Analysis of the impact of dust emissions on aerosol optical depth over the Northern Hemisphere as simulated by CMAQv5.3.2 for the EQUATES project

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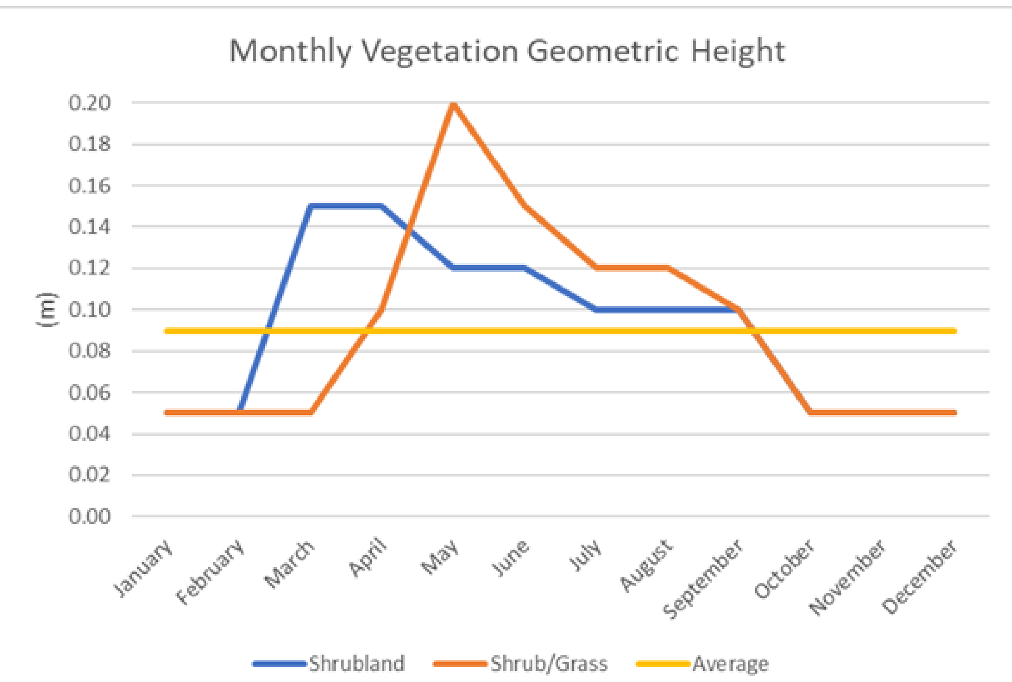
Background

Model simulations were performed for 2002–2017 using WRFv4.1.1 and CMAQv5.3.2 over the Northern Hemisphere. Emissions were represented by a 2002–2017 emissions dataset developed for EPA's Air QUAlity TimE Series (EQUATES) project. Initial findings show seasonal and regional differences between simulated and satellite derived aerosol optical depth (AOD). Initial analyses of $PM_{2.5}$ mass and components suggest that modeled windblown dust emissions may have an influence on modeled AOD, likely contributing a springtime peak in many locations. In this presentation, we examine the impacts of the dust module parameterizations of vegetation height on simulated dust emissions, $PM_{2.5}$ concentrations, and AOD through a CMAQ sensitivity simulation.

Data & Methods

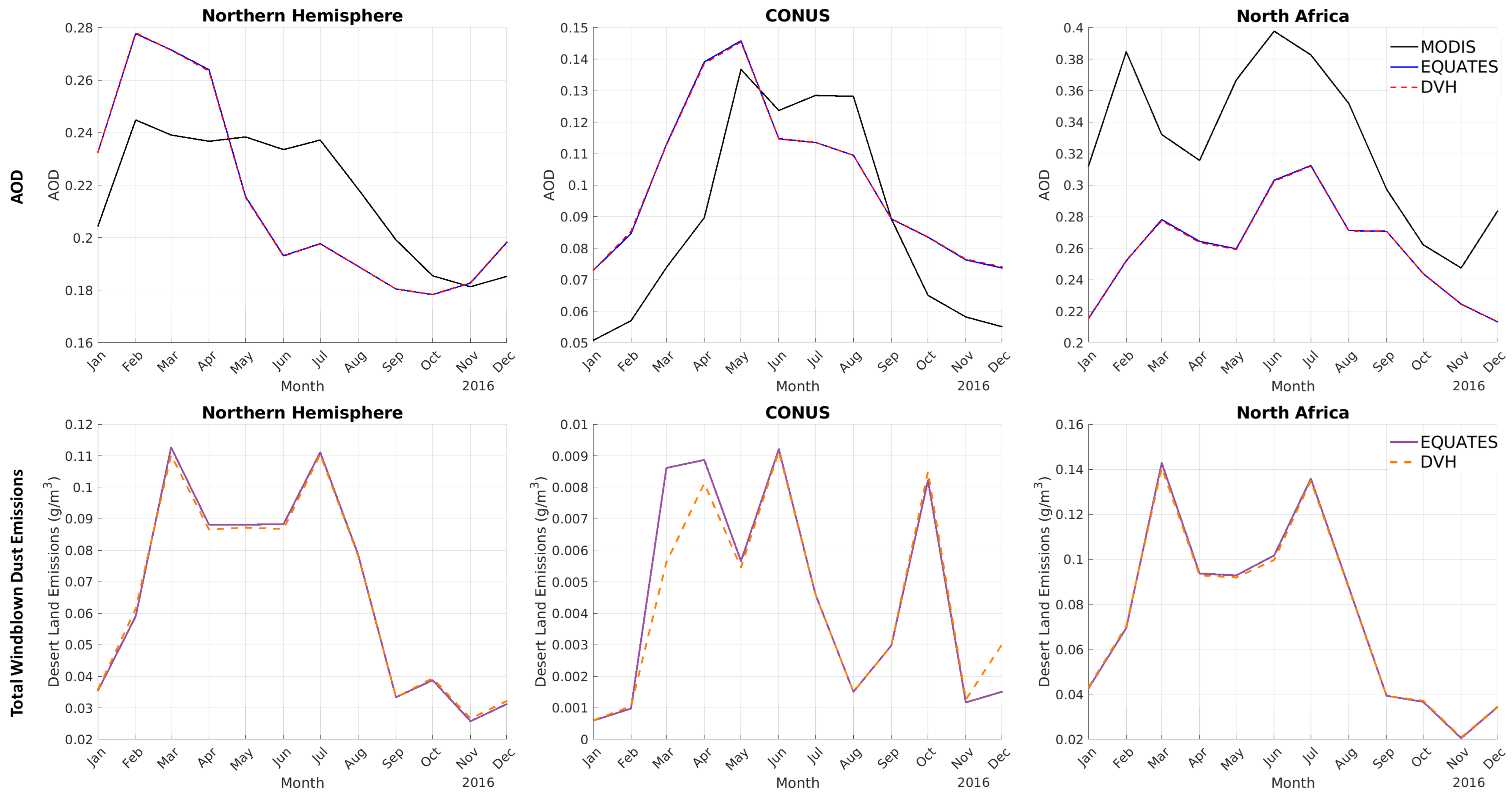
- Monthly average AOD from simulations is calculated for the daily hours 0900–1500 LST to match satellite observations. Monthly average values for all other variables calculated for all hours.
- Monthly average AOD from the Moderate Resolution Imaging Spectroradiometer (MODIS; MOD08_M3, Platnick et al., 2015). The MODIS Deep Blue Dark Target product is used to have a complete picture of the NH and is interpolated to the model grid.
- For the sensitivity simulation (dust vegetation height, DVH), the seasonally varying vegetation geometric height found in the CMAQ dust module is set to a constant value equal to the annual average (0.09m) for two land types: shrubland and shrub/grassland (shown below; Foroutan et al. 2017). Simulation performed for 2016 with all other model options the same as for EQUATES.

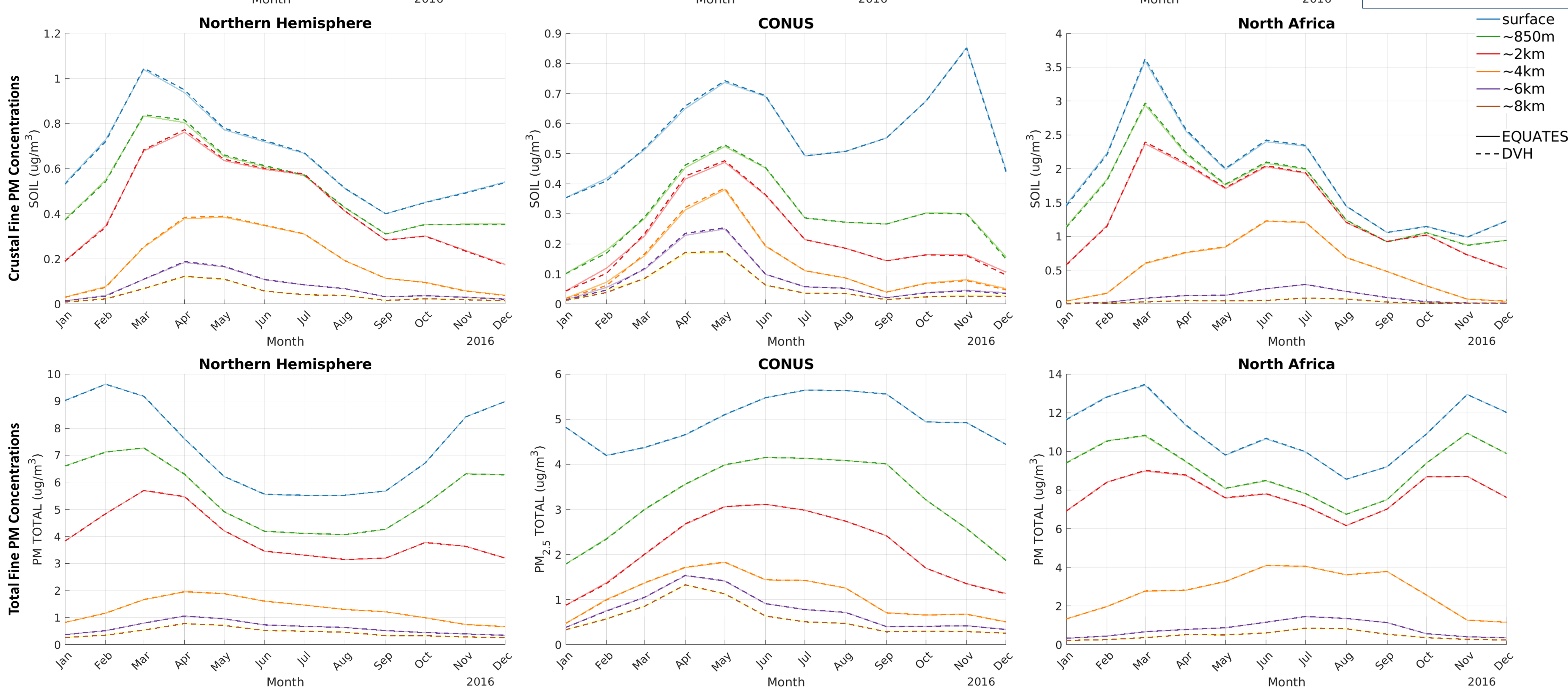


https://www.epa.gov/cmaq/equates

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.

Platnick, S., et al., 2015. MODIS Atmosphere L3 Monthly Product. NASA MODIS Adaptive Processing System, Goddard Space Flight Center, USA: http://dx.doi.org/10.5067/MODIS/MOD08_M3.061



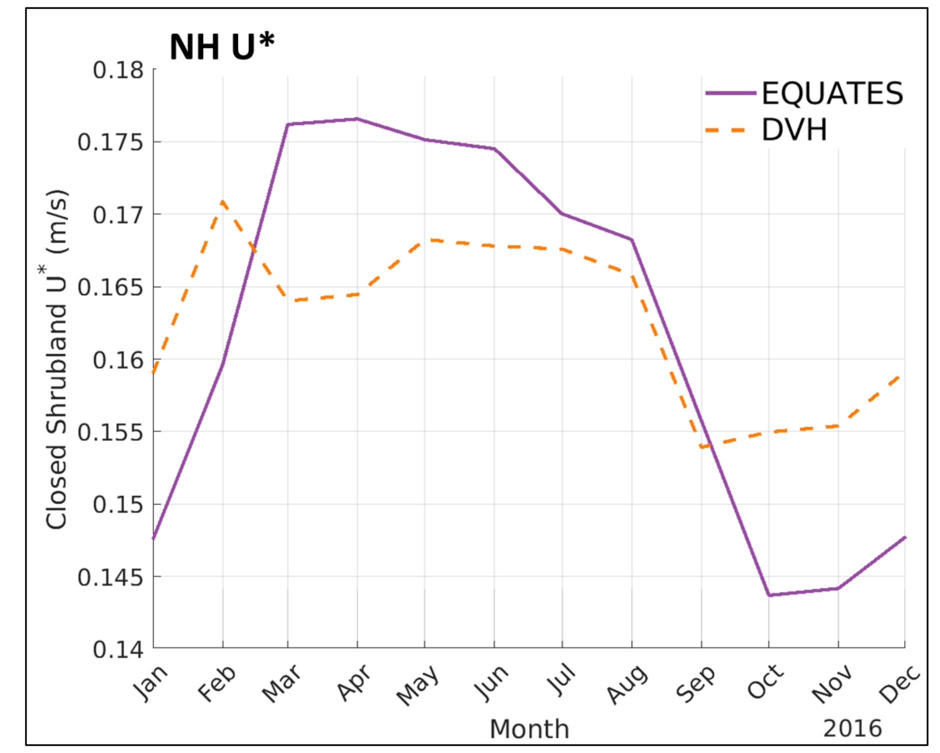


Results

Initial comparison of EQUATES AOD with MODIS satellite observations reveal an overestimated springtime (March, April, May) peak and an underestimation in summertime (June, July, August) modelled AOD (NH and CONUS). Modelled AOD is underestimated for the entire year over North Africa.

The seasonally-varying vegetation height parameter used in the windblown dust module is one of the factors affecting seasonality in windblown dust emissions, along with variations in wind speed, soil moisture, and vegetation fraction. To isolate the effects of the seasonality in prescribed vegetation height on dust emissions, PM concentrations, and AOD, in our sensitivity simulation we increased vegetation height values for winter months and decreased them for summer months. With an increase in vegetation height, there is a proportional increase in the surface friction velocity (U*) which is more likely to exceed the threshold at which soil erosion can occur. The same is true for a decrease in vegetation height that leads to a decrease in U*, and thus a decrease in dust emissions. We see these changes in the modeled dust emissions with the vegetation height changes (DVH).

There is a slight decrease in summertime dust emissions across the NH, CONUS, and North Africa for the DVH simulation. The largest decrease in emissions occurs from March to April over CONUS. Winter months, December to February, experience a slight increase in dust emissions. The largest occurrence of increased dust emissions occurs in December over CONUS. These changes in dust emissions are accompanied by expected changes in U*. There is an increase in U* from October to February and a decrease from March to September. This is also observed over CONUS and North Africa (not shown). These small changes in dust emissions by changing the vegetation height have only a small effect on simulated AOD.



We also observe a springtime peak in crustal fine PM concentrations for all regions. This peak occurs through all layers for the NH average and over CONUS. The springtime peak over North Africa does not extend as high in altitude. DVH simulation changes in crustal fine PM concentrations are very small with slight increases in summer months and slight decreases in winter months. The opposite of dust emission changes. These subtle changes are most pronounces in summer months at lower altitudes.

The regional total fine PM concentrations show similar springtime peaks with NH and North Africa occuring closer to the surface and CONUS experiencing a spring peak at higher altitudes. Changes in the vegetation height led to very small changes in PM concentrations.

Conclusions

- Changing the CMAQ prescribed seasonal variation in vegetation height had the expected qualitative effects on the seasonal variation of dust emissions, $PM_{2.5}$ concentrations, and AOD, but the magnitudes of these changes are small.
- Other factors, such as soil moisture and wind speed, likely play a more dominant role in seasonal variations of dust emissions.

Future Work

- Assess impact of incorporating brown vegetation on seasonal variations in friction velocity, surface roughness, dust emissions, $PM_{2.5}$, and AOD.
- Analysis of simulated optical properties of different $PM_{2.5}$ components to assess the impact of soil-related $PM_{2.5}$ on seasonal variations in AOD.