

A global gridded dataset of GRACE drought severity index (GRACE-DSI)

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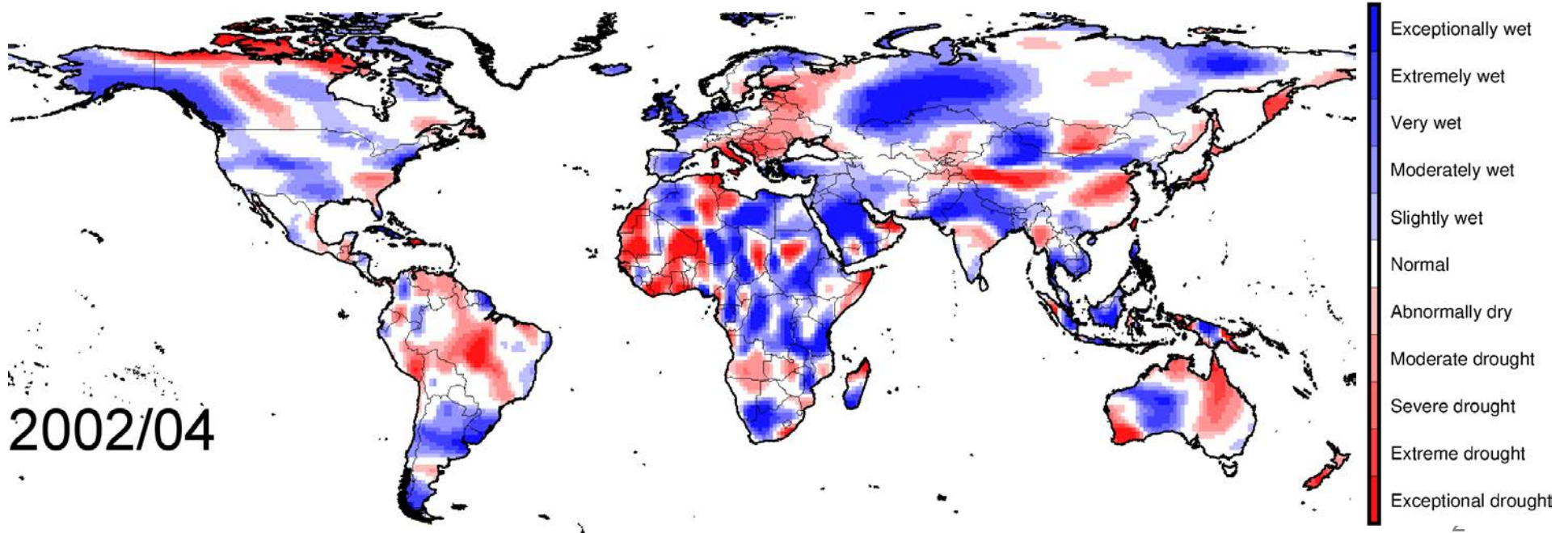
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University of Montana, Missoula, Montana



Definition: $\text{GRACE-DSI}_{ij} = \frac{\text{TWS}_{ij} - \overline{\text{TWS}}_j}{\sigma_j}$

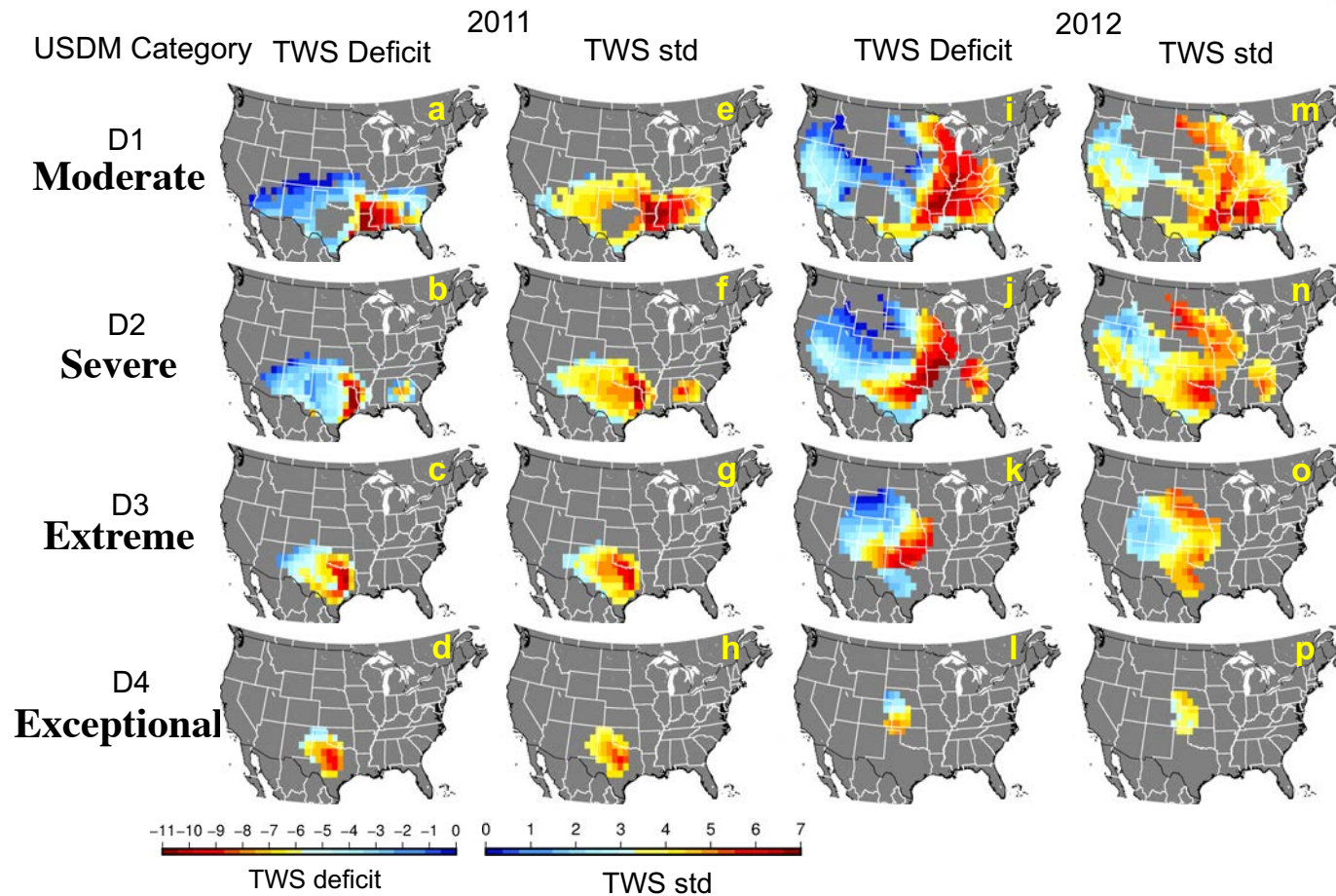
i is year, j is month, TWS_{ij} and σ_j are monthly mean and standard deviation of TWS for month j , respectively.

W4	Exceptionally wet	2.0 or greater	D0	Abnormally dry	−0.50 to −0.79
W3	Extremely wet	1.60 to 1.99	D1	Moderate drought	−0.80 to −1.29
W2	Very wet	1.30 to 1.59	D2	Severe drought	−1.30 to −1.59
W1	Moderately wet	0.80 to 1.29	D3	Extreme drought	−1.60 to −1.99
W0	Slightly wet	0.50 to 0.79	D4	Exceptional drought	−2.0 or less
WD	Near normal	0.49 to −0.49			



Rationale of Standardization

$$\text{GRACE-DSI}_{ij} = \frac{\text{TWS}_{ij} - \overline{\text{TWS}}_j}{\sigma_j}$$



Zhao, M., G. A. I. Velicogna, and J.S. Kimball, 2017. *J. Climate*, **30**, 6297–6308, <https://doi.org/10.1175/JCLI-D-16-0458.1>

What's new to hydrology community?

❑ Standardized index for hydrological drought

- Across space and time comparison

❑ A framework for synergistic use with popular drought indices

- Palmer drought severity index (PDSI, Palmer 1965)
- Standardized precipitation and evapotranspiration index (SPEI, Vicente-Serrano et al. 2010)

❑ Eco-hydrological application

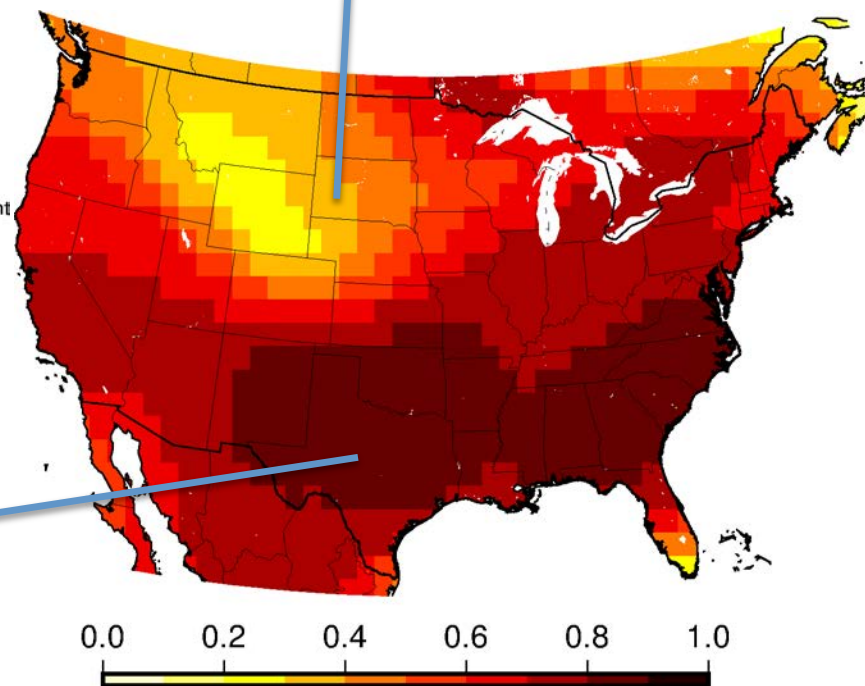
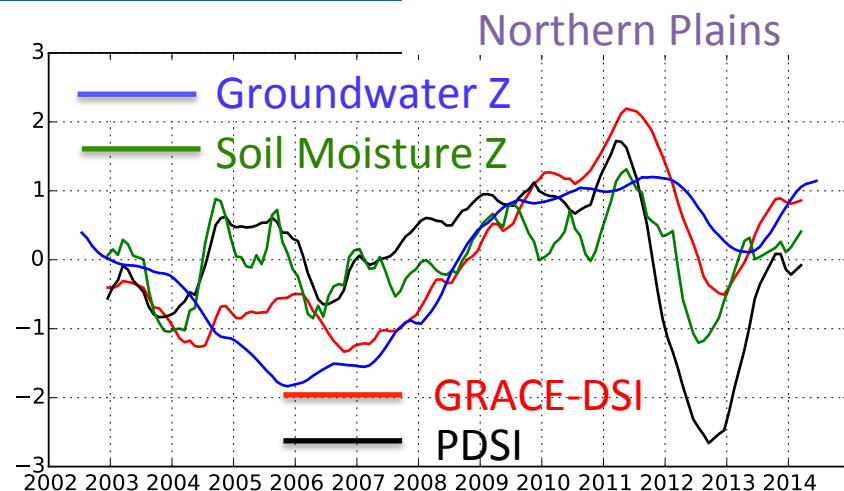
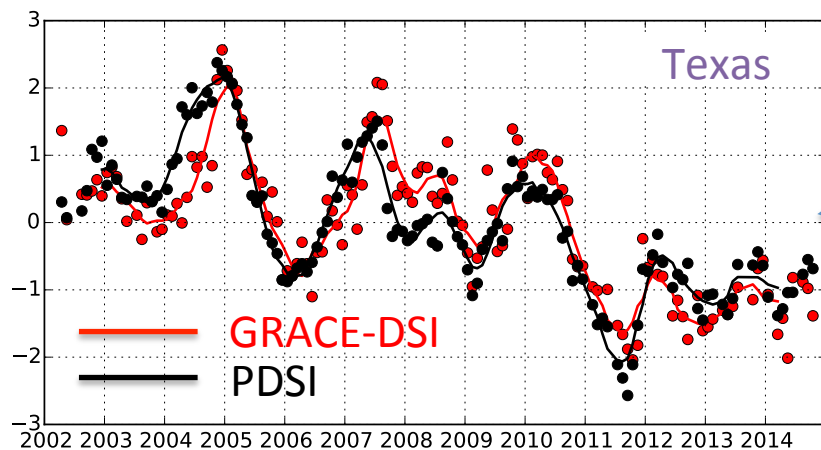
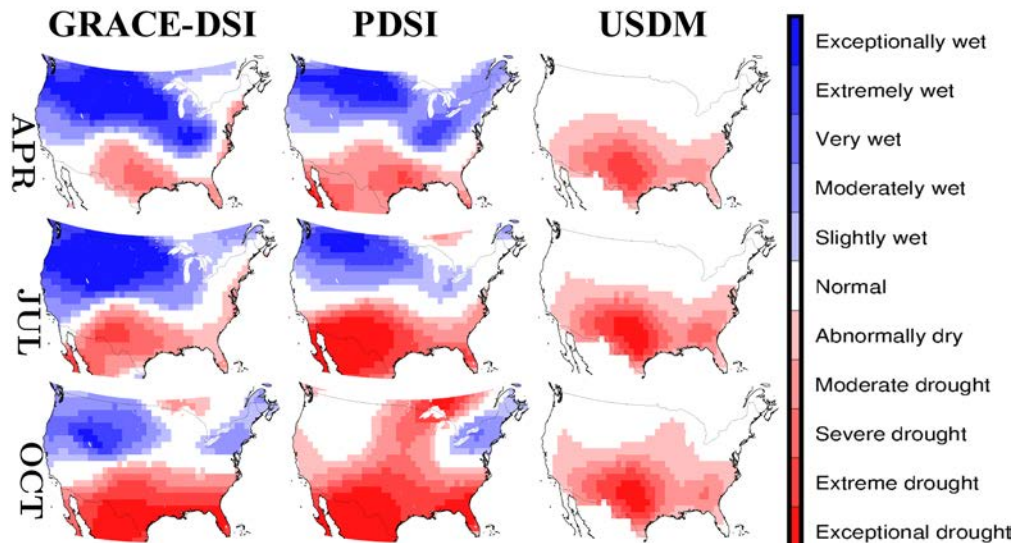
- Microwave surface soil moisture data (AMSR-E, AMSR2, SMAP)
- MODIS Normalized Difference Vegetation Index (NDVI)

❑ Two versions of GRACE-DSI with well-characterized uncertainty

- Spherical harmonics
- JPL mascons

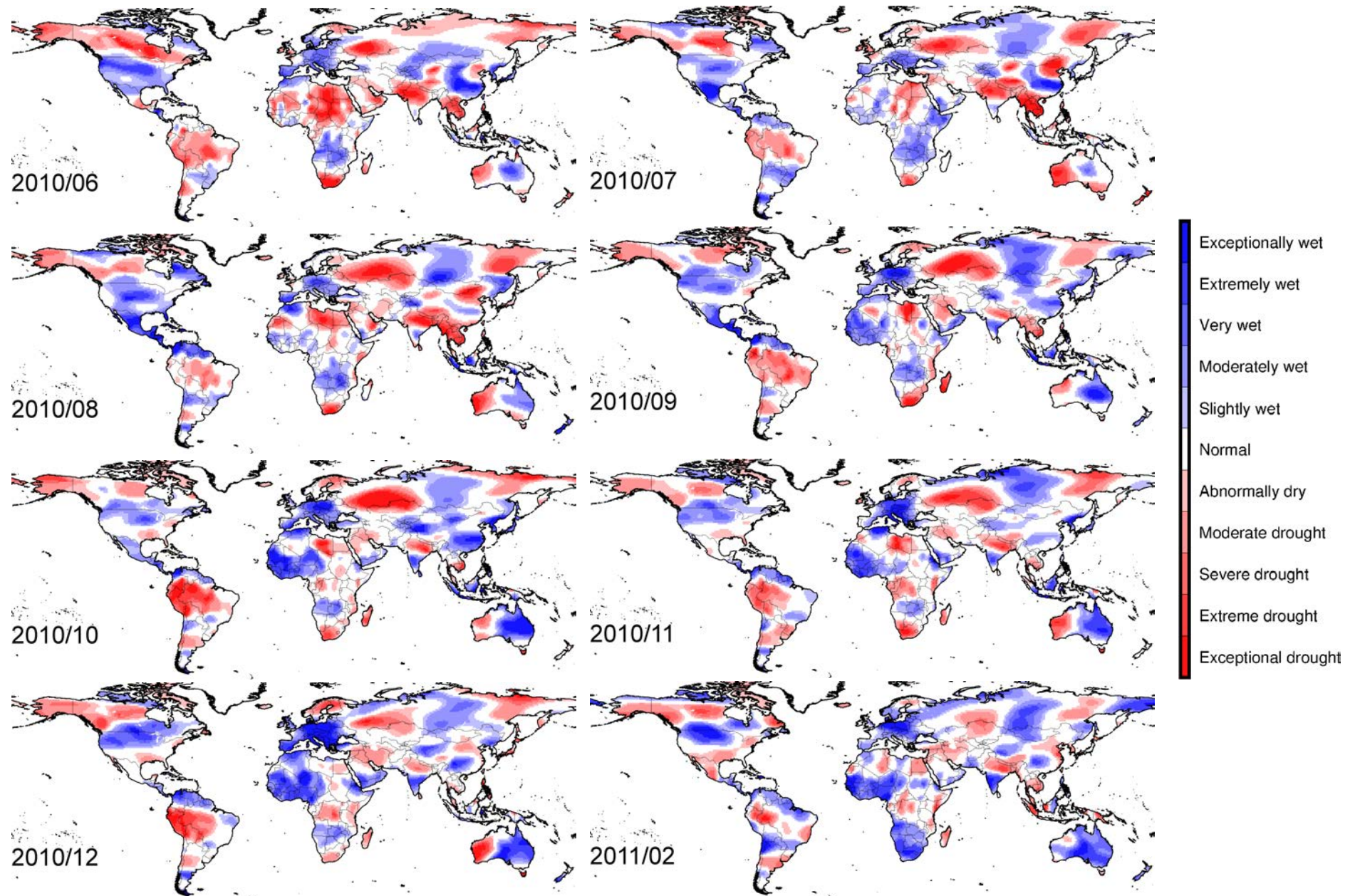
GRACE-DSI in CONUS

Drought Evolution in 2011

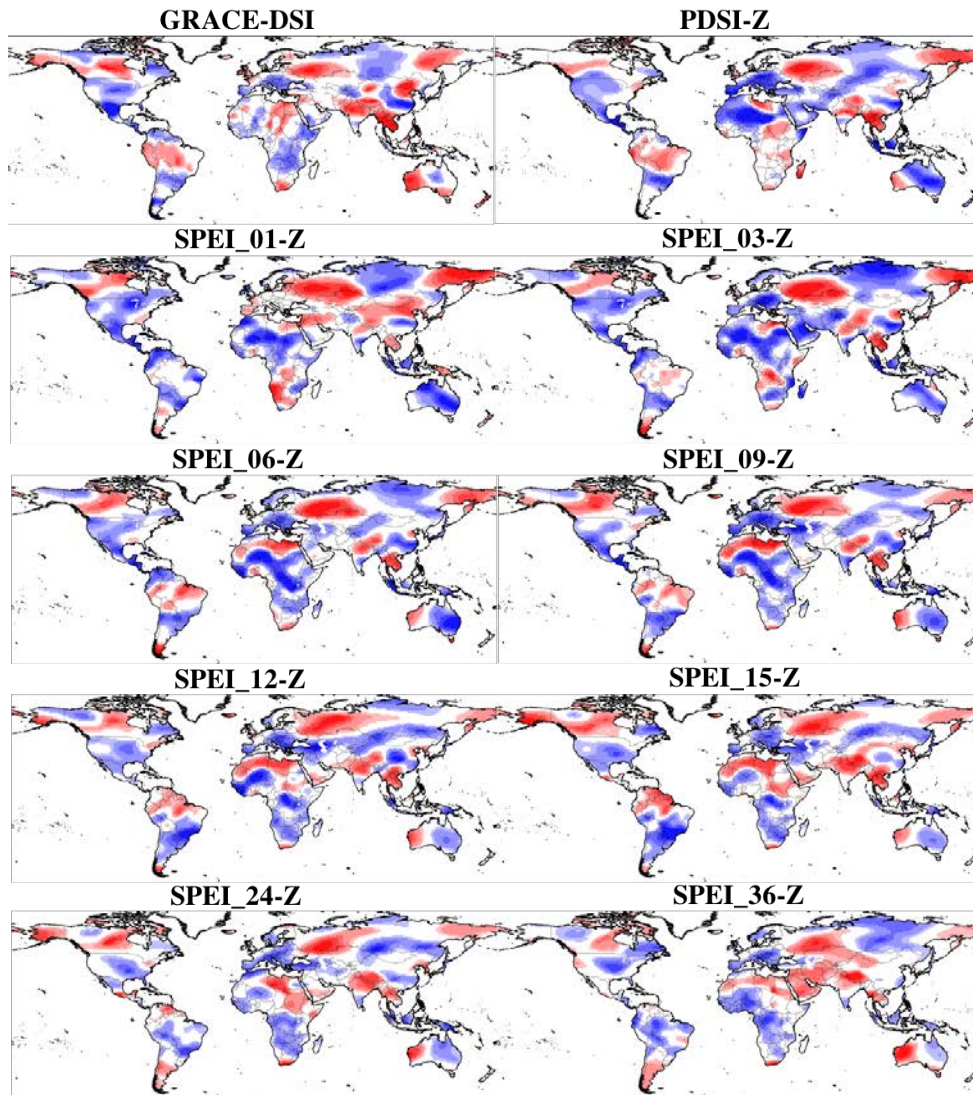


Monthly Correlation of GRACE-DSI and PDSI

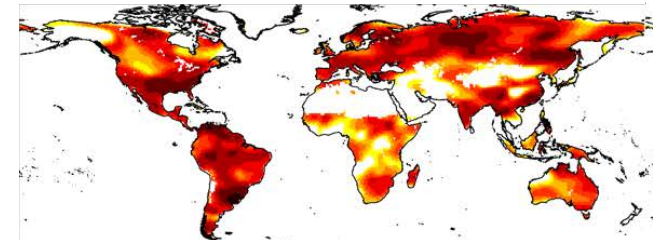
GRACE-DSI for global extreme events in 2010/11



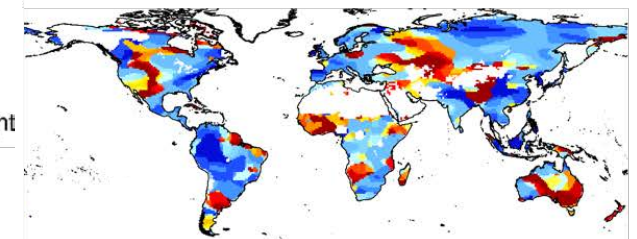
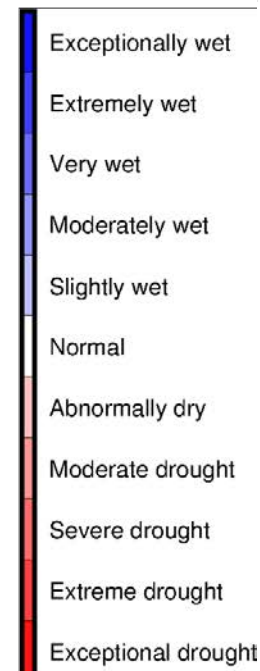
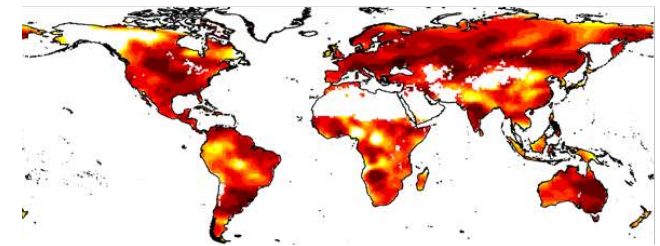
Global patterns of the GRACE-DSI, PDSI, and SPEI drought metrics at selected time scales for July 2010



GRACE-DSI & PDSI Correlation



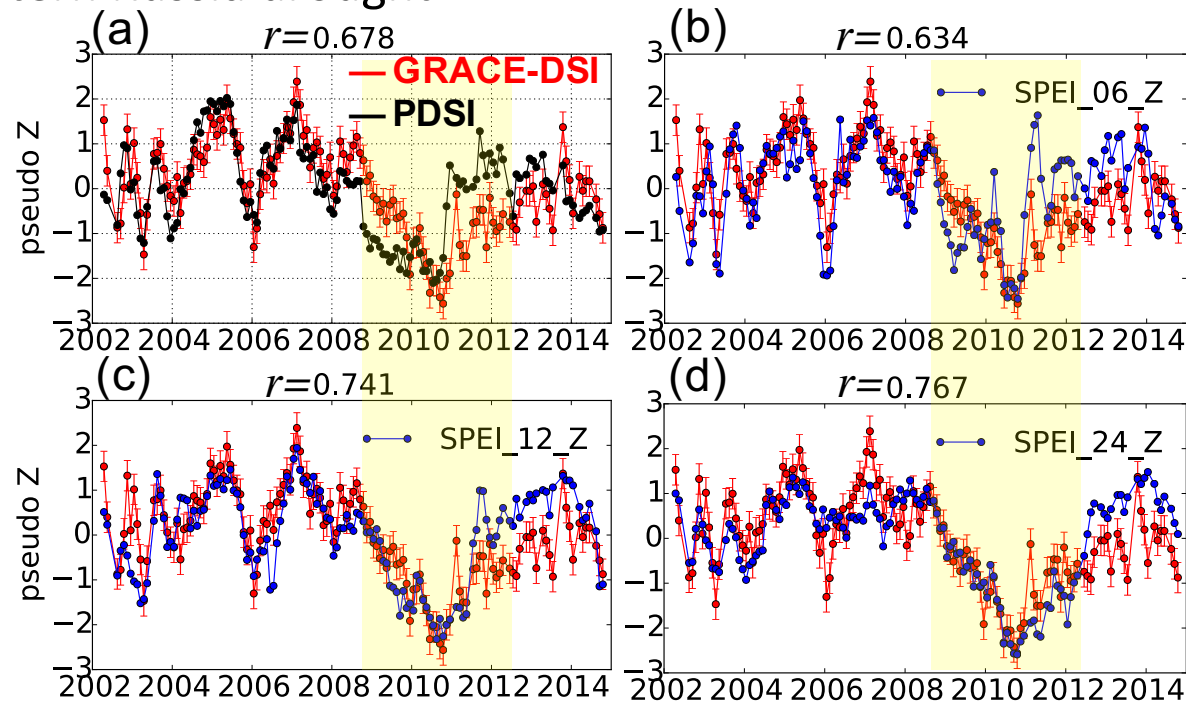
GRACE-DSI & SPEI Max Correlation



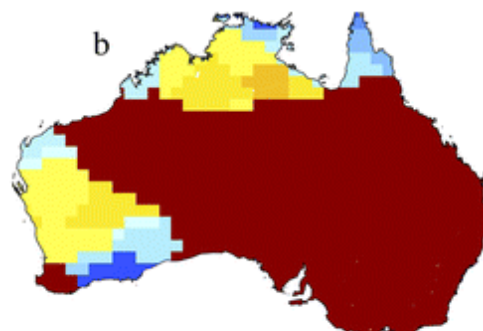
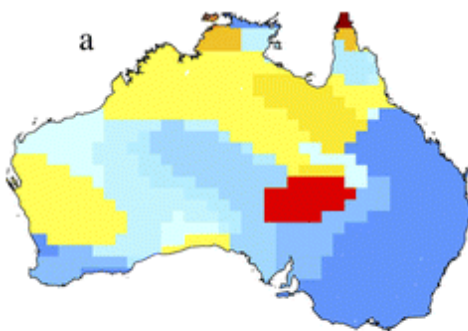
Synergy with popular drought indices

Zhao et al. (2017). *J. Hydrometeorol.*

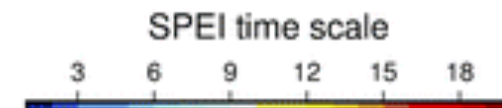
- Hydrological drought characterization framework
 - 2010 Western Russia drought



- The time-scales of the maximum correlation between GRACE-DSI and SPEI



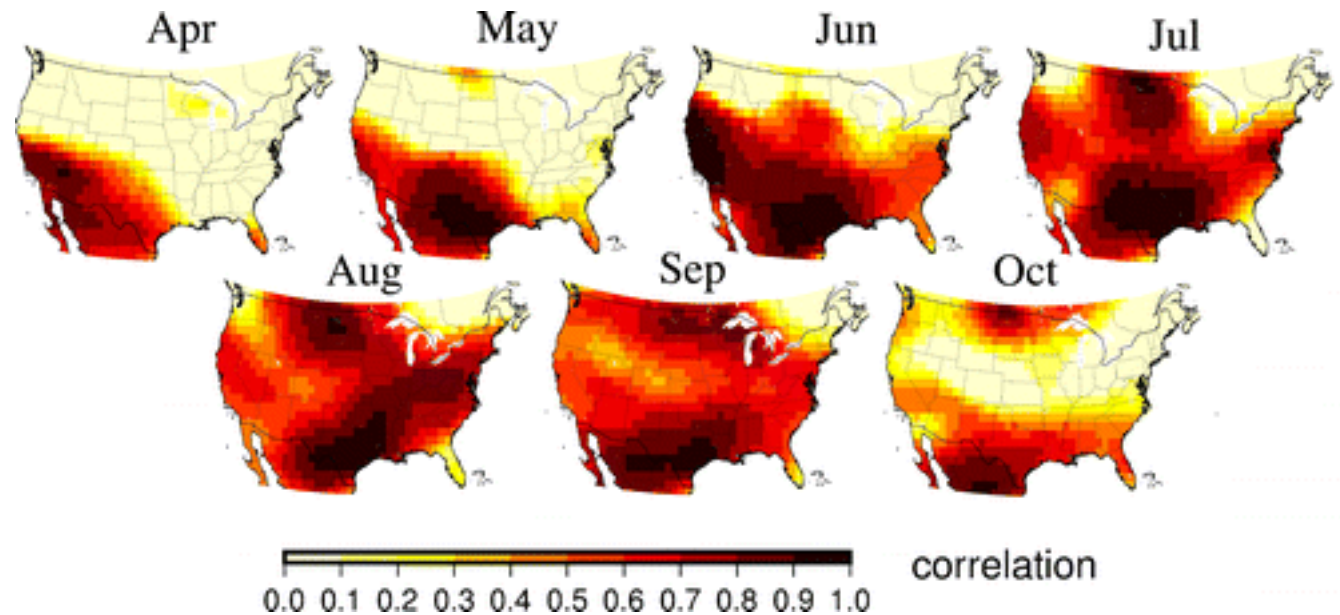
a) NDVI and SPEI
b) GRACE-DSI and SPEI



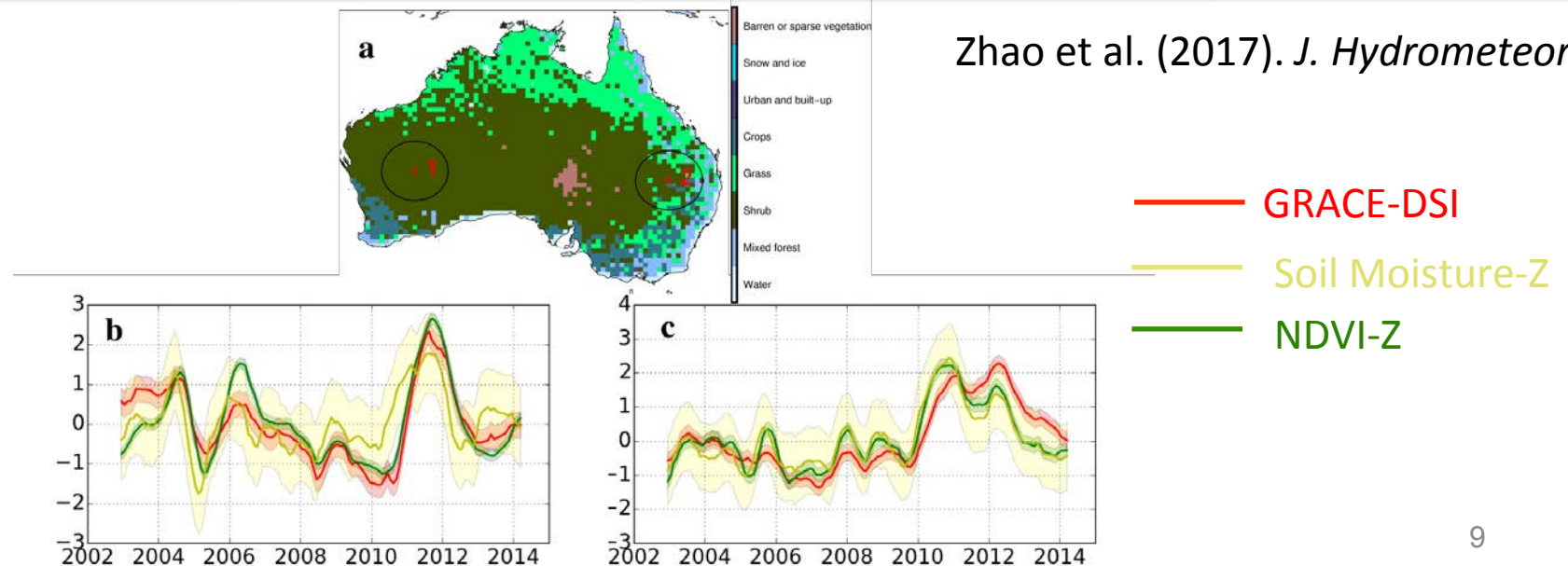
Eco-hydrological Applications

Zhao et al. (2017). *J. Climate*

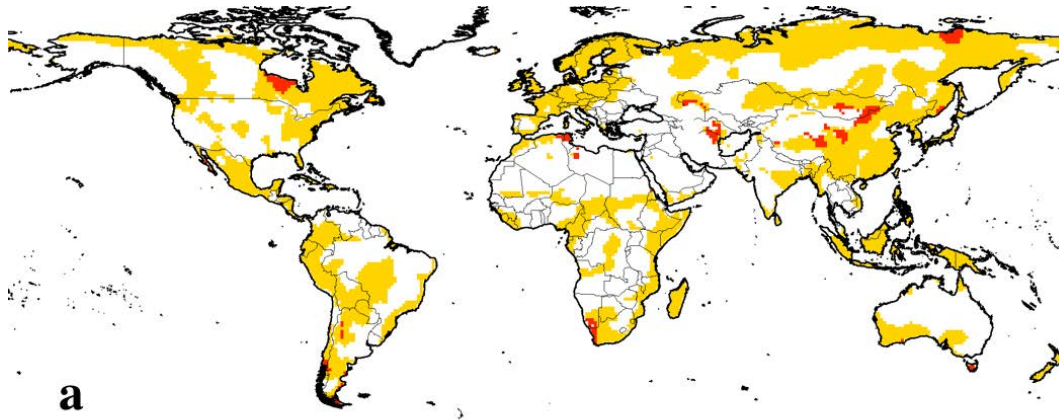
Inter-annual
correlation
coefficient between
GRACE-DSI and
MODIS NDVI by
month



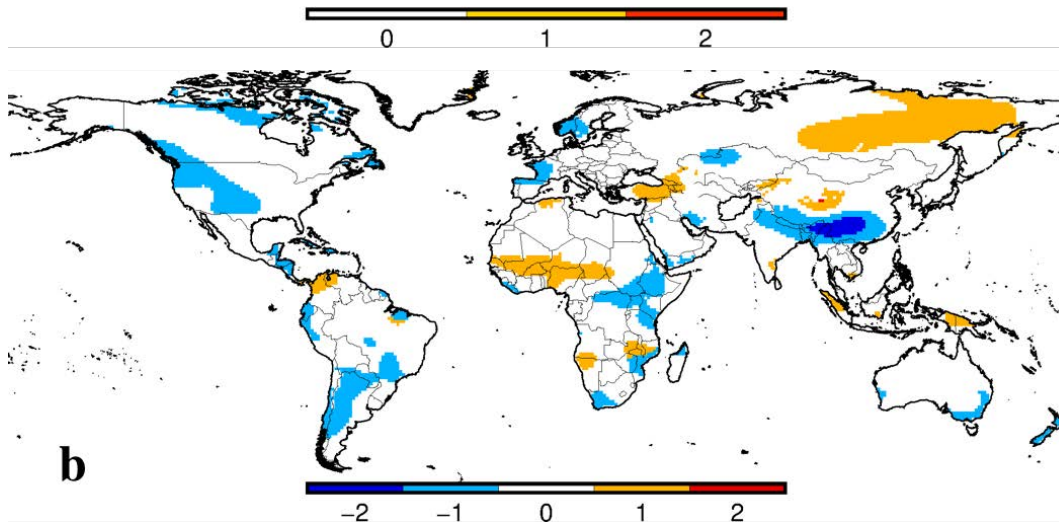
Zhao et al. (2017). *J. Hydrometeorol.*



GRACE-DSI Uncertainty



(a) Global distribution of GRACE-DSI uncertainty in drought category due to GRACE measurement and leakage errors.

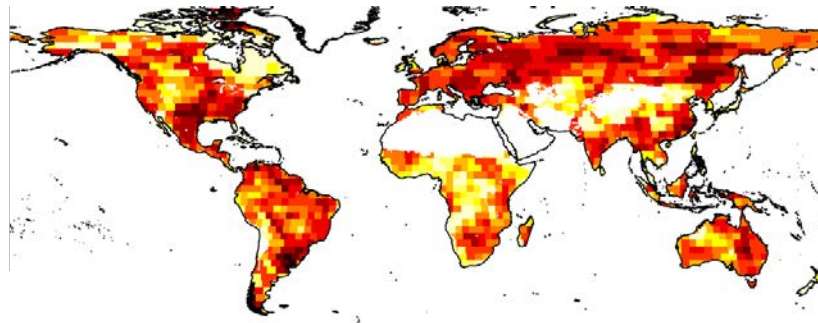


(b) Drought category overestimation (positive value) and underestimation (negative value) using the 2002-14 reference period rather than the 1982-2014 reference period using the PDSI index.

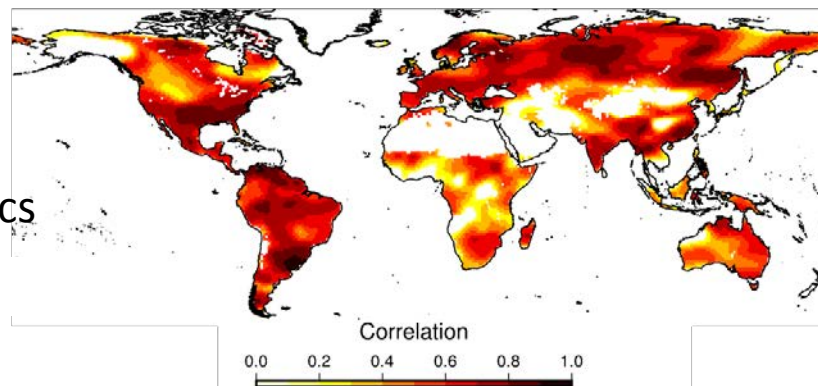
GRACE-DSI calculated from JPL mascon solutions

correlation between GRACE-DSI and PDSI

mascon

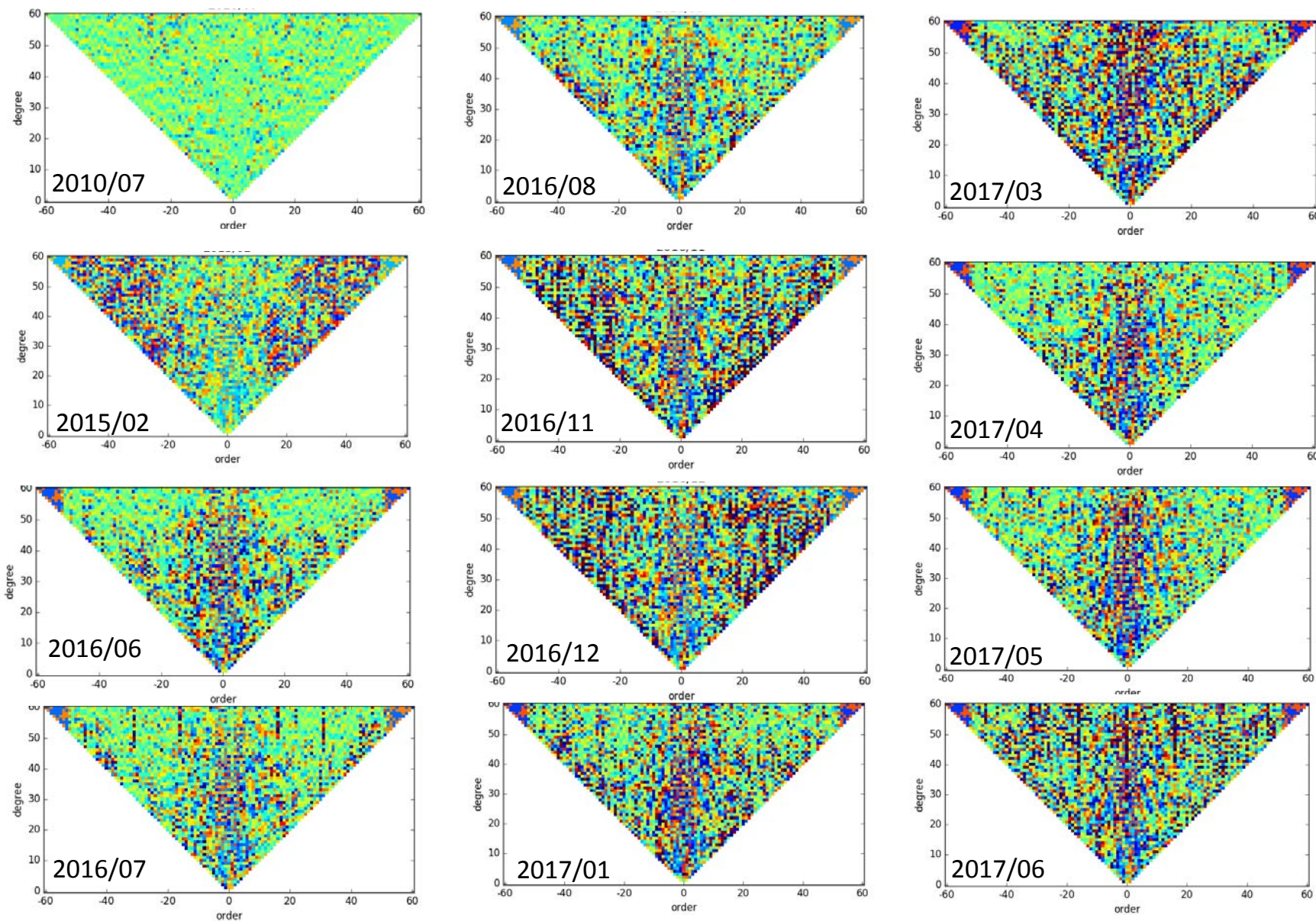
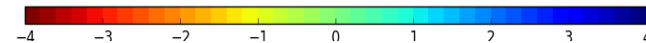


spherical harmonics



The impact of increasing GRACE data noise

Stokes DSI



Summary

- ❑ **A standardized drought index with well-defined uncertainty**
- ❑ **Synergy with popular drought indices**
 - drought onset, propagation, and recovery.
 - the time-scale SPEI agrees with GRACE-DSI infers the relative depth of the water component that dominates a drought.
- ❑ **Plant-water relations**
 - forests, shrublands
- ❑ **The DSI approach is another way to look at errors in GRACE solutions.**

References

- Palmer, W. C., 1965: Meteorological drought. U.S. Weather Bureau Rep., 65 pp.
- Dai, A., 2011: Characteristics and trends in various forms of the Palmer Drought Severity Index during 1900–2008. *J. Geophys. Res.*, 116, D12115, doi:10.1029/2010JD015541.
- Vicente-Serrano, S. M., S. Begueía, and J. I. López-Moreno, 2010a: A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. *J. Climate*, 23, 1696–1718, doi: 10.1175/2009JCLI2909.1.
- Zhao, M., G. A. I. Velicogna, and J.S. Kimball, 2017: Satellite Observations of Regional Drought Severity in the Continental United States Using GRACE-Based Terrestrial Water Storage Changes. *J. Climate*, **30**, 6297–6308, <https://doi.org/10.1175/JCLI-D-16-0458.1>
- Zhao, M., G. A. I. Velicogna, and J.S. Kimball, 2017: A Global Gridded Dataset of GRACE Drought Severity Index for 2002–14: Comparison with PDSI and SPEI and a Case Study of the Australia Millennium Drought. *J. Hydrometeor.*, 18, 2117–2129, <https://doi.org/10.1175/JHM-D-16-0182.1>