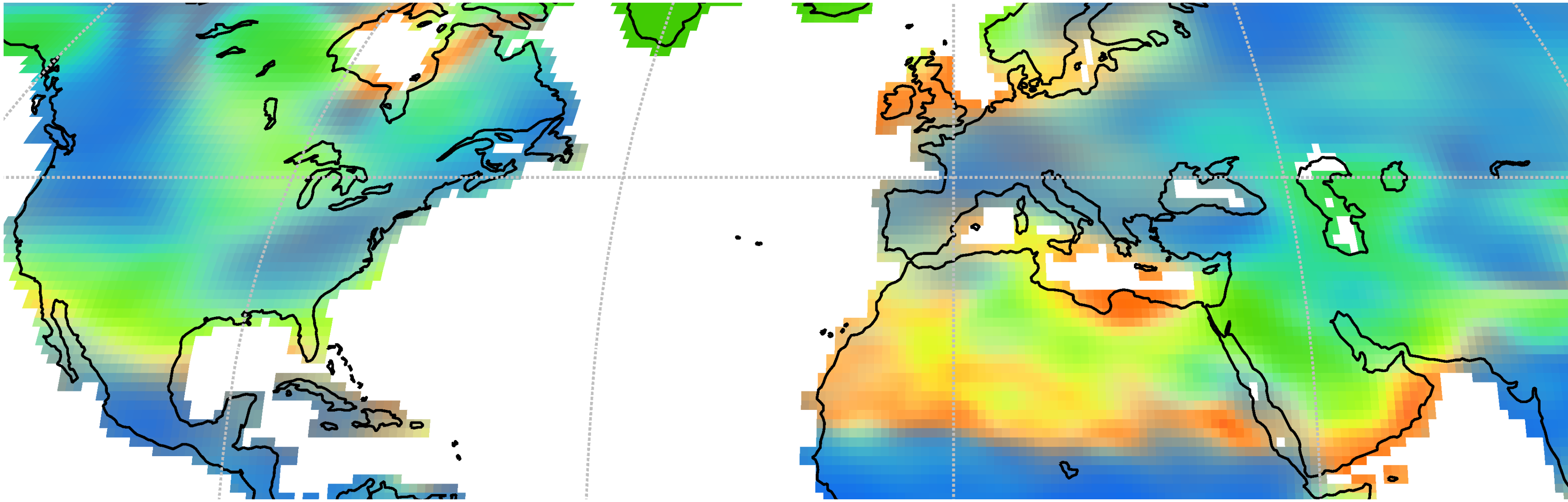


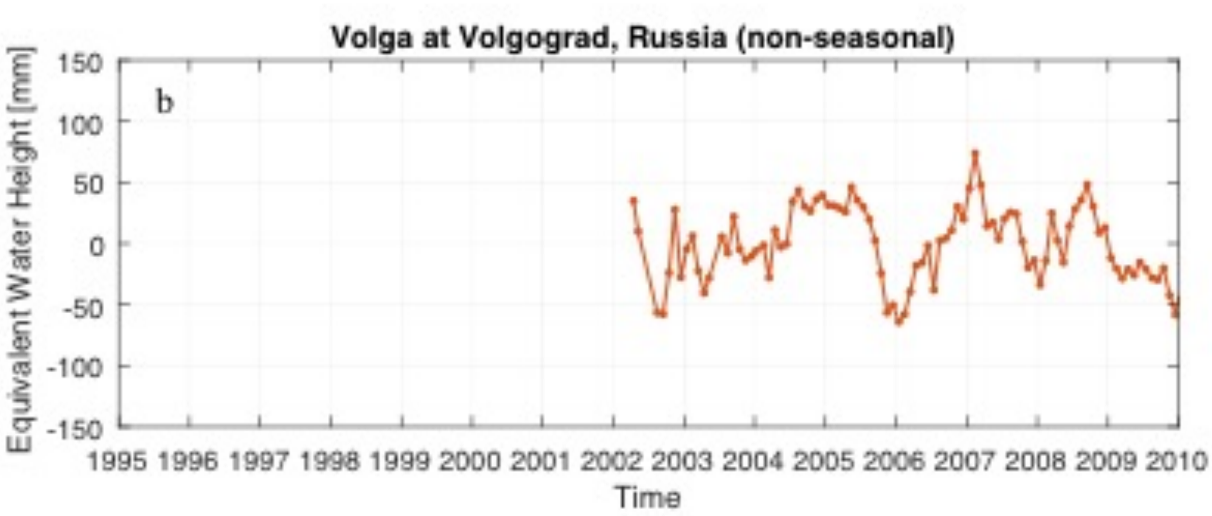
A long-term statistical reconstruction of GRACE water storage to evaluate land surface models

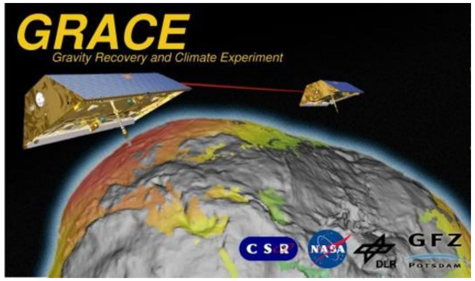
Vincent Humphrey, Lukas Gudmundsson, Sonia I. Seneviratne

Institute for Atmospheric and Climate Science, ETH Zürich

Water storage

- Observational record still relatively short





Water storage

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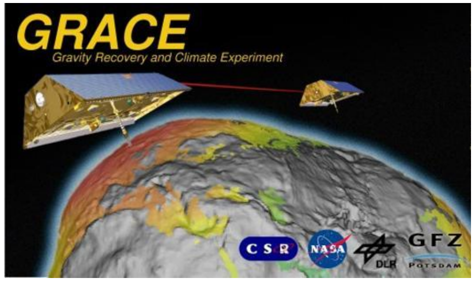
  - Limits evaluation potential for rare features (wet/dry extremes)



Water storage

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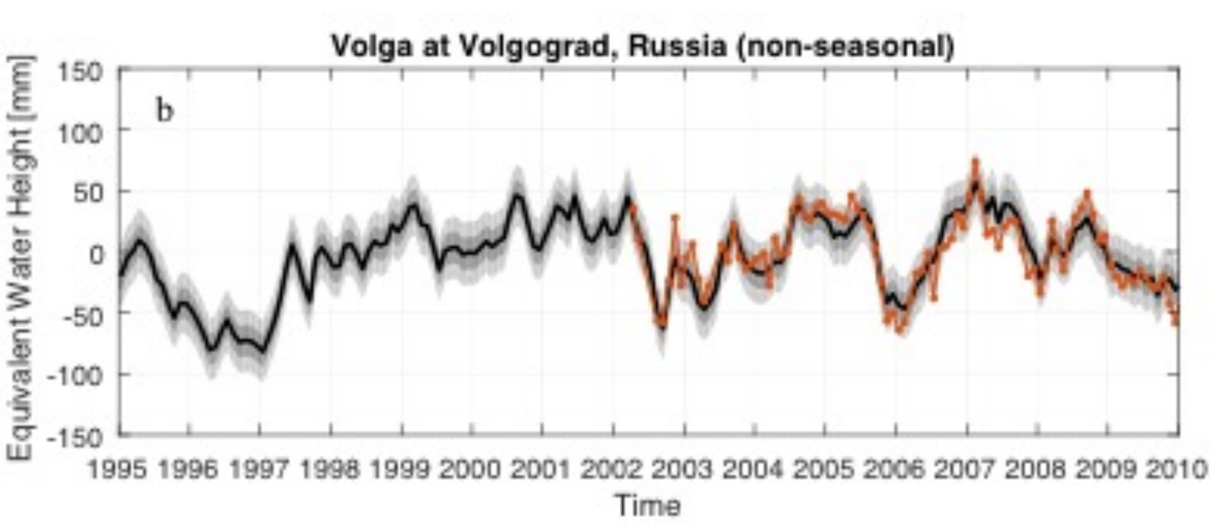
- Can we reconstruct past conditions?



Outline

1. A statistical approach (methodology)
2. Comparison with physical models (e.g. LSMs, GHMs)
3. Open questions / discussion

Objective
A statistical reconstruction of TWS

- Based on atmospheric forcing from reanalysis
  - Precipitation & mean temperature (ERA-Interim)

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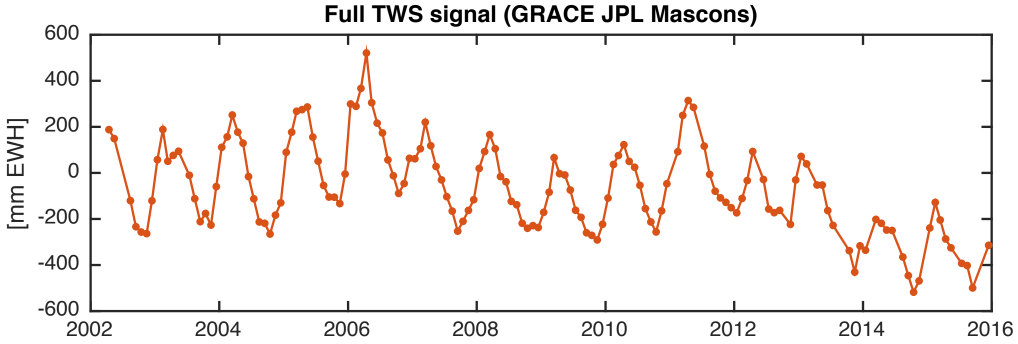
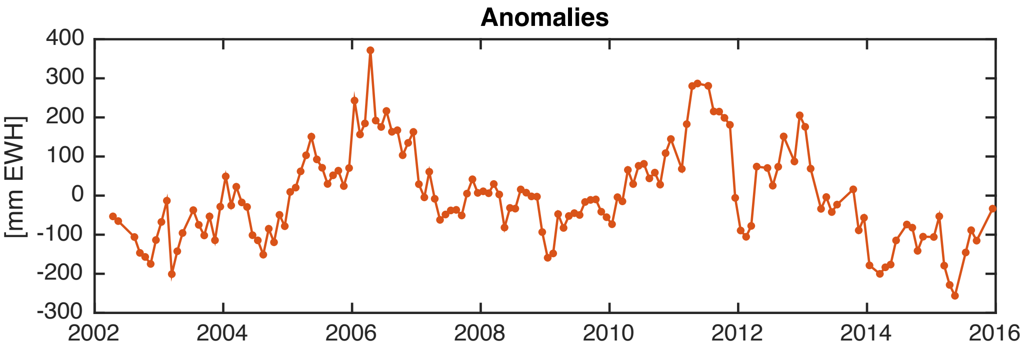
A statistical reconstruction of TWS

- Based on atmospheric forcing from reanalysis
  - Precipitation & mean temperature (ERA-Interim)
- With uncertainty quantification
- Focus on the anomalies (de-seasoned, de-trended signal)

Statistical modeling approach

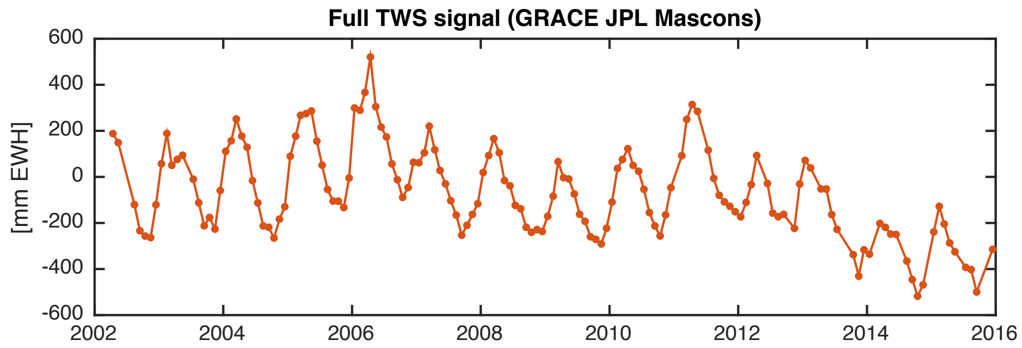
- Anomalies

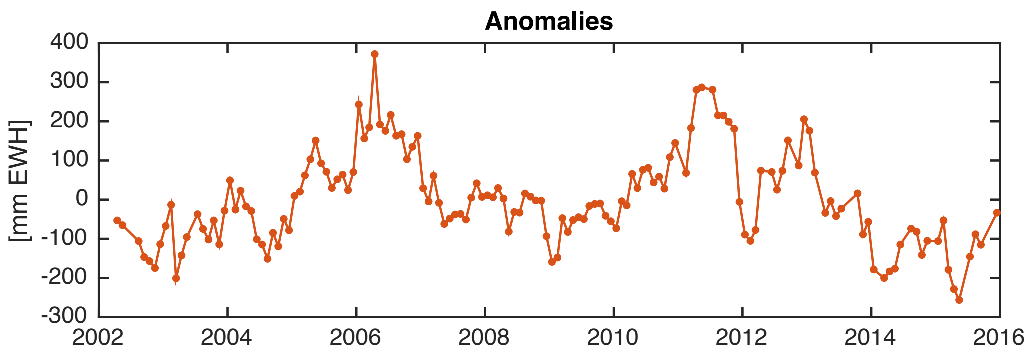




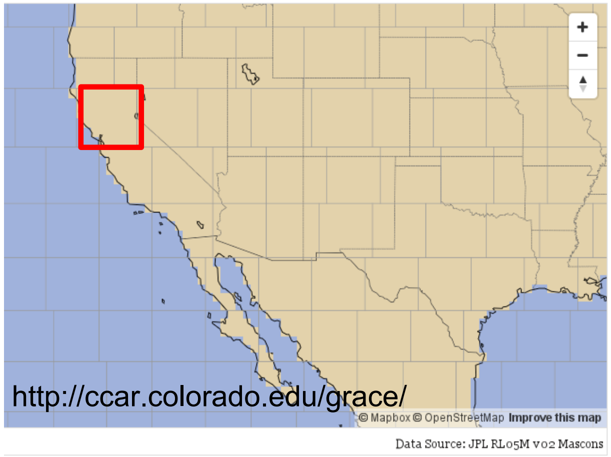
Statistical modeling approach

- Anomalies



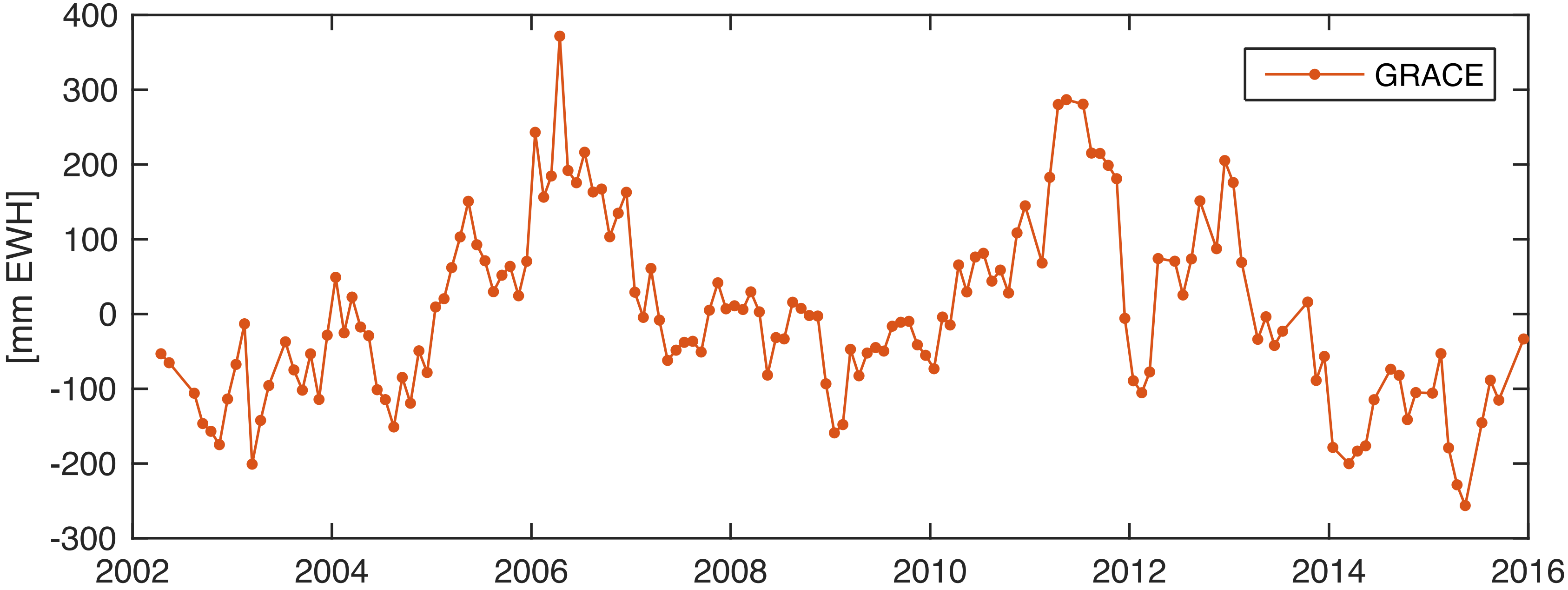


This example is mascon #856



Statistical modeling approach

- How to relate atmospheric drivers to TWS ?



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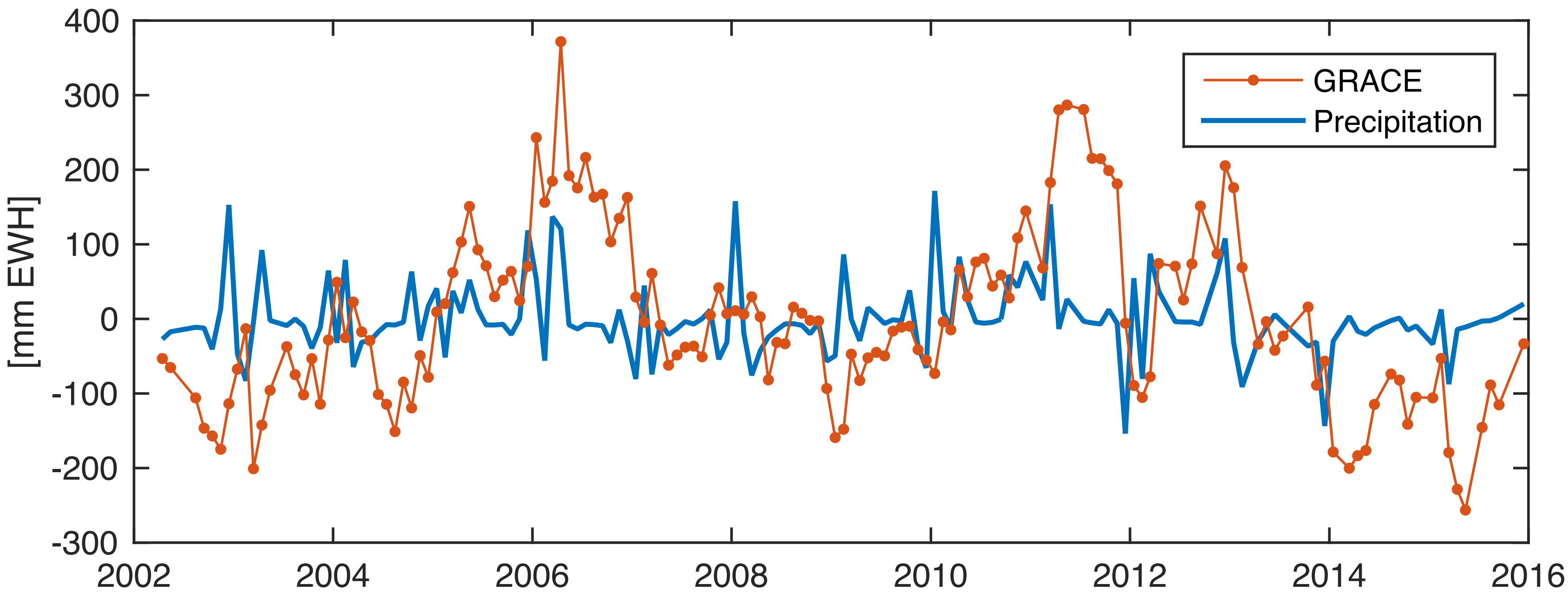

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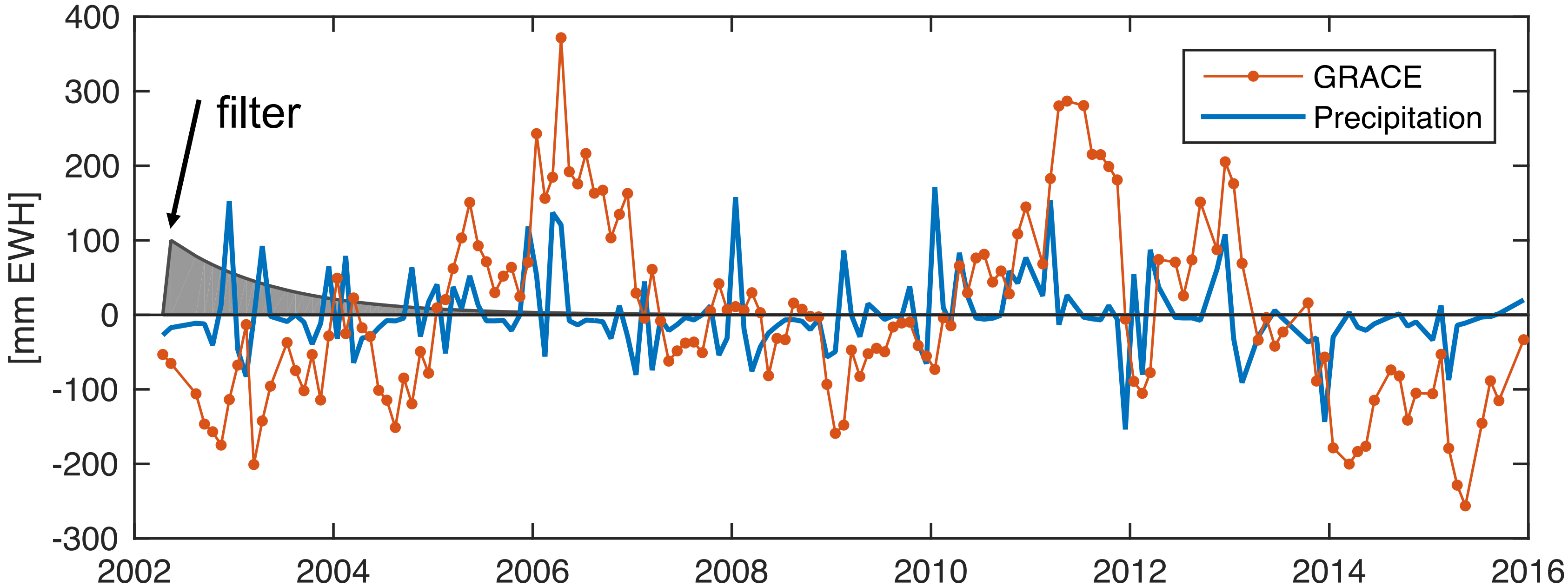
Statistical modeling approach

- How to relate atmospheric drivers to TWS ?
  - Exponential decay filter applied to precipitation (= linear store model)



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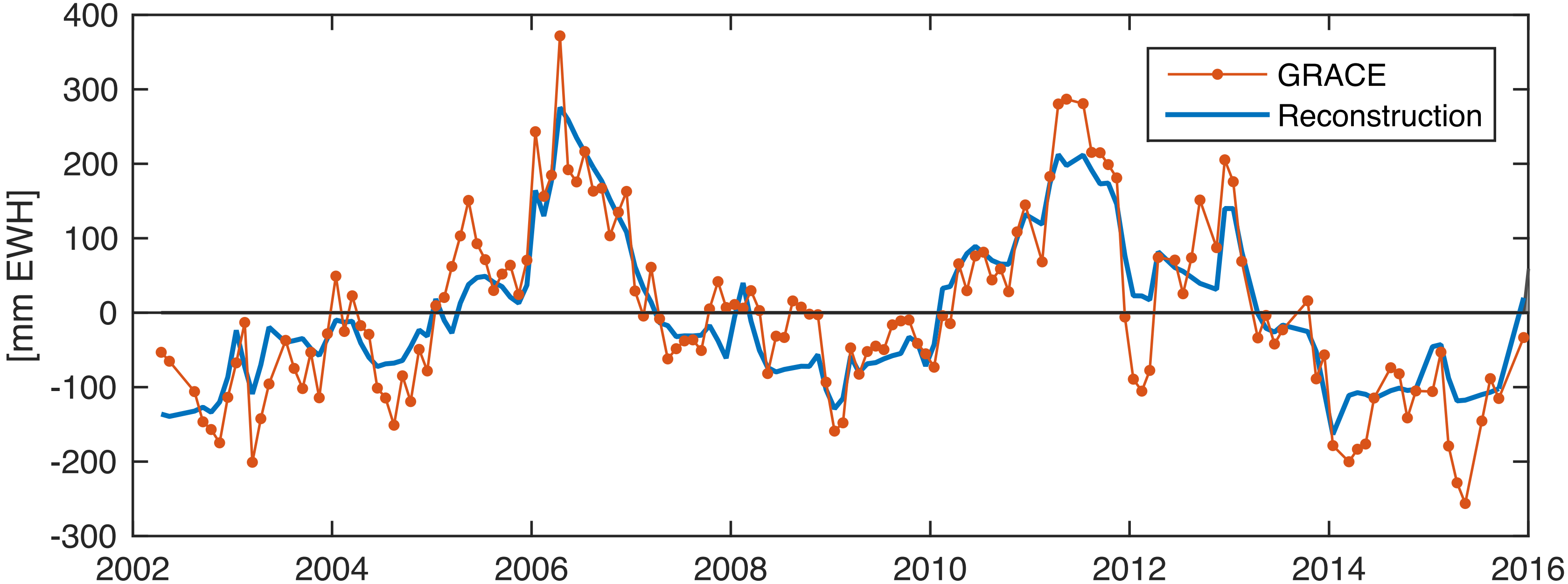

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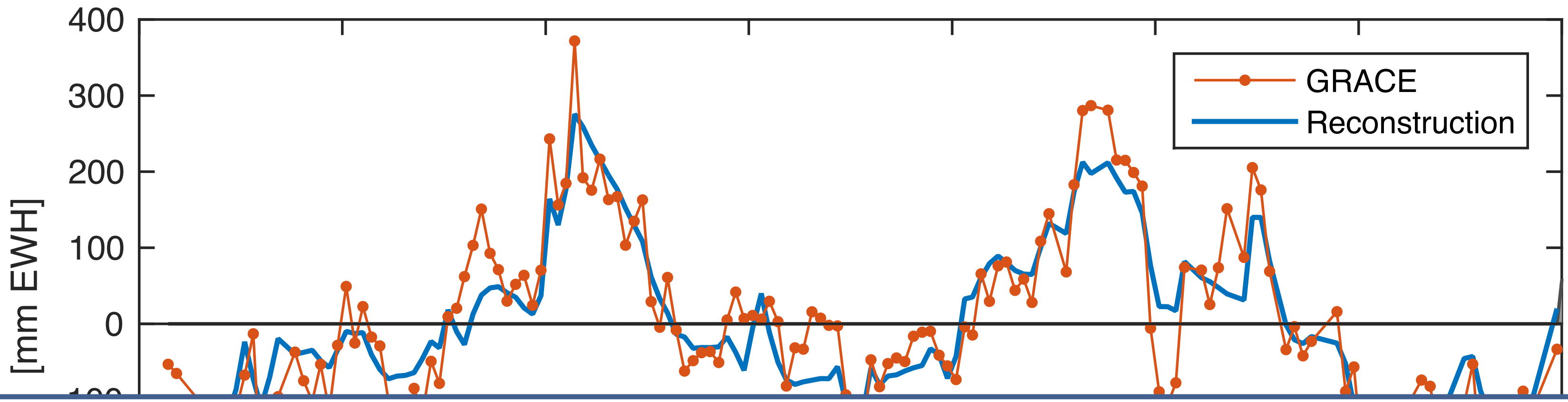
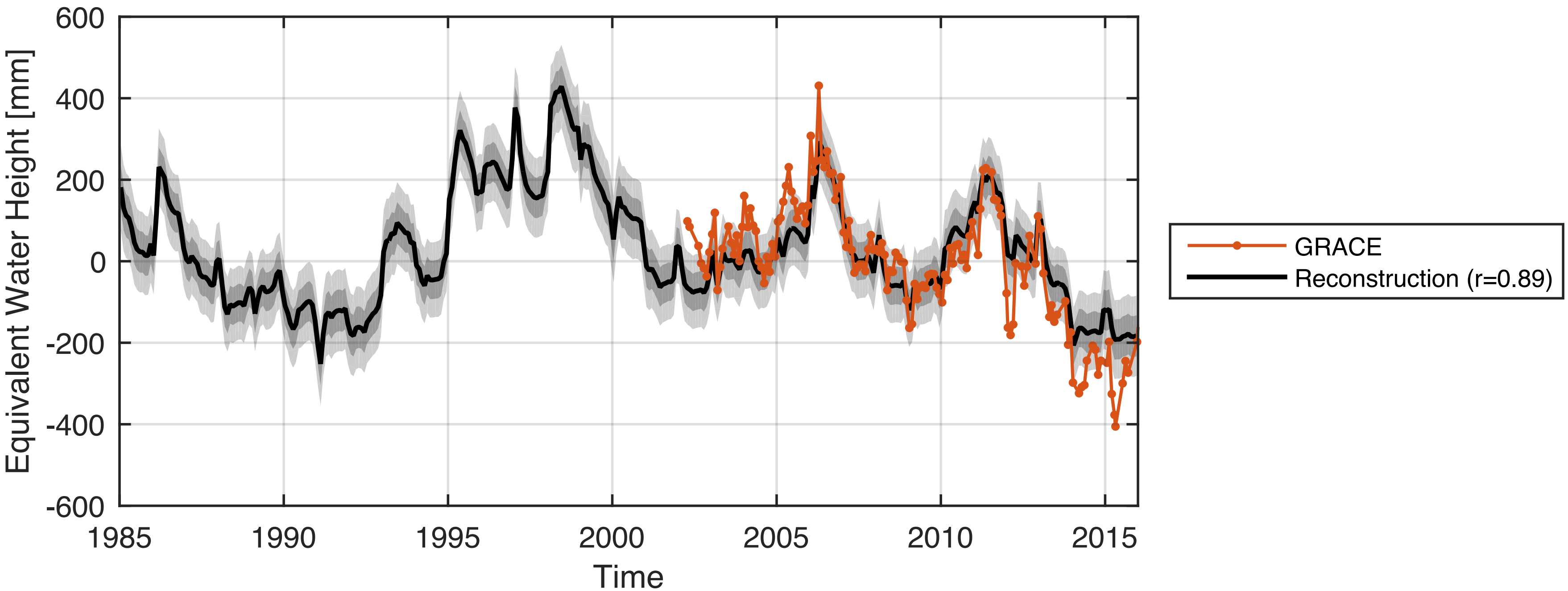


$$TWS_{\mathrm{REC}} = \beta_1 (P^{\tau}_{inter+subseas}) + \beta_2\, T_{inter} + \epsilon$$

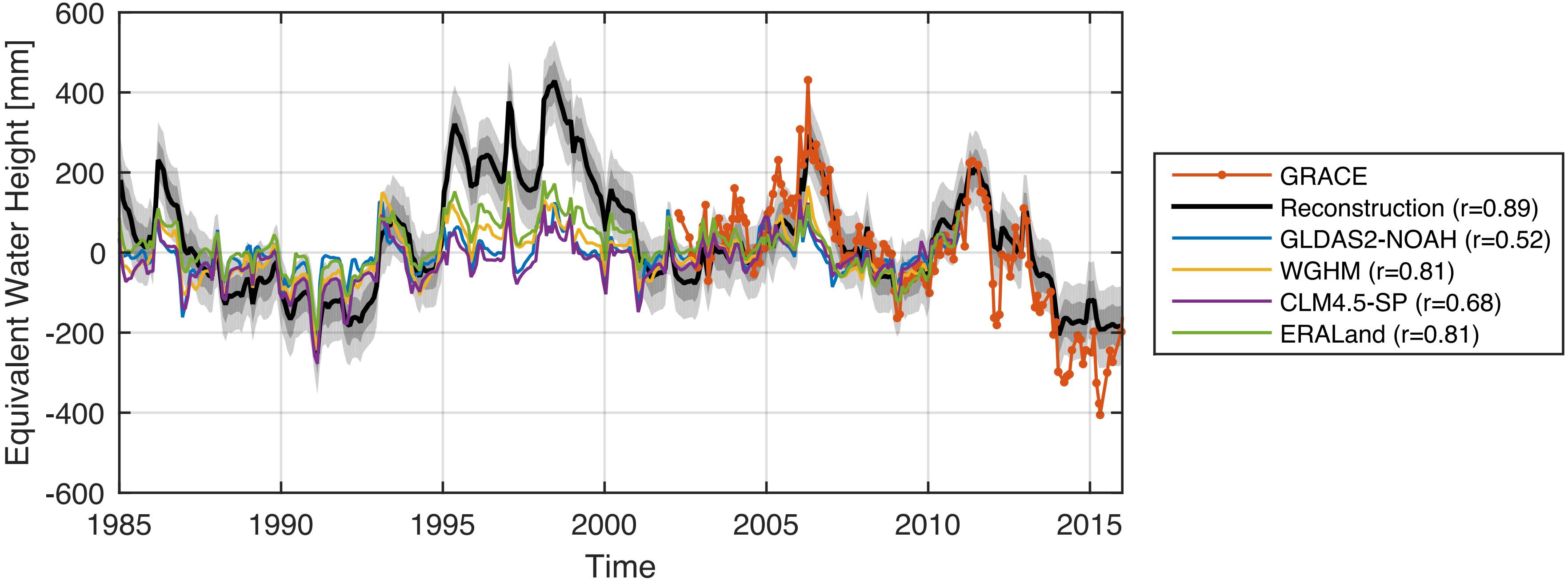
- Three free parameters (τ, β_1, β_2)

Results


600
400
200
0
-200
-400
-600
Equivalent Water Height [mm]
1985
1990
1995
2000
2005
2010
2015
Time
GRACE
Reconstruction (r=0.89)

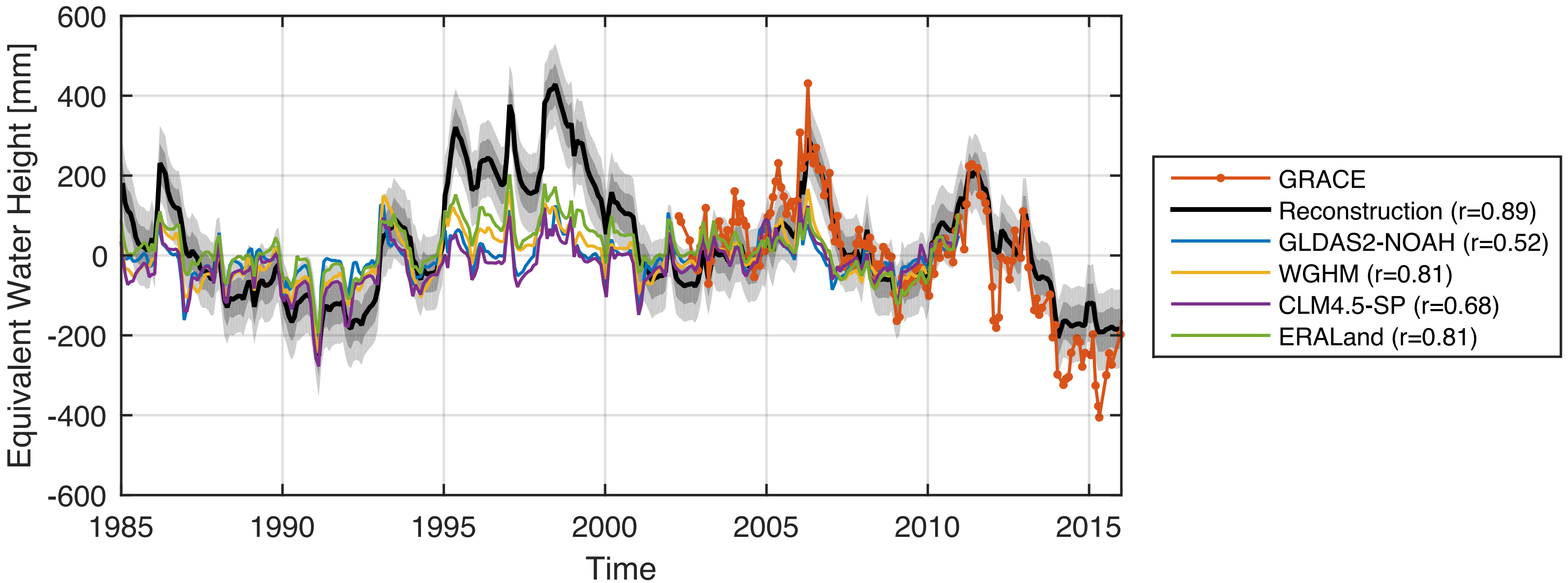
Results

- Short-term dynamics are coherent with physical models

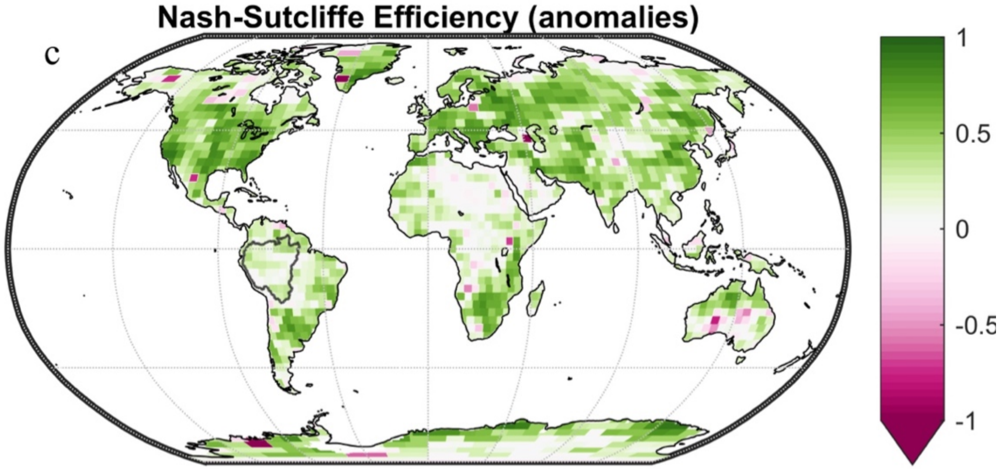


Results

- Short-term dynamics are coherent with physical models
- Better representation of signal amplitude and inter-annual variability



Global model performance (comparing with GRACE)



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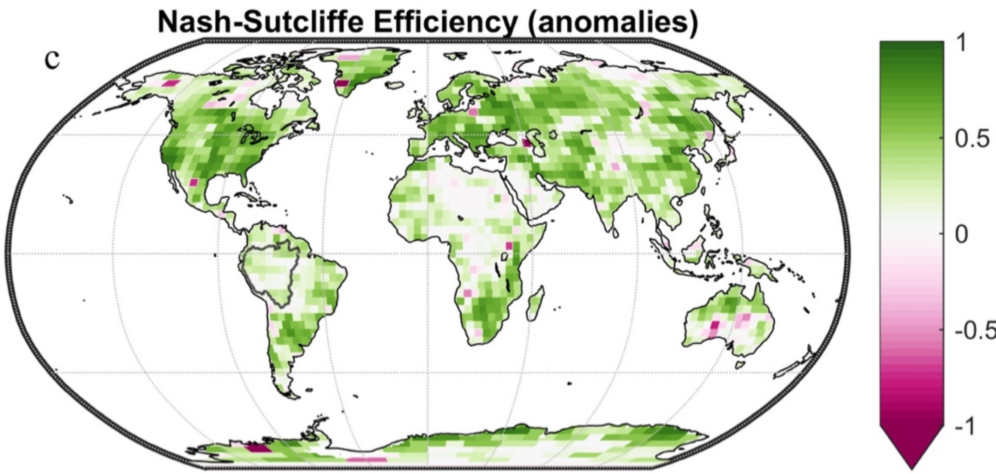

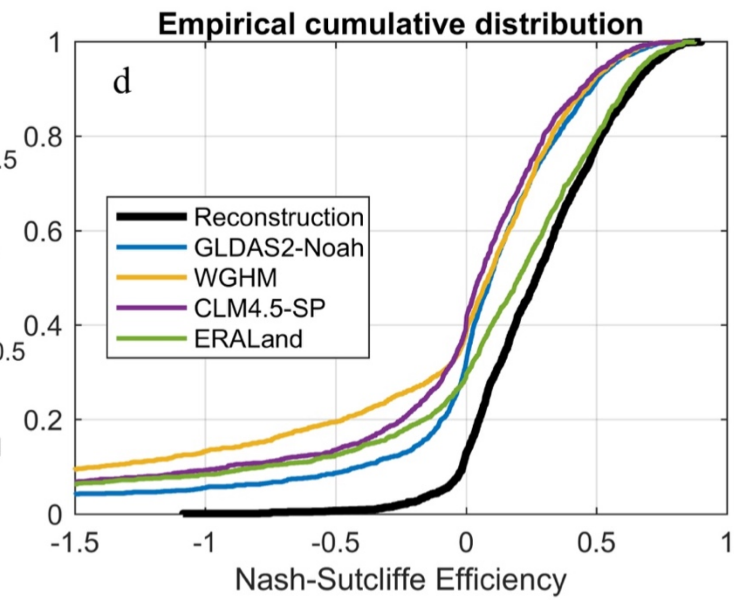

Lower performance ⟷ Better performance

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Limitations

- Only climate-driven TWS is reconstructed
  - No representation of human influences (irrigation, dams, etc)
  - Climate-driven trends to be interpreted with caution

- Sensitive to the quality of the atmospheric forcing

Open question / discussion

- Can (should) we use statistical reconstructions in data assimilation?

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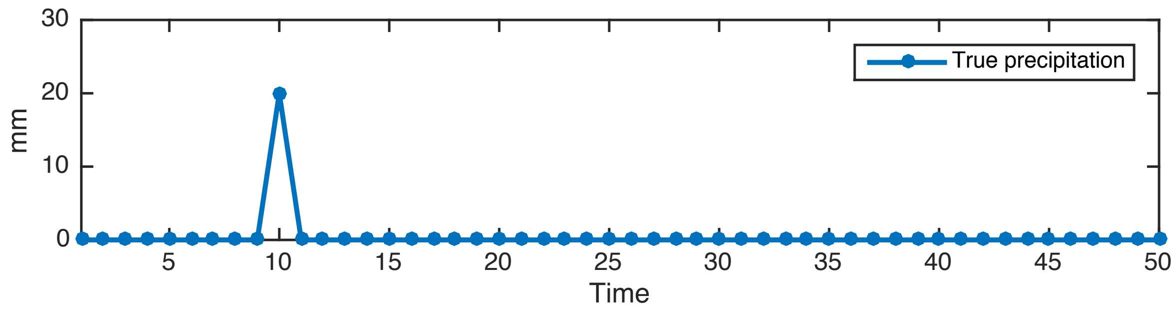

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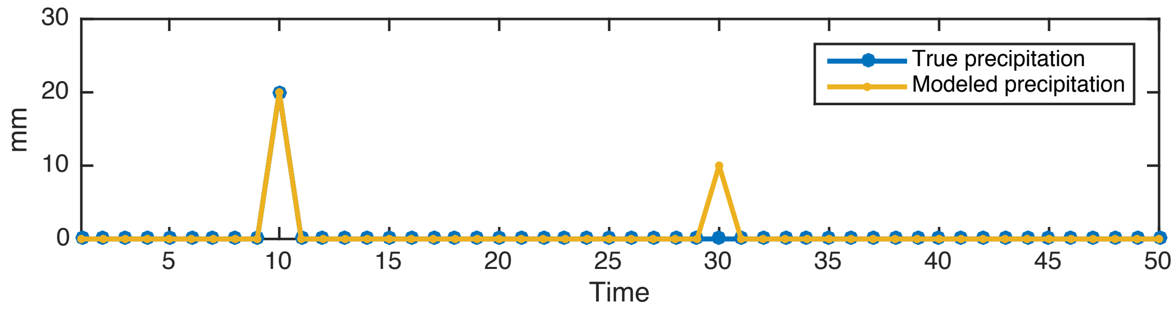

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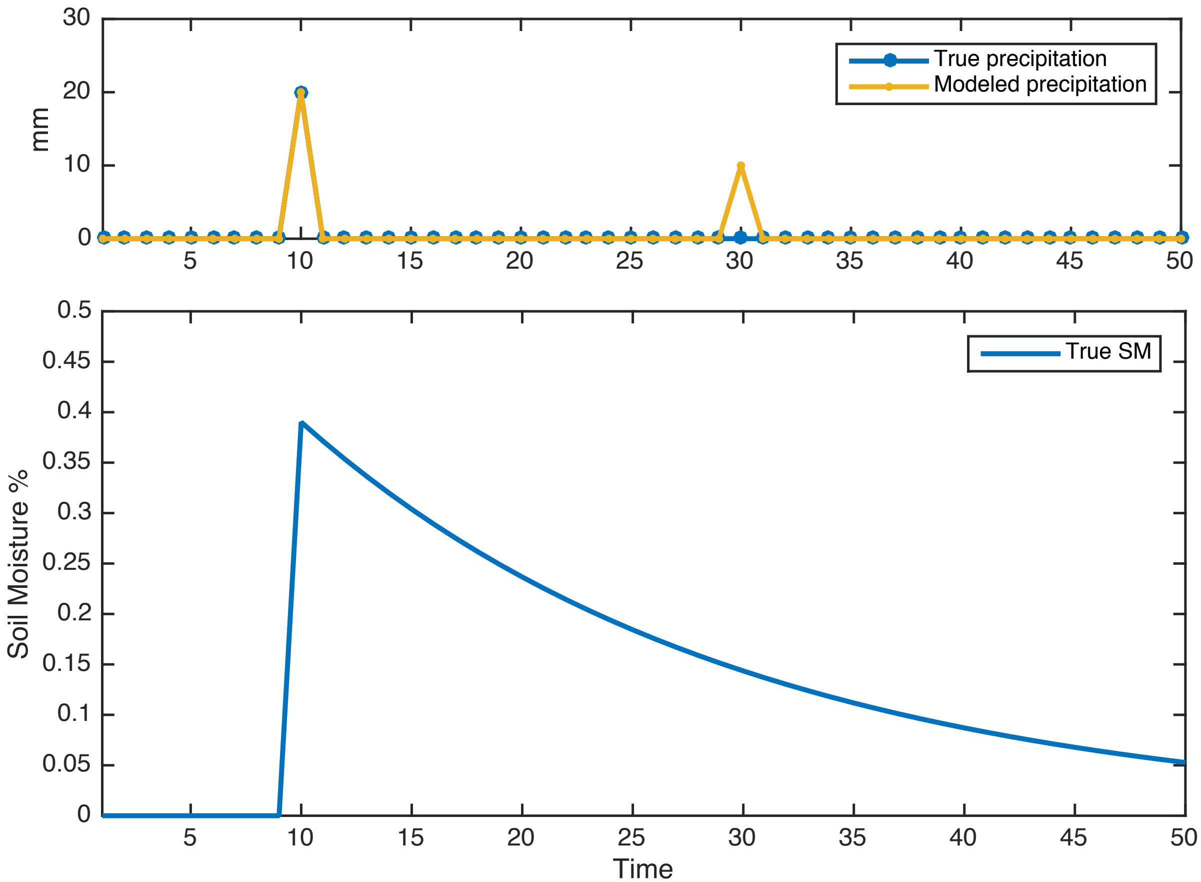

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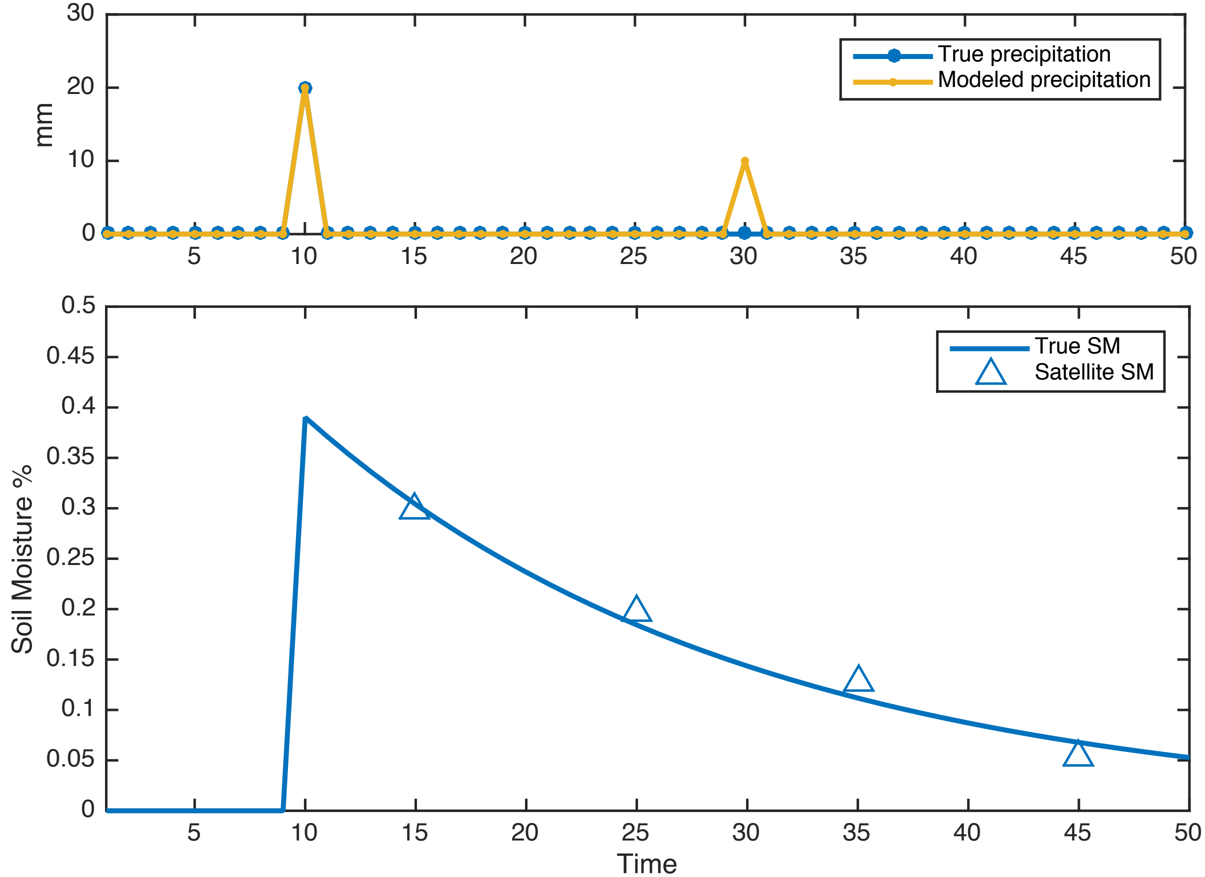

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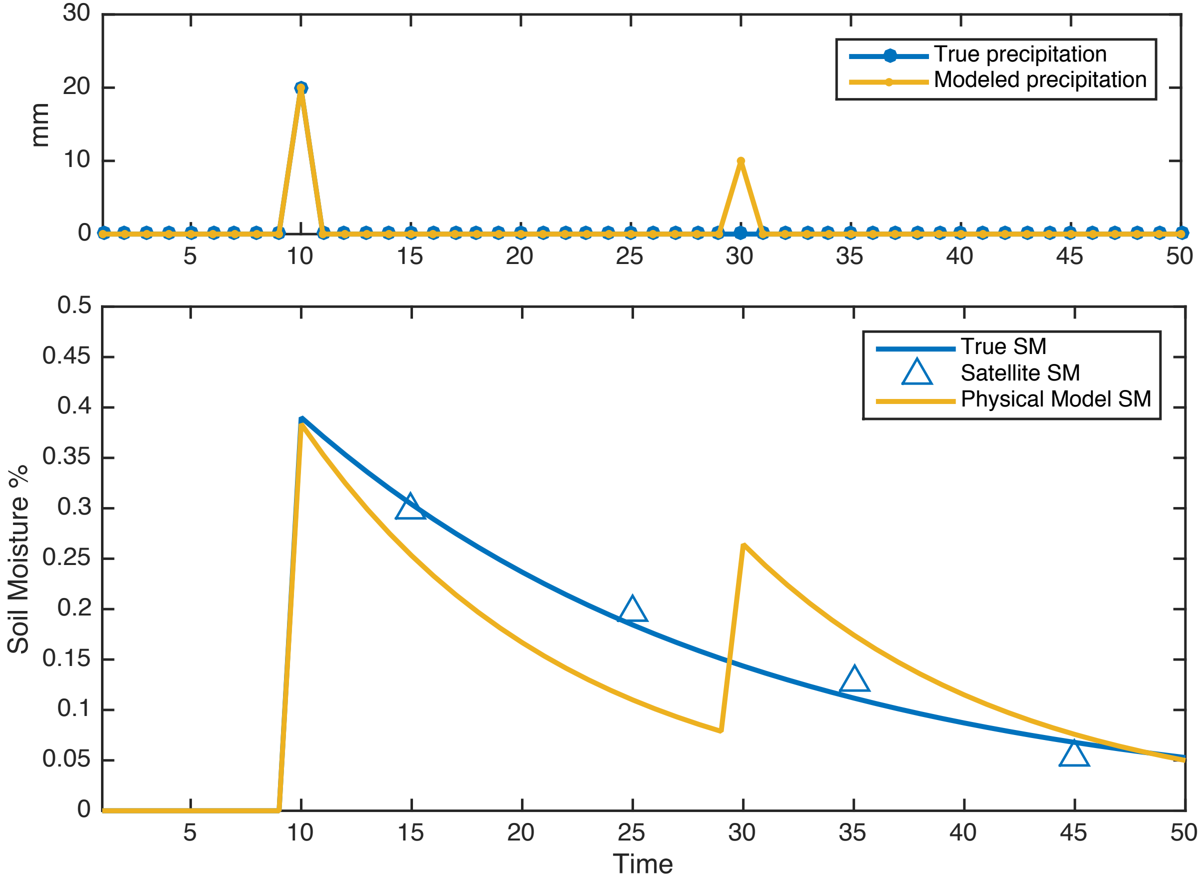

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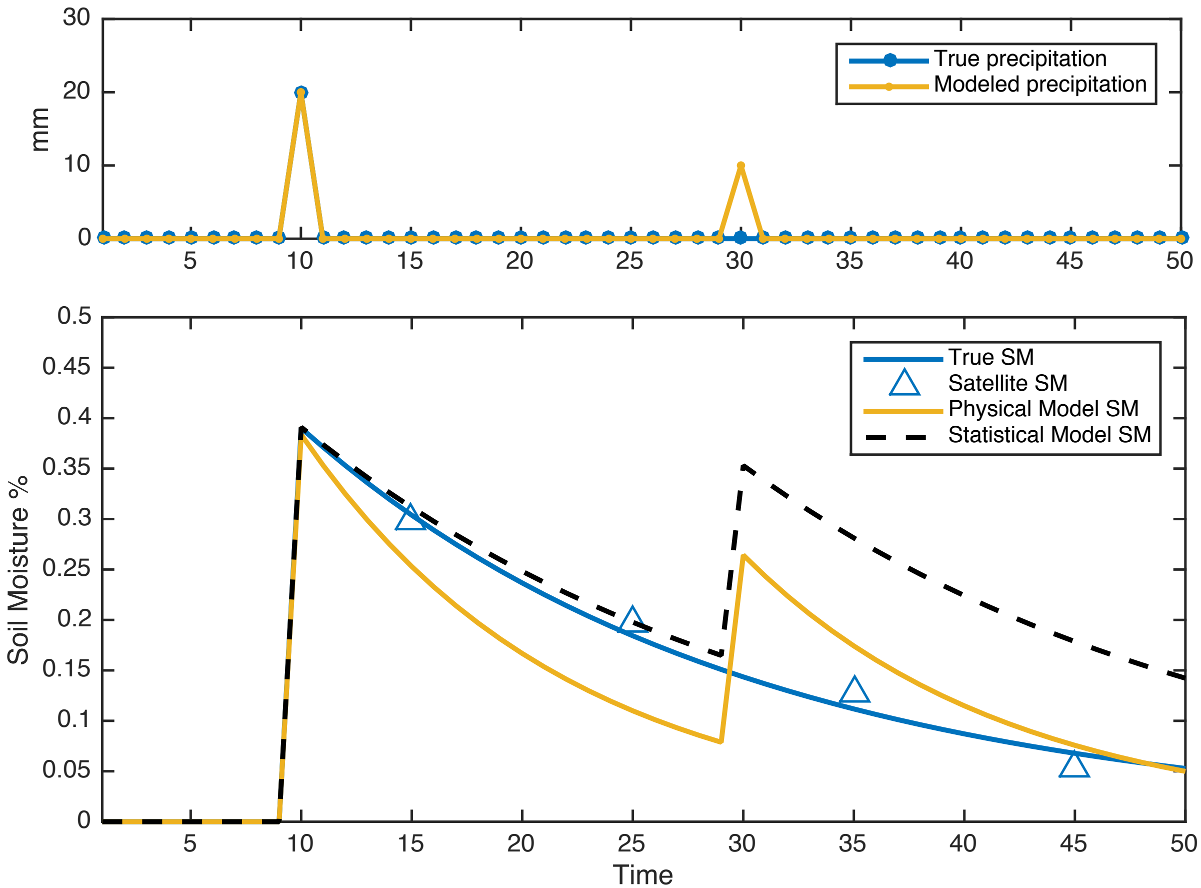

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  - Provides a replacement solution if the EO mission is stopped
  - Diagnose where the DA improvement comes from:
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- Limitation
  - Would not replace Earth observations
  - Highly susceptible to errors in modeled forcing
    - In DA, leads to the confirmation of a model error !

Conclusions

- A data-driven statistical reconstruction of TWS
- For climate-driven TWS variability
- Potential for long-term ESM evaluation

Open-access TWS reconstruction dataset

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Thank you for your attention !

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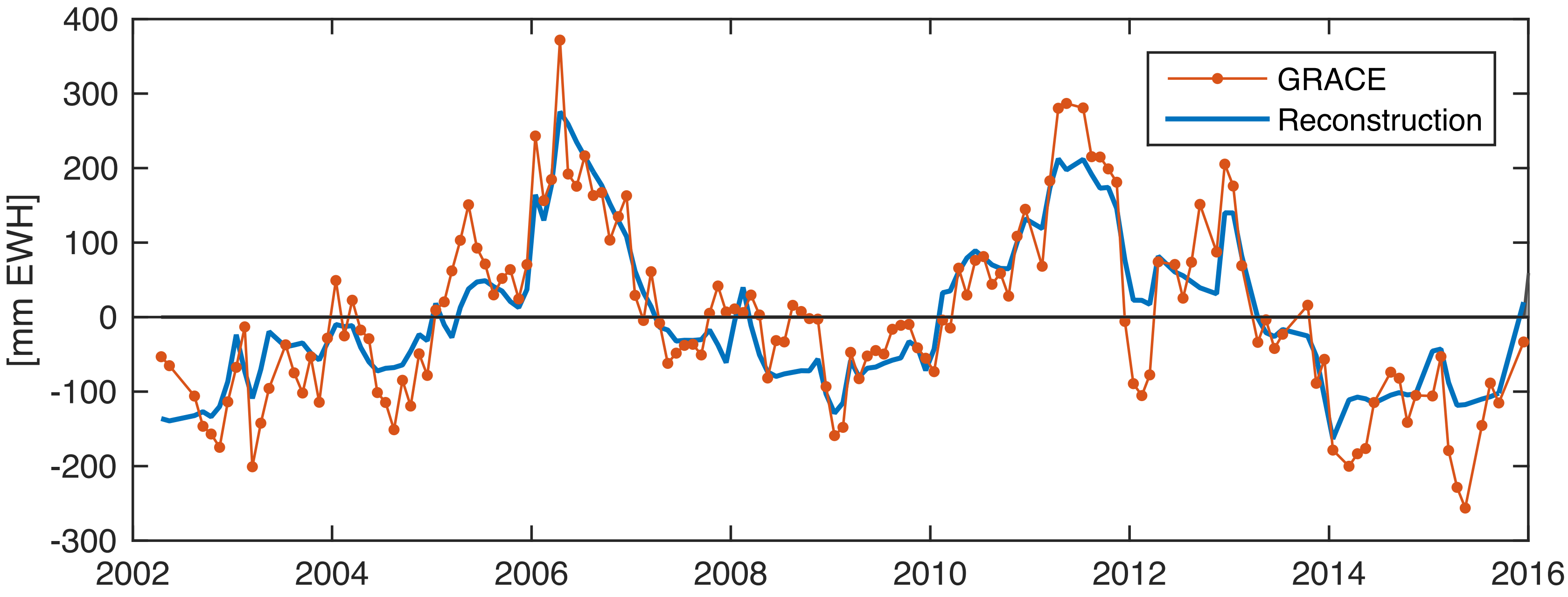
Back-up slides

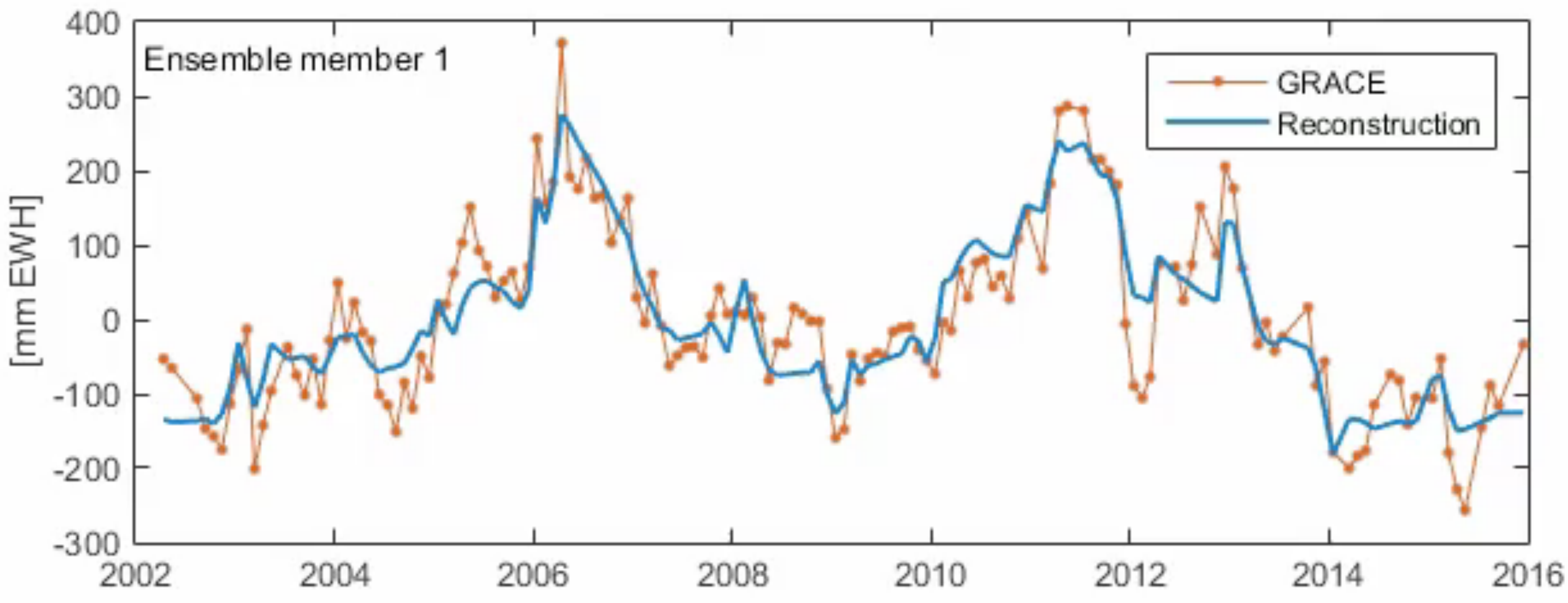
Statistical modeling approach

- How to quantify the uncertainty ?



Statistical modeling approach

- How to quantify the uncertainty ?
  - Parameter uncertainty (through Markov Chain Monte Carlo)



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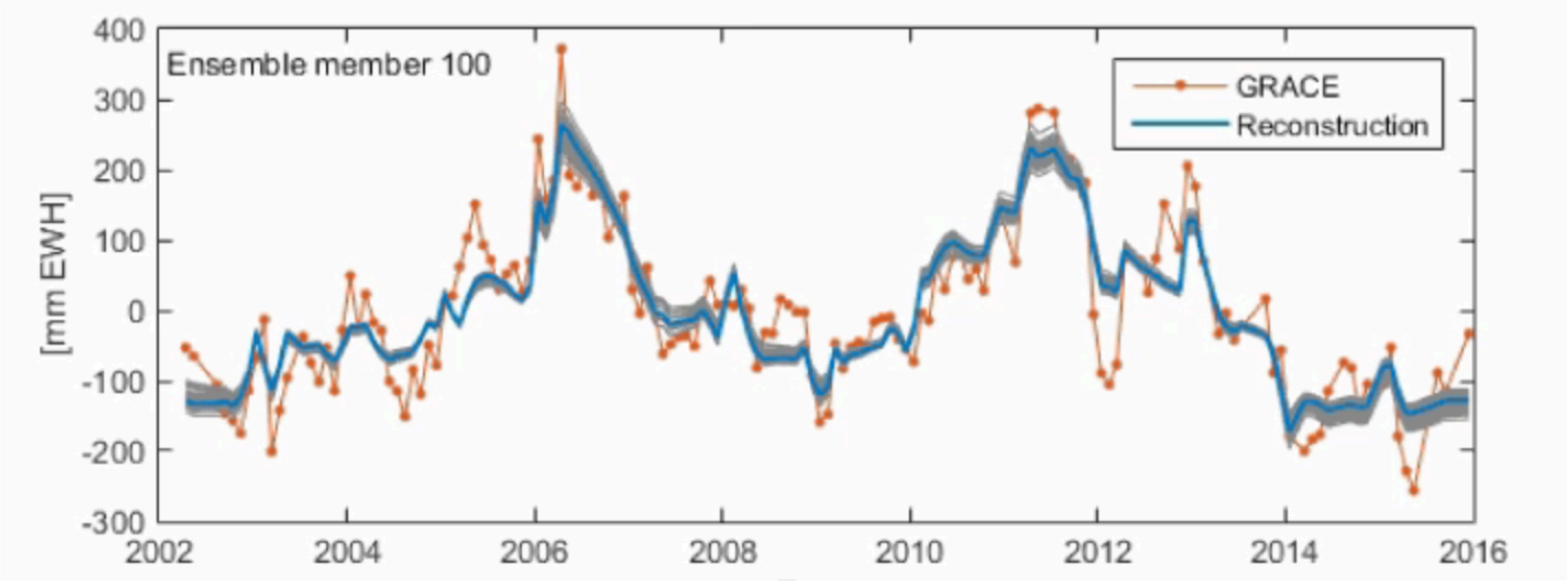

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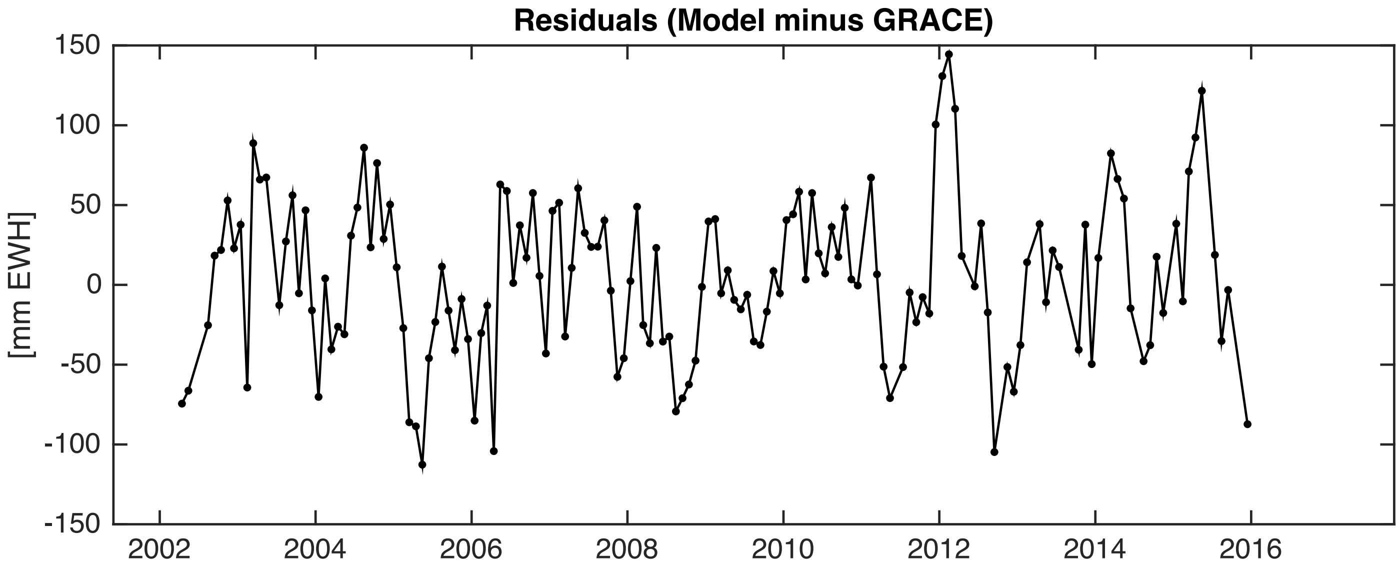
  - Residuals (≈ unmodeled signals + noise)



Residuals: AR(1) Gaussian process, $\epsilon_t = \epsilon_{t-1} \cdot \rho + \mathcal{N}(0, \sigma)$

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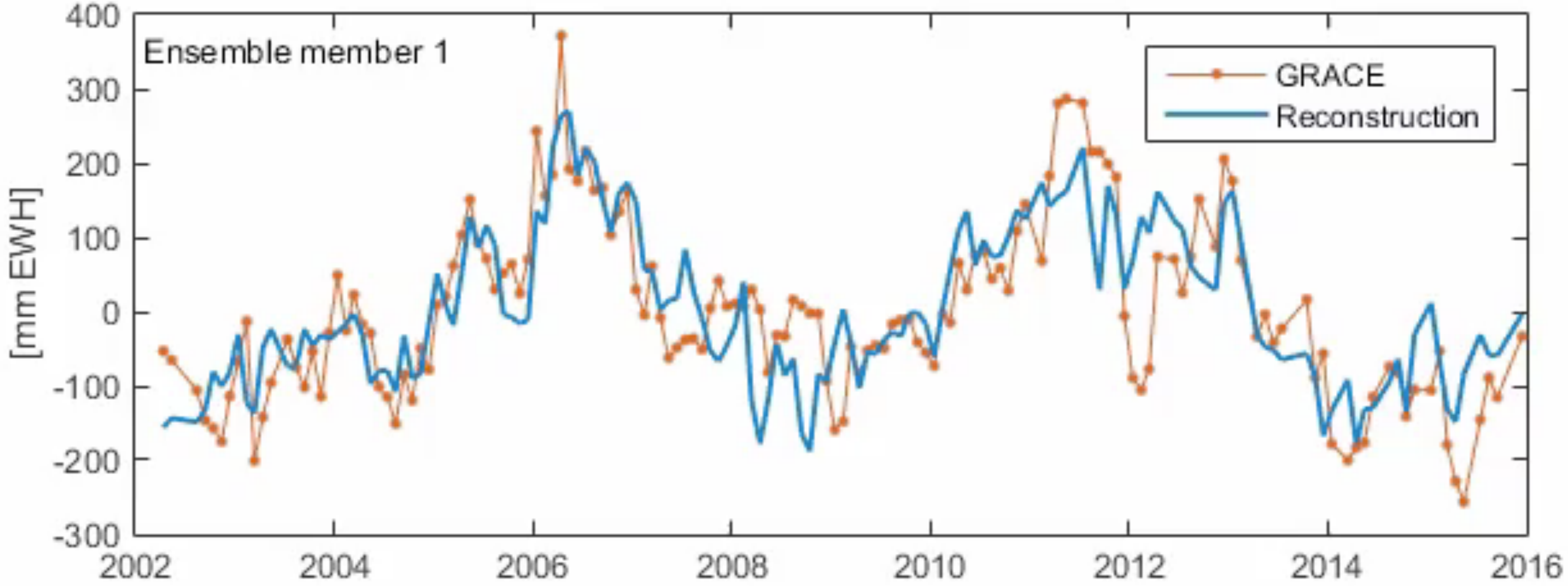

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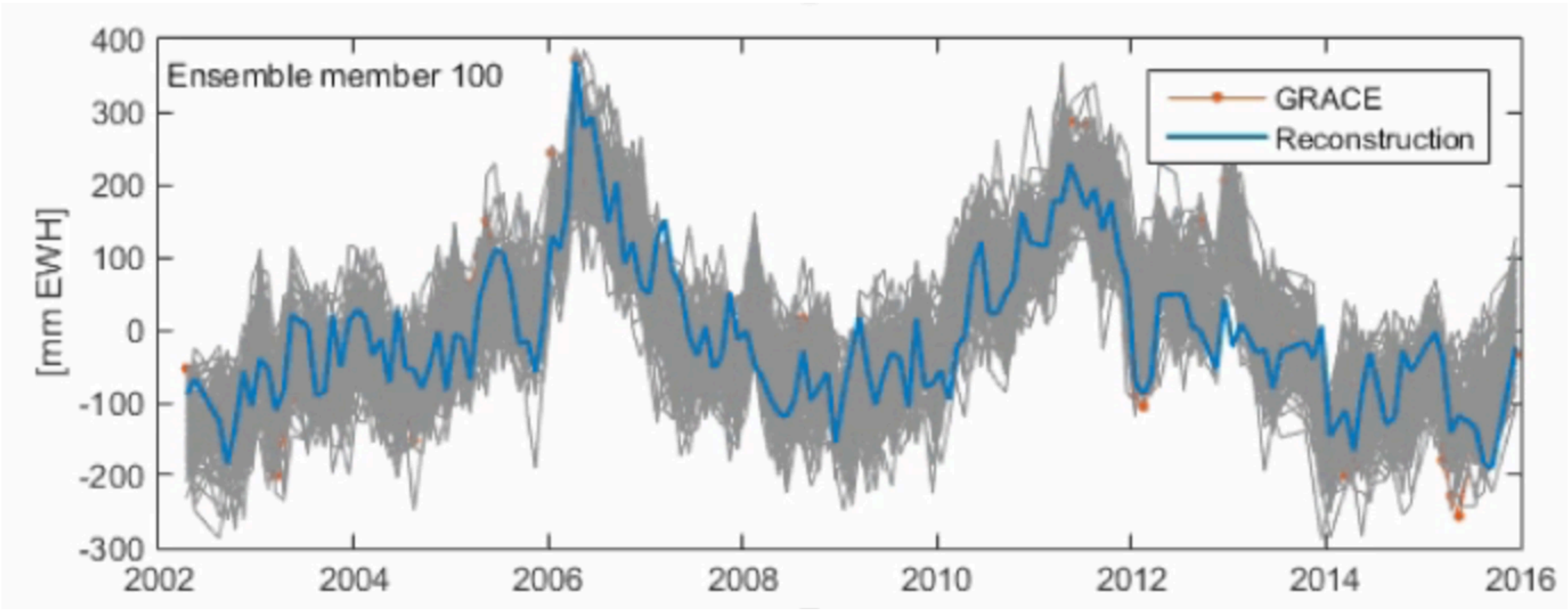
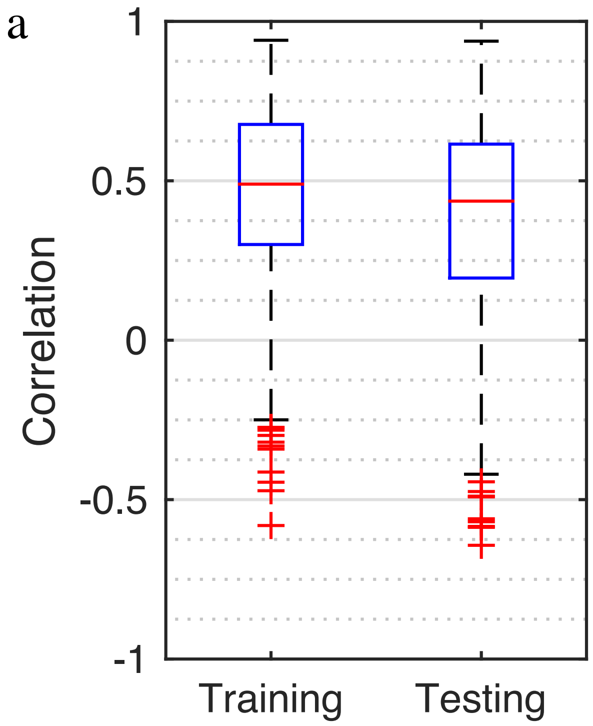


Cross-validation experiment

- Training on the period 2012-2015 (37 months)
- Testing on the period 2002-2010 (102 months)
- Minor degradation in model performance
- Model not prone to overfitting

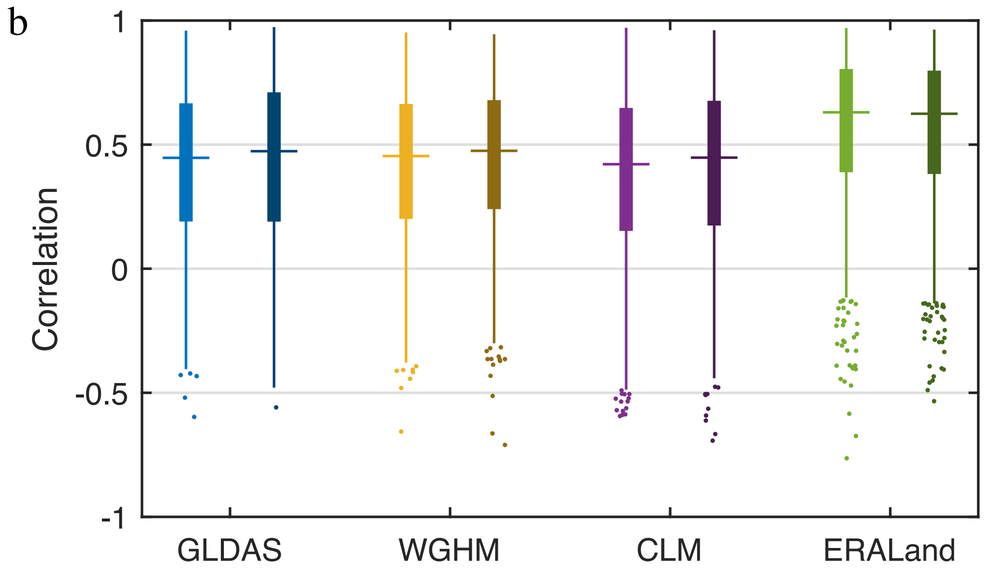


Consistency check

- How does the reconstruction perform in the past ?

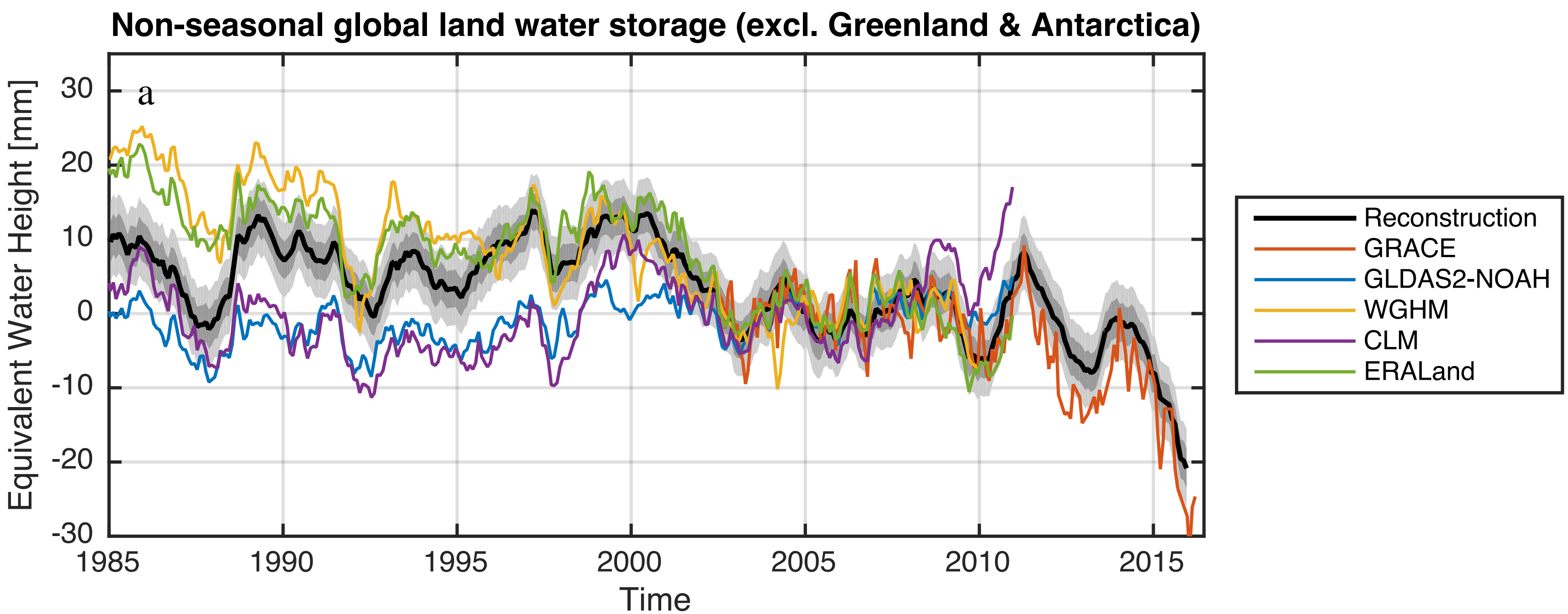
- Compare the reconstruction with LSMs
  - 2002-2009 (left boxplots)
  - 1985-1992 (right boxplots)

- Reconstruction and LSMs compare similarly under present and past conditions



Trends in TWS (1)

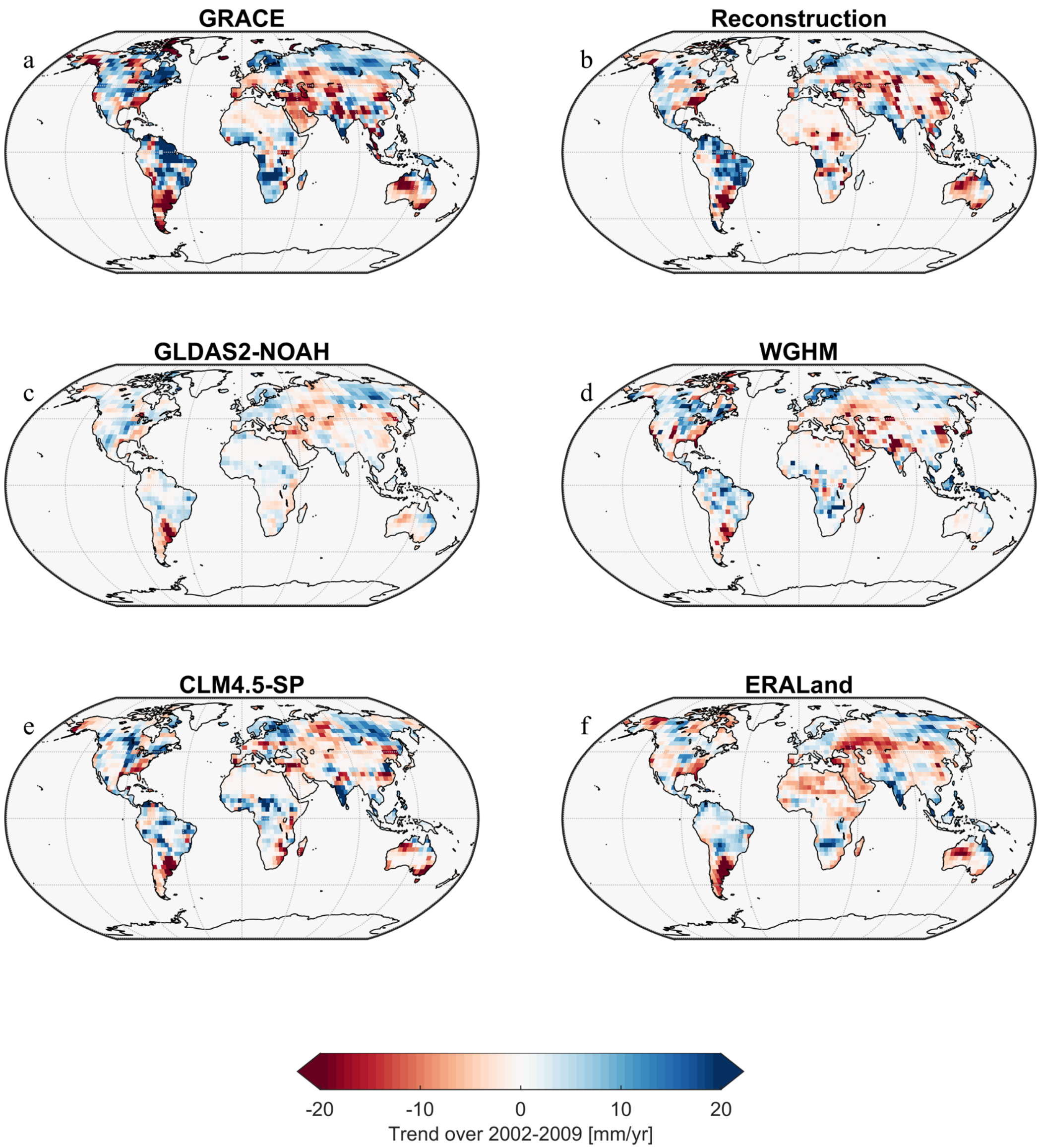
- Trends should be considered very carefully
  - Potential drifts in land surface models
  - Reconstruction not explicitly calibrated/validated for trends



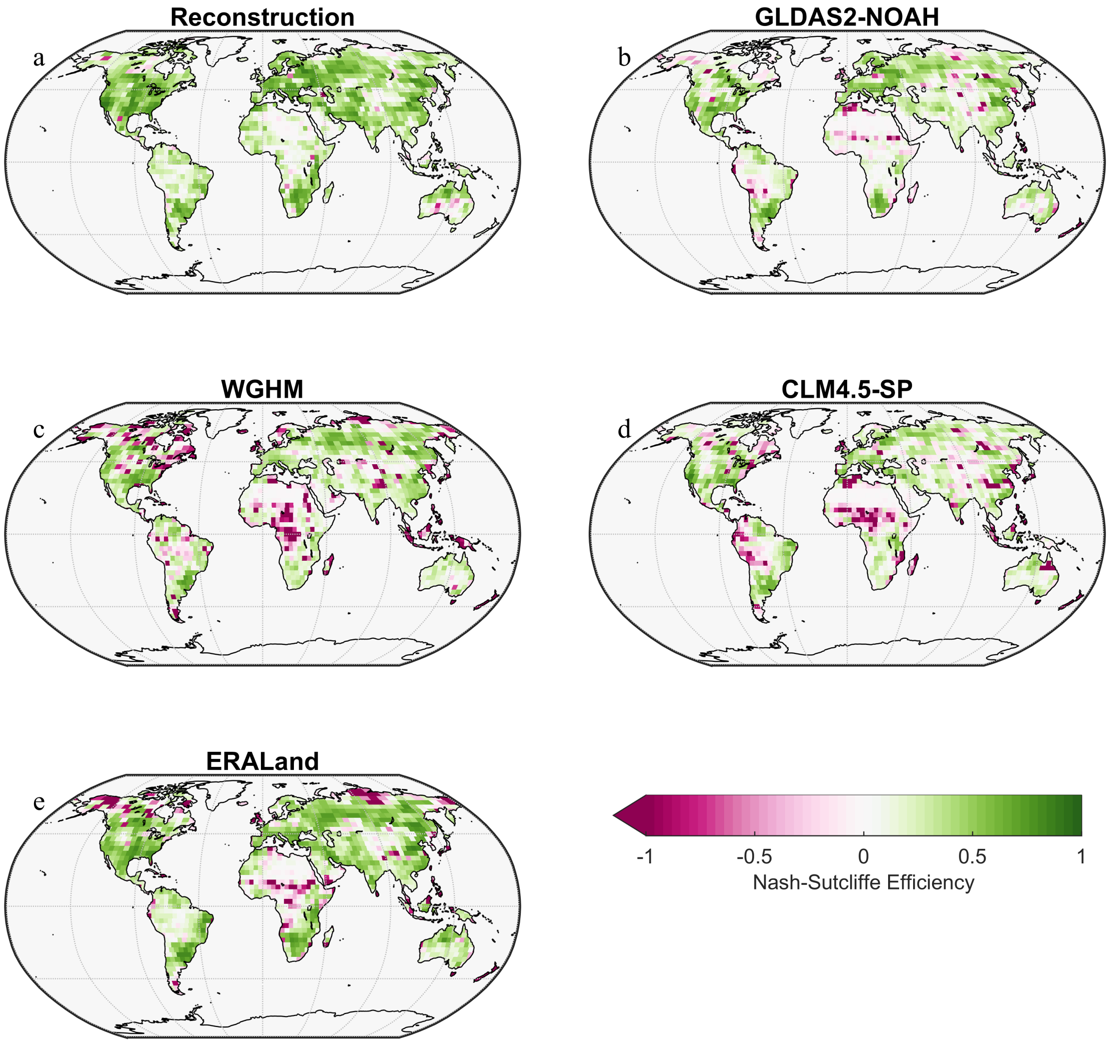
ETH zürich

Trends in TWS (2)

Over 2002-2009



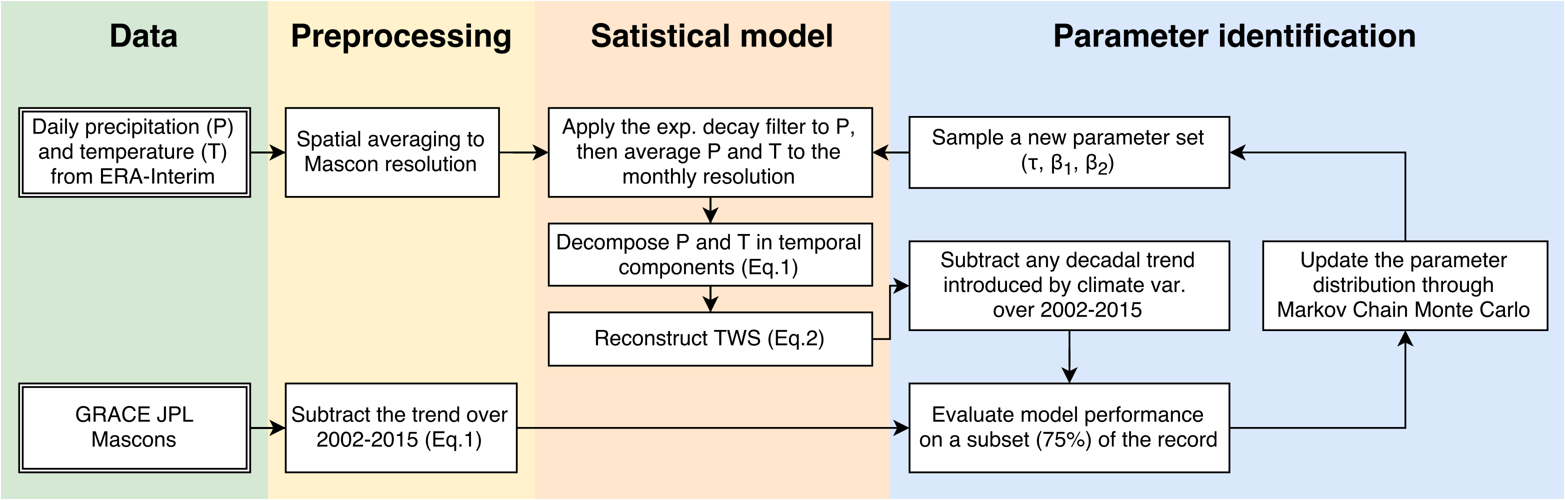
Model performance (all)



Parameter identification

- Bayesian estimation of the parameter distribution
  - Using Marlov Chain Monte Carlo (algorithm of Haario et al. 2006)

- Three free parameters
  - τ : steepness of the decay filter
  - β_1 : scaling coefficient for precipitation
  - β_2 : scaling coefficient for temperature



Decay parameter

- The τ parameter is a GRACE-driven estimate of residence time

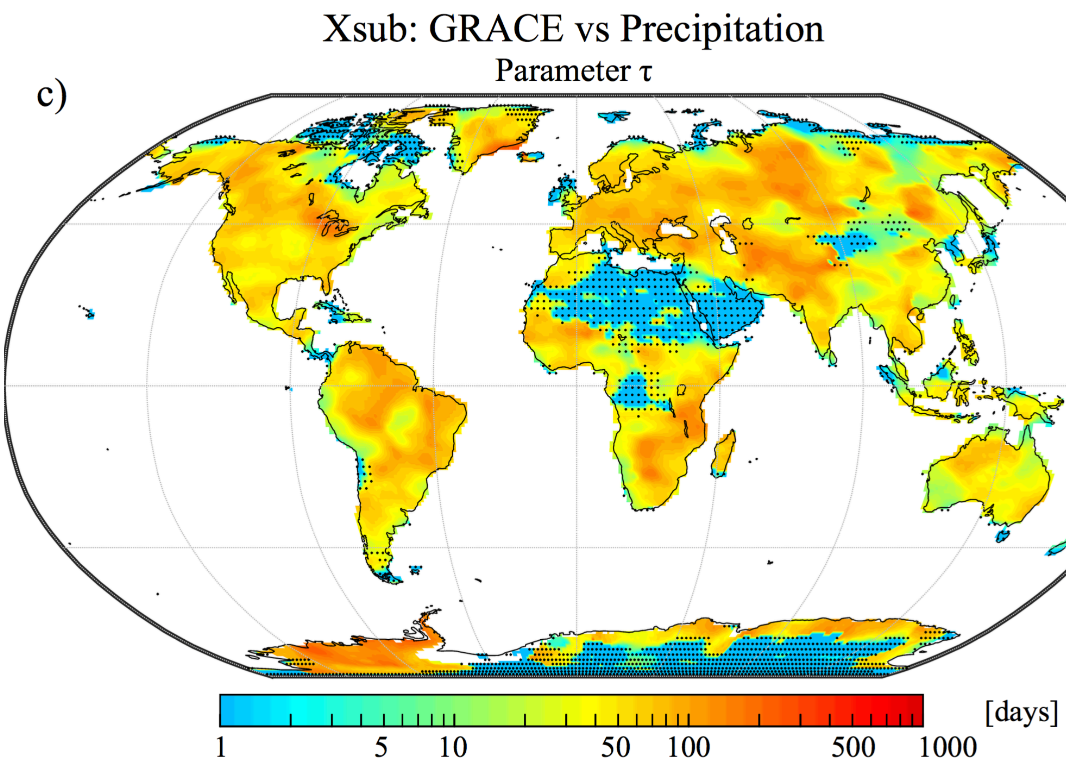


Figure from: **Humphrey et al (2016)**. Assessing Global Water Storage Variability from GRACE: Trends, Seasonal Cycle, Subseasonal Anomalies and Extremes. **Surveys in Geophysics** 37(2)