Models and Standards for ITRF2020

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- Gravity field model with a TVG component
- “Dealiasing products” (atmosphere, ocean)
- Oceanic tidal model
- ALBEDO+IR acceleration computation

- Gravity field model with a TVG component

- CNES proposes to use EIGEN-GRGS.RL04.MEAN-FIELD:

http://gravitegrace.get.obs-mip.fr/grgs.obs-mip.fr/data/RL04/static/EIGEN-GRGS.RL04.MEAN-FIELD.linear_mean_pole.zero_slope_extrapolation

- Other option: Proposed by E. Pavlis for SLR reprocessing

•A new static gravitational model was developed from the recent reanalysis (RL06) of the GRACE mission data using the new definition of the secular pole;

•Subsequently, a complete reanalysis of the SLR data to several satellites were repeated at CSR using the newly defined secular pole;

•A new series of 15-day $\Delta J2$/ $\Delta C(2,0)$ are now available, consistent with the new secular pole and the new static gravity model that RL06 produced;

•A combination of that GRACE model with GOCE data and surface gravity data produced the model that we will adopt, GGM05C [Rieset al., 2016]

EIGEN-GRGS.RL04.MEAN-FIELD

- Is based on 14 years of GRACE data (2002/08 – 2016/06), 3 years of GOCE data and 26 years of SLR data (1993/01 – 2019/02).
- Contains a time-variable gravity (TVG) part until degree and order 90, and a static part coming from the model **GOCE-DIR5** up to degree and order 300.
- The TVG part model is based on the CNES/GRGS **RL04** series of monthly GRACE solutions
  - A description of the **RL04** monthly solution is given here: https://grace.obs-mip.fr/variable-models-grace-lageos/grace-solutions-release-04/rl04-products-description
  - A detailed description of **EIGEN-GRGS.RL04.MEAN-FIELD** was presented at the last IDS Workshops:

    https://ids-doris.org/images/documents/report/ids_workshop_2018/IDS18_s3_LemoineJM_NewtimeVariableGravityFieldModelForPOD.pdf
- The TVG part is modeled for each year as an annual bias + slope + annual and semi-annual periodic components ➔ 6 parameters / year * 14 years * 91x91 spherical harmonics = ~800 000 coefficients

Extrapolation – “retropolation”

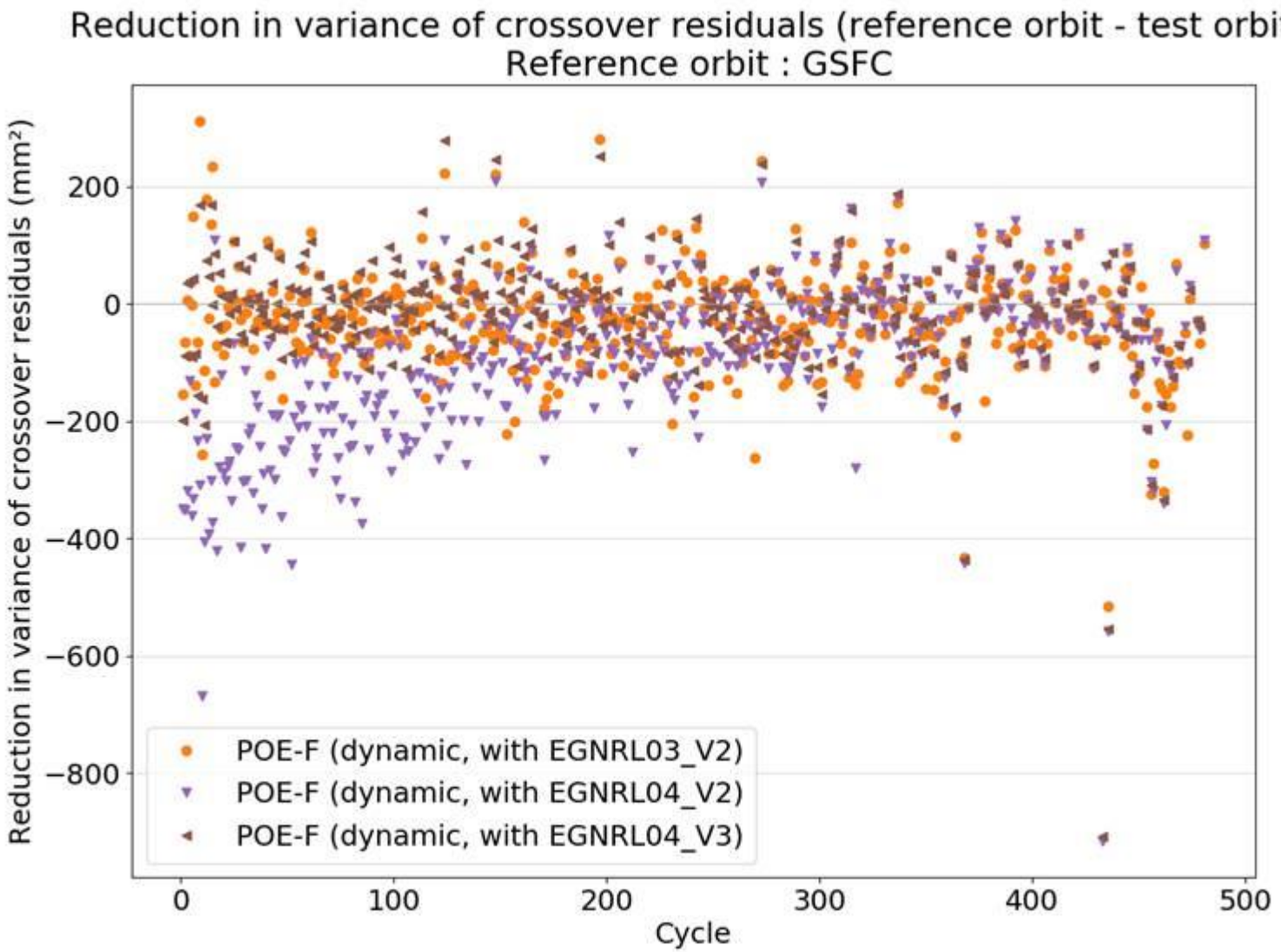
- Extrapolation:
  - For degrees 1 & 2, after 2019/02/14, linear + annual + semi-annual, based on 1993-2019 averages
  - For degrees > 2, after 2016/07/15, linear + annual + semi-annual, based on 2002-2016 averages

- “Retropolation”:
  - For degrees 1 & 2, before 1993/01/01, annual + semi-annual based on 1993-2019 averages, slope (of C20 in particular) given by earlier analysis of SLR
  - For degrees > 2, before 2002/08/01, annual + semi-annual based on 2002-2016 averages, zero slope

On this plot:

EGNRL04_V2 = EIGEN-GRGS.RL04.MEAN-FIELD with **linear** slope “retropolation” before 2002 for degrees >= 3

EGNRL04_V3 = EIGEN-GRGS.RL04.MEAN-FIELD with **zero** slope “retropolation” before 2002 for degrees >= 3



- “Dealiasing products” (atmosphere, ocean)

- ECMWF-ERA-Interim / TUGO-3h:
  - Available from 1980/01/01 to 2017/12/31
  - Time step: 3h
  - Disadvantage: update only every ~ 4 months

- ECMWF-Operational / MPIOM (AOD1B-RL06):
  - Available from 1976/01/01 to today
  - Time step: 3h, max degree: 180
  - Advantage: updated with a very short latency
  - Peculiarity: In RL06, all tidal signals in atmosphere and ocean are estimated and removed from the AOD1B time-series, and are provided in terms of separate sets of Stokes coefficients

ECMWF-Operational / MPIOM (AOD1B-RL06) Post-Processing details:

- 1 – Download raw daily AOD1B files from GFZ ftp: ftp://isdcftp.gfz-potsdam.de/grace/Level-1B/GFZ/AOD/RL06
- 2 – Download tidal waves from: ftp://isdcftp.gfz-potsdam.de/grace/Level-1B/GFZ/AOD/RL06/TIDES
- 3 - for i in ATM_K1 ATM_L2 ATM_M2 ATM_N2 ATM_P1 ATM_R2 ATM_R3 ATM_S1 ATM_S2 ATM_S3 ATM_T2 ATM_T3 OCN_S1 ; do Apply tidal wave corrections ; done
- 4 – Set to 0 degrees 0 and 1
- 5 - Conversion to desired format

This operation is done at CNES, we can if necessary provide the files to the CAs

Orbit tests on “dealiasing products” (atmosphere, ocean)

- DORIS: (Jason-3 from July 2017 to Decembre 2017 (6 months)

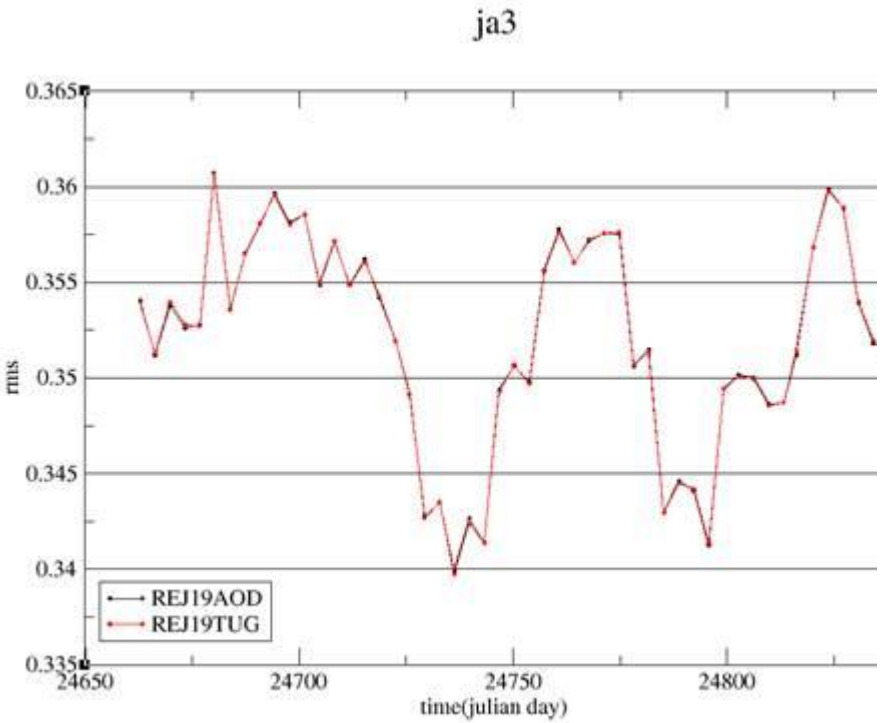
DORIS residuals

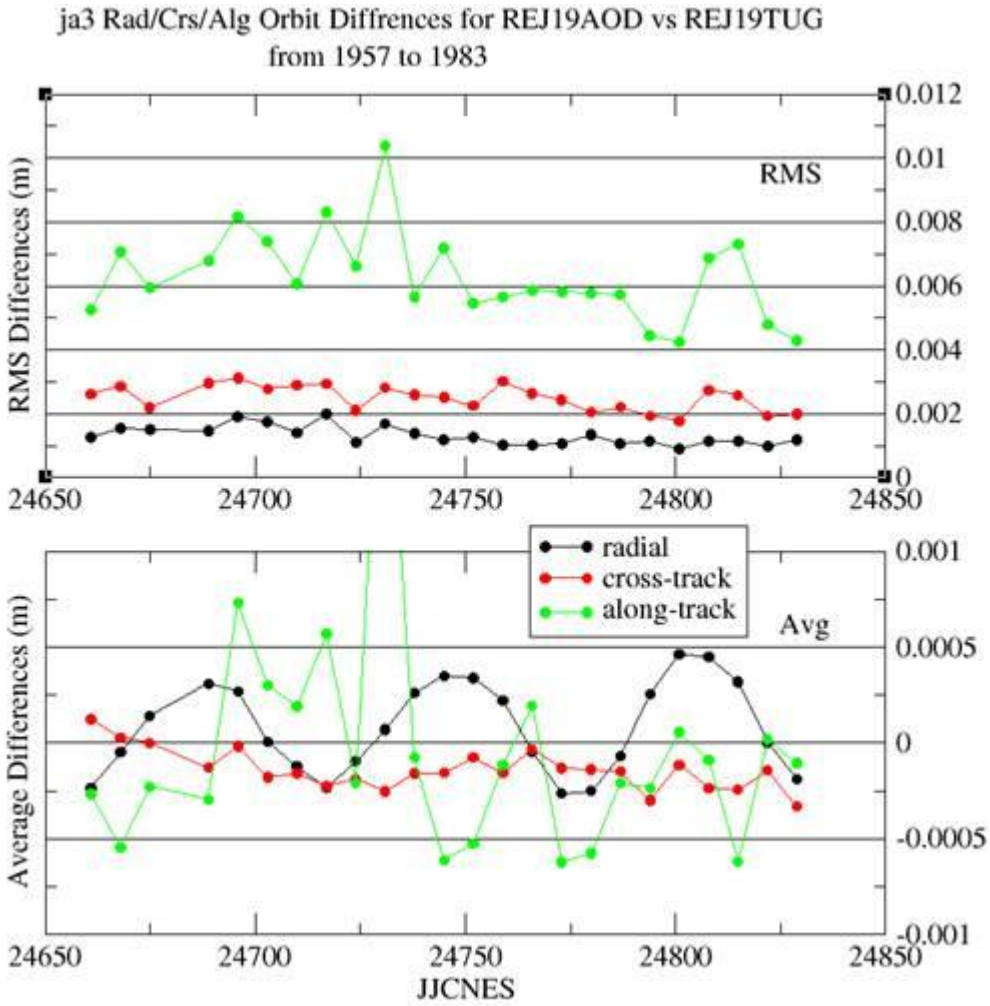
- REJ19TUG mean RMS = **0.352043** mm/s (Dealiasing = ERA-Interim 3d 3h + TUGO 3h)
- REJ19AOD mean RMS = **0.352055** mm/s (Dealiasing = AOD1B-RL06)
- REJ19N mean RMS = **0.352061** mm/s (Dealiasing = “atm.press.” on continents + IB on oceans)

Independent SLR RMS of fit *on Jason-3 orbits*

- REJ19TUG mean RMS = **1.80622** cm (Dealiasing = ERA-Interim 3d 3h + TUGO 3h)
- REJ19AOD mean RMS = **1.79078** (Dealiasing = AOD1B-RL06)
- REJ19N mean RMS = **1.86096** cm (Dealiasing = “atm.press.” on continents + IB on oceans)

Orbit tests on “dealiasing products” (atmosphere, ocean)





- High DORIS residuals when the Sun is in the orbital plane (27708, 24768, 24830)
- Low DORIS residuals when the Sun is perpendicular to the orbital plane (24740, 24800).

What can we conclude?...

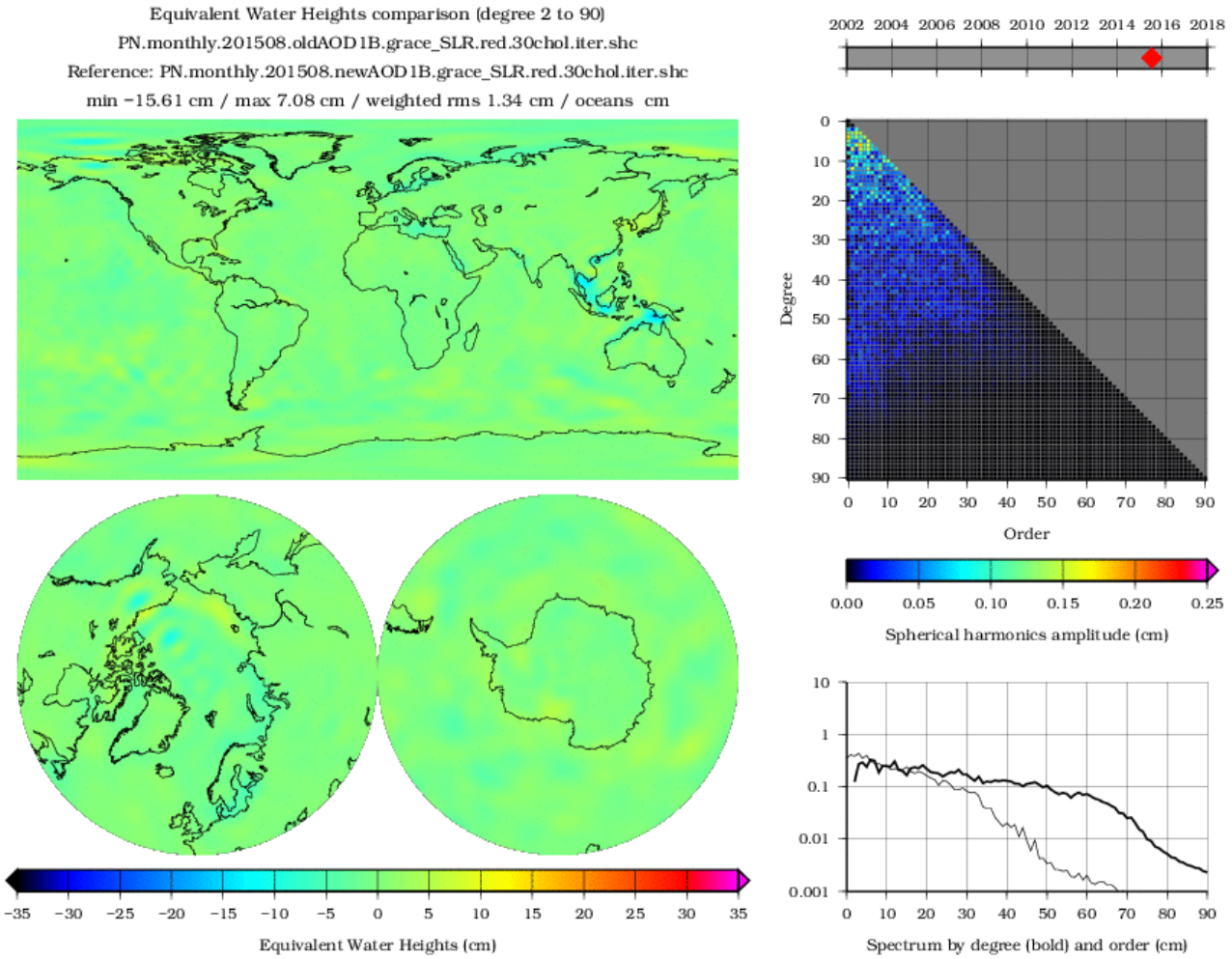
Orbit tests on “dealiasing products” (atmosphere, ocean)

- SLR test: (only 1 Starlette arc for the moment in August 2017)

SLR residuals

- RMS = **0.012149** m (Dealiasing = ERA-Interim 3d 3h + TUGO 3h)
- RMS = **0.012447** m (Dealiasing = AOD1B RL06)
- RMS = **0.017526** m (Dealiasing = “atm.press.” on continents + IB on oceans)

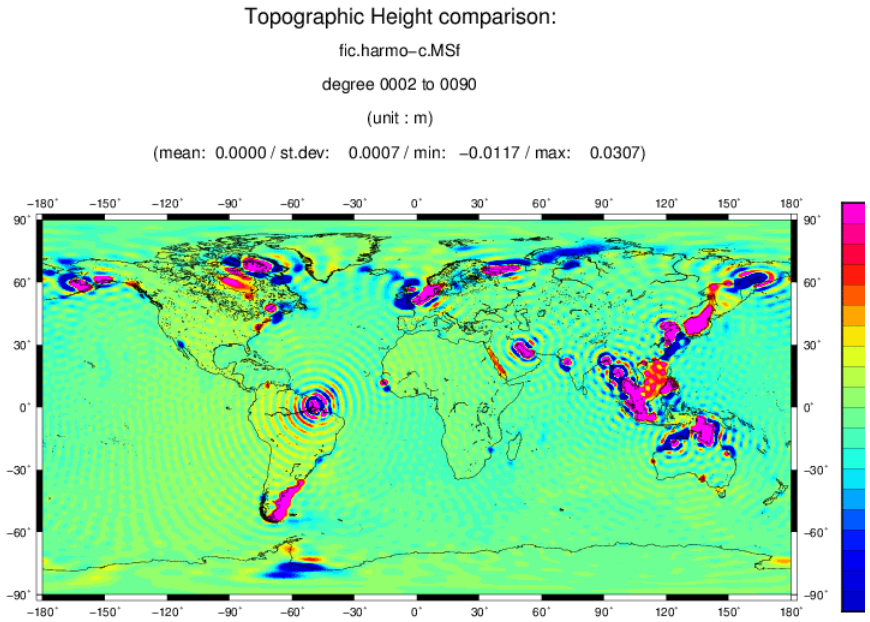
Gravity field recovery test with different “dealiasing products”: 1-month GRACE solution (August 2015)



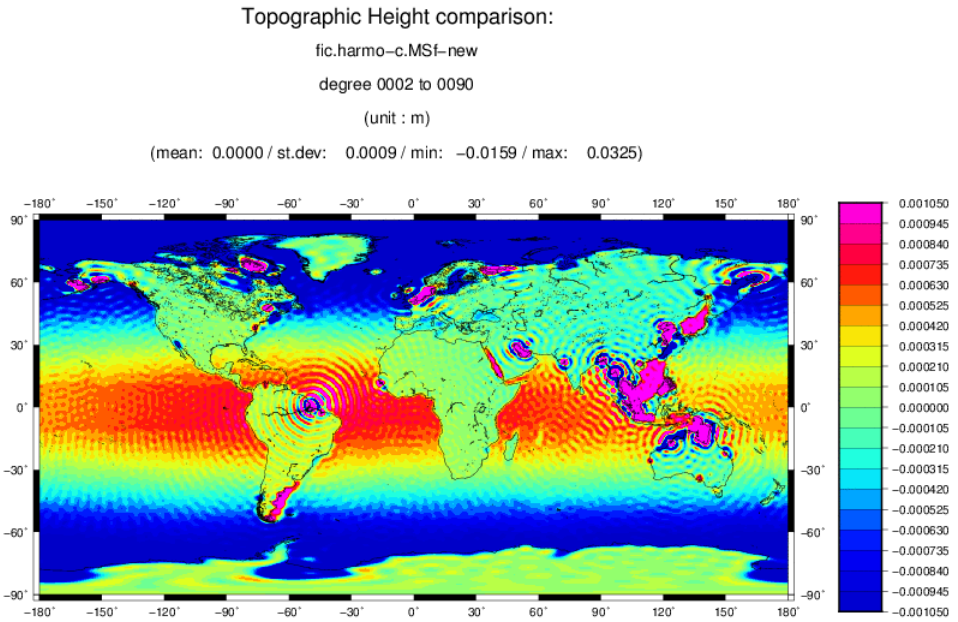
- Ocean tides

- FES2014b is now available with a corrective patch on the MSf wave

Un-corrected MSf



Corrected MSf

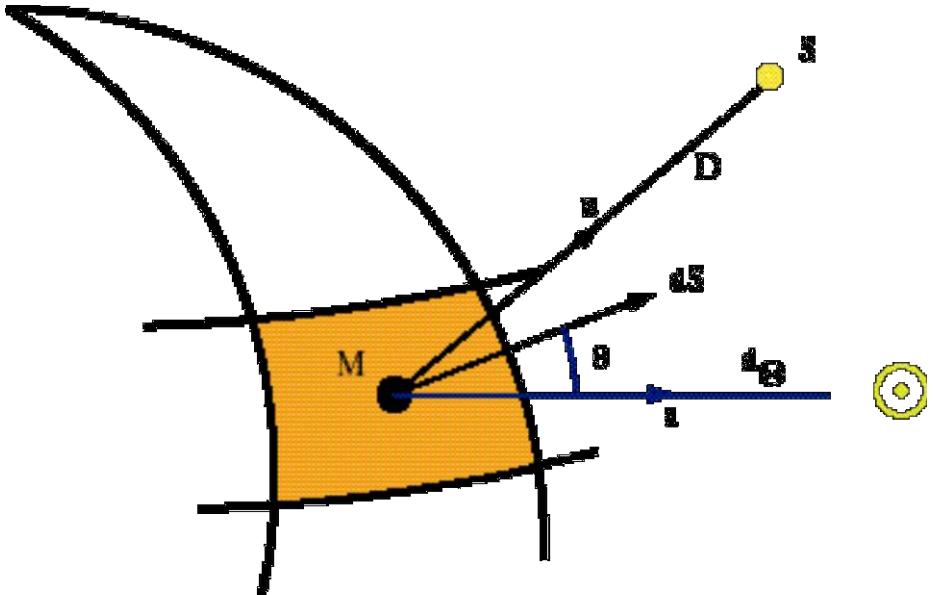


For orbit computation:

- FES2014b is computed on the ellipsoide
- Is completed with Om1 and Om2 (C20 only)
- S1 is suppressed (because it is taken into account by TUGO-3h)

- Albedo + IR daily maps

- The maps come from the ECMWF operational model. The native resolution is 0.5°
- CNES downgrades this resolution to 4.5° and 9°
- One can use any of these classes of resolution, depending on the altitude of the satellite that is being processed. (For instance Starlette/Stella 4.5°, Lageos 9°)
- The files are daily means for albedo and IR data
- These grids are available for other IDS ACs to test or to use



BACKUP SLIDES

- The new **EIGEN-GRGS.RL04.MEAN-FIELD** is available for download:
  - https://grace.obs-mip.fr/variable-models-grace-lageos/mean-fields/release-04/
- We propose to use it for the computation of the future **ITRF2020**.
- It is based on 14 years of GRACE data (2002/08 – 2016/06), 3 years of GOCE data and 26 years of SLR data (1993/01 – 2019/02).
- It contains a time-variable gravity (TVG) part until degree and order 90, and a static part coming from the model **GOCE-DIR5** up to degree and order 300.
- The TVG part model is based on the CNES/GRGS **RL04** series of monthly GRACE solutions
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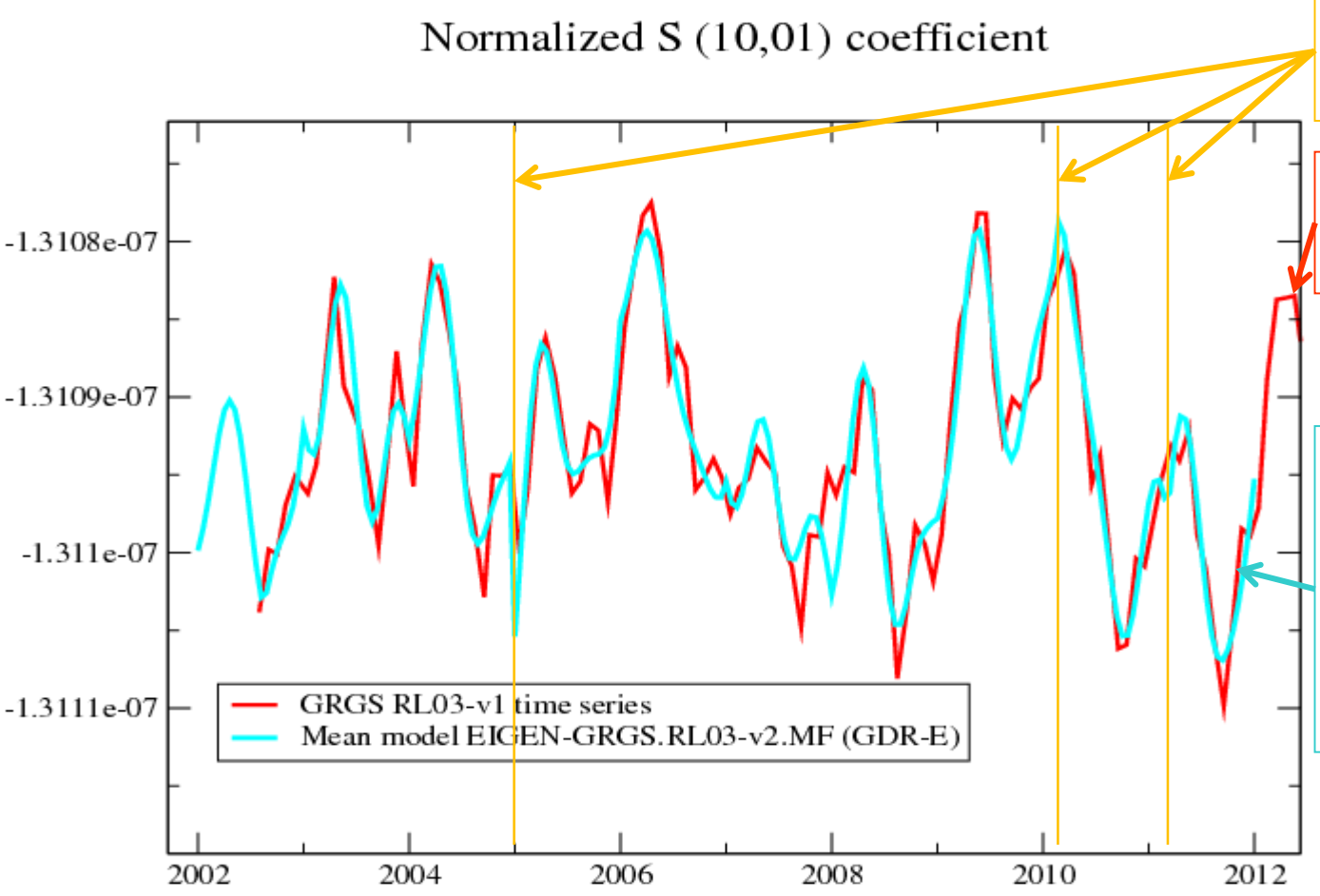
- The TVG part is modeled for each year as an annual bias + slope + annual and semi-annual periodic components ➔ 6 parameters / year * 14 years * 91x91 spherical harmonics = ~800 000 coefficients

- Example for one spherical harmonic coefficient:



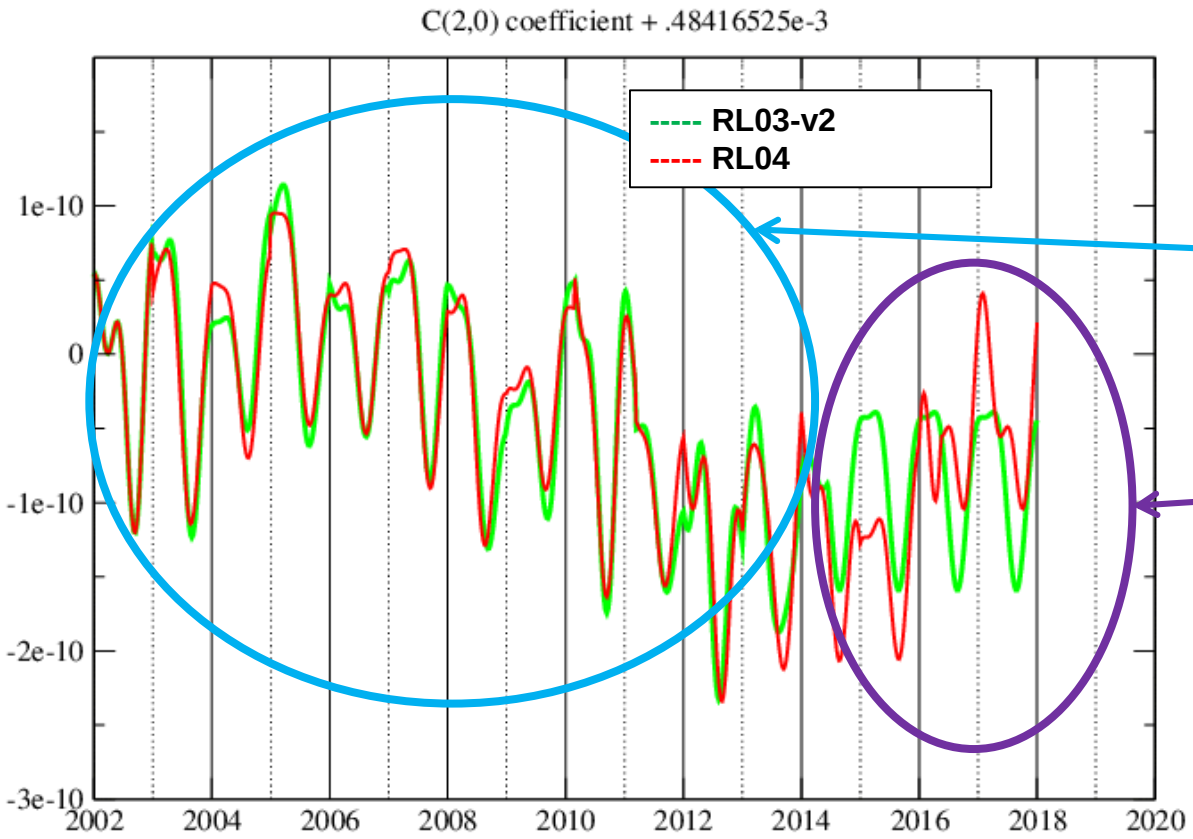
Large Earthquake events

GRACE monthly time series

Mean model with bias, drift per year, annual and semi-annual periodic terms per year

➢ The new mean field updates the previous one over 2 years: mid-2014 to mid-2016.

Example for the C(2,0) spherical harmonic coefficient:



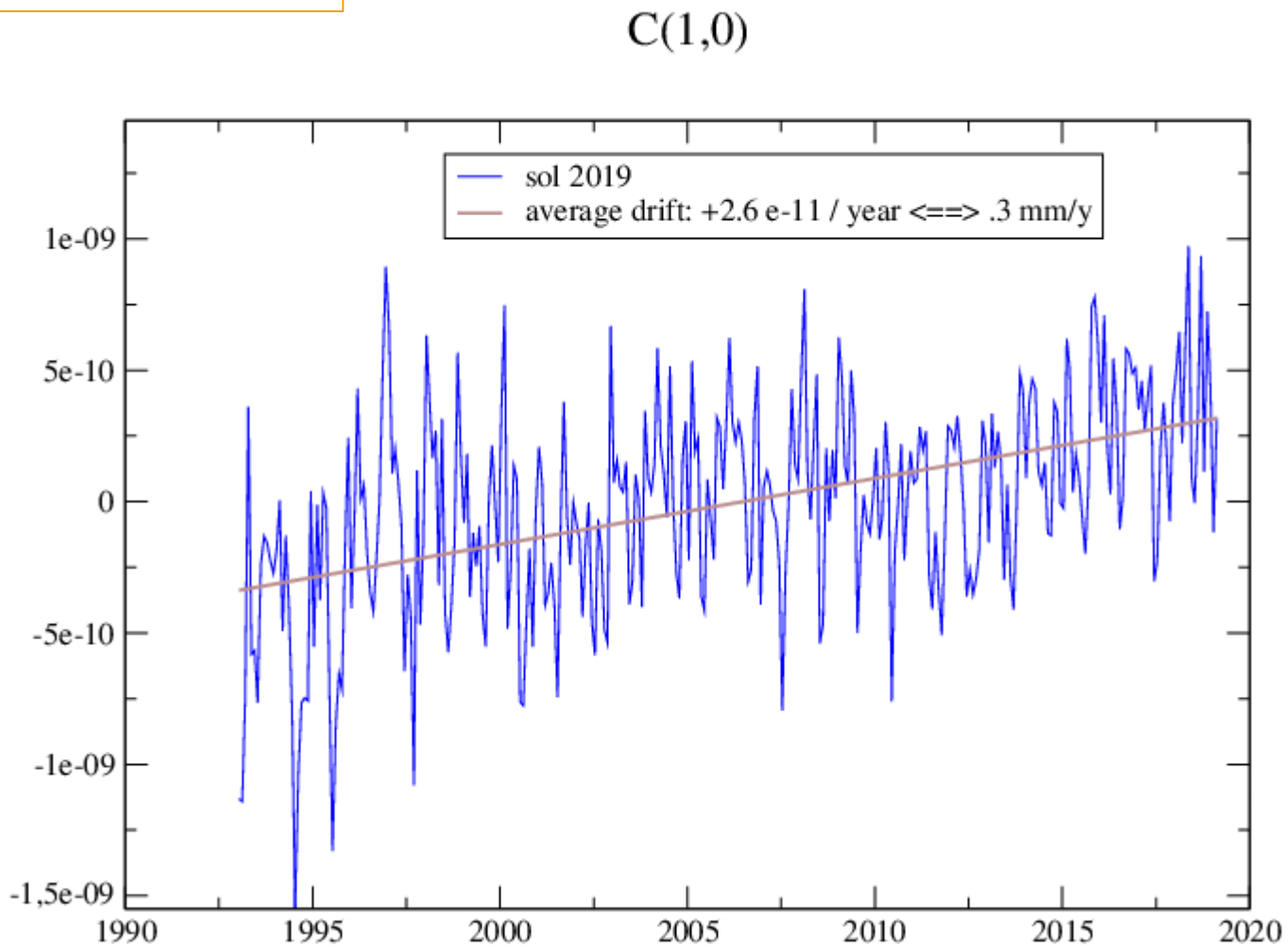
Small changes due to the transition from RL03-v2 to RL04

Important changes due to the addition of 2 more years

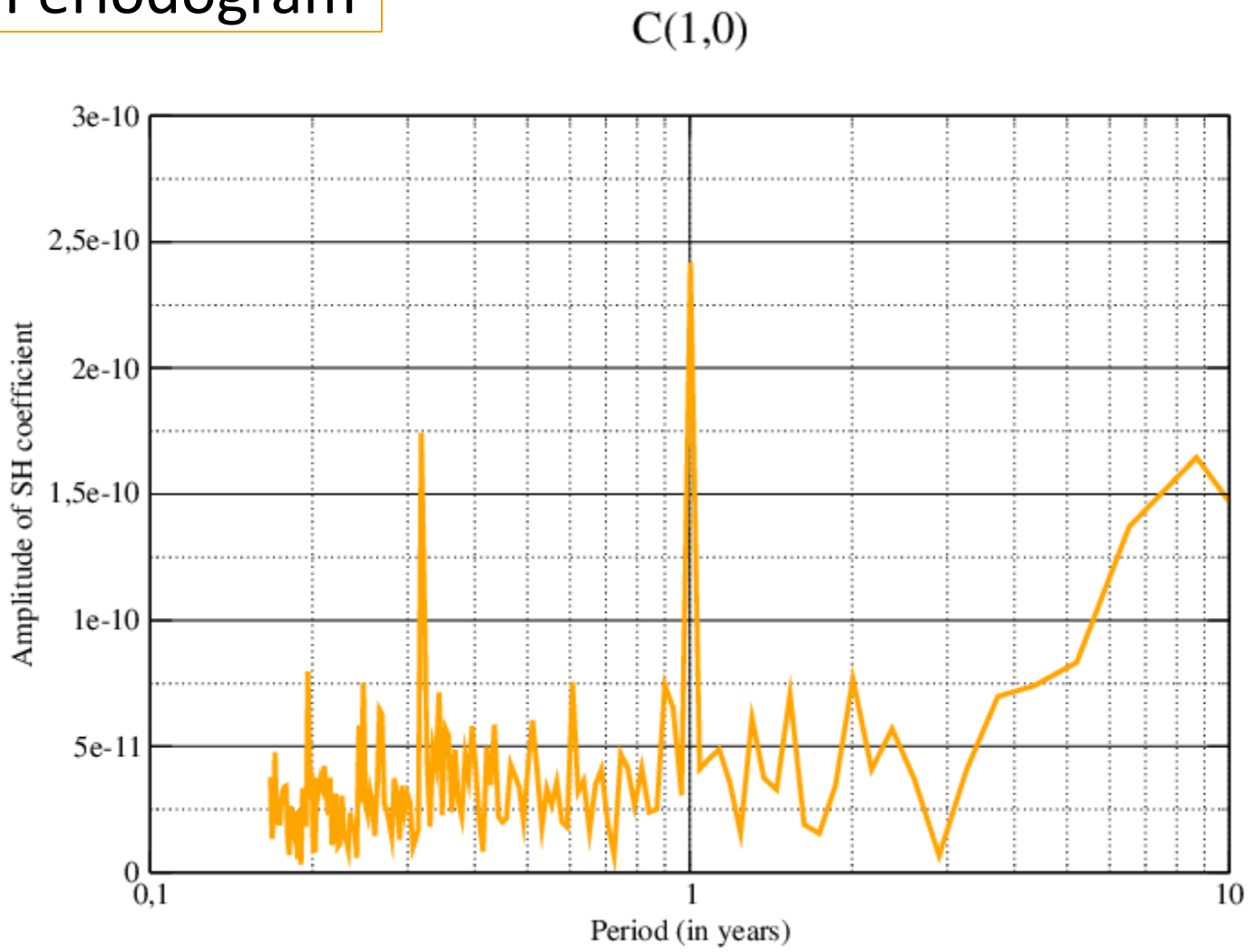
Low degrees

- For POD it is important that the low degrees of the gravity model be very accurate.
- A complete reprocessing of the SLR data from 5 satellites (Lageos, Lageos-2, Starlette, Stella, Ajisai) has been done from 1993/01 to 2019/02 using the latest standards.
- SLR data contribution to EIGEN-GRGS.RL04.MEAN-FIELD:
  - provides the degree 1 solution,
  - contributes to the degree 2 solution.
- **Degree 1:**
  - This new solution, based on a long time span, lets appear a **small drift** of the C(1,0) coefficient: +2.6 e-11 /y ⇔ **0.3 mm/y in Z_Earth**
  - And a small offset of the S(1,1) coefficient of 1.0 e-10 ⇔ **1.1 mm on Y_Earth**
  - The main period present in the solution is annual with a peak at **2.6 mm in Z, 1.0 mm in X and 2.5 mm in Y**
  - There is a second peak in Z at 0.318 y: 1.9 mm

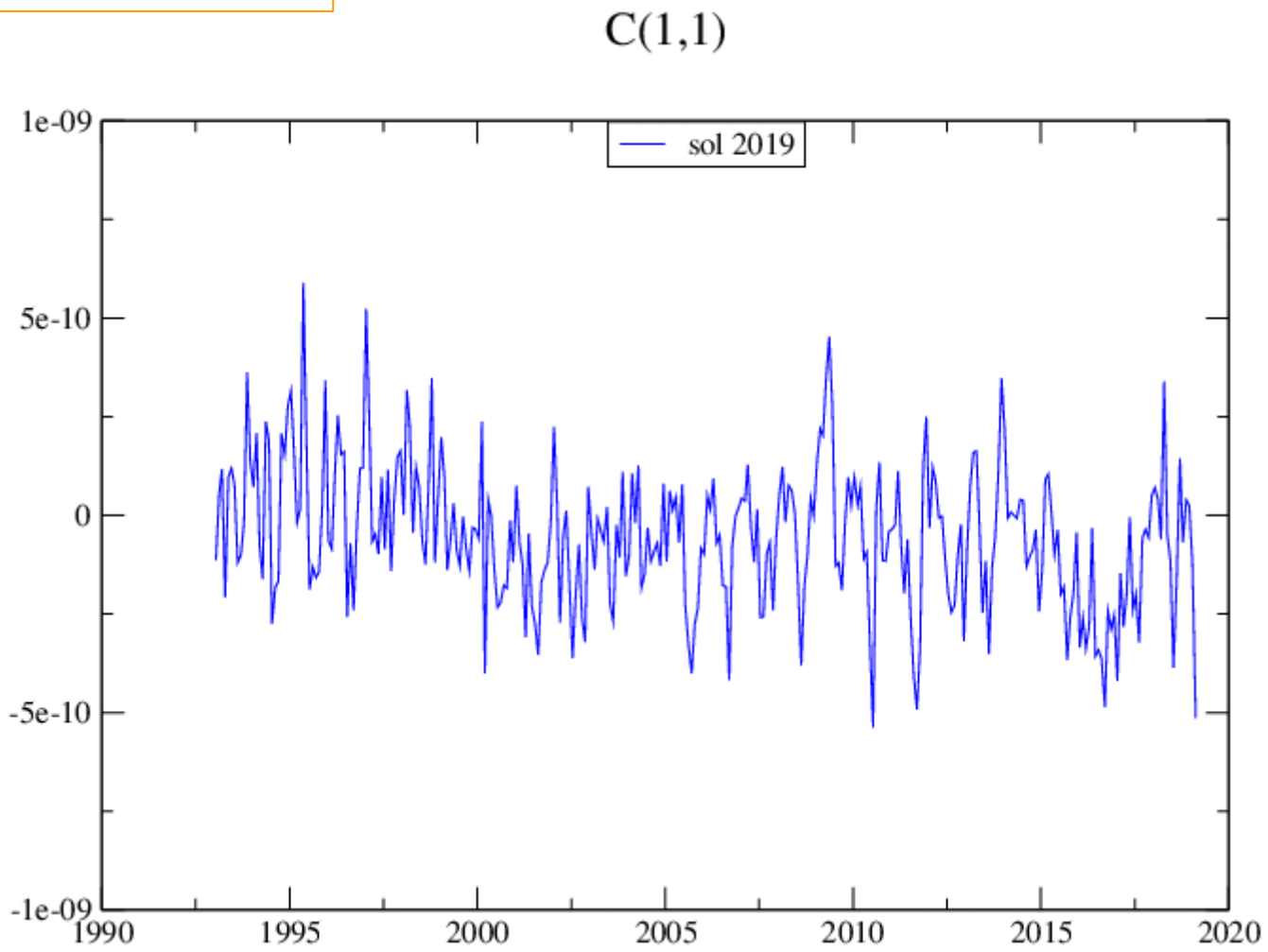
Time series


C(1,0)
sol 2019
average drift: +2.6 e-11 / year <==> .3 mm/y
1e-09
5e-10
0
-5e-10
-1e-09
-1,5e-09
1990
1995
2000
2005
2010
2015
2020

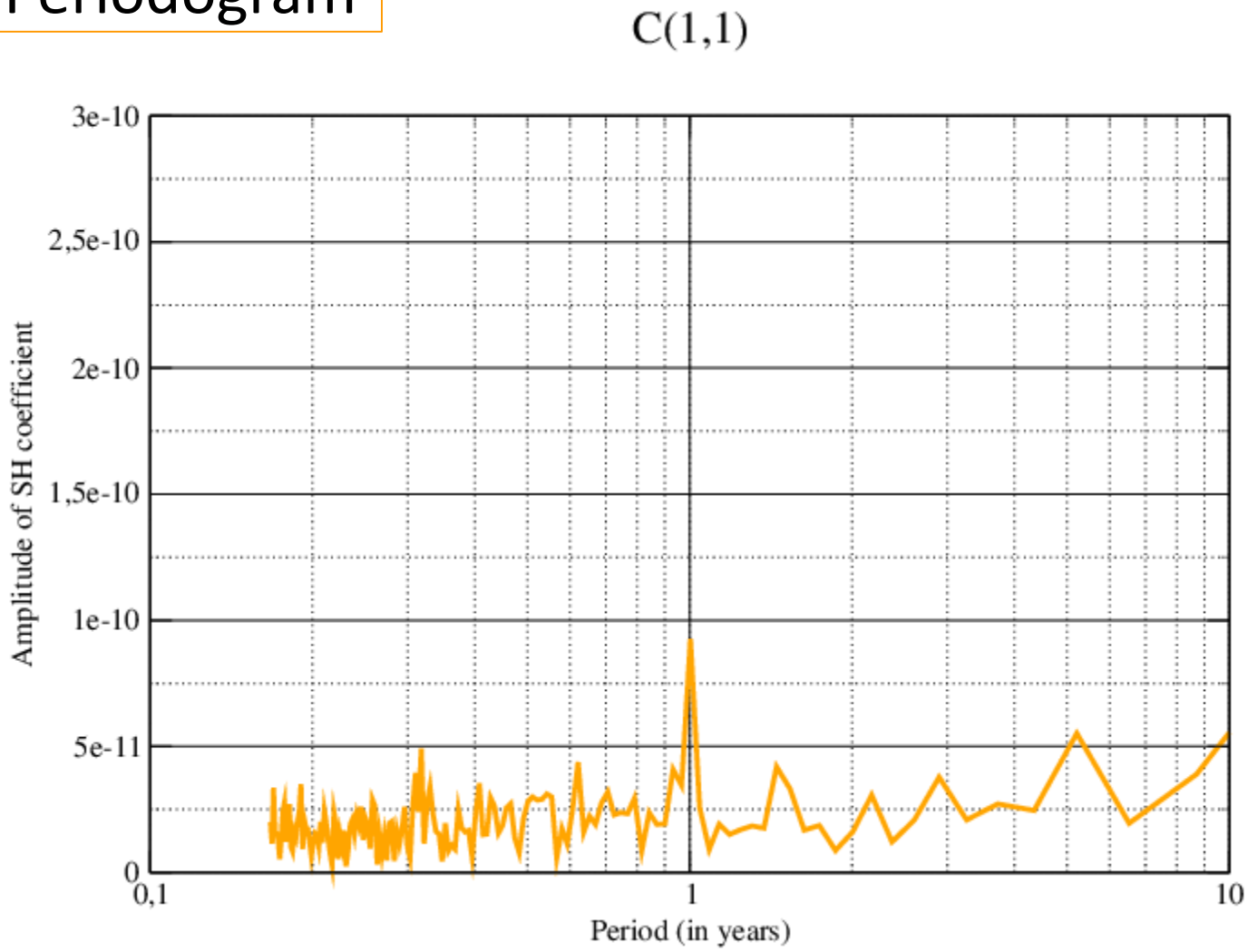
Periodogram



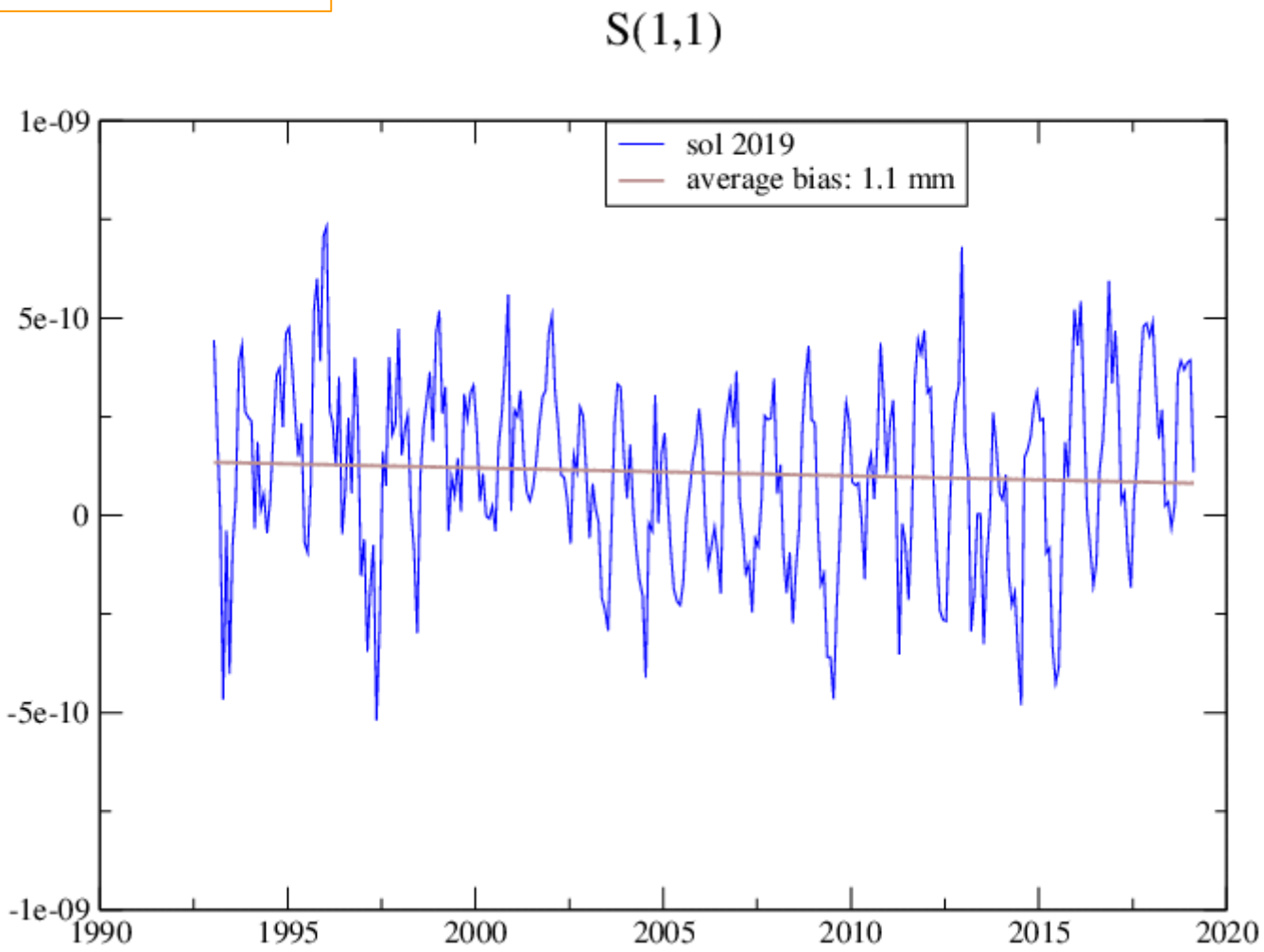
Time series


C(1,1)
sol 2019
1e-09
5e-10
0
-5e-10
-1e-09
1990
1995
2000
2005
2010
2015
2020

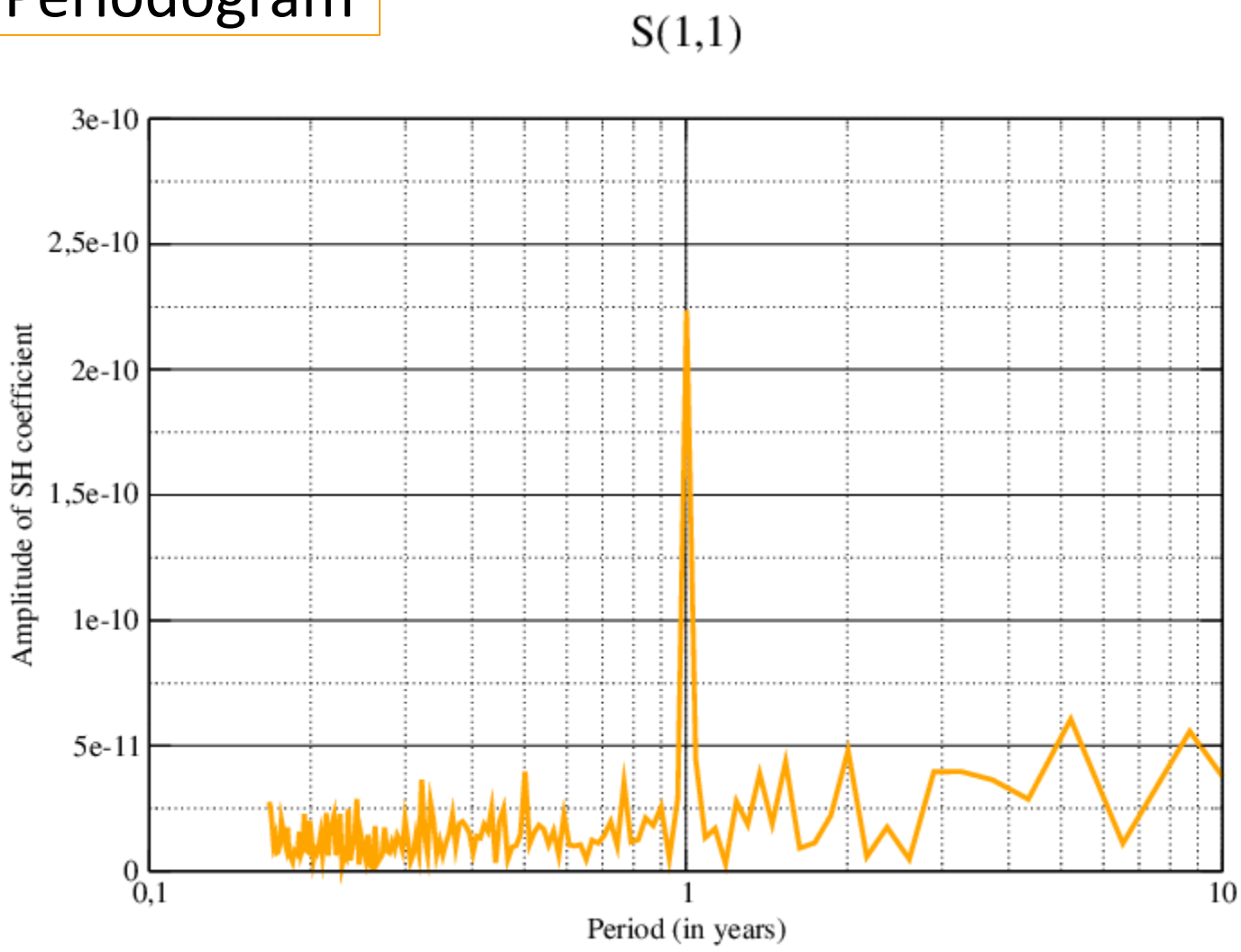
Periodogram



Time series


S(1,1)
sol 2019
average bias: 1.1 mm
1e-09
5e-10
0
-5e-10
-1e-09
1990
1995
2000
2005
2010
2015
2020

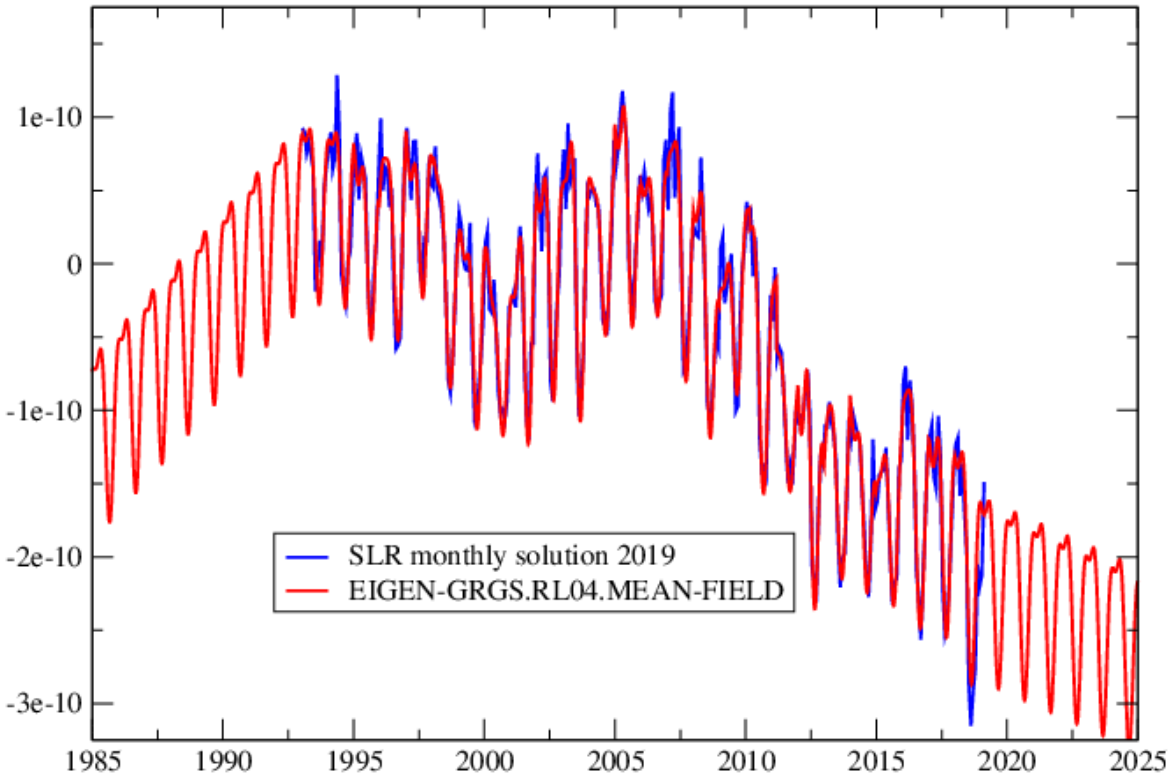
Periodogram



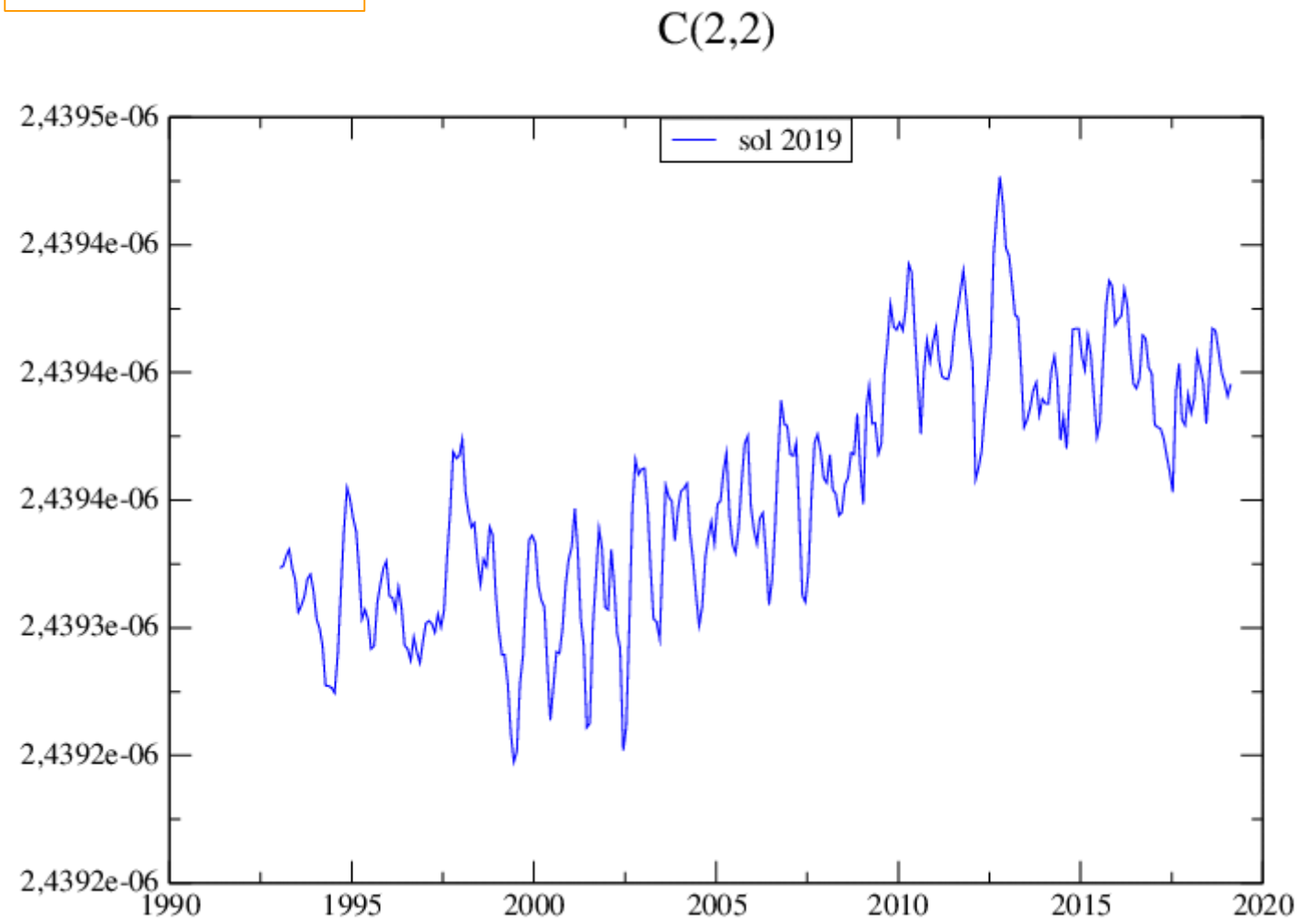
❖ **Degree 2:**

- The **slope** of the C(2,0) coefficient **before 1993** is based on earlier determinations of C(2,0)
- The **slope** of the C(2,0) coefficient **after 2019** is based on the average slope over the recent years: 2012-2019

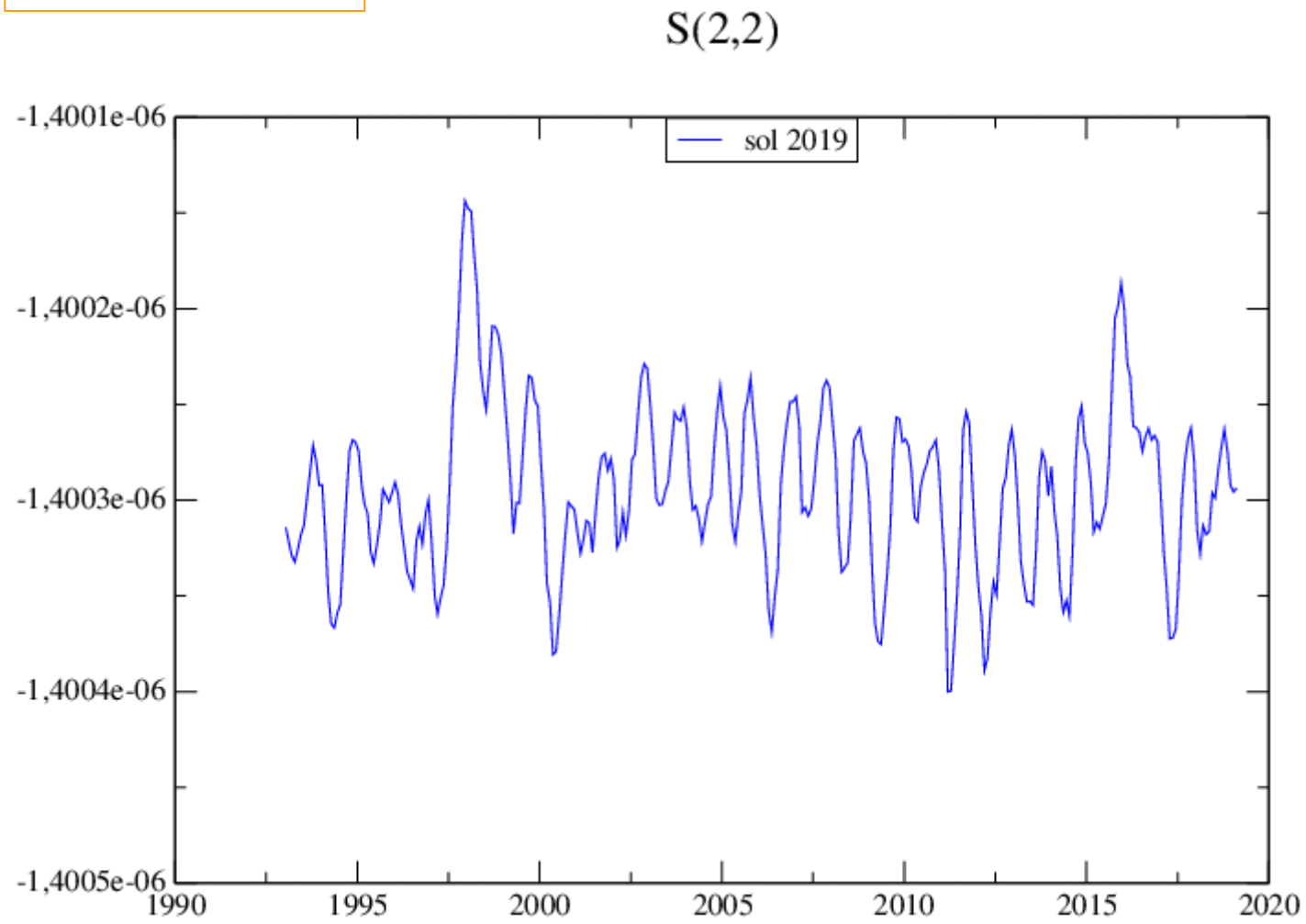
C(2,0) + .00048416525



Time series


C(2,2)
sol 2019
2,4395e-06
2,4394e-06
2,4394e-06
2,4394e-06
2,4393e-06
2,4392e-06
2,4392e-06
1990
1995
2000
2005
2010
2015
2020

Time series


S(2,2)
sol 2019
-1,4001e-06
-1,4002e-06
-1,4003e-06
-1,4004e-06
-1,4005e-06
1990
1995
2000
2005
2010
2015
2020

- Specific case of the **C(2,1) / S(2,1)** coefficients: on Feb 1st, 2018, the IERS convention for the mean pole motion changed from “quadratic” (old IERS2010 conventions) to linear (updated IERS2010 conventions). The change of IERS conventions on the mean pole implies that the CNES/GRGS RL04 solutions (monthly RL04 solutions, as well as mean gravity field model) are **provided in both conventions**.

- **Remarks:**

  - There **has to be** a coherence between the mean pole convention that is adopted (quadratic or linear) and the gravity field that is used.

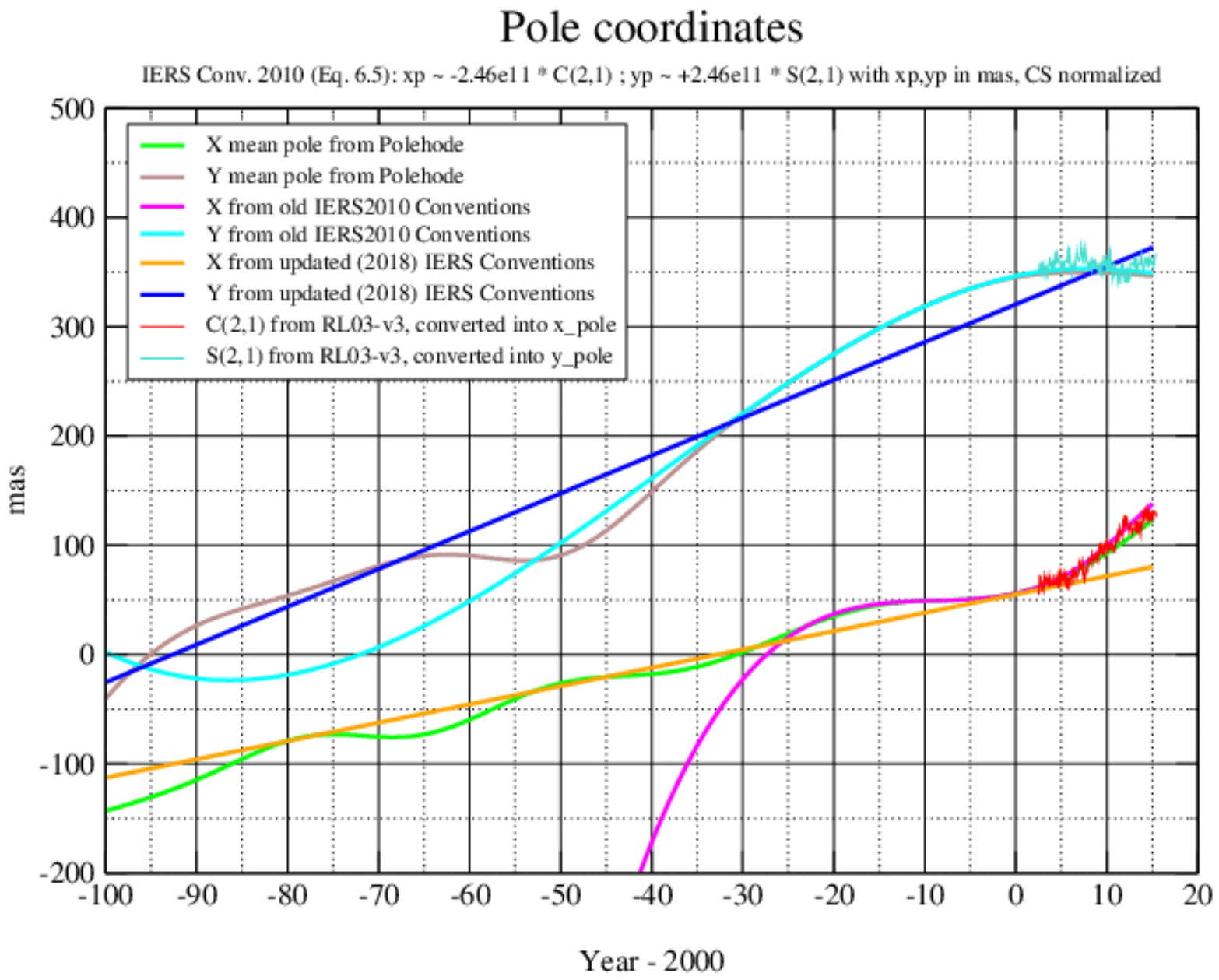
  - In the CNES/GRGS gravity field models a comment in the header indicates which convention is used:

CMMNT Mean pole convention: quadratic

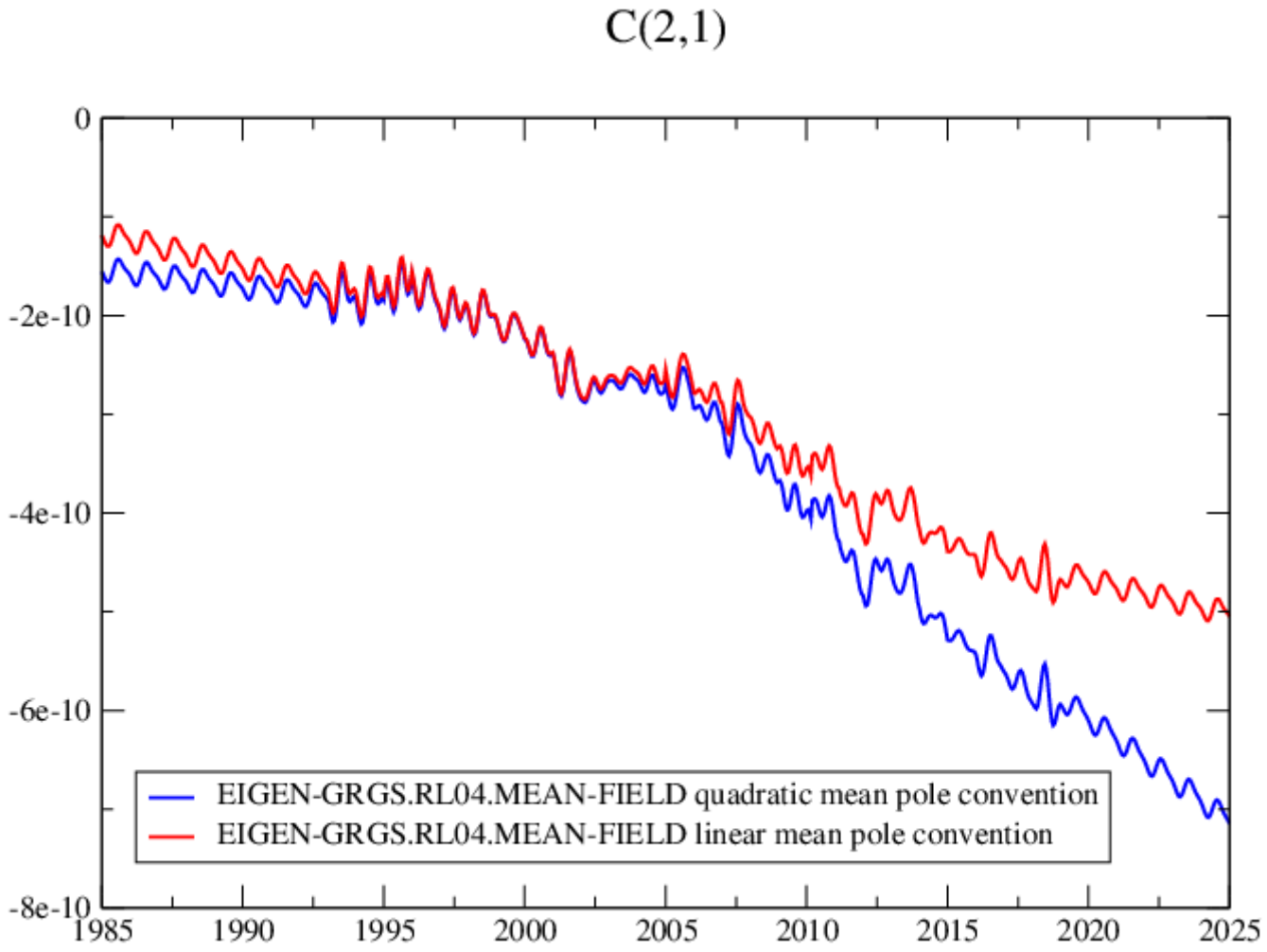
or

CMMNT Mean pole convention: linear

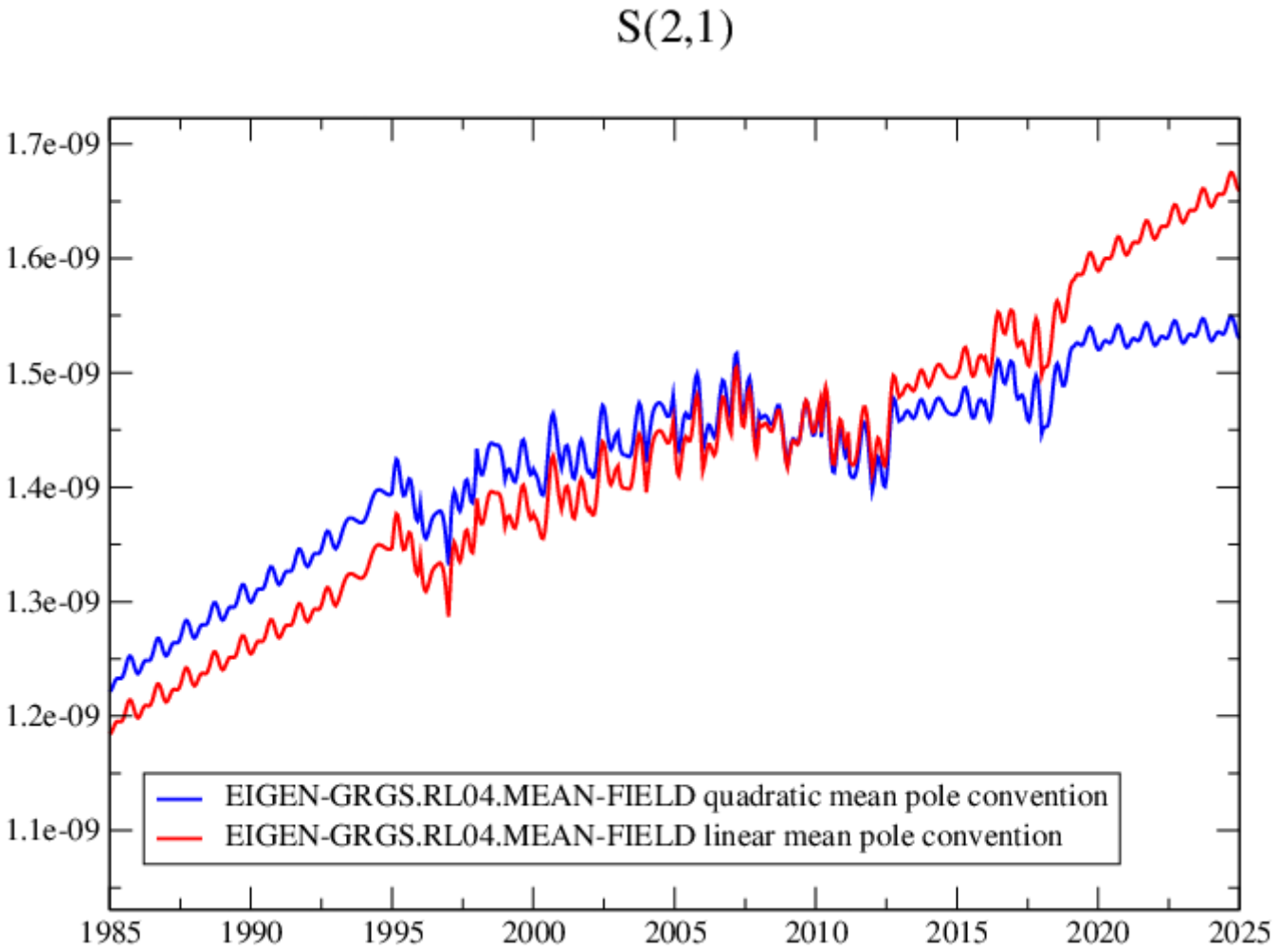
“IERS2010 mean pole”



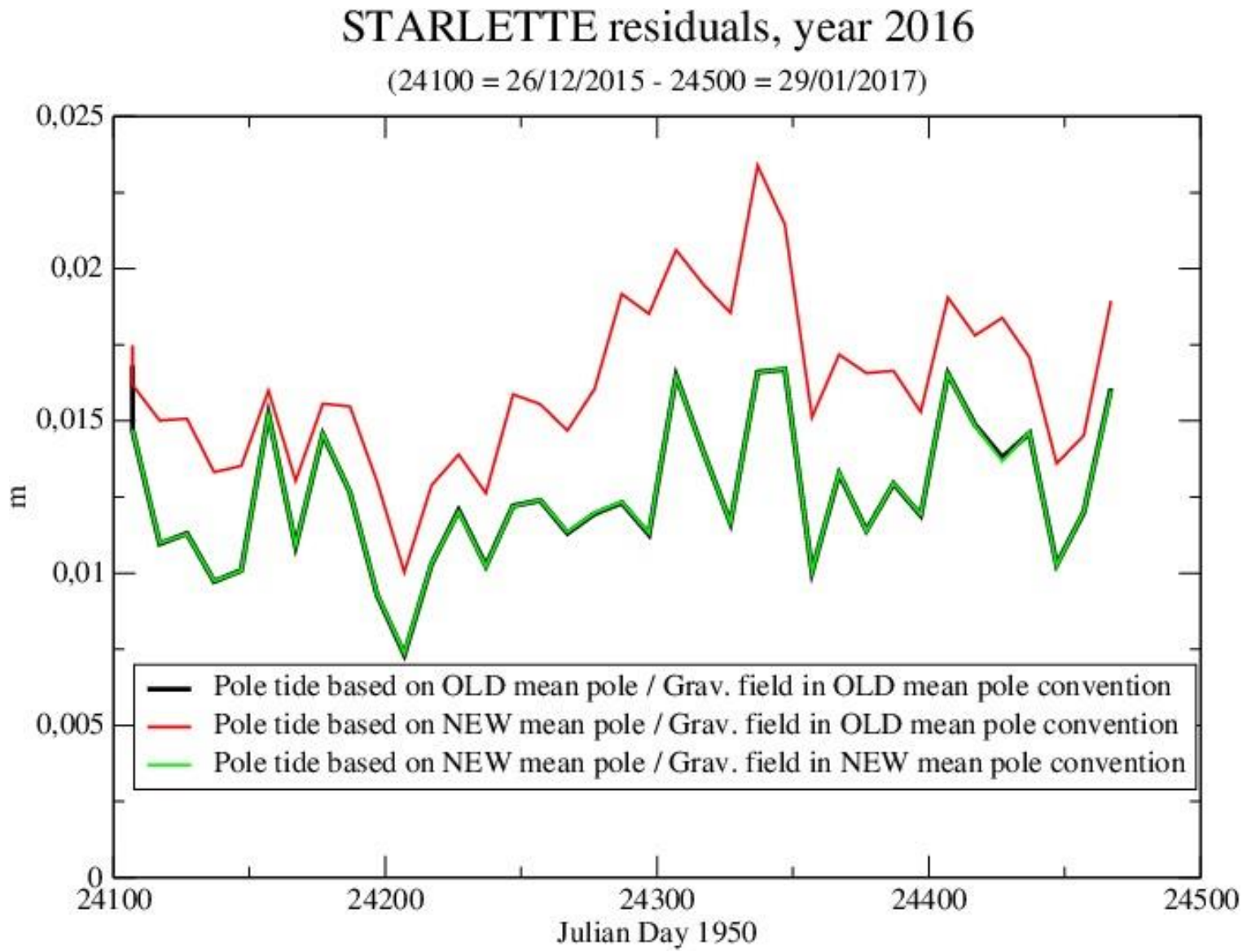
Time series of the models



Time series of the models



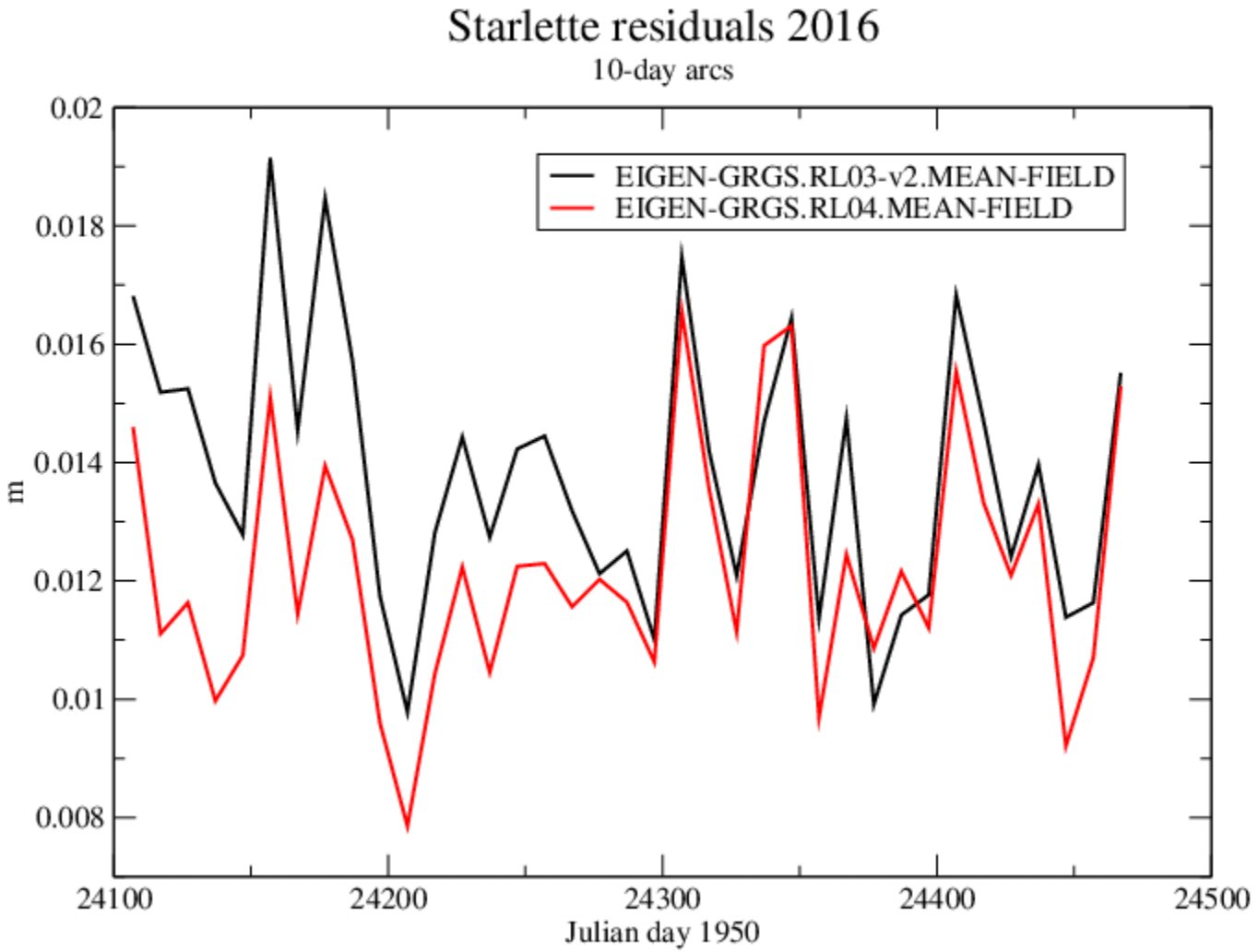
Impact of a non-compatibility between the mean pole and the gravity field model



Quality control on RL04

A- RL04 **monthly time series**: see http://gravitegrace.get.obs-mip.fr/costg/meetings/COSTGM1_CNES_external_validation.pdf

B- POD with **new mean field**: Example of the SLR residuals on Starlette in 2016



Conclusions and perspectives

A. **Very important:**
   When using the C(2,1)/S(2,1) values of a gravity field model, one must adopt **the same mean pole convention** as the one used for the computation of the model. Therefore this information ought to be delivered together with the gravity field model by the makers of the models.

B. The new mean gravity field model is available at: https://grace.obs-mip.fr/variable-models-grace-lageos/mean-fields/release-04/

C. The first tests indicate that **EIGEN-GRGS.RL04.MEAN-FIELD** allows to obtain smaller POD residuals than the previous model EIGEN-GRGS.RL03-v2.MEAN-FIELD.

D. There is also a **new version of FES2014**: FES2014c