The **global land water storage data set GLWS** 2.0

assimilating GRACE and GRACE-FO into a global hydrological model

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MOTIVATION

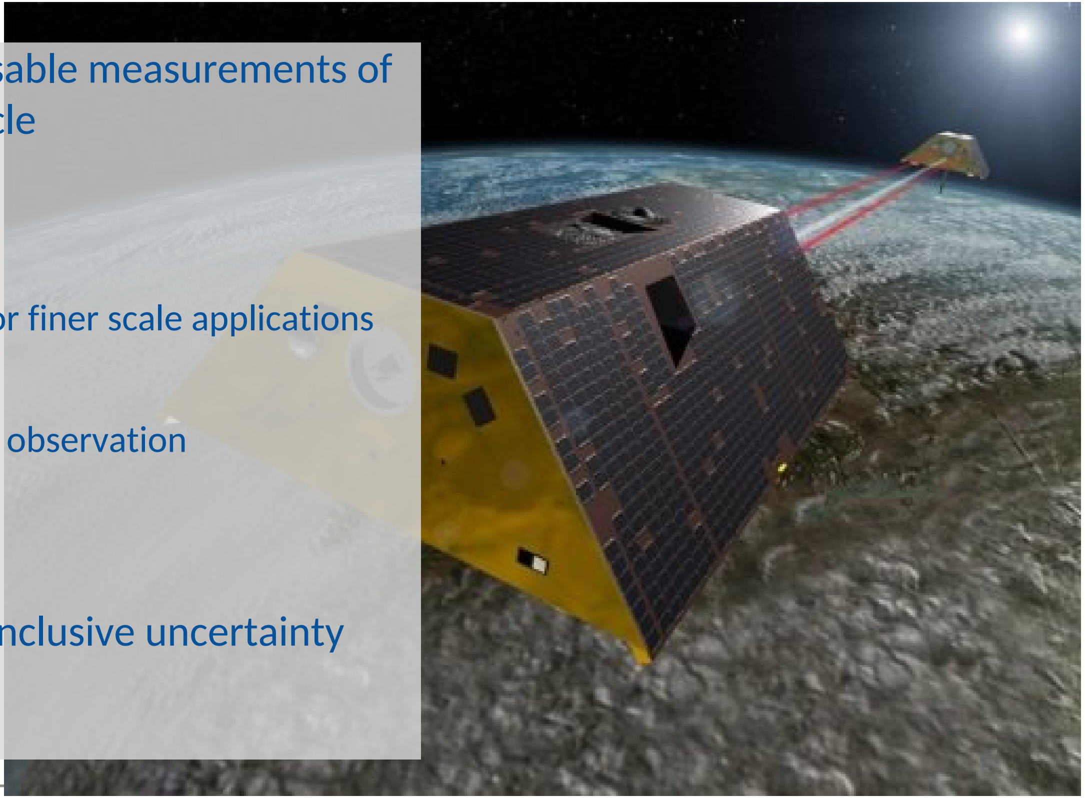
GRACE and GRACE-FO provide indispensable measurements of the global water cycle

But :

- Resolution of a few 100km is too coarse for finer scale applications
- Temporal gaps
- Separation of storages requires additional observation

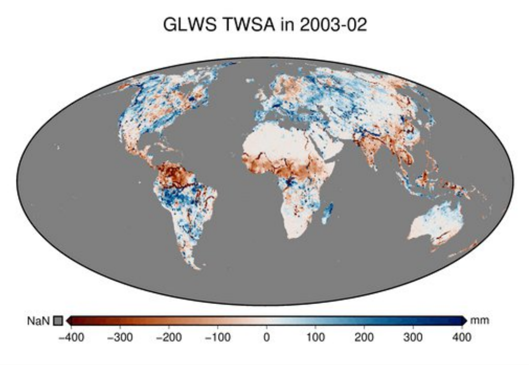
Goal:

- Provide a consistent global data set inclusive uncertainty quantification



GLWS2.0: GLOBAL LAND WATER STORAGE

A monthly global 0.5° data set from 2003 to 2019 for:



- Assimilation of global GRACE and GRACE/-FO TWSA into WaterGAP 2.2e
- Gerdener et al., submitted to Journal of Geodesy, pre-print published on Arxiv (https://arxiv.org/abs/2211.17138)
- GLWS2.0 data set published with PANGAEA

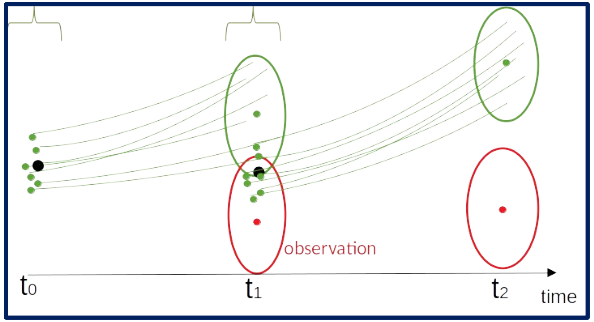
DATA ASSIMILATION FRAMEWORK

PDAF Parallel Data Assimilation Framework

- Based on Eicker et al. (2014) via Ensemble Kalman Filter (EnKF Evensen, 1996)
- Parallel Data Assimilation Framework (PDAF, Nerger and Hiller, 2013)
- Assimilate 4° GRACE TWSA global grids into the WaterGAP 2.2e version based on uncertainty information

  —> ~ 95 % of land surface except Greenland and Antarctica

- More details on PANGAEA, Gerdener et al. (2023)



PREDICTION:

$$X_k^- = [X_k^{(1)-}, \ldots, X_k^{(N)-}]$$

UPDATE:

$$X_k^+ = X_k^- + K_k (Y_k - A X_k^-)$$

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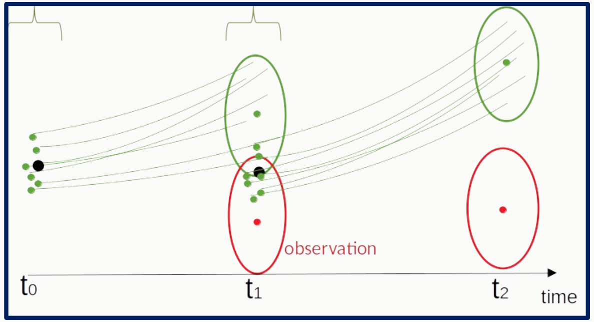

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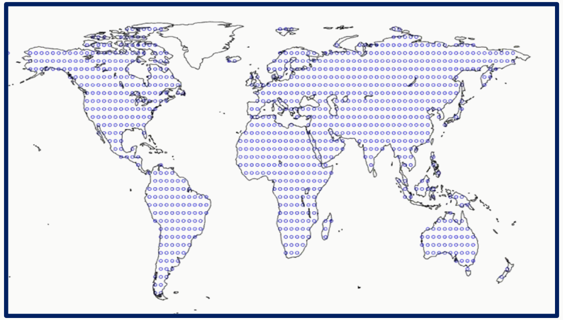
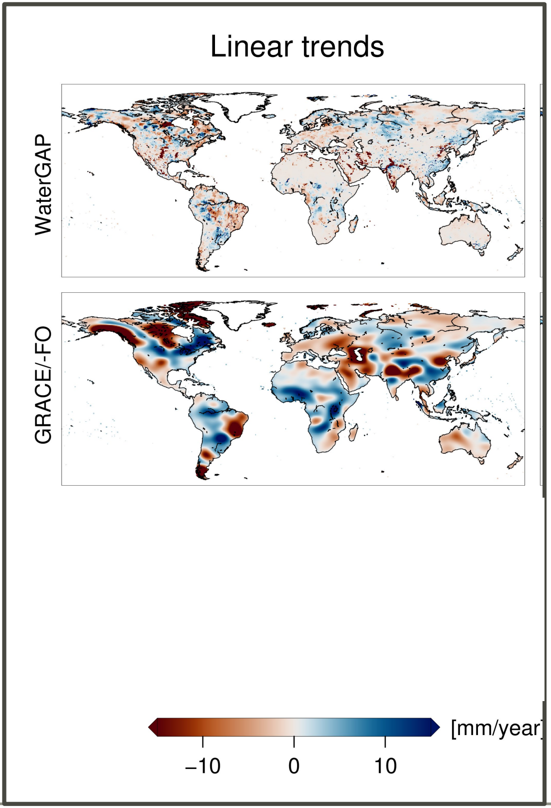
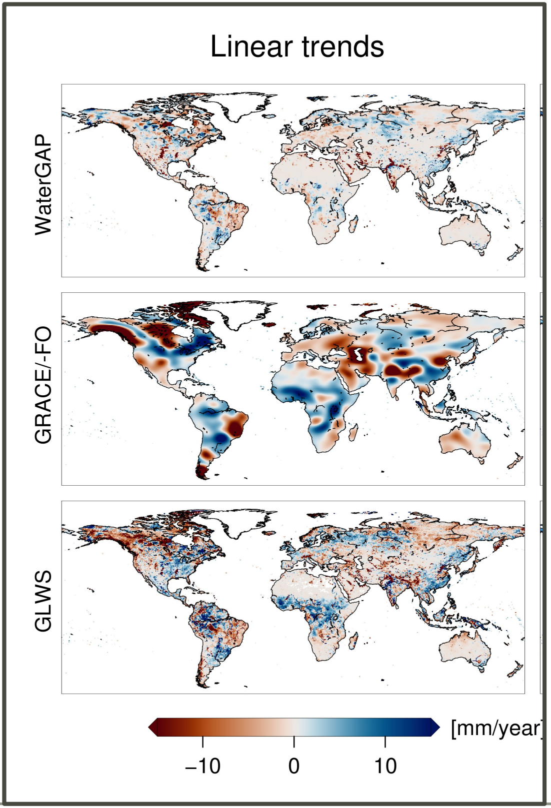


GLWS2.0: GLOBAL LAND WATER STORAGE



- Monthly fields have no temporal gaps
- Higher spatial resolution as compared to GRACE/-FO; ~ 50km (no simple statistical downscaling)
- Underestimation of simulated linear trends (Scanlon et al. (2018) in WaterGAP is improved in GLWS
- For GLWS the ensemble mean is shown

GLWS2.0: GLOBAL LAND WATER STORAGE



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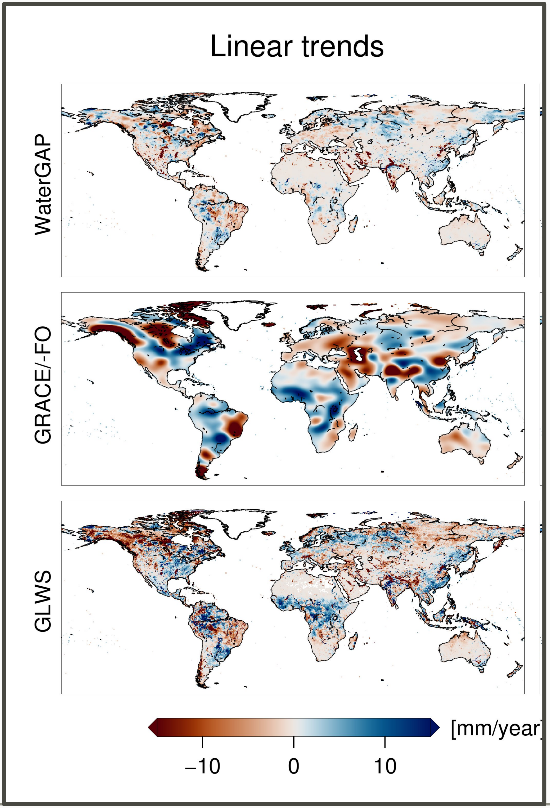

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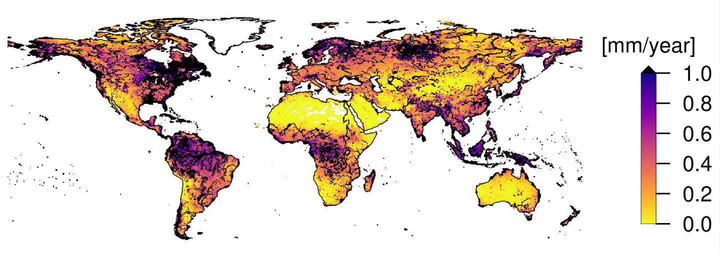
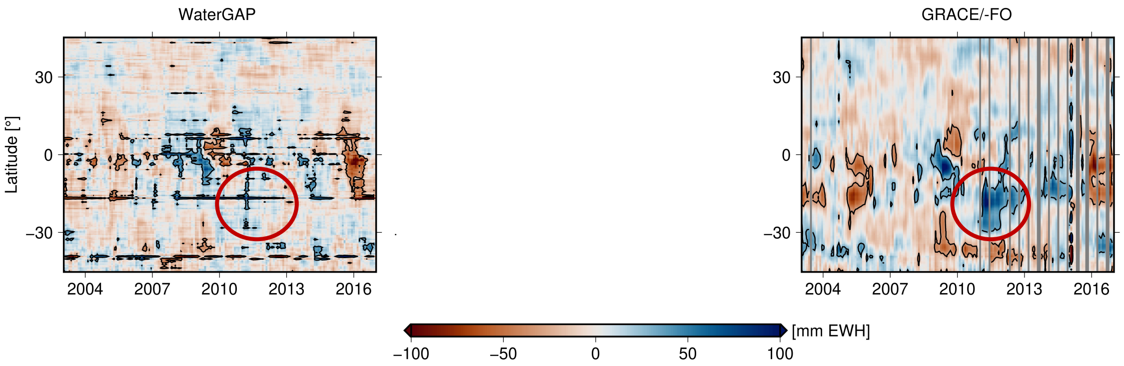
TWSA linear trend uncertainty from ensemble



TRENDS AND NON-SESAONALITY

- Nonseasonal TWSA from GLWS: latitude-averaged vs. Time (compare Tapley et al., 2019)
- Contains all major extreme events that are given in GRACE/-FO as well
- GLWS shows La Nina event in 2010-2012 with more spatial-temporal extent



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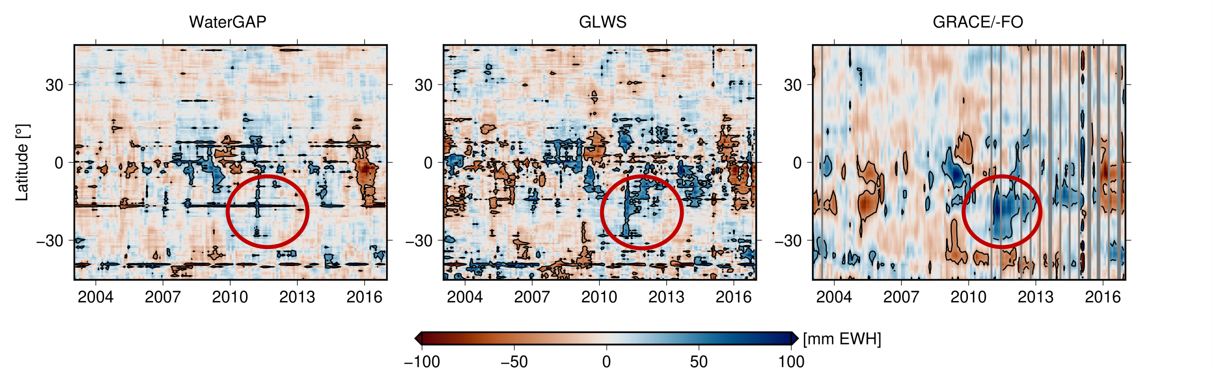
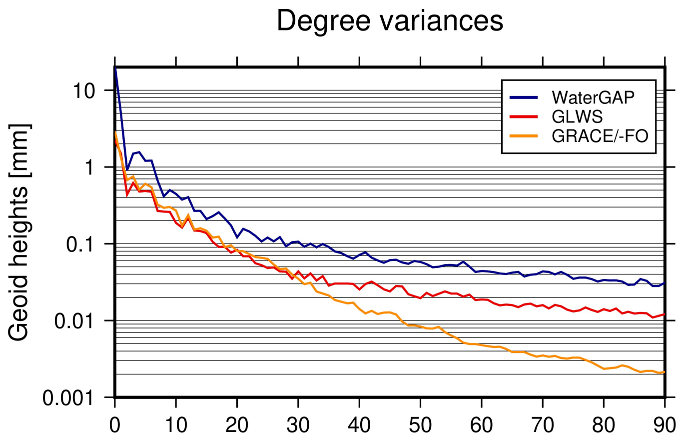


ANALYSIS IN SPECTRAL DOMAIN

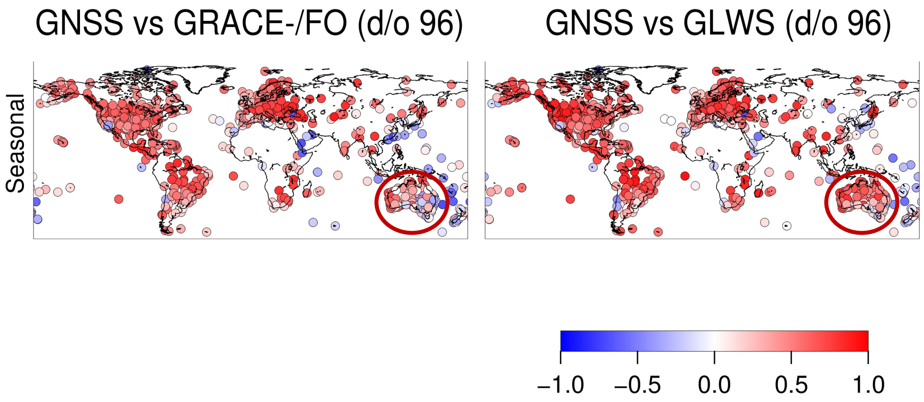
- Power spectrum of GLWS, WaterGAP and GRACE/-FO
- Note: projecting grids to spherical harmonic coefficients (land mass only, Greenland and Antarctica excluded)
- Smooth transition in spectral domain, example August 2010:



VALIDATION WITH GNSS

Correlations of GLWS with 1030 GNSS stations

- Vertical displacements
- Signal separated into sub-signals
- Improvement correlation in all band, e.g.:
  - Australia, seasonal signal



IGS, repro-3 solution, NTAL and NTOL removed with predictions of Vertical displacement by GFZ, detrended

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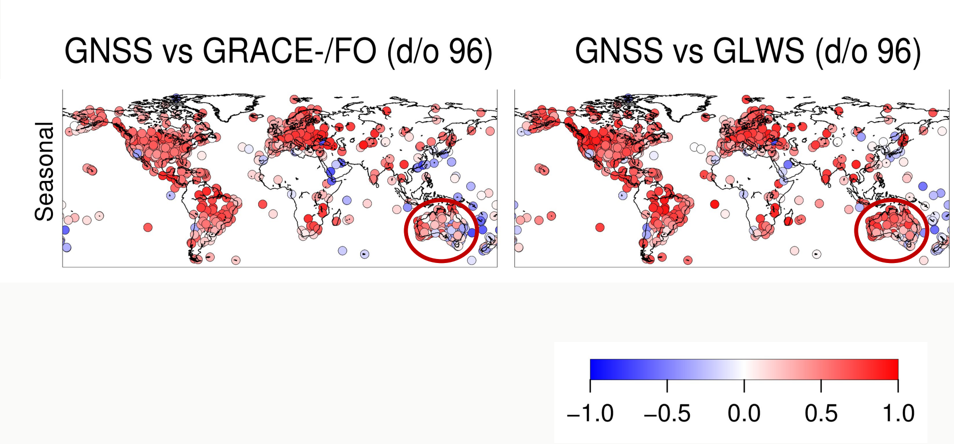

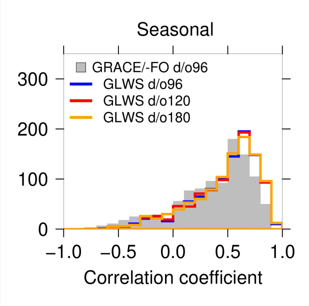

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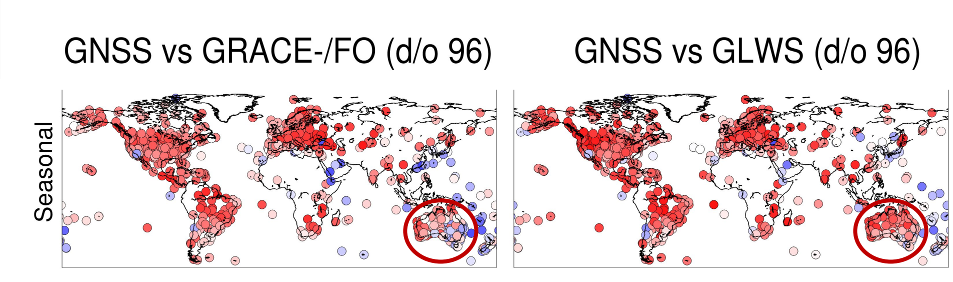

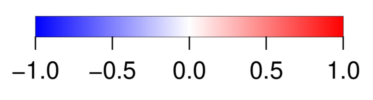

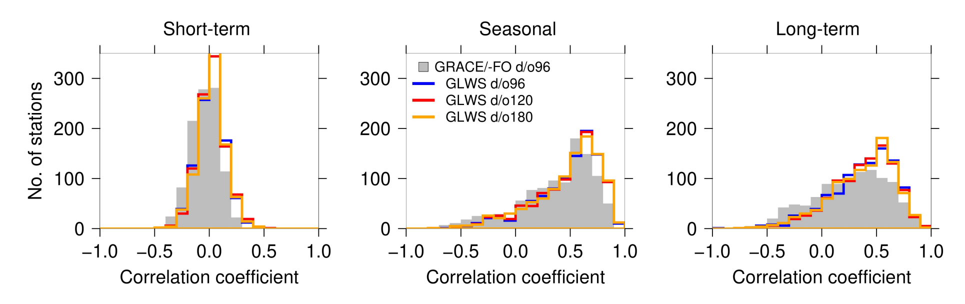

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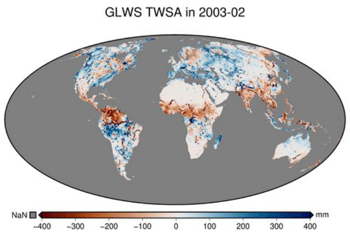
TAKE HOME & OUTLOOK



1) **G**lobal **L**and **W**ater **S**torage (GLWS) 2.0:
new 0.5° monthly data set via global assimilation of GRACE/-FO TWSA into WaterGAP

2) GLWS seems to fit better to GNSS than GRACE/-FO
evaluation ongoing for hydrology, drought applications, extension of framework (localization techniques, daily outputs, calibration and assimilation)

3) Freely available on Pangaea:
Application and evaluation in your research will help to improve
(https://doi.pangaea.de/10.1594/PANGAEA.954742)

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LITERATURE

Eicker, A., Schumacher, M., Kusche, J., Döll, P., & Schmied, H. M. (2014). Calibration/data assimilation approach for integrating GRACE data into the WaterGAP Global Hydrology Model (WGHM) using an ensemble Kalman filter: First results. Surveys in Geophysics, 35(6), 1285-1309.

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Scanlon, B. R., Zhang, Z., Save, H., Sun, A. Y., Schmied, H. M., Van Beek, L. P., ... & Bierkens, M. F. (2018). Global models underestimate large decadal declining and rising water storage trends relative to GRACE satellite data. Proceedings of the National Academy of Sciences, 115(6), E1080-E1089.

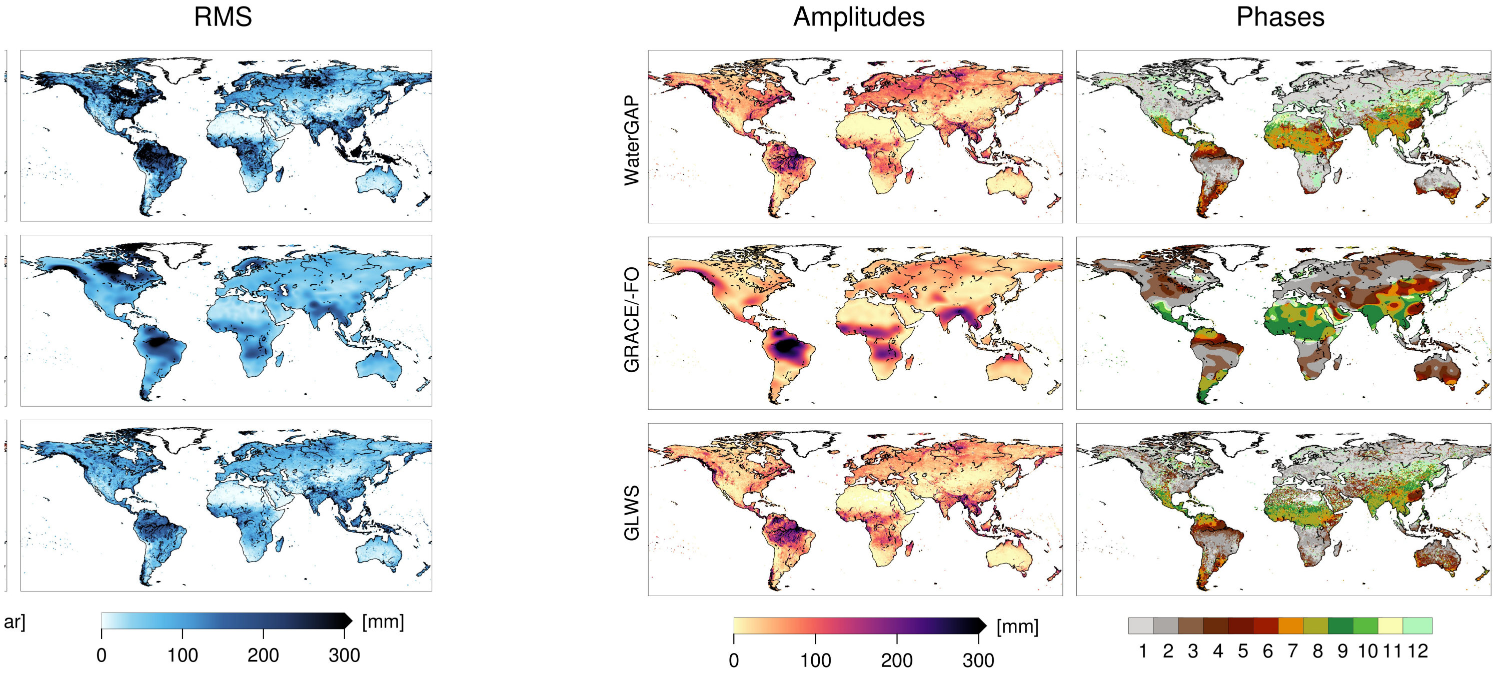
This work is part of the GlobeDrought and the GlobalCDA projects

Global CDA

Globe Drought GRoW - GlobeDrought Characterizing drought risk and impact

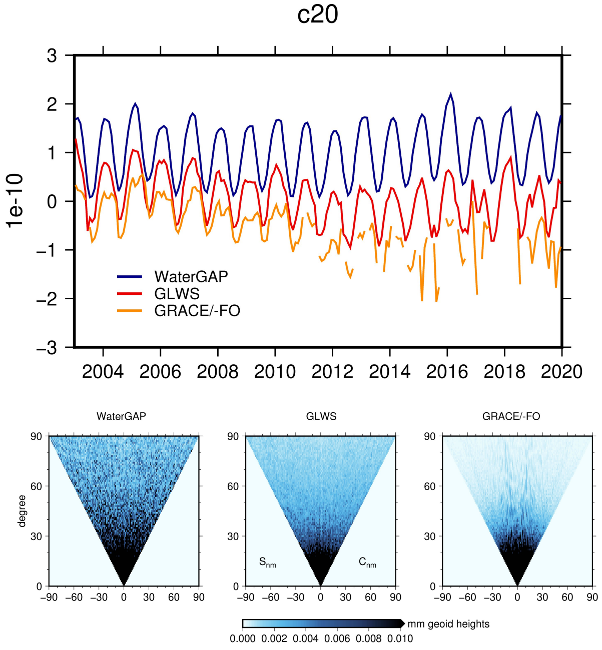
APPENDIX

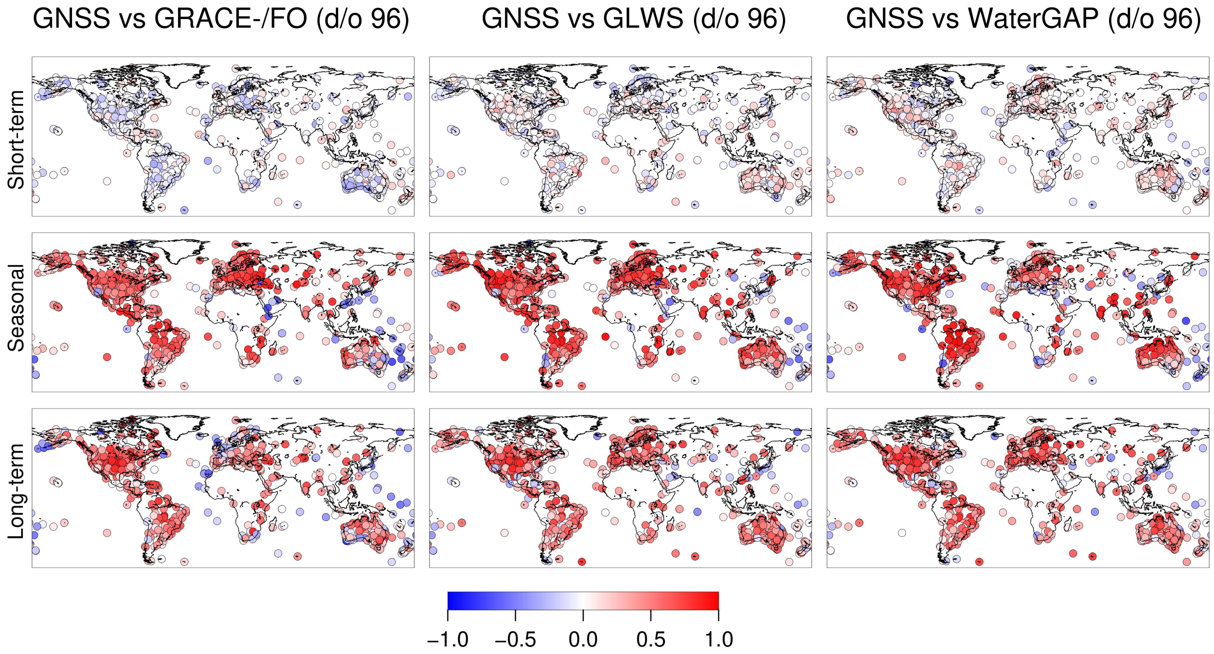
– RMS, Annual amplitudes, and annual phases



APPENDIX

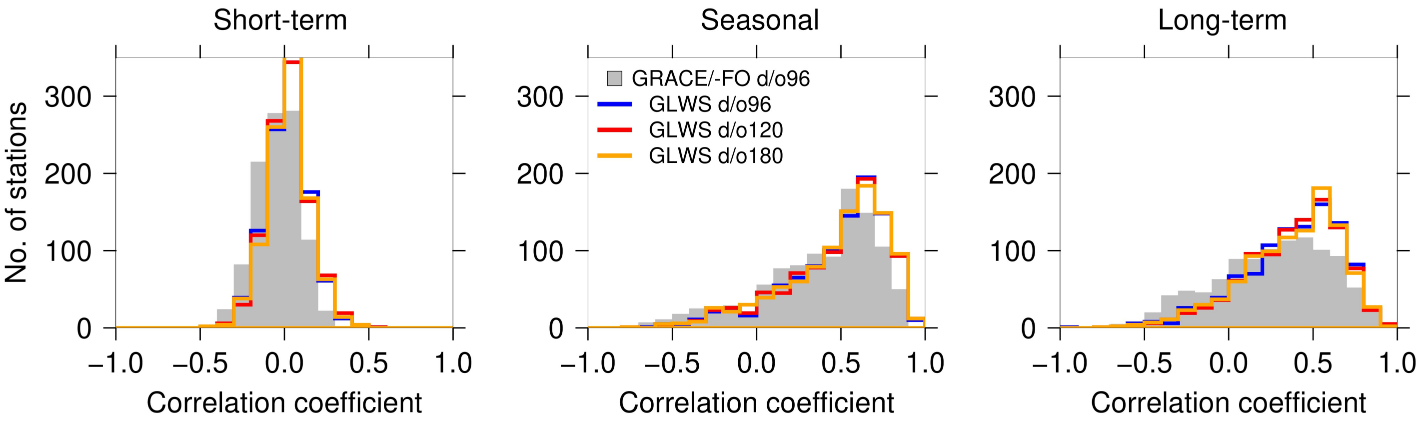
– Degree 20 and GNSS comparison to WaterGAP (d/o 96)





VALIDATION WITH GNSS

- Improvement of correlation with GLWS compared to GRACE/-FO in all temporal bands
- Minor changes between varying maximum d/o



APPENDIX

– Comparison GNSS and GLWS for degrees 120 and 180