Current and Emerging Perspectives on Urban Precipitation and Flooding

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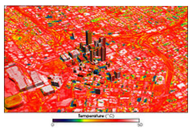
Background

Urbanization is the "other" Anthropogenic climate change as noted by Seto and Shepherd (2009) (table to the right)

Table 1

Various pathways for urbanization to impact the climate system (see text for references)

	Urban land-cover	Urban aerosols	Anthropogenic greenhouse gas (GHG) emissions
Urban heat island and mean surface temperature record	Surface energy budget	Insolation, direct aerosol effect	Radiative warming and feedbacks
Wind flow and turbulence	Surface energy budget, urban morphological parameters, mechanical turbulence, bifurcated flow	Direct and indirect aerosol effects and related dynamic/ thermodynamic response	Radiative warming and feedbacks
Clouds and precipitation	Surface energy budget, UHI-destabilization, UHI meso-circulations, UHI-induced convergence zones	Aerosol indirect effects on cloud-precipitation microphysics, insolation effects	Radiative warming and feedbacks
Land surface hydrology	Surface runoff, reduced infiltration, less evapotranspiration	Aerosol indirect effects on cloud-microphysical and precipitation processes	Radiative warming and feedbacks
Carbon cycle	Replacement of high net primary productivity (NPP) land with impervious surface	Black carbon aerosols	Radiative warming and feedbacks, fluxes of carbon dioxide
Nitrogen cycle	Combustion, fertilization, sewage release, and runoff	Acid rain, nitrates	Radiative warming and feedback, NOx emissions



There is renewed debate on how the urban environment affects *precipitation variability (IPCC 2007, chapter 3)*. Shepherd et al. (2011) and Shepherd (2005) reviewed the literature documenting current and historical findings (e.g. pre-2005) related to urban effects on precipitation and possible mechanisms.

The urban influence on rainfall (hereafter Urban Rainfall Effect or URE is caused by one or a combination of four factors:

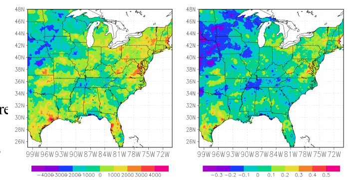
1. Enhanced thermal mixing due to Urban Heat Island (UHI)
2. Increased turbulence and mechanical mixing due to increased aerodynamic roughness created by tall buildings
3. Increased concentrations of cloud condensation nuclei (CCN) from automobiles and industry
4. Splitting of Storms

Global Evidence of Urban-Influenced Precipitation Variability

Satellite analysis is well-suited as much of the urban land cover growth and pollution is in developing nations without robust ground observations. Studies confirm urban influences around the world.

Research Objectives (2010-2013 Period)

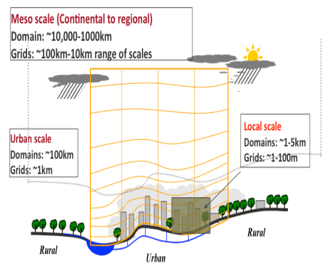
1. Spatio-temporal climatological analysis of precipitation variability as a function of urbanization: Leveraging the lengthening satellite precipitation record



(1) How will different topographical, meteorological geographical, and anthropogenic activities influence the relative roles of urban land cover and aerosols on precipitation processes and can we quantify such relative contributions?

(2) What highly urbanized geographic regions are more likely to exhibit an urban signature in spatio-temporal precipitation variability and can such attributes be integrated into a Geographic Information System for scientific and stakeholder applications?

(3) Can we develop conceptual models or "rules of thumb" to depict favorable conditions for urban land cover, aerosols, or their combination to initiate or modify precipitation?



2. Investigating urban land cover vegetation-evaporation-aerosols feedbacks (U-VEAF) and their role in precipitation formation at convective to regional scales

(1) What role do urban morphological parameters, aerosol, and vegetation and moisture play in precipitation formation, budgets and efficiency?

(2) Can a coupled modeling system with proper characterization of land cover, aerosols, irrigation, and urban canopy simulate such recycling processes?

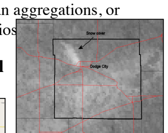
(3) How do U-VEAF processes scale to affect regional climate, large urban aggregations, or future urban growth scenarios?

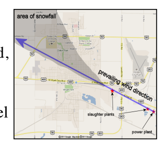
3. Urban effects on frozen precipitation processes and snowfall retrieval

(1) How do urban aerosols and urban heat islands affect snowfall/precipitation formation and melt?

(2) How do urban aerosols affect snow melt on the ground, and are their implications for snowfall retrieval in the GPM era?

(3) Can coupled land surface model and atmosphere model well simulate urban effects on snowfall/snowmelt and where might they be deficient?





NWS Dodge City Area recently documented localized "downwind" snow attributed to Animal Slaughter Houses and Power Plants

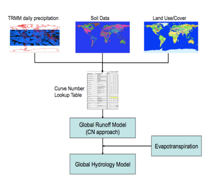
http://www.crh.noaa.gov/news/display_cmsstory.php?wfo=ddc&storyid=62980&source=0

4. Coupling urban rainfall effects with hydrological processes

(1) What is the uncertainty of satellite-based rainfall data in urban areas compared to adjacent non-urban areas and how does it translate to uncertainty of global flood simulation results?

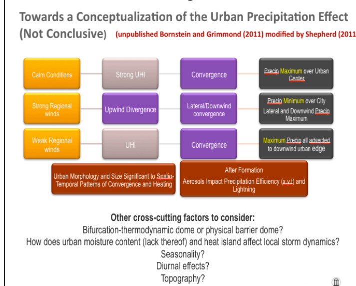
(2) What is the most computational efficient and accurate method(s) to incorporate urbanization effects and TRMM-GPM era rainfall estimates into global hydrology and flood models?

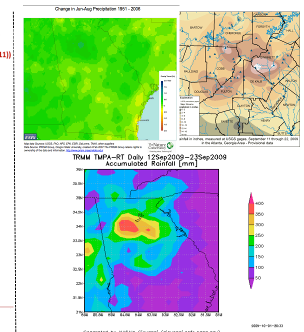
(3) What are the urbanization effects on water cycle at the river basin scale for global assessment of urbanization and how do we properly quantify them?



• Thanks to Ramesh Kakar and NASA/PMM for funding our research

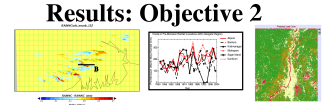
Results: Objective 1





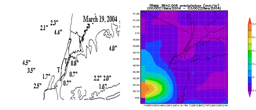
PMM funding is leading to basic understanding (left). We continue to see spatio-temporal evidence of enhanced precipitation in long-term analysis (top) and extreme events like the Atlanta Floods of 2009 (Shepherd et al. 2011).

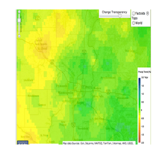
Results: Objective 2



WRF simulations suggests that trends in urban rainfall (top) in Pre-monsoon Kolkata could be linked to urban – Norwestor interactions.

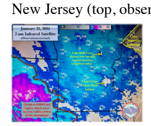
Results: Objective 3



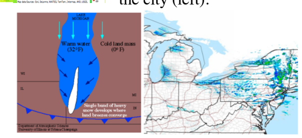


Preliminary analysis from 1951-2006 of Winter (Dec-Feb) Precipitation around Minneapolis, Minnesota suggests that amounts have trended upward downwind of the city (left).

March 19, 2004 2 to 6 inches of snow fell in areas surrounding New York City, while only trace amounts were reported in Manhattan and urban New Jersey (top, observations and TRMM MPA)

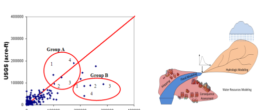


UHI in NYC may have eroded snow cover in the city.



We are exploring a hypothesis that cities may exhibit a "lake effect" snow type forcing mechanism (above)

We are also investigating how urban effects modified snow cover. Implications for snow retrieval algorithms in the GMP era. The figure (above shows how distinctive urban environments within a cold, snowy environment from a space perspective.



Results: Objective 4

Our (Han et al. 2010) preliminary results have shown significant runoff volume differences between a global runoff model driven by TRMM MPA and observations for urbanized river basins. Possible factors to consider that we've identified are seasonal changes in urban vegetation, the impact of slope, and the effect of drainage and flood control infrastructure; (top)-a graphic of Houston where Group B are selected flood scale events that we're overpredicted by the global runoff model – the common tie among these events was the location of the event upstream of city, a large fraction of which was likely captured by flood control facilities not represented in the model. With these successful results we've begun to test the use of TRMM data products in a regional flood forecasting and planning system we developed for the National Infrastructure Simulation and Analysis Center for simulating hurricane and other types of regional flood events.