Modeling Utah Dust Events Using CMAQ 5.3.1

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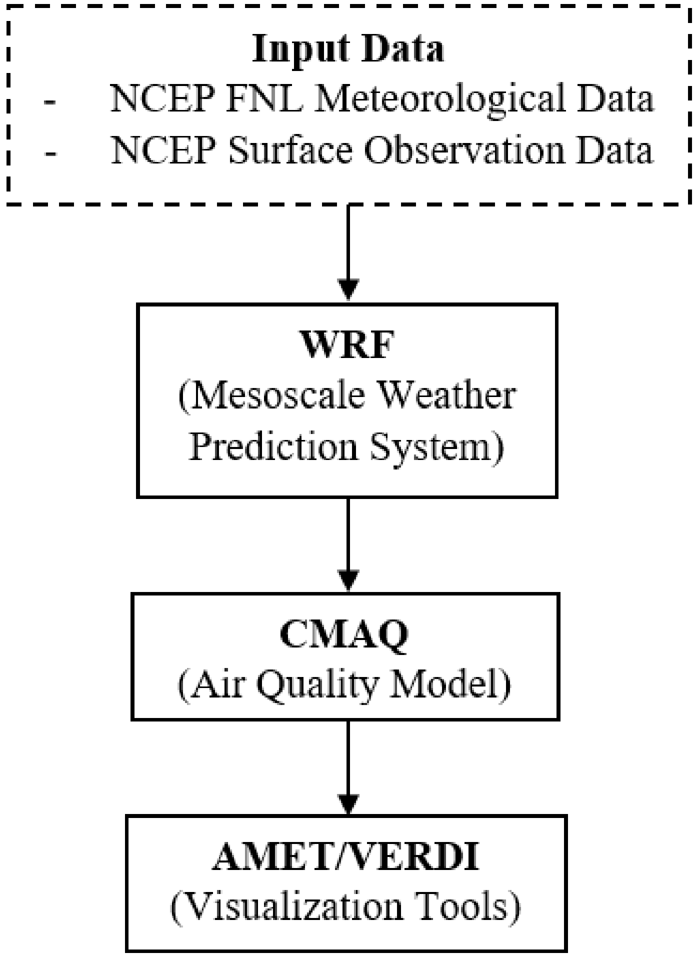
Objectives

- Develop a software framework for modeling Utah-specific dust emission and transport using WRF, CMAQ, and associated property files
- Verify model results using published measurements for two Wasatch Front dust events
- Assess result sensitivity to key model parameters
- Evaluate future impact scenarios by predicting dust concentrations based on changes to land use and soil types in the Great Salt Lake region
    - Shrinking GSL
    - Large Scale Solar Farms

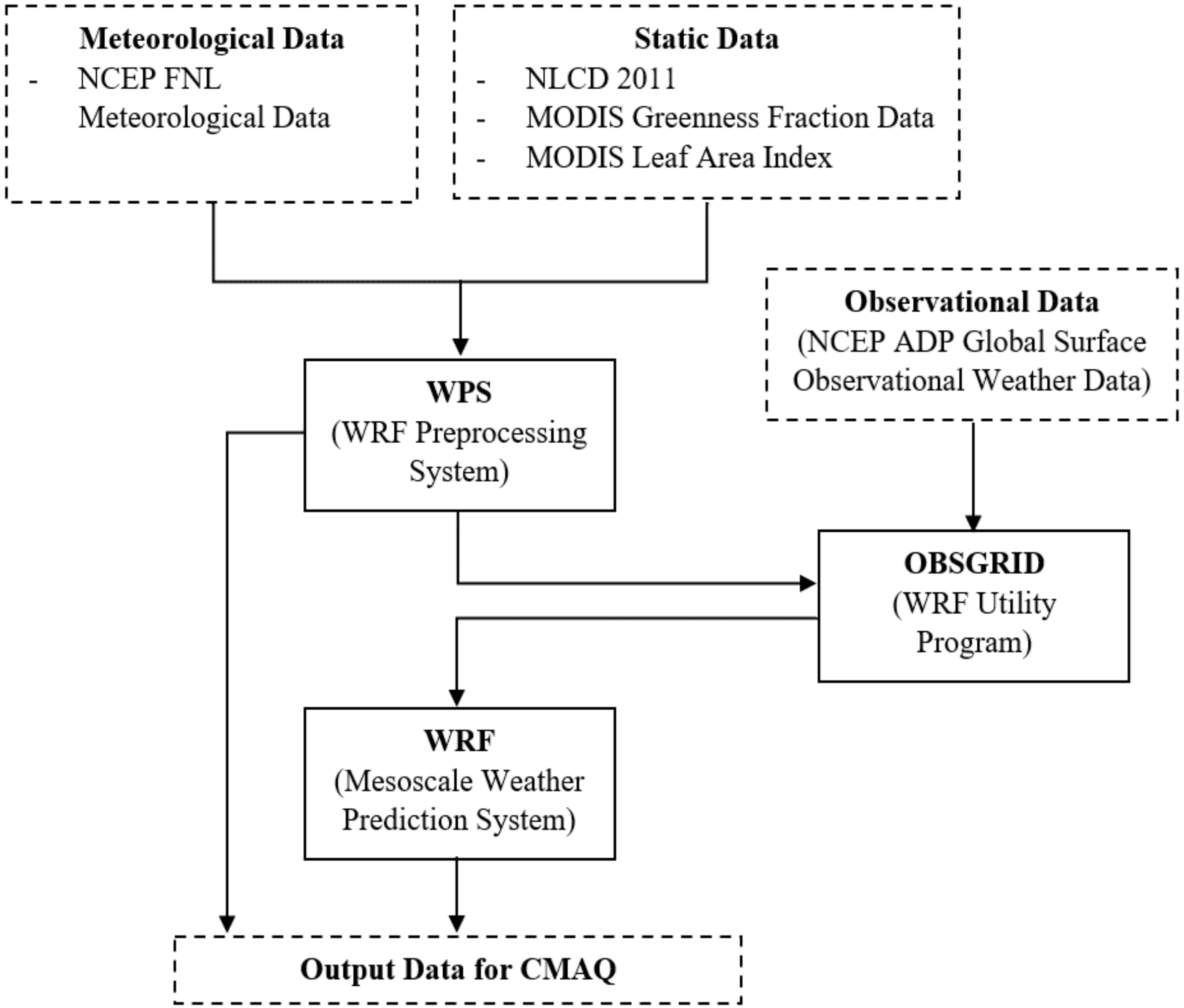
Model Development

- Model inputs include meteorological and land use data taken from multiple national databases
- WRF processes meteorological and land use data
- CMAQ uses WRF outputs to model dust emissions and transport
- AMET used to compare simulation results to observed concentrations
- VERDI used to visualize dust events and their behavior
- User Guide: https://scholarsarchive.byu.edu/facpub/5515/



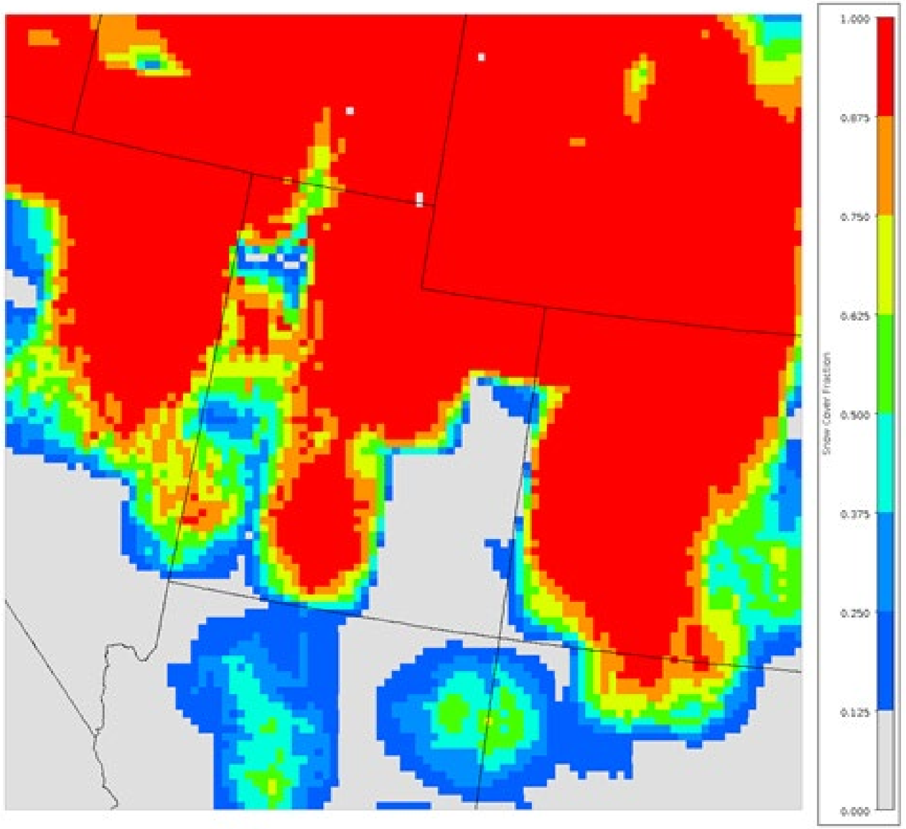
WRF

- WRF calculates met data, land use, soil type for CMAQ
  - CMAQ dust model requires PX-LSM
- WPS grids input data to domain of interest
- OBSGRID incorporates observations into met data to update surface conditions
- Read_wrf_nc.exe is an optional utility used to modify WRF outputs (e.g., land use types)



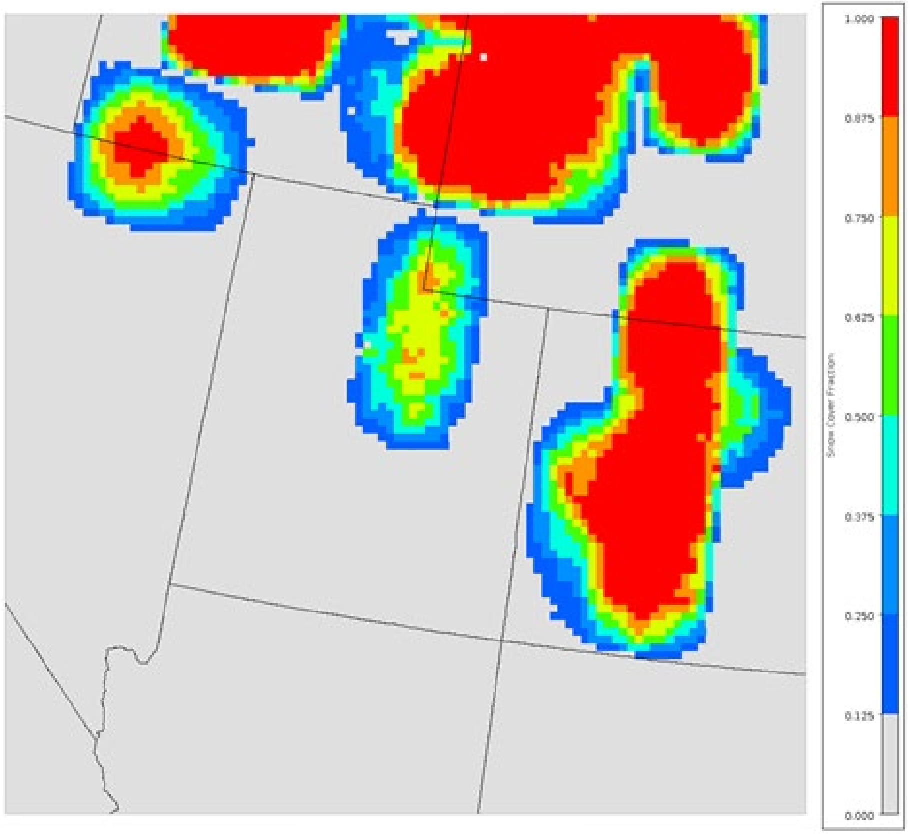
OBSGRID Impact on Snow Cover

Snow Cover without OBSGRID



April 12, 2017

Snow Cover with OBSGRID

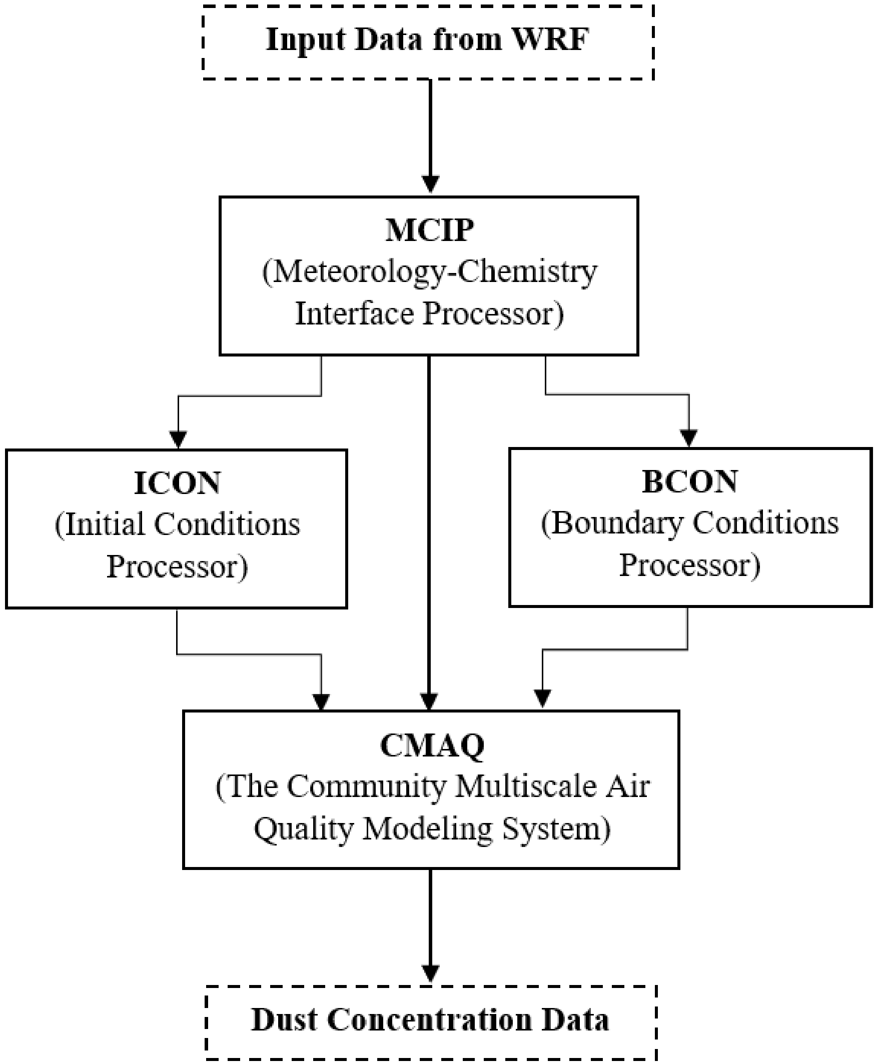


April 12, 2017

Snow cover > 0 prevents dust emission

CMAQ

- CMAQ predicts windblown dust emissions, transport, and deposition
- MCIP, ICON, and BCON process WRF outputs to work with CMAQ
- CMAQ normal chemical reaction calculations turned off (no emission inputs required)
- Dust model modified by changing:
  - Input properties
  - Parameters within the dust emissions module



Data Comparison

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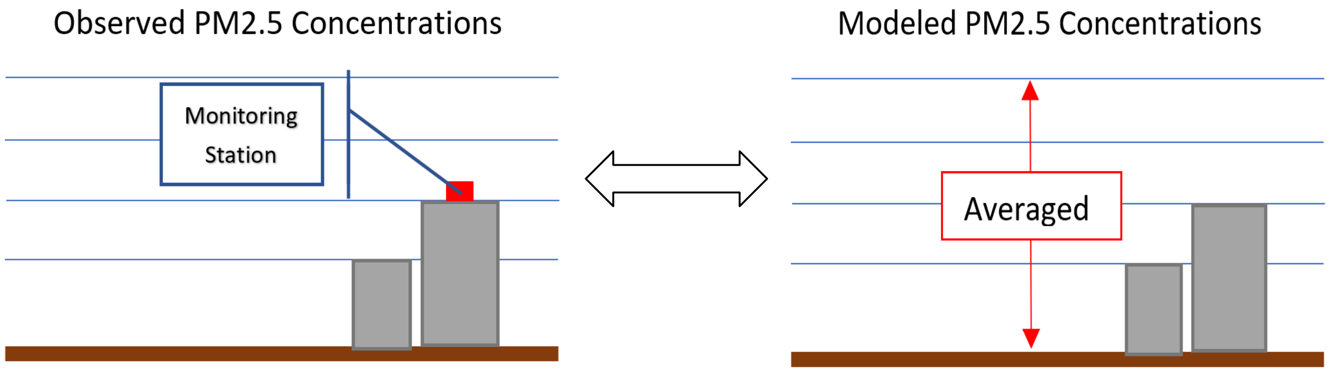
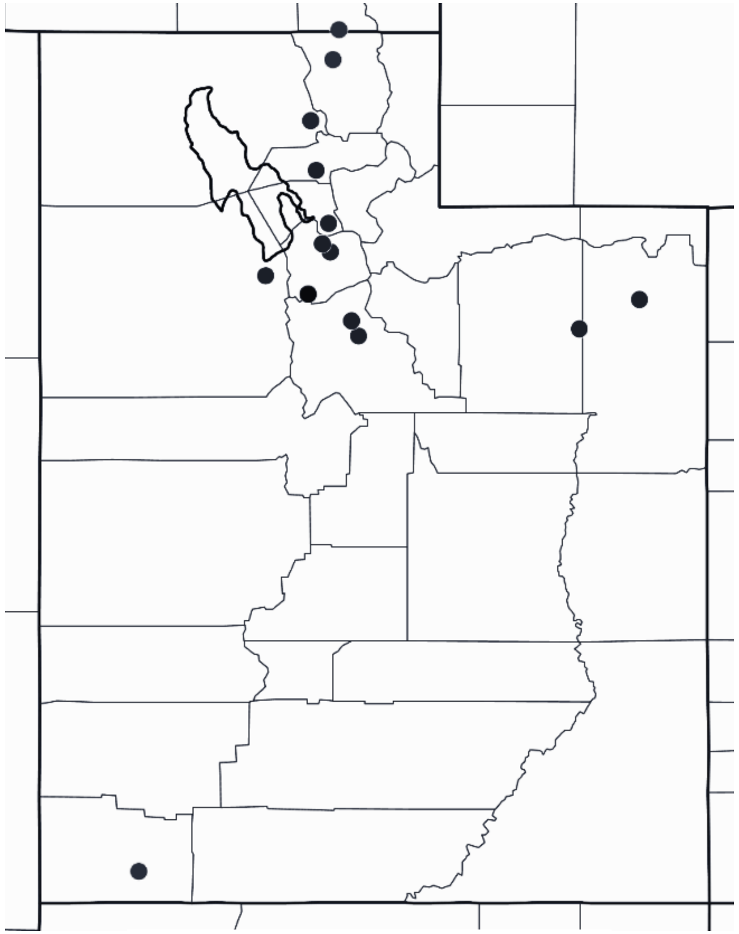
- AMET pairs observations and model output in space and time to compare predictions and observations
- AQS network contains ambient air pollution data collected by different monitoring networks, averaged to hourly concentration
- CMAQ data is averaged over all elevation layers and compared to observations at monitoring stations within the same grid cell
- If more than one monitoring station is used the observations are spatially averaged





Utah April 2017 AQS sites

April 2017 Dust Event

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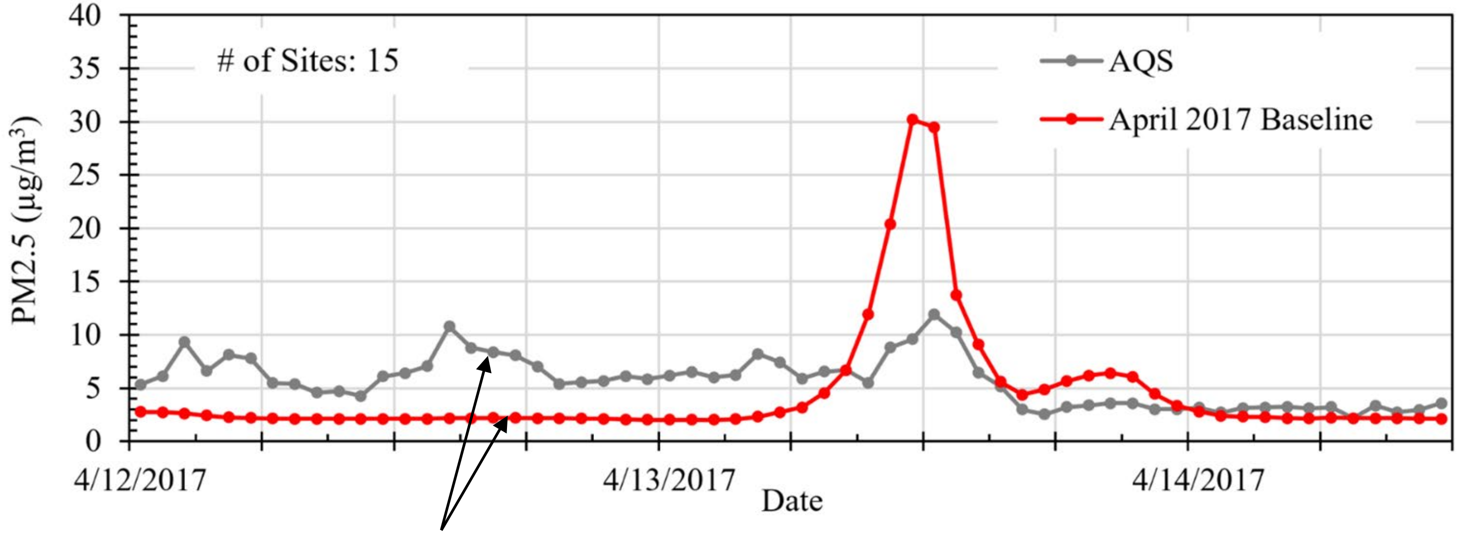
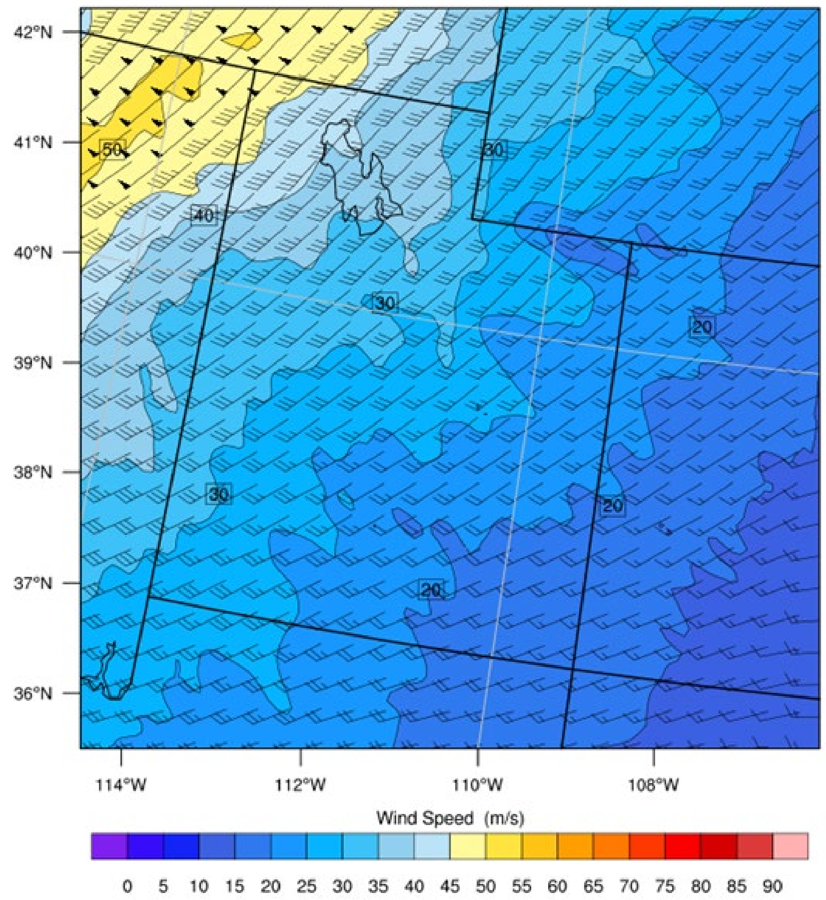
- April 13th, 2017 dust event was studied in a paper by Skiles et al., *Environ. Res. Lett. 13 (2018) 124031*
- Event caused by cold front moving in from Pacific Northwest combined with strong winds coming from southwestern Utah

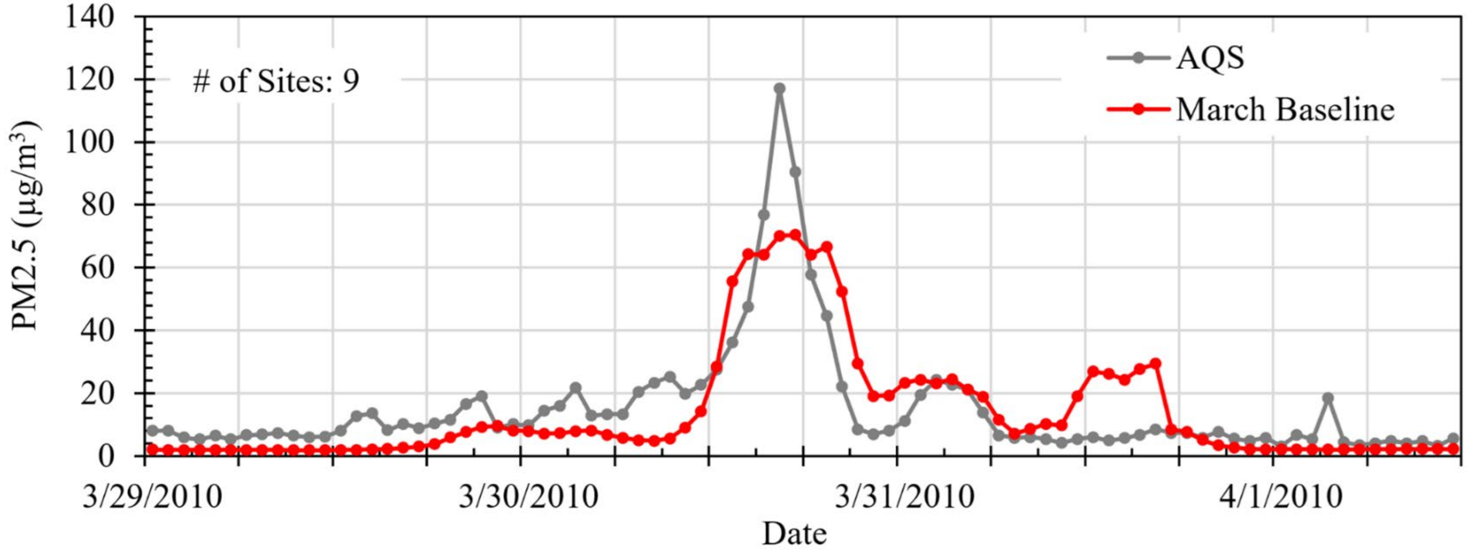


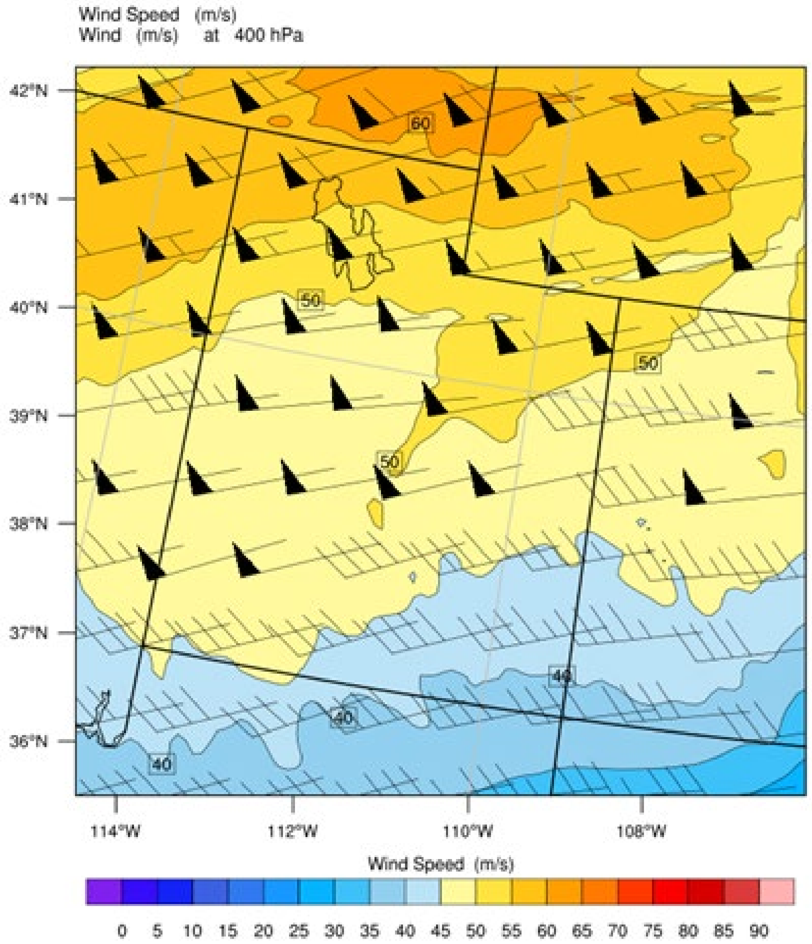
Ambient dust vs ambient PM2.5?



March 2010 Dust Event

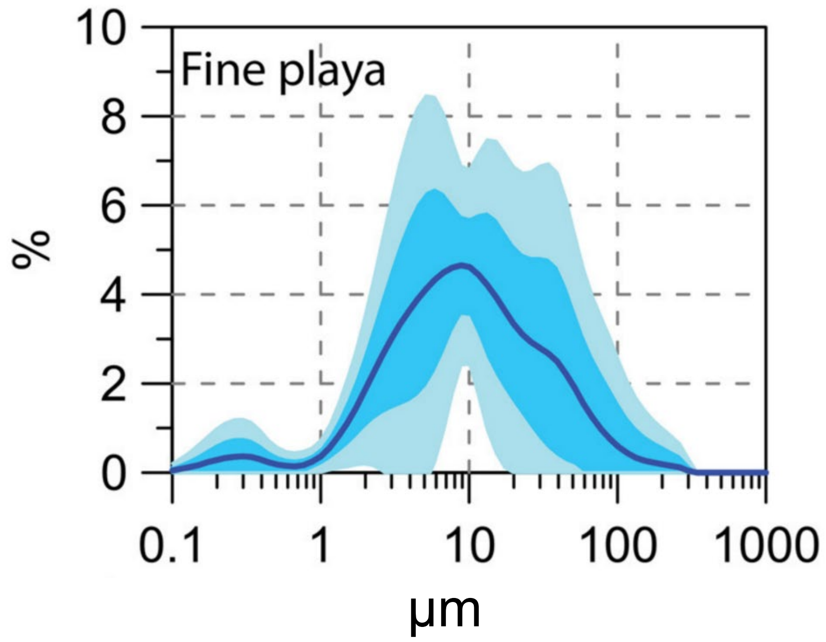
- March 31st, 2010 dust event was studied by Mallia et al., *J Appl Meteorol Clim, 56 (2017), 2845*
- Result of a front moving in the from Northwest (stronger winds than 2017 event)





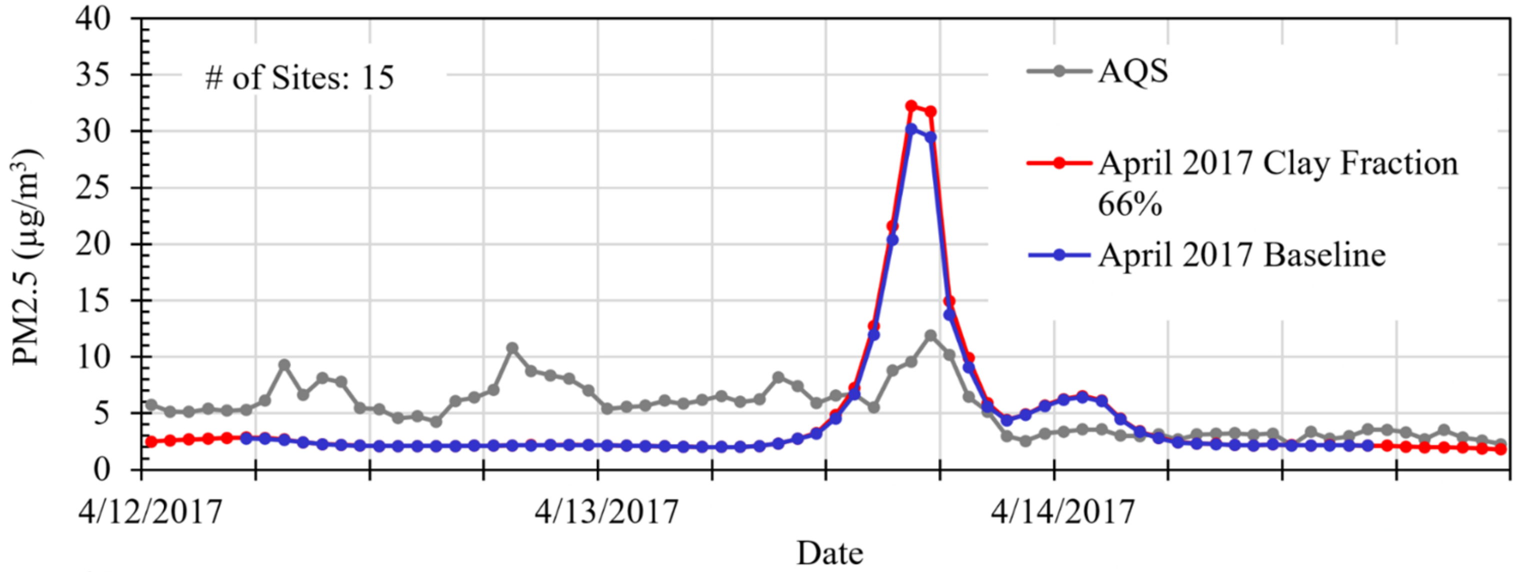
Sensitivity - Soil Texture

- Each soil type is made up of four different basic soil textures: coarse sand, fine-medium sand, silt, and clay
- Soil texture contributes to several dust emission related processes
- Goodman et al. 2019 found that playa dust shows a bias towards silt and clay modeled diameters
    - Default for Utah deserts is clay loam:
      32% fine-medium sand (D=210 μm),
      34% silt (D=125 μm), 34% clay (D=2 μm)
    - Test impact of more silt and clay

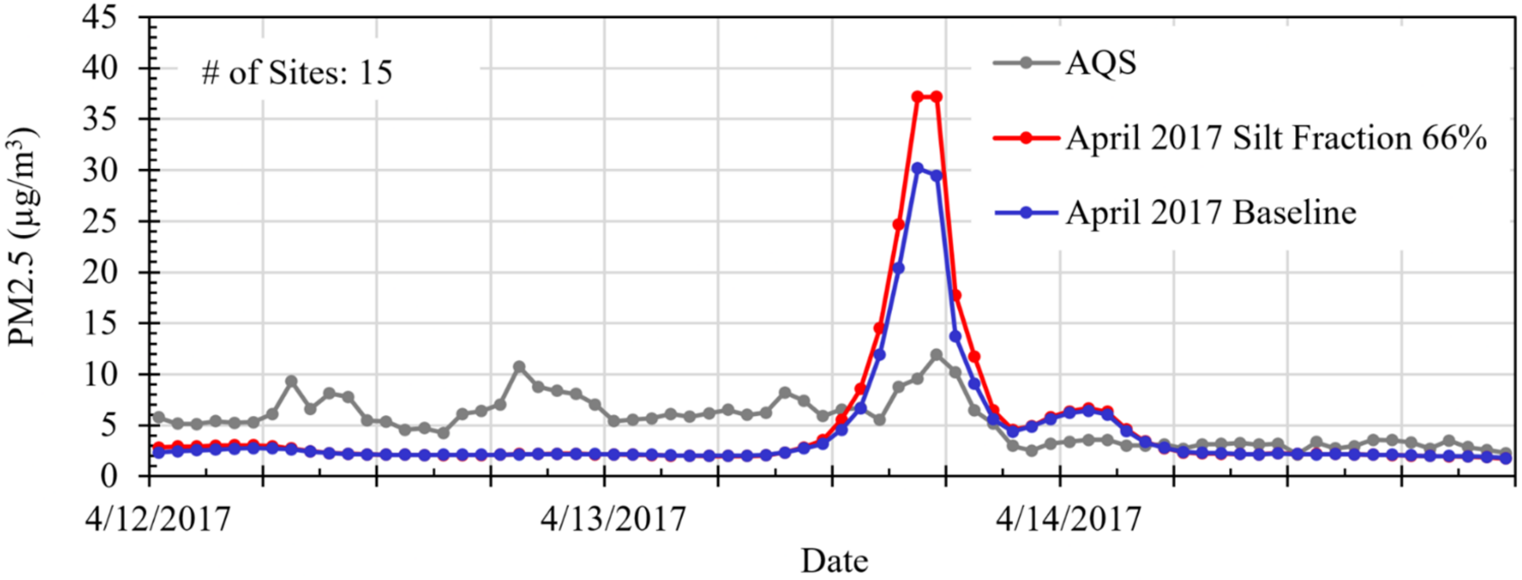


Dust Grain Size Distribution from 16 sample locations in Utah deserts
Goodman et al., Chemical Geology 530 (2019) 119317

Sensitivity - Soil Texture Results



66% clay
34% silt

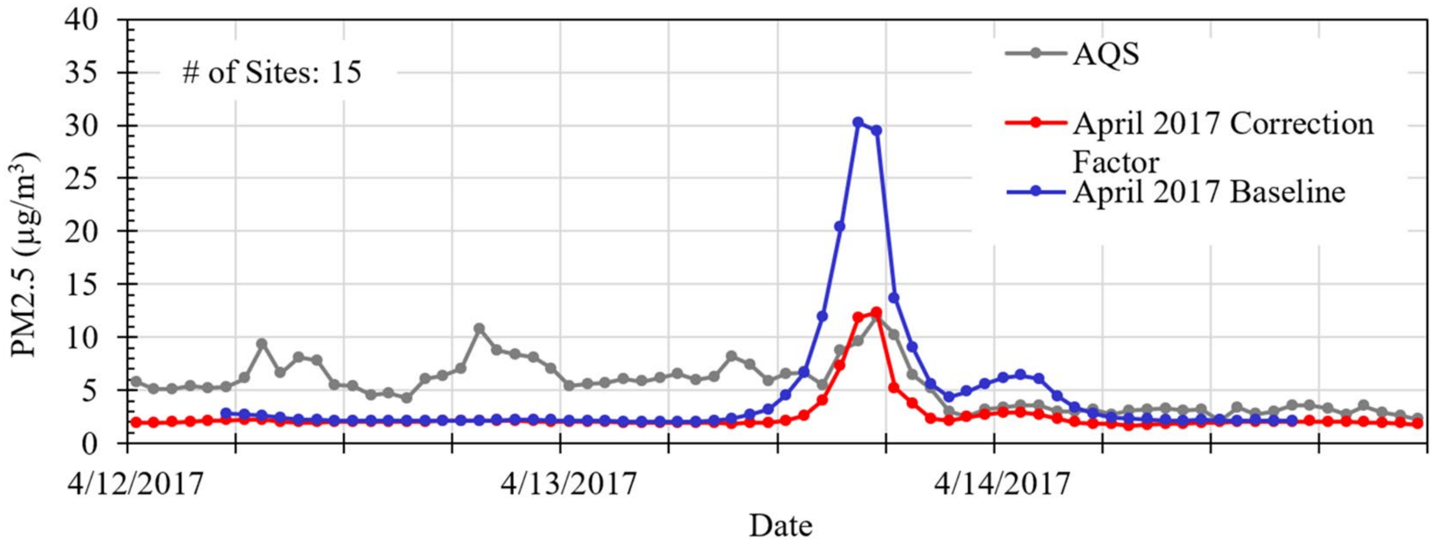


34% clay
66% silt

Sensitivity - Salt and Soil Moisture Correction Factors

- Threshold friction velocity determined by combining ideal threshold friction velocity with correction factors $u_{*,t} = u_{*,t0} f_m f_r f_s f_c$
- Two correction factors are for salt concentration and surface crustiness (default set to unity)
- A *combination correction factor* used to assess sensitivity to parameters (as a group)

Shoreline around receding Great Salt Lake



Sensitivity - Flux Factor Results

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- Flux factors determine the vertical to horizontal particle flux ratio
- Flux factors made up of a variety of soil properties: fraction of fine particles, plastic pressure, bulk soil density, soil particle density
- Flux factors were increased and decreased by an order of magnitude

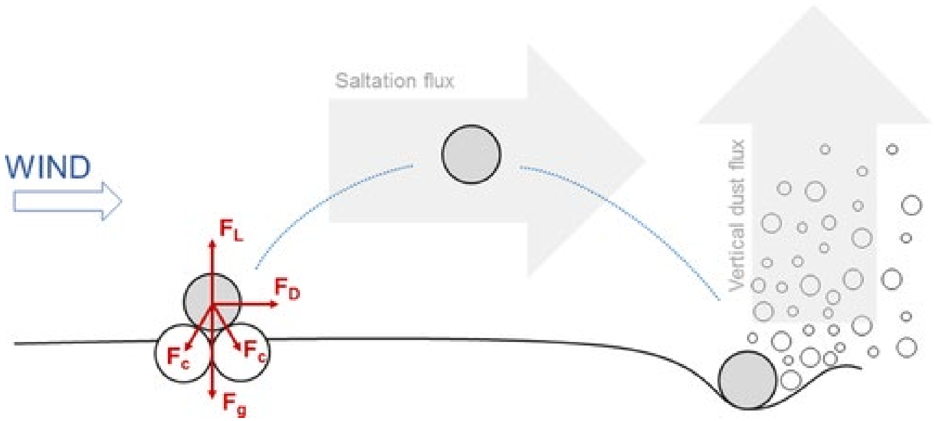
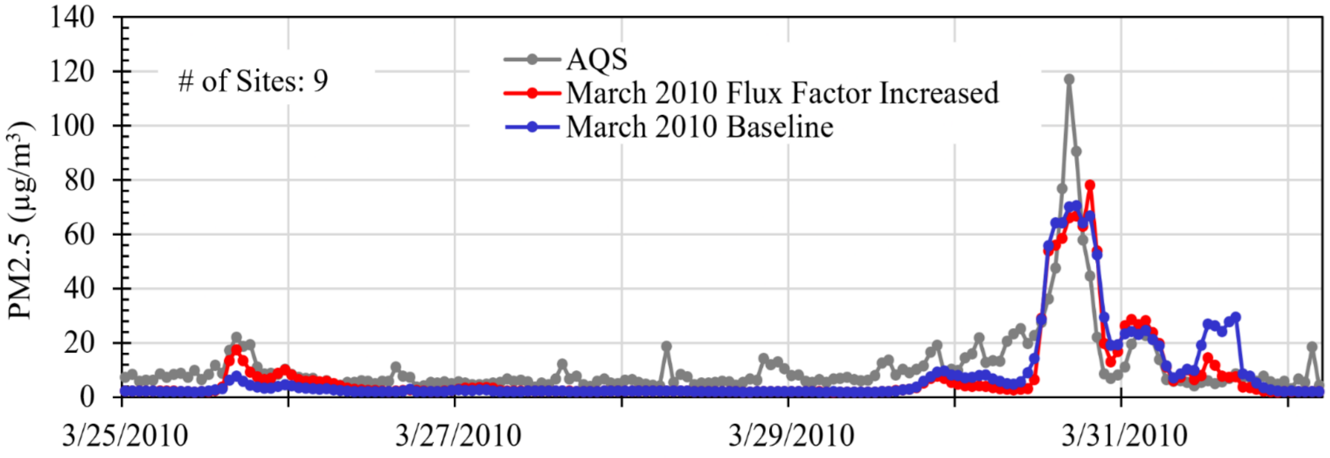
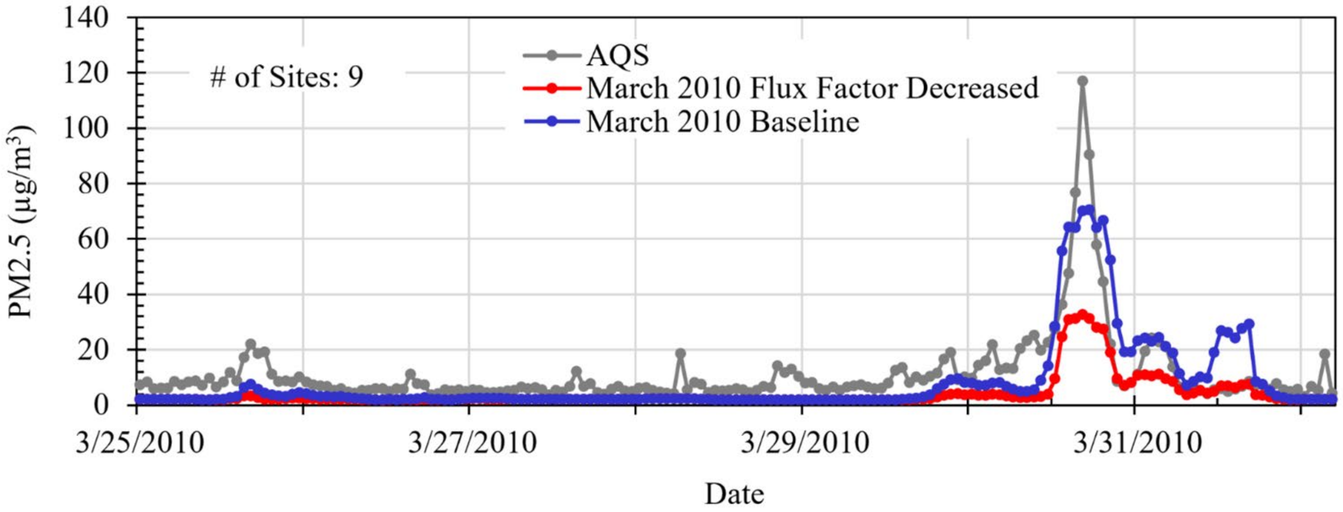


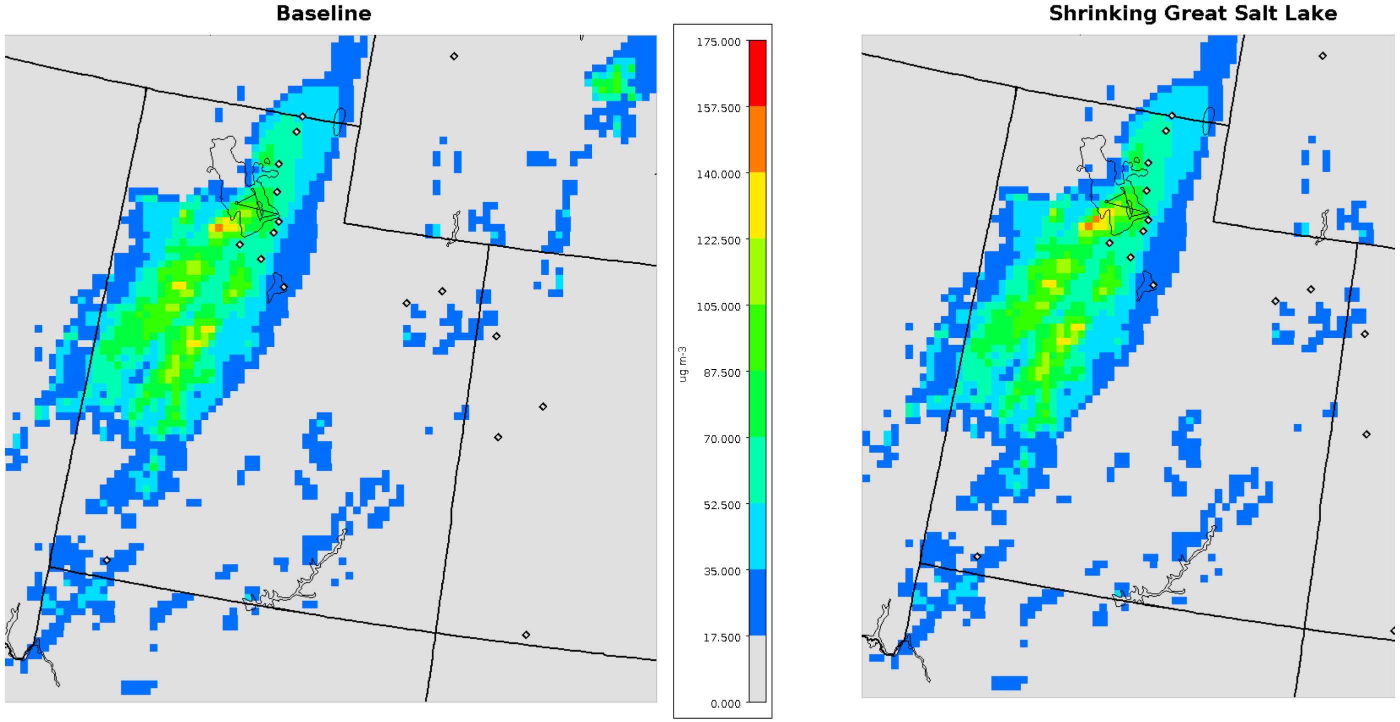
Figure from Foroutan et al. (2017) J Adv Model Earth Syst, 9, 585

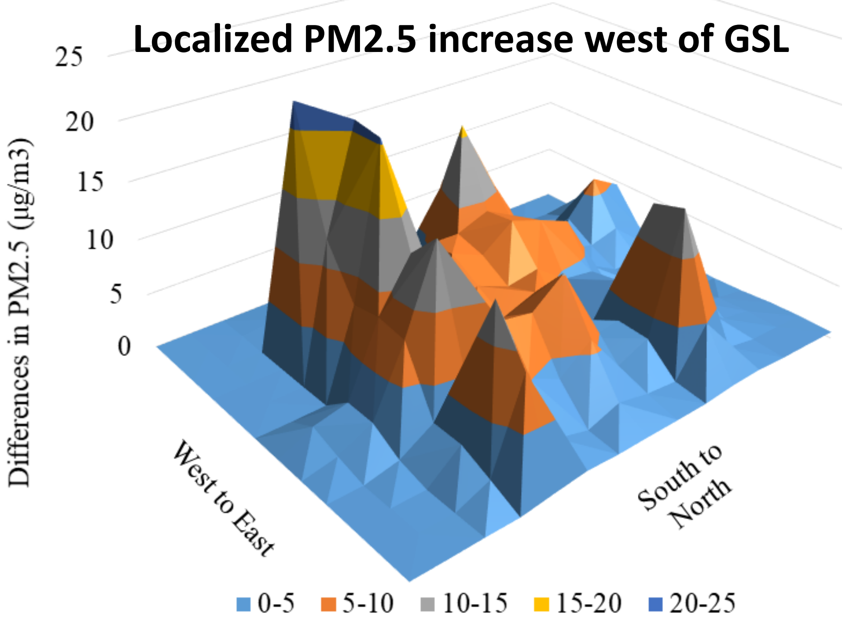




Future Impact Scenario - Shrinking GSL

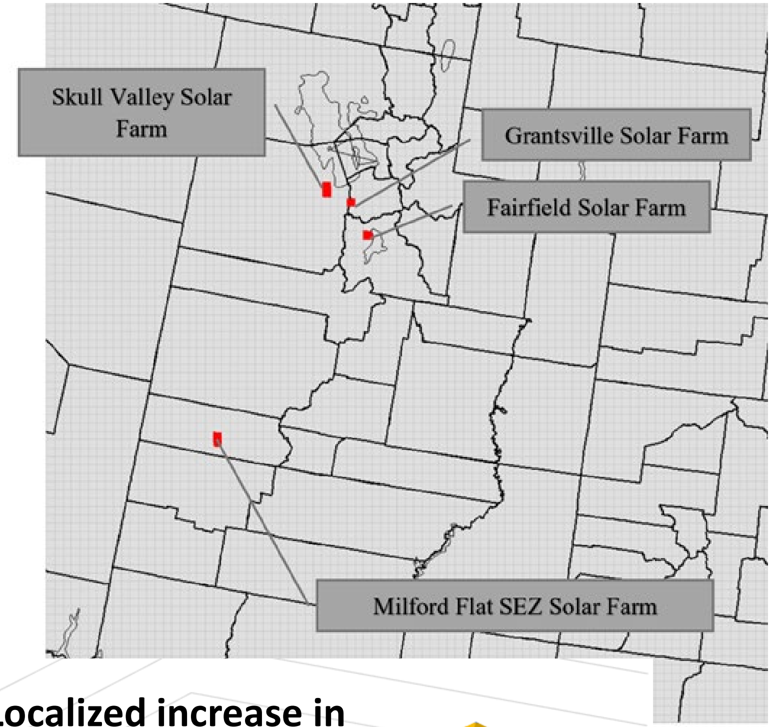
- read_wrf_nc.exe WRF post-processing utility used to "shrink" Great Salt Lake 50-60% from 2016 levels
- Assess with April 2017 dust event meteorology

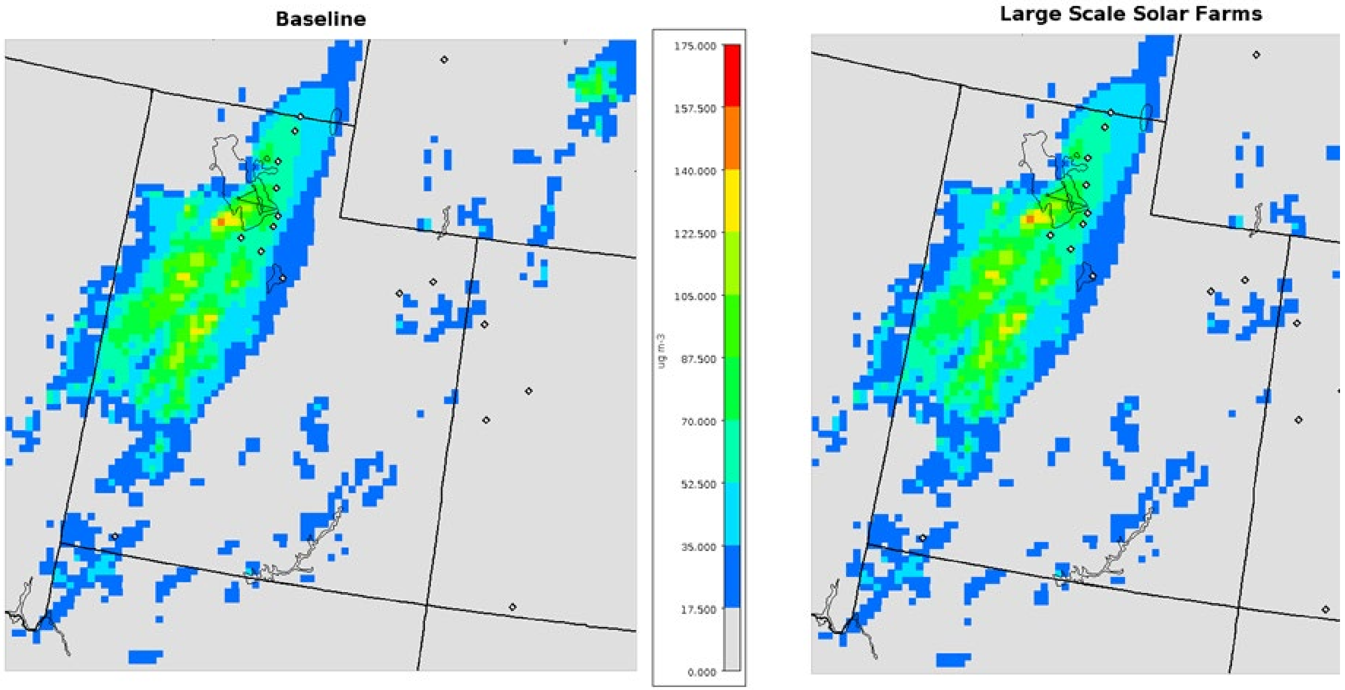


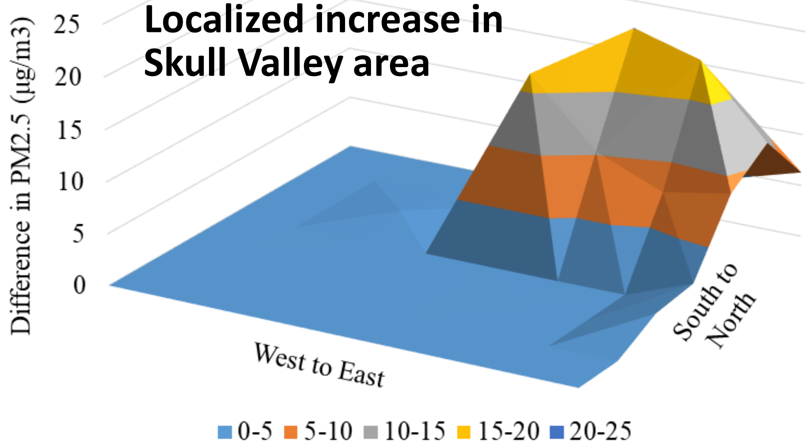


Future Impacts – Large Solar Farms

- Large solar farms (based on 8 km-square refinement) added to four locations in Utah
- read_wrf_nc.exe utility used to modify soil type, land use, and vegetation heights at sites
- Assess with April 2017 dust event meteorology







Summary

- A software framework using WRF 4.2.1 and CMAQ 5.3.1 was developed and verified for dust events along the Wasatch Front
- Sensitivity studies showed more experimental data is needed to refine key parameters in the dust model
    - Salt concentration and surface crustiness factors
    - Flux factors as impacted by soil properties
- Future impact studies showed effects of shrinking the Great Salt Lake and addition of large solar farms were localized for weather conditions studied
- Framework can be used to evaluate future land use and water diversion policies along with impacts of climate change

Acknowledgments

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