Urban Climate News

Quarterly Newsletter of the IAUC

ISSUE NO. 36 JUNE 2010 • www.urban-climate.org • INTERNATIONAL ASSOCIATION FOR URBAN CLIMATE

From the IAUC President

Colleagues, welcome to the 36th edition of *Urban Climate News*.

I should start by congratulating Professor **Sue Grimmond**, who is the recipient of the 2009 Luke Howard Award. Sue is well known to members as a former President and as a colleague whose work has benefited the entire urban climate community by raising its profile significantly through both ground-breaking research and diligent work on scientific committees of varying hue. As a community, we are fortunate to have her as one of our own.

The project reports included in this issue capture the scope of the field and its development over the last two decades very well, I think. Improved computer capacity has allowed researchers to 'urbanise' global and regional models that hitherto did not include the presence of cities. This change has occurred with the recognition that individual urban effects extend well beyond the city boundaries and collectively the urban impact is global in scope. In this vein, **Mark McCarthy** *et al.* of the British Met Office Hadley Centre write on the inclusion of cities in global and regional climate projections.

Much of our detailed knowledge on urban climates is based on the study of just a few cities world-wide; however, this is changing. It is especially satisfying that London, as the original city where the urban effect was first described, is among the cities that have undertaken grand research projects (see **Sylvia Bohnenstengel** *et al.* on *LUCID*), which combine observational studies with modelling and establish links with a broad spectrum of urban decision-makers.

Ideally, the collective knowledge gathered on cities and their effect on climate can be used in other cities, without the need for intensive observational studies. To accomplish this requires that links are established between the form (land-cover) and functions (land-use) of the city and its climatic impact. **Steven Burian** and **Jason Ching** provide a methodology that acquires data and derives urban canopy parameters (using a study of Houston, Texas) suitable for urban modelling.

Inside the Summer issue...

Many of these themes were explored at the AAG conference held in Washington DC in April and reported upon by **Chandana Mitra**.

As the World Cup approaches its climax, **Winston Chow** provides some insights into the microclimates associated with stadiums like the match venues, which are 16 in all and 10 of which are over 1200m above sea-level.

Finally, I would like to thank the editor **David Pearlmutter** for the quality of this production. *Urban Climate News* is the best advertisement for the IAUC and its vigour can be judged by the involvement of its members. I would encourage readers to consider sending in reports on projects, on urban climate research in countries and on conferences. It is particularly important that we gather and share information on the rapidly urbanising, less researched, parts of the world.

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A brief survey of stadium microclimate and sports

As the World Cup heats up in South Africa, **Winston Chow*** *takes a look at some lessons from the field of urban climatology – and tells us how they just might influence the final score*

June, 2010 — Wembley Stadium in 1966. The Estadio Azteca in 1970 and 1986. The Stade de France in 1998. The Olympiastadion in 2006. These cathedrals of football[1] were host to the World Cup finals of the most popular sport in the world, and Soccer City in Johannesburg will join this exclusive list in July. As a long-suffering England fan, I will be following the team's fate with cautious optimism as it competes in the tournament's first foray into the African continent. While I daresay that most (if not all!) IAUC members will also take a well-deserved short break to enjoy this football festival, I'd like to put on my urban climatologist cap for a little bit and discuss some ways in which stadium design – and its resulting microclimates – could affect several professional sports to varying degrees. Although there are numerous sports worthy of review, such as rugby, golf, and American football, I will limit my review to three of my favorites that I often play and watch: football, cricket, and baseball.

Turf quality, shade and missed penalties

I always note the pitch condition before playing (or watching) a football game. Does the field appear "slippery" with many divots? Does the ball roll smoothly or bobble over certain areas? Are there bare patches in the penalty box that affect bounce? You may consider these questions trivial, but for football aficionados, these are important indicators affecting tactics and strategy. For instance, should players wear short or long cleats/studs? Stick with a short, fluid passing game or bypass a bumpy pitch with a direct aerial route? The team that adapts better to imperfect field conditions generally has an advantage over its opponents, and these benefits can make a crucial difference between winning and losing at the professional level.

Figure 1. The San Siro Stadium in Milan. Note how the roof structure and tall stands combine to reduce direct sunlight reaching the pitch. In the 1980s and '90s, the resulting poor turf quality was a serious issue of concern (Source: Wikimedia).

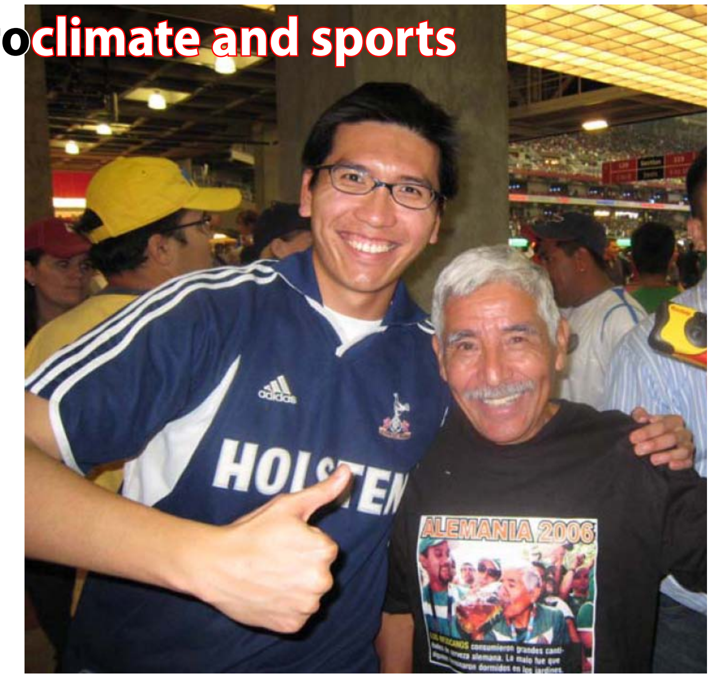

Figure 2. The author (left) in the University of Phoenix Stadium during an international friendly between the U.S.A. and Mexico in February 2007. He is with a proud Mexican football fan who has traveled to every World Cup since 1974 – including the 2006 tournament (see his shirt!). The venue is notable for being a rare stadium with a pitch that can be rolled outdoors when not in use. (*Source*: Author)

So how does pitch condition relate to microclimate? The answer lies in stadium design with respect to the football economics. To cope with rising spectator demand in recent years, professional sports teams – especially several European football clubs – have constructed stadiums with larger and larger stands directly adjacent to the playing surface to increase seating capacity. In England, for instance, Old Trafford (Manchester United) and Stamford Bridge (Chelsea) have undergone significant stadium expansion over the past 10 years. Some teams just move to larger stadiums when expansion is not possible. In 2006, Arsenal F.C. moved from Highbury (capacity: 38,000) to the Emirates Stadium (60,000).

Taller stands, combined with their closeness to the playing surface, increase direct shading at field level. This likely leads to detrimental consequences for turf quality. In a 1995 survey of microclimate in 28 English and Scottish Premier League stadiums, significant differences in turf strength

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[1] As I repeatedly tell my American friends, it is called *football* and not soccer.

**Between matches, Winston T.L. Chow is affiliated with the School of Geographical Sciences & Urban Planning, Arizona State University* were observed between shaded and non-shaded turf, with more divots and shallow rooting occurring in the former.[2] These indicators of poorer pitches would also multiply in magnitude if the stadium is used for other purposes like rock concerts (e.g. the new Wembley Stadium in London). If left unchecked, playing surfaces at the professional level would have to undergo the costly process of being re-laid to lower risk of player injuries on bad pitches. One sad example is Marco van Basten, the former Dutch and A.C. Milan striker, who retired from chronic ankle injuries at the young age of 30. It was widely suspected that playing in the San Siro Stadium (Fig. 1), which had well known problems with poor turf from a lack of direct sunlight from its towering stands aggravated his condition.

Over time, professional groundskeepers are becoming more aware of these microclimate issues from shading, and have adapted accordingly with appropriate sand bases, irrigation and nutrient regimes. The San Siro surface is now impeccable, for instance, despite its heavy use every season by two Serie A teams (A.C. Milan and current European Champions' League winners Inter Milan). Several recently built multi-purpose stadia; however, bypass this problem with an elegant but expensive solution. To facilitate a better playing surface, the pitch is laid on top of rollers, allowing it to be moved outside the arena for growth under natural conditions. These high-tech stadiums include the Veltins-Arena in Gelsenkirchen, Germany, and the University of Phoenix Stadium in Glendale, Arizona (a mere 45 minute drive from my university campus) (Fig. 2).

Apart from potential player injuries, it could be argued that poor turf quality from shading directly impacts football games at crucial moments. David Beckham missed two penalties whilst captaining England against Turkey (during a Euro 2004 qualifier) and Portugal (during the tournament's quarterfinal). Both attempts were hoofed well over the crossbar. Of note were that (i.) Beckham's standing leg slipped during the kick against the Turks, and (ii.) white dust from the penalty spot puffed up when Beckham badly sliced his penalty in the Portugal shoot-out, possibly indicating an uneven surface.[3] Both kicks were also taken at the southern end of each stadium, where turf around the penalty area had less exposure to direct sunlight. Coincidence?

Howzat? The abandoned Test match and the good Dr. Fremantle

The colonial sport of cricket has a long and storied history, of which there are two chapters of interest. In early 2009, England toured the West Indies and played the second of four Test matches in the newly built Sir Viv Richards Stadium in Antigua. When the match started, however, it was apparent that the pitch was completely unsuitable for play as bowlers lost their footing during their delivery strides and risked injury. To the shock of cricket fans everywhere, and to the great embarrassment of the hosts, the match was abandoned after a mere ten balls.[4]

How was this farce possible? This stadium was built two years prior and was plagued with problems from the start, which included inadequate field drainage from excessive sand and poor turf quality in the outfield. The latter characteristic was partly due to the enormous, towering South Stand. Antiguans – including Sir Viv himself – harshly criticized the state of the ground and its poor stadium design, noting "the shadow now cast by the massive roof prevented the grass from getting adequate sunlight during the growing-in process."[5] After this debacle, the stadium underwent further repairs, with approval to stage international matches only being granted earlier this year by the International Cricket Council; however, it is notable that no Tests are scheduled for the Sir Viv in the near future.


Figure 3. The WACA ground in Perth, Australia, with the Swan River and the Indian Ocean in the background (Source: Western Australia Cricket Association).

Of course, stadium microclimates can also influence cricket games under less controversial circumstances. The design of the Western Australian Cricket Association (WACA) ground in Perth (Fig. 3), coupled with its adjacent location to the Swan River, allows for a distinct microclimate phenomenon to influence bowling tactics. During the afternoon, especially in matches played in the Southern Hemisphere summer, a steady sea breeze passes through the WACA; this phenomenon is called the "Fremantle Doctor" as it appears to originate from the coastal town of Fremantle and "travels" upriver,

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[2] Baker, SW. 1995. "The effects of shade and changes in microclimate on the quality of turf at professional soccer clubs. II. Pitch survey" Journal of the Sports Turf Research Institute, 71:75-83.

[3] Incidentally, the Portuguese midfielder Rui Costa also subsequently sliced his penalty over the crossbar during the shoot-out, and looked accusingly at the penalty spot after his miss.

[4] For those unfamiliar with cricket, a Test Match can last up to five days. Having the match abandoned after ten balls is akin to a football match being stopped after the first minute of play.

[5] ESPN Cricinfo, February 13 2009. "The game should never have been allowed to start" Available at http://www.cricinfo.com/wiveng2009/content/story/390681.html

providing relief to spectators from the summer heat.

Due to the relatively open design of the stadium (as opposed to enclosed arenas like football stadia), the breeze usually passes unimpeded across the cricket pitch. Canny fast bowlers have also taken advantage of the additional swing enabled by the good Doctor to take wickets, especially when combined with the bouncy and quick nature of the pitch. This advantage is not limited to the quicker bowlers as accurate off-spinners who thrive on bounce can bowl into the breeze for additional drift.

Some memorable bowling feats have occurred at the WACA, and my favorite would be the great West Indian bowler Curtly Ambrose using the excellent conditions to take seven Australian wickets for just one run in 1993. On the other hand, the windy conditions have also troubled many visiting bowlers unaccustomed to the conditions – especially English bowlers, unfortunately.

Goodbye, home run!...or is it?

Stadium microclimates are also a prominent factor in America's favorite summer pastime: baseball. If the ballpark is not a "dome" (i.e. indoor stadium like Tampa Bay's Tropicana Field), one can expect the prevailing wind fields inside stadiums to have an important role in fly ball movement. Wrigley Field, home of the (cursed?[6]) Chicago Cubs, is located adjacent to Lake Michigan. Just like the WACA, the shifting winds – generally blowing either towards or away from home plate – often affects the distance of fly balls. These can correspond to a pitchers' duel or a batters' slugfest, or can also push foul (or fair) balls back into (or out of) play.

The impact of local-scale or regional winds is also a factor in dispelling one of the game's biggest myths. Located in the mile-high city of Denver, and home to the Colorado Rockies, Coors Field has a reputation for being a hitters' paradise since fly balls travel further at that altitude according to physical laws. A study evaluated this popular claim.[7] It was expected that the mean home run distance would travel 10 percent further than a similar home run hit at sea level due to the lower air density at 1600 m. After analyzing 1994-1998 home run data from all games in National League ballparks with meteorological data collected at Coors Field, the authors concluded that the average home run distance there was significantly less than hypothesized. A major reason for this was that regional upslope winds generally occurred during games – with these winds blowing in from center field towards home plate – and often minimized the effect of lower air density on fly ball distance.

Sometimes, stadium microclimates are not responsible for baseball anomalies, despite assertions to the contrary. When the New York Yankees moved from old to new Yankee Stadium in 2009 (Fig. 4), their fans – who are generally sticklers for the rich tradition and history of the Yankees – were assured that the field dimensions were not altered during the transition. Thus, baseball fans were stunned during its first season when home runs were hit with alarming regularity at the new stadium, both by the Yankees and visiting teams. During its first 20 games, a record 75 home runs were hit, with left-handed pull hitters especially benefiting. Routine fly ball outs to right field in other parks were instead clearing the wall in Yankee Stadium, prompting commentators to call the new ballpark a "joke." Some suspected a mysterious microclimate event to be responsible, such as from different stadium tier slope angles in the new stadium affecting wind flow during games.

Figure 4. The Old (left) and New (right) Yankee Stadium in 2008. When completed for the 2009 season, anomalous home run totals in the new stadium were suspected to be influenced by microclimates (Source: New York Times).

It turns out, however, that the most likely reason was much more prosaic. A study by a meteorological company examined 105 homers out of 29 games at the new Yankee Stadium in June 2009, and found that a slight alteration to the shape and height of the right field wall was responsible for the home run glut. The new right field wall was not concave in shape as its predecessor, owing to a new manual scoreboard built into the wall, thus shortening the distance of right field perimeter to home plate by an average of 4-5 feet. The height of the right field wall was also shorter (8 feet vs. 10 feet) at the new ballpark. These factors accounted for 20 additional home runs in the new stadium, which would have been warning-track fly ball outs instead in the old stadium.

Conclusion

As you can see, microclimates resulting from stadium design can have some impact on the strategy, tactics and outcomes of several professional team sports. I hope you'll keep this in mind as you follow the games of this World Cup, or if you retroactively recall past games in which a memorable play could have been directly affected by a bad bounce or a sudden gust of wind. As for me, I can't wait for the inevitable heart-wrenching English penalty shoot-out loss in the quarterfinals* – I'll blame the pitch, as usual.

* *The overly optimistic author wrote this before the start of the World Cup.*

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[6] The Cubs have not won the World Series since 1908, and last competed for one in 1945. Some say that the Curse of the Billy Goat is responsible for their ill luck.

[7] Chambers, F., Page, B., & Zaidins, C. 2003. "Atmosphere, weather, and baseball: How much farther do baseballs really fly at Denver's Coors Field?" *The Professional Geographer*, 55(4):491-504.

Including cities in Met Office Hadley Centre global and regional climate projections

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With rapid urbanisation expected through the 21st century, the global population of the world is going to have to contend with both the large-scale consequences of climate change induced by emissions of long-lived greenhouse gases, and the local and regional climate change resulting from land use change, and other environmental impacts, associated with urbanisation. These two processes of man-made climate change operate across very different spatial and temporal scales, but they should not be assumed to act independently. In this article we demonstrate ongoing work in representing the urban land surface in the Met Office Hadley Centre Global Climate Model (GCM), and the higher resolution Regional Climate Model (RCM). This work is aimed at quantifying the cumulative impacts and interactions of radiative forcing from greenhouse gases, urban land use, and waste heat emissions in the urban environment.

Introduction

Advances in recent decades have produced a range of numerical models designed to simulate the key physical processes governing the heat, moisture and momentum transfer between the urban canopy and a dynamical atmosphere model such as those used for numerical weather prediction (NWP) and climate research. The Met Office has included a representation of the urban land surface within its operational weather forecast model since 2000 (Best, 2005). However, it has received considerably less attention in the context of the climate model. McCarthy *et al*. (2010) provide an assessment of the urban response to global and local climate forcings. In this article we review these results and discuss further analysis of urban areas in the higher-resolution regional version of the climate model. The GCM and RCM experiments were conducted to address different applications, and are therefore not directly comparable experiments, but they are qualitatively compared here to illustrate common features.

Model

For inclusion in atmospheric climate or NWP models, urban surface schemes must balance the competing requirements of the complex urban terrain with the computational limitations of the atmospheric model (Best, 2006). To address this, the Met Office Unified Model (UM) uses a tiled land-surface scheme to allow for sub-grid scale heterogeneity in the land surface (Essery *et al*. 2003), which includes a simple urban classification that modifies both surface properties and the radiative exchanges between the canopy layer, the lowest atmospheric layer above and the soil model below (Best, 2005, Best *et al*. 2006). Best *et al*. (2006) provide a critical evaluation of this scheme, and it is also being assessed as part of the international urban model inter-comparison (Grimmond *et al*. 2010). In comparison to non-urban surfaces in the model, the urban canopy has a large thermal inertia, large aerodynamic drag, is impervious to water, and has limited surface water storage. Anthropogenic heat release that results from buildings, traffic, and people is also included as an additional term in the surface energy balance equation for the urban surface.

We have conducted a series of climate sensitivity experiments using the HadAM3 atmosphere-only climate model (Pope *et al*., 2000) modified to include the Best (2005) urban scheme. Experiments were run for 25 years and conducted using two values of atmospheric CO_2 concentrations (323 ppm and 645 ppm; see McCarthy *et al*. 2010 for more details) and referred to as C1U and C2U. The HadAM3 model has a horizontal resolution of approximately 300km; consequently, the urban coverage of model grid cells is small. This means there is negligible feedback of the urban tile onto the grid-cell scale climate. However, even where the feedbacks are weak, coupling the urban and climate models in this way enables the urban surface exchange calculations to be conducted at every model time-step, allowing the model to respond to the full diurnal cycle of the simulated meteorology.

The higher resolution regional model of HadRM3 has

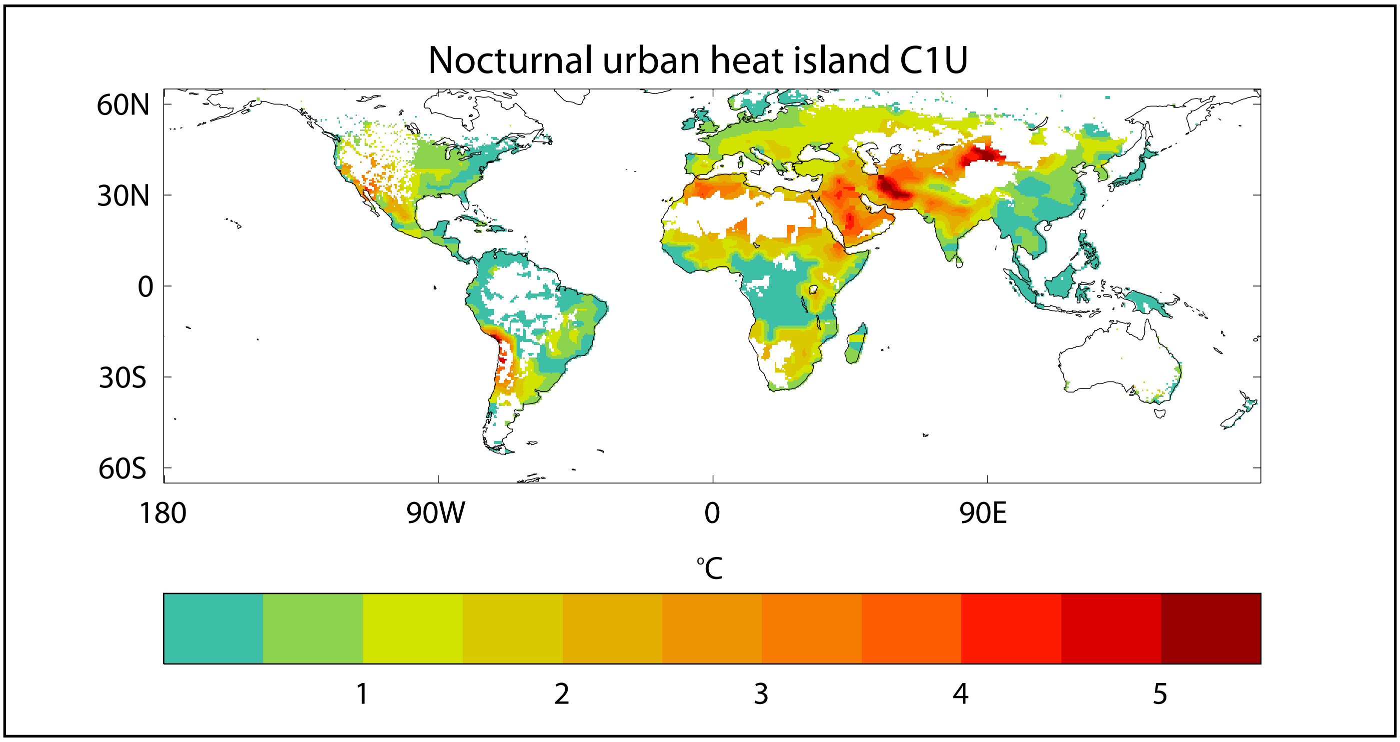


Figure 1. Simulated nocturnal urban heat island in GCM experiment C1U, masked to populated areas (see McCarthy *et al*. 2010, Fig.1).

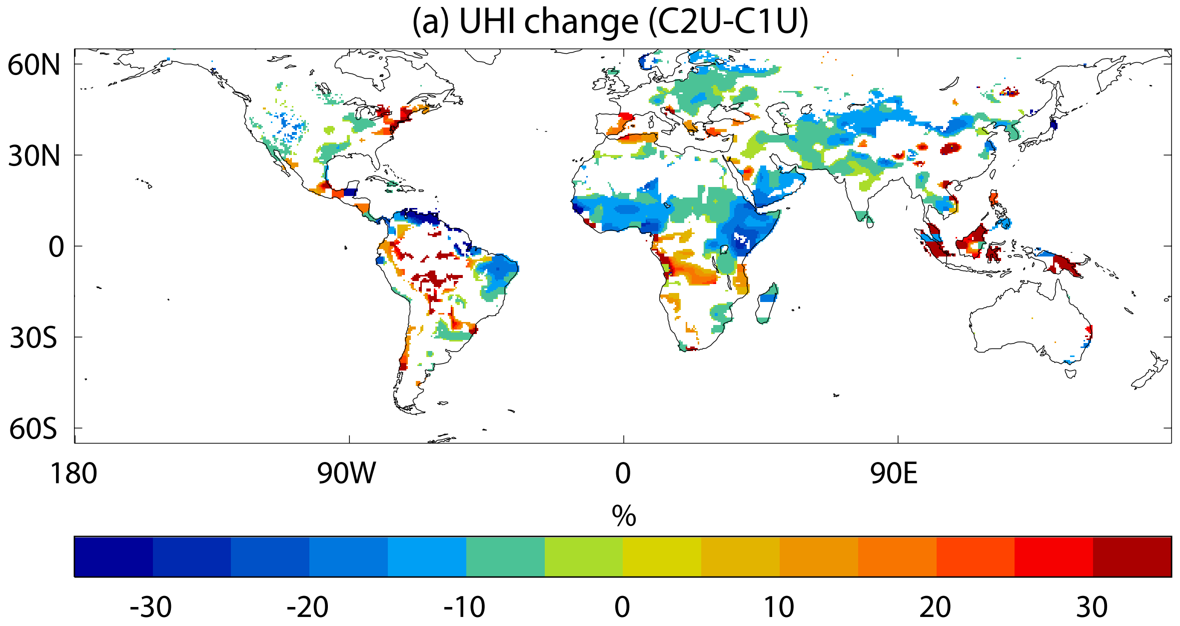
also been run with the urban canopy scheme for the European domain. This provides downscaled climate change projections from the medium emissions (SRES A1B) scenario at 25 km resolution. The RCM was run for a number of time-slice experiments to test urban climate sensitivity for the periods 1971-1990 and 2041-2060, which we will refer to as the 1980s and 2050s respectively, as reported in McCarthy *et al.* (2009). Larger cities such as London and Paris start to be resolved at this resolution, providing greater feedbacks between the urban canopy layer and the regional climate.

Impact of climate on the urban heat island

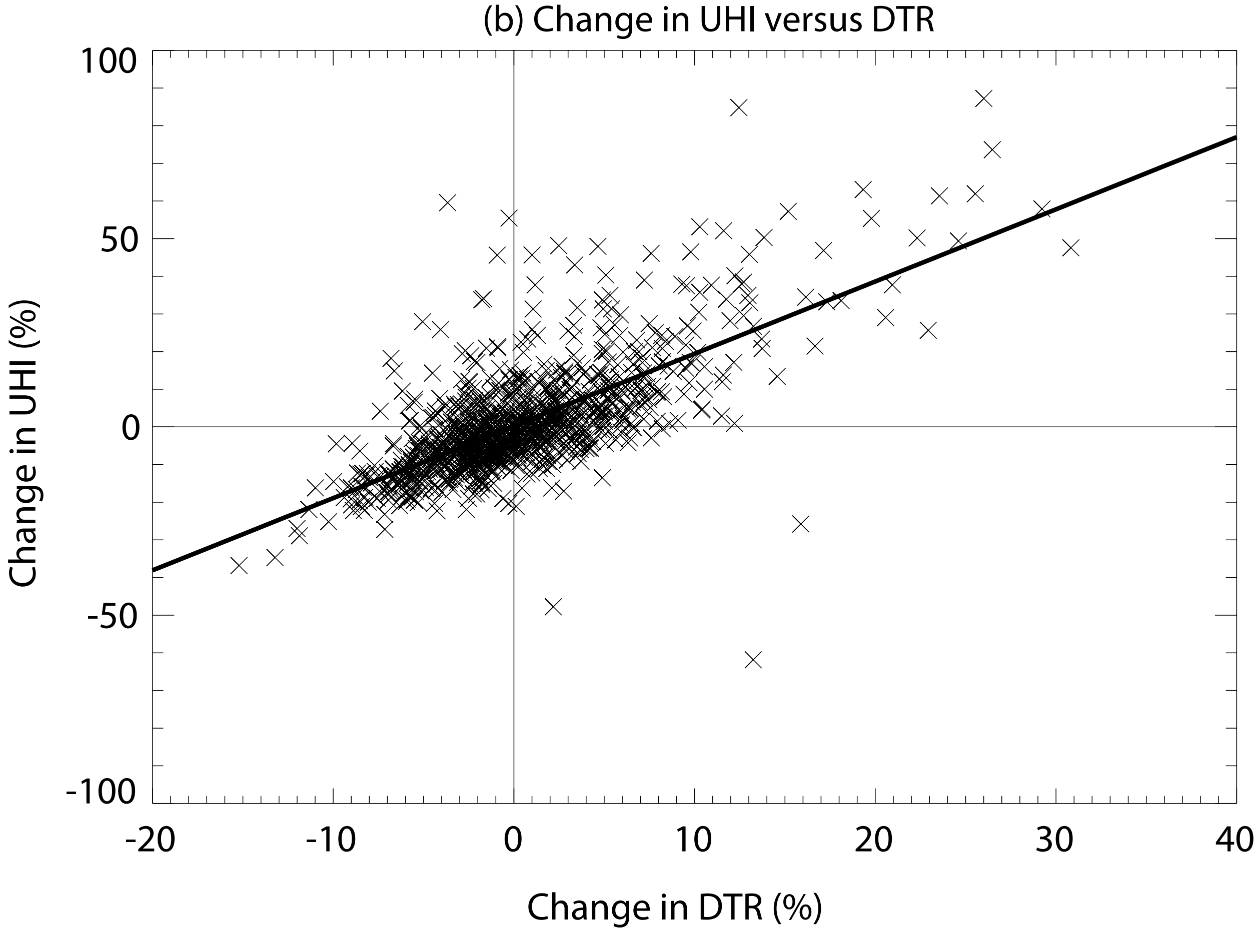
The urban properties are deliberately set to be the same everywhere. This allows us to quantify the relative contribution of the regional climate on the development of urban heat islands, separately from regional variations in urban surface properties. In these experiments we define the simulated nocturnal urban heat island as the near surface minimum air temperature (T_{min}) difference between the urban surface tile, and the dominant non-urban surface tile within each model grid cell. The largest nocturnal heat islands in experiment C1U are found in the subtropical arid climates (Fig. 1) through much of north Africa, central Asia, western USA and along the South Pacific coastline of South America, with heat islands up to five times greater than the global average value of 1°C. Many of these regions also have some of the greatest projected trends in urbanisation through the 21st Century (UN, 2007).

Figure 2 compares the urban heat islands in C2U and C1U. There is an average reduction of approximately 6% in the simulated nocturnal heat islands, for a 3°C global mean temperature rise in C2U. However, in certain locations changes to the urban heat island are in excess of 30%. The simulated urban heat island will respond to those climate feedbacks that influence the local surface radiation budget, such as cloud or soil moisture, demonstrating a need to account for such physical processes within any downscaling of climate change projections to the city-scale. It is found that change in the non-urban diurnal temperature range (DTR) is a good first-order predictor of the change in the urban heat island in this model (lower panel Fig. 2), being sensitive to cloud and soil moisture feedbacks. The slope of the regression in the lower panel of Fig. 2 is 1.9 ± 0.1, with $R^2 = 0.49$.

A similar result is found for the RCM experiment in Figure 3, comparing the 2050s with the 1980s. While the GCM and RCM model results are not directly comparable, they do exhibit similar characteristics such as a tendency for increasing urban heat islands in southwest Europe and north Africa, and decreasing in northeast Europe. The regression against DTR in the RCM has a slope of 1.52 ± 0.02 with $R^2 = 0.70$, indicating a need for further analysis of the influence of resolution on the urban climate feedbacks.



(a) UHI change (C2U-C1U)



(b) Change in UHI versus DTR

Figure 2. (a) Simulated change in nocturnal urban heat island in response to doubled CO_2, as a percentage of the C1U heat island (see McCarthy *et al*. 2010, Fig. 2); and (b) comparison of relative changes in diurnal temperature range (DTR) and urban heat island for GCM model grid cells.

Impact of anthropogenic heat release on climate

Averaged globally, the heating that results from combustion of fossil fuels is negligible at less than 0.03 Wm^{-2}, but continental scale impacts are feasible for future energy consumption scenarios (Flanner, 2009), and city-scale impacts of energy use are well documented in the literature (e.g. Ichinose *et al*. 1999). We considered two scenarios of urban waste heat release in the GCM, at flux densities of 20 Wm^{-2} and 60 Wm^{-2} which result in average increases in urban T_{min} of 0.2°C and 0.6°C respectively. In McCarthy *et al*. (2010) we also demonstrate that increased anthropogenic heat release can have an equivalent or greater impact on the frequency of extreme hot nights as that of doubling CO_2.

The higher resolution regional climate model was run with slightly different (but comparable) values of heat flux to those above, based on energy use statistics for the cities of London and Manchester (25 Wm^{-2} in central London and Manchester, 15 Wm^{-2} for all other urban areas). Figure 4 demonstrates the cumulative impact on the UK from climate change, and an elevated urban heat release. In this scenario the UK experiences a rise in T_{min} of 2.3°C by the 2050s resulting from global climate change, while a tripling of the anthropogenic heat flux in the 2050s (to 75 Wm^{-2} or 45 Wm^{-2}) provides an additional warming of up to 0.8°C in central London. It should be noted that this elevated heat flux does not represent a formal projection of future energy consumption for UK cities. The warming results in an average of 3 additional extreme hot nights (>99th percentile of summer T_{min}, or 18.2°C) per year for the standard climate model without an urban surface, 17 when the urban model is included with present day heat emissions, and 22 for the elevated heat emissions scenario. In both the GCM and RCM the cumulative impact of climate change and heat release disproportionally increases the rural-urban contrast in the frequency of extreme hot nights.

Summary

The results from these climate model experiments provide evidence that:

- Those regions of the world expected to undergo the most dramatic urbanisation through the 21st Century are, in many cases, also climate zones with large sensitivity to the effects of urbanisation.
- The urban micro-climate is not static in a changing climate. Climate feedbacks have the potential to significantly influence the surface radiation balance, with consequences for the urban-rural temperature contrast, and diurnal temperature range.

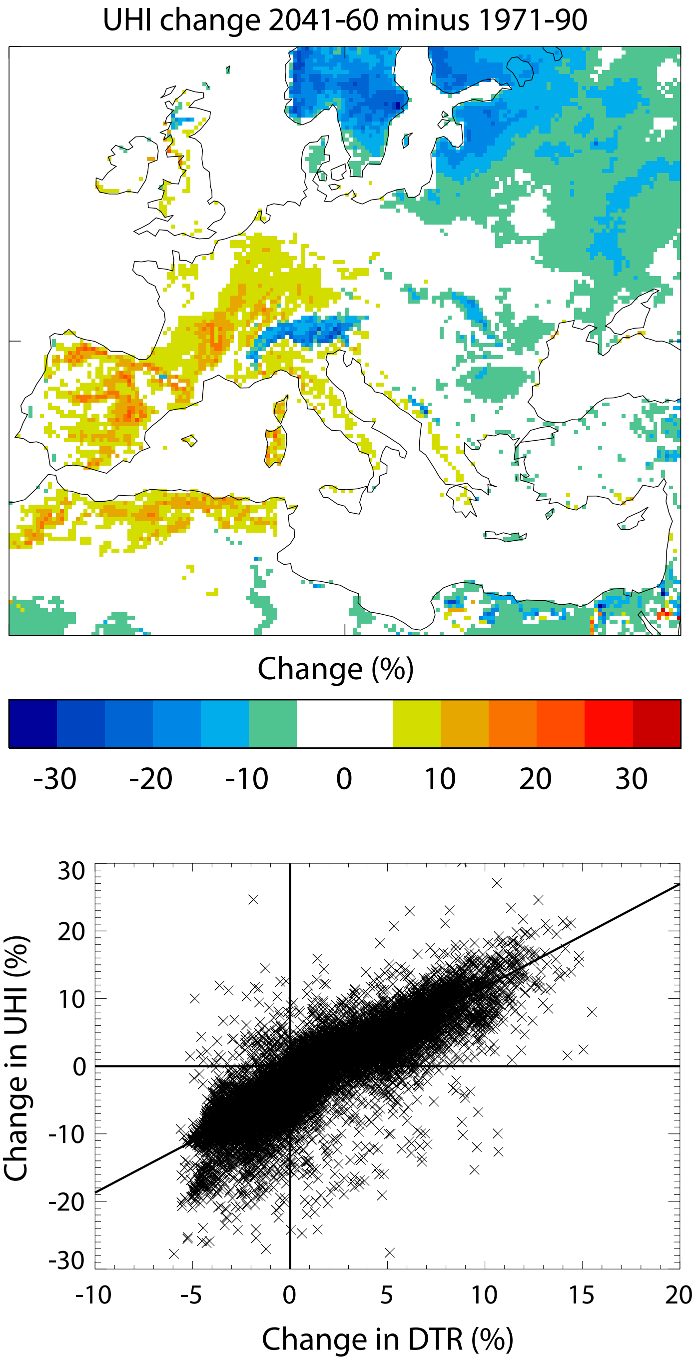


Figure 3. As Fig. 2 from the regional climate model experiments comparing a 2041-2060 SRES A1b climate with 1971-1990.

- Anthropogenic heat release is an important component of local and regional climate to be included in future climate projections.
- The inclusion of urban land use and heat release exacerbates the urban-rural contrast in the frequency of extreme events, particularly hot nights, in future climate scenarios.

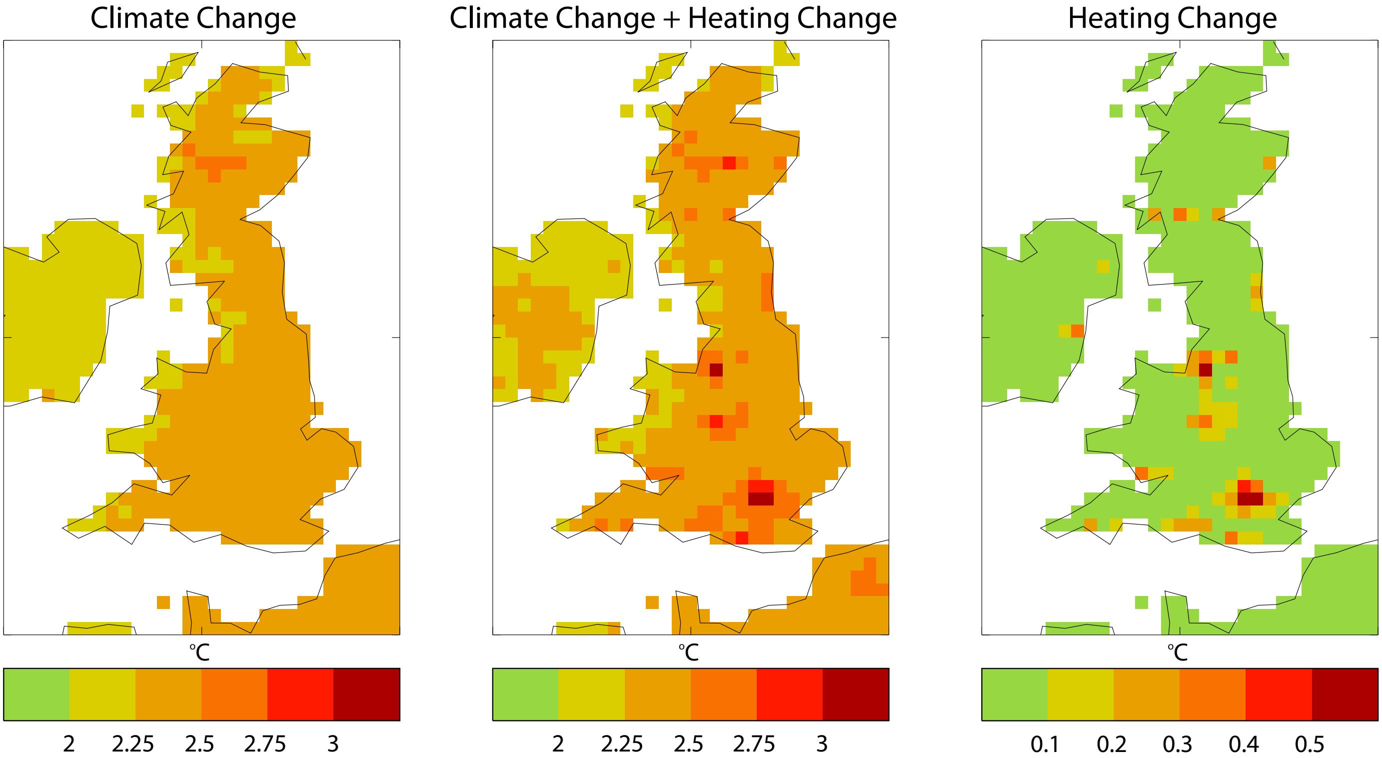


Figure 4. RCM climate change over the UK region (2050s minus 1980s, SRES A1b) due to (left) greenhouse gases (middle) greenhouse gases and increased energy use in urban areas (right) increased energy use only.

The continued development of numerical urban schemes operating across a wide range of spatial and temporal scales will further improve our understanding of urban climate change, combined with further critical evaluation of the efficacy of such models at the resolution of a GCM or RCM. The urban land surface has been included in the next generation Met Office Hadley Centre climate model experiments that will contribute to the fifth assessment report of the Intergovernmental Panel on Climate Change.

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The *LUCID* project: the local urban climate in London

Introduction

The importance of the urban heat island (Oke, 1982) has become increasingly recognized by planning authorities during recent years (e.g. Mayor of London, 2006). The temperature increment generated by European cities like London was found to lead to an increased mortality rate during hot summer periods and with climate change will lead to greater demands for cooling the internal environment (Hacker *et al*., 2005). However, the winter urban temperature increment has benefits: leading to lower mortality rates and lower energy consumption due to warmer night time temperatures and reduced heating (Mavrogianni *et al*., 2009). The *LUCID* project (*The Development of a Local Urban Climate Model and its Application to the Intelligent Design of Cities*) aims to develop a model framework to quantify the local urban climate in London and its impact on comfort, energy use and health.

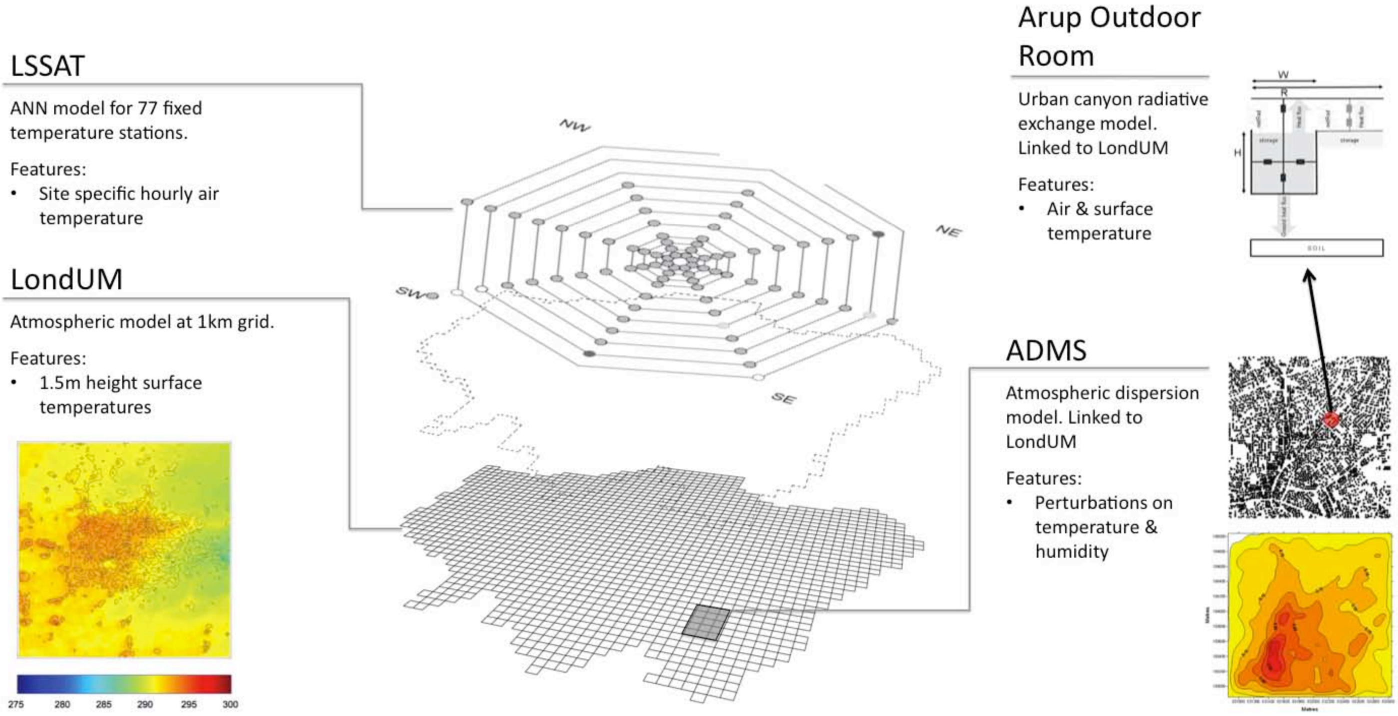

Figure 1. ***LUCID* urban climate models covering three scales – city, neighbourhood and street.**

In this paper we give a brief overview of the *LUCID* project. Then the paper focuses on the city-scale weather prediction model, *LondUM*, which is applied to simulate the London urban heat island and to evaluate interventions to alter the intensity of the London urban heat island.

The *LUCID* project

LUCID brings together a large consortium of meteorologists, engineers, geographers, building designers and epidemiologists. The overall aim of the *LUCID* consortium is to develop tools to model the local urban climate associated with land-use and building fabric and form. Based on this information the impact on comfort, energy use and health is then determined. Therefore, two types of models are developed within *LUCID* . The climate models calculate the urban increment in local temperatures (Figure 1). They range from city-scale models down to neighbourhood scale and street scale models. The impact models (Figure 2) use the local climate information generated by the climate models to calculate the urban increment in energy, comfort and health.

LSSAT (Figure 1) is a statistically-based, neural network model, which predicts hourly screen level temperatures at 77 stations within the Greater London Area based on the temperature at Heathrow. LSSAT was trained with field measurements carried out in 1999 and 2000. LSSAT generates heating degree days (HDD) and cooling degree hours (CDH). Kolokotroni *et al*. (2009) found that heating degree days increase and cooling degree hours decrease with distance from the London city centre. However, the local building stock information, such as aspect ratio, green density ratio etc., had a considerable impact on the spatial variability of HDD and CDH. HDD and CDH are used by the impact models to account for the local urban climate.

LondUM is a specific set-up of the Met Office Unified

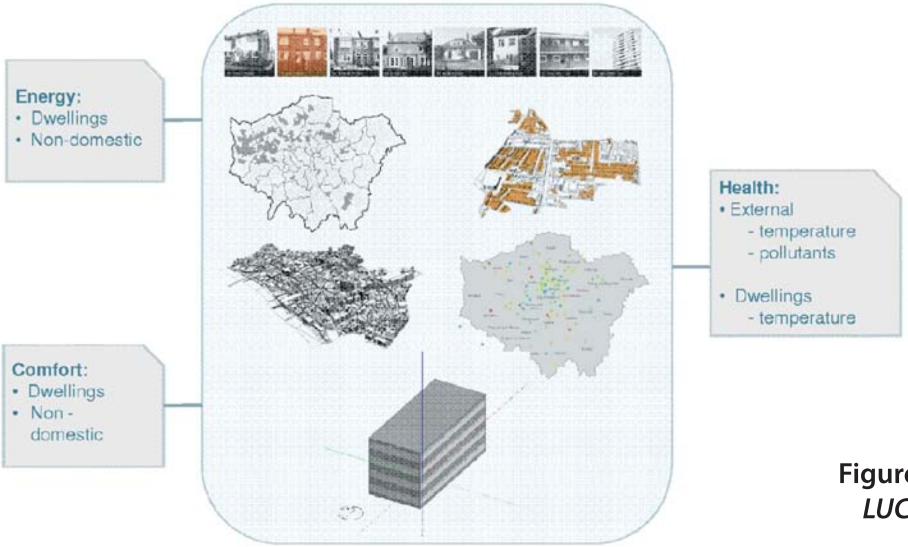

Figure 2. Summary of the *LUCID* impact models.

Model run at a resolution of 1 km^2 (Bohnenstengel *et al.* 2010) with a new 2 tile urban surface energy balance scheme called *MORUSES* (Porson *et al.*, 2010) replacing the operational 1 tile scheme (Best, 1998). *MORUSES* uses geometric building input parameters like frontal and planar area indices following the approach of Harman & Belcher (2006). These data are provided by the Centre for Advanced Spatial Analysis using the Virtual London model (Evans, 2009). Virtual London contains high-resolution 3D building information of London which is recalculated onto the 1km horizontal resolution of LondUM (Bohnenstengel *et al.*, 2010). As a result the building geometry varies over the model domain and so the model describes faithfully the surface energy balance of financial districts, as well as residential areas, in terms of their geometry. Bohnenstengel *et al.* (2010) showed that *LondUM* shows encouraging comparison with measured air temperatures.

Hourly temperature, humidity and flux data from the *LondUM* simulations are fed into the *ADMS* Temperature and Humidity model. This neighbourhood scale model developed by CERC (Cambridge Environmental Research Consultants, Cambridge, UK) calculates perturbations to the upwind meteorological conditions predicted by *LondUM* using local estimates of a range of surface properties and the building density. The purpose of the *ADMS* model is to resolve the sub-grid scale perturbations of temperature and humidity on the metre scale due to changes in the surface cover which are not resolved explicitly by *LondUM*, for example, in order to assess the impact of proposed developments such as the London 2012 Olympics.

OutdoorRoom (ARUP) covers the street scale. It is forced by output data from *LondUM* and provides building design guidance at the street scale. The model accounts for short wave radiation, specular and diffuse reflects of solar radiation, transmission and absorption of radiation through complex glazing systems, thermal radiation, heat conduction through the building material, thermal storage within building and convection at surfaces. *OutdoorRoom* is used to calculate the very local street scale climate and is used for sensitivity studies regarding building design. The aim is to quantify the role of design in alleviating the local contribution to the urban heat island and to assess human comfort in outdoor spaces.

Within *LUCID* three impact models have been developed and applied to determine the local urban increment in energy use, building comfort and health (Mavrogianni *et al.*, 2009). The impact models are based on high resolution building information, energy use information and local weather files (provided by the *LSSAT* and *LondUM* models to date).

The aim of the energy modelling (Mavrogianni *et al.*, 2009) is to identify how the local urban temperature increment, attributed to the urban heat island, affects the heating (and any cooling) demand for different building types. Therefore, a GIS database is used to define the building properties as a function of known attributes like building age, built form and height of the building. For dwellings the building properties and the local weather files from *LSSAT* are fed into a modified version of the Building Research Establishment's Domestic Energy Model (BREDEM) to calculate the variation in energy consumption with building type and location accounting for the local temperature. Using local weather files over London gives a better spatial pattern with regard to where winter urban heat island (UHI) benefits and summer disbenefits can be expected.

The aim of the comfort model is to assess the likelihood of overheating within buildings for a given local urban climate. While a clear decrease of the urban heat island intensity with distance from the London city centre is found, the dependency of indoor comfort on the location is found to be less clear - the thermal quality of the building and very local microclimatic effetcs appear to have significant influence (Oikonomou, 2010; Demanuele, 2010).

Finally, the health model (Wilkinson et al., 2010 and Mavrogianni et al., 2010) calculates the additional mortality burden due to the urban temperature increment based on air temperature generated with *LondUM*. The *LUCID* study is attempting to understand the health impacts of variations in both outdoor (Milojevic *et al.*, 2010) and indoor temperatures.

Spatial structure of London's heat island

The spatial structure of London's heat island is illustrated briefly through analysis of a case study using *LondUM*. A blocking situation occurred with a high pressure system located over the UK leading to light easterly winds over London between 6th May and 9th May 2008. Due to clear skies during the night of the 7th May a strong urban heat island developed over London. The urban heat island during the May case study is analysed in detail by Bohnenstengel *et al.* (2010).

This three day period was simulated with *LondUM* using one-way nesting to produce boundary conditions for the innermost model domain starting with a global simulation. The model chain consists of four domains and the resolution is increased stepwise for each smaller domain by a factor of four for the horizontal grid spacing. The innermost model domain has a horizontal resolution of 1km and covers an area of 100km x 100km with London in the centre of the domain (Figure 3a). The geometric input parameters are strongly correlated with the urban land-use fraction. Both, the planar area index (Figure 3b), indicating the packing density of buildings, and the frontal areas index (Figure 3c), a measure for the depth of street canyons, increase with urban fraction towards the city centre of London.

Processes shaping the urban heat island

The increment in urban screen level temperatures is shown as the difference between a simulation including London's urban land-use fractions and a simulation were urban areas were replaced by grass (Figure 4). In general, the urban heat island pattern is similar to the schematic shown in Oke (1982). The urban heat island shape follows the urban land-use distribution closely. Smaller areas like Richmond Park which are of the order of 2km x 3km are clearly cooler than the surrounding urban areas. Also smaller urban areas outside of London develop their own urban heat island. However, the urban heat island appears to be asymmetric with lower temperatures on the upwind side and higher temperature and the formation of an urban plume on the downwind side of London. With wind coming from easterly directions the urban heat island is displaced towards the west. The warm core is slightly displaced downwind of the city centre where the urban land-use fraction and the values for planar and frontal area indices are highest. Clearly, the urban land-use distribution, together with advection, plays a major role in determining the urban heat island shape.

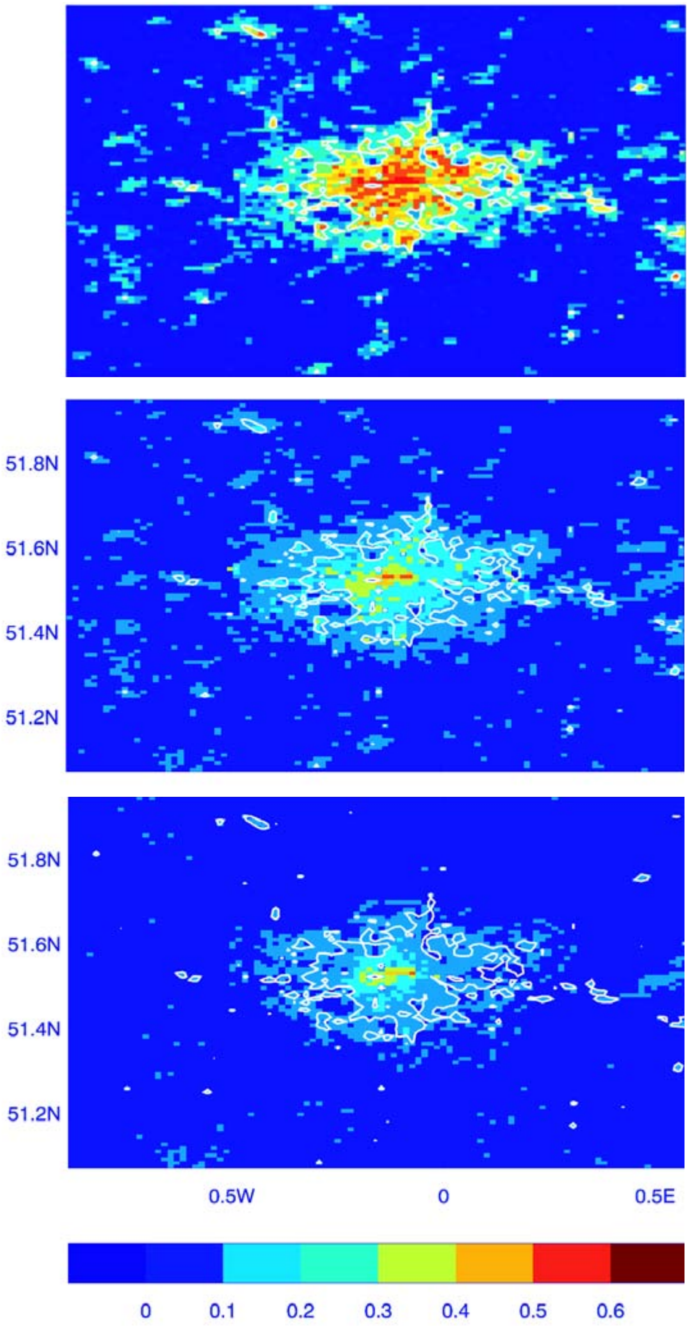

Figure 3. (a) Sub-grid scale urban land-use distribution for the innermost 1km model domain. The white line indicates urban fraction of 0.5 and higher. (b) Planar area index; (c) frontal area index.

Interventions for alleviating the heat island

LondUM is ideally suited to performing scenarios to

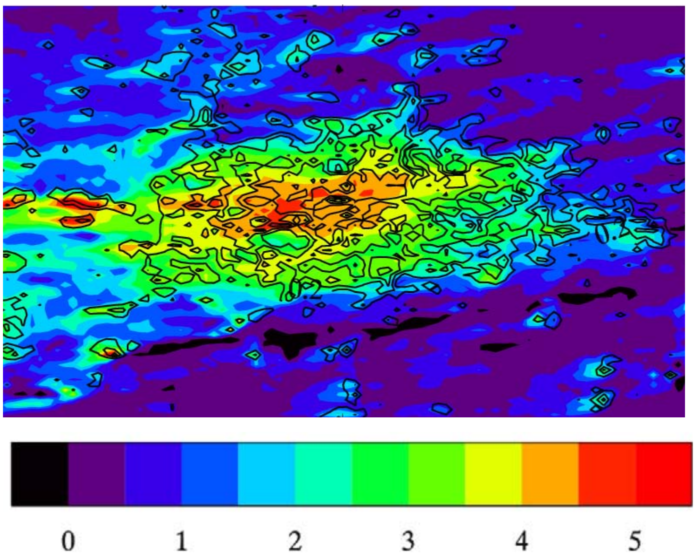

Figure 4. The urban temperature increment as simulated at 2100 local time on 7th May 2008. Temperatures are depicted by colours and urban land-use fractions are indicated by the black isolines.

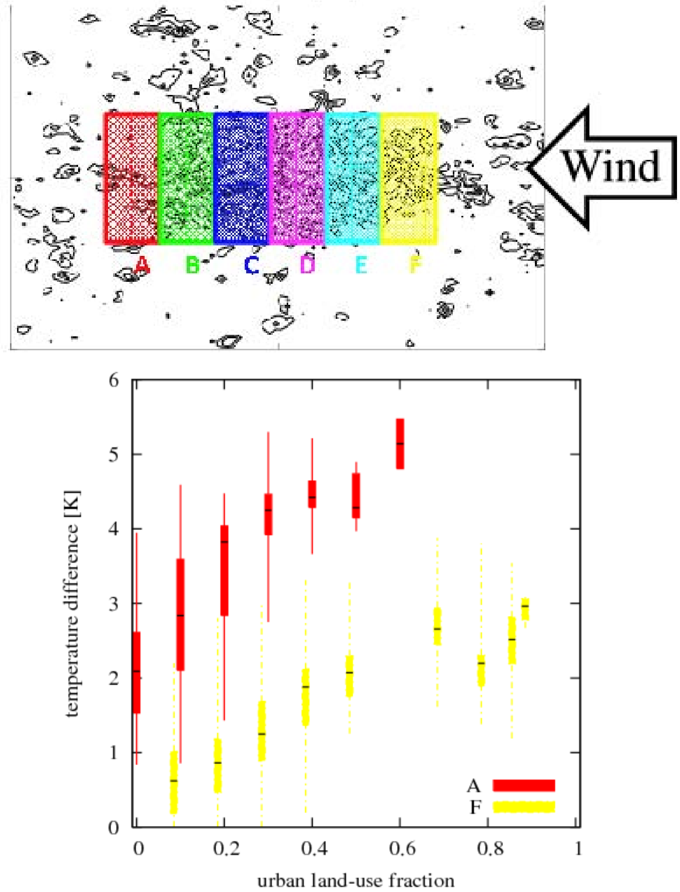

Figure 5. (a) Black isolines indicate the urban land-use distribution for London. Coloured boxes indicate different urban fetches. (b) Box whisker plot showing urban heat island intensity for an upwind and a downwind area of London. The ends of the whiskers indicate the minimum and maximum temperatures and the boxes indicate the 25th and 75th percentile. Bars in the centre of the boxes indicate the median.

investigate how different interventions might change the urban heat island. Such interventions might include changing the albedo, changing the fabric and form of the buildings, or changing the urban land-use fraction, i.e. greening the city. We now describe briefly the effect of such measures on urban screen level temperatures.

Three intervention scenarios are investigated. First the importance of green space within the built environment for mitigating the urban heat island is analysed at the city scale. Second the building geometry over London is altered to determine the variability in the urban heat island intensity due to changes in building morphology at the city scale. The third scenario alters the reflective material properties of London at the city scale.

The box whisker plot (Figure 5b) shows the variability of screen level temperatures with urban land-use fraction (Figure 5a) for 2200h on 7th May 2008. To illustrate the impact of the urban fetch on temperatures, six areas of London are colour-coded representing six different urban fetches (Figure 5a). In this paper the analysis concentrates on the yellow area on the upwind side and the red area on the downwind side of London (Figure 5a). These two regions were analysed since the role of advection is small. A full analysis for all London areas as shown in Figure 5a is done by Bohnenstengel *et al*. (2010). The urban heat island intensity increases with urban fraction up to a value of nearly 6K. A strong gradient is visible for small urban land-use fractions. For large urban land-use fractions a plateau is reached. The whole plot falls into two regimes caused by advection. Over the yellow region on the upwind side of London, temperatures increase linearly with urban land-use fraction. The yellow areas on the upwind side show a slow increase in temperature. This is attributed to the adjustment of the air being advected over the warm urban surface. Over the downwind area (coloured in red) temperatures increase with urban land-use fraction following a convex relationship. Red areas on the downwind side of London show a strong change in temperature with urban fraction. This is caused by the different adjustment length scale of surface temperatures and air temperatures. The air temperature over the downwind side has adjusted to the urban surface temperatures with increasing fetch. However, surface temperatures follow the land-use distribution closely. On the downwind side of London surface temperatures are dropping quickly due to the small or negative sensible heat flux. In contrast, the air temperatures are still warm, since they are being advected from the warm core of London. The 5m air and surface temperatures are coupled according to Monin-Obukhov theory. This strong coupling then leads to the strong gradient of the screen level temperatures over the downwind side

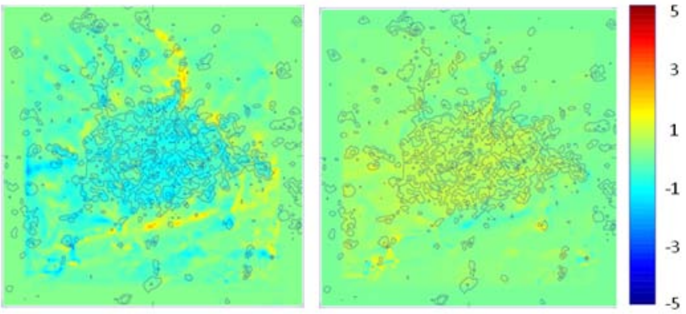

Figure 6. Impact of changing building geometry on screen level air temperatures when (a) increasing the planar area index, (b) increasing the frontal area index at 2200h on 7th May 2008.

of London. In general, the urban land-use distribution is a strong control for the urban heat island. Due to advection of warm air, green areas to mitigate heat on the city scale need to be large. From a simulation filling up the green space in London entirely with urban land-use, it was found that temperatures increase by a further 3K.

Changes in the geometry of street canyons affect the urban heat island magnitude by about 1K. When increasing the planar area index (Figure 6a) from values for London (Figure 3a) to a constant value of 0.5, air temperatures cool down by up to 1K. A change in frontal area index from London values (Figure 3c) to a high value of 0.5, representative of London's financial district, increases screen level air temperatures. The change in air temperature is caused by the difference in the street canyon and the roof characteristics. Street canyons have a large volumetric heat storage capacity due to their large surface area and their materials having high heat capacity, and hence a large thermal inertia. The roofs have a low volumetric heat storage capacity and therefore a small thermal inertia. Therefore, the amplitude of the surface temperature for the roof is large compared to the canyon. This leads to smaller sensible heat fluxes at night. The difference in the heat storage capacity then leads to these differences in air temperature; when the fraction of large heat storage capacity (canyon) is increased on the expense of the fraction of the small heat storage capacity (roof), the sensible heat flux stays positive later into the night and results in warmer air. The opposite effect happens when the fraction of small heat storage capacity is increased on the expense of the fraction of large heat storage capacity.

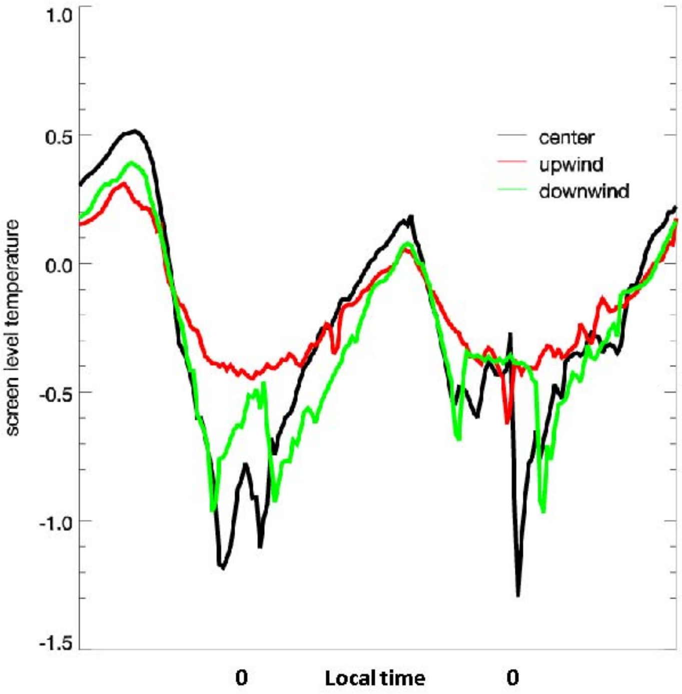

Figure 7. Difference in screen level temperature between a simulation with high material albedo of 0.5 for roof, walls and street and a simulation using material albedo of 0.18 for the roof, 0.5 for the walls and 0.08 for the road. Differences are shown for a city location (black), an upwind (red) and a downwind location (green).

Changing the reflective properties of buildings is a further method to change the urban surface energy balance and hence the air temperatures. Two simulations were compared: simulations with higher and lower values of the material albedo. Figure 7 shows the diurnal cycle of the difference of the screen level air temperature at a city location, an upwind location and a downwind location between the two simulations. Changing the albedo affects the daytime temperatures and only slightly affects the night time temperatures. The magnitude of the change is up to 1K for the central location. Differences in less densely built areas are smaller and of the order of 0.5K.

Conclusions

The *LUCID* project has developed quantitative tools to investigate London's heat island and then quantified the impact of the heat island on comfort, energy use and health.

LondUM with the new urban surface energy balance scheme *MORUSES* captures the differences in the thermal inertia between roof and street canyon. The new scheme has the advantage of being computationally inexpensive and input parameters are easy to access and most importantly, they are physically based using geometric input data.

Three scenarios to tackle the local urban air temperatures were investigated. The urban land-use distribution is the main control for generating the urban heat island; however, advection changes the UHI pattern strongly. The urban morphology alters the UHI of up to 1K, which is about 1/5 of the UHI intensity for this case study. Albedo changes merely change daytime temperatures and the night time temperatures only indirectly via an altered heat intake.

We are now investigating the seasonal pattern of the heat island over London by performing integrations of *LondUM* for the whole of 2006. The results will be used to investigate further the urban increment on comfort, energy use and health.

Acknowledgements

This research was funded by EPSRC grants EP/E016375/1, EP/E016308/1 and EP/E016448/1. Land-use data were made available via the British Atmospheric Data centre BADC. Input parameters were provided by CASA using the GLUD data base. The authors thank Ben Croxford, James Milner and Zhihui Ye for providing the screen level temperature measurements.

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Development of Urban Canopy Parameter Databases for Advanced Urban Meteorological and Air Quality Models

Introduction

Urban morphological characteristics are required to accurately run many mesoscale meteorological, surface energy budget, air quality, and dispersion models. Historically, best guess estimates of urban morphological parameters were made based on literature values and an underlying base dataset (e.g., land use/land cover). Over the past decade the use of gridded fields of urban canopy parameters (UCPs) in advanced urban meteorological and air quality models has emerged as the state-of-the-art. Approaches to efficiently derive the UCPs have developed in concert with advances to urban meteorological and air quality models. The use of three-dimensional building databases, full-feature airborne digital elevation models (DEMs), and a range of satellite data sources have been employed to compute UCPs. The processing of the raw data has been accomplished with the help of geographic information systems (GIS), image processing software, and other computational tools. The effort has enabled models to better represent the effects of complex urban terrain. This article describes a project to develop a gridded UCP database for the Houston, USA metropolitan area using LIDAR data and GIS processing.

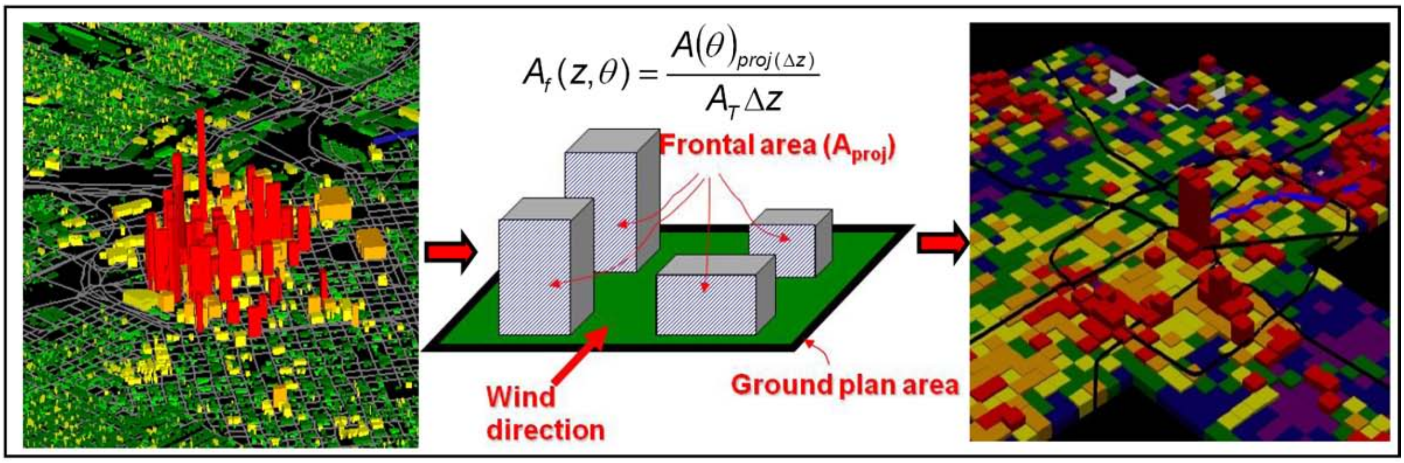

Figure 1. Illustration of approach to derive gridded UCPs. Raw data (left) is processed to produce the gridded field of UCPs (right).

Houston Urban Database

The development of urban databases can be described in general by the graphic in Figure 1. Essentially, a dataset representing the full-feature characteristics of the urban area is processed computationally to produce a gridded set of UCPs. UCPs include height characteristics (e.g., mean building and tree height), density characteristics (e.g., wall-to-plan area ratio, plan area density, top area density, frontal area density), and roughness measures (e.g., height-to-width ratio, roughness length, displacement height, sky view factor). Several researchers pioneered the early approaches to obtain UCPs for small areas using manual assignment based on interpretation of aerial photos (Ellefsen, 1990/1991; Ellefsen and Cionco, 2002) and geographic information system (GIS) datasets (Grimmond and Souch, 1994). Others have developed automated approaches to compute UCPs using image processing software (Ratti and Richens 1999; Ratti *et al*. 2002) and GIS (Burian *et al*. 2002; Long *et al*. 2003). Recent approaches have been developed to estimate UCPs using satellite data (Jeyachandran *et al*. 2010). The derivation approaches seem to be moving towards automation for efficient application and satellite data providing global coverage.

One of the first projects to derive a complete database of gridded UCPs for a metropolitan area following the approach illustrated in Figure 1 was completed for the Houston, USA metropolitan area. The details of the Houston area UCP database development were recently published in a report by the U.S. Environmental Protection Agency (EPA) (Burian and Ching, 2009) and are summarized in the present article. The report may be accessed and downloaded from http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=213904. The goal of the effort was to create a gridded UCP database to implement urban canopy parameterizations introduced into the Community Multi-scale Air Quality (CMAQ)/Penn State/National Center for Atmospheric Research Mesoscale Model (MM5)/DA-SM2-U modeling system. CMAQ and MM5 can be applied at various horizontal scales, which require different levels of fidelity of characteristics of the underlying urban surface characteristics. For the Houston project, the MM5 model was modified to incorporate the urban canopy modeling by DA-SM2-U enabling application at the neighborhood level (~1-km horizontal grid spacing). The CMAQ/MM5/DA-SM2-U modeling domain is centered on the Houston metropolitan area and covers an 82,368-km^2 area, including approximately two-thirds land surface and one-third water surface (primarily the Gulf of Mexico). The modeling domain is subdivided into a modeling grid mesh with 1-km horizontal spatial resolution. Each 1-km^2 grid cell (82,368 total) must have all UCPs defined. To accommodate the high model fidelity a new gridded set of UCPs covering an 82,368 km^2 area was needed.

Data

The new gridded UCP database for the Houston metropolitan area required a high spatial resolution land surface database that accurately captured the full-feature urban morphological characteristics. The dataset selected for the UCP parameter computations was a Light Detection and Ranging (LIDAR) dataset. TerraPoint LLC provided the base layer of elevation data for the project. The elevation data products were derived from data collected using LIDAR technology. LIDAR technology produces x, y, z representation of topography via airborne lasers. Data products are created as an even distribution of data points in evenly spaced grids. The TerraPoint data products were spaced at intervals of 1 and 5 m, with a horizontal accuracy of 15 to 20 cm and a vertical accuracy of 5 to 10 cm. The following seven data products were acquired from TerraPoint: (1) full-feature DEM raster, (2) digital terrain model (DTM) raster, (3) DTM bare earth raster, (4) ground elevation raster, (5) nonground elevation raster, (6) vegetation only raster, and (7) building polygons. The vegetation raster and building polygons datasets were inadequate for the project because the data layers did not cover enough area and the data was found to contain significant errors when cross-referenced with aerial photos collected at approximately the same time. The UCP calculation algorithms operate with absolute heights of the canopy and objects (as opposed to top elevations relative to mean sea level). The required canopy height dataset was derived by subtracting the DTM data layer from the Nonground data layer. The Ground and DEM data products were not needed for this project. A building footprint dataset was obtained from the City of Houston (COH), but the dataset dated to 1983, with small updates in the mid 1990s. Approximately 2 person-months were invested in checking and correcting the COH building footprint dataset for a 1653-km^2 area. The 1653-km^2 area was chosen to include the downtown core area of Houston, the ship channel industrial district, and extensive coverage of the level 2 U.S. Geological Survey (USGS) land use types. The original COH building dataset within the 1653-km^2 Phase I study area included 523,920 building footprints. The modified building dataset contained 664,861 building footprints. Figure 2 presents the building polygon and LIDAR canopy height raster for the Houston downtown core area.

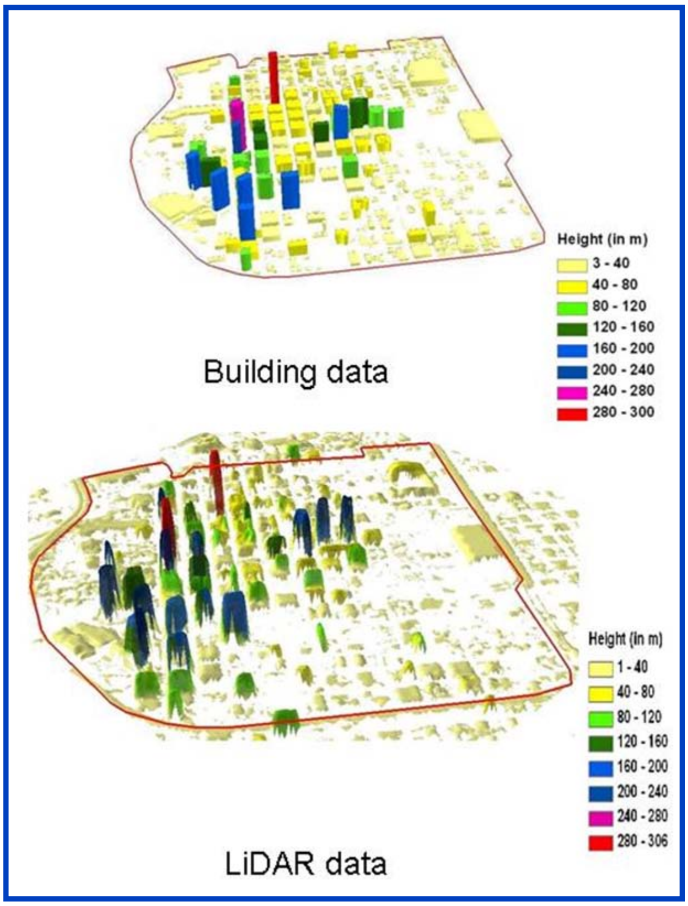

Figure 2. Building polygon (upper) and canopy height raster (lower) datasets used to derive the UCPs for the Houston downtown core area.

Database Development

The data were managed in the ESRI ArcGIS 8.2 GIS software package. Scripts and computer codes were written in Visual Basic for Applications and Fortran to compute 20 urban canopy parameters (UCPs). The database development required writing computer codes to analyze full-feature DEM data within a GIS and compile the computed UCPs into formats recognizable to MM5 and CMAQ. Overall, nearly 30 UCPs were comput-

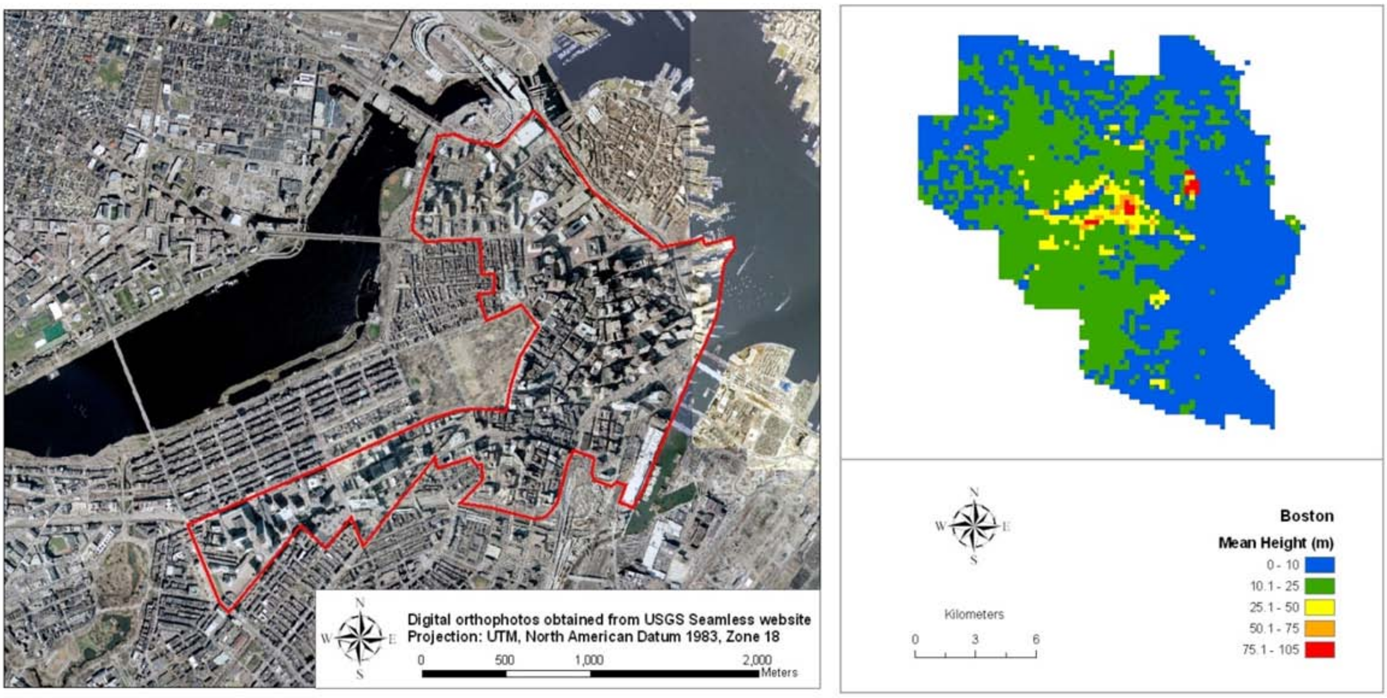

Figure 3. Outline of Tall Building District (left) and mean building height (right) for the Boston, USA metropolitan area contained in the NBSD2.

ed to quantify the height, density, roughness, and surface cover properties of the urban terrain. More details of the UCPs included in the database and the methods used to compute them are available in the Burian and Ching (2009) report. The data processing task was divided into three phases. Phase I of the UCP computations focused on a 1653-km^2 section of the COH and surrounding areas where detailed building footprint and height data were available. Using the building footprint data layer and refined by the digital orthophotos, UCPs were calculated for the buildings only, the vegetation only, and the full canopy. Phase II of the project involved computing only full canopy UCPs for the remaining 3,589-km^2 of Harris County not included in Phase I using the 5,800 km^2 LIDAR dataset. Phase III of the project involved developing an accurate land use data layer for the 1,653-km^2 Phase I study area, correlating the UCPs in the study area to the underlying land use, extrapolating building and vegetation UCPs to the 3,589 grid cells in the Phase II study area, and extrapolating all UCPs to the 77,126 grid cells outside of the Phase I and II study areas.

UCP Database Characteristics

The final Houston UCP database contains the following: 16 UCPs in each model grid cell [82,368 grid cells covering 82,368 km^2, 1,317,888 total values], 9 UCPs (Plan Area Densities, Top Area Densities, and Frontal Area Densities) given as a function of height (one value per meter for a range of 33 to 297 m) for each grid cell [~74,000,000 total values], 2 UCPs (Land Cover Fraction and Building Material Fraction) with five values per grid cell [823,680 total values], 1 UCP (Building Height Histograms) with 62 values per grid cell (62 height increments) [5,106,816 total values]; and the land use fraction has 29 values per grid cell [2,388,672 total values]. In total, the UCP database contains approximately 84 million UCP values!

Summary

This article presented an overview of a project to compute a gridded set of UCPs for mesoscale and air quality models for the Houston metropolitan area. Numerous challenges were faced during the development of the UCP database including data management, computational methods, and uncertainty. These were only partially addressed in the project and further research continues to address the issues. It is important to note that since the completion of the Houston UCP database project, numerous UCP databases similar in format, but having a smaller area coverage, have been developed for numerous other metropolitan areas. For example, the National Building Statistics Database, version 2 (NBSD2) contains 13 UCPs for 44 metropolitan areas in the U.S. in GIS format at 250-m and 1-km horizontal spatial resolution (Figure 3). The building statistics are combined with GIS datasets of defined urban extents and tall building district boundaries providing a useful data for setting meteorological and dispersion model parameters. Finally, an important area of concern is improved access to high-resolution urban morphological features and improved ability to incorporate the advanced databases into meteorological, air quality, and human exposure modeling systems (OFCM 2005). A conceptual approach to address these needs has been devised in the form of the National Urban Database Access Portal and Tool (NUDAPT) (Ching *et al.* 2009). The important feature of the NUDAPT concept is the utilization of web-based technology to enable a widespread user community engagement. The Houston UCP database and ancillary datasets developed for the project described in this article serve as the basis for the NUDAPT prototype.

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Highlighting urban climate studies in the capital: The 2010 AAG Annual Meeting in Washington DC, April 14 – 18

By Chandana Mitra
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Decision Center for a Desert City

Background:

- NSF's Decision Making Under Uncertainty Initiative (SBE Directorate)
- Focused on water decision making in the face of climate change and rapid urban growth
- Impossible to truly predict the future; better aim is to decide on what kind of future we want to have and determine the path or paths necessary to achieve that future

Lake Mead at 48%

The 2010 annual meeting of the Association of American Geographers (AAG) attracted 8342 geographers and related professionals under the same roof, discussing every possible facet of geography. The vibrancy of the capital city added to the attraction of the meeting. Every year the AAG annual meeting continues to grow larger and more diverse. This year 25% of the registered attendees were international. The AAG meeting has become a platform for intellectual discussion and debate and continues to pave the way for future research collaborations.

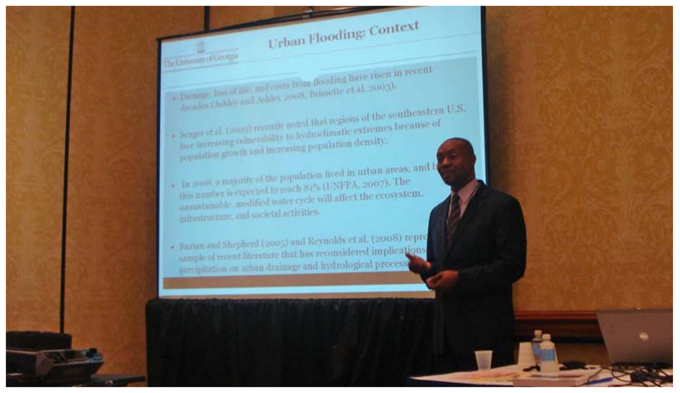
Like every year, urban climate received its share of importance, and urban climate sessions were organized and attended with vigor. Three sessions were organized on urban climate by this author, two paper sessions and one panel session, respectively. The topic of the paper sessions was *Urban Climate: Local, Regional and Global Impacts*. There were nine papers. In the first session, Elizabeth Wentz and Winston Chow (Arizona State University) focused on an arid urban center, Phoenix. Wentz presented on outdoor water consumption and its impact on urban heat in Phoenix. Chow presented an overview and future challenges of urban heat island research in Phoenix. A presentation by this author (University of Georgia) focused on the urban growth of Kolkata city in India over 300 years and its impact on precipitation. Marshall Shepherd (University of Georgia) presented a unique study on the contributions of synoptic, mesoscale, and urban forcing to the disastrous Atlanta floods of 2009. Dale Quattrochi (NASA Marshall Space Flight Center) talked about heat island mitigation measures and improving air quality for the city of Atlanta while highlighting measures such as tree planting and surface albedo modification. In the second session on urban climate, James Carpenter (Florida State University) visualized cloud-to-ground lightning flash patterns around Atlanta, Georgia for the months of May through September over a thirteen-year period (1995-2008). Weekend-weekday contrasts in lightning were evident from the study done by Carpenters and his colleagues. Elena Aguaron Fuente (UCDavis) presented an inventory and forecast of atmospheric carbon dioxide reductions by Sacremento's urban forest. Johannes Feddema (University of Kansas) emphasized the importance of including urbanization in global climate models. His study described an urban sub-model and efforts to develop a global urban extent and properties dataset needed to drive the model. It was unfortunate that Gerald Mills from University College Dublin could not be present at the sessions due to the flight disruptions caused by the Icelandic volcano. His insights on urban climatology and global climate change would have provided a different angle to the sessions.

Why an urban model in a GCM?

- Urban Heat Island - known climate impact that should be included as a human impact on climate
- Source of most emissions – important for short-lived species and atmospheric chemistry simulation
- Interface between climate and most of the world population – Assessment
- Primary locations to evaluate impacts of energy and emissions policies

The panel session was very informative and intriguing with many several key scholars in urban climate involved in the discussion. The panelists included Anthony Brazel (Arizona State), Marshall Shepherd, Dev Niyogi (Purdue University), Dale Quattrochi and Johannes Feddema. Rezaul Mahmood (Western Kentucky University) chaired the panel discussion. Gerald Mills was schedule to join but was unable to attend for the aforementioned reasons. The panel discussion focused on urban climate, its global impact and mitigation techniques. Anthony Brazel talked about his experiences from Phoenix. He was very positive about the way in which authorities and the public are addressing urban climate change issues. The government and planners in Phoenix are also implementing different measures to adapt and mitigate climate changes: (1) federal and local officials have developed a heat wave system, (2) an urban heat island task force has been established; (3) solar power is being generated; and (4) planners are using the ENVI-MET model. One of the most important elements of climate change, water, is not often considered in mitigation measures in Phoenix. Marshall Shepherd focused on urban effects on hydroclimate. He emphasized that there is a consensus that the urban environment can alter local to regional precipitation and related hydroclimate processes. But he emphasized that a synthesis of understanding on the physical mechanisms is still required to understand what he called the "Urban Rainfall Effect". Promising developments that he discussed were the rapid evolution of urban land cover, urban morphology, and aerosols in coupled modeling systems. Professor Shepherd emphasized that natural scientists, social scientists, and planners must continue to interact, which is why he published his most recent work in a planning journal, *Environment Planning B*. Shepherd also emphasized an emerging need for understanding the role of urbanization on frozen precipitation and snow cover.

Dale Quattrochi highlighted the profound effects of urban climate change from multiple perspectives. He noted that urban environments might experience more heat stress, vector borne diseases, allergens, and changes in precipitation, storms, and floods. He suggested the following three actions to improve urban climate studies: aggressive mitigation measures, suitable policies and increased adaptability to climate change. Further, Dr. Quattrochi emphasized the need for urban climate studies tuned for specific locations (e.g., sea level rise in Bangladesh, warming increase in Phoenix, water availability in arid regions, and so on. He pointed out that we need to translate information more effectively to policymakers and communicate to the public in a manner that will help them to understand the role of urbanization on climate. Dr. Quattrochi also commented on the need for more federal and international government coordination on urban climate issues. Dr. Dev Niyogi also focused on land use land cover change on hydroclimate, with a particular emphasis on his recent work on the Indian Monsoons. He mentioned that thunderstorm morphology in cities like Oklahoma City and Indianapolis can change due to the urban landscape. Even in India, observational studies have shown that the Monsoons are more intense over urban areas. Prof. Niyogi also reiterated the need to improve urban parameterization and model initial conditions using remote sensing and in-situ capacity. Johannes Feddema brought a different perspective by considering both tropical and high latitudes. He noted that most of the urban climate change research has focused on the temperate region even though there will be growth in areas like China and India. This notion affirmed the reoccurring recommendation for an integrated approach involving urban planning, urban policies and urban climate science on a global scale. Professor Feddema also highlighted the need for better input data for the models, reflecting the notion that climate models must be coupled with land surface-biogeochemistry-aerosol models. In summary, all the panelists emphasized the need for improving aspects of modeling focused on urban climate change, data quality and collection, and cross-integration into societal planning and awareness.



Urban Flooding: Context

The University of Georgia

- Damage, loss of life, and costs from flooding have risen in recent decades (Ashley and Ashley 2008, Brissette et al. 2003).
- Seager et al. (2009) recently noted that regions of the southeastern U.S. face increasing vulnerability to hydroclimatic extremes because of population growth and increasing population density.
- In 2008, a majority of the population lived in urban areas, and b this number is expected to reach 81% (UNFPA, 2007). The unsustainable, modified water cycle will affect the ecosystem, infrastructure, and societal activities.
- Burian and Shepherd (2005) and Reynolds et al. (2008) repr sample of recent literature that has reconsidered implications precipitation on urban drainage and hydrological process

Sustainable mitigation/adaptation - themes

- Mitigation research through landscape modification via urban vegetation & materials
  - Observations & modeling vis-à-vis urban sustainability
- Urban design & adapting to heat
  - Public awareness of UHI
  - General plans of cities in metropolitan Phoenix

The paper presentations and the panel discussion this year have set the stage for next year's AAG meet at Seattle. Hopefully next year under the patronage of AAG we will get to see more enriched and enhanced research on urban climate.

In this edition a compilation of papers published until April 2010 are listed. Thanks to everyone for their contribution. All readers are invited to send any peer-reviewed references published since May 1st 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 and Abstract.

We are currently formatting the bibliographic compilation from 1996-2008 for inclusion into the online database at http://www.urban-climate.com/bibliography/. The task is quite time consuming, as we need to process a very large amount of references. If you want to give a punctual helping hand for this task please contact the committee. Your help will be much appreciated.

Happy reading,

Julia Hidalgo

Recent publications in Urban Climatology

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Upcoming Conferences...

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

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

CONFERENCE ON URBANIZATION AND GLOBAL ENVIRONMENTAL CHANGE: Opportunities and Challenges for Sustainability in an Urbanizing World
Tempe, Arizona, USA • October 15-17, 2010
www.ugec2010.org • ugec2010@asu.edu

Professor Sue Grimmond named for 2009 IAUC Luke Howard Award

I am delighted to announce that the IAUC Board has awarded the 2009 IAUC Luke Howard Award to Professor Sue Grimmond, of King's College London.

The Luke Howard award is given 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. It is the premier award of this community and is named after the first individual to correctly identify the urban climate effect in early nineteenth century London. The previous awardees include Tim Oke, Ernesto Jauregui, Arieh Bitan, Masatohi Yoshino and Robert Bornstein, each of whom advanced significantly the study of urban climates in the modern era.

Professor Grimmond is at the vanguard of urban climate research. She is well known to the urban climate community for her extensive research in the fields of micrometeorology and hydroclimatology. She has published over 85 papers in peer-reviewed journals and supervised and assiduously mentored graduate students and young academics. She has led or participated in a wide variety of successful national and international research projects that are at the cutting edge of urban climate research. Her work has led to significant progress in our understanding of urban atmospheres and has also been recognised for its importance to the wider atmospheric science community.

Throughout her career, Professor Grimmond has served on national and international committees and acted as a keen advocate for urban climate science. She was Chair of the AMS Board on the Urban Environment, has served as President of the IAUC (2003-2007) and is currently Chair of the World Meteorological Organization Expert Team on Urban and Building Climatology. She is past winner of the AMS Helmut E. Landsberg Award in recognition of her outstanding contributions to climatology.

The entire urban climatology community joins me in congratulating Sue as the recipient of the 2009 Luke Howard Award and wishes her continued success in her endeavours.

Gerald Mills, IAUC President

Board Members & Terms

- Toshiaki Ichinose (National Institute for Environmental Studies, Japan): 2007-2011
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- Jennifer Salmond (University of Birmingham, UK): 2005-2009; Secretary, 2007-2009
- James Voogt (University of Western Ontario, Canada), 2000-2006; Webmaster 2007-*; 2009-2013
- Jason Ching (EPA Atmospheric Modelling & Analysis Division, USA): 2009-2013
- David Pearlmutter (Ben-Gurion University of the Negev, Israel): Newsletter Editor, 2009-*

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Newsletter Contributions

The next edition of ***Urban Climate News*** will appear in late September. Items to be considered for the upcoming issue should be received by **August 31, 2010** and may be sent to David Pearlmutter (davidp@bgu.ac.il) or to 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.