Representing Soil Moisture Spatial Distribution by Assimilating Satellite-based Data into a Land Surface Model

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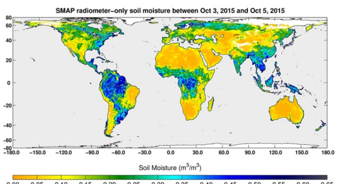
Background

- Spatial distribution of soil moisture (SM) is one of the key drivers in land-atmosphere interactions.
- SM predicted by land surface models (LSMs) can have large errors due to simplified assumptions and uncertain parameters, even when driven by observationally constrained atmospheric forcing.
- Satellite-based SM data (e.g., Soil Moisture Active Passive; SMAP) has much better spatial coverage compared to in-situ obs but has its own uncertainties and can't fully describe physical states in land/soil system at deeper levels.



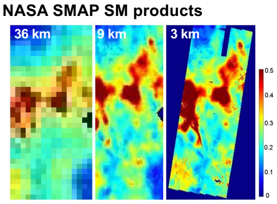
Example of global SM distribution as collected by NASA's Soil Moisture Active Passive (SAMP) mission. (https://smap.jpl.nasa.gov)

Tool and Experiments

❖ NASA Land Information System (LIS)

- Core LSM: Noah-MP V4.0.1
- Grid spacing: 1 km
- Depths: 10, 30, 60, 100 cm
- Met. Forcing: NLDAS2 (primary) + GDAS
- SMAP SM data assimilation (DA, EnKF)
- Period: 2015/01/01~2016/12/31 (**HI-SCALE IOP1:** 2016 Apr-May; **IOP2:** 2016 Aug-Sep)

❖ NASA SMAP SM products



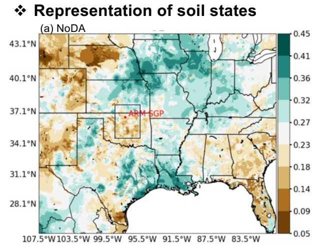
SM content from SMAP products with various resolutions. (Brown et al. 2022)

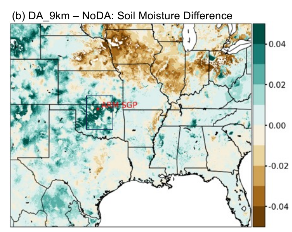
❖ Experiments

- NoDA: Noah-MP integration without DA
- DA_36km: Noah-MP with SMAP 36km DA
- DA_9km: Noah-MP with SMAP 9km DA
- All simulations are run with 1-km grid spacing
- Sensitivity tests (results not shown):
  - Met. forcing interpolation method
  - Length of assimilation window

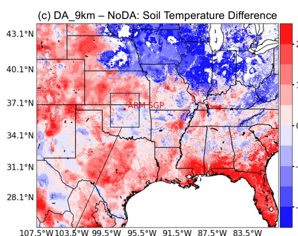
Results

❖ Representation of soil states

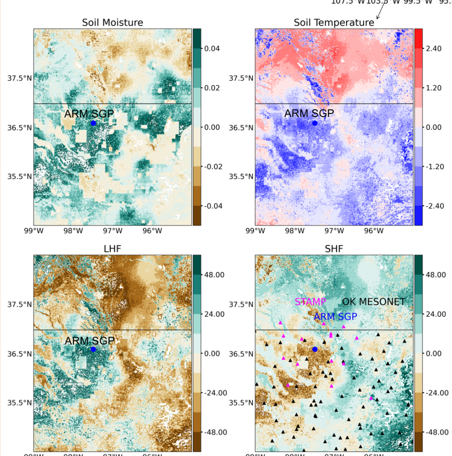




(a) Map showing the LSM domain overlaid with simulated SM (m^3 m^{-3}) at 12 UTC on Aug. 30, 2016, from NoDA. The difference in SM and soil temperature (ST) between DA_9km and NoDA are displayed in (b) and (c). Red dot denotes the ARM SGP site.



✓ Notable large-scale contrast in soil moisture are analyzed after assimilating SMAP SM. Soil temperature changes accordingly.



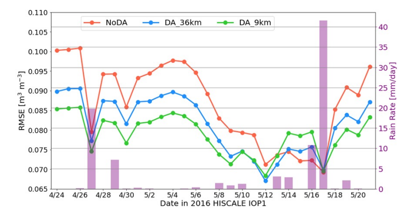
Zoomed-in maps to illustrate differences between DA_9km and NoDA in SM, ST, latent heat flux (LHF, W m^{-2}) and sensible heat flux (SHF, W m^{-2}).

Locations of ARM SGP site, OKMet stations, and STAMP sites are denoted by blue circle, black and magenta triangles, respectively.

✓ Changes in heterogeneity of SM and ST significantly alter how SHF and LHF are represented in the model. These introduced gradients may potentially influence simulated cloud's lifecycle.

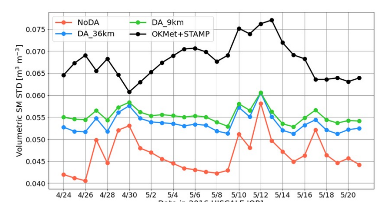
❖ Evaluation

- Oklahoma Mesonet (OKMet)
- ARM STAMP (Soil Temperature and Moisture Profiles)



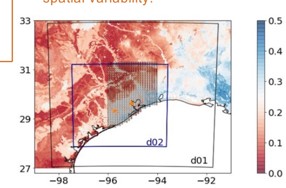
Daily RMSEs during HI-SCALE IOP1 as computed against observations from OKMet and STAMP. Rain rate measured at Central Facility of ARM SGP is given correspondingly.

✓ SM DA overall improves SM representation
✓ High-res SMAP data is beneficial for most cases.
✓ Impact of DA is higher during non-precipitating days when model uncertainty is relatively larger.



Daily SM standard deviations (STDs) during HI-SCALE IOP1. The black line shows result computed from observations collected at sites of OKMet and STAMP. Other lines represent corresponding simulated results computed from each experiment.

✓ Improvement is also seen in SM heterogeneity. More realistic spatial variability!



SM distribution of DA_9km over the area near Houston is shown by contours. Circles with shading are overlaid to represent hybrid data that consists of observations from SMAP and Texas Soil Observation Network (TxSON). d01 and d02 are WRF model domains used for modeling convective clouds associated with urban-rural land use contrasts. (Chen et al. 2023)

Next Step

- Potentials in assimilating other SM observations (AMSR-E and SMOPS, etc.).
- Provide constrained land/soil conditions for modeling study (LES, mesoscale) targeting land-atmosphere-cloud interaction processes.
- Application to other geographic locations (e.g., ARM site at BNF and TRACER).

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