GD1: Surface UHI from satellite

Cities as urban clusters: an empirical and large sample study of urban heat island intensity

Diego Rybski[1], Bin Zhou[1], Jürgen P. Kropp[1,2]
[1]Potsdam Institute for Climate Impact Research (PIK), Germany; [2]University of Potsdam, Germany;
zhou@pik-potsdam.de

Defining cities as connected urban space from CORINE land cover data and their surroundings as equal-sized boundary, we calculate the urban heat island (UHI) intensity from MODIS land surface temperature data, i.e. the difference between the averages in the city and the boundary. The automatized method allows a systematic study of all urban agglomerations in Europe. We find a cross-sectional and time-variant dependence of the UHI intensity on the size. In addition, plotting the UHI intensity versus the background temperature, we identify a hystersis-like seasonality comprising higher intensities in spring than in fall. We explore the influence of parameters involved in the methodology and discuss the implications.

Directional analyses of UHI intensity over Delhi with respect to variations in vegetation cover in the National Capital Region of India

Krishan Kumar, Alok Pandey, Shivesh Berwal
Jawaharlal Nehru University, New Delhi, India, India;
krishan_khatri@yahoo.co.in

This study examines the variations in day time surface urban heat island (SUHI) over Delhi with respect to the regions situated north, south, east and west of Delhi in terms of the changing vegetation cover dynamics in these regions during the year. LISS III satellite data obtained at different times of the year, reveals that regions surrounding Delhi witness significant variations in vegetation cover during the year. This is primarily due to the fact that agriculture is the predominant land use in the regions surrounding Delhi. In the months of February and March, all the regions surrounding Delhi are covered with vegetation and show NDVI values >0.5. In contrast, it is mainly the region situated north-east of Delhi that has noticeable vegetation cover in the summer months of May and June. NDVI values in this region are higher than those observed for the regions situated south and west of Delhi. Further, day-time surface temperatures obtained from MODIS satellite data have been used to compute SUHI intensity over Delhi with respect to the regions surrounding Delhi. It is seen that SUHI intensity with respect to the regions situated north and east of Delhi (3-5 K), is higher than UHI with respect to the regions situated south and west (1-3K) in the month of March. In contrast, Delhi is found to have greater negative SUHI intensity (-5 to -8 K) with respect to the regions lying south and west as compared to SUHI (-1 to -4 K) with respect to the regions situated north and east in the month of May. Similarly, SUHI intensity of -2 to -5 K is observed with respect to the regions lying south and west as compared to SUHI intensity of 0 to -2 K with respect to the regions situated north and east in the month of November.

The Urban 'Oasis': High Resolution Landsat 5TM and ASTER Thermal Imagery Shows the Influence of Water Usage on City-Wide Temperatures in Dubbo, Australia

Nigel James Tapper[1,2], Devna Pankhania[1,2]
[1]School of Earth, Atmosphere and Environment, Monash University, Australia; [2]CRC for Water Sensitive Cities, Australia;
Nigel.Tapper@monash.edu

Vegetation and water availability in a hot-arid urban landscape plays a fundamental role in moderating temperature during periods of extremely hot weather, thereby also mitigating heat-stress related human health impacts. Vegetation provided with an almost unlimited supply of water through irrigation may also promote cooling beyond vegetation boundaries to form an urban 'oasis' at the city scale, via facilitated evaporative mechanisms. This study examines increased surface moisture availability, land surface temperature (LST) and landscape oasis effects in and around the extensively-irrigated rural town of Dubbo Australia, a city that is typically exposed to hot-arid summer climate. High-resolution thermal imagery from ASTER and Landsat 5 TM with spatial resolutions of 90 m and 120 m respectively, was used to retrieve LST for hot days (mostly >30°C). Bands in the red and near infrared range of the electromagnetic spectrum were also used to derive Normalized Difference Vegetation Index (NDVI) maps to classify the health and moisture status of various irrigated and non-irrigated vegetated land covers. A strong negative correlation between NDVI and LST was evident across areas of irrigated urban and rural vegetation on relatively hot-dry days, in comparison to non-irrigated rural vegetation. Additionally, city-scale 'oasis' effects were evident on 15 of the 20 days examined, whereby the surface cooling was up to 4°C compared to the 'untreated' rural landscape. Overall the effects were clearly a result of increased moisture availability, with the cooling disappearing when the entire (urban plus rural) landscape region was moistened by heavy rainfall.

Analysis of the impact of different temporal aggregation techniques of land surface temperature on SUHI indicators and the relationship of surface temperature with population density and night lighting.

Lech Gawuc, Joanna Struzewska
Warsaw University of Technology, Poland;
lech.gawuc@is.pw.edu.pl

Numerous researches in the field of urban climate prove that anthropogenic heat flux (AHF) it is one of the most important components of urban heat island (Sailor & Lu, 2004). AHF is connected with activity of cities' inhabitants, which spatial distribution can be indirectly described by, among others, population density and remotely-sensed night lights (Makar, 2006; Yang, 2014).

Since land surface temperature (LST) is influenced by synoptic conditions, it is widely practiced to use composite datasets for long-term analyses. Surface Urban Heat Island (SUHI - Voogt & Oke, 2003) studies commonly adopt temporally composited remote sensing data, what directly increases the clear sky coverage across urban and rural regions, which are beneficial to SUHI studies. However, most of SUHI studies did not consider the possible errors caused by composite processes (Hu et al., 2013).

Using MODIS (Moderate Resolution Imaging Spectroradiometer) land surface temperature data, we will present analyses of the influence of different temporal aggregation techniques on the urban LST patterns in the city of Warsaw, Poland. The study will be conducted for different seasons, for day and night cases. Also, we will discuss impact of different temporal aggregation techniques on values of several SUHI indicators (reviewed by Schwartz et al., 2011), and relationship between LST, night lights retrieved by DMSP OLI and NPP SUOMI VIIRS satellite instruments and population density.

An introduction to the WUDAPT project

Gerald Mills[1], Ching Jason[2], See Linda[3], Betchel Benjamin[4]
[1]UCD, Ireland; [2]UNC, US; [3]IIASA, Austria; [4]Univ of Hamburg, Germany;
gerald.mills@ucd.ie

There is a pressing need to gather detailed information on the cities of the world that can be used by the urban climate science community (UC) to design observations, run models, compare urban effects, design policy and transfer knowledge. Much of the recent progress in UC has come about by studying the links between aspects of urban form (such as street height to width ratio and impervious surface cover) and the climate outcome. However, in the absence of information on cities generally, this understanding is of limited practical value for addressing urban issues globally. WUDAPT has been conceived as a project for the acquisition, storage and dissemination of climate relevant data on the physical geographies of cities worldwide. The project takes a hierarchal approach to data gathering. At the lowest level (0), cities are decomposed into Local Climate Zones (LCZ), which are culturally neutral descriptions of neighbourhoods. Data at this level is derived using locally-based urban experts and satellite data. Once completed, the LCZ map is used as a sampling frame to gather more detailed (levels 1 and upwards) information on aspects of the form and functions of cities. The data that is gathered will be stored in a geographically referenced database and can be downloaded to support a variety of urban studies. The WUDAPT protocol will enable researchers to contribute to an international project of great relevance for addressing climate and climate change issues. This paper will outline the scope of WUDAPT and progress to this point. It will formally launch the WUDAPT project and invite colleagues to participate in creating a community database that will be of immense value.

CENSUS of Cities: LCZ Classification of Cities (Level 0): Workflow and Initial Results from Various Cities

Benjamin Bechtel[1], Mícheál Foley[2], Gerald Mills[2], Jason Ching[3], Linda See[4], Paul Alexander[5], Martin O'Connor[2], Taciana Albuquerque[6], Maria de Fatima Andrade[7], Maria Brovelli[8], Debashish Das[9], Cidalia Costa Fonte[10], Gwendall Petit[11], Uzma Hanif[12], Jose Jimenez[13], Stefan Lackner[14], Weibo Liu[15], Narein Perera[16], Nur Aulia Rosni[17], Nathalie Theeuwes[18], Tamás Gál[19]
[1]University of Hamburg, Germany; [2]University College Dublin, Ireland; [3]University of North Carolina, USA; [4]IIASA, Austria; [5]National University of Ireland Maynooth, Ireland; [6]Federal University of Minas Gerais, Brazil; [7]University of Sao Paulo, Brazil; [8]Politecnico de Milano, Italy; [9]Jadavpur University, India; [10]University of Coimbra, Portugal; [11]Institute for Research on Urban Sciences and Techniques, France; [12]Government College University Lahore, Pakistan; [13]National University of Colombia, Colombia; [14]University of Vienna, Austria; [15]University of Kansas, USA; [16]University of Moratuwa, Sri Lanka; [17]International Islamic University Malaysia, Malaysia; [18]Wageningen University, The Netherlands; [19]University of Szeged, Hungary;
benjamin.bechtel@uni-hamburg.de

In addition to recent progress in the delimitation of global high resolution urban land cover masks from multispectral optical and SAR imagery, the internal differentiation of urban structures and morphologies from the same data is still a challenging task. Further, the required level of detail and the boundaries between the classes depend on the application. In the urban climatology community the Local Climate Zones (LCZ) scheme has recently gained acceptance as a standard typology for the classification of local scale urban landscapes. The method was originally developed for meta-data communication of observational urban heat island studies, but meanwhile it has been successfully applied to mapping studies as well. An especially promising approach is based on multi-temporal multi-spectral and thermal remote sensing data and modern machine learning methods. Due to the culturally neutral nature of the LCZ scheme, the individual classes have different spectral properties in different parts of the world, which makes local training data unavoidable. Therefore, a universal, simple and objective LCZ mapping method based on free data and free software was designed. The method allows local experts to conduct and validate LCZ-classifications for their respective cities and thus contribute to the generation of the Level 0 product for the worldwide database on urban form and materials, WUDAPT.

In this paper we present conceptual considerations for the development of a common methodology to derive LCZ from remote sensing data. We discuss the appropriateness of LCZ mapping, the requirements, as well as limitations. Further, the results from an expert workshop in Dublin are presented where 16 cities in Africa, Asia Europe, as well as North and South America were classified by local experts according to the proposed method. The resulting LCZ atlas for the 16 cities is seen as a proof-of-concept as well as a major contribution to WUDAPT.

Generating WUDAPT's Specific Scale-dependent Urban Modeling and Activity Parameters: Collection of Level 1 and Level 2 Data

Linda See[1], Jason Ching[2], Valéry Masson[3], Johannes Feddema[4], Gerald Mills[5], Marina Neophytou[6], Mícheál Foley[5], Martin O'Connor[5], Christoph Perger[1], Martina Duerauer[1], Steffen Frtiz[1], Benjamin Bechtel[7]
[1]IIASA, Austria; [2]University of North Carolina, USA; [3]Météo France; [4]University of Kansas, USA; [5]University College Dublin, Ireland; [6]University of Cyprus, Cyprus; [7]University of Hamburg, Germany;
see@iiasa.ac.at

The LCZ framework provides a range of values for a number of different parameters needed as inputs to climate and weather models. These parameters are associated with different characterizations of urban land cover (eg. buildings, roads, other pervious surfaces), building and road geometry (e.g. building heights and footprints, canyon widths), building materials, and urban function and activity (e.g. temperature settings, presence of air conditioning). Level 1 and 2 data provide more refined estimates of these parameters at point locations, which can then be aggregated to the resolution of a particular climate or weather prediction model. For the collection of Level 1 data, LCZs can be used as a sampling frame to estimate average parameter values (with the variation) across different LCZs while Level 2 refers to wall-to-wall or more comprehensive data collection. This can either be collected systematically if there are sufficient resources or ancillary databases (e.g. building footprint files) can be used to extract some Level 2 data variables automatically. Different methods of data collection are proposed. For urban land cover, the Geo-Wiki crowdsourcing tool and Google Earth imagery are used for collection of the data. The results of initial experimentation with the collection of Level 2 urban land cover data for the city of Dublin is presented, in particular to determine the optimal sampling strategy for other cities, and to examine the tradeoffs between Level 1 and Level 2 data collection. Other data collection methods will be presented, e.g. use of Google StreetView for collection of data on building and road geometry and building materials, while data collection on the ground using mobile devices will be needed to complete the full suite of parameters. This paper will present the range of data collection options available, which will be at various stages of implementation.

Demonstrating the Added Value of WUDAPT for Urban Modelling

Johan Feddema[1], Gerald Mills[2], Jason Ching[3]
[1]Department of geography, University of Victoria, Victoria, CA; [2]UCD, Dublin Ireland; [3]Univ of North Carolina, US;
feddema@uvic.ca

There are a number of regional to global scale community-based modeling system for simulating urban climate and weather e.g., the Community Earth System Models (CESM) Community Land Model – Urban component (CLM-U), several Weather Research and Forecasting (WRF) urban components, the Town Energy balance Model (TEB), the Local Scale Meteorological Parameterization Scheme (LUMPS), and similarly configured community systems for air quality, e.g., the Community Multi-scale Air Quality (CMAQ) are powerful state-of-science based systems. These models provide a modeling framework to provide guidance towards meeting the challenges of population growth, climate changes, air quality, urban sustainability, livability, and human comfort confronting decision makers and society. WUDAPT is designed to provide the database infrastructure so these models can be applied to perform and provide urban climate simulations at from city to global scales. This presentation will provide examples of weather, climate, energy balance and air quality simulation results using the requisite gridded urban morphological data for a variety of cities and to illustrate their utility for providing policy relevant assessment and planning guidance.

The Portal Component, Strategic Perspectives and Review of Tactical plans for Full Implementation of WUDAPT

Jason K Ching[1], Gerald Mills[2], Linda See[3], Benjamin Bechtel[4], Johannes Feddema[5], Adel Hanna[1], Grega Milcinski[6], Valery Masson[7], Marina Neophytou[8], Iain Stewart[9], Xuemei Wang[10], Chandana Mitra[11]
[1]UNC, Institute for the Environment, United States of America; [2]City College of Dublin, Dublin, Ireland; [3]IIASA, Vienna, Austria; [4]University of Hamburg, Hamburg, Germany; [5]University of Kansas,United States of America; [6]Sinergise; [7]Meteo France, Toulouse, France; [8]University of Cyprus, Limmasol, Cyprus; [9]University of Toronto, Ontario, Canada; [10]University of Guangzhou, China; [11]Auburn University,United States of America;
jksching@gmail.com

Societal guidance, insights and assurances are needed in this period when the world is becoming increasingly more urbanized and confronted with life-impacting climate and pressing environmental issues. WUDAPT is engaged at this juncture, by its support toward facilitating the utilization of advanced science-based modeling tools towards the anticipated myriad of model applications requiring specialized data for all our current and planned urban centers on urban form and human activity. Recognizing that the science in models is rapidly advancing and embodied with increasing sophistication, WUDAPT, through its innovative data collection approach will both provide the requisite urban morphology and activity data, needed in short order, science consistent, fit-for-purpose and on a worldwide basis. Moreover, the Portal and the suite of tools are being designed to provide stakeholder communities with user friendly targeted capabilities to facilitate a host of urban applications. This presentation will describe unique features of this Portal and provide some example applications. Subsequently, we review and summarize the overall progress and outline detailed plans, describe our websites, opportunities for community involvement, country coordination, and next steps towards achieving the goal of a fully implemented WUDAPT

Comparison and integration of LCZ classification methods based remote sensing and GIS

Tamás Gál[1], Benjamin Bechtel[2], Enikő Lelovics[1], János Unger[1]
[1]University of Szeged, Hungary; [2]University of Hamburg, Germany;
tgal@geo.u-szeged.hu

The Local Climate Zone (LCZ) classification is an outstanding concept for the climate-related classification of urban areas in global scale. One of the most important advantages is the possibility to use these zones for the input of different climate or weather models in order to better represent urban areas. The use of this concept in these models is advantageous because this classification is based on the thermal characteristics of the urban areas, and it is connected to the most obvious alteration of the climate in urban areas, the urban heat island.
The LCZ system was initially designed for the classification of urban measurement sites, but meanwhile several methods for LCZ mapping have been proposed. The aim of this study is to present and compare two different LCZ mapping methods. The first approach is based on free multi-temporal remote sensing data and modern machine learning methods using classifiers like random forest (Bechtel-method). The entire workflow was implemented in the open source GIS SAGA. The second method is a GIS based automatic software tool (Lelovics-Gál-method). As an input it uses different parameters of the urban structure (like building height, sky view factor, fraction of buildings, vegetation, built up areas, albedo) acquired from different sources (e.g. satellite and aerial images, building databases, CORINE land cover dataset, road databases and maps). The basic elements of this GIS method are the building block and the lot area polygon around it. The approach consists of a fuzzy preliminary classification and a post-processing scheme. Initially, all lot area polygons are assigned to a most similar and a second most similar LCZ using the parameter ranges given by the LCZ fact sheets. Consequently, the polygons are aggregated to achieve at least the minimal size of 500 m x 500 m for a single LCZs using similarity rules.
The study area of this comparison is Szeged, Hungary, because in this city all of the needed input parameters are available for both methods. As a part of this comparison we analyze which are the most problematic built up types, and also we try to find the advantage of the methods.
Finally, we aim the integration of both approaches combining the respective advantages. Therefore, we conduct the initial classification using the Bechtel-method, since it needs only few and globally available input data. As the second step, the aggregation of the Lelovics-Gál-method was implemented in a JAVA tool, in order to create LCZs of sufficient size.

Applying "Local Climate Zone (LCZ)" into a High-density High-rise Cities - A Case Study in Hong Kong

Chao REN, Yingsheng ZHENG, Yuan SHI, Kevin LAU, Steve Yim, Justin HO, Edward Ng
The Chinese University of Hong Kong, Hong Kong S.A.R. (China);
renchao@cuhk.edu.hk

During the past few decades, the urban development's impact on urban climatic condition has been reported throughout the world. It is well recognized that site morphology and geometry can modify the local climatic condition and form its unique climatic characteristics. Thus, describing physical site properties in a scientific and precise way is important and necessary for urban climatic analysis and application into urban planning. Tim Oke initiated a scheme of urban climate zone (UCZ) in 2004 (Oke, 2004 & 2006) and later in 2009 Iain Stewart and him further developed a refined comprehensive approach of "local climate zone (LCZ)" classification by using a standardized and quantitative way to present physical surface properties of sites and their local climate features(Stewart & Oke,2009 & 2012).

LCZ classification has 17 standard types including two subsets: 10 built types and 7 land cover types. Each LCZ can be defined quantitatively by using a standard set of parameters. Some case studies have been conducted in cities of Sweden, Japan and Canada, which are located low density city. Unfortunately, there has been no study testing LCZ classification in high-dense cities. The study wishes to fill this knowledge gap by focusing on high density built-up types and land cover types of Hong Kong. Using field measurement, computational numerical simulations, information regarding the metadata and meteorological data could be collated.

First, this study will collect site metadata through the field visit study and up to 20 sites would be surveyed. The survey sample sites will take into account all parameters of LCZ including sky view factor, canyon aspect ratio, building surface fraction, impervious surface fraction, pervious surface fraction, surface admittance, surface albedo and anthropogenic heat flux. Secondly, an experimental study of defining the thermal source area by using thermal sensor and infrared cameras will be also conducted. Thirdly, the study will use both local and micro scale models to do the numerical simulations to capture the thermodynamic features and surface energetics of each survey site. Then, the collected data and simulation result will be analyzed and classified into 'LCZ' of Hong Kong. It would allow not only climatologists, but also planners and governors to gain insight into the "how much, where and what" questions of local climatic condition. The information would allow the formulation of urban planning guidelines and climatic spatial design strategies based on a set of threshold value of urban morphology and its climatic impact.

Evaluating the urban climate using geo-database – GEOCLIM TOOL

Anne Bernabé[1,3], Marjorie Musy[1,4], Isabelle Calmet[1,3], Erwan Bocher[1], Hervé Andrieu[1,2]
[1]Institut de Recherche en Sciences et Techniques de la Ville - FR CNRS 2488, France; [2]Institut français des sciences et technologies des transports, de l'aménagement et des réseaux; [3]Laboratoire de recherche en Hydrodynamique, Énergétique et Environnement Atmosphérique - UMR CNRS 6598, France; [4]Centre de recherche méthodologique d'architecture - UMR CNRS 1563, France;
marjorie.musy@ec-nantes.fr

How urban areas influence on microclimate is a primary concern to adapt city planning and to mitigate the impacts of the combination of the global warming and urban heat island. In this paper, we present a new urban climate model at district scale, GéoClim Tool, which takes into account energy transfers (radiation, conduction, storage, convection, and latent heat), envelope material behaviors and uses (anthropogenic loads). GéoClim Tool processing chain is implemented in the OrbisGIS geographic information system (Bocher et al. 2008) using SQL requests and the Groovy interface.

GéoClim Tool is developed using the geographical database BDTopo® produced by the French IGN. A pre-processing partitions urban territory in relevant elementary areas: the « city blocks » (Lesbegueries et al. 2009) which are defined from the road network to respect the spatial organization of the city and the building configurations. Although the present geo-databases can give some indications on façade materials properties, it is difficult to know the envelope composition or the building occupancy levels. To address these uncertainties different scenarios are proposed based on urban typology, year of construction and thermal regulation evolutions. After a morphological analysis at city block scale (Bernabé et al. 2014), a kmeans clustering technique (Forgy 1965) is used to identify seven types of urban blocks that can be found in most European cities.

GéoClim Tool is constituted of different computation sub-models. A simplified method based on morphological parameters has been developed to evaluate the solar trapping effect and to predict radiative balance of urban structure (Bernabé et al. 2014). A wall thermal model is developed for each surface classes (grounds, walls and roof). GéoClim Tool evaluates the heat budget of a building based on the assumption that it is a single box for each city block. It gives an average room-air temperature or the building energy demand. Energy balance is written at city block scale taking into account the interactions of each city block with its neighbors to obtain the air temperature, at middle height of buildings.

GéoClim Tool outputs are the different energy fluxes, surface and air temperatures and the energy consumption of buildings at city blocks scale. Those data can be observed hour by hour or integrated. Climatic indicators can be computed from model outputs to generate climate maps and help stakeholder to identify the city blocks that are the most vulnerable to urban heat island. To evaluate mitigating actions at city block scale of three cooling strategies are compared: surface albedo improvement, vegetation and water inputs.

Exploiting Earth Observation data products for mapping Local Climate Zones

Zina Mitraka[1], Nektarios Chrysoulakis[1], Jean Philippe Gastellu-Etchegorry[2], Fabio Del Frate[3]
[1]Foundation for Research and Technology – Hellas, Greece; [2]Centre d'Etude Spatiale de la Biosphère, France; [3]Geo-K s.r.l., Italy;
mitraka@iacm.forth.gr

Data collected by Earth Observation (EO) satellites provide a valuable source of information for understanding, monitoring, modelling and thus protecting the environment. The increasing availability of EO systems and the advances in remote sensing techniques increase the opportunities for monitoring the urban environment and its thermal behaviour. Several parameters related to the urban climate can be derived from EO data, providing valuable support for advanced urban studies and climate modelling. Recently, attention has been drawn to the quantitative description of the urban thermal patterns and their correlations to fundamental surface descriptors. Recently, a detailed classification scheme of Local Climate Zones (LCZ) was introduced, based on various former typologies, which explicitly defines urban landscapes according to their thermal properties. The scheme aims to be objective (incorporating measurable and testable features relevant to surface thermal climate), inclusive (sufficiently generic in its representation of local landscapes to not inherit regional or cultural biases) and standardized. The individual classes aim to have relatively homogeneous air temperature within the canopy layer and they are defined by fact sheets with both qualitative and quantitative properties, including several features that can be derived from EO data. In this study, advanced remote sensing techniques are applied and quantitative information required for discriminating between LCZ is derived. Parameters like the pervious and impervious surface fraction and the surface albedo were quantified for a case study (the city of Heraklion, Greece), using EO data. Combining ancillary information for the geometry of the city, parameters like the buildings density and mean building height, the canyon aspect ratio and the terrain roughness are estimated. Having estimated all those properties, a methodology was established to outline possible LCZ in the urban fabric with different thermal behaviour. Time series of land surface temperature estimates derived from satellite data are also employed to identify the thermal patterns and their correspondence to the LCZ.

Building Local Climate Zones basing on socio-economical and topographic vectorial databases

Christine PLUMEJEAUD-PERREAU, Cyril POITEVIN, Cecilia PIGNON-MUSSAUD, Nathalie LONG
UMR 7266 LIENSs, France;
christine.plumejeaud-perreau@univ-lr.fr

(Stewart and Oke, 2009) have acknowledged the need for a more accurate knowledge of ground description at micro-scale levels in order to improve consistency and accuracy in urban climate reporting. To address this, they propose to use Local Climate Zone (LCZ) as geographical objects allowing a finest description of landscape, whatever its nature, urban or rural. We agree that this could hence enhance a lot the understanding of Urban Heat Islands phenomenon, but we are also convinced that LCZ should include somehow the knowledge about citizens behaviour in their in-doors: do they open windows during winter? Do they use intensively air conditioners? This approach has been funded by the French National Agency for Research, in a project named MaPuce. One part of this project consists to automate the computing of urban morphological indicators as well as estimate households' behaviour at the micro-scale levels, in order to incorporate those quantitative data in urban micro-climate simulations. The project specifies that data sources should be available everywhere in France, for free, which is compatible with the goal of contributing to World Urban Databases.

In this proposal, we describe a methodology to automatically build LCZ knowledge from French databases available for free to research and academic domain, covering the national territory: topographic data are provided by the French National Agency, (IGN) and socio-economical datasets are downloaded from the French National Institute for Statistical and Economic Studies (INSEE). The originality of this task is to develop a vectorial approach using geometric shapes of the buildings, roads, vegetation and hydrographic objects, but also by using cadastral parcels to delimit new LCZ objects. It mixes various sources, in order to build an enriched and qualified dataset. However this task is difficult because of the various inconsistencies (buildings may overlap, intersect, or appear twice) in the sources. Furthermore, the income and education level, the age, and the size of the residents' households have to be downscaled at the LCZ level in order to be able to estimate household behavior for energy consumption.

We show in this contribution how this task can be achieved, using programs we have developed under open-source license, and we introduce a zonal object that implements the LCZ specification: the urban islet. It groups as set of buildings separated from each other's by roads or streets or rivers, grouping a set of contiguous cadastral parcels, and it allows for the automatic computing of an accurate topographic and socio-economic classification fitting the LCZ's one. A comparison with LCZ specification is made in order to check whether an islet answers fully the needs raised by LCZ (Stewart I. D. and Oke, T. R. 2012). The workflows automatically fixes geometric and topographic errors in sources, mixes them to build islets with their associated land use. In a second step, it computes automatically socio-economic proxies (like number of inhabitants, households, distribution of households income, etc.) at the building level in order to aggregate data at the LCZ level. We make a comparison with results that could have been obtained using a fine grid of 250m by 250 m. Finally, we show how this can be used in micro-urban simulation, feeding models like TEB (Town Energy Balance), (Masson, 2000). One of the perspectives of this work is also to enhance Energy-Climate assessment, by estimating energy consumption of households at this micro-scale level, and publishing this information for urban planning.

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Urban Heat Island Study using Local Climate Zones Classification: Nagpur City, India

Rajashree Shashikant Kotharkar[1], Meenal Mangesh Surawar[1], Nilesh Kishor Kulkarni[1], Anurag Kandya[2]
[1]Visvesvaraya National Institute of Technology, Nagpur, Maharashtra, India; [2]Indus Institute of Technology and Engineering, Ahmadabad, Gujarat, India;
rskotharkar@gmail.com

Several UHI and urban humidity studies were conducted in India during the 1970s and subsequent decades. Locations include the tropical wet/dry cities of Mumbai (Mukherjee and Daniel, 1976; Kumar et al.,) Calcutta (Padmanabhamurtty, 1986), Madras (Sundersingh, 1990/1991) and Visakhapatnam (Padamnabhamurty, 1986), and the subtropical dry cities Delhi (Padmanabhamurty and Bahl, 1982) and Pune (Padmanabhamurty, 1979; Deosthali, 2000). Sarkar H. (2004) investigated the UHI phenomenon by using remote sensing land-cover data and a GIS database management system for population density. The study revealed that urban heat islands have a direct relation with land cover and population growth in tropical cities.Rose et al. (2005) compared changing land use patterns of Chennai city with average climate conditions to identify the nature of UHI influences. They found that major factors contributing to UHI are changes in land use, street canyon geometry and thermal properties of urban and rural materials.

Badarinath et al. (2005) studied the urban heat island formation using satellite data and concluded that the temperature variations during day and night correlated well with density patterns of urban areas. Mohan et al. (2009) used surface meteorological observations, i.e., data extractions from mini weather stations and meteorological towers in Delhi during summer. It was observed that a much higher UHI effect occurred due to anthropogenic heat emissions. UHI pockets were found primarily in commercial areas, busy traffic intersections, and densely populated residential areas.

Ramachandra and Kumar (2010) reviewed the pattern of growth in Greater Bangalore and its impact on local climate using satellite-derived land surface temperature (LST) measurements. Mohan et al. (2011) studied annual and seasonal temperature trends for maximum, minimum and mean temperatures of the four meteorological stations in the National Capital Region (NCR) of India, namely Safdarjung, Palam, Gurgaon and Rohtak. It was observed that there was a trend in minimum temperatures while no specific trend in the maximum and mean temperatures existed. Increasing warming trends in the night-time temperatures reflect the contribution of changing land-use patterns and additional anthropogenic heat that may enhance UHI intensities in the city.

Most of the UHI studies in India focus on measurements of UHI intensity and the influence of land cover on urban thermal conditions. Though the role of urban morphology in modifying the urban heat island is an established fact, there have been very few studies exploring the relationship between urban morphology and urban climate in an Indian context.

Stewart and Oke (2012) suggested that Standardization of representation and classification of urban areas and their measurement sites was extremely critical for better applicability of urban heat island study. They developed Local Climatic Zone (LCZ) classification system for standardizing the method of study. LCZs are defined on the basis of surface structure, surface cover, type of material and human activity.

This paper investigates the relation between urban morphology and the heat island effect in the context of Indian cities using Local Climate Zone (LCZ) classification system as a spatial and analytical framework. Local Climatic Zones are mapped for Nagpur city using Google Earth and on site documentation. The UHI study is conducted using transverse surveys through specific LCZ types. Finally, air temperature observations are analysed in the context of LCZ types.

Relationship between land use and microclimate based on mobile transect measurements

Kathrin Häb[1], Ariane Middel[2], Benjamin L. Ruddell[3]
[1]Computer Graphics and HCI Group, University of Kaiserslautern, Germany; [2]Julie Ann Wrigley Global Institute of Sustainability, Arizona State University, USA; [3]The Polytechnic School, Arizona State University, USA;
kathrin.haeb@cs.uni-kl.de

Mobile transects are frequently used to collect high-resolution microclimate data along a predefined route. In an urban context, this technique advances the understanding of how urban structure and design affect the atmospheric environment. The relationship between land use/land cover and microclimate at the "human scale" corresponding to human body height and urban structure is dependent on a complex signal corresponding to the surface energy and water balance in the sensor's source area, with intra-canopy atmospheric dynamics integrating heterogeneous patterns.

Currently, source areas are frequently computed to facilitate the interpretation of flux tower measurements. For urban climate studies, utilized sensors in such campaigns are usually installed above the roof level, so that the urban area under investigation can be treated as a 2-dimensional surface with known turbulence and roughness characteristics. For microclimate measurements carried out within the urban canopy layer, however, source area estimation becomes theoretically challenging. Simple statistical techniques relating microclimate observations to surrounding land cover have not performed well, owing to issues of scale, observational accuracy, lack of diverse representative intra-canopy observations, and poorly characterized source areas.

This study utilizes high-resolution mobile intra-canopy transect observations in a residential area in Gilbert, Arizona. Observed mobile data are corrected for sensor lag. Various methods of source area estimation are evaluated in an attempt to establish the empirical limits of the explanatory power of this approach relating land use and microclimate. The performance of the approaches is assessed for multiple canopy structures, seasons, wind conditions, and times of day, with differing domains identified. Based on the findings, a statistical model can be constructed to extrapolate the data over a larger spatial domain.

Estimation of spatial air temperature distribution at sub-mesoclimatic scale using the Local Climate Zone scheme and mobile measurements

François Leconte[1,2,3], Julien Bouyer[1], Rémy Claverie[1], Mathieu Pétrissans[3]
[1]Territorial Division for the Eastern Regions, Cerema, Nancy (France); [2]French Environment and Energy Management Agency, Angers (France); [3]LERMAB, Lorraine University, Nancy (France);
francois.leconte@cerema.fr

Urban planners are strongly encouraged to include climatic information in the urban planning process. In order to tackle this issue, qualitative recommendations are already available. In the meantime, most of the existing numerical models require skills and knowledge in urban climatology in order to use them and to analyse their output. Therefore, decision-makers are looking forward to new accessible approaches that can evaluate quantitatively the climatic impact of different urban planning proposals [1].

The combination of a climatic zoning and mobile measurements offers numerous perspectives regarding the production of quantitative climatic data that can be managed by institutional stakeholders. This paper presents a methodology to create an Urban Heat Island (UHI) map for an entire conurbation based on mobile measurements performed in several neighborhoods [2]. This methodology has been applied on a middle size European city (Nancy, France). The Local Climate Zone (LCZ) [3] scheme has been used to organize the field campaigns and to build areas that are homogeneous in terms of thermal behavior and urban features. The LCZ thermal patterns have already been investigated through the study of the air temperature amplitude and microscale recurrent hotspots and coldspots [4].

The chosen methodology is divided into four steps. First, urban indicators regarding urban morphology and land use have been calculated, and LCZ have been built over the studied conurbation. Second, mobile measurements have been performed to survey the LCZ at high spatial resolution (three meters distance step). Two campaigns have been completed during summer 2012 and 2013. The screen-height temperature has been recorded during daytime and nighttime for a range of cloud cover and wind conditions. Third, the air temperature differences between the investigated LCZ has been presented as thermal maps. Average air temperature difference is about 4.4°C between LCZ type Compact Midrise and LCZ type Low Plants. Fourth, these temperature differences between LCZ types have been extended to many other LCZ of the conurbation. These maps give an overview of the spatial air temperature distribution at sub-mesoclimatic scale. They also allow to investigate the influence of the relative position of the LCZ within the conurbation on their thermal behavior.

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Determining the optimal size of local climate zones for spatial mapping in high-density cities

Kevin Ka-Lun Lau, Yuan Shi, Yingsheng Zheng, Chao Ren
School of Architecture, The Chinese University of Hong Kong, Hong Kong;
kevinlau20@gmail.com

The development of Local Climate Zones (LCZs) allows a quantitative classification of local surface characteristics with regard to their effect on local climate. The size of LCZs generally ranges from hundreds of metres to kilometres according to the homogeneity of surface characteristics. However, in high-density cities like Hong Kong, the surface environment varies considerably within short distances. In order to determine the optimal size of LCZs for spatial mapping in Hong Kong, a sensitivity test was conducted to compare the effect of the size on night-time air temperature (Ta) and relatively humidity (RH) in 14 study areas. Four grid sizes (500m, 400m, 300m, and 200m) were compared for their effect on the spatial average and standard deviation of Ta and RH. Ta and RH values are simulated for individual ground pixels using ENVI-met. Analysis of Variance (ANOVA) test is conducted to examine the effect of LCZ sizes and post-hoc Tukey's test is used to find significant different pairs. According to the ANOVA test, there are no significant differences (α=0.05) in the average of Ta and RH between the LCZ sizes. However, the effect of LCZ sizes is found to be significant in the standard deviation of Ta and RH, suggesting that there are differences in the homogeneity of surface characteristics. The post-hoc Tukey's test also shows that the 200m grid size is significantly different from the other three grid sizes. It was also found that the standard deviation of both Ta and RH decreases with the size of LCZs, suggesting an increasing homogeneity of the surface environment regarding its effect on local climate. Spatial maps of LCZs also show that the variations of surface characteristics within high- and medium-density areas are better captured at 200m resolution. The grid size determined in the present study will subsequently be used in spatial mapping of LCZs in Hong Kong. It also provides a basis for the development of potentially new LCZ classes which are specific to high-density urban environment.

A "Local Climate Zone" based approach to urban planning in Colombo, Sri Lanka

Narein Perera[1], Rohinton Emmanuel[2]
[1]University of Moratuwa, Sri Lanka; [2]Glasgow Caledonian University, UK;
nareinperera@gmail.com

Manipulating the urban fabric is fundamental to managing the warming trend in the growing high-density tropical settings to both mitigate the negative consequences as well as adapt cities to live with these changes. However, the current planning regime is yet to address the challenges posed by local, regional and global warming.

An in-depth understanding of the interaction between the physical form and the climatic context is crucial for the generation of climate sensitive urban planning approaches. However, data needs and methods of analysis remain problematic at present to achieve this.

In this paper, we showcase a simpler method of contextual analysis using the Local Climate Zone (LCZ) system in warm humid Colombo, Sri Lanka. Mean Radiant Temperature (MRT) – key variable in outdoor thermal comfort at street level – is linked to urban indicators encompassing geometric and surface cover characteristics in the LCZ classification, together with climate variables generated by the use of the microclimate simulation model ENVI-met. The simulations include a series of LCZ-based morphology options to reduce MRT in the urban outdoors at present and in a future warm scenario. Statistical analyses of the results test the applicability and sensitivity of urban morphological variables to help mitigate / adapt to local and global warming.

The work contributes towards a deeper understanding of the effect of building morphology on local level warming, with minimal data input. This could help develop climate-sensitive planning and policy in warm humid climates.

ESTIMATING ANTHROPOGENIC HEAT RELEASE FROM MEGACITIES

Iain Douglas Stewart, Chris Kennedy
University of Toronto, Canada;
iain.stewart@utoronto.ca

Anthropogenic heat and moisture release from cities is an important component of the urban energy balance, and contributes directly to the urban heat island effect in both the surface canopy and boundary layers. Estimates of anthropogenic heat release at local and meso scales have been reported in the climate literature for many midlatitude cities, but few tropical cities. Here we use a top-down inventory approach to estimate the sensible component of anthropogenic heat release at meso-scale for the world's 27 'megacities,' most of which are located in tropical and subtropical regions of Asia and Africa. In our estimates, we account for three major sectors of urban anthropogenic activity: vehicle fuel consumption; building and industrial energy use; and human metabolism. We source these data from the "Metabolism of Megacities" dataset housed at the University of Toronto. The anthropogenic estimates are spatially and temporally coarse, but provide the first baseline approximations of waste heat in low/middle income cities. We compare the heat emissions and their sector-based origins across all megacities for 2001 and 2010, and convey the influences of macroclimate, industrial activity, population density, and per capita energy use on sensible heat release from urban environments.

Development of fine-scale urban canopy parameters in Guangzhou city and its application in the WRF-Urban model

Xuemei Wang, Wei Dai
Sun Yat-sen University, China, People's Republic of;
eeswxm@mail.sysu.edu.cn

The fast urbanization in Guangzhou Metro area (with population more than 10 million) has significantly modified local and regional meteorological conditions. As one of the largest industrialized regions in China, Guangzhou has also experienced increased levels of air pollutants. However the current trend of population increase and urban expansion is expected to continue in the future. It is therefore imperative to understand and project effects of urbanization on weather, regional climate and air quality using regional models such as the Weather Research and Forecasting (WRF) model coupled to urban canopy models. However, fine-scale gridded urban canopy parameters (UCPs) are needed to drive the model but yet difficult to obtain in cities where the detailed urban morphological data do not exist. In this study, we developed a new approach to derive UCP database of Guangzhou from Google-earth imagery, which are freely available at high resolution (0.61 meter) and frequently updated. Two images at the same place with different view angles of buildings were used to identify the building span and height and to calculate urban morphology parameters (e.g., mean building height, building plan area fraction, building plan area density). Frontal area index was calculated under 8 wind directions with 45-degree intervals. The sky view factor was calculated with 32 slices number of 1-m resolution and no limit rang of extended distance. Special efforts were undertaken to ensure consistency between various datasets of UCPs, land-use and land-cover (LULC), urban fraction, and plan area fraction in WRF. Numerous high-resolution WRF numerical experiments were conducted using various sources of LULC and UCP data to reveal the impacts of new UCPs on regional weather and air quality.

GENIUS, a methodology to integer building scale data into urban microclimate and energy consumption modelling

Nathalie Tornay, Marion Bonhomme, Serge Faraut
LRA - Laboratoire Recherche en Architecture, France;
nathalie.tornay@toulouse.archi.fr

Accurate simulation of the city energy balance requires studying the thermal behaviour of buildings and therefore it requires knowing many details: at least the buildings geometries, their envelope materials and surroundings ground covering. For instance, information on the shape and location of a building are useful to assess the performance of solar panels; information on the materiality of the facades make it possible to estimate solar gains through the windows and therefore to perform building energy balance simulations; etc.

Consequently, several recent research works have been aiming to integer building scale data into urban scale simulations (microclimate, energy consumption of buildings at the city scale, energy production, etc.). Among those researches, we can quote the WUDAPT project (Ching, 2012) aiming to define a worldwide building database based on the LCZ classification of urban forms (Stewart & Oke, 2009).

The main issue in integrating this type of information to urban scale simulations is the lack of precision of the available data for buildings (Ching et al., 2009). If a limited number of buildings can be very precisely described (through existing Building Information Model (BIM) for instance (Ferries & Bonhomme, 2014), but also through historical studies or architectural inventories), the data at the city scale remains broadly heterogeneous.

In this paper, we will present how we used those localized descriptions of buildings to enrich existing urban database in the context of the MapUCE project (a French research program that aims to integrate quantitative data from urban microclimate, climate and energy in urban policies).

Our working method, called GENIUS (GENerator of Interactive Urban blockS), was to perform a literature review combined with interviews of urban planners to characterize a typology of urban forms in the whole French territory, and to associate it with a wide database. This typology structures the information according to four main themes: (1) type of urban form (pavilions, towers, etc.), (2) buildings use (housing, office building, etc.), (3) buildings location and (4) date of construction. For each combination of (1), (2), (3) and (4), our database provides information regarding: (a) building materiality (envelope materials for walls, roofs and windows), (b) buildings morphology (compactness, number of floors, etc.), (c) integration to the urban fabric (contiguity, alignment, size of plots, vegetation, etc.) and (d) technical features (heating, cooling and ventilation systems, shadings devices, etc.).

This database will allow refining the description of French cities in order to perform interdisciplinary and accurate simulations of energy use, renewable energy and urban microclimate.

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Comparison of modelled thermal comfort during a heatwave in Melbourne, Australia

Stephanie Jeanne Jacobs[1,2], Ailie Gallant[1,2], Nigel Tapper[1,2], Danijel Belusic[1,2]
[1]Monash University, Australia; [2]CRC for Water Sensitive Cities;
stephanie.jacobs@monash.edu

Heatwaves have the highest mortality rates out of any natural disasters and they are becoming hotter, longer and more frequent with global warming. We use a case study of the devastating heatwave that affected Melbourne, Australia in 2009 during which there was an unprecedented three days above 43C, 374 excess deaths and 714 cases of people being admitted to hospital due to heat related illness. We assess the ability of the Weather Research Forecasting model (WRF) to simulate the near-surface temperatures and human thermal comfort during this heatwave. We compare a regular non-urban parameterised WRF run, WRF coupled with an urban land surface model and WRF coupled to a high-resolution urban surface data set. These simulations are then analysed with respect to high-resolution observational meteorological data available for Melbourne. This comparison is a crucial first step to modelling the effectiveness of urban heat mitigation techniques with the aim of improving human thermal comfort, and hence, saving lives during future more extreme heatwaves. Melbourne serves as an example of the viability for the partial mitigation of heatwaves through intelligent urban design. The techniques generated during this study can then be applied to other cities, globally.

H2GIS a spatial database to feed urban climate issues

Erwan Bocher, Petit Gwendall, Nicolas Fortin
Atelier SIG, IRSTV FR CNRS 2488, France;
erwan.bocher@ec-nantes.fr

To understand the urban climate, predict the effect of urbanization or attend to improve the impact of some human activities, it is necessary to have a good understanding of the role of the urban surface. Indeed it has been demonstrated that surface forms affect urban microclimate (Givoni 1989, Oke 1981, 1988) and therefore changes the consumer behaviour of residents especially the building energy consumption (Santamouris, 2001, Ohashi et al., 2007).

The urban territory is continuously changing: high-rise buildings densification, new road infrastructures, increase of impervious surfaces, consumption of agricultural and natural areas… The result is new border, new shapes and new morphology for the urban geometries. In this context, monitoring urban changes became a challenge for urban planners and decision makers.

Geographical Information System (GIS) applications are increasingly being used to compute a set of indicators such as the Sky View Factor, the mean building height, the compactness ratio… All of theses indicators are used to study and monitor the urban structure (Long et al 2003, Bocher et al 2009). Besides, in the late 1990s, a large number of GIS-based tools have been developed by taking advantage of data organisation, spatial analysis and visualisation (eg. cartography). These three functions coincide with the focus of an indicator that needs to organize data, to quantify and to communicate.

If this diversity is valuable, on the other hand it can also act as a disincentive for the scientists and urban stakeholders communities. These tools are often build to answer a particular subject (mono-thematic approach). Moreover, most of them are based on proprietary softwares which limits their distribution, the possibility to examine their implementation (algorithm) since the main software is required to run the tool (black box) (Steiniger and Bocher, 2009, Steiniger and Hay, 2009). Last but not least, the definitions used to compute an indicator may differ according to the authors.

This situation is in sharp contrast with the needs of the scientific community to share results and experiences, and to experiment with new methods. Moreover, it is inconsistent with number of laws and regulations relating to the protection of the environment that promote common indicators.

To fill this gap, we propose a new open source spatial database, called H2GIS (http://www.h2gis.org/), to manipulate and process geographic and alphanumeric data (Gouge et al, 2014). H2GIS is a spatial extension of the Relational Database Management System (RDBMS) H2 Database Engine (http://www.h2database.com/) in the spirit of PostGIS (http://postgis.net/). It adds support for managing spatial features and operations on the new Geometry type of H2. H2GIS is fully compliant with the OGC's Simple Features for SQL (SFSQL) 1.2.1 standards (Herring 2010, 2011).

In this paper we show how the spatial RDBMS H2GIS should be an ideal framework to model the urban data (store and distinguish spatial relationships), create a generic set of spatial urban indicators and used them with massive data (scalable, multi-core processing).

As an illustration, H2GIS is used in the MApUCE project which aims to integrate in urban policies and most relevant legal documents quantitative data from urban microclimate, climate and energy. Based on literature review, we offer an open spatial analysis toolbox to study the urban surface.

Mapping high-resolution urban morphology for urban heat island studies and weather forecasting at intra-urban scale

J J Attema[1,2], R J Ronda[2], G J Steeneveld[2], B G Heusinkveld[2], A A M Holtslag[2]
[1]Netherlands eScience Center, The; [2]Wageningen University, Netherlands, The;
j.attema@esciencecenter.nl

As the urban climate and weather depend strongly on the details of the local environment, an accurate description of local environment is essential. For urban areas this includes morphological data on the built-up environment like building height, building density, and frontal area. However, also the amount of vegetation in the urban canyon is critical.

This study combines data from a variety of sources to create a high spatial resolution (~100m) collection of urban environment properties, representing the whole of the Netherlands in maps. The data sources include the Dutch cadastre and the Dutch statistical office (vector data) and height- and terrain maps, and aerial photographs (raster data). Combining this model with urban temperature time series, an urban heat island (UHI) climatology for the Netherlands on a neighbourhood scale is derived.

The climatological data is made available on an interactive website, assisting urban planners with assessing and mitigating adverse effects of extreme warm weather events. For instance, 15 percent of the elderly population (age 65 and above) is exposed to a large UHI (95th percentile surpasses 4.5K), potentially leading to health issues. The urban data collection can also be used to perform high-resolution weather forecasts with numerical weather prediction models, for example WRF.

Modeling the impact of future development pathways in Dublin on the urban energy and water balance

Paul John Alexander[1], Gerald Mills[2], Rowan Fealy[1]
[1]Irish Climate Analysis & Research Units, Maynooth University, Ireland; [2]School of Geography, Planning & Environmental Policy;
paul.alexander@nuim.ie

Like many European cities, Dublin has seen a decline in development for the past number of years owning to suppressed economic activities. However as documented in national and international news, there is now a significant housing crisis in Dublin as economic recovery begins to take hold and concentrate in the city. This has led to high demand for both housing and office space with virtually no new supply in the past 7 years. In turn, there is increased pressure for the Dublin local authorities to begin development of new residential and commercial units to ease the rising demand. In response to this the government of Ireland recently announced a €1.5 billion investment in direct provision for some 35,000 additional social housing units with development to begin as early as 2016. As with historic developments, this will likely have a significant impact on the near-surface atmosphere, depending on the final extent of sealed urban fabric. The pathways for future developments in Dublin have already been simulated using the MOLAND model in which four scenarios of building density are utilized broadly classified as "high" "medium" "low" and "business as usual development" (Brennan et al, 2009). However consideration has not yet been given to the impact each pathway will have on the thermo-hydrological characteristics of the city. Here, we undertake to simulate the impact each individual development pathway will have the on the urban surface energy and water balance of Dublin city. We employ the Surface Urban Energy and Water Balance Scheme (SUEWS) model to carry out our assessment of the impact on the urban energy (UEB) and urban water (UWB) balance. We model the period 2010-2012 in Dublin and evaluate our simulations against 3 urban flux observation platforms to ensure the modeled UEB and UWB are reasonable – the model is forced using climatically normal forcing data. We then developed Local Climate Zone maps for present day Dublin and for each development pathway scenario (2026) and, using this for land cover, model the diurnal, seasonal and annual energy and water budget for Dublin for each development scenarios. Subsequently we provide an assessment of the each development path on the UEB and UWB. Our primary aim was to aid local authority planners in pursing the development pathway which would have the least impact on canopy-layer climate while still achieving the required 35,000 units by 2026. Arising from our simulations, we provide guidance of the local scale development types that should be pursued to achieve both aims.

60 year variability in meteorological and environmental characteristics of the atmosphere in Moscow megalopolis

Natalia Chubarova[1], Olga Shilovtseva[1], Ekaterina Gorbarenko[1], Irina Eremina[1], Pavel Konstantinov[1], Elena Nezval'[1], Ekaterina Zhdanova[1], Andrei Skorokhod[2], Igor Belikov[2], Mikhail Sviridenkov[2]
[1]Faculty of Geography of Moscow State University Russian Federation; [2]A. M. Obukhov Institute of Atmospheric Physics RAS Moscow Russian Federation;
natalia.chubarova@gmail.com

We analyze the results of meteorological and air quality measurements over the 60-year period (1954–2013) at the Meteorological Observatory of Lomonosov Moscow State University (MSU MO) located in the megalopolis with more than 12 million population. A complex program of meteorological and radiadive observations as well as aerosol, air and precipitation quality measurements has been in operation there according to the guidelines and the standards established by WMO and Russian Hydromet Service.

The significant positive temperature trend (+0,041C/year over 1954–2013) was obtained, which has been increased up to +0,067C/year for 1976–2012. This trend is slightly larger than the rate of temperature increase in the Central Federal District (CFD) (0,059CS / year) and over the whole Russia (0,043C / year). In addition, a long-period variability in net radiation and particular, in long-wave net radiation over 1954-2013 demonstrated a dramatic increase in the last decades. We show the possible mechanism of larger temperature increase in Moscow compared with that in the Central Federal District which can be connected with the greenhouse effect of the urban atmosphere. This mechanism is in accordance with the observed tendency of increasing downwelling long-wave radiation during the last decades.

The long-term measurements of shortwave irradiance, natural illuminance, PAR and UV radiation demonstrate a pronounced decrease in the 1970s and the increase during the last decades due to changes in global scale circulation. The interannual changes in biologically active UV radiation are characterized, in addition, by the large influence of decreasing total ozone content since the end of 1980s. In 2011, for example, we observed the absolute maximum level in biologically active UV radiation (+11%) and especially high UV-B radiation in spring 2011, when the Arctic ozone hole spread over the Moscow district. We propose a method for evaluating the optimum UV level for human health. According to the estimates, in Moscow the UV optimum is observed from the middle of March to the end of April, and from the end of September to the middle October.

The analysis of chemical composition of precipitation and pH since 1980, shows a significant seasonal and inter-annual variability with large frequency of acid precipitation in 1980-1990s, its significant decline in 1999- 2004, and a noticeable increase - since 2005. These variations are accompanied by the change in chemical composition from sulphate to chloride dominating ions. The analysis has revealed the effects of local pollution of Moscow megalopolis and the significant role of de-icing salts in increasing the chloride ions concentration and the acidity of the precipitation.

Aerosol studies since 1955 demonstrate a pronounced negative trend in aerosol optical thickness (AOT) from 1990s. According to the AERONET measurements since 2001 in MSU MO the negative AOT trend is observed in the last decade as well. The trend is characterized by the substantial decrease in aerosol fine mode fraction. Long-term AERONET collocated measurements at the MSU MO and at the Zvenigorod Scientific Station of the IAP RAS, which is located in background conditions, have revealed the Moscow aerosol pollution effect of about 0.02 for AOT at 500 nm with the increase of up to 0.04 in winter time. According to RT modelling we show the consequences of this effect on solar radiation in different spectral regions. Column aerosol content as well as the surface concentrations of aerosol particles smaller than 2.5 microns (PM2.5) demonstrate a summer maximum due to the active processes of second aerosol generation. The analysis of daily average PM2.5 in Moscow shows that the excess of maximum allowable concentration was detected 4 times in 2011, 10 times - in 2012 and 31 times - in 2013. In comparison with other megalopolis areas of Eurasia and America a moderate level of gaseous air pollution in Moscow is observed. The worst air pollution provides by nitrogen oxides, which content is comparable to that in cities of the industrialized countries.

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The influence of wind advection on an urban heat island using the HiTemp network of sensors

Richard Bassett[1], Xiaoming Cai[1], Lee Chapman[1], John Thornes[1,2], Clare Heaviside[1,2]
[1]University of Birmingham, United Kingdom; [2]Public Health England;
rxb549@bham.ac.uk

A series of recent projects have examined the exact nature of the UHI in Birmingham using a variety of approaches. Whilst the magnitude and spatial aspect of the UHI has been quantified (approx. 6°C), there has been little notion to the dynamic nature of the UHI. It has been hypothesised through modelling that wind travelling across urban areas will transport heat downwind (Heaviside et al. 2014). A network of automatic weather stations (HiTemp) has been installed across Birmingham that commenced observations in January 2013. In conjunction with existing Met Office weather stations a total of 29 station datasets are available across a broad range of land use types for a period of 20 months. This data (filtered for night-time, low cloud cover and low wind speed) is used in this study to analyse the effects of wind advection on the spatial UHI pattern. Preliminary results using station pairs across the city show that mean temperatures on the downwind side to be up to 0.8°C warmer. Subsequent spatial interpolations (kriging) of the whole dataset shows a distinct UHI pattern linked directly to landuse. Using a methodology adapted from Heaviside et al. (2014), who decomposed a modelled UHI field into local and advected warming, a clear secondary signature is found whereby the downwind side of Birmingham is warmer than the mean and upwind cooler. The overall aim is to quantify heat advection contribution for different windspeeds and at different scales, i.e. neighbourhood to city.

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Urban heat island and inertial effects : analyse from field data to spatial analysis

Jérémy Bernard[2], Marjorie Musy[5], Isabelle Calmet[4], Erwan Bocher[3], Pascal Kéravec[1]
[1]L'UNAM, L'UNAM, CNRS, LHEEA/IRSTV, France; [2]L'UNAM, ENSA Nantes, CERMA/IRSTV , ADEME, France; [3]L'UNAM, EC Nantes, IRSTV, France; [4]L'UNAM, EC Nantes, LHEEA/IRSTV, France; [5]L'UNAM, ENSA Nantes, CERMA/IRSTV, France;
jeremy.bernard@cerma.archi.fr

The maximum urban heat island often occurs few hours after sunset. This may be explained by the thermal inertia of the urban canopy which is often much higher than that of rural sites. The cooling rate is an indicator of urban thermal inertia computed from on-site measurement but is mainly used to dissociate thermal behaviour difference between urban and rural sites. This paper proposes a new method to better dissociate the thermal inertia properties between urban sites from air temperature measurement.

The first part of our paper presents the method of computation, its results under different meteorological conditions which are then compared to the results obtained from the cooling rate calculation. Our method is based on the phase shift computation of temperature diurnal cycles between several urban stations and a reference rural station. Fifteen minutes data collected during four years from ten temperature stations are used. The stations network is located in Nantes, the 6th largest city of France with a total population in its metropolitan area of 590 000 inhabitants. The climate is western European oceanic and is characterized by a relatively mild summer. The phase shift was first calculated considering different meteorological situations. The results show that the sun radiation amount affects directly the phase shift difference values. The wind speed and direction also play a role on the results even if the influence is lower. In a second step, our indicator is compared to the average cooling rate after sunset, an usual indicator of thermal inertia. The results show that the phase shift better dissociates the stations than the cooling rate regarding to their thermal inertia properties.

In a second step, the phase shift results are analysed in relation with geographical indicators (facade density, vegetation density, etc.) calculated from BDTopo®. The reference surface for the spatial analysis is defined by concentric circles of different sizes around each measurement station. Results of linear regressions show that our new thermal inertia indicator is well correlated to geographical parameters ($R^2 > 0,5$ - e.g. for aspect ratio). These results can be used to identify high thermal inertia zones, where the urban heat island is expected to occur during night-time.

Investigating the Effect of Land Use/Land Cover on Urban Surface Temperature in Makurdi, Nigeria

Bernard Tarza Tyubee[1], Raymond R. C. Anyadike[2]
[1]Benue State University, Nigeria; [2]University of Nigeria, Nsukka, Nigeria; bentyubee@yahoo.com

The study utilizes remote sensing, in conjunction with geographic information system (GIS), to explore the effect of LULC change on land surface temperature (ST) over 15-year period in Makurdi, North central Nigeria. A total of twelve (12) Landsat TM/ETM+ images are acquired for April, June and January of 1991, 1996, 2001 and 2006 for the study. The Landsat TM/ETM+ images are analyzed using Integrated Land and Water Information System (ILWIS) 3.3, ERDAS Imagine 8.6 and ArcGIS 9.3 software. The Normalized Difference Vegetation Index (NDVI), Normalized Difference Wetness Index (NDWI) and Normalized Difference Built-up Index (NDBI) are used to represent the dominant land use/land cover (LULC) types in the study area. In order to investigate changes in areas of ST, ST is grouped into seven (7) classes namely 27oC-29oC, 29oC-33oC, 33oC-37oC, 37oC-41oC, 41oC-45oC, 45oC-48oC and 48oC-51oC respectively. The effect of NDVI, NDWI and NDBI on ST is investigated using pixel-by-pixel correlation analysis. The results show that areas of water, forest, undergrowth/wetland and cultivated land have decreased by 4km2, 37km2, 119km2 and 19km2 from 1991-2006. Conversely the area of built-up land has increased by 179km2 during the same period. The areas of ST classes above 33oC (below 33oC) have increased (declined) by 249.1km2 (249.1km2) from 1991 to 2006. The ST is negatively correlated with NDVI and NDWI but positively correlated with NDBI for all the months/seasons and years. The results suggest that change in land use/land cover, driven by urbanization, is the primary driver of surface and atmospheric temperatures in Makurdi.

Spatial Distribution of Urban Heat Island and Intra-urban Air Temperature Variability in High-density Urban Areas in Hong Kong

Yingsheng ZHENG, Yuan SHI, Chao REN, Hung Lam, Steve YIM, Yuk Fo, Derrick LAI, Ka Lun,Kevin LAU
The Chinese University of Hong Kong, Hong Kong S.A.R. (China);
zhengyingsheng@gmail.com

High level of urbanization in Hong Kong causes urban heat island effect (UHI), which is considered as one of the major urban climatic problems in recent years. Understanding the spatial distribution of UHI intensity as well as intra-urban air temperature differences is the basis of urban climatic planning for UHI mitigation. Many studies have investigated the impacts of urban surface properties and geographical characteristics on UHI intensity. However, given the unique urban morphology and complicated geographical environment in Hong Kong, the climatic conditions and UHI pattern at local scale exhibit greater diversity compared to other cities. Thus, there is a need to investigate the spatial pattern of UHI intensity, identify its relationships with urban morphological parameters, and propose planning strategies for UHI mitigation.

This paper firstly examines ten years of meteorological observations (2002- 2012) from Hong Kong Observatory (HKO) automatic weather stations (AWSs) to understand the diurnal urban heat island profile, and find out the linkages of urban heat island intensity with cloud amount and wind speed. Base on the data analysis, UHI intensities are found to be maximized during nighttime with calm wind and clear sky conditions. Secondly, this paper analyzes air temperature data captured by six mobile traverse measurements at street level (2.3m above ground) during calm and clear summer nights (8PM to 10PM) in 2014 to study the UHI intensity pattern over four high-density areas: Kowloon peninsula, north part of Hong Kong Island, Tuen Mun and Yuen Long. Thirdly, urban morphological parameters, such as building height, ground coverage ratio, sky view factor, aspect ratio, calculated using GIS are reported and compared with the traverse measurement data. The results indicate that, the compact high-rise commercial area Mong Kok (in Kowloon), Causeway Bay (in Hong Kong Island), Castle Peak Road (in Yuen Long) are the hotspot areas with higher UHI intensity of 3-5 °C. Intra-urban air temperature difference are identified to be 1.5-3.5 °C due to the variations in urban geometry and geographical conditions. Finally, the discussion part of this paper makes summaries about the spatial characteristics of nocturnal urban heat island effect as well as intra-urban air temperature differences, and also presents UHI mitigation strategies through optimization in land-use planning and building design.

Study of heat island phenomenon in andean colombian tropical city, case of study: manizales, Caldas -Colommbia

Dalia Nuith Roncancio Rubio, Fernando Mejia
Universidad Nacional de Colombia sede Manizales, Colombia; nuith9@gmail.com

The way the cities were built and their shapes, has effects on the incidence of solar radiation, remaining and heating the entire surface. Industrial activities also generate heat and emissions, which influence in the increased temperatures, changing the urban environment, favour the effect of a climatic phenomenon known as Urban Heat Island (UHI).

The Colombian cities, due to their topography, geographic ubication and anthropogenic activities can be affected for this phenomenon, making necessary and appropriate to develop studies of environmental urban temperature, to know the climatic dynamic and establish if exists or not the urban heat island in there.

In the case of Manizales ubicated in Caldas State, was developed UHI study, using the method of night thermal transects in 13 mobile stations, located at characteristic points of the city, used a pick-up truck in which, automatic mobile weather station Davis Instruments® was installed, belonging to the Environmental Studies Institute IDEA from National University of Colombia in Manizales headquarters.

The environmental temperature and wind speed data took at each point, making an altitude correction of sampled temperatures to develop thermal and wind speed maps. Also correlated these data with the temperature and wind speed of Environmental Studies Institute, IDEA network stations, although was calculated UHI intensity and temperature trend in the last eight years in the city.

The thermal maps, evidence that, environmental temperature of the city is concentrated in downtown of Manizales. The Pearson correlation between sampling temperature and wind speed data of network stations as well the UHI intensity and wind speed relation, was negative -0.119 and -0.114 respectively.

This indicates, the structural shape to the city of Manizales influence on the temperature rise in downtown, because there coincide with the commercial, the historical center, the political center (Caldas Office Governor and Mayor of Manizales), religious (Cathedral of Manizales) and Financial District, which influence in the high population density that goes around there daily and exerts a pressure on urban environmental factors, causing climatic environmental problems such as the heat island phenomenon.

The temperature trend in the last eight years has been the influence of the presence of El Niño phenomenon in 2010 and the La Niña in 2007, 2008 and 2009, years was affected by the phenomenon, produced invaluable economic damages in the Colombia Andean Region.

Key words: UHI, downtown, Temperature, wind speed.

Changing perspectives: Significance of long-term temperature observations in major cities

Alvin Varquez, Manabu Kanda
Tokyo Institute of Technology, Japan;
varquez.a.aa@m.titech.ac.jp

Filtering out observation data from weather stations located in urban areas is a common procedure when estimating global surface temperature trends; urban stations are claimed to have little contribution to the estimated trends for large grids (>100-km grid spacing). Observations at urban stations can be likened to noise in grid-estimated trends due to the rapid land surface changes in urban areas. The disregard of surface temperature trends in urban areas can cause society to underestimate the significance of their own local climate. This study aims to investigate the trend differences of surface temperature of weather stations and the larger grid to which it belongs. The Berkeley Earth Surface Temperature (BEST) gridded data, along with the quality controlled urban weather stations, were utilized. Stations within cities in Southeast Asia, East Asia, and the Middle East with available long-term observation records were selected. Trends of monthly values of the minimum temperature, maximum temperature and the average temperature were acquired from linear regression using least squares fitting. The period covered was from the 1960s to the present. Subtracting the trend of an urban weather station and its encompassing grid allows the estimation of the trend of urban heat island (UHI). Results show that surface temperature has been rising faster in urban areas than the grid-estimated surface temperature especially in Southeast and East Asian cities. Similar to global temperature trends, UHI trend estimated from minimum monthly temperature (minimum temperature twice than that of the grid-estimated values) was found to be larger than the UHI trend estimated from average and maximum monthly temperature. UHI trend estimated from maximum temperature was also found to be positive but much less than UHI trend estimated from minimum temperature. The differences in the trend of UHI per continent suggest that UHI depends not only on the rate and level of urbanization but also to the climate zone to which it belongs. Ranking the UHI trend estimates, East Asian cities such as in Japan and South Korea have slightly more rapid increase in UHI (>0.2 to 0.6 K/100 years) than Southeast Asian cities. Interestingly, observed long-term temperatures in Middle Eastern cities, which are mostly arid, revealed lesser or insignificant UHI trend. With the increase in urban-rural population ratio and GDP in developing countries of Southeast Asia, the trend in UHI can be a critical parameter aside from the trend of global surface temperature.

Exploring the Spatial and Temporal Variation of Air Temperature in the Extreme Desert Climate of Doha, Qatar

M Salim Ferwati[1], Yasuyo Makido[2], Vivek Shandas[2], David Sailor[2], Dylan BothamMyint[2]
[1]Qatar University, Qatar; [2]Portland State University, USA;
sferwati@qu.edu.qa

The question of mitigating extreme urban heat takes on a new dimension and challenge in a desert climate such as Doha, Qatar. Throughout much of the year the daytime air temperatures remain unbearable, limiting outdoor activities to late evening strolls along the Corniche waterfront promenade. Urban heat mitigation in such a climate will have little effect on the tolerability of daytime extreme temperatures, but may have the potential to increase accessibility to moderate outdoor conditions in the early morning and late evening hours. A first step in estimating the potential for mitigating heat in such an extreme desert climate is to understand the spatial and temporal variation of air temperature throughout the city. Once this understanding is in place, this knowledge can be combined with information on spatial variations in surface characteristics and activity patterns in an attempt to develop a predictive model that relates these physical characteristics to the corresponding variations in near-surface air temperatures.

To address this challenge we have established a network of rooftop weather stations distributed across the city. These stations have recorded conditions at 15 minute intervals since September 2014. These data have been combined with a spatially denser array of vehicle-based traverse measurements and available parcel-level land cover data to develop an initial assessment of the spatial and temporal variability of air temperature in this desert city and prospects for mitigation. The resulting analysis will provide insight into the role of local land cover in temperature variations across the city, leading to the development of specific recommendations for future development in the region.

Analysis of observed temperature trends over urban, town and rural areas of Pakistan

Sajjad Hussain SAJJAD[1,2], Nadège BLOND[1,2], Manon KOHLER[2], Alain CLAPPIER[1,2]
[1]University of Sargodha, Sargodha - PAKISTAN, Pakistan; [2]Laboratoire Image Ville et Environnement, Université de Strasbourg, France;
shsajjad@hotmail.com

The purpose of this work is to study the evolution of temperatures at several locations in Pakistan. A comparative quantification of the changes in temperatures on urban, town and rural areas of Pakistan has been done. For this purpose, daily mean (Tm) minimum (Tn) and maximum (Tx) temperatures data averaged on an annual, monthly and seasonal basis from 1950 to 2004 of 42 stations were obtained from Pakistan Meteorological Department (PMD). The data was homogenized by using Standard Normal Homogeneity Test (SNHT). The resulting homogenized data was analyzed by using least square linear regression for two different periods: 1950–1979 and 1980–2004. The analysis shows that the annual mean, minimum and maximum temperatures over Pakistan are increasing. The trends of annual mean, minimum and maximum temperature observed over urban, town and rural stations during 1980–2004 are significantly higher than the trends observed during 1950–1979. A higher growth in minimum and maximum temperature over urban and town areas is observed. The increase in minimum temperatures is more important on urban areas than on town areas, while the maximum temperatures increase more on town areas than on urban areas. The tendencies are less important in summer than other seasons of the year.

Spatial Geotechnologies and GIS tools for urban planners applied to the analysis of urban heat island. Case Caracas city, Venezuela.

KARENIA CORDOVA SAEZ
UNIVERSIDAD CENTRAL DE VENEZUELA, Venezuela, Bolivarian Republic of;
KARENIAC@GMAIL.COM

The city of Caracas, as many others Latin-American cities, has experimented a fast growth in the late 20 years, demographic pressures, and the lack of an appropriate urban planification, and others socio-economic problems, tend to reinforce the urbanization phenomena, that has transformed the environment, and the quality of life in these cities. Geospatial tools has provide an interesting perspective to understand the dynamics of these phenomena, the use of thermal band to measure the extension an intensity of urban heat island has been used combined with terrestrial observations, to explain the changes in the urban surface patterns. Combining radiometric, resampling and geometrics corrections techniques, and integrating this information into a GIS, it is possible to compare urban land use to urban surface temperature and identified urban heat critical areas, more accuracy. These works shows the result of the observations develops in the city of Caracas. The geospatial analysis was developed, using LANDSAT 7 ETM + images for the period of selected, ERDAS 11 for image processing, and Arc-Gis 10 for cartographic development. Geometric correction (pixel by pixel) with ERDAS, allow us to work at urban scales, in order to observe the variations in the urban canopy related to the urban surface temperatures patterns. Results of the study were useful to identify critical areas and urban structures related to these thermal patterns. This information will be use by urban planners, to develop mitigations and adaptation strategies, in order to prevent the intensification of the urban heat island, during the occurrence of an strong dry season, or heat waves, which might affect the city, the populations and the environment.

Key words: GIS, urban heat patterns, adaptation-mitigation strategies.

Fusion of World-view2 stereo and TerraSAR-X images for 3D building extraction in high-density urban areas

Yong Xu, Peifeng Ma, Hui Lin, Edward Ng
The Chinese University of Hong Kong, Hong Kong S.A.R. (China);
xuyong@cuhk.edu.hk

In this paper, we investigated the joint use of both a pair of high resolution WorldView-2 optical satellite images and the TerraSAR-X synthetic aperture radar satellite images, to extract 3D building information (including 2D building footprints and the third dimension building height) in high density urban areas. The main idea of the proposed fusion model is to take full advantage of both datasets for building extraction. Compared with SAR images, optical satellite images are more suitable for extracting building footprints, and can be applied to retrieve the heights of low buildings with higher accuracy. Whereas SAR images perform much better in retrieving the heights for tall buildings. But due to positioning errors and mutual interference of surrounding buildings, SAR images cannot be applied to retrieve the heights of low buildings efficiently. Therefore, in this study, both dataset are combined to generate 3D building product for high density urban area, where a large number of both tall and low buildings are included.

The proposed approach includes two main stages. Firstly, building footprints extraction. Optical satellite images are utilized to extract building footprints by using object-based analysis method, in which both building spectral, texture, contextual and elevation information are used. Secondly, building height retrieval. Initial heights of buildings are retrieved from both Stereo images and SAR images using photogrammetry and SAR interferometry techniques separately, then both initial results are combined with a novel object match based fusion method, in which heights of points for the same building footprint are retrieved and integrated. The proposed approach is especially suitable for building extraction in high-density urban area where single satellite data has certain limitations. Experimental tests on Mong Kok area of Hong Kong city showed that the proposed approach with both stereo images and SAR images can achieve a mean absolute height retrieval error of 6.8 m, superior to the results from stereo images or SAR images with a mean absolute error of 9.4 m and 12.4 m, respectively. Accuracy of the extracted 3D building product meet the requirement of urban climate simulation, which has also been verified in our urban climate model at different scales in Hong Kong study area.