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IAUC NEWSLETTER

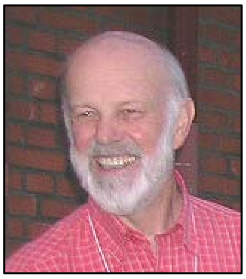
INTERNATIONAL ASSOCIATION FOR URBAN CLIMATE

www.urban-climate.org

President's Column

This newsletter marks **Gerald Mills'** fourth anniversary as editor. I would like to thank him for having done an excellent job during these past years and everyone else who has edited sections and written articles for their time and effort.

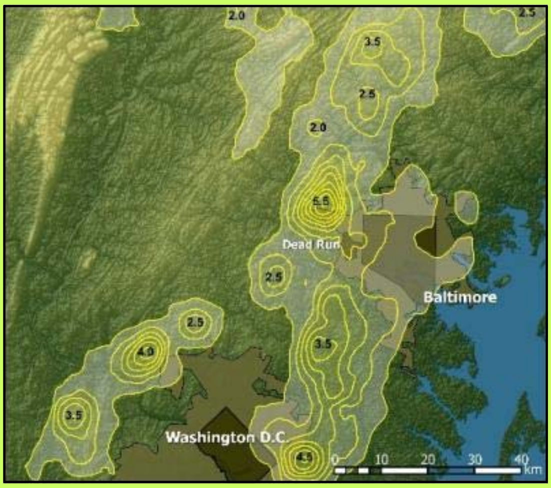
I am very pleased to announce (and I apologize for the delay) that **Tim Oke** is the recipient of the inaugural 2007 Helmut E. Landsberg Award of the *American Meteorological Society*. This award recognizes an individual or team for exemplary contributions to the fields of urban meteorology, climatology, or hydrology. Quoting from the citation Tim has received the award "for visionary leadership in urban climatology and meteorology and seminal contributions to the science over four decades, as reflected by substantive and enlightening publications and through mentoring of many young scientists currently engaged in urban research". Tim Oke is professor emeritus, Department of Geography, University of British Columbia, Vancouver, Canada, the recipient of the IAUC Luke Howard Award in 2004 and Past President (2000-2003) of IAUC.



In this newsletter we have another country report "**Urban climate research in Singapore"**. Some of the earliest urban climate work in tropical regions has been conducted in the early 1960s in Singapore and a small urban climate community is still active to date. I would encourage those of you from countries which are not represented yet in the country report series to submit an article. As is evident from past submissions the format can be varied and this series provides an excellent opportunity to showcase work to the international community.

I would like to draw your attention to **The Seventh Symposium on the Urban Environment**, sponsored by the American Meteorological Society (AMS) and organized by the AMS Board on the Urban Environment, which will be held 10–13 September 2007 in San Diego. Unfortunately I will not be able to attend but I am sure that many IAUC members will be enjoying a stimulating meeting.

Urban Image



This shows the pattern of lightning strikes near Baltimore and Washington, D.C. during the rare and extreme 2004 thunderstorm (See p2). The number of strikes for a given area can be found in the center of concentric yellow circles. Much of the lightning during the 2004 storm wrapped around the western edges of Baltimore and Washington, D.C., to the south. (Courtesy Alexander Ntelekos, Princeton University School of Engineering, Princeton University).

Finally, please note the call for nominations for the **Luke Howard Award** presented at the end of the newsletter (also distributed via urbclim mailing list). I strongly encourage you to nominate colleagues worthy of this recognition by the deadline of 1 October 2007.

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Contents

Urban Climate News

Cities incite thunderstorms

Source: www.eurekalert.org/pubnews.php

Summer thunderstorms become much more fierce when they collide with a city than they would otherwise be in the open countryside, according to research led by Princeton engineers. Alexandros A. Ntelekos and James A. Smith of Princeton University's School of Engineering and Applied Science based their conclusion on computer models and detailed observations of an extreme thunderstorm that hit Baltimore in July of 2004.

Their modeling suggests that the city of Baltimore experienced about 30 percent more rainfall than the region it occupies would have experienced had there been no buildings where the city now sits.

A storm of the intensity of the 2004 event in Baltimore is extremely rare, occurring only once every 200 years or so. However, climate change is expected to make such events more frequent, according to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC). Observational data shows that, during the 2004 storm, parts of Baltimore experienced as many lightning strikes in the space of two hours as they normally receive during the course of a year. Much of the lightning during the 2004 storm wrapped around the western edges of Baltimore and Washington, D.C., to the south. "It's as if all of a sudden the lightning can 'feel' the city," said Ntelekos.

The interaction between storm and city has serious consequences for urbanites as well as policymakers. Hydrologists have observed evidence in the past that urban environments alter the behavior of storms. But they have mostly noted average increases in rainfall over long periods of time. Until now, they have not made observations of specific extreme storms because they lacked the right tools to do so.

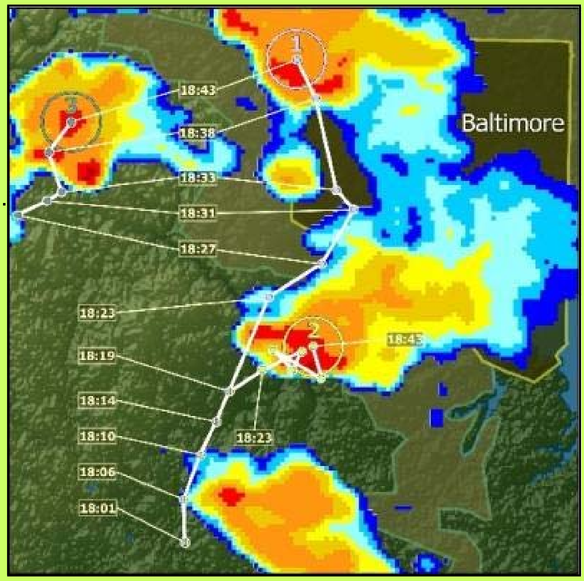
The scientific consensus so far has been that, during a storm, greater rainfall occurs on the downwind part of the city than on the upwind side. However, the researchers found that during the 2004 Baltimore storm, the western part of the city - not the upwind, northern part - was hit harder by rainfall and thus extreme flooding, according to Ntelekos. "Previous studies basically came from cities where the terrain was simple, where you had a town in the middle of nothing - no mountains, no water," he said. "But most of the hub cities are close to either mountains or water as well as being close to other cities. So we have to understand how extreme thunderstorms behave over complex terrains."

Exactly how does the urban environment alter the evolution of thunderstorms? The researchers described three mechanisms:

Urban heat islands: Cities produce heat and are often 2 to 5 degrees Fahrenheit hotter than the surrounding environment. In milder storms, this "heat island" can provide fuel for a modest thunderstorm. But in their study of the 2004 thunderstorm, the Ntelekos and Smith found that the heat island had little effect because high winds leveled temperatures.

Urban canopies: While forests have tree canopies, cities have building canopies. The height and placement of buildings alters a storm's low-level wind field, a key ingredient in its behavior. The tall buildings increase wind drag on the city, resulting in vertical velocities – essentially a boiling action – that can enhance rainfall. The urban canopy had a large effect during the 2004 storm, the researchers found, which was exacerbated all the more by the presence of the Chesapeake Bay to the east.

Urban aerosols. These are essentially minuscule particles in the atmosphere that are at elevated levels in urban environments due to industrial and automobile emissions. Traditionally, researchers have thought that air pollution tends to suppress precipitation. But Ntelekos and Smith believe their research points to the possibility that urban aerosols actually increase rainfall. Ntelekos plans to build on his Baltimore research in a more detailed study of the effect of aerosols on thunderstorms in New York City.



This figure shows the trajectories (represented by the white lines) of what were initially two storm-cells (cells 1 and 2 were initially one storm cell; cell 3 remained a single storm cell). The first cell approached Baltimore from the south (starting at 18:01, the first double colored circle at the bottom). This individual cell, when it reached the urban environment, split into two cells: cells 1 and 2 (notice that the circles showing the path of this cell become one color after 18:19, when the cell splits). Cell 1 moved toward the center of the city but didn't make it over the city and was deflected (at 18:31) toward the western part. Cell 2 got trapped at the southwest part of the city and remained stationary for almost half an hour. "We saw this pattern repeating several times during the storm based on radar observations," said Alexander Ntelekos. Cell 3 originated to the west of Baltimore and never made a pass over the city. (Source: Alexander Ntelekos, Princeton University School of Engineering).

Greener cities – Urban warriors leading the climate battle

www.climatechangecorp.com

The following has been abstracted from an article published on a climate change website (www.climatechangecorp.com).

Nick Jones 7 Aug 07

City authorities are outstripping national governments in responding to climate change. Look out over the semi-urban stretch of land that is the Thames Gateway, and you can see the hopes and fears that climate change has brought to London.

The area had been largely ignored by developers because of its high flood risk. But demand for homes in the fast-growing south-east of England has overruled these concerns, turning it into a major development corridor, just as concerns mount over rising sea levels.

London's authorities have chosen a site here for an "exemplar" scheme that aims to show how urban living can be brought into harmony with the environment. Six groups of companies tendered for the carbon-neutral Gallion Park development, in a competition that pitted their environmental credentials against one another's.

The contest underlines a growing trend. Cities across the world are using their own powers to confront climate change, sending clear signals to industry through their procurement and planning systems, their ability to shape public behaviour and their co-operative initiatives with other cities.

The most ambitious initiative led by a group of cities is the Energy Efficiency Building Retrofit Program, launched in May by former US president Bill Clinton. London, Berlin, Paris, Rome and Madrid are among 40 cities working on the scheme, which is administered by the Clinton Foundation and builds on an innovative environmental finance technique.

Refitting a building to make it more energy efficient can cut the amount of energy needed to heat it, reducing emissions and saving the owner money. If an energy firm guarantees the savings a refit will achieve, a bank can then finance the work on the basis of those future savings – allowing it to go ahead at no upfront cost.

The result is a scheme that aims to double the size of the global market for energy efficiency improvements to buildings in a single move. Five banks including ABN Amro and Citigroup have agreed to create a pool of $5 billion, while four energy firms including Siemens and Honeywell committed to scale-up their capacity to carry out energy audits and refits.

For Gary Page, a senior financier at ABN Amro involved in the programme, the scheme has a strong commercial rationale. "Buildings consume 40% of the world's energy and account for one third of greenhouse gases," he says. "Increasing the energy efficiency of their facilities can make a significant impact, both to an organisation's carbon footprint and to its bottom line."

The programme is the first major initiative of the C-40 Large Cities Leadership Group, a network of 40 cities from around the world, which was established in 2004 to co-operate on climate change matters. Whereas climate negotiations between national leaders face many obstacles, co-operation between cities appears to be remarkably smooth and trouble-free.

"The cities converged early on around the idea of retrofitting existing buildings," a spokesman for the Clinton Climate Initiative explains. "The fact that we launched in August 2006, and nine months later had our first initiative speaks to the way the cities were willing to work together quickly to get it off the ground."

A number of factors strengthen the role that cities are playing in creating the commercial realities of a low carbon world.

First, their variety of economies, cultures and natural settings means that cities are testing out different solutions to climate change under a diverse set of conditions. Iceland lacks its own fossil fuels, and Reykjavik has responded by pioneering a transport system based on hydrogen-powered fuel cells. A law in Barcelona has made solar panels mandatory on new or refurbished buildings, while Copenhagen has built on its tradition of neighbourhood heating systems to slash its dependence on remotely generated power.

Second, globalisation is giving the largest cities a stronger position on the international stage. Growing trade, finance and communications – together with a worldwide trend towards political decentralisation – allow them to act as nodes in a set of international relationships, rather than just being part of a national economy. Other networks include Cities for Climate Protection programme, a 650-strong network of members that runs a programme of work to cut emissions in each city and adds to the pressure for government action.

Third, taking action on climate change is becoming a vote-winner. Delegates at the C-40 Cities conference in New York recently discussed how the issue has helped many mayors to win elections.

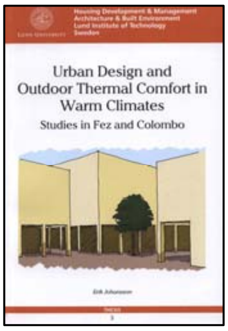
More than half of the UK public thinks climate change requires immediate "radical" action, according to an October 2006 poll commissioned by EDF Energy, while only 2% say the concerns are "scaremongering". By hitching their administrations to the issue, mayors can boost their popularity and raise their profile.

Source: www.climatechangecorp.com. Image from the London Thames Gateway Forum (www.ltgf.co.uk).

Urban Project
Urban design and outdoor thermal comfort in warm climates – Studies in Fez (Morocco) and Colombo (Sri Lanka)

Introduction

This report summarizes a recently finished PhD project which studied the relationship between urban design, microclimate and outdoor thermal comfort in warm climates. In such climates, urban warming leads to decreased thermal comfort in urban areas, which has a negative effect on people's well-being, e.g. reduced mental and physical performance and the risk for serious health problems.



The cities studied, Fez in Morocco (34.0°N, 5.0°W) and Colombo in Sri Lanka (6.9°N, 79.9°E), represent two types of climate typical of many urban areas in developing countries. Fez, which has approx. 1 million inhabitants (Fig. 1), is situated in the hot, dry climate of North Africa, whereas Colombo (Fig. 2), which has about 1.4 million inhabitants, belongs to the hot, humid climate of South Asia. Fez has an inland climate characterized by large diurnal temperature variations and distinct summer and winter seasons. The coastal climate of Colombo, on the other hand, is characterized by small diurnal and annual temperature variations. Both cities are experiencing problems of rapid population growth, leading to considerable horizontal expansion of urban development, characterised by inefficient land-use.

Methodology

The research methodology included a combination of microclimate measurements, numerical microclimate simulations and studies of the urban planning process. Field measurements were conducted in areas with significantly differing characteristics, including variations in urban geometry and distance to the sea, to map variations in microclimate and outdoor thermal comfort within each city. The field measurements were carried out in cooperation with the National Laboratory for Tests and Studies (LPEE), Morocco, and the dept. of Architecture, University of Moratuwa, Sri Lanka (see Country Report Sri Lanka, IAUC Newsletter no. 12)

To cover a wider range of urban design, to test the impact of different design parameters on outdoor thermal comfort and to achieve optimum design solutions, microclimate simulations were conducted using ENVI-met (see IAUC Newsletter no. 5). This software provides a detailed output of microclimate variables which enables the calculation of the physiologically equivalent temperature (PET) – a thermal comfort index that takes air temperature, mean radiant temperature, humidity and wind speed into account (Höppe 1999). Since the comfort limits of this index have not been defined for warm climates, the upper comfort limit was assumed to be PET = 33°C based on the study of Ahmed (2003). This limit is shown as a dashed line in Figs. 3–7.

The urban codes in Fez and Colombo were analysed to determine whether they favour or hinder climate-conscious urban design, while the interviews with urban planners and designers aimed at investigating the extent to which climate aspects are included in urban design.

Fig. 1. Examples of streets in Fez, Morocco. Left: an alley in the old city (the Medina), right: a residential suburb (Adarissa).

Fig. 2. Examples of streets in Colombo, Sri Lanka. Left: Galle Road, south of the city centre, right: the Central Business District.

Results

The results of the simulations showed that the height-to-width ratio (H/W) of street canyons, street orientation and provision of horizontal shading had the greatest influence on thermal comfort at street level. Moreover, it was shown that PET decreased with increasing thermal admittance and decreasing surface reflectivity (albedo), although the effect of these parameters was limited (which may, partly, be due to the fact that ENVI-met does not consider thermal mass of buildings).

In the case of Fez, both measurements and simulations showed that canyons with high H/W, where buildings provide shade, represent an advantage under summer conditions. On the other hand, for the winter season, a dispersed urban form, with streets with low H/W, is preferable. However, since the summer season is longer than the winter season and since it is more difficult to adapt behaviour and clothing to warm conditions, the majority of streets should be designed for good summer comfort. The simulation study suggested that H/W ratios for east-west streets should be as high as 4 to provide comfort in the summer. Still, overhead shading will be necessary to provide comfort during hours when direct solar radiation enters the canyon (morning and afternoon), see Fig. 3. The effect of colonnades and shading trees is shown in Fig. 4. For north-south streets, which turned out to be less problematic in terms of thermal comfort, a H/W of about 2 provided acceptable conditions both in summer and winter. However, to provide comfort in summer around solar noon, overhead shading

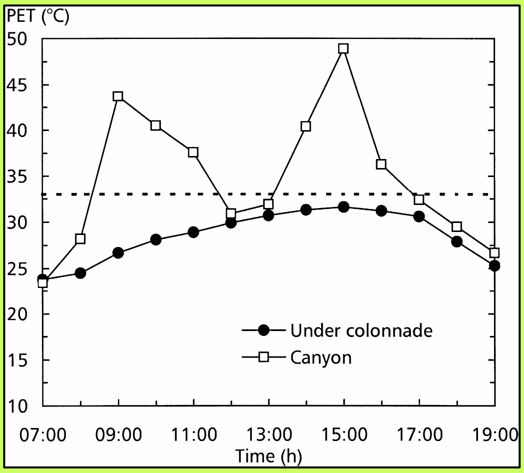


Fig. 3. Simulated PET variation for the summer in Fez for an east-west street of H/W = 4 with a colonnade on the northern side.

is necessary. To provide thermal comfort also in winter, at least some streets, preferably oriented east-west, should be wider to allow for solar access. The canyon of H/W = 0.67 with a colonnade on its northern side and trees planted along the southern side provided sufficient solar access under the colonnade in winter (Fig. 5), while providing sufficient shade under the same colonnade and under the shading trees on the southern side in summer. Deciduous trees are suitable since they provide shade in summer and allow solar access in winter. Open public spaces should preferably be small, but sufficiently large to allow solar access in winter.

The results from Colombo were similar to those of the summer in Fez, although PET values were slightly higher. The simulation study suggested that H/W ratios for east-west streets should be as high as 4 to provide comfort in the summer. For north-south streets, which proved less problematic in terms of thermal comfort, a H/W of about 2 provides acceptable conditions, although overhead shading is necessary to provide shade around noon (Fig. 6). In Colombo, spacing between buildings is preferable to permit air flow. This is especially important for the coastal strip to allow the westerly sea breeze to penetrate the city. Consequently, some east-west oriented streets in coastal areas should have low H/W ratios. Such shallow canyons result in very high PET values, but if overhead shading is used thermal comfort improves considerably (Fig. 7). A way to improve comfort conditions in a hot, humid climate would be to use detached tower blocks, since they provide a large amount of shade while allowing the wind through and, in fact, stimulating air flow. A blend of high-rise towers and lower buildings, and the use of buildings raised on columns would probably promote even greater air flow.

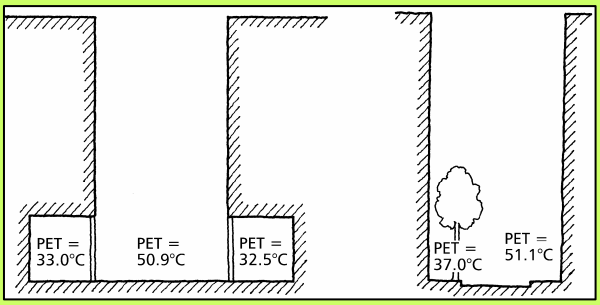
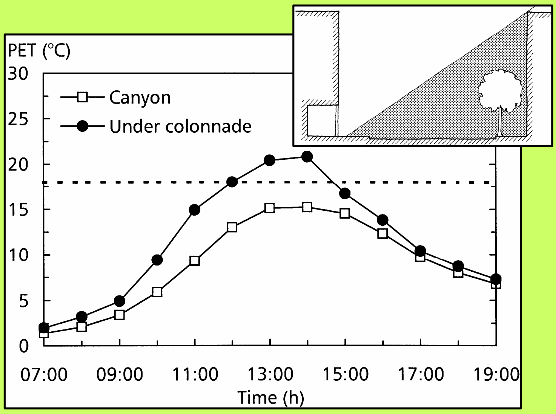


Fig. 4. The effect of overhead shading in an east-west canyon of H/W = 2 in Fez during the summer. The graphs show the simulated maximum PET at 15:00 h under colonnades and under a row of shading trees.

Fig. 5. Simulated PET variation in an east-west street of H/W=0.67 for the winter in Fez. The street has a colonnade on its northern side and a row of shading trees on its southern side.



In both Fez and Colombo there should be no front setbacks, as is now the case, in order to increase opportunities to provide shade for pedestrians at street level (in Colombo, however, side setbacks would be preferable to avoid continuous rows of buildings blocking the air flow). Moreover, overhead shading should be provided in the form of projected upper floors, colonnades, shading trees or other devices to improve thermal comfort for pedestrians. Similarly, open public spaces should be provided with overhead shading to improve comfort.

Urban codes, which include regulations on building heights, street widths, plot coverage, setbacks etc, were found to have a major impact on urban design in both Fez and Colombo since they tend to be followed strictly in formal construction. However, most of the proposed street designs are not possible to achieve given current urban regulations, particularly not in low-rise residential areas. There is thus a need to revise the codes to permit higher H/W for streets than is currently the case. Such a shift to higher building densities would also lead to higher population densities, which is in line with the aims of the national authorities in both countries. Future codes should also promote projecting upper floors and colonnades, which provide shade at street level. Similarly, horizontal shading devices and shading trees should be encouraged.

The interviews with urban planners conducted in this study revealed that the consideration of climate in urban planning and design is limited both in Fez and Colombo. There are a number of constraints explaining this, e.g. the lack of knowledge about climate issues and the lack of user-friendly tools to predict the effect of urban design on the microclimate.

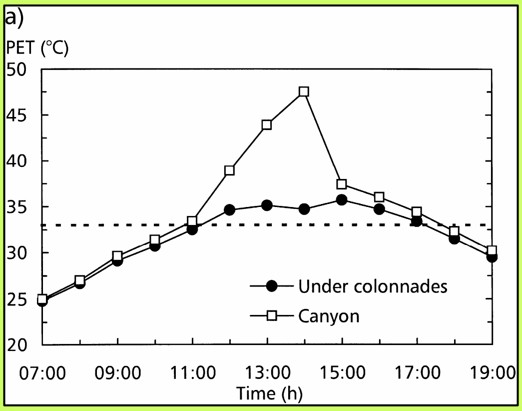


Fig. 6. Simulated PET variation for Colombo for a north-south street of H/W = 2 with colonnades on both sides of the street.

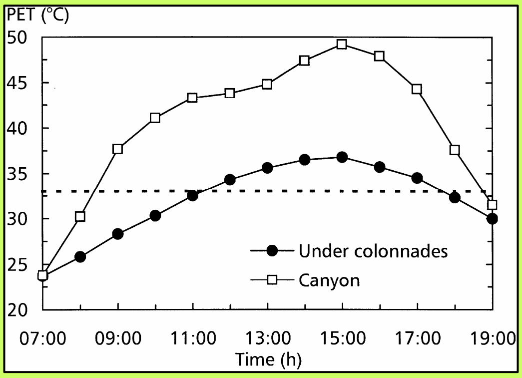


Fig. 7. Simulated PET variation for Colombo for an east-west street of H/W = 0.5, with colonnades on both sides, designed to allow the westerly sea breeze to penetrate the city.

Future work

In the future, there is a need to develop detailed, climate-conscious urban design guidelines and regulations for cities in hot dry and hot humid cities. Such guidelines should include other street orientations than east-west and north-south oriented streets as well as the effect of vegetation. Moreover, field surveys are needed to determine actual comfort zones in hot dry and hot humid climates. In hot humid climates, ways to design urban areas to promote air flow needs to be studied.

In order to increase opportunities for urban designers to design comfortable outdoor environments, there is a need to develop user-friendly design tools. Such development should preferably be conducted in cooperation between urban climatologists and urban designers.

The thesis can be ordered from HDM, Lund University, Sweden.

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Country Report
UHI Research in Singapore

Figure 1: The main Singapore island which is separated from the Malay peninsula by the narrow Straits of Johor to its north, and from Indonesia by the much wider Singapore Strait in the south. Built-up areas are colored in dark red. The main island measures about 45 km east-west and 30 km north-south.

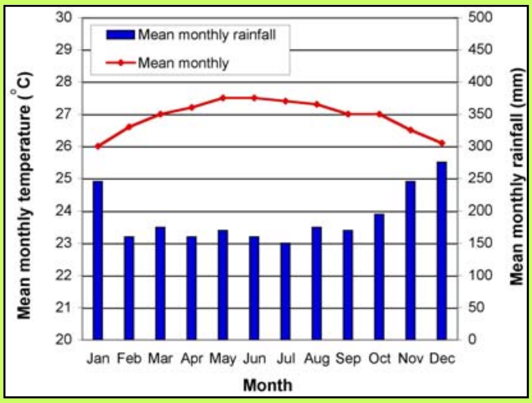

Figure 2: Climograph of Singapore from 1872 – 1988 data (Singapore Meteorological Service, various issues).

General climate and urban development

Singapore (1 °N, 104 °E) is an island state with an area of ~700 km^2 located at the southern tip of the Malaysian peninsula (Fig. 1). Its geographical location translates to an equatorial wet climate with consistently high monthly mean temperatures (yearly average of ~27 °C) and rainfall (yearly total of ~2300 mm) (Fig. 2). Singapore is also subject to climate variations from the Asian monsoon, with surface winds predominantly from the northeast during the winter months, and a regular seasonal reversal from the south and southwest occurs during the summer (Fig. 3). Wind direction during the inter-monsoon seasons is highly variable. The impact of the monsoon is not only restricted to seasonal changes in wind directions. For instance, a notable peak in monthly precipitation occurs from November–January resulting from storms associated with the northeast (winter) monsoon. Conversely, slightly lower than average precipitation occurs during the relatively drier southwest (summer) monsoon months of May–August.

Since gaining independence from Malaysia in 1965, Singapore has undergone rapid urbanization. Population increased from 1.8 million in 1965 to 4.4 million in 2006, resulting in a very high mean population density of ~6,400 persons/km^2. Land-use change has also been rapid both visibly (Fig. 4) and statistically, with a doubling of the built-up area between 1965–2000 (e.g. Chow and Roth 2006). The majority of this urban development is manifested by numerous high-rise Housing Development Board (HDB) residential apartments (with heights of between 15 and 55 m) that house about 85% of the population as well as by large industrial and commercial estates located near the east coast and on the western part of the island. During this period the public housing authority removed the traditional shanty-type settlement (colloquially known as *kampongs)* and concentrated their inhabitants in several high-rise residential clusters known locally as 'new towns' (Fig. 5). This program of urban re-development has resulted in population densities within the residential areas of the dozen or so new towns ranging from 6,066 persons/km^2 in Choa Chu Kang to 103,473 persons/km^2 in Toa

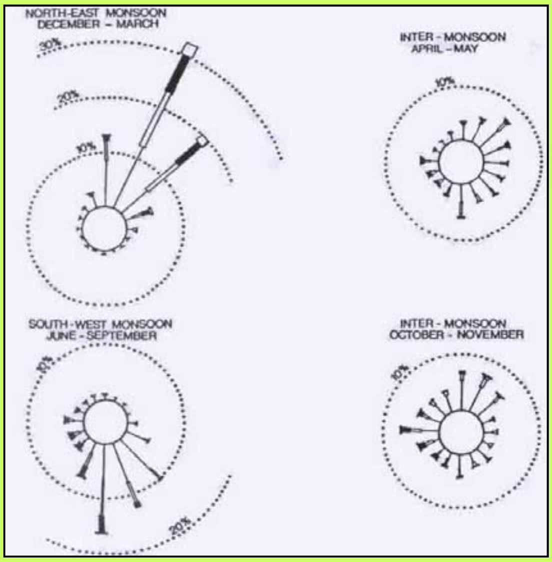

Figure 3: Seasonal surface wind roses from 1956–1980; data taken at Paya Lebar Airfield (Chia and Foong, 1991).

Figure 4: The commercial district of Orchard Road viewed from the same hotel rooftop in 1972 (left), and in 1990 (right). Source: De Koninck (1992).

Figure 5: HDB flats in Singapore (http://www.flickr.com/groups/).

Figure 6: Financial district (http://www.pbase.com/budiraha/image/43404040).

Payoh (HDB 1987, cited in de Dear and Leow 1990). A large commercial area consisting of shopping malls, hotels and entertainment complexes can be found in the south quarter of the island, and the central business district (CBD), which houses the financial centre and numerous tall skyscrapers (maximum height = 280m), is located close to the island's central south coast (Fig. 6).

Such rapid urbanization has significant consequences for the atmospheric environment. Understanding the influence of rapid urbanization on micro- and local-scale tropical climates is important and questions on these impacts have resulted in some level of academic research in Singapore dating back to the early 1960s. Simon Nieuwolt's study on the urban heat island (UHI) of Singapore (Nieuwolt 1966) in the *Journal of Tropical Geography*, then published by the Departments of Geography of the University of Singapore and University of Malaya (now known as *The Singapore Journal of Tropical Geography* published by the Department of Geography, National University of Singapore) probably constitutes the first UHI study documented in the English literature from any tropical city. This work was immediately followed by one of the first local studies to investigate the role of housing type on the physiological reaction of people to temperature and humidity (Greenwood and Hill, 1968), also published in the same journal. These two pioneering publications laid the foundation for similar research that followed in subsequent decades. This work precedes the pioneering and comprehensive research started by Sham Sani in the 1970s in Kuala Lumpur, Malaysia, another tropical hot and humid city located 400 km to the north of Singapore and which has been reviewed in the IAUC Newsletter No. 12. The present report examines the literature available on the urban thermal climate in Singapore with a focus on UHI work. Recent research on energy balance and carbon dioxide fluxes will be presented as a separate project report in a forthcoming IAUC newsletter.

Canopy layer UHI studies

Nieuwolt (1966) and a team of university students used wet/dry thermometers stationed at several points across southern Singapore to measure air temperatures, which were then compared to a "rural" site at the Paya Lebar airport located at the then-outskirts of the city. Data was collected for

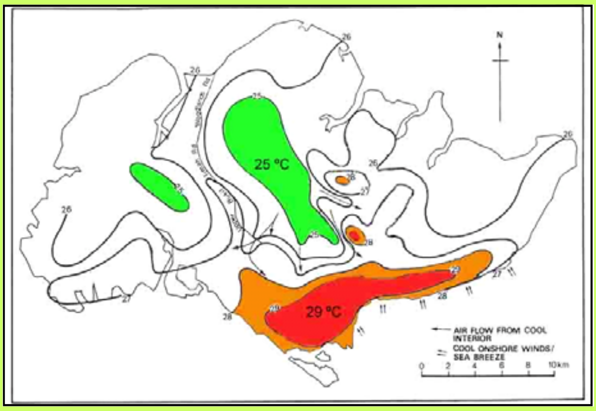

Figure 7: Spatial variation of the Singapore UHI during "warm" summer monsoon conditions (SMS, 1986).

several days in June 1964 to examine the daytime UHI effect, with the peak UHI intensity ($\Delta T_{u\text{-}r,\,MAX}$) of 3.5 °C observed in the densely built-up China Street area on days of "fine weather, with occasional cloud cover and no precipitation". Nocturnal UHI observations taken during a clear and calm night in October 1965 revealed nocturnal $\Delta T_{u\text{-}r,\,MAX}$ of ~4.5 °C occurring around 23:00 hrs LT (Local Time = GMT +8). During cloudy nights, $\Delta T_{u\text{-}r,\,MAX}$ was lower by ~1.5–2 °C.

During several months in 1979 and in 1981, the Singapore Meteorological Service (SMS, 1986) utilized combined site observations from 4 airfield meteorological stations (Changi, Tengah, Paya Lebar and Seletar), and from volunteer residences spread throughout Singapore with traverse temperature measurements to determine the spatial extent of the UHI. Following the assumptions of Chandler's study of the London UHI (1965), temperatures were measured between 22:00–23:00 hrs LT as this was presumed to be when $\Delta T_{u\text{-}r,\,MAX}$ occurs, although site measurements continued past midnight. Southern Singapore was found to have a broad belt of elevated nocturnal temperatures due to the high urban density located there (Fig. 7). This was in contrast to two distinct cool areas; one in central Singapore in a tropical rainforest nature reserve, and another located in the farms and forested military training areas in north-western Singapore. $\Delta T_{u\text{-}r,\,MAX}$ in ideal clear/calm conditions were also found to differ significantly between seasons. Maximum UHI magnitudes were 5 °C and 2.5 °C during the mid-year summer monsoon and year-end winter monsoon months, respectively.

Over several weeks in 1996, Goh and Chang (1998) mapped the spatial distribution of Singapore's UHI to compare how the 22:00 hrs LT UHI has varied since the SMS (1986) study. Using site observations by volunteers spread throughout Singapore, combined with secondary data from the same airfield meteorological stations used by the SMS study, they measured temperatures over 7-day periods in 4 phases corresponding to monsoonal and inter-monsoonal seasons. $\Delta T_{u\text{-}r,\,MAX}$ measurements during clear/calm conditions in both summer (4.8 °C) and winter monsoon seasons (2.5 °C) were similar in magnitude to those measured by the SMS study. There were some changes in the phenomena's spatial extent, however, as previous undeveloped areas in the island's eastern flank were converted to high-density residential areas resulting in higher air temperatures when compared to previous SMS data.

For two nights in 2002 (9 July and 13 September), Wong and Yu (2005) utilized traverses to sample nocturnal air temperature between 02:00–04:00 hrs LT. The second night's study utilized vehicles traversing along 4 routes that maximized spatial coverage. $\Delta T_{u\text{-}r}$ of ~4 ºC was measured between the CBD and a section of forest in the island's north-west. However, there was no mention of the general weather conditions during the traverses for both days.

Chow and Roth (2006) analyzed hourly temperatures measured between March 2003 – March 2004 at four urban stations (Commercial, CBD, high-rise, and low-rise residential are) and compared them with a rural station within a secondary rainforest site in north-western Singapore. The diurnal and seasonal UHI temporal dynamics was evaluated and the peak UHI intensities usually observed 3–5 hrs after sunset at the commercial site and close to midnight at other sites. As with other studies, highest (lowest) seasonal UHI intensities

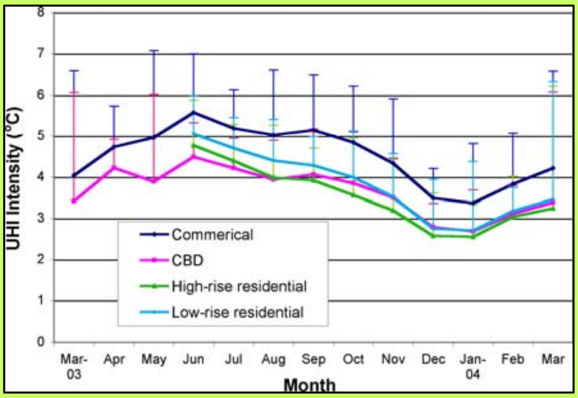

Figure 8: Mean (solid lines) and range of daily maximum (error bars) heat island intensities between March 2003 – March 2004 for four sites. Commercial – Orchard Road site; CBD – Central Business District Site; High-rise residential – HDB site; Low-rise residential – semi-detached housing site (Chow, 2004).

were measured during the summer (winter) monsoon. Chow and Roth (2006) also investigated the seasonal variation of UHI intensity with building density or urban land use. Mean and maximum monthly heat island intensities for the CBD, HDB and low-rise residential sites were consistently lower compared to the ones measured in the commercial center near Orchard Road (Fig. 8).

All these studies confirm the existence of a nocturnal canopy-layer UHI in Singapore. The highest temperatures are found in the commercial areas and CBD district in the south-central part of the island, slightly lower temperatures are observed in the residential suburbs and the lowest temperatures are measured in the rural, least developed areas located in the island's centre and north-west. October nighttime heat island intensity observations are available from a number of studies since the early 1960s. They allow an assessment of changes in the street-level thermal environment over time under similar climatic conditions. The data show that the UHI has increased from ~4.5°C in 1965 (Nieuwolt, 1966) to ~6°C in 2003 (Fig. 8, Chow 2004). This amplification can be attributed to building density, traffic, commercial activities and air conditioning use which emits warm air which have all increased significantly during the last 40 years. The largest ever UHI intensity of 7 °C was recorded in May 2003 ~3 hrs after sunset in the commercial district of Orchard Road under clear and calm weather conditions (Chow and Roth 2006).

Thermal remote sensing of the UHI

Satellite imagery has been used by Janet Nichol who worked in the Division of Geography at Nanyang Technological University (Singapore) in the 1990s. Using Landsat Thematic Mapper data from an overpass at 10:40 am LT on 24 May 1989 (Fig. 9) she investigated high-resolution (120 m) temperature patterns in nine of Singapore's HDB estates located near the center of the island (Nichol 1994). Using a GIS-based approach she found a strong correlation between the surface temperature patterns which were correlated to the amount of vegetation (biomass) and daytime air temperatures. The high-resolution thermal data further suggested a mosaic of potential micro-climates at or below rooftop level, influenced by the thermal characteristics of the immediate active surface rather than horizontal advection. The influence of building geometry and landscape features at different times of the year in two HDB estates located in the center of the island was studied using an additional image acquired at 10:40 am LT on 15 March 1991. Overall a remarkable degree of similarity in surface temperatures was observed between the two images representing Bishan East and Serangoon Central

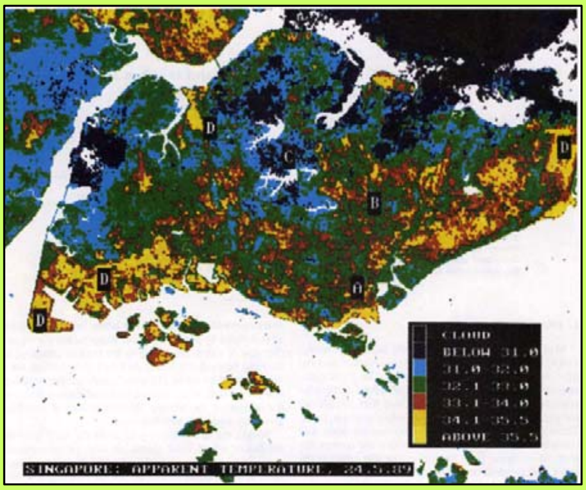

Figure 9: Landsat TM thermal image of Singapore showing surface temperatures at 10:40 LT on 24 May 1989. Note the high temperatures (yellow) particularly in the SW and E which are industrial areas and the international airport surrounded by reclaimed land, respectively (Source: Nichol 1996).

neighborhoods (Nichol 1996). Using simultaneous observations of surface and air temperatures in urban canyons, the author concluded that for daytime conditions, which are usually characterized by low wind speeds, satellite-derived surface temperature patterns are a good indicator of the daytime UHI. A cooling effect of 1.5 – 2 ºC of urban tree canopies on daytime air temperatures was also detectable on the satellite images. No significant cooling effect was observed for grassy surfaces. Nichol (1998) used the Landsat image from 24 May 1989 to create a model representing the temperature of the complete urban surface, i.e. interpolating the 2D thermal satellite data over the 3D urban surface using a GIS interface. Due to the close correspondence between morning surface and air temperatures in HDB districts already postulated by Nichol (1996), Nichol (1998) concluded that the model is capable of indicating micro-scale climatic variations due to variations in building geometry and surface materials which are not readily apparent from the 2D perspective.

Future considerations

Singapore plans to augment its population by more than 40% to about 6.5 million, a growth target recently communicated by PAP, the local ruling party. Such growth on an island with limited space will inevitably lead to increasing pressure on the environment. The UHI data presented in this report demonstrate that increasing urbanization and its associated activities have a measurable effect on the thermal environment. High day- and nighttime temperatures and high humidity which are characteristic of equatorial/wet climates present a challenging living environment for people. Temperature increase associated with the UHI further decreases human comfort, productivity and increases heat-related illnesses. It will be important to monitor the state of the atmosphere in the future and produce data and results which can be used to manage such significant urban growth in a sustainable way which does not occur at the expense of human comfort.

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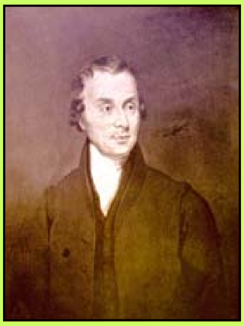
The Luke Howard Award

The Luke Howard Award



Call for nominations

Deadline: 1 October 2007

Dear IAUC Members,

The Luke Howard Award is given annually to an individual who has made outstanding contributions to the field of urban climatology in a combination of research, teaching and/or service to the international community of urban climatologists. Past winners include:
2004 Prof. Tim Oke
2005 Prof. Ernesto Jauregui
2006 Prof. Arieh Bitan

Nomination materials for the 2007 Award will be collected and coordinated by the first person to notify Manabu Kanda (kanda@ide.titech.ac.jp), Chair of the IAUC Awards Committee, that a particular person is to be nominated. Posthumous awards will not be made, no self-nominations are permitted and current Awards Committee members cannot be nominated.

Coordinators must collect the following documentation and submit it (in a single electronic submission) to the Chair of Awards Committee by 1 October 2007: Three-page candidate-CV and two-page letters of recommendation from three IAUC members from at least two different countries.

Please check the IAUC website (http://www.urban-climate.org) for more details and award schedule or contact the Chair of the Awards Committee for additional information.

Tony Brazel (USA)
Ingegard Eliasson (Sweden)
Ernesto Jauregui (Mexico)
Manabu Kanda (Chair, Japan)

Previous Award Winners

2004
Tim Oke receives a presentation copy from Jamie Voogt at UBC, Vancouver, Canada.

2005
Ernesto Jauregui (centre) receives a presentation from Dr. Carlos Gay García (on the right) and Dr. René Drucker Colín at UNAM, México.

2006
Arieh Bitan receives a presentation from Hadas Saaroni at Tel Aviv University, Israel.

IAUC Committee Reports

Bibliography

Thanks to everyone for their contributions this month. Please send any further references to papers published since January 1 2007 for inclusion in the next newsletter to j.salmond@auckland.ac.nz. As before, please mark the header of your email with 'IAUC Publications 2006'. In order to facilitate entering the information into the data base please use the following format:

Author:
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Journal:
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Dates:
Keywords:
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We look forward to hearing from you soon!

Jennifer Salmond
j.salmond@auckland.ac.nz

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(Languages are specified where the publication is known to be in a language other than in English.)

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Newsletter Contributions

The next edition will appear in early April. Items to be considered for the next edition should be received by **July 31, 2007.** The following individuals compile submissions in various categories. Contributions should be sent to the relevant editor:

News:	Dr. J. Marshall Shepherd marshall.shepherd@nasa.gov
Conferences:	Jamie Voogt javoogt@uwo.ca
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General submissions should be relatively short (1-2 A4 pages of text), written in a manner that is accessible to a wide audience and incorporate figures and photographs where appropriate. In addition we like to receive any images that you think may be of interest to the IAUC community.

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Date: 22-26 September, 2008

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Congress Theme: Harmony within Nature

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Congress Organizer: International Society of Biometeorology

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