GRACE-FO accelerometer data recovery within ITSG-Grace2018 data processing

Saniya Behzadpour, Torsten Mayer-Gürr, Andreas Kvas, Sandro Krauss, Sebastian Strasser, and Barbara Süsser-Rechberger

Institute of Geodesy
Graz University of Technology

EGU General Assembly, Vienna

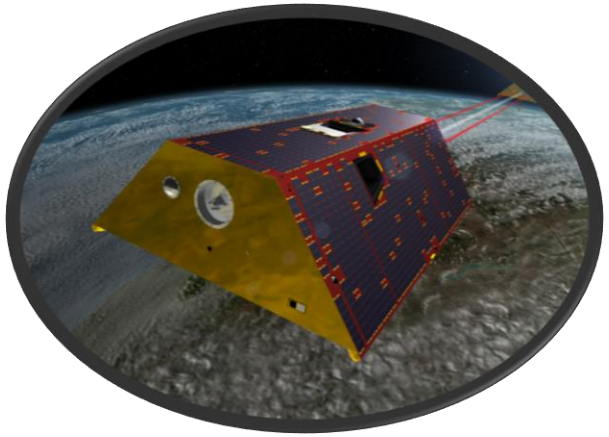
2020-05-08

Operational ITSG-Grace2018

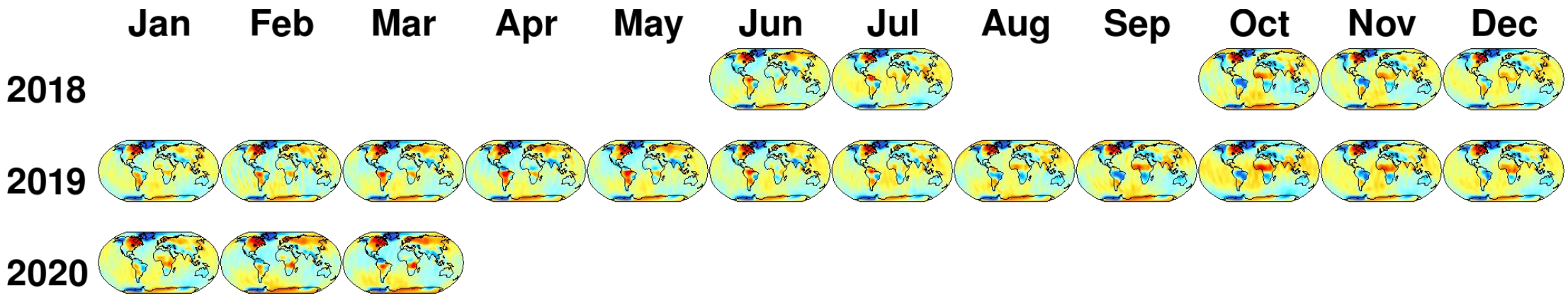
- ITSG-Grace series of gravity field solutions are computed at Institute of Geodesy, Graz University of Technology.

- **ITSG-Grace2018 GRACE-FO** solutions available since November 15, 2019.
  - Unconstrained monthly solutions: degree/order 60, 96, 120.

- **Differences from GRACE processing:**
  - Updated background models,
  - Revisited parameterization,
  - **In-house ACT1B products for GRACE-D**



GRACE-FO mission, Source: NASA.

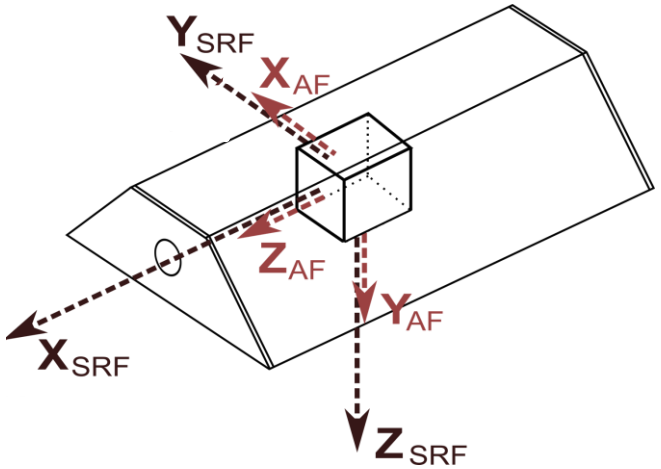


ITSG-Grace2018 GRACE-FO monthly solutions.

GRACE Follow-On Accelerometer

- **Instrument**
  - Three-axis ultra-sensitive electrostatic accelerometer (ONERA)
  - **Two high-sensitive axes:** along-track, radial
  - **One less-sensitive axis:** cross-track

- **ACC Level-1A data:**
  - Large spikes on the measurement, Known as Phantom Accelerations,
  - Improper response at thruster firing,
  - Degradation of GRACE-D since mode change on June 21, 2018,



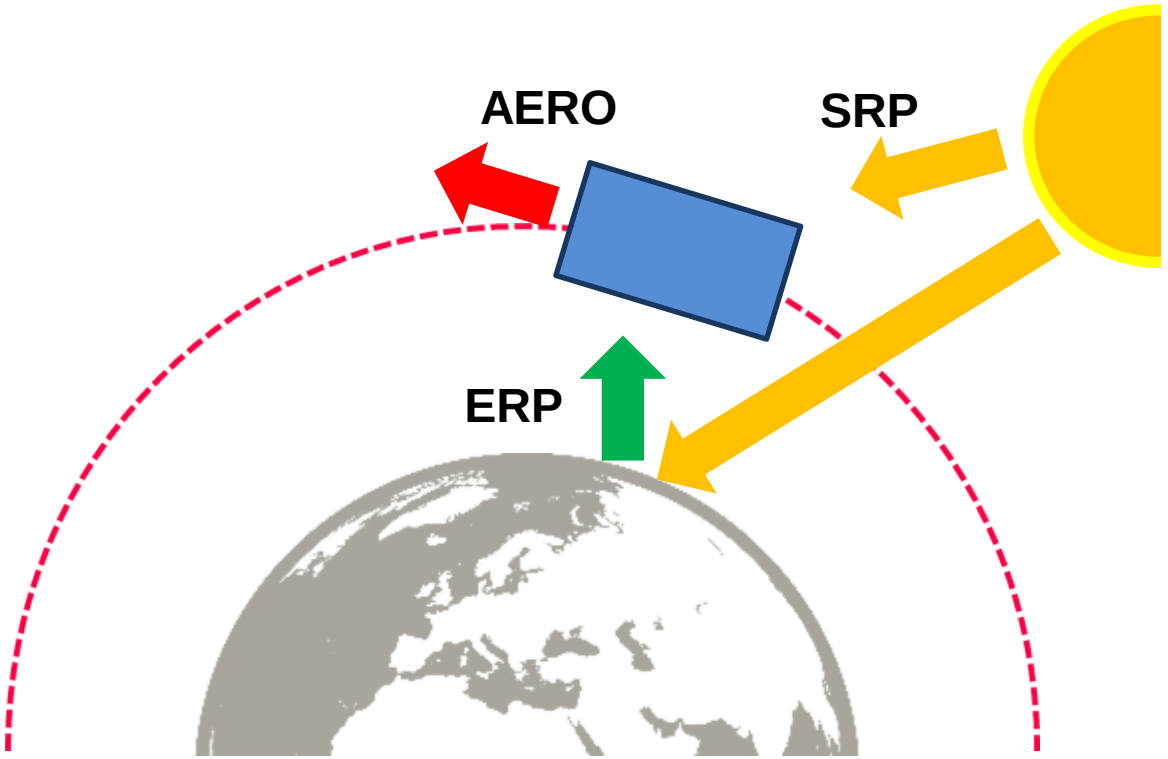
ACC frame vs. Satellite referance frame.

- **ACT products: Calibrated Accelerometer Data** (McCullough et al., 2019)
  - Model-based thruster responses for GRACE-C and GRACE-D,
  - **GRACE-D:** after 2018-06-21 accelerometer transplant data from GRACE-C (Bandikova et al. , 2019) .

Accelerometer measurments

- **Non-gravitational forces**
  - Aerodynamic force,
  - Solar radiation pressure (SRP),
  - Earth radiation pressure (ERP),
  - Thermal radiation pressure (TRP).

- **Disturbances due to satellite's operation/environment**
  - Thruster spikes,
  - Phantom Accelerations,
  - Magnetic torques spikes,
  - …

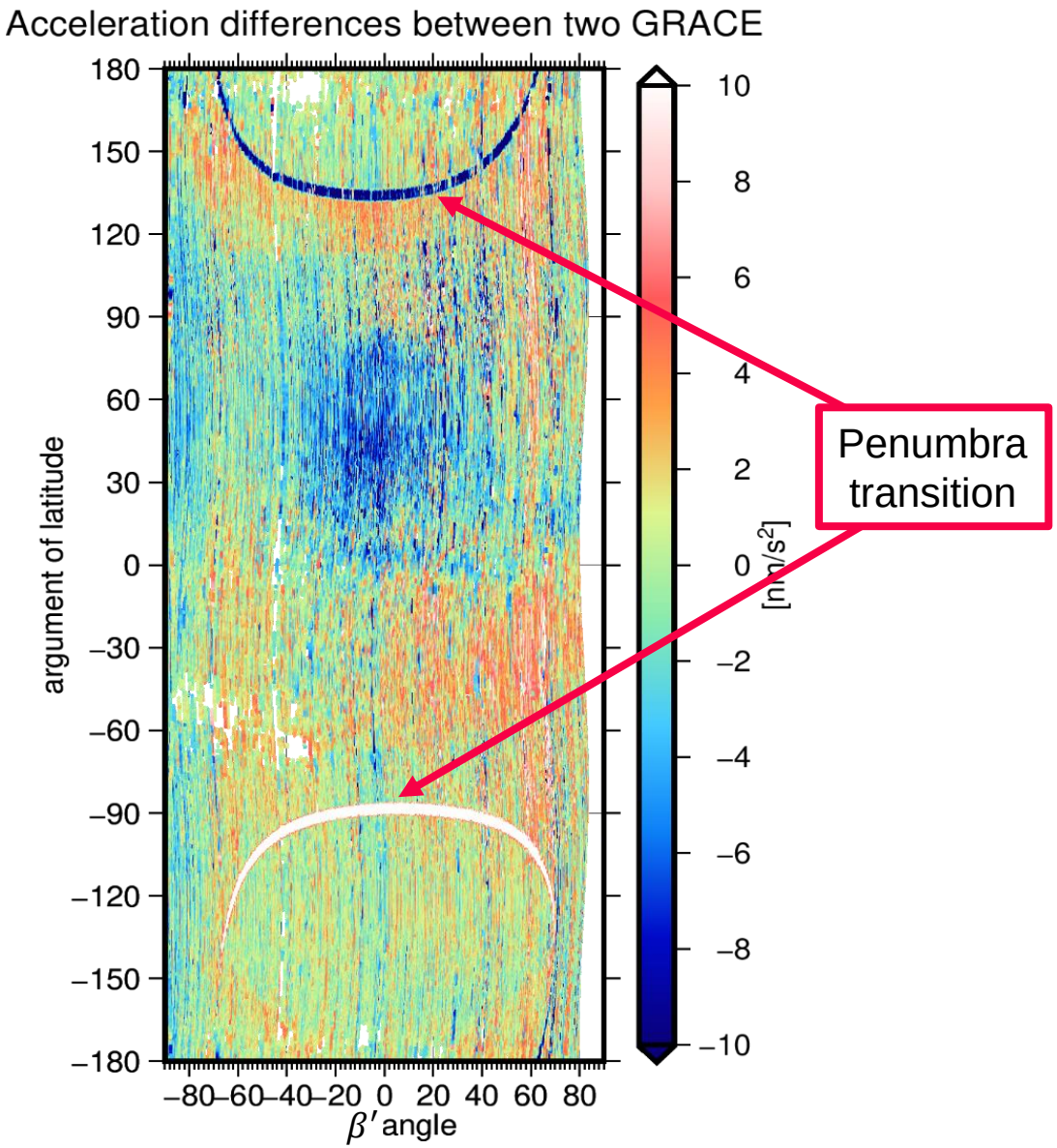


Non-gravitational forces acting on a satellite.

GRACE accelerometer measurments

- **GRACE-Like mission:** Co-orbiting of two satellites,
  - Both satellites are expected to experience the same forces at the same position.
- **GRACE:** Average difference between two ACC measurements in 2007 after applying time and attitude corrections: $3\mathrm{nm}/s^2$
  - Penumbra Transitions of satellites,
  - Low β' angle: More fluctuation in atmosphere density in direct sunlight condition (Meyer et al., 2012).

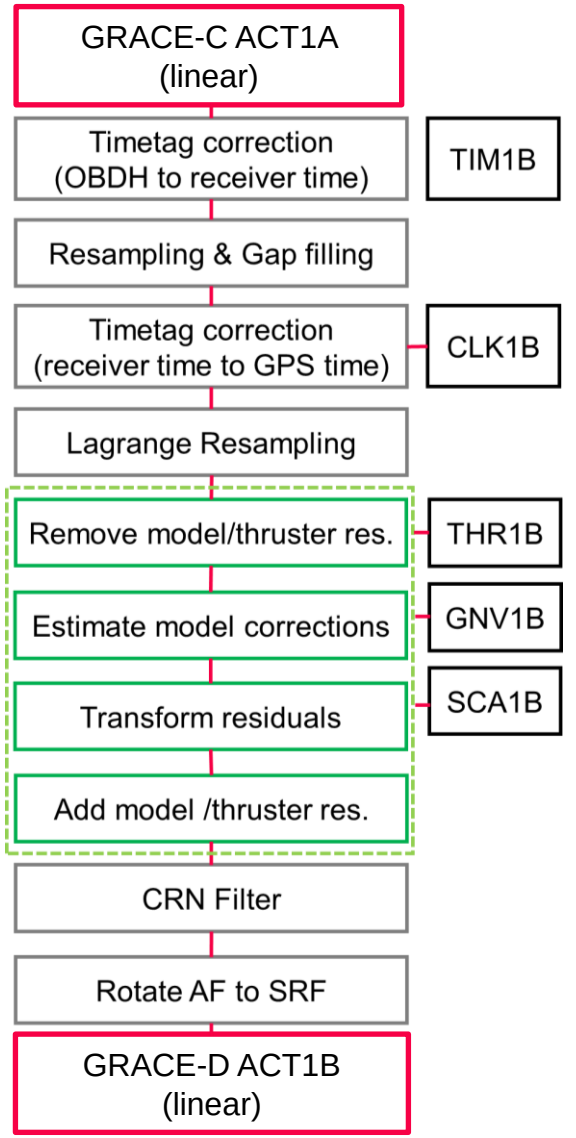
Incorporate the non-gravitational forces in GRACE-D accelerometer recovery



GRACE-D accelerometer recovery

- **Recovery steps** from GRACE-C ACT data:
  - Calibrating and Removing force models and THR events,
  - Estimate aerodynamic and TRP force model scales and obtain residuals,
  - Transferring the residuals to GRACE-D by applying time and attitude corrections,
  - Adding force models, force model scales and thruster responses of GRACE-D.

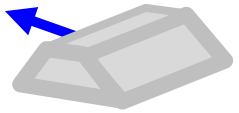
Force model	Description	source
Atmospheric force	Time variable drag and lift coefficients	Krauss (2013) Moe and Moe (2005)
Solar radiation pressure (SRP)	Physical shadow factor, infrared solar flux	Robertson (2015) Vielberg et al. (2020) Montenbruck and Gill (2001)
Earth radiation pressure (ERP)	albedo modeling using reflectivity and emissivity coefficients of the Earth	Rodriguez-Solano et al. (2009)
Thermal radiation pressure (TRP)	Surface temprature dependent	Wetterer et al. (2014)

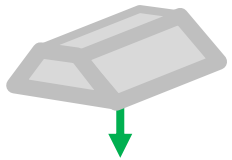


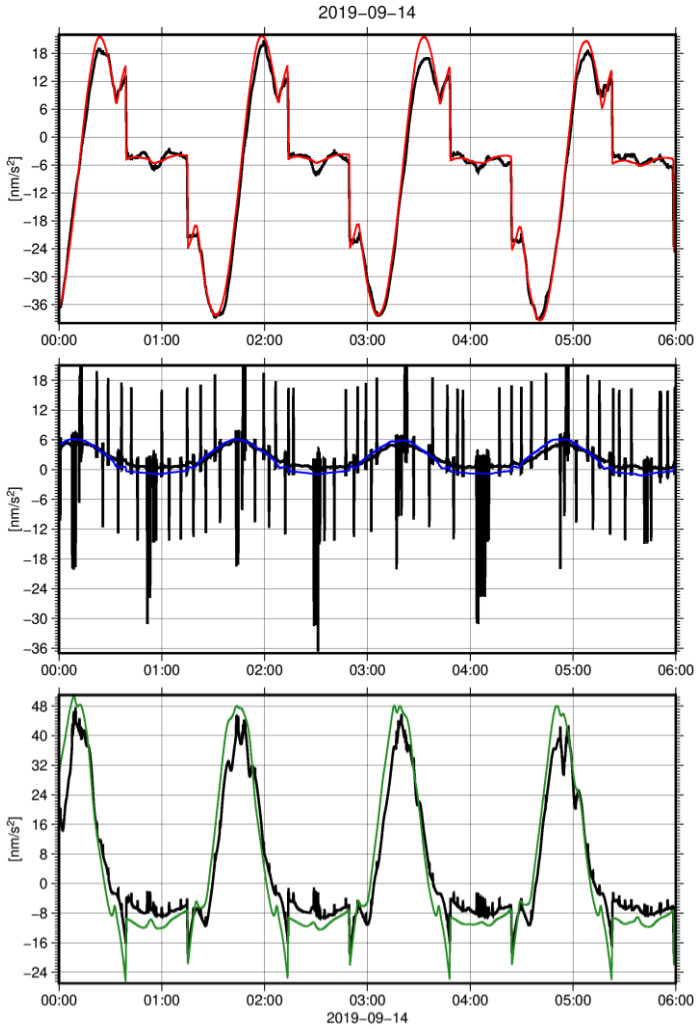
GRACE-D accelerometer recovery (TODO)

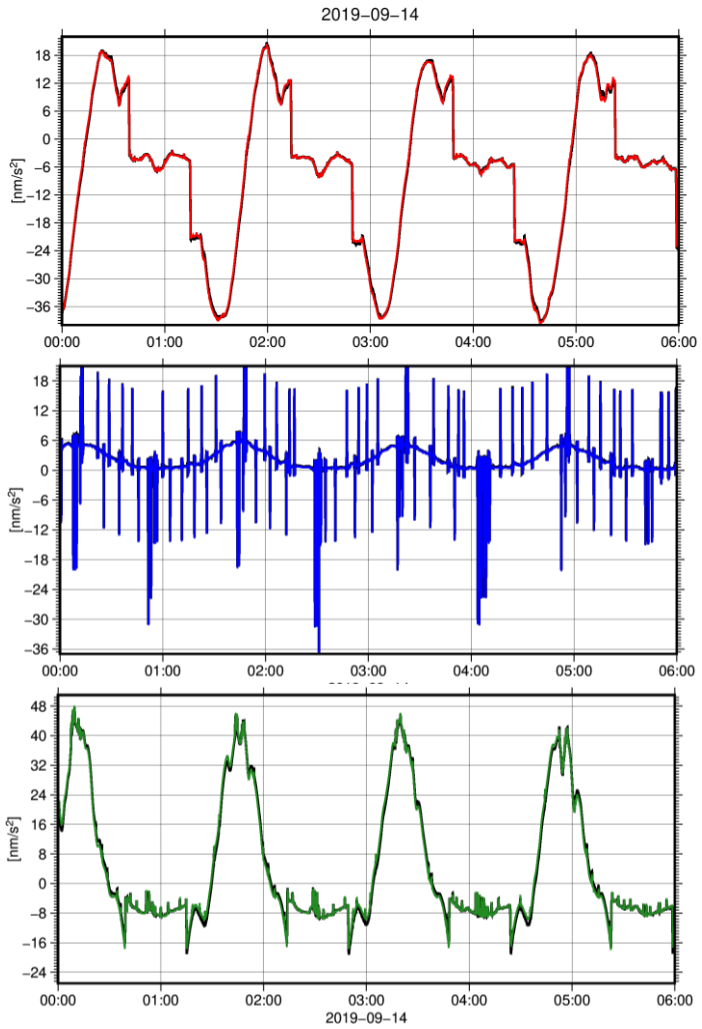
Improved force models → **ITSG ACT1B**

ACT1B



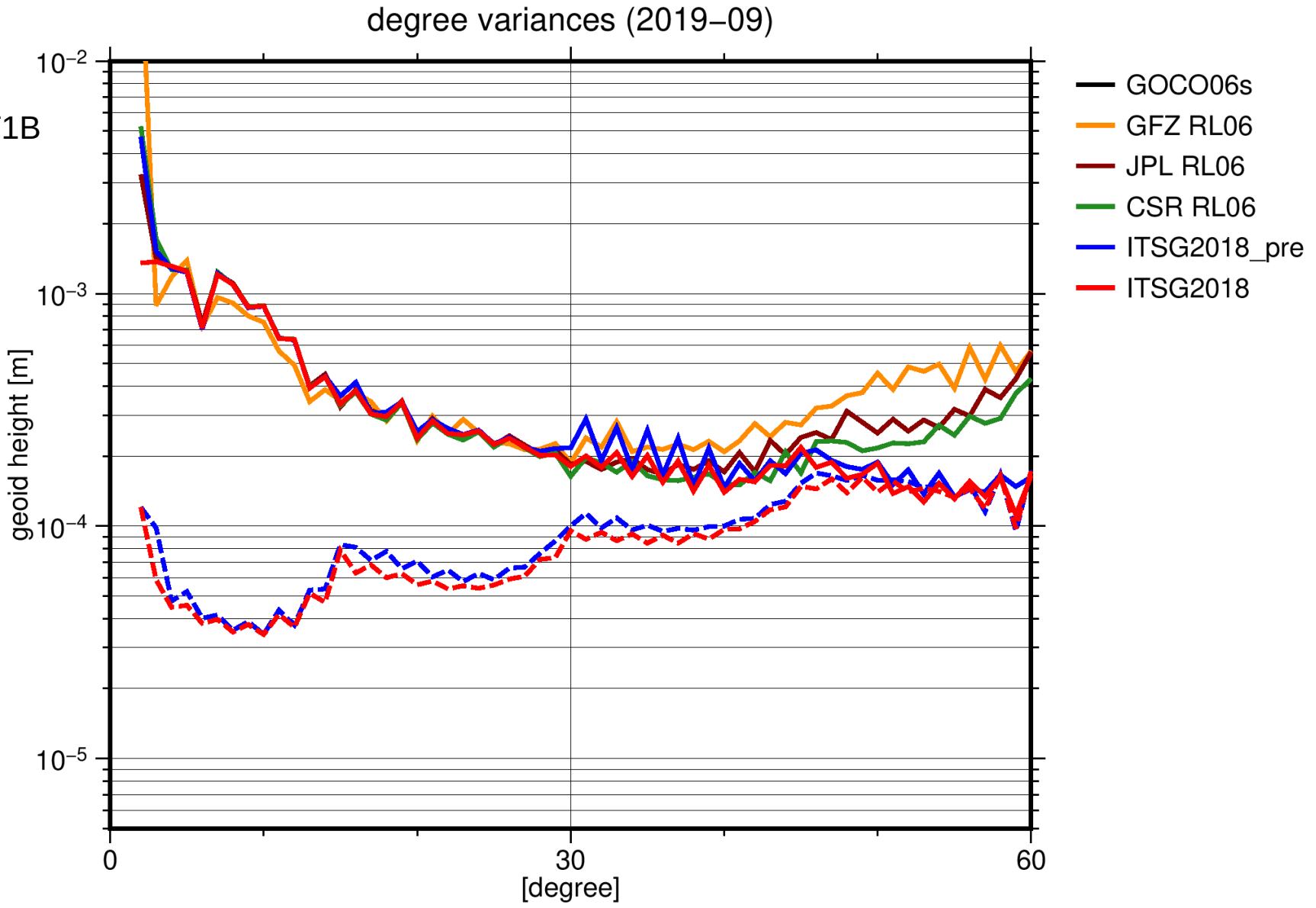




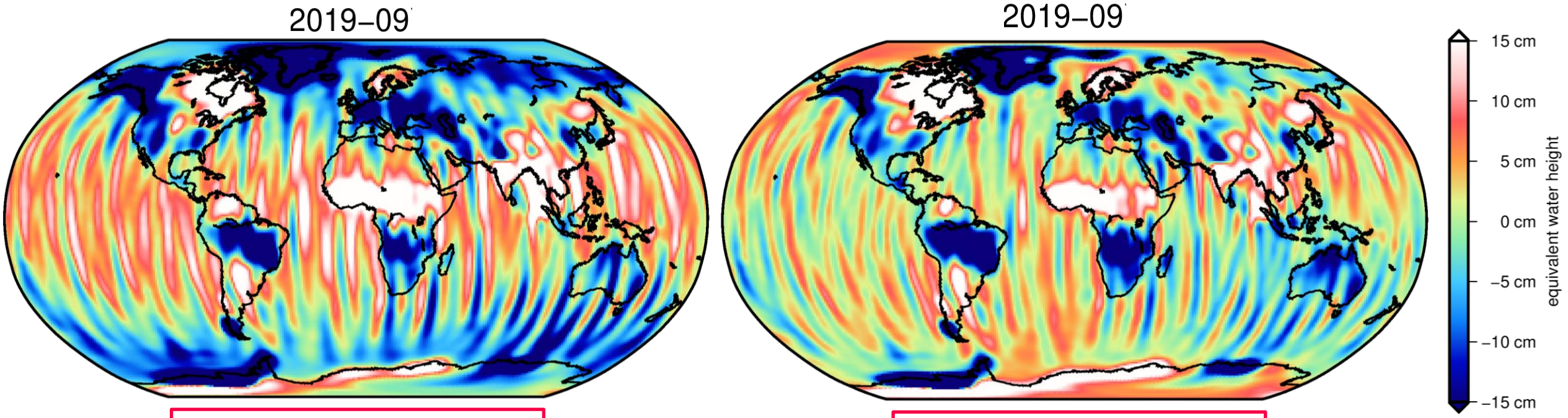


Impact on gravity field

- **ITSG2018_pre**:
  Gravity recovery with the official ACT1B
- **ITSG2018:**
  Gravity recovery with ITSG ACT1B



Impact on gravity field

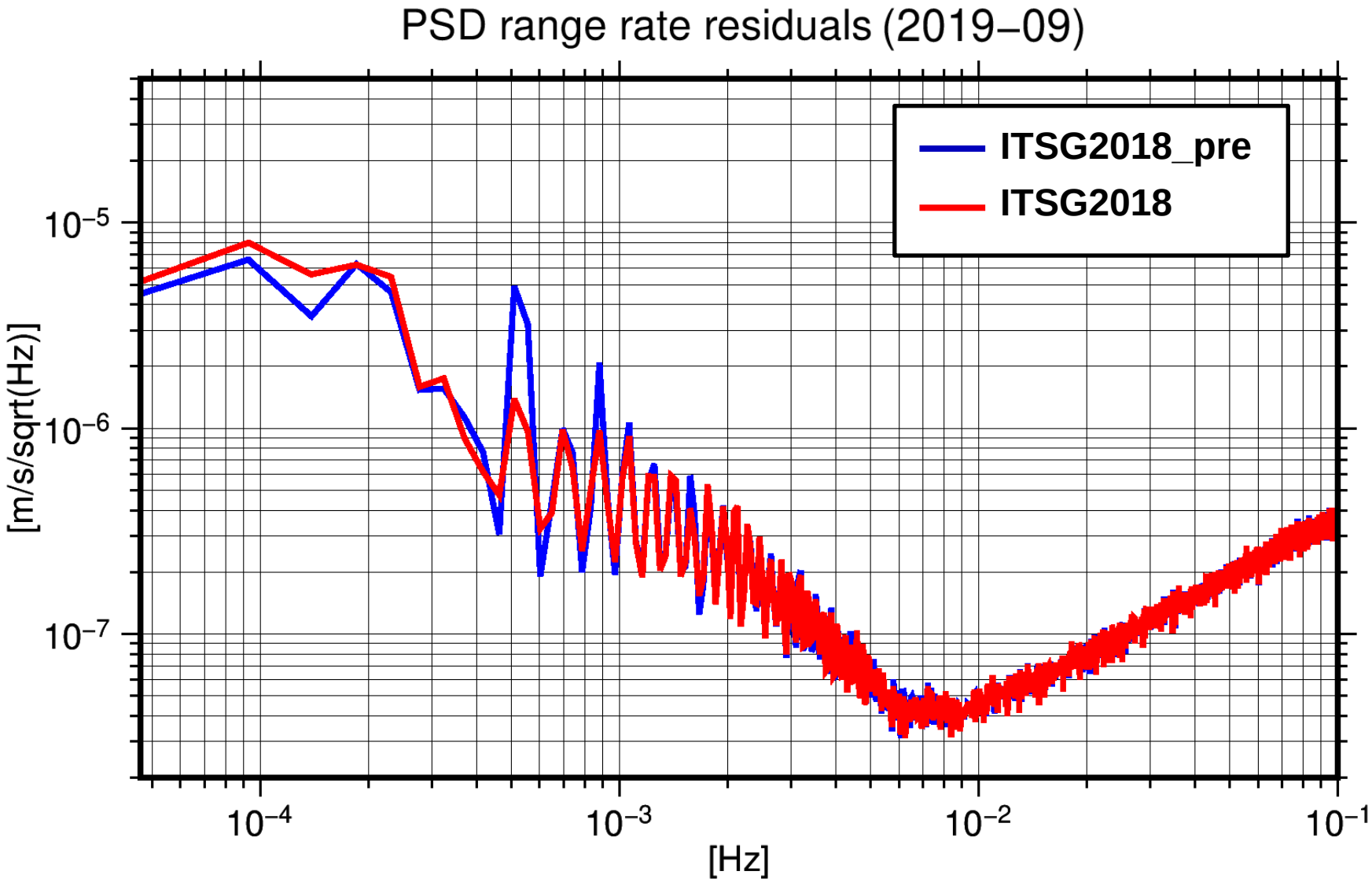


ITSG_pre, RMS = 13.48 cm

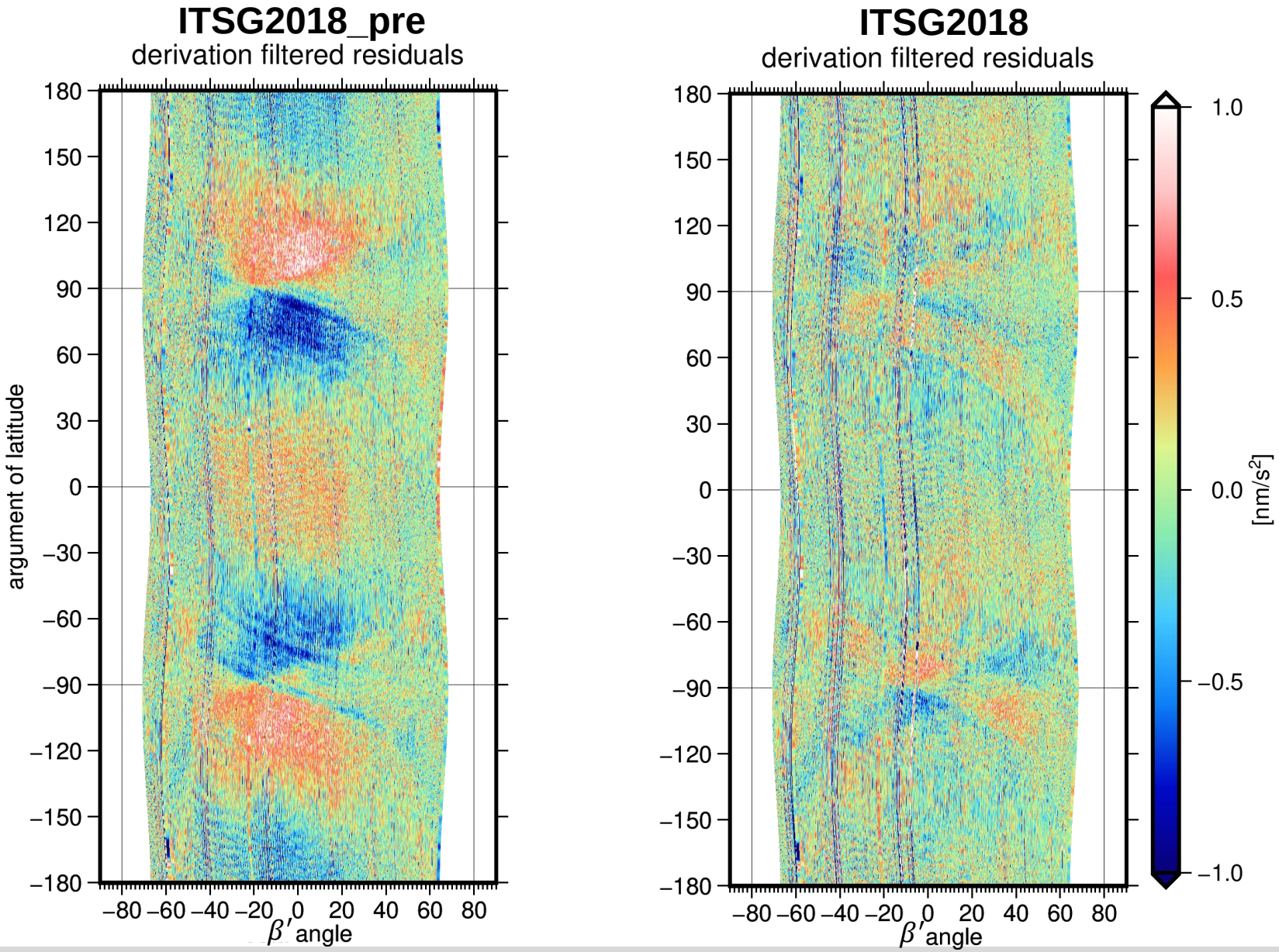
ITSG, RMS = 11.85 cm

300 km Gaussiuan filter is applied.

Postfit residuals

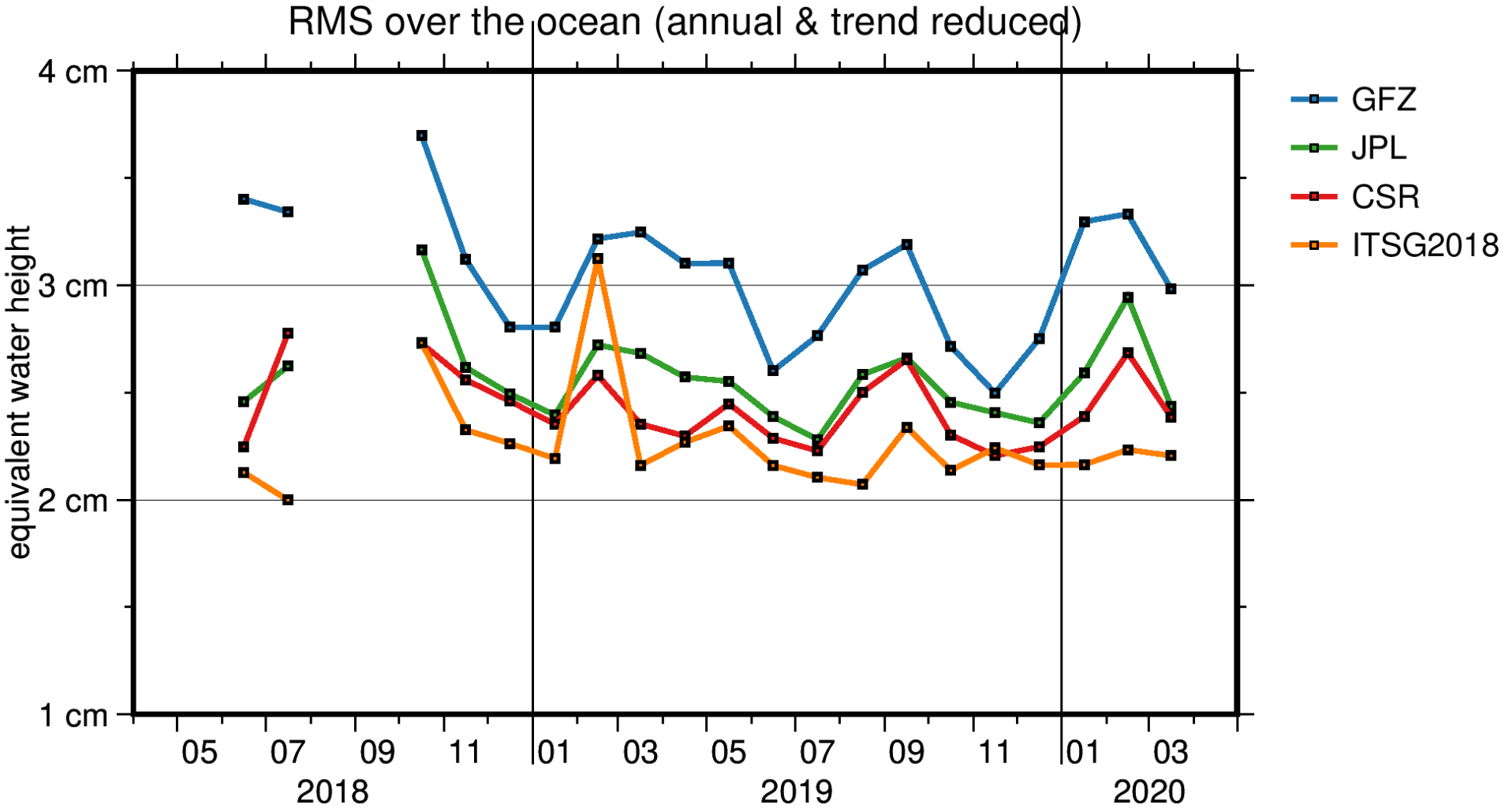


Residual Analysis (2018-2019)



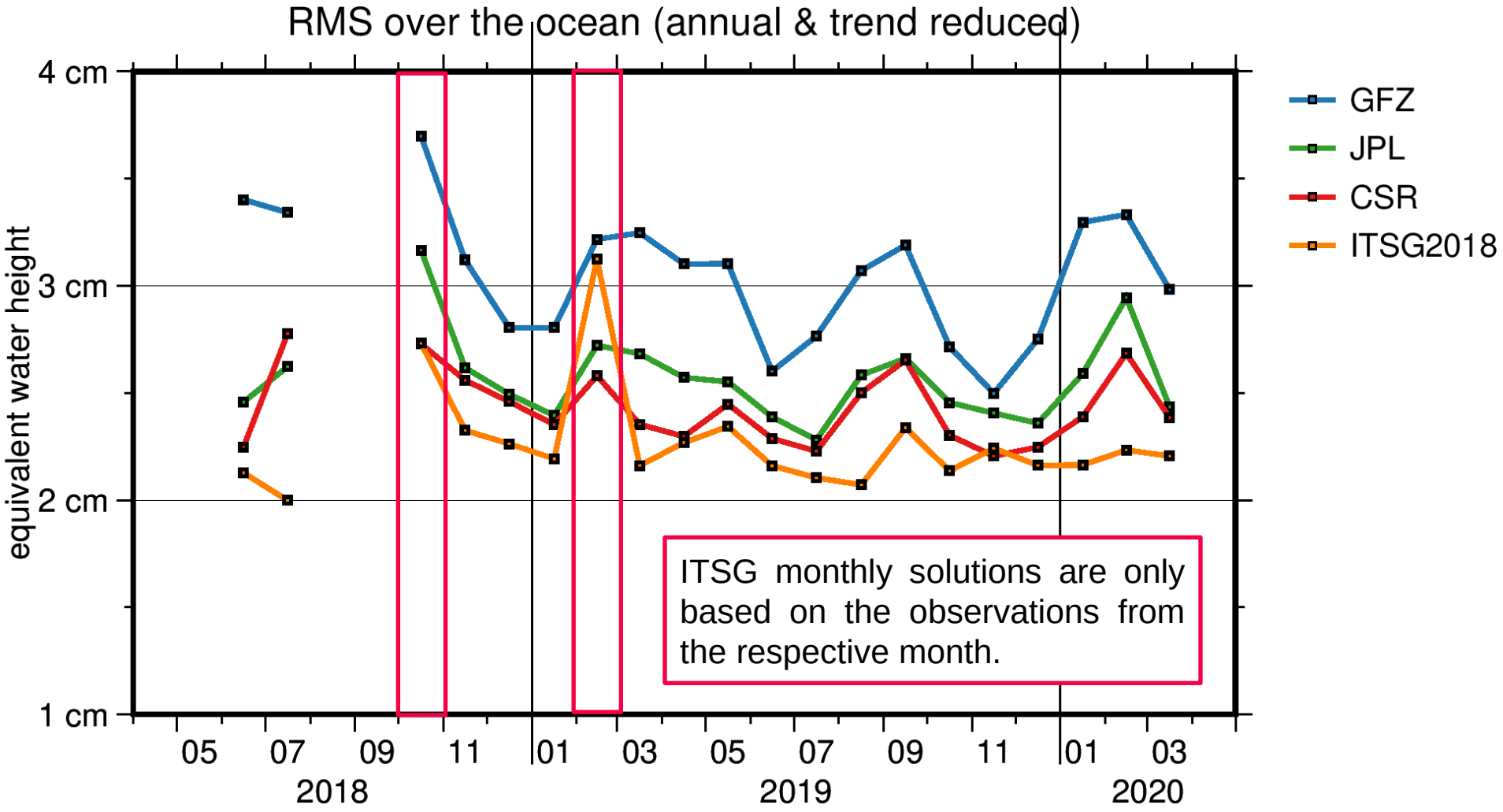
Monthly RMS over the ocean

- Trend and annual signals are reduced and a gaussian filter with 400 km radius is applied.

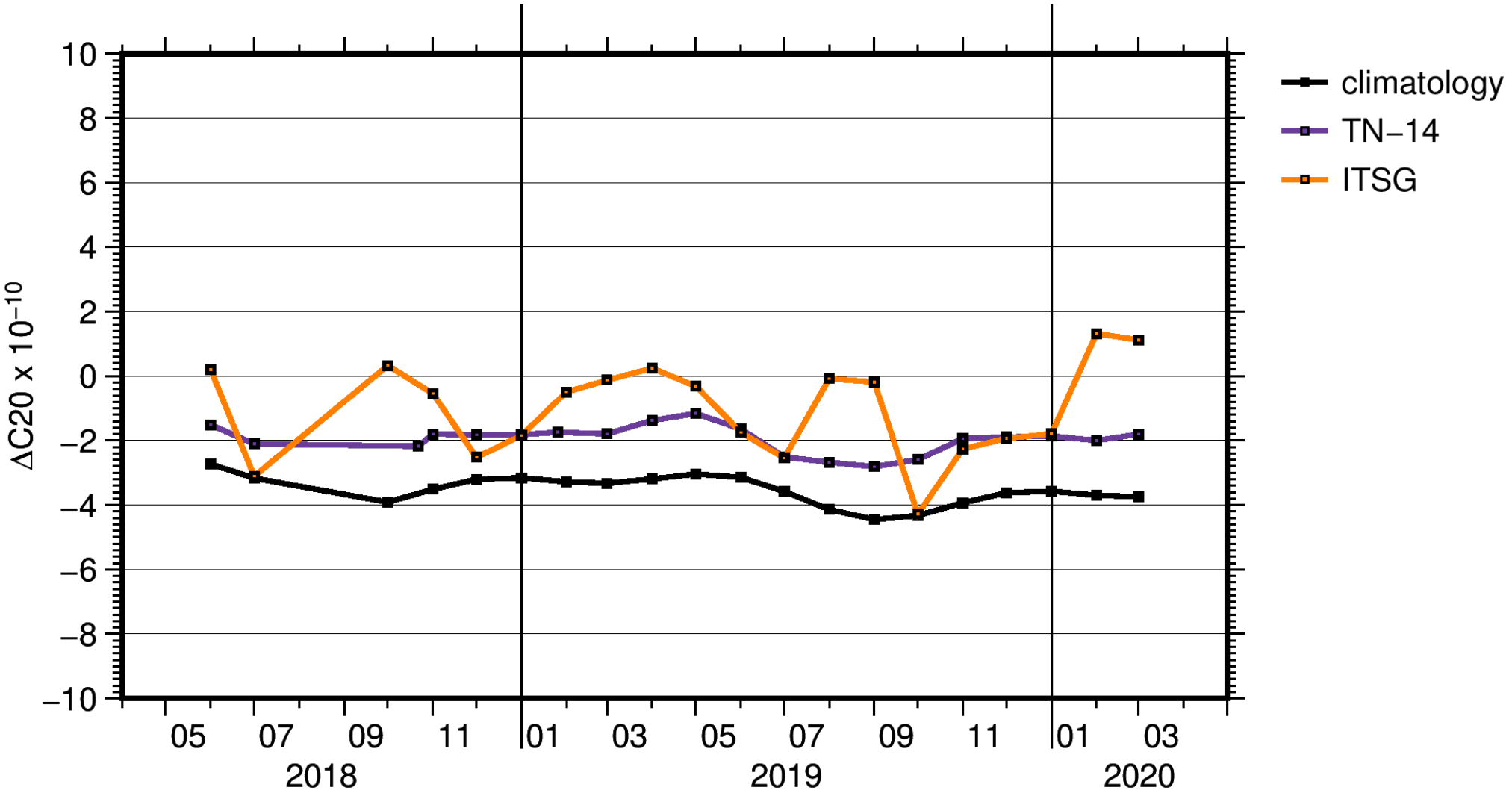


Monthly RMS over the ocean

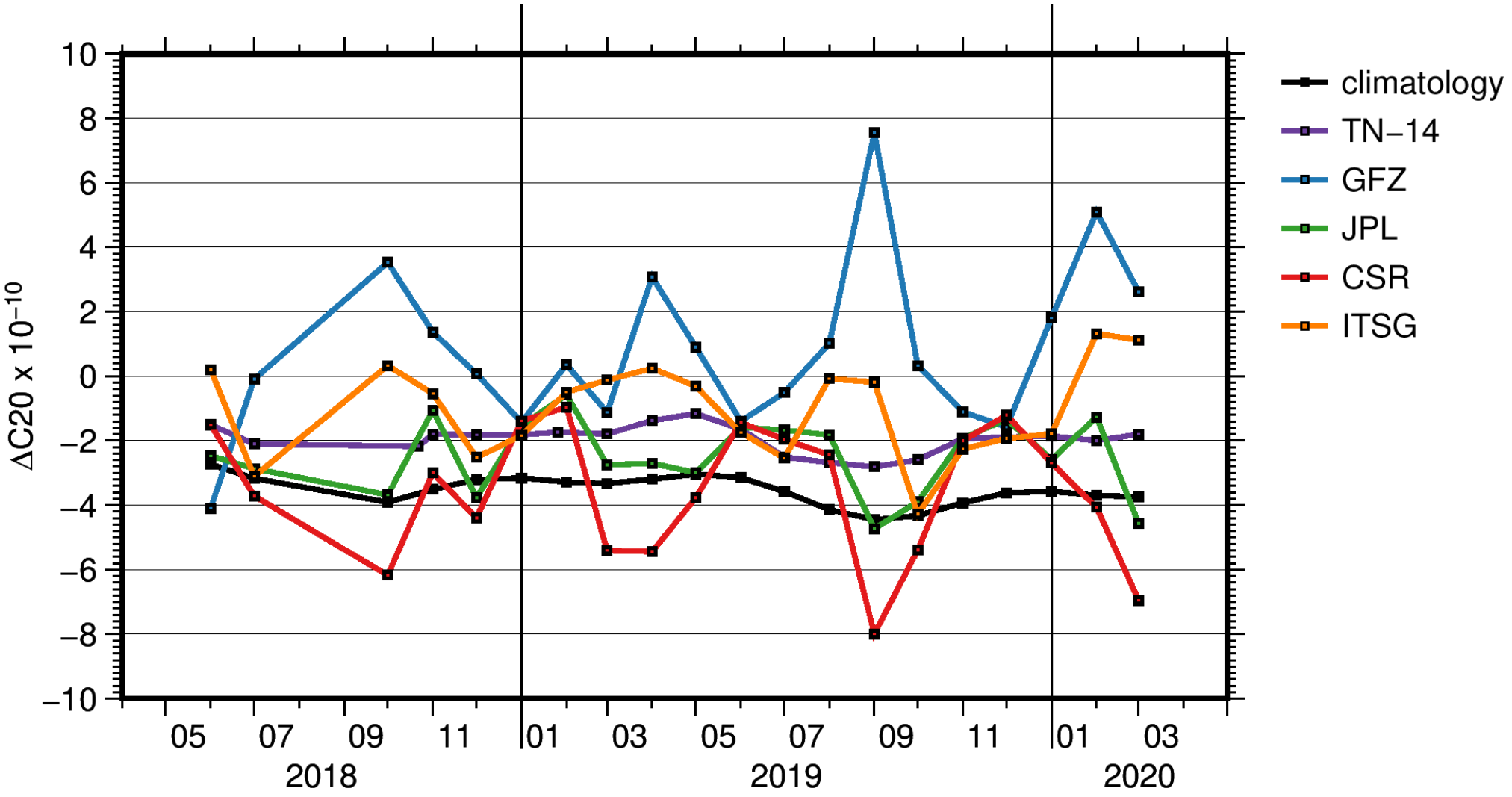
- Trend and annual signals are reduced and a gaussian filter with 400 km radius is applied.



Impact on low degrees-C20

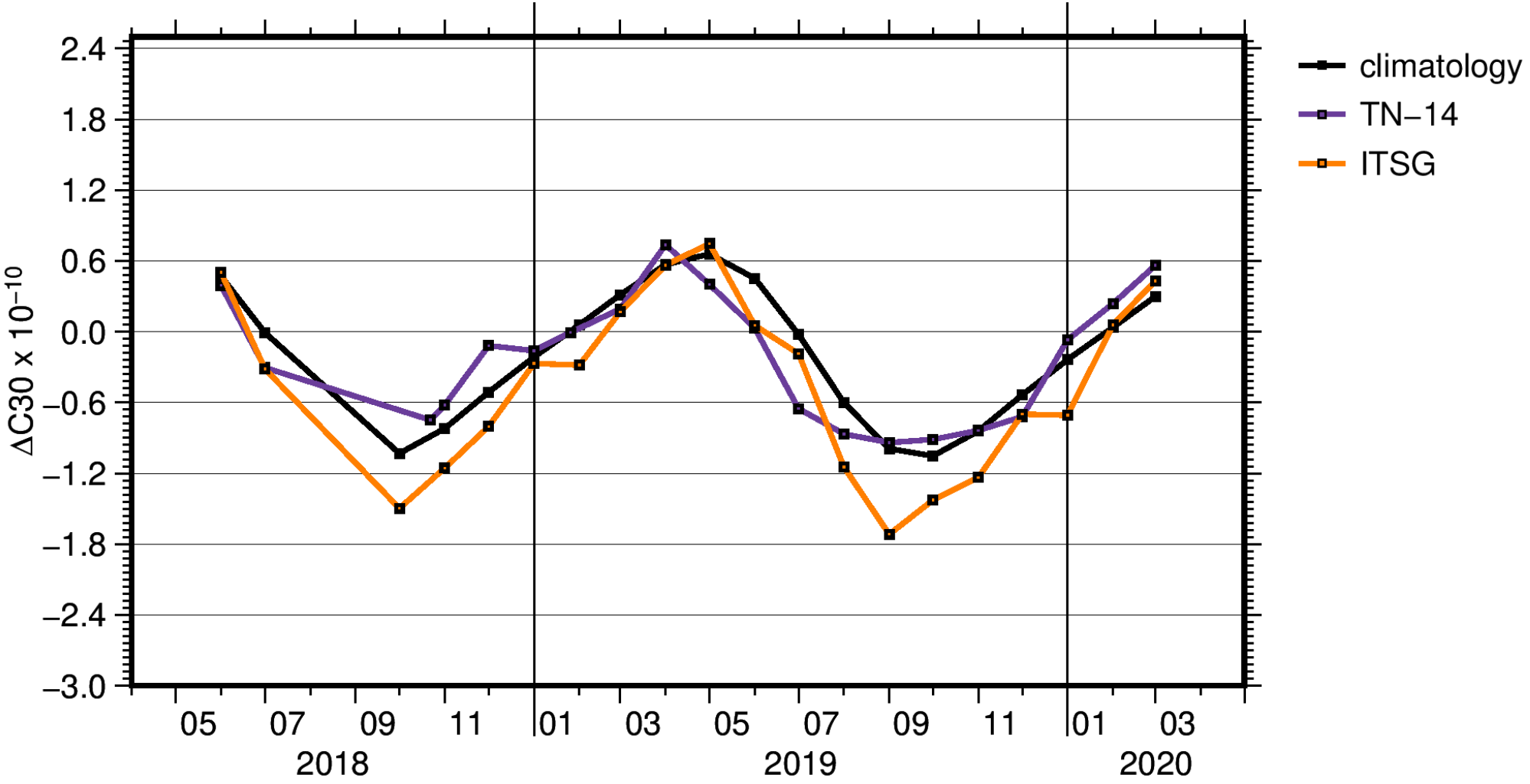


Impact on low degrees-C20



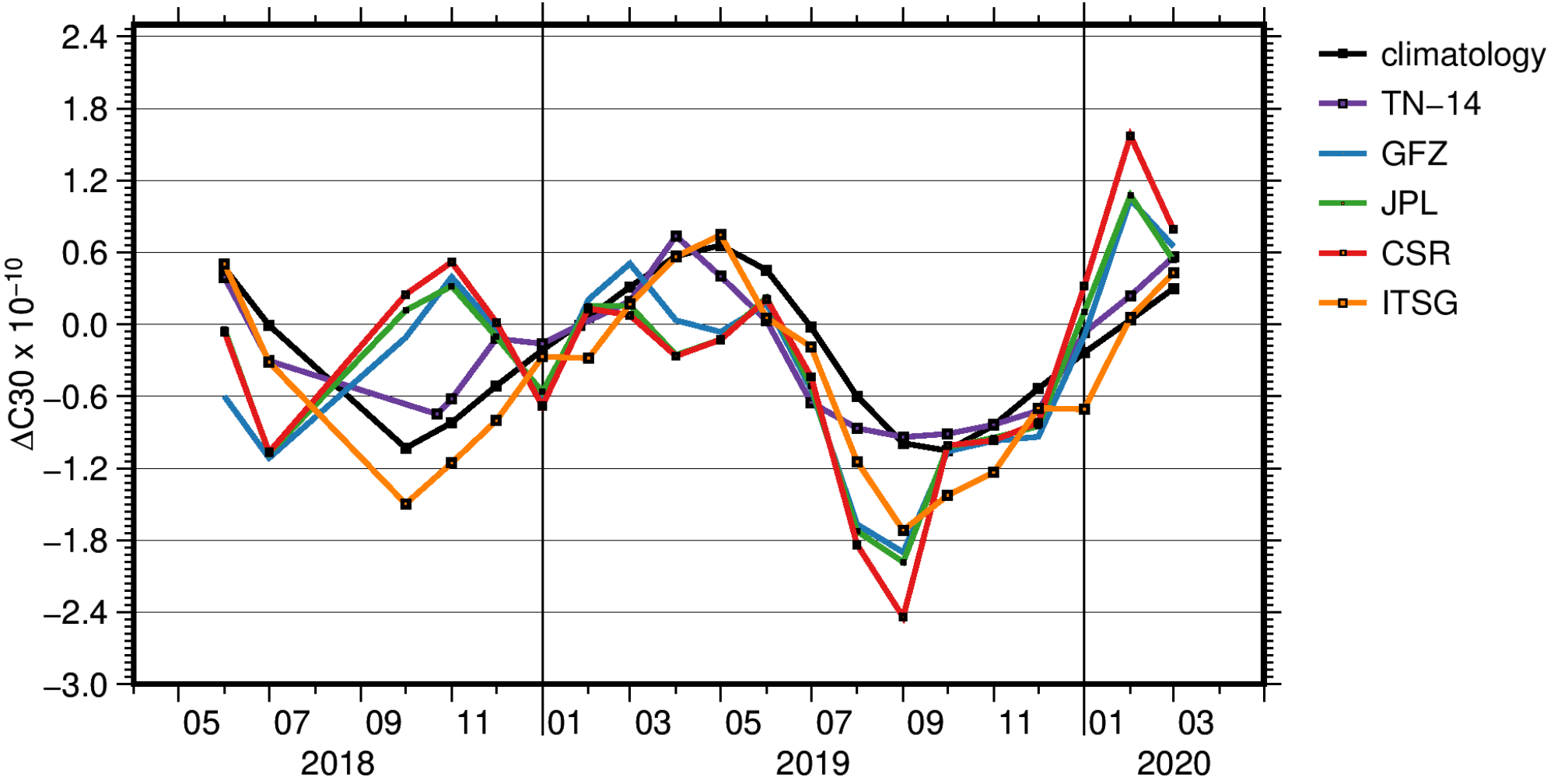
Impact on low degrees-C30

- Offset with respect to TN-14 values is reduced.



Impact on low degrees-C30

- Offset with respect to TN-14 values is reduced.



Summary and outlook

- The accuracy of monthly gravity field solutions is extremely sensitive to GRACE-FO accelerometer data quality.
- Alternative ACT1A processing is proposed for recovering GRACE-D accelerometer measurements.
- The ITSG ACT1B products significantly improves estimates of C30 coefficients.
- Using ITSG ACT1B also influences:
  - Other low degree zonal coefficients
  - Overall accuracy of monthly gravity field solutions
- Further analysis:
  - Ideal parametrization of model calibrations
  - Improve thruster response modeling

References

Bandikova, T., McCullough, C., Kruizinga, G. L., Save, H., Christophe, B., 2019. GRACE accelerometer data transplant, Advances in Space Research 64(3), 623-644, https://doi.org/10.1016/j.asr.2019.05.021.

Krauss, S., 2013. Response of the Earth's thermosphere during extreme solar events a contribution of satellite observations to atmospheric evolution studies, Graz University of Technology, Dissertation.

Loomis, B. D., Rachlin, K. E., Wiese, D. N., Landerer, F. W., & Luthcke, S. B. 2020. Replacing GRACE/GRACE-FO With Satellite Laser Ranging: Impacts on Antarctic Ice Sheet Mass Change. Geophysical Research Letters, 47(3). https://doi.org/10.1029/2019gl085488.

McCullough, C., Harvey, N., Save, H., Bandikova, T., 2019. Description of Calibrated GRACE-FO Accelerometer DataProducts (ACT) Level-1 Product Version 04. Technical report, NASA Jet Propulsion Laboratory / California Institute of Technology.

Meyer U., Jäggi A., Beutler G., 2012. The Impact of Attitude Control on GRACE Accelerometry and Orbits. In: Kenyon S., Pacino M., Marti U. (eds) Geodesy for Planet Earth. International Association of Geodesy Symposia, vol 136. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-20338-1

Moe, K. and Moe, M., 2005. Gas-surface interactions and satellite drag coefficients, Planet. Space Sci.,53, 793–801, https://doi.org/10.1016/j.pss.2005.03.005.

Montenbruck, O. and Gill, E., 2001. Satellite Orbits - Models, Methods, and Applications. 2nd corrected edition. Berlin Heidelberg New York: Springer. ISBN: 978-3-642-58351-3.

Robertson, R. V., 2015. Highly Physical Solar Radiation Pressure Modeling During Penumbra Transitions. Ph.D., Department of Aerospace and Ocean Engineering at Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Vielberg, K., Kusche, J., 2020. Extended forward and inverse modeling of radiation pressure accelerations for LEO satellites. J Geod 94, 43. https://doi.org/10.1007/s00190-020-01368-6

Wetterer, C. J., R. Linares, J. L. Crassidis, T. M. Kelecy, M. K. Ziebart, M. K. Jah, and P. J. Cefola, 2014. Refining space object radiation pressure modeling with bidirectional reectance distribution functions. Journal of Guidance, Control, and Dynamics 37(1), 185-196.

Thank you for your attention!

Funding provided by:

- the *Austrian Research Promotion Agency*
- the European Union's
  Horizon 2020 research and innovative programme
  under grant agreement No. 870353

GRACE-FO accelerometer data recovery within ITSG-Grace2018 data processing

Saniya Behzadpour, Torsten Mayer-Gürr, Andreas Kvas, Sandro Krauss, Sebastian Strasser, and Barbara Süsser-Rechberger

Institute of Geodesy
Graz University of Technology

EGU General Assembly, Vienna

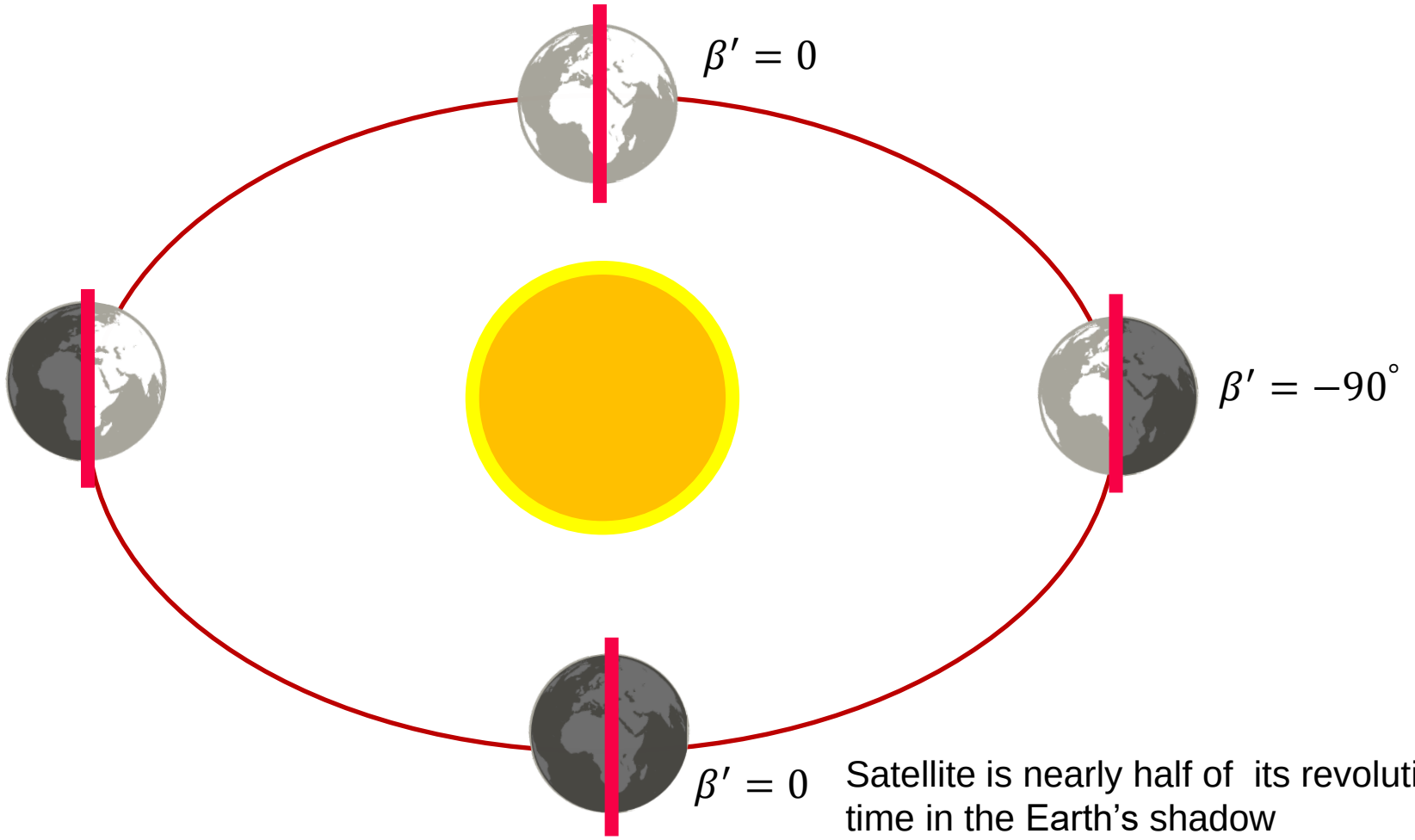
2020-05-08

Beta prime angle

- β angle: Angle between the normal vector of $\boldsymbol{n}$ orbital plane and Sun-Earth direction $\boldsymbol{r}_{sun}$:

$$\beta = acos \frac{\boldsymbol{n} \,.\, \boldsymbol{r}_{sun}}{|\boldsymbol{n}| \,.\, |\boldsymbol{r}_{sun}|}$$

$$\beta' = \beta - 90^{\circ}$$



Satellite is illuminated at all time

Satellite is nearly half of its revolution time in the Earth's shadow