This document provides a brief description of sensitivity simulations performed with CMAQv5.4 to quantify the impacts of different WRF configuration choices for land use (LU) schemes and vegetation fraction (VEGF) on CMAQ inline windblown dust (WBD) emissions and resulting $PM_{2.5}$ concentrations. The simulations were performed over the Contiguous U.S. for the year 2018 using a 12 km horizontal grid spacing and are summarized in this table:

Label	**CMAQ**	**WBD**	**WRF Land Use**	**WRF Vegetation Fraction**
No WBD*	CMAQv5.4	Off	MODIS	Lookup Table
WBD_MODIS_TABLE	CMAQv5.4	On	MODIS	Lookup Table
WBD_NLCD40_TABLE	CMAQv5.4	On	NLCD40	Lookup Table
WBD_NLCD40_SATELLITE	CMAQv5.4	On	NLCD40	Satellite

The representation of LU and VEGF in WRF directly impacts whether any given grid cell is considered to have “erodible land” that then has the potential to emit dust in the CMAQ inline WBD module. In the WBD module, “erodible land” is calculated as the product of “desert land” and (1 – VEGF), with different native WRF LU types (closed shrublands, open shrublands, sparsely vegetated, and barren tundra for MODIS and closed shrublands, open shrublands, sparsely vegetated, barren land, dwarf scrub, and shrub/scrub for NLCD40) considered to be “desert land”. The presence of “erodible land” in a grid cell is a necessary but not sufficient for WBD emissions to occur in a given grid cell. Other factors such as rain, snow, wind speed, soil moisture, and soil texture also are taken into account when calculating the occurrence and magnitude of WBD emissions (Foroutan et al., 2017).

It should be noted that only a single CMAQ simulation without WBD was performed, using the MODIS LU and Lookup Table VEGF WRF configuration. Therefore, comparing the WBD emissions and $PM_{2.5}$ concentrations from the CMAQ simulations driven by the two NLCD40 WRF configurations to the “No WBD” simulation reflects not only the direct effects of these configuration options on surface characteristics (“desert land”, vegetation coverage) in the WBD module but also their effects on meteorology through the WRF land-surface model. However, separate analyses with an offline implementation of the CMAQ WBD module suggest that the first effect is much stronger than the second effect in terms of its impact on WBD emissions and resulting impacts on $PM_{2.5}$ concentrations.

Figure 1 shows the “erodible land” fractions resulting from the three WRF configurations used in this analysis as well as their differences. They illustrate that “erodible land” is generally higher and more widespread with NLCD40 than MODIS (both with lookup table VEGF) and that using satellite rather than lookup table VEGF (both with NLCD40 LU) yields slightly higher “erodible land”

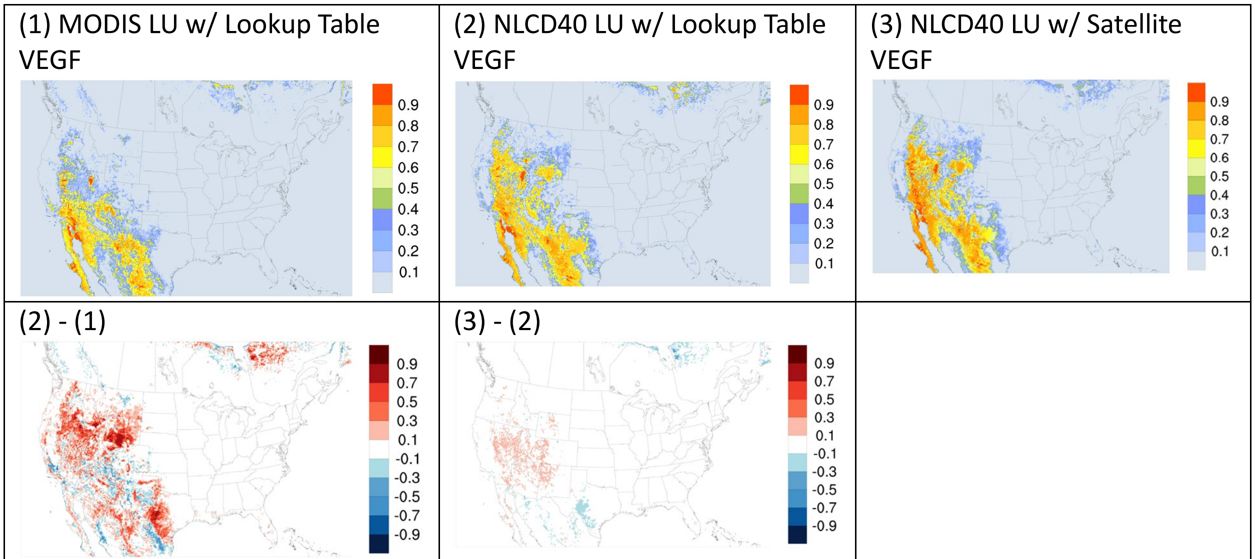

Figure 1

Figure 2 shows the annual domain total PM emissions calculated by the CMAQv5.4 inline WBD dust module using the three different WRF configurations. The estimates are highly sensitive to the WRF LU and vegetation fraction configuration, with estimates differing by a factor of 4. The lowest WBD emissions are calculated for WBD_MODIS_TABLE while the highest emissions are calculated for WBD_NLCD40_SATELLITE.

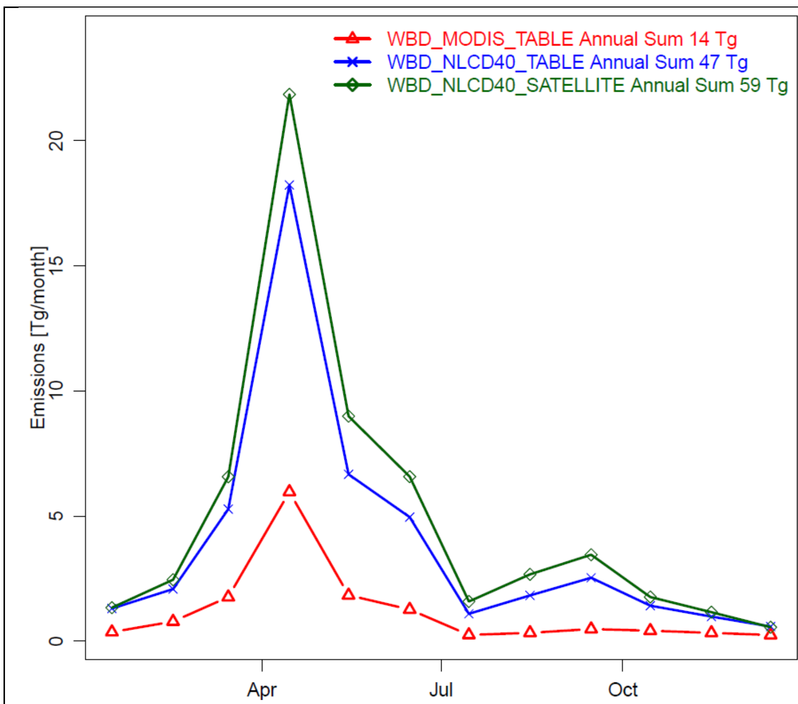

Figure 2

Figure 3 provides an illustration of the impacts of these different WBD estimates on CMAQ-simulated springtime $PM_{2.5}$ concentrations. These impacts are calculated as difference between the three WBD simulations with different WRF configurations and the "No WBD" simulation. Consistent with Figure 2, the WBD effect is generally smallest for WBD_MODIS_TABLE (mostly 1 – 3 μg/m^3 over the Southwestern U.S.) and largest for WBD_NLCD40_SATELLITE (5 – 10 μg/m$_3$ over significant portions of the Southwestern U.S.)

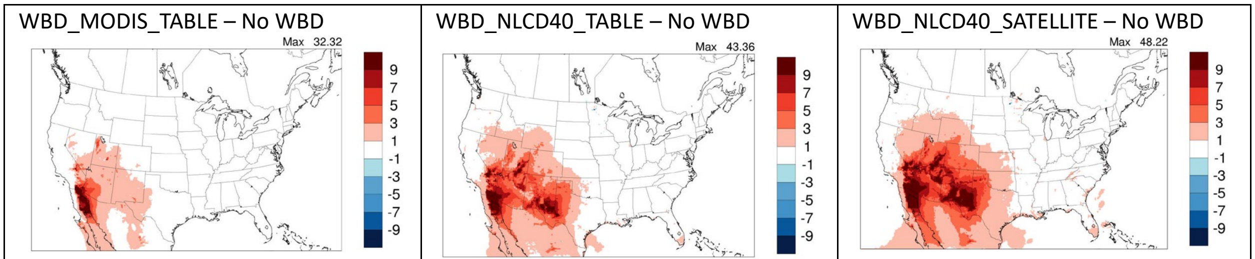

Figure 3

Figures 4 and 5 provide February – May time series of observed and modeled $PM_{2.5}$ "soil" and total mass concentrations as well as biases over the Southwest climate region (AZ, NM, CO, and UT). Figure 4 shows that the "No WBD" simulation misses several observed peaks that appear related to WBD (February 19, April 17, May 11). The "WBD_MODIS_TABLE" simulation better captures the April 17 and May 11 events but generally overpredicts observed "soil" concentrations. The WBD_NLCD40_TABLE and WBD_NLCD40_SATELLITE strongly overpredict observed "soil" at all times, especially during WBD events.

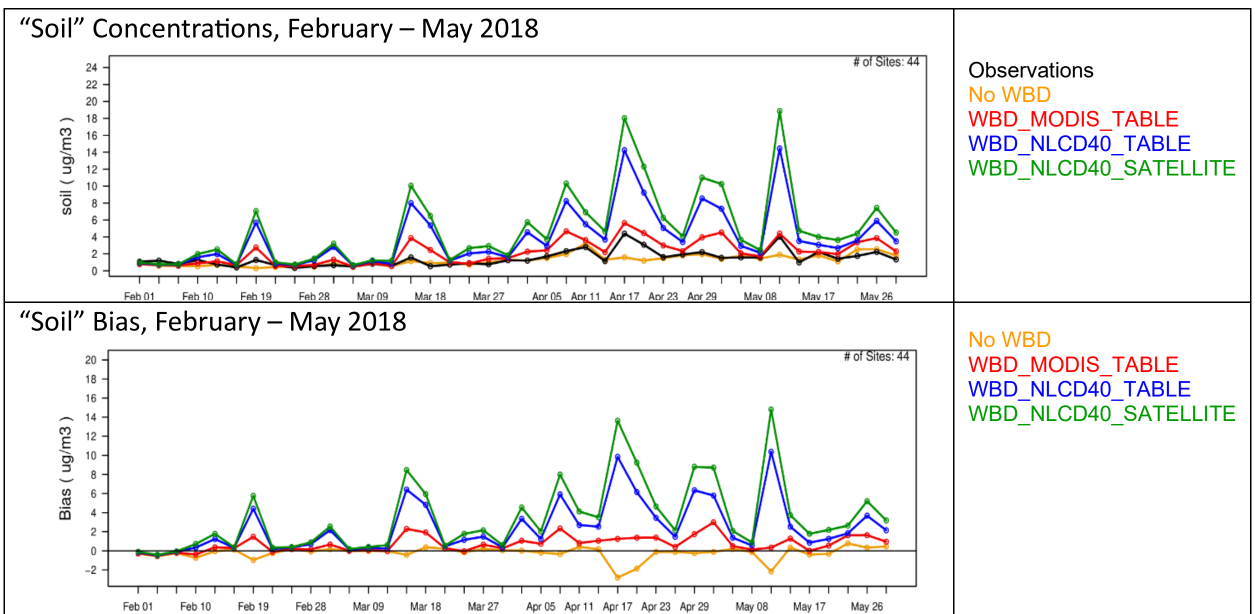

Figure 4

Figure 5 shows that like for the "soil" component, the "No WBD" simulation misses several observed total $PM_{2.5}$ peaks that appear related to WBD. However, while the simulations with WBD capture the timing of several events, they generally cause $PM_{2.5}$ overestimations, especially for the WBD_NLCD40_TABLE and WBD_NLCD40_SATELLITE configurations.

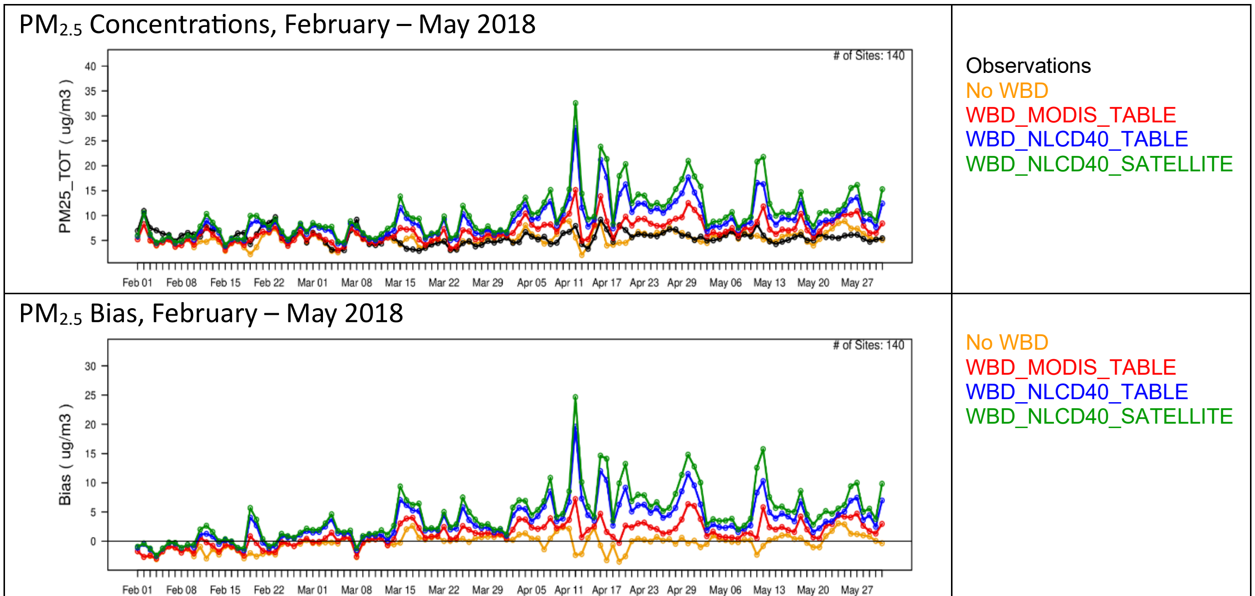

Figure 5

Figure 6 shows time series of $PM_{2.5}$ “soil” concentrations and bias over the Southwest Climate region for the entire year. This Figure illustrates that the significant overestimations for the WBD_NLCD40_TABLE and WBD_NLCD40_SATELLITE configurations are largely confined to springtime and that all simulations, including the three simulations with WBD emissions, tend to underestimate the observed concentrations during the July – September period.

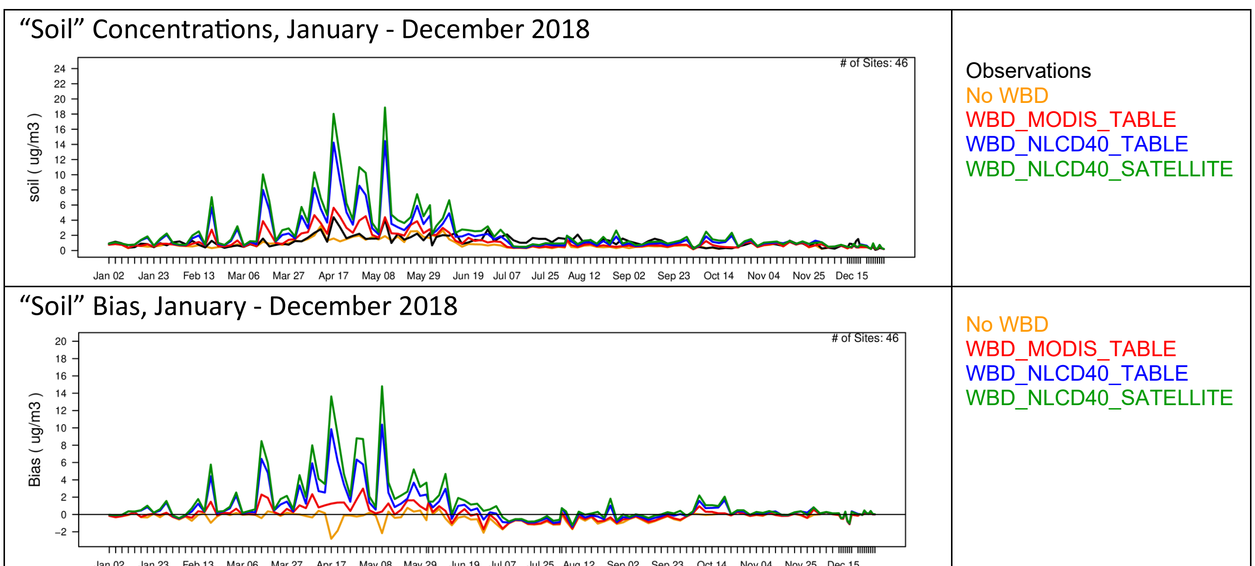

Figure 6

Finally, Figure 7 compares spatial patterns of observed “soil” concentrations and biases for the “No WBD” and “WBD_MODIS_TABLE” simulations for April 14 – 24, a period for which Figure 4 showed elevated concentrations. In particular, the observed “soil” concentrations reached 2 - 4 $\mu g/m^3$ in AZ and NM. The simulation without WBD significantly underestimates these high observed values. The

WBD_MODIS_TABLE simulation remedies these underestimates, but often the increase is too large. Overall, the number of sites showing decreased vs. increased absolute bias when including WBD is roughly equal.

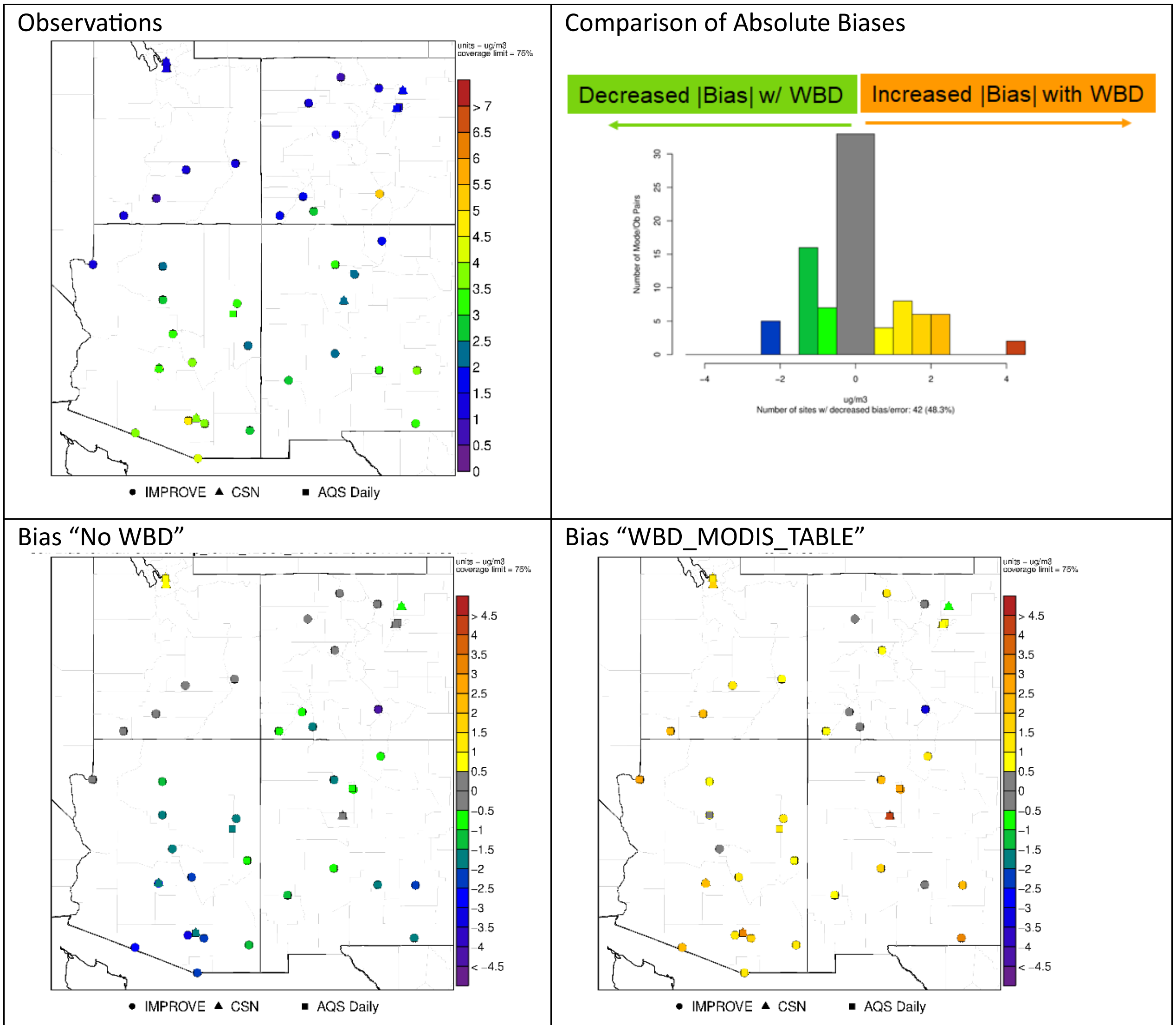

Figure 7

Reference:

Foroutan, H., J. Young, S. Napelenok, L. Ran, K. W. Appel, R. C. Gilliam, and J. E. Pleim (2017), Development and evaluation of a physics-based windblown dust emission scheme implemented in the CMAQ modeling system, J. Adv. Model. Earth Syst., 9, 585–608, doi:10.1002/2016MS000823