

# Summer- and Wintertime Variations of the Surface and Near-surface UHI in a Semiarid Environment

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# Motivation:

- 1) Recently, *Salamanca et al.* (2018, *JGR Atm*) augmented the capabilities of the WRF-urban modeling system by coupling three urban canopy models available in the WRF model with the new community Noah-MP LSM
- 2) Nevertheless, the authors never evaluated the Noah-MP LSM's (coupled to WRF-urban) ability to reproduce the diurnal cycle of near-surface meteorology and LST under wintertime weather conditions
- 3) Therefore, the aim of this work is twofold:
  - 3.1) On one hand, to examine summer- and wintertime variations of the surface and near-surface UHI for a semiarid urban environment using MODIS and surface meteorological observations, and on the other hand
  - 3.2) To evaluate the WRF-urban modeling system's (coupled to Noah-MP LSM) ability to reproduce the diurnal cycle of near-surface meteorology and LST during both summer- and wintertime periods

# Summer- and Wintertime Variations of the Surface and Near-Surface UHI

- Four WRF model experiments are performed with three two-way nested domains with a grid spacing of 9 (276 x 296), 3 (250 x 283), and 1 (391 x 364) km respectively.
- All WRF model experiments are conducted with the NCEP Final Analyses data (ds083.2), two covering the same 31-day summertime period and two the same 31-day wintertime period in 2012.
- The US Geological Survey (30 m) 2006 NLCD set was used to represent modern-day LULC within the Noah-MP LSM for the urban domain. Three different urban classes describes the morphology of the cities: COI, HIR, and LIR.
- All WRF-experiments are performed with the multilayer urban canopy model (**sf\_urban\_physics=3**) coupled to the Noah-MP LSM.
- To evaluate the WRF model's sensitivity to the PBL parameterization, two WRF model experiments are performed with the *Bougeault and Lacarrere (1989)* turbulent scheme (**bl\_pbl\_physics=8**) and two with the *Mellor-Yamada-Janjic (1994)* turbulent parameterization (**bl\_pbl\_physics=2**).

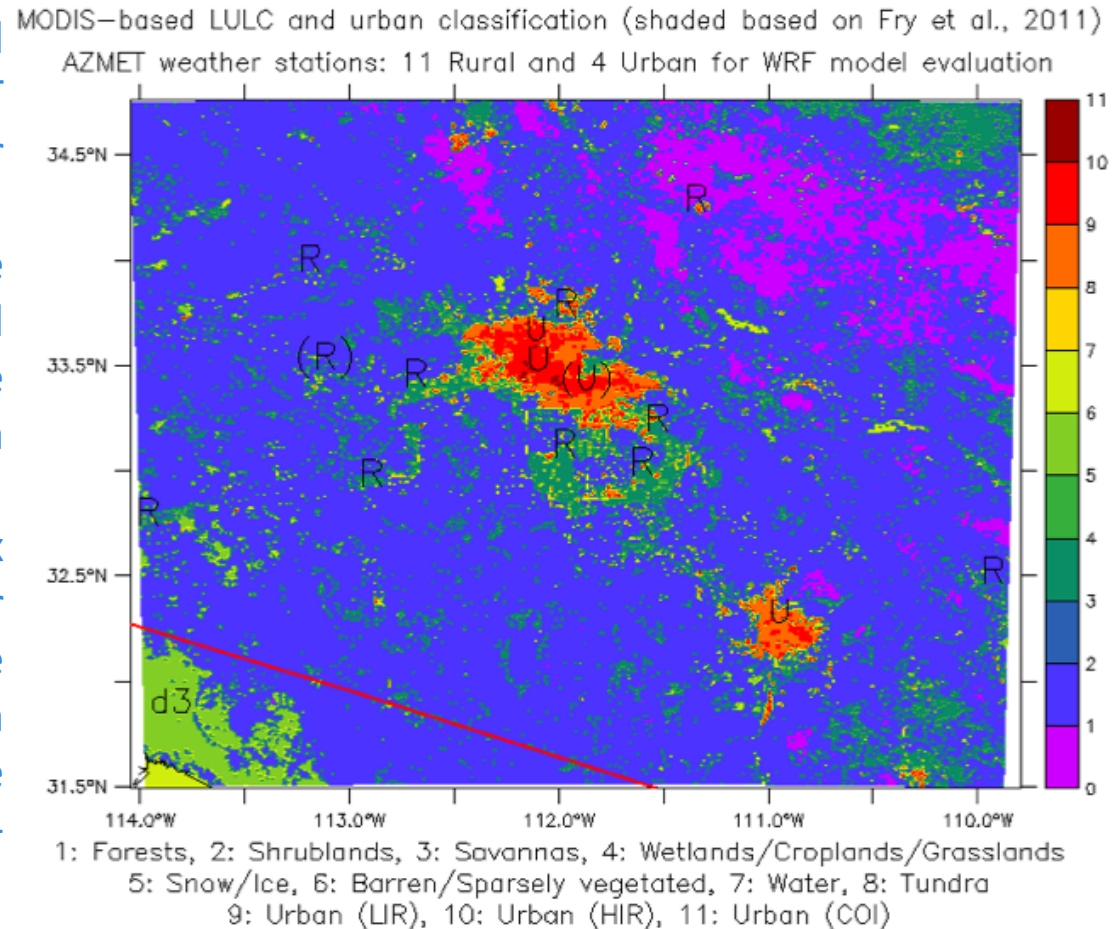
## Summer- and Wintertime Variations of the Surface and Near-Surface UHI

WRF model experiments	Land surface model	Urban parameterization (sf_urban_physics)	Planetary Boundary-Layer scheme (bl_pbl_physics)
MP_PBL2 (summer)	Noah-MP	3	2
MP_PBL2 (winter)	Noah-MP	3	2
MP_PBL8 (summer)	Noah-MP	3	8
MP_PBL8 (winter)	Noah-MP	3	8

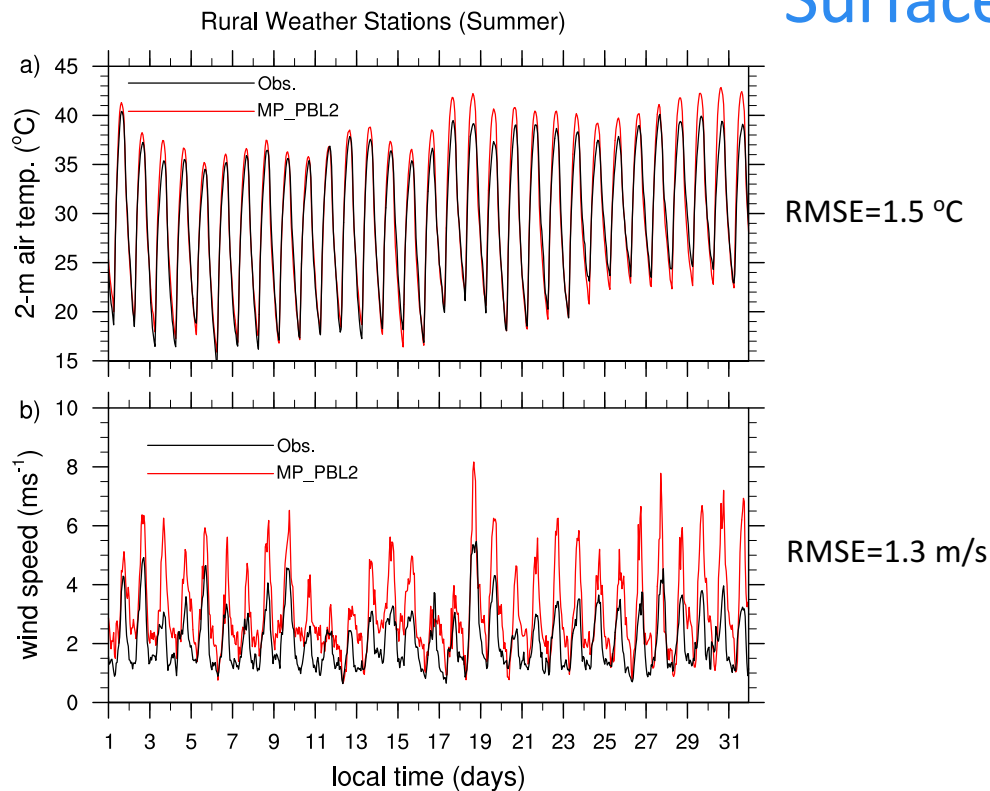


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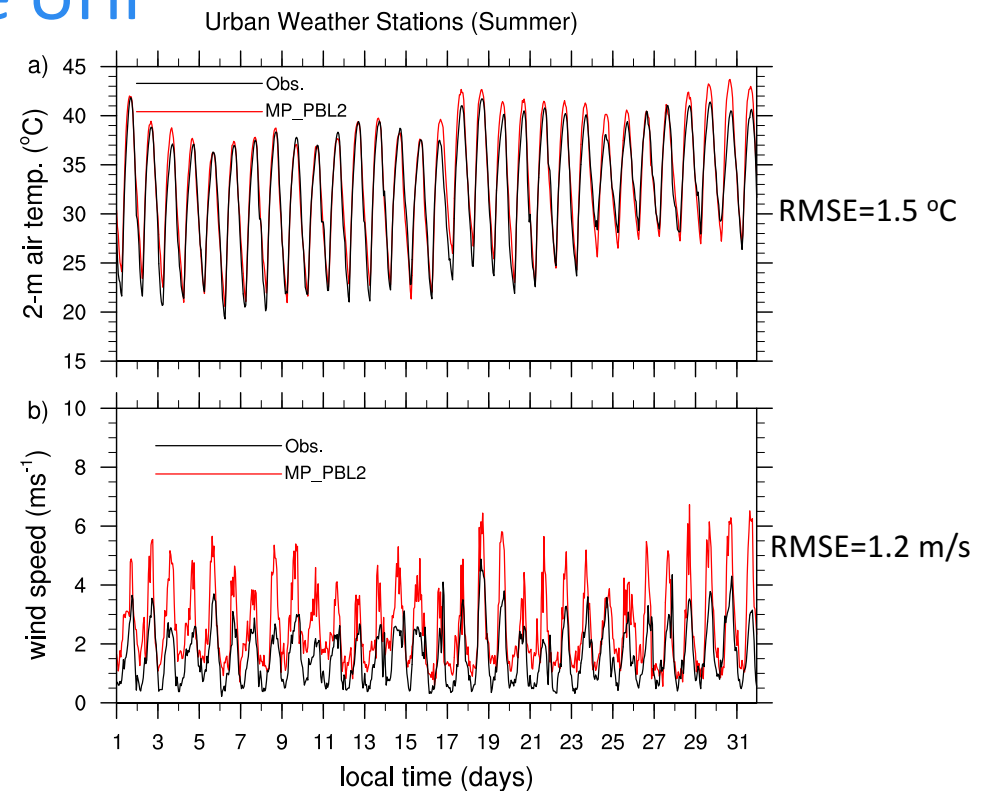
- All WRF model experiments are verified against 11 rural and 4 urban AZMET surface weather stations for air temperature and wind speed.
- WRF-modeled surface skin temperature is compared against daytime and nighttime MODIS land surface temperatures, which are available on a daily basis at 1 km spatial resolution.
- Finally, an urban domain of  $\sim 16.5$  km x 16.5 km surrounding Mesa weather station and a rural domain of the same extension surrounding Harquahala weather station are chosen for the characterization of the surface and near-surface UHI for metro Phoenix.



# Summer- and Wintertime Variations of the Surface and Near-Surface UHI

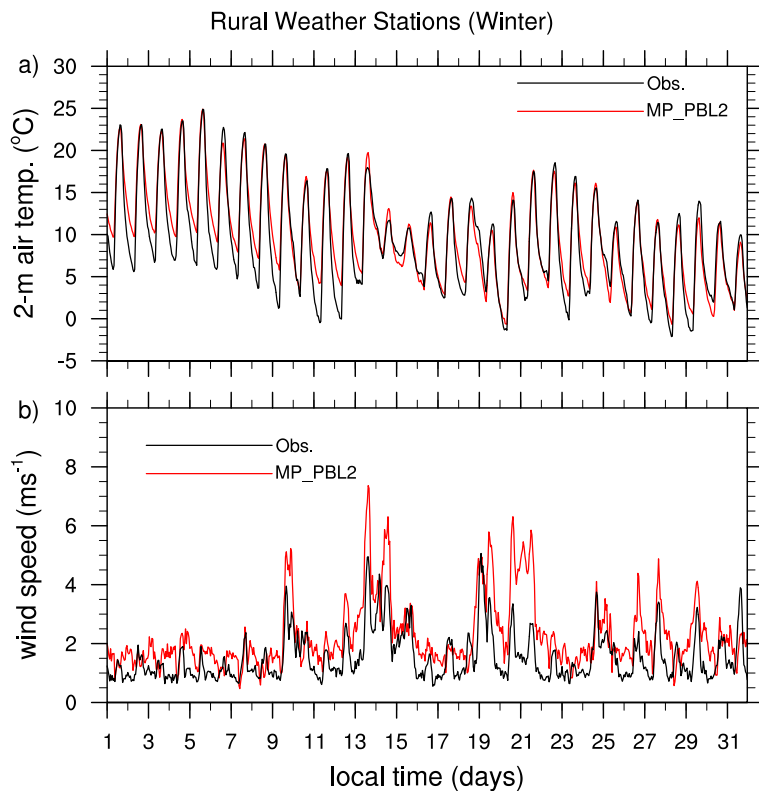


(a) Time series of observed (black) and MP\_PBL2-modeled (red) 2-m air temperature (°C) for the rural stations during a 31-day summertime period in 2012. (b) Same as in (a) but for the 10-m wind speed (m/s)



(a) Time series of observed (black) and MP\_PBL2-modeled (red) 2-m air temperature (°C) for the urban stations during a 31-day summertime period in 2012. (b) Same as in (a) but for the 10-m wind speed (m/s)

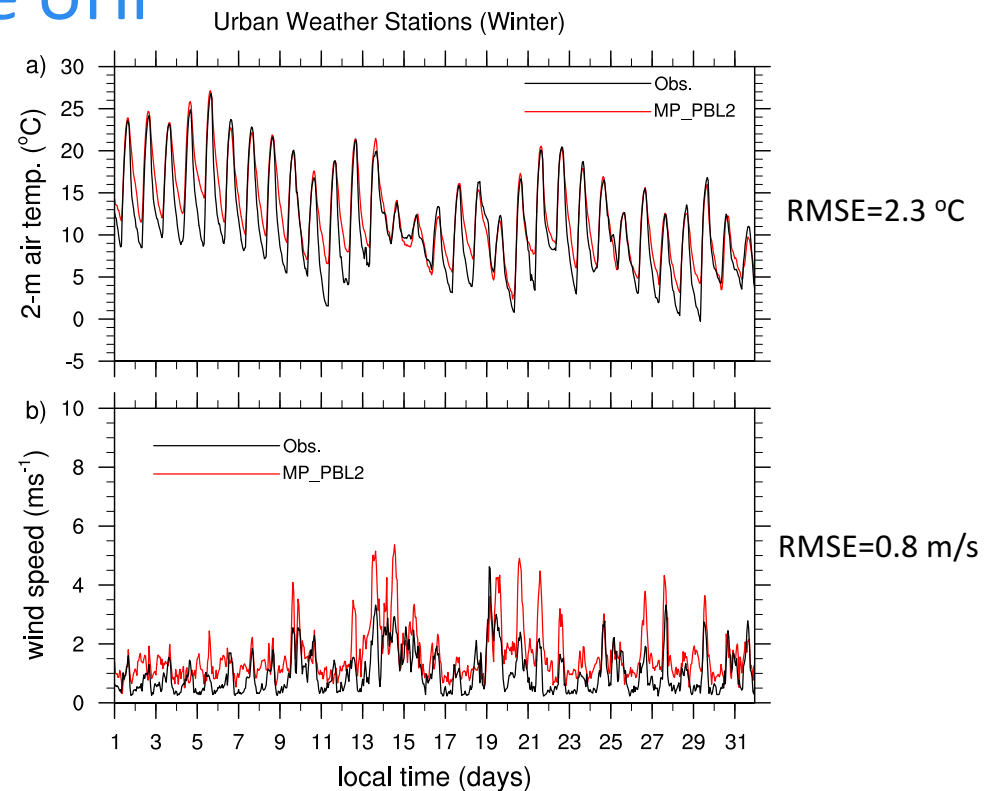
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RMSE=1.9 °C

RMSE=1.1 m/s

(a) Time series of observed (black) and MP\_PBL2-modeled (red) 2-m air temperature (°C) for the rural stations during a 31-day wintertime period in 2012. (b) Same as in (a) but for the 10-m wind speed (m/s)

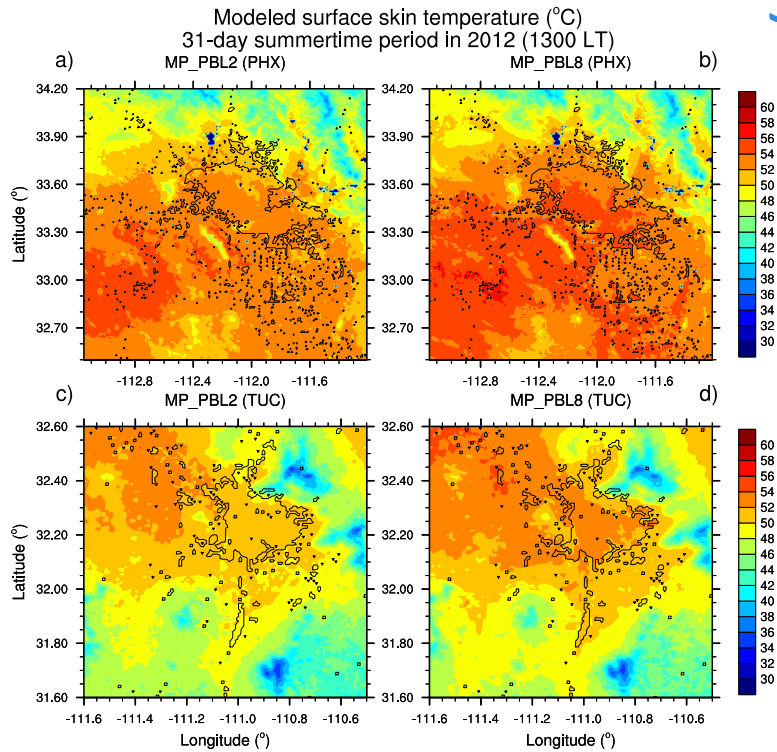


RMSE=2.3 °C

RMSE=0.8 m/s

(a) Time series of observed (black) and MP\_PBL2-modeled (red) 2-m air temperature (°C) for the urban stations during a 31-day wintertime period in 2012. (b) Same as in (a) but for the 10-m wind speed (m/s)

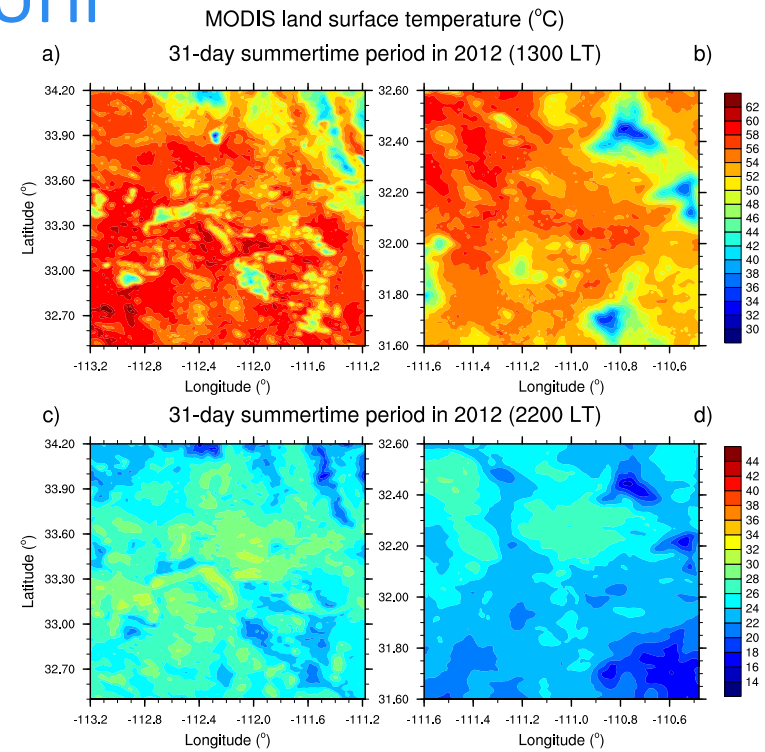
# Summer- and Wintertime Variations of the Surface and Near-Surface UHI



MP\_PBL2

MP\_PBL8

(a-b) MP\_PBL2 (left) and MP\_PBL8 (right) WRF-modeled mean surface skin temperature (°C) averaged for the entire 31-day summertime period (at 1300 LT) in 2012 and across the Phoenix region. (c-d) Same as in (a-b) but across the Tucson region.

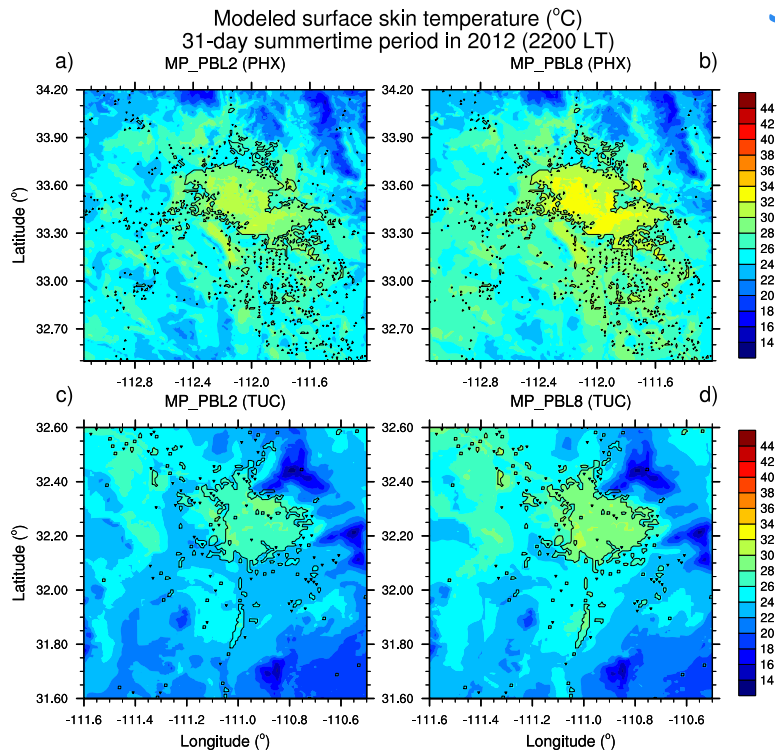


Phoenix

Tucson

(a-b) Daytime MODIS/Aqua land surface temperature (°C) averaged for the entire 31-day summertime period and across the Phoenix (left) and Tucson (right) regions. (c-d) Same as in (a-b) but for the nighttime MODIS/Terra land surface temperature (°C).

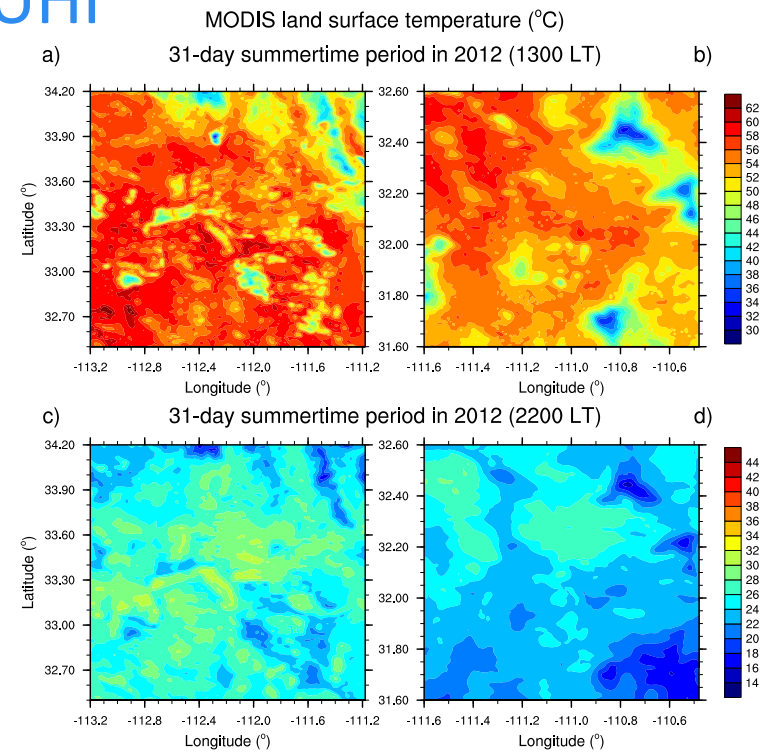
# Summer- and Wintertime Variations of the Surface and Near-Surface UHI



MP\_PBL2

MP\_PBL8

(a-b) MP\_PBL2 (left) and MP\_PBL8 (right) WRF-modeled mean surface skin temperature (°C) averaged for the entire 31-day summertime period (at 2200 LT) in 2012 and across the Phoenix region. (c-d) Same as in (a-b) but across the Tucson region.



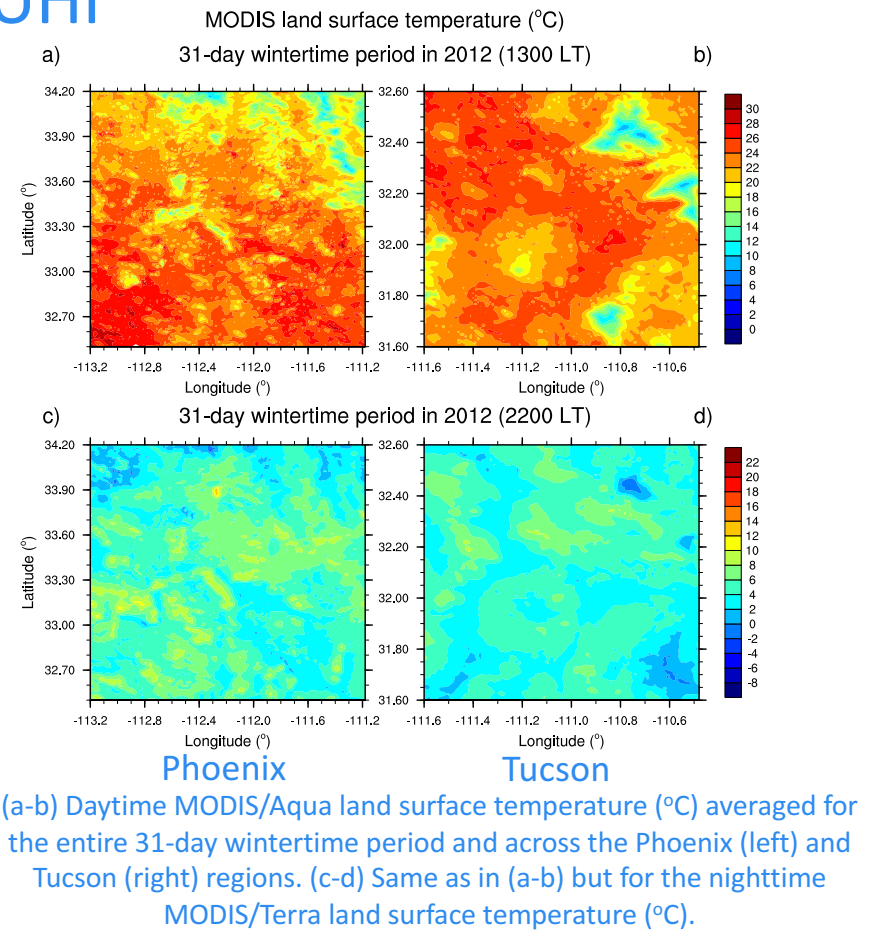
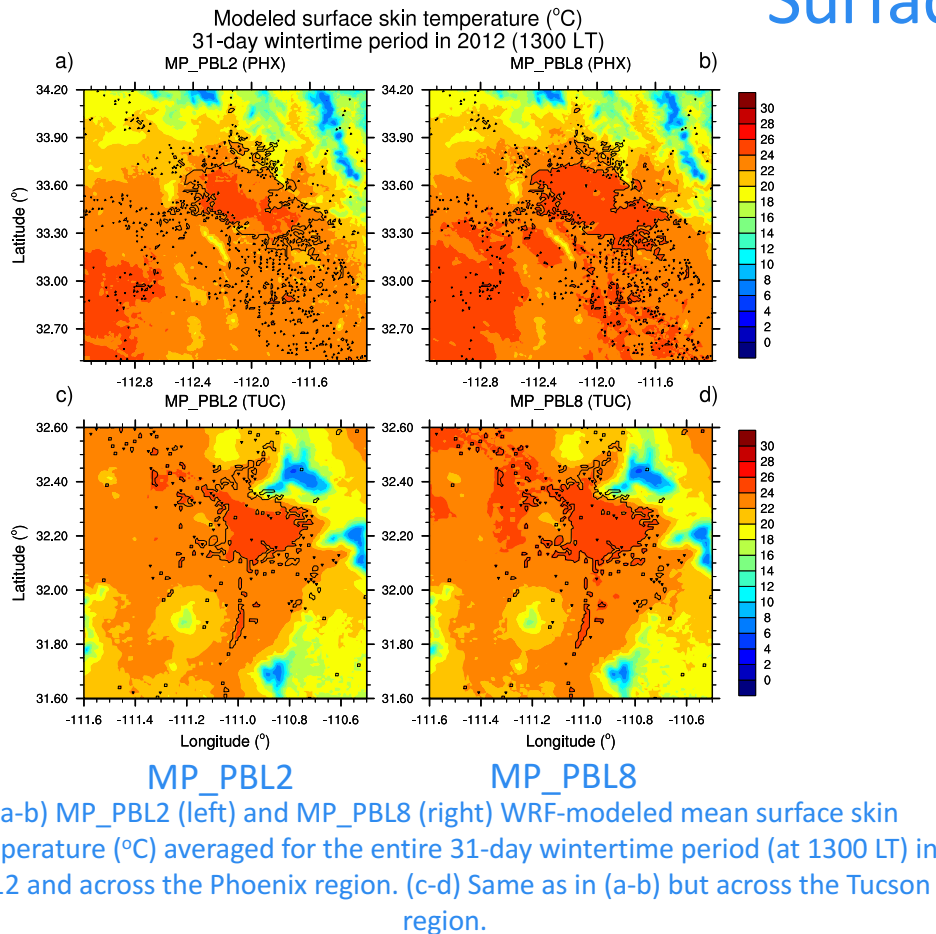
Phoenix

Tucson

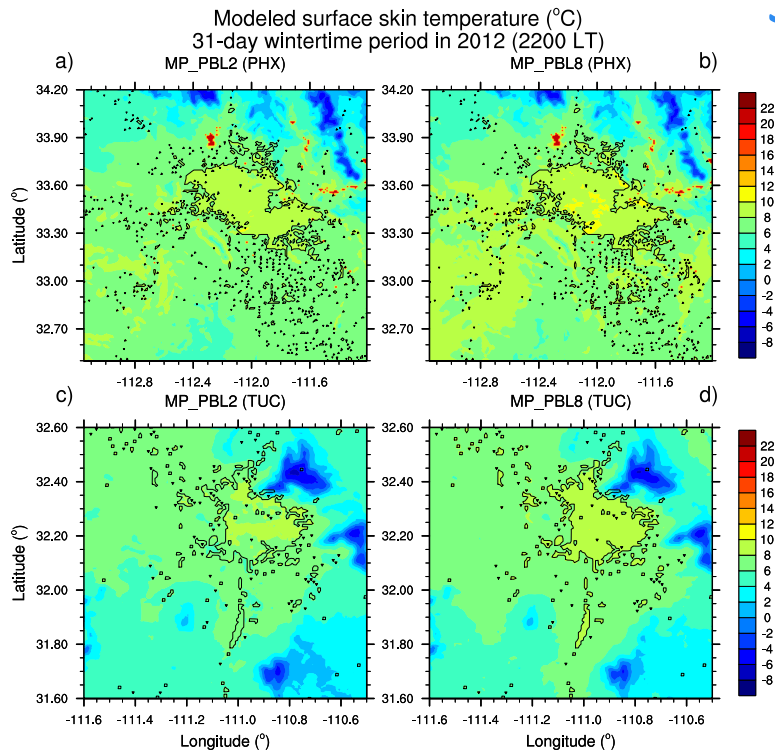
(a-b) Daytime MODIS/Aqua land surface temperature (°C) averaged for the entire 31-day summertime period and across the Phoenix (left) and Tucson (right) regions. (c-d) Same as in (a-b) but for the nighttime MODIS/Terra land surface temperature (°C).



# Summer- and Wintertime Variations of the Surface and Near-Surface UHI



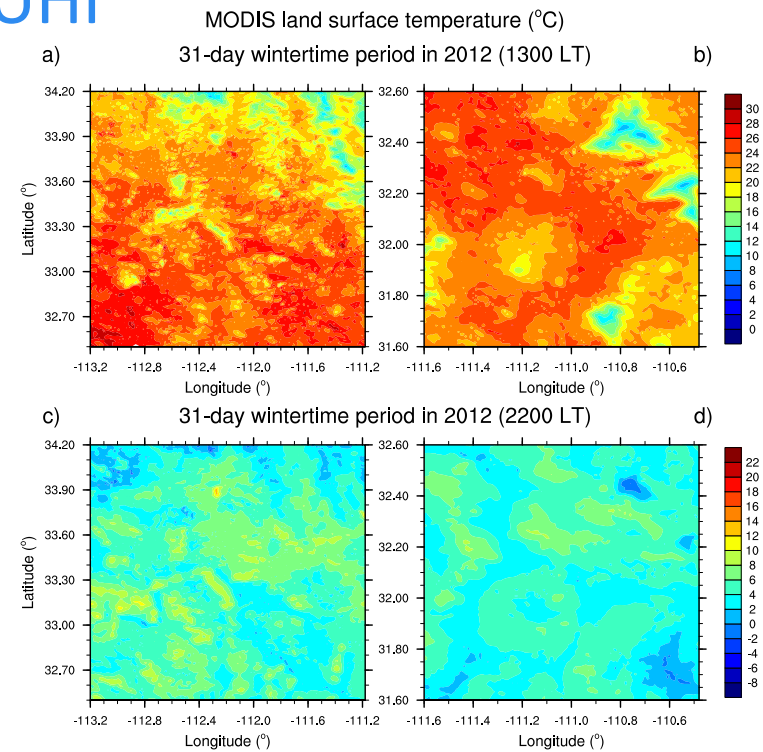
# Summer- and Wintertime Variations of the Surface and Near-Surface UHI



MP\_PBL2

MP\_PBL8

(a-b) MP\_PBL2 (left) and MP\_PBL8 (right) WRF-modeled mean surface skin temperature (°C) averaged for the entire 31-day wintertime period (at 2200 LT) in 2012 and across the Phoenix region. (c-d) Same as in (a-b) but across the Tucson region.



Phoenix

Tucson

(a-b) Daytime MODIS/Aqua land surface temperature (°C) averaged for the entire 31-day wintertime period and across the Phoenix (left) and Tucson (right) regions. (c-d) Same as in (a-b) but for the nighttime MODIS/Terra land surface temperature (°C).

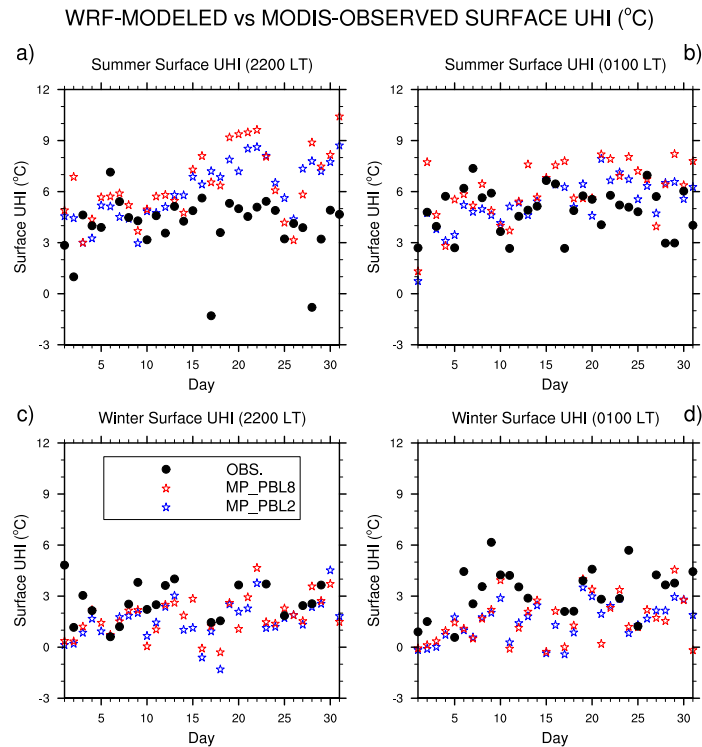
# Summer and Wintertime Variations of the Surface and Near-Surface UHI

Spatial mean of daytime and nighttime MODIS-observed and WRF-modeled land surface temperature (°C) averaged for the entire 31-day summer- and 31-day wintertime periods and across the Phoenix (PHX) and Tucson (TUC) regions

WRF-experiments	PHX (°C) 1100 LT	TUC (°C) 1100 LT	PHX (°C) 1300 LT	TUC (°C) 1300 LT	PHX (°C) 2200 LT	TUC (°C) 2200 LT	PHX (°C) 0100 LT	TUC (°C) 0100 LT
MP_PBL2 (summer)	47.807	45.594	51.150	48.456	25.379	23.184	21.573	19.207
MP_PBL8 (summer)	48.653	46.252	52.096	49.428	26.437	24.094	22.445	19.899
<b>MODIS (summer)</b>	<b>51.664</b>	<b>49.417</b>	<b>55.166</b>	<b>53.068</b>	<b>26.118</b>	<b>23.355</b>	<b>22.118</b>	<b>19.637</b>
MP_PBL2 (winter)	17.050	17.100	21.547	21.283	6.547	5.227	5.362	3.999
MP_PBL8 (winter)	17.812	17.690	22.317	21.699	7.173	5.883	5.958	4.689
<b>MODIS (winter)</b>	<b>19.945</b>	<b>18.958</b>	<b>22.636</b>	<b>22.673</b>	<b>5.070</b>	<b>4.305</b>	<b>3.371</b>	<b>2.645</b>



# Summer- and Wintertime Variations of the Surface and Near-Surface UHI



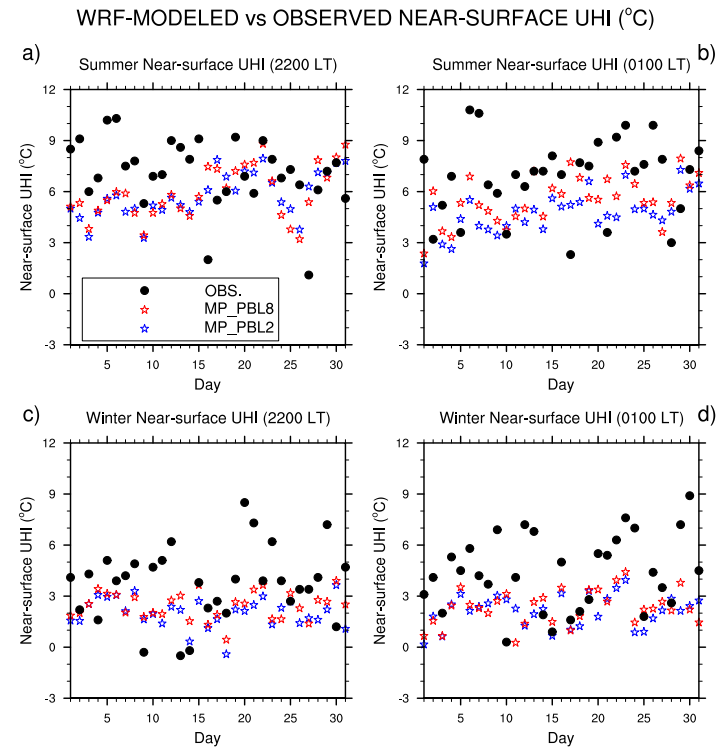
**Table.** 31-day Mean Nighttime MODIS-observed and WRF-modeled Surface UHI (°C) for the Phoenix metropolitan area during the summer- and wintertime periods.

WRF-experiments	Summer (2200 LT)	Summer (0100 LT)	Winter (2200 LT)	Winter (0100 LT)
MP_PBL2	6.044	5.363	1.567	1.546
MP_PBL8	6.479	6.070	1.801	1.616
MODIS	4.022	4.887	2.628	3.305

(a-b) Daily variations of nighttime MODIS-observed and WRF-modeled Surface UHI (°C) for the Phoenix metropolitan area during the 31-day summertime period.

(c-d) Same as in (a-b) but for the 31-day wintertime period.

# Summer- and Wintertime Variations of the Surface and Near-Surface UHI



**Table.** 31-day Mean Nighttime AZMET-observed and WRF-modeled Near-surface UHI (°C) for the Phoenix metropolitan area during the summer- and wintertime periods.

WRF-experiments	Summer (2200 LT)	Summer (0100 LT)	Winter (2200 LT)	Winter (0100 LT)
MP_PBL2	5.795	4.770	2.052	2.155
MP_PBL8	5.930	5.579	2.463	2.360
AZMET	7.116	6.845	3.761	4.419

(a-b) Daily variations of nighttime AZMET-observed and WRF-modeled Near-surface UHI (°C) for the Phoenix metropolitan area during the 31-day summertime period. (c-d) Same as in (a-b) but for the 31-day wintertime period.

# Conclusions:

- 1) The Surface UHI is found to be higher at night and during the warm season.
- 2) The morning Surface UHI is low and frequently exhibits an Urban Cool Island that increases during the summertime period.
- 3) The Near-surface UHI is higher at night and during summertime.
- 4) The morning Near-surface UHI is low but rarely exhibits an Urban Cool Island.
- 5) WRF (coupled to Noah-MP) model tends to slightly underestimate surface skin temperature during daytime but overestimate nighttime values during wintertime
- 6) WRF (coupled to Noah-MP) model tends to accurately reproduce the diurnal cycle of near-surface air temperature and wind speed during summertime, but overestimate near-surface nighttime temperature during wintertime.

# Summer- and Wintertime Variations of the Surface and Near-surface UHI over a Semiarid Environment

Thank you for your attention !!!