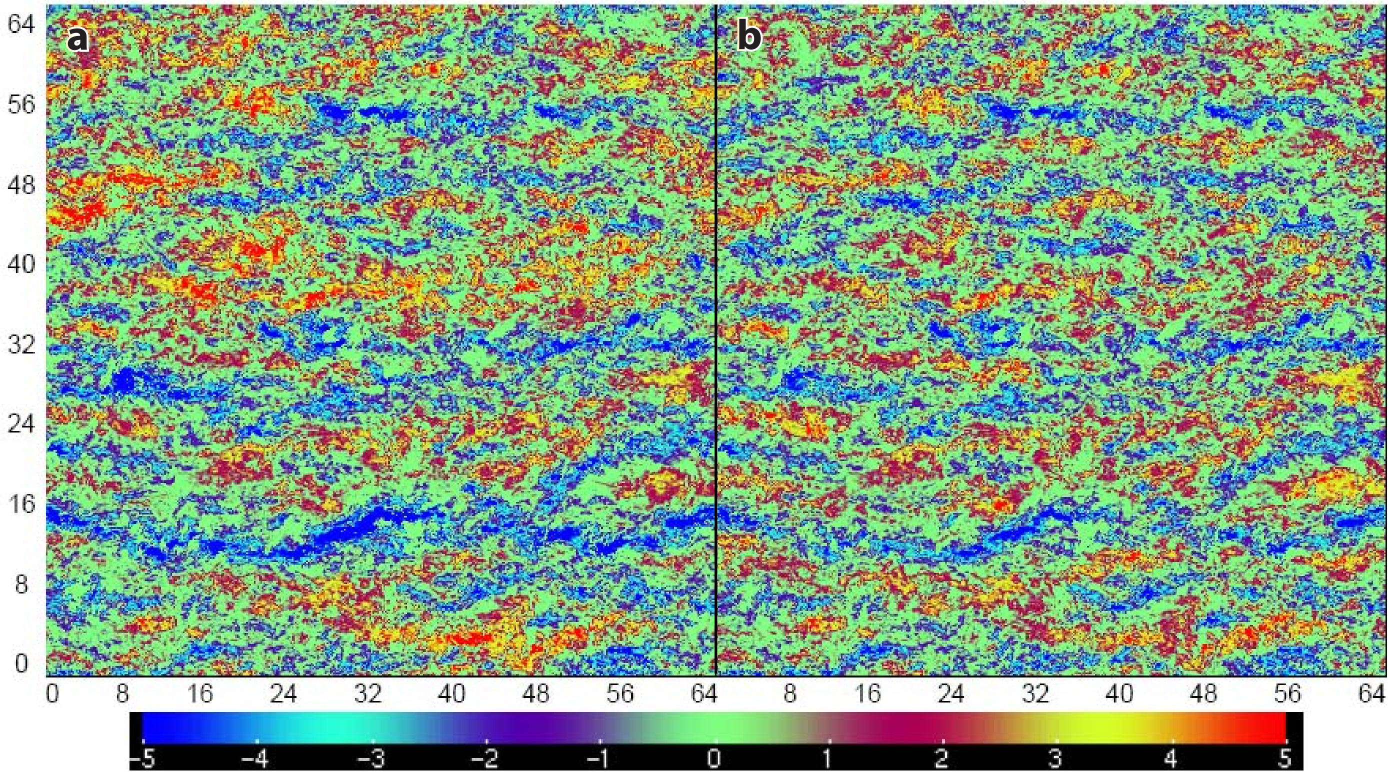

Figure 4. Instantaneous streamwise fluctuation fields, a) original, b) filtered. Distances in terms of H, fluctuations in m/s.

and cross correlation. These cross correlations are consistent with counter-rotating vortices, with maximum values at the midpoint of the x-axis, positive values for positive y, and negative values for negative y. Comparing the conditional averages, Q2-Q4 events seem to have more organization than LMR averages, and are more closely consistent with the unconditional contours. This may be due to the higher incidence of Q2-Q4 events relative to LMR's.

Conclusions

At the logarithmic layer of a near-neutral urban boundary layer, the general horizontal pattern of structures, associated with the coherent structure signatures of inner and outer turbulence, are similar. Through spatial filtering, inner structures and low momentum regions were found to be smaller than outer structures and the original fluctuation field, respectively. Ejection and sweep events have higher correlation with unconditional averages and swirling strength.

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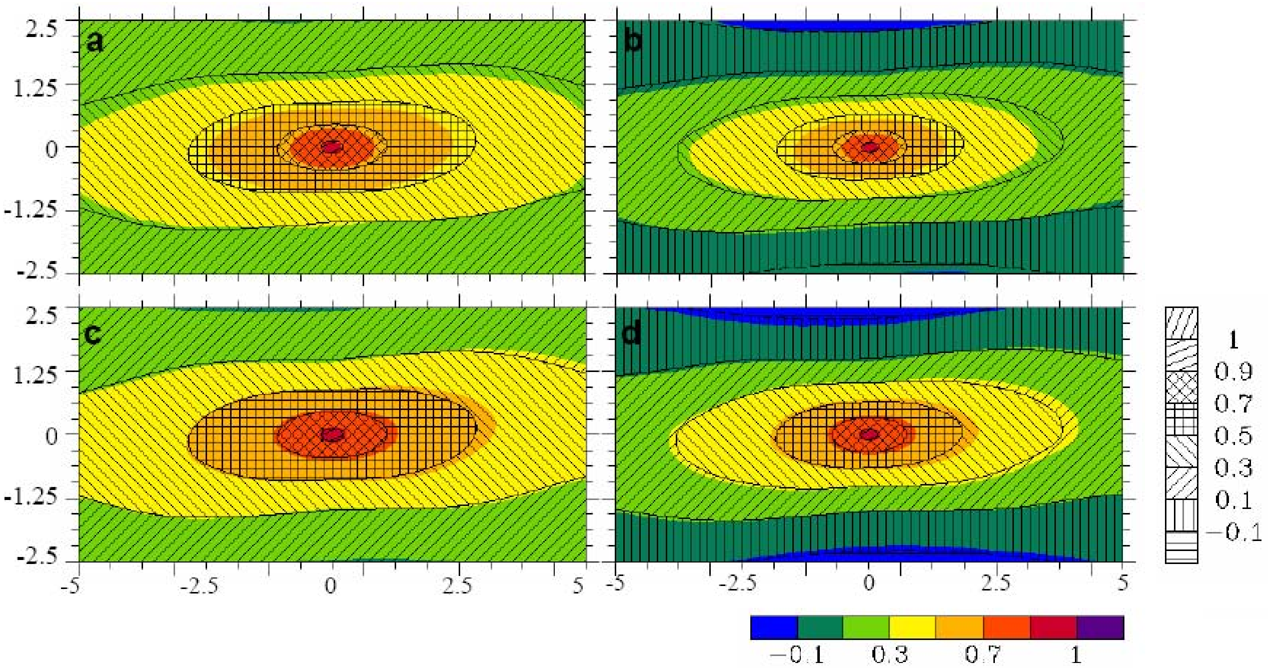

Figure 5. Two-point correlations of streamwise velocity fluctuations. Hashed marks pertain to unconditional values, while colored overlay for conditions of low momentum regions (LMR) and ejection-sweep events (Q2-Q4). a) & c) unfiltered u', b) & d) filtered u'', a) & b) LMR, c) & d) Q2-Q4.

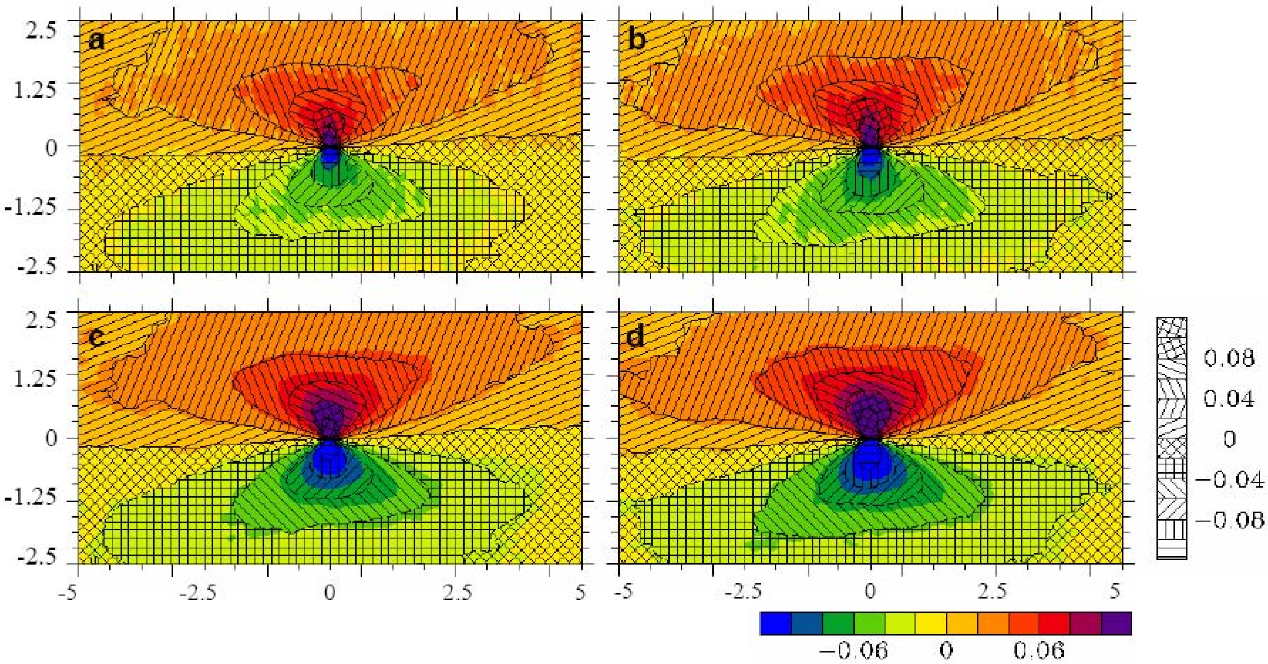

Figure 6. Cross correlations of streamwise velocity fluctuations and swirling strength. Hashed marks pertain to unconditional values, while colored overlay for conditions of low momentum regions (LMR) and ejection-sweep events (Q2-Q4). a) & c) unfiltered u', b) & d) filtered u'', a) & b) LMR, c) & d) Q2-Q4.

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Computational modelling of convective heat and moisture transfer at exterior building surfaces

1. Introduction

Quantifying convective heat and moisture transfer at exterior building surfaces is of interest for several building and urban engineering applications, such as thermal performance analysis of buildings, urban canopy flux modelling, hygrothermal analysis of the building envelope (e.g. drying of facades wetted by wind-driven rain) and several related physical, chemical and biological weathering processes such as microbiological vegetation (algae), mould growth, reaction of deposited pollutants on the wetted surface, freeze-thaw degradation, salt transport, crystallisation and related deterioration.

Usually convective heat and moisture transfer coefficients (CHTCs and CMTCs) are used in modelling, for example in Urban Canopy Models, Building Energy Simulation models and building envelope Heat, Air and Moisture (HAM) models. Often, CHTCs are estimated using empirical correlations of the CHTC with the wind speed, while CMTCs are mostly determined out of CHTC data, using the heat and moisture transfer analogy. The convective transfer coefficients (CTCs) used in these numerical models have, however, some limitations: limited or even no spatial variation of the CTCs over a building surface is accounted for, the temporal variation of the CTCs is not considered and convective heat and moisture transfer are considered to be uncoupled.

These assumptions can lead to significant simplifications of some convective heat and moisture transfer problems, for example when looking at drying of a building surface, wetted by wind-driven rain (WDR). From Figure 1 (Blocken *et al*. 2009), it is clear that both the WDR load and the CHTC are not uniformly distributed over the windward surface of the building, where the highest values are found at the top corners. Hence these corners experience the highest moisture load but, since the CHTC is related to the CMTC, they will also dry out faster. Although the spatial distribution is usually not taken into account in modelling, this example shows that it can be important for some cases.

In order to quantify the convective heat and moisture response of building walls more accurately compared to the conventional approach, which uses constant (spatial and temporal) and uncoupled CTCs, a more detailed numerical model is developed and is evaluated in a case study, namely the drying of a building wall after a WDR shower (see also Defraeye *et al*. 2009).

2. Case study

A 2D (infinitely long) square-shaped building in an atmospheric boundary layer (ABL) is considered (see Figure 2) where the heat and moisture transfer in the windward vertical wall is evaluated after a WDR shower. The building has a height of 10 m but the actual height of the windward wall is 9.8 m, accounting for the roof. The wall is a cavity wall, consisting of an outer and inner leaf and a cavity in between. Only the outer leaf, consisting of ceramic brick, is taken into account in the numerical model. The cavity is filled with an air- and moisture-tight insulation material, namely extruded polystyrene (XPS).

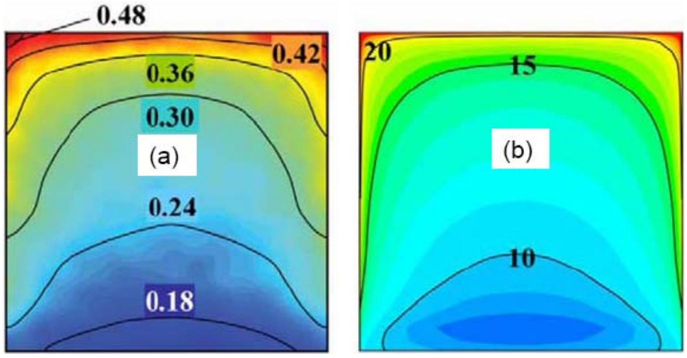

Figure 1. (a) Typical distribution of the WDR catch ratio across the windward surface of a cubic building; (b) Typical distribution of the CHTC across the windward surface of a cubic building (from Blocken *et al*. 2009).

3. Numerical modelling

In order to quantify the drying rate of the outer (windward) leaf, it is modelled with a HAM model, which calculates heat and moisture (vapour and liquid) transport in porous (building) materials. Two different approaches are used to represent the outside convective boundary conditions at the exterior wall surface: (1) Conventional modelling using constant (spatial and temporal) CTCs (referred to as HAM); (2) Coupling of the HAM model with CFD, which represents the outside environment, by exchanging boundary conditions between these models at the interface, namely at the exterior wall surface (referred to as CHAM). Note that the coupled approach allows for spatially and temporally varying CTCs due to, among other things, the specific features of the wind-flow pattern around the building.

For the HAM simulations with constant CTCs, the CHTC (4.7 W/m^{2}K) is determined according to Sharples (1984), based on U_{10}, and the CMTC (3.4x10^{-8} s/m) is determined according to the heat and moisture transfer analogy. For the coupled simulation, the wind environment (Figure 2a) is modelled with CFD. The CFD and HAM programs are coupled in an explicit way by executing the CFD program for one time step, after which boundary condition information (heat and moisture fluxes) is transferred to the HAM program which is subsequently executed for

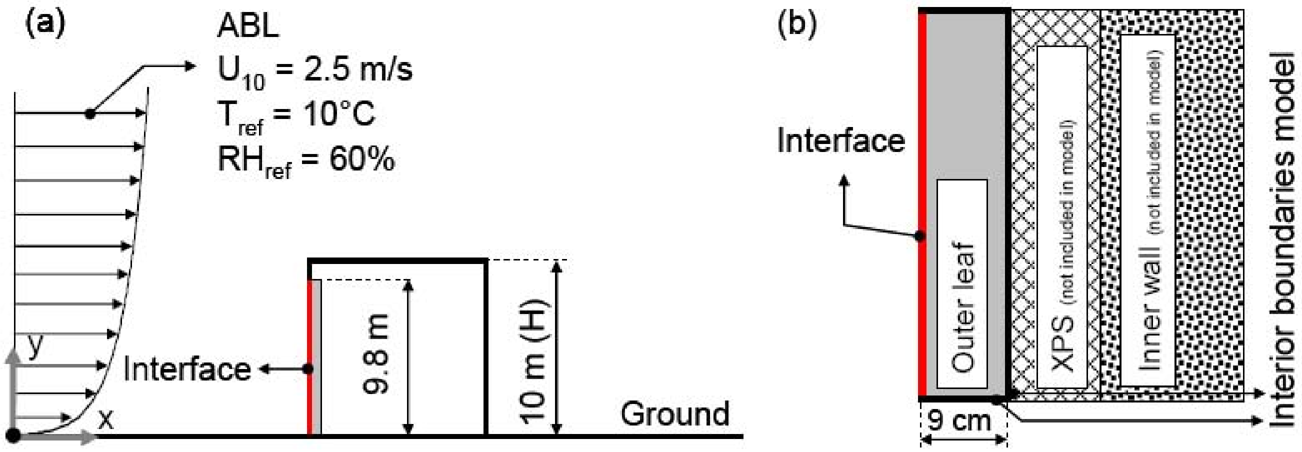

Figure 2. Model for numerical analysis: (a) Environment; (b) Wall composition (U_{10} = wind speed at height of 10 m).

the same time step. At the end of the time step, boundary condition information (temperatures and vapour pressures) is transferred to CFD for the calculation of the next time step. This explicit coupling is justified if sufficiently small time steps (e.g. 0.1 s) are used so the fluxes do not change significantly over the time step. Details on the HAM code can be found in Janssen et al. (2007). For the CFD simulations, the steady Reynolds-Averaged Navier-Stokes approach is used in combination with a k-ε turbulence model.

4. Results

Drying of outer leaf - In Figure 3a, the drying rates are compared for HAM (with constant CTCs) and CHAM for different locations on the wall. The average drying rate for CHAM is also given and does not differ significantly from the drying rate of HAM. A notable variation over the wall is found however with CHAM, showing high drying rates near the roof top, which are caused by the high wind speeds at that location (Figure 4).

The significant decrease in drying rates (for CHAM at 4h, 6h and 9h for y = 9.8, 7.5 and 5 m respectively and for HAM at 10h) can be explained by Figure 3b, where the temperature and RH at the exterior wall surface (interface) are shown. As long as the surface is almost saturated (RH ≈ 100%), a relatively high but steadily decreas-

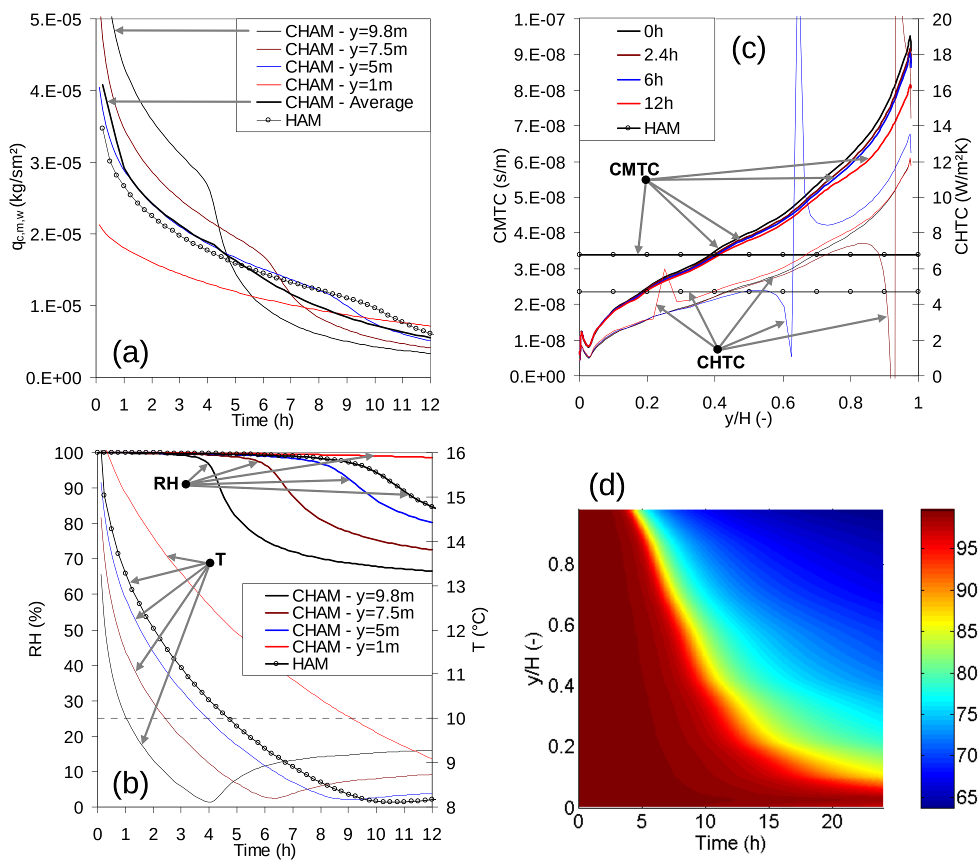

Figure 3. (a-b) Comparison between HAM and CHAM at different positions on the exterior wall surface: (a) Drying rate, (b) Surface temperature and RH; (c) Distribution of CHTC and CMTC over exterior wall surface at different points in time for HAM and CHAM; (d) RH (%) distribution (with CHAM) over exterior wall surface as a function of time and location on surface.

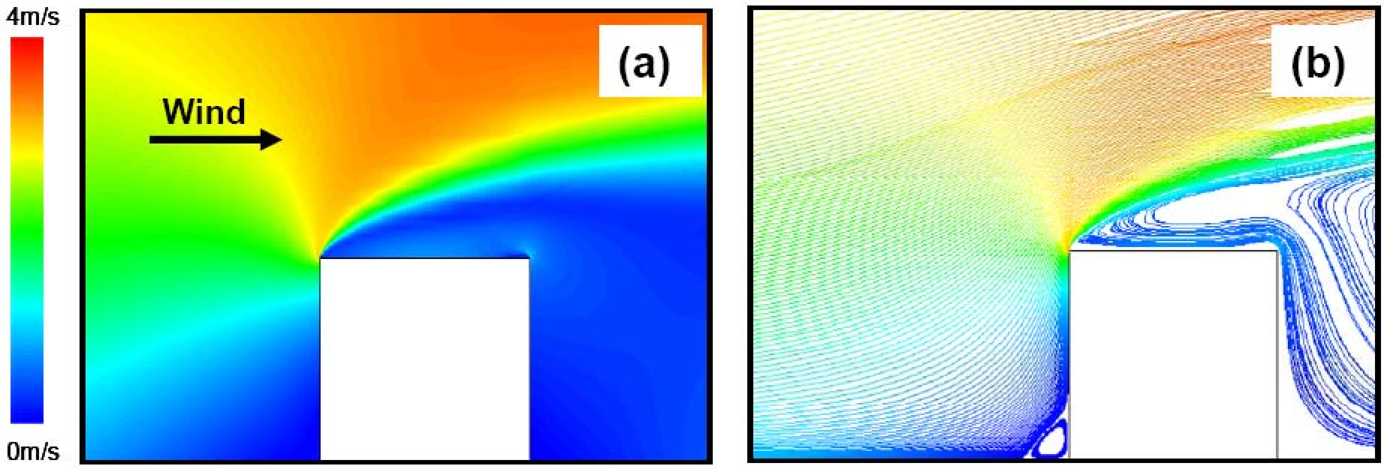

Figure 4. (a) Contours of mean wind speed around building; (b) Streamlines around building, coloured by mean wind speed magnitude.

ing drying rate is found together with a temperature decrease (below T_{ref}), caused by the extraction of heat required for evaporation at the surface. When the RH at the surface drops below 100%, the dry layer at the exterior of the material results in an additional vapour resistance for drying, causing a sudden decrease in drying rate. This decrease in drying rate results in an increase in temperature since less heat is required for the evaporation of water. Note that a relatively low wind speed is used in the simulations (U_{10} = 2.5 m/s) and that the drying time will decrease at higher wind speeds.

CTCs - The spatial variation of the CHTC and CMTC over the outer leaf is shown in Figure 3c, at different points in time. As expected, the increased drying rate near the roof top is also reflected in the CTC distribution. In Figure 3d, the RH distribution on the exterior wall surface is shown, as a function of time and location on the surface, clearly showing the importance of the spatial variation of the CTCs in the analysis of drying of the outer leaf, which could be successfully investigated with the CHAM approach.

A relatively small temporal variation of the CTCs can also be noticed in Figure 3c, which is more pronounced for the CMTC. The peaks found for the CHTC are due to the fact that the surface temperature (T) drops below the reference temperature T_{ref} (see Figure 3b) due to the evaporation at the surface, resulting in local peaks. These anomalies are intrinsically resulting from the way the CHTC is defined, namely based on the temperature difference: $T-T_{ref}$.

5. Conclusions

For this case study, the use of the coupled approach, using CFD to provide information on the flow field, allowed a detailed analysis of 2D heat and moisture transfer during drying of the outer leaf which showed an added value compared to the use of constant (spatial and temporal) CTCs. A significant spatial variation in the drying behaviour and of the CTCs was observed by means of the coupled CFD-HAM approach although the temporal variation was found to be quite limited. This case study showed that the use of constant CTCs is not always appropriate for some urban engineering applications, for example when considering drying of building surfaces.

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Long-term and seasonal trends in SPM concentration and its spatial distribution in the Kanto region, Japan

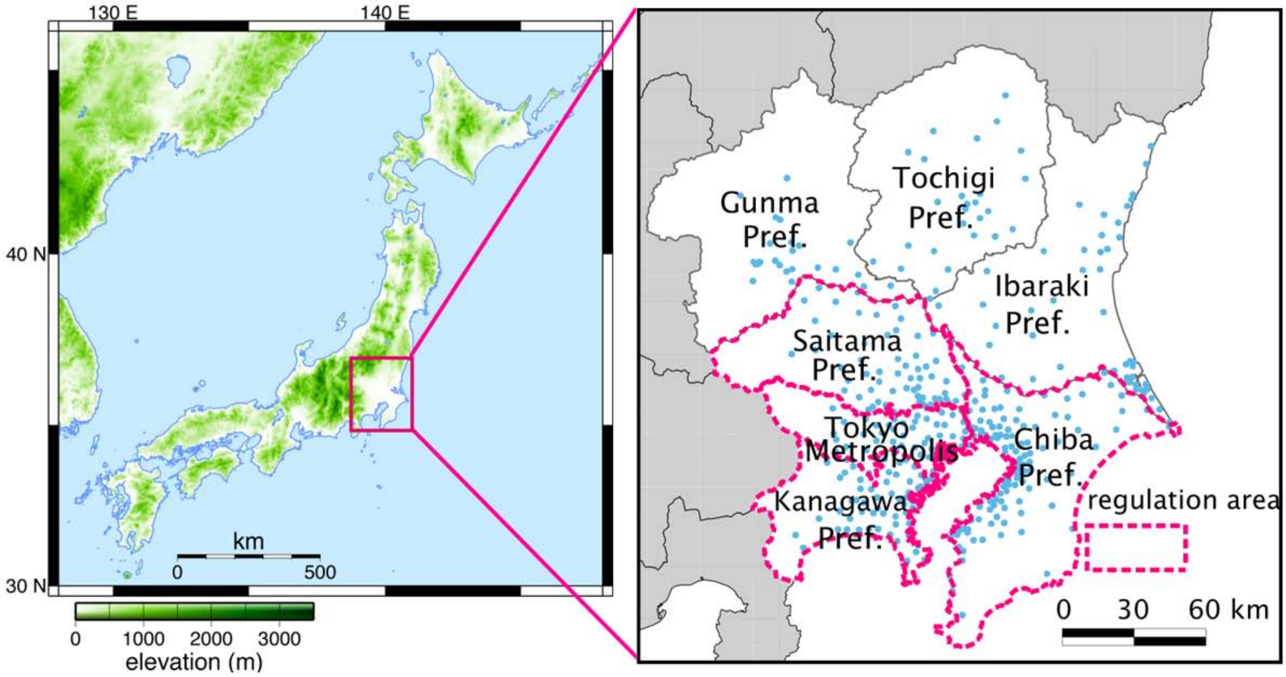

Figure 1. Study area and location of SPM monitoring stations in the Kanto region. Monitoring stations are indicated by blue dots. Areas where diesel exhaust gases are restricted are shown by dotted outlines.

Introduction

Suspended particulate matter (SPM) is a kind of air pollutant defined in Japan as particles with a diameter of less than 10 μm.

The Kanto region, including the largest plain in Japan, is located in the central part of Japan's main island, Honshu (Fig. 1). Population, industry and traffic have concentrated in the southern part of this region, including the Tokyo metropolis and its surrounding urban areas. Various regulations on anthropogenic air pollution sources have been enforced in Japan. Regulations on vehicle emissions were also established during the mid-1990s. Furthermore, strict ordinances on diesel emissions began in 2003 in four prefectures in southern Kanto. These controls may strongly influence SPM concentration.

Current studies have suggested that SPM concentration in the regulated areas have notably reduced recently (Mizuno 2006; Minoura *et al*. 2006). However, it seems that the SPM concentration in this region is not only decreasing but also shows a variety of long-term trends. In addition, the SPM concentration and its spatial patterns are strongly influenced by climatological factors.

The purpose of this paper is to report on long-term trends in SPM concentration and their spatial differences in the Kanto region since the 1990s. Spatial variations in SPM trends are detected by principal component analysis (PCA).

Data and methods

We use hourly monitoring data of SPM at over 300 stations in the Kanto region. Fig. 1 shows the research area of this study and locations of ambient air monitoring stations. Diesel regulations are in effect in the southern four prefectures. The analysis period covers 15 years, from FY 1991 to 2005 (FY = Fiscal Year in Japan, from April to March).

PCA was conducted to find several dominant patterns of SPM spatial distribution and their long-term changes.

Results

• *Long-term and seasonal characteristics of SPM concentration*

Fig. 2 shows yearly and seasonal variations of averaged SPM concentration for all monitoring stations in the Kanto region. The variation of SPM concentration in this area has two seasonal peaks.

The winter peak of SPM concentration appears in early winter around November–December and shows high levels of concentration in the early 1990s. The summertime peak can be seen mainly in July–August. Both seasonal peaks have reduced in recent years. Minoura *et al*. (2006) proved that the reduction trend of SPM in the wintertime was attributed to a decrease in fine particles from motor vehicles by multi-year observations in down-

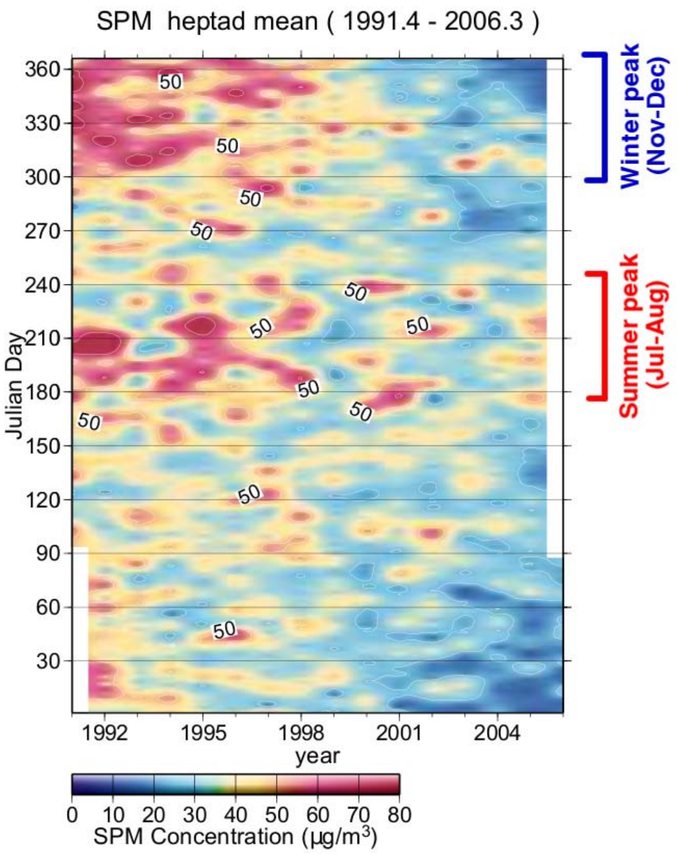

Figure 2. Day-year isopleth for heptad mean SPM concentration in all of Kanto. Each value is obtained from averages of daily mean SPM concentration at every station in this area.

town Tokyo. In addition, NO_x concentration also shows a reduction trend in winter (not shown). These results indicate that winter SPM concentration in the whole Kanto region decreased with a decrease in artificial primary particles.

Although the SPM trend in summertime also has started to decrease since the late 1990s, its reduction trend is weaker than that in winter. On the other hand, O_x concentration has increased, especially in the 2000s (not shown). Since it is known that photochemical reactants contribute to production of SPM secondary particles during summer, the contribution of emission control to SPM concentration is less than that of winter.

• *Distribution and decreasing trend of SPM*

Since the SPM concentration tends to have its seasonal peaks in winter and summer, we elaborate on the spatial distribution of SPM in these seasons. Fig. 3 (a) and (b) show the spatial distribution of seasonal mean SPM concentration during this period. Fig. 3 (a) illustrates that high concentration areas are located around Tokyo Bay and midtown in winter. The high concentration area spreads to northwesterly inland areas during summer [Fig. 3 (b)]. These seasonal distribution patterns of SPM are attributed to the climatology in this region.

It is known that heavy air pollution in winter occurs under cold and calm weather conditions. Therefore, the area of high concentration is expected to appear near emission sources in winter.

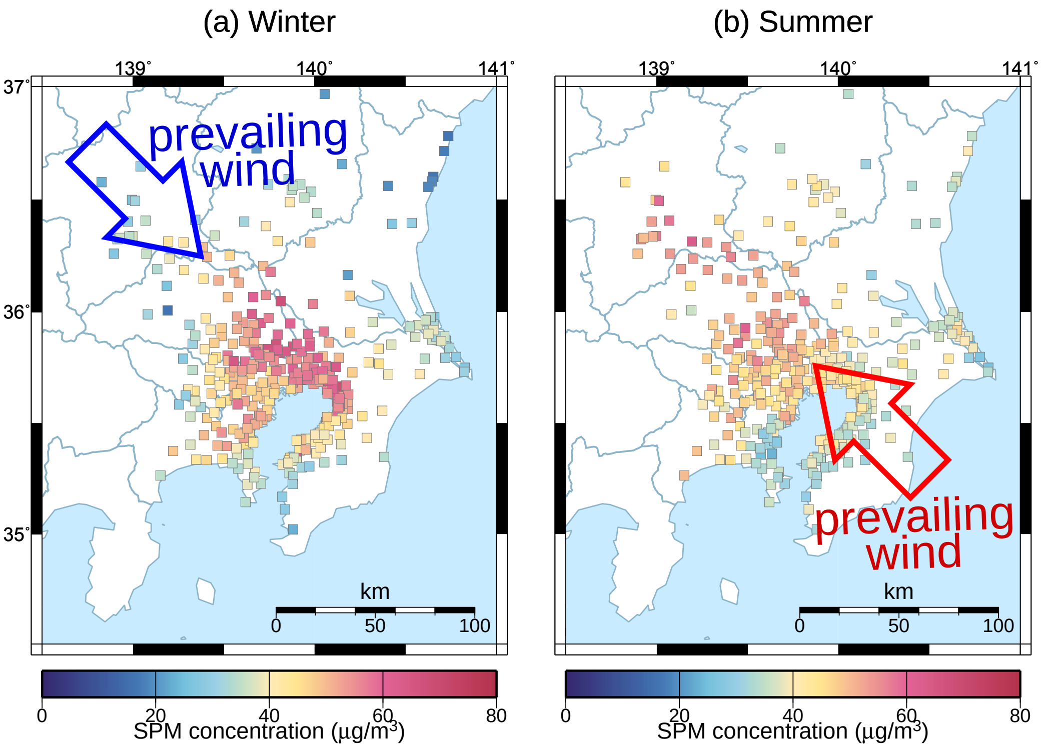

Figure 3. Spatial distributions of seasonal mean SPM concentration for 15 years (a) in winter (November–December) and (b) in summer (July–August). Arrows indicate seasonal prevailing wind in this region.

In summer, because of southeasterly prevailing winds in the daytime, precursors from emission sources around Tokyo Bay are transported to the inland area while producing photochemical components over the region because of the wind (e.g. Wakamatsu *et al*. 1999). Therefore, despite the relative lack of emission sources, SPM concentration in the inland area tends to be higher than that in the southern urbanised area in summer.

Thus, the spatial distribution of SPM shows different patterns in winter and summer.

• *Spatial differences in long-term SPM trends*

Regional differences in long-term trends of SPM concentration were analysed by PCA. The PCA was computed using a correlation matrix for hourly SPM concentration. To avoid missing values during this period, monitoring data were converted into 15-minute grid area means (see Fig. 4). The results are summarised in Table 1 and Fig. 4.

Table 1. Proportions of variance explained by the first four principal components.

Component	**PC1**	**PC2**	**PC3**	**PC3**
Proportions of variance (%)	64.8	10.4	5.2	3.5

The variation of time coefficients for PC1 (explained variance 64.8%) shows an increasing trend. The PC1 score increases with decreasing regional mean SPM concentration (not shown). The distribution of eigenvectors for PC1 shows a concentric pattern centred on central Tokyo. In addition, large negative values of PC1 eigenvectors are distributed around the Tokyo metropolitan area, where many emission sources exist. These results indicate that the reduction trend in SPM concentration is more remarkable in highly polluted areas. PC1 was found to be a component that reflects a regression trend of SPM concentration in the whole of this region.

The eigenvectors in PC2 (10.4%) are distributed in two

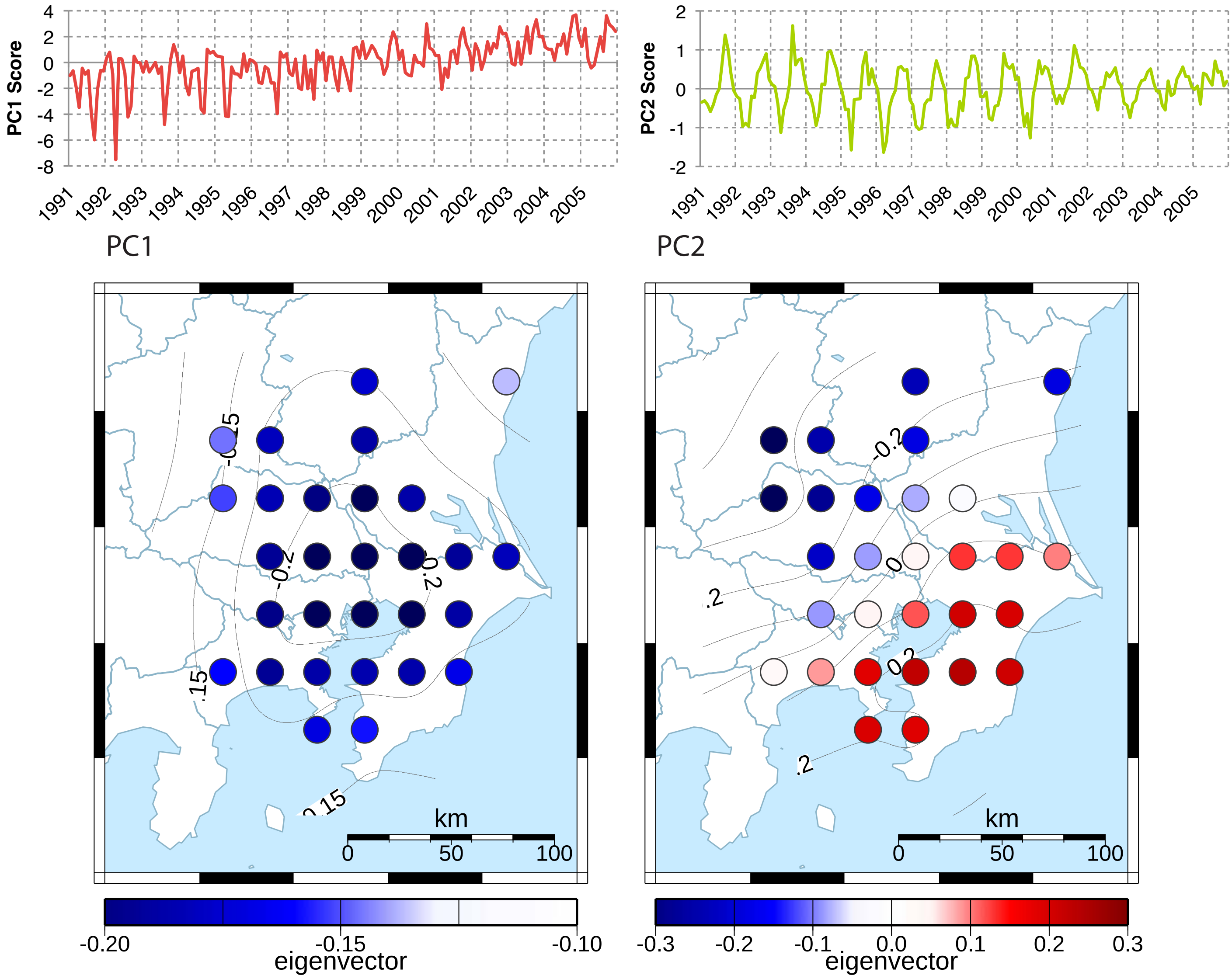

Figure 4. Variations of monthly mean time coefficients (upper panel) and spatial distribution of eigenvectors (lower panel) for PC1 (left) and PC2 (right). Both contours and symbols represent the eigenvectors.

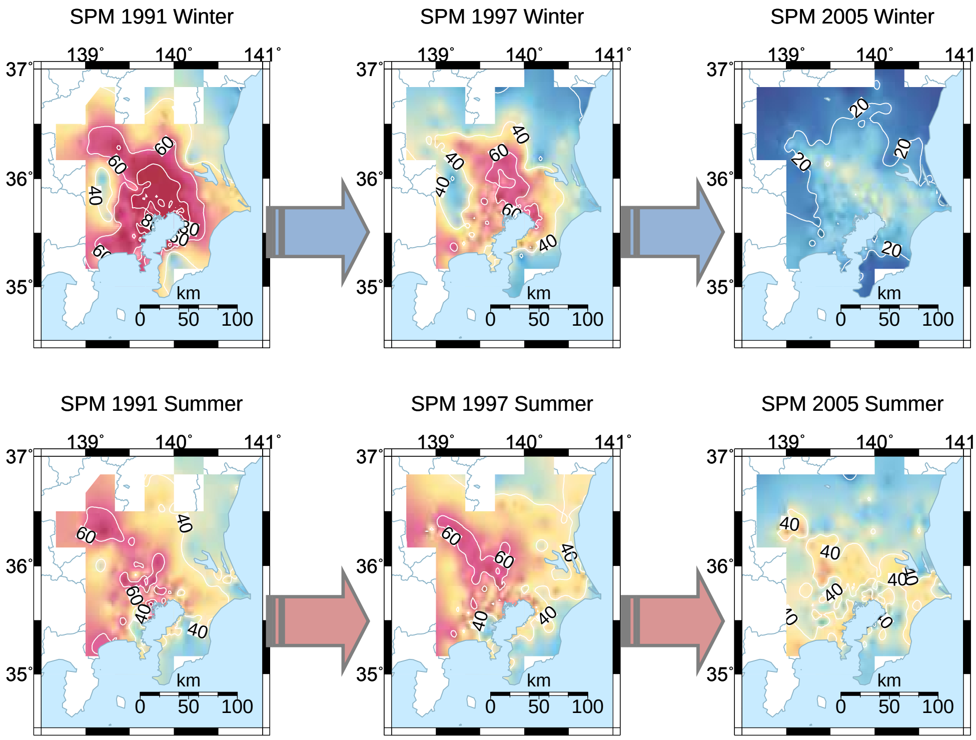

Figure 5. Variations of seasonal mean SPM for winter (upper panels) and summer (lower panels).

parts, on the southeast and northwest sides. A positive (negative) value of PC2 corresponds to the spatial distribution of SPM in winter (summer), as shown in Fig. 3. The variation of time coefficients has seasonal cycles with values high in winter and low in summer. These patterns reflect the seasonal patterns for SPM spatial distribution. In other words, PC2 is associated with seasonal differences in the spatial distribution of SPM for summer and winter. Absolute values of PC2 decrease with time. It is evident that the regional contrast in SPM concentration between the northern and southern parts of Kanto has been weakening.

The results of PCA for SPM concentration showed that the first two components could explain more than 75% of the spatial differences in SPM concentration in this region. The first component is consistent with SPM reduction in regulated urban areas, and the second is in good agreement with seasonal and spatial patterns of SPM. In particular, spatial contrast in SPM concentration between urban and rural areas in this region has decreased with reduction of SPM by emission controls.

Summary and conclusion

The results of this study can be summarised as follows:

(1) SPM concentration in the Kanto region has seasonal peaks in winter and summer. In winter, highly polluted areas appear in the urban part of this region because of abundant artificial emissions and calm and cold air conditions. In contrast, the SPM spatial distribution in summer is higher in the inland area in this region as a result of photochemical reactions with precursors from the windward urban area due to southeasterly prevailing winds.

(2) Because of various emission controls, SPM concentration has reduced notably in high-emission areas in winter and at inland areas leeward of prevailing winds in summer (Fig. 5). SPM concentration has decreased not only in the diesel regulation area but also in the whole Kanto region, reflecting the seasonal characteristics.

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CAPAC (Climate and Air Pollution of Cairo)

Introduction

More than half of the world's population lives in cities. This percentage is still increasing, and even more people will live in artificial environments whose characteristics are different from natural or rural areas. Especially in mega-cities like Cairo, the life quality of the inhabitants can be dramatically altered. This fact makes the urban climatology an important field for environmental research.

The city of Cairo was chosen because of its unique location: Situated in a hot and dry climate and nonetheless partly surrounded by agriculture, a variety of different rural and urban microclimates are evolving. This spatial heterogeneity asks for a process-oriented approach that accounts for the climatic differences in the spatial domain. Further, Cairo is one of the most heavily polluted megacities in the world. The pollution, originating from traffic and industries is dangerous to human health and furthermore has an impact on the radiation budget.

CAPAC is dedicated to the understanding of the urban energy balance in Cairo through measurements at ground stations and from satellites in space. The in-situ measurements shall provide a focused insight in three carefully chosen microclimates and provide at the same time ground truth data for the satellite images, which will expand our acquired knowledge into the spatial domain.

A side aspect of CAPAC focuses on the air pollution of the city. In-situ measurements at different locations will provide a first understanding of background and street-side concentrations of coarse and fine particulate matter. Further, very high resolution CO_2-fluxes will round out the picture.

The energy balance

The energy balance is formed by the net all-wave radiation and the heat fluxes. The radiation balance is the sum of all incoming and outgoing radiation fluxes – and includes therefore the shortwave irradiation of the sun and the thermal emission of the Earth. The remaining energy from the radiation balance is split into the different heat fluxes: the sensible heat flux, the latent heat flux and the ground heat flux.

Whilst the energy balance is measured routinely with in-situ instrumentation, intensive research on the remote sensing energy balance is going on.

Figure 1. Upper left and middle: The eddy covariance tower at Cairo University. Upper right: Sigma-2 Sampler at Cairo University. Down left: 10th Ramadan station. Down right: Bahteem station.

Measurement campaign in Greater Cairo

From November 1st 2007 to March 1st 2008 an energy balance campaign was conducted in Cairo. For this three suitable sites were chosen. The first site was located at the campus of Cairo University on a rooftop. The second and third sites were located in the suburban environment on an irrigated farmland and in the desert. Measurement masts were mounted to carry the meteorological instruments, which include: CNR1 radiometer for measuring the radiation budget, ultrasonic anemometer for the turbulent sensible heat fluxes (CSAT-3), fast hygrometer (LiCor and KH2O), which were coupled with the sonic, for the latent heat and additionally CO_2 flux measurement. Further, there were soil heat plates and thermocouples at the rural sites for the soil heat flux and several psychrometers for air temperature and humidity measurement. Coarse particulate matter measurements were done using passive Sigma-2 Samplers. For a visual impression of the sites, see Figure 1.

Beside the scientific demands, the selection of the sites was dominated by security and networking considerations, as Egypt is a third-world country. Permanent protection of the stations was required, as was permission from the authorities for the mounting of the stations. Therefore the stations were mounted only on restricted sites on governmental ground. The cooperation with the two organizations (Cairo University and EMA – Egyptian Meteorological Authority) ensured a protected zone for the measurements.

As the main concern in this work is the calculation of the energy balance using remote sensing data, the in-situ

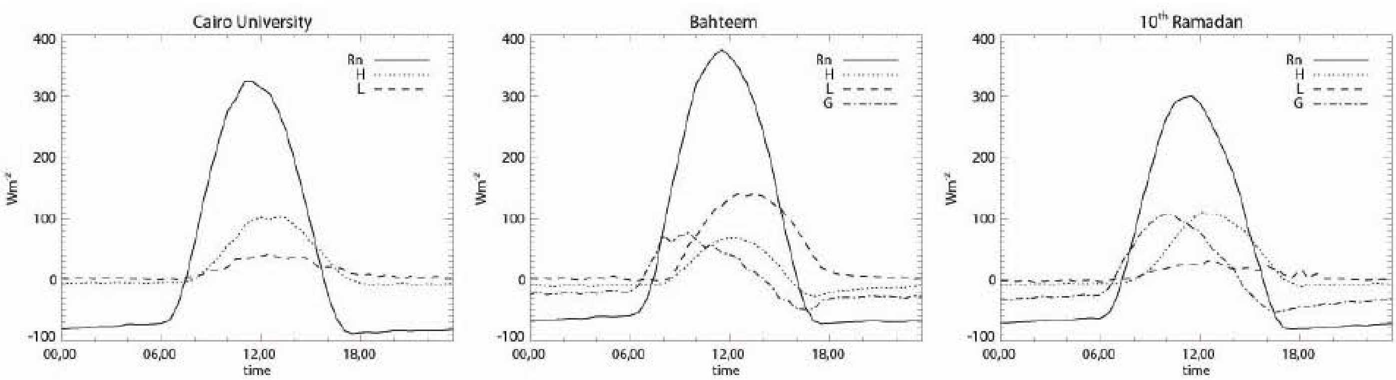

Figure 2. Mean terms of the energy balance of Cairo University, Bahteem and 10th Ramadan from November, 20 2007 to February, 20 2008

data were processed using standard correction methods as given in Figure 3. Figure 2 shows the mean terms of the energy balance measured at the three stations for the whole measurement campaign. Net radiation is highest at Bahteem, due to the low albedo of the crop surface. Lowest net radiation occurs at 10th Ramadan, where the albedo is very high due to the desert surface. The sensible heat flux is almost the same at Cairo University and 10th Ramadan station, where in both cases the latent heat flux is low. Bahteem station features naturally a high latent heat flux. The ground heat flux is missing at Cairo University, as it cannot be measured directly in the urban environment. But at both other stations it takes a considerable amount of the net radiation.

The radiation balance is not closed in both Bahteem and 10th Ramadan station. During the day a considerable gap is present.

The correct estimation of these parameters was identified as a crucial point in the whole processing chain.

Research is going on, on the determination of the turbulent and ground heat fluxes. S-Sebi (Roerink *et al*. 2000) was found to be not usable. The method assumes that for each albedo there is one maximum temperature available, which is reached when no evaporation occurs. However, the large desert areas proved the contrary. Pixels featuring the same albedo were found to have various temperatures. Therefore this method cannot be applied.

Two other methods, the aerodynamic resistance method (ARM) (Voogt & Grimmond 2000) and the LUMPS-scheme (Grimmond & Oke 2002) proved to be promising and current research tries to optimize these methods for the Cairo environment. ARM for example needs many unknown input variables, which have to be estimated for various land uses. These estimates increase the factor

Satellite data

During the field campaign 8 satellite images were acquired by the ASTER satellite (NASA) and by 2 by CHRIS/PROBA (ESA). ASTER and CHRIS have a similar spatial resolution like the traditional satellite LANDSAT ETM+. The ASTER images are being used for the quantitative spatial analysis of the urban energy budget.

The atmospheric correction includes the two terms path radiance and transmissivity. They have both to be defined for each pixel of the image. Both path radiance and transmissivity are dependent on the aerosol optical depth. Further path radiance is dependent on the surface albedo. So for each pixel adjusted values have to be applied.

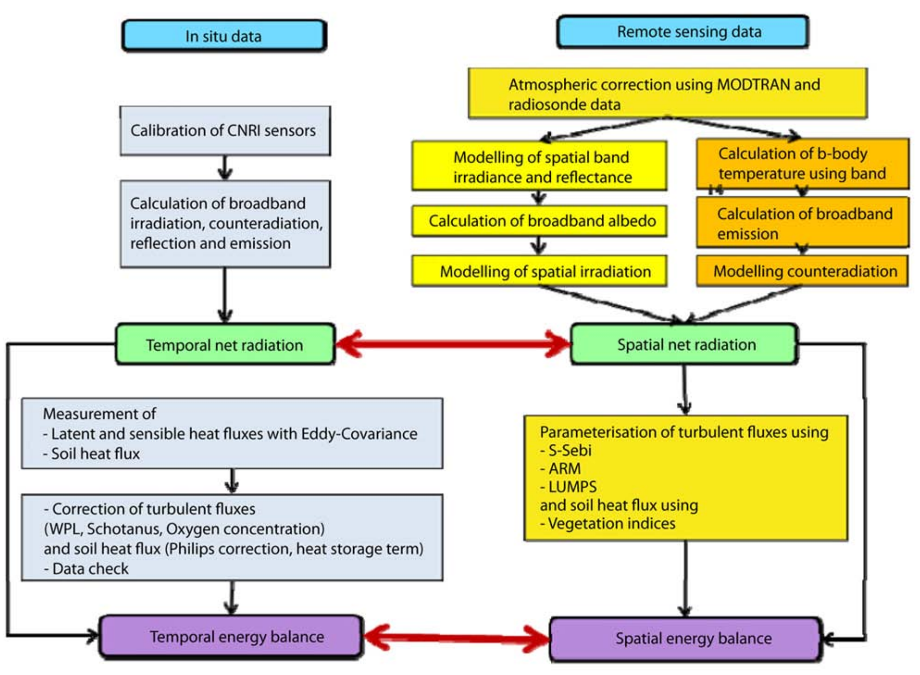

Figure 3. Calculation of the energy balance

of uncertainty considerably. LUMPS on the other hand works with the available energy for turbulent fluxes which needs the ground heat flux to be known. As the latter is not measured directly at Cairo University station, uncertainty results from the fact that the energy balance is not closed. Further, LUMPS allows determining two semi-empirical coefficients from the measurement data. However, these coefficients might not be representative for all land uses across the ASTER scene.

Figure 3 shows the main processing steps of the calculation of the temporal and spatial energy balance as a flowchart.

The CHRIS/Proba images were used to assess the urban BRF effect (Bidirectional Reflectance Function). BRF is highly dependent on the sun position. CHRIS/Proba is a hyperspectral instrument and acquires the same scene 5 times from different viewing angles. Figure 4 shows the acquisition geometry of the CHRIS/Proba scene. Observation 3 and 5 (Obs3 and Obs5) are "looking" from a similar direction as the sun, therefore mainly seeing sunlit surfaces. Naturally, these two observations produce the highest reflectivities. Observations 1, 2 and 4 saw more shaded surfaces and therefore result in lower reflectivities (Figure 5). Two urban surfaces were chosen: A high and a medium density housing district. Even though interspaces between houses differed considerably, no significant difference in the acquired angular reflectances was found.

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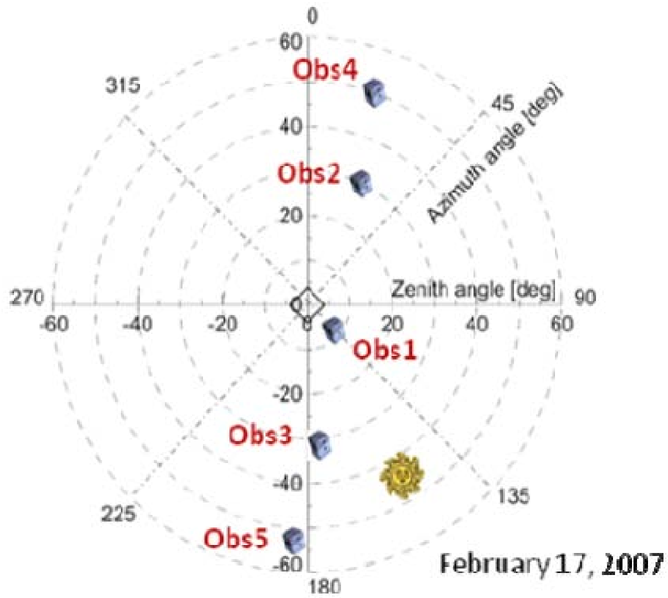

Figure 4. Acquisition geometry of the CHRIS/Proba scene of Cairo

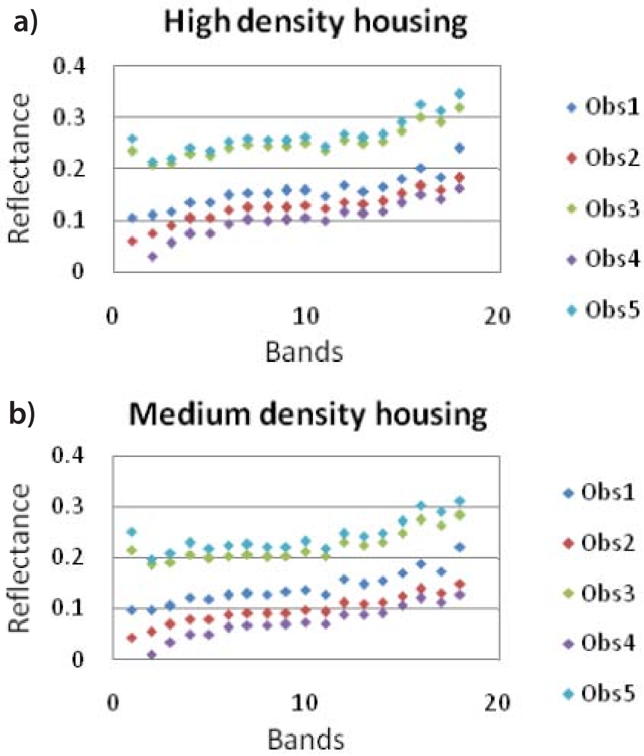

Figure 5. a) Mean reflectances of high density housing, and b) mean reflectances of medium density housing

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Continuous monitoring of urban air quality with a pulsed DOAS technique

We demonstrate here the trace gas observation campaign in the Tokyo metropolitan area in summer 2008. In this campaign, we have observed the temporal profiles of nitrogen dioxide (NO_2) by a pulsed differential optical absorption spectroscopy (PDOAS) technique. Two PDOAS apparatuses were used to characterize the regional profile of the average density of NO_2 through long path lengths of 7 and 6.3 km. The temporal profile of NO_2 was also measured by a normal NO_x meter, which was compared with data from the PDOAS. We obtained long distance slant column NO_2 concentrations for two directions from 1st to 23rd August, 2008.

1. Introduction

NO_2 is emitted from anthropogenic sources and has a large influence on the production and extinction of tropospheric ozone. Therefore, in urban areas, the continuous observation of NO_2 concentrations is important to control air quality. We present an NO_2 monitoring technique of pulsed differential optical absorption spectroscopy (PDOAS) (Fuqi *et al*., 2005, Yoshii *et al*., 2003) and its demonstration in the trace gas observation campaign in the Tokyo metropolitan area in summer 2008.

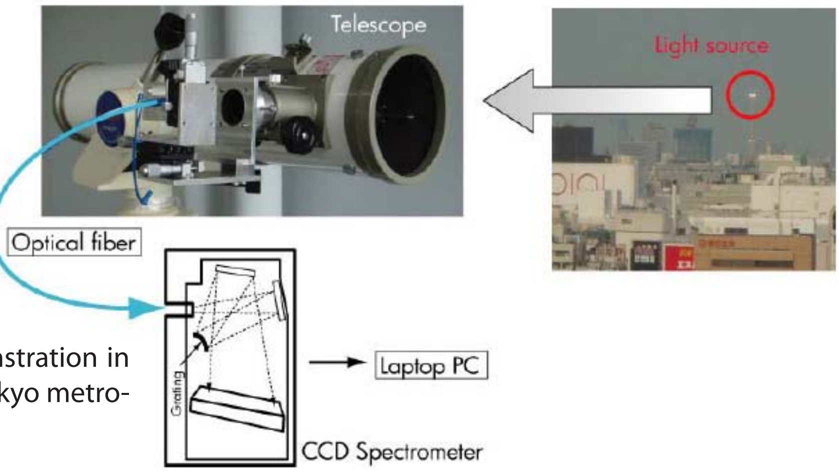

Figure 1. Experimental setup for measuring NO_2.

2. Experimental

The measurement system consists of a light source, a telescope, a small CCD spectrometer, and a laptop PC (Figure 1). In the campaign, two PDOAS systems were utilized simultaneously to retrieve NO_2 column densities along different directions. As the light sources, high-intensity flashing white obstruction lights available on the top of exhaust flues of incinerator plants were employed, in which one Xe lamp light source was located 6.3-km east and another was 7-km north from the observation site at the Hongo campus of the University of Tokyo (Figure 2). Both of the flash lights are focused by the telescopes and detected by the CCD spectrometers through optical fibers.

3. Analytical Technique

The observed light spectra subtracted from the background lights are decayed by the absorption of NO_2 and the extinction of Rayleigh/Mie scattering in the range of 400-450 nm. In this range, there is no absorption of other trace gases except NO_2, so that the observed spectra is

$$I(\lambda) = kI_{ref}(\lambda)T_{NO2}(\lambda)T_m(\lambda)T_a(\lambda)$$

Here $I(\lambda)$ is the measured intensity, k is the system constant, $I_{ref}(\lambda)$ the unattenuated reference intensity, $T_{NO2}(\lambda)$ the NO_2 transmittance, $T_m(\lambda)$ the transmittance of air molecules (Rayleigh scattering), and Ta(λ) the transmittance of aerosol particles by Mie scattering. The NO_2 transmittance is related to its optical density, by means of the Lambert-Beer law, expressed as

$$T_{NO2}(\lambda) = exp[-\sigma(\lambda)Nl]$$

where $\sigma(\lambda)$, N, and l stand for the absorption cross section of NO_2, number density, and optical path length, respectively. The air molecule transmittance is exhibited as $T_m(\lambda) = exp[-\tau_m(\lambda)]$, where

$$\tau_m(\lambda) = (p/p_0)\ 0.00864\ \lambda^{-(3.916+0.074\lambda+0.05/\lambda)}$$

for an optical path of 7 km (Flohlich *et al*., 1980). Moreover, if it is assumed that the aerosol optical thickness exhibits wavelength dependence as given by the Angstrom exponent, we obtain

$$\tau_a(\lambda) = B\lambda^{-A}$$

where A is the Angstrom parameter and B is the turbidity constant (Smirnov *et al*., 2000).

The observed spectra are deformed so that the known and observed components are to the left-hand side and the others are to the right side.

$$\ln I'(\lambda) = \ln \frac{I(\lambda)}{I_{ref}(\lambda)T_m(\lambda)} = \ln k - B\lambda^{-A} - \sigma(\lambda)Nl$$

The deformed spectra have two components; one varies rapidly with wavelength and another varies slowly. The differential absorption spectra are obtained by removing the slowly changing part (smooth line) which is fitted to the observed spectra. Then, in the slowly varying component of the observed spectra, there is the effect of the extinction of Mie scattering and the slowly varying absorption cross-section, so that the resulting structure of the observed spectra is only caused by the rapidly varying NO_2 cross-section. The slowly changing part is linearly fitted as

$$\Delta\tau_g(\lambda) = -[\ln \frac{I(\lambda)}{I_{ref}(\lambda)T_m(\lambda)} - (a\lambda+b)]$$

where a and b are constants.

The differential absorption cross-section is defined by considering the absolute cross-section as the sum of the spectrum, which varies rapidly with wavelength and a slowly varying component. The rapidly changing part is expressed as

$$\sigma'(\lambda) = \sigma(\lambda) - \sigma^s(\lambda)$$

where $\sigma'(\lambda)$ is the fast varying absolute cross section. $\sigma(\lambda)$ is the absolute cross-section, and $\sigma^s(\lambda)$ is the slowly varying absolute cross section. Finally we obtain the NO_2 concentration by peak-to-peak spectrum matching of the differential absorption spectra and the differential absorption cross-section (Figure 3).

4. Results and discussions: Concentration of NO_2 from two PDOAS and ground measurements

We performed two PDOAS system runs in the daytime from 1st to 23rd August, 2008, and for the reference, the NO_2 concentration was also measured by the single-point ground-based chemiluminescence analyzer. Figure 4 shows the NO_2 concentrations by the single-point ground-based observation and the PDOAS observation to the north and the east directions.

As is evident in Fig. 4, the NO_2 concentrations measured by the single-point ground-based chemiluminescence analyzer show a quantitative agreement with those from PDOAS (east) or, alternatively, from PDOAS (north). This result suggests that the spatial and temporal distributions of the NO_2 concentrations were highly inhomogeneous during the observation campaign.

In the PDOAS systems we have demonstrated, they are free from frequent and complicated maintenance, and generally high-intensity flashing white obstruction lights are available on the top of buildings in urban areas. The telescope we utilized in this study is commercially available and inexpensive. Thus, we can conclude that the PDOAS system is feasible for long-term automated operation for urban air quality monitoring in the daytime.

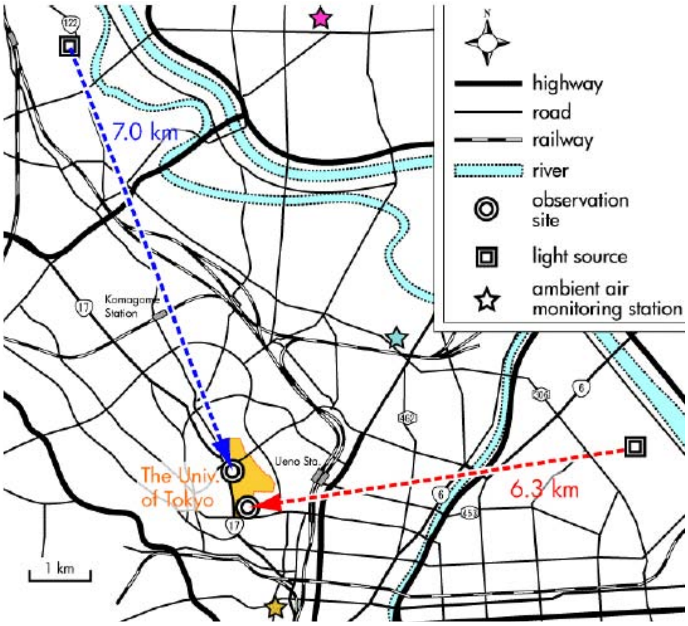

Figure 2. The PDOAS observation sites and the light sources. Two direction light paths for the PDOAS measurement are shown by dotted lines.

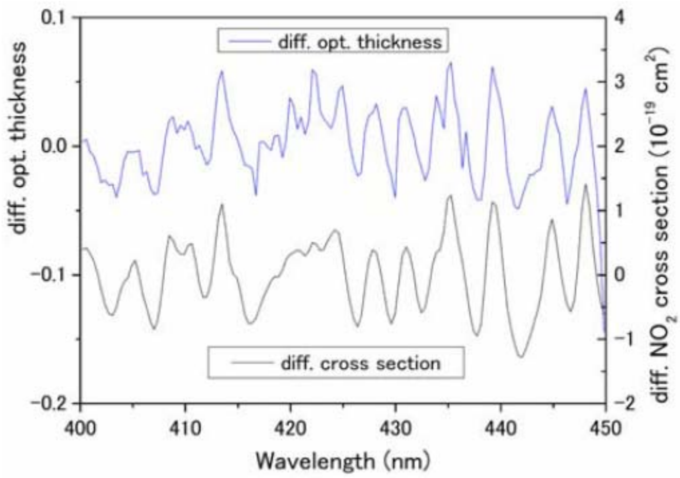

Figure 3. Spectrum matching between the differential absorption and the cross-sectional data (smoothed to the same resolution of the differential absorption).

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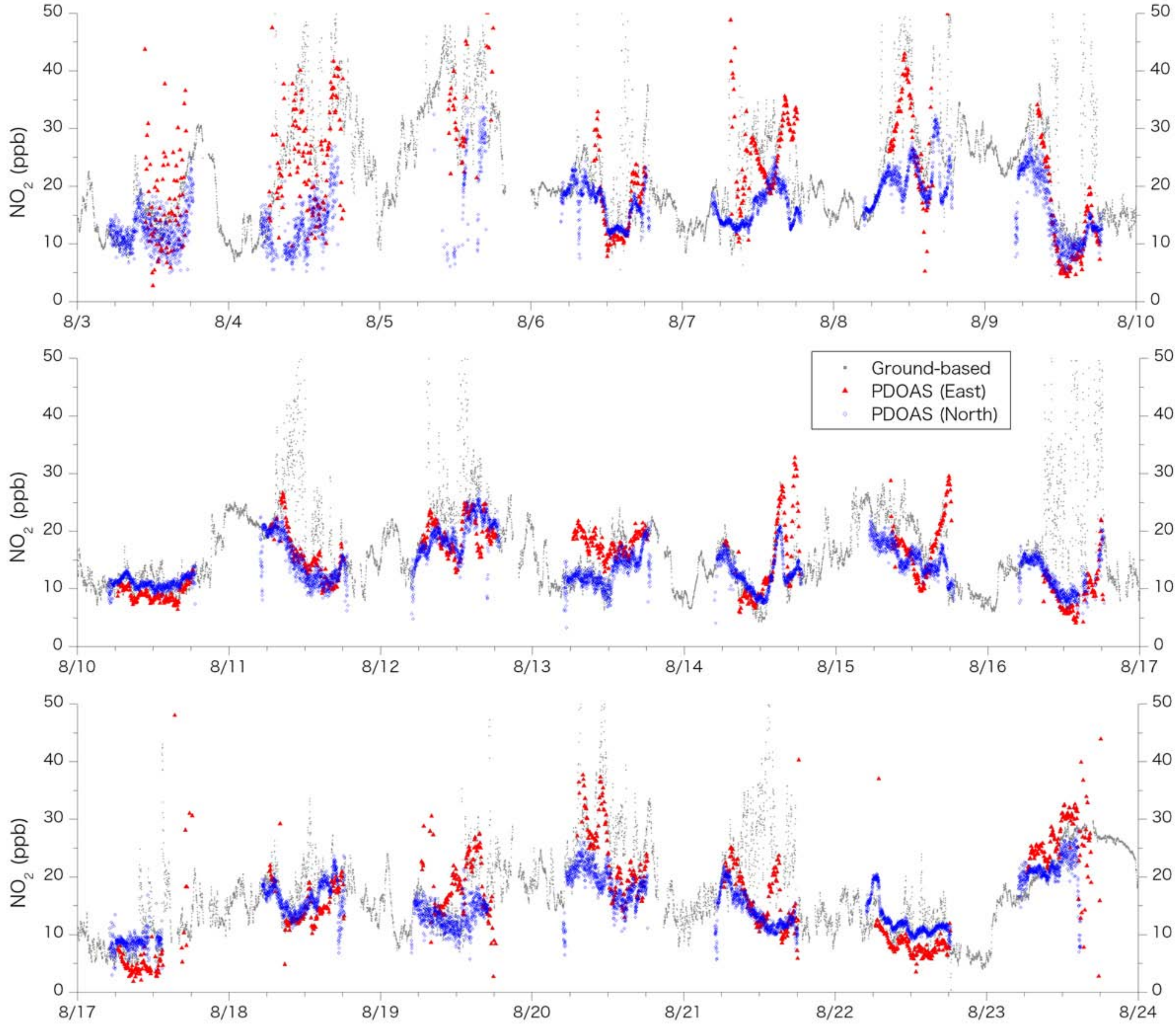

Figure 4. A time series of NO_2 concentrations by the north and the east PDOAS system and the ground-based analyzer.

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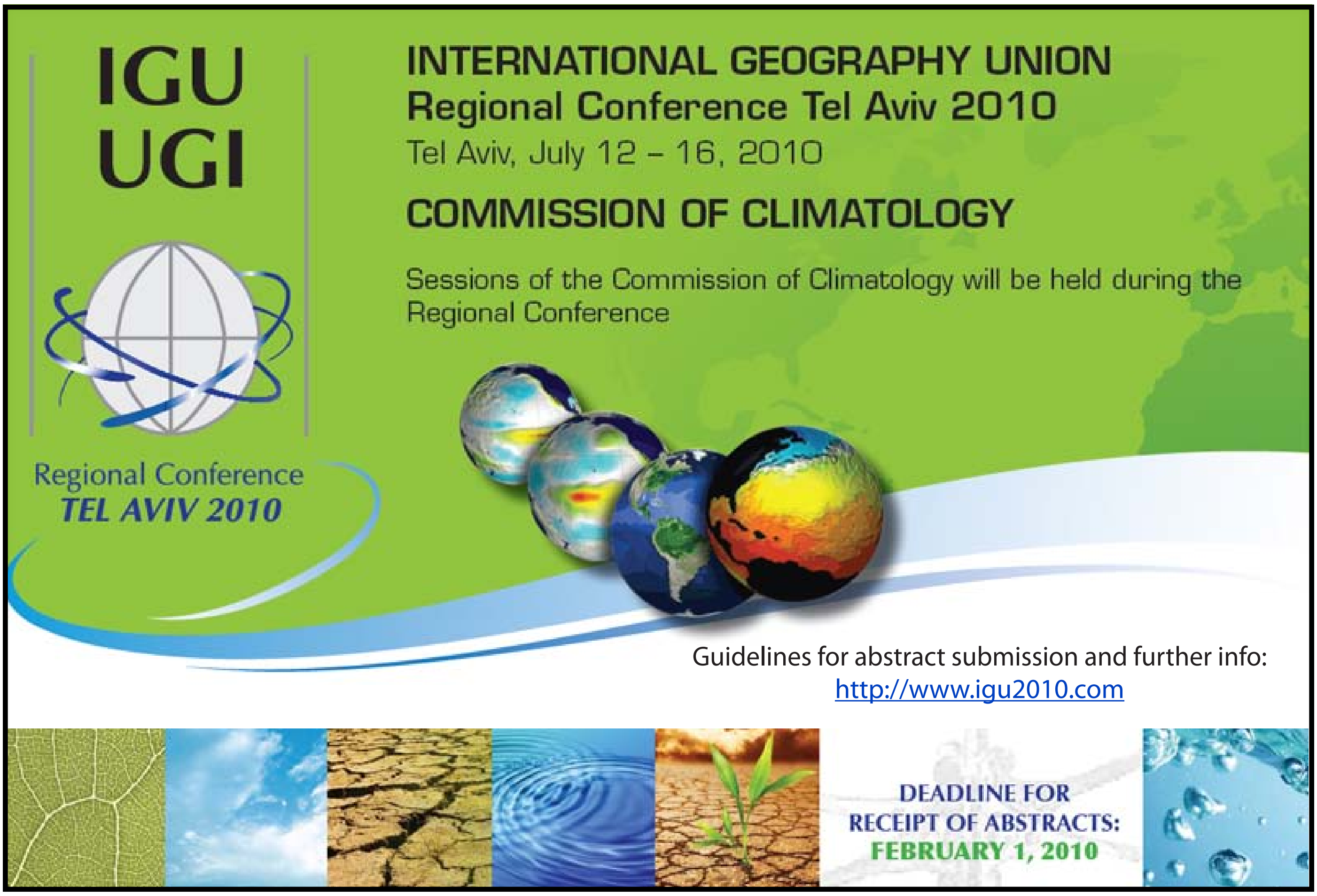

Recent publications in Urban Climatology

In this edition, papers published up until August 2009 are presented. References have also been included on the bibliographic database at http://www.urban-climate.com/bibliography/.

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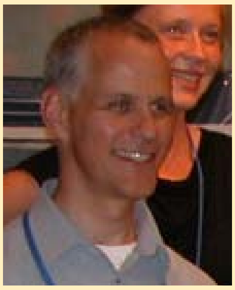
IAUC Board Elections 2009

It is my great pleasure to inform you that the following have been elected to the Board of the IAUC for a 4-year period starting in August 2009:

Jason Ching, PhD.

Atmospheric Modelling and Analysis Division, US EPA.



James Voogt, PhD.

University of Western Ontario, Canada

The Board would like to thank all the other candidates who generously agreed to stand for this position.

The Board would also like to take this opportunity to thank Sven Lindqvist and Manabu Kanda for their contributions to the IAUC. Sven will leave the Board while Manabu will stay on as past local organizer of ICUC-7.

Jennifer Salmond

Secretary, IAUC.

Call for Nominations: 2009 Luke Howard Award

The IAUC awards committee is pleased to announce the call for nominations for the prestigious 2009 IAUC Luke Howard Award.

The Luke Howard Award is given annually to an individual who has made outstanding contributions to the field of urban climatology in a combination of research, teaching, and/or service to the international community of urban climatologists.

Luke Howard Award Nomination Process

1. Nomination materials should be collected by a nomination coordinator. This is usually the first person to notify the Interim Chair of the IAUC Awards Committee (j.salmond@auckland.ac.nz) that a particular person will be nominated. Self nominations are NOT permitted and current Awards Committee members cannot be nominated.
2. The coordinator should collect the following documentation:
   a) a three page candidate CV
   b) three letters of recommendation from IAUC members from at least two different countries which are two pages in length.
3. Complete packages should reach the Interim Chair by October 31st 2009. Please advise the Interim Chair of the committee early in the nomination process of the candidate you have selected to avoid duplicated effort.

The IAUC Awards committee will recommend to the IAUC Board the recipient of this award. The IAUC Awards committee can elect not to give an award in a given year.

Previous winners include:

2008 Professor Bob Bornstein, San José State University

2007 Dr. Sci. Masatoshi Yoshino, University of Tsukuba

2006 Professor Arieh Bitan, Tel Aviv University, Israel

2005 Professor Ernesto Jauregui, UNAM, Mexico

2004 Professor Tim Oke, UBC, Canada

Luke Howard Award Schedule

15 October: Expressions of interest due to Committee chair

31 October: Complete nomination packets (single electronic submission) due to Committee chair

15 November: Committee votes and Chair forwards nominee's packet (electronically) to Board

1 December: Board makes decision and announces winner

Jennifer Salmond
Interim Chair, IAUC Awards Committee

Newsletter Contributions

The next edition will appear in late December. Items to be considered for the next edition should be received by **November 30, 2009**. Contributions may be sent to David Pearlmutter (davidp@bgu.ac.il) or the relevant editor:

News: Winston Chow (wtchow@asu.edu)
Conferences: Jamie Voogt (javoogt@uwo.ca)
Bibliography: Julia Hidalgo (jhidalgo@labein.es)
Projects: Sue Grimmond (Sue.Grimmond@kcl.ac.uk)

General submissions should be short (1-2 A4 pages of text), written in a manner that is accessible to a wide audience, and incorporate figures and photographs. Images you think would be of interest to the IAUC community are welcome.