University of Bremen

CENTER OF APPLIED SPACE TECHNOLOGY AND MICROGRAVITY

ZARM

EGU24 G4.1 - SATELLITE GRAVIMETRY

GRACE-FO gravity-field results incorporating the ZARM accelerometer transplant based on high-precision environment modeling

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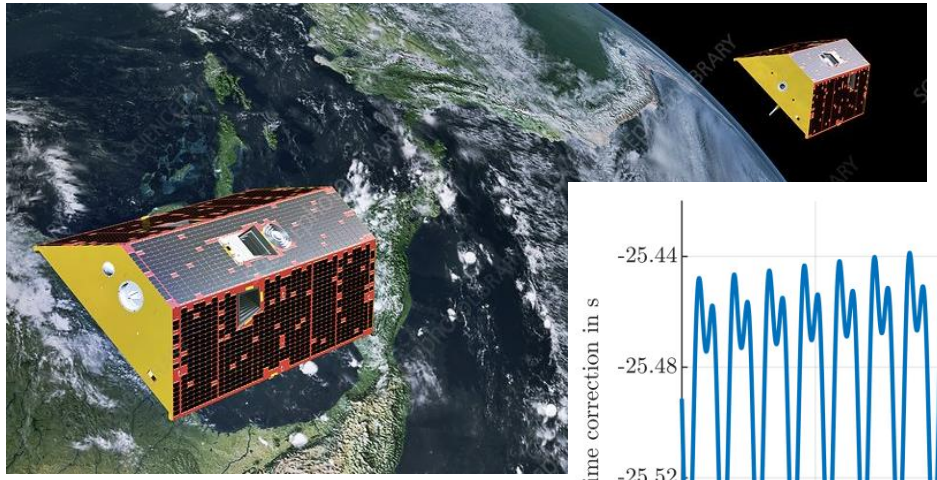
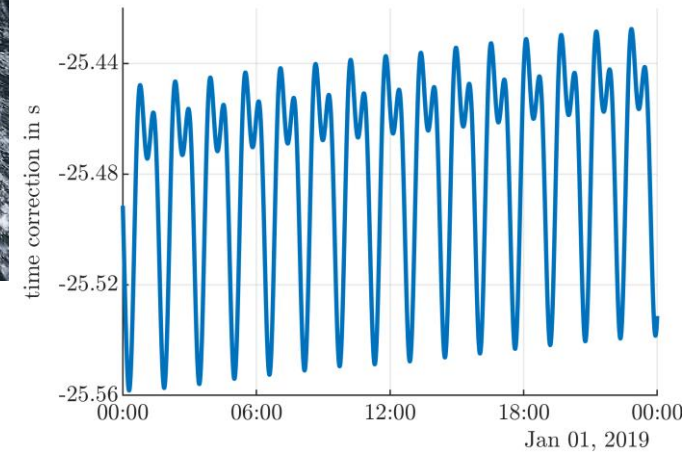
Vienna, 18 April 2024

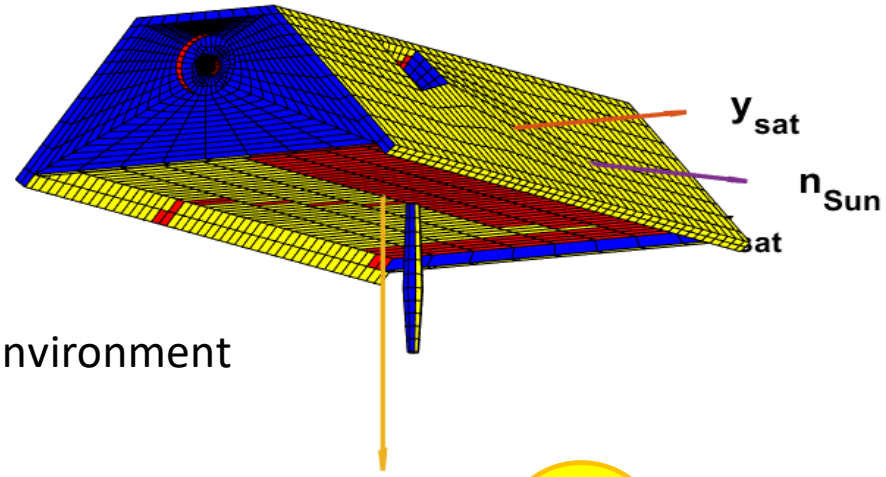
Motivation

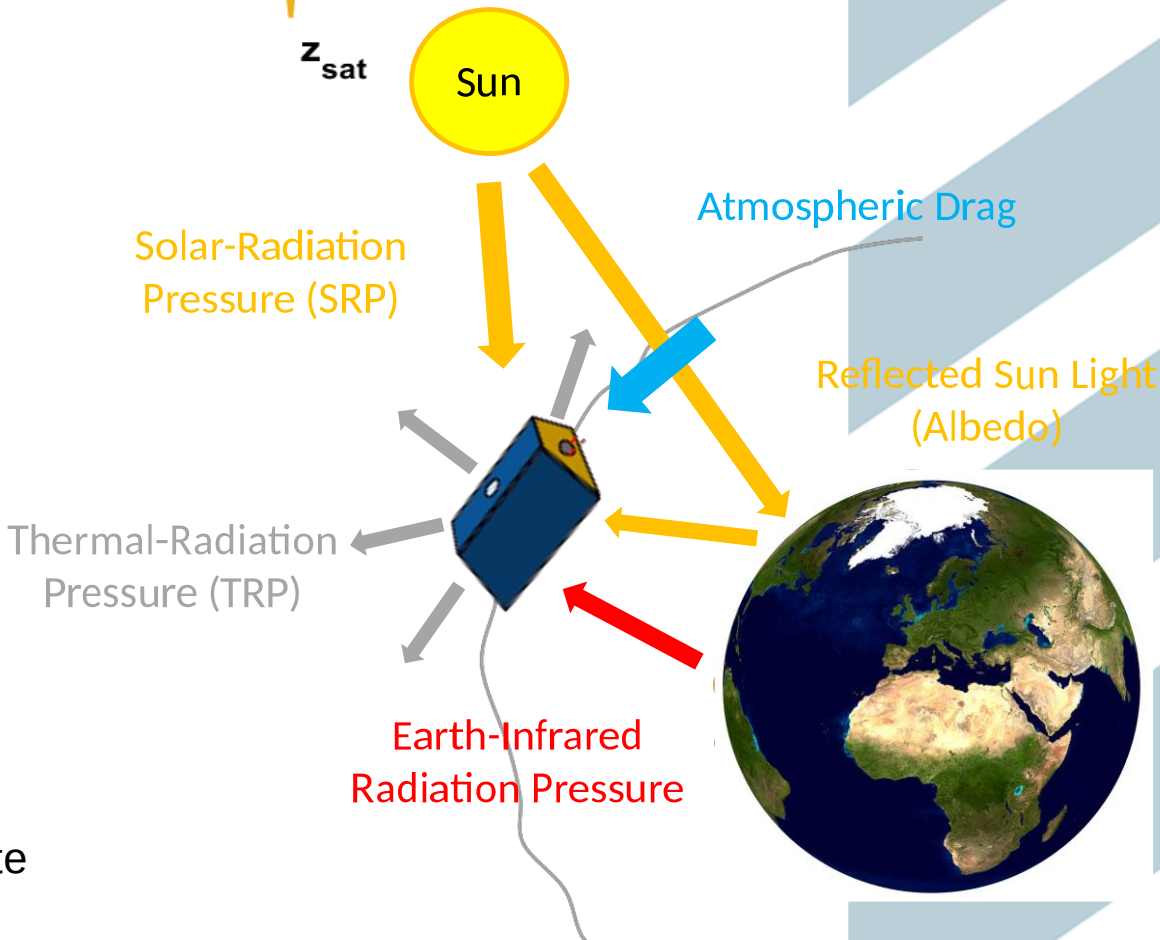
- Accelerometer data recovery through high-precision environment modeling
- Drag model limiting factor
- Physically motivated transplant





Time correction between satellite 1 and 2 for one day





Transplant

- Estimation of density at positions of GRACE-C and time-correction to GRACE-D positions
- $\vec{a}_{drag} = ACT - \vec{a}_{mod,\,rad}$
- Atmospheric density ρ follows from:
- $\vec{a}_{drag} = \frac{1}{2}\,\rho\, C_D\, A_{proj} |\,\vec{v}_{inc}|\vec{v}_{inc}$
- ACT data need to be calibrated

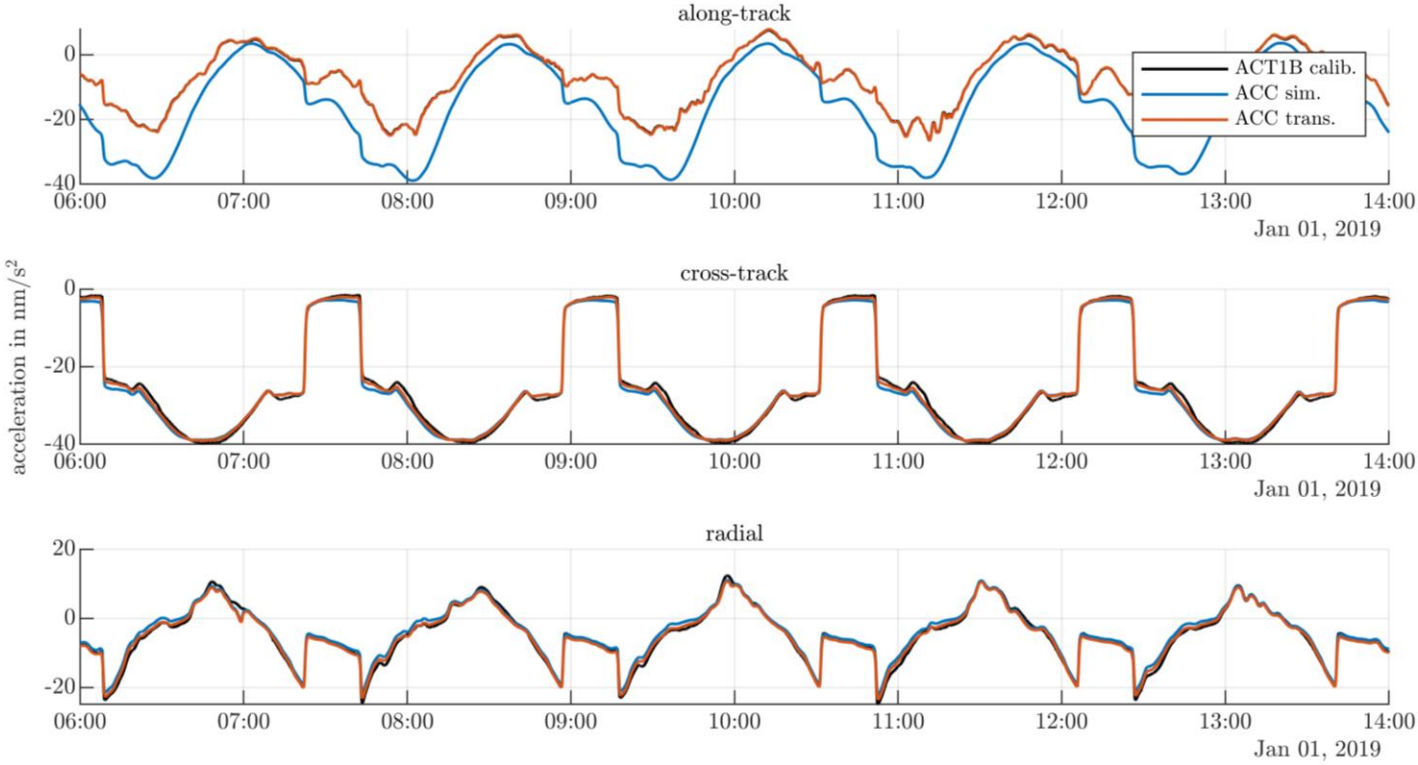


Figure 1: Comparison of simulated accelerations and calibrated ACT1B data for January 1. 2019

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Transplant

- Minimalistic approach
- Estimation of density at positions of GRACE-C and time-correction to GRACE-D positions
- $\vec{a}_{drag} = ACC - \vec{a}_{mod,\,rad}$
- Atmospheric density ρ follows from:
- $\vec{a}_{drag} = \frac{1}{2}\,\rho\, C_D\, A_{proj} |\,\vec{v}_{inc}|\vec{v}_{inc}$
- ACC data need to be calibrated

- For low solar activity basically only effect in along-track
- For high solar activity increased effect also in cross-track

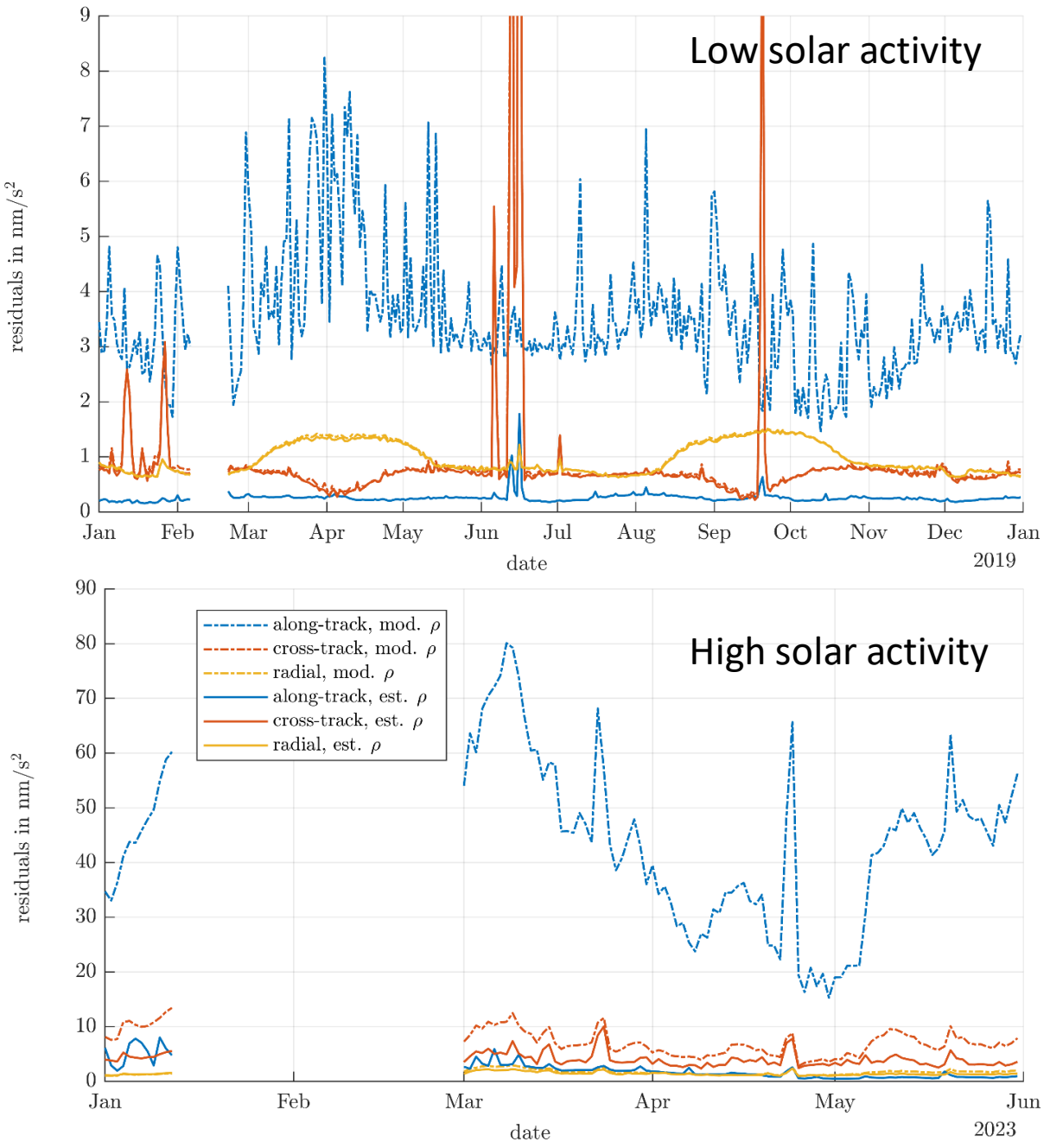

Figure 3: Residuals of ZARM simulation and transplant data to ACH for GRACE-D for 2019 and 2023

Calibration for Transplant

- Calibration of JPL ACT for GRACE-C
- External calibration parameters from POD
  - Const. scale vector **s**
  - Three hourly const. bias vector **b**
  - No fitting of modelling errors
- Additional calibration of cross-track (y) and radial (z) direction
  - improves limitations of POD parameters

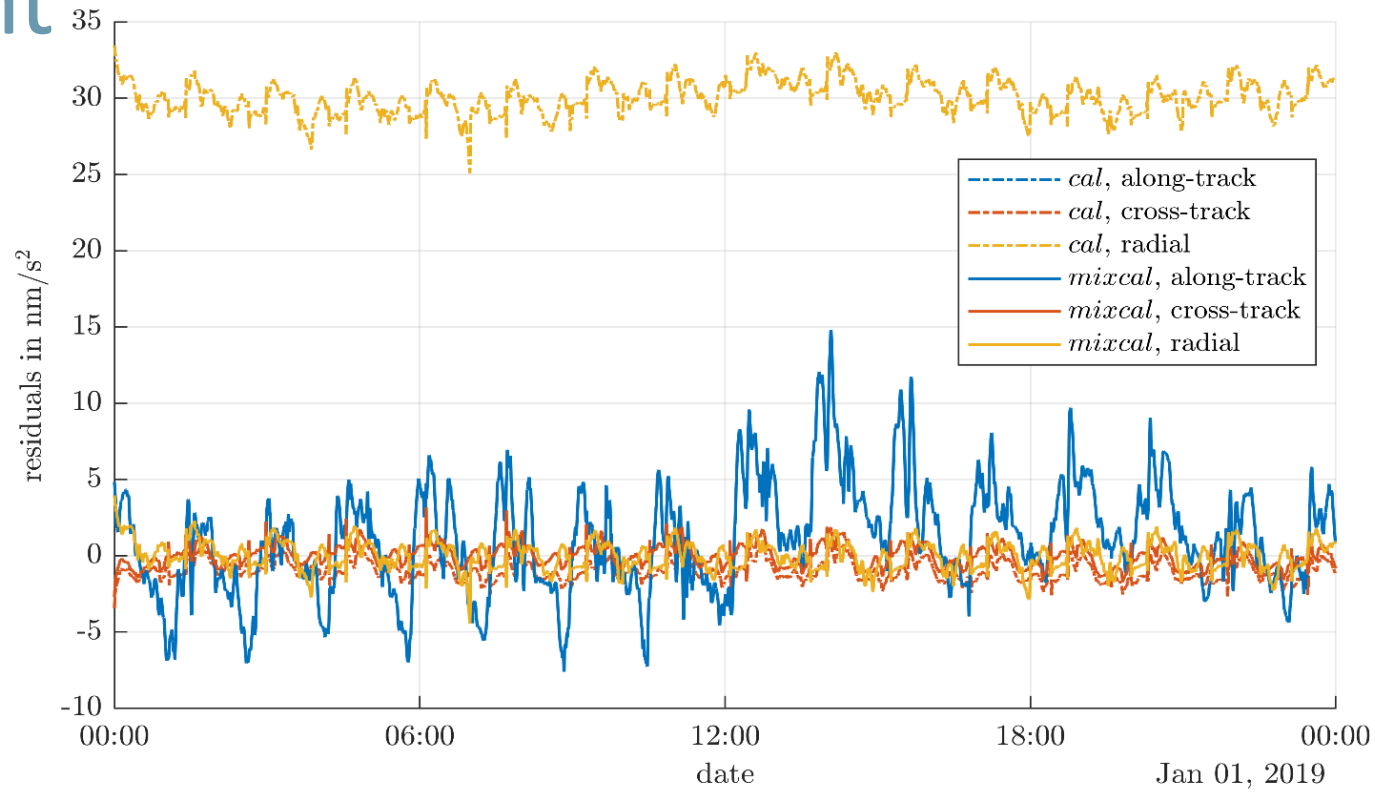

Figure 2: Residuals of ACT to simulated data after POD calibration and additional simulation calibration for January 01 2019

Comparison to other Transplants

- Solutions with GROOPS
  - ZARM Transplant and modeled data
  - JPL Transplant
  - TUG Transplant
- Official solution
  - ITSG

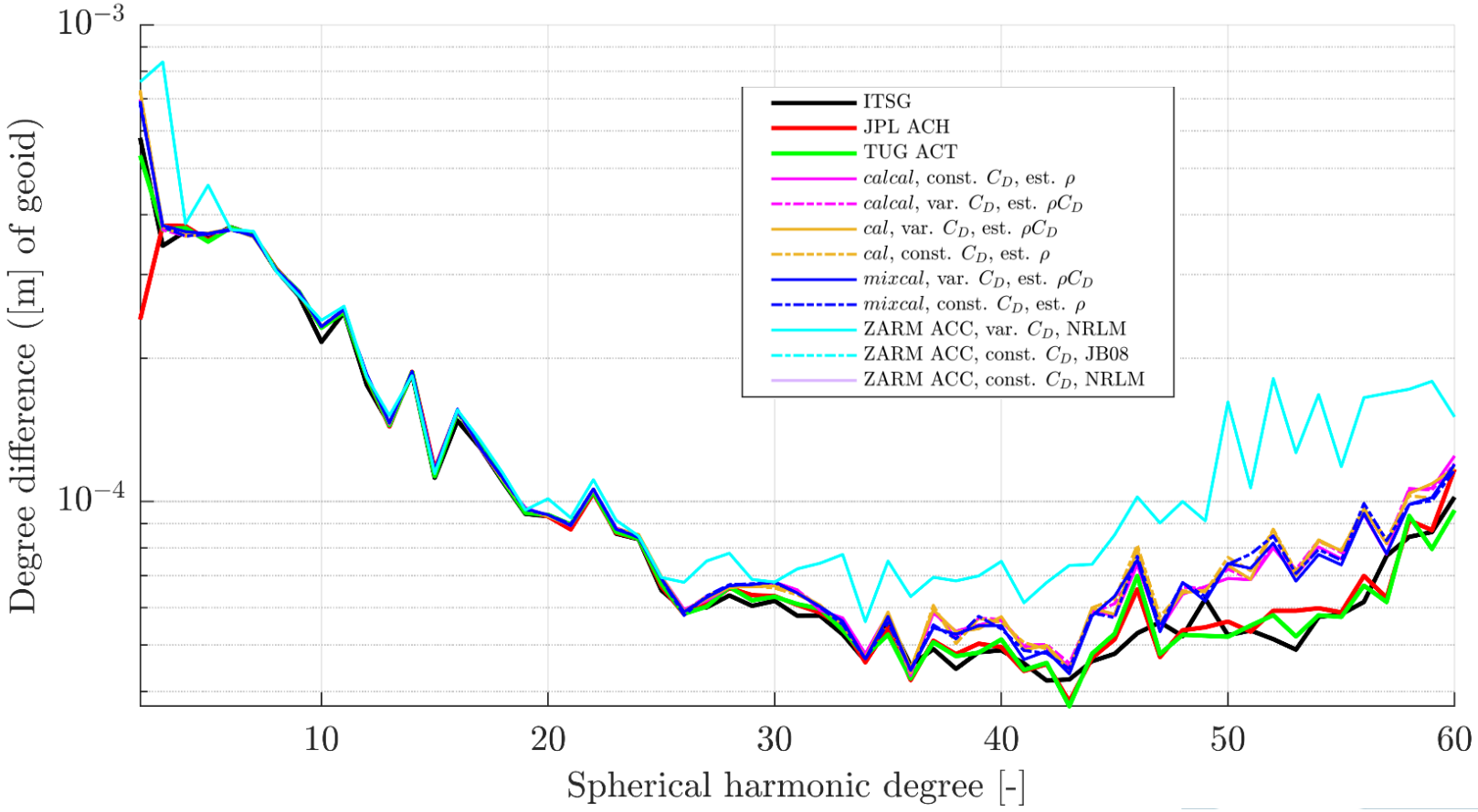

Figure 4: 2019 mean degree difference of transplant results w.r.t. mean 2019 GOCO06s

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Validation of Transplant

- Comparison to transplant of TUG
- Only systematic errors
  - J2
  - Higher degrees
- Validation of our transplant procedure

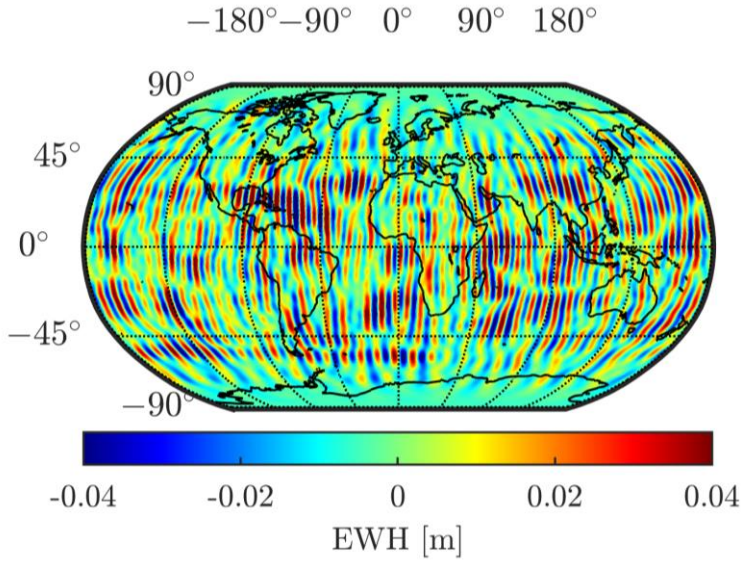
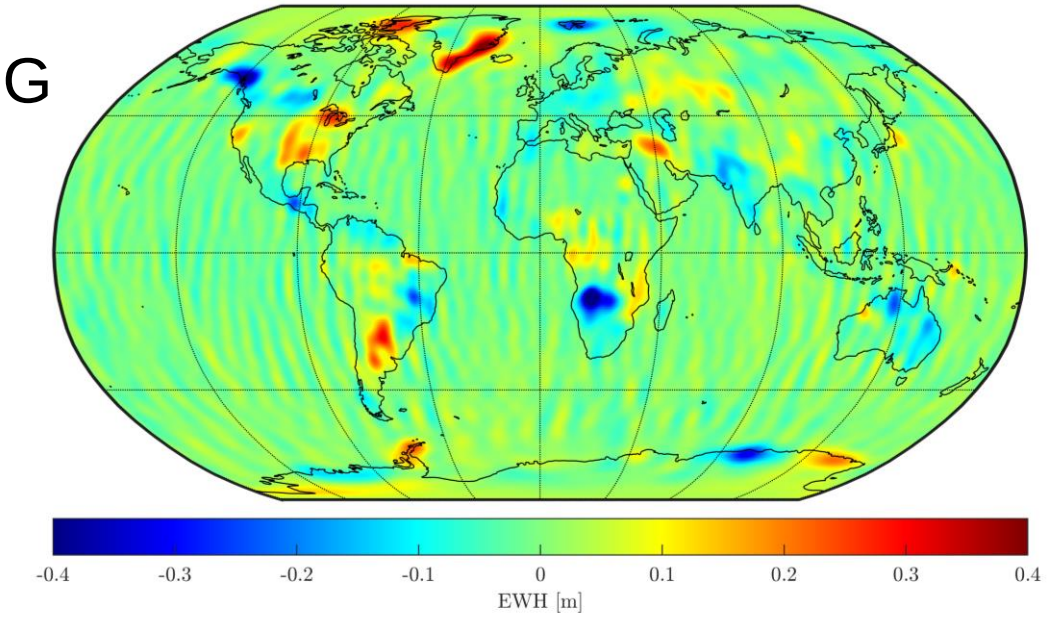


Figure 5: 2019 mean difference of ZARM and TUG transplant results in terms of EWH.

TUG



ZARM

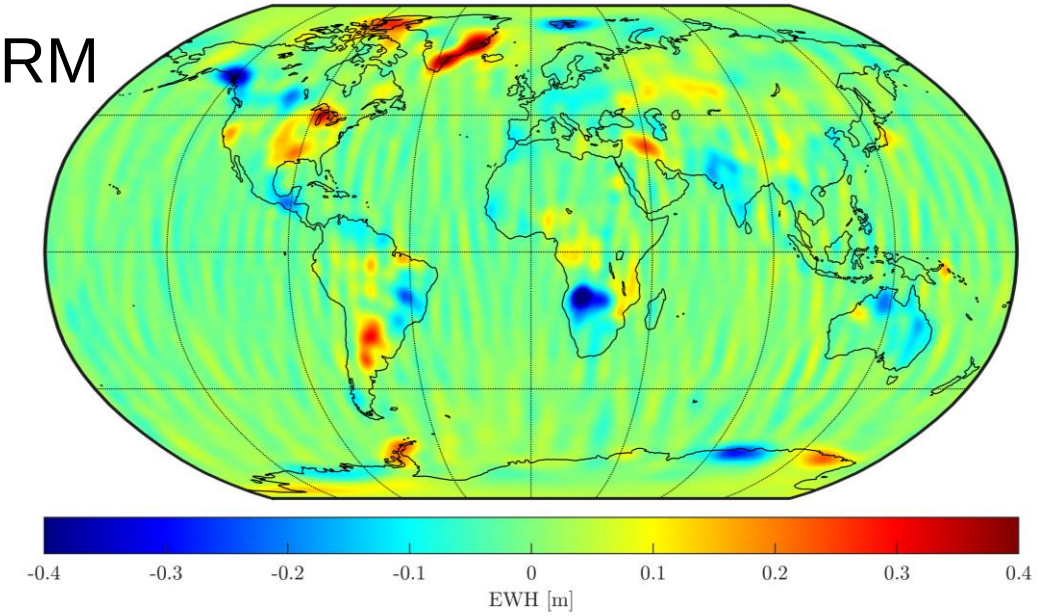


Figure 6: 2019 mean results in terms of EWH w.r.t. mean 2019 GOCO06s

Low and high solar activity periods

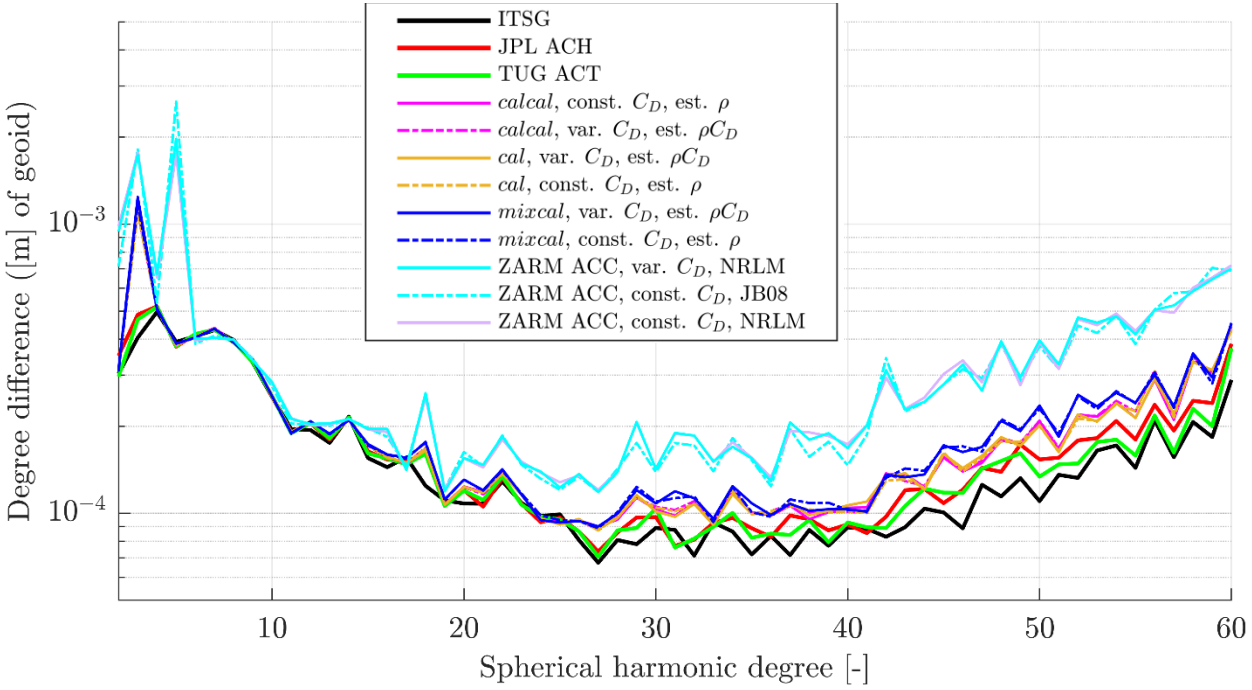


Figure 7: January 2019 degree difference of transplants w.r.t. mean 2019 GOCO06s

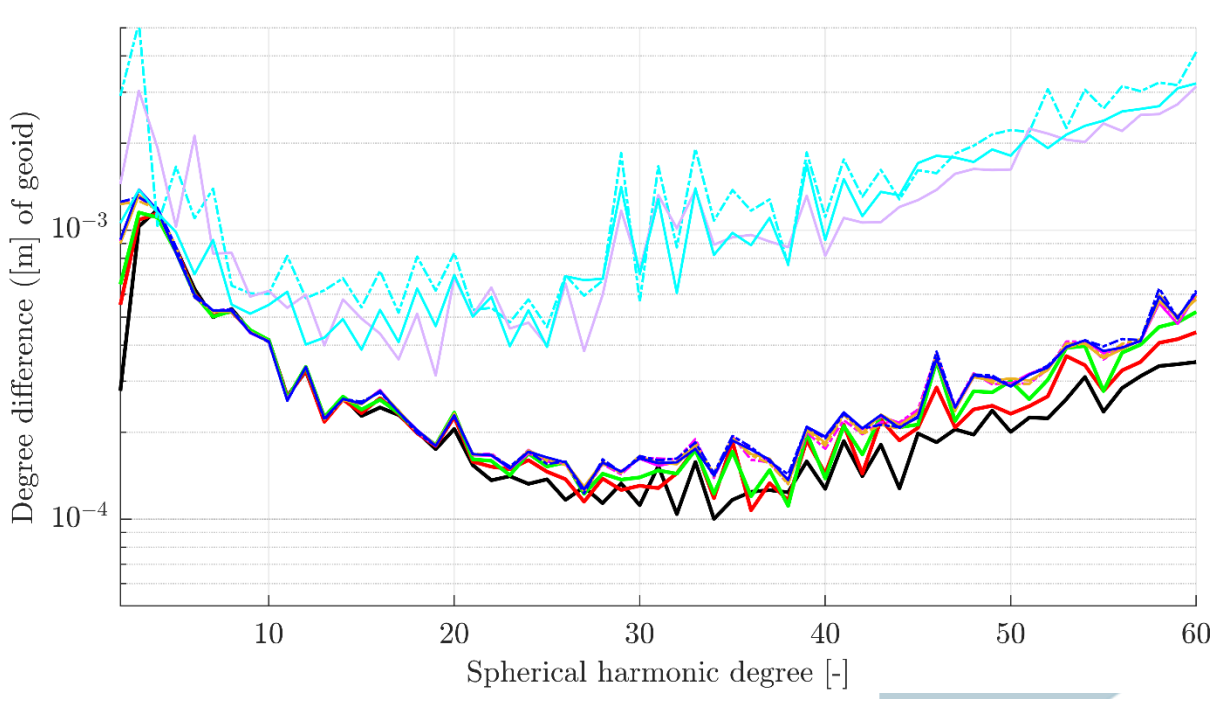
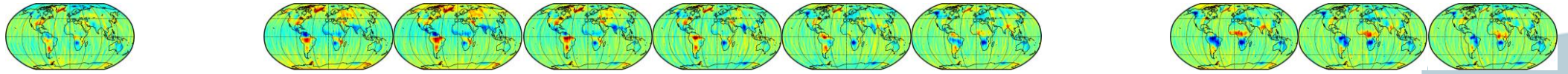
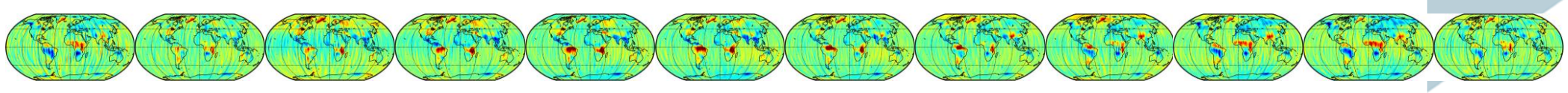
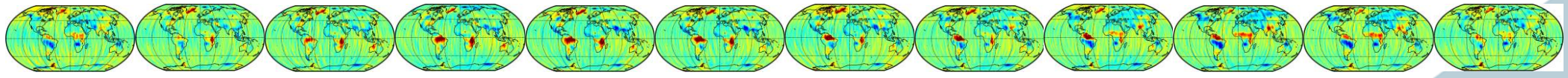
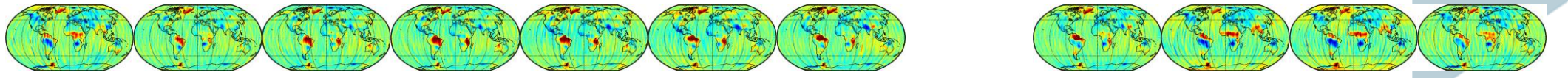
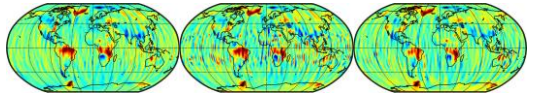


Figure 8: May 2023 degree difference of transplants w.r.t. mean 2023 GOCO06s

Monthly Gravity Fields

- 2019 
- 2020 
- 2021 
- 2022 
- 2023 

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Publication of Data

- https://zarm.uni-bremen.de/zarm_daten/
  - GRACE-D Accelerometer Transplant
  - GRACE-C/D Modeled Radiation Acceleration
  - Estimated Density + complementary data
  - Monthly gravity fields
  - Paper published: https://doi.org/10.1016/j.asr.2024.03.068

```
   COLUMN  1: GPS time [s] - Continuous seconds past 01-Jan-2000 11:59:47 UTC
   COLUMN  2: Satellite ID [-]
   COLUMN  3: acceleration x [m/s^2]
   COLUMN  4: acceleration y [m/s^2]
   COLUMN  5: acceleration z [m/s^2]
# END OF HEADER
599572800 D -1.764162323244558e-08 -2.207747093966789e-08 -7.448168274818788e-09
599572801 D -1.765571410849392e-08 -2.200691521717946e-08 -7.439417660225845e-09
599572802 D -1.766950249255106e-08 -2.193424072768702e-08 -7.430215815176617e-09
599572803 D -1.768333971947378e-08 -2.187034288166556e-08 -7.422143707492660e-09
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599572806 D -1.772986779336325e-08 -2.187731047212518e-08 -7.426118943968856e-09
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   COLUMN  2: Satellite ID [-]
   COLUMN  3: SRP acceleration x [m/s^2]
   COLUMN  4: SRP acceleration y [m/s^2]
   COLUMN  5: SRP acceleration z [m/s^2]
   COLUMN  6: ALB acceleration x [m/s^2]
   COLUMN  7: ALB acceleration y [m/s^2]
   COLUMN  8: ALB acceleration z [m/s^2]
   COLUMN  9: IR acceleration x [m/s^2]
   COLUMN 10: IR acceleration y [m/s^2]
   COLUMN 11: IR acceleration z [m/s^2]
   COLUMN 12: TRP acceleration x [m/s^2]
   COLUMN 13: TRP acceleration y [m/s^2]
   COLUMN 14: TRP acceleration z [m/s^2]
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Thank you!

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References

[1] Bandikova, T., McCullough, C., Kruizinga, G. L., Save, H., & Christophe, B. (2019). GRACE accelerometer data transplant. Advances in Space Research, 64(3), 623–644.

[2] Sentman, L.H. (1961). Free Molecule Flow Theory and its Application to the Determination of Aerodynamic Forces.

[3] Doornbos,E. (2010). Thermospheric Density and Wind Determination from Satellite Dynamics