

Time variable gravity

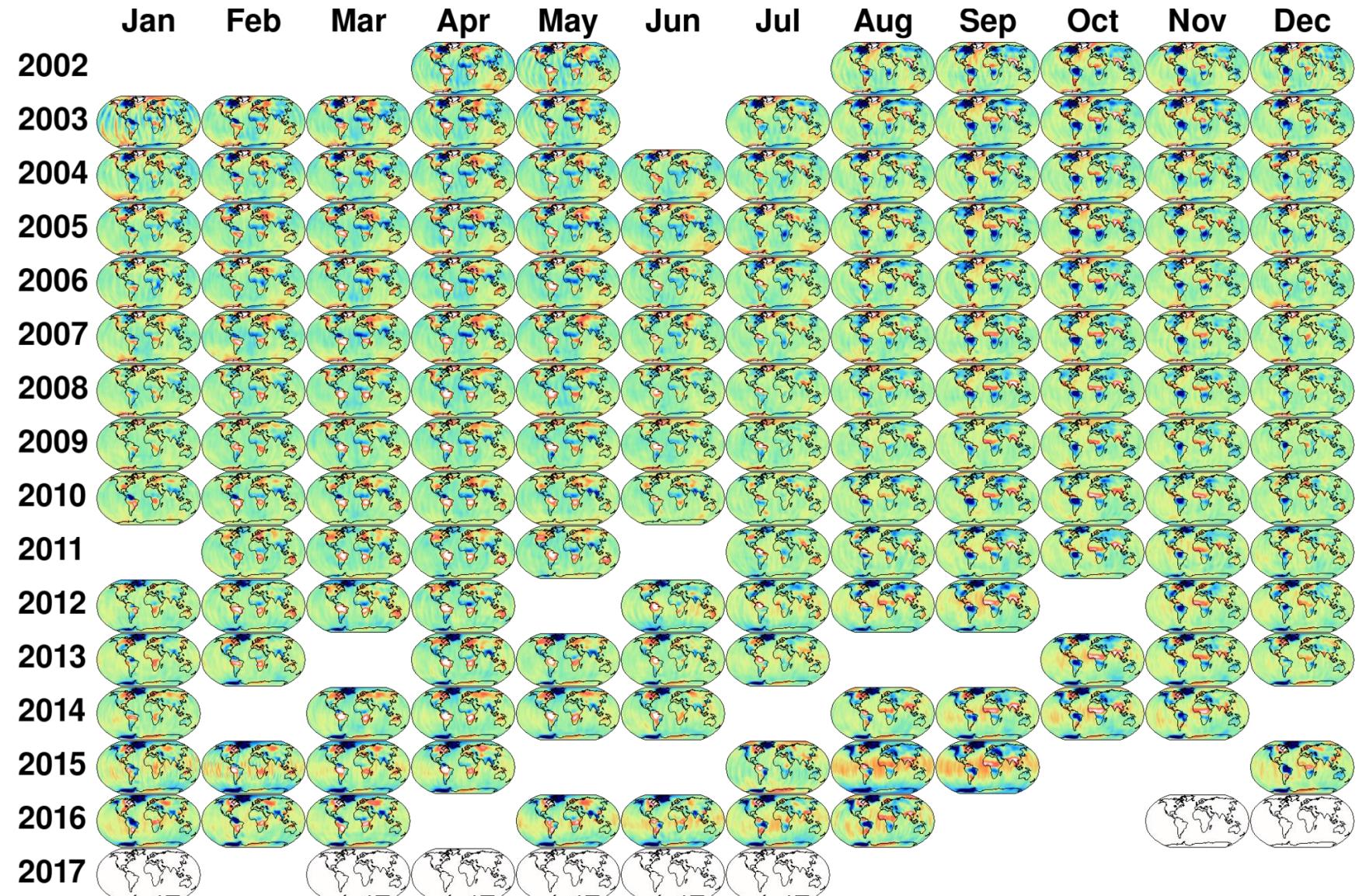
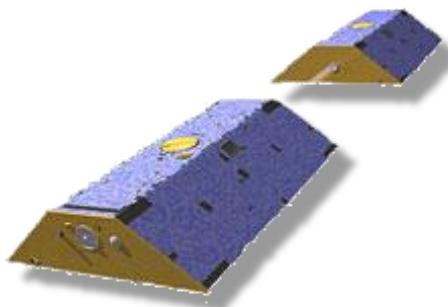
Torsten Mayer-Gürr

Institute of Geodesy
Graz University of Technology

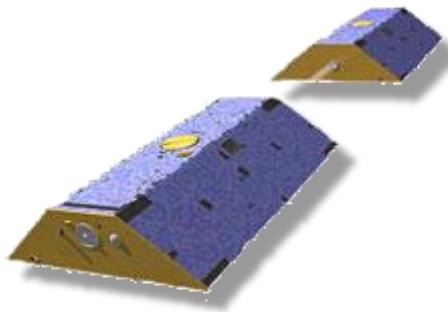
IGS AC workshop - Potsdam

2019-04-16

ITSG-Grace2018 – monthly solutions

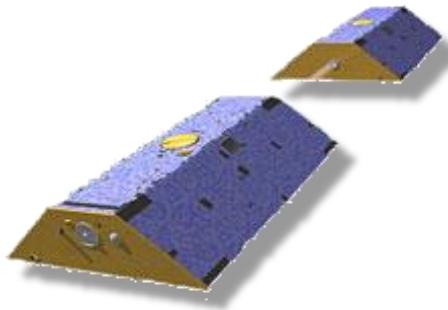


ITSG-Grace2018 – background models



Force models	ITSG-Grace2018
Static field + annual + trend	GOCO06s
Atmosphere + Ocean	AOD1B RL06
Hydrology	LSDM (submonthly part)
Astronomical tides	JPL DE421
Earth tides	IERS2010
Ocean tides	FES2014b + GRACE estimates
Atmospheric tides	AOD1B RL06
Pole tides	IERS2010 (linear mean pole)
Ocean pole tides	Desai 2004 (linear mean pole)
Non-Conservative forces	Accelerometer L1B
Relativistic effects	IERS2010

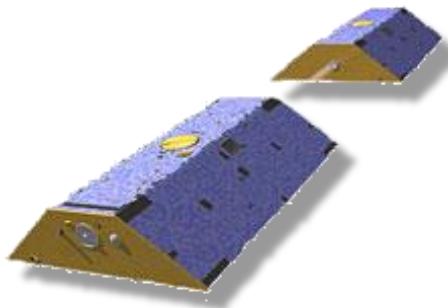
ITSG-Grace2018 – background models



Permanent tides
• Tide free
• Zero tide

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ITSG-Grace2018 – background models



GOCO06s trend is compatible with linear mean pole

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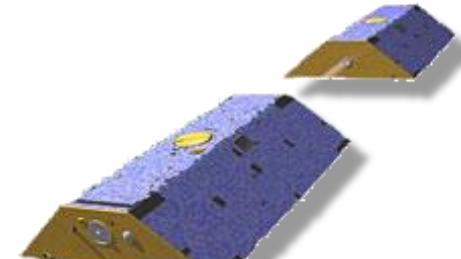
ITSG-Grace2018 – background models



- GOCO06s contains the full signal
- AOD1B must be reduced by trend, annual

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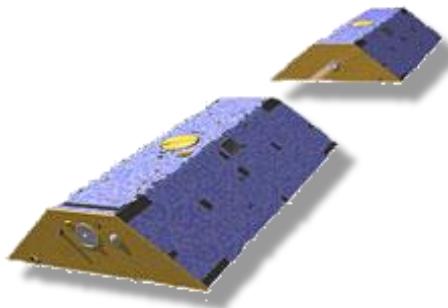
ITSG-Grace2018 – background models



- AOD1B RL06 includes no tides anymore
- Ocean tide must contain S1

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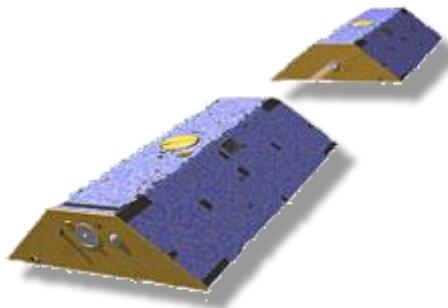
ITSG-Grace2018 – background models



Update to FES2014c

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ITSG-Grace2018 – background models



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Gravity Observation Combination (GOCO)



Technical University of Munich, Institute of Astronomical and Physical Geodesy

Roland Pail, Thomas Gruber



University of Bonn, Institute of Geodesy and Geoinformation

Jan Martin Brockmann, Till Schubert, Wolf-Dieter Schuh



Graz University of Technology, Institute of Geodesy

Andreas Kvas, Torsten Mayer-Gürr, Sandro Krauss



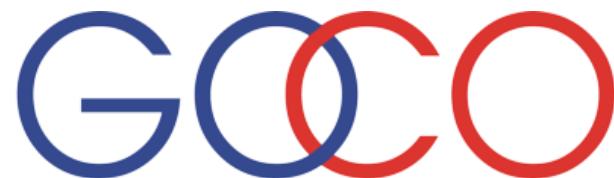
Austrian Academy of Sciences, Space Research Institute

Sandro Krauss



University of Bern, Astronomical Institute

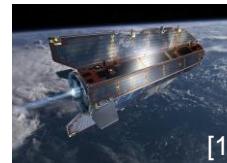
Adrian Jäggi, Ulrich Meyer



GOCO06s – Input Data

- More than 1,160,000,000 observations from 19 satellites

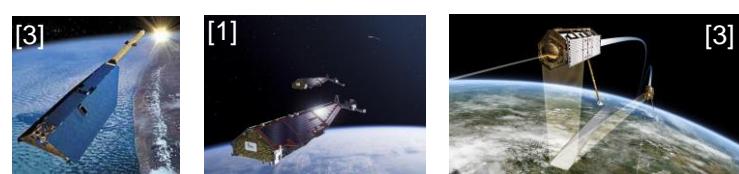
- GOCE
 - TIM6 SGG



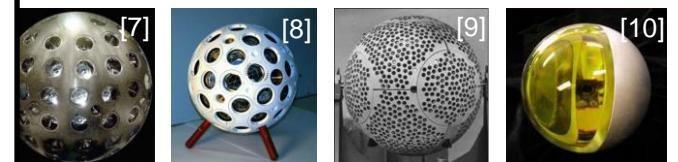
- GRACE
 - ITSG-Grace2018s



- Kinematic orbits
 - CHAMP, SWARM A+B+C, TerraSAR-X, TanDEM-X, GRACE A+B, GOCE



- SLR
 - LAGEOS1/2, Ajisai, Stell,LARES, LARETS, Etalon



Public available next month directly after the ESA Living Planet Symposium

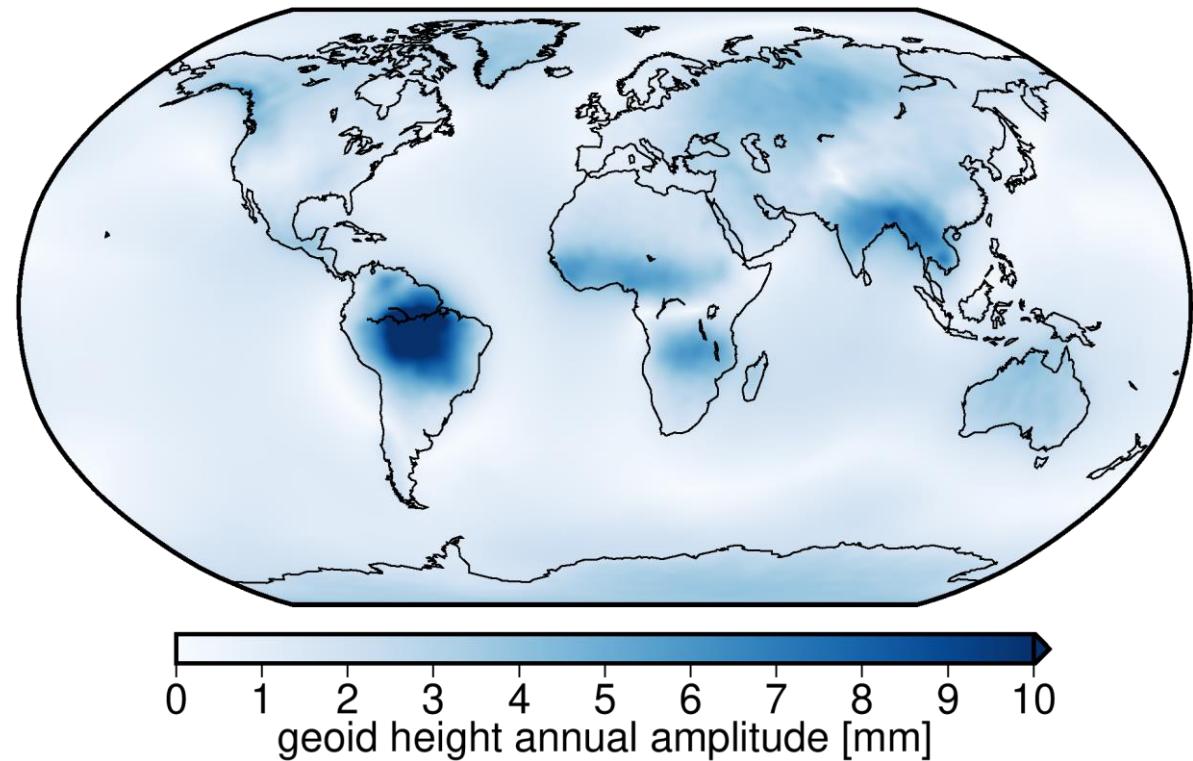
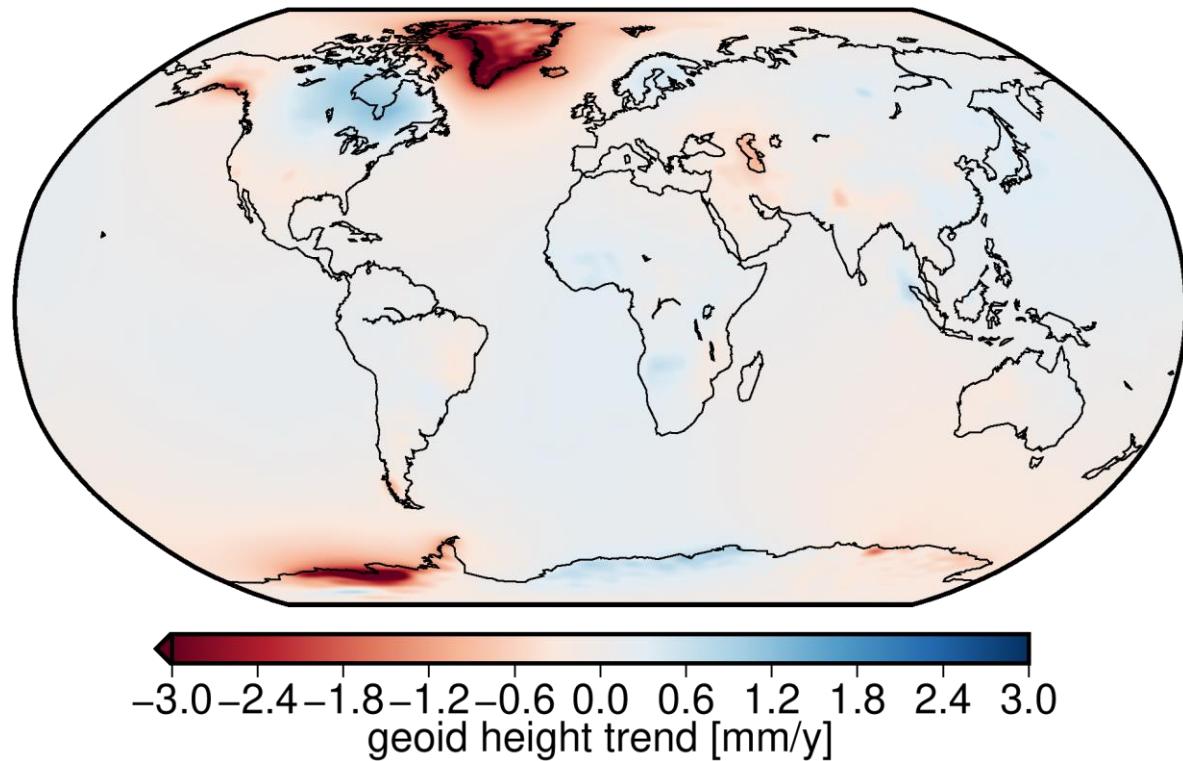
Image credit: ESA¹, NASA², DLR³, ASI⁴, JAXA⁵, CNES⁶, LARES Team⁷, IPIE⁸, FAS⁹, NIIPP¹⁰

GOCO06s – Temporal Variations

- Simple parametric model consisting of:
 - Linear trend
 - Annual oscillation

$$a_{nm}(t) = a_{nm}^{\text{static}} + a_{nm}^{\text{trend}} \cdot (t - t_0) +$$

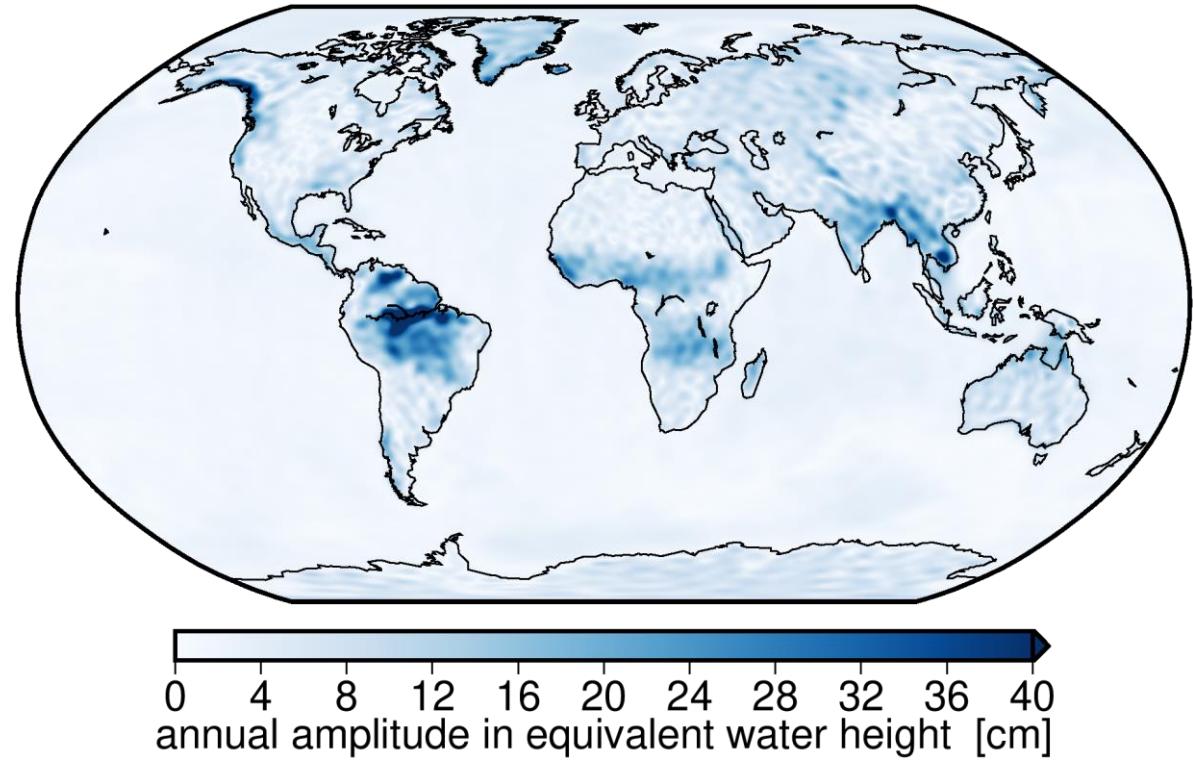
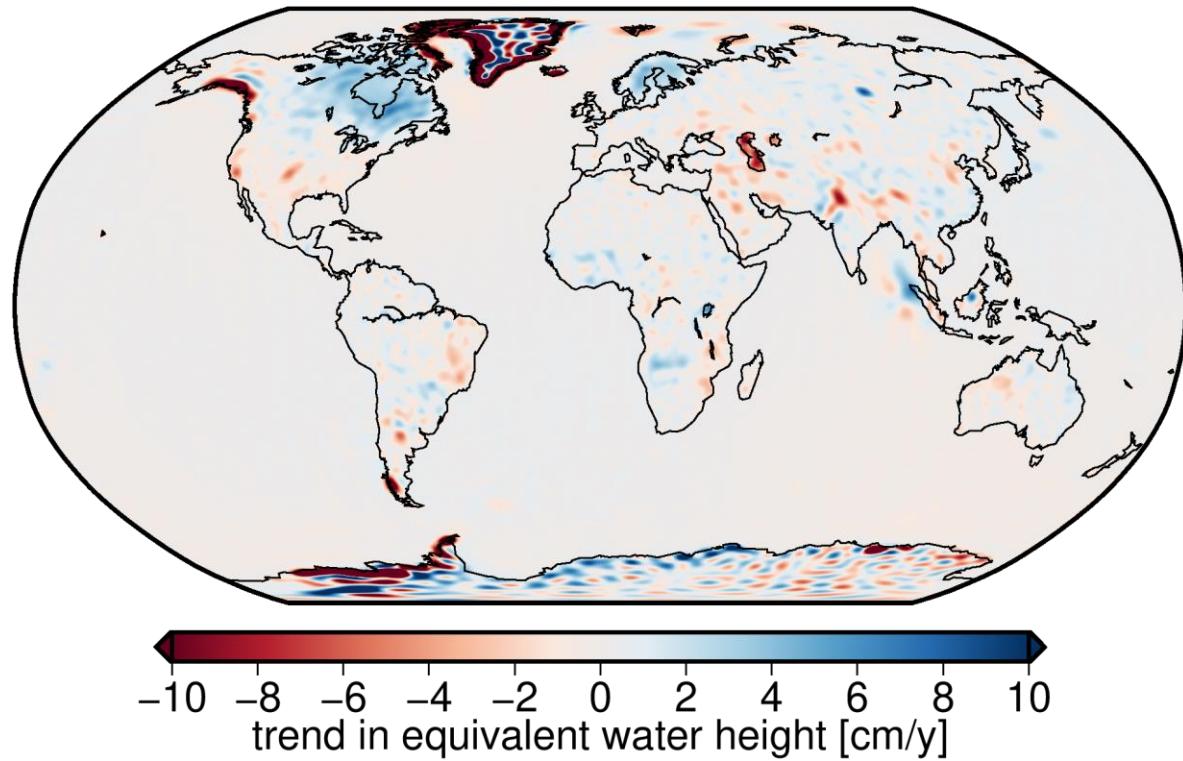
$$a_{nm}^{\cos} \cdot \cos\left[2\pi \frac{1}{365.25} (t - t_0)\right] + a_{nm}^{\sin} \cdot \sin\left[2\pi \frac{1}{365.25} (t - t_0)\right]$$



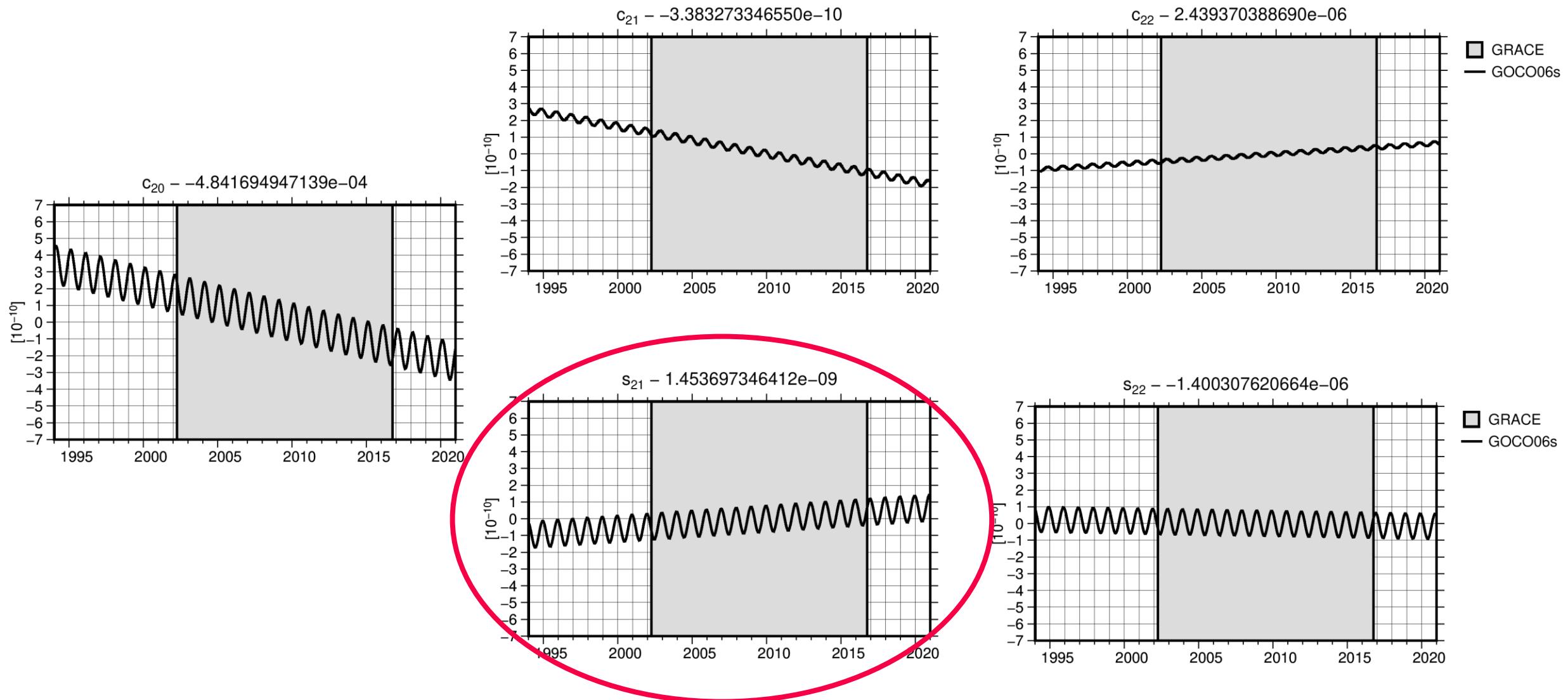
GOCO06s – Temporal Variations

- Simple parametric model consisting of:
 - Linear trend
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$$a_{nm}(t) = a_{nm}^{\text{static}} + a_{nm}^{\text{trend}} \cdot (t - t_0) + \\ a_{nm}^{\cos} \cdot \cos \left[2\pi \frac{1}{365.25} (t - t_0) \right] + a_{nm}^{\sin} \cdot \sin \left[2\pi \frac{1}{365.25} (t - t_0) \right]$$

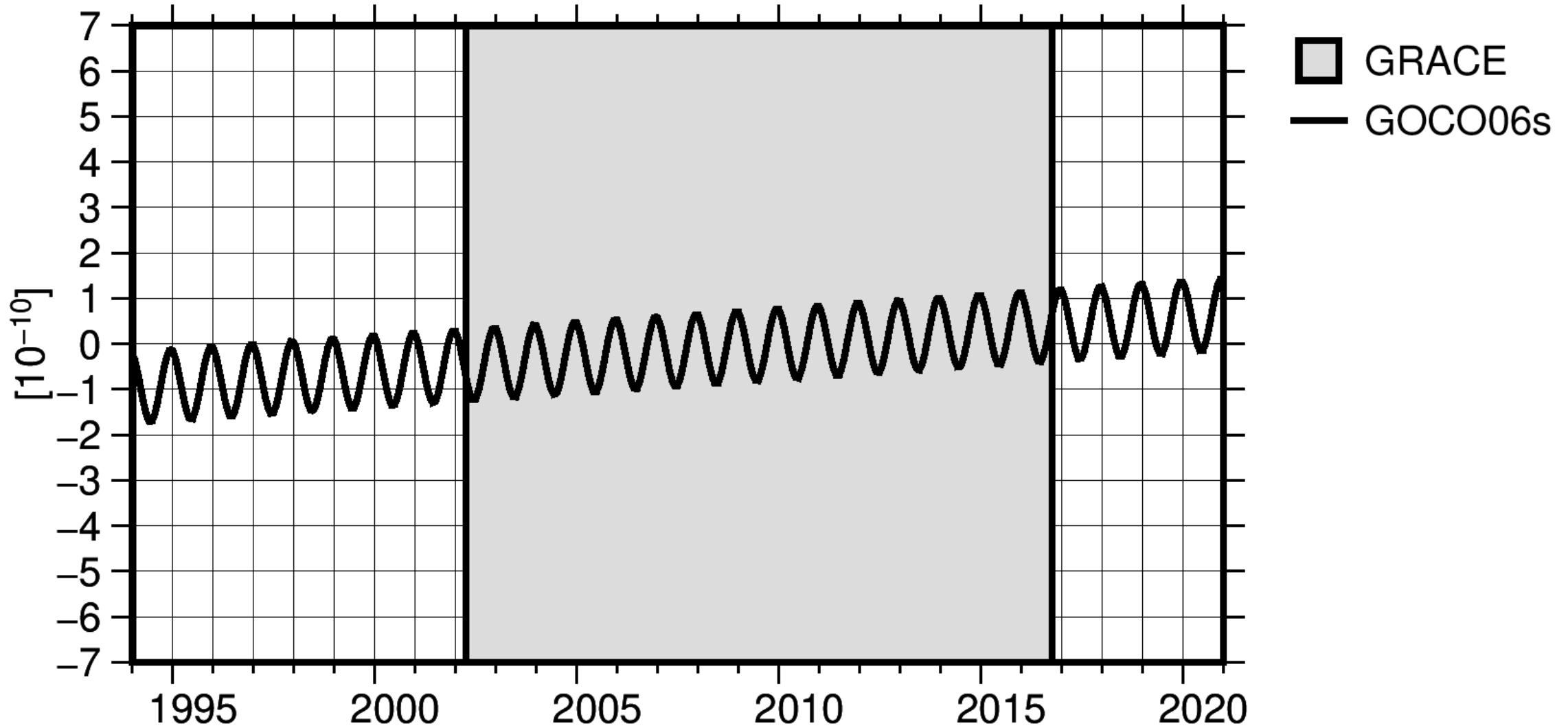


GOCO06s – Degree 2 coefficients



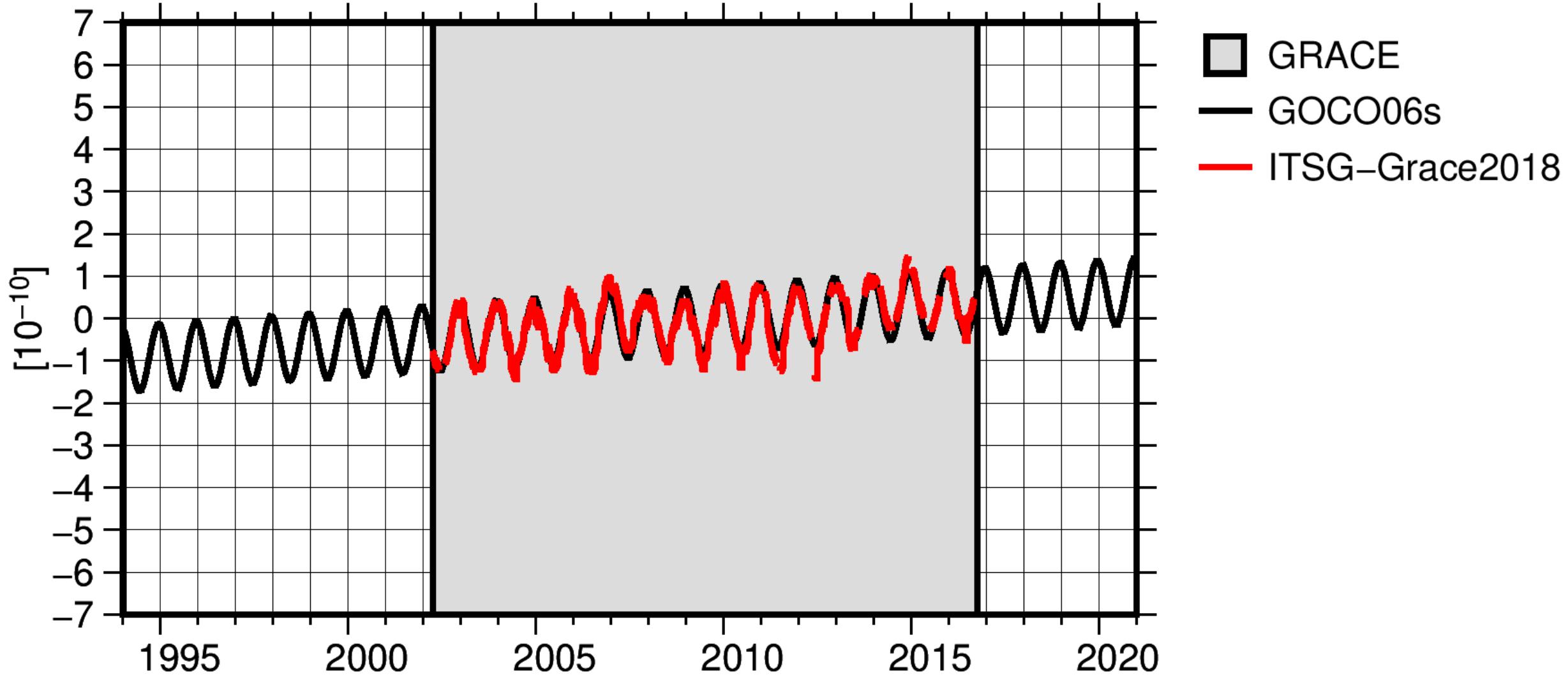
GOCO06s – Degree 2 coefficients

$$s_{21} - 1.453697346412e-09$$



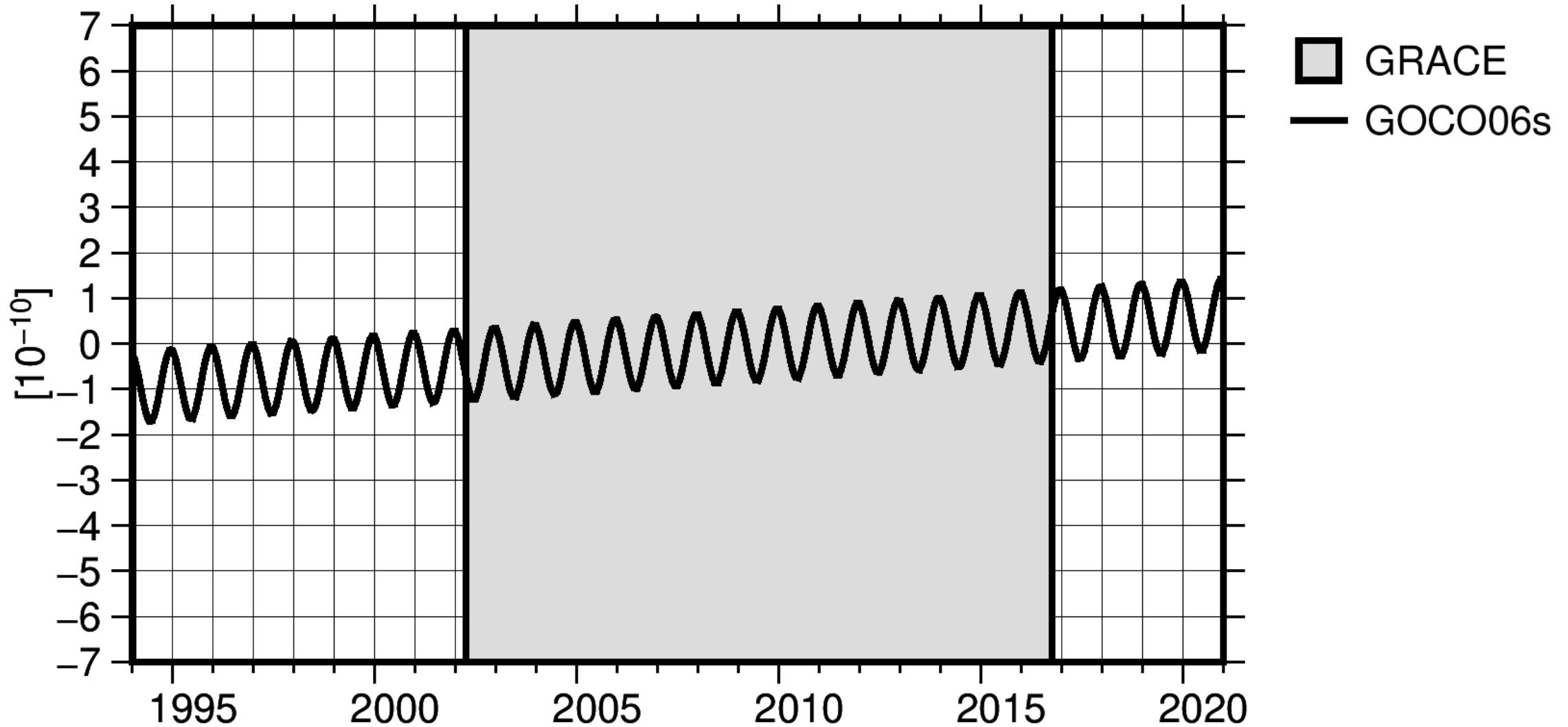
GOCO06s – Degree 2 coefficients

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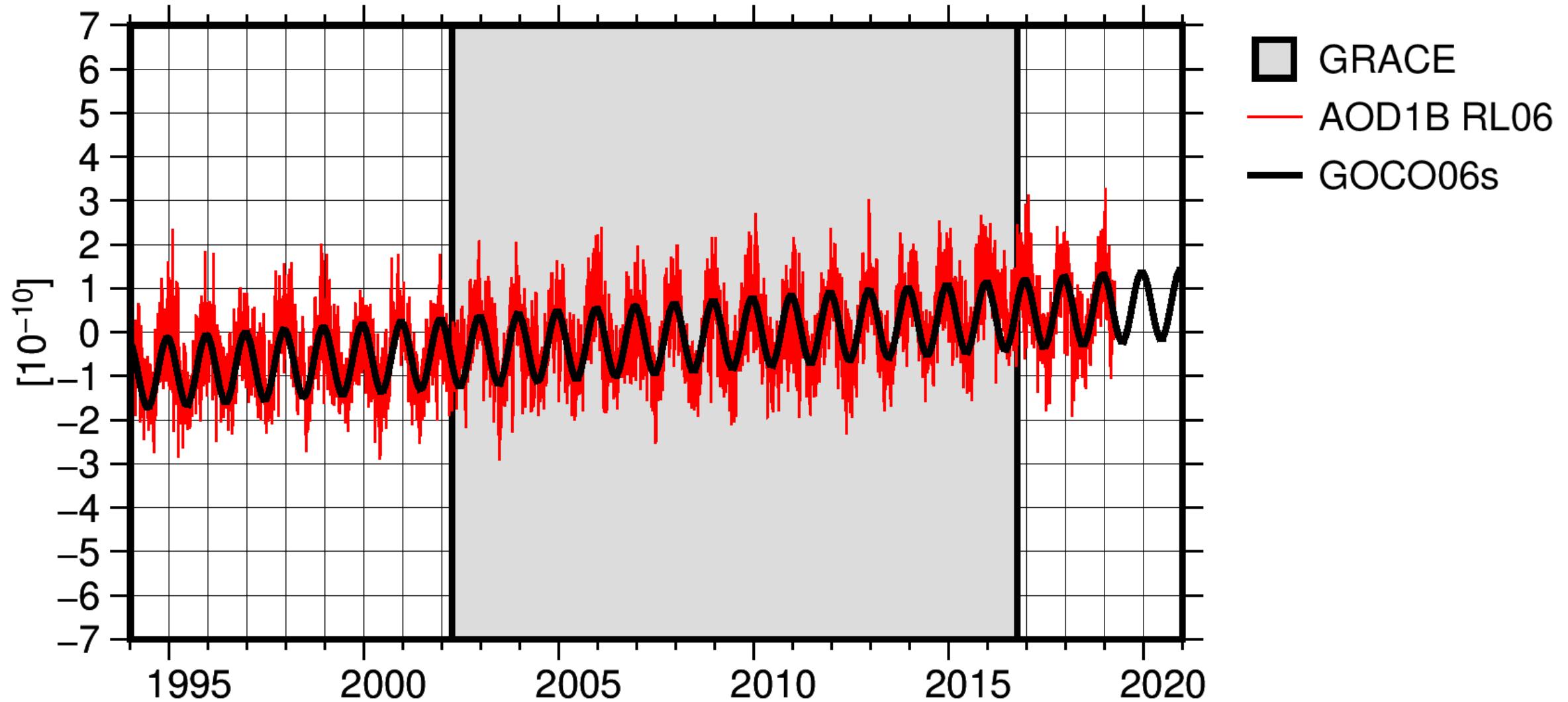
GOCO06s – Degree 2 coefficients

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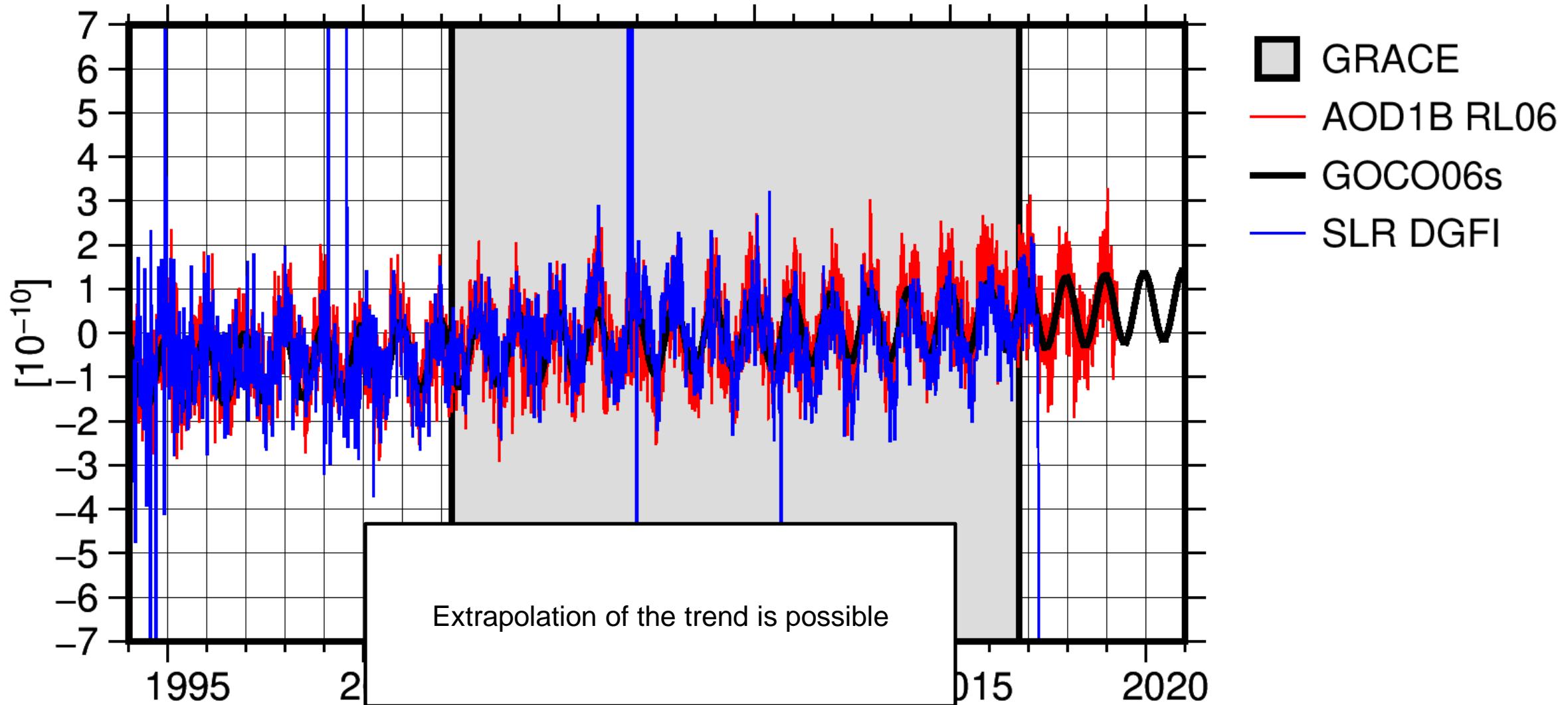
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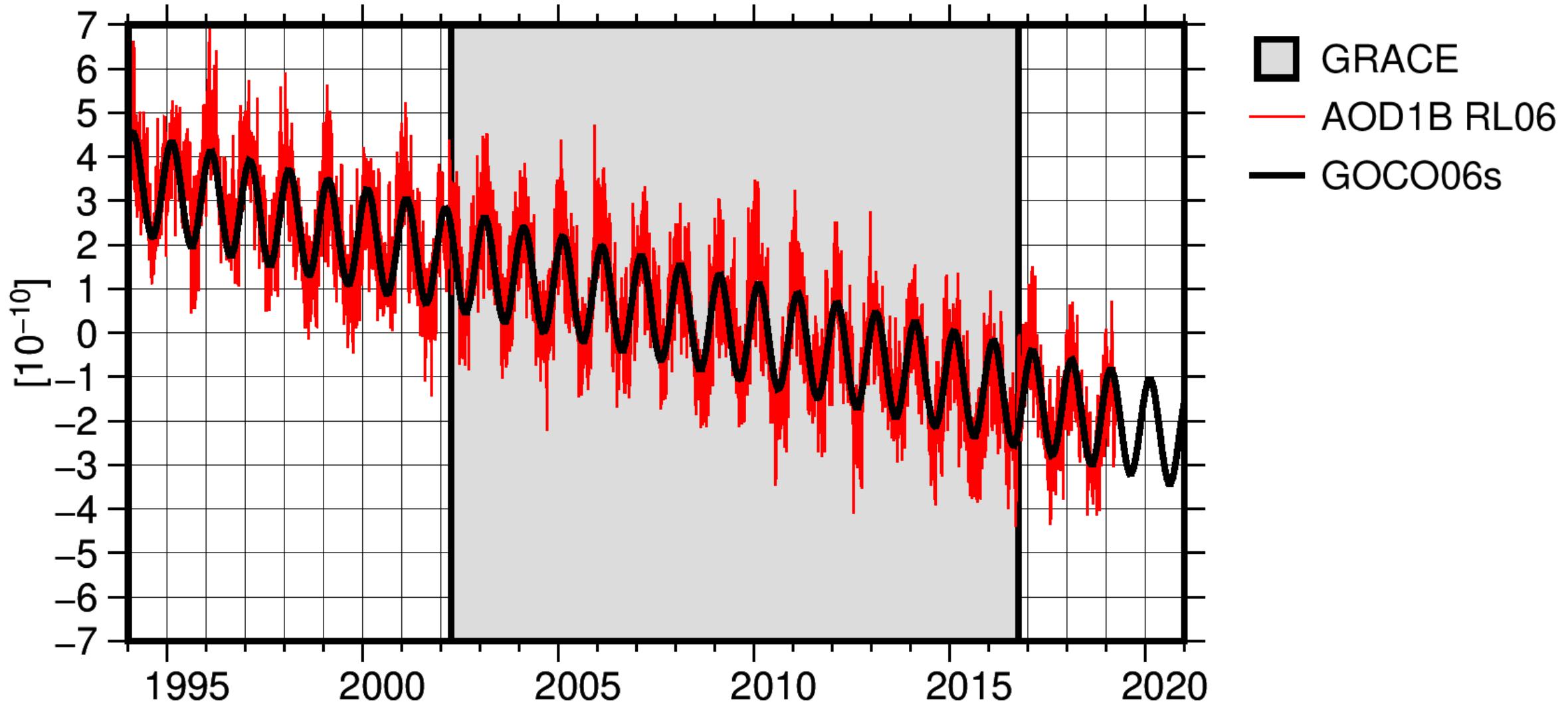
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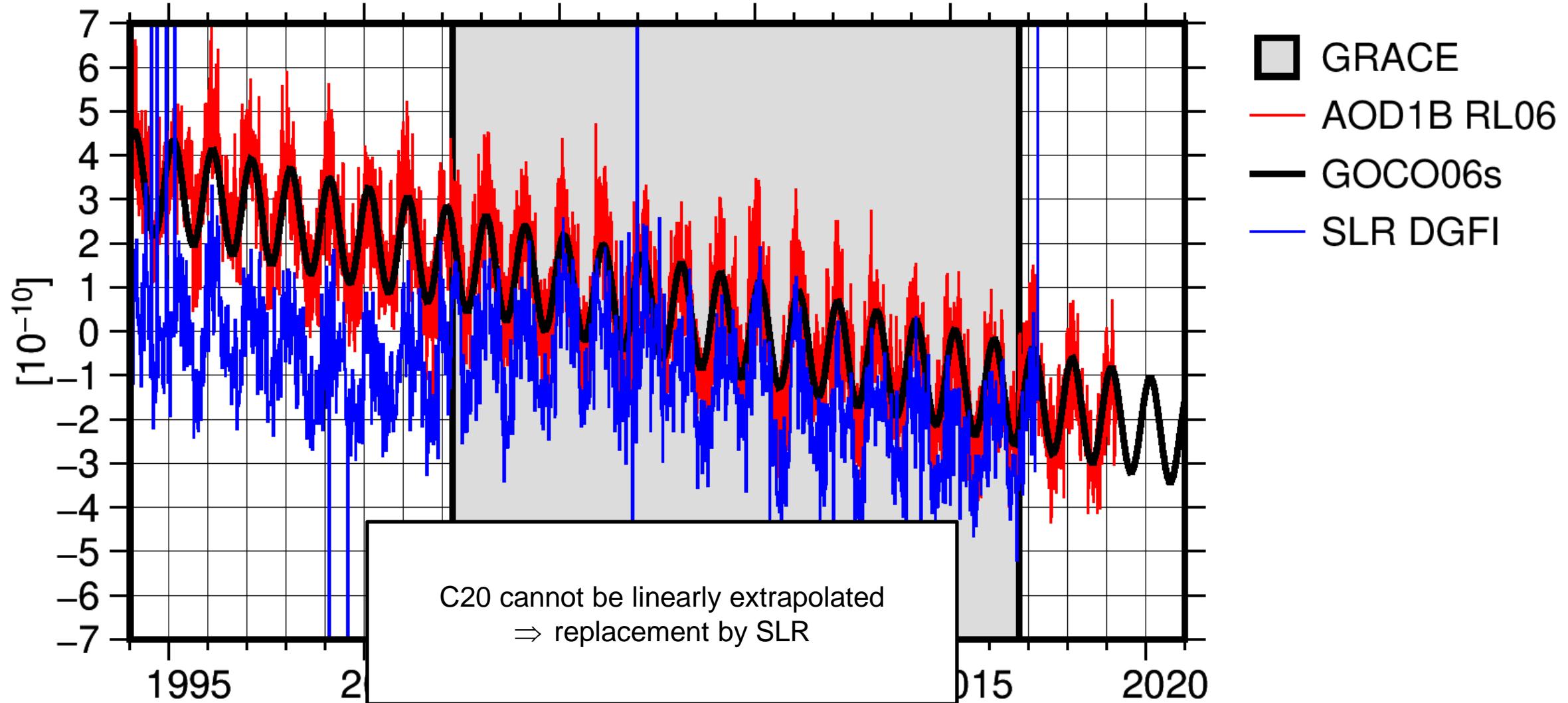
GOCO06s – Degree 2 coefficients

$$c_{20} = -4.841694947139e-04$$

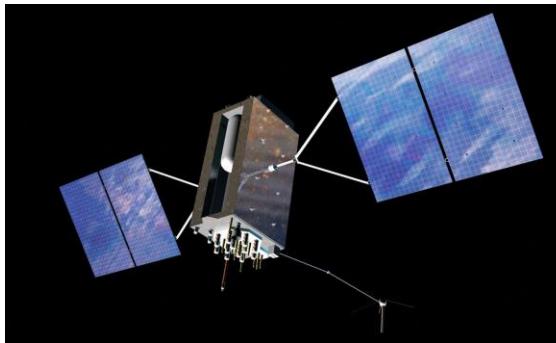


GOCO06s – Degree 2 coefficients

$$c_{20} = -4.841694947139e-04$$



GNSS – plan for TUG repro



All models up to
degree/order 40
(to be on the safe side)

Force models	TUG repro3
Static field + annual + trend	GOCO06s
C20 replacement	SLR (DGFI?) weekly
Atmosphere + Ocean	AOD1B RL06
Astronomical tides	JPL DE421
Earth tides	IERS2010
Ocean tides	FES2014c + GRACE estimates
Atmospheric tides	AOD1B RL06
Pole tides	IERS2010 (linear mean pole)
Ocean pole tides	Desai 2004 (linear mean pole)
Solar radiation	Boxwing + ECOM2
Antenna thrust	Steigenberger et. al.
Relativistic effects	IERS2010

Mass transports => time variable gravity

Solid Earth

Atmosphere

Ocean

Hydrology

Ice

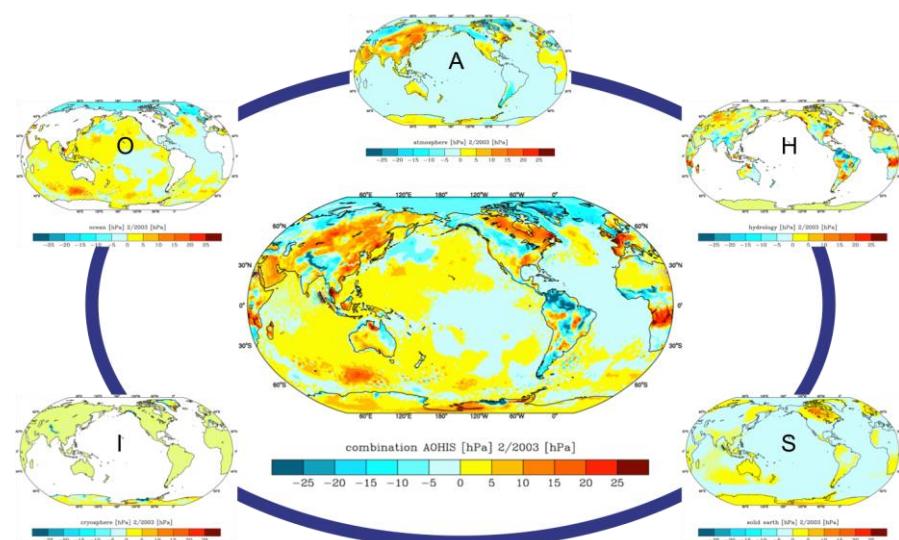
- Solid Earth tides
- Glacial isostatic adjustment (GIA)
- Pole tides
- Earthquakes
- Plate motion
- Mantle convections
- Loading deformation
- ...

- Pressure variations
- Water content
- Tides
- ...

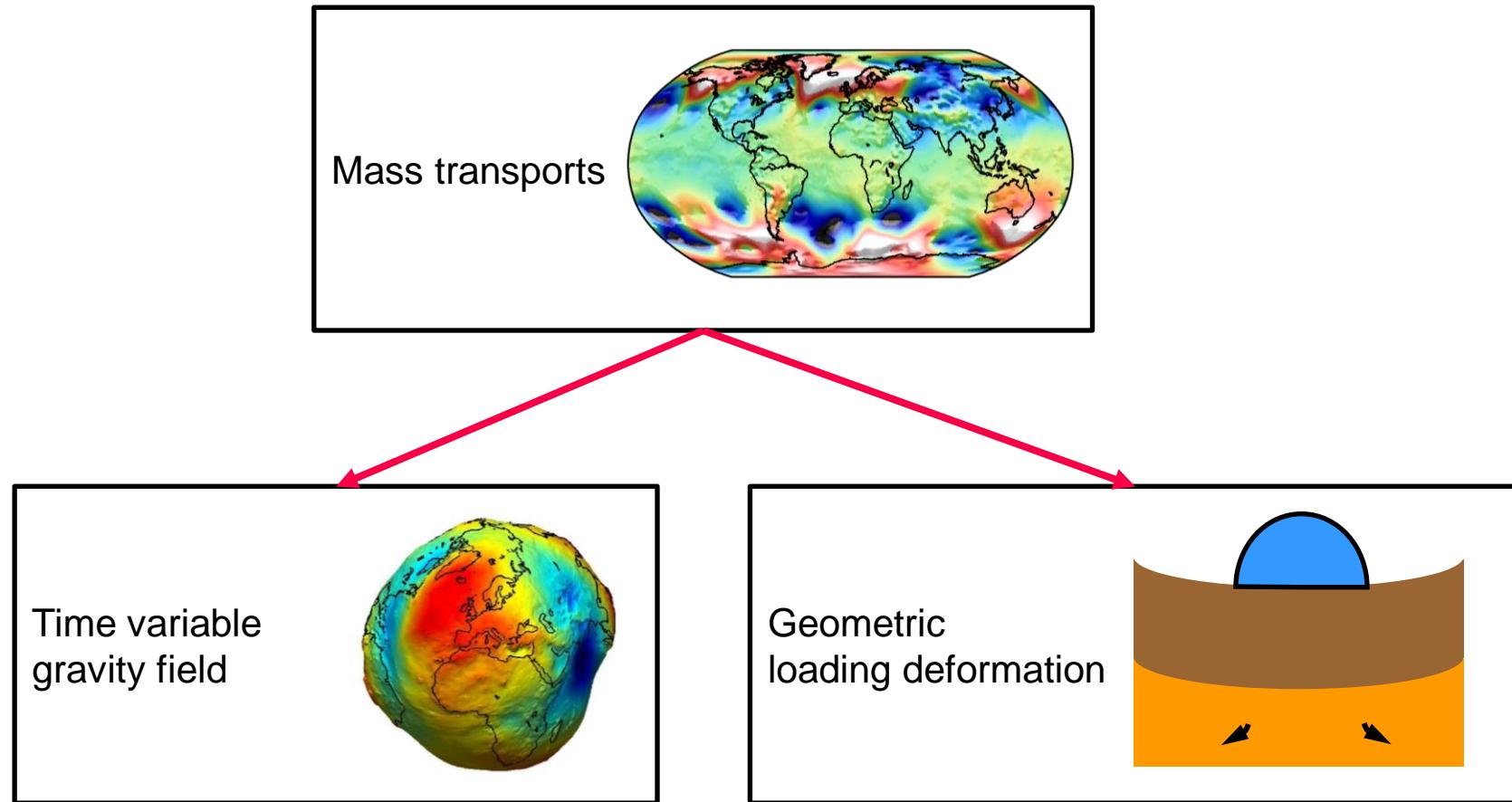
- Barotropic currents
- Ocean tides
- Ocean pole tides
- Sea level rise
- ...

- Groundwater
- Soil moisture
- Canopy
- River / lakes
- ...

- Continental ice shelves
- Glaciers
- Permanent frost
- Snow
- ...



Mass transports



Should it be consistent?

Orbit product in SP3 format

- GNSS orbits (and stations) are estimated in a center of mass (CM) frame
- IERS conventions 2010, Chapter 7. „Displacement of reference points“ (!!!!!):

Ocean tides, Center of mass correction

“... This correction should be applied, for instance, in the transformation of GPS orbits from the center-of-mass to the **crust-fixed frame** expected in the sp3 orbit format ...”

- I found no comments in the SP3 format description
- Are there other „corrections“ needed, stated elsewhere?
- It is not a real crust-fixed system (center of figure (CF))?
because all other geocenter variations (atmosphere, ocean, hydrology, GIA, ...) are missing
- The definition depends purely on models
- I am confused and need advise. Please help me!

Backup

Estimated ocean tides from GRACE data

- Complete GRACE time series
- Full normals: tides+daily+annual+trend
- Constrained towards FES2014b
- Contains atmospheric and ocean tides
- Introduced as new background model

