Influence of urban land cover on Mexico City's meteorological conditions.

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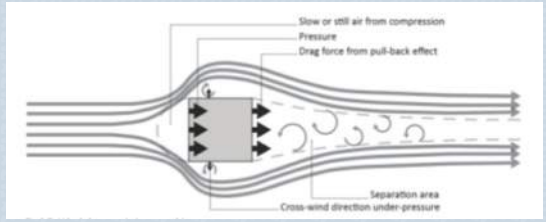
Urban effects on the airflow

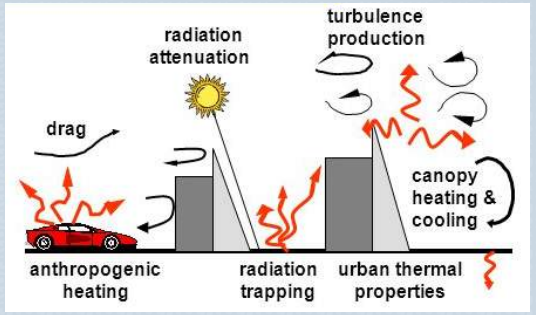
Mechanical

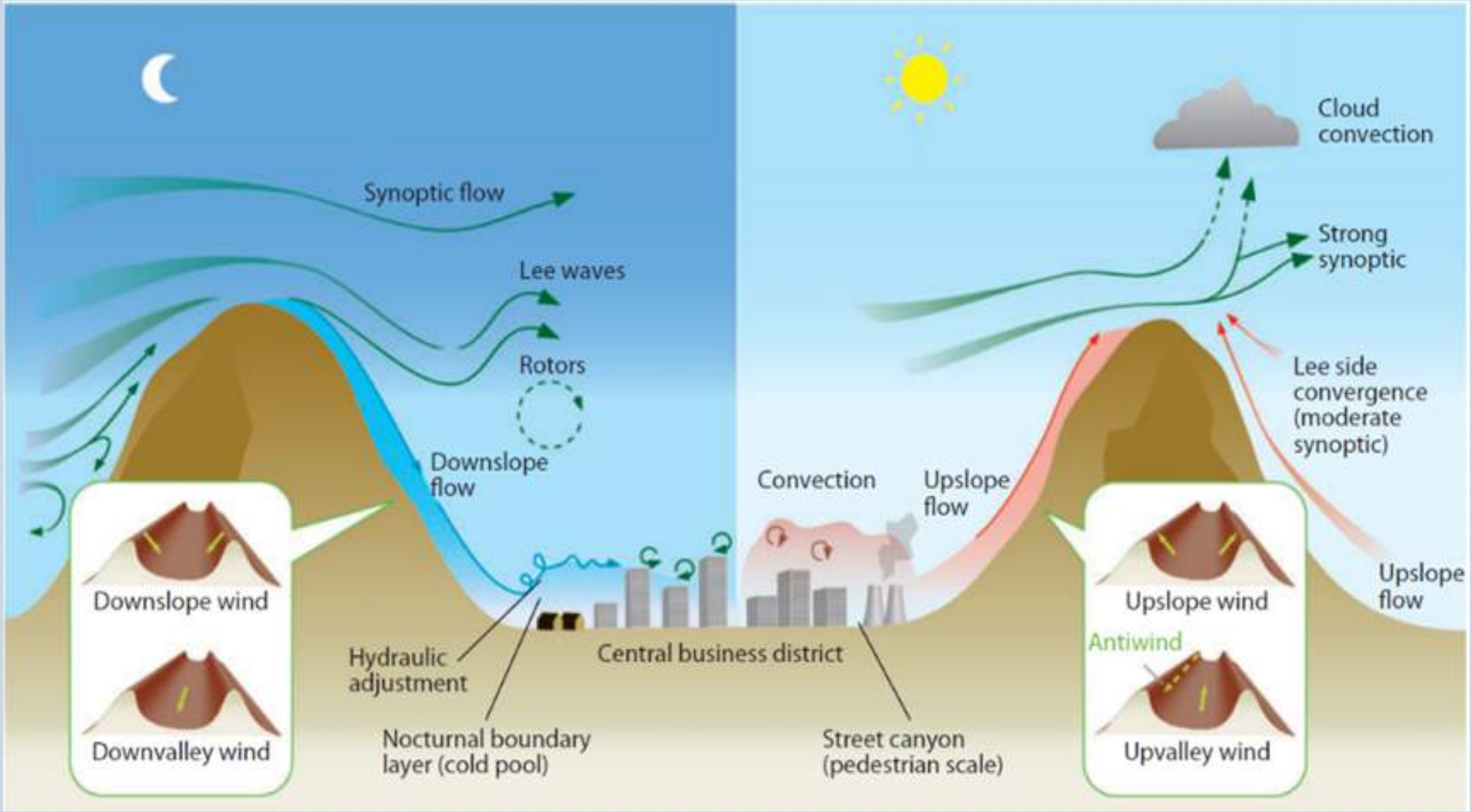
- Drag force induced by the presence of buildings with consequent loss of momentum.
- Buildings also increase energy transfer.
- The mean kinetic energy of the flow is converted into turbulent kinetic energy (TKE).



Thermal

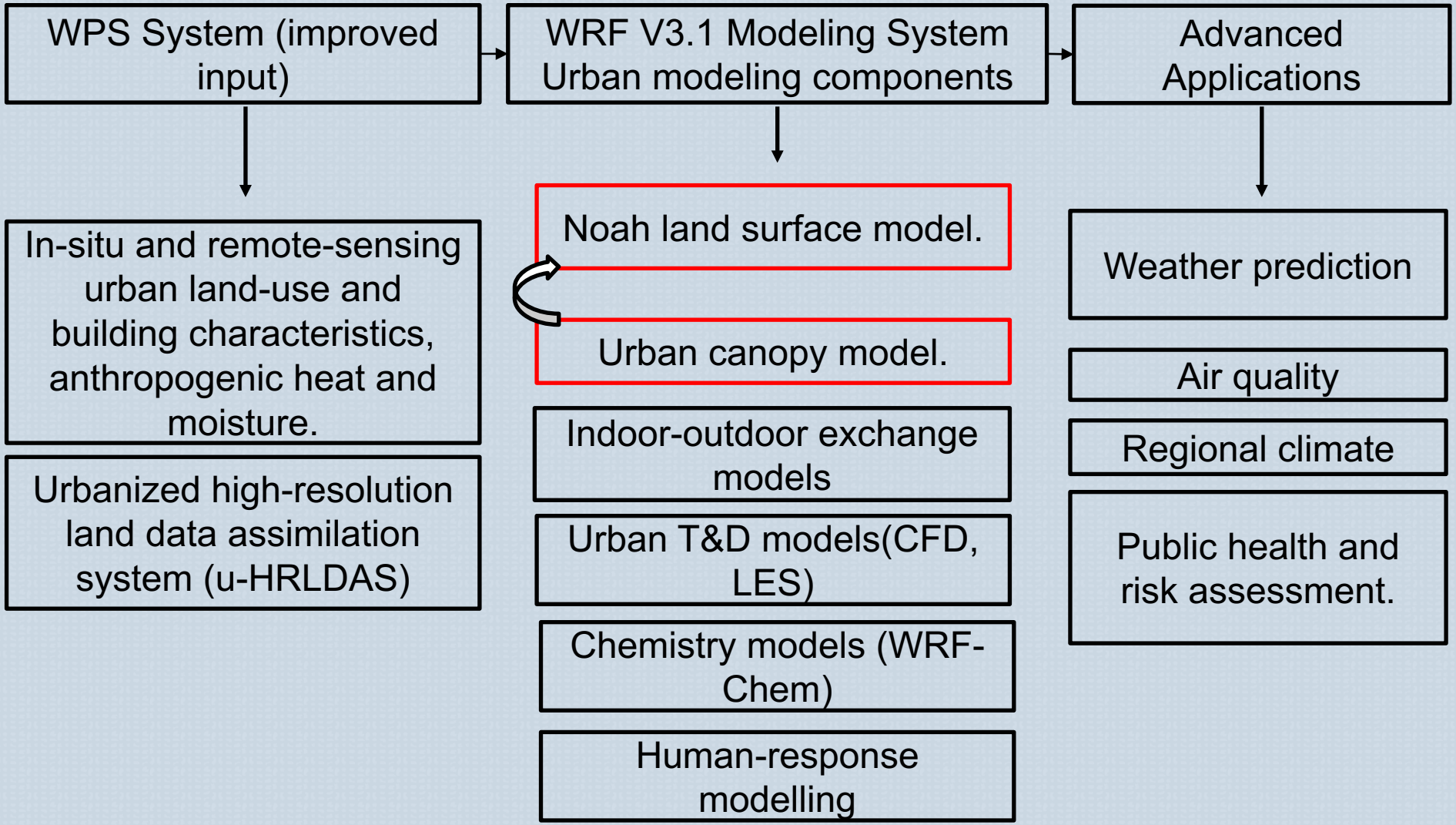
- Differential heating or cooling of sunlit or shaded surfaces respectively.
- Radiation trapping effects in street canyons and heat storage in buildings.
- Urban heat island (UHI) effect.



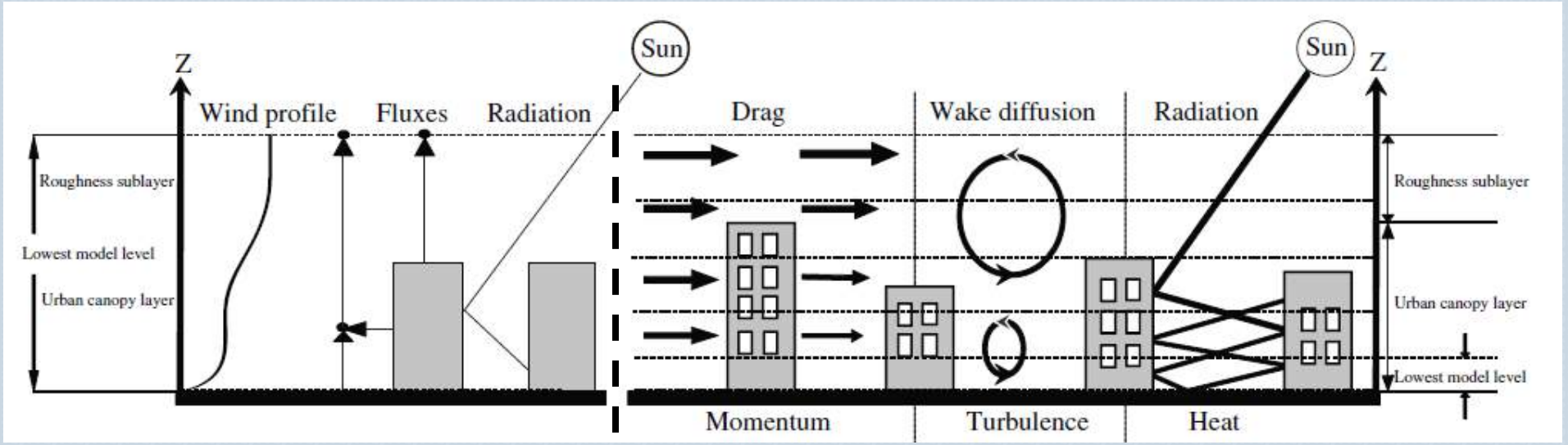


Source: Fernando (2010).

Integrated WRF/Urban Cross-scale modeling framework.



Urban Canopy Model (UCM)



Single layer urban-canopy model (SLUCM, based in Kusaka 2001). Released in WRF V2.2 (Dic. 2006).

Multi-layer UCM (**Building Effect Parameterization, BEP**) by Martilli et al. (2002). Released in WRF V3.1 (Abril 2009).

$$\vec{F}u_{IU}^{V} = -\rho C_{\text{drag}} |U_{IU}^{\text{ort}}| \vec{U}_{IU}^{\text{ort}} S_{IU}^{V},$$

$\vec{U}_{IU}^{ort}$: wind speed orthogonal to the street direction

S_{IU}^{V} : total area of vertical surfaces

C_{drag} : 0.4 (Raupach (1992))

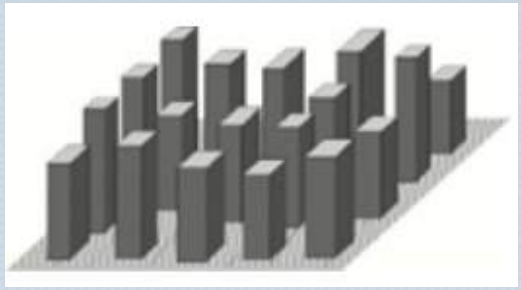
Urban land cover data

World Urban Database and Access Portal Tools (WUDAPT)

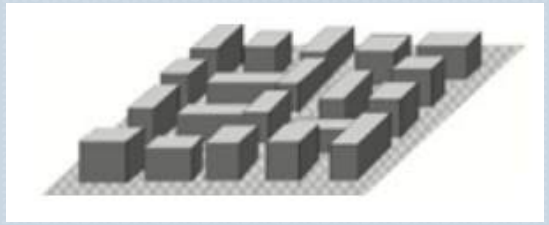
- Use the **Local Climate Zone (LCZ)** classification framework.
- Use Geo-Wiki to sample land cover and land use types across LCZs.
- Develop tools (online and mobile-based) to obtain other parameters such as building materials, building dimensions, canopy widths, etc.
- Provide open access to this dataset so that researchers around the world can use the data for many different types of applications, from climate and weather modeling to energy balance studies.

Urban Climates Zones (UCZ)

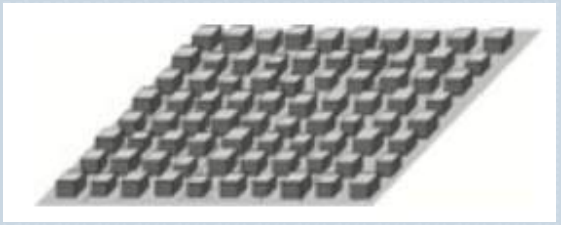
LCZ 1: Compact high-rise



LCZ 2: Compact mid-rise



LCZ 3: Compact low-rise

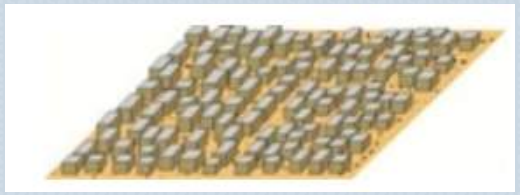


LCZ 4: Open high-rise

LCZ 5: Open mid-rise

LCZ 6: Open low-rise

LCZ 7: Lightweight low-rise

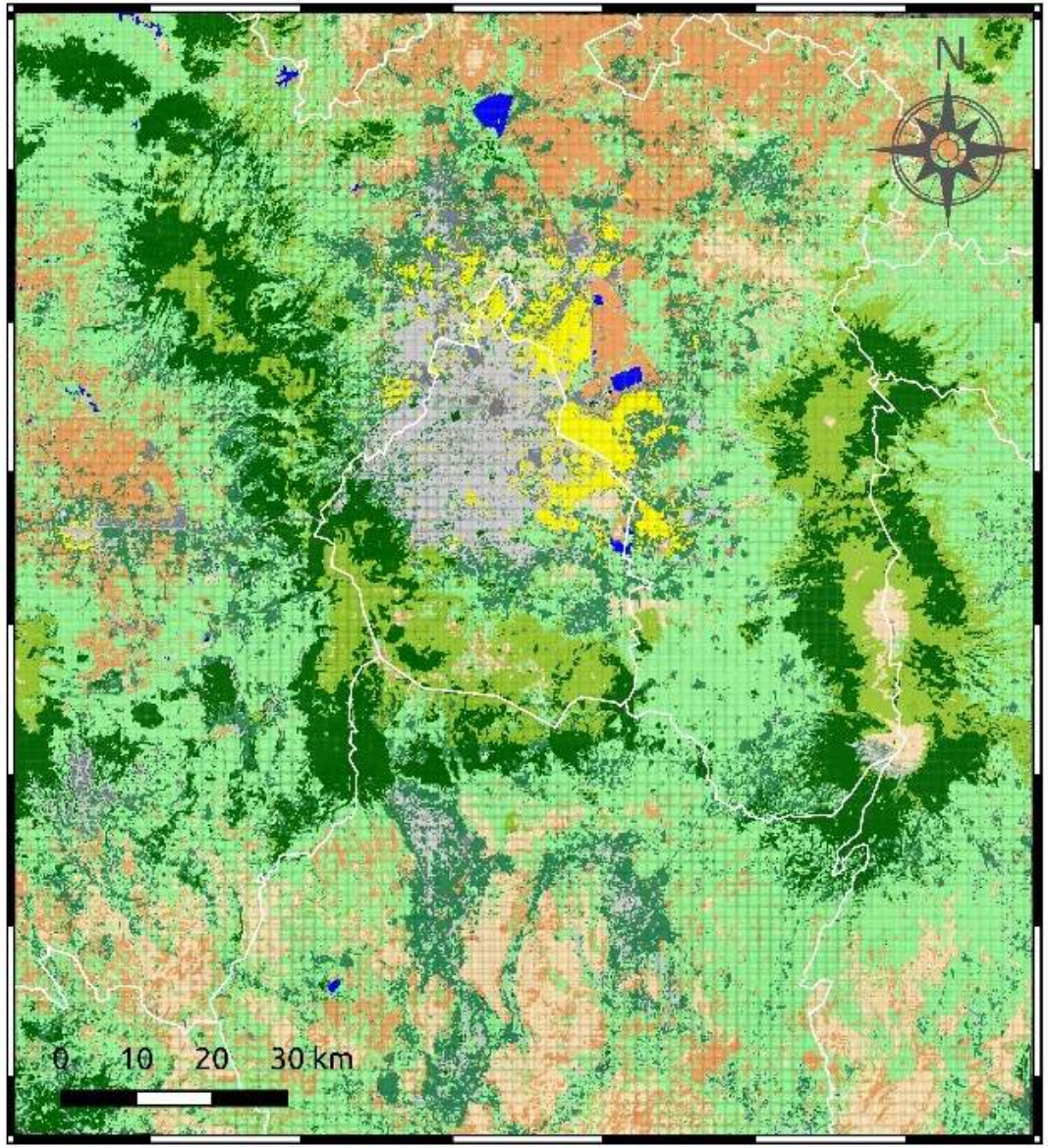


LCZ 8: Large low-rise

LCZ 9: Sparsely built

LCZ 10: Heavy industry

Mexico City land cover map by WUDAPT.



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LCZ Classification:

- 1. Compact high-rise
- 2. Compact midrise
- 3. Compact low-rise
- 4. Open high-rise
- 5. Open midrise
- 6. Open low-rise
- 7. Lightweight low-rise
- 8. Large low-rise
- 9. Sparsely built
- 10. Heavy industry
- A. Dense trees
- B. Scattered trees
- C. Bush, scrub
- D. Low plants
- E. Bare rock or paved
- F. Bare soil or sand
- G. Water

Google Satellite

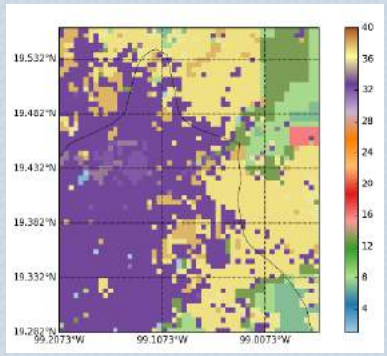
Research Goal

Implement the WUDAPT urban land cover classifications in the WRF/urban modeling system in order to simulate meteorological conditions of Mexico City.

Scheme for using WUDAPT in multi-layer urban canopy versions of WRF.

LCZ map obtained by WUDAPT 120m resolution.

- Fortran(close pixel value)



Land use of CDMX in WPS

New Land use Index in WPS (500m resolution).

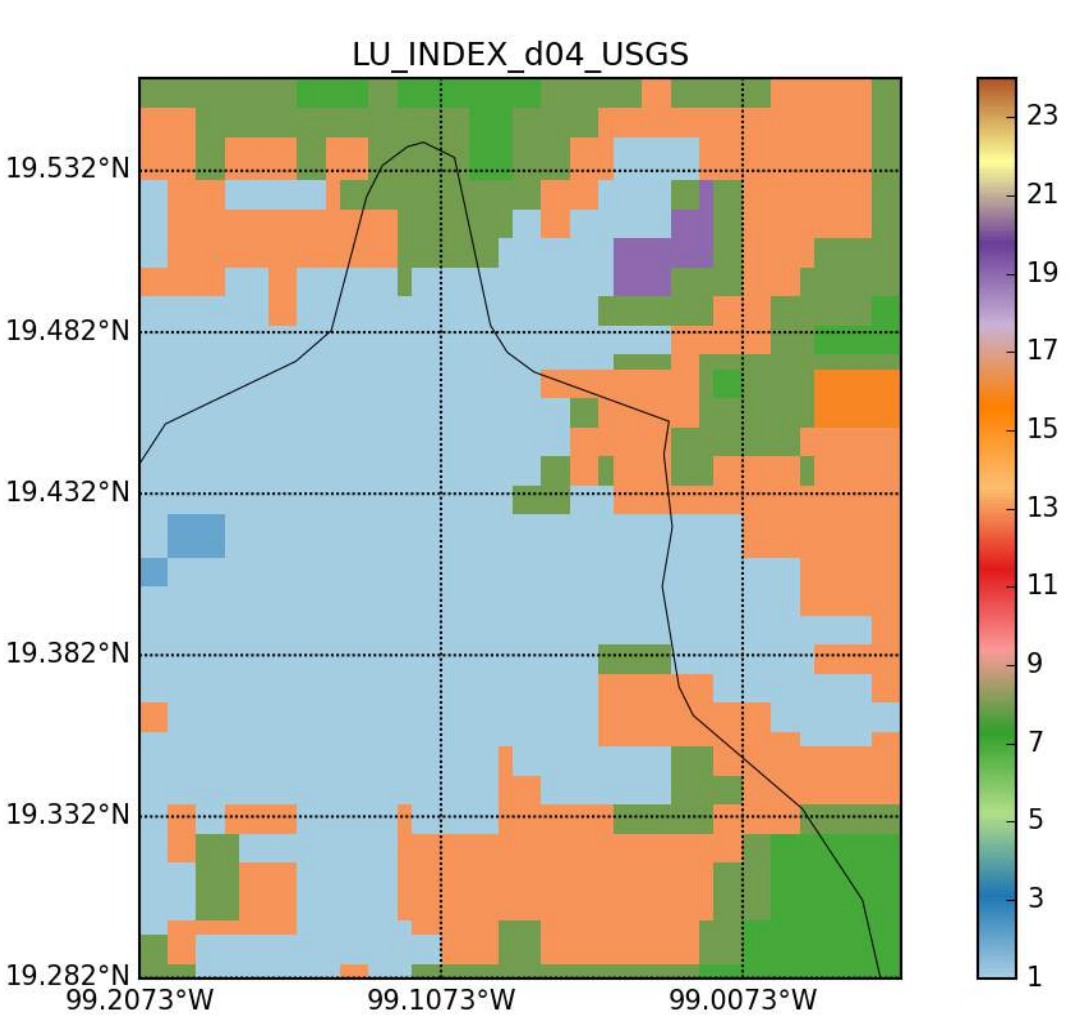
- LCZ values are from 31 to 40(31=LCZ1)

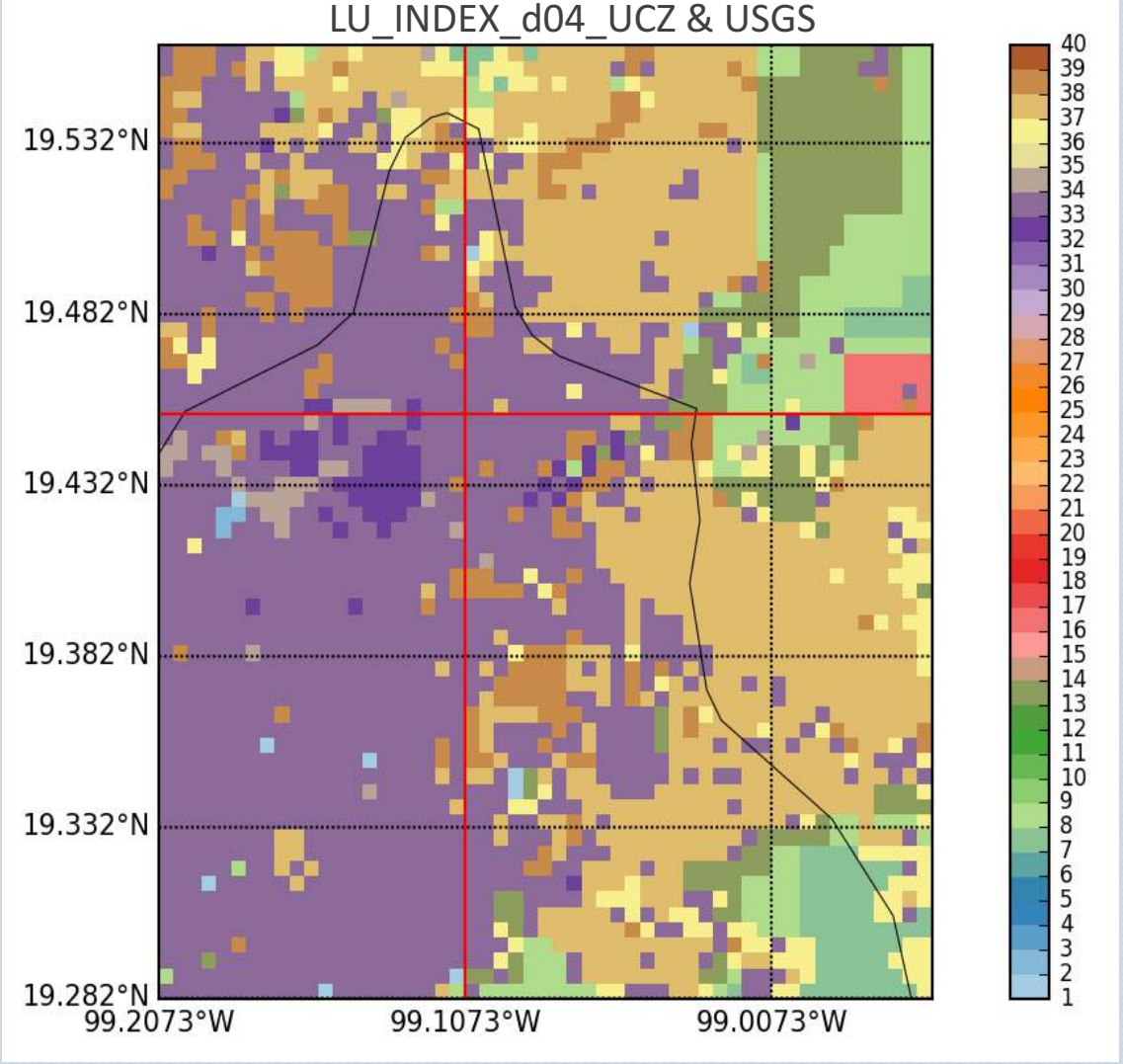
URBPARM.TBL

- Using (Stewart & Oke, 2012) supplement for urban fraction, buildings & roads width and height.
- Using (Stewart & Oke, 2014) for building &roads heat capacity and thermal conductivity.

Running WRF model.

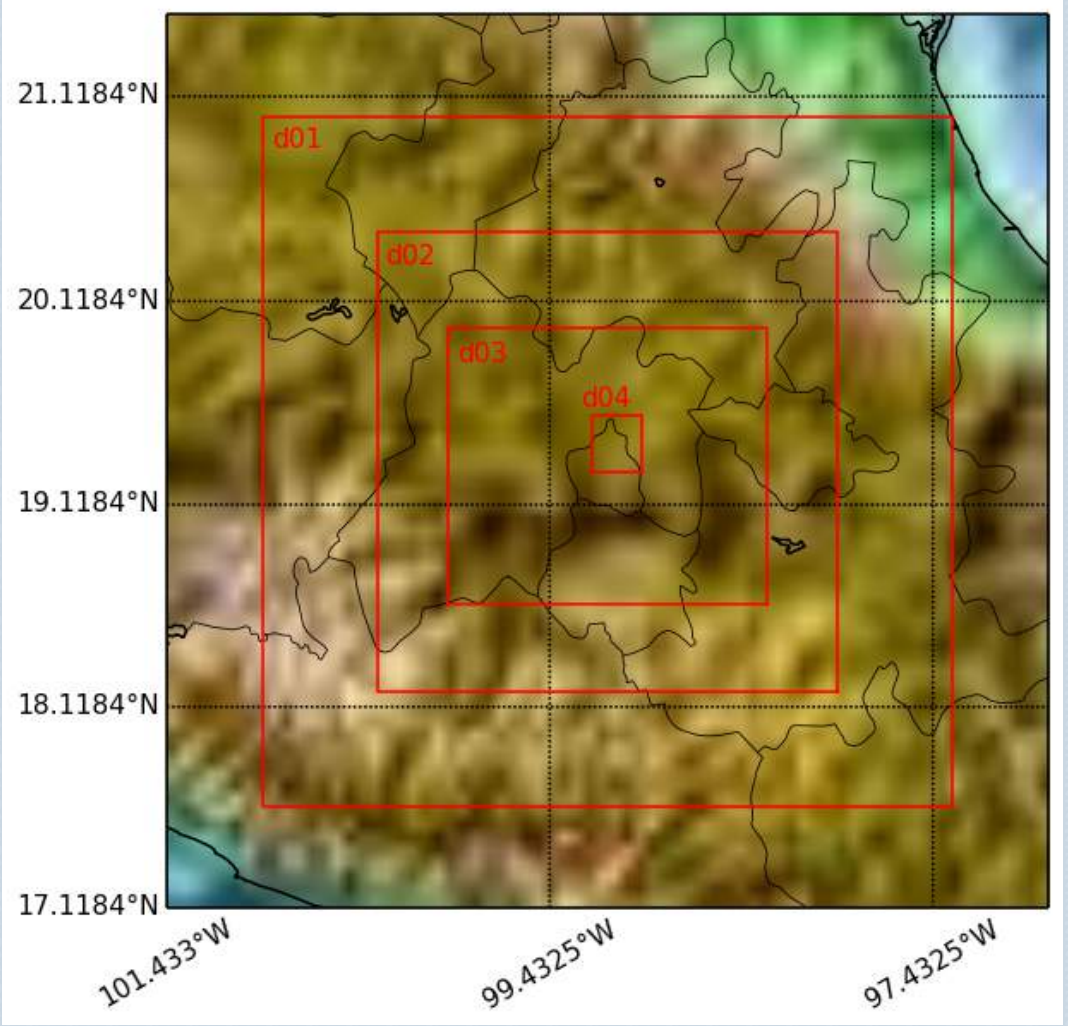
Land cover changes





Model Configuration

- WRF-ARW V3.2 coupled with:
  - Noah LSM / Multi-layer BEP UCM
- 4 nested domains (19.327 º N - 99.131 º W):
  - **Domain 4:** 0.5km resolution and 55 x 64 points of grid.
- **Projection**: Mercator.
- 51 verticals levels.
- **Boundary and initial conditions**: *GFS-ANL* with 1 x 1 grade of resolution every 6 hours.



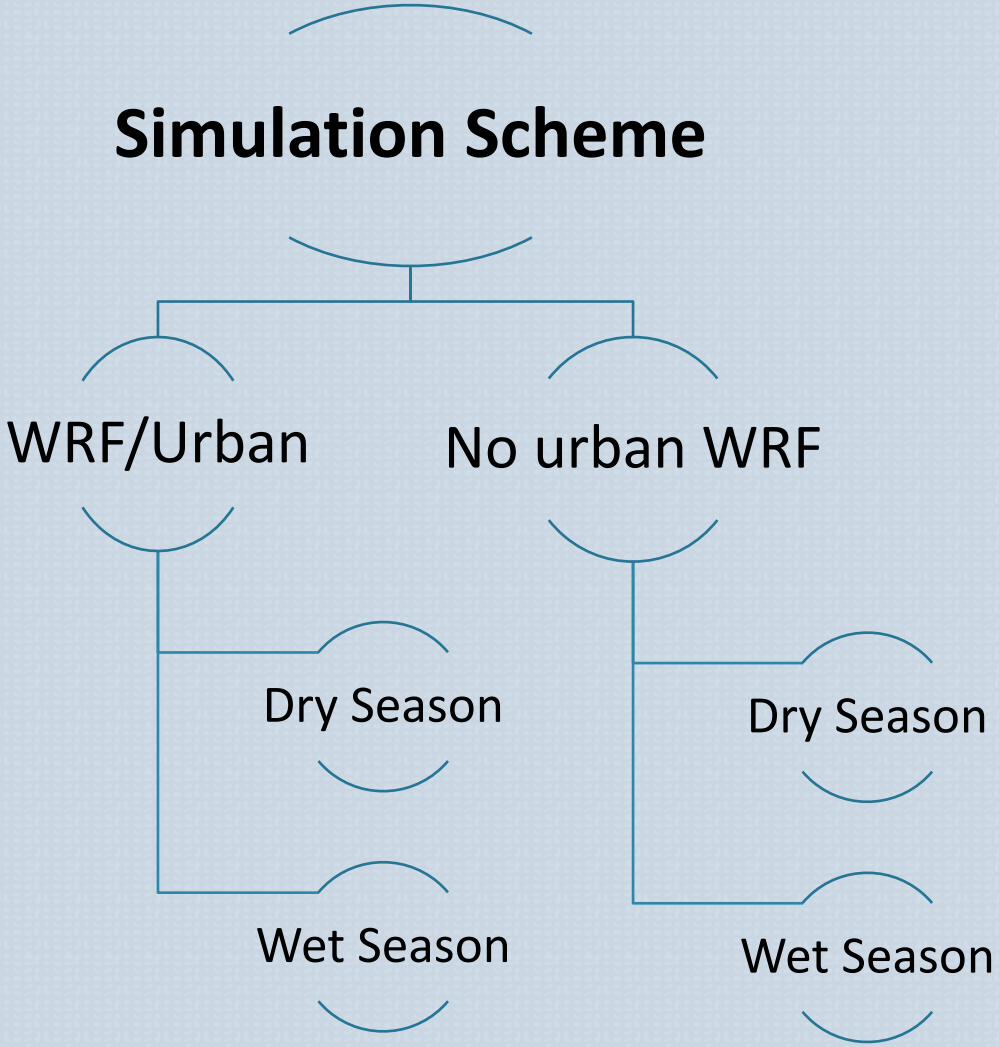
Model Configuration

- 51 verticals levels

- **Parametrizations**:
  - **Microphysics:** *WSM 6 – class* (Hong & Lim, 2006).
  - **Short/large wave radiation:** *RRTM* (Mlawer, Taubman, Brown, Iacono, & Clough, 1997)/*Dudhia* (Dudhia, 1989).
  - **PBL:** Bougeault–Lacarrere (*BouLac*) (Bougeault & Lacarrere, 1989).

- **Boundary and initial conditions**: *GFS-ANL* with 1 x 1 grade of resolution every 6 hours.

Simulation Scheme



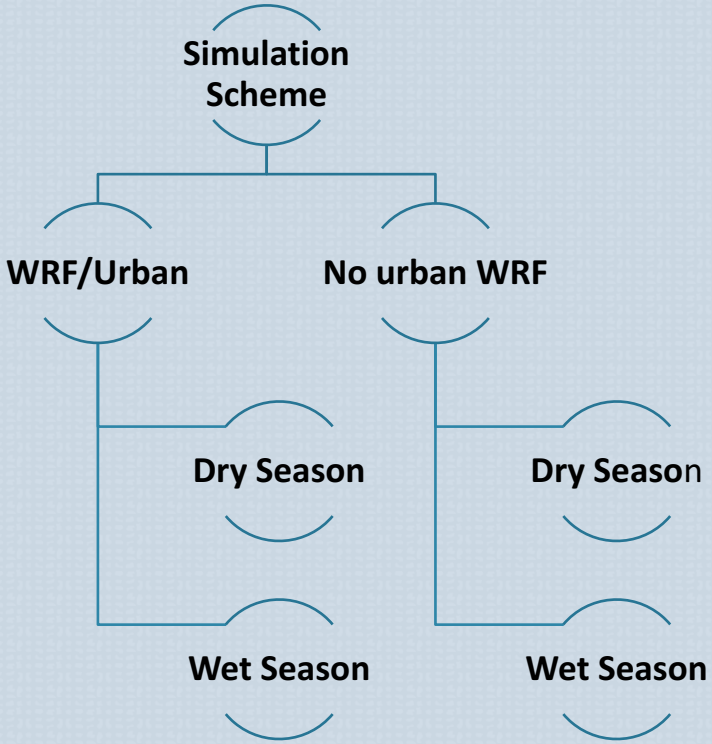
WRF/Urban:
Activated urban parametrization (**BEP UCM**)
No urban WRF:
No activated urban parametrization

Simulations Periods:
21/01/2016 - 23/01/2016 (dry season)
14/08/2016 - 16/08/2016 (wet season)

Results

Variables of interest:

- **Potential temperature**
- **Air temperature**
- **Wind at 10m**
- **PBL height.**



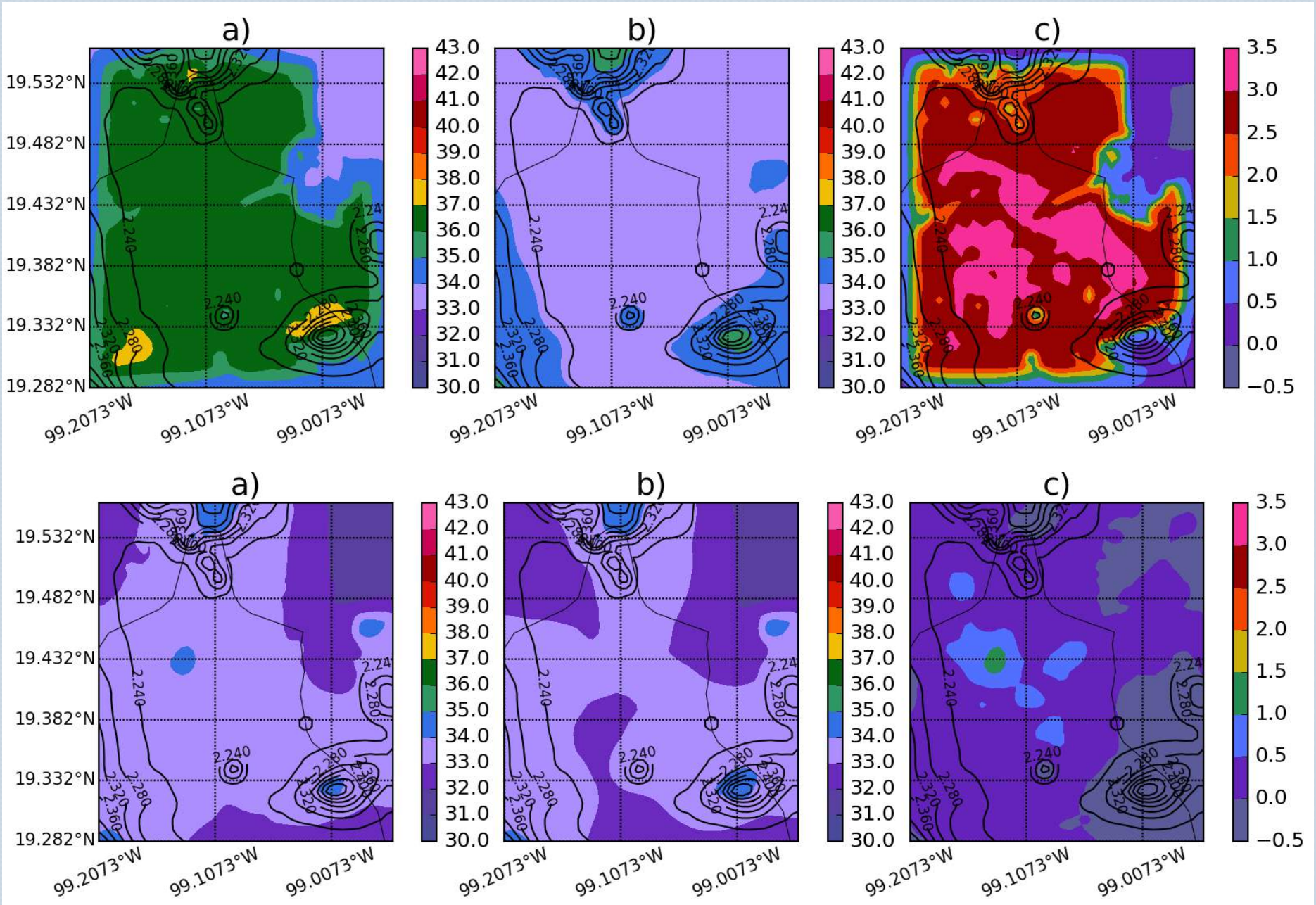
1. Average hourly behavior of variables of interest.
2. Wind speed cross section.
3. Comparison of simulated results with measurements.
4. Statistical evaluation

Average hourly behavior of **potential temperature** in dry season.

Daytime

a) Urban
b) No Urban
c) uWRF - WRF

Night time



Average hourly behavior of **potential temperature** in wet season.

Daytime

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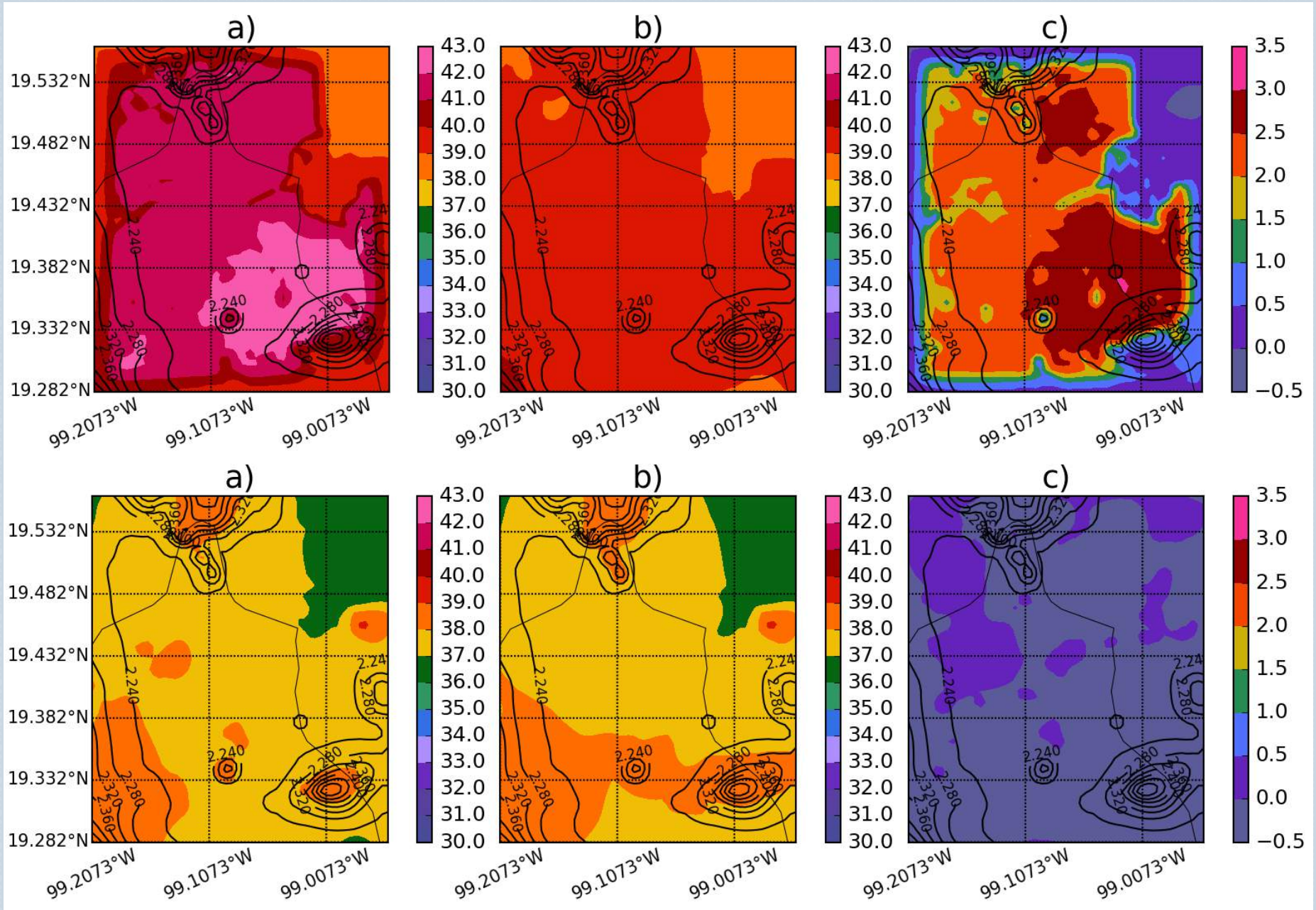
b) No Urban
c) uWRF - WRF

Night time

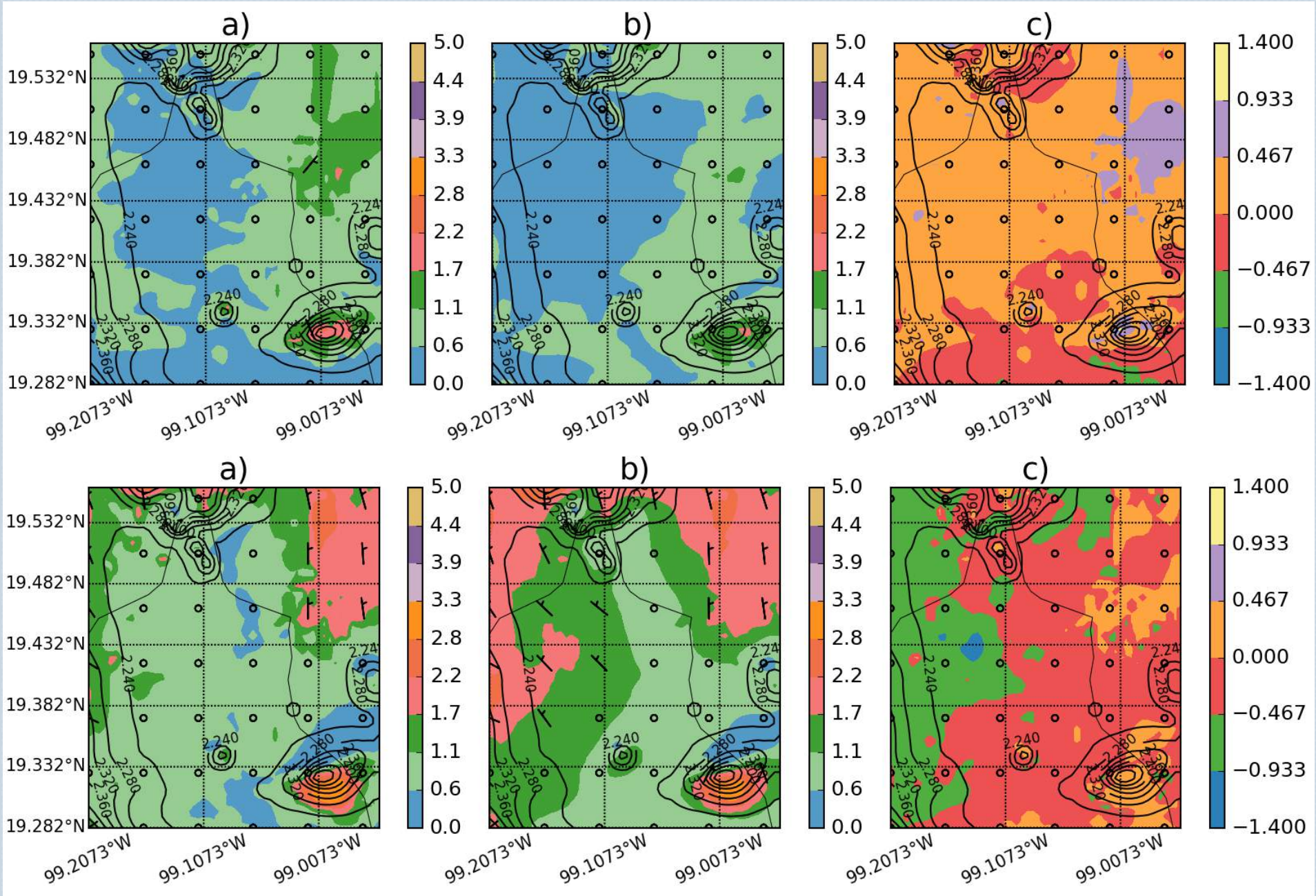


Average hourly behavior of the **wind at 10m** in dry season.

Daytime

a) Urban
b) No Urban
c) uWRF - WRF

Night time



Average hourly behavior of the **wind at 10m** in wet season.

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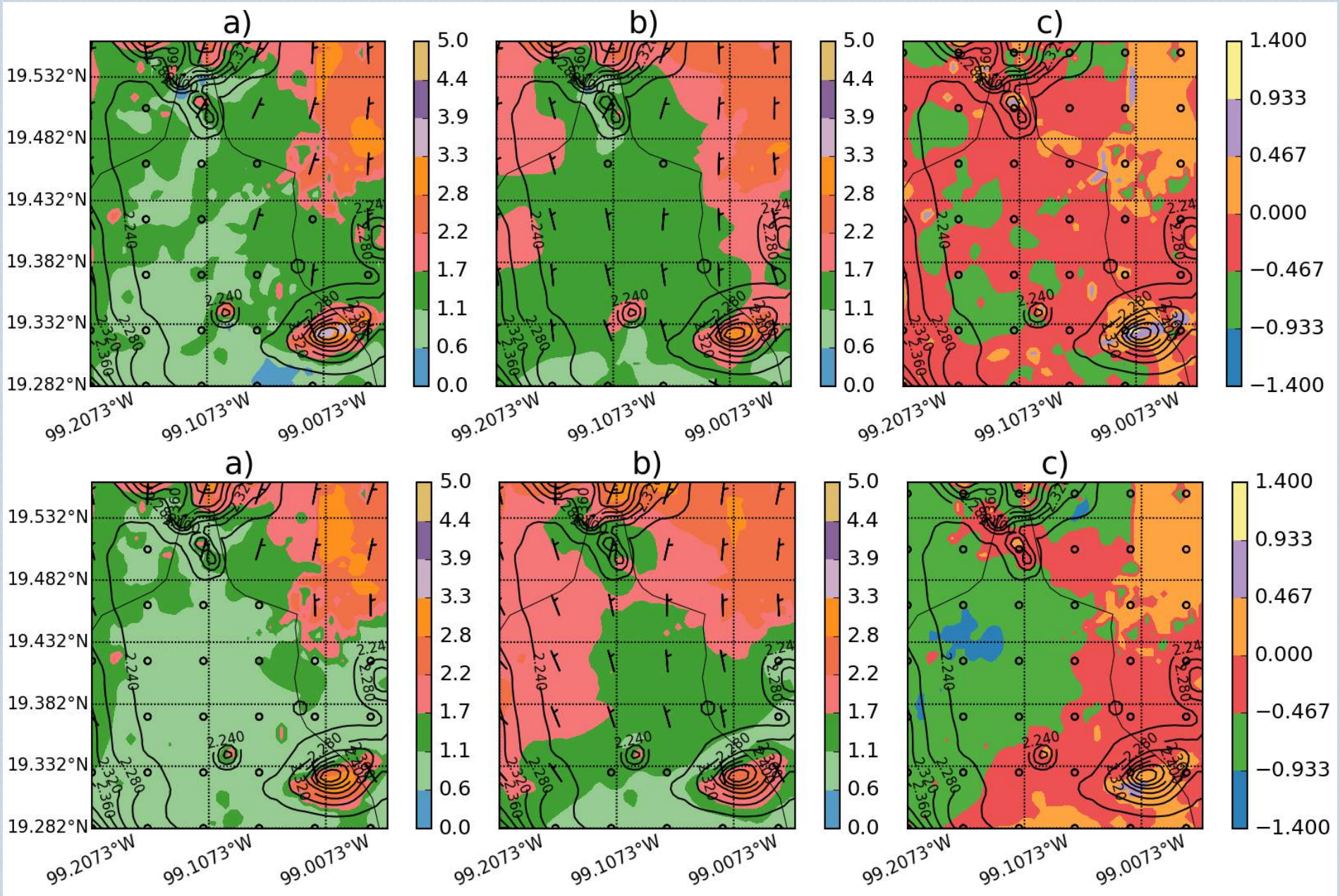
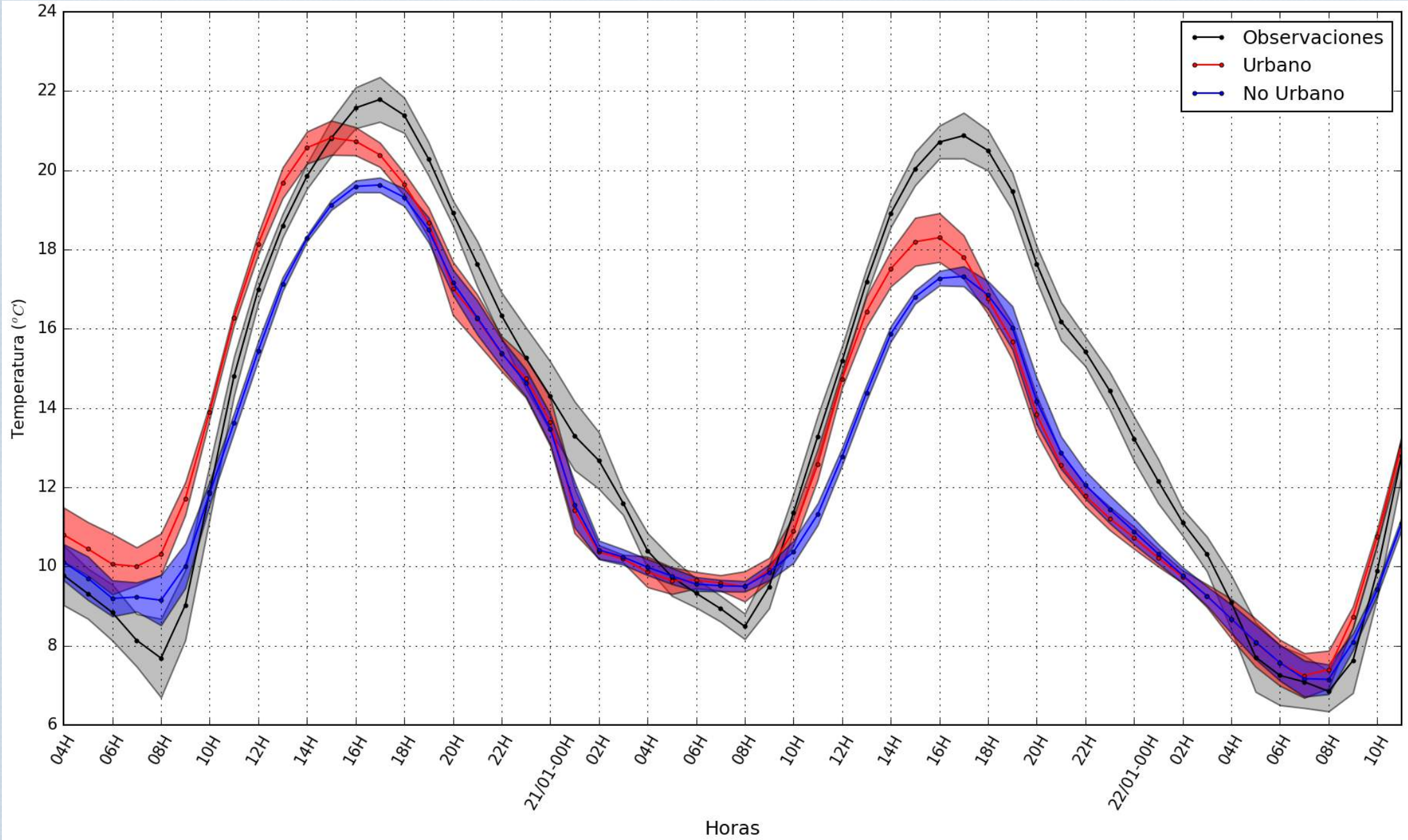
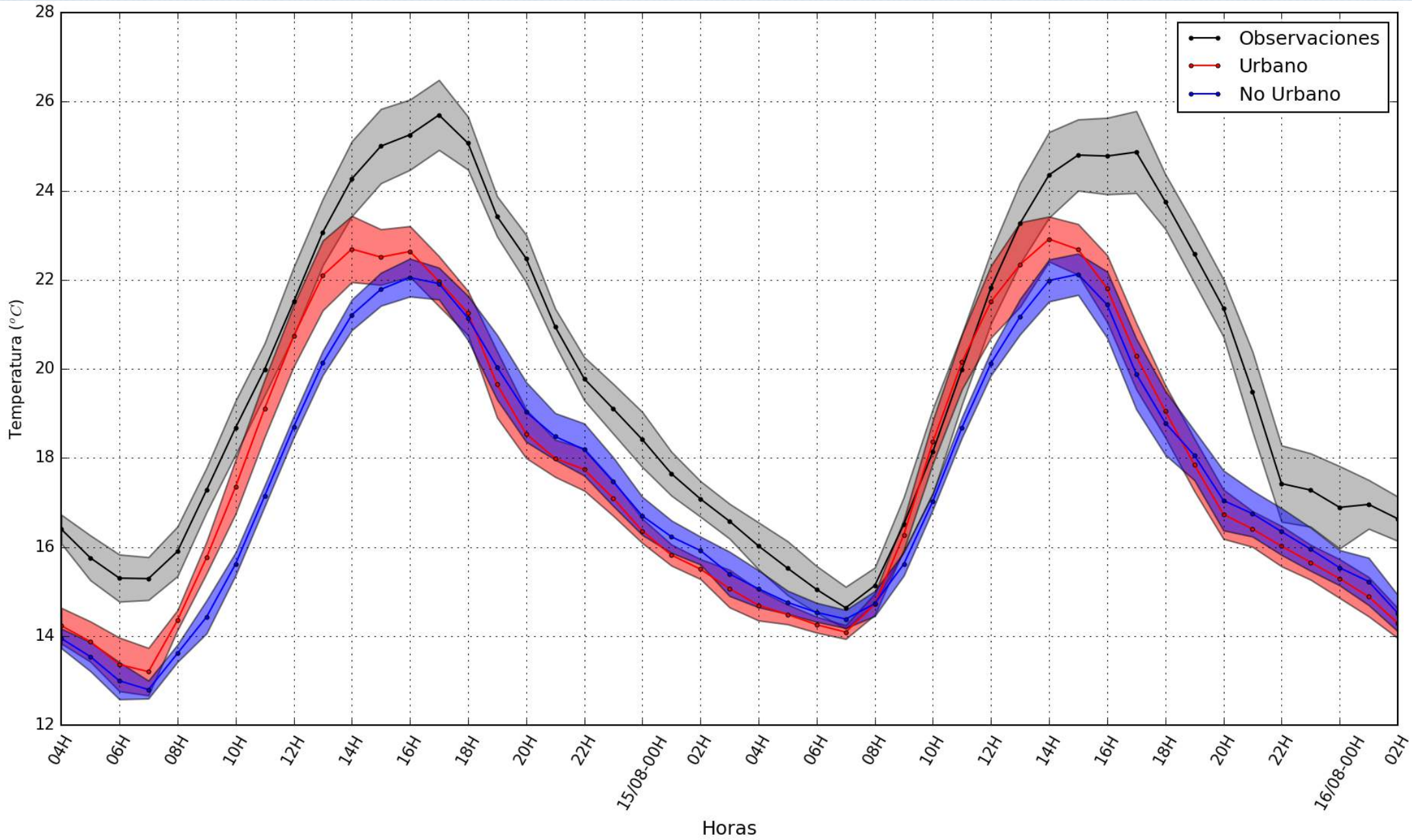
Night time



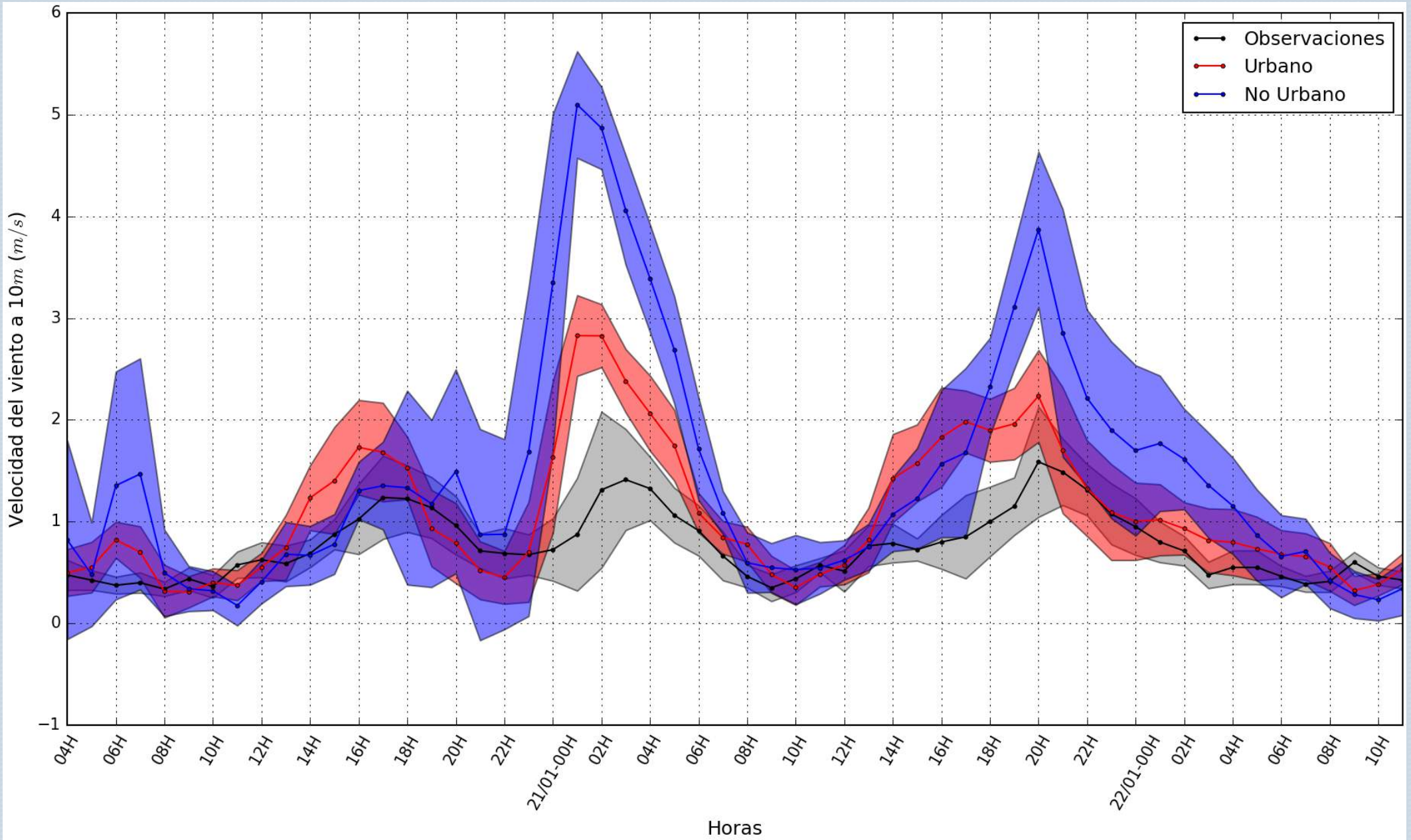
Dry season daily cycle of air temperature



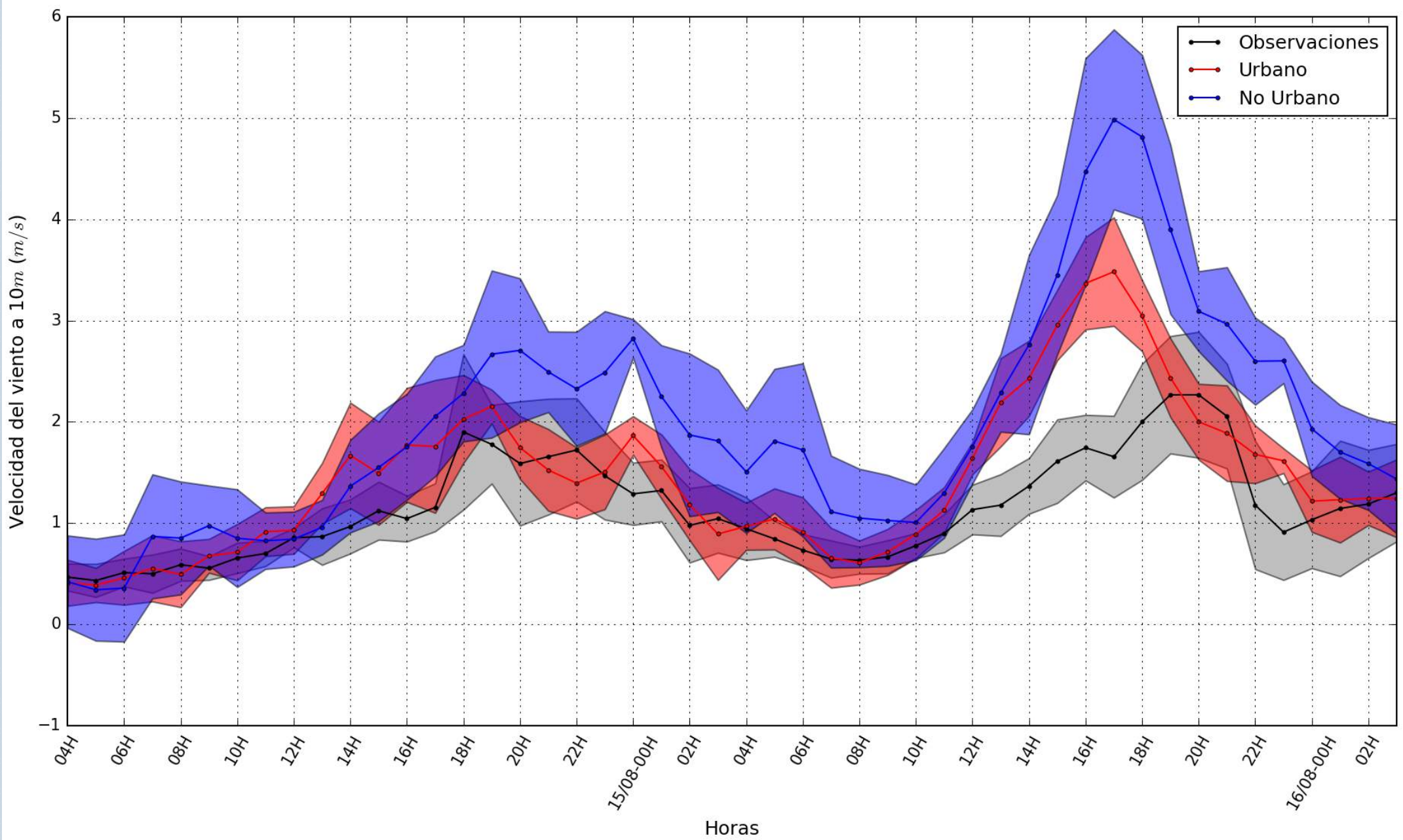
Wet season daily cycle of air temperature



Dry season daily cycle of wind speed



Wet season daily cycle of wind speed



Conclusions

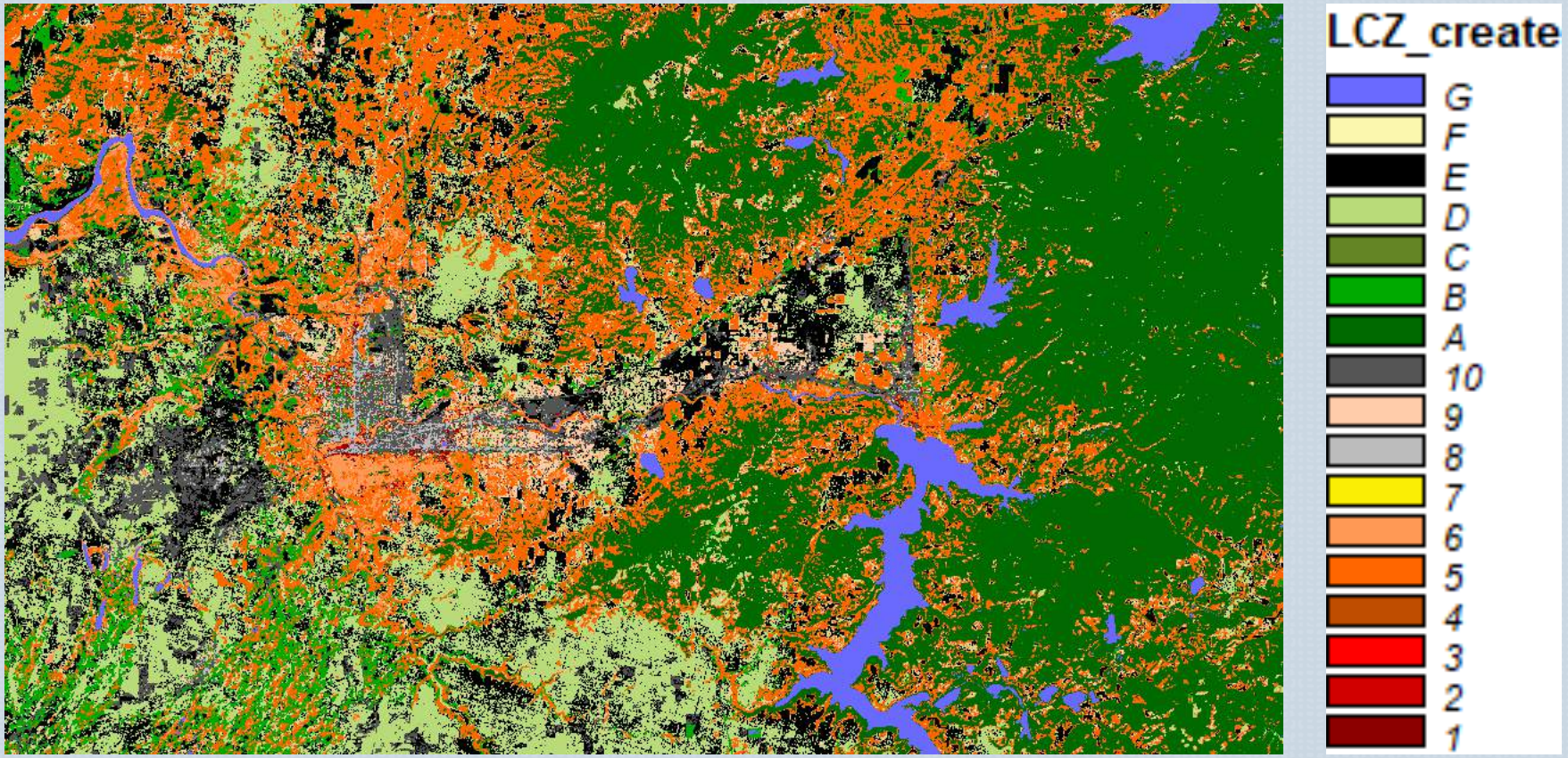
- New urban land cover classification was added to the integrated WRF/urban system, resulting in the first atmospheric modeling system for Mexico City that recognizes diverse urban structures.
- UHI daytime effect (January and August) is observed by the uWRF with intensities up to a value of 3°C
- Temperature simulations using uWRF were closer to the measurements than the ones with WRF for both periods studied, especially at noon.

Conclusions

- It was found that uWRF takes into account the morphological differences among the diverse urban classes, when simulating the wind speed depending on the spatial distribution of these classes.
- The uWRF simulated wind speed results were closer to the measurements in both seasons. The greatest deviation occurred during the night time.
- In general, the momentum and heat fluxes are modified in all the urban area, especially the zone in the NW and center of the domain.

For my Ph.D research

- Building a WRF-urban-Chem modeling framework for Spokane Smart City project (Urbanova):



THANK YOU

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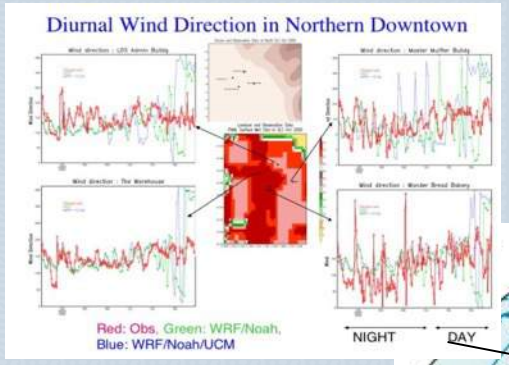
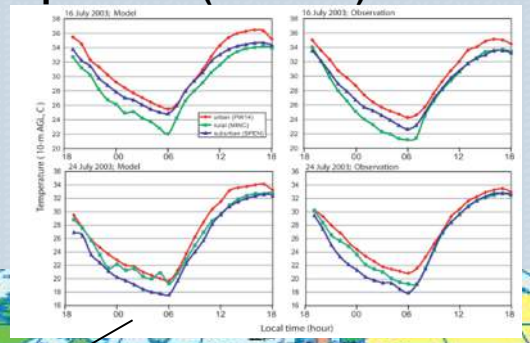
WRF/Urban applications

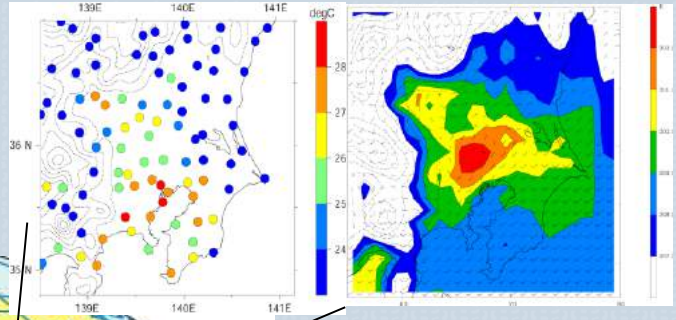
Salt Lake City: Diurnal wind direction (URBAN-2000)



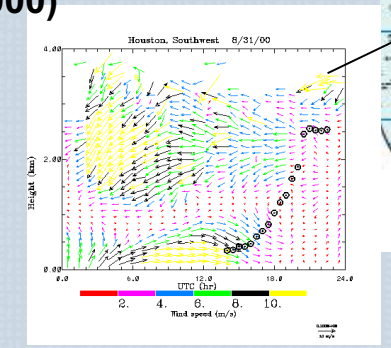
Oklahoma City: 2-m temperature (JU-2003)



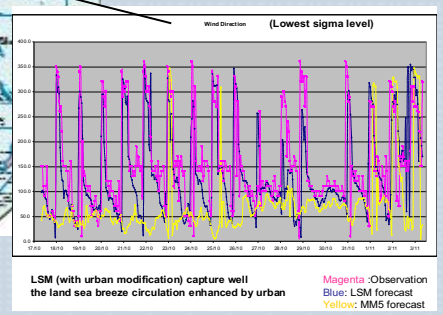
Beijing and Tokyo: surface weather, precipitation



Houston: Diurnal cycle of wind profile (TexAQS-2000)

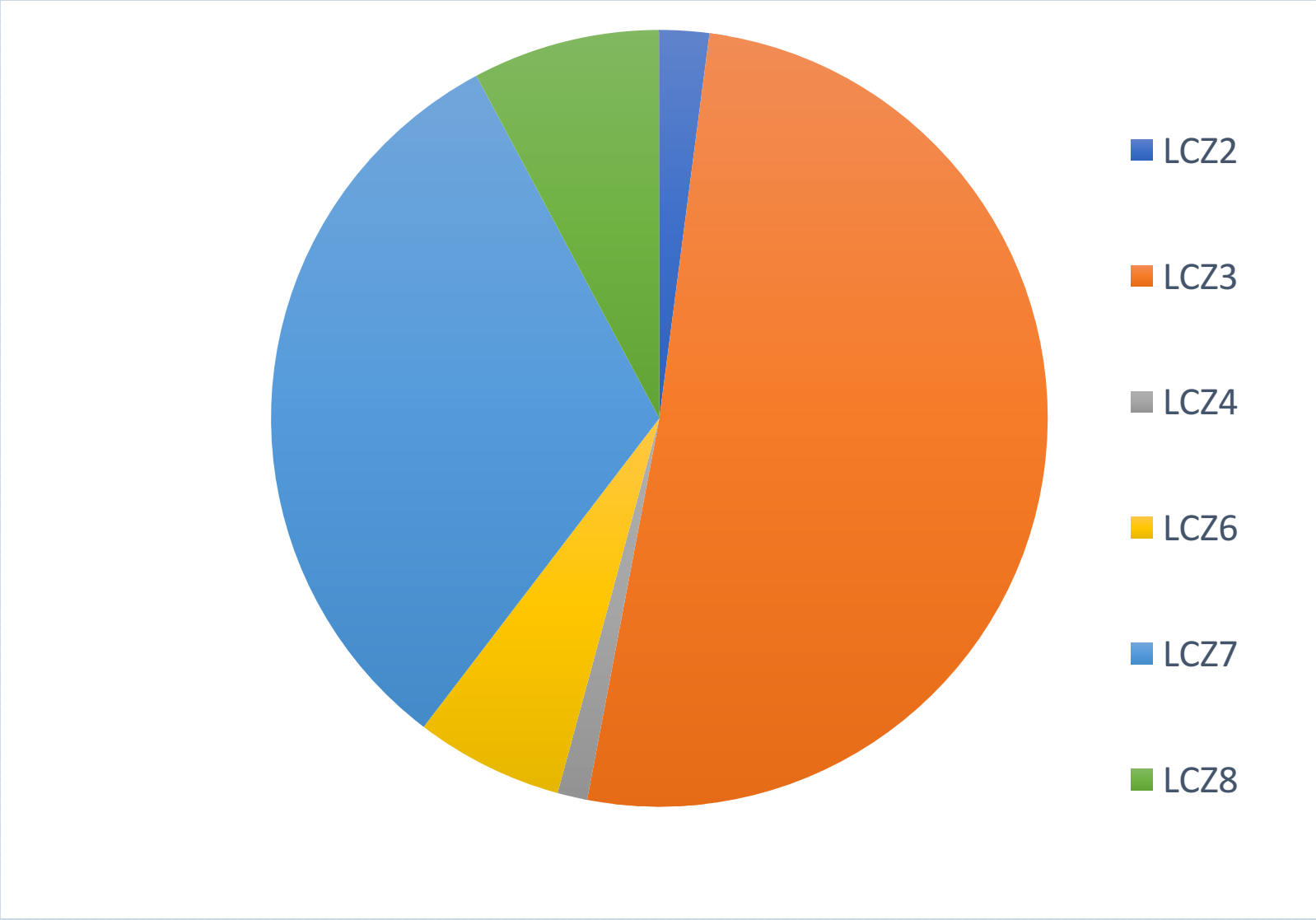


Hong Kong: 10-day surface wind

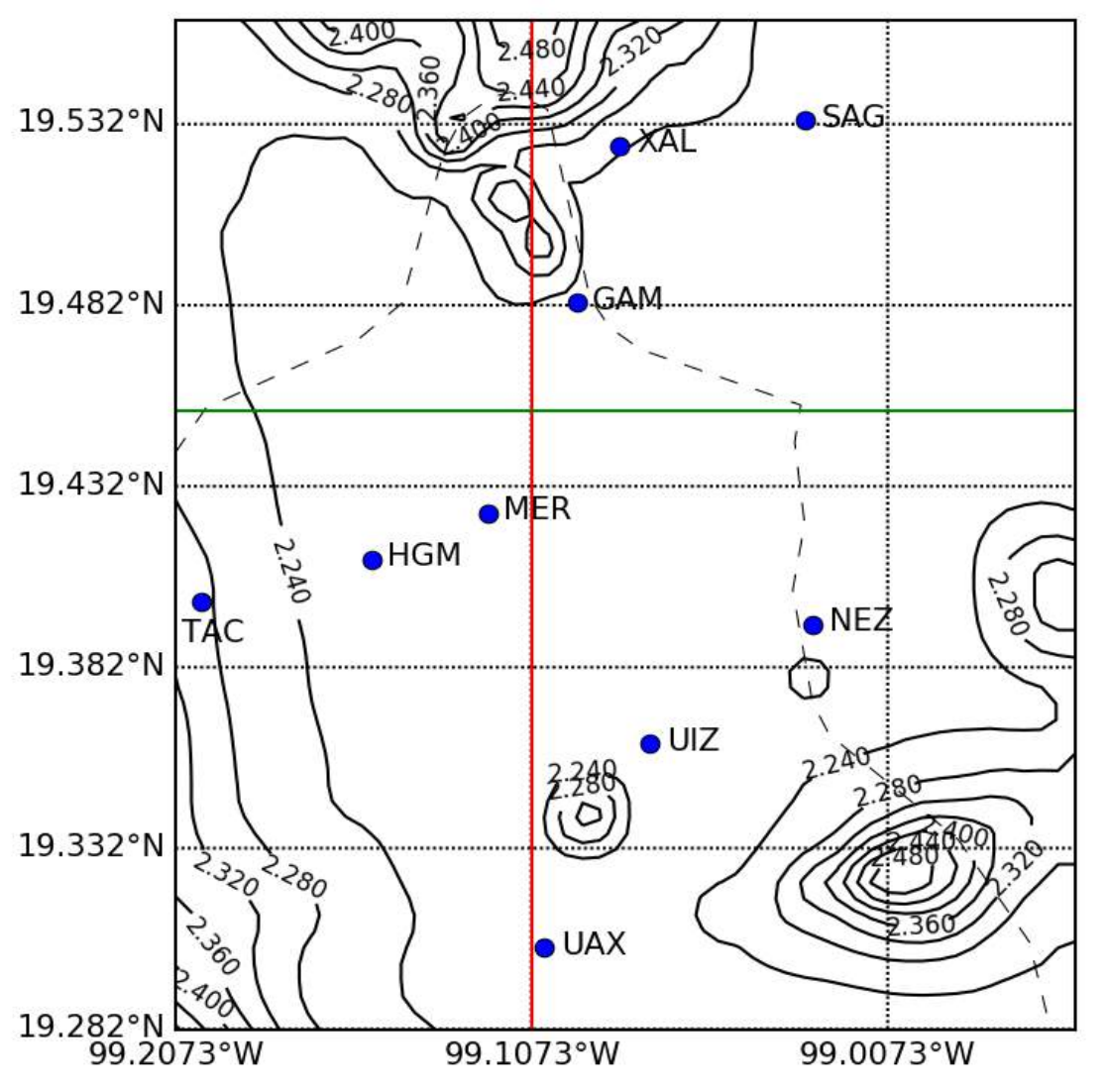


Sources:
Liu, Chen, Warner, and Basara: 2006, J Appli. Meteorol.
Lo, Lau, Chen, and Fung, 2007: J. Appli. Meteorol.
Lo, Lau, Fung, and Chen, 2006: J Geophys. Res.
Zhang, Chen, and Miao 2006: J Geophys. Res., in revision.

Representation of the urban classes



Stations used for comparison.

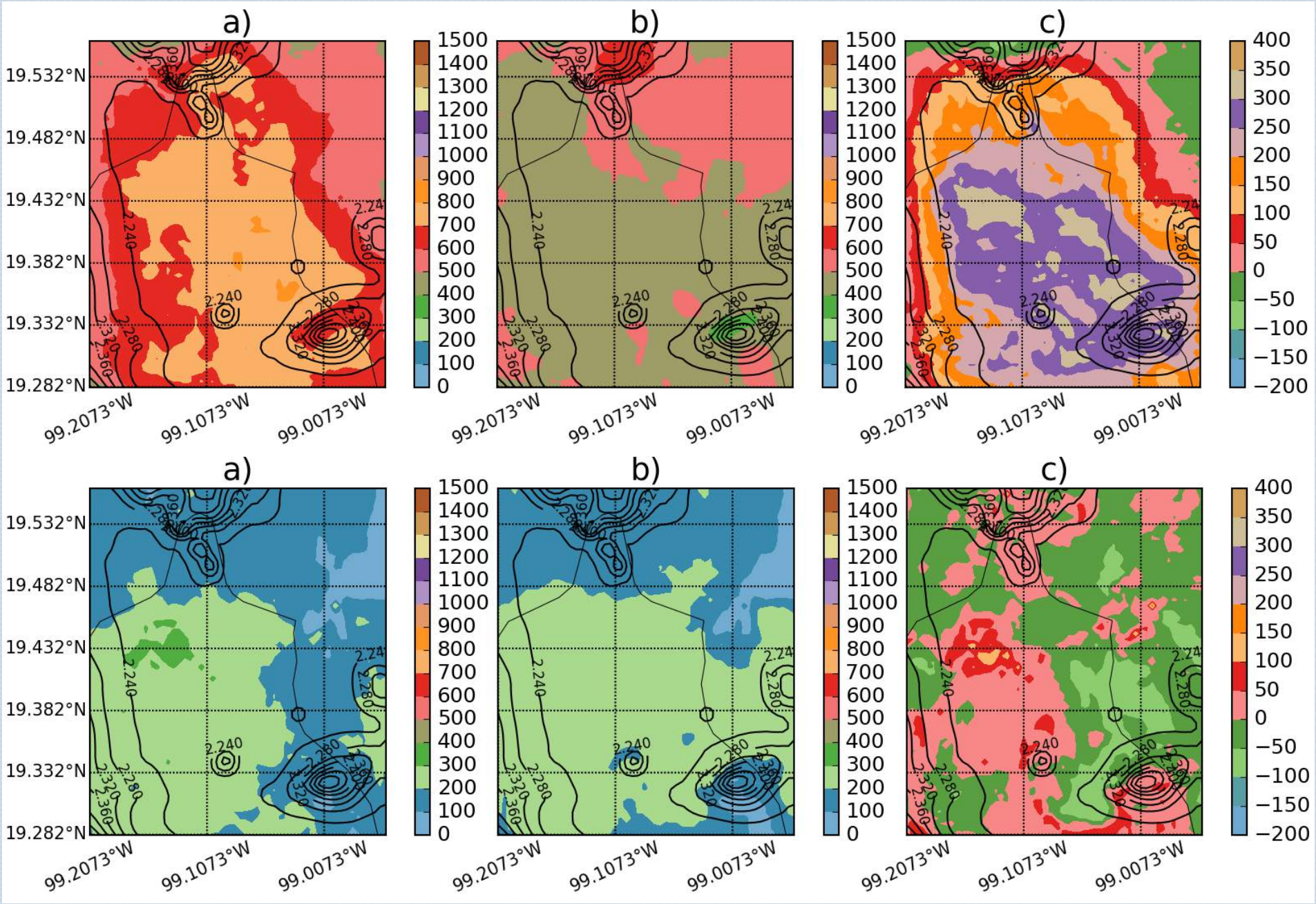


Average hourly behavior of the **PBLH** in dry season.

Daytime

a) Urban
b) No Urban
c) uWRF - WRF

Night time

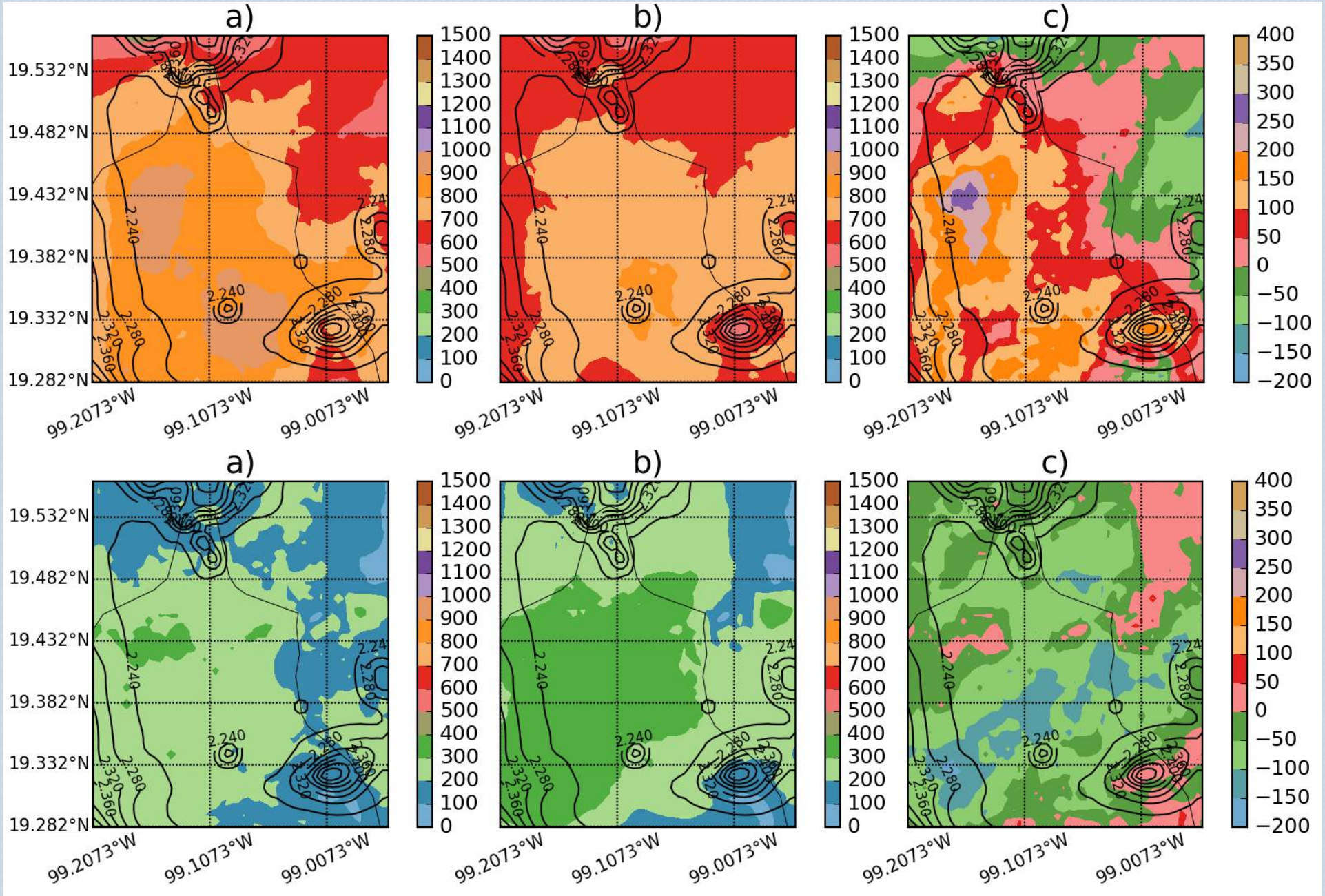


Average hourly behavior of the **PBLH** in wet season.

Daytime

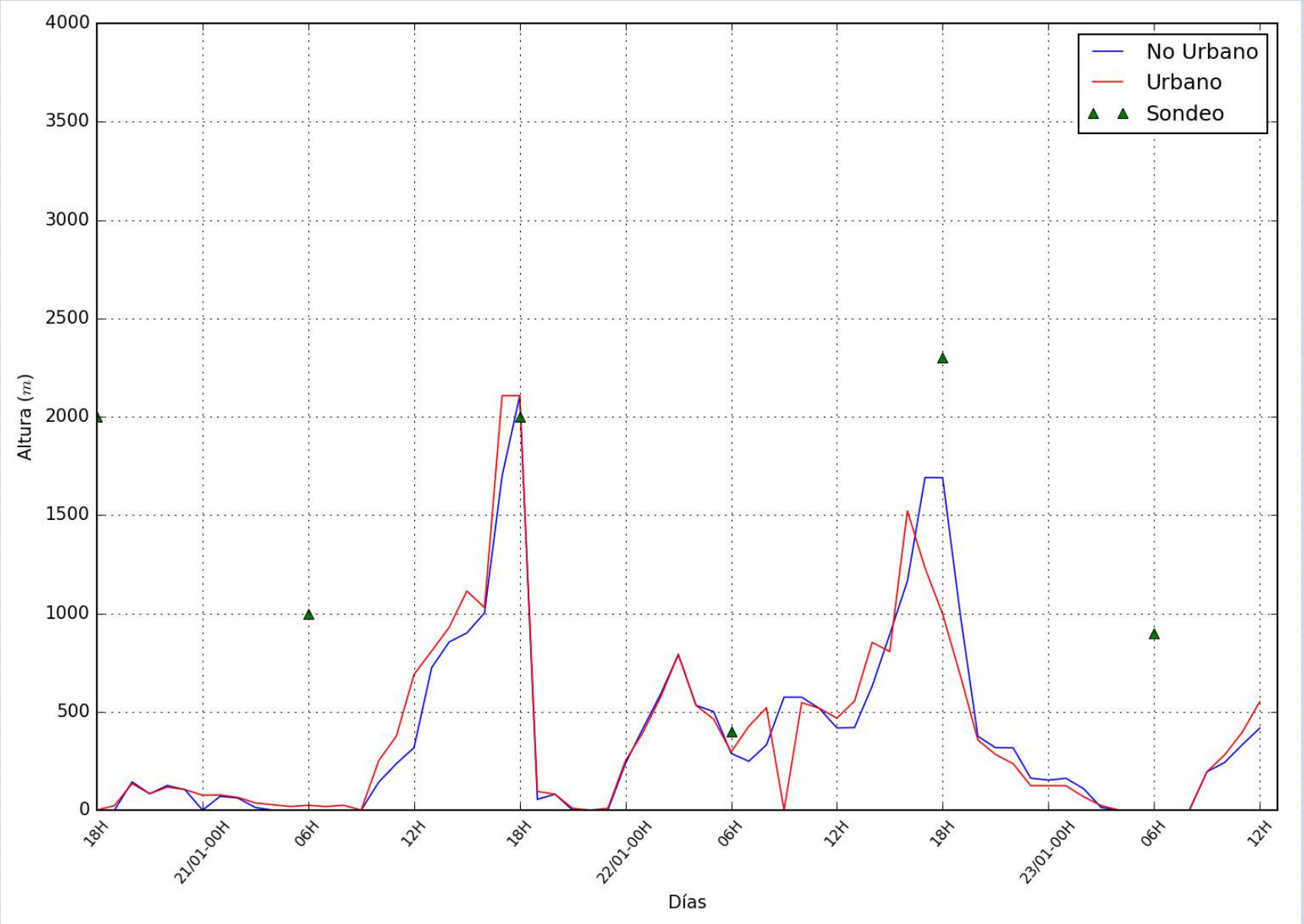
a) Urban
b) No Urban
c) uWRF - WRF

Night time

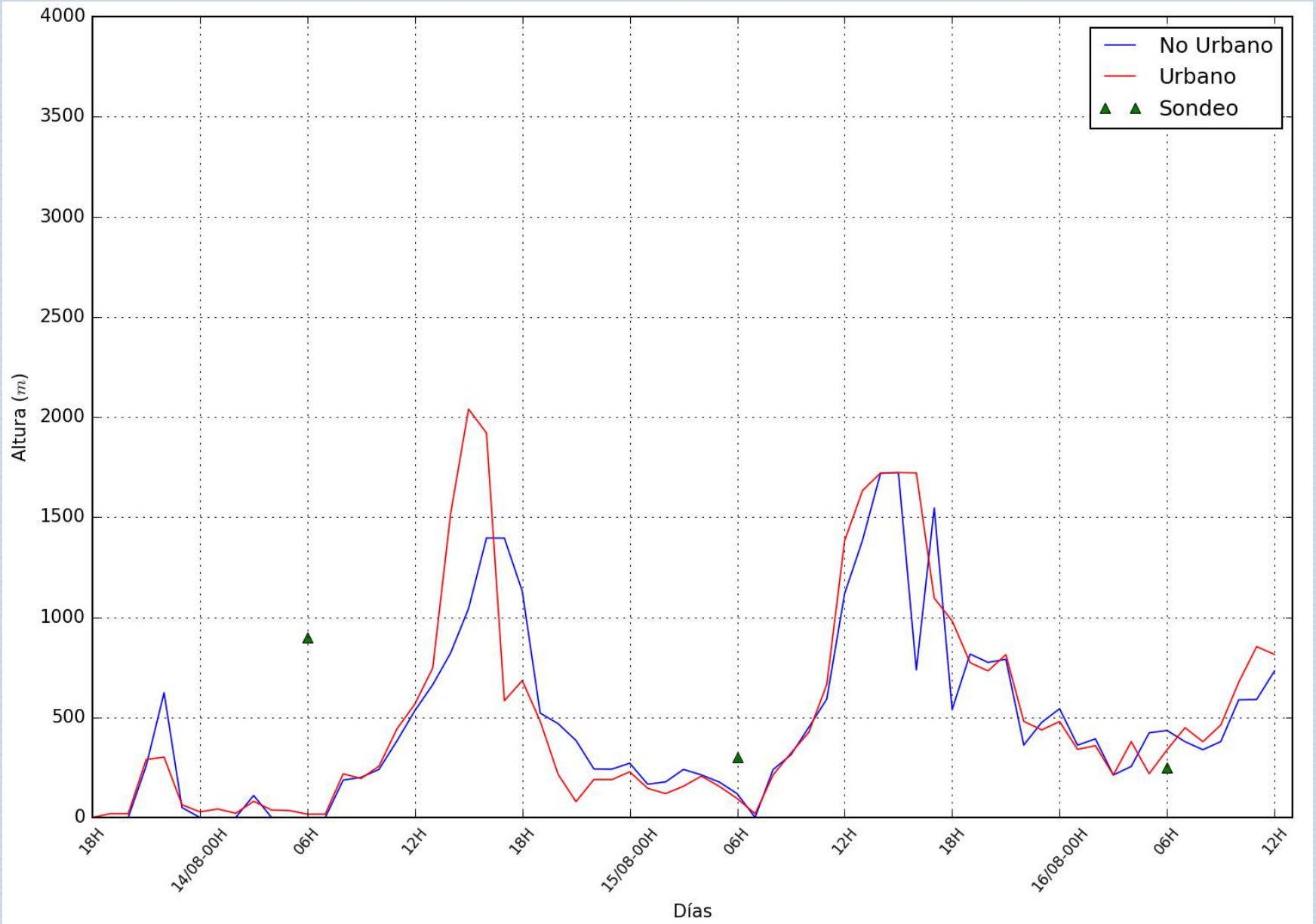


Comparación de las variables de interés

Dry season daily cycle of PBL height

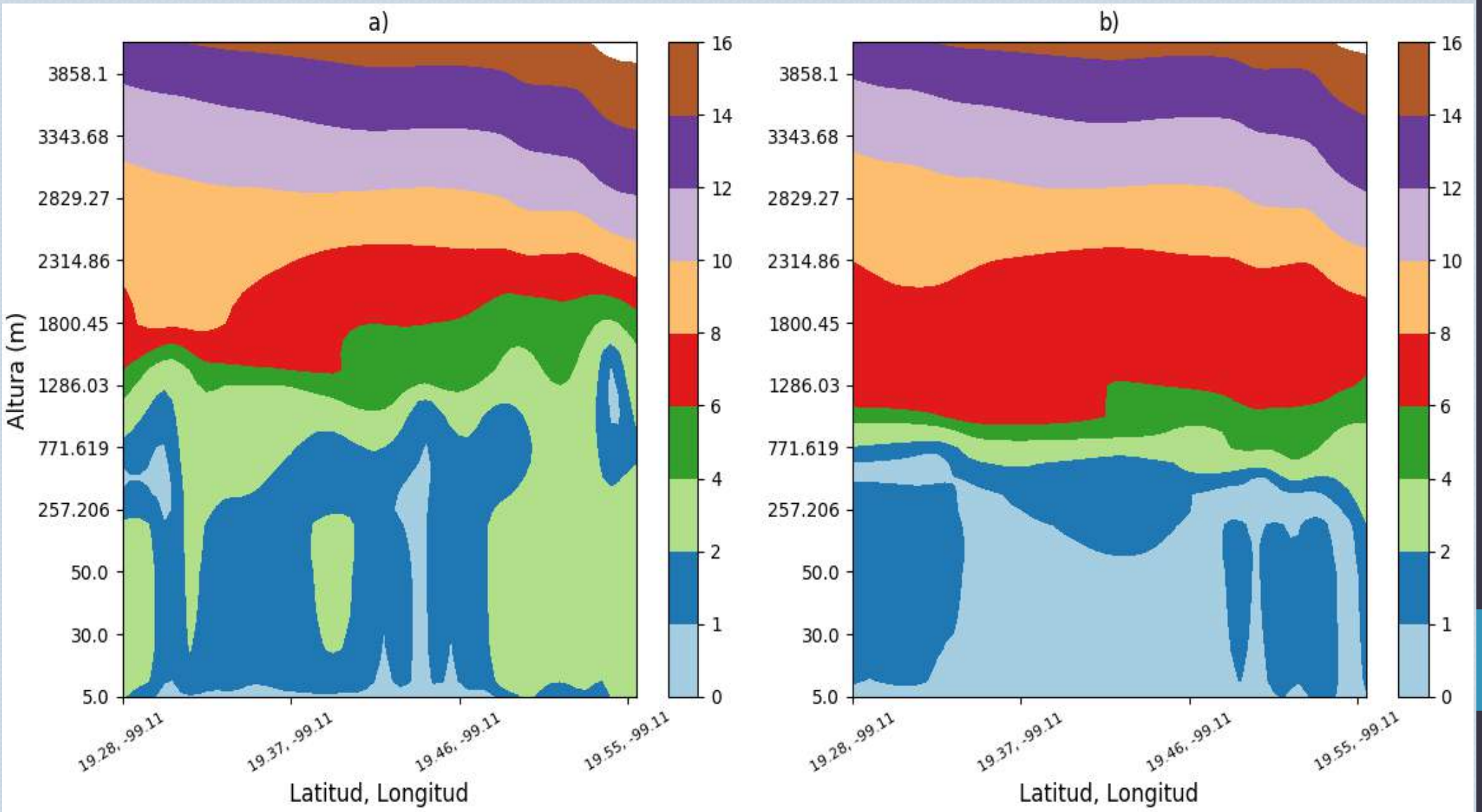


Ciclo diurno de PBLH periodo lluvioso



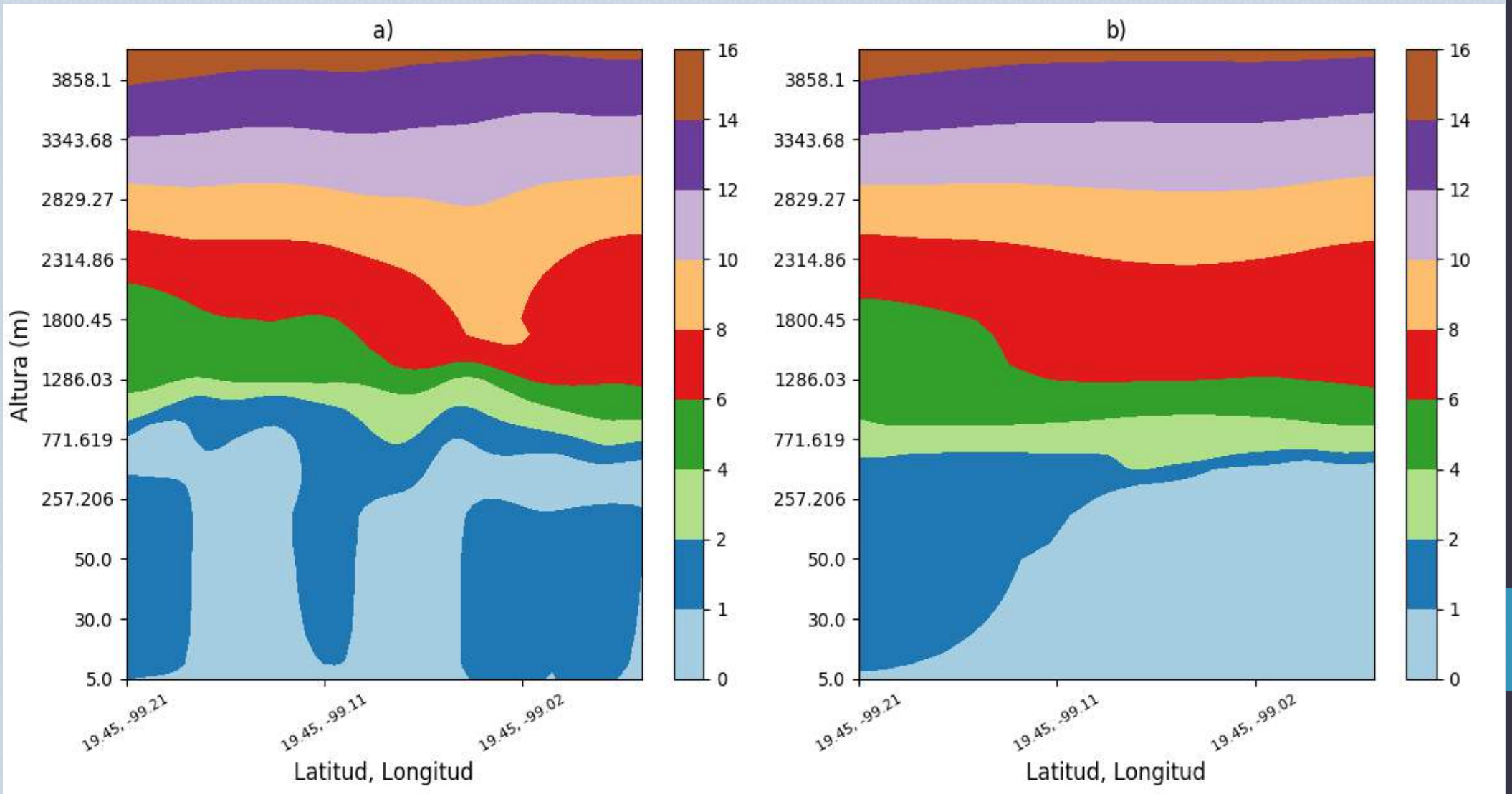
Wind speed cross section

Longitudinal cross section at January 21 at 13h



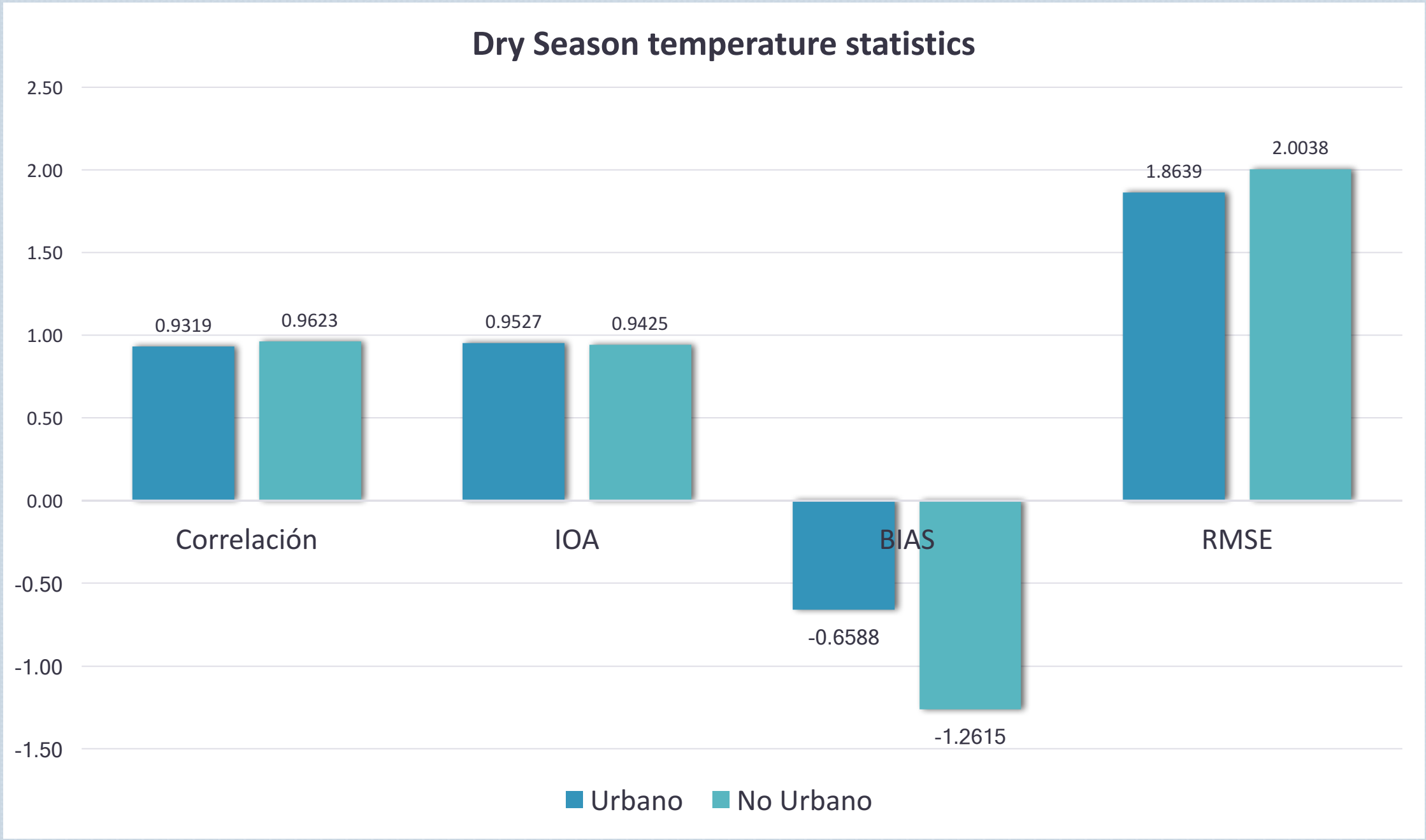
a) Urban
b) No Urban

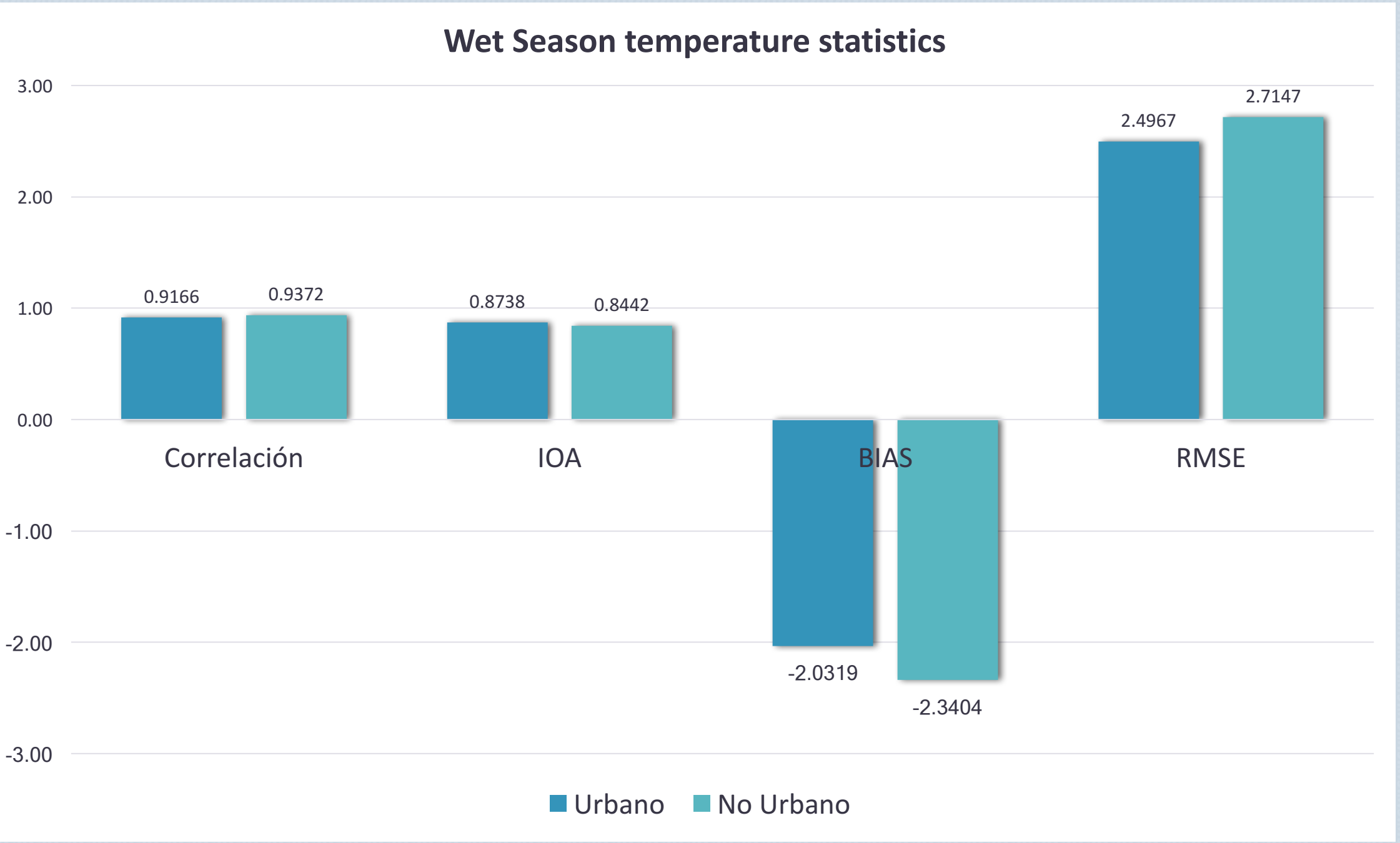
Latitudinal cross section at January 21 at 13h

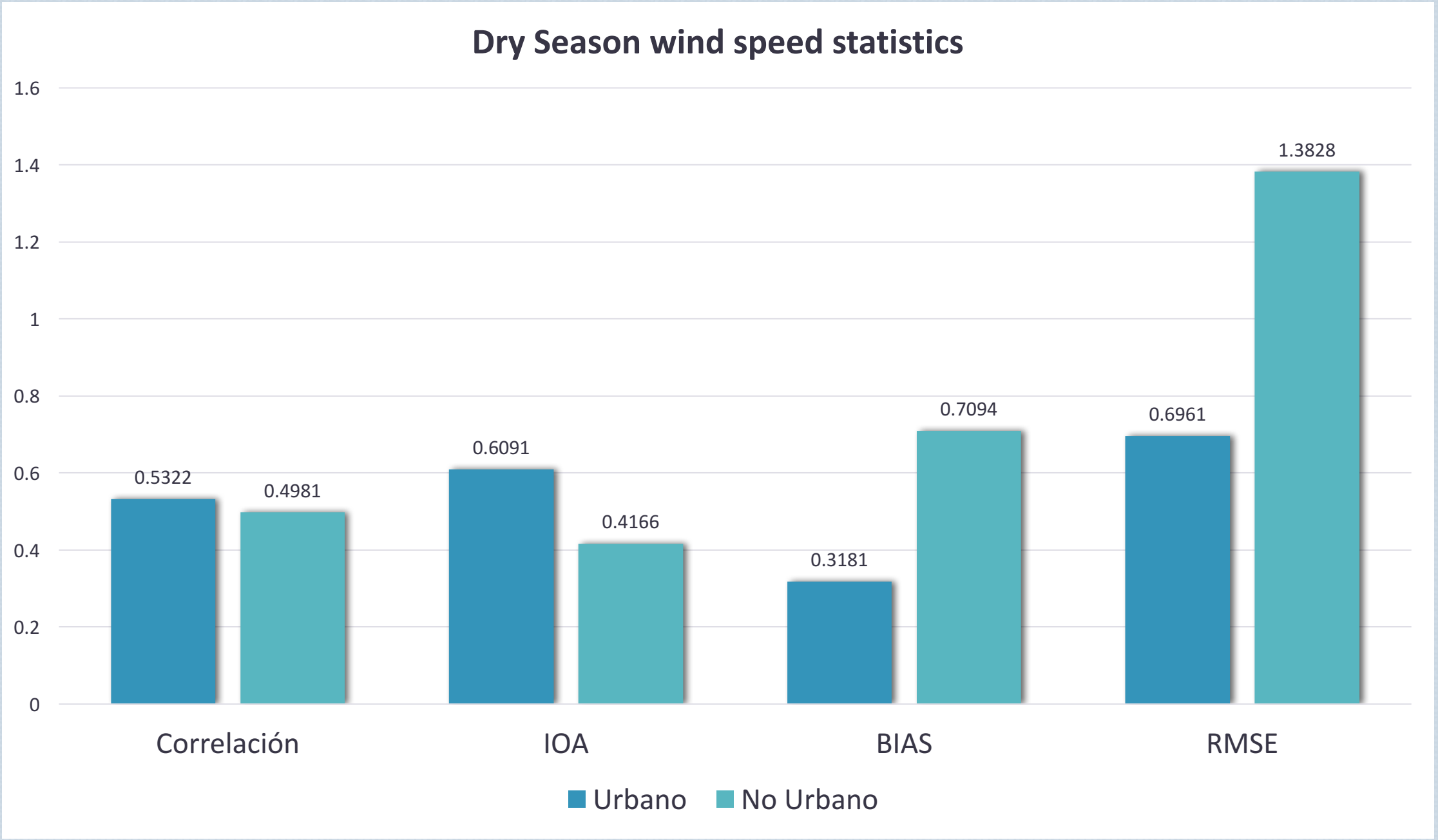


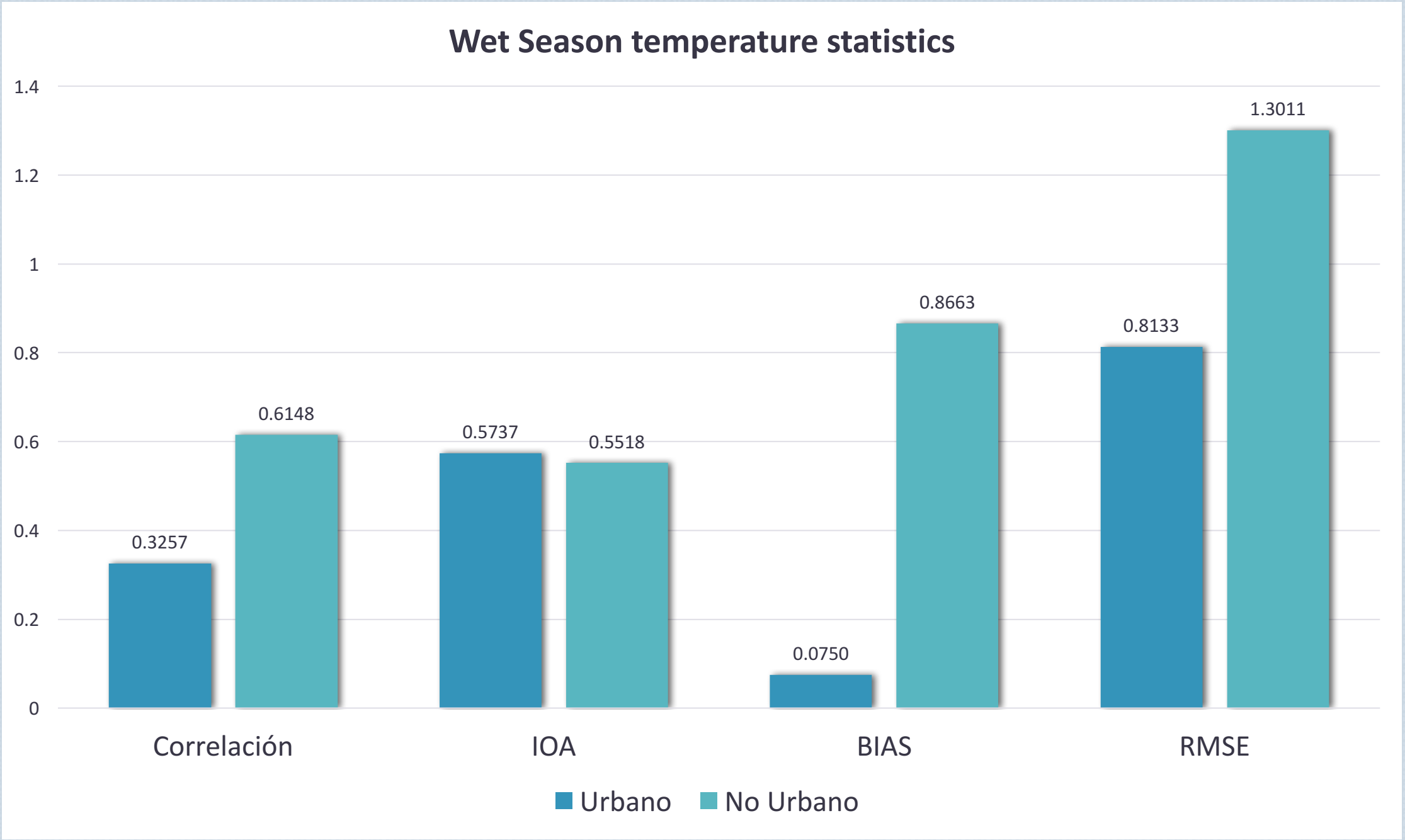
a) Urban
b) No Urban

Interest variable evaluation.


Dry Season temperature statistics
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
0.9319
0.9623
0.9527
0.9425
-0.6588
-1.2615
1.8639
2.0038
Correlación
IOA
BIAS
RMSE
Urbano
No Urbano


Wet Season temperature statistics
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
0.9166
0.9372
0.8738
0.8442
-2.0319
-2.3404
2.4967
2.7147
Correlación
IOA
BIAS
RMSE
Urbano
No Urbano


Dry Season wind speed statistics
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.5322
0.4981
0.6091
0.4166
0.3181
0.7094
0.6961
1.3828
Correlación
IOA
BIAS
RMSE
Urbano
No Urbano


Wet Season temperature statistics
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.3257
0.6148
0.5737
0.5518
0.0750
0.8663
0.8133
1.3011
Correlación
IOA
BIAS
RMSE
Urbano
No Urbano

Recomendaciones

- Ampliar el dominio de estudio para la Zona Metropolitana del Valle de México en dependencia de la disponibilidad de datos de clasificaciones urbanas.
- Realizar simulaciones en otros periodos del año, en particular durante eventos de contingencia ambiental.
- Comparar los resultados obtenidos con una estación ubicada en zonas rurales, en particular la UHI.
- Implementar el sistema uWRF-Chem para conocer el comportamiento de la calidad del aire sobre la CDMX.
- Acoplar las salidas de uWRF a modelos de flujo dinámico para investigar a detalle las principales zonas identificadas por uWRF donde se modifica el flujo atmosférico.

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