Observation error specification for near-surface soil moisture assimilation: does it matter?

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Motivation:

- The observation error variances assumed in the data assimilation (DA) of remotely sensed near-surface soil moisture observations are known to have unrealistic spatial patterns. The temporal variability in the errors is also typically neglected.
- Soil moisture errors cannot be directly calculated at large scales, and the globally distributed errors are unknown
- We apply several approaches to estimating the observation errors (R matrix) for near-surface soil moisture DA experiments, to establish whether the assumed errors are important to the DA performance, and hence whether uncertainty in the observation error specification is a likely source of uncertainty in soil moisture DA output.

Soil moisture obs. error estimation:

The errors are typically specified in two steps:

- Estimation of the observation error standard deviation in observation space (e),
- Rescaling of e into the model space (e').

The second step is performed together with the rescaling of the observations themselves.

Assimilation experiments:

ASCAT and SMOS near-surface soil moisture observations were assimilated into the Catchment model using the NASA GMAO Ensemble Kalman Filter over the contiguous US, from 2010/05 – 2016/12. The experiments were evaluated by comparison to in situ soil moisture observations from the SCAN and USCRN networks.

References:
Yilmaz, M. and W. Crow, 2013: The Optimality of Potential Rescaling Approaches in Land Data Assimilation. J. Hydrometeor., 14, 650–660.

Soil moisture obs. error estimation:

Four methods were used to estimate e:

- **eCONST**: e is a constant (10% for ASCAT and 0.04 m^3m^{-3} for SMOS)
- **eFRACN**: e is a fraction (10%) of the observation time series standard deviation
- eRTVL-?: the retrieval uncertainty provided with the observations is used
  - **eRTVL-M** : the time series mean of the retrieval uncertainties is used
  - **eRTVL-I** : the instantaneous values of the retrieval uncertainties is used

Two methods were used to rescale e to e':

- **rS**: multiplication by the ratio of the standard deviations of the modeled and observed soil moisture time series.
- **rR**: multiplication by the linear regression coefficient from regressing the modeled soil moisture onto the observed soil moisture time series.

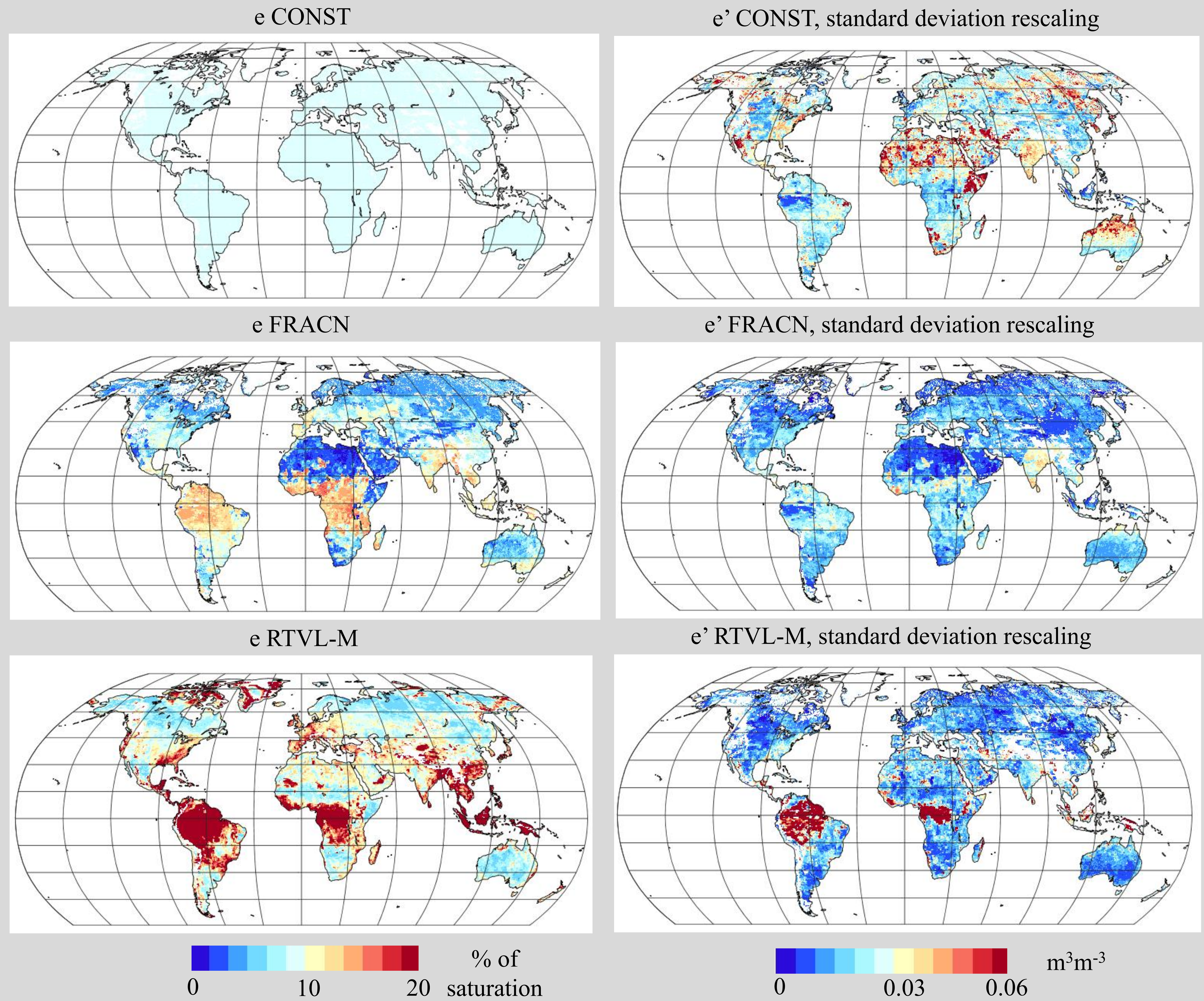
The first is common practice, although from Yilmaz and Crow (2013), the second is closer to optimal. For all experiments after CONST, e' was multiplied by a global constant to give a mean e' across the in situ sites equal to that from CONST.

Results

Mean anomaly correlation with in situ data at 185 sites.

	Surface	Root-zone
Open loop (no assim.)	0.59	0.52
DA eCONST_rS	0.64	0.54
DA eFRACN_rS	0.64	0.54
DA eRTVL-M_rS	0.64	0.54
DA eRTVL-I_rS	0.64	0.54
DA eCONST_rR	0.63	0.53
DA eFRACN_rR	0.64	0.53
DA eRTVL-M_rR	0.62	0.52
DA eRTVL-I_rR	0.64	0.54

Example: error standard deviations for ASCAT, ascending pass:



Conclusions

- The difference between the DA experiments was insignificant (<0.01 differences in the mean anomaly correlation).
- Given the substantial differences between the tested error estimation methods, including the introduction of spatial and temporal variability, and the introduction of much more realistic spatial patterns, we conclude that for the GMAO system, the observation error specification is of little importance to the near-surface soil moisture DA.
- This may be because the observation errors are artificially tuned downwards to prevent the assimilation from introducing noise into the modeled root-zone soil moisture.

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