Urban Climate News

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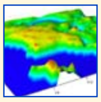
Inside the Spring issue...

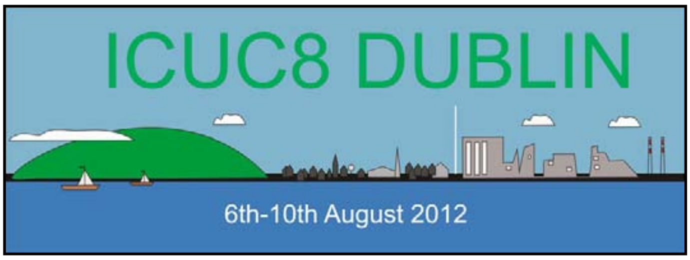


From the IAUC President

Colleagues,

The amount of material that is appearing in the broad area of urban climates is growing at a surprising rate. This month UN Habitat published the *Global Report on Human Settlements 2011 - Cities and Climate Change*. In his introduction to the volume, Dr. Joan Clos (Under-Secretary-General and Executive Director) outlines the scope of the publication – highlighting the fact that, as global carbon emissions substantially arise from urban areas, they represent an obvious scale at which to act. He states that *Cities and Climate Change* "seeks to improve knowledge among governments and all those interested in urban development and in climate change, on the contribution of cities to climate change, the impacts of climate change on cities, and how cities are mitigating and adapting to climate change. More importantly, the *Report* identifies promising mitigation and adaptation measures that are supportive of more sustainable and resilient urban development paths."

The need for place-specific responses is implicit in one of the report's principles: no single mitigation or adaptation policy is equally well-suited to all cities. However, it is not clear to me that we have a multi-scale approach to the science of climate change yet. I think that Lowry's classic paper on the urban climate problem is of some relevance in this regard. In essence, his work distinguished between a background climate and the urban climate effect. While the mitigation issue is linked to the latter, the adaptation issue is connected to addressing the changing background climate. However, both will have to be addressed simultaneously at city scales, including those of buildings and 'neighbourhoods' – the scales at which people live.



Moreover, climate-based policies will have to be more precisely tuned to take account of the scales of urban effect and the relationship of cities to their background climates. This is where urban climate knowledge can be of most benefit, I believe. In this regard I would draw your attention to *Urban Microclimate: Designing the Spaces Between Buildings*, which has also been published recently and is reviewed here. It is distinguished by its focus on the management of climate at urban scales, and addresses many of the place-specific considerations that must underpin an approach to climate change that is based on the notion of resilience.

This edition of *Urban Climate News* also includes notice of the 8th International Conference on Urban Climate (ICUC-8), which will take place in Dublin (Ireland) from 6th to 10th August 2012. From this point onwards, regular updates will appear in *Urban Climate News* and on the conference website (www.icuc8.org).

In 2009, ICUC-7 was held in Yokohama (Japan), and many of us attended that marvellous event. More generally, the urban climate community has a special affinity with our Japanese colleagues whose work has been at the forefront of urban climate science. On behalf of the IAUC and its members, I would like to express our deep concern over the tragic events occurring in Japan, and offer our support to colleagues during this trying time.

Gerald Mills
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Global sensor network tracks spread of Japan radiation, helping to assess release levels and gauge exposure over populated areas

March 2011 — As radioactive contamination from the Fukushima Dai-ichi nuclear power plant spreads, a global network of sensors is tracking it across oceans and continents. The network was originally set up to detect nuclear weapons testing, but scientists now hope it can tell them more about the accident.

The Comprehensive Test Ban Treaty Organization began setting up its monitoring stations about a decade ago, with the eventual goal of enforcing a worldwide ban on nuclear weapons tests.

"We have currently over 280 sensors worldwide, monitoring underground, the atmosphere, the oceans for any sign of a nuclear explosion, and we're also sniffing the air for any sign of radioactivity," says spokesperson Annika Thunborg.

That now includes radioactivity from the Japanese plant. Explosions at three reactors and a fire at a spent fuel pool have released radiation into the atmosphere.

Gerhard Wotawa, with the Austrian meteorological institute, has been studying data coming in from the monitoring stations and says there's no doubt that what they're picking up comes from Japan.

"Data like that I have never seen in my career," he says, "so it is pretty much clear where it comes from."

The sensors are registering radioactive elements including iodine-131 and cesium-137 — byproducts from nuclear fission inside the core of a reactor. Wotawa has been feeding the data into computer models that can forecast where the radiation will go. He also uses the models to work backward and calculate the amount of material first released. Based on those calculations he says the accident, in some ways, is roughly the size of Chernobyl.

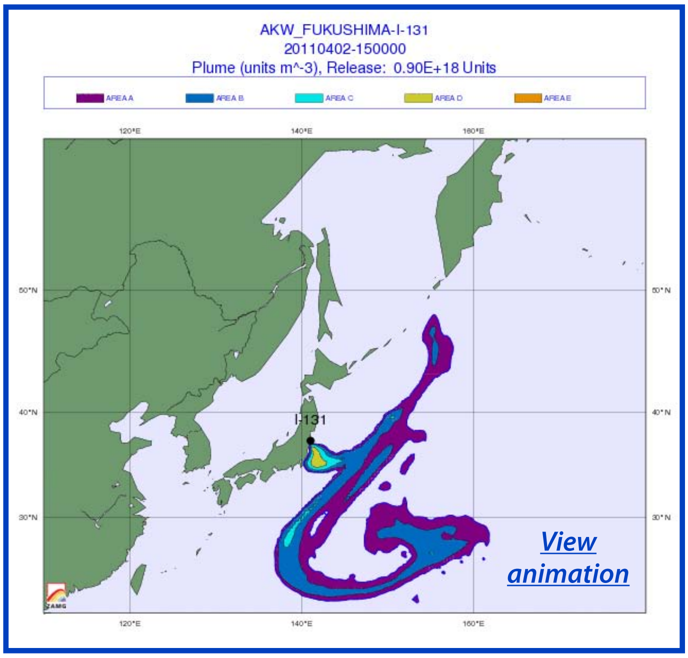
"The daily release is comparable to what was released in Chernobyl," he says. "However, the effect of the power plant accident in Japan is not comparable to the effect of Chernobyl on the former Soviet Union."

That's partially because Chernobyl was inland, and radiation contaminated land in all directions. Fukushima is on the coast, and winds are blowing much of the material out over the Pacific.

Is The Worst Behind Us?

Wotawa's calculations are an estimate, though, and not everyone agrees that the accident is comparable to Chernobyl.

"If I had to guess, I would say the release levels or more like Three Mile Island and less like Chernobyl, but we'll see as time goes forward," says Harry Miley, a nuclear physicist at Pacific Northwest National Laboratory in Washington state. He says analyzing the types and amounts of radioactive material picked up by the sensor network will tell researchers around the world more about what happened inside the reactors at Fukushima.



View animation

A computer model shows how a plume of radioactive iodine-131 could spread in the atmosphere. ***Source:*** ***ZAMG***

"We might determine things like what was the temperature of the material when the radioactivity was emitted, and which material it was," he says. "There are three reactors, and there are spent fuel pools and so forth — they're all potential sources, and we should be able to nail down which source is which."

For now this system may be the only way to measure what's happened — radiation levels on the site are far too high to take a direct look. The sensors should also provide people with a sense of reassurance. Even though radiation from the plant has been picked up across the United States, Miley says that the levels aren't dangerous.

"The highest detection that we've gotten here in the U.S. has been far lower than the natural radioactivity that's already there, so I don't think there's any increased risk to the U.S. public," he says.

And there's more good news — the latest readings in America seem to indicate that radiation from the plant is decreasing. Miley is hopeful that the worst of the accident may be behind us. — *Geoff Brumfiel for NPR*

Source: http://www.npr.org/2011/03/25/134833909/built-for-bombs-sensors-now-track-japan-radiation

Aerosol plumes downwind of oil spill yield insights for urban air quality

March, 2010 — During a special airborne mission to study the air-quality impacts of the BP *Deepwater Horizon* oil spill last June, NOAA researchers discovered an important new mechanism by which air pollution particles form. Although predicted four years ago, this discovery now confirms the importance of this pollution mechanism and could change the way urban air quality is understood and predicted.

The NOAA-led team showed that although the lightest compounds in the oil evaporated within hours, it was the heavier compounds, which took longer to evaporate, that contributed most to the formation of air pollution particles downwind. Because those compounds are also emitted by vehicles and other combustion sources, the discovery is important for understanding air quality in general, not only near oil spills.

"We were able to confirm a theory that a major portion of particulate air pollution is formed from chemicals that few are measuring, and which we once assumed were not abundant enough to cause harm," said Joost de Gouw, lead author of a new paper on the finding, published in the March 11 edition of *Science*.

De Gouw is an atmospheric scientist in the Chemical Sciences Division of NOAA's Earth System Research Laboratory in Boulder, Colo. and a Fellow at CIRES, the Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder.

NOAA sent a research aircraft to the Gulf region in June 2010 to help other agencies assess pollutant levels in the air. The Lockheed WP-3D Orion aircraft, best known as NOAA's "hurricane hunter," was in California for an air quality and climate science mission. When diverted to the Gulf, the P-3 was already loaded with instruments designed to measure many types of air pollution particles – including "organic aerosol" – and the chemicals from which they are formed in air.

Organic aerosol, or OA, makes up about half of the air pollution particles in polluted U.S. cities. Air pollution particles can damage people's lung and heart function, and they also affect climate, with some aerosol, including OA, partially offsetting the warming from greenhouse gases by reflecting incoming sunlight or changing cloud properties, and other aerosol amplifying warming by increasing the amount of sunlight absorbed in the atmosphere.

De Gouw said he and his colleagues knew where to expect OA particles downwind from the oil spill based on conventional understanding: OA should form when the most lightweight, or "volatile," components of surface oil evaporate, undergo chemical reactions, and condense onto existing airborne particles.

Twenty to 30 percent of the surface oil fell into this volatile category, evaporating into the atmosphere within hours, according to the new analysis. That gave it little time to spread out, so emissions came from the area immediately surrounding the spill. A steady wind – such as the one blowing during a June 10, 2010 research flight – drew those emissions into a thin, linear streak of pollution in which organic aerosol was expected to form.

The oil slick, as seen from the window of an NOAA research aircraft. *Source*: ScienceDaily.com

"But that's not what we saw," de Gouw said. "We saw this very broad plume of organic aerosol instead." OA levels in that plume were similar to levels found in U.S. urban air.

So de Gouw and his colleagues set about trying to figure out what else might have contributed to the pollution particles. In 2007, other atmospheric scientists had proposed that heavier, or "less volatile" components could theoretically help to create OA, but it had proven to be near impossible to study this process in the real world.

"The problem is that the heavier and lighter species are emitted at the same time from the same sources, so we could not study them separately in the atmosphere – until *Deepwater Horizon,*" de Gouw said.

Heavier components of oil take longer to evaporate, so they had more time to spread on the surface farther from the spill source than their lightweight siblings. When de Gouw and his colleagues ran a series of models showing how spilled oil spread across the Gulf, and how long it should take for various heavy, medium, and light fractions to evaporate, the conclusion was clear. The heavier, less-volatile compounds from the oil – that were not actually measured by all the sophisticated instruments onboard the aircraft – were the culprit.

These heavier compounds are not measured in most air quality monitoring programs, which were designed to capture the conventional contributors to poor air quality. The new findings may also help understand why there is more organic aerosol in the polluted atmosphere than scientists can explain.

"This chemistry could be a very important source of aerosol in the United States and elsewhere," de Gouw said. "What we learned from this study will actually help us to improve air quality understanding and prediction."

Source: http://www.sciencedaily.com/releases/2011/03/110310141416.htm

Cities may be attracting hurricanes

Powerful hurricanes can wreak havoc when they strike heavily populated coastal areas. New research shows that the cities themselves might be partly responsible for attracting these storms, with the extra friction created by "rough" landscapes such as tall buildings significantly diverting the path of a storm.

A hurricane, or tropical cyclone, is a system of winds rotating inwards to an area of low pressure. Stretching hundreds of kilometres across, they feed on the heat given off by moist air as it rises and condenses. As such, they form over large expanses of warm water – normally tropical seas – and lose strength if they reach land.

In May the National Oceanic and Atmospheric Administration (NOAA) in the US said that this season the Atlantic would probably see more hurricanes than normal, giving a 70% probability of between three and seven really big storms in 2010. Currently, the NOAA is able to provide a 24-hour forecast of the position of a hurricane's centre with a margin of error of about 100 km – but it becomes especially difficult to predict the path of hurricanes once they reach land.

Scientists know that wind speeds drop significantly due to the extra friction that a hurricane experiences once it makes "landfall," and they have also observed how the reduction in moisture inland causes a hurricane to peter out. Now Johnny Chan and Andie Au-Yeung of the City University of Hong Kong in China have extended these analyses to find out the effects of variations in roughness and moisture levels over land.

They did this by using the Weather Research and Forecasting model to simulate a hurricane approaching a north-south coastline from the east and then passing over rough land. Roughness could be generated by tall buildings, hilly terrain or forests; marshland or agricultural land, for example would be smoother.

Rougher land

In one simulation the researchers studied what happened when they made some of the coast rough and some smooth. With the northerly portion rough they found that the hurricane drifted several tens of kilometres northwards and likewise when the southerly section was rough the hurricane shifted southwards. They say that over rougher land, greater friction causes the air to become more compressed, which forces it to rise up and release more of its latent heat. This heating in turn then causes the air to spin faster, which pulls the hurricane in that direction.

On 28 August 2005, Hurricane Katrina was in the Gulf of Mexico where it powered up to a category 5 storm on the Saffir-Simpson hurricane scale, packing winds estimated at 175 mph (Courtesy: NOAA). ***Source*****:** ***PhysicsWorld.com***

Chan and Au-Yeung say that their research shows the importance of including land-surface variation in hurricane forecasting in the future. But they admit that more needs to be done to confirm the results of their study. They say they will now improve their simulations so that they include the very slight variation in rotation that the Earth experiences at different latitudes, which, they say, causes a larger drift in a hurricane's position than surface roughness. They say they will also put in more detailed features, such as mountains or jagged coastlines.

Harold Brooks of the NOAA's National Severe Storms Laboratory in Oklahoma says he doesn't think the research will make much of a difference to forecasting a hurricane's position but believes it might help us better understand how the intensity of a hurricane changes. "It has been observed that frequently hurricanes lose intensity just before landfall," he says. "The reason for this is not clear. It is possible that a better understanding of coastal processes could address that question."

Source: http://physicsworld.com/cws/article/news/43381

Meso-urban modeling in support of heat-island mitigation

By Haider Taha (haider@altostratus.com)

Altostratus Inc., Martinez, California, USA

It has been recognized, especially over the last two decades, that mitigation of urban heat islands (UHI) can impart several beneficial effects, both direct and indirect. For example, reductions in energy use (Taha et al. 1999, Rosenfeld et al. 1995), emissions of ozone precursors and carbon dioxide (Taha et al. 1998, Taha 1996,1997), heat stress (Taha et al. 2004), and improvements in air quality (Taha 2005,2007) are some such benefits that can be anticipated. Taha (2001) also showed that UHI control can have a potential to locally offset the effects of climate change (e.g., IPCC scenarios for years 2050 and 2090) on ozone air quality. Clearly, the magnitude of UHI mitigation benefits will vary depending on weather, location, pollutant emissions and transport, level or urbanization, energy use, and so on, but the benefits appear to persist across a range of conditions. In addition, the existence of a UHI is not a prerequisite for achieving those benefits. In other words, if a certain region does not have a UHI to begin with, and many regions don't, the implementation of these measures can still create more comfortable summer environmental conditions, reduce cooling energy use, and improve air quality.

1. Heat island mitigation

UHI mitigation measures include increased albedo on various urban and built-up surfaces, increased vegetative cover, decreased runoff, i.e., control of impervious surface area, decreased anthropogenic heating, increased structural and natural shading, and green roofs. However, because of their effectiveness, two such measures, namely, increased urban albedo and vegetative cover, have been evaluated more extensively than others, e.g., via modeling and / or observational field studies. In the U.S., many energy, environmental, and regulatory agencies, e.g., US EPA, California Energy Commission, California Air Resources Board, and several Air Quality Management Districts, have shown interest in one aspect or the other of the UHI mitigation portfolio as a potential strategy to reduce energy use, reduce emissions of ozone precursors and carbon dioxide, improve air quality, provide a cooling effect on climate via negative radiative forcing, and local ambient cooling.

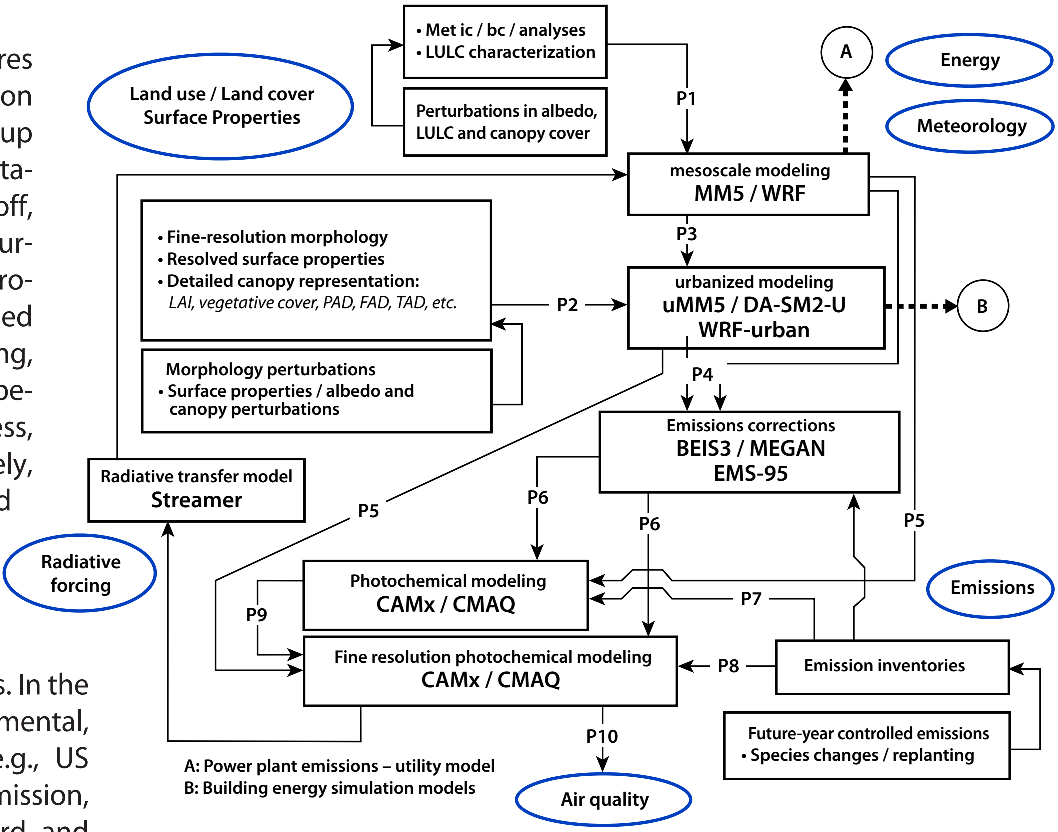


Figure 1. Main models and linkages in simulating UHI mitigation; more information in Taha (2007)

This article briefly touches upon some on-going modeling projects at Altostratus Inc. that quantify the meteorological, emissions, and air quality impacts of UHI mitigation measures. As these studies are on-going, no publishable results are provided here – the focus of the following discussion is on a description of the goals and approaches of these studies along with some initial, work-in-progress examples of products and findings.

2. Evaluation of UHI mitigation under seasonal and multi-episodic conditions

Several past modeling studies, e.g., Taha (2005,2007) addressed the meteorological, emissions, and air-quality benefits of UHI mitigation on episodic time scales. While this type of modeling is useful in capturing the effectiveness of UHI control under some of the more extreme conditions (e.g., high ozone and large precursor-emission rates), such conditions are not always prevalent during the ozone season, especially in more recent years where improved emission controls have reduced the occurrence of high-ozone episodes. It is thus desirable to evaluate the effectiveness of UHI mitigation under average and frequently-occurring conditions in addition to those worst-case scenarios. Such evaluations are important for cities and communities if and when they decide to adopt selected UHI-mitigation measures and thus need, for planning purposes, more specific estimates of their long-term potential benefits as well as possible inadvertent negative impacts. Thus the main goal of this study is to perform extensive, multi-episodic and seasonal modeling, spanning a period of ten years (1995 – 2005), to examine the effectiveness of UHI mitigation under varied meteorological conditions and emission scenarios.

UHI mitigation is evaluated using state-of-science models that have been further modified and updated to suit the particulars of this application (Fig. 1). In this study, the meteorological modeling is done with the mesoscale MM5 (Dudhia 1993) and the urbanized version, uMM5 (Taha 2008a,b) which is a modified version of the DA-SM2-U model of DuPont et al. (2004) that incorporates the drag-force approach of Martilli et al. (2002). These meteorological models are linked with emission models (SMOKE / BEIS3 or MEGAN), photochemical models (CAMx or CMAQ), and radiative transfer models (Streamer) as discussed in Taha (2008a-c) and Taha and Sailor (2010).

The fine-resolution modeling requires detailed characterizations of the physical, geometrical, land-use, land-cover, and morphological properties of urban areas. This can be based on urban data, e.g., NUDAPT (Ching et al. 2009), local surveys and region-specific data generated for areas of interest (Taha 2005,2007), and other sources of general information such as Google Earth Pro (Taha 2008a). Improvements are also made on biogenic volatile organic compound (BVOC) emissions calculation methodologies relative to approaches typically used in conventional, regulatory modeling.

A large number of modeling episodes (ranging from 8 to 30 days each) were selected based on observed daily peak ozone (at each of 134 air quality monitors in several counties in California) and on meteorology. For this purpose, an analysis was carried out to characterize the meteorological regimes conducive to various levels of ozone (marginal, moderate, high, extreme), via classification and regression tree (CART) approach, an example of which is shown in Figure 2. Because the relationships between ozone formation and meteorology differ significantly from one region to another, CART analysis can be useful in capturing some of the non-linear effects involved (Thompson et al. 2000).

Selection of the predictor meteorological variables for CART analysis depends on a region's synoptic meteorological characteristics, location and topographical features, and spatial patterns of emissions, but certain variables are almost always present. From a large number of meteorological variables, Cox and Chu (1996) found that the most relevant ones for urban areas are maximum surface temperature, wind speed, relative humidity, mixing height, and cloud cover. Other researchers used pressure and geopotential height, assuming that they are surrogates for other meteorological variables (Pryor et al. 1995). Upper-air observations are included in CART analysis and are useful in predicting peak ozone regimes because upper-air conditions are indicative of large-scale / synoptic weather patterns (Davis et al. 1998).

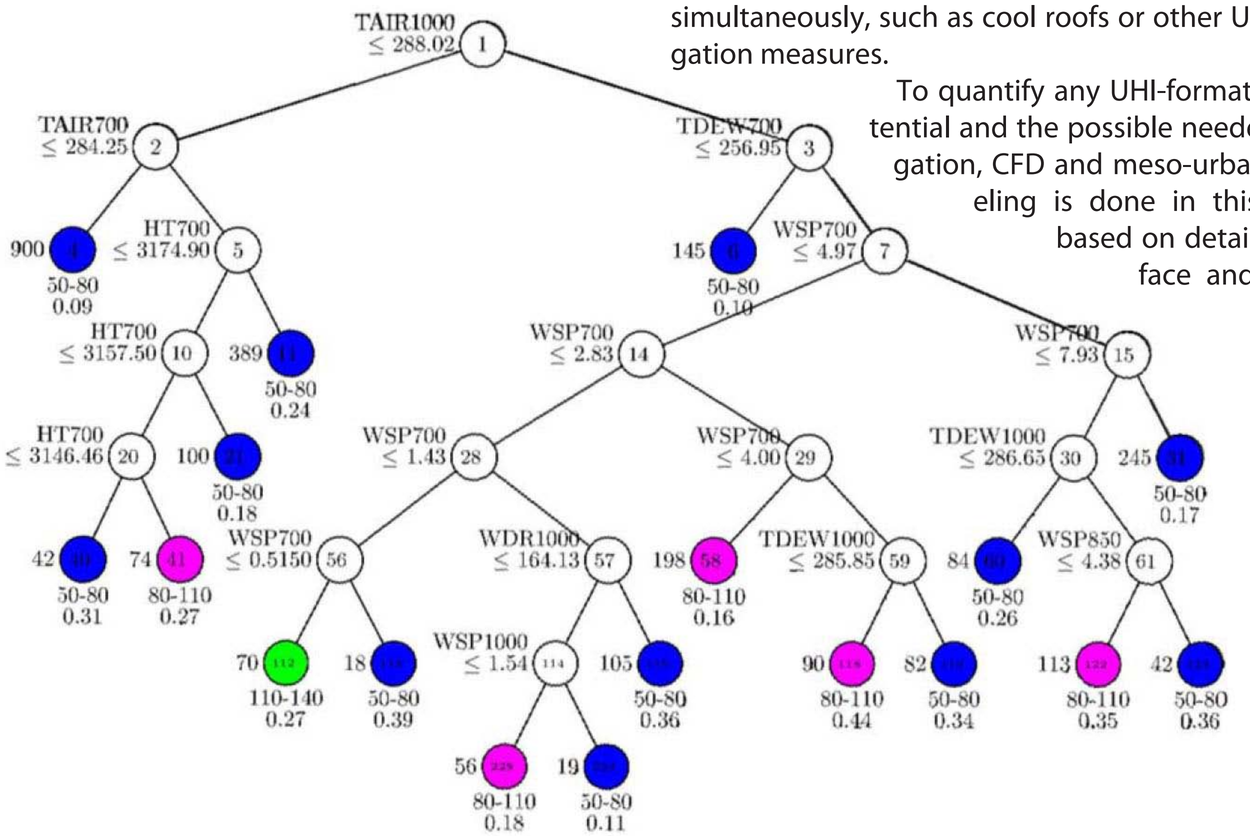
For CART analysis in this study, hourly and daily-peak ozone concentrations at each of 134 monitors are binned (into 30-ppb bins) and correlated with air temperature, dewpoint temperature, pressure height, wind speed, and wind direction from several surface and upper-air stations, and at various levels, including 1000, 850, and 700 hPa. The purpose of this analysis is to determine the representativeness of each set of meteorological conditions leading to certain ozone concentration bins, e.g., extreme, high, moderate, and marginal. Thus a large number of trees (one for each of the 134 monitors) are generated to capture the various conditions examined in this study for the 10-year period. In this CART analysis, weekdays and weekends are evaluated separately (separate trees) to avoid masking the weekend effect on emissions and air quality.

Of interest to the particular goals of this study is that similar ozone bins (concentration ranges) can be reached via different pathways, i.e., different combinations of meteorological variable ranges (see, for example, Figure 2 and as summarized in the table). This is useful in evaluating the representativeness of each set of meteorological conditions and the effectiveness of UHI mitigation for each set.

3. Modeling the potential impacts of urban solar systems

A task related to the project discussed above is to assess the heat-island formation potential of large-scale deployment of urban solar systems, e.g., photovoltaics and passive / active solar technologies. Since these systems absorb solar energy and their surfaces become hot, ambient air temperature can increase, too, thus resulting in a heat island effect. In theory this could offset, to a certain extent, the benefits from deploying solar systems, which include generating electricity and space heating / cooling to conserve energy. This study evaluates, via detailed modeling, the magnitude of this heat island effect and determines 1) whether that effect is significant enough to be accounted for, and 2) if compensating technologies, at community scale, need to be implemented simultaneously, such as cool roofs or other UHI-mitigation measures.

To quantify any UHI-formation potential and the possible needed mitigation, CFD and meso-urban modeling is done in this study based on detailed surface and urban



O3 bin	Frequency	Of which	Tair1000	Tair700	WSP700	Tdew700	HT700
🟩 110-140	2.5%	100% occurs –>	>288 K		<0.5 m/s		
80-110	19.2%	14% occurs –>	<288 K	>284 K			>3146
		11%	>288 K		<2.83 m/s	>257 K	
		37%	>288 K		<4.00 m/s		
		16%	>288 K		<4.90 m/s		
		21%	>288 K		<7.93 m/s		
50-80	78.3%	66% occurs –>	<288 K				

Figure 2. An example CART analysis showing Alameda County ozone peaks (in 30-ppb bins) vs. Oakland airport surface and upper-air meteorology variables at 1200 UTC over a period of 5 years (weekdays) at three levels (1000, 850, and 700 hPa). Here, HT is geopotential height (m), TAIR is air temperature (K), TDEW is dewpoint temperature (K), and WDR (°) and WSP (m/s) are wind direction and speed, respectively. Thus for example, WSP850 indicates wind speed at the 850 hPa pressure level. The splitting variable and its value are shown to the left of the nodes; the node number is inside the circle, and the number of nodes to the left of it. Below each circle is the ozone bin (ppb range) and a misclassification cost.

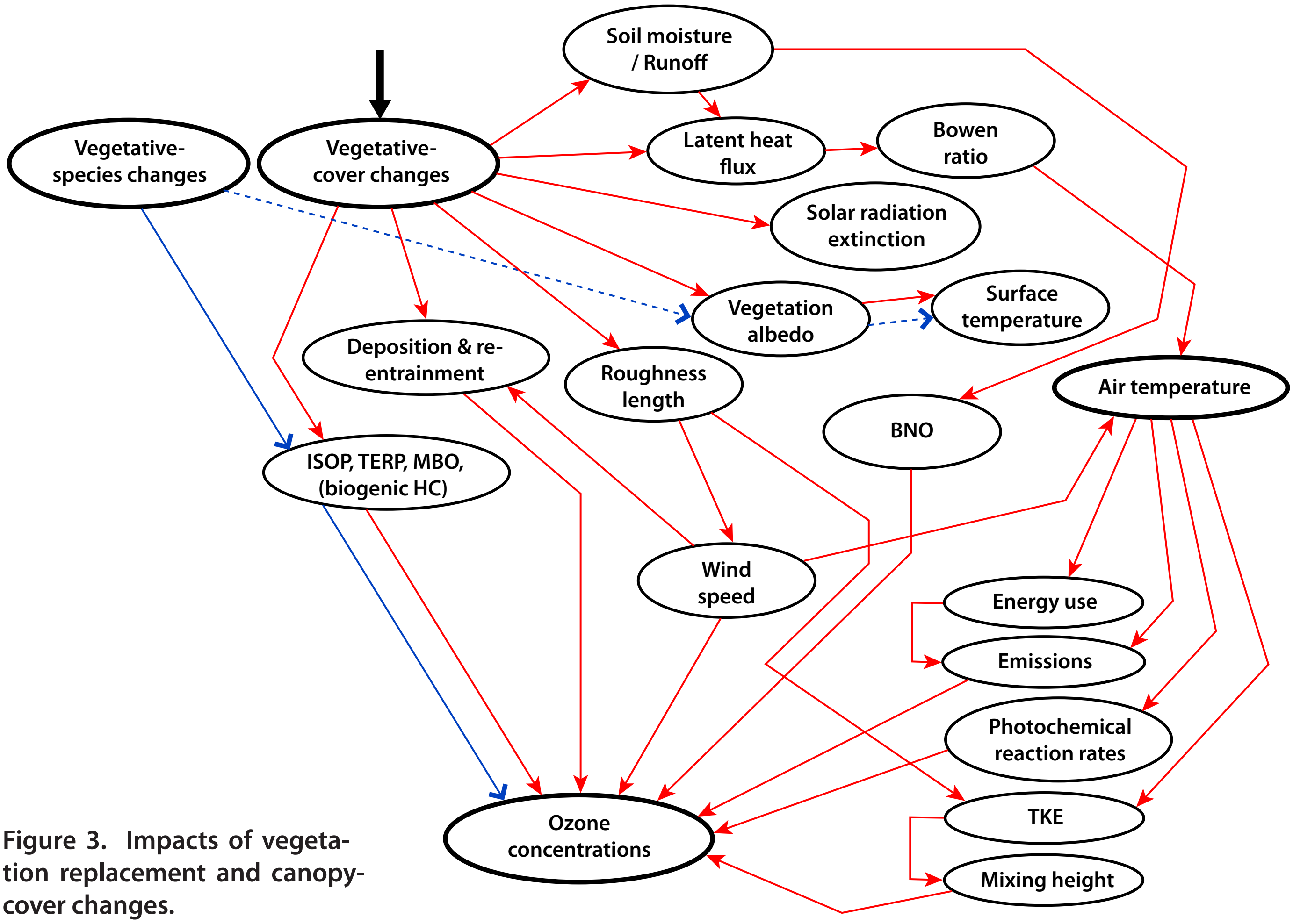


Figure 3. Impacts of vegetation replacement and canopy-cover changes.

morphological characterization, assessment of potential solar-system penetration, and solar deployment potential (e.g., Taha 2007, Chaves and Bahill 2010). If the impact is found to be significant, then the analysis will also evaluate the associated effects on emissions of ozone precursors and on ozone formation. This study also lays the groundwork for potential future modeling of large solar power plants, such as those being currently approved and licensed by the California Energy Commission.

4. UHI modeling in support of a voluntary control measure

In Sacramento, California, the Sacramento Metropolitan Air Quality Management District (SMAQMD), in collaboration with the Sacramento Tree Foundation (STF) and the UC Davis Center for Urban Forest Research (CUFR), is currently developing a voluntary control measure for ozone, based on reducing the BVOC emissions from urban forests to help the region attain and maintain the Federal 8-hour ozone standard. Our role in this project is to perform detailed atmospheric modeling in support of the control measure.

The measure's strategies are to shift the current tree-species mix in the region to one with more abundant medium- and low-emitter species, and to increase the canopy cover, particularly in the new urbanizing areas of Sacramento. The latter strategy will help counteract the local urban heat island effect and reduce temperature-dependent BVOC emissions as well. The overall strategy focuses on emissions reductions but also on some canopy-cover changes (replacement canopies can be larger and changes in land-use can result in increased canopy cover). The increase in canopy cover can entail significant meteorological effects, i.e., as a result of increased soil moisture / evapotranspiration, roughness length, and changes in albedo relative to that of the underlying surface. These two strategies directly and indirectly impact ozone formation as sketched in Figure 3. The Sacramento Urban Forest Ecosystem Study (McPherson, 1998) concludes that the existing regional canopy cover in the Sacramento region is 14% in developed areas and 5% in undeveloped areas that are slated for development. This is where increasing canopy cover from 5% to 14% would occur (to maintain an overall cover of 14% in the region).

Urban forests can help improve air quality via meteorological, deposition, and emissions / photochemical mechanisms. As with most control strategies, the implementation of increased canopy cover can impart both positive (beneficial) and negative (inadvertent) effects on air quality, as a large number of factors and non-linear, competing effects are present. Previous studies have shown that the relative benefits and disbenefits of urban forests differ significantly from region to region (Taha 1996) and that it is possible to maximize the potential benefits on a region-specific basis by finding the optimal mix of strategies for each location. In addition, the potential effectiveness of urban reforestation, unlike conventional air-pollution control strategies, also depends on meteorological conditions, thus adding another dimension to the complexity of evaluating potential ozone air-quality benefits of this control measure.

As shown in Figure 3, the modeling captures several interrelated processes resulting from changes in vegetation cover, canopy structure, and species. Species replacement and increasing vegetative cover can result in modification to the soil-vegetation system's albedo. Thus it is important to evaluate vegetation-canopy albedo relative to that of the underlying surface and how, in turn, it affects energy balance. While vegetation albedo can sometimes be higher than that of urban surfaces, the main effect arises from the introduction of new vegetation canopy not the replacement of species. Vegetation also impacts roughness length, soil moisture and evapotranspiration. At the mesoscale simulations level (4-km resolution in this study), roughness length is unchanged in response to replacement trees or canopies that are immediately adjacent to buildings, since the assumption is that there is either no change in canopy structure (replacement) or that the increase in canopy is uniform with buildings. However, at the finer meso-urban scale (e.g., sub-kilometer in the horizontal and a few meters in the vertical, in this study) impacts of canopy roughness are accounted for via the drag-force approach of the urbanized MM5 (Dupont et al. 2004, Taha 2008a,b). Another aspect of vegetation that is related to roughness is deposition velocity. In the air-quality model, as modified in this study, the calculation of deposition velocity is improved upon with more accurate land-use, land-cover, and morphology characterizations that are then used in more resolved roughness-length calculations, e.g., using the approach of MacDonald et al. (1998). Figure 4 shows an example of roughness length computed following this approach for Sacramento, California.

Changes in BVOC emission rates as a result of species replacement and varying meteorology (effects of changing photosynthetically-active radiation (PAR) and temperature) are modeled using the relations of Guenther and Wiedinmyer (2004) and Guenther et al.

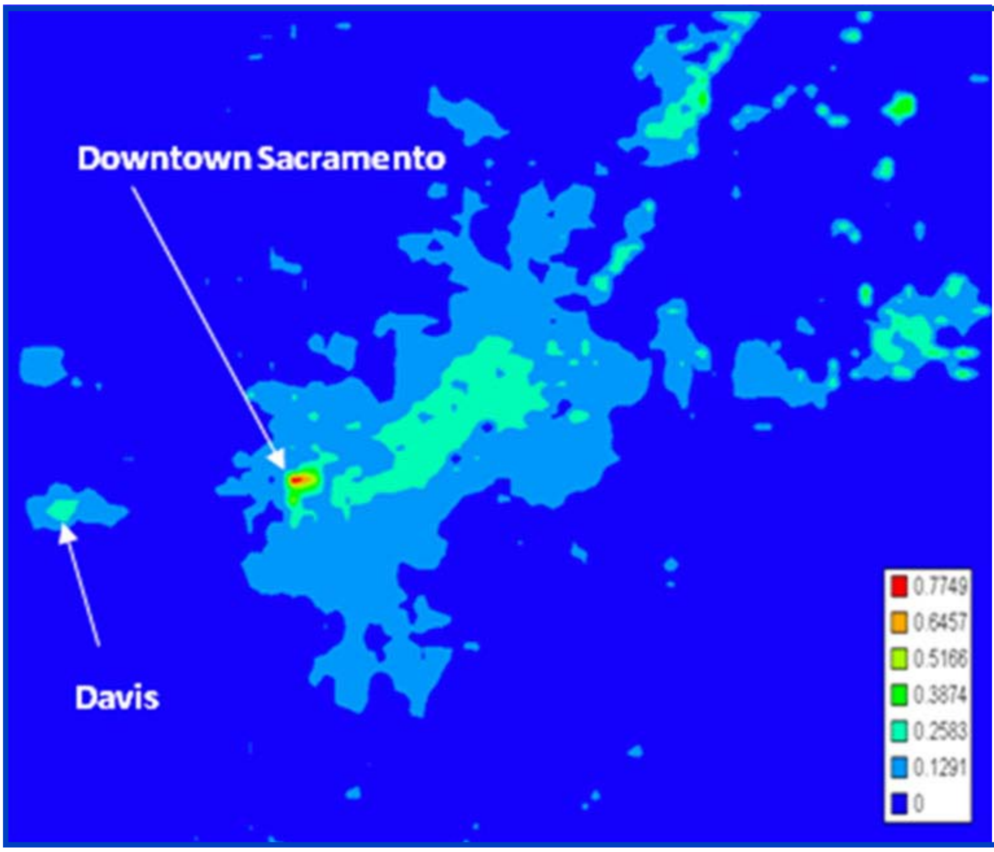


Figure 4. 1-km resolution roughness length (m) in the Sacramento uMM5 modeling domain.

(1993). The BVOC emissions of interest include those of isoprene, monoterpenes, oxygenated VOC, and methyl butenol. Because the simulations in this study are done at fine resolutions, a few meters in the vertical, the temperature and PAR fields are well resolved spatially thus increasing the accuracy and specificity of emission-inventories input to photochemical models.

Figure 5 shows an example output from fine-resolution meteorological simulations in this study. The figure depicts the maximum daytime UHI over Sacramento, 2K warmer than upwind areas to the southwest. Flow divergence and slowing over the urban area is evident as is the advection of UHI temperatures to the southeast beyond the core urban area. The eastern part of the domain consists of higher terrain (Sierra-Nevada mountain range) and thus is cooler.

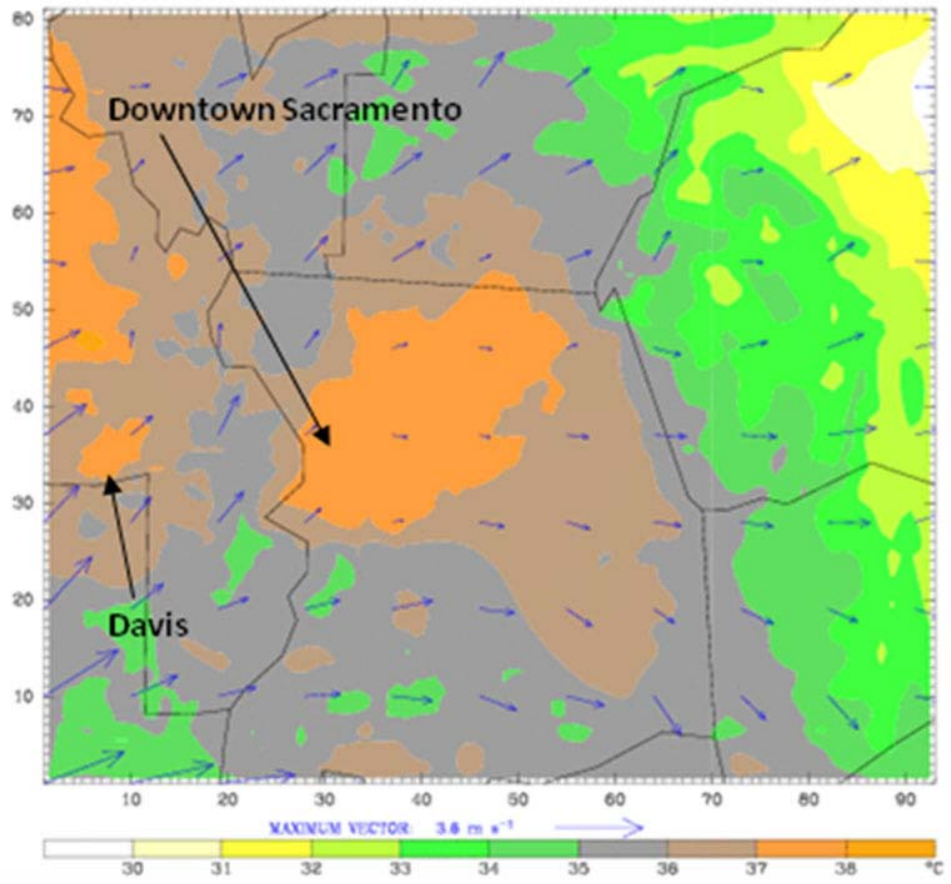


Figure 5. Peak daytime UHI (2K) at 3m AGL in the Sacramento region at 1700 PDT on 11 July 1999.

5. Ranking of UHI mitigation measures by indirect effect

The goal of this project is to develop a ranking system and tool to help prioritize the deployment of community-scale UHI control and energy measures, based on their individual and combined indirect atmospheric effects, e.g., impacts on peak temperatures, temperature range, heating / cooling degree-hours, winds, and urban-canopy layer energy fluxes. The community-scale measures include 1) increased urban albedo on roofs, walls, pavements, and streets, 2) control of runoff (impervious surface area), 3) structural shading and sky-view factor control, 4) urban forestation (evapotranspirative cooling and shading) for buildings, parking lots, and streets, 5) photovoltaics and active/passive solar systems, 6) green roofs an green walls, and 7) control of anthropogenic heating. The effects of each measure are evaluated alone and in various combinations with other measures at 180 locations (climates) in California, as seen in the white circles in Figure 6. The reason for performing the analysis over 180 climate points, representing different urban areas in California, is to increase the level of information and resolution relative to California's standard 16 climate zones (background of figure) that are typically used in energy calculations and building energy modeling.

A customizable ranking system with prioritization tool is needed because building energy models, community-energy planning tools, and land-use models commonly used in evaluating energy use at community scale do not account for the indirect effects. Thus performance of these models and tools can be improved upon (made closer to observations) and their reliability in forecasting energy consumption under a range of conditions be increased if the indirect effects are quantified and factored in the calculations. Previous studies have shown that the indirect effects of UHI mitigation measures can be of similar magnitude (or even larger) than the direct effects. Planners may also need a tool to help in evaluating a number of community-scale measures and combinations thereof (that can cancel each other's effects) and prioritize deployment of most effective strategies at specific locations (e.g., for specific climates, land-use / land-covers properties, etc.).

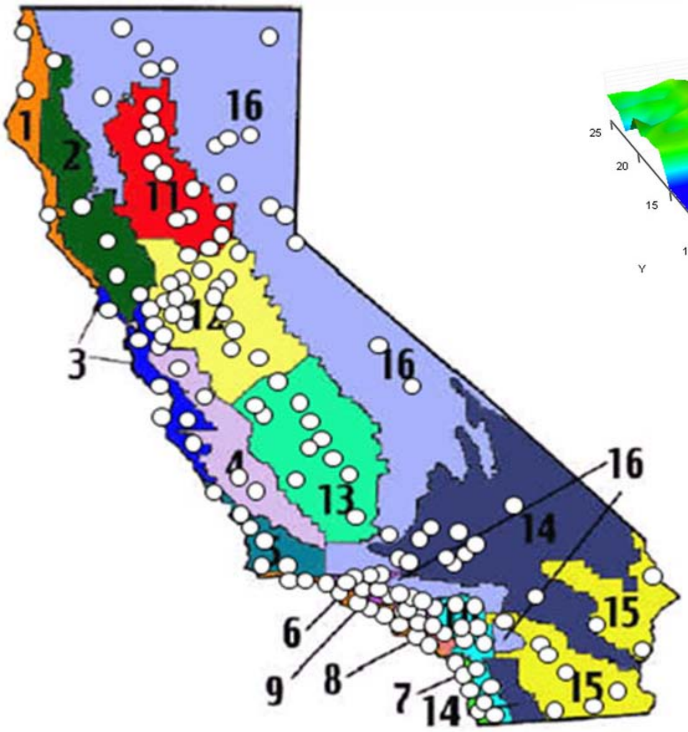


Figure 6. The project's 180 climate zones / idealized communities (white circles), superimposed on California's 16 climates zones in the background. Figure background credit: CEC.

As in the studies discussed earlier, this project's tasks also include performing detailed characterizations of urban surfaces, land-use, climate (for each zone/city), detailed calculations of deployment potentials for each measure and each region (gridded domains), numerical modeling (using the models discussed above), and developing the ranking system. Calculation of deployment potentials for each UHI mitigation measure listed above is based on surface and land-use characterizations. For example, the deployment potential for high-albedo materials for each 200-m computational grid cell ($\Delta\alpha_{200m}$) in the modeling domain is calculated as follows:

$$\begin{aligned}\Delta\alpha_{200m} = {} & f_{roof} \times fr_{flat} \times \Delta\alpha_{rflat} + f_{roof} \times fr_{pitch} \times \Delta\alpha_{rpitch} + \\ & f_{street} \times fs_{asph} \times \Delta\alpha_{sasph} + f_{street} \times fs_{conc} \times \Delta\alpha_{sconc} + \\ & f_{paved} \times fp_{asph} \times \Delta\alpha_{pasph} + f_{paved} \times fp_{conc} \times \Delta\alpha_{pconc} + \\ & w2p \times fw_{wood} \times \Delta\alpha_{wwood} + w2p \times fw_{mason} \times \Delta\alpha_{wmason} + \\ & w2p \times fw_{conc} \times \Delta\alpha_{wconc} + w2p \times fw_{curt} \times \Delta\alpha_{wcurt}\end{aligned}$$

based on the characterizations (in each 200-m cell) of roof, street, and pavement areas (f_{roof}, f_{street}, f_{paved}), flat-roof and pitched-roof fractions (fr_{flat}, fr_{pitch}), asphalt- and cement-street fractions (fs_{asph}, fs_{conc}), asphalt- and cement-pavement fractions (fp_{asph}, fp_{conc}), levels of increase in flat-and pitched-roof albedo ($\Delta\alpha_{rflat}$, ($\Delta\alpha_{rpitch}$), asphalt- and cement-street albedo ($\Delta\alpha_{sasph}$, ($\Delta\alpha_{sconc}$), and asphalt- and cement-pavements albedo ($\Delta\alpha_{pasph}$, $\Delta\alpha_{pconc}$), buildings wall-to-plan ratios (w2p), fractions of wood walls, masonry walls, concrete walls, and curtain walls (fw_{wood}, fw_{mason}, fw_{conc}, fw_{curt}), and their respective levels of increase in albedo ($\Delta\alpha_{wwood}$, $\Delta\alpha_{wmason}$,$\Delta\alpha_{wconc}$, $\Delta\alpha_{wcurt}$). The parameters in these calculations can be provided based on results from this study or can be user-specified for the particulars of a region being studied, if better data is available. Figure 7 depicts the albedo deployment potential (for a moderate-increase scenario) calculated in this manner for the Los Angeles region. The scale ranges from 0.01 to 0.08 (at the 200-m resolution level).

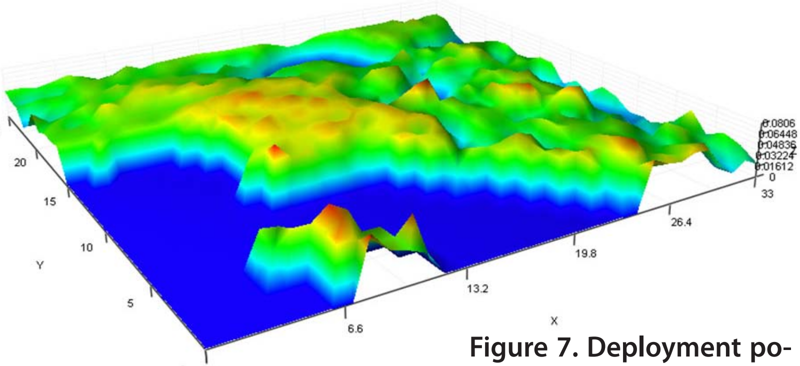


Figure 7. Deployment potential for albedo in the Los Angeles region.

The deployment potentials for all community-scale measures in all urban areas in California are characterized in this manner but, of course, with different parameters. These urban areas are then simulated with mesoscale and meso-urban models, as discussed above, to evaluate the effects of each UHI-mitigation measure separately and then in a number of possible combinations with other measures. In addition to simulating actual urban areas, such as Los Angeles, Fresno, and Sacramento, the modeling in this project also involves simulating the standalone and combined deployments of community-scale measures in 180 idealized communities representing each of the 180 climate points shown in Figure 6. Idealized communities, each 1 km^2 in area, are developed for the analysis by constructing statistically-representative urban areas that resemble, in terms of land-use makeup and land-cover characteristics, the existing urban areas that are closest to each. The purpose of modeling these idealized communities is to generate region-specific data that can assist urban planners / developers in ranking the measures when planning new developments at any of these 180 locations.

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Heat wave in Moscow city in summer of 2010: Results of meteorological measurements and possible explanations

In the summer of 2010, anomalous hot weather took place in the Central part of European Russia – in Moscow city and in some other regions around the Russian capital. As was shown by Professor B.A. Revich, an additional mortality in the area of European Russia – where a temperature anomaly of +5 °C or more was observed during this heat wave – consisted of 58,000 people (including nearly of 11,000 inhabitants of Moscow city) in comparison with the same summer time in the previous year (2009). Thus, the mortality evidently connected with hot weather in European Russia seems to be even higher than in Western Europe in 2003.

The reason for this catastrophic event was an extremely steady, high (up to 100 hPa isobaric level) and long-lived blocking anticyclone with a center above the East of European Russia from the second half of June until the middle of August. As a result, an extremely hot tropical air mass from Africa or from Central Asia was invading into central Russia by steady southern and southeastern winds during a long time period.

On July the 29th, as seen in Figure 1, the maximal air temperature T_{max} in Moscow consisted of 38.1 °C (at Moscow University), whereas the previous maximum-maximorum value of T for Moscow city, in 1920, was equal to only 36.8 °C. It should be noted that just in the center of Moscow city at Balchug station (near the Kremlin), the maximal air temperature on the same day was equal to 39.0 °C – probably due to the additional local effect of the urban 'heat island'. The reason for this conclusion is the high density of buildings in the center of Moscow city. In contrast, there are a lot of green park zones on the southwestern periphery where the University is situated. That is why the value of T_{max} at the University as well as at three other stations around the center was a bit less – from 0.4 to 1.0 °C (Fig.1). Thus the structure of the urban 'heat island' sometimes may be seen not only in the pattern of average or minimal air temperatures, but in the pattern of daily maximal temperatures as well. It should also be noted that the air temperature in Moscow for the first time exceeded 100 °F, and the body temperature of a healthy person.

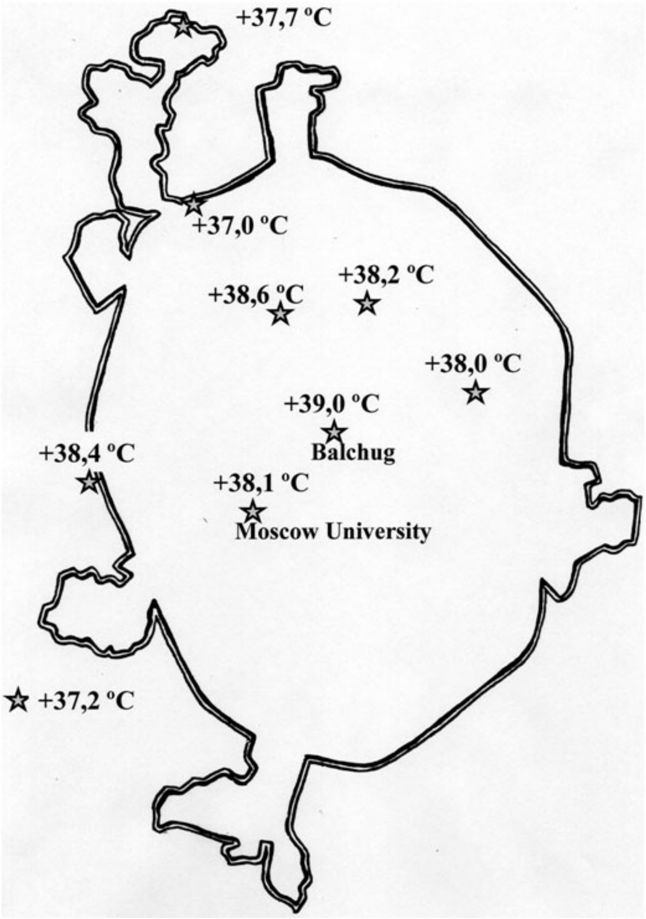

Figure 1. The daily maximal air temperatures during July 29th, 2010 – the warmest day in Moscow city during the last 130 years. Double lines are margins of the city; asterisks are meteorological stations.

The monthly-averaged air temperature in July of 2010 in Moscow consisted of 26.4 °C (red rhombus in Figure 2), which is the highest value during last 230 years (since 1780). This value is 3 °C more than the previous maximal monthly-averaged value for July. The monthly-averaged air temperature for August of 2010 (22.2 °C) became the highest value as well during the whole history of meteorological measurements in Moscow for August. The daily maximal air temperature exceeded 23 times (during 4 separate days in June, 10 days in July and 9 days in August) the maximal values for these days since 1879. For the first time, the daily average air temperature (31.4 °C) was seen as more than 30 °C. The surface temperature in Moscow (62.3 °C) for the first time exceeded 60 °C.

The minimal relative humidity was equal to 16%; the maximal humidity deficit for the first exceeded 50 hPa (56 hPa). As a result, the amount of precipitation was extremely low – only 7.4 mm during July. Such a low monthly value of precipitation was never before observed in July according to all known data since the 19th century (the average precipitation in July in Moscow is 91 mm). As a result, a lot of forest fires broke out in the Moscow region and a strong haze existed above Russian capital during a long period. The thermal wave connected with the disastrous heat (i.e.

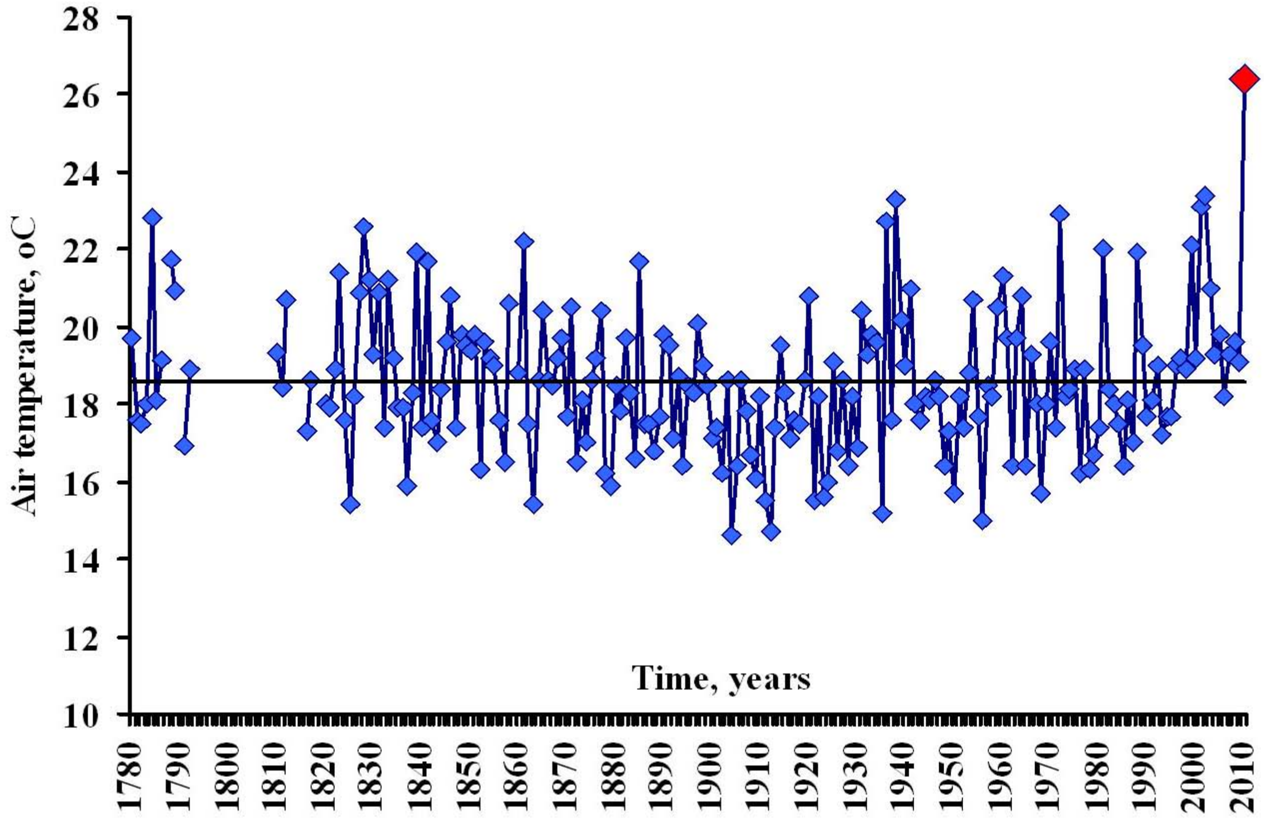

Figure 2. Monthly-averaged air temperature in Moscow in July during all the history of meteorological measurements since 1780 (accordingly to the data collected by Lokoshchenko and Vasilenko; see Proc. ICUC-7, B8-5). Linear trend is close to zero.

maximal values of soil temperature during the last 45 years) was detected at a soil depth of 320 cm below the surface until the middle of December of 2010, i.e. four months later.

Recently some different explanations of this event have been suggested. According to one of them, it was a result of two separate phenomena. As studied by Academician Valentin P. Dymnikov and his colleague from the Russian Institute of Numerical Mathematics of the Russian Academy of Sciences Professor Evgeniy M. Volodin, an unusually strong drought took place during spring of 2010, just before the beginning of the heat wave, in the Caspian region, i.e. up-stream to the southern flows along the Western periphery of the blocking anticyclone. As a result of this drought, the tropical air mass was not transformed significantly during its passage to Central Russia above the very dry surface layer of soil in the Caspian region. Both of these events – the long-lived blocking anticyclone and the drought in the southeastern part of European Russia – are rare (occuring on average one time during 10 or 20 years). Thus, accordingly to V.P. Dymnikov and E.M. Volodin, a combined probability of their simultaneous existence may be assumed to be equal to the product of their separate probabilities because both events are independent from each other. Thus, their combined probability seems to be extremely low (only once during several centuries), and that is why, this disaster took place for the first time during the entire history of regular meteorological measurements in Moscow since the 18th century.

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Spatial geotechnology applied to urban climate studies: Thermal analysis of urban surface and land use in the city of Caracas

The urban saturation and the enlargement of the built space have determined environmental changes, increasing the already precarious condition of the natural systems in these spaces of high saturation. In recent years urban heat waves, extreme droughts and forest fires have been reported with increased frequency, disturbing the environmental dynamics and the quality of life in the affected cities. Using remote sensing techniques, it is possible to analyze the thermal and environmental information gathered through earth observation satellites to produce maps of the urban surface temperature, land use and vegetation index, which can help identifying areas that are susceptible to greater risk in case those weather anomalies occur. The purpose of this study is to analyze the spatial variation of these socio-environmental conditions related to the urban surface temperatures in the city of Caracas.

1. Introduction

The World Meteorological Organization reported 2001, 2002 and 2003 as three of the five warmest years since 1997-1998 (WMO, 2003). Land surface temperatures in 2003 were 0.83°C above the 1880-2003 mean, ranking third in the period of record, while ocean temperatures ranked as second warmest with 0.44°C above the average (NCDC-NOAA, 2003). In the same year, during a positive ENSO event, drought and heat waves hit India and Central Europe, leading to emergency health and environmental problems. Critical conditions of drought and heat were also described during a positive ENSO for many regions in Central and South America, and in the Caribbean area (Aguilar et al., 2005).

The city of Caracas is located in the north of South America (10°20'–10°35'N and 66°45'–67°0´W). It is settled in a narrow valley (30 km length) near the Caribbean Sea (900m-asl) with a complex topography (Fig. 1). The city has a population of about 4 million inhabitants, with very high construction and population densities and, consequently, a high pressure on water resources and soil. Most of the low-income population (1.5 million inhabitants) lives in the southwest and western areas of the city, which is the sector with the most difficult socio-environmental problems.

Political strategies and urban planning policies in Venezuela have been oriented to strategies that provide solutions to urgent issues related to poverty, water scarcity and health, while leaving behind the problems related to the urban environment and climate change. Recently there is renewed interest in these issues, especially because in March 2003, the city suffered an intensification of the dry season – with an increase in drought and forest fires that was observed to be related to the high temperatures during the peak of the dry season. At that time, the global temperature average registered a positive anomaly of 0.59°C in the northern hemisphere according to the WMO, in the presence of a positive "El Niño" event in the equatorial pacific (WMO, 2003). In some areas of the city, especially in low-income sectors, such situations turned into serious environmental and health risks.

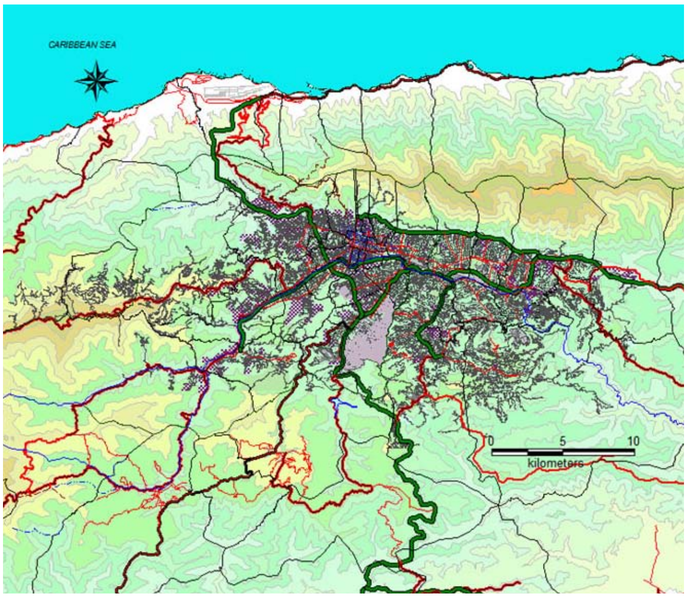

Figure1. Map of the city of Caracas, showing location of the study area. ***Source: Cartographical Databases-IGSBV*****.**

The purpose of this study is to analyze the spatial variation of these socio-environmental conditions related to urban surface temperatures (the urban heat island phenomena) using remote sensing techniques to determine possible links between global change and climate variability with environmental conditions in urban areas. The city of Caracas is presented as a case-study. This work also seeks to improve the information available for urban planners and decision makers in these matters.

The variables analyzed with remote sensing techniques were urban surface temperatures, urban land use and vegetation index conditions for the period 2001-2008. A set of images from Landsat-7 ETM+ for the rainy or dry season were used to verify the seasonal changes in urban surface temperature. Two critical

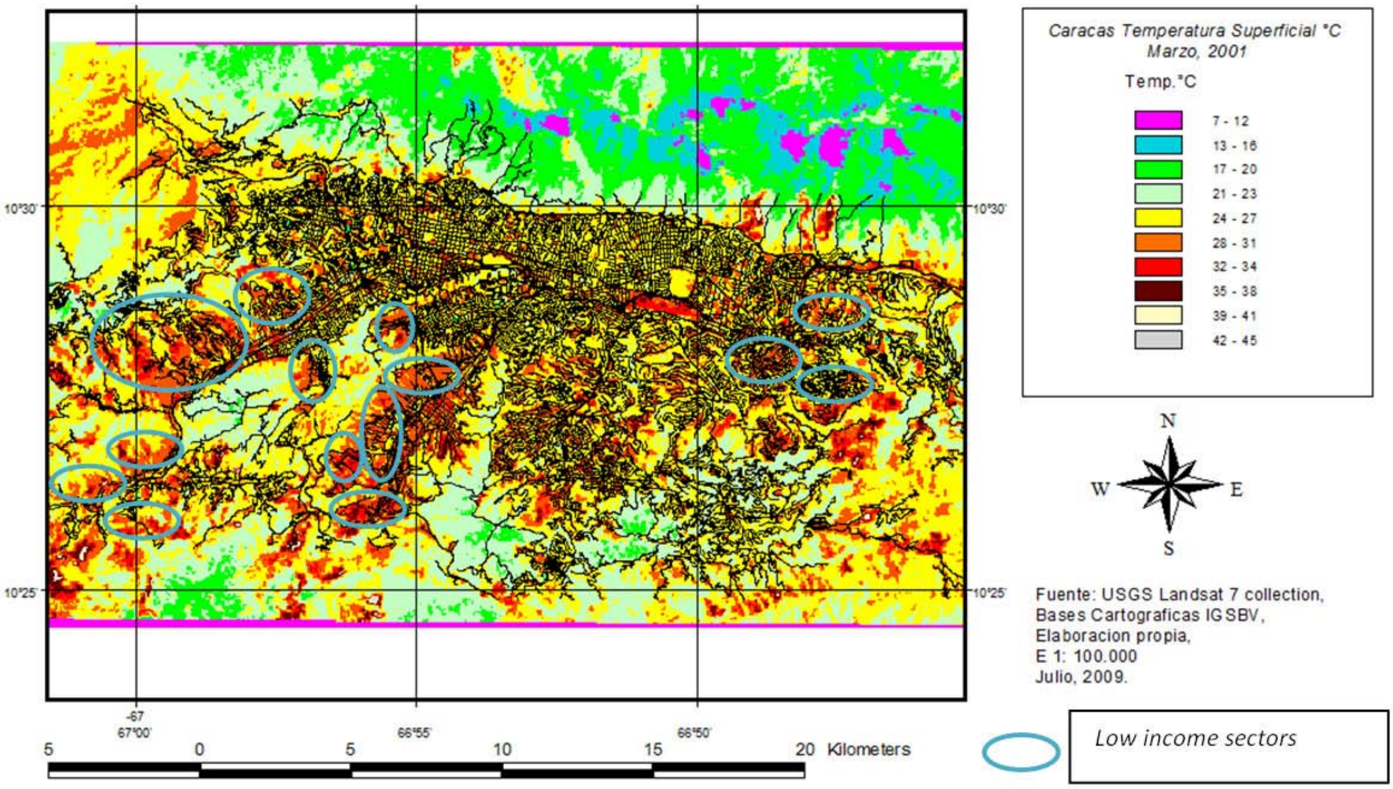

Figure 2. Superface temperature patterns for the city of Caracas, March 2001. ***Source: USGS Landsat 7 collection, Cartographic data bases - IGSBV.***

years were selected for this study: 2001 with a global anomaly in surface temperature reported around 0.42 °C, and 2003 with a global increase in temperature around 0.46°C (WMO 2001; 2003).

2. Methodology

A set of images from Landsat-7 ETM+ were selected considering the pixel resolution in the thermal band (60 meters) for medium size cities, i.e. Caracas (30 km length). Other satellites like MODIS, ASTER (90mts), and AVHRR (1 km) have thermal bands but with a low resolution. Cloud coverage, seasonal period (dry or rainy season) and information gaps were other selection criteria. The period of analysis was 2001-2008, considering that during this decade climate anomalies had been frequently reported, and in some cases, with serious impact on urban communities. This analysis, however, focuses on the two critical years of 2001 and 2003.

Thermal analysis, land use and vegetation index (NDVI), were carried out using image analysis (image algebra) techniques, and image classification techniques with ERDAS 9.1 and Arc-Gis 9.2 , ArcView 3.2 licensed programs available at the Central University of Venezuela. Seasonal analyses were also developed when possible, according to the image available, in order to understand the dynamics of the urban heat island (UHI) phenomena. Urban surface temperature was calculated by converting thermal band (high gain mode) radiant temperature in K (Kelvin) to brightness temperature in °C (Celsius). Radiometric correction was done by converting the digital number values in the Landsat thermal bands to radiance values, and then changing them into an effective temperature values (as detailed in Córdova, 2009).

Vector layers of roads and street directions in the city were integrated with the raster models of surface temperatures and NDVI index into GIS, allowing us to identify and locate the areas with thermal anomalies or under major risk of forest fire occurrence, for urban and environmental planning purposes. Raster models and vector layers were reprojected with ERDAS 9.1 and ArcGis 9.2 from UTM/WGS84 to Lat/Long WGS84.

NDVI analysis (complementary to the thermal surface analysis) was carried out due to the high incidence of forest fires in the critical years selected. Land use was analyzed by sectors, comparing the thermal response between the west and southwest areas of the city, which show high urban density and where the majority of the low- income sectors are located, and the east and southeast areas, with lower urban density and greater natural vegetation areas.

3. Results and discussion

Urban surface temperature patterns show significant differences between the east and southeast sectors characterized by lower urban density and greater vegetation areas, and the low-income and crowded sectors, located in the west and southwest areas of the city. Temperatures between 28°C and 34°C were observed in most of these low-income sectors in the southwest and west areas (Fig. 2). These areas are characterized by informal construction, using brick, wood panels, and metallic roofs (zinc, galvanized, aluminum), with improvised infrastructure services for electricity, potable water and sewage (Fig. 3). The effect of large urban surfaces covered by such metal roof construction has been described in Brazilian cities as "febrile cities." High surface temperatures have been reported for galvanized metal (57.9°C) and aluminum (69.4 °C), commonly used as roof materials in the houses of the low income areas (Sant' Anna et al., 2008).

In contrast, comfortable temperatures between 24°C and 27°C degrees were observed in most of the east and southeast sectors (Fig. 4), with only a few critical areas between 28°C and 31°C related to areas where the soils are exposed due to the urbanization process. Residential areas, close to the El Ávila National Park in the north and central-north part of the city, also show temperatures between 24°C and 27°C (Fig. 2). This sector benefits from the proximity to El Ávila National Park, which provides moisture and fresh air to the northern area of the valley. La Carlota airport (central-east), an open space covered by asphalt with little vegetation, is one of the hottest places in the city. Wide avenues, highways, and burned areas also show high values of surface temperature (28-34°C or more).

Data recorded in the thermal band of the sensor (Landsat-7 ETM+) is collected at 10:15 in the morning (the revisit time of the remote sensor). Climatological information registered for the city of Caracas has shown a maximum soil temperature (in the first 2 cm of depth) of 63°C degrees at noon in March (Table 1). Surface temperatures observed with the remote sensor can therefore register an increase depending on the physical properties of the surface during the day.

Temperatures recorded in climatological stations for the city of Caracas also show a relationship between

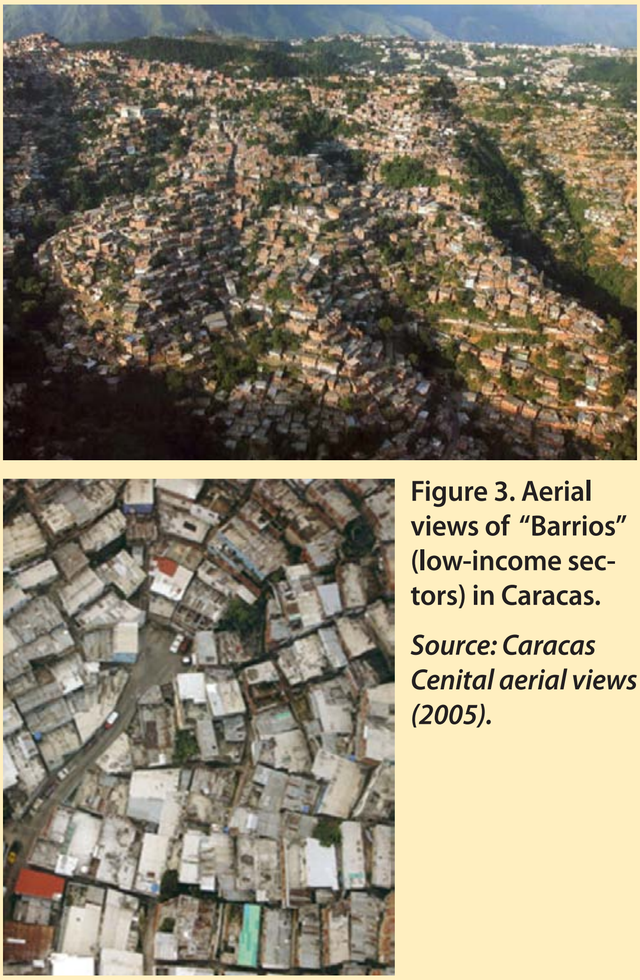

Figure 3. Aerial views of "Barrios" (low-income sectors) in Caracas.

Source: Caracas Cenital aerial views (2005).

Figure 4. Views of southeast Caracas. *Source: K. Cordova, personal collection, 2007.*

Table 1. Maximum temperatures of air and soil (top 2 cm) in Caracas, 1973-2003. *Source: UCV Climatological Station, Central University of Venezuela.*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. Abs. Air Temp. (°C)	32.0	33.7	35.2	34.0	32.8	32.5	30.2	33.2	33.0	32.5	31.7	30.5
Max. Abs. Soil Temp. (°C)	42	60	63	59	56	45	46.5	46.5	46	45	40	41.8

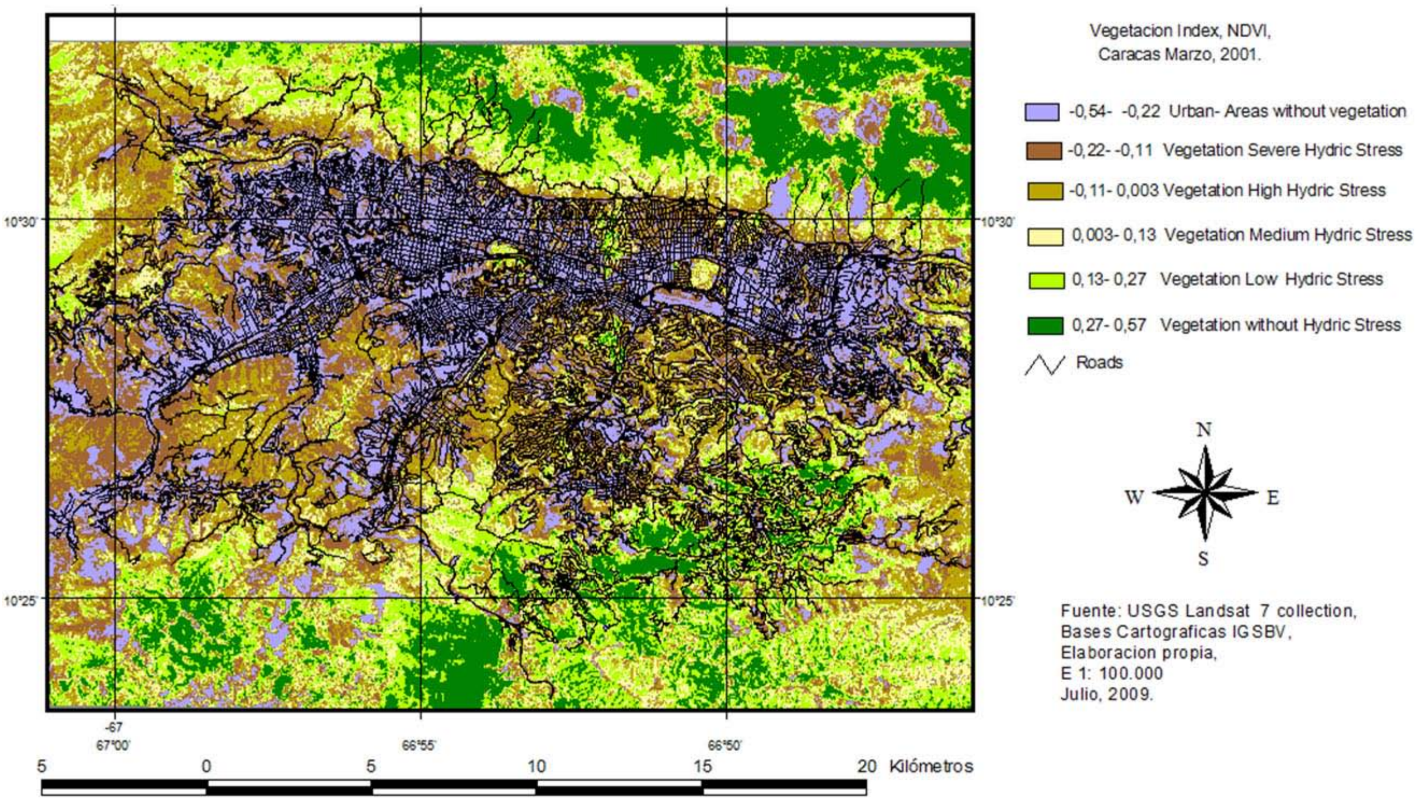

Figure 5. Vegetation (NDVI) index patterns in the city of Caracas, March 2001. ***Source: USGS Landsat-7 collection, Cartographic data bases - IGSBV.***

maximum soil temperature and maximum air temperature during the peak of the dry season in March (Table 1). Images taken during the rainy season have a high probability of rain; therefore, some of the images evaluated for Caracas, as it was determined in daily data, were taken on rainy days – causing a mitigation of the superficial heat at the moment in which the remote sensor collected the data. Further research is necessary for the rainy season, involving other superficial and climatological techniques, to determine the intensity and extension of the phenomena.

The incidence of forest fires is also related to the hydric condition of the vegetation. During the dry season in 2001, high levels of hydric stress were detected in most of the peri-urban areas covered by deciduous vegetation, related to NDVI values between -0.22 and 0.003 (shown as brown colors in Fig. 5). This is the vegetation generally exposed to seasonal forest fires, especially the dehydrated grass or deciduous vegetation (bushed). Only the tops of the mountain and hills still remain with some humidity due to orographic precipitation (NDVI values between 0.13 and 0.57). Burned vegetation in the peri-urban perimeter are considered as areas with no vegetation, like urban sectors (NDVI values between -0.54 and -0.22) in light grey color (Fig. 5). NDVI values show the areas under major risk of fire occurrence as a consequence of the hydric stress and urban proximity. Problems with waste disposal, intentional fires, heat and abundance of dry biomass are important causes of these urban fires.

Differences in urban temperature patterns are more evident in 2001 than in 2003. In 2001 (Fig. 2), even under a global condition of a positive anomaly in the temperature (0.42 °C), the dry season was less intense than in 2003 (Fig. 6). In 2003, a strong "El Niño" event, and a positive anomaly in global surface temperatures (0.46°C) caused one of the most intense drought events of the present decade (Fig. 6). Almost all the city was in critical condition, due to the high temperatures, the heat, and forest fire incidences. An important extension of the warmest areas at the southwest and west areas of the city was observed, mainly affecting the low-income sectors (Fig. 6). The surface temperature in 2003 shows an increase in 5 degrees when compared to 2001. Low temperatures between 7°C and 12°C degrees, usually registered over the top of the mountain, (El Avila National Park) vanished. Most of the low-income sectors in the southwest and western areas of the city were affected by these high temperatures (Fig. 6).

The worst occurrence of forest fires was also in the peri-urban areas, surrounding these sectors. Water reservoirs were also in critical condition; an emergency plan of water supply was developed, restricting the

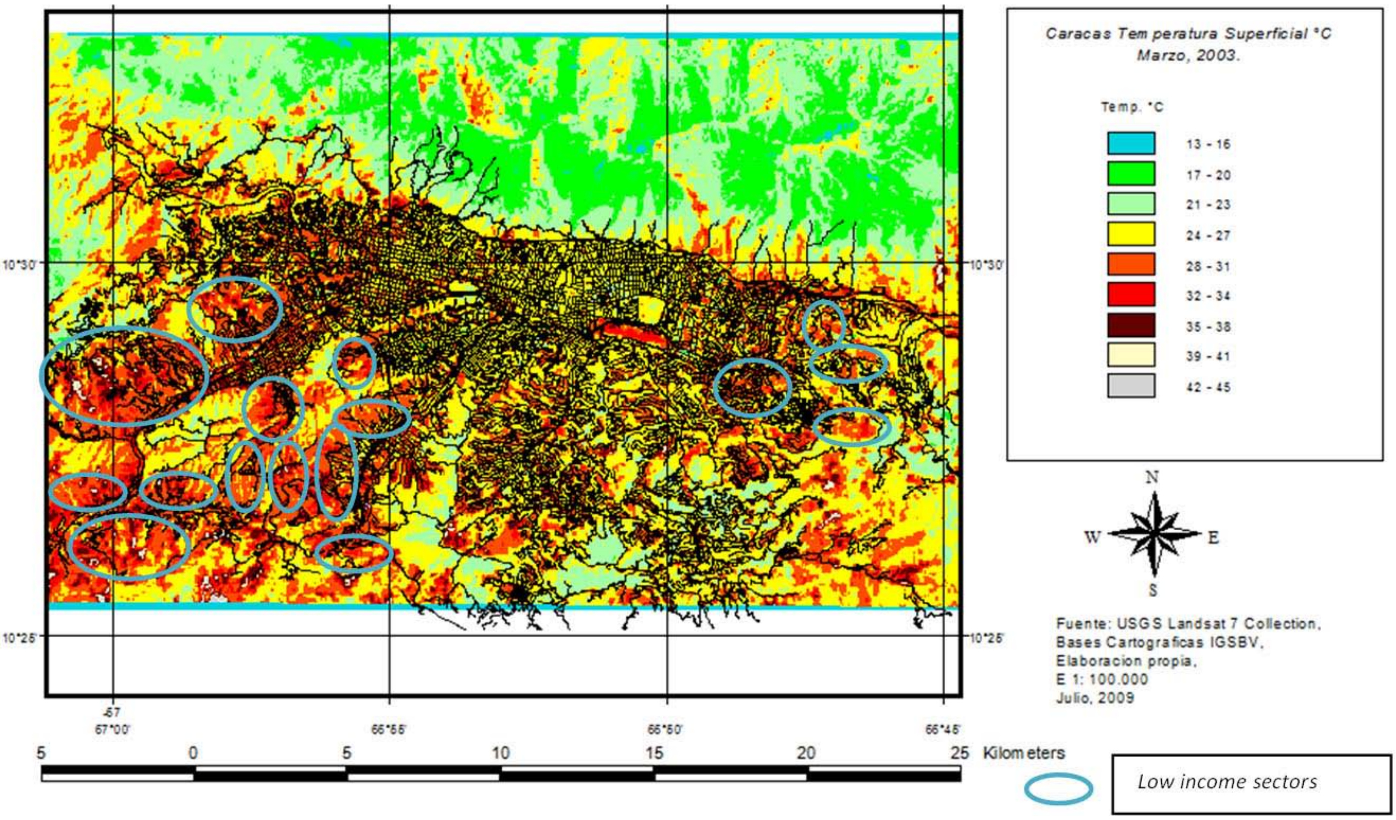

Figure 6. Superface temperature patterns for the city of Caracas, March 2003. ***Source: USGS Landsat 7 collection, Cartographic data bases - IGSBV.***

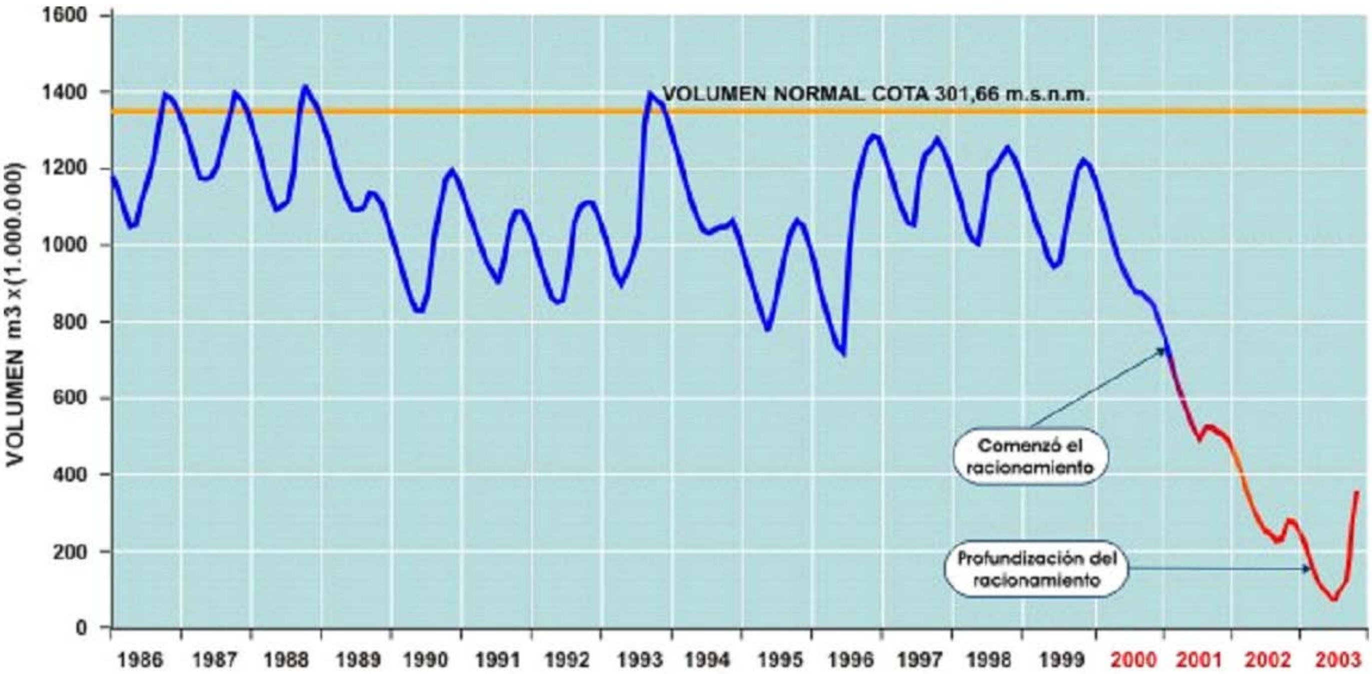

Figure 7. Camatagua Reservoir levels, 1986-2003. ***Source:*** http://www.hidrocapital.com.ve/

water supply service by sectors to one day per week. Levels in Camatagua dam, one of the most important water reservoirs for the city of Caracas, experienced a continuous fall since 2001 (Fig. 7).

The vegetation conditions during the dry season in 2003 were critical, due to an extension of the areas under high hydric stress that was observed in the southwest and west sectors of the city, as well as the incidence of forest fires in these sectors. NDVI values were below 0.5, even at the top of the mountains and hills where there is usually more humidity. The role of vegetation in the mitigation of high temperatures

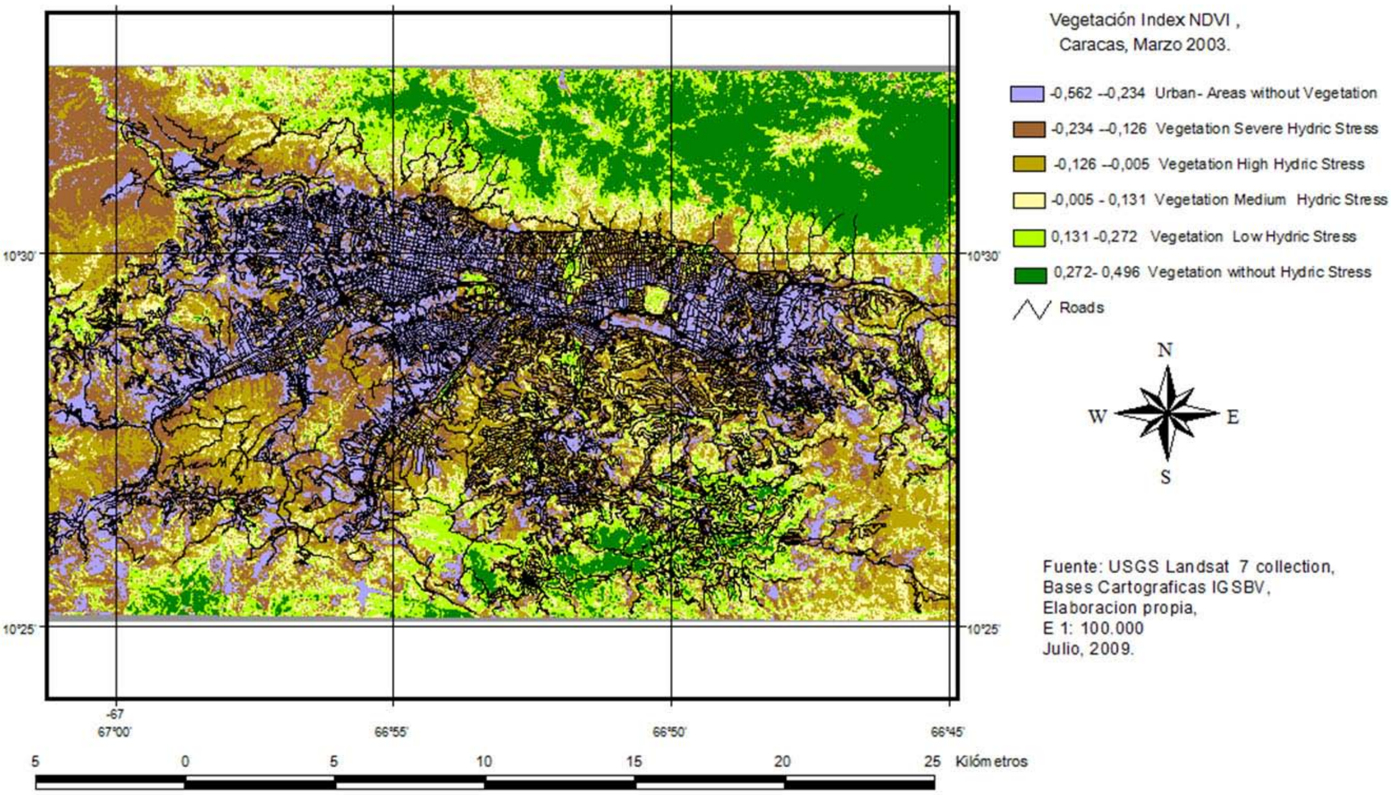

Figure 8. Vegetation (NDVI) index patterns in the city of Caracas, March 2003. ***Source: USGS Landsat-7 collection, Cartographic data bases - IGSBV.***

is minimized during the dry season, due to the hydric stress (Fig. 8).

4. Conclusions

The dry season in 2003 was one of the worst events of heat and drought in the city, in all the period analyzed (2001-2008). The heat patterns show significant differences between the east and southeast sectors, and the west and southwest sectors of the city. These differences are related not only to the urban density and the amount of vegetation, but also to the quality of the construction materials of the houses in the low-income sectors. Fire incidences were particularly high in the peri-urban areas near these sectors. The practice of burning garbage due to the lack of waste disposal, or burning vegetation for expanding the housing areas, has put a tremendous pressure on the remaining natural areas, and consequently the urban landscape is changing faster than the urban planning possibilities (Fig. 9). Drought and fires together increase the incidence of health and environmental problems, intensifying the air pollution and the incidence of respiratory diseases. These accelerated changes modify the quality of the urban climate, as more and more natural vegetation is lost with no replacement and the urban surface temperatures rise, increasing the urban heat island phenomenon across the city, mainly during the dry season. However, further research is necessary during the rainy season.

An important relationship between climate anomalies and climate variability was found too. In the presence of an intensive "El Niño" phenomena, and a global anomaly in the surface temperatures (more than 11 months of positive anomaly for ENSO variability and an increased 0.46°C in surface temperature reported by the WMO), an intensification of the dry season for the Caribbean area affecting the northern and coastal regions of Venezuela has been observed (CAF, 2000; Aguilar et al., 2005). These were the circumstances during 2003, when an intensification of the dry season impacted the city, causing a severe drought, critical conditions for water supply and high incidence of forest fires. These facts are calling attention to the necessity for the monitoring of climate variability (in this case of ENSO variability), and especially of the possible development of such mega events – as well as other socio-economical and environmental conditions in the city.

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Figure 9. Recent occupation process of surrounding natural areas in the city Caracas, 2009. ***Source: K. Cordova, personal collection, 2007.***

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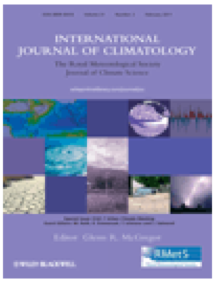
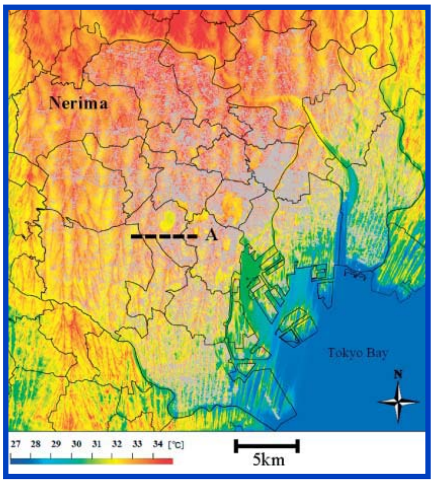
Special ICUC-7 journal issue showcases urban climate research



By Matthias Roth, Rohinton Emmanuel, Toshiaki Ichinose and Jennifer Salmond

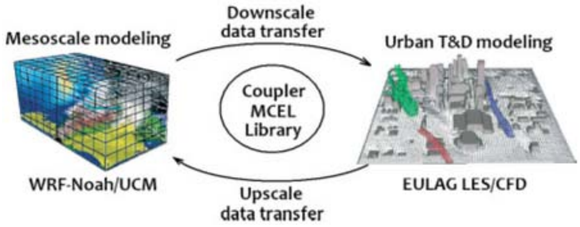
(Originally published in the February 2011 issue of International Journal of Climatology)

The world's population lives in an increasingly urbanized world. The current generation is the first where more people live in cities than in rural areas (United Nations, 2010). Much of the urban growth is taking place in Asia where the urban transition now underway involves a volume of population much larger than in any other region in the world and is taking place on a scale unprecedented in human history. Demographic projections show that by 2025, 16 of the world's 29 megacities (cities with more than 10 million people) will be located in Asia, many of which have very basic problems in terms of environmental quality (Asian Development Bank, 2008). Cities have a direct impact on the local climate and also impact and are affected by climate change in many ways and at many scales. The continued growth of urban populations means that most people experience weather and climate that is significantly different from that of undeveloped, natural areas. Cities also affect the regional and global climates through the emission of air pollutants and the consumption of about three-quarters of the world's energy, releasing vast quantities of the greenhouse gases (GHGs) that are thought to warm the planet. Cities further have an important role to play in mitigating climate change but at present, climate action often dismisses effective local (city-scale) actions in favor of international announcements and prospective efforts (e.g. in terms of cutting GHG emissions).



Our scientific understanding of urban climates has advanced substantially over the past two decades including improved conceptualization, field observations, analysis of processes and model building. A Special issue of the *International Journal of Climatology* has been put together to highlight some of the research currently being undertaken in urban climatology. The papers were selected from the wide range of cutting edge research in urban climate presented at the Seventh International Conference on Urban Climate (ICUC-7), held in Yokohama, Japan, from 29 June to 3 July 2009. This conference, organized by the International Association for Urban Climate (IAUC), is part of a series of similar urban climate conferences which first started in Kyoto, Japan, in 1989 and take place about every 3 years. ICUC conferences provide an international forum where the world's urban climatologists can meet to showcase their research and discuss modern developments in the application of climatic knowledge to the design of better cities. About 330 people from 36 countries attended ICUC-7. Two hundred and sixteen oral presentations were delivered and 222 posters exhibited, covering a spectrum of urban climate issues ranging from pollutant transport to human thermal perception as part of two streams of parallel sessions on physical processes in urban areas and applied urban climatology, respectively. Extended abstracts of the presentations can be found at http://www.ide.titech.ac.jp/~icuc7/extended_abstracts/index-web.html. The 12 papers included in this Special issue illustrate the diversity in research. Three of the papers were presented as invited plenary lectures by leading researchers (Fujibe, Ashie and Kono, and Sailor). The other nine papers were selected from the oral presentations as examples of contemporary urban climate research on urban measurements (Stewart, Frey et al., Pawlak et al.), modeling (Grimmond et al., Chen et al., Rasheed et al.) and application of urban climate data (Lin et al., Dousset et al., Thorsson et al.).

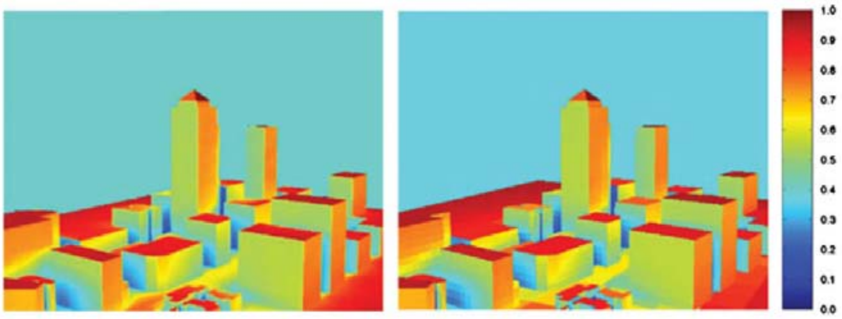
The first paper in this issue reviews urban warming studies in Japan (Fujibe, 2011). Analysis of data from a dense nation-wide monitoring network shows that recorded temperatures increase a few degrees per century. An urban bias is present in recent temperature trends which is not limited to large cities but can also be detected at less urbanized sites. The paper stresses the need for a careful assessment of temperature records used for the evaluation of warming trends and climate change. Ashie and Kono (2011) demonstrate the increasing capability of numerical models to predict small-scale urban processes covering entire cities. Wind and temperature fields are simulated with a CFD model using ~5 billion computational grid cells with a horizontal grid spacing of 5 m covering the 23 wards of Tokyo (Japan). The model is used to evaluate an urban redevelopment plan and illustrates the temperature mitigation potential of reducing the built-up area. Sailor (2011) provides a review of methods for estimating anthropogenic heat and moisture emissions in the urban environment and the associated anthropogenic impacts on the urban energy balance. The paper highlights some fundamental limitations of past approaches (e.g. most attempts focus on the sensible heat component thereby largely ignoring moisture emissions) and suggests a roadmap forward for including anthropogenic heat and moisture in modeling of the urban environment.



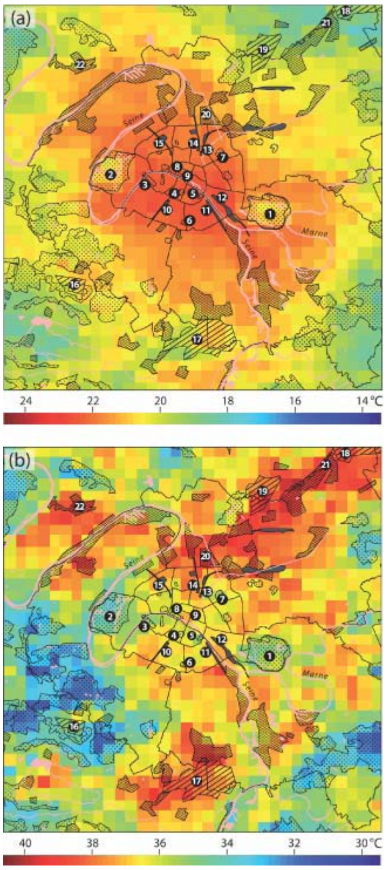
The three papers on observations discuss methodological issues and report in situ measurements of energy balance and carbon dioxide fluxes. A systematic review and scientific critique of heat island literature covering 190 studies from 1950–2007 by Stewart (2011) discouragingly concludes that nearly half of all urban heat island magnitudes reported in the sample do not meet the assessment criteria. Half of the studies fail to sufficiently control the confounding effects of weather, relief or time on the reported heat island magnitudes and three-quarters fail to communicate basic metadata. Frey et al. (2011) present rare in situ data of the urban energy balance for a hot and dry city (Cairo, Egypt). All key variables of the energy balance were measured using standard eddy covariance instrumentation in three typical microclimates: an urban, a suburban-agricultural, and a suburban-desert station. The purpose of these measurements was to measure ground-truth data for a remote sensing based energy balance study and the paper makes conclusions regarding the direct usage of the in situ flux data for input in models later applied to remote sensing data. Pawlak et al. (2011) present two years of continuous measurements of carbon dioxide fluxes carried out with the eddy covariance method in the densely built-up city centre of Łódź (Poland). The results show characteristic features in the diurnal and annual course of the carbon flux with generally positive fluxes which peak during the cold season, and have higher values during the day and during weekdays.

Recent advances in urban climate modeling are considered by three papers. Grimmond et al. (2011) report initial results from Phase 2 of the 'International Urban Energy Balance Comparison Project'. A systematic evaluation of 32 urban land surface schemes reveals wide variations in the performance of the models for individual fluxes and no individual model performs best for all fluxes. Grimmond et al. conclude that as many models do not perform well across all fluxes there is need for caution in their application and users should be aware of the implications for applications and decision making. Chen et al. (2011) provide an overview of the coupled WRF/urban modeling system as a community tool to address urban environmental issues. They discuss the daunting challenges of initializing the coupled model and of specifying the potentially vast number of parameters required for its execution. The ability of WRF/urban to capture urban heat islands, complex boundary-layer structures aloft, and urban plume transport and dispersion is demonstrated for several major metropolitan regions using recent applications. Rasheed et al. (2011) test the assumption shared by most urban parameterizations that a city is made up either of a regular array of parallelepipeds or of infinitely long canopies. The effects of complexity in urban geometry are investigated in relation to spatially averaged drag forces and shortwave radiation exchange. A new approach for fitting an array of cubes to any complex (realistic) geometry is subsequently suggested, so that new or existing urban parameterization schemes can be used with confidence.

Applications of urban climate research in the form of human thermal comfort and heat stress studies are represented by three papers. Lin et al. (2011) examine the effect of thermal adaptation on seasonal outdoor thermal comfort using 1644 interviews with concurrent micrometeorological measurements conducted outdoors in central Taiwan. The study confirms the effect of thermal adaptation on seasonal outdoor thermal comfort and demonstrates the limitation of thermal indices based exclusively on a heat-balance analysis of the human subjects in predicting their thermal preferences. Analysis reveals that people's thermal perceptions were strongly related to the air temperature and mean radiant temperature, but not significantly to wind speed and humidity. Dousset et al. (2011) present a study which documents the satellite monitoring of the August 2003 nine-day heat wave over the Paris metropolitan area. The thermal images show contrasting nighttime and daytime heat island patterns which are related to surface characteristics and land uses. The results confirm the influence of nocturnal temperatures on heat wave intensity, heat stress and excess mortality, and show the contribution of urban heat islands in intensifying the heat wave by absorbing heat during the day and progressively raising minimum nocturnal temperatures. The study reported by Thorsson et al. (2011) explores the influence of urban geometry on potential changes in outdoor thermal comfort due to climate change in a compact mid-rise high-latitude city (Gothenburg, Sweden). The results show that large intra-urban temporal variations exists for mean radiant temperature (T_{mrt}) as a result of urban geometry. Densely built structures are shown to mitigate extreme swings in T_{mrt}, improving outdoor comfort conditions both in summer and in winter. The relationship between the increase in daytime T_{mrt} and air temperature is found to be non-linear for their selected climate change scenario. The authors highlight the importance of including information on either T_{mrt} or thermal comfort in climate change scenarios to describe the combined effects of changes in multiple climate variables and to more realistically measure the impact on humans.



There is little doubt that urban climate issues will grow in significance in the coming decades. High quality, innovative research in urban climate is necessary to help mitigate against many of the most potent current environmental issues occurring in urban areas resulting from degradation of urban air quality and climate change. The papers included in this Special issue address some of the gaps in existing knowledge as identified below (from Grimmond et al., 2010):



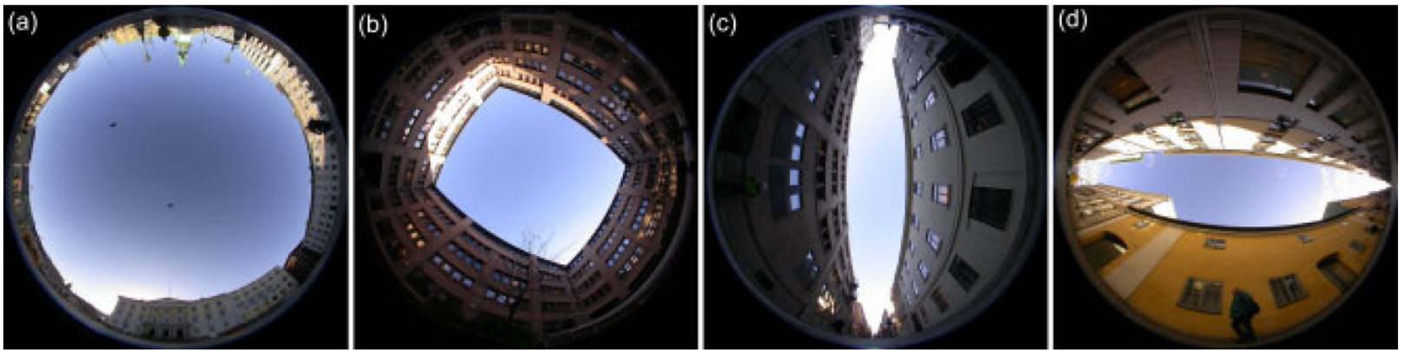
(i) Implications of global climate change for cities have not been adequately assessed to date. Potential impacts of global climate change on cities are not well known. More research on the interactions between global and urban climate change and the incorporation of urban land surface schemes into global climate models are needed (see Chen et al., 2011; Fujibe, 2011; Grimmond et al., 2010).

(ii) In terms of air pollution and health, there is a need to improve short-range, high-resolution numerical prediction of weather, air quality and chemical dispersion in the urban zone. There is also a need for model studies of wind and pollutant transport in complex urban geometries and those which include the combined effects of wind and buoyancy (see Ashie and Kono, 2011; Rasheed et al., 2011).

(iii) Urban climate information is not being translated effectively into the design and construction of more sustainable cities. Issues here concern communication between researchers with different backgrounds and between researchers and planners or architects. There is also a lack of tools to assist in climate-sensitive design (see Dousset et al., 2011; Lin et al., 2011; Thorssonet al., 2011).

(iv) The lack of appropriate data is a major obstacle in providing suitable urban climate information to address the various knowledge gaps. Operational urban measurement station and networks, especially in rapidly developing cities in hot climates and in their surroundings are needed. Vertical profiles of physical and chemical variables should be sampled and long term measurement stations should be preserved or established in cities with different urban morphologies to determine universal flow and flux characteristics (see Frey et al., 2011; Pawlak et al., 2011, Sailor, 2011; Stewart, 2011).

Despite the progress made so far more research is still needed to improve understanding to match that acquired for other environments. Many of these new findings will be presented at the next IAUC conference (ICUC-8) which



will be held in Dublin, Ireland from 6–12 August, 2012 (http://www.icuc8.org). The Guest Editors of this Special issue wish to thank the contributors, the reviewers and the publishers.

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Recent publications in Urban Climatology

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Crawford, B.; Grimmond, C. & Christen, A. (2011), Five years of carbon dioxide fluxes measurements in a highly vegetated suburban area, *Atmospheric Environment* **45**(4), 896--905.

Cândido, C.; d Dear, R. & Lamberts, R. (2011), Combined thermal acceptability and air movement assessments in a hot humid climate, *Building and Environment* **46**(1), 379-385.

After the departure of Corinne Frey, in the last edition we called for new volunteers motivated to join the Bibliographic Committee. We are fortunate to have three new members: **Anurag Kandya** from the Department of Civil Engineering of Nirma University (India), **Bruno Bueno** from the Department of architecture of the Massachusetts Institute of Technology (USA) and **Matthias Demuzere** from the Department of Earth & Environmental Sciences at the Catholic University of Leuven (Belgium).

In this edition you will find the compilation of papers published until February 2011. Thanks to everyone for their contribution. All readers are invited to send any peer-reviewed references published since April 1st 2011 for inclusion in the next newsletter and the online database. Please send your references to julia.hidalgo@ymail.com with a header "IAUC publications" and the following format: Author, Title, Journal, Volume, Pages, Dates, Keywords, Language, Url, and Abstract.

* * *

It is our great pleasure to announce that **the complete compilation done from 1996-2007 is now available in the bibliographic online database**. We have gone from 700 to 1800 publications and more than 4000 authors. I would like to thank the existing and new members of the Committee for the help in this task!

This first version still has some formatting deficiencies, some keywords or authors' names are duplicated but this will be improved little by little. Please, write us if you notice a mistake or an absence/lack in your references.

Happy reading,

Julia Hidalgo

Dou, H. & Zhao, X. (2011), Climate change and its human dimensions based on GIS and meteorological statistics in Pearl River Delta, Southern China, *Met. Apps* **18**(1), 111--122.

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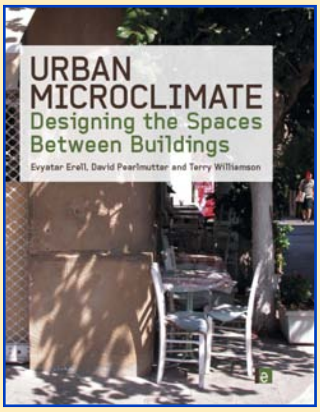
Vianna, N. A.; Gonçalves, D.; Brandão, F.; de Barros, R. P.;

Book Review

Urban Microclimate: Designing the Spaces Between Buildings. By Evyatar Erell, David Pearlmutter and Terry Williamson, Earthscan 266 p.



A number of years ago, a reporter asked me to explain to her the importance of green architecture. When I started talking about it from the meso-scale downwards, she started to get impatient. A few weeks ago, I was asked to assist in the design of Hong Kong's first zero energy building. I tried to enlighten the architect that we must start working on the problem from beyond the site boundary. He was puzzled and told me the client does not own the land outside the site. I have been thinking that if only I can hand them, and many others, a volume on urban microclimate, my job of explaining to them would be made easier.

Urban Microclimate by Evyatar Erell, David Pearlmutter and Terry Williamson may have provided an answer to my prayer. All architects should start reading Chapter 1 on *Scales of Climate Study* and start realizing that our buildings in the city are located amidst many others that provide the climatic context upon which we have to design.

The scientific basis of this understanding is explained in detail in the following three chapters. For architects in dense urban spaces in the tropics like Hong Kong, Chapter 4 on urban air flow is particularly important. I only hope that it can extend the understanding to include conditions of higher building height-to-street width and higher frontal area density. With the rapid densification of many large cities on earth, this will become more important.

We design our cities for human activities. Human thermal comfort is something that is very important to get right when one needs to function among all the man-made materials, surfaces and structures. Chapter 5 and 6 of the book have nicely introduce the understanding of how to do this.

For an architect like me, Chapter 7 onwards gets more relevant. However, it appears that the study is focused largely on the climatic type of Israel. Readers wishing for information on other climatic zones may need to refer to Baruch Givnoi's book *Climate Considerations in Building and Urban Design*, or David Lloyd Jones' volume *Architecture and the Environment*.

The chapter on vegetation nicely introduces to the designers that the building is not the end of a design. Trees and greeneries can significantly improve our living environment. It is after all very difficult to "design" an ugly tree.

Two case studies nicely conclude the book. I am particularly interested in reading the study on Clarke Quay. I was in Clark Quay a couple of times and can say that the canopy can make a difference. I am, however, not that sure about the water spray and water features due to the already high humidity of the environment. It is of interest to point out that the place is normally quite empty; most of the people still hide in their AC spaces. It only gets lively in the evening; as such, the Christmas tree effect of the canopy provides a bit of entertainment.

All good thing comes to an end. Just as I am beginning to enjoy it – the case studies in particular – I come to the back cover. I am sure while I am mumbling about it, the authors are busy writing their sequel with more case studies. I am looking forward to reading them – more than the next episode of Harry Potter.

Gerald Mills et. al. recently published a position paper in WMO's WCC3. The needs have been meticulously deliberated. I can see that with *Urban Microclimate* we are making progress.

Edward Ng

Professor , School of Architecture, Chinese University of Hong Kong

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Upcoming Conferences...

"URBAN CLIMATE, URBAN HEAT ISLAND & URBAN BIOMETEOROLOGY" at EGU General Assembly
Vienna, Austria • April 3-8, 2011
http://meetings.copernicus.org/egu2011/

"WEATHER, GEOGRAPHICAL CONTEXTS AND SPATIAL BEHAVIOUR" at Association of American Geographers (AAG) Annual Meeting
Seattle, WA, USA • April 12-16, 2011
http://www.aag.org/cs/annualmeeting

CITY WEATHERS: METEOROLOGY AND URBAN DESIGN 1950-2010
Manchester, UK • June 23-24, 2011
http://www.chstm.manchester.ac.uk/newsandevents/conferences/cityweathers/CFP-cityweathers.pdf

INTERNATIONAL WORKSHOP ON URBAN WEATHER AND CLIMATE: OBSERVATION AND MODELING
Beijing China • July 12-15, 2011
wksp@ium.cn

COHERENT FLOW STRUCTURES IN GEOPHYSICAL FLOWS AT EARTH'S SURFACE
Burnaby, British Columbia • August 3-5, 2011
http://www.sfu.ca/CoherentFlowStructures/

"URBANIZATION AND ITS IMPACTS ON TERRESTRIAL ECOSYSTEM" and "URBAN GREEN SPACES, HUMAN HEALTH AND ECO-ENVIRONMENT QUALITY," special symposia at the 8th International Association of Landscape Ecology (IALE) World Congress
Beijing China • August 18-23, 2011
http://www.iale2011.org

URBAN MORPHOLOGY AND THE POST-CARBON CITY: 18th International Seminar on Urban Form
Montréal, Canada • August 26- 29, 2011
http://www.isuf2011.com/

14TH INTERNATIONAL CONFERENCE ON HARMONISATION WITHIN ATMOSPHERIC DISPERSION MODELLING FOR REGULATORY PURPOSES
Kos Island, Greece • October 2-6, 2011
http://www.harmo.org/

WORLD RENEWABLE ENERGY ASIA REGIONAL CONGRESS AND EXHIBITION
Chongqing, China • October 28-31, 2011
http://www.wrenuk.co.uk/index.html

19TH INTERNATIONAL CONGRESS OF BIOMETEOROLOGY (ICB2011)
December 5-9, 2011, Auckland, New Zealand
http://www.icb2011.com

The 8th International Conference on Urban Climate will take place in Dublin (Ireland) in 16 months' time. An initial schedule is presented below and it is expected that the first call for papers will be issued at the end of July. The event is planned to accommodate 350-400 participants, of which perhaps a third will be graduate students. Based on previous ICUC events, we hope that the participants will be drawn from diverse academic and professional backgrounds and represent the international nature of urban climate research. The main sponsoring body is of course the IAUC but, on this occasion, the event is co-sponsored by the Board of the Urban Environment, a specialty group within the American Meteorological Society (AMS).

At this stage the basic framework for the event is in place. The meeting will take place on a university campus, which is three miles south of the city centre and is well served by public transport (including regular buses to Dublin Airport). Some accommodation on campus has been set aside and a special rate secured at nearby hotels. The facilities on campus that we will use are modern and consist of both large lecture theatres and small meeting rooms. In addition to the meeting itself, there will be a full programme of events for the evenings and a schedule of daytime events for partners.

At this stage the local organisers are beginning the process of obtaining sponsorship. In the coming months, more details will be presented through the pages of *Urban Climate News* and via the IAUC website. The conference website is www.icuc8.org and this will be regularly updated in the coming months. – *Gerald Mills*

Dublin, August 2012	
First call for papers	July 31
Second call for papers	October 31
Closing date for submission of abstracts	January 31
Abstract review by Scientific Committee	February 31
Extended abstract deadline	May 31
Early online registration	March 31 - May 1
Late registration	June 1 - July 15
Conference Website: www.icuc8.org	

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- Aude Lemonsu (CNRS/Meteo France), 2010-2014
- Silvana di Sabatino (Univ. of Salento, Italy), 2010-2014
- 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 June. Items to be considered for the upcoming issue should be received by **May 31, 2011** and may be sent to editor David Pearlmutter (davidp@bgu.ac.il) or to the relevant section editor:

News: Winston Chow (wtchow@asu.edu)
Conferences: Jamie Voogt (javoogt@uwo.ca)
Bibliography: Julia Hidalgo (julia.hidalgo@ymail.com)
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.