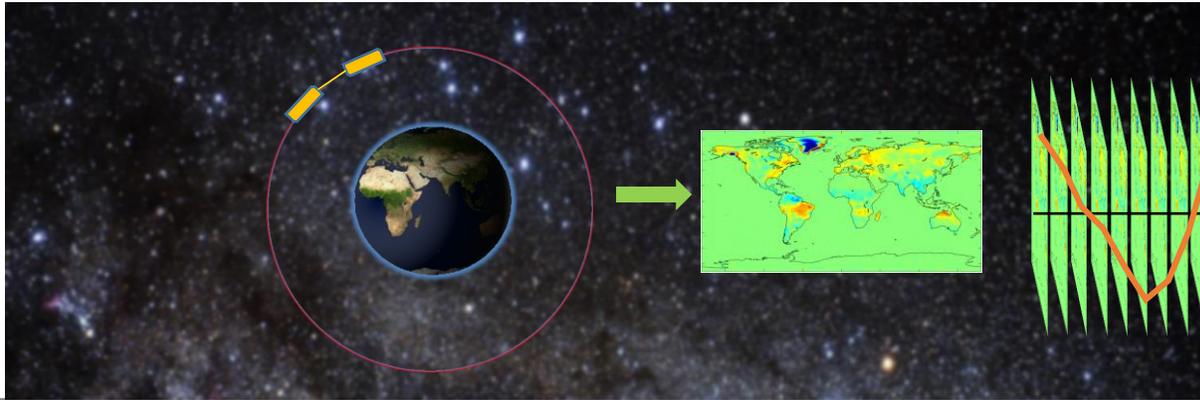


Evaluating linear trends with respect to past decadal variability can help us assess the severity of GRACE observed water storage change

J. L. Bamber, B. D. Vishwakarma, P. Bates, N. Sneeuw, and R. M. Westaway

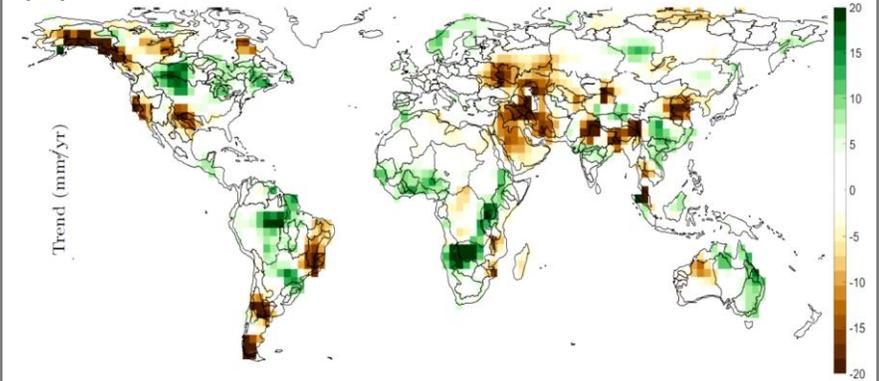
(a)

GRACE satellite mission



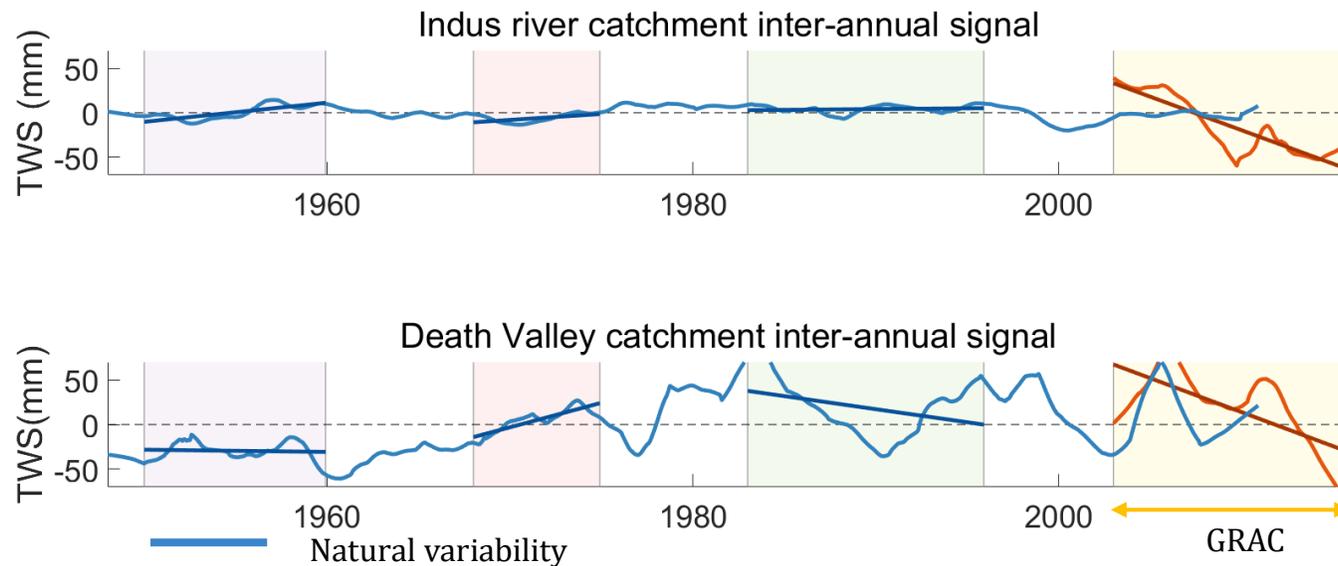
(b)

Trends from GRACE time series



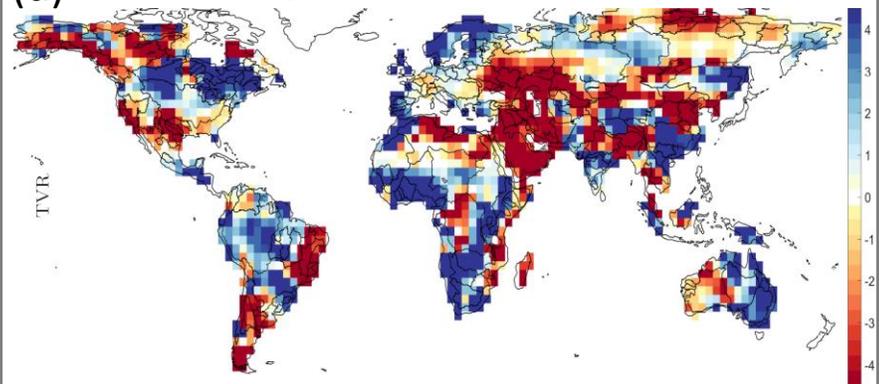
(c)

Same trend different meaning!



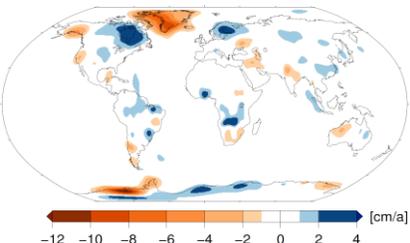
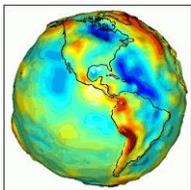
(d)

Including past variability helps



- A new metric to determine when a trend means exceptional change!
- >3.5 billion people in regions that experienced exceptional water loss between 2003—2015.

Evaluating linear trends with respect to past decadal variability can help us assess the severity of GRACE observed water storage change

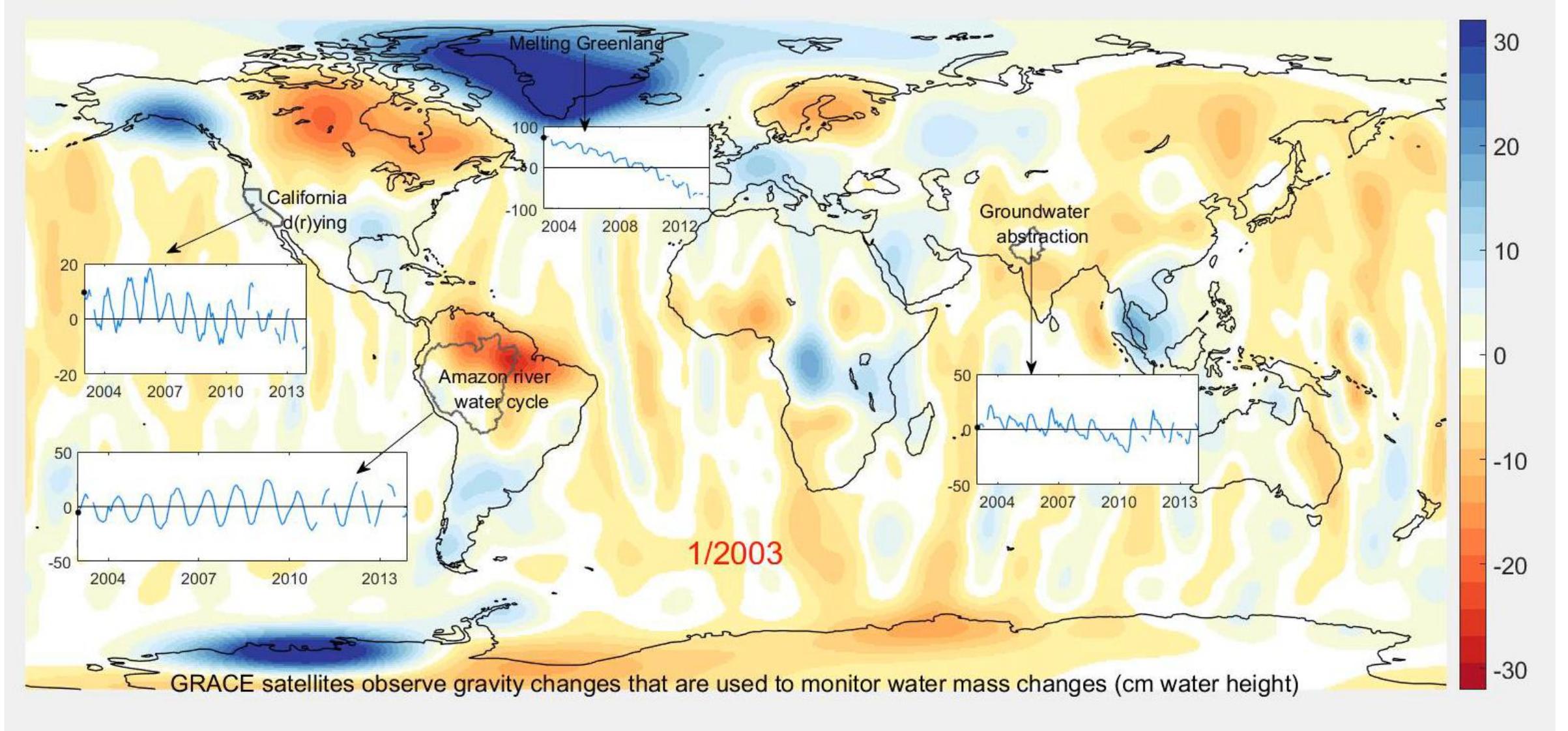


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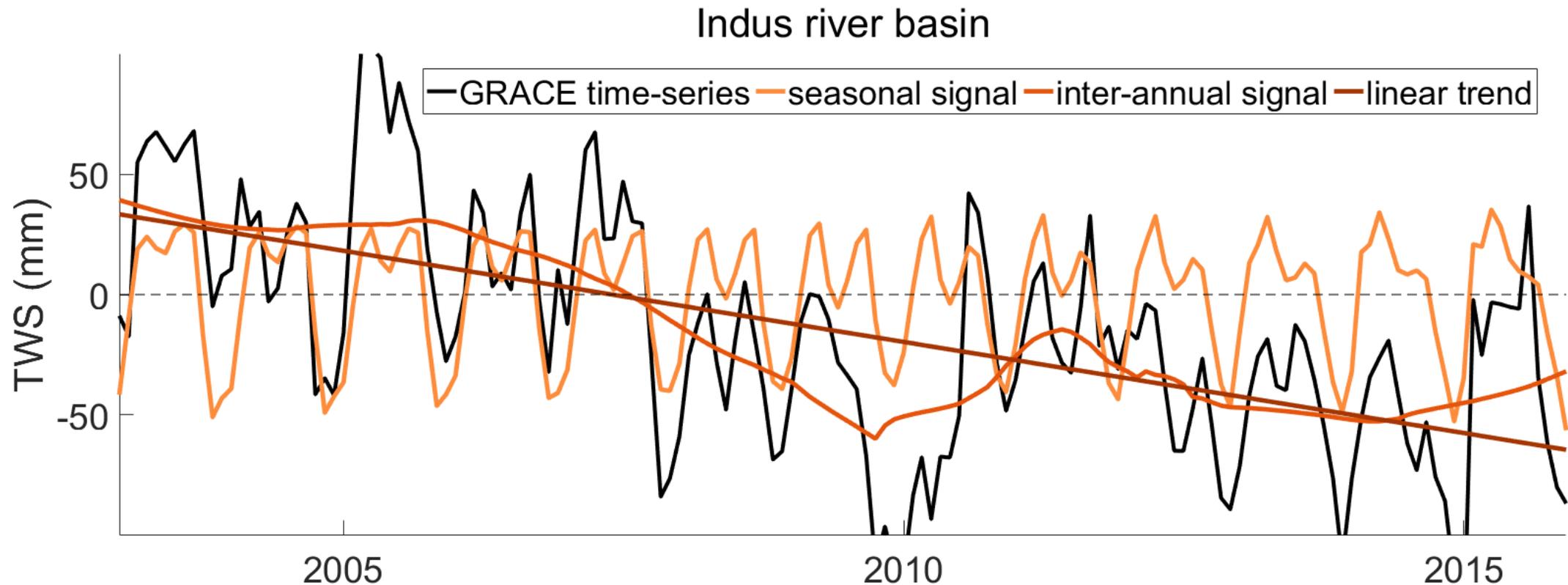
²Institute of Geodesy, University of Stuttgart





GRACE can see spatiotemporal water mass redistribution

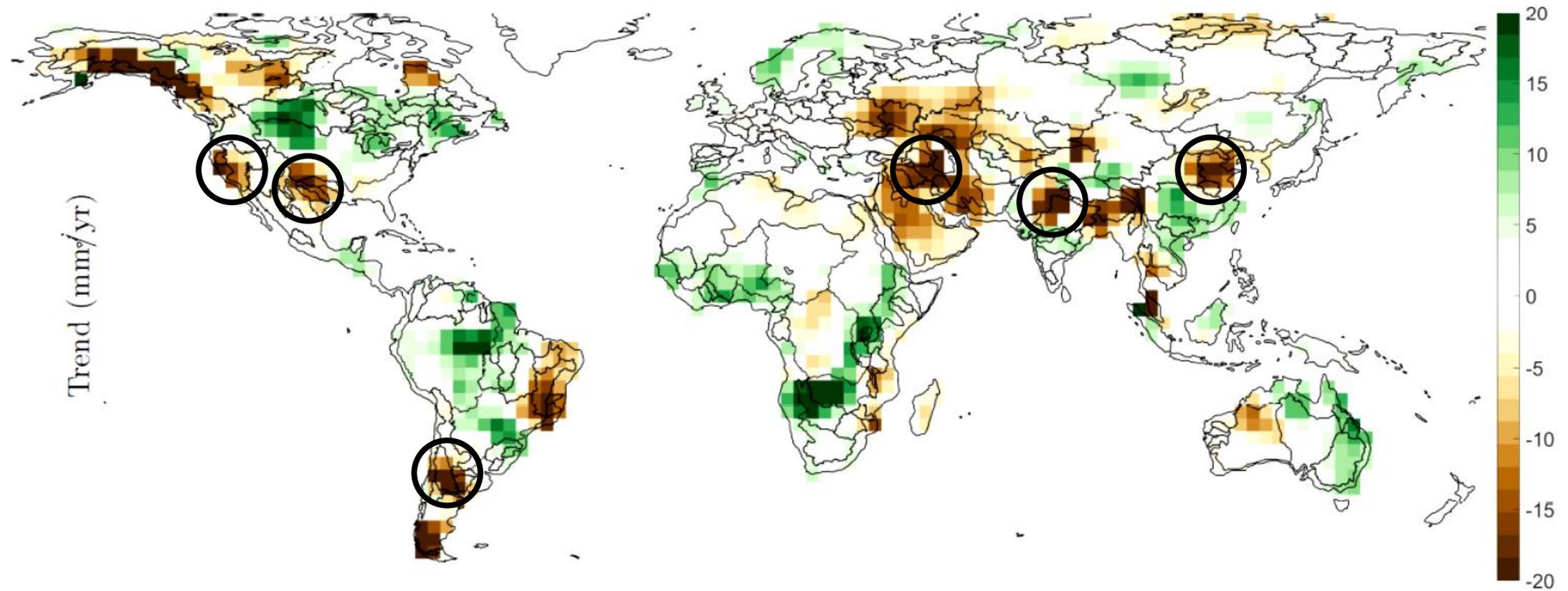
Decomposing GRACE time-series



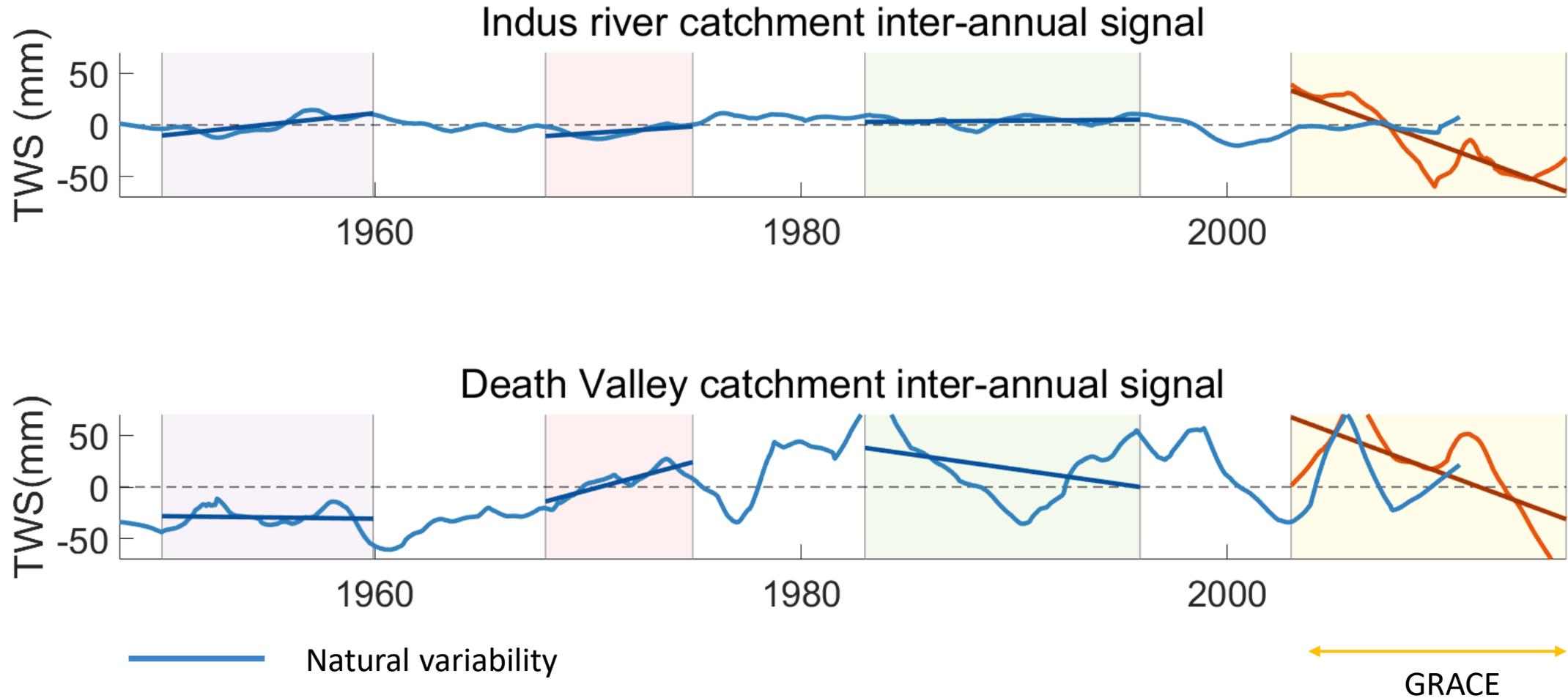
The TWS (total water storage) time series from GRACE can be decomposed into linear and seasonal components

Interpreting GRACE trends:

- Negative trend: water loss → water-stress
- Default approach: the severity of TWS change is assumed to be proportional to the magnitude of trend and we can rank regions based on trend values



Interpreting GRACE trends



Same trend observed in the GRACE data for these two catchments, but when compared to past natural variability from a land surface model, we find that TWS trend for Indus is more severe!

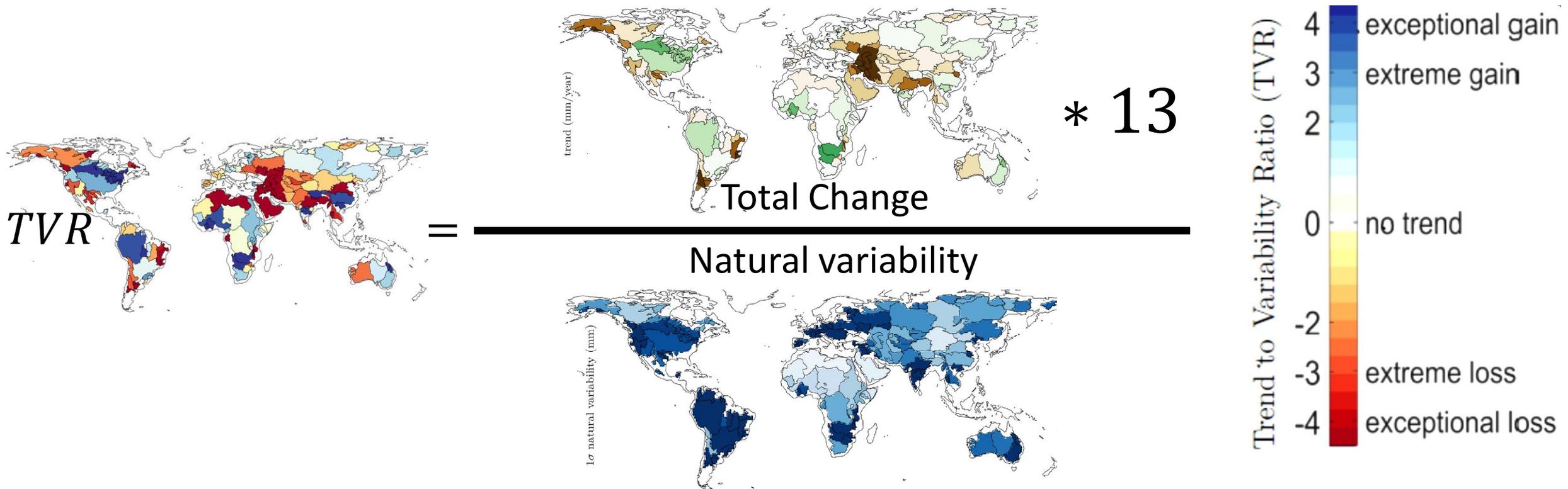
Challenges!

- GRACE time series length is less than two decades: not long enough to capture climatology!
- Every catchment has a distinct spatio-temporal hydrological variability: using trend magnitude to compare catchments is not justified.
- How can we infer severity of trends?

Using model based multi-decadal TWS time-series to represent natural variability may help!

TVR: trend to variability ratio, a new metric to assess severity of trends

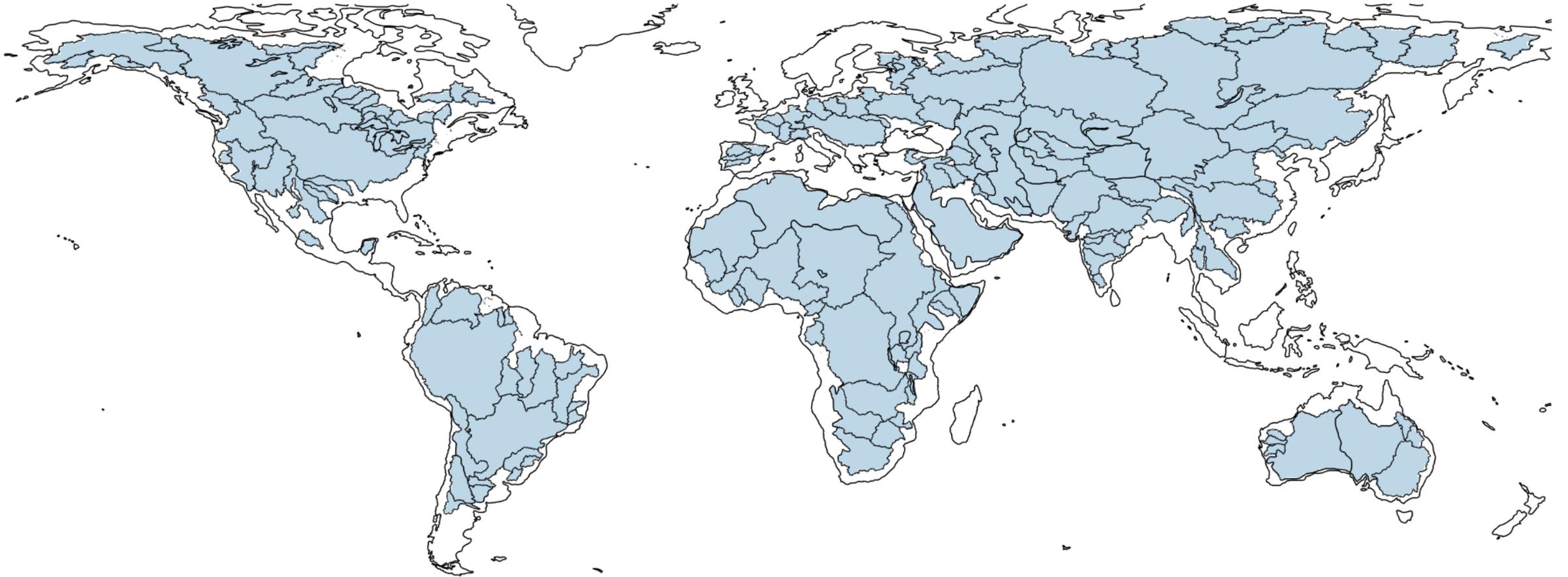
- $TVR = \frac{(t * n)}{\sigma}$, t : trend, n : number of years, σ : std. dev. of natural variability



Estimating natural variability

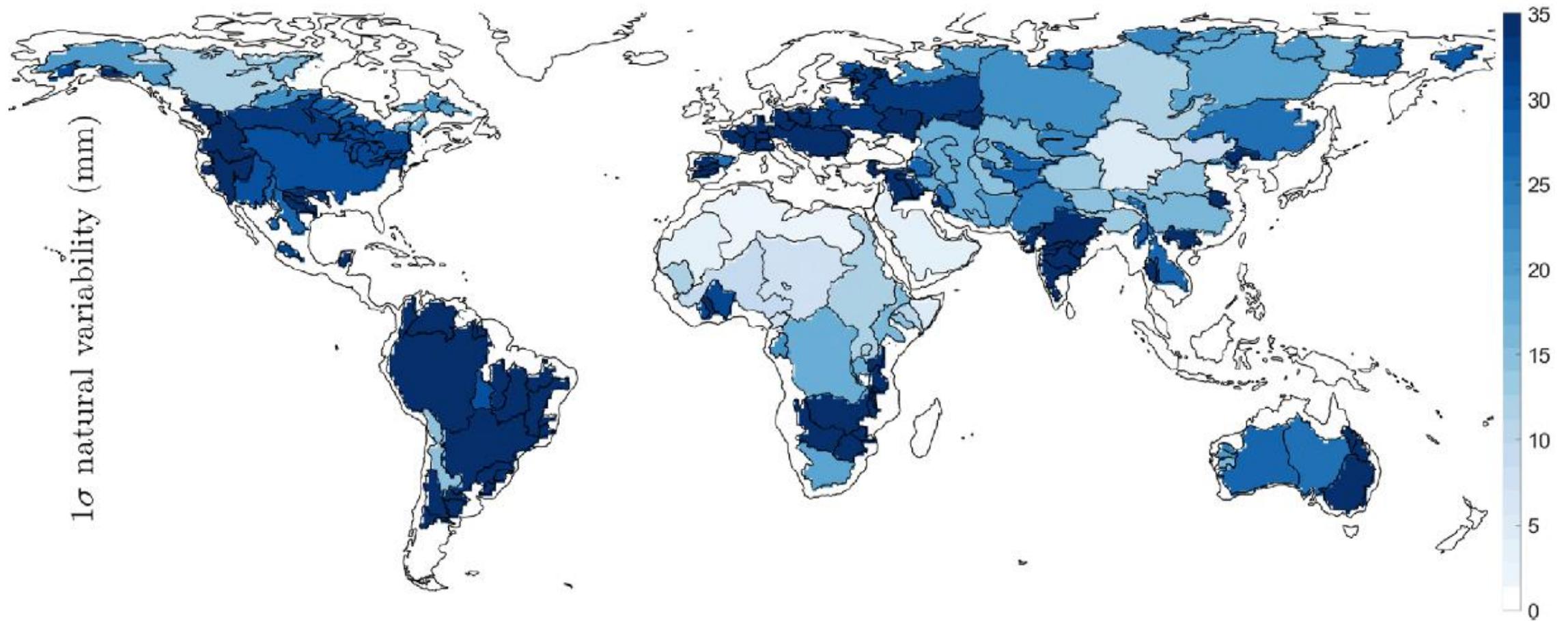
- Use GRACE-REC time series from Humphrey et al. 2019
- Statistical relation between detrended TWS, Precipitation and Temperature
- Long time-series of climate driven interannual variability in TWS (1901—2010)
- Mean of 600 ensemble members from GRACE-REC (1979 to 2019)
- Standard deviation of the mean time-series = natural variability

In this study: 160 catchments

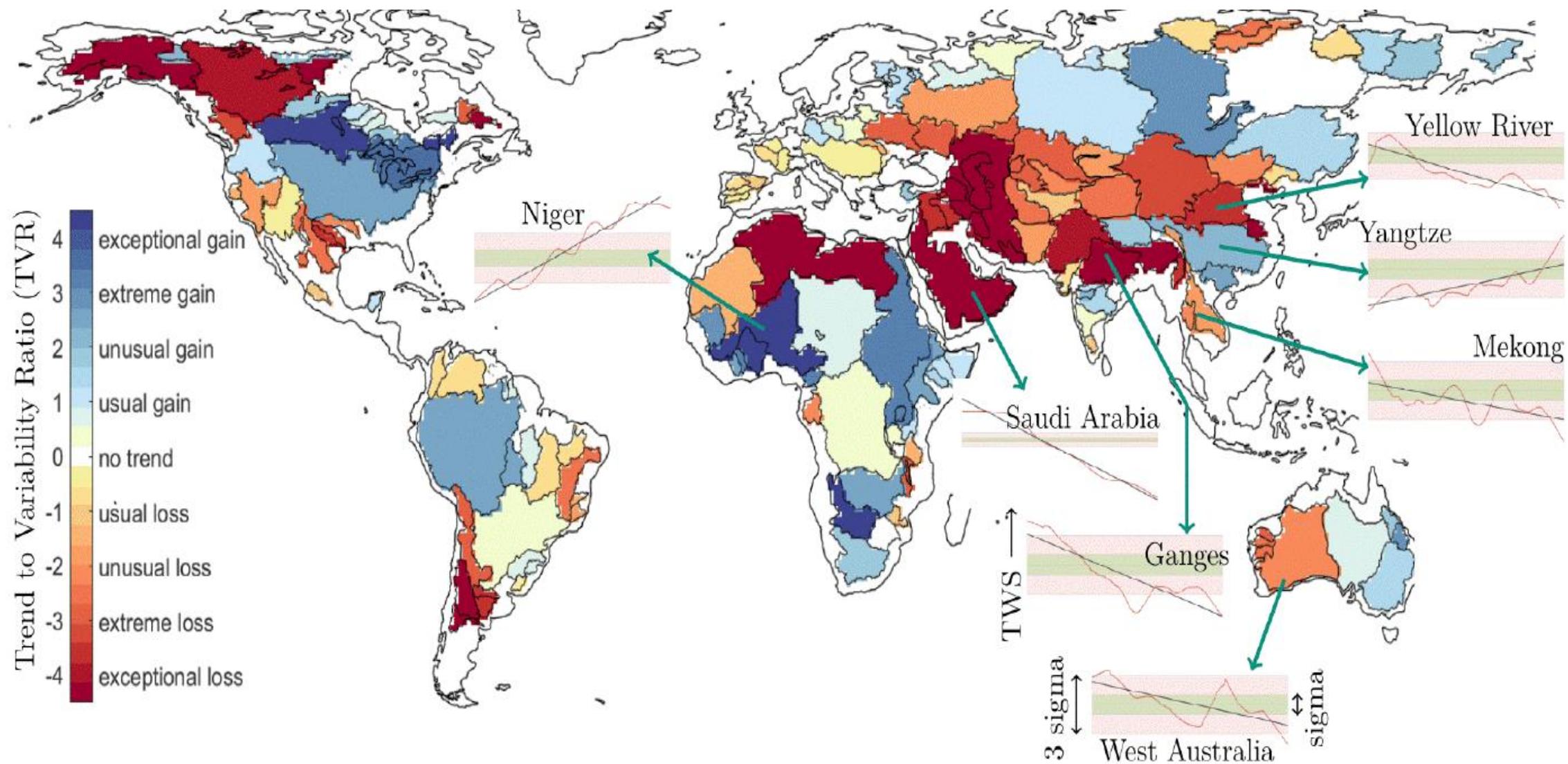


Minimum catchment size: 68 000 sq. km

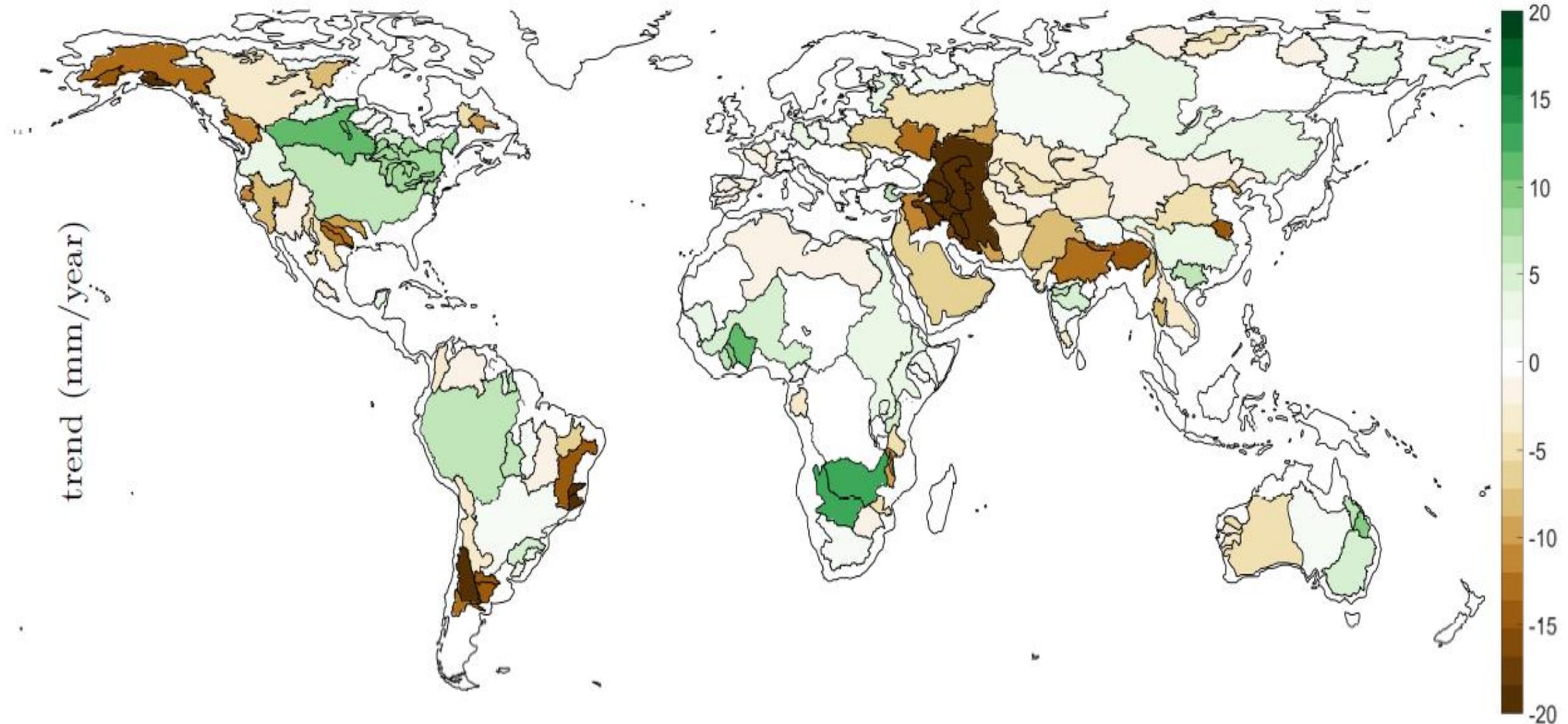
Standard deviation of natural variability from GRACE-REC



TVR



Trend map from GRACE (2003 – 2015)



* Caveats

- TVR sensitive to estimates of natural variability, hence to TWS model
Switching from GRACE-REC to a different model would change the results. Hence users should choose a model they believe captures the natural variability very well. We have confidence in GRACE-REC.
- Length of time series for TWS model is crucial for meaningful interpretation
We have used 40 years long time-series because we believe that it is long enough to capture more than two decade-long natural cycles. If we choose a longer model time series, let's assume 100 years, then we are including longer wavelengths as well as extreme events that occur only a few times in a century. The TVR in this case will flag alarm if an extreme event occurred during GRACE time. We believe that using a 40 years time-series makes TVR based assessment an excellent tool for policy makers interested in 5 to 10 years of planning.

Conclusion

- GRACE provides a unique measurement: water mass change
- Using magnitude of GRACE trends to comment on severity of global water-storage change: misleading
- Developed a novel metric, TVR, to measure severity of water storage change
- Obtain a realistic interpretation of GRACE trends with respect to past 40 years of hydrological variability!
- TVR, can be used in other studies as well, sea level rise, global warming, ...

ENVIRONMENTAL RESEARCH
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**Abstract**

Monitoring changes in freshwater availability is critical for human society and sustainable economic development. To identify regions experiencing secular change in their water resources, many studies compute linear trends in the total water storage (TWS) anomaly derived from the Gravity Recovery and Climate Experiment (GRACE) mission data. Such analyses suggest that several major water systems are under stress (Rodell *et al* 2009 *Nature* **460** 999–1002; Long *et al* 2013 *Geophys. Res. Lett.* **40** 3395–401; Richey *et al* 2015 *Water Resour. Res.* **51** 5217–38; Voss *et al*

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Data:

- GRACE: ftp://ftp.tugraz.at/outgoing/ITSG/GRACE/ITSG-Grace2016/monthly/monthly_n90
- C_{20} and degree 1 spherical harmonic coefficients: grace.jpl.nasa.gov
- catchment boundaries: <http://www.bafg.de/GRDC/EN/02srvcs/22gslrs/221MRB/riverbasinsnode.html>,
- GIA ICE-6GD model: <http://www.atmosp.physics.utoronto.ca/~peltier/data.php>
- Humphrey et. al., 2019: <https://doi.org/10.6084/m9.figshare.7670849>

Thank you!

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