A spatial covariance model for GRACE and GRACE-FO terrestrial water storage data

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Introduction

- Why do we need GRACE and GRACE-FO covariances?
  - Such covariances allow to estimate uncertainties of regional TWS time series
  - Further use of data requires these uncertainties, e.g. data combination and model assimilation, or trend analysis
- Properties of the covariance model?
  - Observation system of GRACE and GRACE-FO leads to longer correlation length in North-South than East-West direction → anisotropy
  - Due to the orbit configuration the uncertainty should be latitude-dependent → non-homogeneity
  - Short-repeat orbit phases, time-variable instrument uncertainties, temporally variable environmental influences etc. lead to time-dependent uncertainties → non-stationarity

Anisotropic + non-homogeneous + non-stationary covariance model

- Covariance between two points
  $$C(\lambda_i, \theta_i, \lambda_j, \theta_j, t) = \sigma_i(t)\sigma_j(t)C_1(\lambda_i, \theta_i, \lambda_j, \theta_j)$$
- Latitude-depending model by scaling correlation function C_0 with even Legendre polynomials up to degree 8
- C_0 wave-effect function based on Bessel function of the first kind J_v and direction-depending shape parameter a
  $$C_0(\cdot) = \frac{c_0}{a(\cdot)d(\cdot)} J_\nu(a(\cdot)d(\cdot))$$
- Shape parameter latitude-depending via Legendre polynomials

Regional standard deviation

- Regional variance:

$$var(t) = \sum_{i=1}^{m} \sum_{j=1}^{m} w_i w_j C(\lambda_i, \theta_i, \lambda_j, \theta_j, t)$$

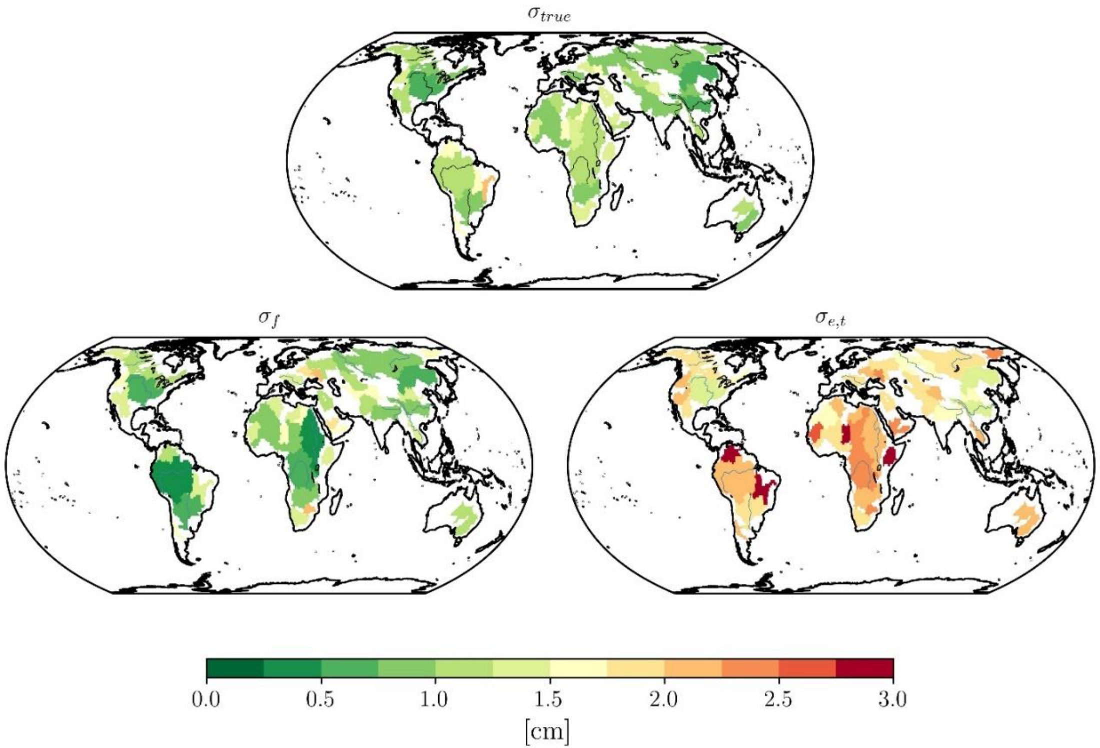
- Standard deviations of the 50 largest discharge basins

Realisation of the covariance model

Case 1:

- Tested on simulated GRACE-FO data from Flechtner et al. (2016)
- This allows validation against true uncertainty from difference between simulated TWS and input mass distributions: $\boldsymbol{\sigma_{true}}$
- Grid point standard deviations are given as the standard deviations of all residual TWS data at given time step: $\boldsymbol{\sigma_{e,t}}$
- Stokes coefficients are provided with formal errors which are variance-propagated to grid: $\boldsymbol{\sigma_{f}}$

Case 1: Basin standard deviation



- Validation by means of correlation coefficient R and global scaling factor S

	σ_f	$\sigma_{e,t}$
R	0.48	0.83
S	0.95	0.5

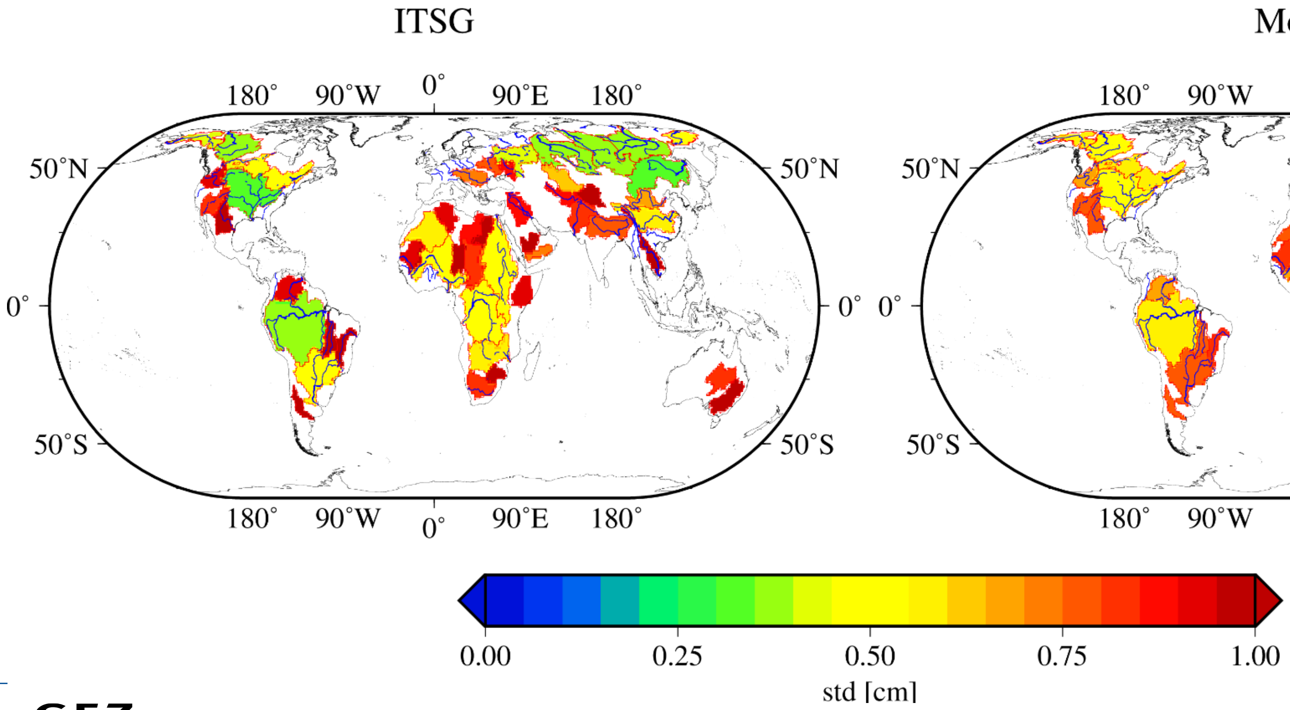
- Modelled uncertainties fit spatial pattern well but overestimate the uncertainty

Realisation of the covariance model

Case 2:

- GFZ RL06 TWS data: used for parameter estimation of covariance model and grid point standard deviations
- ITSG-Grace2018 solution as proxy for the new COST-G combination data set: Full variance-covariance matrices of Stokes coefficients are variance-propagated to grid

Case 2: Basin standard deviation



High agreement in terms of spatial pattern (R=0.84) and scale (S=0.95)

Conclusion

- New anisotropic, non-homogeneous, and non-stationary covariance model for gridded TWS data
- Covariance model represents well the spatial pattern of mean basin uncertainties in simulation environment
- High agreement in order of magnitude and spatial pattern between modelled uncertainties and uncertainties derived from full formal variance-covariance information

More details in: Boergens et al., Modelling spatial covariances for terrestrial water storage variations verified with synthetic GRACE-FO data (under revision in IJGE)

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