PROGRESS AND CHALLENGES IN IRRIGATION MODELING

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Overview

1) NASA-GSFC capabilities and strategy

   i. LIS and data assimilation

   ii. Irrigation modeling

2) Challenges to modeling irrigation

3) Ways to support the "anthropocene" effort in the future

Motivation

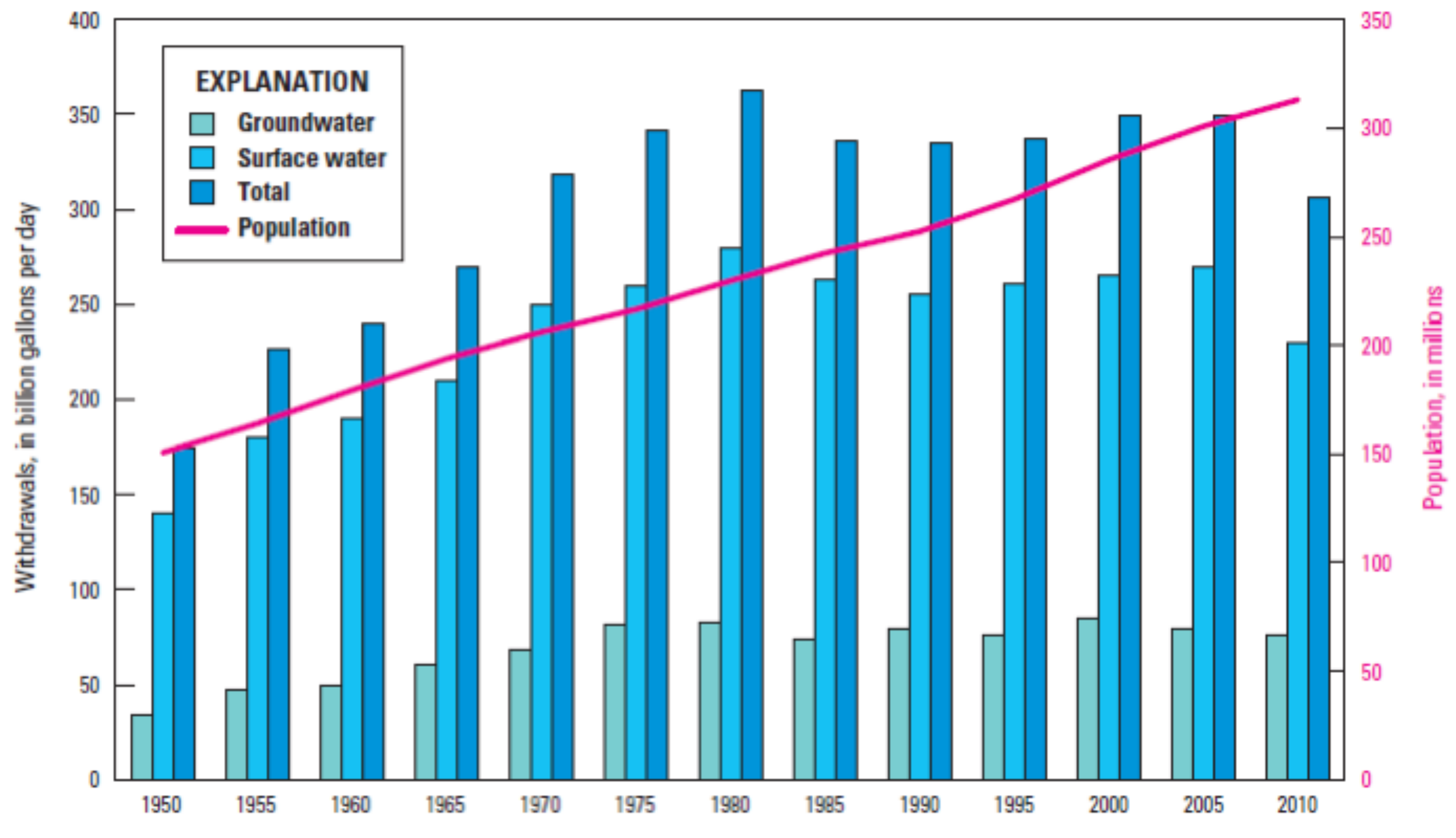

Figure 13. Trends in population and freshwater withdrawals by source, 1950–2010.

Maupin, M.A., Kenny, J.F., Hutson, S.S., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2014. *Estimated use of water in the United States in 2010 (No. 1405)*. US Geological Survey.

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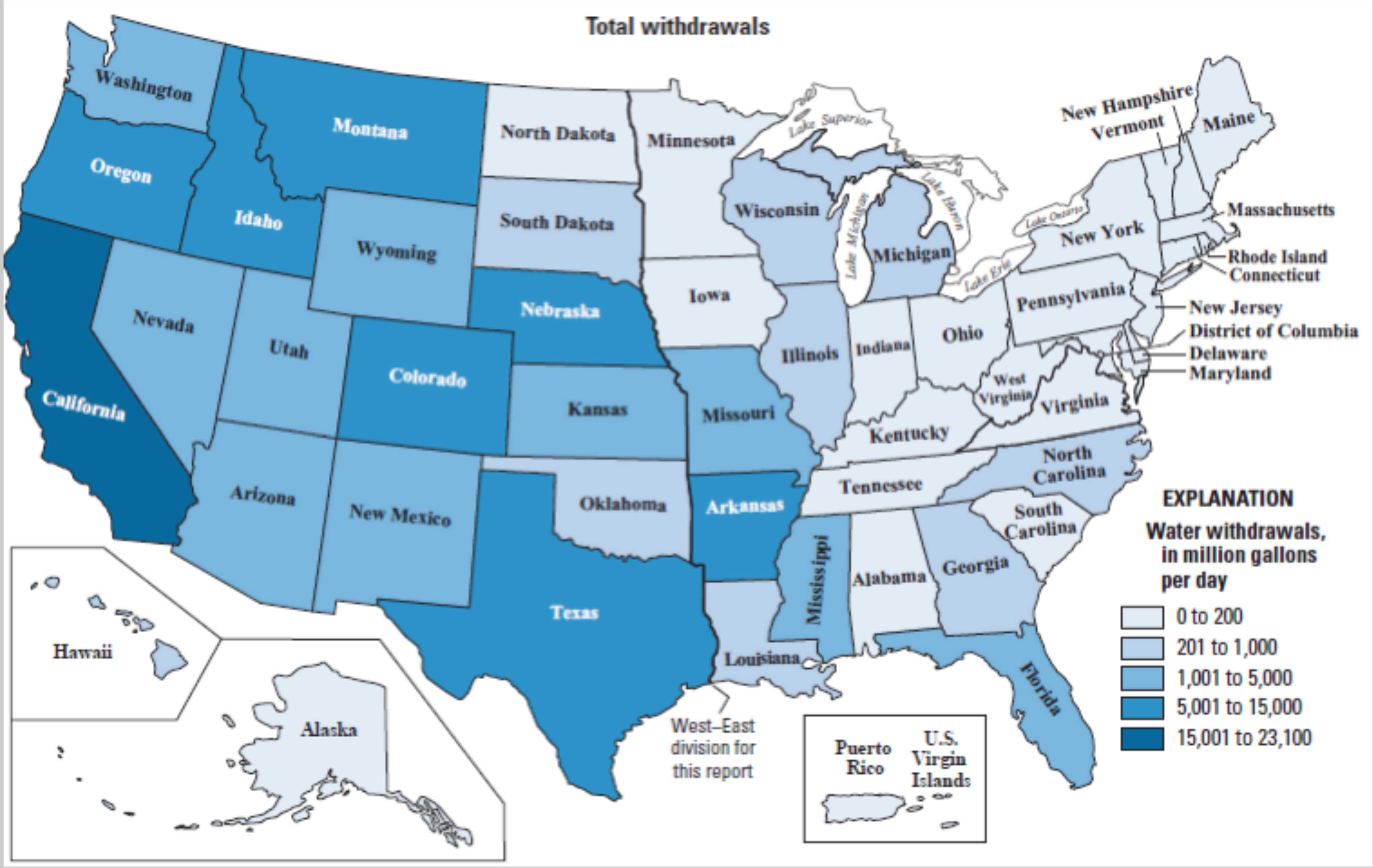

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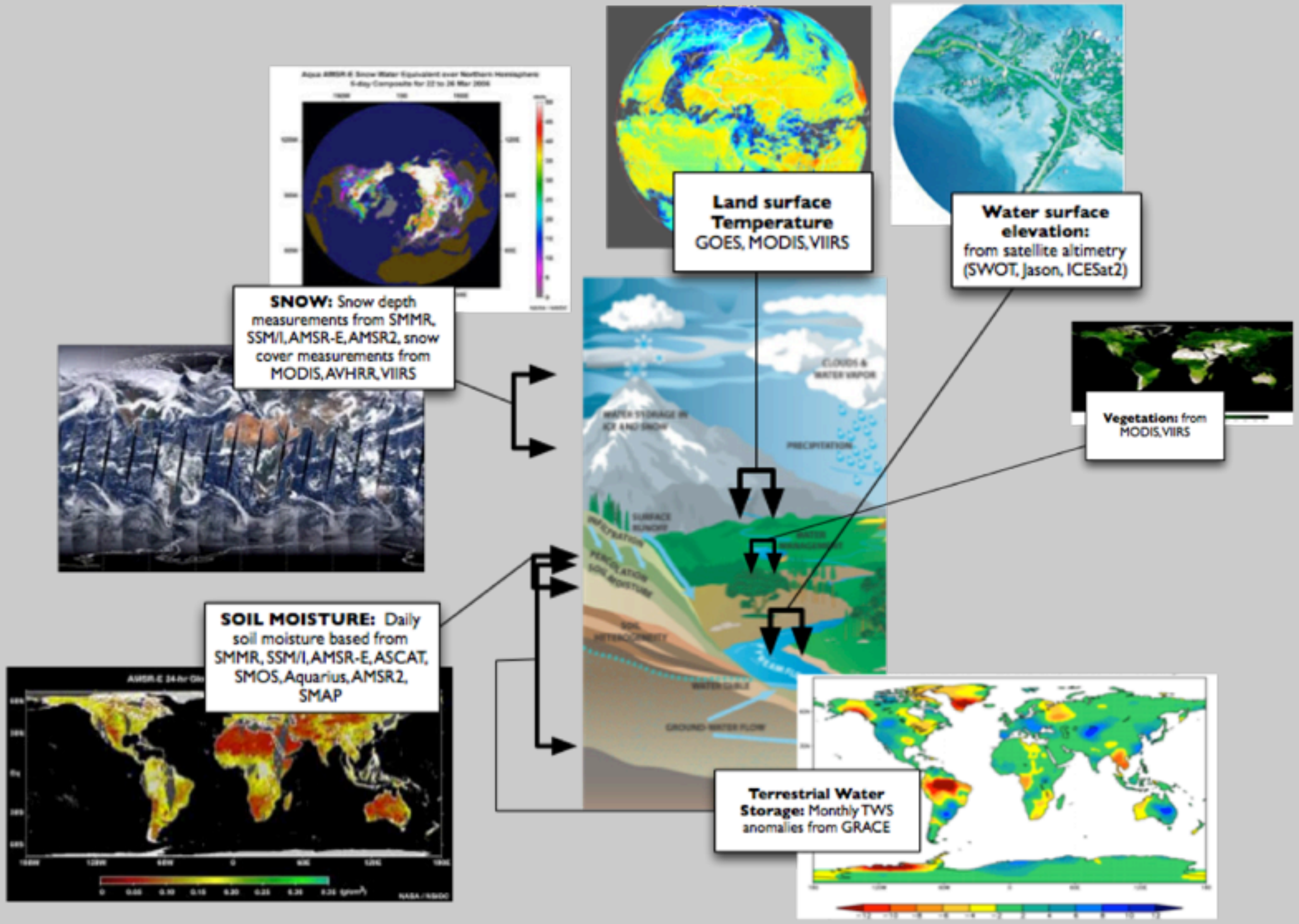
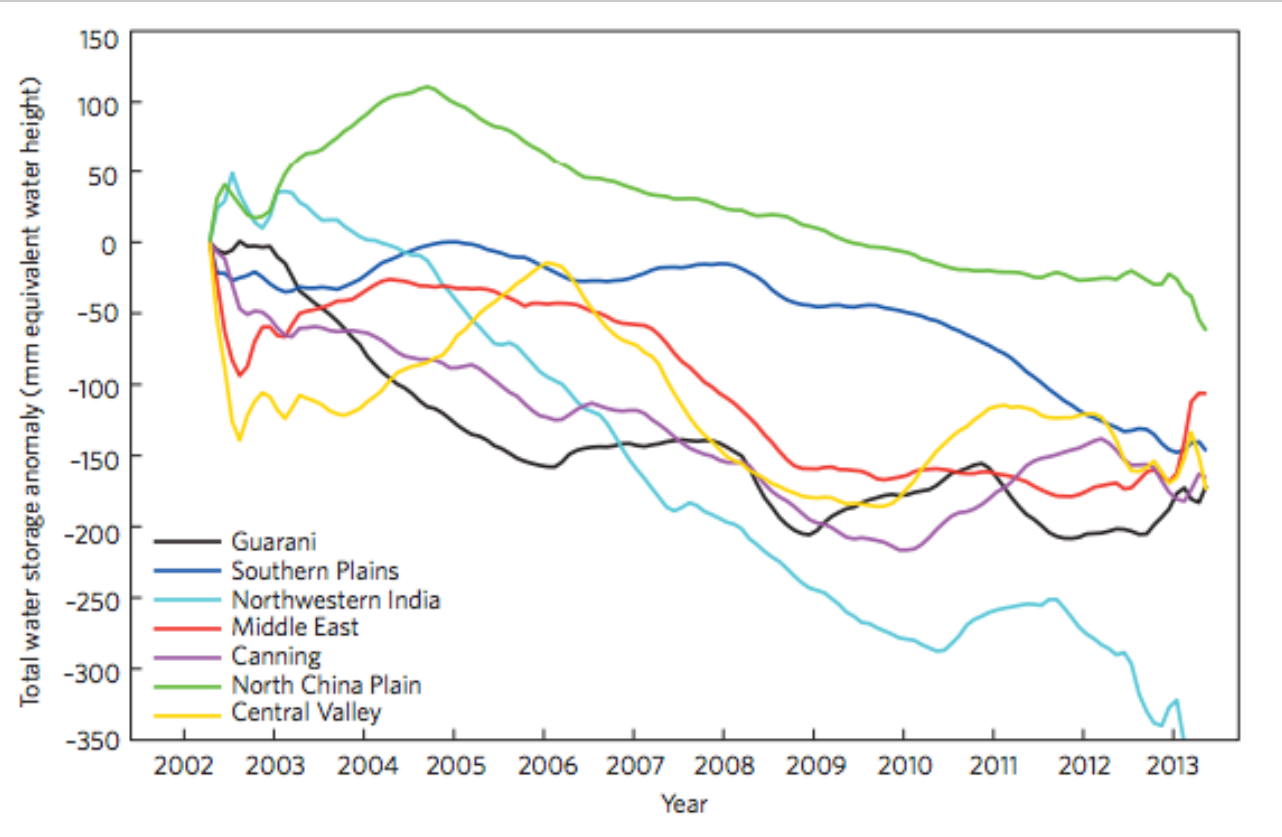
Goddard's Strategy

- Use **satellite observation** based datasets and algorithms that we have developed over the years and integrate them into **NASA Goddard's Land Information System (LIS)**

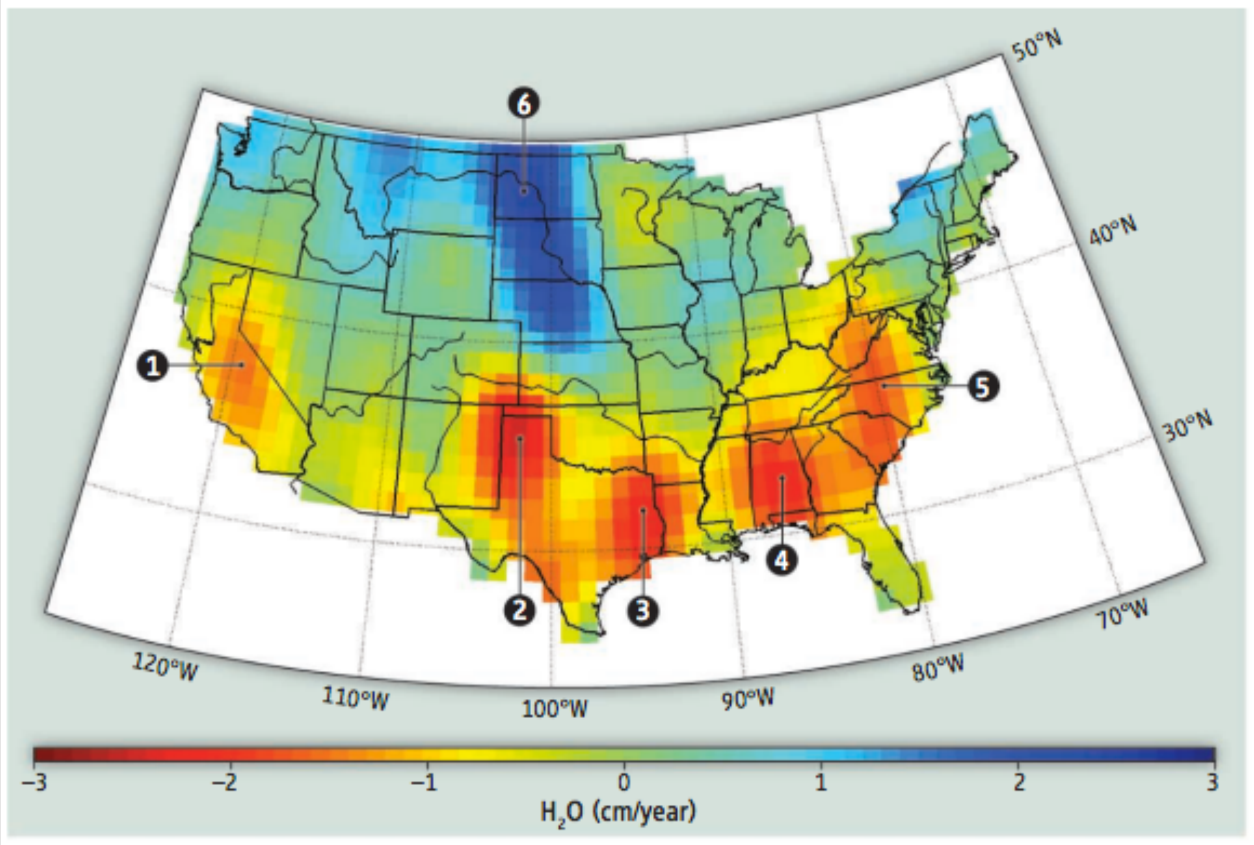


Capabilities: GRACE Terrestrial Water Storage

- GRACE provides estimates of groundwater withdrawal in data-sparse, agricultural, and drought-stricken regions
- LIS-DA can be used to 1) improve these estimates in time and space, and 2) specifically account for water withdrawals, irrigation use, etc.



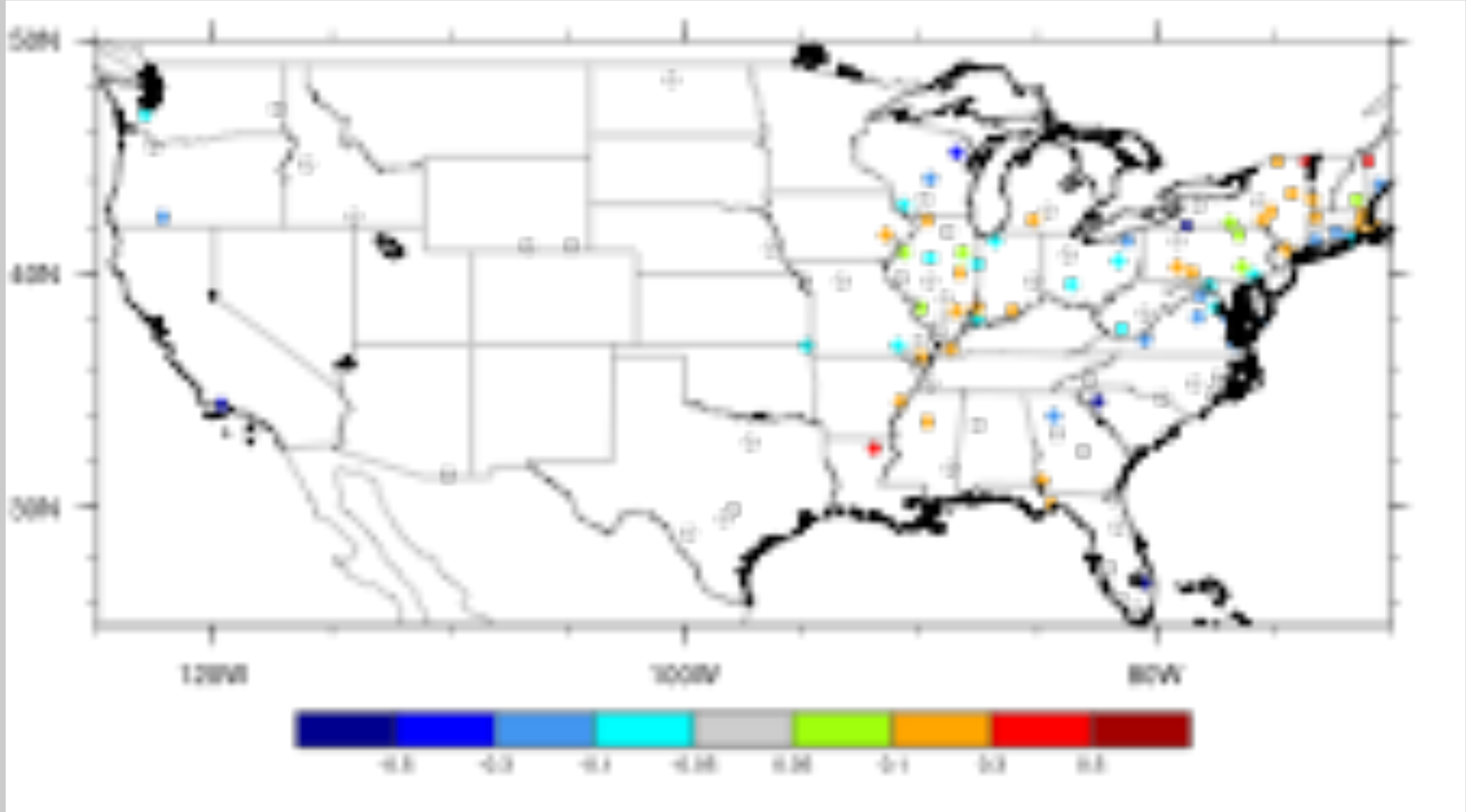
Famiglietti 2014: *The global groundwater crisis.* Nature Climate Change.



Famiglietti and Rodell, 2013: *Water in the Balance.* Science, 340, 1300.

Capabilities: GRACE Terrestrial Water Storage Assimilation

- Compared to quality controlled USGS **groundwater** well data
- Anomaly R differences (DA-OL)
- Warm colors indicate improvements from DA, cool colors indicate degradations
- **Systematic improvements in Upper Mississippi, parts of Northeast, Degradations in the Missouri basin stations**



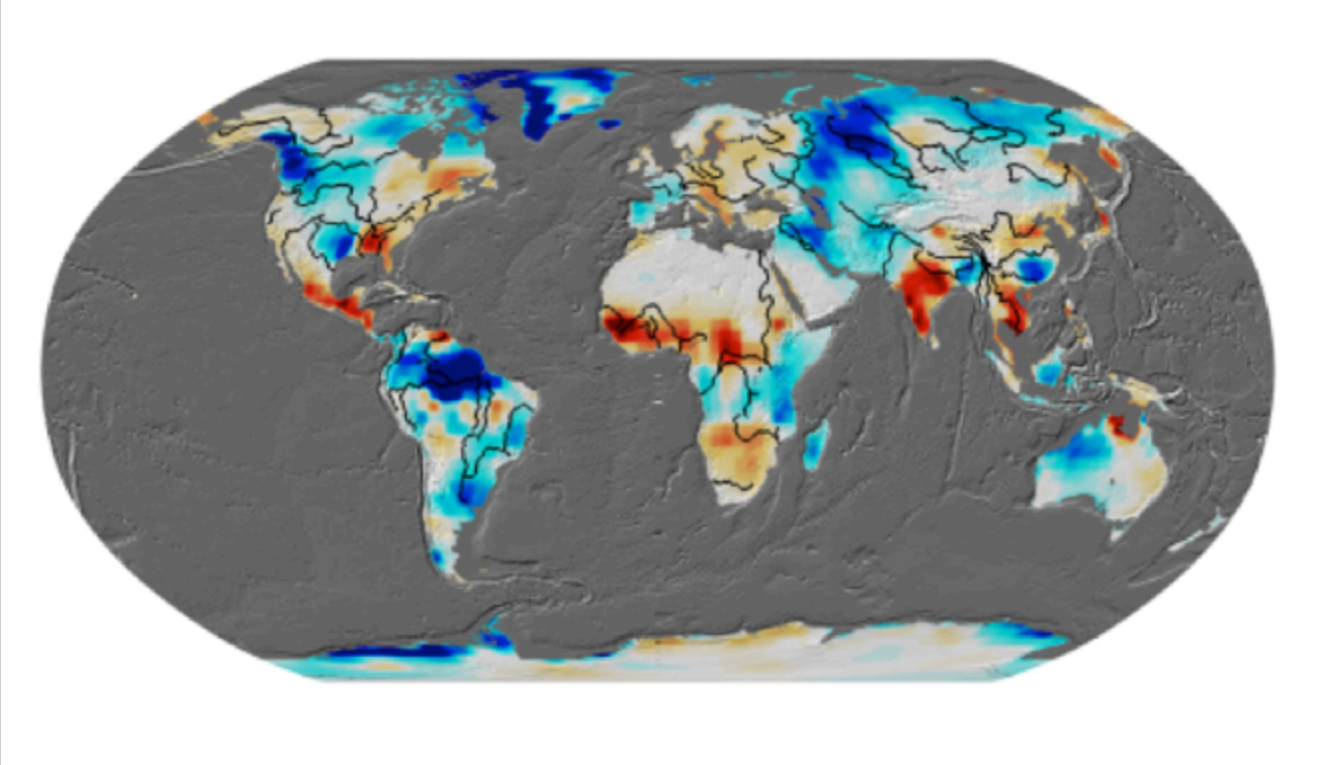
	OL	DA
Anomaly R	0.67+/- 0.02	**0.69 +/- 0.02**

Kumar et al. 2016: *Assimilation of gridded GRACE terrestrial water storage estimates in the North American Land Data Assimilation System*. J. Hydrometeor.

Capabilities (Future): GRACE Science Team Project

- LSMs supported by LIS do not account for groundwater withdrawals, surface reservoirs, or changing lake levels, resulting in inconsistency between GRACE trend analysis and GRACE Data Assimilation System

- **GOAL:** Improve representation of human impacts in models in order for the models to be more compatible with GRACE and GRACE-FO for data assimilation

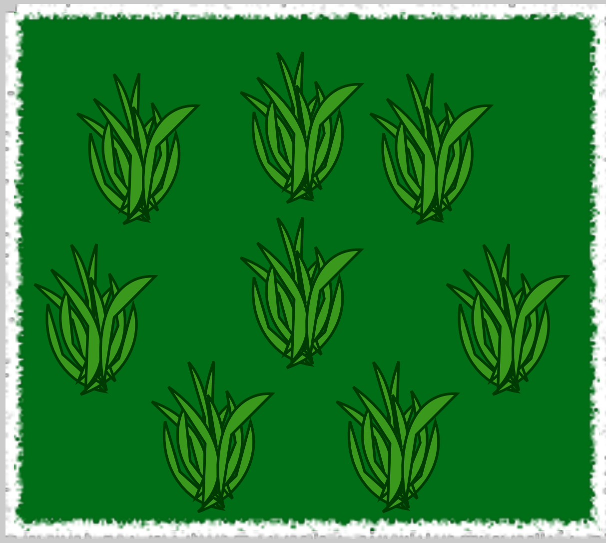


Capabilities: LIS Irrigation

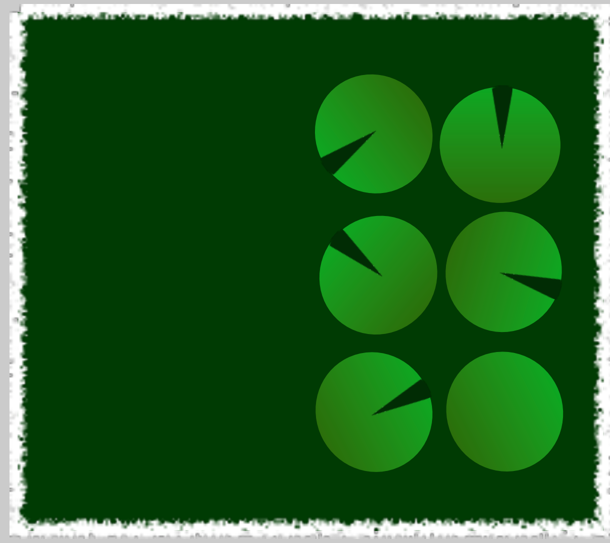
- Irrigation Options
  - Flood
  - Drip
  - Sprinkler
- Available offline and coupled to NASA-Unified Weather Research and Forecasting (NU-WRF) atmospheric model

Photos by Jeff Vanuga, USDA Natural Resources Conservation Service

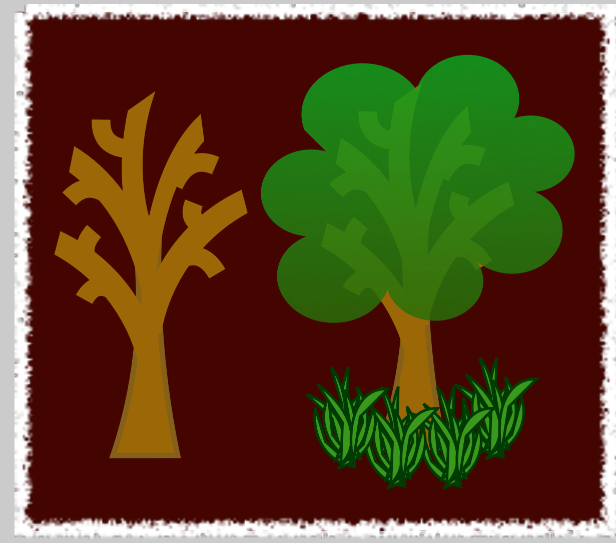
Capabilities: Sprinkler Irrigation Triggering in LIS



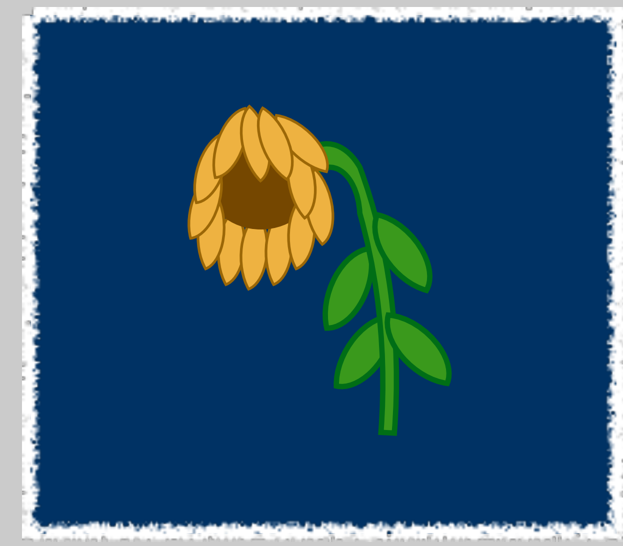
Is the landcover irrigable?



Is it irrigated?



Is it the growing season?



Is soil dry enough to require irrigation?

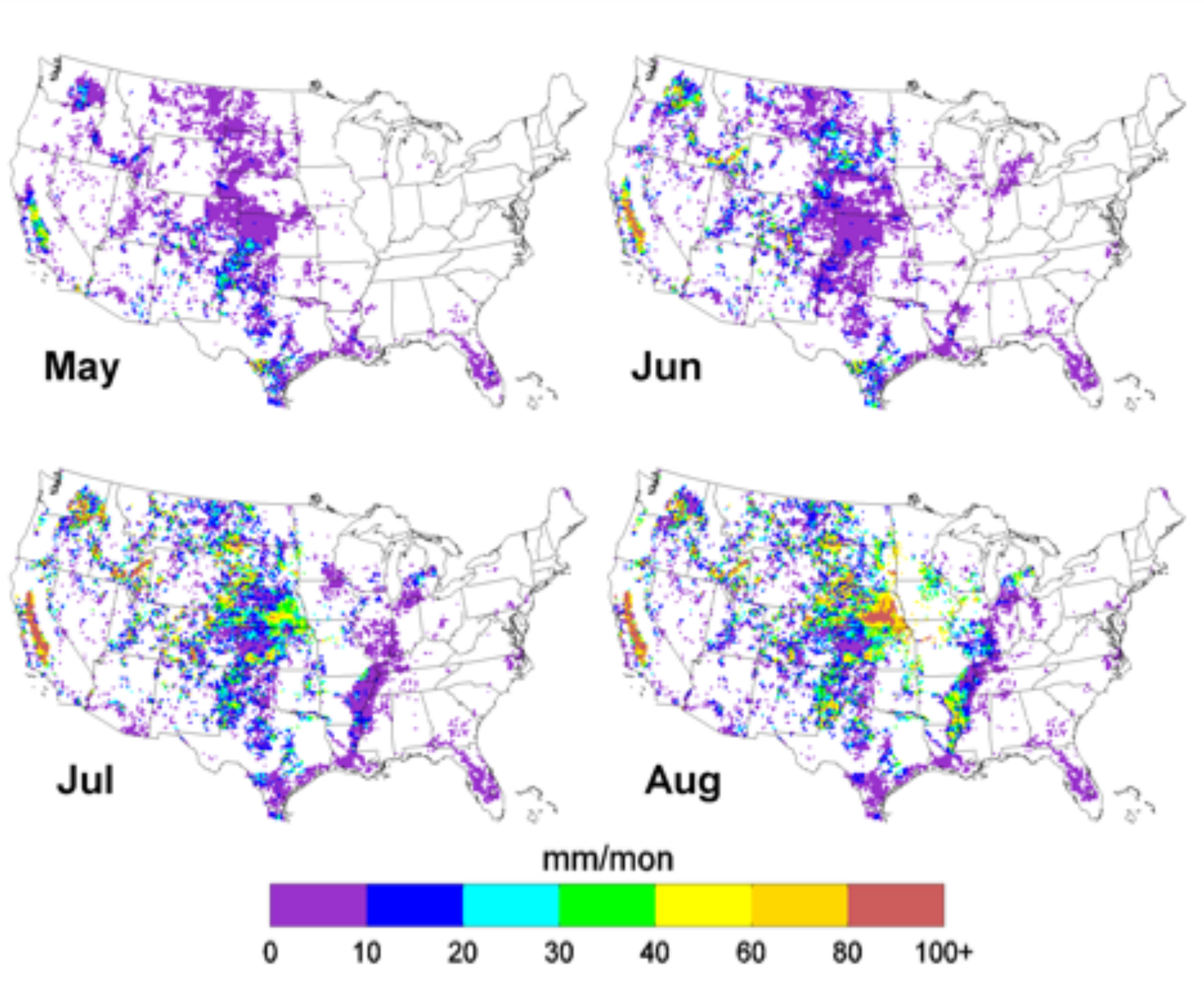
Irrigation on if MA < 50% Field Capacity

MA = (SM - SMwp)/(SMfc - SMwp)

MA: Root zone moisture availability
SM: Root zone soil moisture
SMwp: Wilting point (function of soil type)
SMfc: Field capacity (function of soil type)

Capabilities: LIS Irrigation Results - Offline

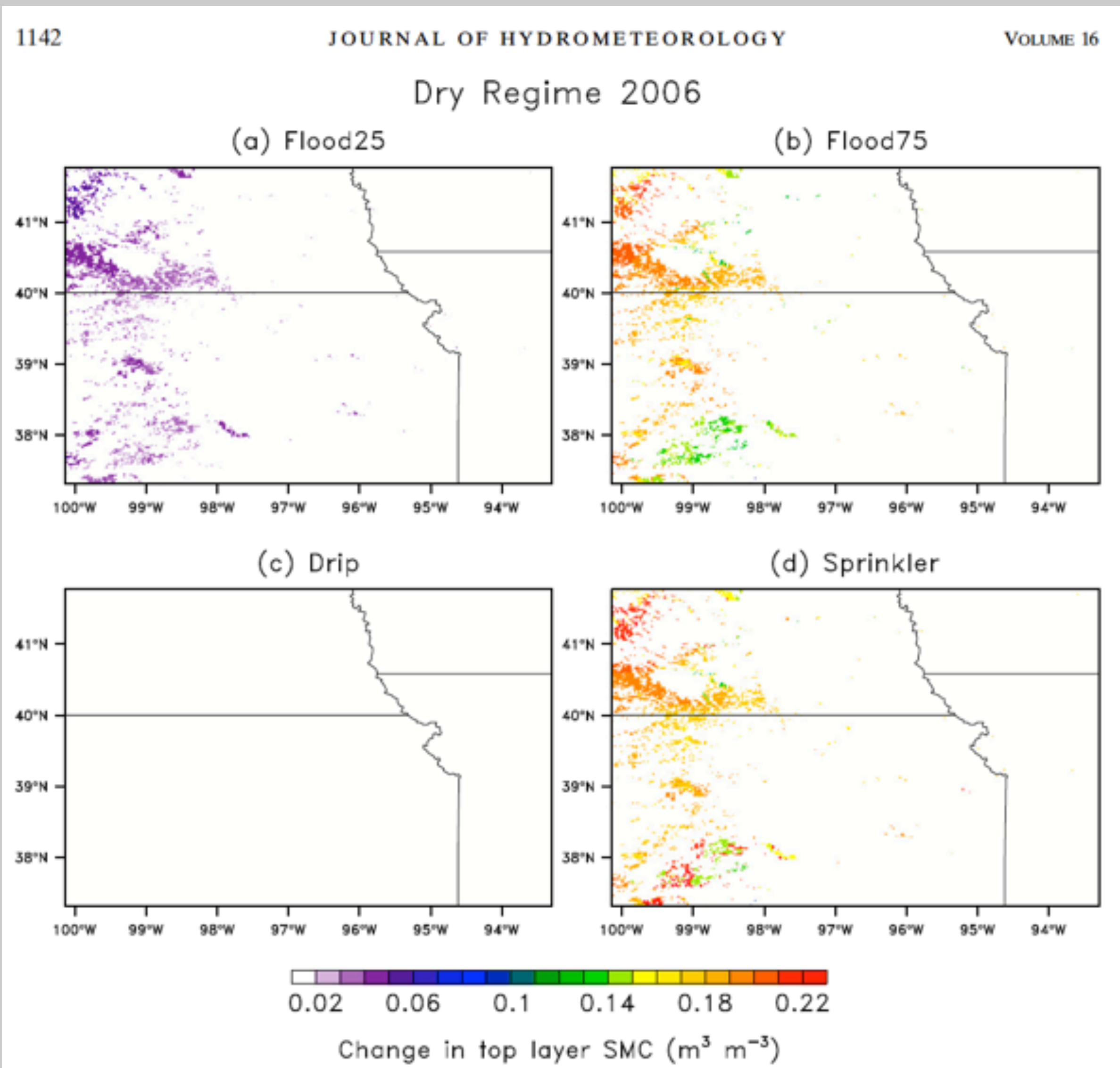
Irrigation significantly impacts U.S. water and energy budgets

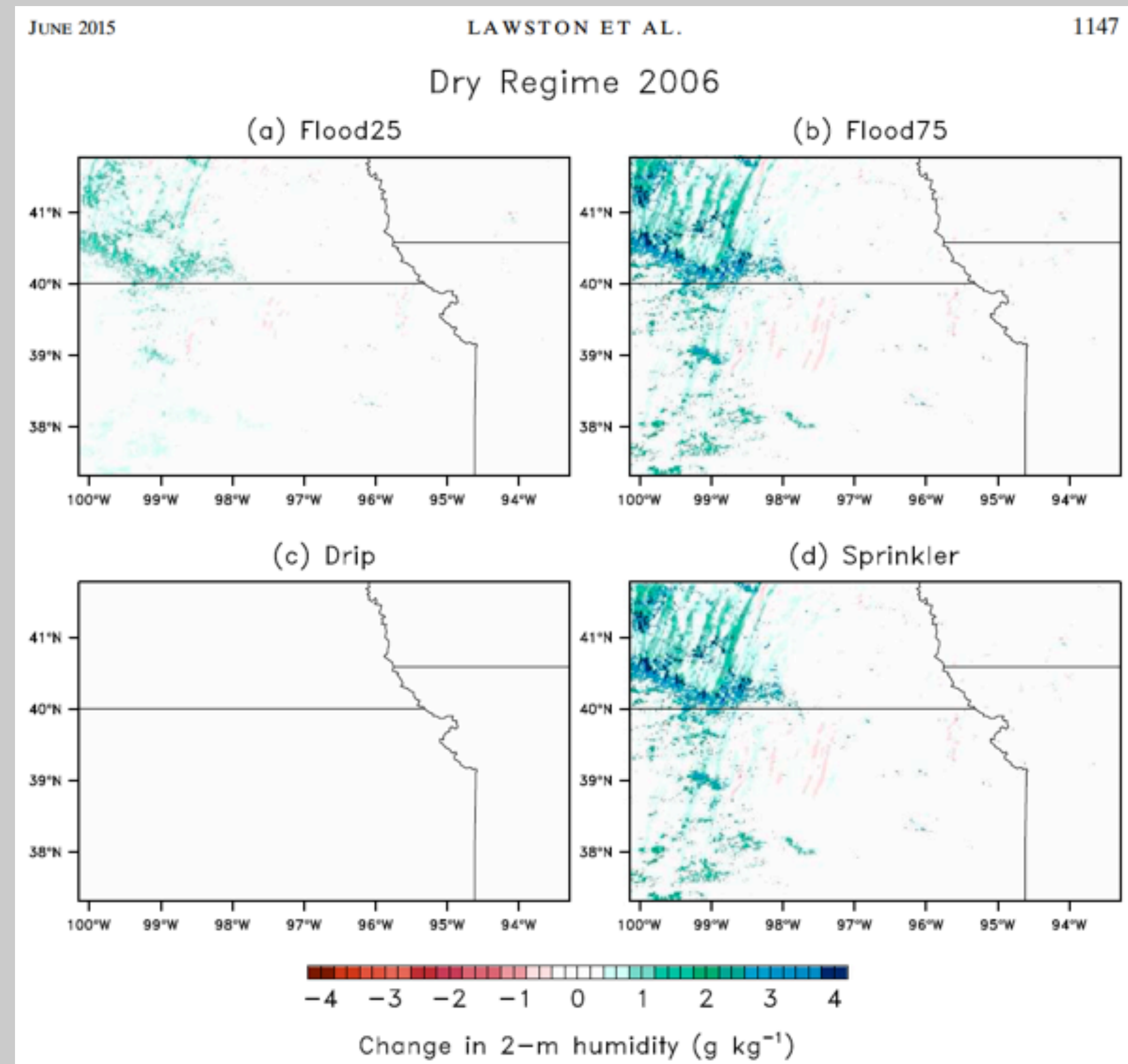


Increase in evapotranspiration due to irrigation, from *Ozdogan et al., J. Hydrometeor, 2010.* The increase in ET due to irrigation, averaged over the entire contiguous U.S., was 4% during the growing season, which is a huge impact on the water budget that also affects temperature and the energy budget.

Capabilities: LIS Irrigation Results - Coupled

Irrigation scheme differences matter for coupled impacts



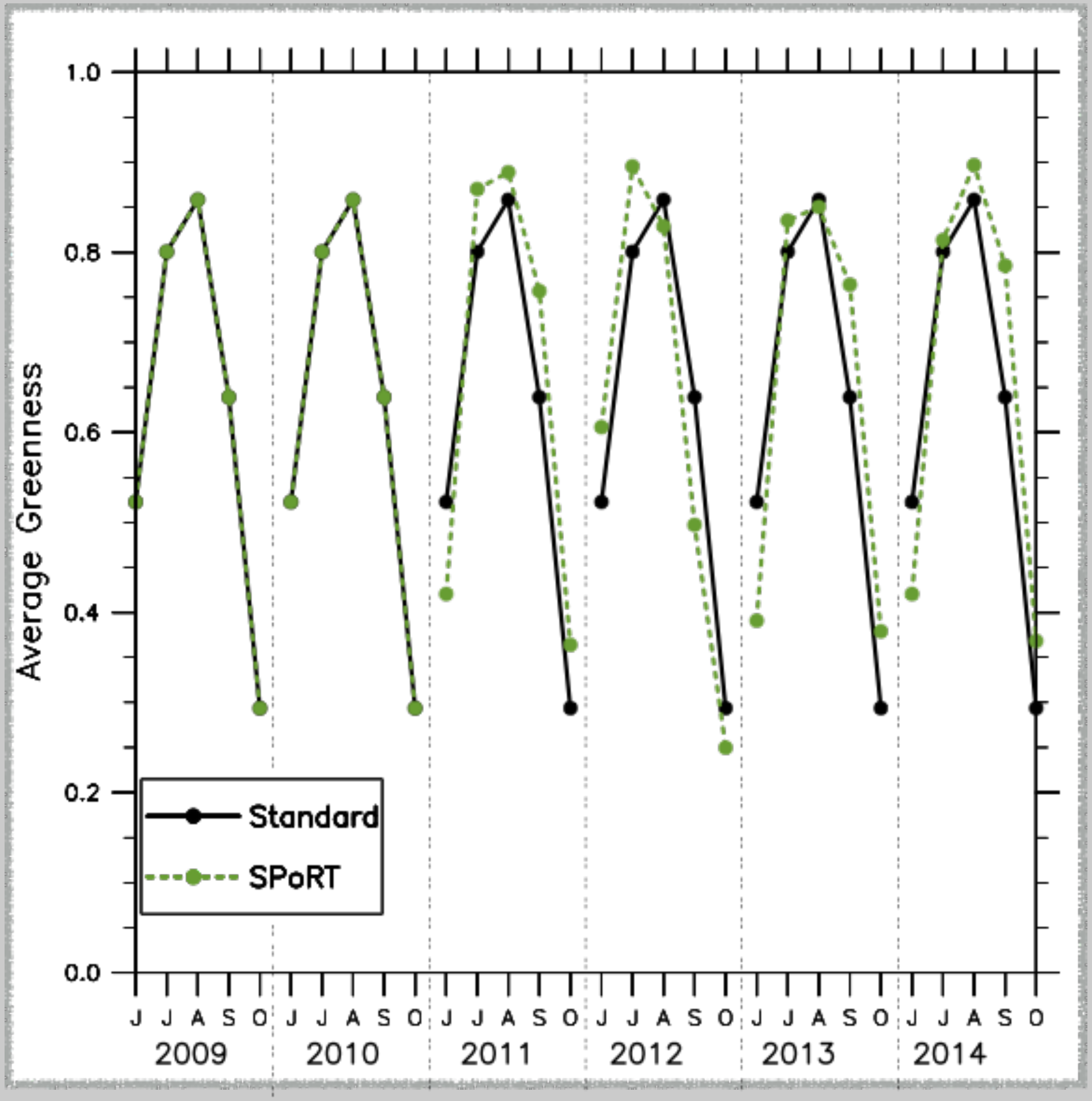


Top layer soil moisture increases by 0 to 0.2 m3/m3

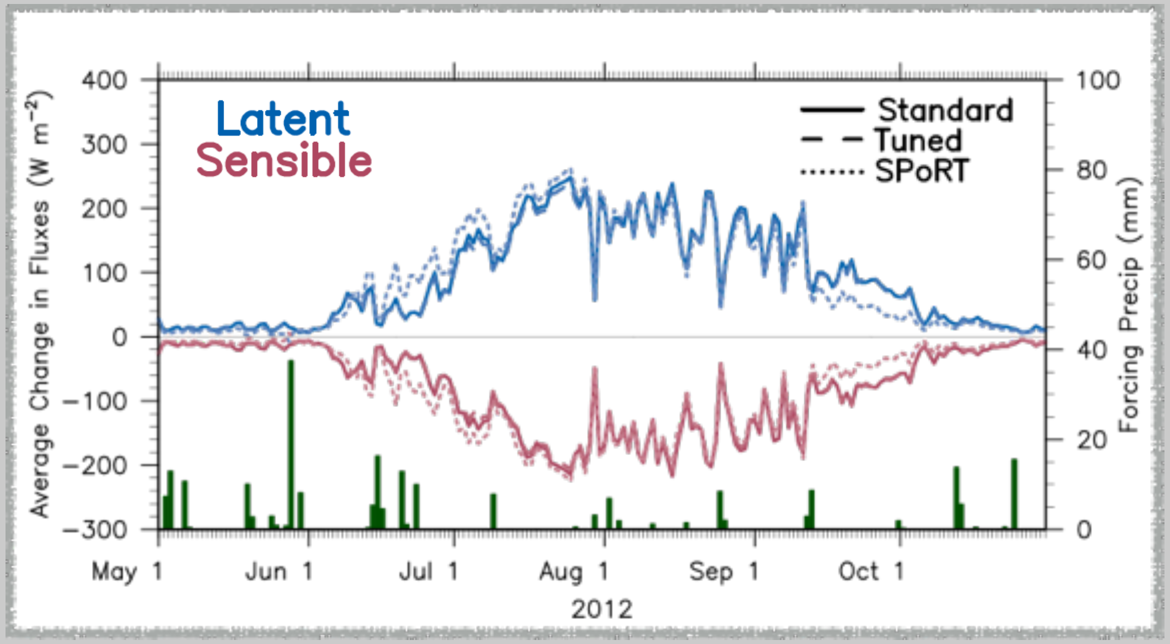
Humidity increases by up to 4 g/kg

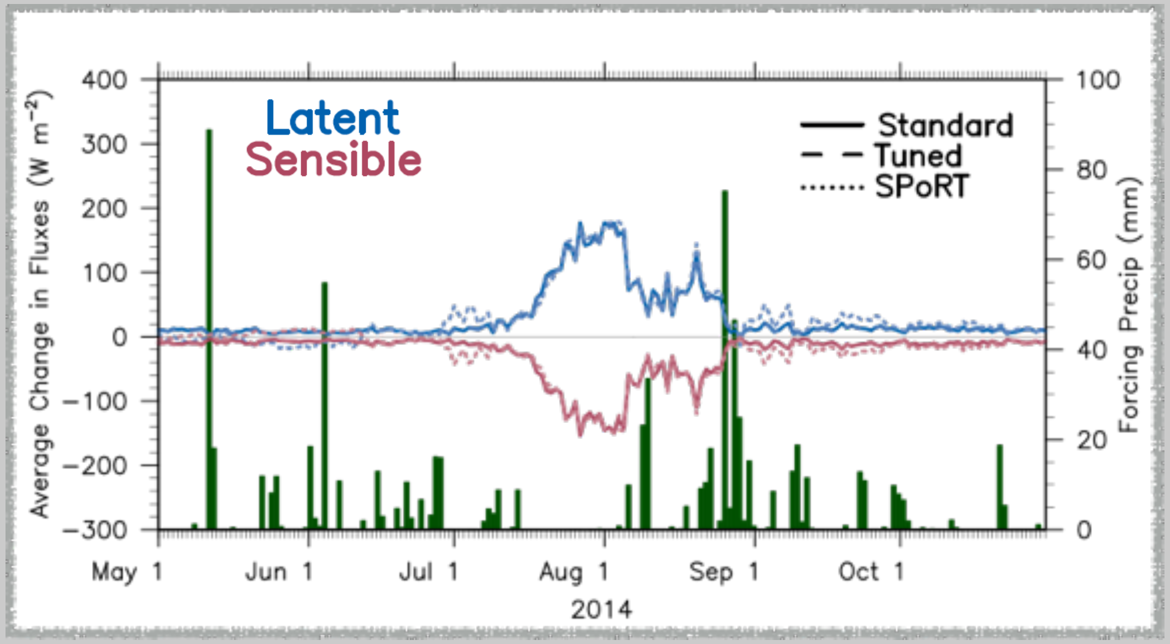
Capabilities: Tuning of Irrigation Schemes

High quality datasets are needed for accurate irrigation triggering



Climatological and Real-time Greenness datasets

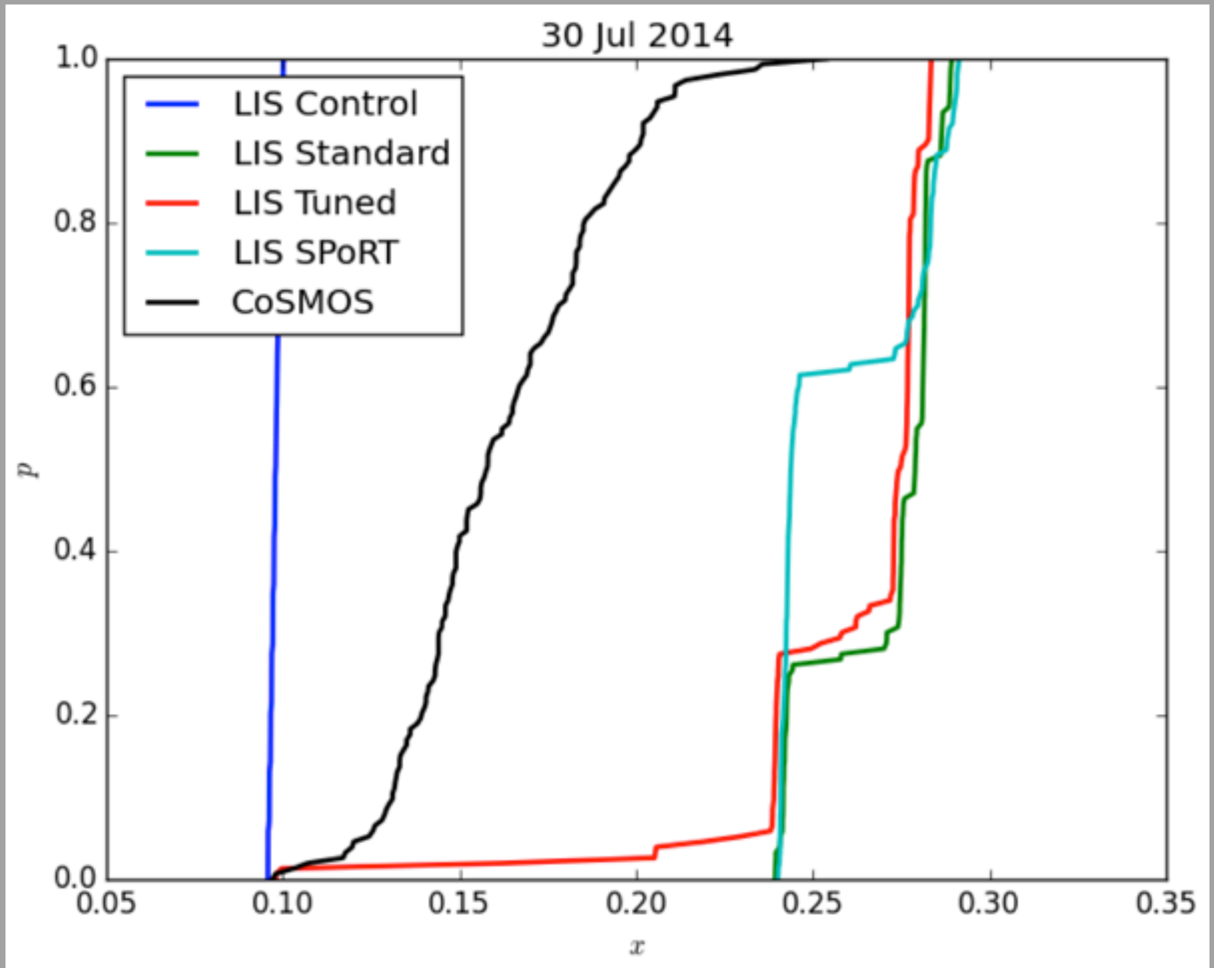




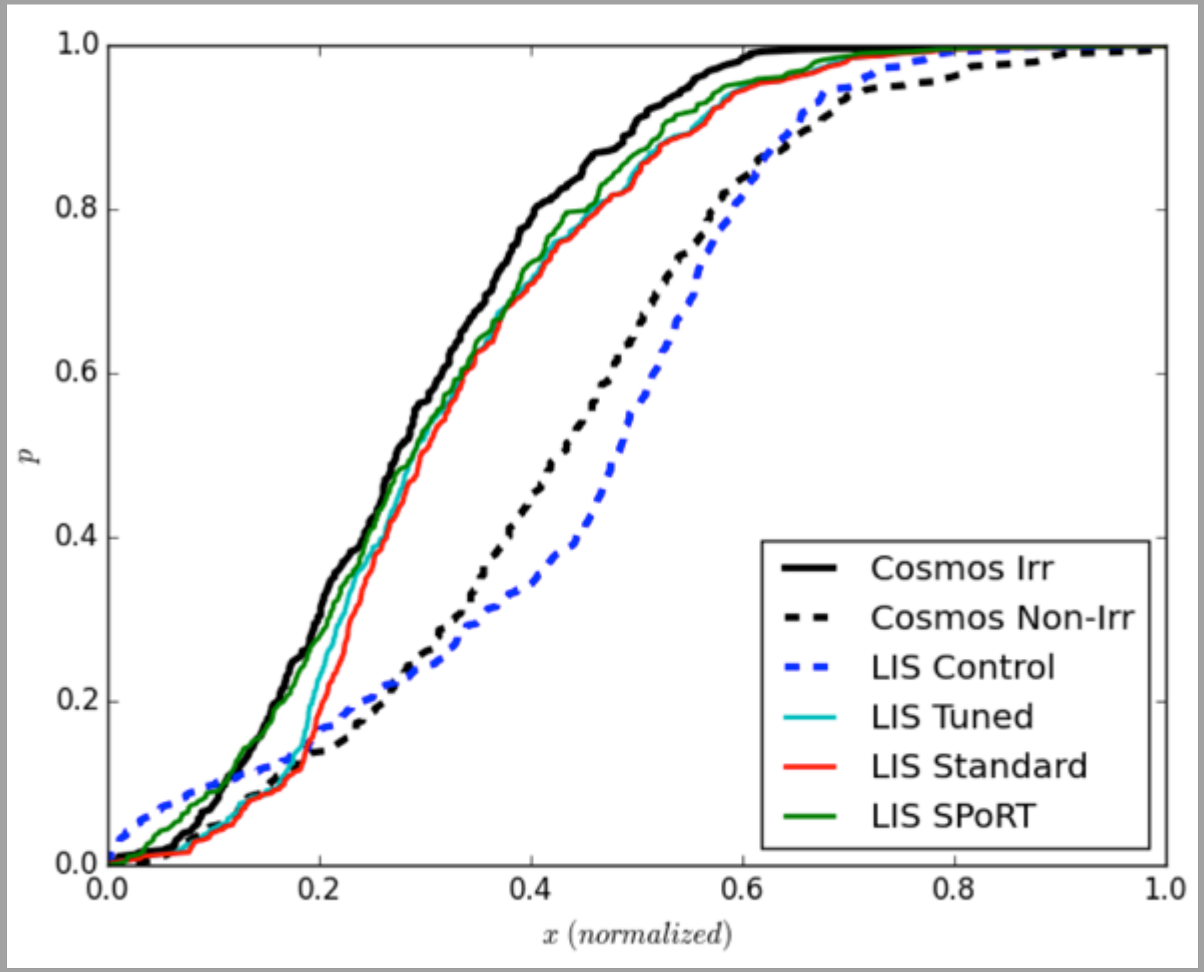
Meteorological forcing, especially precip, is important to irrigation timing

Validation of Irrigation Schemes is difficult

- Need time-varying datasets of irrigation intensity and irrigation water usage
- Validation of triggering thresholds and parameters difficult due to lack of observations and scale differences of between model and observations



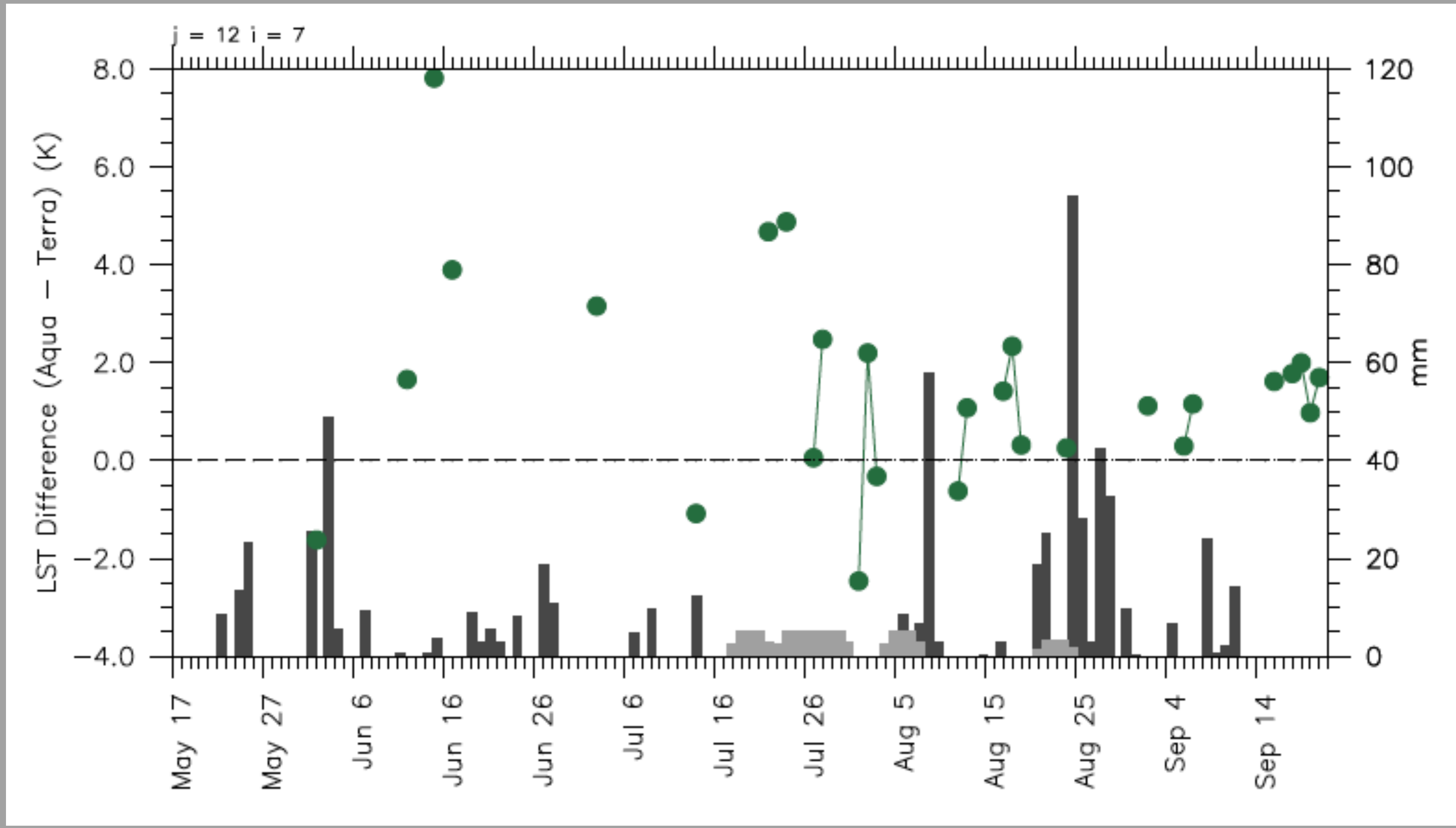
Spatial variability during irrigation events is not well simulated



Growing season variability simulated well as compared to observations

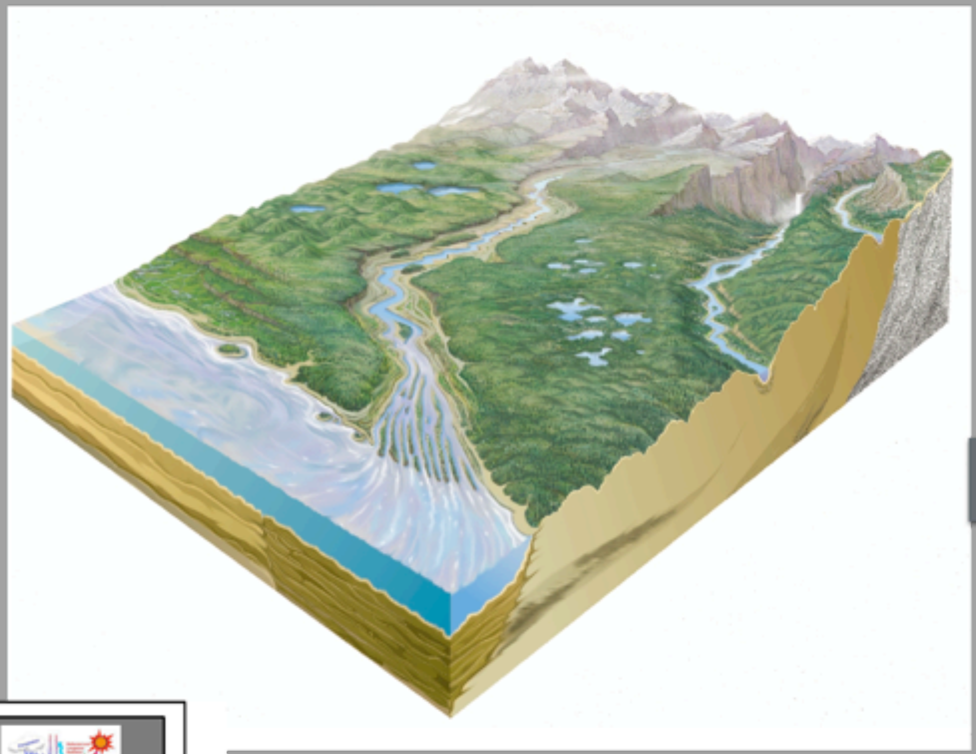
Utility of LST and ET as proxy for irrigation

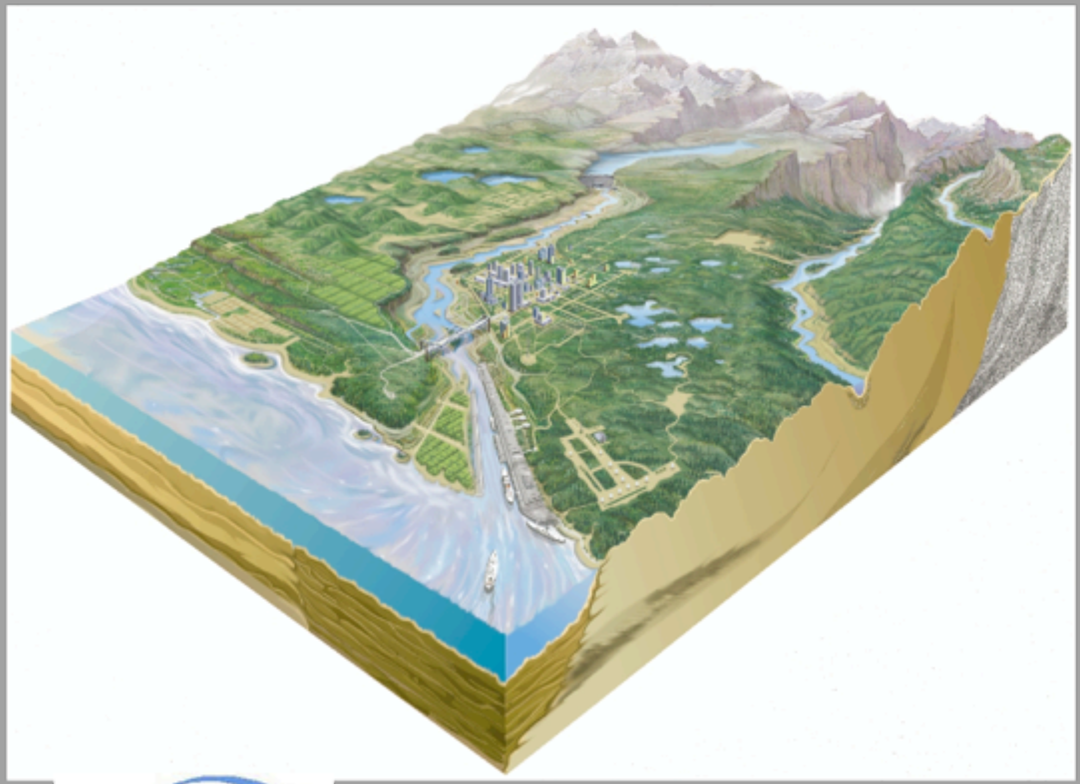
- MODIS-based ET products not capable of reproducing the dynamics influencing model output
- Inconsistency in timing and location of overpasses seemed to smear irrigated and non-irrigated fields



Utility of Satellite Retrievals to Detect Irrigation

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

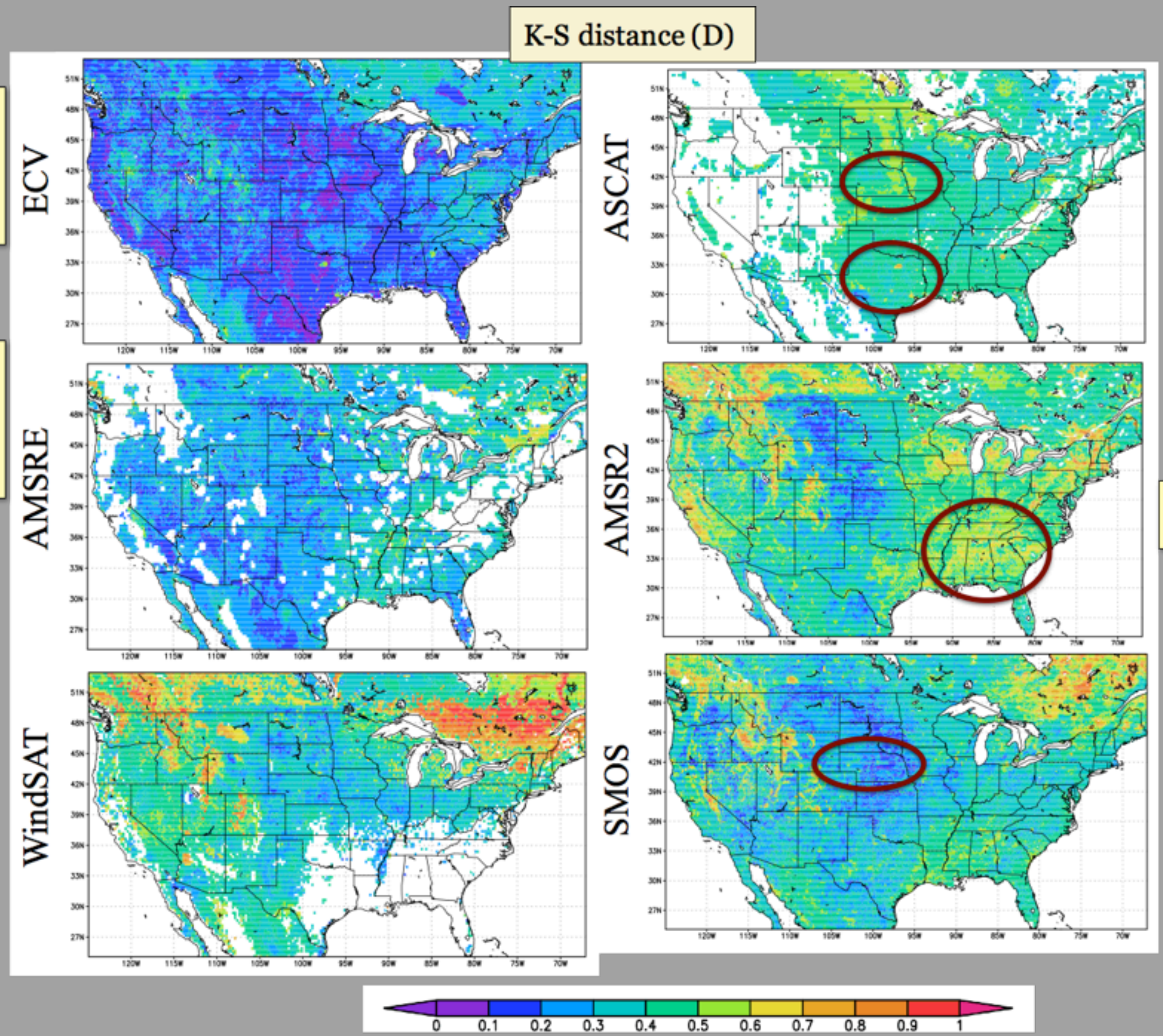
Remote sensing: practical method to observe these 'unmodeled' features

Kumar et al. 2015: *Evaluating the utility of satellite soil moisture retrievals over irrigated areas and the ability of land data assimilation methods to correct for unmodeled processes.* Hydrol. Earth Syst. Sci

Utility of Satellite Retrievals to Detect Irrigation

ECV shows the lowest D values (possibly because ECV was generated by CDF matching soil moisture estimates from different sensors to GLDAS Noah)

Larger differences seen with other sensors – a mix of biases from instrument noise, retrieval algorithm errors and **unmodeled observational processes**



Larger D values in eastern Nebraska – possible signal of irrigation

Signal of urban areas – Dallas, Houston

Strong signal of vegetation density in the eastern U.S.

Low D values in the SMOS comparison over Nebraska – an indication that SMOS retrievals are not doing a good job at detecting irrigation

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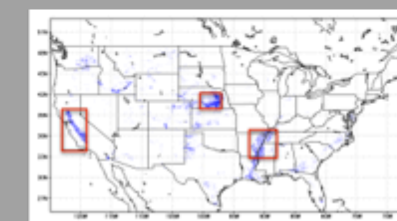
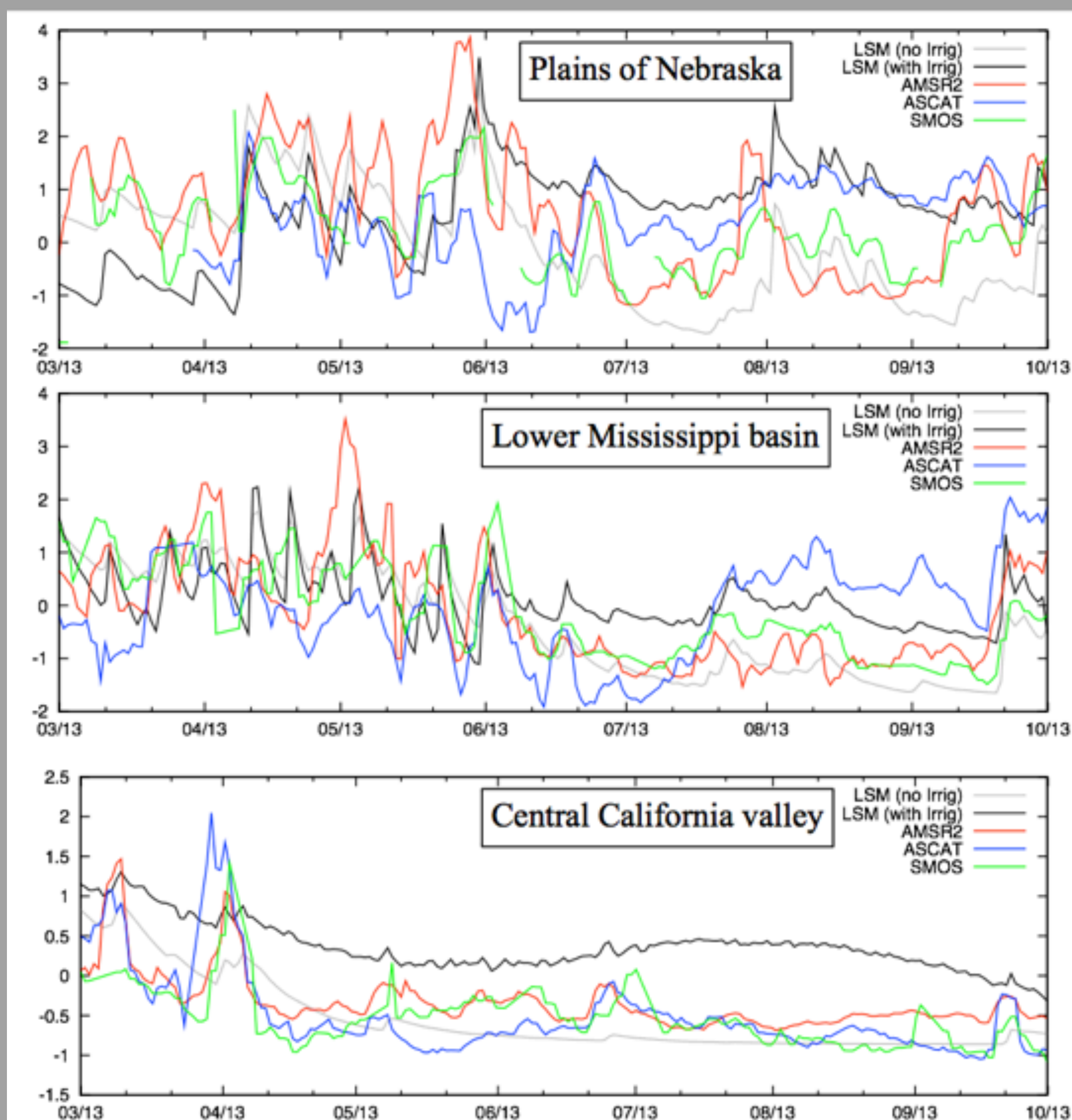
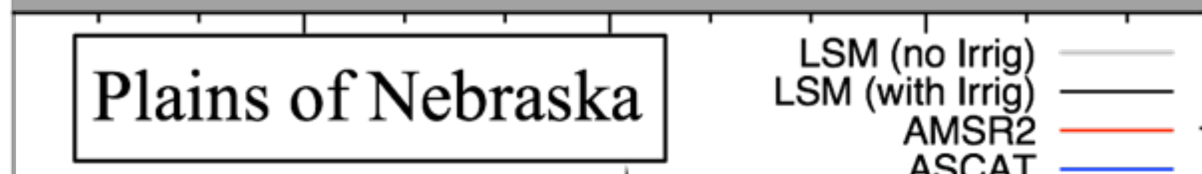


Normalized soil moisture time series averaged over the irrigation hot-spots





ASCAT time series shows better agreement with the LSM with irrigation time series in the summer and fall months (Nebraska, Lower Mississippi); No such distinct contrast in the central California valley.

AMSR2 and SMOS time series show better agreement with LSM without irrigation

The skill of AMSR2 and SMOS retrievals are low in detecting irrigation whereas ASCAT retrievals are somewhat effective in detecting these features

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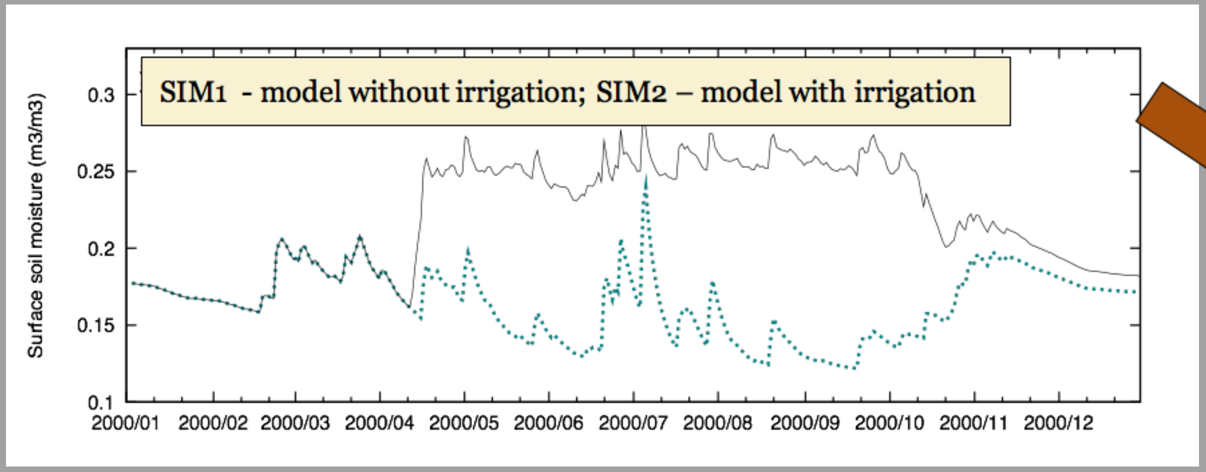
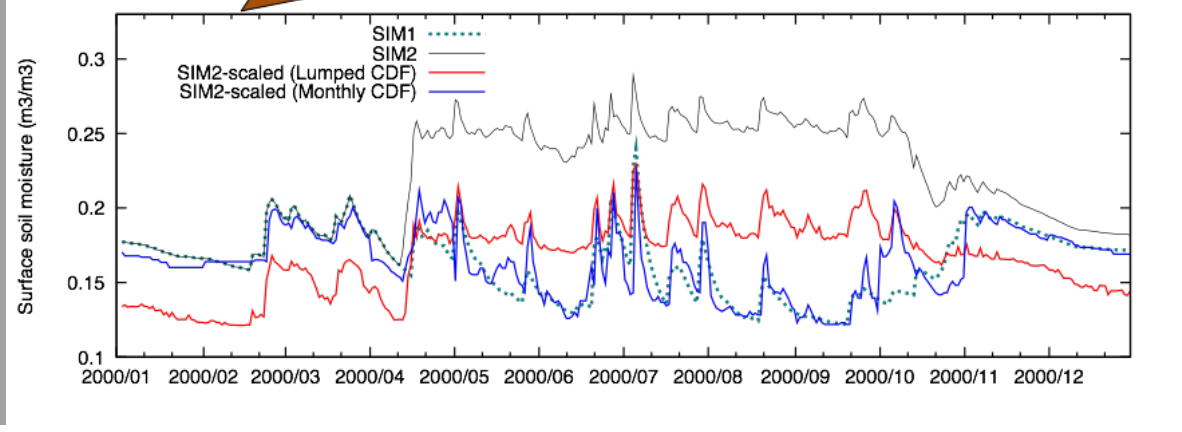
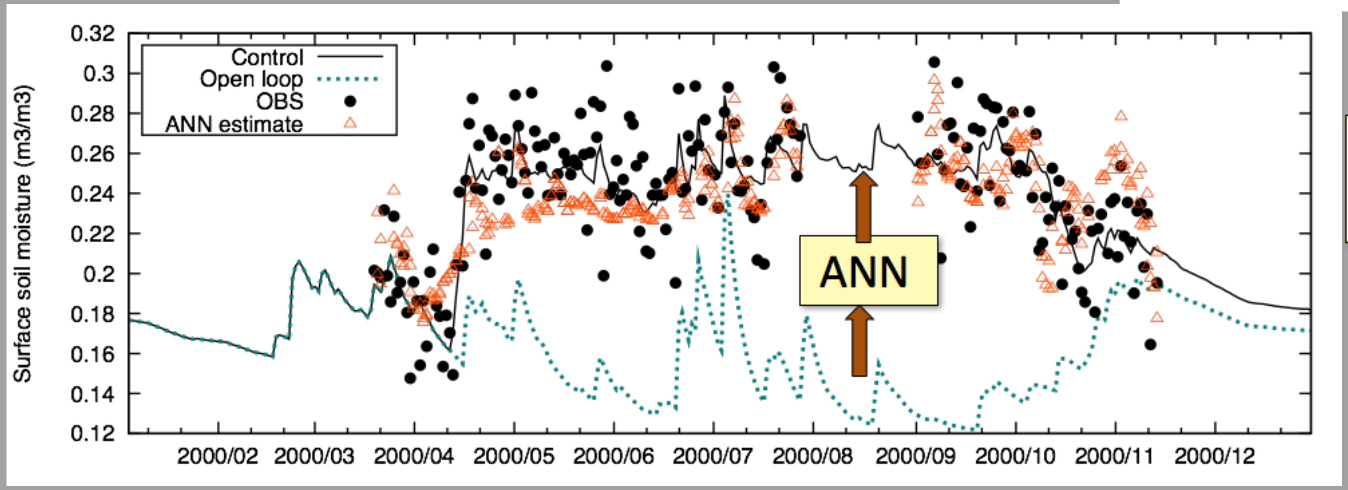


Lumped CDF matching (CDFs computed using all years and all seasons lumped together)

Monthly CDF matching (CDFs computed separately for each month)



Spurious statistical artifacts introduced in the lumped CDF matching approach, which are reduced when CDF matching is more finely temporally resolved



Trained ANN simulates the anomalous wet signals of irrigation

Kumar et al. 2015: *Evaluating the utility of satellite soil moisture retrievals over irrigated areas and the ability of land data assimilation methods to correct for unmodeled processes*. Hydrol. Earth Syst. Sci

Utility of Satellite Retrievals to Detect Irrigation

- Models and satellites must progress together; one cannot correct for the other
- What other unmodeled artifacts will we need to deal with in the future?

Kumar et al. 2015: *Evaluating the utility of satellite soil moisture retrievals over irrigated areas and the ability of land data assimilation methods to correct for unmodeled processes.* Hydrol. Earth Syst. Sci

Ideas to continue support of anthropocene effort

- Earth Interactions (AMS) is expanding and rebranding with an anthropogenic focus
  - Earth Interactions publishes a wide variety of research on the interactions between the atmosphere, hydrosphere, biosphere, and lithosphere. These include, but are not limited to, **research on human impacts that drive hydrospheric, atmospheric, biospheric, and lithospheric processes and their interactions, such as land cover change, irrigation, dams/reservoirs, urbanization, pollution,** and landslides. Earth Interactions is a joint publication of the American Meteorological Society, American Geophysical Union, and American Association of Geographers.
- Convene a dedicated AGU session focused on this topic
  - Original: "Advances in Irrigation Hydrology: Measurements, Modeling and Multi-Scale Impacts on Water Resources"
  - Merged: "Remote Sensing Applications for Irrigation and Water resources Management Including Droughts, Floods, and Associated Water Cycle Extremes"