



Urban Effect on Precipitation – A Case Study over Houston

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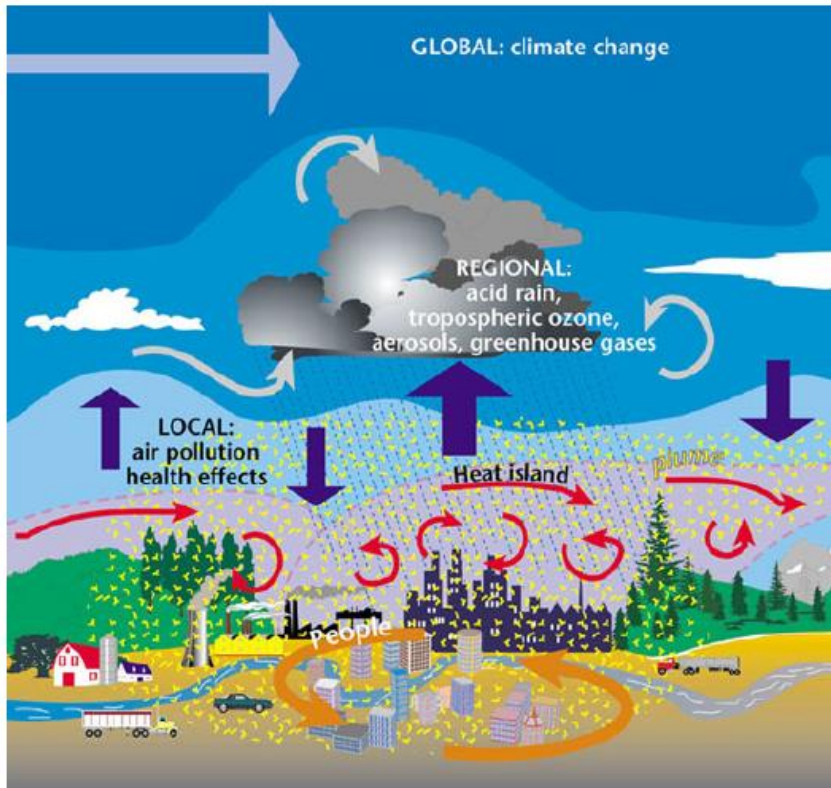


Acknowledgement

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Background

With **< 1%** of total Earth land, urban space attracts more than **50%** of world population and the ensuing social and economical activities, leading to unique urban microenvironment that affects planetary boundary layer (PBL) processes and precipitation;



Multiscale urban-atmosphere coupling
(adapted from Hidalgo et al. 2008)

The human-nature feedbacks over city build-up are manifest in multiple aspects and go far beyond urban boundaries, as illustrated in left figure (local – regional – global);

This investigation focuses on two factors: 1) **urban LULC** that exhibits unique surface albedo, roughness, and emissivity to influence urban PBL energy/water budget;

and 2) **anthropogenic aerosol emissions** in urban area that affects PBL processes and precipitation via complex aerosol-cloud-radiation (ACR) interactions.

Science Questions

- 1) Can cities, via urban landscapes and/or associated aerosol processes, initiate or modify precipitating cloud systems?
- 2) If so, what processes are of first-order significance in urban-influenced precipitating storms?

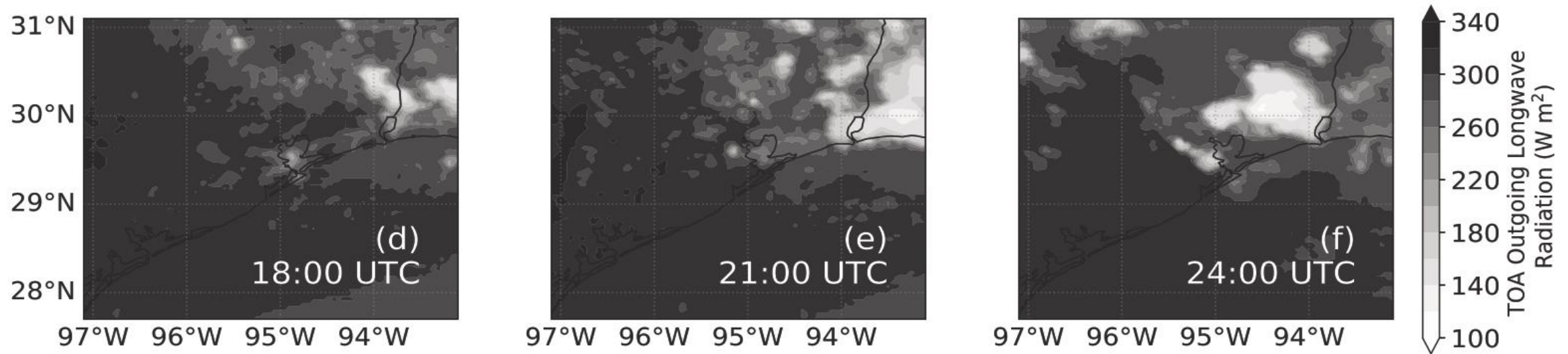
This study aims to answer above science questions using NASA Unified Weather Research and Forecasting (NU-WRF) modeling system to investigate the synergistic urban LULC and anthropogenic aerosol impacts under the hypothesis:

- *Heating & dynamics associated with urban landcover impacts convection*
- *Aerosol-cloud-radiation interaction modifies precipitation efficiency*

Case study over Houston metropolitan region on June 19-20, 2013

What happened in Houston on June 19-20, 2013?

A case of sea breeze induced convective clouds developed near Houston in the afternoon of June 19, 2013. A moderate rainfall ensued over the region – **more than 1 inch of rain was recorded at the George Bush International Airport (IAH) from 7-9 pm CST (i.e., 24 UTC – 2 UTC of June 20, 2013).**

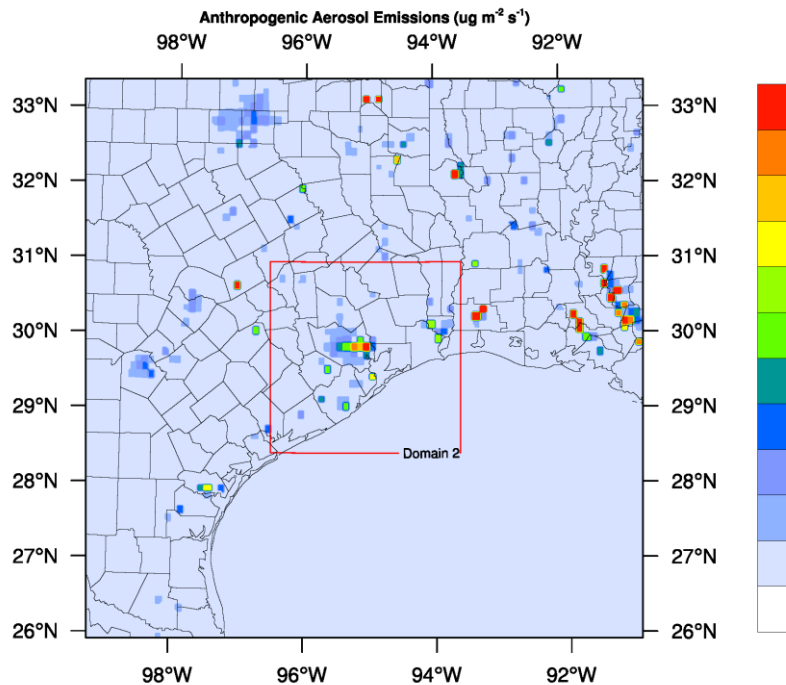


This is a target case of the Aerosol–Cloud–Precipitation–Climate international working group (ACPC), a model intercomparison project (MIP) (Marinescu et al. 2021).

NU-WRF Experiment Design

Configuration

- Goddard 4ice MP
- Goddard SW/LW radiation schemes
- MYJ PBL scheme
- Single layer urban canopy model (UCM)
- Noah LSM



Experiment	Aerosols	Land Surface Properties
Pristine	Clean with ACR	Pre-urban conditions
No_ApAero	Clean with ACR	Current-urban conditions
No_urban	Polluted with ACR	Pre-urban conditions
Baseline	Polluted with ACR	Current-urban conditions

Quantification of urban impact using factor separation analysis

Overall impact = Baseline - Pristine

Impact from urban LULC only = NoApAero – Pristine

Impact from aerosol effect = No_urban - Pristine

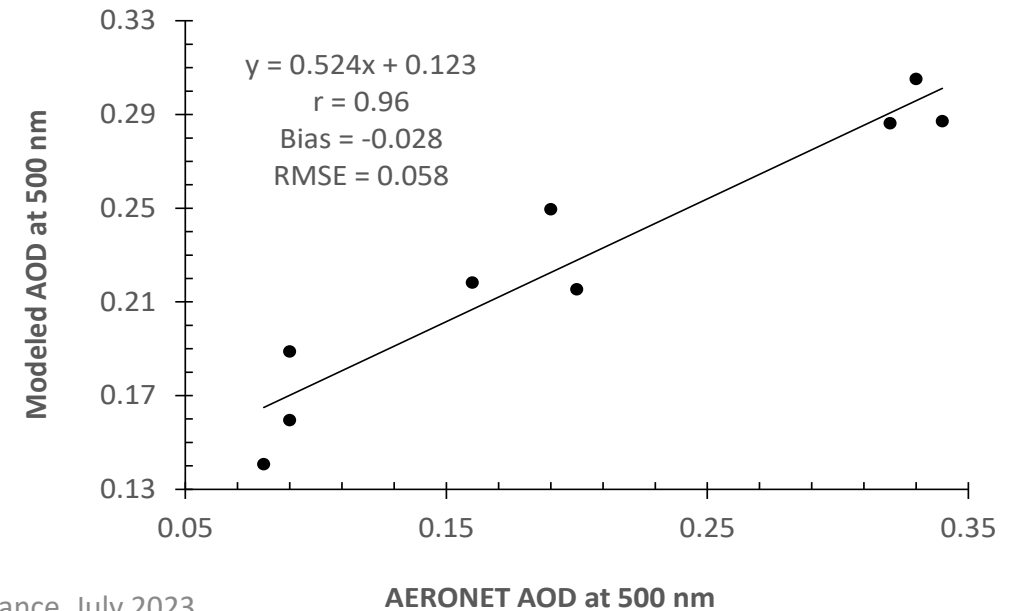
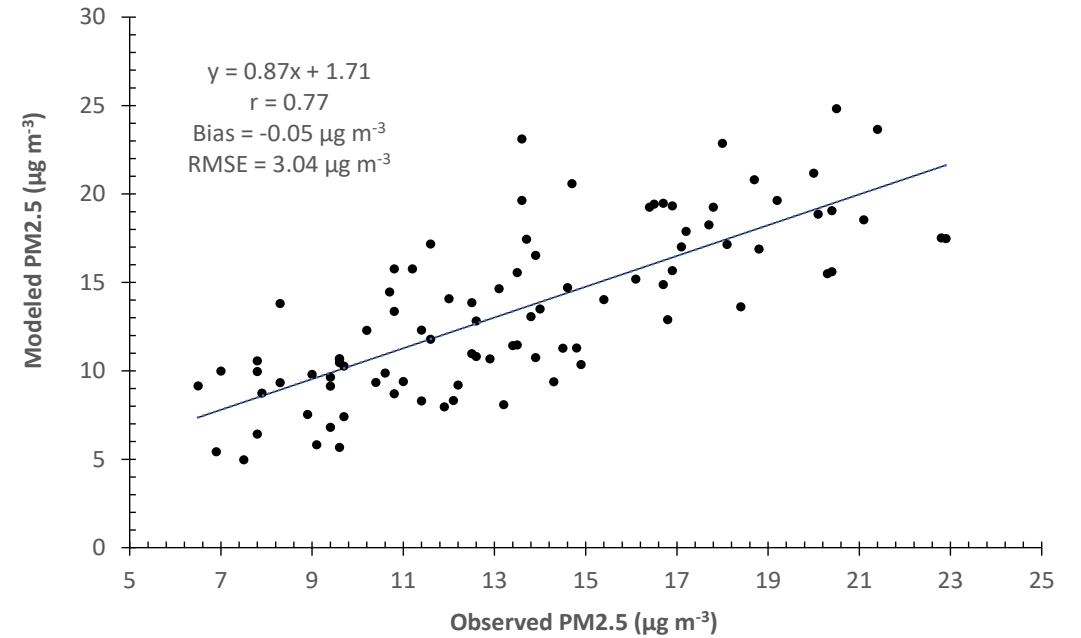
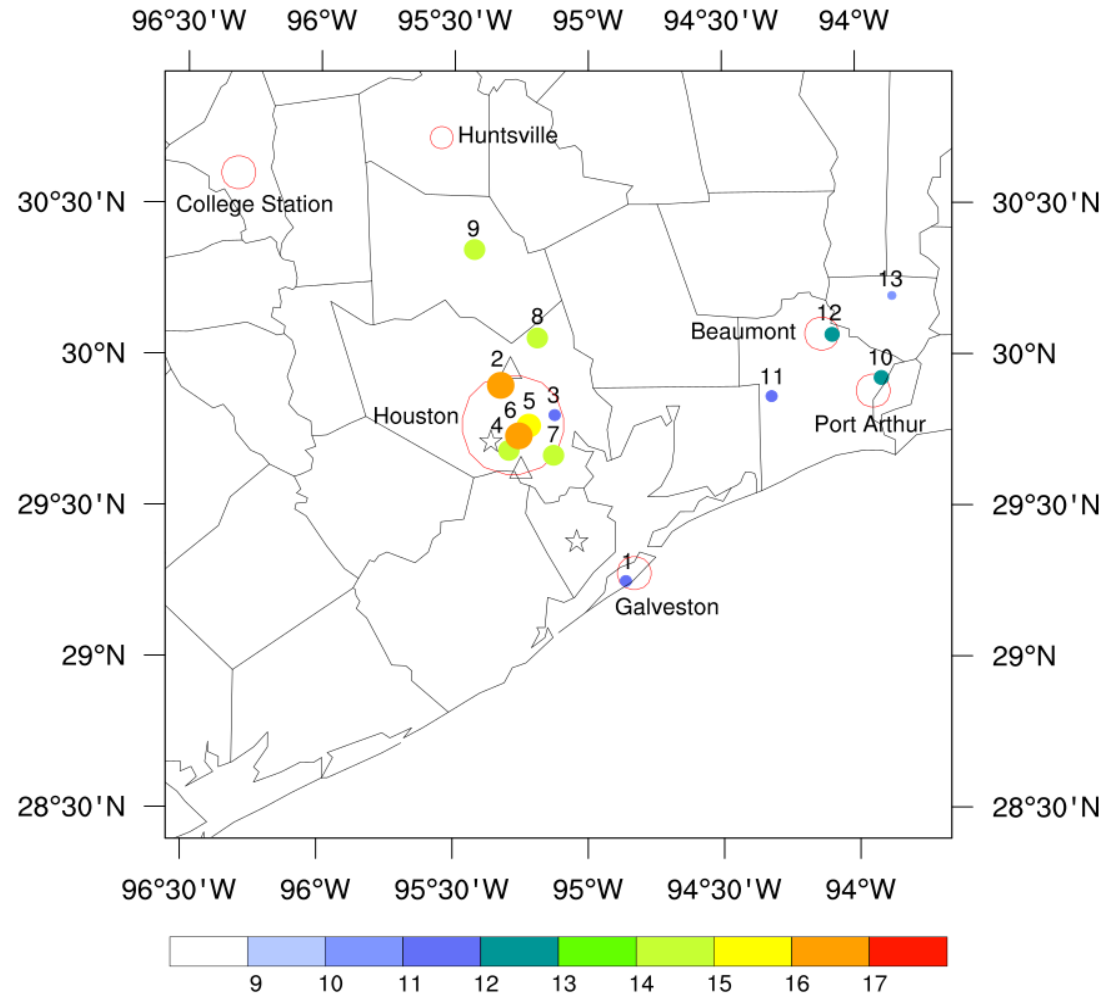
Synergistic impact = Overall impact – other 2 impacts

- NU-WRF GOCART aerosol and chemistry using 3- and 1-km grid
- Weeklong simulation (6/16~6/23/2013)

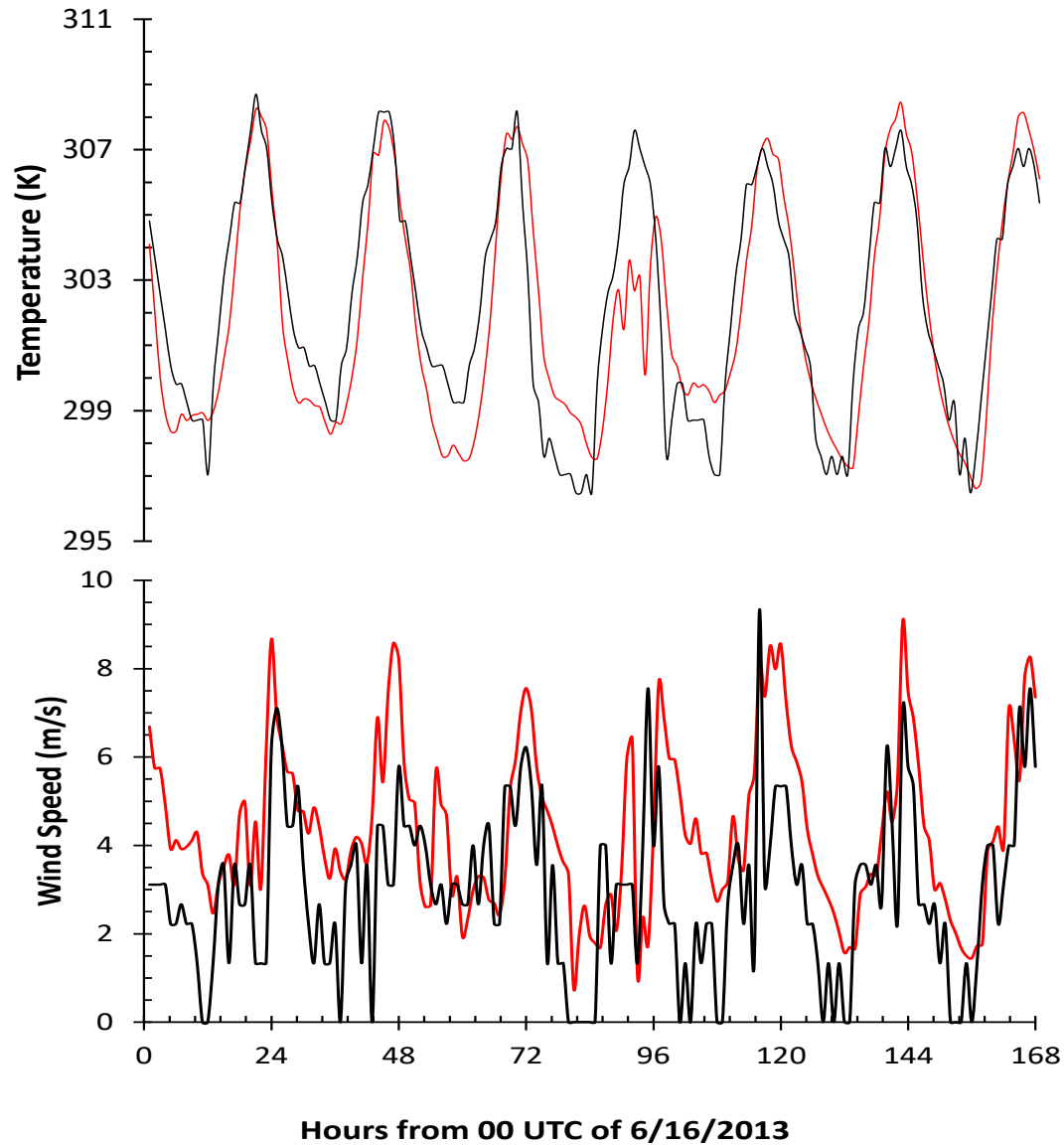
Brute-force:

- 1) replace urban LULC with cropland/natural vegetation mosaic LULC
- 2) zero anthropogenic emissions

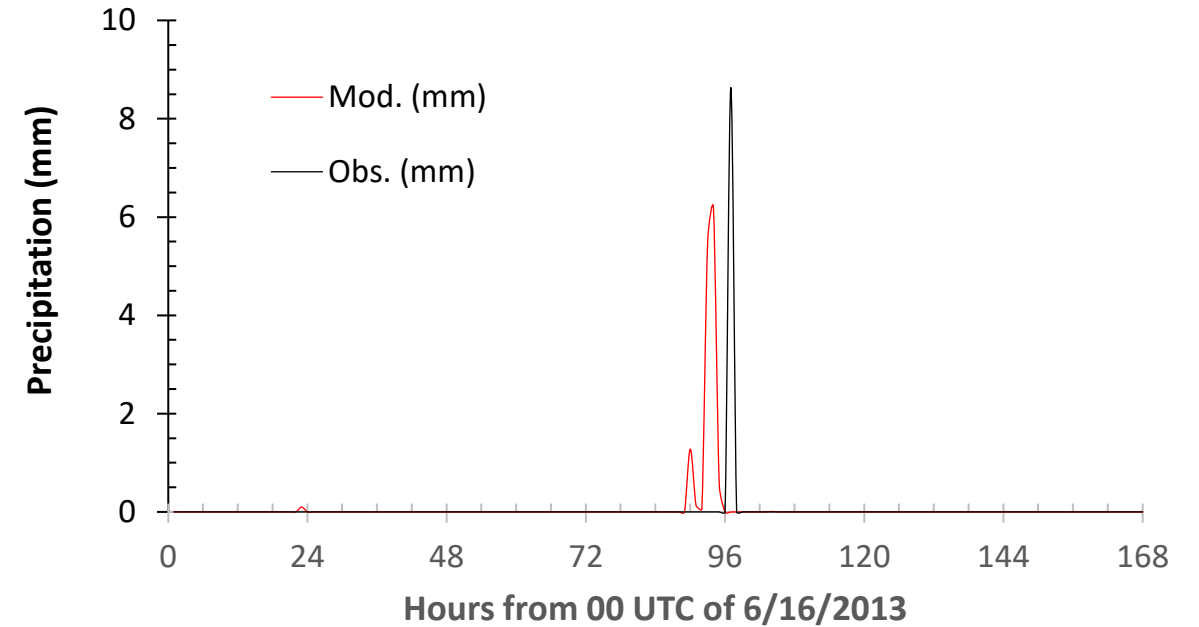
Model evaluation – aerosols (AQS, AERONET)



Houston George Bush International Airport (IAH, 29.93N, 95.31W)



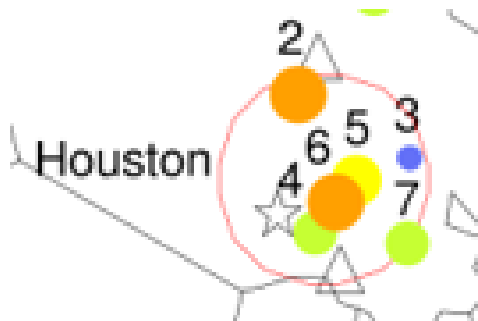
Model evaluation – meteorology



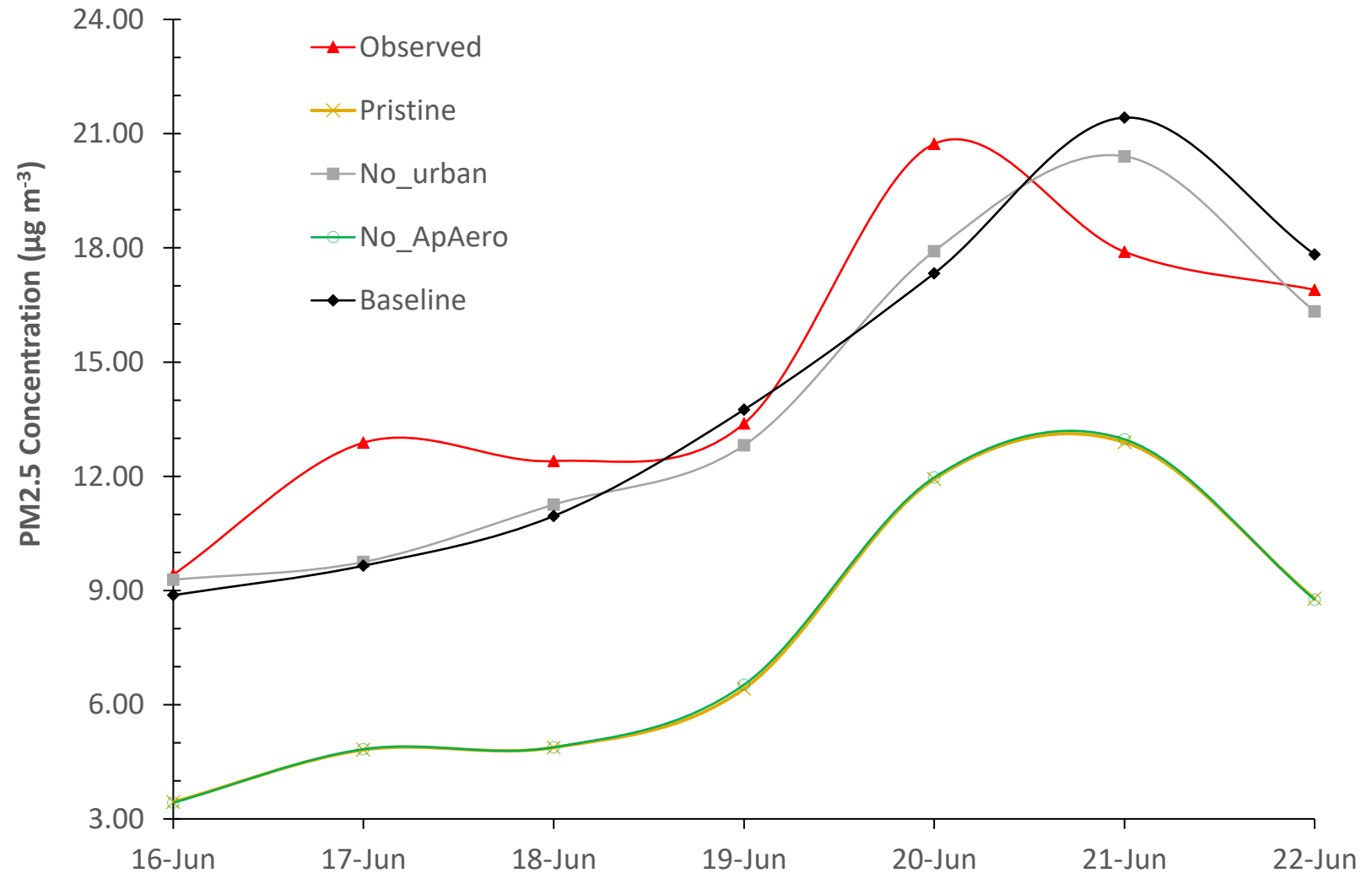
	Bias	RMSE	r
Temperature (K)	-0.40	1.81	0.87
Wind speed (m/s)	1.42	2.19	0.60
Precipitation (mm)	0.03	0.93	-

Impact on PM2.5

- Anthropogenic aerosols contribute heavily (~60%) of total surface PM2.5 over Houston
- Consideration of urban LULC further reduces bias (-0.55 vs. -0.84 $\mu\text{g m}^{-3}$) with comparable correlation (0.72 vs. 0.74)

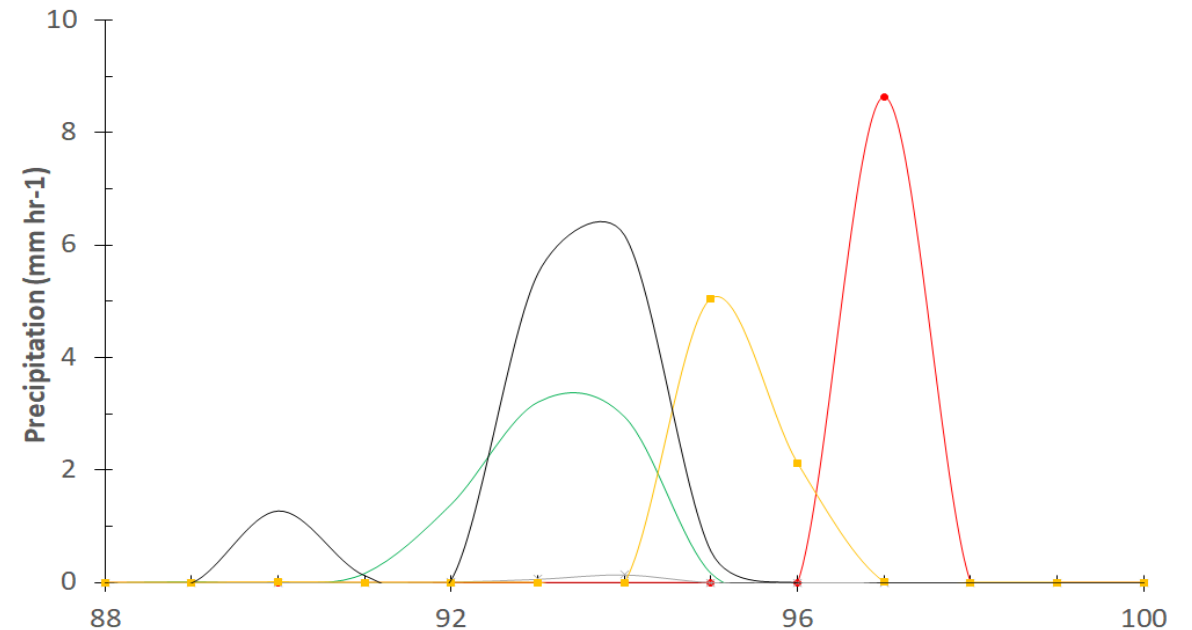
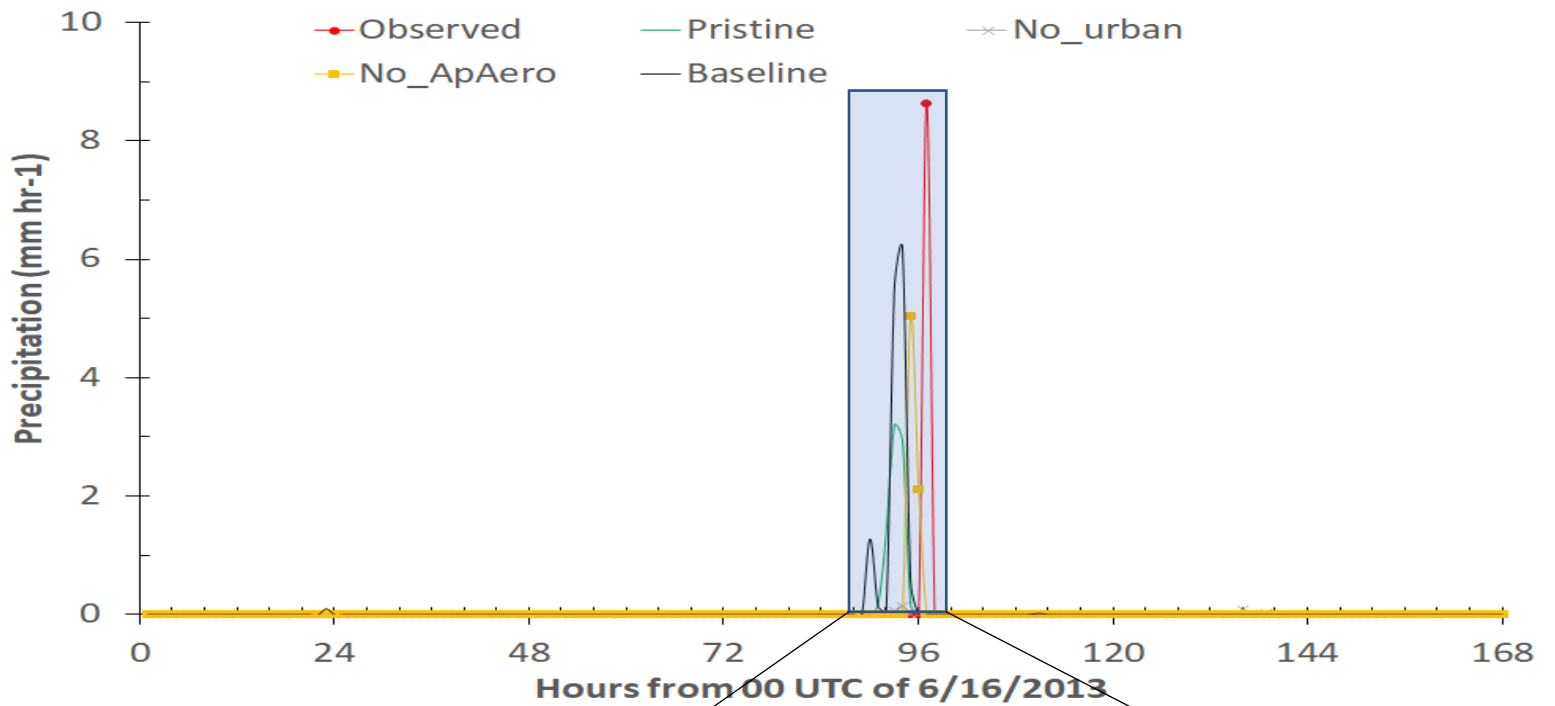


Modeled vs. observed Surface PM2.5 averaged at Houston AQS sites



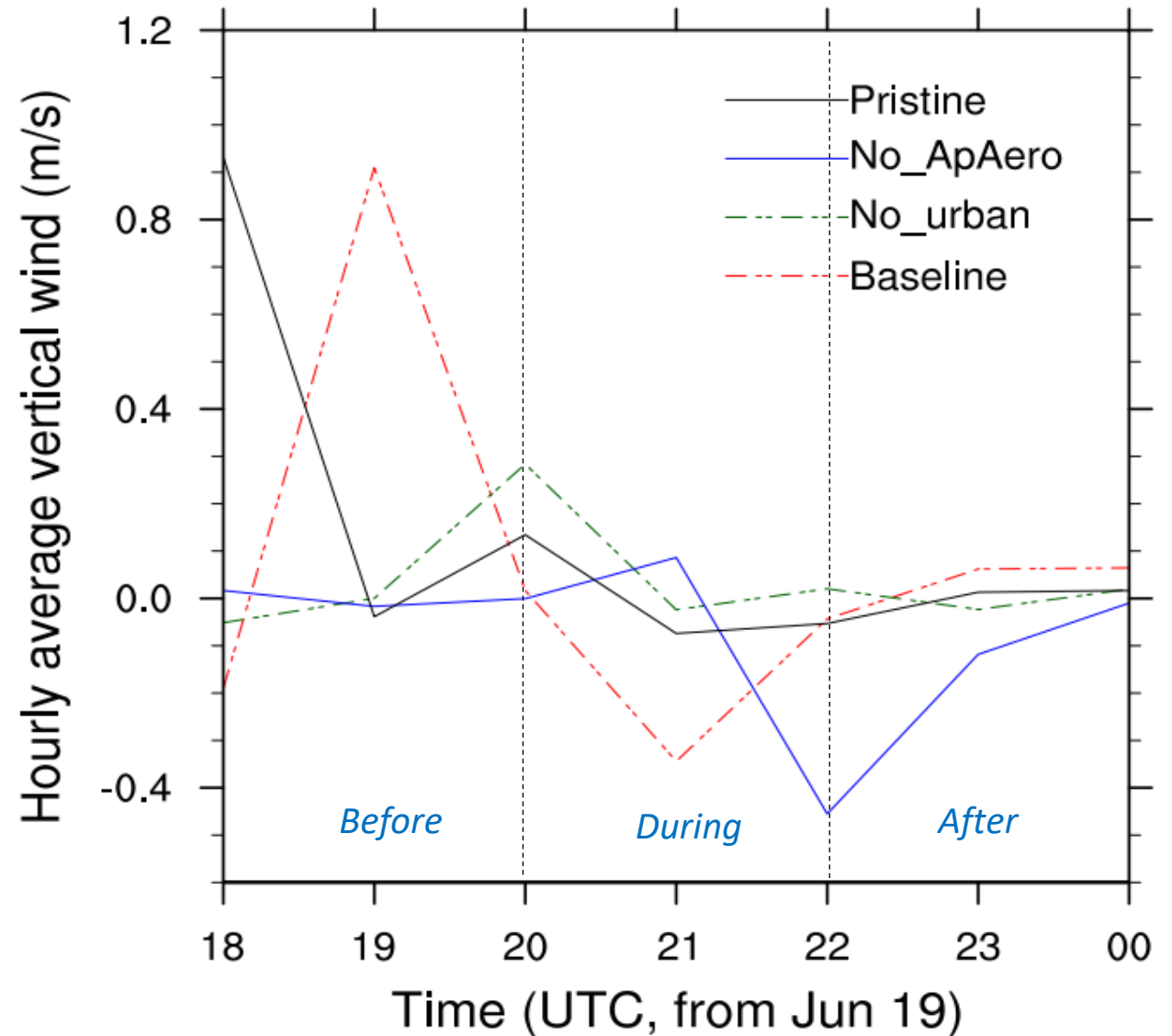
Impact on precipitation

- Under natural LULC (no urban), introduction of aerosols severely suppressed precipitation (grey vs. green lines)
- Under urban LULC, addition of anthrop. aerosols initiated the precipitation 3-4 hrs. earlier and enhanced overall precipitation by 70% (black vs. brown lines)
- Complex nonlinearity of urban LULC and anthropogenic aerosols led to the similar onset of precipitation and a 55% overall increase in amount (black vs. green lines)
- Compared with observation, modeled **peak precipitation** was ~2hr earlier and ~27% lower (black vs. red lines)



Impact on precipitation

- Before rain, urban effects greatly enhance updraft (convection) and sea breeze intensity, mainly via ACR interactions due to anthrop. aerosol addition
- During rain, urban effects increase downdraft, mainly via the nonlinear synergist between urban LULC and anthrop. aerosols.
- After rain, urban effects change vertical movement direction (from downdraft to updraft), mainly via urban LULC implementation



Take-home message

- Urban effects, through unique characteristics of LULC and the associated emissions of man-made aerosols, can initiate and modify local/regional precipitation
- For this Houston case, urban effects greatly enhanced convection right before rainfall, mainly through ACR interaction
- For the same storm system, depending on underlying LULCs, aerosols can either suppress or intensify precipitation

Thank you for your attention!

