Evaluation of WRF Simulations for Two High Ozone Episodes in El Paso, Texas

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Introduction

On June 21, 2015 the maximum daily average 8 hour (MDA8) ozone peaked at 77 ppbv at the University of Texas El Paso (UTEP) monitoring location and exceeded 60 ppbv at 5 monitoring locations in the El Paso area. Similarly on June 23, 2016, the MDA8 ozone peaked at 84 ppbv at the Chamizal El Paso monitoring location and exceeded 70 ppbv at 4 monitoring locations in the El Paso area. These episodes featured ozone levels near or above the EPA National Ambient Air Quality Standards. Photochemical modeling may be used to better understand the causes of such episodes and will require accurate model-ready meteorological inputs generated with numerical weather prediction (NWP) model simulations. Simulating accurate meteorological inputs presents a challenge due to the complex topography of the region which features semi-arid mountain slopes bounding the Rio Grande Valley, which encompasses the two moderate sized neighboring cities of El Paso and Ciudad Juárez, Mexico. Exploratory WRF simulations with horizontal grid sizes down to 1 km were performed for the five days leading up to and including the two high ozone days of June 21, 2015 and June 23, 2016.

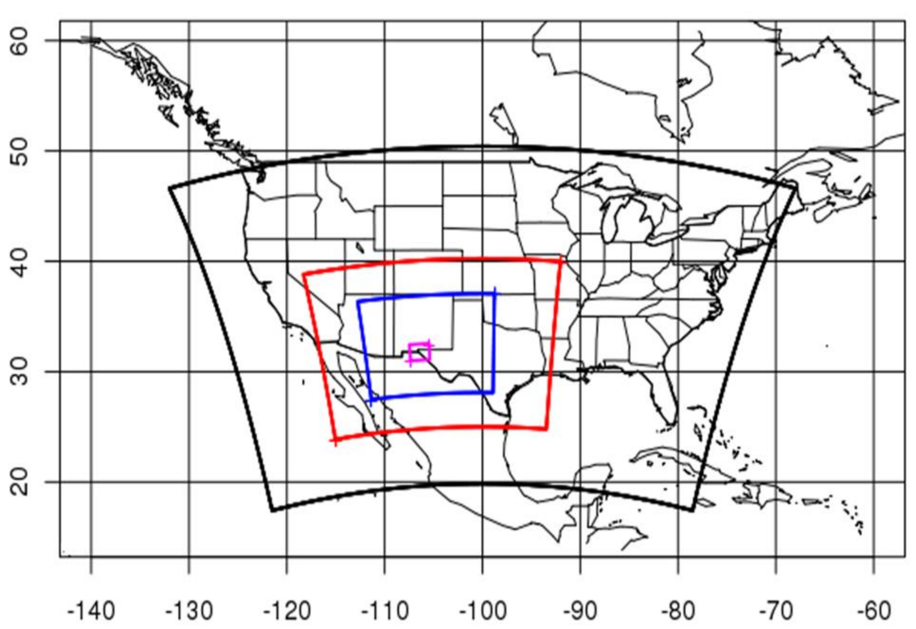
The main objectives of this modeling study were:

1. To test different WRF physics options for simulating the fine-scale meteorology associated with high ozone episodes in El Paso, and
2. To assess the feasibility of improving the El Paso WRF simulations with observational nudging.

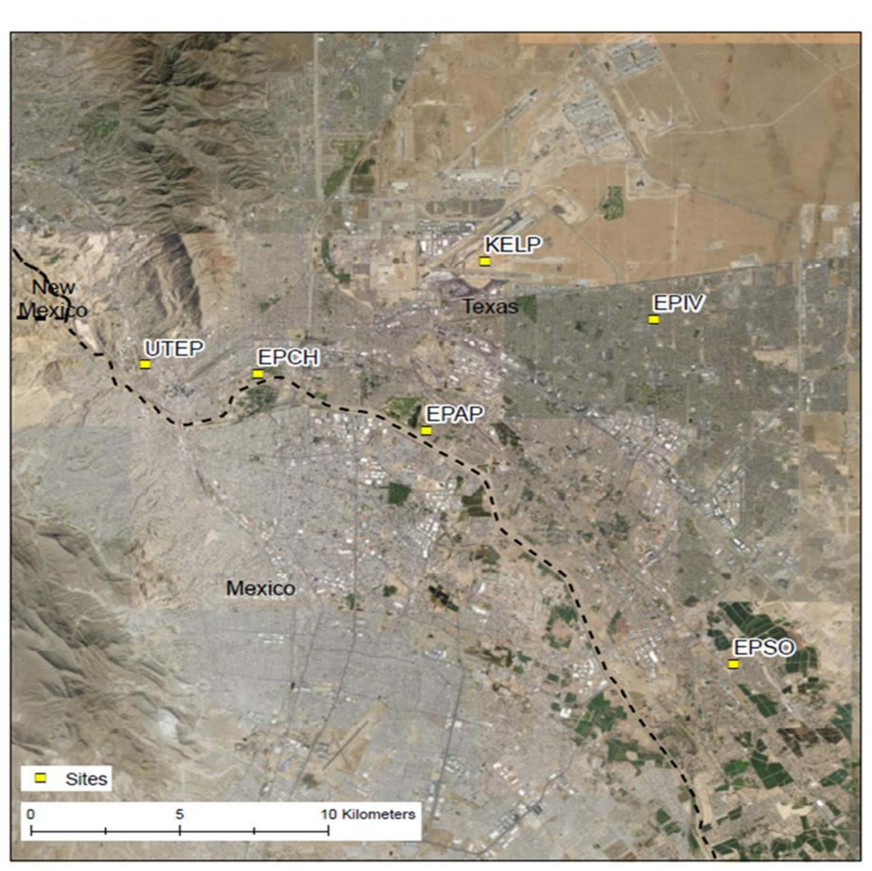
Methods

WRF Domains and Options

- Advanced Research WRF Version 3.9.1 with 4 nest levels of 27, 9, 3, and 1 km
- 43 vertical levels from surface to 100 hPa
- Mellor Yamada Janjić (MYJ), Level 2.5 Mellor-Yamada-Nakanishi-Niino (MYNN), and Shin-Hong (SH) PBL schemes
- Eta and Revised MM5 surface layers
- Grell Freitas (GF) cumulus parameterization from WRF 3.8.1
- Noah land surface model (Noah)
  - Noah with multi-parameterization options (Noah-MP) tested but results not shown
- Single-layer urban canopy model (UCM)
- Initial and boundary conditions from North American Regional Reanalysis (NARR)
- Daily re-initialization and grid nudging above PBL
- Optional observational nudging to surface, radiosonde, and aircraft observations



WRF 27, 9, 3 and 1 km domains



Locations of El Paso observation sites for WRF time series evaluation

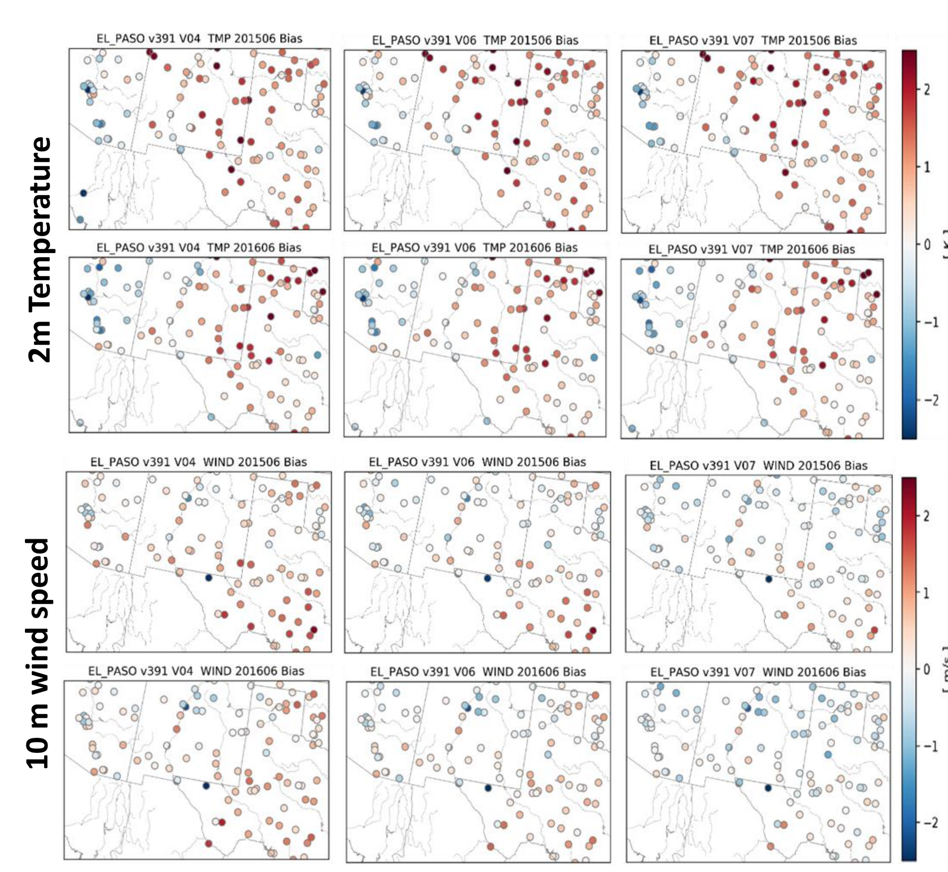
After initial testing and evaluation of many different model option combinations four WRF configurations, shown in the table below, were chosen for enhanced evaluations.

Configuration	PBL / Sfc Layer	Land SFC. Model	Cum. Par.	Obs. Nudge
V04	MYJ / Eta	Noah UCM	GF 3.8.1	Off
V06	MYNN / Eta	Noah UCM	GF 3.8.1	Off
V07	SH / Revised MM5	Noah UCM	GF 3.8.1	Off
V10	SH / Revised MM5	Noah UCM	GF 3.8.1	3 km, 1 km

The WRF-MET software package was used to generate model validation statistics for the 5-day WRF simulations of the June 2015 and June 2016 cases. The model bias and root mean square error (rmse) statistics for the surface variables for configurations V04, V06, and V07 are shown in the table below. The observational nudging configuration, V10, was only run for 2-days of the 2016 case and those statistics are not shown. The statistics are for the 3 km domain.

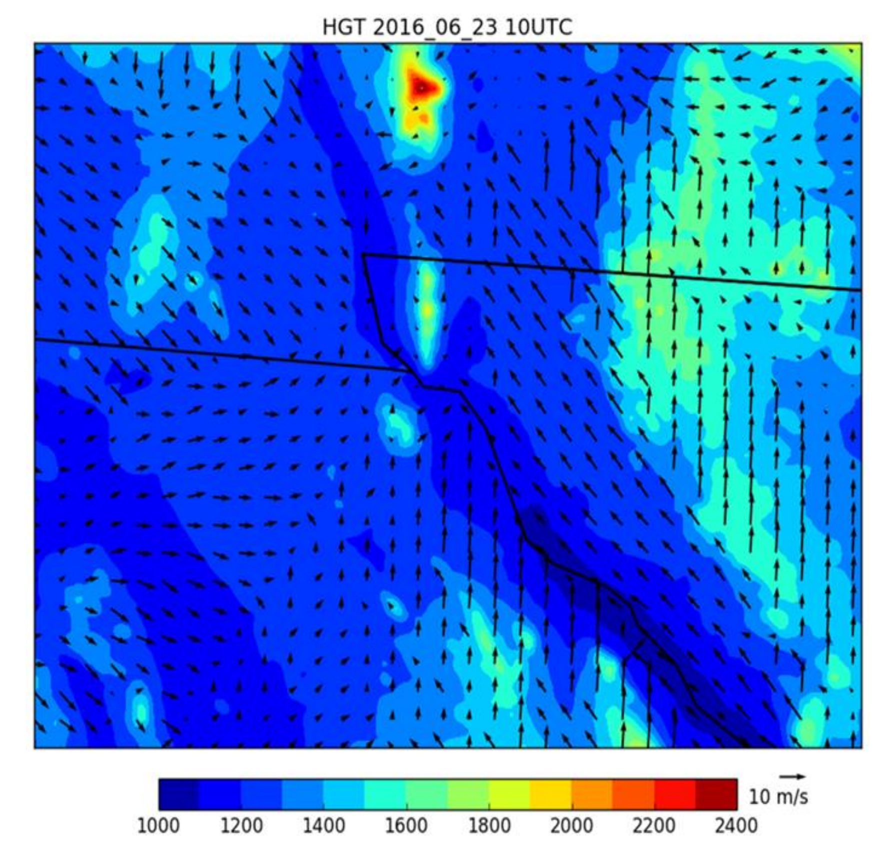
	2m Temperature (K)		2m Dewpoint (K)		10m Wind Speed (m/s)	
	bias	rmse	bias	rmse	bias	rmse
2015						
V04	0.77	2.07	-0.04	2.52	0.49	1.86
V06	0.87	2.06	-0.45	2.59	0.22	1.78
V07	0.94	2.16	-0.81	2.67	-0.06	1.63
2016						
V04	0.46	1.97	0.41	2.64	0.36	1.91
V06	0.47	1.92	-0.03	2.64	0.10	1.83
V07	0.49	2.03	-0.21	2.59	-0.23	1.78

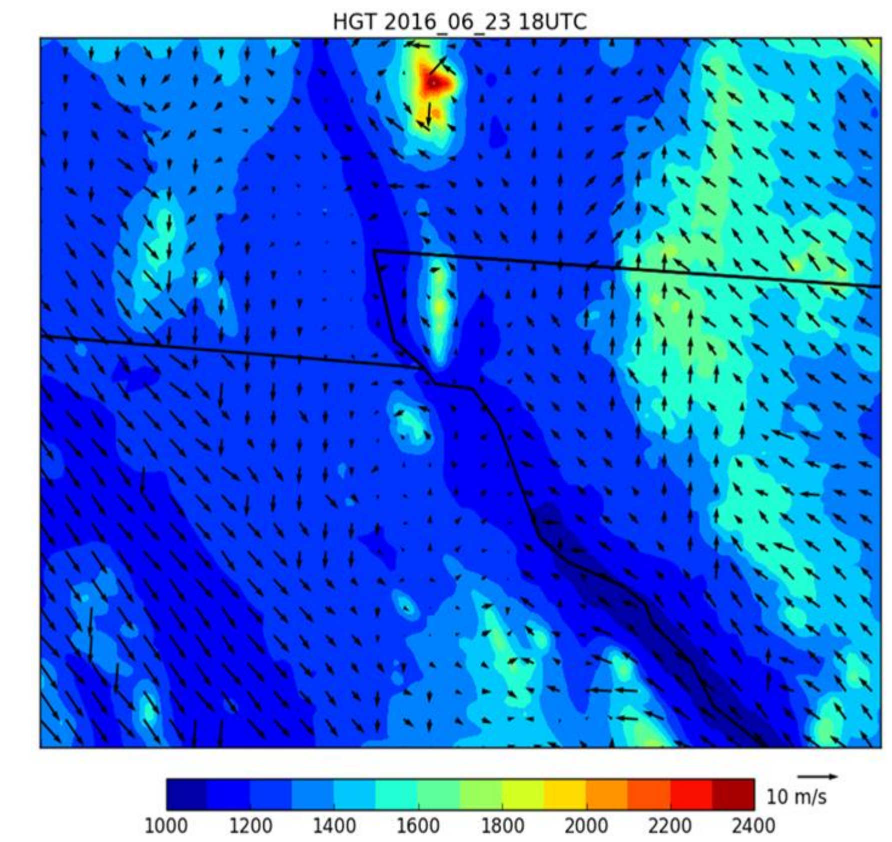
The model error statistics were within the ranges reported in previous studies and there were only minor differences between each configuration. Overall, the V07 configuration that used the SH PBL scheme had lower wind errors. The spatial distribution of errors as shown in the bias bubble plots below were similar across model configurations and for both cases.



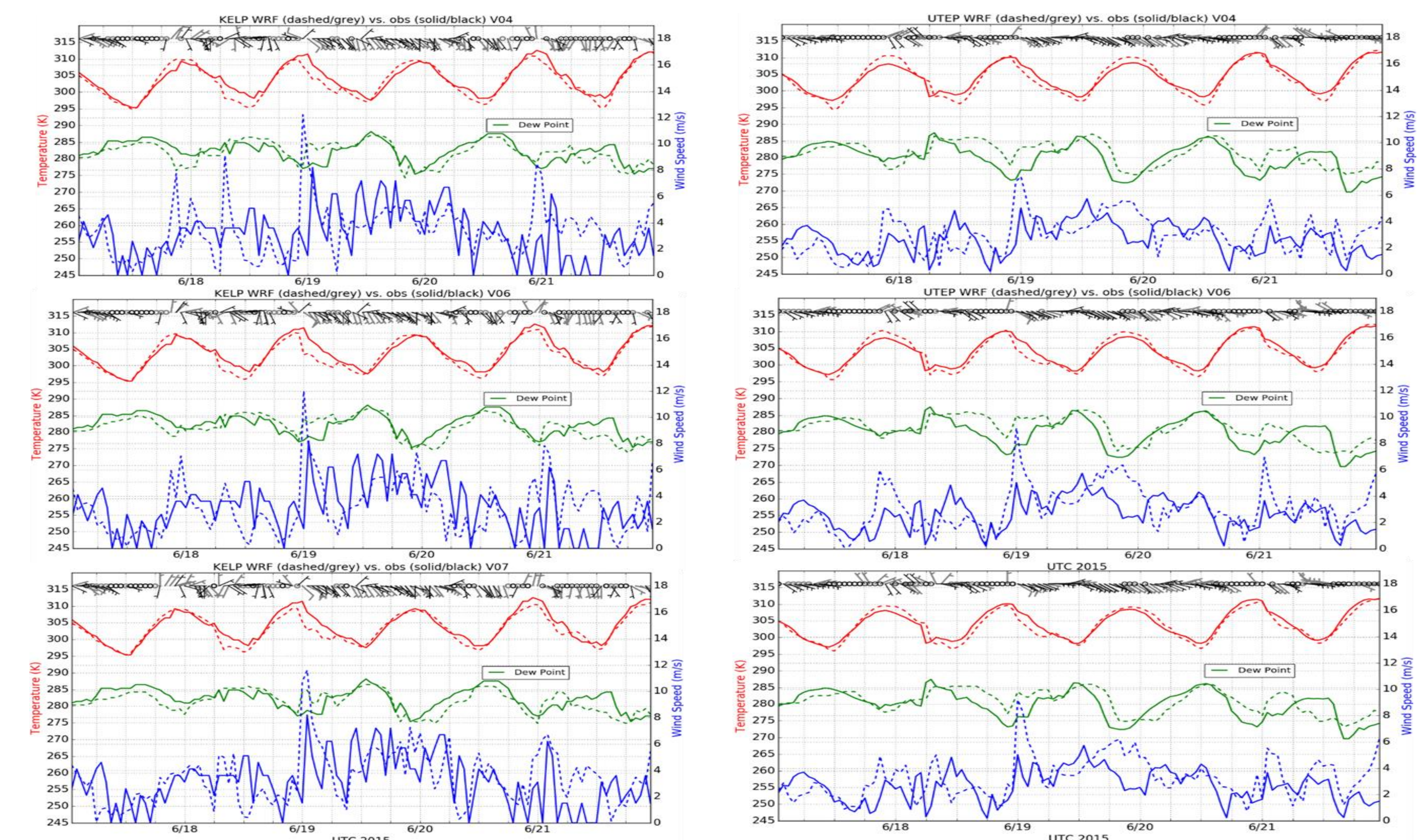
Time series of WRF outputs and observations were also compared at several locations in El Paso. The locations shown on the image to the left include the El Paso International Airport (KELP) and several monitoring stations maintained by the Texas Commission on Environmental Quality (TCEQ).

Case Analysis

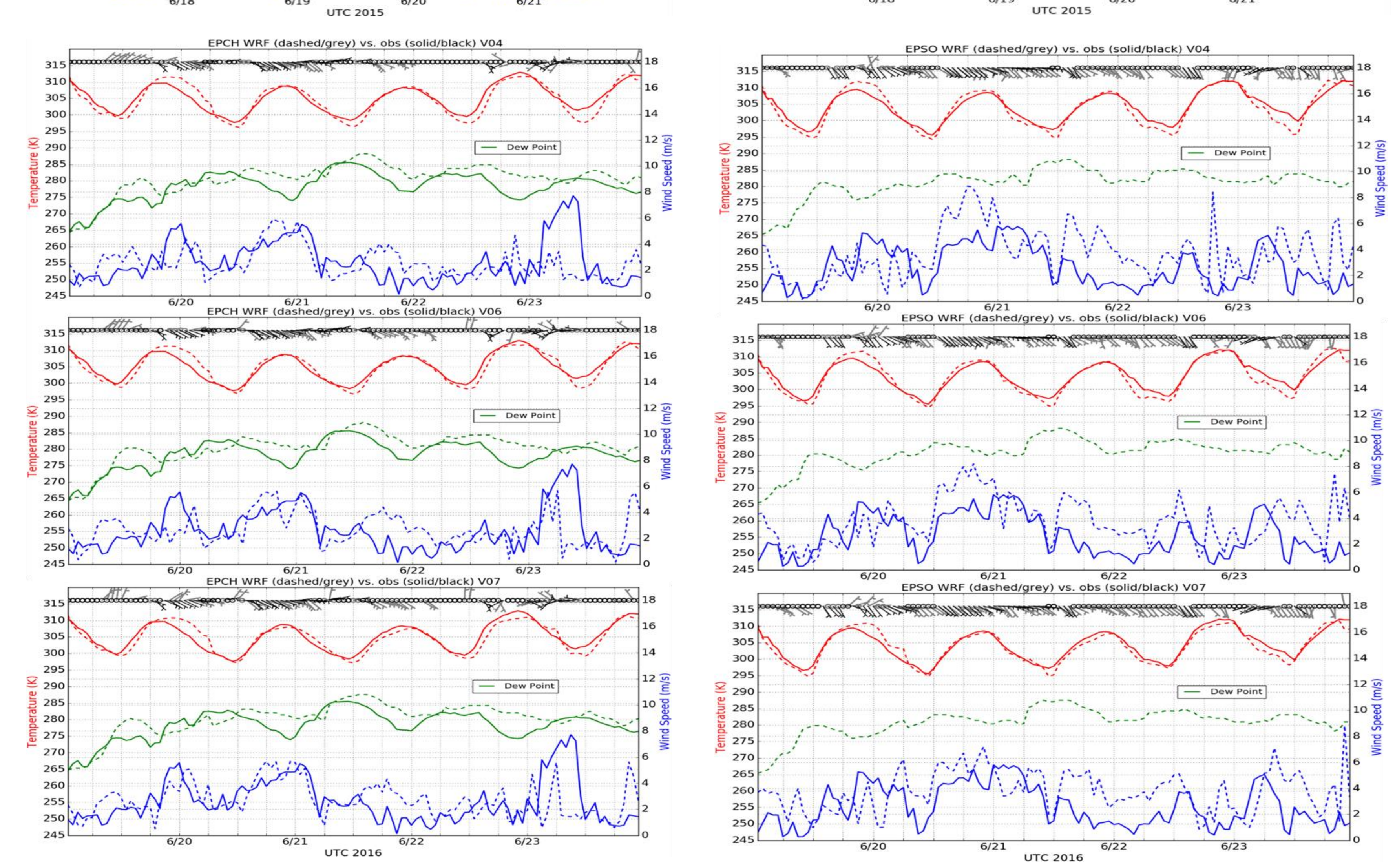




The plots on the left show the WRF 1 km domain terrain height (m color shaded) and 10 m winds (m s^{-1}, arrows) for the WRF V07 at 1000 UTC (left) and 1800 UTC (right) June 23, 2016. The WRF simulations were able to capture the general terrain –induced wind flow patterns. These patterns included channeling of the winds in the Rio Grande Valley with upslope winds during the day and downslope winds at nighttime.

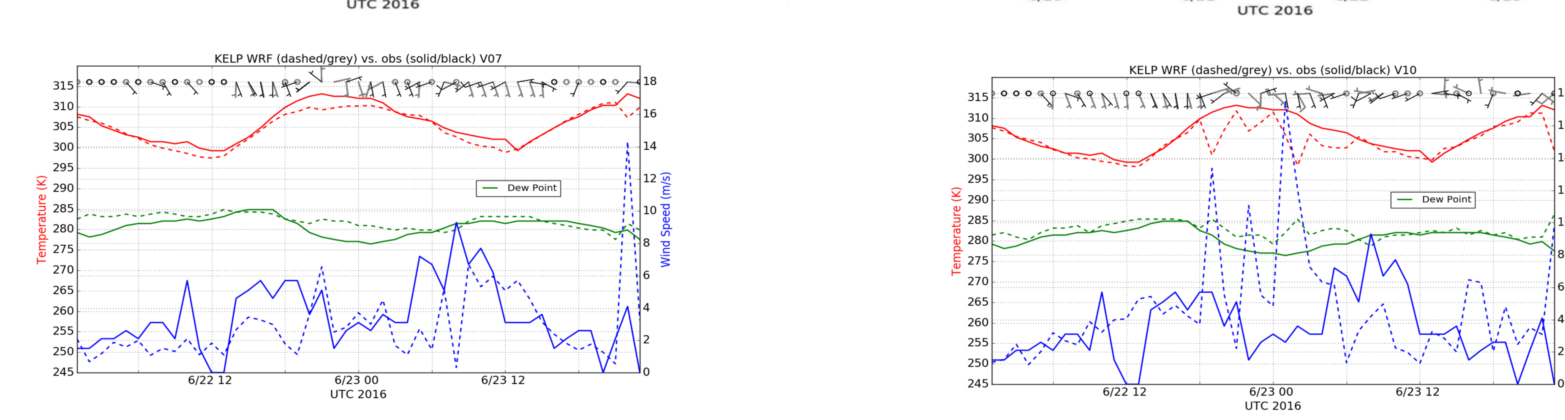


The time series plots on the left show observed and WRF 2m temperature and dewpoint temperature and 10 m winds at the El Paso International Airport (KELP, right) and the University of Texas El Paso (UTEP , left) for June 17- 21, 2015. The WRF outputs are shown for the 1 km domain for WRF configurations V04, V06 and V07.



The time series plots on the left show the observed and WRF 2m temperature and dewpoint temperature and 10 m winds at the TCEQ Chamizal monitoring site (EPCH, left) and the TCEQ Socorro Hueco monitoring site (EPSO, right) for June 19- 23, 2016. The WRF outputs are shown for the 1 km domain for WRF configurations V04, V06 and V07.

Overall for both the 2015 and 2016 cases the model runs captured the diurnal variation in temperature and dewpoint temperature and reproduced with reasonable accuracy the winds at nighttime. However, the model runs did an inferior job simulating the winds during the afternoon. This is likely due to the influence of outflows associated with transient convective cells simulated by the model.



The time series plots to the left demonstrate the affect of observational nudging on the simulated 2m temperature 2m dewpoint temperature and 10 m winds at KELP for June 22 - June 23, 2016. The leftmost plot is V07 and does not include observational nudging and the rightmost plot is V10 and does. The observational nudging improved the pre-dawn temperatures particularly on June 22 but it produced large wind fluctuations that were not observed. These fluctuations were due to the enhancement of the simulated transient convective cells.

Acknowledgements

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