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From urban meteorology, climate and environment research to integrated city services

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ABSTRACT

Accelerating growth of urban populations, especially in developing countries, has become a driving force of human development. Crowded cities are centres of creativity and economic progress, but polluted air, flooding and other climate impacts, means they also face major weather, climate and environment-related challenges. Increasingly dense, complex and interdependent urban systems leave cities vulnerable: a single extreme event can lead to a widespread breakdown of a city's infrastructure often through domino effects. The World Meteorological Organization (WMO) recognizes that rapid urbanization necessitates new types of services which make the best use of science and technology and considers the challenge of delivering these as one of the main priorities for the meteorological community. Such Integrated Urban Weather, Environment and Climate Services should assist cities in facing hazards such as storm surges, flooding, heat waves, and air pollution episodes, especially in changing climates. The aim is to build urban services that meet the special needs of cities through a combination of dense observation networks, high-resolution forecasts, multi-hazard early warning systems, and climate services for reducing emissions, that will enable the building of resilient, thriving sustainable cities that promote the Sustainable Development Goals. A number of recent international studies have been initiated to explore these issues. The paper provides a brief overview of recent WMO and collaborators research programs and activities in urban hydrometeorology, climate and air pollution; describes the novel concept of urban integrated weather, climate

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and environment related services; and highlights research needs for their realisation.

1. Introduction

Over the past few hundred years humans have clustered increasingly in large settlements, to the point where the urban population now exceeds the rural population. Concentrated on less than 3% of the Earth's land surface, this population is in settlements of greatly varying size. In 2009, 16% of the world's population lived in cities with more than 5 million inhabitants (UN, 2012). Cities depend heavily on infrastructure (e.g. transport systems - road, rail, pedestrian, bicycle, etc.), water and power supply, sanitation and drainage systems, communication networks, etc.), the complexity of which may add to the settlements' vulnerability in a non-linear manner with size (e.g., doubling city size may more (or less) than double the complexity and vulnerability).

Cities share many common characteristics, notably high population densities, making them more sensitive and vulnerable to weather/air quality/climate variations inducing/enhancing health impacts (e.g. epidemics, chronic respiratory diseases, heat stress, flooding etc.) and affecting economic activities (transportation, tourism, construction, school access, etc.). A single extreme event can through a domino of effects lead to a broad breakdown of a city's infrastructure (e.g., hurricanes Sandy in New York, Katrina in New Orleans; recent examples of air pollution in Beijing, Delhi, London, Paris etc.).

Increasingly is it recognised that current rapid urbanization necessitates new types of services to make the best use of science and technology. The New UN Urban Agenda, adopted by the 3rd UN Conference on Housing and Sustainable Urban Development in October 2016 (Habitat-III, 2016) considers urban resilience, climate and environment sustainability and disaster risk management (DRM) as key issues for urban sustainable development for the next 20 years. At the 17th World Meteorological Congress in June 2015 (Resolution 68, see WMC-17, 2015), the WMO emphasized such Integrated Urban Weather, Environment and Climate Services (Grimmond et al., 2014a, 2014b; Baklanov et al., 2016) should assist cities in facing hazards such as storm surges, flooding, heat waves, and air pollution episodes, especially in changing climates.

The objective of this paper is to provide a brief overview of recent WMO and collaborators research programs and activities in urban hydrometeorology, climate and air pollution, presenting the emerging concept of urban integrated weather, climate and environment related services, and research needs for their realisation at scales both within and beyond the city.

2. Urban Research Meteorology & Environment (GURME) and High Impact Weather (HIW) projects

Cities affect weather and climate at local, regional and global scales through two main mechanisms. Firstly, urban features such as the morphology of buildings and heat emissions influence local temperatures, air circulation and alter the formation of precipitation and the frequency and intensity of thunderstorms. Secondly, changing chemical emissions and feedbacks with atmospheric pollutants affect weather and climate, both locally and further afield.

Many features in cities can influence atmospheric flow, its turbulence regime, and the microclimate, and thus can modify the transport, dispersion, and deposition of atmospheric pollutants both within and downstream of urban areas (one form of which is acid rain). As described by Baklanov et al. (2007) and Cleugh and Grimmond (2012), key examples include: (i) distribution of buildings, and other obstacles (or more generally of all roughness elements), affects the turbulence regime, speed and direction of the flow; (ii) extensive use of impervious materials and the common reduction of vegetation in urban areas affects the hydrometeorological regime and pollutant deposition; (iii) release of anthropogenic heat by human activities (transportation; building heating/cooling) affects the thermal

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