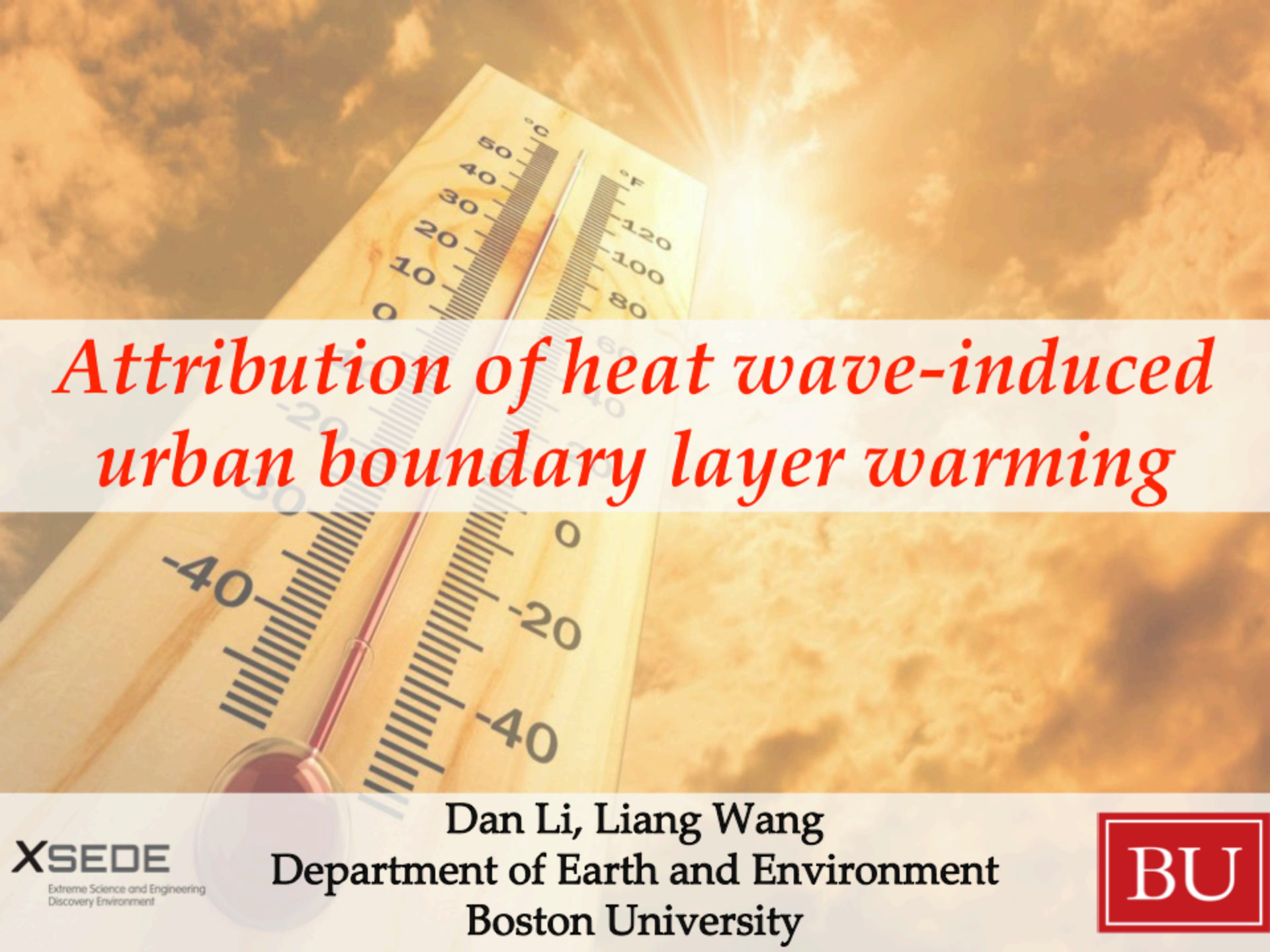


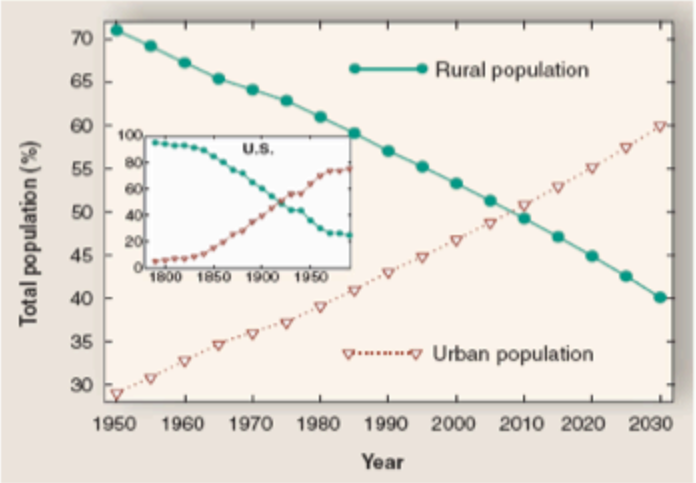
Attribution of heat wave-induced urban boundary layer warming

Dan Li, Liang Wang
Department of Earth and Environment
Boston University

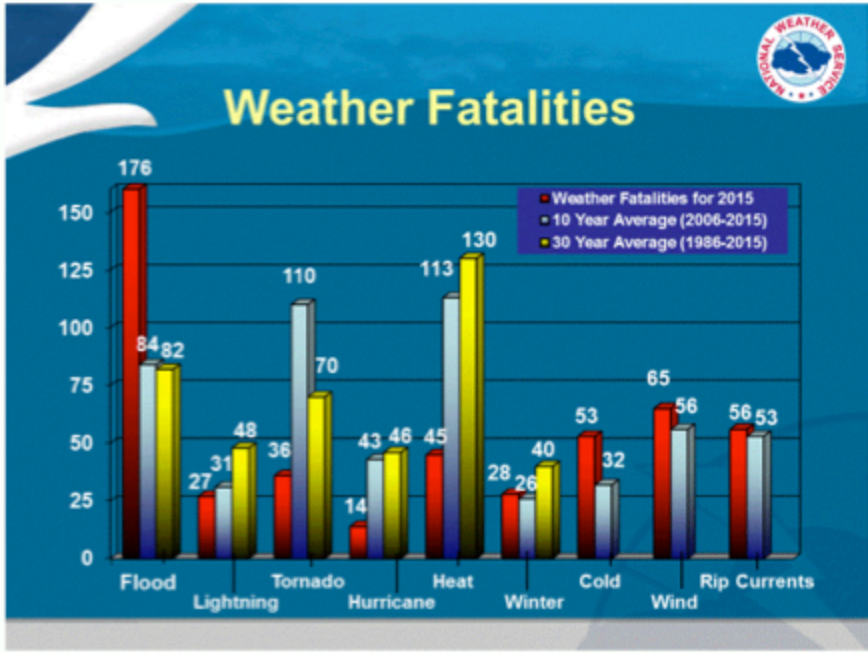
XSEDE
Extreme Science and Engineering Discovery Environment

BU

The world is urbanizing and will face more heat waves under climate change



Grimm et al.(2008) *Science*



http://www.nws.noaa.gov/om/hazstats.shtml

Science

More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century

Gerald A. Meehl and Claudia Tebaldi

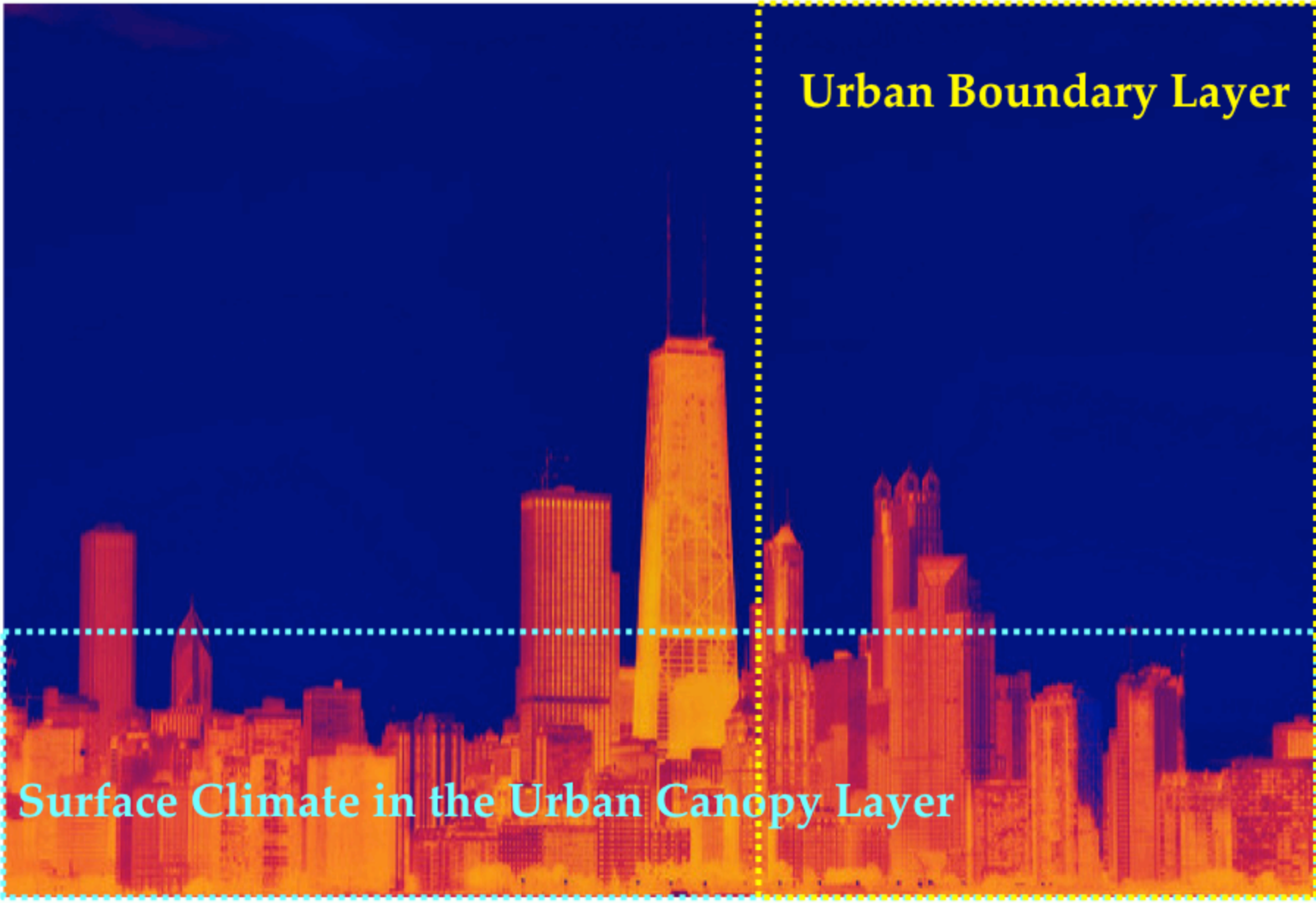
CNN World + Live TV U.S. Edition +

Deadly heat waves becoming more common due to climate change

By Brandon Miller, CNN Meteorologist

Updated 11:12 AM ET, Wed August 2, 2017

Understanding the impacts of heat waves on the urban environment is important

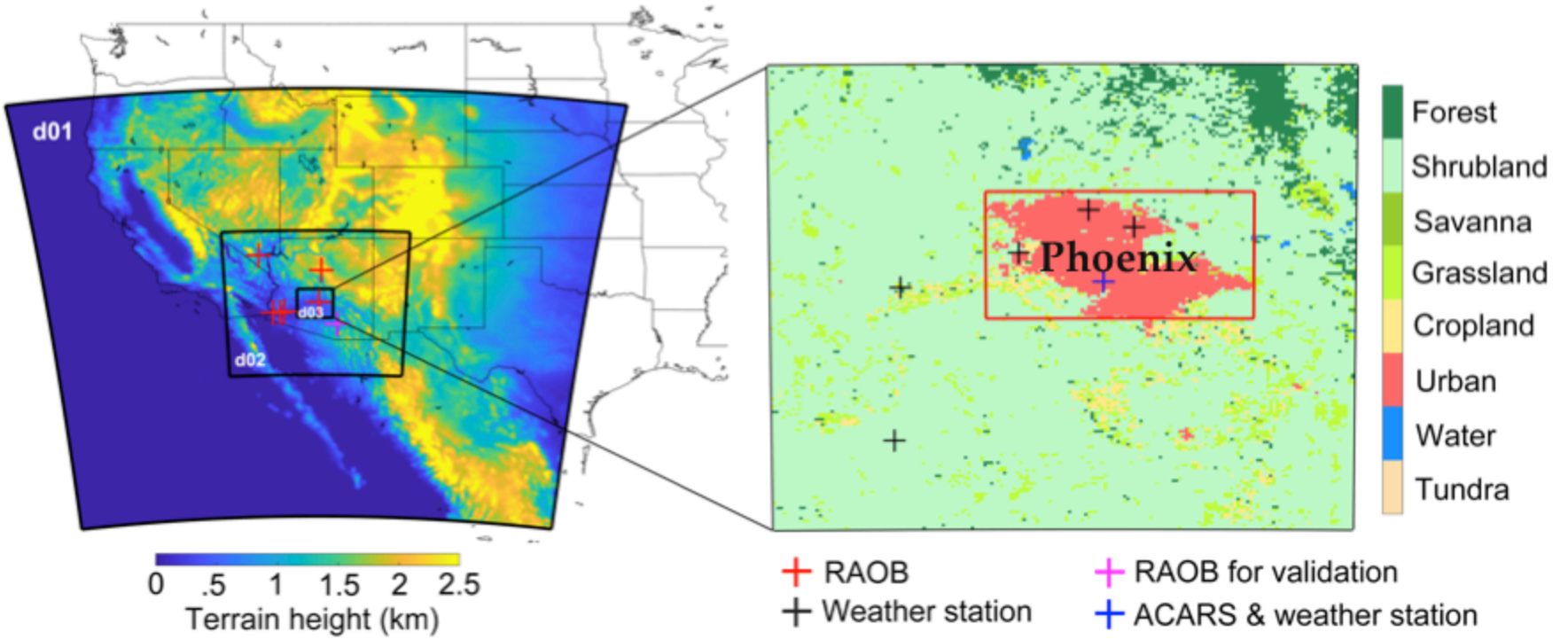


What processes mostly contribute to the daytime warming of the urban boundary layer under heat waves?

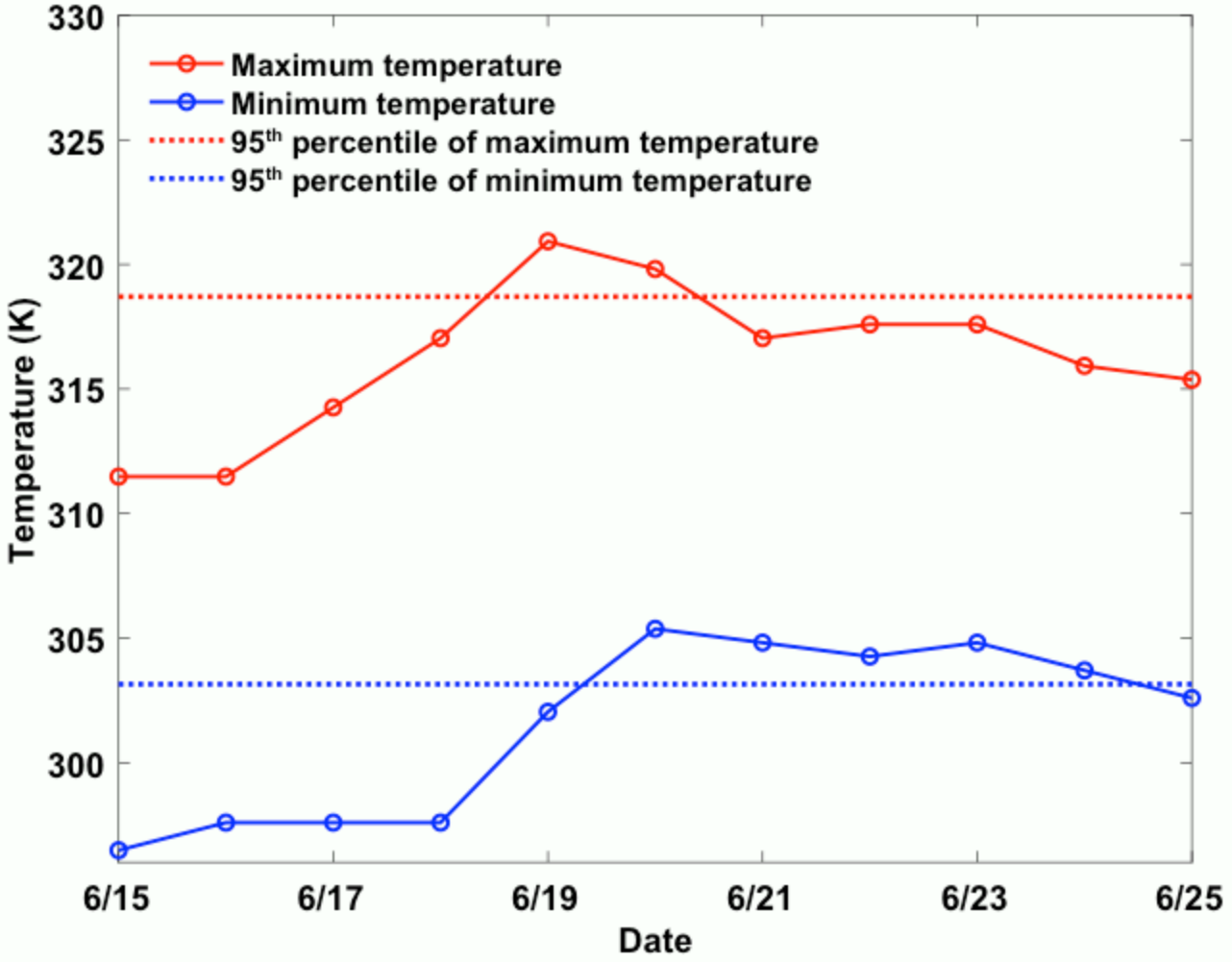
While surface heating always warms the boundary layer in the daytime, the vertical and horizontal transport of heat into/out of the urban boundary layer plays an important role in controlling the degree of warming and is more affected by heat waves.

Observations (Radiosonde or RAOB, Aircraft or ACARS, Weather Station, Flux Tower)
Weather Research and Forecasting (WRF) Model Runs
Boundary Layer Heat Budget Analysis

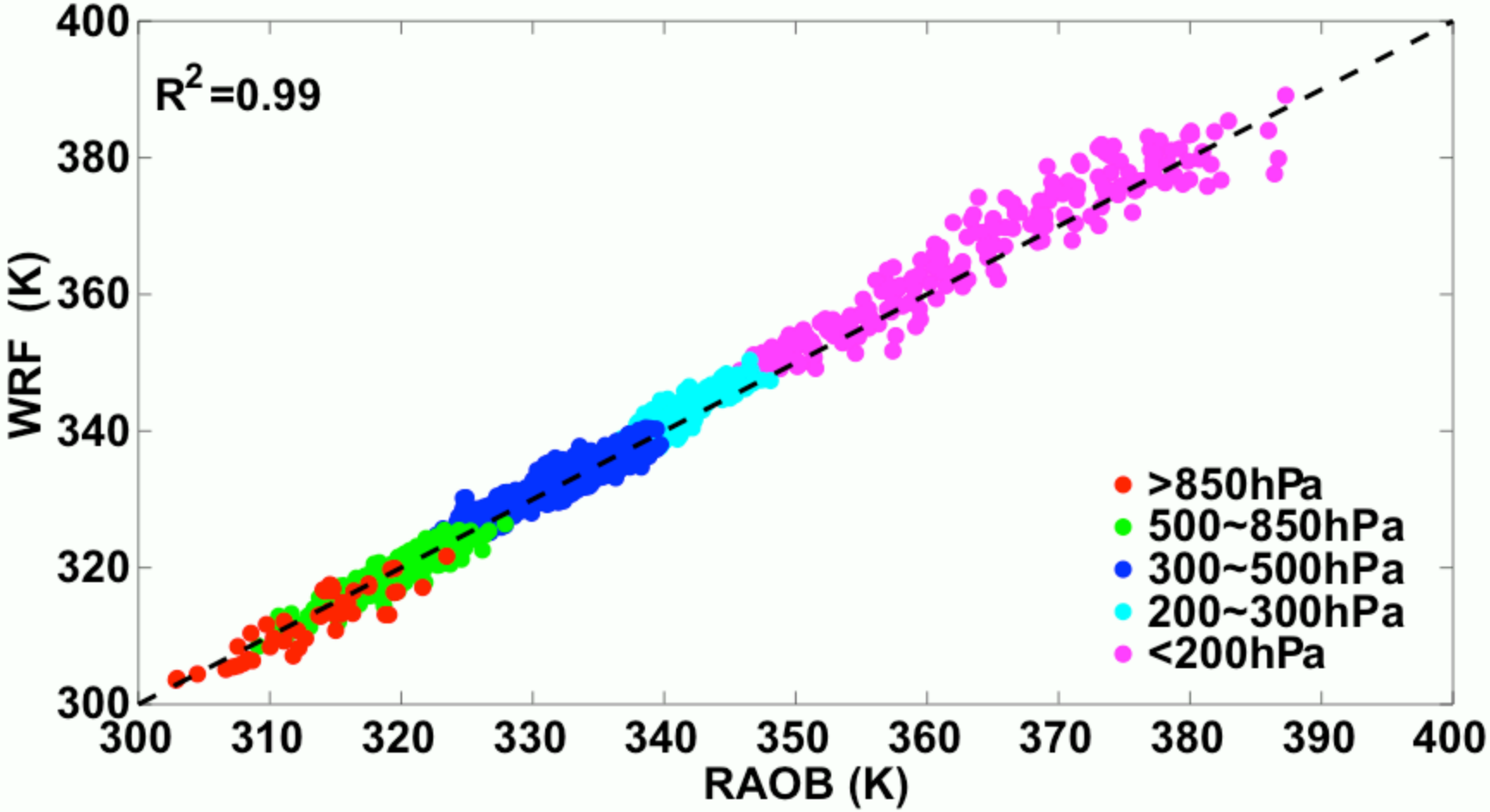
A case study over the Phoenix metropolitan area



Daily maximum and minimum temperatures measured at the Phoenix international airport

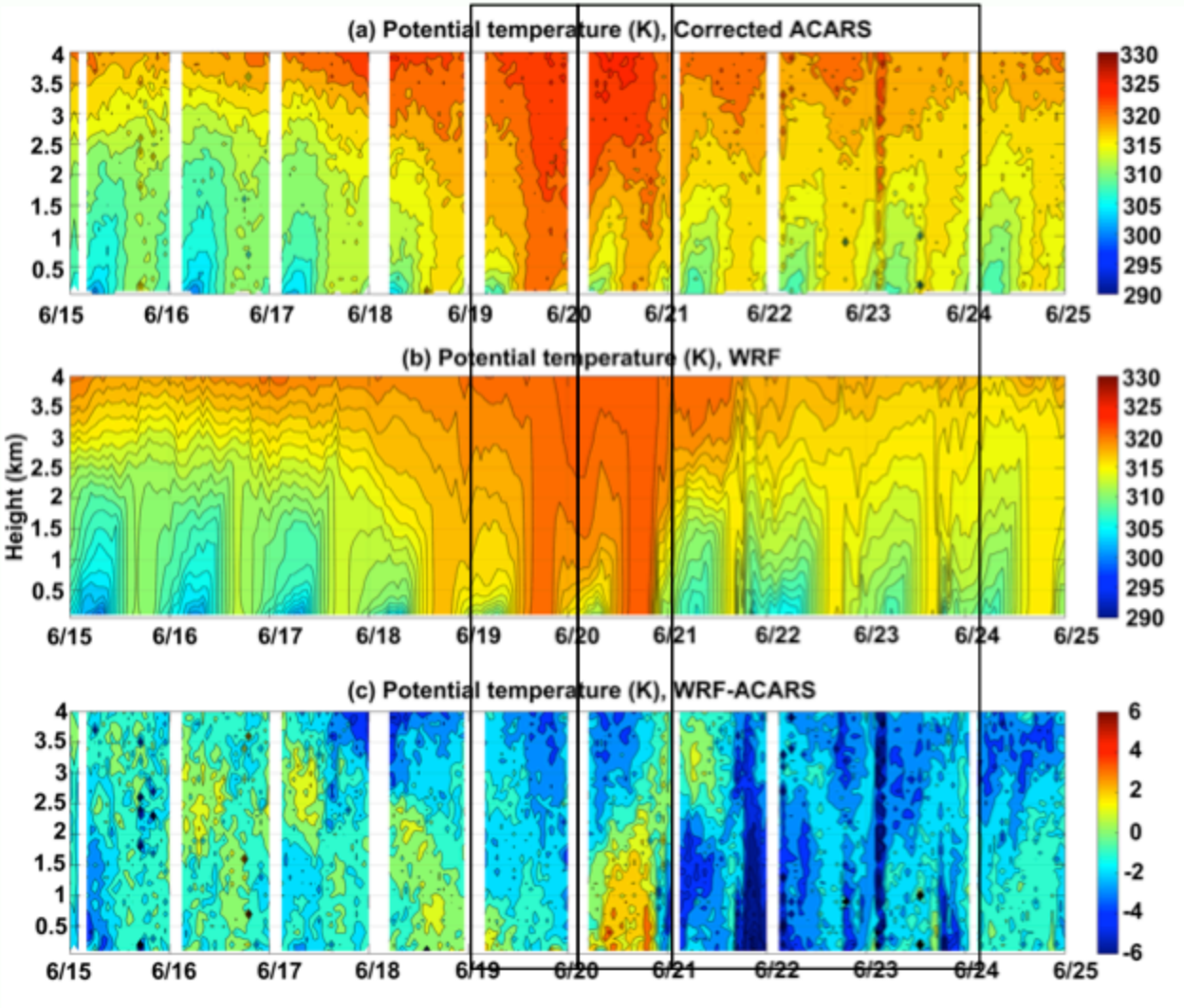


Validation of model simulations: radiosonde (RAOB) data



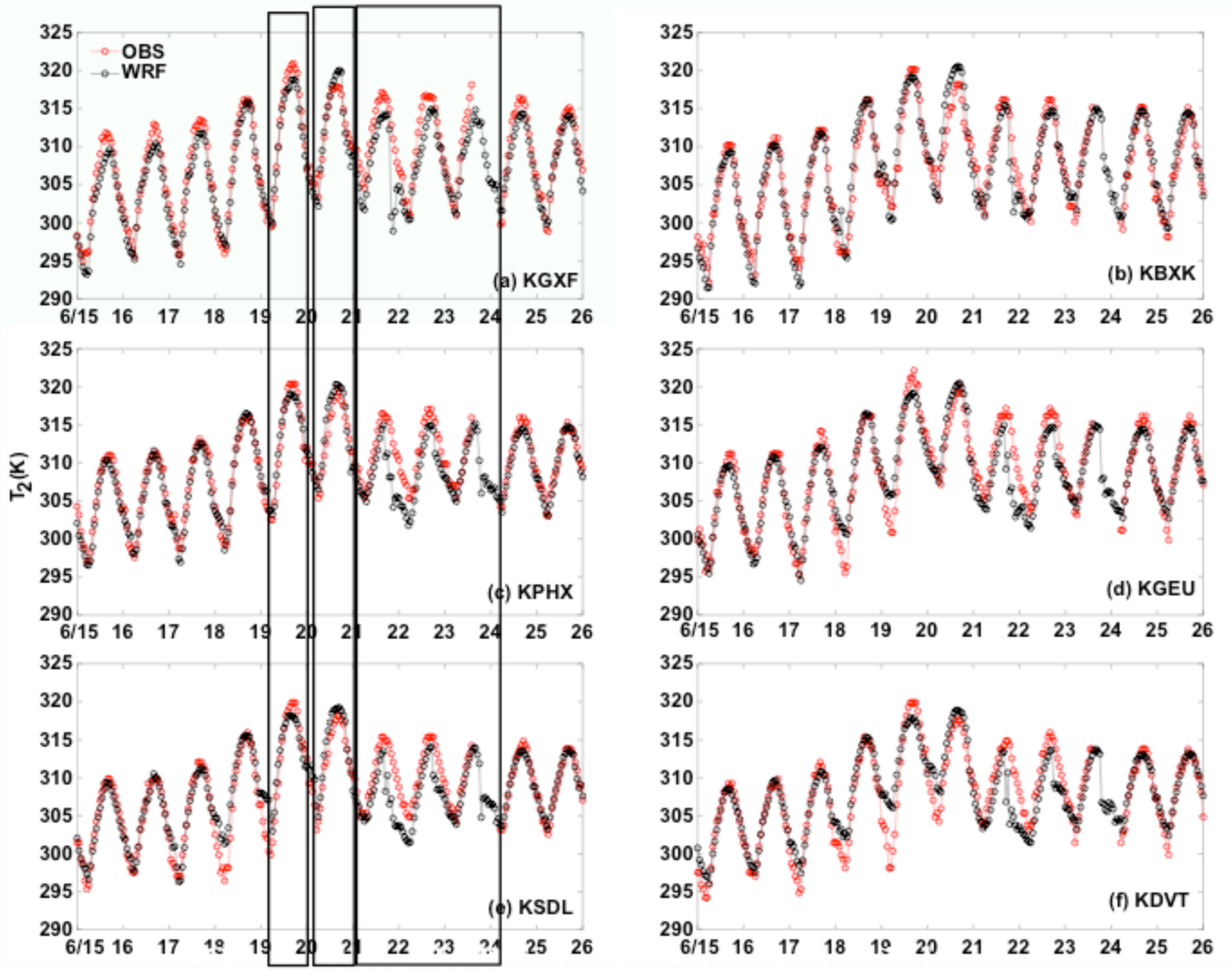
Overall the WRF simulation shows good agreement with the radiosonde data.

Validation of model simulations: aircraft (ACARS) data

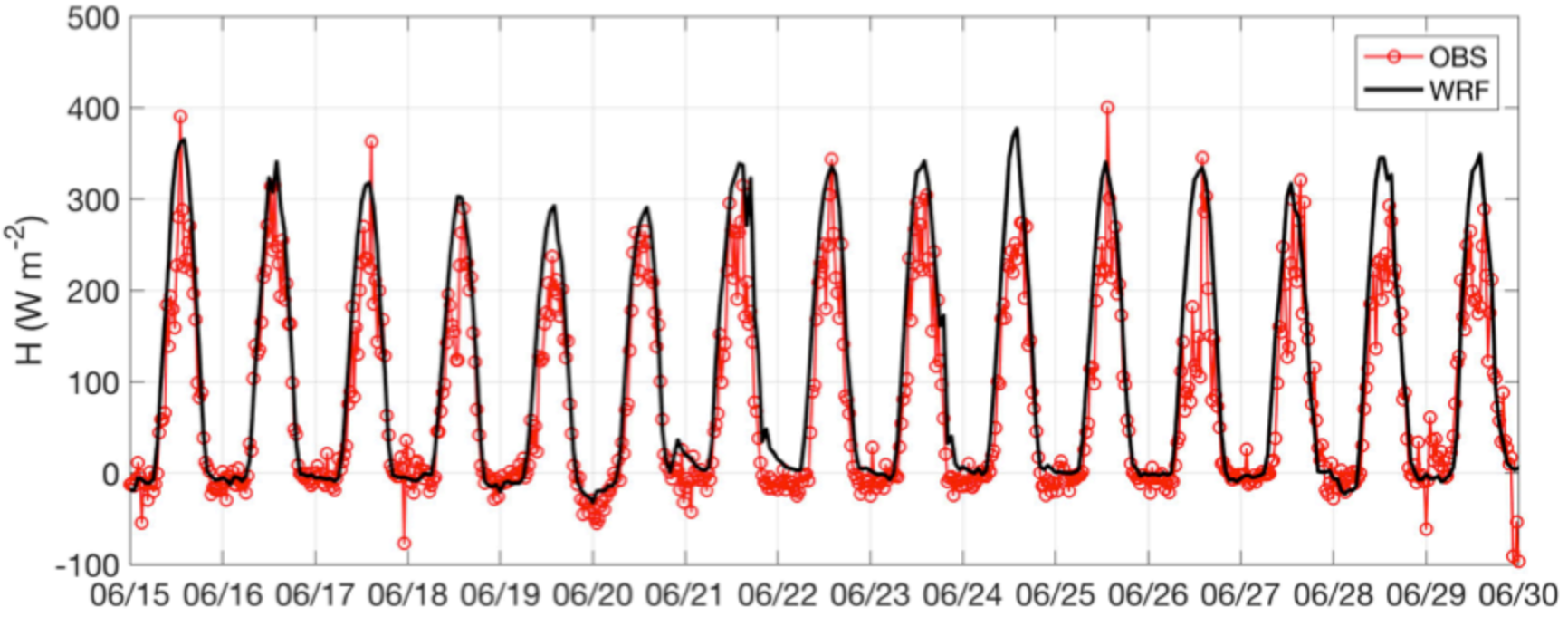


The WRF simulated urban boundary layer response to heat wave is delayed, and then shows large cooler biases.

Validation of model simulations: weather station data



Validation of model simulations: sensible heat flux

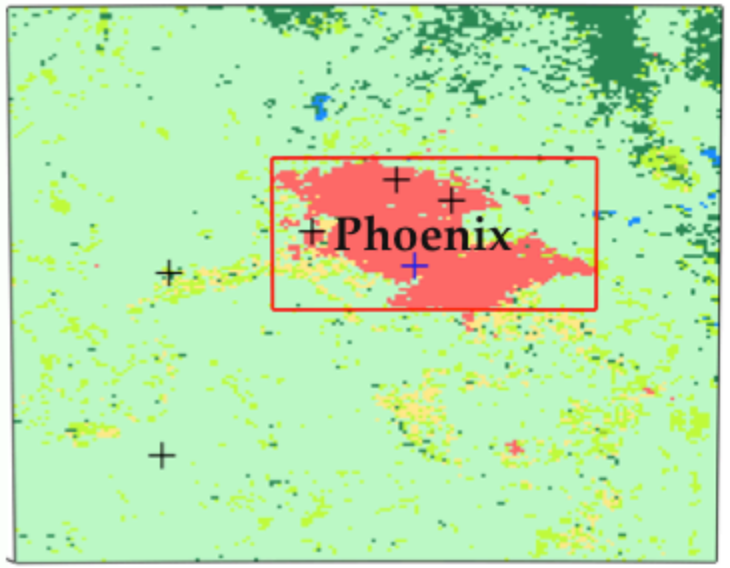


WRF almost always overestimates the sensible heat flux, suggesting that the alternate cooler/warmer biases in the temperature field are not solely caused by biases in the sensible heat flux.

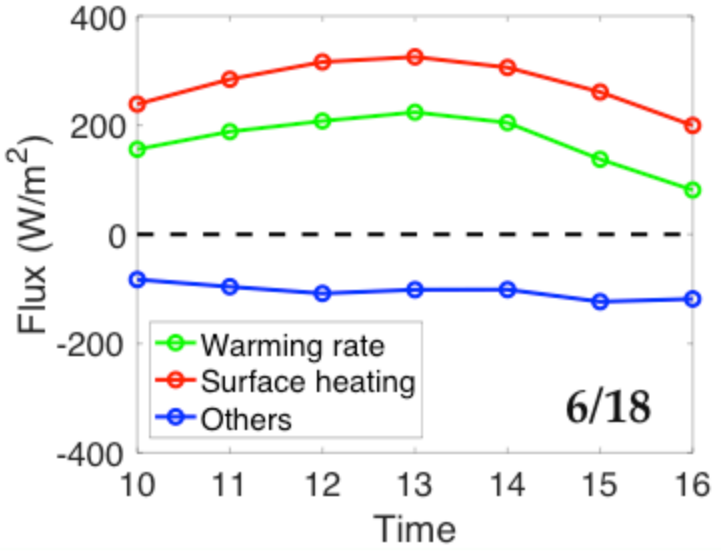
Attribution of urban boundary layer warming

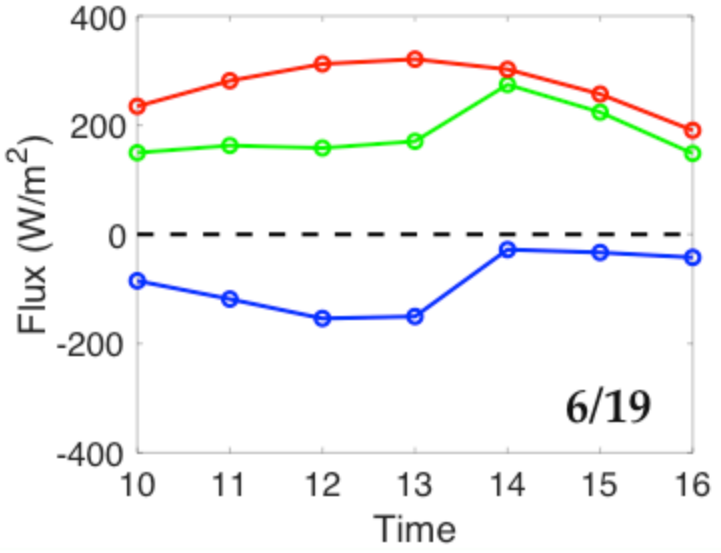
the Warming of Urban Boundary Layer

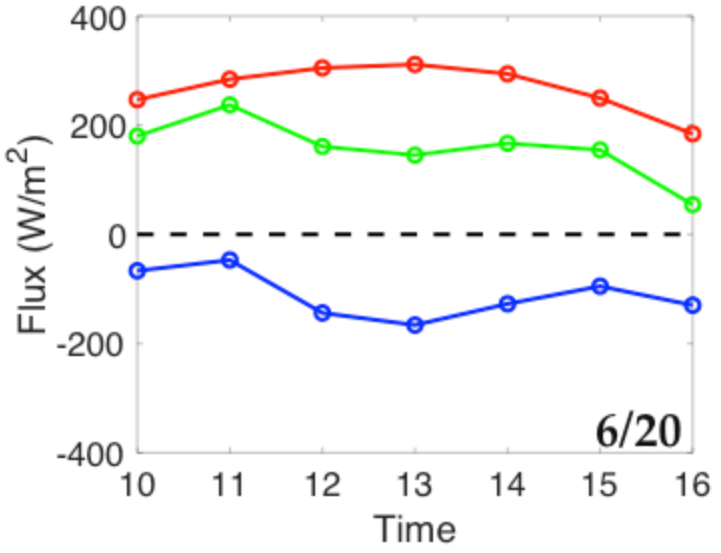
- Surface heating
- Urban Rural Advection
- Subsidence
- Entrainment

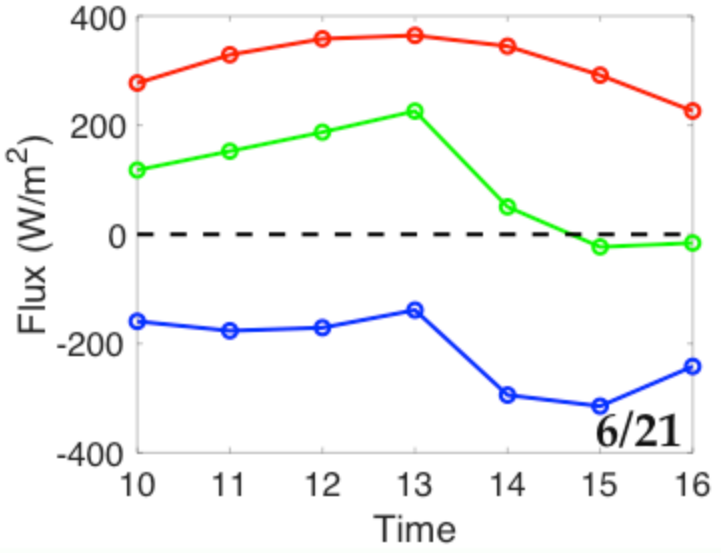


Surface warming vs the combination of three other processes during daytime

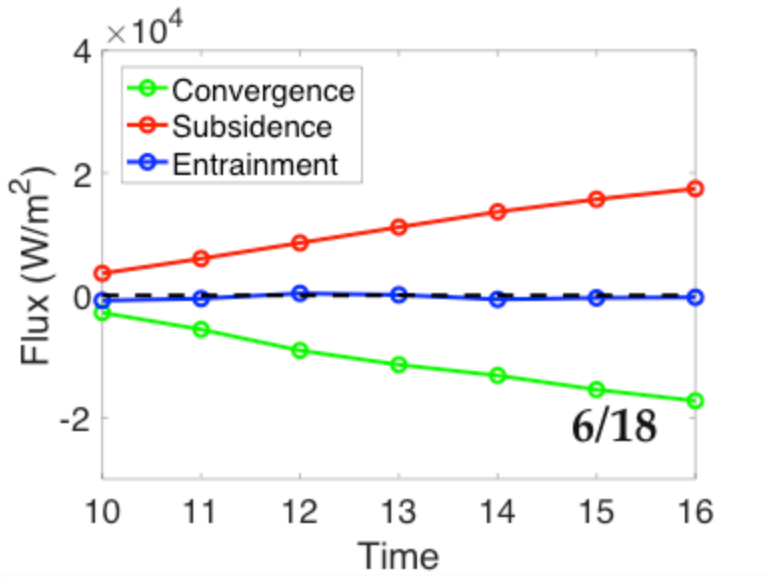


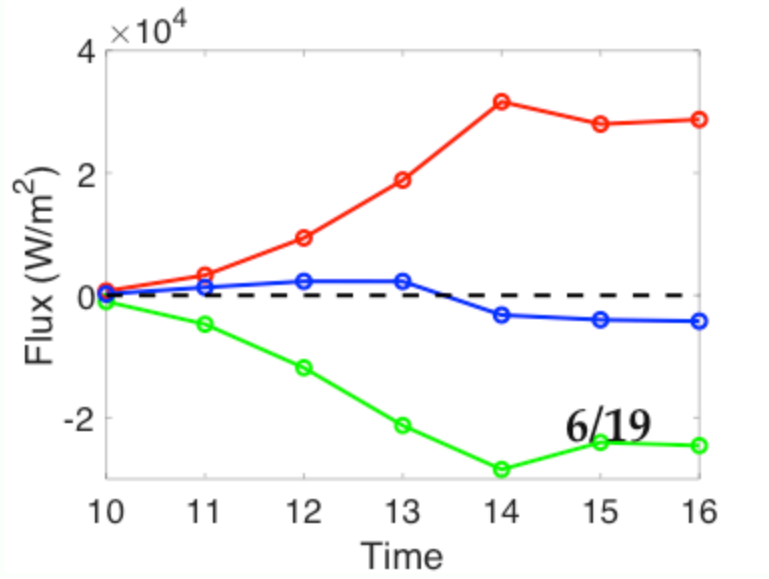


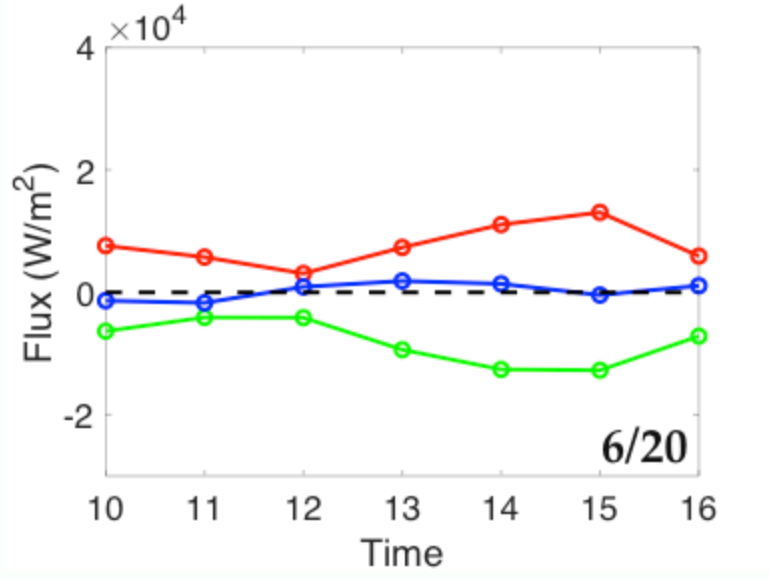


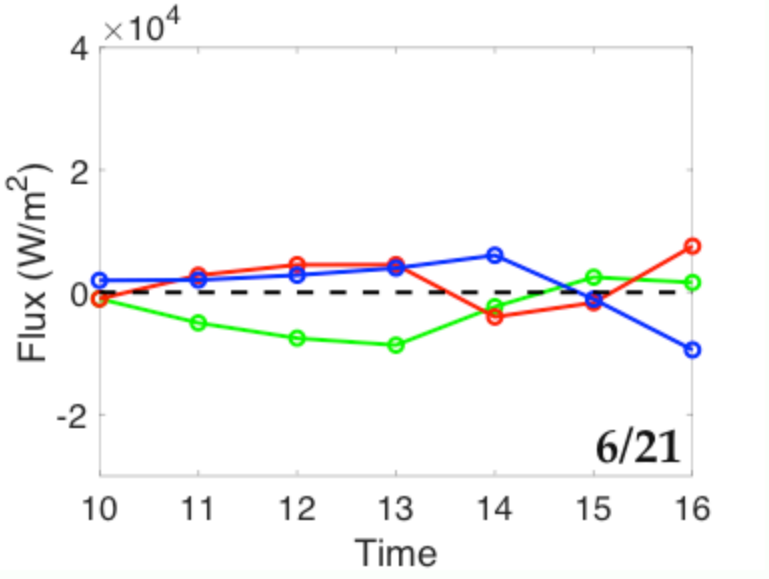


The subsidence produces heating two orders of magnitude larger than the surface heat flux, but is mediated by divergence.









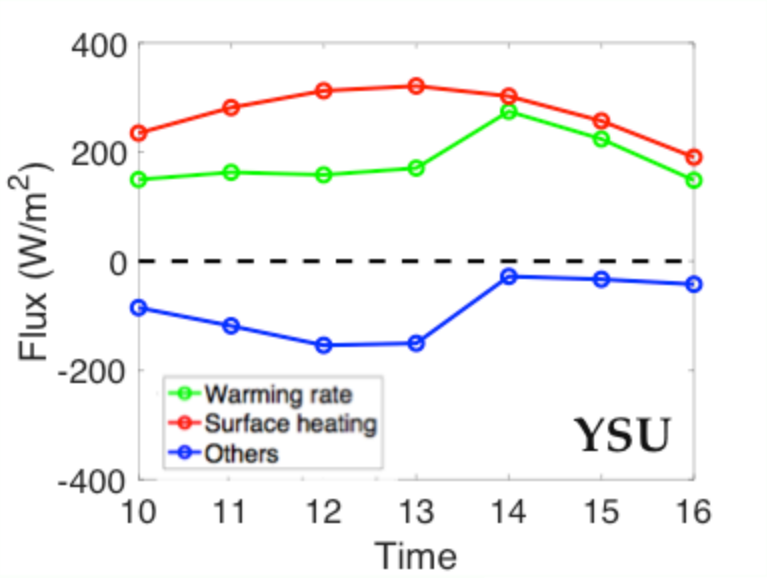
Summary

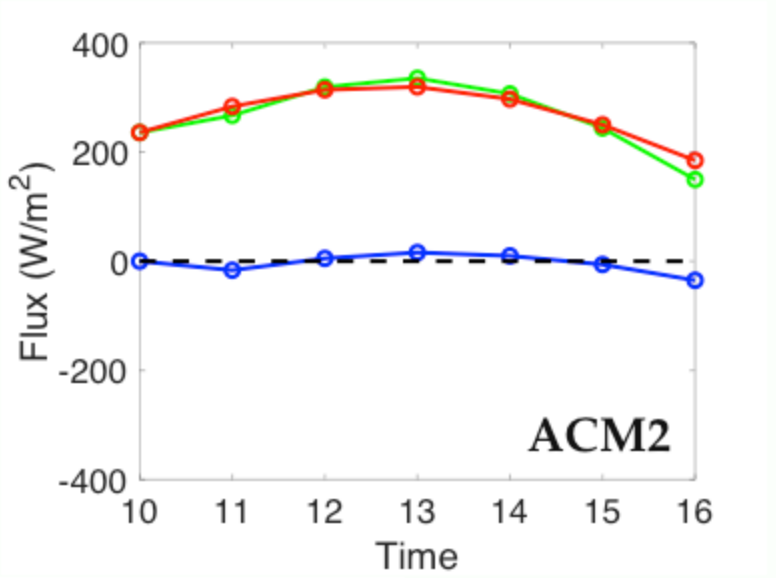
- WRF produces a delayed response of urban boundary layer warming to heat wave, but it consistently overestimates surface heat flux.
- The vertical and horizontal transport of heat into/out of the urban boundary layer plays an important role in controlling the degree of warming, and is more affected by heat waves.
- These results suggest the importance of boundary layer dynamics in quantifying the impacts of heat waves on the urban environment.

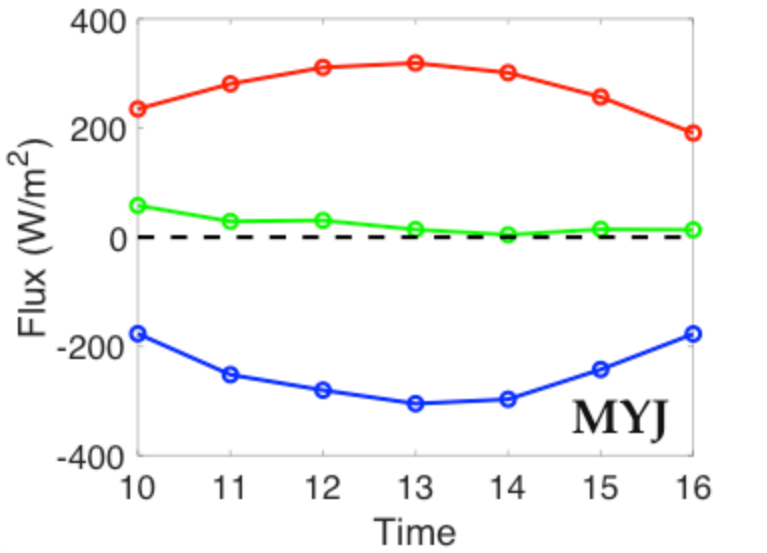
Future work

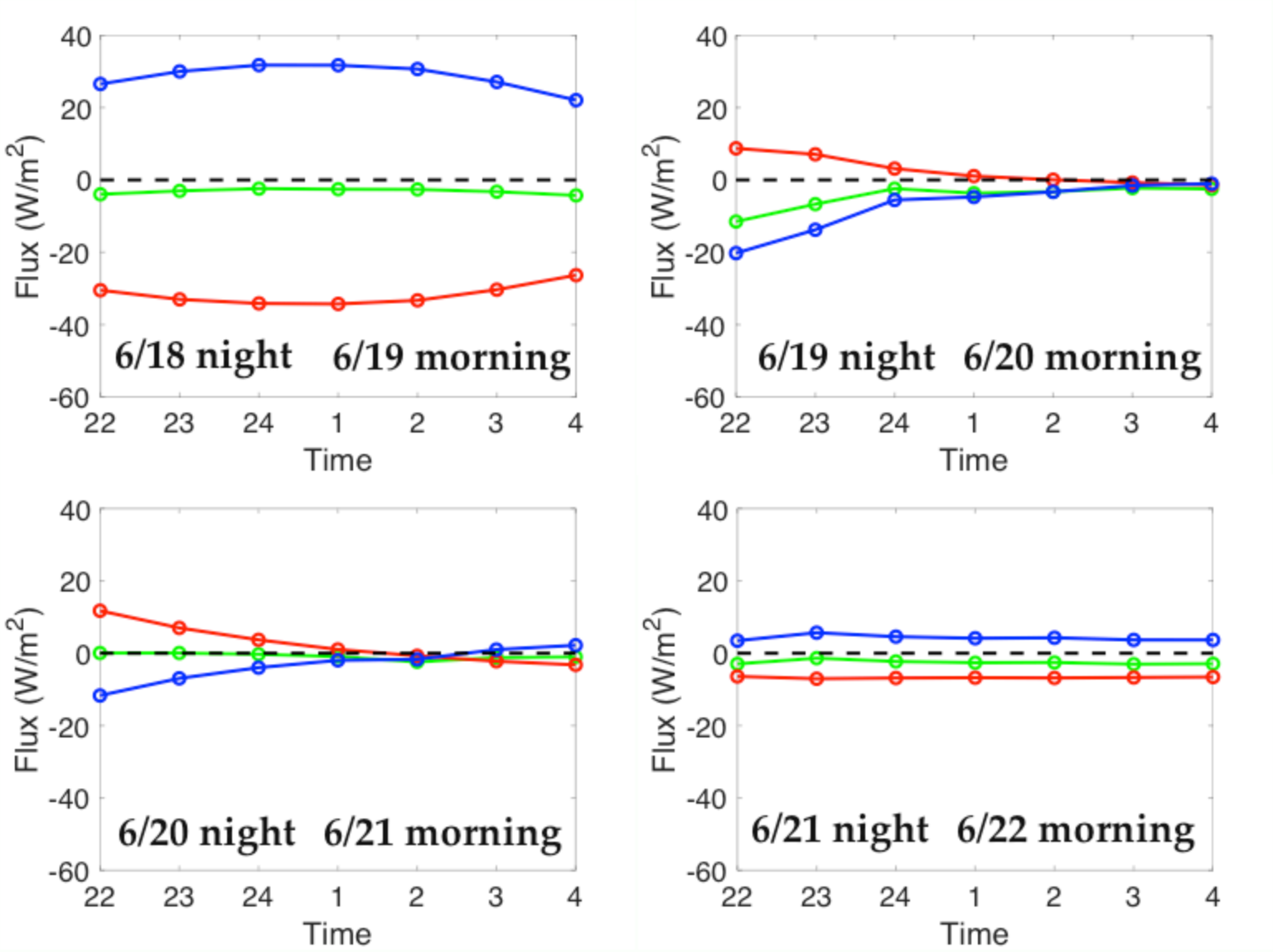
- Multiple cases over different urban regions.
- Nighttime warming under heat waves.
- Humidity effects.

The warming rate is highly affected by the boundary layer scheme








40
20
0
-20
-40
-60
Flux (W/m^2)
22
23
24
1
2
3
4
Time
6/18 night 6/19 morning
6/19 night 6/20 morning
6/20 night 6/21 morning
6/21 night 6/22 morning