A Model-based Groundwater Drought Indicator

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Objective: monitoring shallow groundwater storage changes

- 2.5 billion people rely on groundwater exclusively for drinking water
- 43% irrigation water comes from aquifers

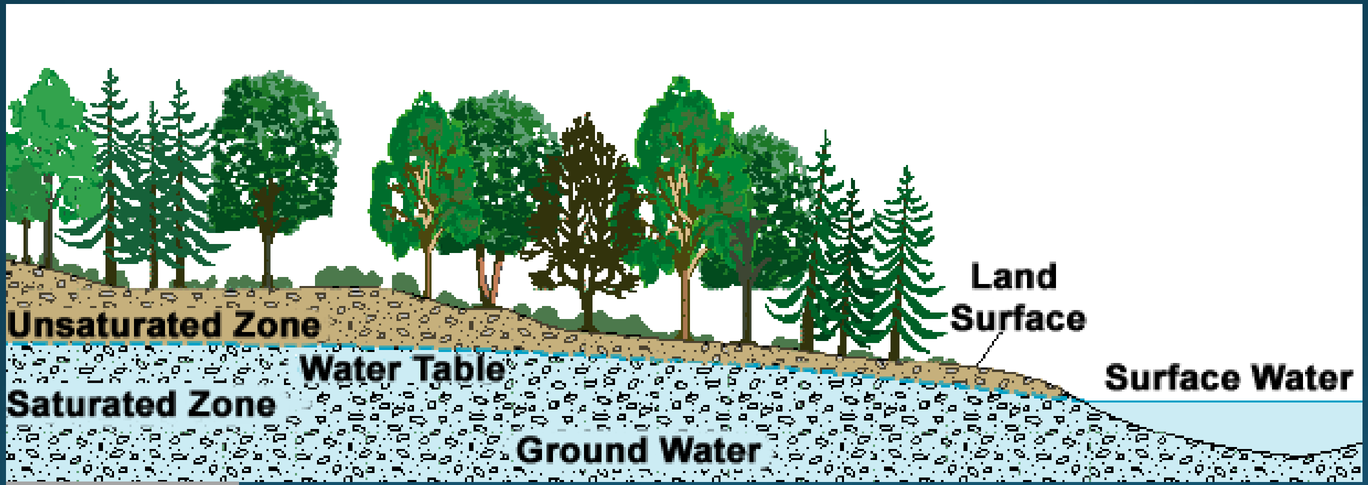


Image by USGS

Monitoring groundwater drought complements drought monitoring efforts in other processes.

The Catchment land surface model (CLSM)

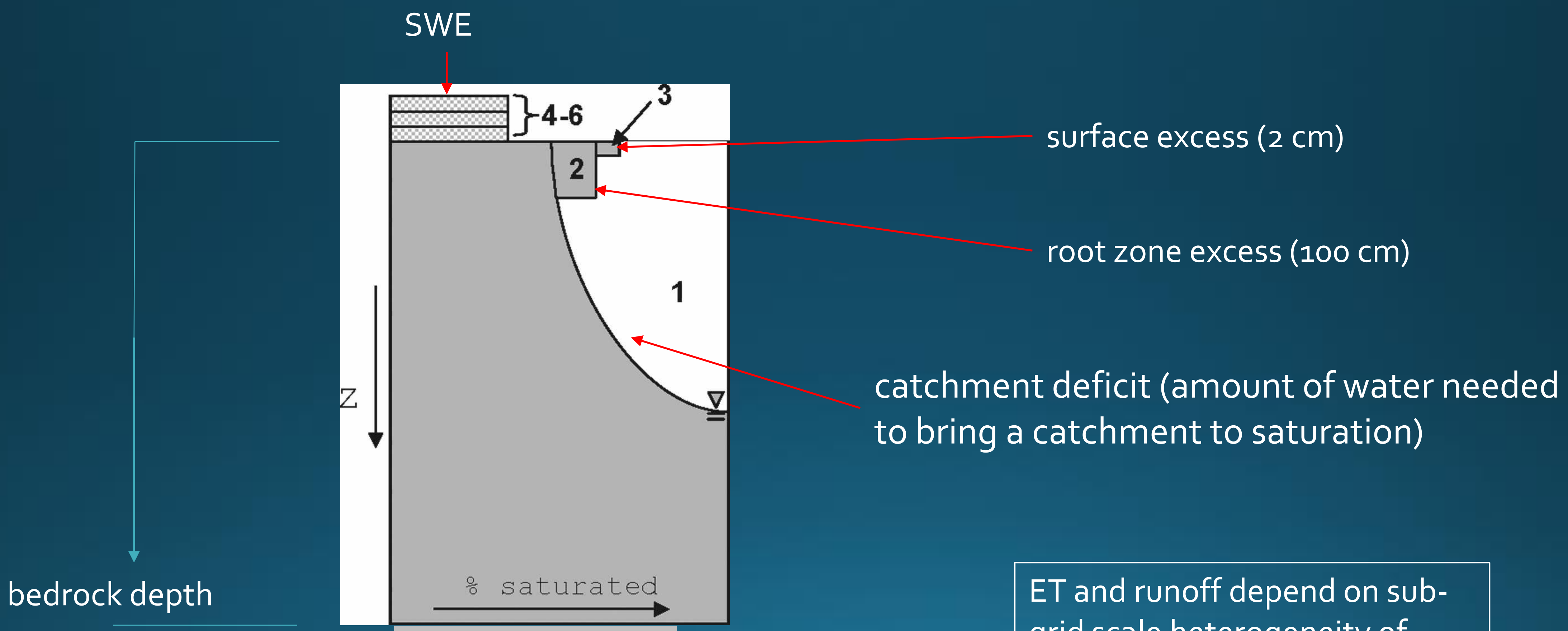
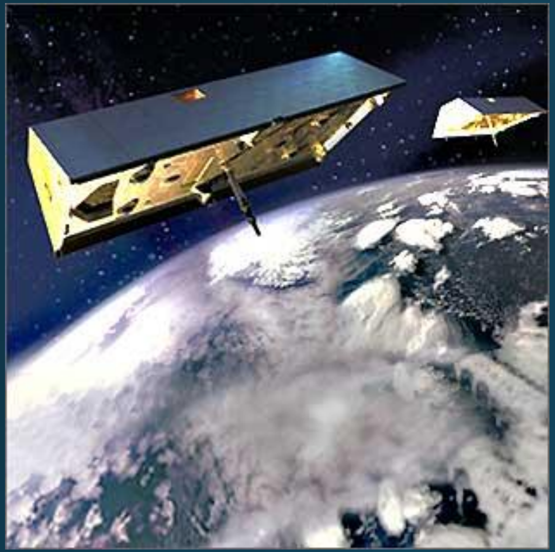


Image by Zaitchik et al. (2008)

ET and runoff depend on sub-grid scale heterogeneity of modeled states

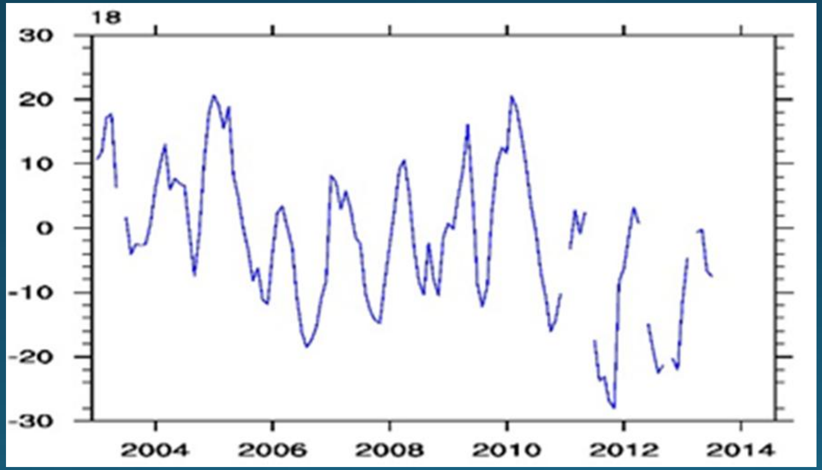
Improving groundwater estimates through assimilating GRACE terrestrial water storage (TWS) anomalies

GRACE satellites



Gravity field → temporal variability / removing air mass & temporal mean → TWS (include soil moisture, groundwater, snow and surface water)

GRACE TWS at Red-LM



Pros:
- anomalies
- sensitive to drought in all seasons
- detecting groundwater

Cons
- vertically integrated
- coarser spatial and temporal resolutions
- shorter records and data latency

Derivation of drought indices

Climatology

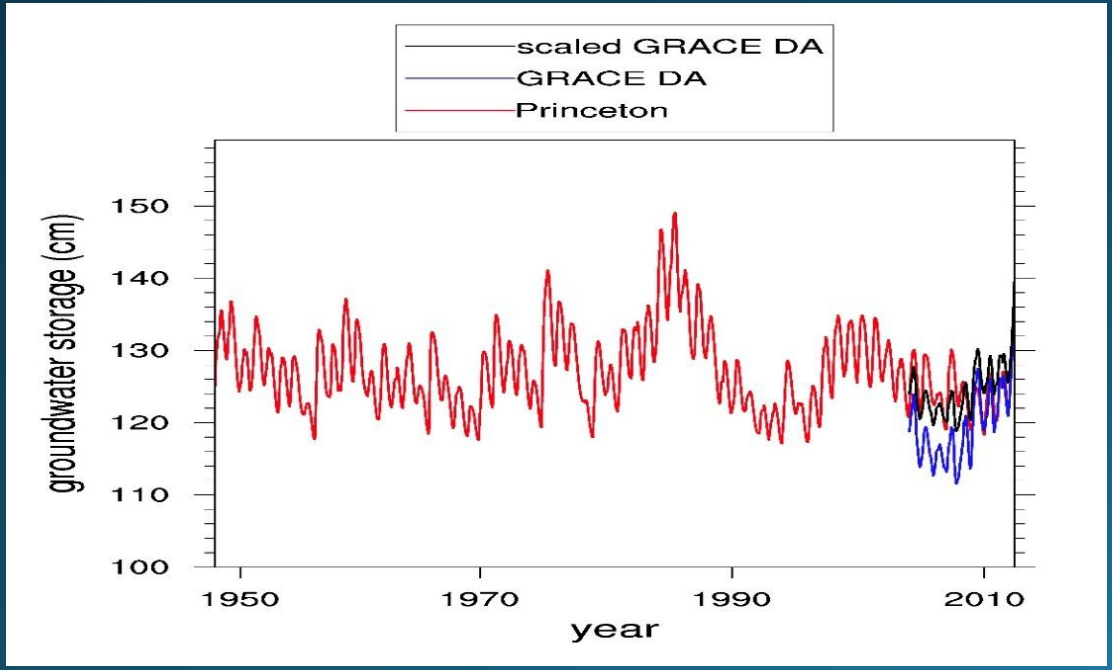
1948 — Princeton forcing fields — 2012

forcing bias correction

GRACE DA and near-real time simulation

2002 — ECMWF/NLDAS — present

output scaling



Climatology was derived using daily states within individual calendar months

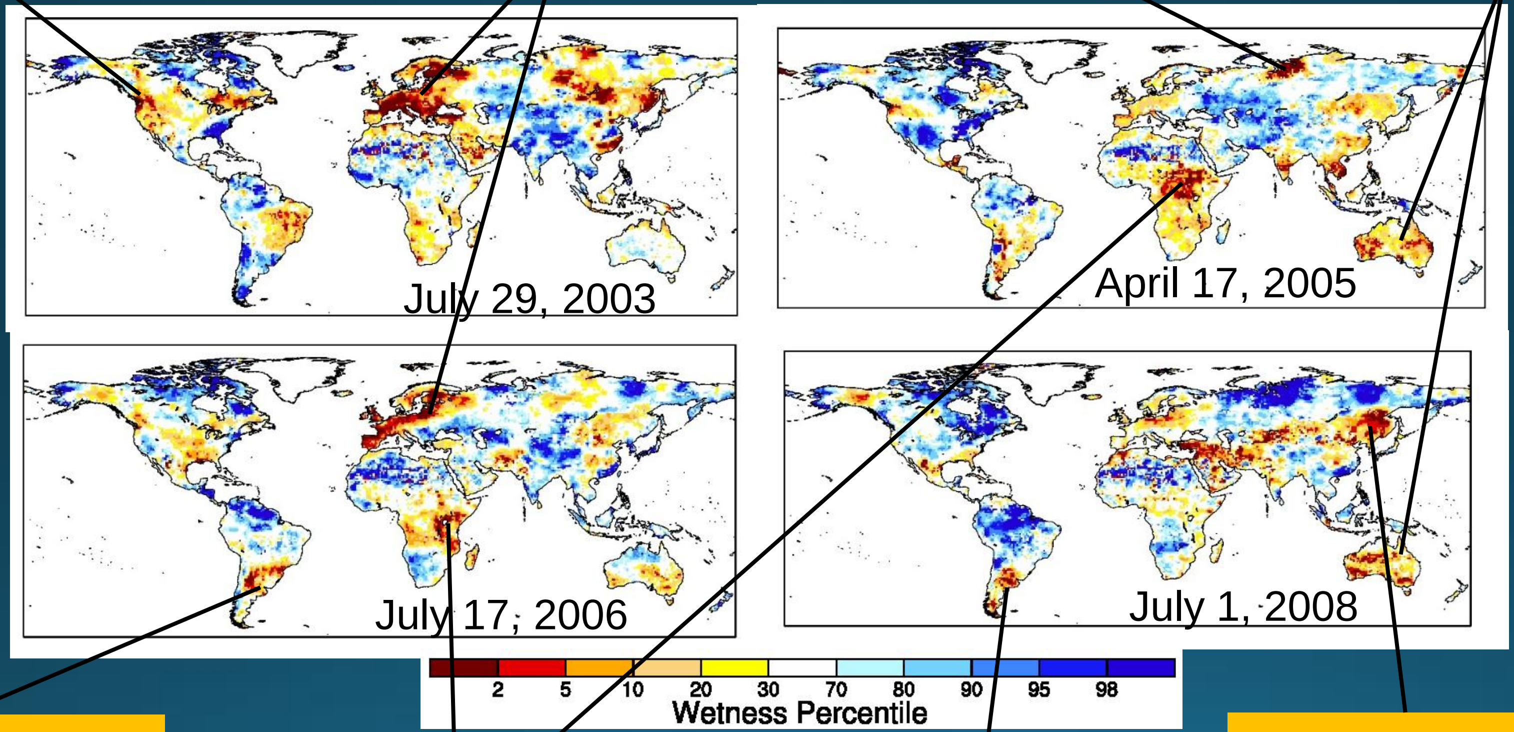
Global groundwater drought indices from GRACE data assimilation

Continuation of multi-year drought in western U.S.

Drought, heat wave, and wildfires across Europe

Low snow cover and high temperatures in Russia

Drought and high temperatures across Australia



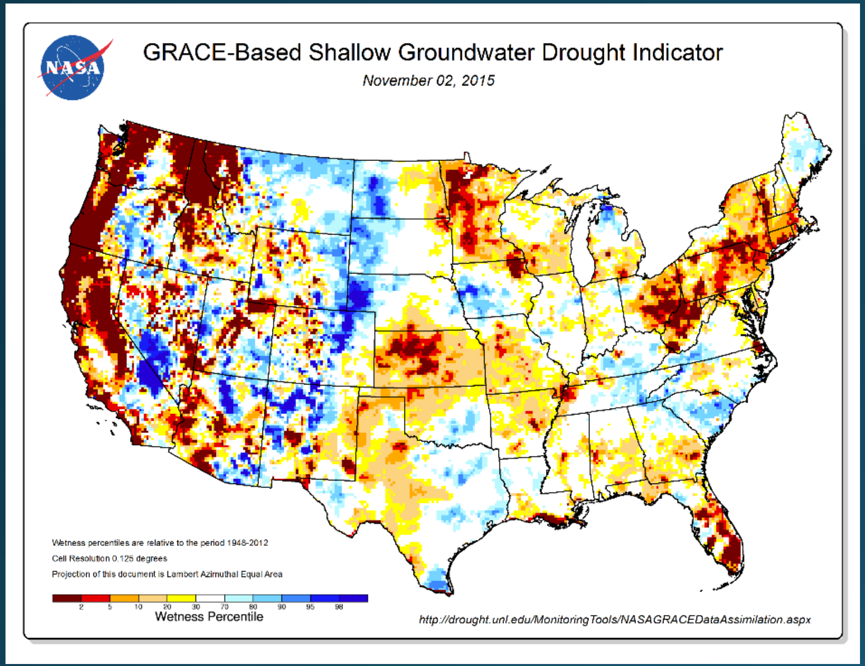
Drought in southern Brazil impacts crop yields

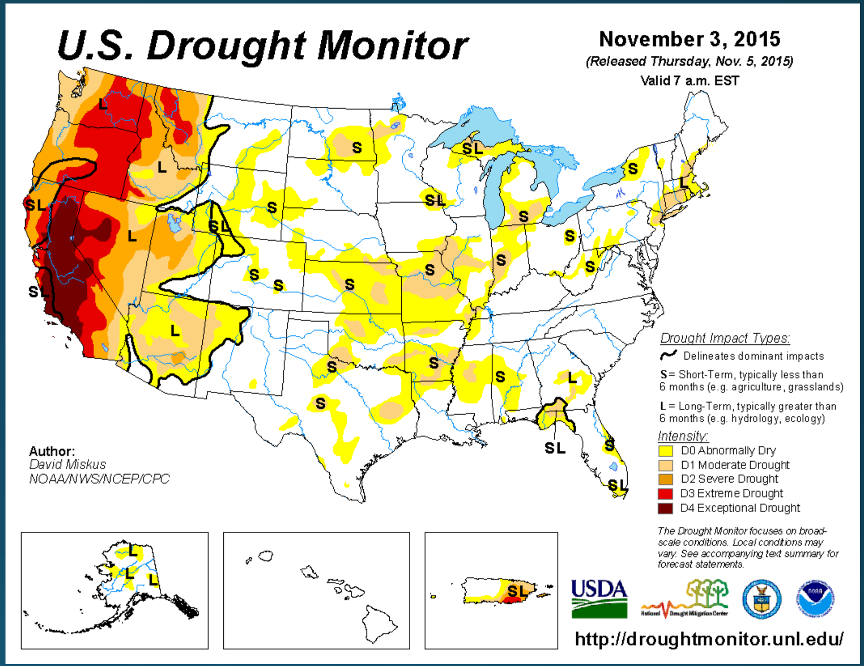
Continued long term drought in east Africa

Prolonged drought in Chile, Argentina, Paraguay, and Uruguay

Severe drought in northern China was overshadowed by a bigger weather story in 2008: powerful winter storms in central and southern China

GRACE based groundwater drought indices in comparison with US Drought Monitor

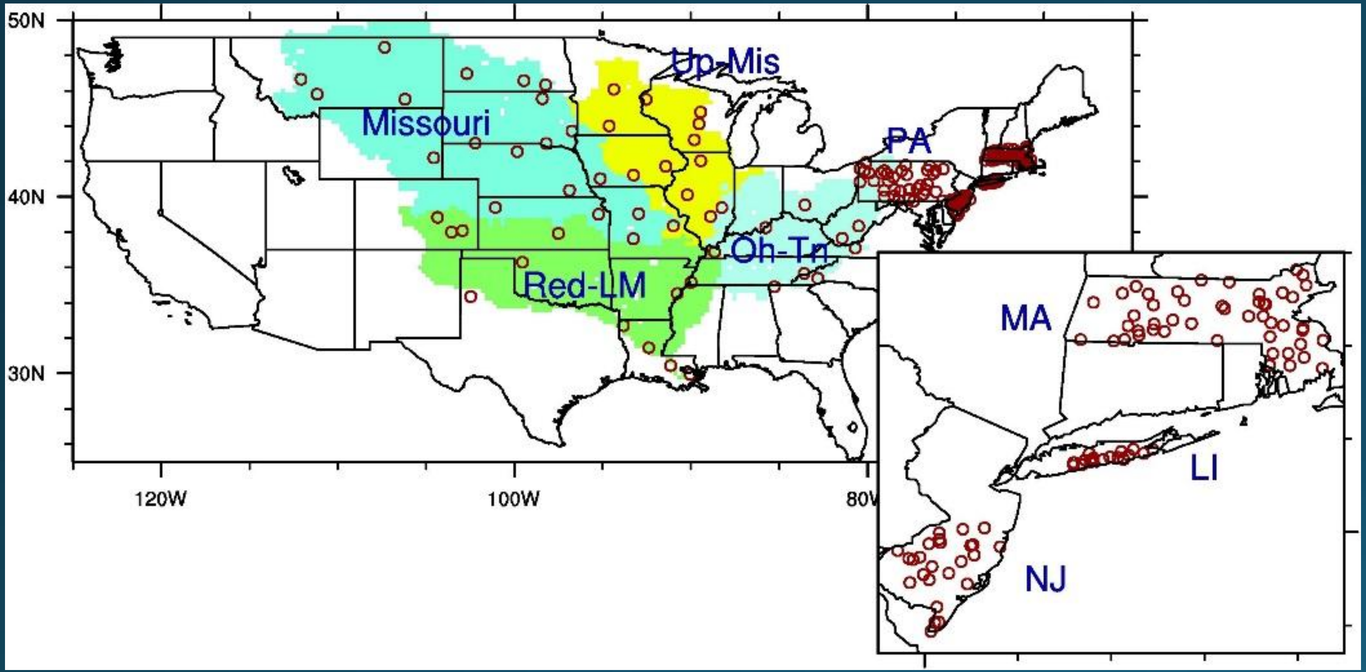




These maps are updated weekly and available at http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx

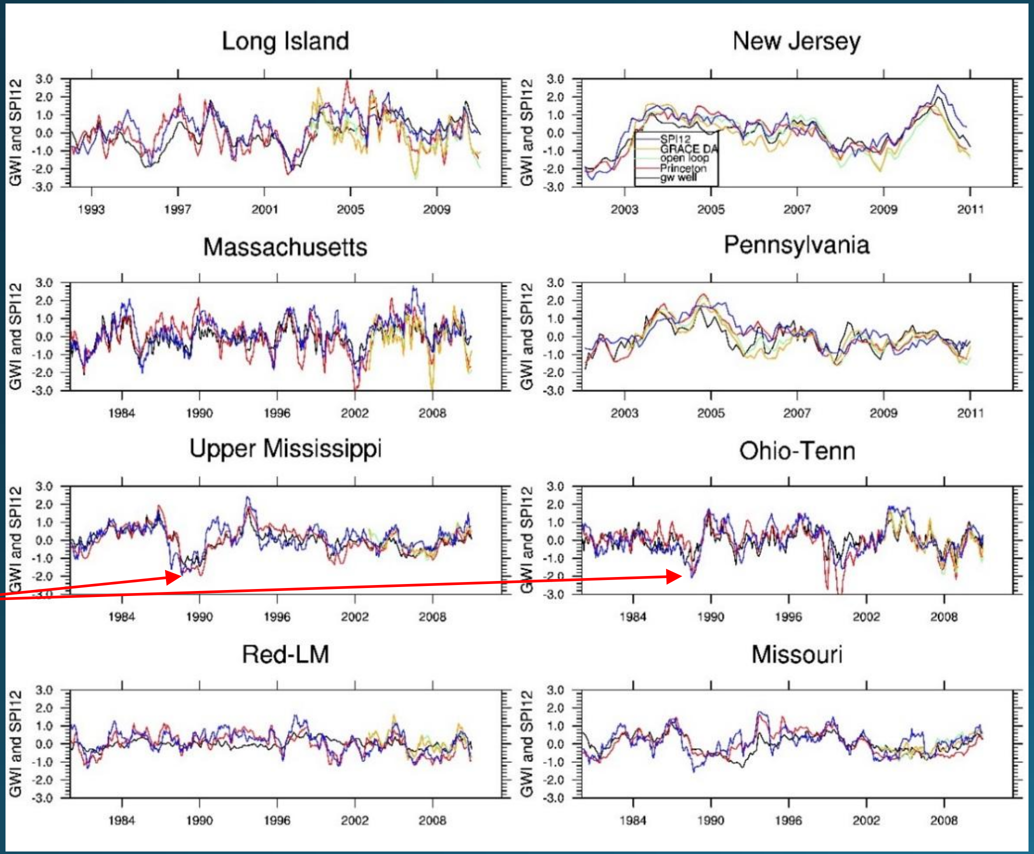
Evaluation using in situ groundwater data

groundwater well locations



- 10 – 30 years of depth to water table measurements
- wells located in confined or semi-confined aquifers
- exhibit seasonal variation

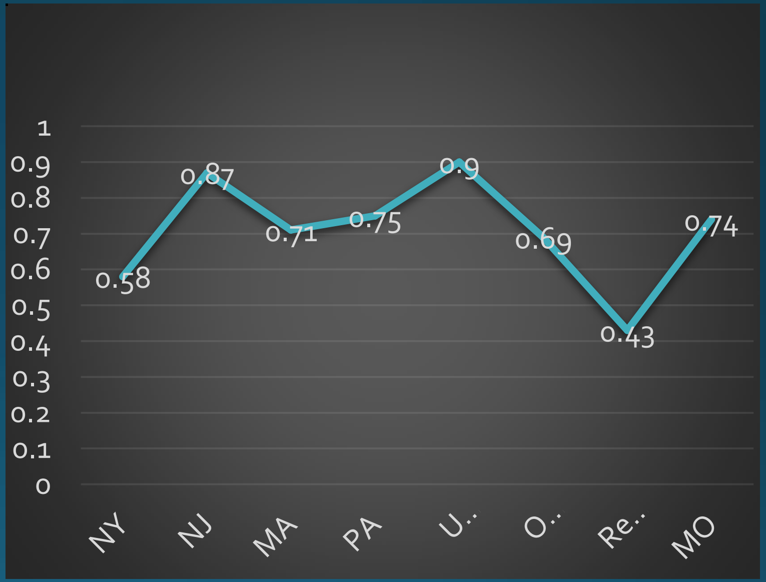
CLSM based drought indices correlate well with similarly derived drought indices based on in situ data



severe drought

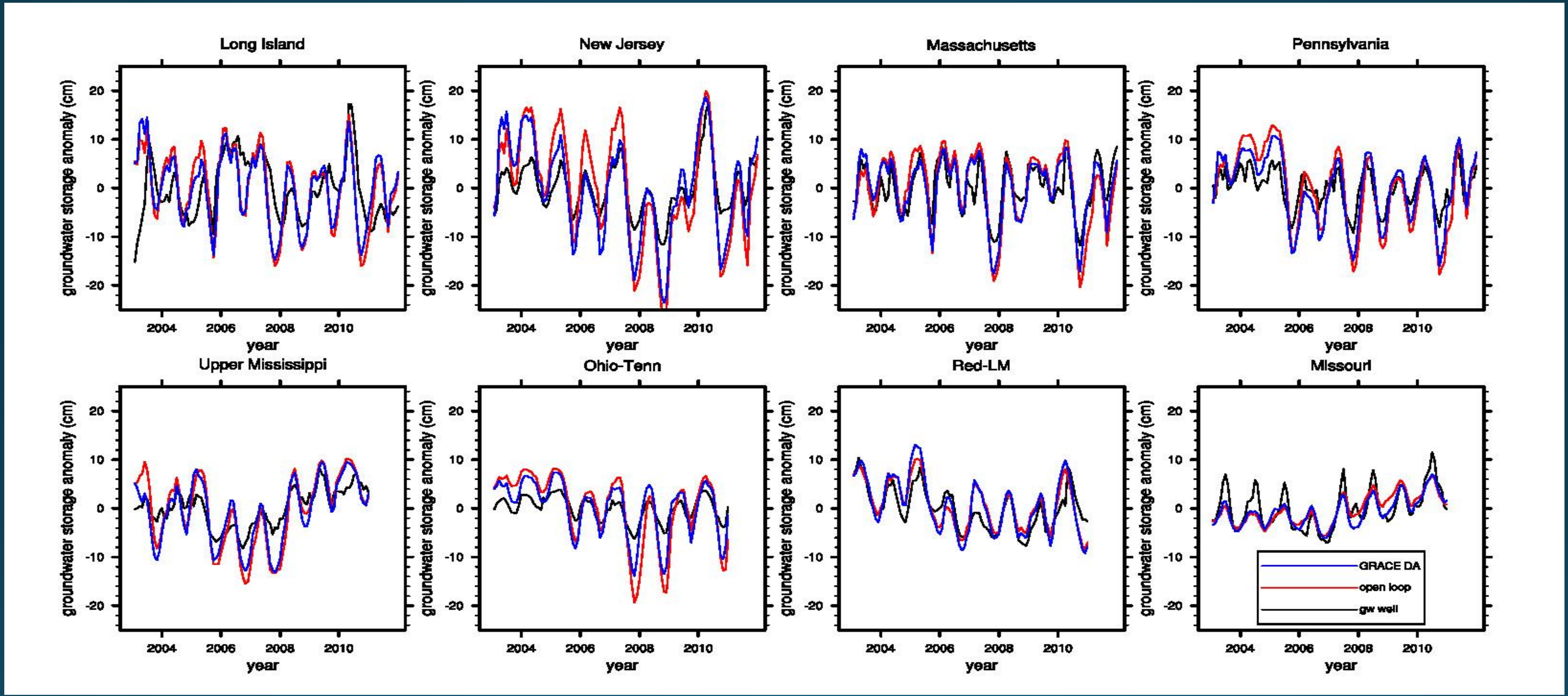
In situ CLSM Princeton

Correlation between groundwater estimates driven by Princeton and in situ groundwater



GWI: standardized groundwater storage anomalies (seasonal mean removed)
SPI: standardized precipitation index

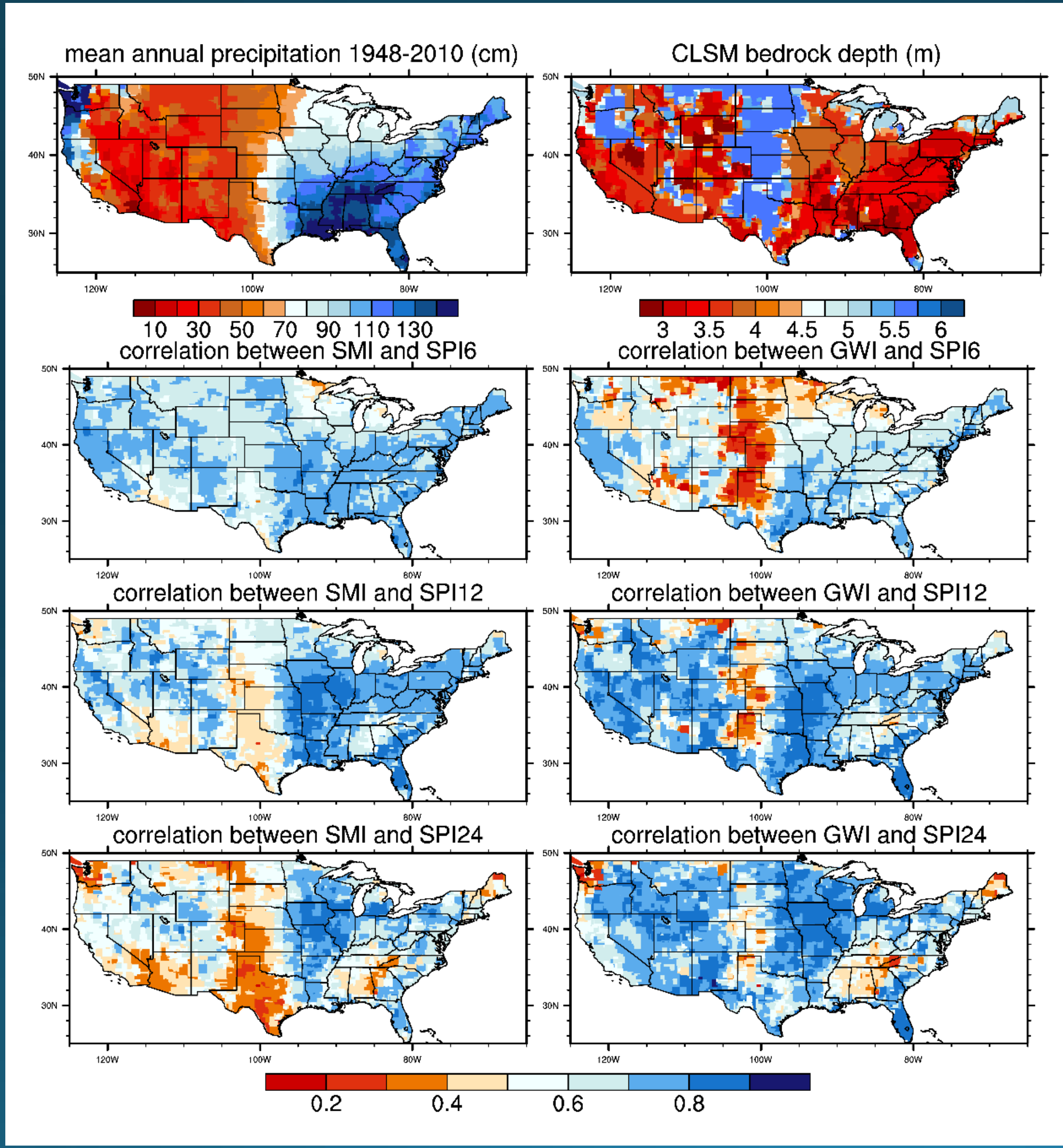
GRACE data assimilation reduced RMSE and improved correlation between CLSM and in situ groundwater



Regional average of groundwater storage anomalies (relative to temporal mean) from in situ data and model simulations

Correlations of GWI and SMI with SPIs (based on estimates from 1948-2012)

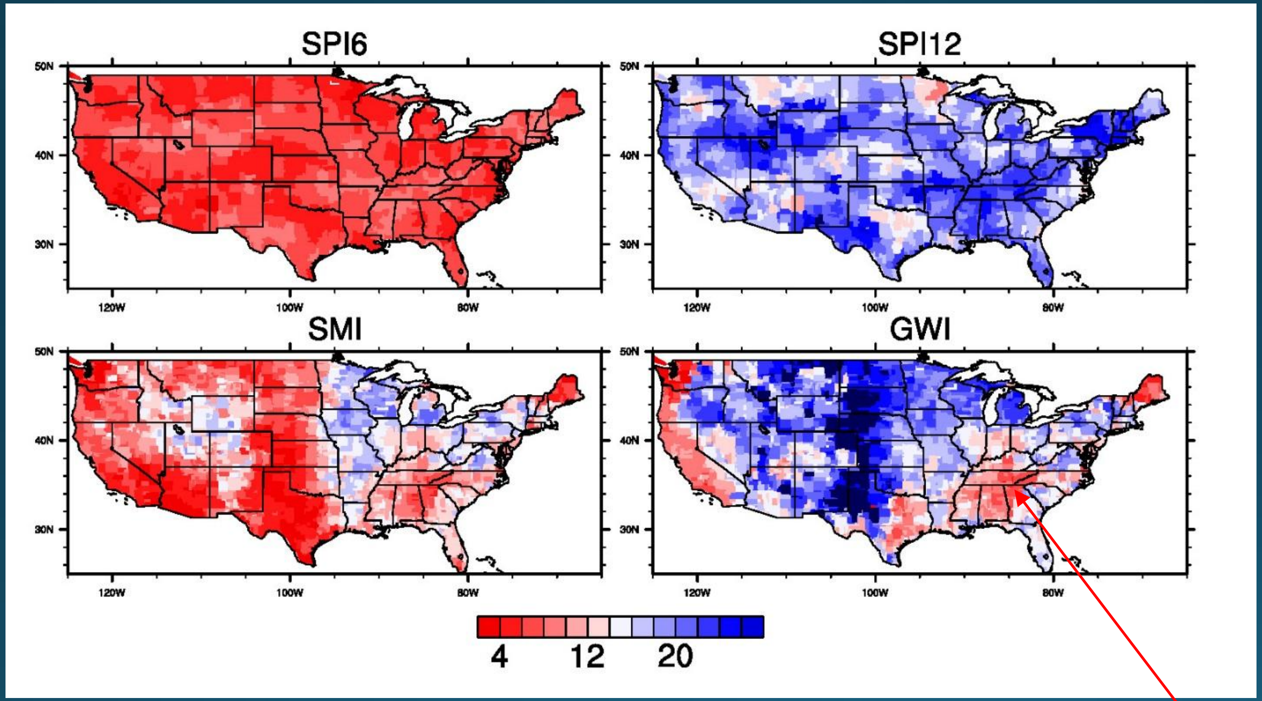
SMI: standardized root zone soil moisture anomalies (relative to seasonal mean)
GWI: standardized groundwater storage anomalies (relative to seasonal mean)



1. Groundwater correlates more strongly with longer scale SPIs
2. Bedrock depths have a significant impact on temporal variability of groundwater and soil moisture

Groundwater drought is a different type of drought

Persistence (weighted sum of autocorrelation)



- Groundwater shows longer persistence
- may be strongly impacted by model parameters
- SMI shows longer persistence in the eastern US than in the west

Shorter persistence due to stronger short-scale precipitation variability

Conclusions

1. Groundwater drought has unique temporal variability
   - Influences of climate conditions and model physics
   - groundwater drought indices are realistic at regional scales
2. GRACE TWS provides useful information for improving model estimates
   - GRACE data assimilation enables downscaling (including vertical dis-aggregation) and near real time drought monitoring
   - Improvements for the model and assimilation method are still needed
3. Model evaluation using in situ data is important
   - Limitation of GRACE and data assimilation techniques
   - using other types of in situ observations (streamflow and soil moisture)

References

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