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# Urban Multi-scale Environmental Predictor (UMEP): An integrated tool for city-based climate services

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A B S T R A C T

UMEP (Urban Multi-scale Environmental Predictor), a city-based climate service tool, combines models and tools essential for climate simulations. Applications are presented to illustrate UMEP's potential in the identification of heat waves and cold waves; the impact of green infrastructure on runoff; the effects of buildings on human thermal stress; solar energy production; and the impact of human activities on heat emissions. UMEP has broad utility for applications related to outdoor thermal comfort, wind, urban energy consumption and climate change mitigation. It includes tools to enable users to input atmospheric and surface data from multiple sources, to characterise the urban environment, to prepare meteorological data for use in cities, to undertake simulations and consider scenarios, and to compare and visualise different combinations of climate indicators. An open-source tool, UMEP is designed to be easily updated as new data and tools are developed, and to be accessible to researchers, decision-makers and practitioners.



## 1. Introduction

Urban environments are particularly vulnerable to high impact weather given the high population densities in many cities and the associated assets and infrastructure (e.g. as evidenced by the impacts of Hurricane Sandy on New York City, Solecki, 2015). With weather extremes frequently exceeding climate records, and with urban areas growing rapidly, the ability to deliver city-based climate services to those operating and planning different aspects of city life (transport, energy demand, water supply etc.) is critical (Horton et al., 2016; Baklanov et al., 2017). A common toolbox, accessible to researchers, decision-makers and practitioners, offers great potential for better informed climate-related decisions in cities.

Scientists and practitioners from a broad range of disciplines including architecture (e.g. Ren et al., 2011), climatology (e.g. Eliasson, 2000), planning (e.g. Alcoforado et al., 2009), engineering and geography have long been interested in how weather and climate affects cities and their occupants (Baklanov et al., 2017). However, the development and adoption of city-based climate services, which require production, translation, transfer,

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communication, and use of climate knowledge and information for urban planning, building design and the operation of cities, is not straight-forward (Chrysoulakis et al., 2013; Grimmond et al., 2014; Masson et al., 2014; Baklanov et al., 2017). Appropriate input data (surface and atmospheric) can be challenging to access and specialist formats often make them inaccessible to many end-users (Grimmond, 2013). Communication between producers and users of climate services has been poor, with outputs often not easily interpretable by non-specialists. Tools that are more user-friendly, and are technically and economically accessible to users, are needed to improve communication across disciplines, researchers and users; to better identify user needs; to ensure common assumptions across models; to build capacity to address urban climate and weather concerns; and transfer research into practice. Past initiatives have tended to focus on specific processes (e.g. Herbert et al., 1998) or restricted spatial or temporal scales (e.g. Bruse and Fleer, 1998), with applications most often intended for specialist researchers. Many of these studies have focused on water and waste water management (e.g. Paton et al., 2014; Saagi et al., 2017) and not on integrated hydro-climatological models appropriate for application at multiple scales (neighbourhood to city) which account for feedbacks and complex interactions (for example the effect of water on heat exchanges as well as on flooding).

Here we introduce UMEP (Urban Multi-scale Environmental Predictor), an integrated tool for urban climatology and climate-sensitive planning applications. While elements of UMEP have been presented elsewhere (see further discussion below and summary in Table 1), this is the first full description of UMEP and its potential across a broad range of applications.

In its current form, the tool can be used for applications related to outdoor thermal comfort, urban energy consumption and climate change mitigation. UMEP consists of a coupled modelling system which combines state-of-the-art 1-D and 2-D models with systems to input data from multiple sources, formats and at different temporal and spatial scales, and to generate output as data, graphs and maps. An important feature of UMEP is its ability to couple relevant processes and to use common data across a range of applications. Here the basic structure of UMEP is described, followed by examples of applications to illustrate the potential of this tool.

## 2. UMEP overview

UMEP is being developed as a community, open-source tool to enable its use without restriction with respect to cost, license or rights issues. Users are encouraged to contribute to the tool to enhance and extend its capabilities. One of its major features is the ability for users to interact with spatial information to determine model parameters, and to edit, map and visualise inputs and results. For this reason, the software is written as a plug-in to QGIS, a cross-platform, free and open source desktop geographic information system (GIS) application (QGIS Development Team, 2017).

UMEP has three main elements (Fig. 1): *pre-processor* (for inputs of meteorological and surface information); *processor* (modelling system e.g. Urban Land Surface Models, ULSM); and *post-processor* (tools to analyse the outputs (individual case and ensemble, indicators of uncertainty, user applications *etc.*)). Each element is described briefly in Table 1, with more complete details presented in the online manual (http://www.urban-climate.net/umep/UMEP). UMEP allows users to: integrate atmospheric and surface data from multiple sources; take meteorological data measured at 'standard' sites and adapt them to be representative of the urban environment; use reanalysis or climate prediction data; and compare and visualise results or scenarios for different climate indicators of interest (heat indices, intense precipitation, water/energy demand). This all can be done at a range of spatial scales consistent with end-users' needs and interests (Table 1). To aid uptake and use of the model, and to develop capacity in urban modelling more generally, a series of tutorials have been developed (http://www.urban-climate.net/umep/UMEP_Manual#Tutorials).

One key contribution of UMEP is to facilitate the preparation of input data required for City-Based Climate Services (CBCS). UMEP provides both guidance and tools that enable the preparation and manipulation of data (Table 1). This is particularly important as most end-users are familiar with some, but not the full spectrum of, data needed for applications. For example, planners are knowledgeable about building heights, materials and their spatial arrangement (i.e. urban surface data) and often have GIS skills, but they may not necessarily have detailed knowledge of meteorological data. Equally, those knowledgeable of the latter may not be expert of the former. Although remotely sensed data may play a very useful part in CBCS, these data may require further processing to be applicable in urban areas. UMEP has been designed to enhance their integration. The tools within UMEP can also be used to provide data to export to other more complex weather, climate, hydrological, environment modelling systems. Alternatively, data from more complex models may be imported into UMEP.

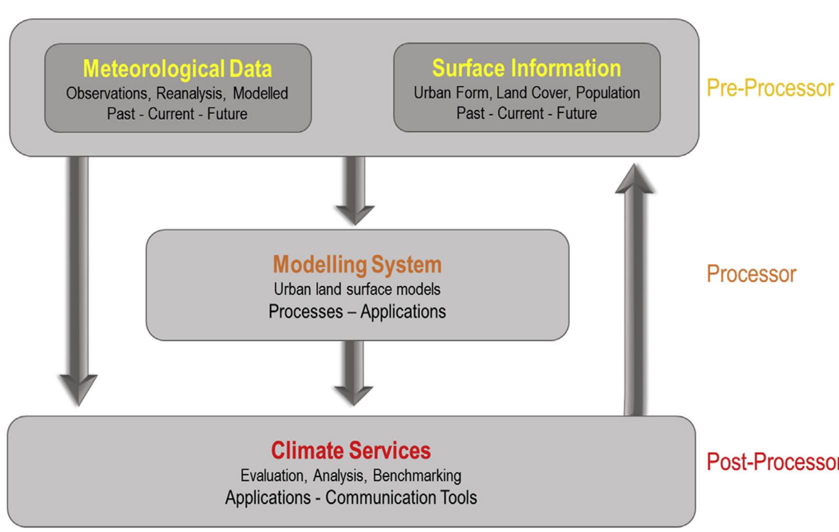


**Fig. 1.** Structure of UMEP (Urban Multi-scale Environmental Predictor).