Urban Climate News

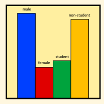
Quarterly Newsletter of the IAUC

ISSUE NO. 34 DECEMBER 2009 • www.urban-climate.org • INTERNATIONAL ASSOCIATION FOR URBAN CLIMATE

From the IAUC President

It has been a very good year for IAUC. The highlight of 2009 certainly was the ICUC-7 conference in Yokohama (Japan) which was attended by ~350 participants from 6 continents. The visibility of IAUC also kept growing in 2009 as illustrated by invitations to lead the recent WCC-3 workshop on 'Climate and More Sustainable Cities' organized by WMO in Geneva (Switzerland) and to be represented at the forthcoming first meeting of the new International Forum of Meteorological Societies (IFMS) this coming January in Atlanta (USA). Other highlights include the launch of two new on-line databases, the WMO/IAUC Bibliography on Urban and Building Climatology and the IAUC Urban Flux Network. Both are important, path-leading urban climate community initiatives. Another significant development is our growing relationship with WMO, being helped with the establishment of an official Working Arrangement in 2008 which opens up new opportunities. Besides WCC-3, IAUC members will also be involved in the WMO/CCI (Commission for Climatology) Inter-Regional Training Workshop on Urban Climatology in Pune (India) scheduled for 2010.

Inside the Winter issue...



Similar to the last newsletter, the regular items in the present edition have been contributed by ICUC-7 prize winners. The **Feature Article** introduces a new approach to site classification for urban climate studies and is written by Iain D Stewart. The **Urban Project Reports** include two human comfort studies and two studies on modeling near surface air temperature and wind characteristics in urban settlements, respectively. The **Country Report** provides an update of urban climate research in Nigeria. If numbers are anything to go by, then IAUC is in good shape. The **Membership Report** (see p. 39) shows that IAUC at present has about 1,600 members (an increase of about 50% since 2006) from 100 countries.

The Board of the International Association for Urban Climate is delighted to announce that the **Eighth International Conference on Urban Climate (ICUC-8)** will be held in Dublin (Ireland) in 2012. Gerald Mills (School of Geography, Planning and Environmental Policy, University College Dublin) will be the chair of the local organizing committee. The IAUC Board found it difficult to make a decision because it was presented with truly excellent proposals. As arrangements for ICUC-8 are proceeding, information will be posted on the IAUC website and distributed via the *urbclim* e-mail list.

This is the last time I am writing this column as President of IAUC. Gerald Mills will take up the role of President effective January 2010, assisted by Rohinton Emmanuel as the new Secretary. In retrospect, the last three years have been hard work but, at the same time, they have also been very enjoyable. I now know that IAUC's success is due to a hardworking group of volunteers. I would therefore like to thank everybody who has taken their time to serve on the IAUC Board or the various IAUC committees. But in particular I would like to acknowledge the great effort of our Secretary, Jennifer Salmond. She has efficiently handled a wide range of issues, mostly of administrative nature and behind-the-scene, often acting at short notice but always delivering superior assistance.

It has been an honour and privilege to be President of IAUC. I wish everyone a happy and healthy New Year in 2010.

Matthias Roth
geomr@nus.edu.sg

C40 Large Cities Climate Summit 2009 — from Seoul to Copenhagen

Special News Report
by **Hang Ryeol Na** (hrna@fs.fed.us)
and **Gordon M. Heisler** (gheisler@fs.fed.us),
USDA Forest Service, Syracuse, NY

About 500 mayors and delegates from major cities of 41 countries and four international organizations, including the United Nations Human Settlements Programme (UN-HABITAT) and the U.N. Environmental Programme (UNEP), participated in the biennial summit of the C40 Large Cities Climate Leadership Group on May 18-21, 2009, in Seoul, South Korea. Previous summits were held in London (2005) and New York (2007). The mayors also had an opportunity to discuss global climate initiatives during the Climate Summit for Mayors, which was held December 14–17, 2009 in Copenhagen, Denmark, concurrently with the U.N. Climate Change Conference, COP-15 .

The primary objective of the C40 Group of the world's largest cities is to reduce emissions of greenhouse gases in urban areas. The purpose of the Seoul Summit, whose theme was *Cities' Achievements and Challenges in the Fight against Climate Change*, was to review progress by cities in reducing greenhouse gases and to assess future challenges.

Beginning with representatives from 18 world cities who met in London in October 2005, the C40 Group grew to have 40 participating cities (Table 1) and added 17 affiliate cities by May 2009. The Group was strengthened in August 2006 when it entered into a partnership arrangement with the Clinton Climate Initiative, a project of a foundation established by former U.S. president, Bill Clinton, who was keynote speaker at the Seoul Summit.

Table 1: C40 Cities

1. Addis Ababa	21. Lima
2. Athens	22. London
3. Bangkok	23. Los Angeles
4. Beijing	24. Madrid
5. Berlin	25. Melbourne
6. Bogota	26. Mexico City
7. Buenos Aires	27. Moscow
8. Cairo	28. Mumbai
9. Caracas	29. New York
10. Chicago	30. Paris
11. Delhi NCT	31. Philadelphia
12. Dhaka	32. Rio de Janeiro
13. Hanoi	33. Rome
14. Houston	34. Sao Paulo
15. Hong Kong	35. Seoul
16. Istanbul	36. Shanghai
17. Jakarta	37. Sydney
18. Johannesburg	38. Tokyo
19. Karachi	39. Toronto
20. Lagos	40. Warsaw

Source: http://www.c40seoulsummit.com

Seoul Summit

Information on the Seoul Summit is available at http://www.c40seoulsummit.com, where 54 PowerPoint presentations are posted; on the websites of some of the participating cities; and in newspapers such as The Korea Times. We searched through these documents for evidence that delegates used knowledge or had appreciation of the link between urban climate, that is, micro- or local-scale climate (Oke 1987) and carbon emissions. Because tree cover influences urban climate (Heisler et al. 2006; Oke 1989), we also looked for applications of urban forestry to moderate urban climate or sequester carbon dioxide (CO_2).

Among the urban-climate issues discussed during six plenary and 16 parallel sessions were green energy, sustainable transport, and sustainable adaptation measures. Other presentations focused on the social and political aspects of urban life. Anna Tibaijuka, executive director of UN-HABITAT, praised South Korea's contribution to the International Urban Training Center in Hongcheon, Gangwon Province. "First, a city should be socially inclusive and think of the people living in the city," she said in an interview with The Korea Times. "Second, it should be governed in a democratically and participatory way." Other suggestions included preserving cultural heritages, providing efficient public transportation, and maintaining economic vibrancy.

The rationale for the mayors' activism was reflected in remarks by David Miller, mayor of Toronto and chairman of the C40 Group. "Waiting for nations to take the lead with a new climate protocol in Copenhagen in December is not an option," he said. "If governments talk about reducing CO_2, cities are the ones that show how it's done."

In some countries that did not ratify the Kyoto Protocol, cities took it upon themselves to reduce their own carbon footprint. For example, the United States has not endorsed the Protocol, yet 1016 U.S. mayors have signed on to a climate protection agreement that embraces the goals of the Kyoto Protocol, according to the Mayors Climate Protection Center. Mayors Climate Protection Center is a subgroup of the U.S. Conference of Mayors, founded in 2007 to provide mayors with the guidance and assistance they need to lead their cities' efforts to reduce the greenhouse gas emissions that are linked to climate change.

With respect to urban forests, presentations by the cities of Seattle and Seoul stood out. Amanda Eichel, Seattle's climate protection advisor, discussed "Seattle reLeaf," the city's forest management program that was developed following a significant decline in the urban forest during the last several decades. In carrying out activities to enhance Seattle's urban forest, reLeaf officials recognize the need to achieve a balance among often conflicting goals for managing growth, enhancing livability, protecting the environmental, fostering economic growth, maintaining vibrant public spaces, and creating recreational opportunities.

Urban trees contribute to all of these goals in various ways (City of Seattle April 2007). For example, Seattle's current urban forest stores 52,400 tons of carbon at a value of nearly $1.6 million. The planting of street trees, which shades pavement, is a cost-effective method for reducing zones of increased temperature (heat islands) in urban areas (Seattle reLeaf 2009). Seattle hopes to increase citywide tree canopy cover from 23 to 30 percent by 2037. This includes more than doubling tree cover in the downtown area (Table 2). As with many other cities, Seattle is using remote-sensing tools to determine the amount of urban land cover (Figure 1).

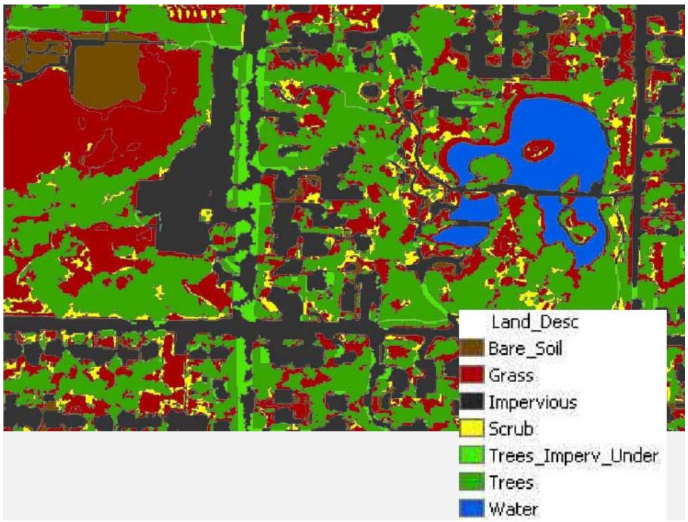


Figure 1. Seven-class landcover classification of a portion of Seattle (Eichel 2009). Note the important category of trees over impervious ground surface, which often is not available in analyses of urban cover.

Ahn Seung-Il, director general of Green Seoul Bureau, presented Seoul's plan to enhance green spaces. As of May 2009, the area of urban forest is 166.05 km^2, or 15.92 m^2 per capita. To expand its urban forest by 3.3 × 106 m^2 in residential areas, Seoul is developing large-size parks and plans to build roof parks (roof gardens) (Figure 2). According to Ahn, the driving forces behind the plan are the urban heat island effects and increasing price of land. Seoul Metropolitan Government will subsidize 90 percent of the cost of roof gardens for public buildings and 50 percent for private properties (Figure 2).

Boris Johnson, mayor of London, laid out that city's plan to make the 2012 summer Olympics the greenest sports event ever. "By 2012," he said, "the city will have the newest green park in Europe. It will also have 'Cycle

Table 2: Canopy-Cover Goals for Seattle by Land Use (Eichel 2009)

Land Use	Canopy Cover (%)		
	2002	2007	2037 Goal
Commercial/ Mixed Use	8.4	9.7	15
Developed Park or Boulevard	25.9	25.5	25
Downtown	4.2	4.7	12
Major Institution	18.4	19.4	20
Manufacturing/ Industrial	3.8	4.3	10
Multi-Family	16.6	17.1	20
Parks Natural Area	82.5	80.4	80
Single Family	25.2	25.7	31
TOTAL	22.5	22.9	30

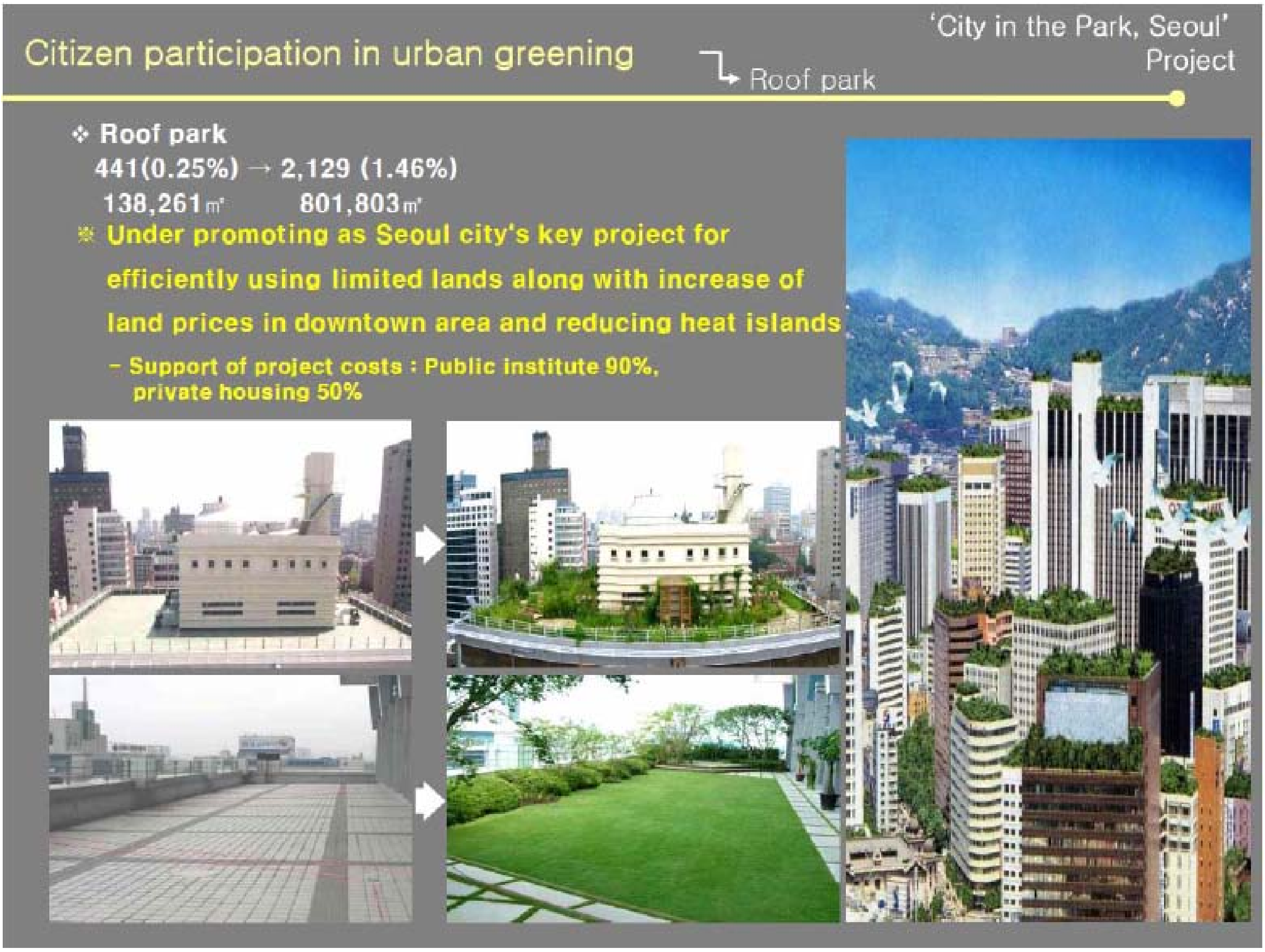


Figure 2. Artist's conception of plans for roof gardens in Seoul (Ahn 2009).

Superhighways,' a bike track at the Olympic sites that will allow spectators to move from one facility to another via bicycle." While in Seoul, Johnson toured the city that hosted the 1988 summer Olympic Games.

London's plan to develop a bicycle superhighway drew the attention of Laurel Prussing, mayor of Urbana, Illinois. "We also are working on the citywide revision of bicycle paths," she said. "We already have bicycle lanes but we plan to connect all of the paths. We are using LED (Light-Emitting Diode) traffic lights in the city and will use them in street lights as well." Urbana already has refurbished heating and cooling systems in public buildings, which now are more environmentally friendly and energy efficient, and currently is replacing lighting systems. According to Prussing, arborists maintain city trees and advise homeowners on what kinds of trees to plant. The city has long acknowledged community-wide benefits of urban trees in sequestering CO_2 and conserving building energy (City of Urbana 2009).

Although we were looking for presentations that specifically addressed urban-scale climate, most described mixed activities at both urban and global scales. For example, Mayor Miller noted that the Seoul Summit provided opportunities for the participants to share their accomplishments and that it launched the Climate Positive Development Program, which is designed to build new neighborhoods that not only are carbon neutral but also offset emissions of greenhouse gas. Toronto plans to develop renewable energy such as solar hot water heating, and plant 6 million trees.

The C40 Seoul conference provided other evidence that many mayors of large cities are increasingly aware of the importance of global and urban climate issues and are responding with tangible actions. For example, Berlin is making a major push for solar power; Tokyo is adopting a carbon exchange program in conjunction with other Japanese cities; Helsinki is shifting to LED streetlights; and Seoul is implementing a retrofit plan for buildings, a 'green transportation' initiative that entails the increased use of bicycles and buses that are fueled by compressed natural gas, and an $80 million climate-change fund for renewable energy and the construction of parks on former wasteland.

In remarks on the topic of global climate change at the start of Seoul C40, Bill Clinton said; "If we let the worst happen, we won't be able to save the planet for our grandchildren unless we take extremely expensive measures which can be avoided if we move now. I think it's important to be as specific and swift as possible on this matter." The 'Seoul Declaration', which the mayors adopted on the final day of the summit, stressed that more than half of the world's population lives in cities, which account for 75 percent of global energy consumption and 80 percent of global emissions of greenhouse gases.

Copenhagen Summit

The next C40 Summit will be held in Sao Paulo, Brazil, in 2011, but concurrently with the COP-15 U.N. Conference , the mayors also held the Climate Summit for Mayors, December 14–17, 2009 in Copenhagen. Although the dominant issue in Copenhagen was global-scale climate, mayors' awareness of urban climate challenges was recognizable. For example, Michael Bloomberg, mayor of New York City, said at a panel session that the city planted 300,000 of 1 million new trees, extended bike lanes over 200 miles of streets, and encouraged conversion to hybrid vehicles of 22 percent of the taxi fleet, among other emissions-saving steps (Olsen and Hanley 2009). In fact, New York City, through its 'MillionTreesNYC' project aiming to plant one million new trees across the city over the decade, is now ahead of schedule in meeting the goal (City of New York 2009 — see related story).

A couple of remarkable news items from Copenhagen are the announcement of the first Assessment Report on Climate Change in Cities (ARC3) and C40 Electric Vehicle Network (EVN). The ARC3 will be published by the Urban Climate Change Research Network (UCCRN), which explores how climate change will affect cities around the world, and what cities are doing to both mitigate and adapt to climate change. The EVN is a collaboration of 14 cities of C40 with the Clinton Climate Initiative and four leading vehicle manufacturers – BYD, Mitsubishi Motors Corporation (MMC), Nissan, and Renault. The EVN will coordinate consumer incentives for electric vehicle purchases, expand the number of electric vehicles in city fleets, and streamline the permitting process for electric charging equipment (Hammer 2009). Transportation has been found to make up more than 60% of the anthropomorphic heat flux in cities in summer (Sailor and Lu 2004), so the EVN may affect urban climate as well as reduce CO_2 emissions.

One conclusion we draw from the C40 activities is that urban climate researchers might find increasing opportunities for financial support from city governments. Also, cities may be increasingly amenable to the construction of towers and other infrastructure that are required to conduct urban-climate research.

References

Ahn, S.-I., cited 2009: Policy of Seoul's Parks and Green Spaces. In: C40 Large Cities Summit Seoul 2009. [Available online from http://www.c40seoulsummit.com/]

City of New York: plaNYC Progress Report 2009. [Available online from http://www.nyc.gov/html/planyc2030/html/home/home.shtml]

City of Seattle, cited 2009: Urban Forest Management Plan. [Available online from http://www.seattle.gov/environment/documents/Final_UFMP.pdf]

City of Urbana, cited 2009: Urbana… 'Green' before it was cool. [Available online from http://www.city.urbana.il.us/urbana/public_works/environmental_management/sustainable_urbana/Earth_Day.pdf]

Eichel, A., cited 2009: Seattle Urban Forest Management Program, In: C40 Large Cities Summit Seoul 2009. [Available online from http://www.c40seoulsummit.com/]

Hammer, S.: Cities Are Moving Ahead. [Available online from http://blogs.ei.columbia.edu/blog/2009/12/22/cities-are-moving-ahead/]

Heisler, G., J. Walton, S. Grimmond, R. Pouyat, K. Belt, D. Nowak, I. Yesilonis, and J. Hom, 2006: Land-cover influences on air temperatures in and near Baltimore, MD. 6th International Conference on Urban Climate, Gothenburg, Sweden, International Association for Urban Climate, [Available online http://www.gvc2.gu.se/icuc6//index.htm], 392-395.

Oke, T. R., 1987: Boundary Layer Climates. Methuen, 435 pp.

——, 1989: The micrometeorology of the urban forest. Philosophical Transactions of the Royal Society of London. Series B, 324, 335-349.

Olsen, J. M. and C. J. Hanley: World mayors compare notes on saving climate. [Available online from http://www.businessweek.com/ap/financialnews/D9CJVG100.htm]

Sailor, D. J. and L. Lu, 2004: A top–down methodology for developing diurnal and seasonal anthropogenic heating profiles for urban areas. Atmospheric Environment, 38, 2737-2748.

Seattle reLeaf, cited 2009: Benefits of Urban Trees to the Environment. [Available online from http://www.seattle.gov/trees/environment.htm]

Manhattan Street-Level Air Pollution Survey presented at COP-15

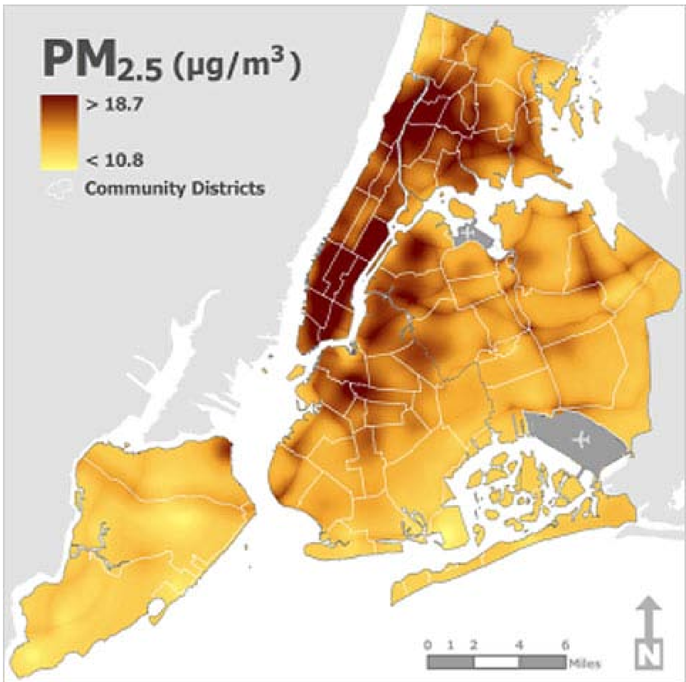
December 2009 — New York City health officials on Tuesday released the results of the first survey of street-level air quality ever taken in the city. While the key finding — that Manhattan and other built-up, high-traffic parts of the city have the worst concentrations of particulates — will come as little surprise to those who live and work in Manhattan, it will stand in contrast to most indicators that show Manhattan leading the city's five boroughs in indicators of social and economic well-being.

Over all, the Community Air Survey, conducted last winter, showed wide variations in air quality. Not only vehicular traffic, but also concentrations in oil-burning boilers in commercial and residential buildings, accounted for particulate concentrations.

Mayor Michael R. Bloomberg discussed the study, begun as part of his PlaNYC strategy for long-term environmental stability, at the United Nations Climate Change Conference (COP-15) in Copenhagen.

"This study clearly demonstrates the impacts that pollution from vehicles and certain oil-burning boilers has on our neighborhoods — and it shows us that the most densely populated areas are also the most polluted," he said.

Researchers collected and analyzed air samples from 150 sites across the five boroughs last winter. The survey found that fine-particle and sulfur dioxide pollution was concentrated in areas where more buildings burn oil for heat, and levels were especially high in areas where buildings use so-called residual oil (also known as No. 4 and No. 6 oil) in their boilers.



Particulate-matter concentrations as measured last winter over New York City. ***Source*****:** Department of Health and Mental Hygiene

Such pollutants can cause respiratory disease and premature death, and they put young and elderly people at particular risk.

Source: Sewell Chan, New York Times (http://cityroom.blogs.nytimes.com/2009/12/16/survey-finds-street-level-air-pollution-in-manhattan/)

Energy-Saving Buildings Play Big Role In Solving Climate Change

December 2009 — The importance of energy-efficient buildings in mitigating effects of climate change was highlighted recently at the COP-15 climate conference in Copenhagen. The United Nations Environment Programme (UNEP) released a report Dec. 11 urging that buildings be considered as a major component of any strategy concerning emissions reduction.

UNEP's report, "Buildings and Climate Change - Summary for Decision Makers," emphasizes that buildings are an untapped area of great potential to thwart climate change. The report is a result of three years of study by UNEP's Sustainable Buildings and Climate Initiative (SBCI), a think tank and partnership between the United Nations and leading companies and organizations in the building sector.

Buildings account for more than 30 percent of worldwide energy use. However, buildings present huge possibilities to reduce energy consumption and related greenhouse gas emissions. Globally, buildings generate the equivalent of 8.6 billion tons of CO_2 a year, according to the report, and this amount is expected to nearly double over the next two decades. Population growth and urbanization are cited as the impetus for new construction growth.

For example, new construction in China over the next ten years will be so prolific that it will equal the size of all existing buildings in the United States, the report says. Investment in new buildings is also expected in South Africa. UNEP warns booms like these will likely double the amount of pollution associated with energy use in buildings.

Along with the report, the climate summit served as the debut of SBCI's global Common Carbon Metric for Buildings to measure energy efficiency and greenhouse gas emissions of buildings. The new metrics were created in conjunction with the International Energy Agency, International Standardization organization, World Green Building Council, International Initiative for the Sustainable Built Environment and Sustainable Buildings Alliance as well as private sector companies and associations.

Source: http://www.greenandsave.com/green_news/green-building/energy-saving-buildings-play-big-role-solving-climate-change-5566

A green reckoning in Copenhagen?

December 2009 — In anticipation of COP-15, efforts have been stepped up to promote what Copenhagen's tourist literature calls "the world's greenest capital city". In August laws were passed to reduce carbon dioxide emissions 20 per cent within five years, the aim being to become the world's "model eco-city".

Cycling makes up a sizeable chunk of Copenhagen's green image. Thirty-five per cent of journeys are by bike – many all-year round – along a network of 307km of bicycle lanes. The aim is to raise this to 50-60 per cent by 2020. Its transport infrastructure is an acknowledged world leader, with more than three-quarters of its housing energy mix coming from district-based, rather than oil-based heating, redirecting waste heat from refuse incineration plants, and biomass-powered combined heat and power plants.

Copenhagen was also an early adopter of "industrial metabolism", an earlier version of the heavily hyped "cradle to cradle design" or "C2C", which imitates natural systems so that materials and products are reused repeatedly, rather than going to incineration or landfill. The city runs the largest renewable materials plant in northern Europe; 90 per cent of materials are reused. All this, together with advanced urban design – the city-centre Stroget shopping street was pedestrianised in 1966, Europe's first – has led to the evolution of the beguiling phrases "to Copenhagenise" and "Copenhagenisation".

On top of this comes one of the most ambitious eco-development projects in Europe: Nordhavnen. Though little known across mainland Europe, it is the largest metropolitan eco-district development in Scandinavia, arguably rivalling the United Arab Emirates' Masdar and Shanghai's ill-fated Dongtan initiatives. It covers a prime site on the northern edge of Nordhavnen harbour's post-industrial cityscape, with 3.5km of defunct docklands to be turned into homes and workspaces for 40,000 people over the next half-century. The team charged with executing the project has envisioned a future "using what we're good at ... from bicycle culture to energy drawn from large-scale offshore wind-farms", in the words of the team's young Aarhus-based master planner, Soren Leth.

Yet some of the people closely involved in Danish urban planning suggest that Copenhagen's eco-reputation is both more complicated and mixed than it appears. Nordhavnen, the latest public-private collaboration between the City and Port Development and Copenhagen Municipality, follows on from Orestad and Sluseholm, other recent big developments that have met with less than ecstatic reactions. For quite a few people, the hopes surrounding Nordhavnen are tempered with trepidation.

Asked how sustainable his home city is, Jens Kvorning's eyebrows rise: "I call Copenhagen a Jekyll and Hyde town – a double city," says the professor of urban planning at the Royal Danish Art and Architecture Academy. "On the one hand you have a dense inner city and the phenomenon of Copenhagen as a cycle city. On the other hand there are the postwar suburban districts. There, distances are too great for cycling and people simply use their cars." While commuting in inner city Copenhagen has been reduced and is at a low level, work journeys by car from satellite towns are increasing, as are high energy-use lifestyle and leisure activities during non-working hours. "There is nothing we can do about what people choose here and how they choose to travel. So while controlling energy consumption related to lifestyle isn't impossible, it's very different [from the city centre] and a big problem, requiring a different type of planning policy."

Nordhavnen, Copenhagen's 'eco-district' (*Source:* FT.com)

Nordhavnen, as a compact, dense area, is one large-scale attempt. According to Leth, "Nordhavnen is a combination of Dutch urbanism, Danish suburbia and Tokyo – self growing, very dense." The master plan – which was exhibited during COP-15 – envisages a 50-50 divide between new and rebuild, all zero energy, with high recycling levels in the materials mix. "The Danes are good at re-using old materials," Leth says. In keeping with Copenhagen's skyline, buildings do not rise higher than six storeys, as part of an attempt to emphasise human-scale intimacy. As elsewhere in Copenhagen's re-creation of its extensive harbours, old mills will be turned into homes, with canals threading through its 3.5 sq km in a kind of eco-Venice of the north. The sustainable highlight, however, is "The Green Loop", a multi-level Metro and cycle route circling the district that will be within 500 metres of all those living and working in the new district.

Despite Nordhavnen's grand ambitions, eco-cities have an uncanny knack of turning out rather differently from their initial vaunted dreams; and so far none has been completed. Then again, this is northern Europe, where contemporary environmentalism is at its most advanced. If there is any part of the world where such a project is has a chance to succeed it is the Nordic world. If it does, it will be a mighty feather in Copenhagen's eco-cap.

Source: O. Lowenstein, Financial Times (http://www.ft.com/cms/s/2/4e55de48-e44d-11de-a0ea-00144feab49a.html)

Classifying Urban Climate Field Sites by "Local Climate Zones"

By Iain Stewart (stewarti@interchange.ubc.ca)

Urban Climate Research Group, Department of Geography, University of British Columbia, Vancouver, Canada

Classification of field sites in urban climatology traditionally relies on simplistic descriptors like "urban" and "rural." These descriptors might appropriately describe the background setting of a climate investigation, but they convey little in the way of micro- and local-scale site properties. At present, urban climatologists have little choice but to follow this tradition until an alternative approach is adopted.

In this report, I demonstrate a possible new approach to site classification using a prototype version of "local climate zones." I apply these zones to "urban" and "rural" field sites in observational heat island studies of Japan, Sweden, and Hungary. The field sites correspond well with local climate zones, and the zones overall provide a more purposeful interpretation of the landscape than simply "urban" and "rural." Local climate zones can also be applied to field stations of long-term regional or global temperature studies, and to removing urban temperature "bias" from those studies. With further refinement, local climate zones can improve consistency and accuracy in climate reporting.

Local Climate Zones

Local climate zones (LCZ) are defined as regions of relatively uniform surface-air temperature distribution across horizontal scales of 10^2 to 10^4 metres (Stewart and Oke 2009a, 2009b). The zones are differentiated on surface properties that directly influence temperature climate, such as built surface fraction, building height-to-width ratio (H/W), sky view factor (SVF), height of roughness elements (Z_H), anthropogenic heat flux (Q_F), and surface thermal admittance (μ). By these differentiating properties, the "urban-rural" continuum is reduced to 15 generic classes, or "zones," that broadly represent the range of sites used in urban climate field studies (Figure 1).

The LCZ system consists of two series: "built" and "natural." The built series comprises 10 zones and corresponds closely with Oke's (2004) Urban Climate Zone scheme. Built zones by definition have at least 25 per-

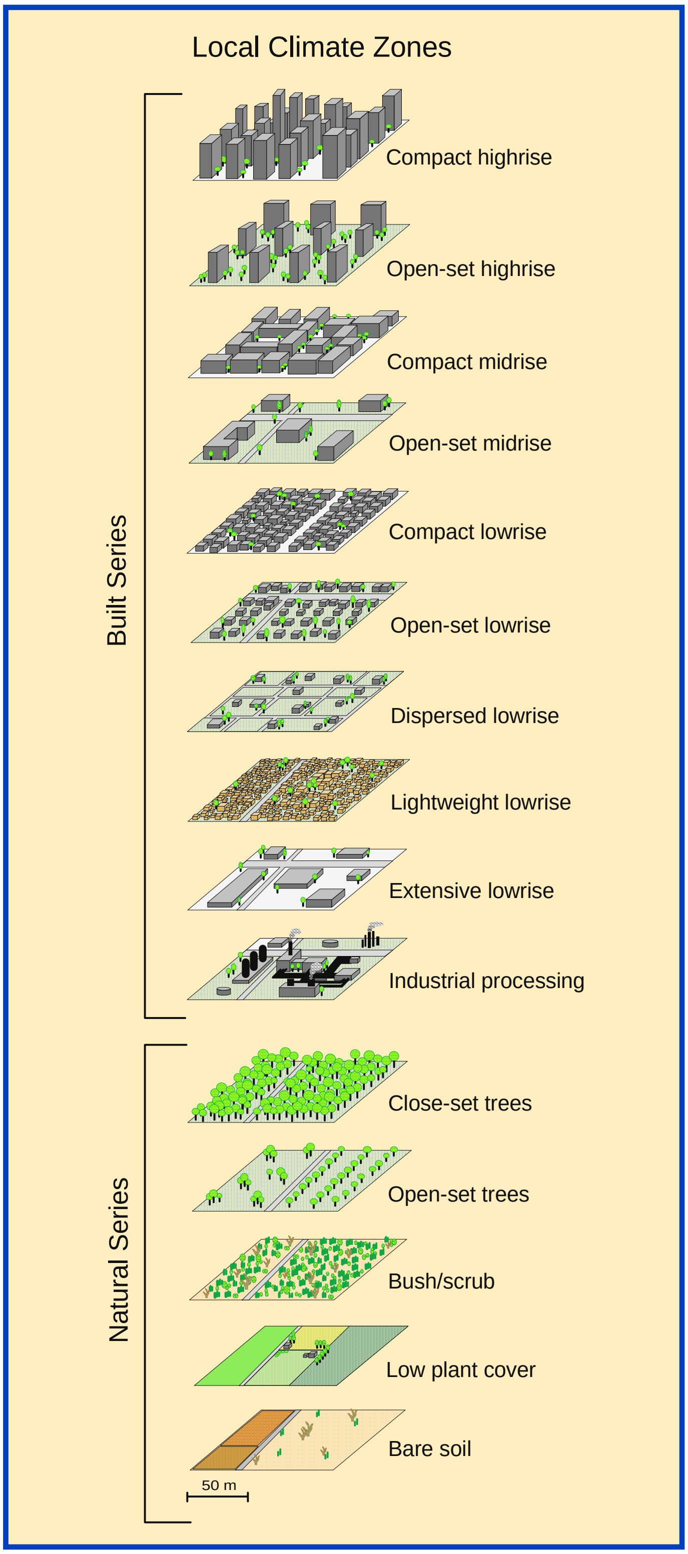


Figure 1. Prototype version of the local climate zone classification system (after Stewart and Oke 2009a).

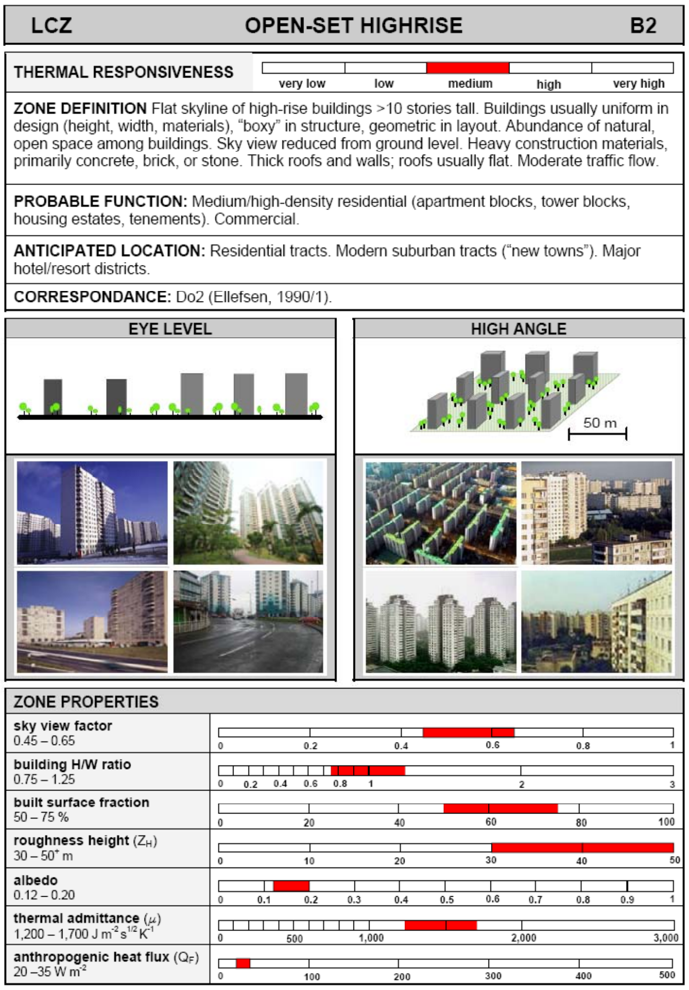


Figure 2. LCZ datasheet for "open-set highrise."

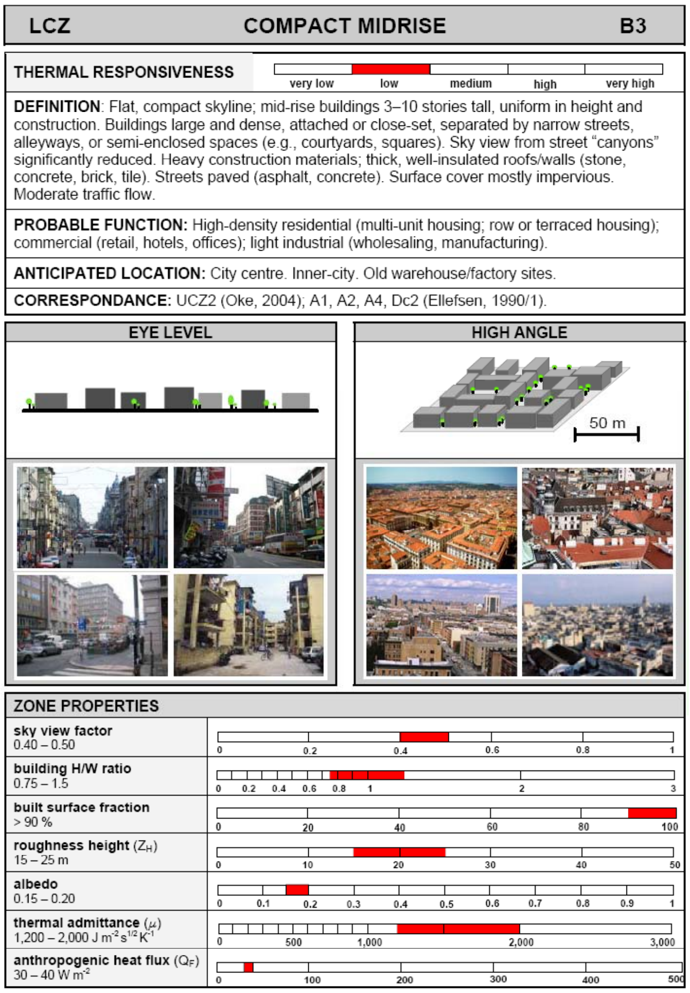


Figure 3. LCZ datasheet for "compact midrise."

cent impervious cover. The natural series, in contrast, is smaller but climatologically more sensitive to wet and dry surface conditions due to its abundance of pervious cover. Natural zones can therefore be differentiated further on surface-moisture criteria. Empirical testing and computer modelling are underway to quantify the thermal "responsiveness" of all zones to diurnal heating and cooling cycles, and to soil moisture and snow-cover conditions (e.g., Krayenhoff, Stewart, and Oke 2009). The zones are individually described and illustrated in standardized data sheets (for samples, see Figures 2 and 3).

Classifying Urban Climate Field Sites

Five "urban" and "rural" field sites were selected for LCZ classification. These sites were previously used in observational heat island reports of Tokyo (Yamashita 1990); Goteborg, Sweden (Eliasson 1994); and Szeged, Hungary (Unger et al. 2001). The sites are ideal for LCZ classification because surface cover, structure, and human activity are reasonably uniform across the local-scale surroundings of each site. The site surroundings were parameterized with metadata extracted from the original heat island reports. Additional metadata were obtained from the lead investigators of each report, from visitations to the field sites, and from online portals for digital mapping and satellite imagery, such as *Google Earth©*.

Methods

Scale is paramount in the classification process, and especially in parameterizing field sites. All field sites are essentially defined by a "circle of influence" (also known as source area or footprint) whose radius extends from metres to kilometres depending on instrument height, boundary-layer conditions, and surface geometry (Oke 2004). Temperature measurements at shelter height (1–2 m agl) and among compact buildings, for example, are representative of smaller "circles of influence" than measurements high above open fields. The spatial dimensions of the local climate zones are therefore flexible to the measurement conditions imposed by the site, and to the measurement set-up of a particular urban climate investigation.

Empirical evidence suggests that the circle of influence around a temperature sensor at shelter height is no more than a few hundred metres in radius (e.g., Chandler 1964; Oke 2004). Thus, using a radius of 200 metres, the source area of each field site was parameterized by the differentiating properties of the LCZ classes. The LCZ that best matched the measured or estimated properties of a field site was then identified. Photographs alone substantiated reasonably accurate matches between field sites and LCZs, but a direct relation between the measured properties and the zone datasheets ultimately supported a more objective and reproducible outcome. The most important properties to consider in this process are built surface fraction, building height-to-width ratio, and surface thermal admittance.

Like all classification systems, the LCZ scheme serves only as a general guide. Therefore, the *best*—not *exact*—match for each field site was sought using the information contained in the zone datasheets. If site metadata were incomplete or poorly aligned with the datasheets, the process of selecting "best fit" zones became one of skilled judgement rather than automated matching.

Results

Overall, the "urban" and "rural" field sites are well represented by LCZs (Table 1). With minor exceptions, the metadata for each site compare favourably with the

Table 1. Classification of "urban" and "rural" field sites by local climate zones.

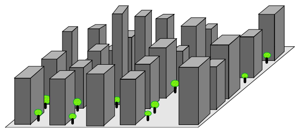
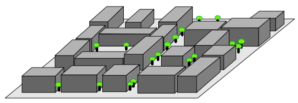
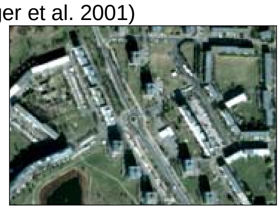
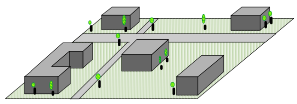
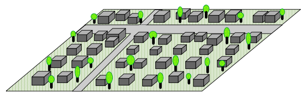
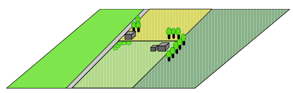
Site Photographs	Site Photographs	Traditional Classification & Site Metadata	*Local Climate Zone* Classification
Eye Level	High Angle*		
Tokyo (Yamashita 1990) 		<u>Urban</u> Weather observatory in central Tokyo, next to busy roads, expressways, and close-set concrete buildings 10–20 stories tall. SVF~0.65 Vegetation scarce. Built fraction ~90 %. Heavy traffic flow.	<u>COMPACT HIGHRISE</u> 
Goteborg (Eliasson 1994) 		<u>Urban</u> Narrow street canyon in central Goteborg. Compact brick buildings 5–8 stories tall. SVF=0.5 H/W=1.4 Z_H=20 m. Few trees or green surfaces. Built fraction ~75 %. Moderate traffic flow.	<u>COMPACT MIDRISE</u> 
Szeged (Unger et al. 2001) 		<u>Urban</u> Housing estate on the outskirts of Szeged. Concrete towers 5–11 stories tall, widely set, uniform in design and layout. Z_H=19 m. SVF=0.85 Abundant vegetation and open space. Built fraction 54 %. Low-moderate traffic flow.	<u>OPEN-SET MIDRISE</u> 
Tokyo (Yamashita 1990) 		<u>Rural</u> Residential site 60 km NW of Tokyo. Detached, open-set homes 1–2 stories tall, separated by green spaces and small trees. SVF~0.75 Built fraction ~70 %. Low traffic flow.	<u>OPEN-SET LOWRISE</u> 
Szeged (Unger et al. 2001) 		<u>Rural</u> Cultivated fields 4.5 km west of Szeged. Fields uniformly cropped. No trees. Dry soils. Crop canopy 1 m agl. SVF=1 Built fraction < 1 %. Traffic flow nil.	<u>LOW PLANT COVER</u> 

*image size approx. 250 m by 350 m

general zone properties. The three "urban" sites are differentiated primarily by high, medium, and low building heights and densities. The two "rural" sites are differentiated by anthropogenic heat flux and built surface fraction.

Implications

Classification of urban climate field sites is relatively unambiguous if the system being used is appropriately defined and scaled, and is effectively universal in coverage. The LCZ system offers an improvement over traditional "urban-rural" classification because it is suitably scaled to the surface properties that directly influence local climate. Moreover, the LCZ system communicates these properties in clear, standardized format.

Substantiating cross-study differences in urban heat island (UHI) magnitude is a useful application of the LCZ system. UHI magnitude is expressed more objectively through "inter-zone" temperature differences than through arbitrary "urban-rural" differences (Stewart and Oke 2009a). Heat islands defined this way become more robust indicators of city climate modification than those defined by "$\Delta T_{u\text{-}r}$." The temptation to interpret cross-study differences in UHI magnitude through surrogates like population or land use is less enticing if the surface properties that control heat island formation are implicit in the site classification system.

Classifying "urban" and "rural" field stations in long-term regional or global temperature studies is another useful application of the LCZ system. Rather than classifying stations on criteria of population or land use—neither of which is directly relevant to surface thermal climate—LCZs classify the landscape on measureable site properties that control surface temperature regimes. The extent to which these regimes have been "contaminated" by an urban bias can then be assessed.

Future Work

The simple aim of the LCZ classification system is to standardize reporting of urban climate field sites. The system is therefore designed to be inclusive, accessible, and reproducible. LCZs should work reasonably well in all regions, regardless of language, culture, or geography; they should be easy to use, especially by those who have limited resources to classify field sites or carry out sophisticated measurements; and they should yield consistent results with repeated use, regardless of who is using the system. In helping to bring the LCZ system closer to its optimal balance of these classification principles, I encourage potential users in the climate community to consider local climate zones when classifying or describing "urban" and "rural" field sites in any region. Feedback from attempts at using local climate zones for this purpose will help me to further improve the nomenclature, definition, and logical structure of the system.

Acknowledgements

I acknowledge the Natural Sciences and Engineering Research Council of Canada for funding this research, and I thank my PhD supervisor, Professor T.R. Oke, for encouraging this project.

References

Chandler, T.J., 1964. City growth and urban climates. Weather 19: 170-1.

Eliasson, I., 1994. Urban-suburban-rural air temperature differences related to street geometry. Physical Geography 15: 1–22.

Ellefsen, R., 1990/1. Mapping and measuring buildings in the urban canopy boundary layer in ten US cities. Energy and Buildings 15-16: 1025–49.

Krayenhoff, S., Stewart, I., and T.R. Oke, 2009. Estimating thermal responsiveness of local- scale climate 'zones' with a numerical modeling approach. Preprints, T.R. Oke Symposium & Eighth Symposium on Urban Environment, January 11–15, Phoenix, AZ.

Oke, T.R., 2004. Initial Guidance to Obtain Representative Meteorological Observations at Urban Sites. IOM Report 81, World Meteorological Organization, Geneva.

Stewart, I.D., and T.R. Oke, 2009a. Newly developed "thermal climate zones" for defining and measuring urban heat island magnitude in the canopy layer. Preprints, T.R. Oke Symposium & Eighth Symposium on Urban Environment, January 11–15, Phoenix, AZ.

Stewart, I.D., and T.R. Oke, 2009b. Classifying urban climate field sites by "local climate zones": The case of Nagano, Japan. Preprints, Seventh International Conference on Urban Climate, June 29–July 3, Yokohama, Japan.

Unger, J., Sümeghy, Z., Gulyás, Á., Bottyán, Z., and L. Mucsi, 2001. Land-use and meteorological aspects of the urban heat island. Meteorological Applications 8: 189–94.

Yamashita, S., 1990. The urban climate of Tokyo. Geographical Review of Japan 63B: 98–107.

Modeling Human Radiation Exchange in Outdoor Urban Environments

Introduction

Thermal exchange with the surrounding environment has direct effects on people's comfort, health and well-being. The human body exchanges energy with both the atmosphere and surrounding solid environment. A major way people are affecting their environment is through alteration of the landscape, especially urban development.

The variables and parameters of human radiation exchange analysis fall into two main categories, human factors and urban environment factors. The human factors include body area factors.

Currently, work at the University of Victoria, Dept. of Geography is focusing on improving our ability to estimate the effects of urban environments on human radiation exchange. Initial emphasis has been on estimating human body area factors.

The important body area factors are the effective radiation area factor (f_{eff}) and projected area factor (f_p). Body shape and posture control the area exposed to direct beam solar radiation (projected area, A_p) and the proportion of the total body surface area exposed to the surrounding radiant environment rather than to other body parts (effective radiation area, A_{eff}). f_p is A_p / A_{eff} and is used in the calculation of absorbed direct beam solar radiation. f_{eff} is A_{eff} / A_D (where A_D is the total body surface area) and is employed to estimate all solar and longwave radiation exchanges.

Recently, several researchers have used three different approaches to human body shape. The first one is experimental results from a photographic method such as used in the PMV (Predicted Mean Vote, Fanger 1972) and PET (Physiological Equivalent Temperature, Höppe 1993) models. The second is that the human body is assumed a cylinder used in the COMFA (COMfort FormulA; Brown and Gillespie 1986, Kenny et al. 2008) and OUT_SET* (Pickup and de Dear 2000) models. The COMFA model uses a directionless cylinder, and the OUT_SET* model uses Underwood and Ward's (1966) elliptical cylinder (direction: facing the sun). The last is a cube combined with 6-direction measured radiation data (4 cardinal directions, upward and downward) (Ali-Toudert et al. 2005, Matzarakis et al. 2007, Thorsson et al. 2007).

In this study, results from the radiation components of five existing human thermal exchange models [COMFA, MENEX (Man-ENvironment heat Exchange; Blazejczyk 1994, 2004), PET, OUT_SET* and Burt (Burt 1979 and modified by Tuller 1990) models] along with the 6 directional method (VDI 1998) and a new model (Park and Tuller model) employing recently derived average body area factors of standing and walking postures determined from a sample of normal- and over-weight Caucasian adults in Canada are compared. Emphasis is on the effect of differences in human body area factors.

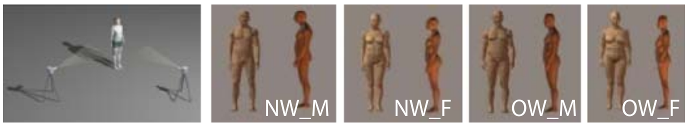


Figure 1. The process for creating 3D computer body models: (a) taking pictures; (b) 3D computer standing models. NW_M: normal-weight male, NW_F: normal-weight female, OW_M: over-weight male, and OW_F: over-weight female

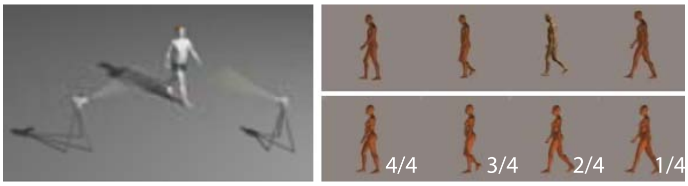


Figure 2. (a) Recording videos; (b) Walking postures of 1/4, 2/4, 3/4 and 4/4 positions of a stride from normal-weight male (top) and female (bottom) 3D models.

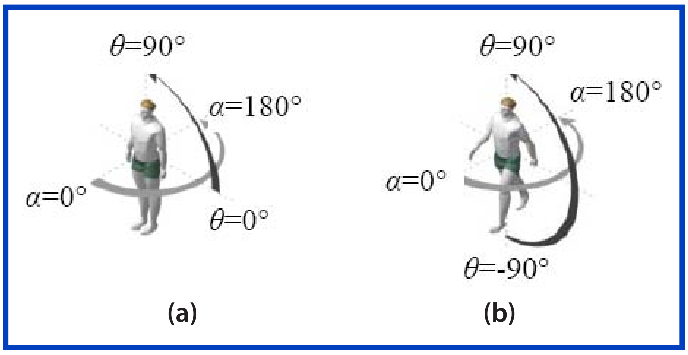


Figure 3. Variation of azimuth (α) and altitude (θ) angles for f_p values: (a) a quarter sphere ($0° \leq \alpha \leq 180°$, $0° \leq \theta \leq 90°$) for f_p values of standing posture since the body shape is symmetrical in the posture, (b) half a sphere ($0° \leq \alpha \leq 180°$, $-90° \leq \theta \leq 90°$) for walking posture because of asymmetrical body shape.

New human body model (Park and Tuller model)

The mean Body Mass Index (BMI) of contemporary Caucasian adults in Canada belongs to the over-weight category (Statistics Canada 2005), but the mean has been changing over time and varies with location/region. So, 139 subjects' body data (31 and 40 normal-weight male and female, 48 and 20 over-weight male and female, respectively) were analyzed using several computer software programs (e.g. ACDSee, AutoCad, Adobe Photoshop, 3DS Max and Poser). Standing and walking human body models were created (Figures 1 and 2) and used to find f_p and f_{eff} values (Figure 3).

The f_{eff} values of standing and walking postures had very small differences so that the representative f_{eff} value for human radiation exchange analysis in outdoor urban environments is 0.836, which means 83.6 percentage of human body surface area interacts with surrounding radiant environments.

Depending on the f_p application, we can consider two extremes of human body orientation. The first is the directionless orientation used when people are facing a variety of different directions. This mode is used in general modeling studies when we do not know the actual body orientation (Figure 4). The second is the directional orientation used when people face a known, consistent direction (Figure 5).

For more accurate radiation analysis, it is recommended that directional f_p should be considered primarily if the direction could be known.

Comparison of net radiation with existing human thermal exchange models

Materials and methods

To compare the existing radiation models simply, the effect of clothing was not included and clear summer data collected at 3 times at 13 measurement sites in Guelph, Ontario, Canada (43° 32´ N, 80° 14´ W) were used: in the morning (7:30-9:00 A.M.), at noon (11:30-1:00 P.M.) and in the afternoon (3:30-5:00 P.M.) (Figure 6). For this study, only the data observed at sunny sites were used. For more detail, see Park (2003).

The quantities of absorbed solar and net longwave radiation on the body surface area were compared among the models. The differences among them would be caused by their different adopted concepts of body shapes which resulted in various body area factors (Table 1). They also use different formulas to estimate sky emissivities (ε_{sky}) in longwave radiation algorithms. In this study, converted projected area factors ($f_p^*=A_p/A_D=f_p \times f_{eff}$) were used in computing absorbed K_b because the OUT_SET*, COMFA, Burt and MENEX models used f_p^* directly in their formulas.

Results and Discussion

f_p^* is important in estimating human direct beam solar radiation. The greatest differences between models occur at low solar altitudes, up to 0.31 at θ = 20° (Figure 7). They are in the range of about 0.12 - 0.15 between θ = 60° and 80°. Effects in urban modeling applications would depend on the urban morphology. They would be greater in more open landscapes where people on the ground are exposed to the low angle sun but be much less of a factor in low sky view factor environments where direct beam solar radiation will only reach the ground at high solar altitudes. f_p^* in three of the models, COMFA, PET and Park & Tuller, are relatively close and follow the same general trend through the entire range of solar altitudes.

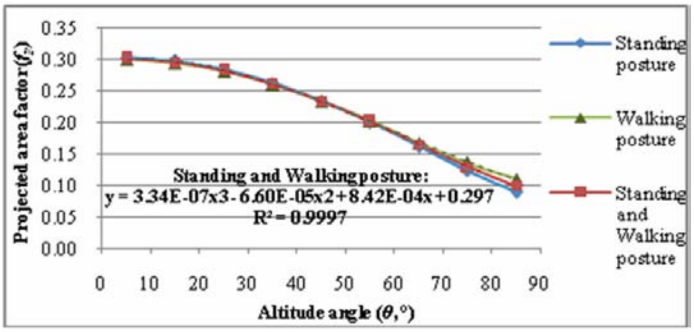


Figure 4. Directionless projected area factors (f_p) of standing and walking postures.

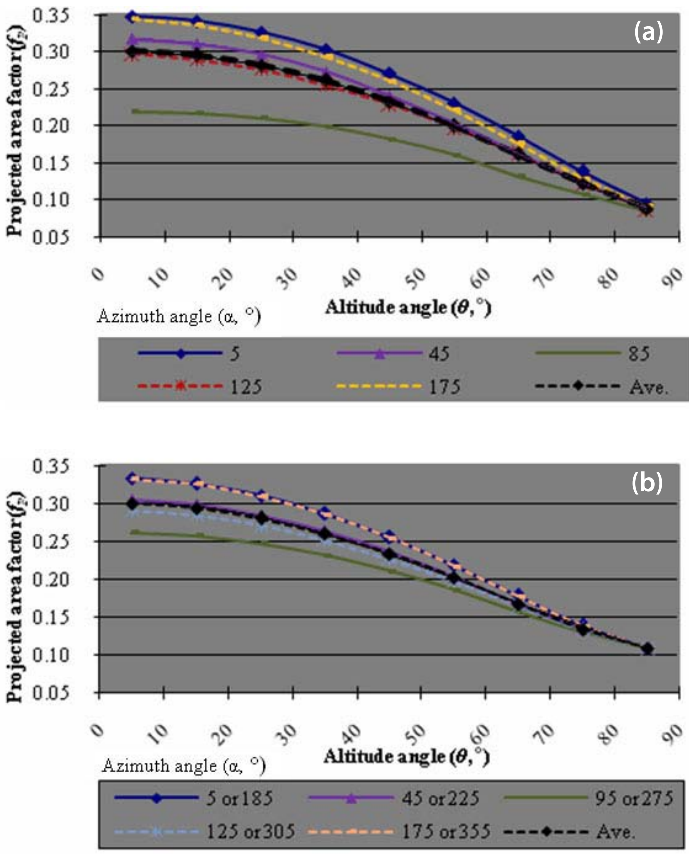


Figure 5. Directional projected area factors (f_p) dependent on solar altitude (θ) for (a) standing posture and (b) walking posture.

All five radiation estimation models and one experimental model, the 6-directional method, were compared in absorbed solar, net longwave and total net radiation (Figure 8).

There was a large range in computed human absorbed solar radiation between models at times and locations (150 - 175 Wm^{-2}) (Figure 8a). Model results fall into two groups in the morning and afternoon when solar altitudes were lowest. The PET, Park and Tuller, COMFA and 6-direction method model results comprise the low-value group. Human absorbed solar radiation computed

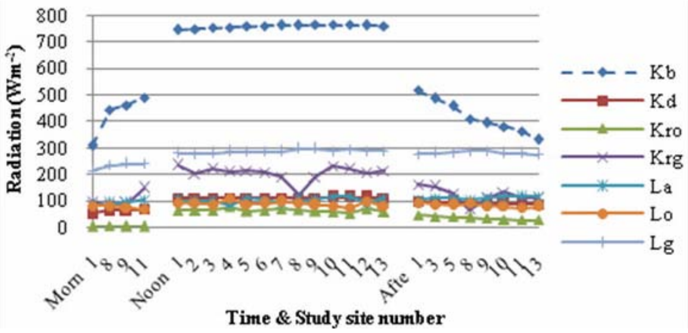


Figure 6. Observed incoming solar and longwave radiation. Incoming direct beam (K_b), diffuse beam (K_d), reflected (K_r) by vertical objects (buildings, trees and other structures) in the sky hemisphere (K_{ro}) and by the ground (K_{rg}) solar radiation; and longwave radiation coming from the sky (L_a) and objects (L_o, e.g. buildings, trees and other structures) in the sky hemisphere and ground (L_g) before being absorbed by the human body surface were set to constant, observed values and were directly used in all radiation models.

Table 1: The various f_p and f_{eff} values used in the models[a]

Model	f_{eff}	f_p
PET	0.725	$f_p = 3.81E-07\theta^3 - 6.55E-05\theta^2 + 3.02E-04\theta + 0.308$
OUT_SET*	0.75	$f_p^* = (0.42\cos\theta + 0.043\sin\theta)$
COMFA	0.78	$f_p^* = (1/\tan\theta)/\pi$
Burt	0.725	$f_p^* = 4.278\exp(-0.05120\theta)$
MENEX	No use	if $\theta \leq 5°$, $f_p^* = 1.4e^{(-0.51+0.368\theta)}$ if $\theta > 5°$, $f_p^* = 26.34/\theta - 0.329$
Park and Tuller	0.836	$f_p = 3.34E-07\theta^3 - 6.60E-05\theta^2 + 8.42E-04\theta + 0.297$

[a] $f_p^* = f_p \times f_{eff}$. The OUT_SET*, COMFA, Burt and MENEX models used directly f_p^*.

via the OUT_SET*, MENEX, and Burt models were about 100 Wm^{-2} greater than the lower-value group. The Burt model joined the lower-value group at noon.

Morning and afternoon differences in absorbed solar radiation reflect the lower solar altitude differences in f_p^* values (Figure 7 and 8a). Absorbed diffuse beam and solar radiation reflected from the surroundings computed via the MENEX model are higher than those from other models (Figure 8d). Employed f_{eff} values also create some differences between the models (Table 1 and Figure8a).

Maximum time and location differences in net longwave radiation were less than 39 Wm^{-2} (Figure 8b). The differences between models were consistent. The major control was differences in f_{eff} values.

Differences in total net-radiation were largely determined by those in absorbed solar radiation (Figure 8c and 8a). The differences explained above between the Park and Tuller model and the other models were shown in the averaged values by time in Figure 8d. The COMFA model had the closest results for all day with the Park and Tuller model. However, because the model estimated more in the morning and afternoon in absorbed solar radiation and estimated less in the morning and afternoon in net longwave radiation, the differences looked smaller but actually were much greater by each radiation. The PET model kept less estimation of average 22 Wm^{-2} with all solar altitudes in this study.

Conclusion

The major differences in human net-radiation between models were from the absorbed solar radiation component. Moreover, the f_p^* values were a major contributor to the absorbed solar radiation differences. Direct beam solar radiation incident on a human body has a major effect on the human total net radiation, but the effect in urban outdoor areas can be limited because of the shadows created by urban morphology. Diffuse and reflected solar radiation controlled by f_{eff} can be a key variable in dense urban outdoor areas. The f_{eff} differences were constant for all times and locations yielding relatively consistent differences between models in the various components of human-environment radiation exchange. The differences of f_p^* and f_{eff} make a significant contribution to the human radiation exchange.

Therefore, proper f_p and f_{eff} values should be used to make an accurate estimation of absorbed solar and net longwave radiation. The Park and Tuller model's body area factors (f_p and f_{eff}) are close to those of a number of recent studies and seem to hold promise for improving radiation analysis in human thermal exchange models.

In continuing work, urban environment factors will be compared with measured radiation data from various urban sites using 3D computer software programs. Modified urban area factors and new body area factors will be used to develop a more precise and convenient tool for urban/landscape planners to adapt to their works.

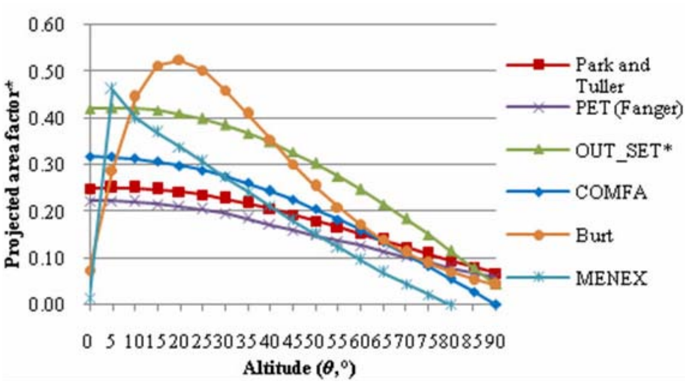


Figure 7. Comparison of projected area factors (f_p^*) incident on a horizontal surface.

References

Ali-Toudert, F., Djenane, M., Bensalem, R., and Mayer, H., 2005. Outdoor thermal comfort in the old desert city of Beni-Isguen, Algeria. Climate Research 28: 243-256.

Blazejczyk, K., 1994. New climatological-and-physiological model of the human heat balance outdoor (MENEX) and its applications in bioclimatological studies in different scales. In: Blazejczyk K, Krawczyk B (eds) Bioclimatic Research of the Human Heat Balance. Polish Academy of Sciences, Institute of Geography and Spatial Organization, Warsaw, pp. 27-58.

Blazejczyk, K., 2004. Assessment of radiation balance in man in various meteorological and geographical conditions, Geographia Polonica 77: 63-76.

Brown, R.D., and Gillespie, T.J., 1986. Estimating outdoor thermal comfort using a cylindrical radiation thermometer and an energy budget model, Int J Biometeorol 30: 43-52.

Burt, J.E., 1979. A Model of Human Thermal Comfort and Associated Comfort Patterns for the United States. C. 1BW. Thornthwaite Associates, Centerton, NJ, USA.

Fanger, P.O., 1972. Thermal Comfort: Analysis and Applications in Environmental Engineering. McGraw-Hill, NY, USA.

Höppe, P.R., 1993. Heat balance modeling, Experientia 49: 741-746.

Kenny, N.A., Warland, J.S., Brown, R.D., and Gillespie, T.G., 2008. Estimating the radiation absorbed by a human, Int J Biometeorol 52: 491-503.

Matzarakis, A., Rutz, F., and Mayer, H., 2007. Modelling radiation fluxes in simple and complex environments-application of the RayMan model. Int J Biometeorol 51: 323-334.

Park, S., 2003. Estimating Radiation Received by a Person in the Landscape. MSc thesis, University of Guelph, Guelph, Ontario, Canada.

Pickup, J., and de Dear, R., 2000. An outdoor thermal comfort index (OUT-SET*) – Part I - the model and its assumptions. In: de Dear R, Kalma J, Oke T, Auliciems A (eds) Biometeorology and Urban Climatology at the Turn of the Millennium-selected papers from the Conference ICB-ICUC'99 (Sydney, 8-12 November 1999), WCASP-50, WMO/ TD-No. 1026, World Meterological Organization, Geneva, Switzerland, pp. 279-283.

Statistics Canada, 2005. Canadian Community Health Survey (CCHS 2004): Nutrition. Minister of Industry, Ottawa, Canada.

Thorsson, S., Lindberg, F., Eliasson, I., and Holmer, B., 2007. Different methods for estimating the mean radiant temperature in an outdoor urban setting. Int J Climatol 27: 1983-1993.

Tuller, S.E., 1990. Standard seasons, Int J Biometeorol 34: 181-188.

Underwood, C.R., and Ward, E.J., 1966. The solar radiation area of man. Ergonomics 9: 155-168.

VDI, 1998. VDI 3787, Part 2: Environmental Meteorology-Methods for the Human Biometeorolog-ical Evaluation of Climate and Air Quality for Urban and Regional Planning at Regional Level Part 1: Climate. Berlin, Germany.

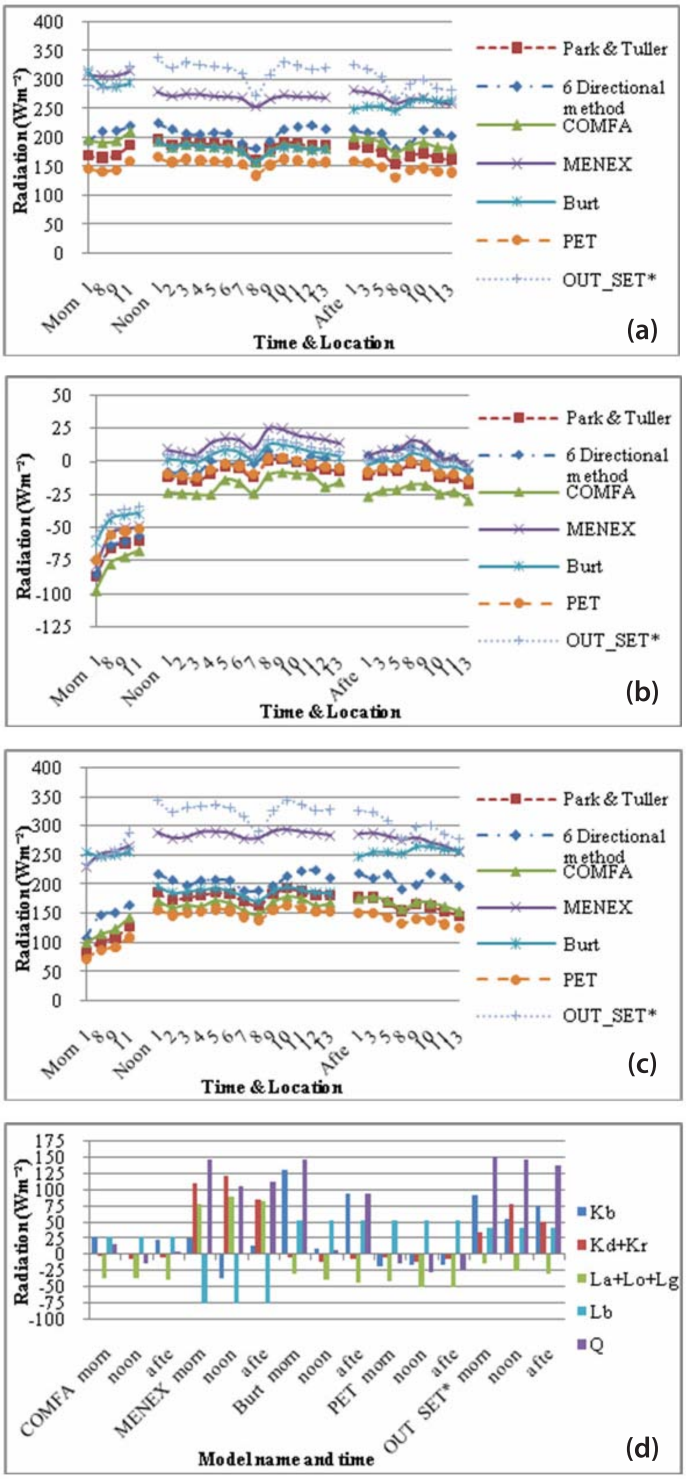


Figure 8. Comparison of (a) absorbed solar radiation, (b) net longwave radiation, (c) total net radiation and (d) differences on absorbed radiation (the Park and Tuller model – the other models).


Sookuk Park
sooland@gmail.com

Stanton E. Tuller
stuller@mail.geog.uvic.ca

Climate Lab, Department of Geography,
University of Victoria, Victoria, B.C., Canada

The Effects of Building Parameters on Wind Velocity and Air-flow Type in Urban Settlements

Today, performance of built environment from the viewpoint of the environmental factors can be calculated in the design phase by using computer based simulation of mathematical models in most of developed countries and in Turkey. But theoretical methods or models related to the wind effects have not satisfactorily been developed to obtain realistic data on the evaluation of the built environment alternatives.

In this report the results of the TUBITAK-INTAG 214 project, an experimental study, has been conducted in I.T.U. Faculty of Architecture Physical Environment Control Laboratory wind tunnel, for investigating the effects of design factors on wind velocity and flow type in urban settlements are presented (Ok et al., 1996).

Wind effects on urban areas

Wind is a natural environmental factor which has impacts on the buildings such as pressure and snow load statically, vibration dynamically and in terms of health and comfort thermal transmission, pollution dispersion, noise scattering, spread of fire, leak of rain etc. environmentally.

Nowadays, building designers and urban planners have to solve the problems that could occur because of those impacts. It's very easy and reliable to evaluate the performance of all building alternatives by objective criteria in design phase as opposed to evaluating by intuitive approaches in practice as ancient days. The effects of the many of the universal elements on performance of the building models can be simulated by mathematical models in computers in many of the developed countries and also in Turkey. When the natural factor to be discussed is "wind", numerical methods that would be used for evaluating the performance of the model buildings wouldn't be enough. Nevertheless, the performance of the much more complex settlement models could be evaluated experimentaly.

The wind velocities and flow types depending on the geometrical variables related to the buildings in settlements and open spaces are altered. These variables related to the open space in urban settlement are dimensions of the open space, shape and placement.

Figure 1. Wind tunnel of Physical Environment Control Laboratory of Faculty of Architecture. Air entry to the tunnel is provided by a bell-mouth of 250x250x0.30 m. Two flow-shaping modules are of 2.00x2.00x0.92 m in section. Square-section observation module of 1.05x1.05 m connects flow shaping module with an adaptor of 1.30 m in length. An axial type fan has been mounted to the other side of the tunnel. The engine has a power of 1.5 kW and has a period of 1450 pulse/sec.

An experimental study has been done on a prototype settlement for investigating the effects of these variables. The results and findings of the dimensions of open space derived from the experiment will be summarized hereafter.

Experimental tools

The wind tunnel of Physical Environment Control Laboratory in which the experiments have been implemented is an absorbtive-type tunnel that can be seen in Fig. 1.

In order to observe velocity dispersion either with models or not, Hot-wire CTA (Constant Temperature Anemometer) produced by DANTEC has been used in the experiments.

The measurements giving effectiveness of the open-space dimensions

The velocity measurements have been done on a profile plane passing through the middle of a square form in order to examine the effectiveness of the open-space dimensions. The open-space urban model consists of several touching cubic building forms which have a dimension of $d_x=d_y=d_z=0.04$ m.

The effectiveness of the open urban space along

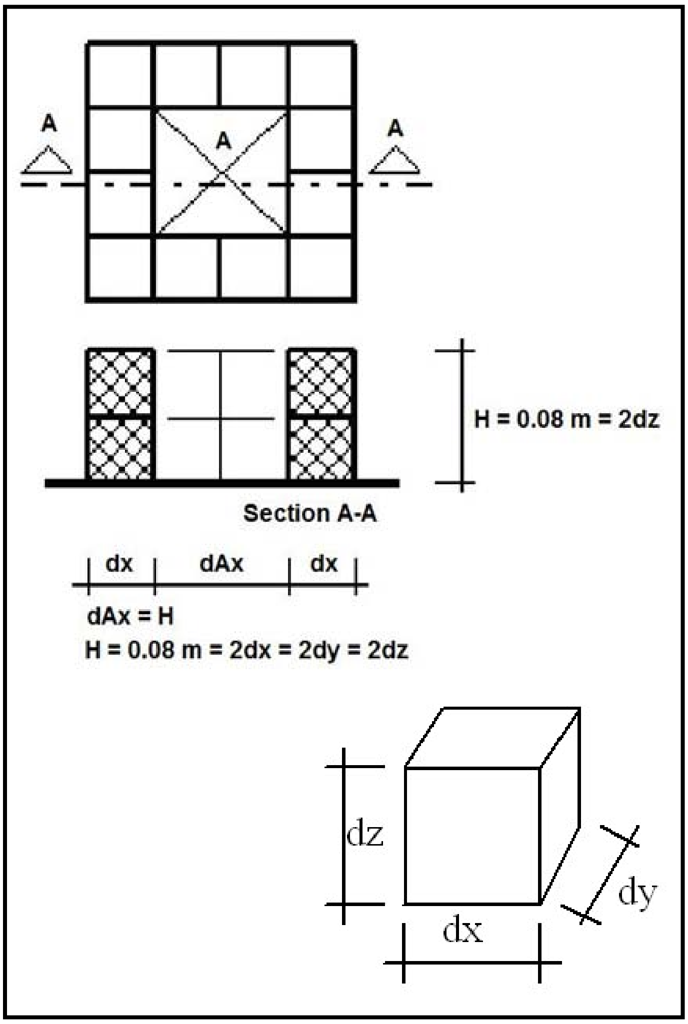


Figure 2. The plans that have been used for examining the effects of the dimensions or the measures of an open space on the wind velocity.

with the air flow has been examined by changing the dimensions of the courtyard as dA_x= H, 2H, 3H, 6H and 8H. The building height has been arranged as H=0.08 m or H=2d_z for the position that one side of open urban space equals the whole building height, as can be seen in Fig. 2. That is because the unit measure of 0.04 m could not be sufficient for the replacement of measurement nib (probe).

The deviation of the velocities that are obtained from the measurements has been taken in the middle vertical and horizontal axes of the observation room along with the flow direction are taken place around 0.18. The mean velocity value is ~6.5 ms^{-1} and the turbulence intensity value is ~0.020 with max. of 0.045 and min. of 0.006. These values of turbulence intensity are appropriate for the characteristic obtained in open ground and in empty observation room (Yüksel, 1974; Rayment & Yhap, 1976).

The profiles derived from the velocity measure-

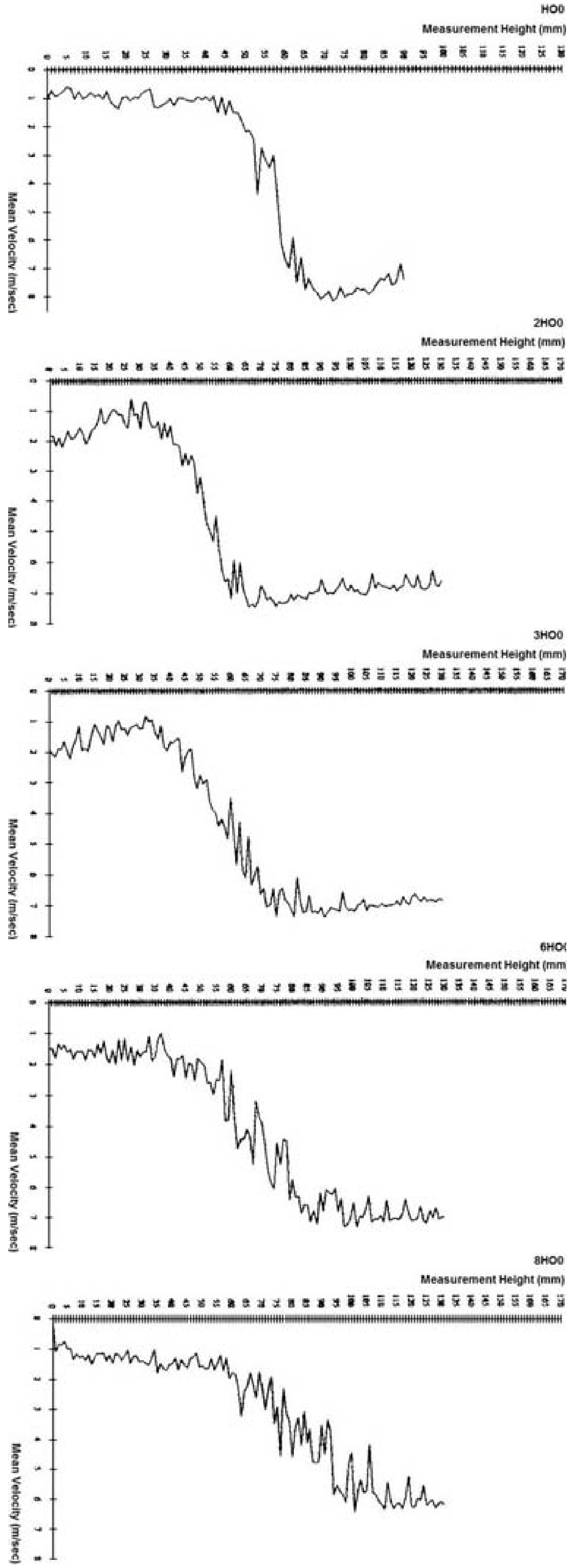


Figure 3. Standard deviations in velocities in the point of r=0.65 *l*

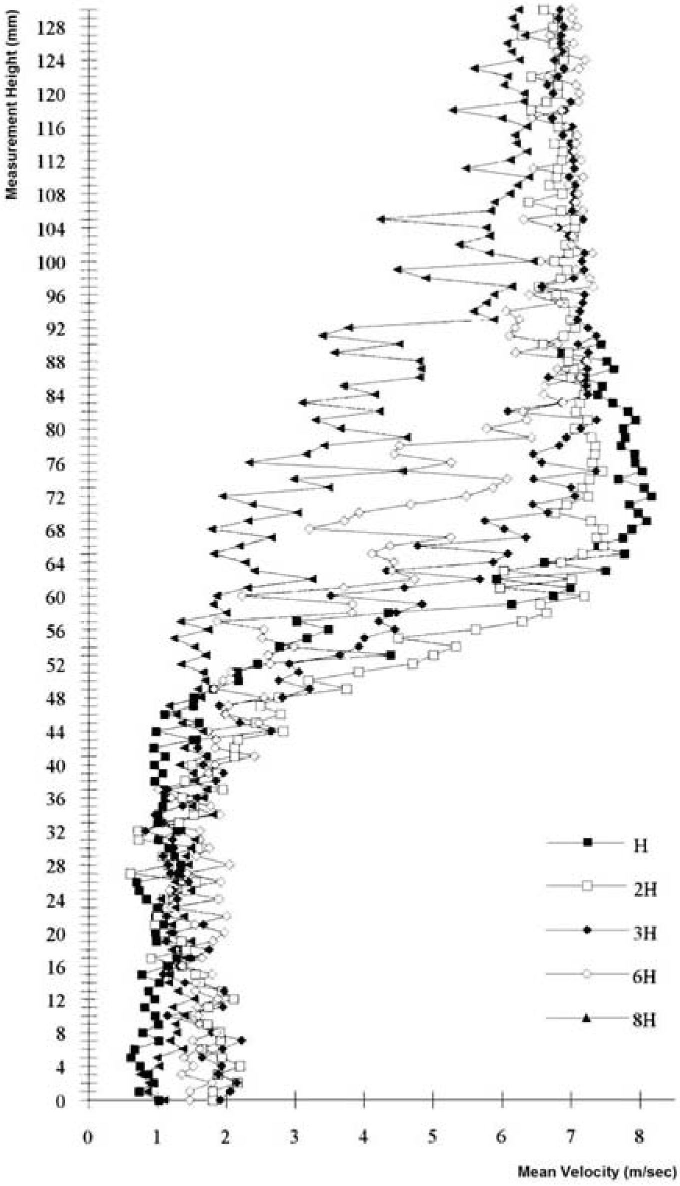


Figure 4. Mean velocity profiles versus measurement height.

ments has been done along with the observation room, starting from the distance of x=0.07 *l* to the collector, in the points of x=0.13 *l*, x=0.20 *l*, x=0.27 *l*, x=0.67 *l*, x=0.83 *l* and in a distance of "ε" to the base of the observation room till z=1.70 m in 1 mm intervals shows that the laminar current converts to the turbulence current. When the curve fitting process has been applied to the profile that has been obtained in the entry of the observation room whilst *α* was 0.04 than it has reached till 0.09 in the following. The standard deviations in velocities in the point of r=0.65 l that was the most successful point in being curve fitting process amongst the profile planes as can be seen in Fig. 3 has created great oscillation between 0-40 mm and has produced a boundary layer with turbulence.

Interpretation of the velocity profiles obtained by variations in the dimension, form and settlement of the open space

The datum of H, 2H and 6H of this research in comparison with the datum of Castro and Robins' measurements indicated as x=0, $x=1^{Hb}$, $x=2^{Hb}$ the velocity profiles look like with each other as can be seen in Fig. 4. The position of dA_x=2H and the measurement distance of x=H are consistent with the "D" position in terms of absolute values and formation. The variation till z=0.60H in positive values appearing as if in decrease, is constituted in negative values between this altitude and the first one; however the hot wire anemometer shows these values positive because the way of current transfer on the wire is not indicated. When this condition is taking into account, the proportional velocity U/U_{ref} starts at -0.15, passes by zero at 0.6H then increases quickly and reaches 1.1 at 1.6H. After these altitudes, as can be seen in Fig. 5, the U value equals U_{ref} around z=2.5H. This condition suits to the measurements of Castro and Robins (Zhang et al., 1993).

The formation of the velocity profiles depending on the increasing on the dA_x when compared with the velocity profiles of the studies of Okamoto, Nakaso, Kawai for the position of the distance of obstructions equal to the 8H, very close results have been obtained. According to these conclusions some profiles can be compared with each other like dA_x=8H with X/D=4.5 (Okamoto et al., 1993).

The horizontal component velocity values measured by Hotwire Anemometer are decreasing to the lowest levels in z=0.5H because of the velocity vectors or the current becomes vertical near the recirculation area of the model building (Hunter, Watson, Johnson, 1990/91).

Conclusions

The effect of dimension of an open space which is one of the variations of an artificial environment on vertical velocity profiles and current type arises by the differentiation on the levels that the velocities reach on various altitudes. If the open space dimension equals to dA_x=H, the lowest level velocities occur in very close points to the surface. Opposite of that if the space dimension equals to dA_x=2H and dA_x=3H, the highest level velocities and to dA_x=6H and dA_x=2H, medium level velocities occur but as reaching the highest altitudes because of the reverse effect on dA_x=2H and dA_x=3H, the dropping point of the velocities occur on z=0.7H. On the points of dA_x=6H and dA_x=8H after a small decrease on the velocities on z=0.5H, it shows a stable variation curve with a slow continuing increase.

These effects are consistent with the existent researches with when being compared and also the results that causes to expose the geometry of track area of windward side building.

The same variable produces the same effect on the current type. The increases and the decreases on the turbulence intensities are having almost the same effect as pointed out above.

Another parameter effecting by the open space dimension is discomfort parameter. The discomfort level has dropped from 0.7 to 0.4 especially on the points that are close to the earth used for walking purposes like pavements, as the values of dA_x=2H, dA_x=3H, dA_x=dH, dA_x=8H increase in spite of formation of the space. The discomfort parameter value become greater than 1 on the measurements of dA_x=H, 2H, 3H at the roof level of the building and increases as buildings get closer to each other.

References

Hunter, L.J., Watson, I.D., Johnson, G.T., 1990/91. Modeling air flow regimes in urban canyons, Energy and Buildings, 15-16, 315-324.

Ok, V., Özsoy, A., Atlı, V., Özgünler, M., Serteser, N. et al., 1996. An analysis of the effect of design parameters on wind speed and flow type in an urban open space, TUBITAK (Turkish Scientific and Technical Research Council) INTAG-214, İstanbul.

Okamoto, S., Nakaso, K., Kawai, I., 1993. Effects of rows of two dimensional square ribs on flow property along plane wall, JSME International Journal, Series B., 36, No.1, 121-129.

Rayment, R., Yhap, B.J., 1976. Boundary layer simulation in a small wind tunnel, BRS, Current paper, 80/76.

Yüksel, A.N., 1974. Application of experimental aerodynamics to the industry. Thesis, İ.T.Ü. Faculty of Mechanical Engineering.

Zhang, Y.Q., Huber, A.H. Arya, S.P., Synder, W.H., Numerical simulation to determine the effects of incident wind shear and turbulance level on the flow around a building, Journal of Wind Engineering and Industrial Aerodynamics, 46&47, 129-134.

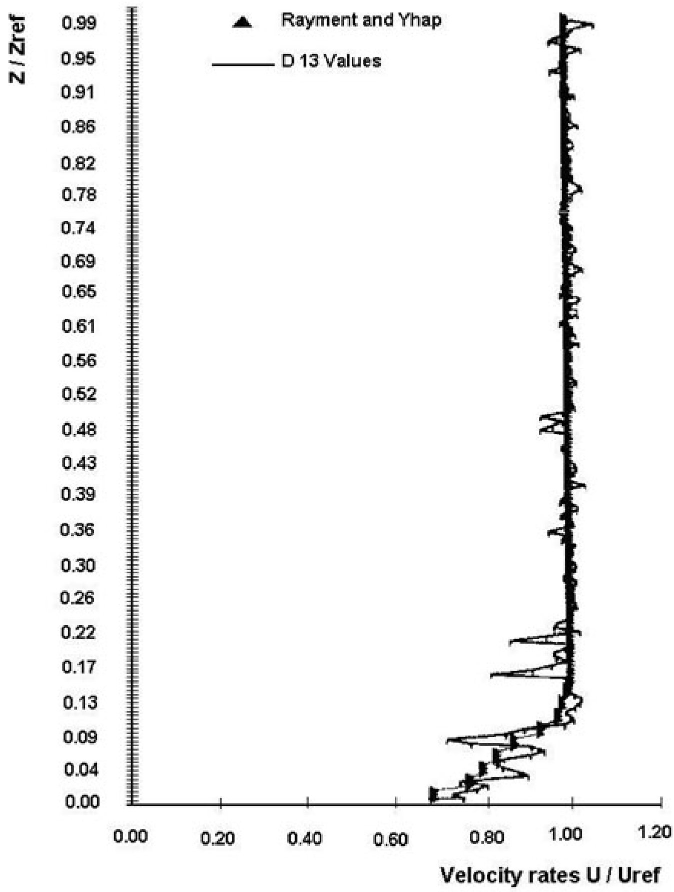


Figure 5. Velocity rates versus Z/Z_{ref}.

Nuri Serteser
serteser@itu.edu.tr

Vildan Ok

Istanbul Technical University
Faculty of Architecture
Building Technology Division
Istanbul, Turkey

Near Ground Air Temperature Calculation Model Based on Heat Transfer of Vertical Turbulent and Horizontal Air Flow

In order to calculate the air temperature of the near surface layer in urban environment, the surface layer air was divided into several layers in the vertical direction, and some energy balance equations were developed for each air layer, in which the heat exchange due to vertical turbulence and horizontal air flow was taken into account. Then, the vertical temperature distribution of the surface layer air was obtained through the coupled calculation using the energy balance equations of underlying surfaces and building walls. Moreover, the measured air temperatures in a small area (with a horizontal scale of less than 500 m) and a large area (with a horizontal scale of more than 1000 m) in Guangzhou in summer were used to validate the proposed model. The calculated results accord well with the measured ones, with a maximum relative error of 4.18%. It is thus concluded that the proposed model is a high-accuracy method to theoretically analyze the urban heat island and the thermal environment.

1. INTRODUCTION

The surface layer is a system of the atmospheric boundary layer close to the ground with the thickness being 1/10 of the whole atmospheric boundary layer. Generally, it is considered that the thickness of surface layer is several hundred meters. The human being lives within the surface layer mainly, so it keeps a close relationship with human being's life. At present, the issue of surface layer over special underlaying surface such as surface layer of urban areas and different vegetations as well as the mutual relationship between it and underlaying surface is still researchable.

2. SURFACE THERMAL EQUILIBRIUM EQUATION

The thermal equilibrium of any surface i in the area can be expressed as Formula (1), where these surfaces include roof, external wall and ground.

$$S\downarrow_i - S\uparrow_i + L\downarrow_i - L\uparrow_i = Q_{c(i)} + Q_{d(i)} + Q_{e(i)} \quad (1)$$

where S is short wave radiation, L is long wave radiation, ↓ ↑ are for downward and upward radiation, Q_c is convection heat exchange between air and surface, Q_d is conduction heat transfer of solid meterial, and Q_e is evaporation heat transfer.

3. THERMAL EQUILIBRIUM OF SURFACE LAYER AIR

The thermal transfers of air and external environment are:

(1) Sensible thermal transfer between underlaying surface and surface layer;

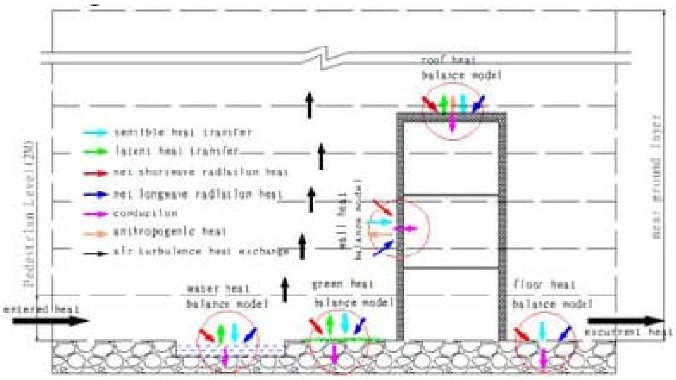


Figure 1. Near ground air heat balance model.

(2) Energy brought and taken away through air inflow and outflow;

(3) Sensible thermal transfer between external building wall and ambient air;

(4) Anthropogenic Heat.

The thermal transfer within the surface layer includes mainly: thermal transfer caused by air molecular diffusion and turbulence. As for the thermal equilibrium schematic of surface layer air, see Fig. 1.

In the urban surface layer shown in Fig. 1, take out a thin layer along with the contour, then the thermal equilibriums considered are:

(1) Horizontal air flow: if the mass flow in the area within unit time is V_{mi}, the heat brought is $C_a V_{mi} T_{in}$ and if the mass flow in the area is V_{mo}, the heat taken away is $C_a V_{mo} T$, the internal heat change in the thin layer caused by horizontal air flow within unit time can be obtained from Formula (2).

$$Q_1 = C_a V_{mi} T_{in} - C_a V_{mo} T \quad (2)$$

where C_a is air specific heat, T_{in} is incoming air temperature, T is mean air temperature of the thin layer.

(2) Internal thermal source: the internal thermal source in the thin layer is divided into two parts; Part 1 is the sensible thermal transfer between other surface (wall surface) and air of the thin layer; Part 2 is the man-made heat dissipating capacity of other surface in the thin layer.

$$Q_2 = \left[\sum_{i=1}^{n} H_{c,i} A_i (T_{s,i} - T) + \sum_{i=1}^{n} Q_{a,i} A_i\right] \quad (3)$$

where $H_{c,i}$ is convection heat exchange between air and surface i, A_i is area of surface i, $T_{s,i}$ is external surface temperature of surface i, and $Q_{a,i}$ is anthropogenic heat of unit area.

(3) Diffusion: the heat from surface z to the thin layer within unit time due to diffusion is

$$-C_a\rho A(D+K_t)\frac{\partial T}{\partial z},$$

the heat from Surface $z+\Delta z$ to the thin layer is

$$-C_a\rho A(D+K_t)\frac{\partial T}{\partial z}+\frac{\partial}{\partial z}\left[-C_a\rho A(D+K_t)\frac{\partial T}{\partial z}\right]dz,$$

the heat change caused within unit time due to diffusion can be obtained from Formula (4):

$$Q_3=\frac{\partial}{\partial z}\left[C_a\rho A(D+K_t)\frac{\partial T}{\partial z}\right]dz \qquad (4)$$

where D is air molecular thermal diffusion coefficient, K_t is air turbulence thermal diffusion coefficient, A is horizontal area excluding building area, and dz is the thickness of thin layer.

The internal heat change of the above thin layer that will cause the air temperature change in the thin layer can be obtained from Formula (5):

$$Q_4=-C_a\rho\frac{\partial T}{\partial \tau}Adz \qquad (5)$$

Formula (6) can be obtained from the thermal equilibrium in the thin layer.

$$Q_1+Q_2+Q_3+Q_4=0 \qquad (6)$$

Put the above expressions of Q_1~Q_4 into Formula (6), and Formula (7) can be obtained after rearrangement:

$$M_{a,j}C_a\frac{\partial T}{\partial \tau}=(C_aV_{mi}T_{in}-C_aV_{mo}T)+C_a\rho A(D+K_t)dz\frac{\partial^2 T}{\partial z^2}+Q_v \qquad (7)$$

where $M_{a,j}$ is the weight of air in the thin layer, and Q_v is the inner heat source.

Equation (7) is the control equation of the air temperature model of surface layer. After the discreteness of this equation, if the initial condition and boundary condition are given, all air temperatures can be obtained through forward elimination and backward substitution.

4. CALCULATION OF THE HEAT EXCHANGE COEFFICIENT OF TURBULENCE

According to the first order closure scheme (K theory), the air turbulent motion is similar to the air molecular motion. And the turbulence thermal transmission is similar to molecular thermal transmission, so the thermal flux caused by turbulence can be:

$$H_t=-c\rho K_t\frac{dT}{dz} \qquad (8)$$

When the aerosphere section is unstable and the turbulence transmission is much faster than molecular transmission, $K_t >> D$, and at this time, the thermal transmission in the air $H=H_d+H_t\approx H_t$, so due to unit mass temperature change caused by thermal transmission in the air can be expressed as:

$$\frac{dT}{d\tau}=K_t\frac{\partial^2 T}{\partial z^2} \qquad (9)$$

That is to say the turbulence thermal diffusivity is subject to typical heat conduction equation, where K_t value changes in accordance with the change of air condition.

The turbulence thermal diffusivity is not the fixed air physical property parameter but a changeable parameter at any time, so it can only be obtained through iterative computation based on area roughness, air temperature, air velocity and stableness. K_t can be expressed as Formula 10 (for concrete calculation methods see Zhang Qiang, Lv Shi-hua, 2003; Gao Zhiqiu, et al., 2002; Jun Tanimoto, et al., 2004; Sang-Hyun Lee, Soon-Ung Park, 2008; Ian N. Harman, John J. Finnigan, 2007; David Hamlyn, et al., 2007).

$$K_t=\kappa u_* z/\phi_2 \qquad (10)$$

where κ is karman constant, u_* is friction velocity, z is vertical height, and ϕ_2 is profile function of air temperature.

5. MODEL VERIFICATION AND RESULT

In order to verify the accuracy of the above theoretical model and calculation method, the measurement results for the small sized area (Donghu area of the South China University of Technology) and large sized area (Guangzhou University City) in Guangzhou are adopted. The air temperature of Donghu area of the South China University of Technology was measured from July 9 to 13, 2007.

The meteorological data recorded in weather station during the measurement was adopted as the incoming flow parameter. And the average air temperature within the human activities height (2m) obtained from the calculation model for surface layer air temperature mentioned in this text was adopted and compared with the measured result of Donghu area, see Fig. 2 and Table 1.

From Fig. 2 and Table 1, the change trends of calculated values and measured values are similar to each other. The maximum relative error is 4.18%, which was occurred at 13:00 on July 12. The average relative error is 1.25%, and number of hours with relative errors being less than 3% accounts for 93.3% of those for measurement, from which it can be concluded that the accuracy of average temperature obtained through this model for human activities height is much higher.

The error between measured air temperature and calculated value is caused probably by the following points:

(1) Some simplified and assumed treatments of model caused the error, for instance, other surfaces were probably under insulation boundary conditions in addition to the heat exchange along with the air flow, which would reduce the heat exchange between the calculated area and other areas in parallel with the air flow;

(2) The complicated geometrical relation of outdoor environment caused the error. Some simplified treatments were performed for the model when the angle factor and shadow factor were calculated, causing the main heat source of the area; deviation occurred during calculation of solar radiation;

(3) During this calculation, influence of man-made heat was not considered, which was one of the reasons for causing errors.

The air temperature vertical distribution diagram for Donghu area at four typical hours on July 13 was made as Fig. 3. From Fig. 3, the temperature of surface layer is under a temperature inversion condition at 1:00 am, where air temperature the bottom is 30.54°C, while that of the top is 30.61°C. And at 6:00 during sunrise and 18:00 during sunset, the temperature gradient is low, which is isothermal. At 12:00 at noon, the bottom is 35.66°C, while that of the top is 34.62°C, showing that the temperature of surface layer is unstable. In addition, during the calculation for the temperature of surface layer for Donghu area, the calculated surface layer height is 300m, showing that at 12:00 at noon, the influence of the thermal environment of underlaying surface on the temperature of surface layer can reach up to about 300m; when this height is exceeded, the surface layer height calculated is added, the influence on the air 2m away from the ground will be less than 0.1°C. According to Document: the thickness of surface layer will change along with the change of stability; when it is unstable, it can reach up to 100m or even higher; when it is stable, it can be only

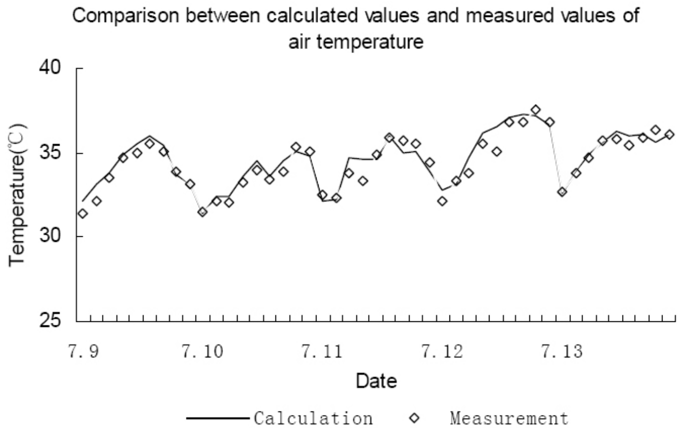


Figure 2. Comparison between calculated values and measured values.

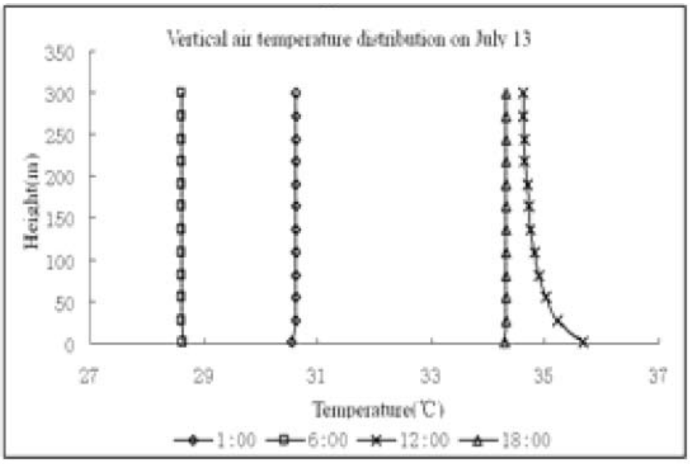


Figure 3. Vertical air temperature distribution of East Lake.

10m or 20m. The analysis result of this text is similar to the description of this document, showing that the calculation model mentioned in the text is reasonable for the description of the air temperature of surface layer.

The comparison between the air temperatures of Guangzhou University City measured from August 28 ~ 30 2007 and those calculated from the model is adopted.

During the two comparing periods, the average relative error is 1.96%, where the hours with relative error being less than 5% account for 93.7% of the whole pe-

Table 1. Statistics analysis of calculated values and measured values of air temperature at East Lake area.

Item	Sample	Mean	Standard Deviation
Measurement/℃	45	34.38	1.57
Calculation/℃	45	34.59	1.54
absolute error /℃	45	0.43	0.33
Relative error /%	45	1.25	0.98

Table 2. Statistics of calculated value and measured value.

Item	Sample	Mean	Standard Deviation
Measurement/℃	144	30.06	3.11
Calculation/℃	144	30.25	3.68
Absolute error /℃	144	1.96	2.26
Relative error /%	144	0.63	0.78

riod; the hours with relative error being more than 5% account for 6.3% of the whole period; the hours under day time solar radiation with higher temperature is 10:00 ~ 15:00; the hours with relative error being less than 1% account for 41% which are almost under night. This can show further that the underlaying surface is the main heat resource for surface layer air. During day time when the influence of solar radiation on underlaying surface temperature is high, the calculation for underlaying surface temperature is determined by the calculation for air temperature.

The temperature variation at vertical direction of Guangzhou University City area at four typical hours on August 29 was made too, see Fig. 5. It is shown that the temperature variation trend at the height direction of Guangzhou University City area at four typical hours is similar to that of Donghu area, where the difference is that, due to the large size of the university area, the influence of underlaying surface on the air temperature of surface layer rises, at noon of August 29, the maximum influenced height can reach up to 850m.

6. CONCLUSION

In this article, the surface layer of urban area at vertical direction is divided into several sub-layers, and energy balance equations for all air sub-layers are established, where the heat exchange of turbulence at vertical direction and that of incoming air at horizontal direction are considered. From the combined calculation of ground and building wall surface equations, the air temperature of surface layer is distributed vertically.

From the comparison between the measured air temperature of small sized Donghu area and average air temperature calculated through this model within 2m high from the ground, the error from both area are low, the maximum relative error is 4.18% and the average relative error is 1.25%.

From the comparison between the results measured from August 28~30 and October 5 ~7 2007 for Guangzhou University City, the average relative error for the measured value and calculated value is 1.96%, hours with relative error being less than 5% account for 93.7% of the whole period.

The calculation model for air temperature of surface layer mentioned in this text can meet the accuracy requirement of thermal environment research basically, and can be used for the calculation for air temperature of surface layer of urban area and is suitable for the simplified formula for WBGT (Wet Bulb Globe Temperature) as well as predicting thermal environment quality after performance of urban plan and building design.

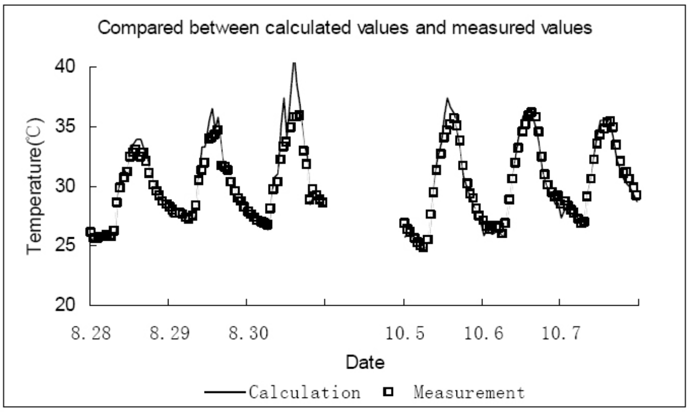


Figure 4. Comparison between calculated value and measured values.

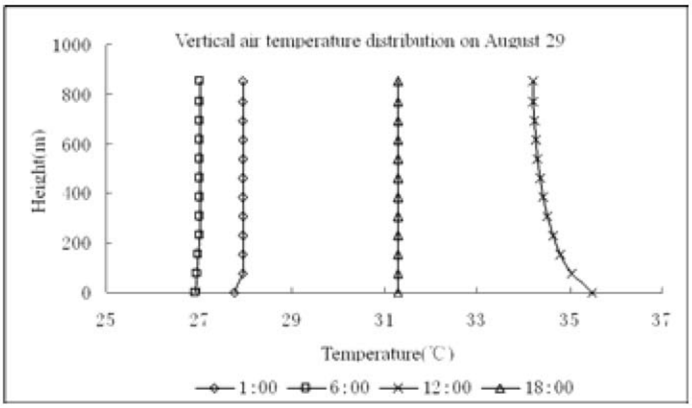


Figure 5. Vertical air temperature distribution of Guangzhou University City.

7. ACKNOWLEDGEMENTS

The study was supported by National Natural Science Foundation of China (Project No. 50538040, 50720165805, 50808083), Natural Science Foundation of Guangdong Province of China (Project No. 8251064101000006), the 111 Project (Project No. 111-2-13) .

We are grateful to IAUC and ICUC-7 for giving us an opportunity to exchange urban climate research progress with scholars around the world. At the ICUC-7, we submitted eight papers, among them, three papers were oral presentation and five papers were poster presentation.

REFERENCES

David Hamlyn, Trevor Hilderman, Rex Britter. A simple network approach to modelling dispersion among large groups of obstacles [J]. Atmospheric Environment, 2007,41(28): 5848–5862.

G. Mills. An Urban Canopy-Layer Climate Model [J]. Theoretical and Applied Climatology. 1997.57(3-4):229-244.

Gao Zhiqiu, Bian Lingen, Lu Changgui, et al.Estimation of aerodynamic parameters in urban areas [J]. Quarterly Journal of Applied Meteorlolgy, 2002,13(1):26-33.

Hiroyuki Kusaka, Hiroaki Kondo, Yokihiro Kikegawa, et al. A Simple Single-Layer Urban Canopy Model For Atmospheric Models: Comparison With Multi-Layer And Slab Models [J]. Boundary-Layer Meteorology, 2001,101(12): 329–358.

Hiroaki Kondo,Yutaka Genchi, Yukihiro Kikegawa, et al. Development of a Multi-Layer Urban Canopy Model for the Analysis of Energy Consumption in a Big City: Structure of the Urban Canopy Model and its Basic Performance [J]. Boundary-Layer Meteorology, 2005,116(9): 395–421.

Ian N. Harman, John J. Finnigan. A simple unified theory for flow in the canopy and roughness sublayer [J]. Boundary-Layer Meteorol, 2007,123(5):339–363.

Jun Tanimoto, Aya Hagishima, Parichart Chimklai. An approach for coupled simulation of building thermal effects and urban climatology [J]. Energy and Buildings, 2004.36: 781–793.

Meng Qinglin, Chen Qigao, Ran Maoyu,et al. Derivation of the vaporising heat transfer coefficient he [J]. Acta Energiae Solaris Sinica, 1999, 20(2):216-219.

Ran Maoyu, Yang Ruohan, Meng Qinglin. Prediction model and calculation method of the boundary surface temperature of out door space under solar radiation [J]. Acta Energiae Solaris Sinica, 2006,27(7):719-724.

Sang-Hyun Lee, Soon-Ung Park. A Vegetated Urban Canopy Model for Meteorological and Environmental Modelling [J]. Boundary-Layer Meteorol, 2008,126(1): 73-102.

Xiao Yongquan, Wang Fei. Building envelope's dynamic heat balance model under solar radiation and example analysis [J]. Acta Energiae Solaris Sinica, 2006, 27(3):270-273.

Zhang lei, Meng Qinglin, Shu Lifan. Analysis on Dynamic Thermal Balance Model of Landscape Water and its Numerical Simulation [J]. Building Science, 2007,23(10):58-61.

Zhang Qiang, Lv Shi-hua. The Determination of Roughness Length over City Surface [J]. Plateau Meteorology, 2003,22(1):24-32.

Qinglin Meng
arqlmeng@scut.edu.cn

Lei Zhang
arzhang@scut.edu.cn

State Key Laboratory of Subtropical Building Science
South China University of Technology, Guangzhou 510640, China
Web site: www.beel.net.cn

Pedestrian Thermal Comfort Index Applied to Wind Tunnel Erosion Technique Pictures

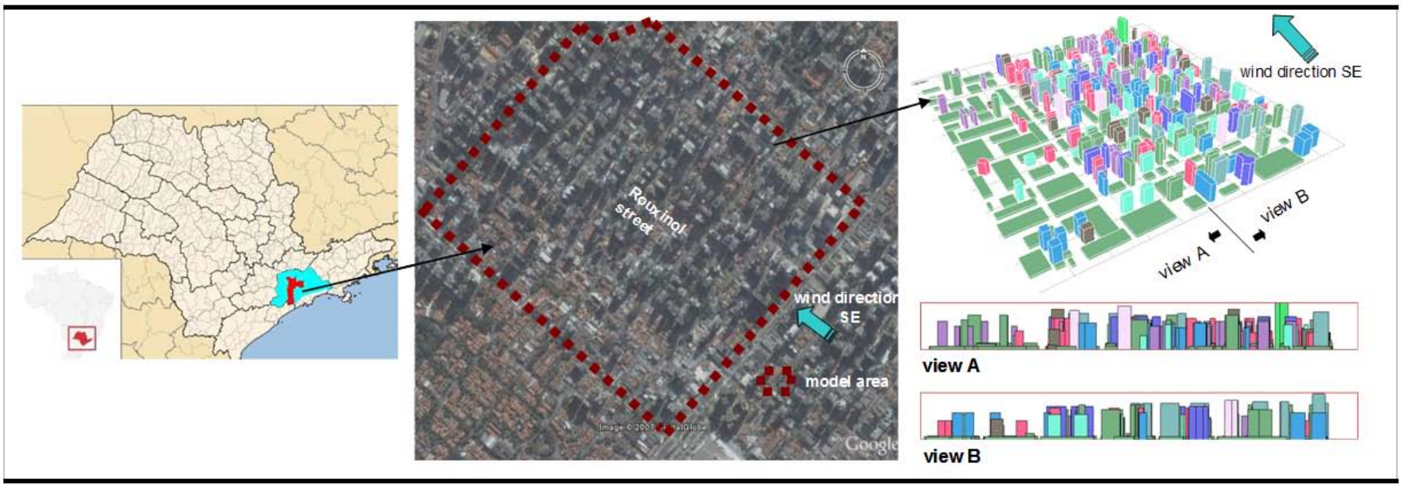


Figure 1: Brazil, Sao Paulo state and location the study area in Sao Paulo city

INTRODUCTION

The influence of the effect of the wind on the pedestrians and the applicability of an index of environmental comfort for external spaces, according to data of wind tunnel simulations, were the goals of this research. The simulations were performed for the case study of Moema, an upper middle class verticalized residential neighbourhood in Sao Paulo, Brazil. The index used was the Physiological Equivalent Temperature (PET), established specifically for the evaluation of subtropical climates such as the one from the study area. Figures obtained from wind tunnel simulations, using erosion techniques, were used to visualize the field of speed in the level of pedestrian, describing the areas affected by the action of different wind speeds The index was applied on the erosion technique pictures, defining the areas of greater and lesser influence in terms of the effect of wind on the climatic conditions of the site. As a result, one may verify the assessment of the area under study, observing the conditions of comfort and discomfort in light of changes in the values of wind speed. The area of study is within the metropolitan region of São Paulo, which has 20 million inhabitants, 11 million of which live within the capital's boundaries. The city is crossed by the Tropic of Capricorn, located at the latitude of 23° 37′ south and longitude of 46°39′ west. The study area is the district of Moema, located on the southeastern area of the city, one of the most affected by the verticalization and densification processes, with buildings ranging from 21 to 90 meters of height.

METHODS

Wind was chosen as the climatic variable for this study, since natural ventilation is the main strategy to attain comfort in São Paulo's climate. Data for from a Test Reference Year (TRY), presented by Goulart et al (1997) was used for calculating the Physiological Equivalent Temperature (PET), which allowed for a visualization of the impact of wind distribution on pedestrian thermal comfort. Air temperature (ta) was determined from the top and bottom 5% frequency of occurrence from 6h to 18h. Three scenarios were established: a summer condition (ta=29,6°C), a winter condition (ta=14,9°C) and an average condition (ta= 22,3°C, the annual average temperature during the study period). In order to calculate relative humidity, absolute humidity from the period where Δta= ±1 was averaged, which resulted in three reference relative humidity values. Mean radiant temperature was estimated from averaged solar radiation data for the periods where Δta= ±1. Solar radiation was calculated using a model from Kuwabara et al (2005), sky temperature by using the Bliss model (Duffie & Beckman, 1980), surface temperatures, according to IRC (2000) and surrounding temperatures from EDSL (2004). Whenever pedestrians were in shaded areas, mean radiant temperature was considered to be equal to air temperature. The calculations considered only wind data from the southeastern octant (azimuth = 135° ± 22,5°), with scalar wind speeds averaged for periods with Δta= ±1. Final scenarios for the three studied conditions were summer (ta °C= 29,6; ur%=42; trm °C=56,8 e v m/s=2,43), average (ta °C= 22,3; ur%=70; trm °C=37,4 e v m/s=2,02) e winter (ta °C= 14,9; ur%=92; trm °C=25,9e v m/s=1,64). Wind data was corrected according to BS5925 (1991), using k = 0,21 and a =0,33 (typical of city centers). Wind speeds for each isolines were corrected from the basic data present in item 2.3, resulting in eight values for each one of the three scenarios (Table 1). Clothes insulation was considered to be Icl = 0,5 in summer, 0,75 in average conditions and 1,0 in winter. Metabolical activity was considered to be M = 135 W/m^2.

Considering wind tunnel testing and physical modelling, this research used IPT's Atmospheric Boundary Layer Wind Tunnel (IPT - Instituto de Pesquisas Tecnológicas) (Figure 2). The tunnel works in a sub-sonic speed range (up to 30 m/s), low pressure and can generate two types of speed profiles. The test section is 3.00 m wide, 2.00 m tall and 28.00 m long, with a variable-height roof. The model was built with 1:500 scaling, resulting in a 170x170cm area, representing a 600x600m actual area (Figure 2). Scale was determined so that blockage area would be inferior to 2% of the testing section of the wind tunnel. The study was carried on for the prevailing wind for São Paulo (Southeast-SE).

The main technique applied was the erosion figure one, which allows for the visualization of the wind field at pedestrian level. It consists on spreading over the model floor (study area) a thin layer of sand. The air movement causes the sand to move and the erosion indicates wind speed above a given threshold around buildings (Janeiro Borges et al., 1979). By varying flow speed, one can obtain a group of lines/figures that correspond to the same boundary condition – friction velocity. Correction values below the unit indicate areas that are considered to be exposed, i.e. the sheer stress over that surface is above the one verified in undisturbed flow. Correction values above the unit indicate sheltered areas where the erosive action of wind flow is reduced (Table 2). Figure 3 shows the wind field inside the study urban area, for a southeast incidence. Areas in white (not eroded) are areas with higher number of vertical buildings, which are also closer to each other. This area might present high turbulence problems, dust accumulation and/or areas where wind speed is not enough to remove the sand. Openings at pedestrian level throughout the group of buildings are indicated in order to increase air circulation around the area.

Table 1. Scalar wind speeds in the isolines

isoline	velocity m/s (1,5m)		
	summer	average	winter
1	0,58	0,48	0,39
2	0,52	0,43	0,35
3	0,47	0,39	0,31
4	0,39	0,32	0,26
5	0,35	0,29	0,24
6	0,33	0,27	0,22
7	0,30	0,25	0,21
8	0,28	0,24	0,19

THERMAL COMFORT INDEX

Höppe (1999) proposes the Munich Model (MEMI), based on the human body thermal balance equation and on parameters from the two node model by Gagge (1986). Höppe's model differs from Gagge's model in the way of calculating regulatory sweat rate (as a function of tsk – skin surface temperature and tcl – clothed body external surface temperature) and the heat fluxes, for it considers clothed and unclothed body parts separately. By solving three equations (energy balance, heat flux from body core to skin surface and heat flux from skin surface to clothes external surface), one can determine the clothing external surface temperature (tcl), the skin surface temperature and the core temperature (tc). Höppe defines the Physiological Equivalent Temperature (PET) for a given situation as the equivalent temperature to the air temperature in which, for a typical internal situation, the thermal balance of the human does not change, considering the same core and skin temperatures as in the original situation. In order to calculate the PET, one should proceed accordingly to the follow-

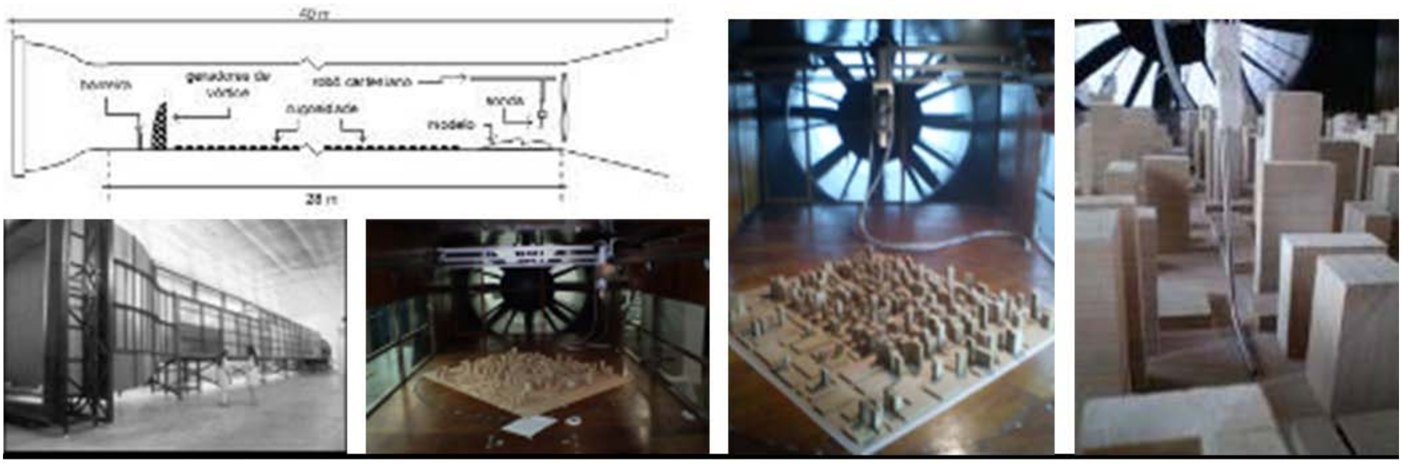


Figure 2. Physical model and the wind tunnel testing.

ing steps: (1) calculate the body's thermal conditions (tsk and tc), using the equation system from the MEMI model for the given combination of meteorological and individual parameter combination; (2) insert tsk and tc in the MEMI model, solving the system for air temperature (ta), considering mrt = ta, w =0,1 m/s (proposed by the original model and recalculated for this paper, using wind speeds previously presented), pv = 12hPa, M = 114 W and Iclo= 0,9 clo; (3) the resultant air temperature is the PET. The PET index originally did not present reference ranges for interpretation, since it was developed to provide comparison with a reference environment. Monteiro (2008) has proposed a calibration for the thermal sensation according to the following PET ranges: > 43= very hot; 31 – 43= hot; 26 – 31= warm; 18 – 26= neutral; 12 – 18= cool; 4 – 12= cold e < 4= very cold.

RESULTS AND SUMMARY

The PET index is often used in environmental comfort researches for analyzing physiological behavior of users/pedestrians according to environmental conditions (effect of buildings and climate). Table 3 presents the results for the eroded areas from the wind tunnel tests, considering corrected wind speeds for the given urban configuration. The thermal sensation range is determined by the equivalent temperature, but it is important to consider on the final result the effect of local characteristics and of wind speeds. In this case, wind speed was the most significant variable for determining the PET thermal sensation range in the winter and summer situations, while exposed to sun. In both cases, numerical values indicate proximity to neutrality, despite of the different variable inputs. Therefore, evaluation of pedestrian

Table 2. Correction values - isolines

isoline	velocity	*correction*
1	7,40	1
2	8,35	1,13
3	9,27	1,25
4	11,20	1,51
5	12,18	1,65
6	13,20	1,78
7	14,17	1,91
8	15,16	2,05

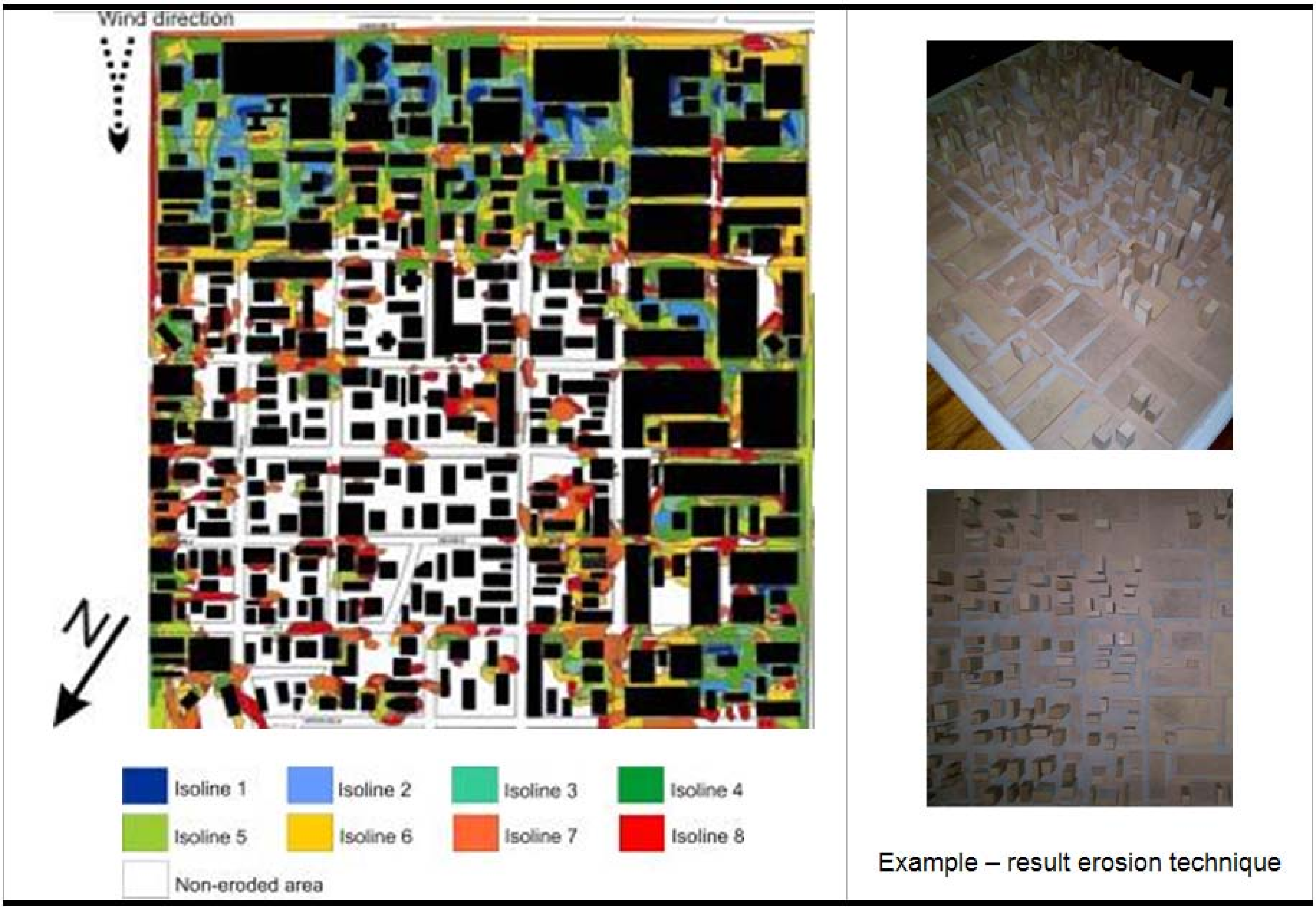


Figure 3. Results the erosion technique to study area – wind direction (Southeast-SE).

Table 3. Results of PET, in ºC and calibration for the thermal sensation - Monteiro (2008)

Colors - legend	isoline	summer		average		winter	
		Under the sun	In the shadow	Under the sun	In the shadow	Under the sun	In the shadow
very cold	1	42,1	27,9	27,8	20,8	17,8	13,0
cold	2	42,3	28,1	28,1	21,1	18,0	13,2
cool	3	42,6	28,2	28,4	21,2	18,2	13,4
neutral	4	43,1	28,3	28,6	21,4	18,6	13,5
warm	5	43,3	28,4	28,8	21,5	18,9	13,6
hot	6	43,4	28,4	29,0	21,6	19,2	13,8
very hot	7	43,6	28,5	29,4	21,8	19,4	14,0
	8	43,7	28,5	29,8	22,0	19,6	14, 2

thermal conditions and integration of physical simulation with mathematical models may provide significant information for the definition of design strategies, which may assist the designer in defining use distribution and occupation directives for different areas.

ACKNOWLEDGEMENTS

The authors would like to thank Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), for funding this research, to Instituto de Pesquisas Tecnológicas do Estado de São Paulo (IPT) for the support in the wind-tunnel simulations, to Laboratório de Modelos e Ensaios (LAME/FAUUSP) for the support in the physical models.

REFERENCES

British standard BS5925:1991 - Code of practice for ventilation principles and designing for natural ventilation, 1.

Duffie, J. A.; Beckman, W.A. 1980. Solar Engineering of Thermal Processes. New York, Wiley-Interscience.

Environmental Design Solutions Limited. 2004. A-TAS Theory Manual. Versão 9.0.5. Milton Keynes, EDSL.

Gagge, A. P. 1986. A standard predictive index of human response to the thermal environment. ASHRAE Trans, 92, p. 709-731.

Goulart, S., Lamberts, R., Firmino, S. 1997. Dados climáticos para projeto e avaliação energética de edificações para 14 cidades brasileiras. Florianópolis: Núcleo de Pesquisa em Construção/UFSC.

Goulart, S. 1993. Dados Climáticos para Avaliação de Desempenho Térmico de Edificações em Florianópolis. 111 f. Dissertação (Mestrado em Engenharia Civil). Florianópolis: UFSC.

Höppe, P. R. 1999. The physiological equivalent temperature: a universal index for the assessment of the thermal environment. International Journal of Biometeorology, 43, p.71-5.

Institute for Research in Construction. 2000. Construction codes. Construction Innovation, 4. National Research Council Canada.

Janeiro Borges, A. R. e Saraiva, J. A. G. 1979. An erosion technique for assessing ground level winds. Wind Engineering, Proceeding of the Fifth International Conference, Fort Collins, Colorado, USA Edited by Cermak, Pergamon Press, Oxford, july,pp.235 a 242.

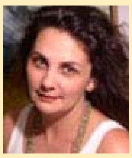
Kuwabara, K.; Mochida, T.; Nagano, K.; Shimakura, K. 2005. Effective radiant temperature including solar radiation. Environmental Ergonomics, p.257-262.

Prata, A. R., Brunelli, G.; Jabardo, P. J. S.; Marciotto, E. R.; Nader, G. 2005. Urban Ventilation: influence of physical models' scale in wind tunnel tests. PLEA2005 - The 22nd Conference on Passive and Low Energy Architecture. Beirut, Lebanon, Nov. 6p.

Prata Shimomura, A. R. 2007. Relatório 1 FAPESP. Programa Pós-Doutoramento. São Paulo, Dez.

Monteiro, L. M. 2008. Thermal comfort predictive models: quantification of relationships between microclimatic and thermal sensation variables for outdoor spaces assessment and design. 378p. Thesis (Doctoral). Faculty of Architeture and Urbanism, University of Sao Paulo, Sao Paulo.

Monteiro, L. M.; Alucci, M. P. 2007. Conforto térmico em espaços abertos com diferentes abrangências microclimáticas. Parte 2: proposição de calibração de modelos preditivos. In: VIIII Encontro Nacional e V Encontro Latino-Americano sobre Conforto no Ambiente Construído, Ouro Preto. Anais... ANTAC.



Alessandra R. Prata-Shimomura | Leonardo M. Monteiro | Anésia Barros Frota

arprata@terra.com.br

Laboratory of Environmental and Energy Studies, Faculty of Architeture and Urbanism, University of Sao Paulo LABAUT/FAUUSP, Sao Paulo, Brazil

Progress in urban climate research in Nigeria




By Ahmed A. Balogun[1], Ifeoluwa A. Balogun[1], Abdulhamid A. Ibrahim[2] and Jimmy O. Adegoke[3]
[1]Dept. of Meteorology, Federal University of Technology, Akure, Nigeria (abalogun99@yahoo.com)
[2]Dept. of Geography, Ahmadu Bello University, Zaria, Nigeria
[3]Dept. of Geosciences, University of Missouri, Kansas City, MO

Over the last 50 years the developing world, much of which is located in the tropic and subtropical regions, has seen dramatic growth of its urban population associated with serious degradation of environmental quality. The urban canopy heat island (UHI) is perhaps the most distinctive urban climate feature, characterized by the higher warmth of the urban centers compared to its surrounding rural areas. The UHI generates different effects in temperate and tropical cities. It can be both beneficial (winter) and detrimental (summer) in temperate regions-reducing the heating energy consumption and increasing the cooling energy use in summer. In the tropics it is detrimental year round. There is considerable interest in determining its characteristics to aid decisions on strategic urban planning and heat island mitigation.

However, the total number of urban climate studies from the tropics is relatively few, accounting for less than 20% of global urban climate studies (Roth, 2007). Also, the studies in tropical and subtropical environments are still not amenable to generalization because of their insufficient number, and this is especially true for Sub-Sahara Africa (Jonsson, 2004). Recent progress in urban climate research in Nigeria attempts to make important contributions at bridging this knowledge gap.

In 2005, Adelekan reviewed urban climate research in Nigeria in this newsletter from the 70s to the early 90s. Balogun et al (2009a) also presented results of efforts at the Department of Meteorology, Federal University of Technology, Akure on the characteristics of the UHI during the harmattan and monsoon seasons of 1997 in Akure. For a decade after that, urban climate research in Nigeria was in a lull. The lack of experts in the field, enabling environment, research facilities, funding and other non-urban research interests of the few existing climatologists and meteorologists in Africa are major limitations to urban climate research in Africa and not just Nigeria. This makes focus on capacity building a crucial step in revitalising urban climate research in the continent. This realisation motivated the lead author to seek out promising PhD candidates in Nigerian universities for training and development in urban climatology. The first beneficiaries of this personal crusade are Ifeoluwa Balogun (Dept. of Meteorology, Federal University of Technology, Akure, Nigeria) and Abdulhamid Ibrahim (Dept. of Geography, Ahmadu Bello University, Zaria, Nigeria). The Ph.D (2008 – 2012) studies of both candidates on urban heat island are currently self-funded with support from Twins & Associates Ltd., an educational, environmental and meteorological service consultancy firm and the University of Missouri, Kansas City. Ifeoluwa's research is on "Variations of carbon monoxide, thermal comfort and urban heat island in Akure, Nigeria" while Abdulhamid's research is on "Spatio-temporal variations of the urban heat island in Kano city, Nigeria". Fig. 1 shows the location of Akure and Kano cities in Nigeria. Preliminary findings and recent progress in their work presented at the 7th International Conference on Urban Climate (ICUC-7)

Figure 1. Location map of Akure and Kano cities in Nigeria.

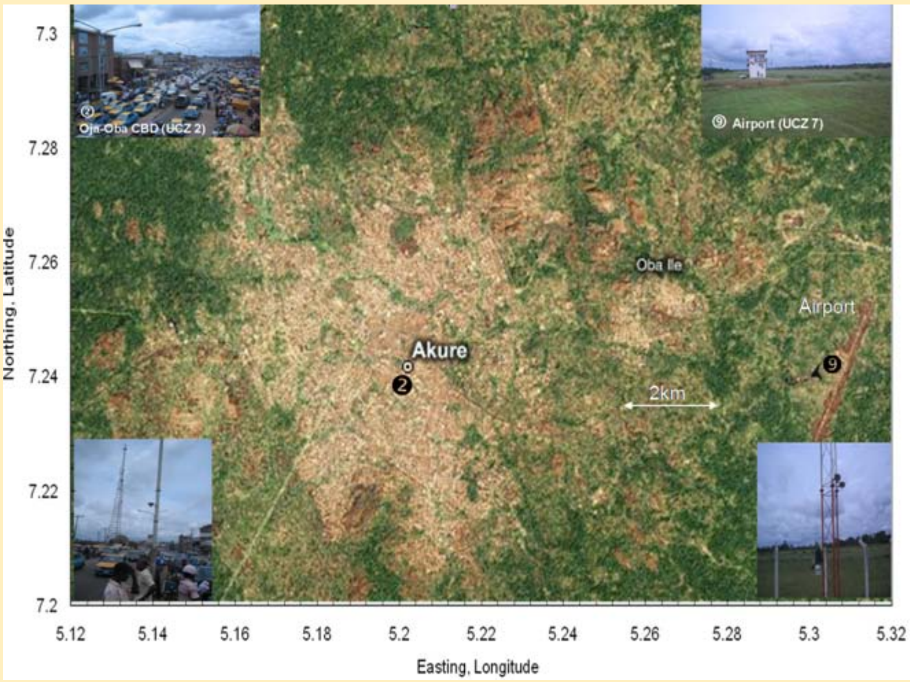


Figure 2. Google map of Akure showing the City centre (2) and Airport (9) sites. Inset (left and right) are photos of the sites and measurement systems respectively.

in Yokohama, Japan where Ifeoluwa also won the WP Lowry Award are summarised here.

The study cities and methodology

Akure

Akure (7.25°N, 5.20°E) is one of the fastest growing medium size humid tropical city in south-western Nigeria, and capital of Ondo State. It is also presently one of the seven African Millennium Cities Initiative (MCI) project cities. MCI is led by a team based at the Earth Institute at Columbia University and the Columbia Program on International Investment and is working closely with the MDG Support team at the United Nations Development Programme (UNDP). MCI aims to assist through research and policy analysis selected mid-sized cities across sub-Saharan Africa, located near Millennium Villages, to achieve the Millennium Development Goals (MDGs). The city has a population of approximately 500,000. The people are of the Yoruba ethnic group.

In Akure simultaneous measurements of Temperature (T) and relative humidity (RH) commenced in October, 2008, using shielded portable Lascar EL-USB-2 temperature/humidity data loggers, sampled at 5 minute intervals and mounted on a lamp post above head height (3 m) in the city centre, classified as "old core" (2) in the city series and at the same height on a mast at the airport, classified as "Open ground" (9) in the mixed series of the new local climate zone classification system (Stewart and Oke, 2009). CO measurements commenced in March 2009 using Lascar EL-USB-CO portable data logger. The CO logger was sampled every 30 seconds. Required time averages were then computed from the raw data, these were then averaged by day of week for the 31 days in March 2009.

Fig. 2 shows the locations and photos of the sites and measurement set-up. We analysed bioclimatic conditions in terms of maximum, minimum, and mean hourly values of the thermohygrometric index (THI, defined by air temperature and relative humidity), Kyle (1994) for January – March, 2009. Further details are provided by Balogun et al (2009b).

Kano

Kano (12°N, 8.5°E) is the state capital of Kano State in northern Nigeria. It recently dethroned Ibadan as the second largest city in Nigeria after Lagos , with an estimated population of 3.85 million. The principal inhabitants of the city are the Hausa people. The lack of funding and research facilities are some of the major limitations to urban climate research in developing countries. Advancements in electronics technology have recently resulted in the production of lower-cost, miniaturized, robust and reliable temperature data loggers (e.g. Hobo, Stowaway Tidbit, Optic Tinytalk, Thermochron iButton, etc) that can be used for UHI studies. The Thermochron iButton is a 17.35mm diameter by 6 mm-thick instrument that costs $25 per iButton, but can be < $15 when ordered in large quantity, It has been reported that the iButton is an accurate, durable and low-cost alternative to more expensive temperature data logging systems, and is well suited for obtaining quality spatially distributed data for environmental investigations (Hubbart et al. 2005, Johnson et al. 2005). We have acquired a few for the Kano studies, we report here preliminary evaluation of the performance of the thermochron iButton (DS1921G-F52) within a designed solar radiation shield. Our preliminary performance evaluation of the ibutton is based on the assessment of the precision and variability between individual devices and the efficacy of the designed solar radiation shield.

Thirteen iButtons and their respective shields were divided into two groups of five (facing up and eight (facing down) and exposed for a 24 h period under similar conditions to assess the precision of the sensors and efficacy of the designed solar radiation shields. Fig. 3 shows the thirteen DS1921G-F52 iButtons used in this study and accessories (USB adapter and reader), the performance evaluation layout and the potential UHI study sites in Kano, Ibrahim et al (2009). Its software is downloadable from Maxim-ic's website.

Results and discussion

Akure

Air temperature differences: Fig. 4a show that the UHI exists in Akure throughout the day except in November and December where urban cool island (UCI) is observed for few hours in the afternoon in both months. The highest daytime UHI is also observed in the dry season, this is in agreement with Balogun et al. 2009 that reported higher UHI values in January/February than October/November and UCI at 1500 in Akure in the wet season. The figure further show that the maximum UHI occurs between 1800 to 2200 hours local time. This is the first complete diurnal data reported for Akure. Earlier data reported for Akure have been restricted to the daytime period. This result therefore provides new information on the diurnal characteristics of the UHI in Akure.

Relative humidity and vapour pressure differences: Fig. 4b shows the diurnal course of differences in relative humidity between the urban and rural site. The figure show that urban moisture deficit (UMD) exists throughout the day for all months with the highest difference observed at night around the time of the maximum UHI. Also the UMD was more pronounced in the dry season (December/January). Fig. 4c shows the diurnal course of differences in vapour pressure between the urban and rural site. The figure shows that urban moisture excess (UME) exists throughout the day for all months with the highest difference observed in the early morning, except in wet months of October - December where UMD was predominant between 0900 and 2100. Similar patterns have been reported in Lodz, poland and Krefeld, Germany (Kuttler et al., 2007).

Thermal Comfort: Data analysis over the 3-month period, Table 1 reveal that the urban city centre was far less comfortable than the rural airport and five THI categories (cool, comfortable, hot, very hot and torrid) can be identified. Hot conditions were predominant at both sites, comfortable conditions were only experienced in the morning and evenings of January at both sites, but the rural area has more pleasant morning and evenings and less of very hot and torrid conditions. The city centre did not register any cool conditions at all with very hot and torrid afternoons. The month of January is the lowest in hotness and torridness while March is the highest. Comfortable conditions were restricted to the morning in January and brief periods in the evenings of all months for minimum THI. The rural area registered cool conditions in the morning in January. Unlike in temperate regions where higher warmth of the city is beneficial in winter, it is a significant thermal heat stress risk in hot humid environments like Akure.

CO Concentrations: CO concentrations at the city centre in Akure exhibited distinct diurnal and day-of-week variations, while the rural site exhibited a consistent cyclic diurnal pattern throughout the week, Figs. 5 and 6. At the urban site, Fig. 5a show that Sundays have the lowest CO concentrations with a triple peak (7:00, 13:00 and 19:00) and the highest maximum round the

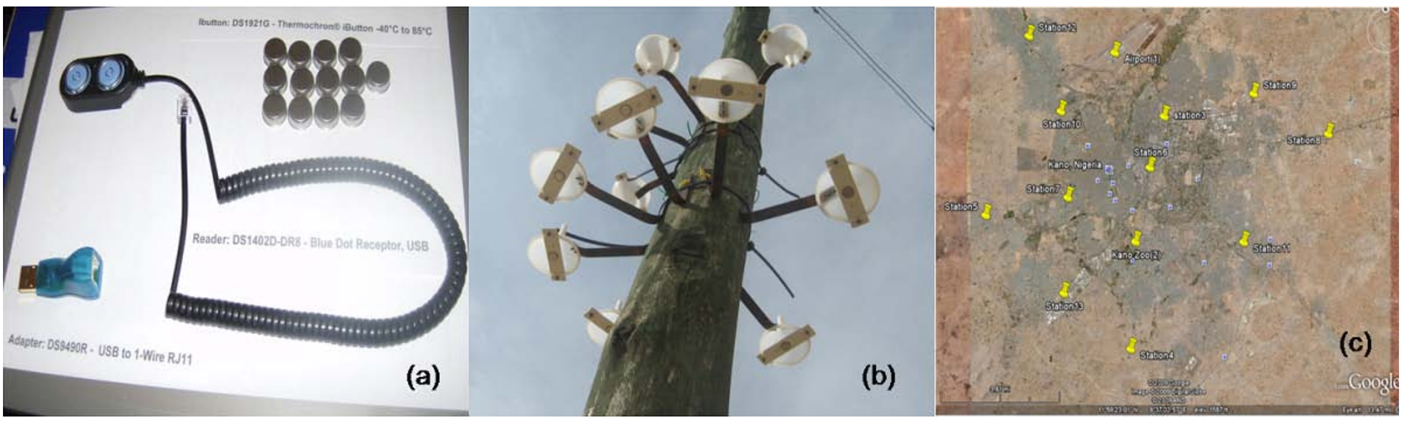


Figure 3. (a) iButtons and accessories, (b) performance evaluation of iButtons and radiation shields, (c) locations of planned pilot air temperature measurements in Kano.

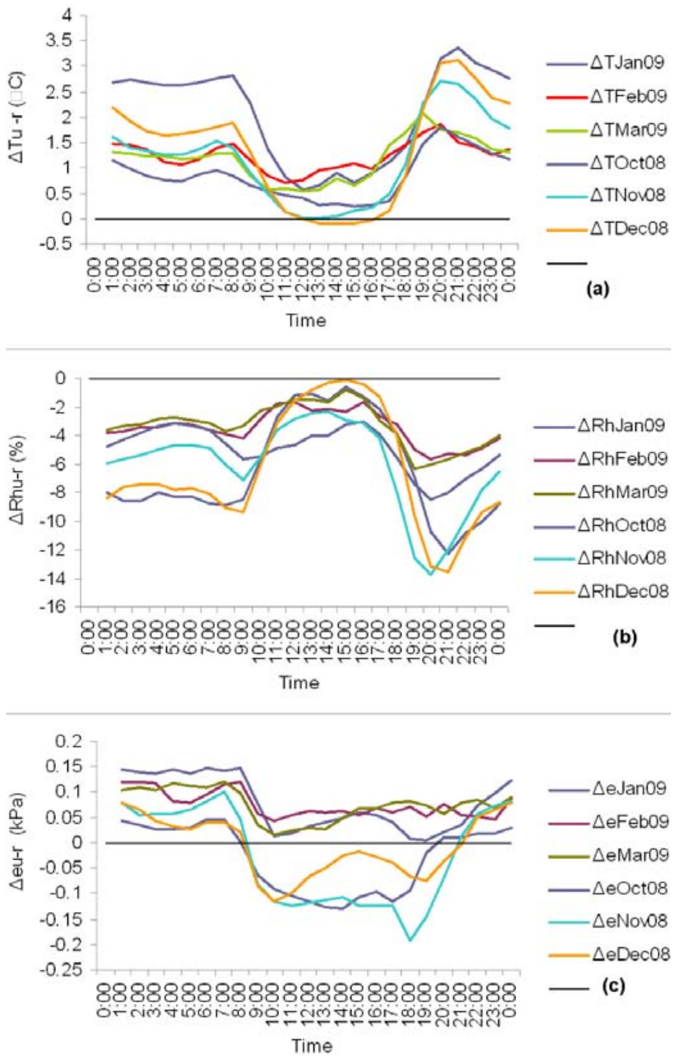


Fig. 4: Diurnal variation of mean monthly urban – rural differences of (a) air temperature, (b) relative humidity and (c) vapour pressure.

period people go to and return from church services. Fig. 5b also shows that Saturday evenings have a distinct evening peak associated with merry makers and party traffic. Urban CO levels show a diurnal pattern with three peaks during morning and evening rush hours, and between 14:00 and 16:00 associated with school runs to pick children from schools, during week days, Fig. 5c. Friday is the most polluted of all week days. WHO recommendations were not exceeded for 15minute, 30minute and 1 hour averages, however the average 8 hour recommendation (10 ppm) were consistently exceeded between 12:00 to 18:00, except on Sundays, Fig. 5d. This is different from observations in Burkina-Faso where two peaks during morning and evening rush hours have been reported (Linden et. al., 2008). They also reported that average 8-hr urban background CO concentrations never exceeded WHO recommendations for maximum 8-h exposure during their two measurement campaigns. Fig. 6a show that rural CO levels exhibit a diurnal pattern with maximum between 14:00 and 16:00 associated with time of maximum insolation and atmospheric instability. WHO recommendations were also not exceeded for 15minute, 30minute, 1 hour, and 8 hour averages, Fig. 6b.

Performance evaluation of ibuttons: Figs. 7a and 7b show that shielded iButtons facing down are lower and less variable than those facing up, with maximum values of 31.6°C and 34°C respectively. However, those facing up recorded the lowest mean and minimum daily temperatures of 23.7 and 19.7°C compared to 24.2 and 20°C recorded by the iButtons facing down. This suggests the sensors are affected by long wave radiation at night. Fig. 7c shows the difference between the two groups. The mean precision of the two groups (facing down and

Table 1. Variation of the THI at the urban and rural site

	Urban									Rural								
	THI_mean			THI_max			THI_min			THI_mean			THI_max			THI_min		
Months/Hours	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
00:00																		
01:00	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	3	4	3
02:00	4	4	4	4	4	6	3	4	4	4	4	4	4	4	4	3	4	4
03:00	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	3	4	4
04:00	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	3	4	4
05:00	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	2	4	4
06:00	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	2	4	3
07:00	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	2	3	3
08:00	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	2	4	3
09:00	4	4	4	4	4	5	3	4	4	4	4	4	4	4	4	3	4	4
10:00	4	4	6	6	5	5	3	4	4	4	4	4	4	5	5	3	4	4
11:00	4	5	5	5	5	5	4	4	4	4	4	5	5	5	5	4	4	4
12:00	4	5	5	5	5	6	4	4	4	4	5	5	5	5	5	4	4	4
13:00	5	5	5	5	6	6	4	4	4	4	5	5	5	6	5	4	4	4
14:00	5	5	5	6	6	6	4	4	6	5	5	5	6	6	6	4	4	4
15:00	5	5	5	6	6	6	4	4	4	5	5	5	6	6	6	4	4	4
16:00	5	5	5	6	6	6	4	4	4	5	5	5	6	6	6	4	4	4
17:00	5	5	5	6	6	6	4	4	4	5	5	5	6	6	6	4	4	4
18:00	5	5	5	6	6	6	4	4	4	4	5	5	6	6	6	4	4	4
19:00	6	5	5	6	6	6	4	4	4	4	5	5	5	6	6	4	4	3
20:00	4	5	5	5	6	6	4	4	3	4	4	4	5	5	5	3	4	4
21:00	4	4	4	5	5	5	4	3	4	4	4	4	5	5	5	3	3	3
22:00	4	4	4	5	5	5	4	4	4	4	4	4	4	5	5	3	4	4
23:00	4	4	4	5	5	5	4	4	3	4	4	4	4	4	4	3	4	3
00:00	4	4	4	4	4	5	3	4	4	4	4	4	4	4	4	3	4	3
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar

THI Categories: Cold 1, Cool 2, Comfort 3, Hot 4, Very Hot 5, Torrid 6

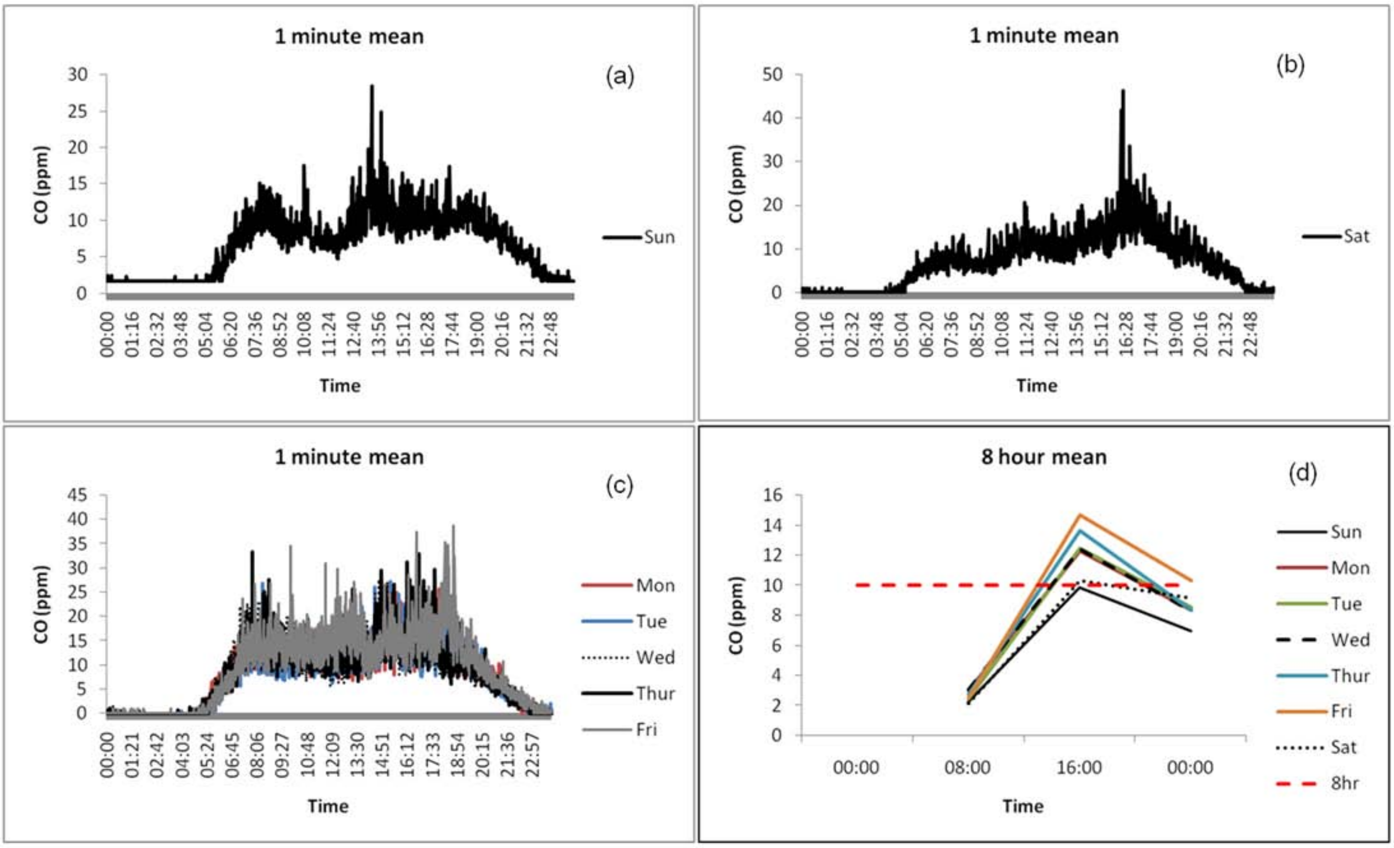


Figure 5. Mean diurnal variation of urban CO concentrations averaged over all (a) Sundays, (b) Saturdays, (c) Week work days and (d) 8 hour mean for all days in March, 2009.

facing up) were ±0.41 and ±0.62 respectively at the 95% confidence interval. In both groups the uncertainty was consistently low (< 0.5 °C) at night but increased with solar heating, indicating that the influence of direct solar radiation is the major source of errors. It was however significantly lower for the systems facing down, (Figs. 7a and 7b). The precision observed in this study for systems facing down is close to the ±0.4 reported by Johnson et al. (2005). It may be possible that occasional shadows from the telecom pole may also have contributed to the higher uncertainty of the systems facing up. One-way ANOVA also indicated that, there was a significant difference ($p < 0.05$) between the daily temperature means of the two groups. Our preliminary evaluation has been positive and has given us an insight into the performance of the sensors and the limitations of our present radiation shield design. Improvements to be evaluated on the current design will include a white plastic disc or another funnel at the bottom to shield the iButtons from reflected and longwave radiation. The iButtons have provided us with a robust and affordable tool for monitoring the urban canopy heat island in Kano city.

Future plans: Another set of 16 ibuttons have also been acquired for use in Akure. A more detailed perfor-

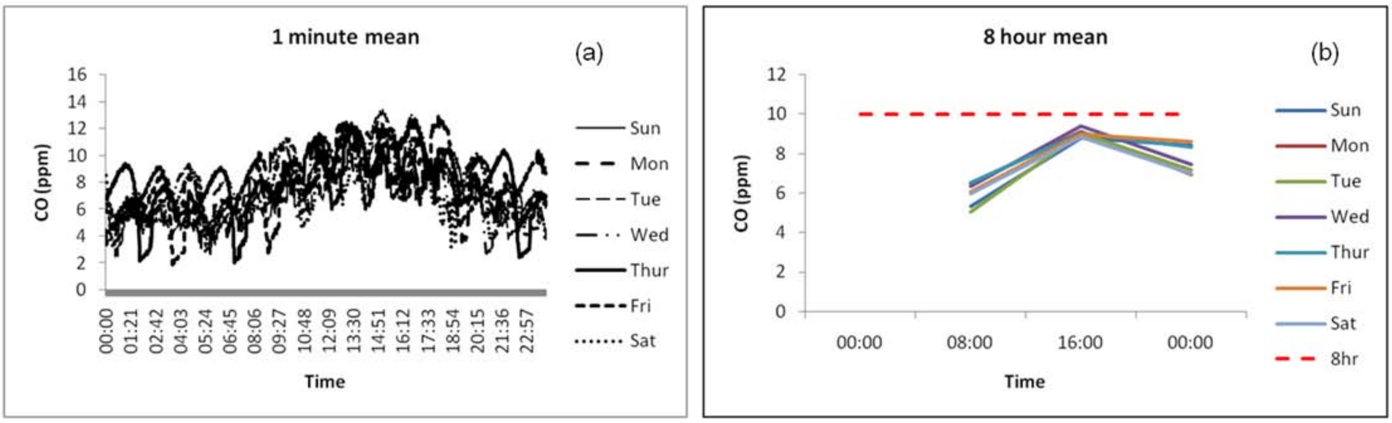


Figure 6. Mean diurnal variation of rural CO concentrations averaged over all (a) Week days and (b) 8 hour mean for all week days in March, 2009.

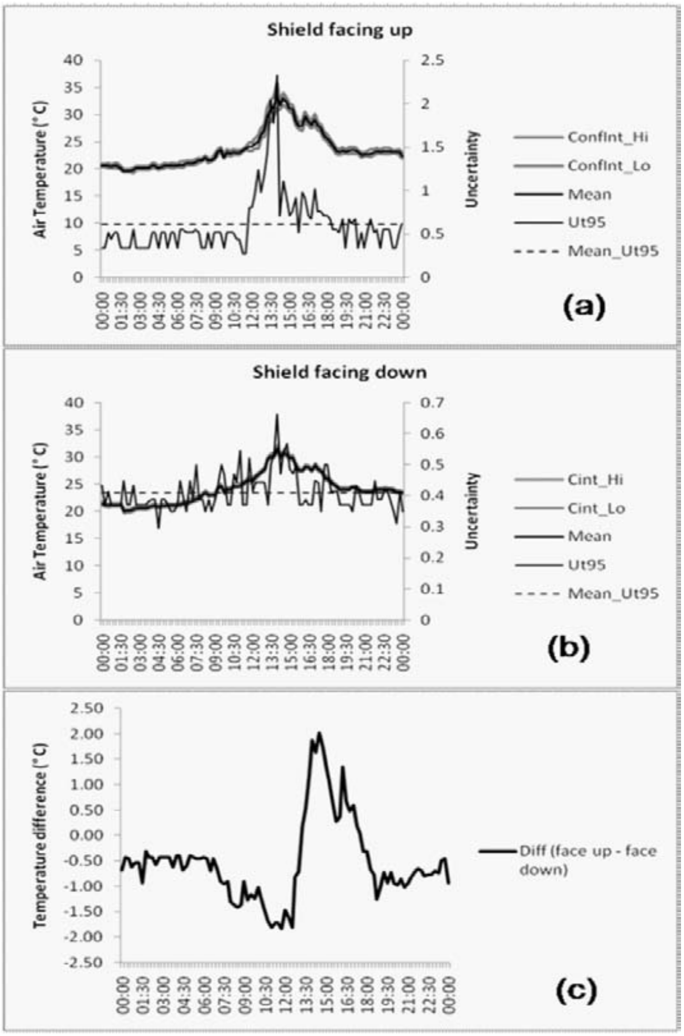


Figure 7. Responses of Thermochron iButtons within designed solar radiation shields (a) shields facing up, (b) shields facing down and (c) difference between shields facing up and facing down on 9/5/2009.

mance evaluation with improved radiation shields for both the Akure and Kano sensors are planned for the coming month before deployment. The studies will also continue with site classification according to the new local climate zone classification system (Stewart and Oke, 2009). Efforts are being made to relate the CO concentrations to traffic volume and atmospheric stability. A number of publications are presently under preparation. We are looking forward to exploring joint collaboration opportunities to conduct an extensive study on the urban climate of Lagos (Mega city) and other important coastal and inland cities of West Africa with established urban climate groups in the IAUC.

Acknowledgements

We are grateful to Prof. Tim Oke for his support and encouragement. The IAUC/WMO conference grant to Ifeoluwa and Abdulhamid to attend ICUC-7 is also gratefully acknowledged. We also acknowledge with thanks the assistance of Alison Tomlin, James Tate and Colin Oates with the ibuttons, without whom starting this research project would not have been nearly as expeditious. We are grateful to Twins & Associates Ltd and the University of Missouri, Kansas City for equipment and material support.

References

Adelekan I. 2005. Urban climate research in Nigeria. http://www.urban-climate.org/IAUC013

Balogun AA, Balogun IA, Adegoke JO. 2009a. Variability of carbon monoxide and bioclimatic conditions in Akure, Nigeria - A comparison of urban and rural measurements. Preprints, 7th International Conference on Urban Climate (ICUC-7), 29 June - 3 July 2009, Yokohama, Japan. CD-ROM, B15-8

Balogun AA, Balogun IA, Adefisan AE, Abatan AA. 2009b. Observed characteristics of the urban heat island during the harmattan and monsoon in Akure, Nigeria. 8th Conference on the Urban Environment. AMS 89th Annual Meeting, 11 – 15 January, 2009, Phoenix, AZ. Paper JP4.6, available

Ibrahim AA, Balogun AA, Iguisi EO, Nduka IC. 2009. Evaluation of a low-cost temperature measurement system for the investigation of the characteristics of the urban canopy heat island in Kano city, Nigeria. Preprints, 7th International Conference on Urban Climate (ICUC-7), 29 June - 3 July 2009, Yokohama, Japan. CD-ROM, B16-3

Johnson AN, Boer BR, Woessner WW, Stanford JA, Poole GC, Thomas SA, O'Daniel SJ. 2005. Evaluation of an inexpensive small-diameter temperature logger for documenting ground water–river interactions. Ground Water Monitoring and Remediation 25, no. 4: 68–74.

Jonsson P. 2004. Vegetation as an urban climate control in the subtropical city of Gaborone, Botswana. Int. J. Climatol. 24: 1307-1322

Hubbart, J., Link, T., and Doug Cobos, 2005. Evaluation of a low-cost temperature measurement system for environmental applications. Hydrol. Process. 19, 1517-1523.

Kuttler W, Weber S, Schonnefeld J, Hesselschwerd, A. 2007. Urban/rural atmospheric water vapour pressure differences and urban moisture excess in Krefeld, Germany. Int. J. Climatol. 27, 2005-2015. DOI: 10.1002/joc.1558

Kyle, W.J., 1994. The human bioclimate of Hong Kong. In Brazdil R, Kolar, M. (eds) Proceedings of the Contemporary Climatology Conference, Brno. TISK LITERA, Brno., pp 345–350

Linden, L, Thorsson, S and Eliasson, I. 2008. Carbon monoxide in Ougadougou, Burkina Faso- A comparison between urban background, roadside and in-traffic measurements. Water, Air, Soil Pollut. 188, 345-353.

Roth, M. 2007. Review of urban climate research in (sub)tropical regions. Int. J. Climatol. 27: 1859-1873

Stewart ID, Oke T. 2009. Classifying urban climate field sites by "local climate zones": The case of Nagano, Japan. Preprints, 7th International Conference on Urban Climate (ICUC-7), 29 June - 3 July 2009, Yokohama, Japan. CD-ROM, B17-5

WHO, 2004. Environmental Health Criteria 213: Carbon Monoxide, 2nd ed.

WMO INTER-REGIONAL CLIPS TRAINING WORKSHOP ON URBAN CLIMATOLOGY
Pune, India • January 25-29, 2010
http://www.wmo.int/pages/prog/wcp/wcasp/UrbanClimate.html

ASSOCIATION OF AMERICAN GEOGRAPHERS (AAG) ANNUAL MEETING
Washington, DC USA • April 14-18, 2010
http://www.aag.org/

5TH INTERNATIONAL SYMPOSIUM ON COMPUTATIONAL WIND ENGINEERING
Chapel Hill, NC USA • May 23-27, 2010
http://www.cwe2010.org

ICLEI RESILIENT CITIES 2010: 1ST WORLD CONGRESS ON CITIES & ADAPTATION TO CLIMATE CHANGE
Bonn, Germany • May 28-30, 2010
http://resilient-cities.iclei.org/bonn2010/

URBAN ENVIRONMENTAL POLLUTION - UEP 2010
Boston, USA • June 20-23, 2010
http://www.uep2010.com

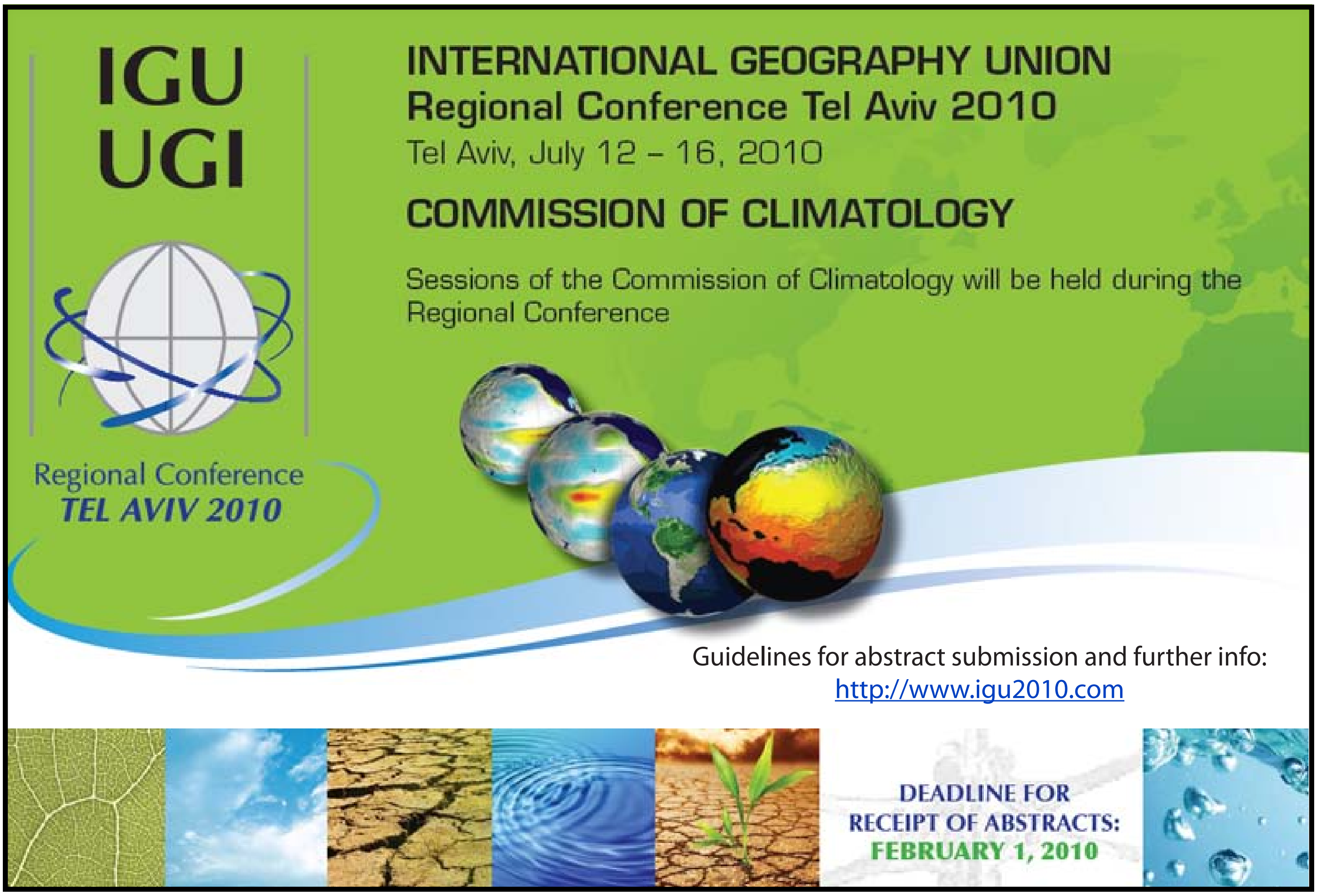
13TH INTL. CONFERENCE ON HARMONISATION WITHIN ATMOSPHERIC DISPERSION MODELLING
Paris, France • June 1-4, 2010
http://www.harmo.org/harmo13

WORLD CITIES SUMMIT: LIVABLE AND SUSTAINABLE CITIES FOR THE FUTURE
Singapore • June 28-30, 2010
http://www.worldcities.com.sg/index.html

2010 INTERNATIONAL CLIMATE CHANGE ADAPTATION CONFERENCE
Queensland, Australia • June 29 - July 1, 2010
http://www.nccarf.edu.au/conference2010

5TH INTERNATIONAL CONFERENCE ON FOG, FOG COLLECTION AND DEW
Münster, Germany • July 25 – 30, 2010
http://www.fogconference.org/

NINTH SYMPOSIUM ON THE URBAN ENVIRONMENT
Keystone, Colorado USA • August 2-6, 2010
http://www.ametsoc.org/MEET/fainst/201029agforest19blt9urban.html



Recent publications in Urban Climatology

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

As usual, all readers are invited to send any peer-reviewed references published since January 1, 2010 for inclusion in the next newsletter and the online database. Please send me your references to jhidalgo@labein.es with a header "IAUC publications" and the following format:

Author:

Title:

Journal:

Volume:

Pages:

Dates:

Keywords:

Language:

Abstract:

Happy reading,

Julia Hidalgo

jhidalgo@labein.es

Anna-Maria, V. (2009) Evaluation of a sustainable Greek vernacular settlement and its landscape: Architectural typology and building physics, *Building and Environment* **44** (6), 1095 - 1106.

Baldinelli, G. (2009) Double skin façades for warm climate regions: Analysis of a solution with an integrated movable shading system, *Building and Environment* **44** (6), 1107-1118.

Balázs, B.; Unger, J.; Gál, T.; Sümeghy, Z.; Geiger, J. & Szegedi, S. (2009) Simulation of the mean urban heat island using 2D surface parameters: empirical modelling, verification and extension, *Meteorological Applications* **16**(3), 275--287.

Bigot, D.; Miranville, F.; Fakra, A. & Boyer, H. (2009) A nodal thermal model for photovoltaic systems: Impact on building temperature fields and elements of validation for tropical and humid climatic conditions, *Energy and Buildings* **41**(11), 1117-1126.

Bourbia, F. & Boucheriba, F. (2010) Impact of street design on urban microclimate for semi arid climate (Constantine), *Renewable Energy* **35**(2), 343 - 347.

Bu, Z.; Kato, S.; Ishida, Y. & Huang, H. (2009) New criteria for assessing local wind environment at pedestrian level based on exceedance probability analysis, *Building and Environment* **44** (7), 1501 - 1508.

Buccolieri, R.; Gromke, C.; Sabatino, S. D. & Ruck, B. (2009) Aerodynamic effects of trees on pollutant concentration in street canyons, *Science of The Total Environment* **407**(19), 5247 - 5256.

Cao, Y. Z.; Wang, S.; Zhang, G.; Luo, J. & Lu, S. (2009) Chemical characteristics of wet precipitation at an urban site of Guangzhou, South China, *Atmos. Res.* **94**, 462-469.

Champollion, C.; Drobinski, P.; Haeffelin, M.; Bock, O.; Tarniewicz, J.; Bouin, M. N. & Vautard, R. (2009) Water vapour variability induced by urban/rural surface heterogeneities during convective conditions, *Quarterly Journal of the Royal Meteorological Society* **135**(642), 1266--1276.

Chen, H.; Ooka, R.; Huang, H. & Tsuchiya, T. (2009) Study on mitigation measures for outdoor thermal environment on present urban blocks in Tokyo using coupled simulation, *Building and Environment* **44**(11), 2290-2299.

Chen, J.; Wang, W.; Zhang, J.; Liu, H.; Ren, L.; Liu, X.; Zhang, W. & Wang, X. (2009) Characteristics of gaseous pollutants near a main traffic line in Beijing and its influencing factors, *Atmos. Res.* **94**, 470-480.

Chrysikou, L. P. & Samara, C. A. (2009) Seasonal variation of the size distribution of urban particulate matter and associated organic pollutants in the ambient air, *Atmospheric Environment* **43**(30), 4557 - 4569.

Day, A.; Jones, P. & Maidment, G. (2009) Forecasting future cooling demand in London, *Energy and Buildings* **41**(9), 942-948.

Ding, W.; Stepinski, T. F.; Parmar, R.; Jiang, D. & Eick, C. F. (2009) Discovery of feature-based hot spots using supervised clustering, *Computers &Geosciences* **35** (7), 1508 - 1516.

Dodson, R. E.; Houseman, E. A.; Morin, B. & Levy, J. I. (2009) An analysis of continuous black carbon concentrations in proximity to an airport and major roadways, *Atmospheric Environment* **43**(24), 3764 - 3773.

Donnelly, R.; Lyons, T. & Flassak, T. (2009) Evaluation of results of a numerical simulation of dispersion in an idealised urban area for emergency response modelling, *Atmospheric Environment* **43**(29), 4416 - 4423.

Donovan, G. H. & Butry, D. T. (2009) The value of shade: Estimating the effect of urban trees on summertime electricity use, *Energy and Buildings* **41** (6), 662 - 668.

Faghih, A. K. & Bahadori, M. N. (2009) Solar radiation on domed roofs, *Energy and Buildings* **41**(11), 1238-1245.

Fahmy, M. & Sharples, S. (2009) On the development of an urban passive thermal comfort system in Cairo, Egypt, *Building and Environment* **44**(9), 1907-1916.

Fong, W.; Matsumoto, H. & Lun, Y. (2009) Application of System Dynamics model as decision making tool in urban planning process toward stabilizing carbon dioxide emissions from cities, *Building and Environment* **44** (7), 1528 - 1537.

Fujibe, F. (2009) Detection of urban warming in recent temperature trends in Japan, *International Journal of Climatology* **29**(12), 1811-1822.

Giridharan, R. & Kolokotroni, M. (2009) Urban heat island characteristics in London during winter, *Solar Energy* **83**(9), 1668 - 1682.

Halwatura, R. & Jayasinghe, M. (2009) Influence of insulated roof slabs on air conditioned spaces in tropical climatic conditions. A life cycle cost approach, *Energy and Buildings* **41**(6), 678 -686.

Hang, J.; Sandberg, M. & Li, Y. (2009) Age of air and air exchange efficiency in idealized city models, *Building and Environment* **44** (8), 1714 - 1723.

Hefny, M. M. & Ooka, R. (2009) CFD analysis of pollutant dispersion around buildings: Effect of cell geometry, *Building and Environment* **44** (8), 1699 - 1706.

Hwang, R.; Cheng, M.; Lin, T. & Ho, M. (2009) Thermal perceptions, general adaptation methods and occupants idea about the trade-off between thermal comfort and energy saving in hot-humid regions, *Building and Environment* **44** (6), 1128 - 1134.

Jensen, S. S.; Larson, T.; Deepti, K. & Kaufman, J. D. (2009) Modeling traffic air pollution in street canyons in New York City for intra-urban exposure assessment in the US Multi-Ethnic Study of atherosclerosis and air pollution, *Atmospheric Environment* **43**(30), 4544 - 4556.

Kolokotsa, D.; Psomas, A. & Karapidakis, E. (2009) Urban heat island in southern Europe: The case study of Hania, Crete, *Solar Energy* **83**(10), 1871 - 1883.

Kubota, T.; Chyee, D. T. H. & Ahmad, S. (2009) The effects of night ventilation technique on indoor thermal environment for residential buildings in hot-humid climate of Malaysia, *Energy and Buildings* **41**(8), 829 - 839.

Lin, T. (2009) Thermal perception, adaptation and attendance in a public square in hot and humid regions, *Building and Environment* **44**(10), 2017-2026.

Liu, X.; Hewings, G. J. & Wang, S. (2009) Evaluation on the impacts of the implementation of civil building energy efficiency standards on Chinese economic system and environment, *Energy and Buildings* **41**(10), 1084-1090.

Lun, I.; Mochida, A. & Ooka, R. (2009) Progress in Numerical Modelling for Urban Thermal Environment Studies, *Advances in Building Energy Research* **3**(1), 147-188.

Macias, M.; Gaona, J.; Luxan, J. & Gomez, G. (2009) Low cost passive cooling system for social housing in dry hot climate, *Energy and Buildings* **41**(9), 915-921.

Matzarakis, A.; Rocco, M. D. & Najjar, G. (2009) Thermal bioclimate in Strasbourg - the 2003 heat wave, *Theoretical and Applied Climatology* **98**(3-4), 209-220.

Memon, R. A.; Leung, D. Y. C. & Liu, C. H. (2009) An investigation of urban heat island intensity (UHII) as an indicator of urban heating, *Atmos. Res.* **94**, 491-500.

Meyn, S. K. & Oke, T. (2009) Heat fluxes through roofs and their relevance to estimates of urban heat storage, *Energy and Buildings* **41** (7), 745 - 752.

Mithraratne, N. (2009) Roof-top wind turbines for microgeneration in urban houses in New Zealand, *Energy and Buildings* **41**(10), 1013-1018.

Ng, E. (2009) Policies and technical guidelines for urban planning of high-density cities - air ventilation assessment (AVA) of Hong Kong, *Building and Environment* **44** (7), 1478 - 1488.

Oliveira, J.; Hagishima, A. & Tanimoto, J. (2009) Estimation of passive cooling efficiency for environmental design in Brazil, *Energy and Buildings* **41** (8), 809 - 813.

Ouyang, J. & Hokao, K. (2009) Energy-saving potential by improving occupants behavior in urban residential sector in Hangzhou City, China, *Energy and Buildings* **41** (7), 711 - 720.

Priyadarsini, R. (2009) Urban Heat Island and its Impact on Building Energy Consumption, *Advances in Building Energy Research* **3**(1), 261-270.

Reinstorf, F.; Leschik, S.; Musolff, A.; Osenbrück, K.; Strauch, G.; Möder, M. & Schirmer, M. (2009) Quantification of large-scale urban mass fluxes of xenobiotics and of the river-groundwater interaction in the city of Halle, Germany, *Physics and Chemistry of the Earth*, Parts A/B/C **34**(8-9), 574-579.

Righi, S.; Lucialli, P. & Pollini, E. (2009) Statistical and diagnostic evaluation of the ADMS-Urban model compared with an urban air quality monitoring network, *Atmospheric Environment* **43**(25), 3850 - 3857.

Schlünzen, K. H.; Hoffmann, P.; Rosenhagen, G. & Riecke, W. (2009) Long-term changes and regional differences in temperature and precipitation in the metropolitan area of Hamburg, *International Journal of Climatology* DOI: 10.1002/joc.1968.

Shashua-Bar, L.; Pearlmutter, D. & Erell, E. (2009) The cooling efficiency of urban landscape strategies in a hot dry climate, *Landscape and Urban Planning* **92**(3-4), 179 - 186.

Smith, C.; Lindley, S. & Levermore, G. (2009) Estimating spatial and temporal patterns of urban anthropogenic heat fluxes for UK cities: the case of Manchester, *Theoretical and Applied Climatology* **98**(1-2), 19-35.

Stewart, I. & Oke, T. (2009), A New Classification System for Urban Climate Sites, *Bulletin of the American Meteorological Society* **90**(7), 922-923.

Sun, C.; Brazel, A. J.; Chow, W. T. L.; Hedquist, B. C. & Prashad, L. (2009) Desert heat island study in winter by mobile transect and remote sensing techniques, *Theoretical and Applied Climatology* **98**(3-4), 323-335.

Svoma, B. M. & Jr, R. C. B. (2009) An anthropogenic signal in Phoenix, Arizona winter precipitation, *Theoretical and Applied Climatology* **98**(3-4), 315-321.

Tablada, A.; Troyer, F. D.; Blocken, B.; Carmeliet, J. & Verschure, H. (2009) On natural ventilation and thermal comfort in compact urban environments – the Old Havana case, *Building and Environment* **44**(9), 1943-1958.

Takebayashi, H. & Moriyama, M. (2009) Study on the urban heat island mitigation effect achieved by converting to grass-covered parking, *Solar Energy* **83**(8), 1211 - 1223.

Velasco, E.; Pressley, S.; Grivicke, R.; Allwine, E.; Coons, T.; Foster, W.; Jobson, T.; Westberg, H.; Ramos, R.; Hernández, F.; Molina, L. T. & Lamb, B. (2009) Eddy covariance flux measurements of pollutant gases in urban Mexico City, *Atmospheric Chemistry and Physics* **9**, 7325-7342.

Xiao, R.; Takegawa, N.; Kondo, Y.; Miyazaki, Y.; Miyakawa, T.; Hu, M.; Shao, M.; Zeng, L.; Hofzumahaus, A.; Holland, F.; Lu, K.; Sugimoto, N.; Zhao, Y. & Zhang, Y. (2009) Formation of submicron sulfate and organic aerosols in the outflow from the urban region of the Pearl River Delta in China, *Atmospheric Environment* **43**(24), 3754 - 3763.

Xu, S. (2009) An approach to analyzing the intensity of the daytime surface urban heat island effect at a local scale, *Environmental Monitoring and Assessment* **151**(1), 289-300.

Yao, R.; Li, B. & Liu, J. (2009) A theoretical adaptive model of thermal comfort – Adaptive Predicted Mean Vote (aPMV), *Building and Environment* **44**(10), 2089-2096.

Yim, S.; Fung, J.; Lau, A. & Kot, S. (2009) Air ventilation impacts of the 'wall effect' resulting from the alignment of high-rise buildings, *Atmospheric Environment* **43**(32), 4982--4994.

Yu, B.; Liu, H.; Wu, J. & Lin, W. (2009) Investigating impacts of urban morphology on spatio-temporal variations of solar radiation with airborne LIDAR data and a solar flux model: a case study of downtown Houston, *International Journal of Remote Sensing* **30**(17), 4359-4385.

Yu, C. & Hien, W. N. (2009) Thermal Impact of Strategic Landscaping in Cities: A Review, *Advances in Building Energy Research* **3**(1), 237-260.

Zhao, J.; Zhu, N. & Lu, S. (2009) Productivity model in hot and humid environment based on heat tolerance time analysis, *Building and Environment* **44**(11), 2202-2207.

IAUC Membership Update

Janet Barlow, University of Reading

Kevin Gallo, NOAA/NESDIS

Petra Klein, University of Oklahoma

This Update presents the membership statistics as of November 2009 and a historical perspective, when the statistics were available, for previous years.

Overall Membership

An assessment has been made of the available membership statistics for the IAUC. The total membership of the IAUC as of November 2009 was 1616 members. The membership has been growing fairly steady since the number of members was first available in 2003. A nearly linear increase of 14 members per month has been observed since 2003 (Figure 1).

Membership Diversity

The membership as of November 2009 includes approximately 1141 (72%) males and 437 (28%) females[1] (Figure 2). The ratio of males to females has remained fairly steady as 25% of the membership was female in 2003 and 2004. Thirty-three percent of the members that provided detailed information in 2009 had indicated that they were current students while 67% were non-students. The student membership has increased from a ratio of 19% in 2003.

[1]The numbers for the various categories do not sum to the total number of 1616 members due to incomplete information available for some members.

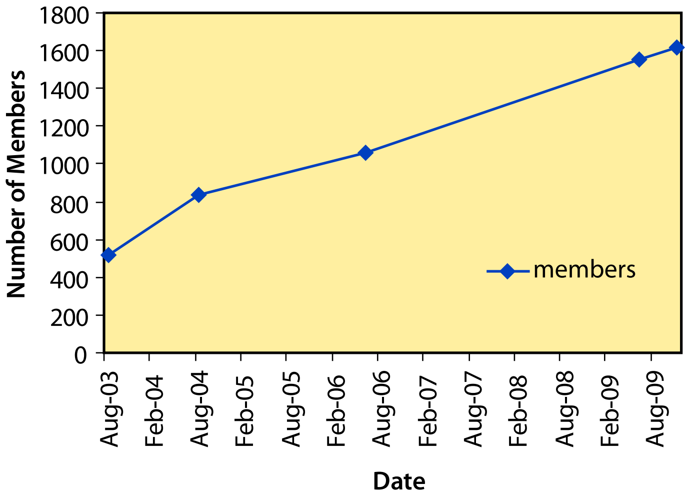


Figure 1. Total number of members by date of membership.

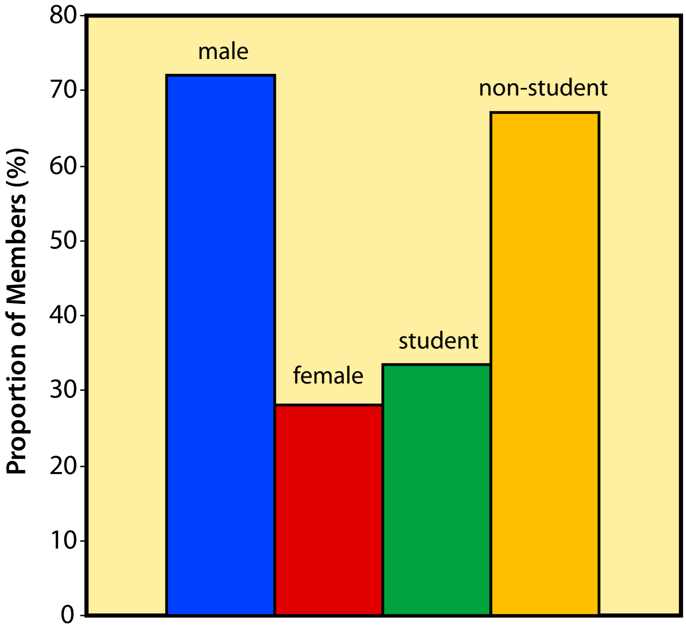


Figure 2. Proportion of members per category.

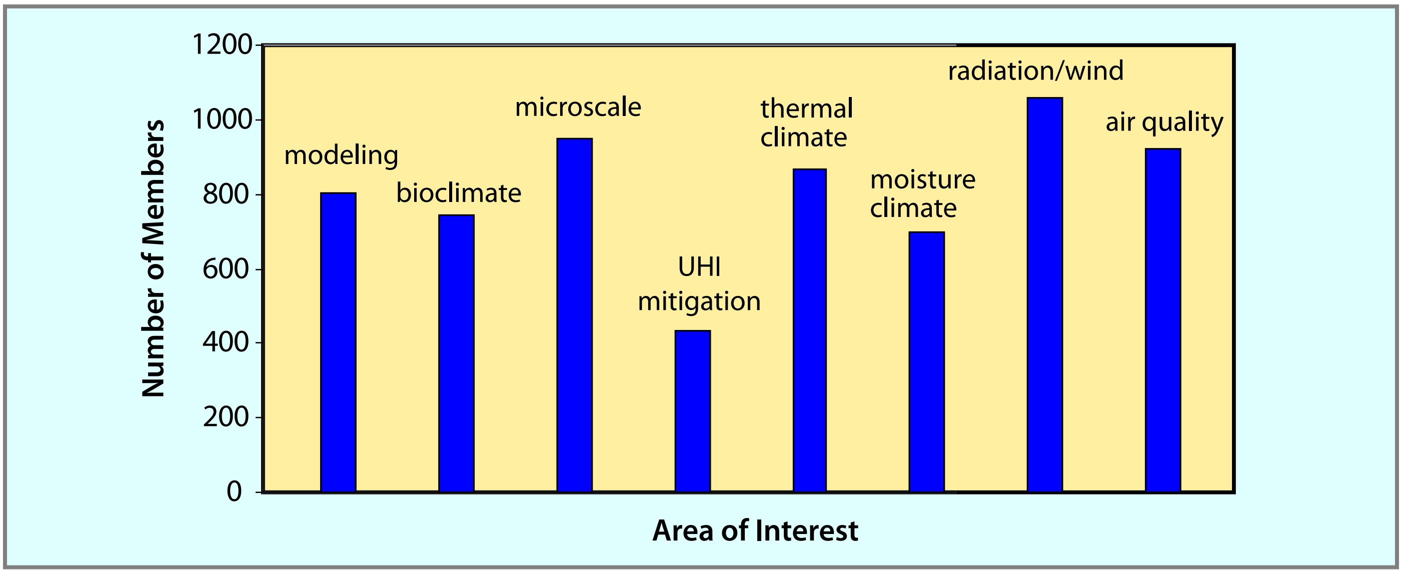


Figure 3. Number of members per general topical area of interest.

Topical Areas of Member Interest

There was a fairly even spread of interest of the membership across 8 topic areas. Members were permitted, and often did, indicate more than one category of interest (Figure 3). The top three categories of interest included radiation/wind, microscale, and air quality.

Distribution of Membership

Lastly, the IAUC currently has members from some 100 countries. The number of members per country, for the top 20 countries by membership, is shown in Figure 4.

We would like to thank the members that responded to these and other questions included on the IAUC webpage that allowed the computation of these statistics.

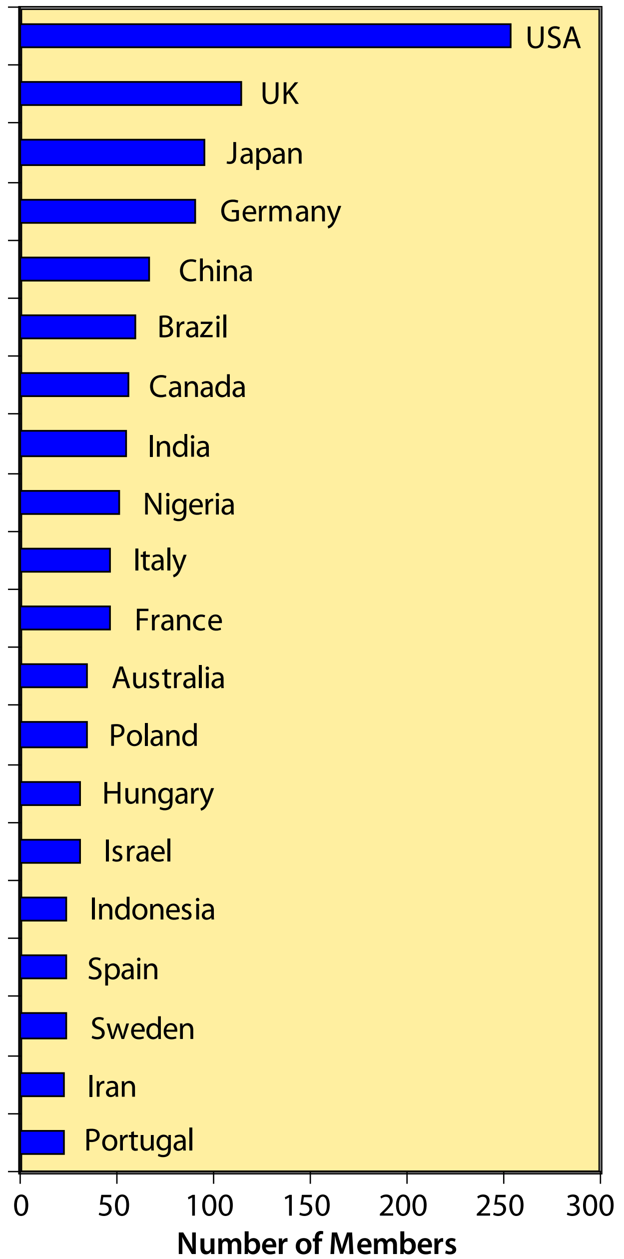


Figure 4. Number of members by country, in top 20 membership countries.

Newsletter Contributions

The next edition will appear in late March. Items to be considered for the next edition should be received by **February 28, 2010**. 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.