Data Assimilation to Extract Soil Moisture Information From SMAP Observations

J. Kolassa\textsuperscript{1,2}, R. H. Reichle\textsuperscript{1}, Q. Liu\textsuperscript{1,3}, S. H. Alemohammad\textsuperscript{4} and P. Gentine\textsuperscript{4}

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(1) Global Modeling and Assimilation Office, NASA Goddard Spaceflight Center
(2) Universities Space Research Association, GESTAR
(3) Science Systems and Applications
(4) Columbia University in the City of New York
• Motivation
• Method
  o SMAP NN Retrievals
  o Data Assimilation Experiments
• Results
  o Impact on Soil Moisture Climatology
  o Evaluation vs. In Situ Measurements
  o Impact on Evaporation and Runoff
• Conclusions
**Objective:**
Efficiently assimilate SMAP observations into the NASA Catchment model.

**Issue:**
Localized observation rescaling removes some independent information from very skillful SMAP retrievals.

Compare which rescaling method uses independent satellite information most efficiently.

**Fig 1.** Effect of localized bias correction (CDF-matching) on soil moisture retrieval.
- Neural Networks (NN) retrieve soil moisture in model climatology (mean, variance, higher moments) \((Kolassa\ et\ al.\ 2017,\ in\ review)\)
- **Global** dynamic range and bias from model (GEOS-5)
- Spatial and temporal patterns from observations (SMAP + ancillary data)

**Can NN retrievals reduce the need for further bias correction prior to assimilation and thus avoid removing independent satellite information?**
Experiments

- **OL**: Model-only simulation (no assimilation)
- **DA-NN**: Assimilate NN retrievals **without further bias correction**
- **DA-NN-CDF**: Assimilate NN retrievals with **local bias correction**
- **DA-L2P-gCDF**: Assimilate L2 passive retrievals (*O’Neill et al.,* 2015) with **global bias correction**
- **DA-L4**: Assimilate **locally rescaled brightness temperatures in SMAP L4_SM system**

- April 2015 – March 2017
- 9 km EASE v2 grid
- Contiguous United States
- 3-hourly analysis

→ Assess skill improvements of DA over OL at SMAP core validation sites
  
  *(Jackson *et al.*, 2016; *Colliander et al.*, 2017)*
Global rescaling experiments introduce more of the SMAP retrieval information.
Evaluation vs. In Situ Measurements: Global vs. Local Rescaling

ΔR [-]

Δ|bias| [m³ m⁻³]

ΔubRMSE [m³ m⁻³]
Evaluation vs. In Situ Measurements: Global vs. Local Rescaling

Surface Soil Moisture

- $\Delta R [-]$ vs. All Sites
- $\Delta |\text{bias}| [m^3 m^{-3}]$ vs. All Sites
- $\Delta \text{ubRMSE} [m^3 m^{-3}]$ vs. All Sites

Root-Zone Soil Moisture

- $\Delta R [-]$ vs. All Sites
- $\Delta |\text{bias}| [m^3 m^{-3}]$ vs. All Sites
- $\Delta \text{ubRMSE} [m^3 m^{-3}]$ vs. All Sites
Global bias correction has potential for greater skill improvements but makes assimilation estimates more vulnerable to bias in retrievals.
Evaluation vs. In Situ Measurements: NN vs. L2P Assimilation

Surface Soil Moisture

$\Delta R [-]$

$\Delta |\text{bias}| [m^3 m^{-3}]$

$\Delta \text{ubRMSE} [m^3 m^{-3}]$
Evaluation vs. In Situ Measurements: NN vs. L2P Assimilation

Surface Soil Moisture

ΔR [-]

Δ|bias| [m$^3$m$^{-3}$]

ΔubRMSE [m$^3$m$^{-3}$]

Root-Zone Soil Moisture

ΔR [-]

Δ|bias| [m$^3$m$^{-3}$]

ΔubRMSE [m$^3$m$^{-3}$]
Local skill values very similar for assimilation of NN retrievals (without further rescaling) and globally rescaled L2P retrievals.
Evaluation vs. In Situ Measurements: NN vs. Tb Assimilation

Surface Soil Moisture

- \( \Delta R \) [-]
- \( \Delta |\text{bias}| \) [m\(^3\)m\(^{-3}\)]
- \( \Delta \text{ubRMSE} \) [m\(^3\)m\(^{-3}\)]
Evaluation vs. In Situ Measurements: NN vs. Tb Assimilation

Surface Soil Moisture

- ΔR [-]
- Δ|bias| [m³m⁻³]
- ΔubRMSE [m³m⁻³]

All Sites

Root-Zone Soil Moisture

All Sites

Legend:
- DA-NN
- DA-L4
Skill values similar on average but different locally for assimilation of NN retrievals (without further rescaling) and L4_SM.
Surface Soil Moisture

\[ \Delta R [-] \]

\[ \Delta |\text{bias}| [m^3/m^3] \]

\[ \Delta \text{ubRMSE} [m^3/m^3] \]

Root-Zone Soil Moisture

Evaluation vs. In Situ Measurements

DA-NN
DA-NN-CDF
DA-L2P-gCDF
DA-L4
Fig 5. Difference (OL minus DA) in mean evaporation and runoff.

Evaporation and runoff changes reflect changes in soil moisture patterns where fluxes are sensitive to soil moisture.
Conclusions

• Global bias correction retains more independent satellite information.
  o Potential for greater improvements over model skill.
  o Assimilation skill more sensitive to retrieval bias.
  o Good QC and error characterization is crucial.

• Assimilation of NN and L2P retrievals (w/ global rescaling) results in very similar local skill values.

• Soil moisture and Tb assimilation have similar average skill with local differences.

• Evaporation and runoff changes reflect changes in soil moisture patterns.
References

Kolassa, J., et al. (2017a), Estimating surface soil moisture from SMAP observations using a Neural Network technique, \textit{(in review)}.

Kolassa, J., et al. (2017b), Data assimilation to extract soil moisture information from SMAP observations \textit{(in preparation)}.

