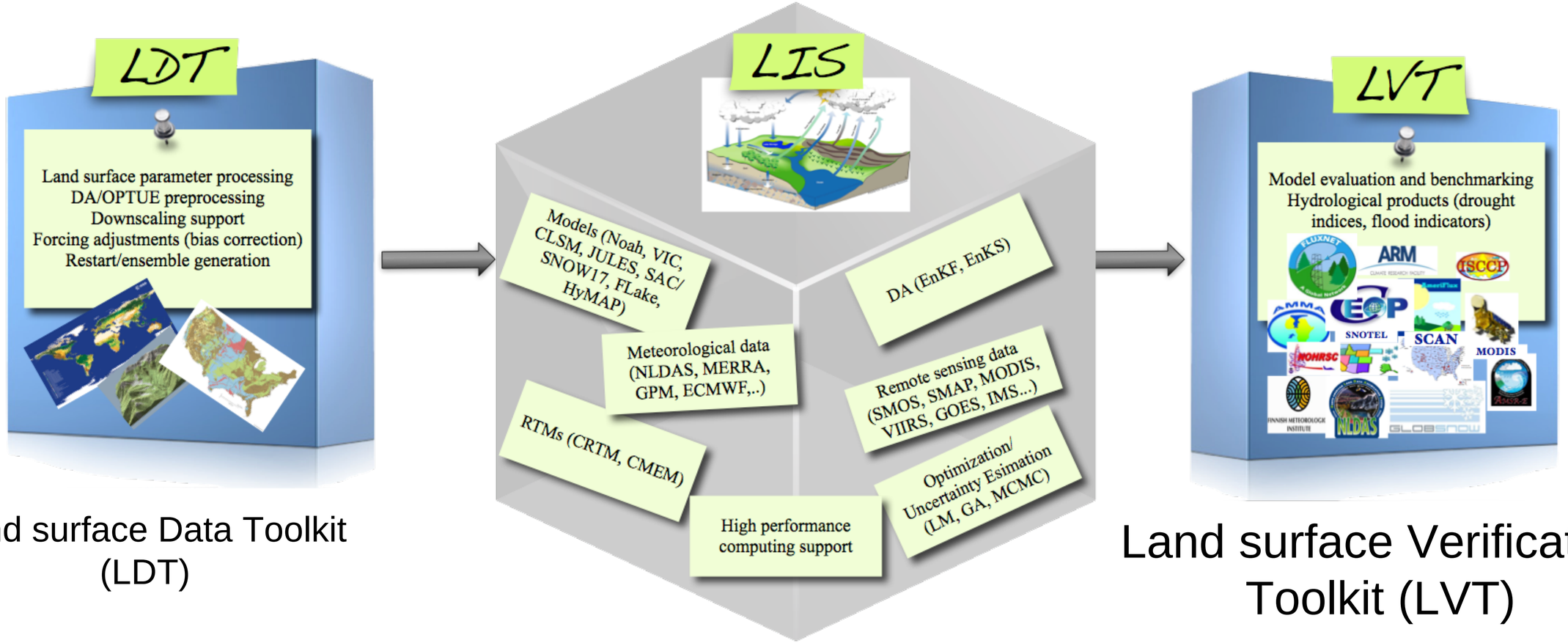
Soil moisture modeling and data assimilation at NASA GSFC – Advances, Gaps, Challenges

Sujay Kumar, David Mocko and the LIS team

http://lis.gsfc.nasa.gov

The NASA Land Information System (LIS) modeling suite

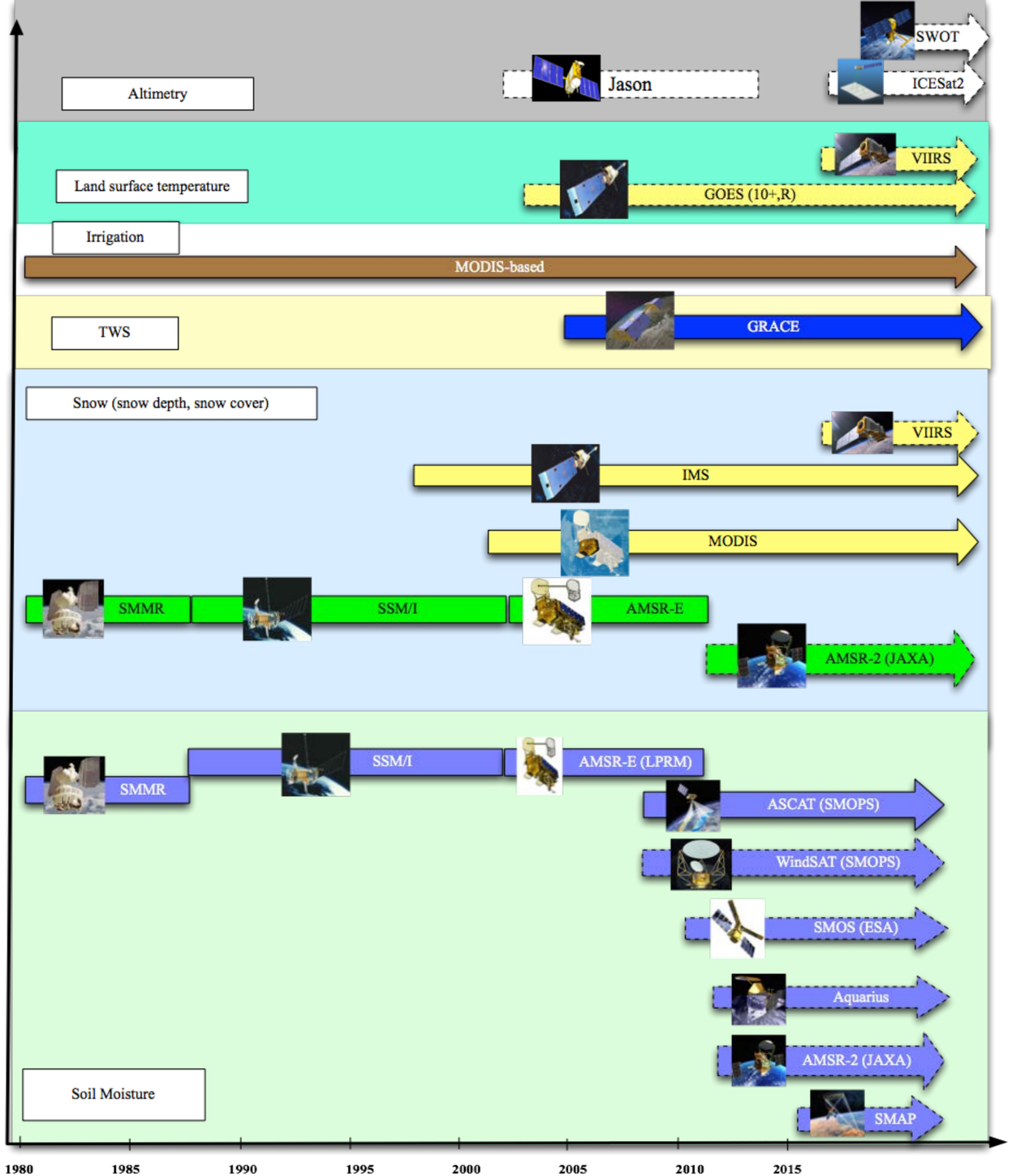


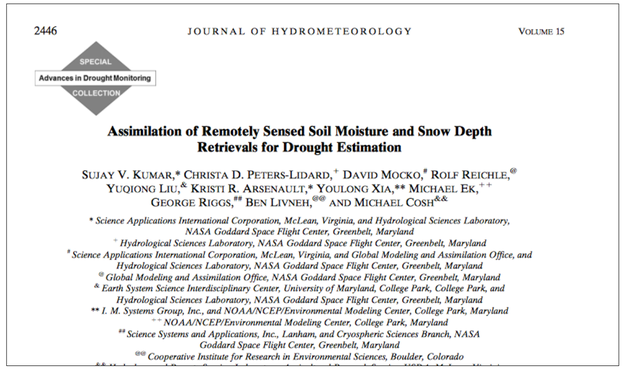
Land surface Data Toolkit (LDT)

Land surface Verification Toolkit (LVT)

- LIS consists of a large suite of land surface models (Noah, Noah-MP, CLM, JULES, Catchment, VIC, …) and data assimilation algorithms (EnKF, EnKS, ..) and support for remote sensing data (SMAP, SMOS, AMSR2, ASCAT, AMSR-E, SSM/I, SMMR, ….).
- LVT includes the support of in-situ (SCAN, USDA, NASMD, ISMN, …), remote sensing and model/analysis datasets for model benchmarking and evaluation.

Enabling of DA capabilities in NLDAS





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SPECIAL Advances in Drought Monitoring COLLECTION

Assimilation of Remotely Sensed Soil Moisture and Snow Depth Retrievals for Drought Estimation

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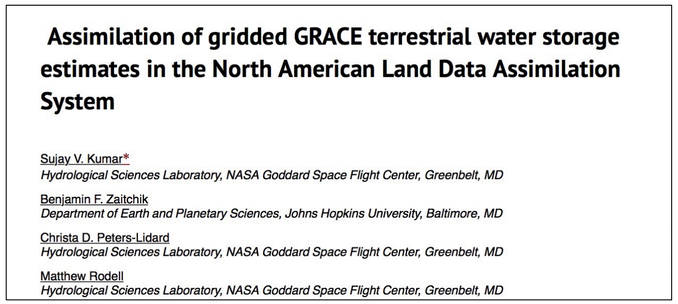

Assimilation of gridded GRACE terrestrial water storage estimates in the North American Land Data Assimilation System

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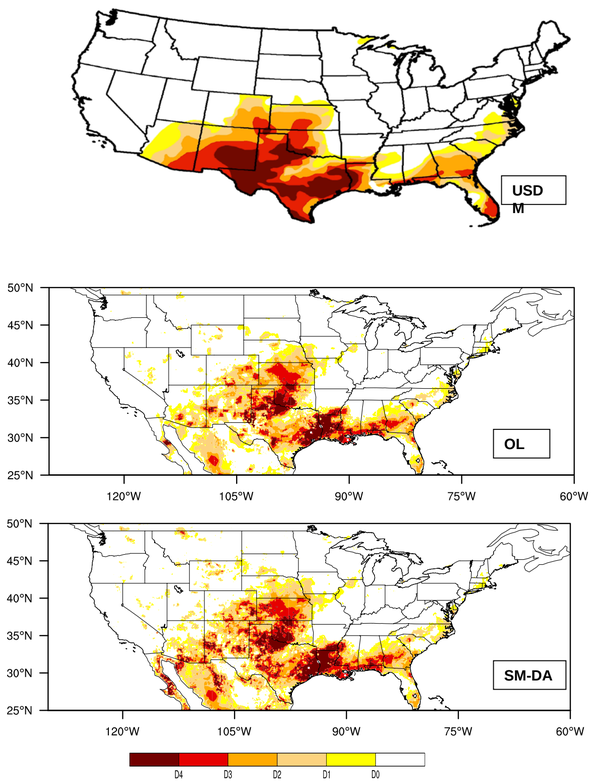
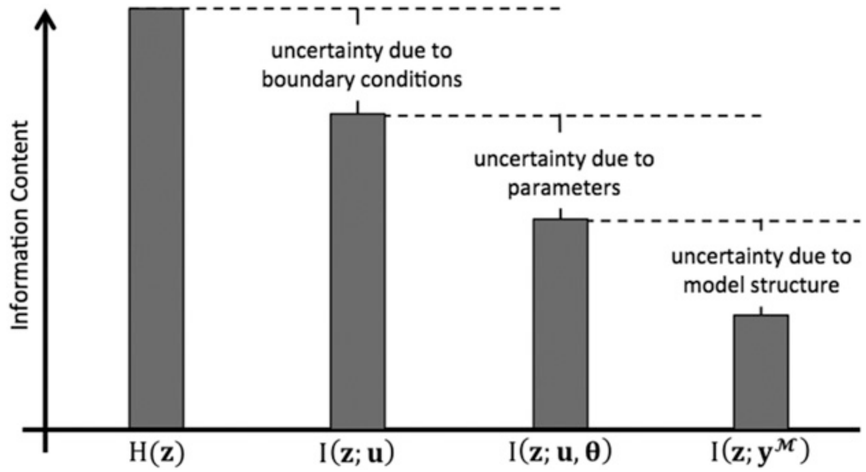
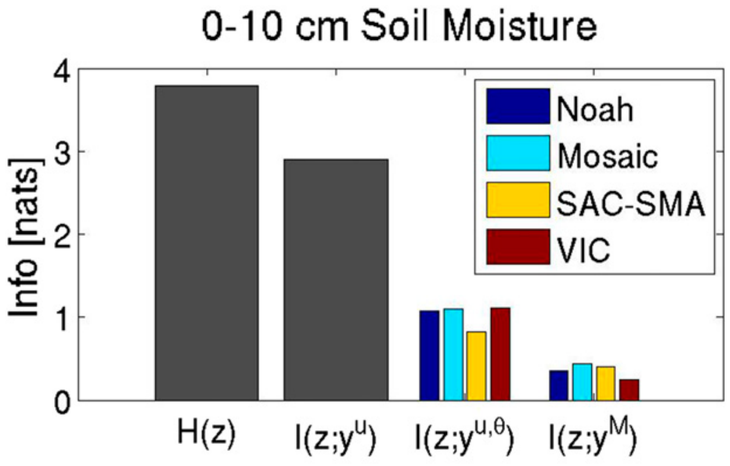


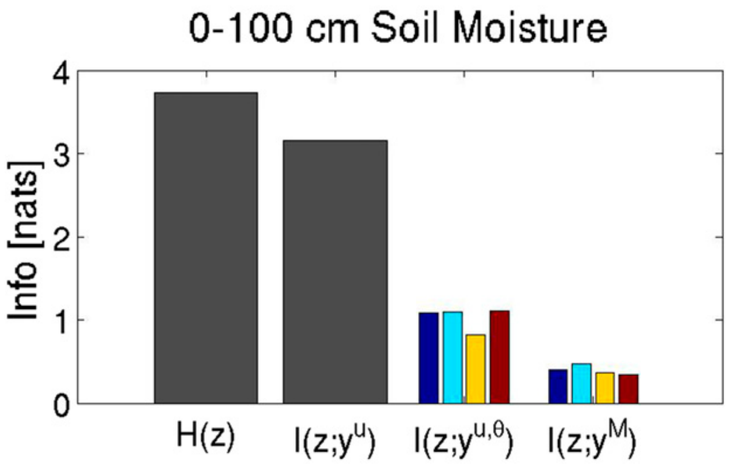
Impact of soil moisture DA on drought estimates (May 10-17, 2011).

- The data assimilation capabilities in LIS is being leveraged for the next phases of NLDAS to enable the "DA" in NLDAS.
- The univariate data assimilation experiments demonstrated that assimilation of soil moisture, snow and terrestrial water storage observations are helpful in improving water cycle components of soil moisture, snow, terrestrial water storage and evapotranspiration.
- These improvements also translated to short-term improvements for applications such as drought monitoring.

Using in-situ soil moisture data to quantify sources of uncertainty in LSMs







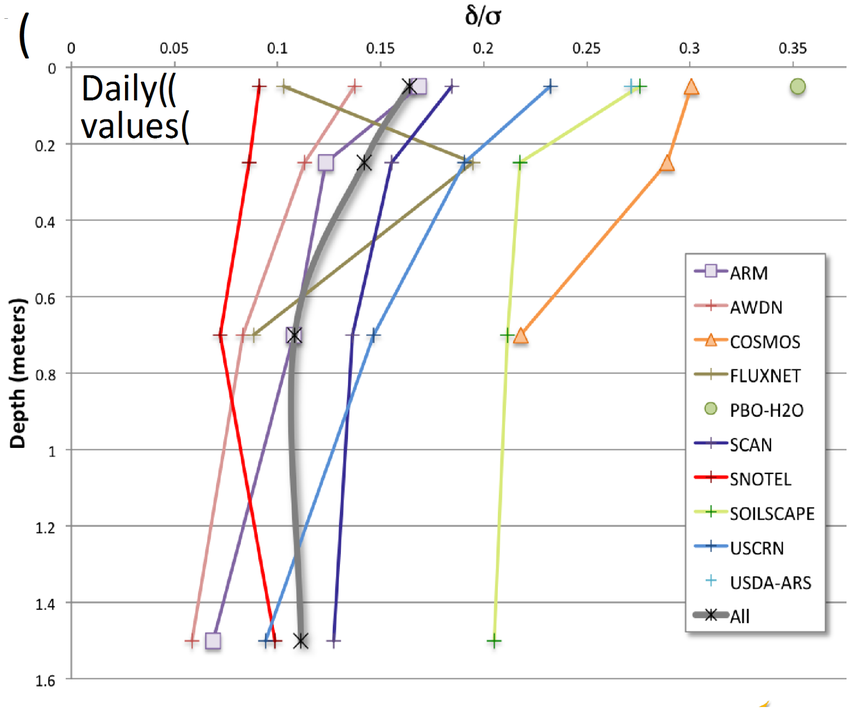
- Model simulations compared to a statistical benchmark derived from out-of-sample regressions of SCAN in-situ soil moisture data.
- Uncertainty quantified using information-theory metrics.
- Largest sources of uncertainty are the model parameters.
- Benchmarking to help understand where to spend efforts on improving model estimates.

Nearing. et al. (2016), Benchmarking NLDAS2 soil moisture and evaporation to separate uncertainty contributions, *J. Hydrometeor.*, 17(3), 745-759.

Soil moisture memory and error

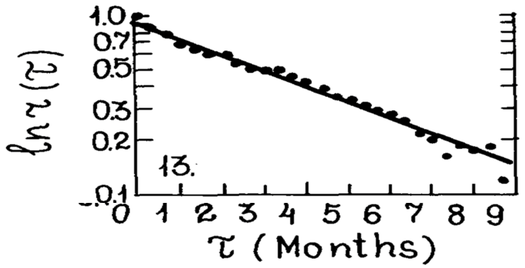
- Soil moisture, due to its memory can be described as a first order Markov process (red noise)
- Lagged autocorrelation of soil moisture drops exponentially with time: $r(t) = e^{-t/\tau}$
- A linear regression of $ln(r)$ vs . τ does not pass through the origin due to measurement error $r(0) = 1 - a$
- RMS of measurement error: $\delta = \sigma_{obs}\sqrt{\frac{a}{1+a}}$
- Relative measurement error:

$$\delta/\sigma_{obs} = \sqrt{\frac{a}{1+a}}$$



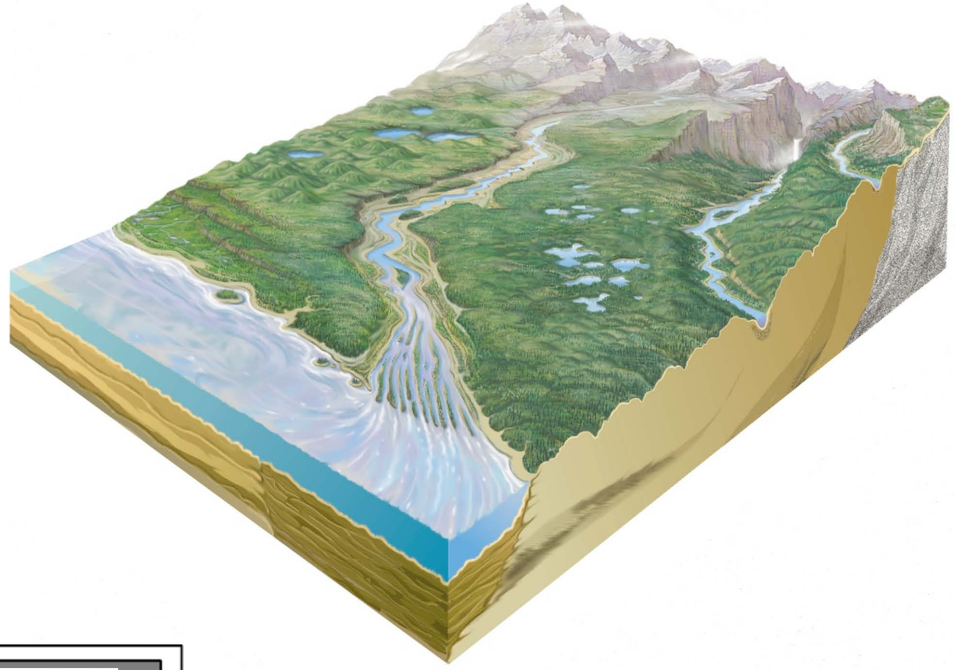
Source: Paul Dirmeyer, COLA/GMU

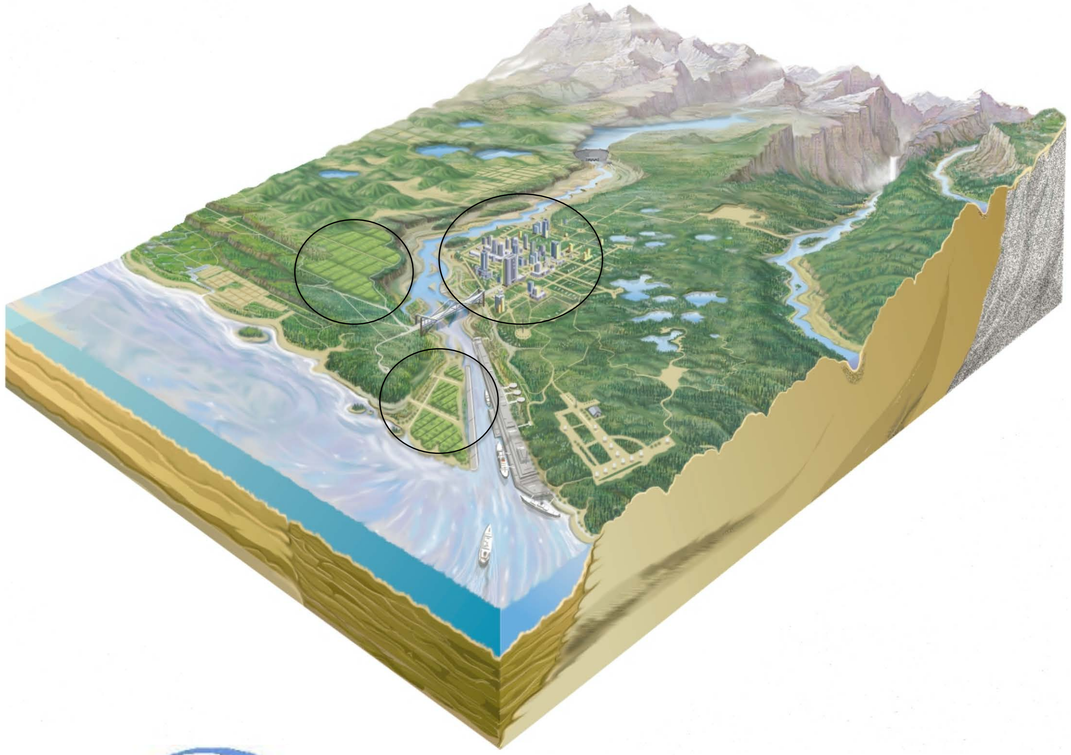
Vinnikov & Yeserkepova , (1991; J. Climate)
Robock et al. (1995, J. Climate)
Vinnikov et al. (1996; JGR)
Vinnikov et al. (1999: JGR)



Value of remote sensing data assimilation

Human impacts from expansion of agriculture and infrastructure have significantly (>50%) transformed the natural features of the land surface

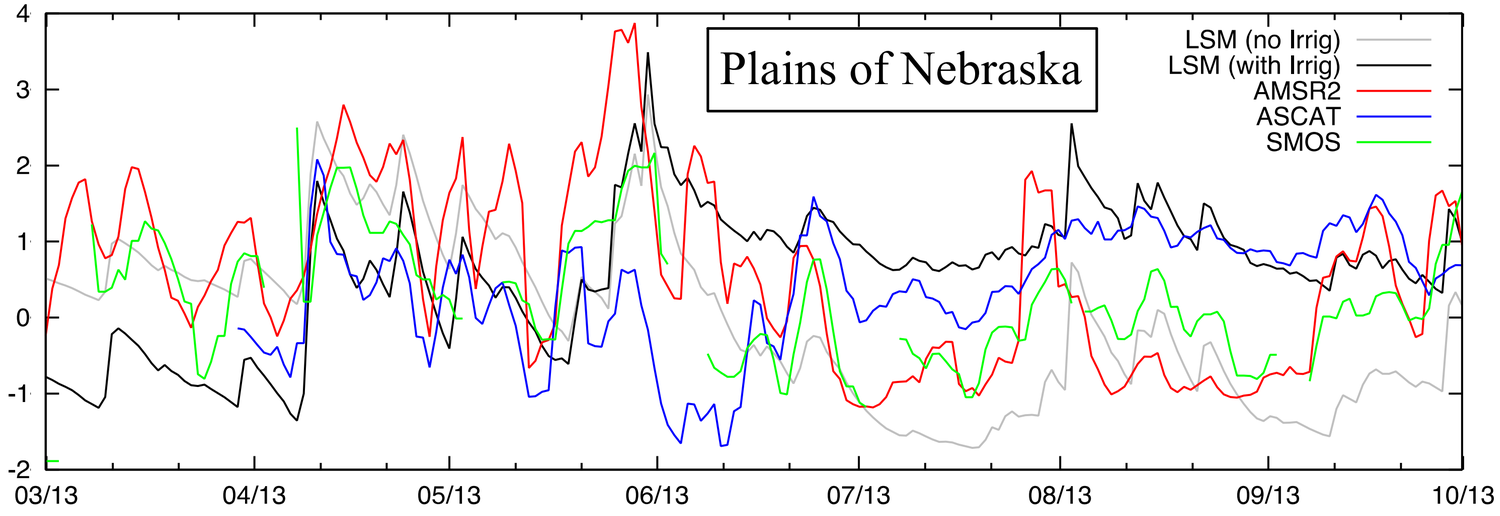


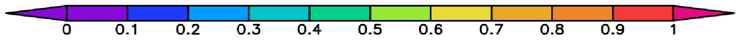


Land surface models : fairly utopian; hard to realistically represent subjective practices

Remote sensing: practical method to observe these ‘unmodeled’ features

Challenges in remote sensing and simulation of irrigation





Unitless degree of difference between the remote sensing product and a model simulation that lacks irrigation

The skill of the passive microwave soil moisture retrievals in detecting features of large-scale seasonal irrigation was mixed, with ASCAT retrievals more effective than SMOS and AMSR2 products.

Kumar, S.V. et al. (2015), Evaluating the utility of modern soil moisture remote sensing retrievals over irrigated areas and the suitability of data assimilation methods for incorporating unmodeled artifacts, *HESS*, 19, 4463—4478.

Needs/Gaps/Requirements

- Lack of “observability” of soil moisture estimates, due to model representations, sensing depth differences, model biases. Most soil moisture comparisons are in the “wetness” space. It becomes hard to establish a “true” soil moisture reference.
- Representation soil moisture over human managed landscapes (timing/magnitude of irrigation/agricultural practices).
- Representativeness issues between the grid-scale model and point-scale in-situ data is a big problem. Similar to the efforts in the flux community, can NSMN produce a gridded reference soil moisture data?
- Land surface models provide high-quality soil moisture estimates (Anomaly R ~ 0.6 -0.8) when forced with good quality precipitation. The NLDAS estimates can be used as an additional input for the National Soil Moisture Network.
- Near real-time reference soil moisture data is required for evaluation of operational NLDAS runs.