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Demonstrating the Added Value of WUDAPT for Urban Climate Modelling

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1. Introduction

Over the last few decades, urban climate models have evolved significantly from standalone systems to simulate the climate of specific locations, to modeling systems that simulate urban climate, air quality and human energy consumption across widely different climate types and socio-economic conditions globally. Example modeling frameworks include regional and global scale community-based modeling systems such as the Community Earth System Models (CESM) Community Land Model (CLM) – 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 system models for air quality such as the Community Multi-scale Air Quality (CMAQ). Each of these models are powerful state-of-science based systems and they constitute 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. However, like many modeling systems, the quality of the model output is in part dependent on the availability and reliability of the data used to drive the models. As these models become more sophisticated, these input requirements are also becoming more detailed parameter settings require more information about the morphology and thermal properties of cities and their urban fabrics. Although some input requirements for model inputs can be provided through top-down systematic data collection with satellite platforms, many critical parameters are not as easy to collect as they depend on human decision-making and behaviors that cannot necessarily be observed remotely. For example, building materials can have widely different thermal and radiative properties and energy consumption by buildings is in large part dependent on choices of heating and cooling systems and the relative amount of use of these systems as controlled by thermostats or local access to energy resources. Since climate mitigation and adaptation schemes are heavily dependent of human energy consumption, these types of variables must be collected, not only to simulate urban climates in the present, but also to provide guidance for policy relevant assessment of human energy consumption and impacts on urban climates and air quality. The World Urban Database and Access Portal Tools (WUDAPT) data collection effort is designed to provide the type regionally specific and relevant information that can be used by a variety of different models to better represent regional urban characteristics and human behavior within these regions.

2. WUDAPT

Initiated at the ICUC8 meetings in Dublin, WUDAPT (Mills et al. 2015, Ching et al. 2015, See et al. 2015) is intended to provide a mechanism for collecting and characterizing urban information that can be directly related to urban climate model parameter needs at roughly the neighborhood scale for cities around the world. Initially modeled after the NUDAPT project (Ching et al. 2009), which characterized cities across the U.S.A., using high resolution LIDAR and other satellite data as a primary source. However, such information is not readily available in most other regions of the world, hence a different data gathering methodology has to be developed. To facilitate data collection, the problem can be subdivided into several steps. The first step is to identify geographical areas of cities that have similar morphology characteristics. Using a combination of satellite data, the Local Climate Zone (LCZ) urban classification scheme (Stewart and Oke, 2012) and local expert knowledge to relate the two, urban areas within a city can be classified into separate LCZ classes (Bechtel et al. 2015). Once the areas are defined, typical LCZ urban morphology attributes can be attributed to these urban regions, or where applicable the local experts can narrow the information down to reflect the unique attributes to specific city locations. The use of local experts also allows exploration of additional information about the LCZ regions. For example, beyond urban morphology the local expert can provide information about the most common building materials used and typical uses of buildings within a specific LCZ. This information can be translated into typical thermal and radiative properties representative of that particular setting. For example, if an area is comprised primarily of brick buildings, its heat capacity and insulation properties would differ greatly from a location where building are primarily made from wood or some other building material. Finally, local experts may also be able to provide information on typical human use of the building, for example by specifying the types of heating and cooling systems typically used in a location and potentially the human actions that control these systems. For example, an estimate of typical thermostat settings in representative buildings of an LCZ can help to simulate building energy consumption from the amount of heating or cooling that takes place in an area. This talk will focus on how WUDAPT can be used to refine existing urban climate simulation and how this data can be used to develop better future climate change scenarios.

2. Demonstrating the need for WUDAPT for climate modeling

While numerous models have been developed to simulate urban heat island and other aspects of urban climatology (Grimmond et al., 2010) parameterizing such models to best reflect actual surface characteristics is still lacking. WUDAPT is intended to fill that gap. To illustrate this need, Jackson et al. (2010), showed that improved representation of urban characteristic based on broad based generalizations can make significant differences in outcomes (Figure 1). In this simulation with the CESM CLMU model, there is a systematic difference in the model output simulation of urban heat island calculations when a single city set of parameters (Vancouver based on values from Voogt and Grimmond, 2000) is compared to the data from Jackson et al. (2010). Urban heat islands are significantly lower in the tropics when more representative data are used over 33 regions of the world (figure 1). The cause of the reduced heat island could be due to a number of factors, including the vegetative fraction in the urban fabric of cities, the morphology, and thermal and albedo values that characterize regional cities. While Jackson et al. (2010) was a first attempt to capture this information on a global scale, WUDAPT is an effort to greatly improve the quantity and quality of the data to characterize urban properties globally, with significant input from local experts.

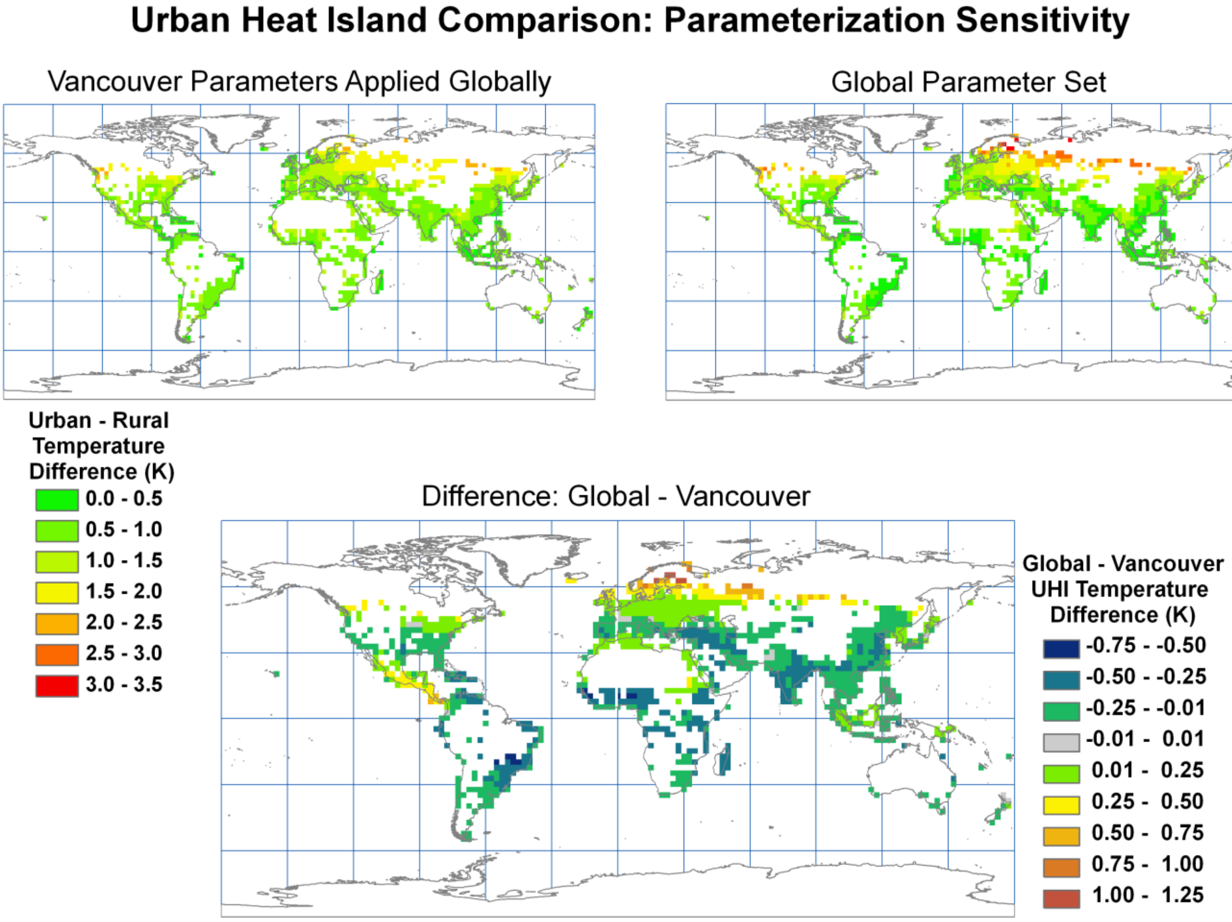

Figure 1: Urban heat island differences based on using Vancouver urban parameter settings from Voogt and Grimmond (2000) compared to Jackson et al (2010) regional parameter estimates (figure from Jackson et al. 2010)

Similarly, a study by Oleson et al. (2010) demonstrates the potential for models to assist with potential benefits and costs associated with policies to mitigate urban climate change. In Oleson et al. (2010), the Jackson et al (2010) data were modified so that roof areas were given much greater albedo values. This simulation was intended to test the assumption that introducing high albedo roofs (white roofs) on a global scale would effectively reduce energy consumption by decreasing energy demand. Results show that indeed most regions experience a marked reduction to their urban heat island temperatures. However, despite this marked impact on climate the experiment did not reduce energy consumption on a global scale in part because in cold regions the low albedo roofs led to an increased need for winter heating of buildings, and in part because relatively few regions have the economic resources to use air conditioning during warm periods, and thus on a global scale, energy gains from cool roofs are limited in geographic extent and the energy gains over these regions are offset by the increased energy needs in winter. Oleson et al. (2010) is a demonstration for how policy to alter urban characteristics can be tested for a broad range of climate types and regions, and how socioeconomic factors must be incorporated when performing such analyses. Such studies can be greatly improved if there are better base line data as WUDAPT is intended to do, and if there is improved knowledge of how urban climate policies are implemented in different regions; a process that can be made more realistic using WUDAPT data and information about local resources available for implementing urban climate mitigation and adaptation strategies.

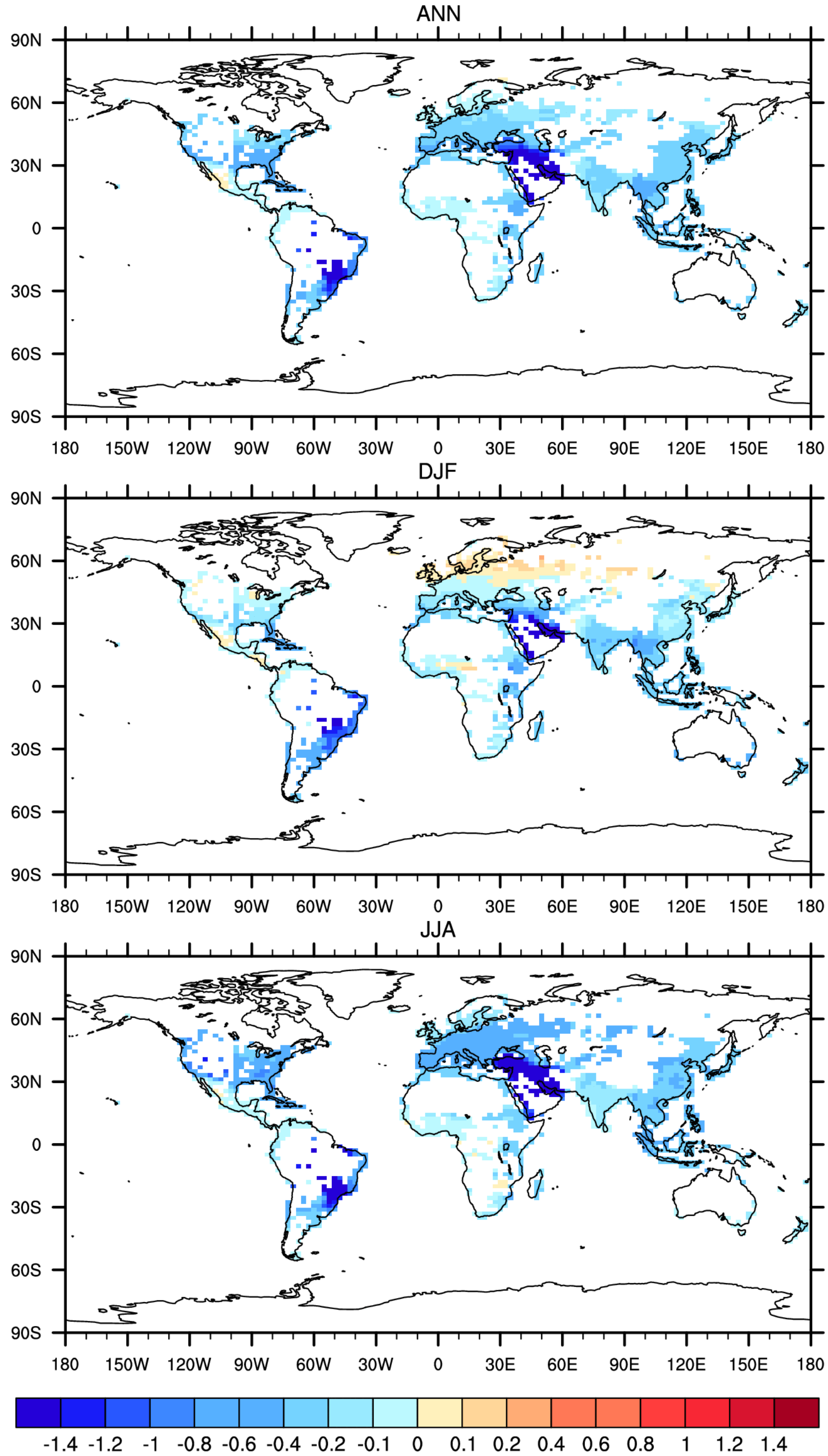

Figure 2: Simulated annual (ANN), June – August (JJA) and December- February (DJF) changes in urban heat island temperatures by increasing roof albedo globally (figure from Oleson et al. 2010)

2. Future research directions using WUDAPT

Development of the WUDAPT dataset should greatly improve the quality of existing urban input parameters (urban morphology and urban thermal and radiative properties) for climate modeling, and has the potential to introduce new parameters (e.g. parameters that include human decision making and behavior modification such as thermostat settings) that can be very useful for exploring how effective various climate policies might be to mitigate and adapt to climate change in urban environments across the globe. For example, by combining the structure of the Jackson et al. (2010) dataset with improved information about specific building components and their use in different regions it is now possible to simulate the impacts of exchanging different quality of building materials (represented as wall or roof types) and window types (e.g. single pane vs double pane) on urban heat island magnitudes and energy consumption across different climate types and under different socio-economic conditions (similar to the white roof sensitivity test performed in Oleson et al. 2010). In addition, because WUDAPT uses local expert knowledge in its development it is also possible to tap into that knowledge to better understand the likelihood of adaptation of different policy options in various regions thus providing a better insight to potential outcomes from a socio-economic perspective. While the focus of this study is on climate modeling, it is anticipated that WUDAPT will also further enhance the quality and utilization of other models throughout the world including meso to fine scale meteorological and air quality models for the myriad of urban focused applications e.g., assessing health risks from heat stresses and air pollution, for urban planning dealing with urbanization strategies to accommodate climate changes.

Acknowledgment

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