Role of soil moisture on the Earth's radiative balance through modulations of the dust direct and indirect effects

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18 August 2021

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

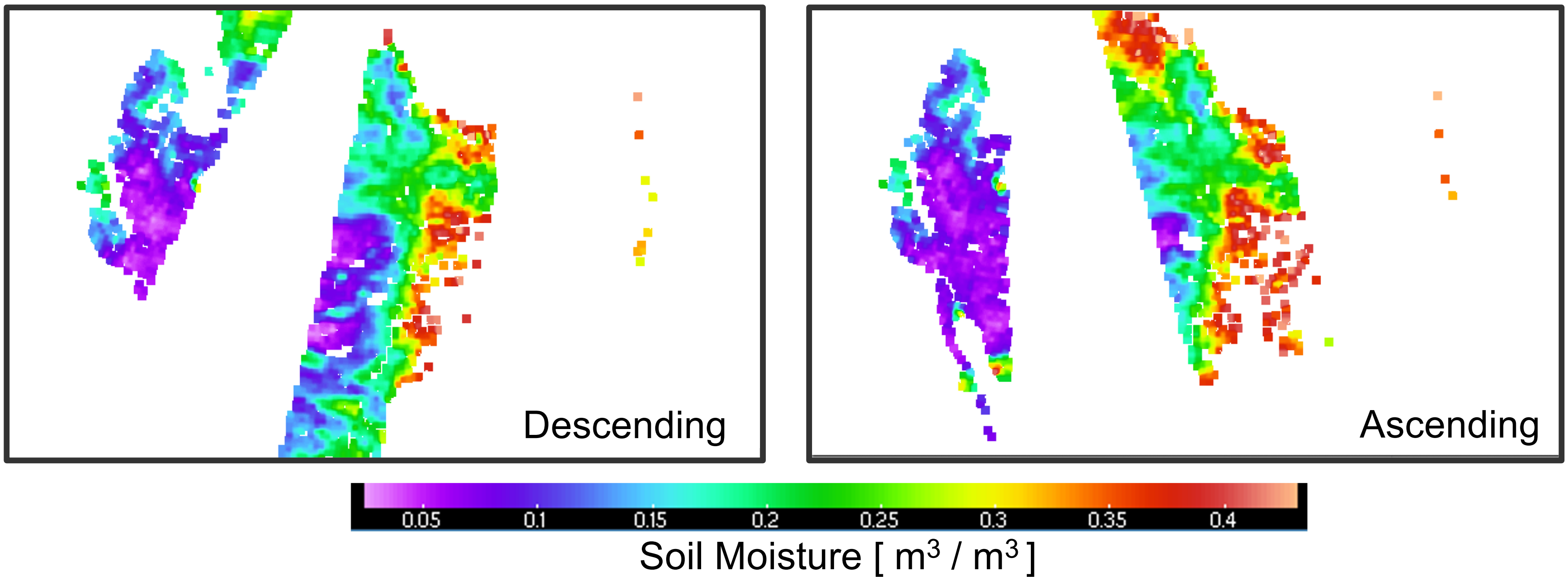
Motivation

- Dust is an abundant atmospheric aerosol contributing to both the direct and indirect effects and thus contributes to the Earth's radiative balance.
- Dust emissions are sensitive to the soil composition, and dust mobilization which mainly depends on wind speed (responsible for lifting the soil particles) and soil moisture (increases cohesive forces between the soil particles).
- Our ultimate goal is to increase our fundamental understanding of the modulations that soil moisture exerts on the Earth's radiative balance through modulations of the dust emissions.
- Appropriate modeling of winds and soil moisture is therefore necessary to analyze the dust radiative effects with numerical weather prediction models.
- Explore the potential of using SMAP soil moisture retrievals to improve dust simulations performed with the WRF-Chem model.

SMAP soil moisture retrievals

- We use the SMAP L2 product LM_SM_P (version 7) that provides soil moisture retrievals at 36 km grid spacing
- Only soil moisture retrievals with recommended quality are used

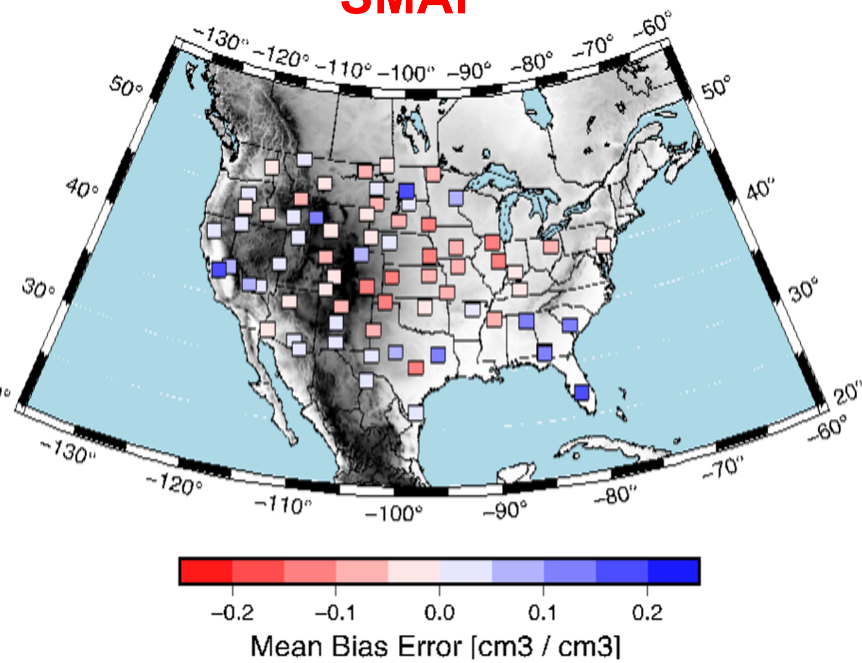
SOIL MOISTURE RETRIEVALS OVER THE CONTIGUOUS U.S. DURING A 24 H PERIOD



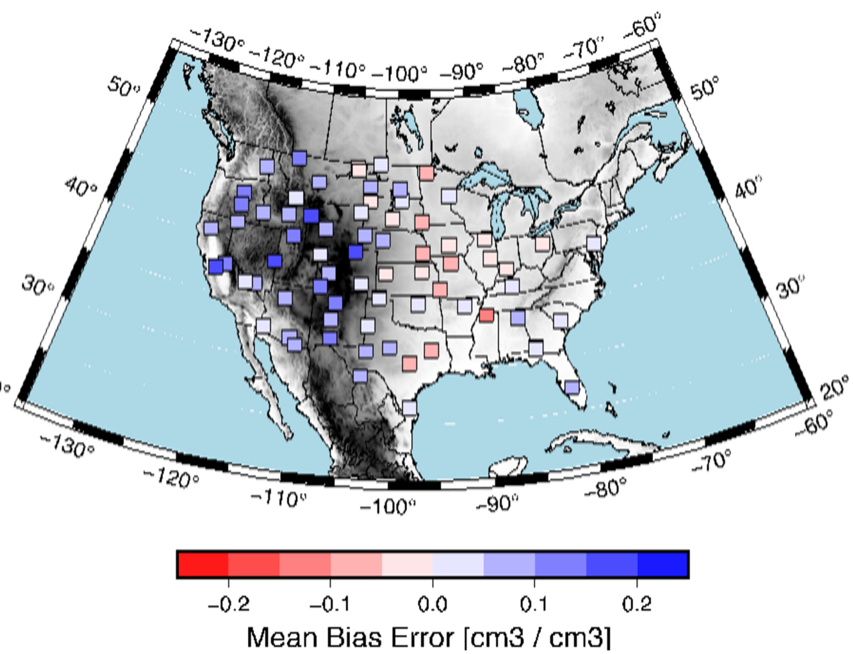
Added value of SMAP with respect to WRF simulations: mean bias error

- Evaluation period: April 2015 – June 2020
- SMAP retrievals and WRF simulations compared against USCRN observations

SMAP



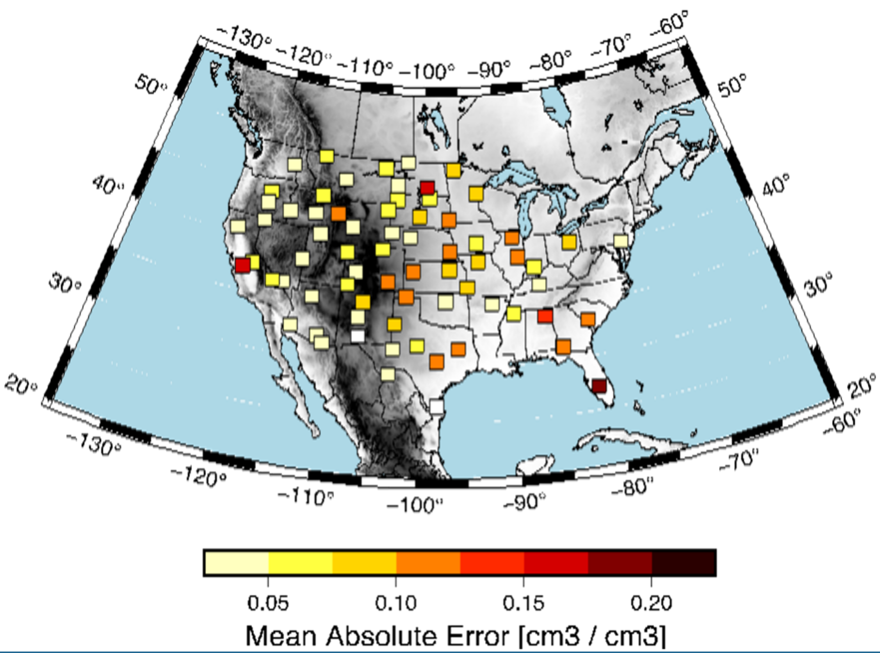
WRF



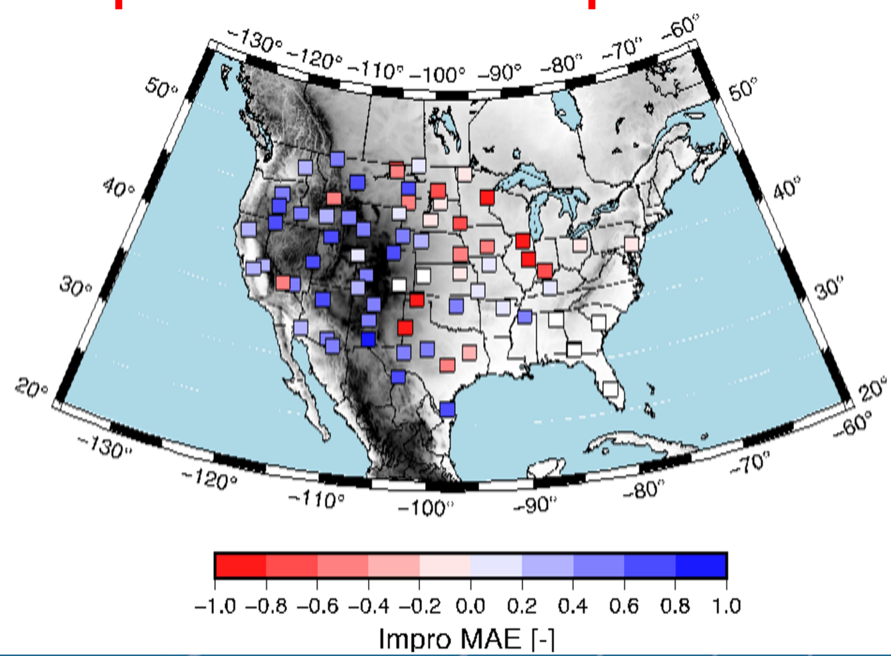
Added value of SMAP with respect to WRF simulations: mean absolute error

- Evaluation period: April 2015 – June 2020
- SMAP retrievals and WRF simulations compared against USCRN observations

SMAP



SMAP Improvement with respect to WRF

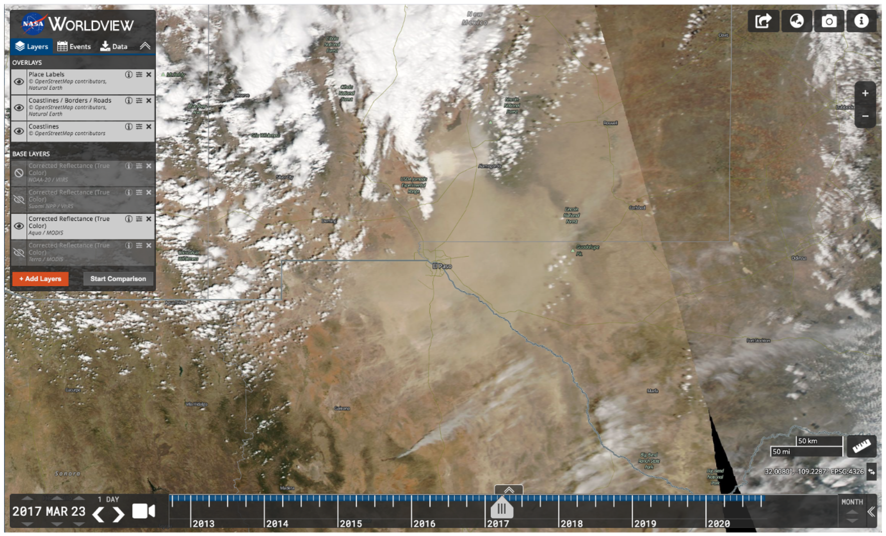


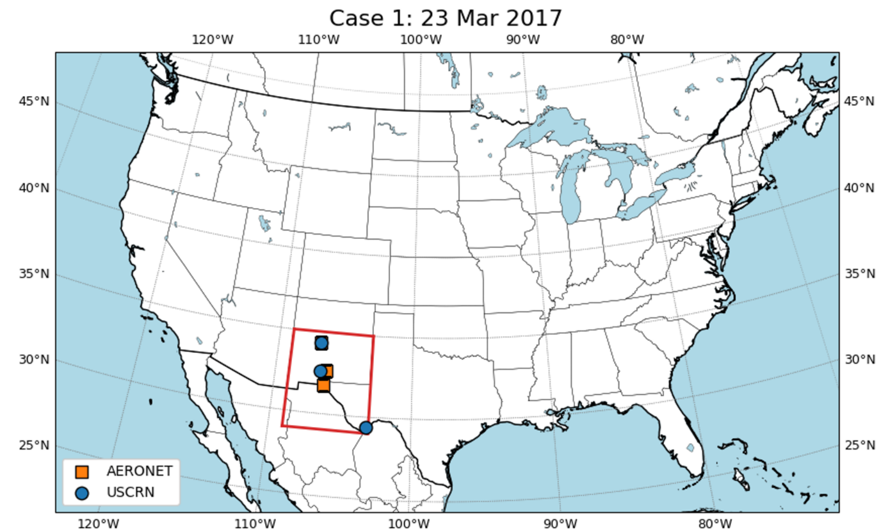
Impact of SMAP soil moisture assimilation in WRF-Chem simulations

- Six dust episodes over the contiguous U.S. have been selected for analysis
- WRF-Chem simulations at 9 km grid spacing:
  - initial and boundary conditions, and spectral nudging of large scale features, from MERRA-2
  - GOCART aerosol model
  - AFWA dust emission model
  - Noah MP land surface (LSM) model
  - Anthropogenic emissions based on NEI 2017 and Fire emissions based on FINN v1.5

- WRF-Chem experiments:
  - No soil moisture assimilation
  - Direct insertion of SMAP soil moisture retrievals
  - Direct insertion of SMAP soil moisture retrievals in the LSM space

Dust outbreak case of 23 March 2017



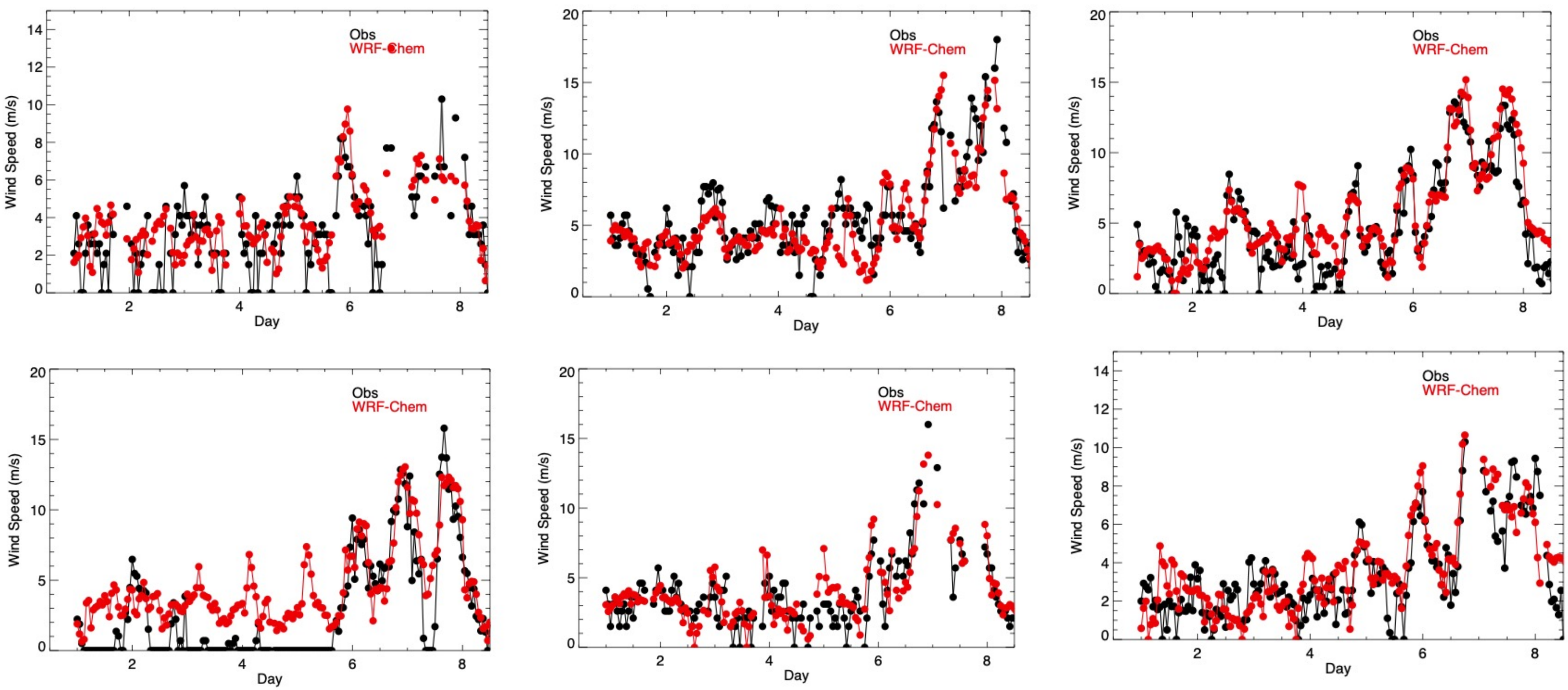


Evaluation against:

1. Surface wind speed from METAR stations
2. Soil moisture observations from the USCRN network
3. Aerosol optical properties from the AERONET Network and MODIS retrievals

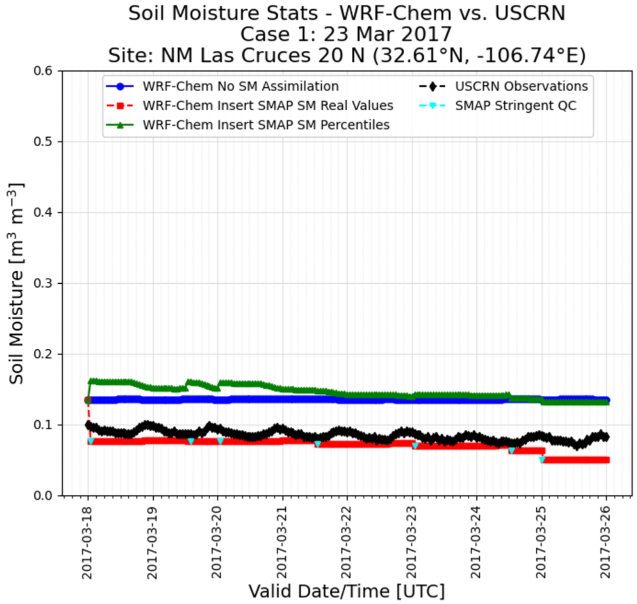
Dust outbreak case of 23 March 2017

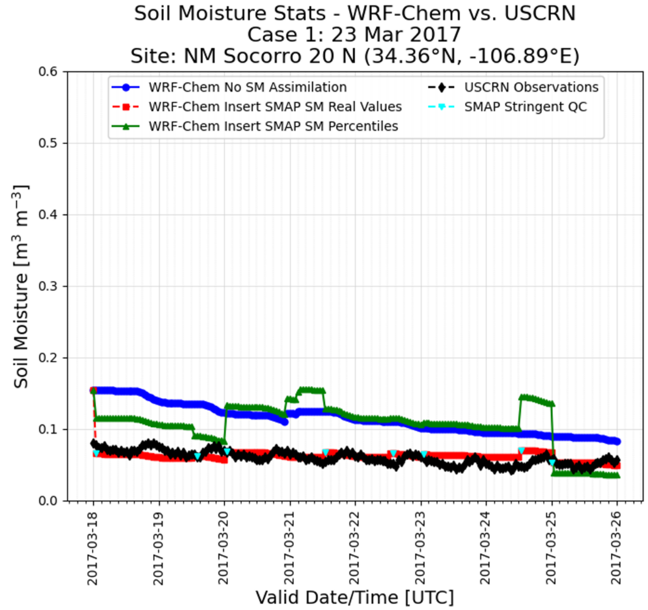
Wind speed (METARs)

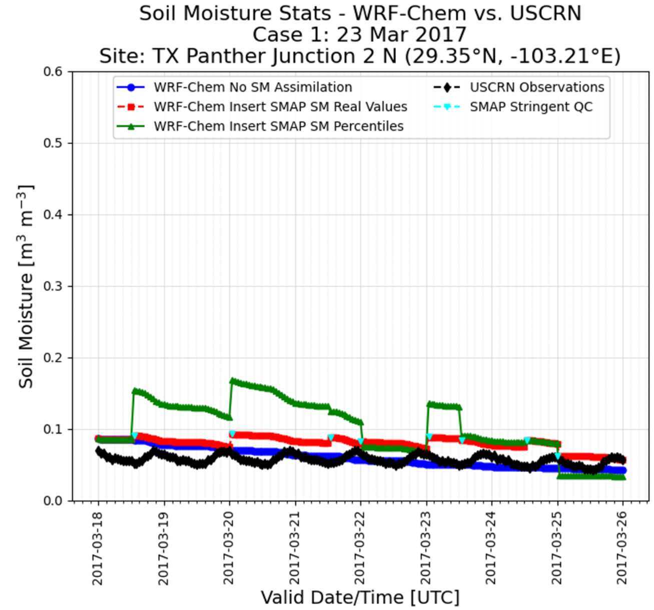


Dust outbreak case of 23 March 2017

USCRN sites

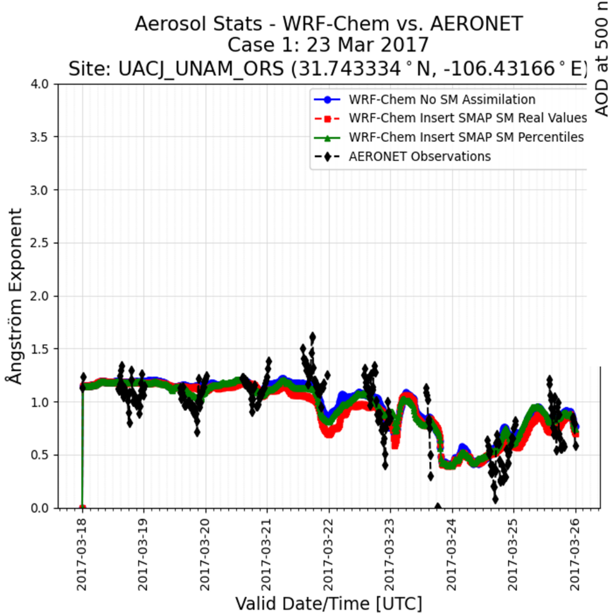


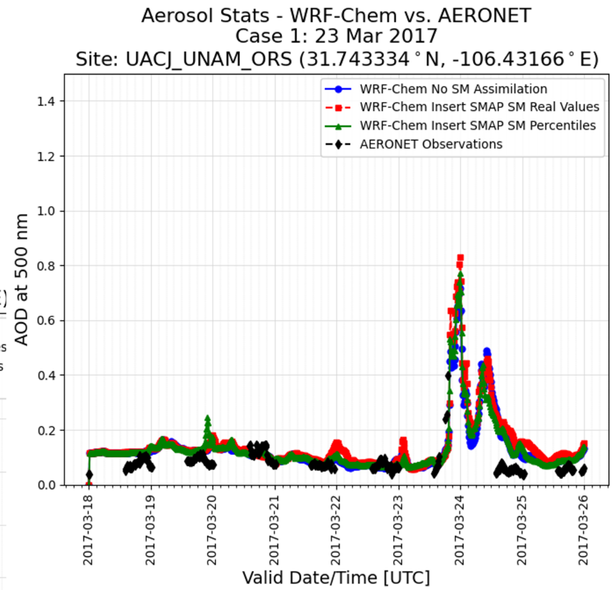




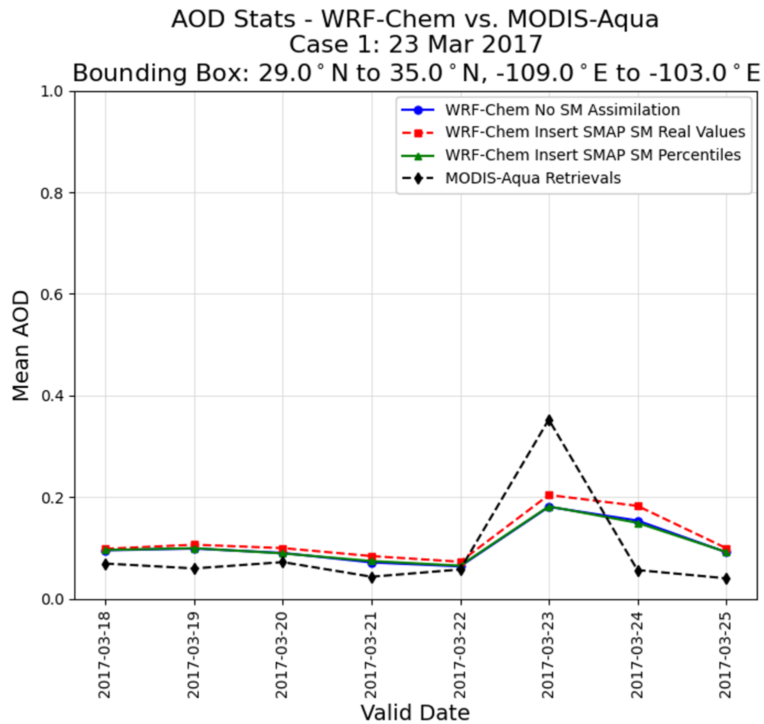
Dust outbreak case of 23 March 2017

AERONET





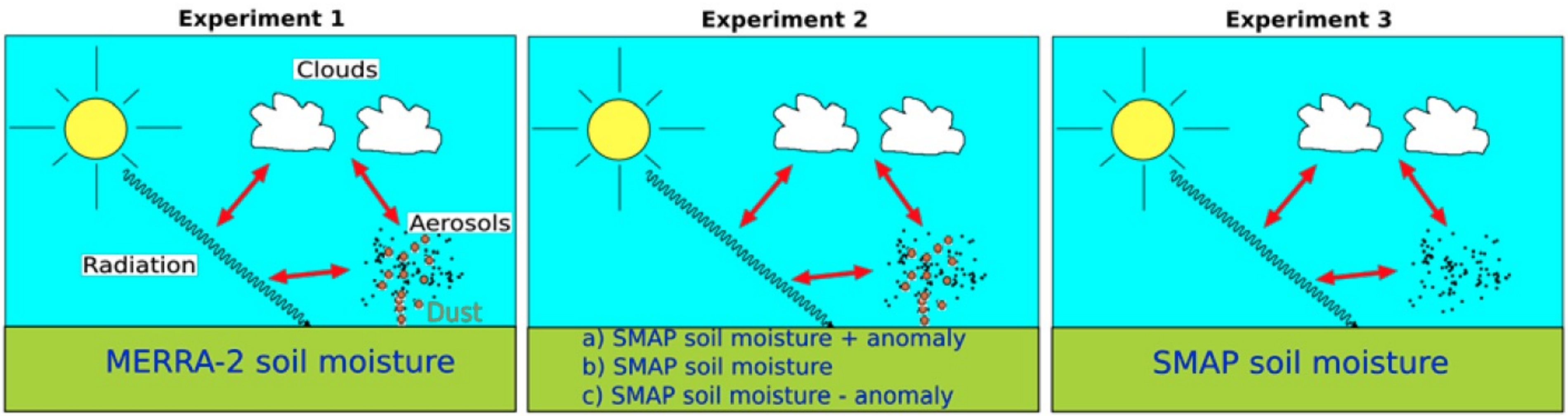
MODIS



Conclusions

- SMAP soil moisture retrievals clearly show the added value with respect to WRF soil moisture simulations over western U.S.
- Combining the SMAP retrievals with ground observations can further increase the added value
- Direct assimilation of SMAP retrievals does not show any drawback in comparison with the assimilation of retrievals in the LSM space
- Difficult to quantify the added value of the soil moisture assimilation during dust outbreaks because
  - The strong winds which reduce the sensitivity to soil moisture in dust mobilization
  - Errors in the retrievals during the cases which may not be representative of the long term behavior
- Planning to 1) analyze impact of correcting SMAP retrievals with ground observations and 2) running long continuous simulations to provide a statistically robust characterization of the added value of SMAP

Long term WRF-Chem simulations



1. Comparison of Experiment 1 and Experiment 2 will quantify the added value of SMAP retrievals
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2. Comparison of experiment 2 and 3 will quantify the modulations that soil moisture exerts on the Earth's radiative balance through modulations of the dust emissions