Update on time variable gravity models

J.-M. Lemoine [1], *S. Bourgogne* [2], *F. Reinquin* [1]

1) *CNES/GRGS, Toulouse, France*
2) *Stellar Space Studies , Toulouse, France*

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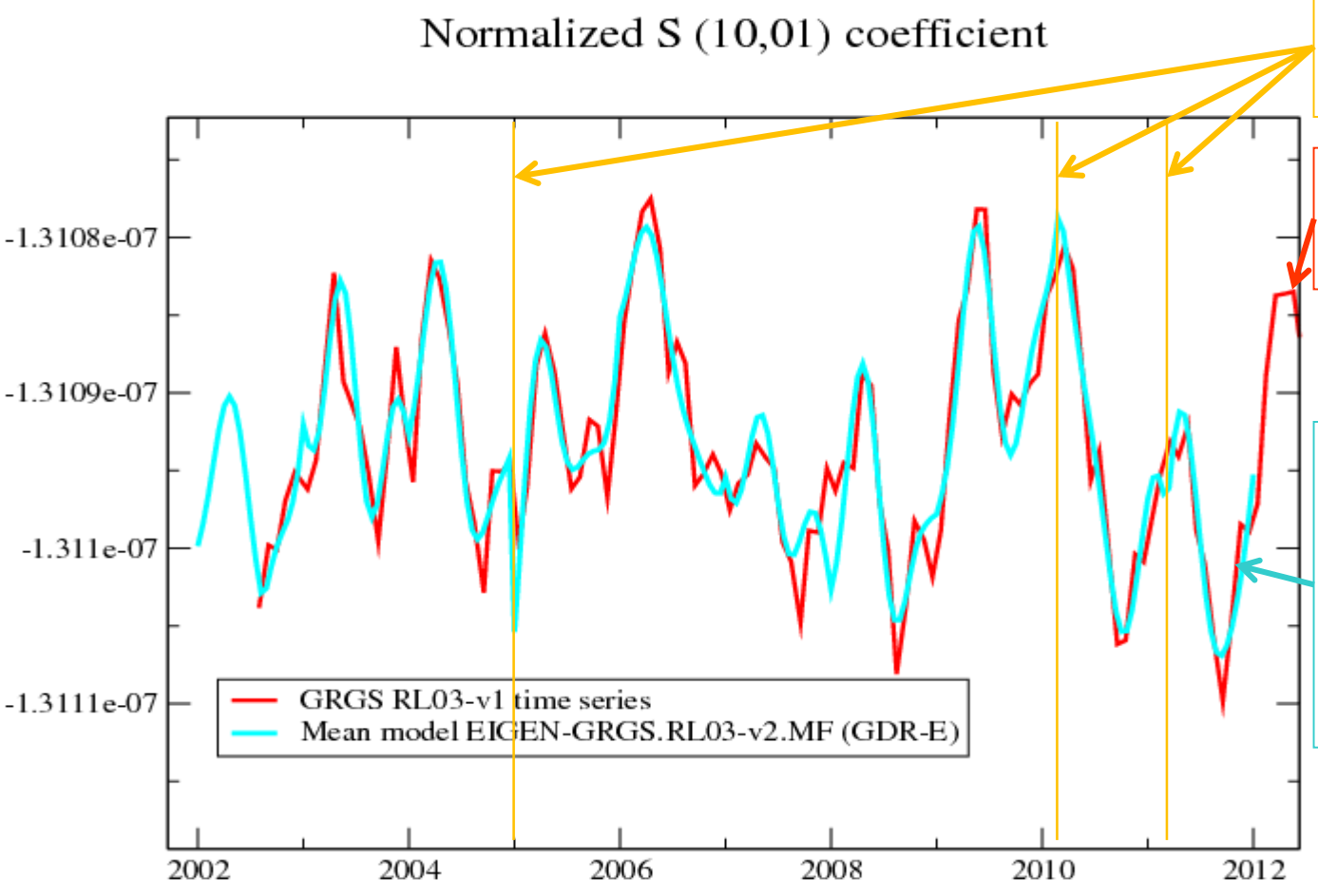
- The new **EIGEN-GRGS.RL04.MEAN-FIELD** is available for download:
  - https://grace.obs-mip.fr/variable-models-grace-lageos/mean-fields/release-04/
- We propose to use it for the computation of the future **ITRF2020**.
- It is based on 14 years of GRACE data (2002/08 – 2016/06), 3 years of GOCE data 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
  - which was presented at the last IDS Workshop: https://ids-doris.org/images/documents/report/ids_workshop_2018/IDS18_s3_LemoineJM_NewtimeVariableGravityFieldModelForPOD.pdf
  - A description of **RL04** is also given here: https://grace.obs-mip.fr/variable-models-grace-lageos/grace-solutions-release-04/rl04-products-description
- 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

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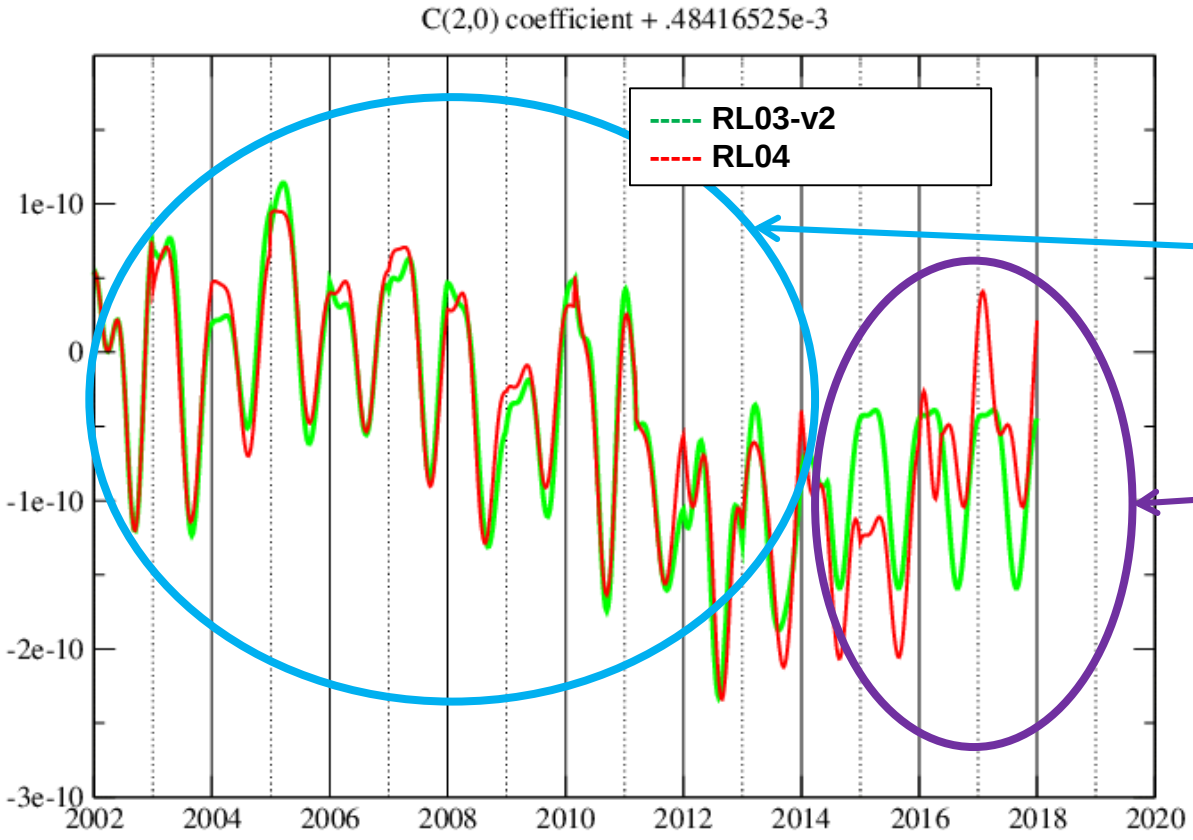
➢ The new mean field updates the previous one over 2 years: mid-2014 to mid-2016.

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

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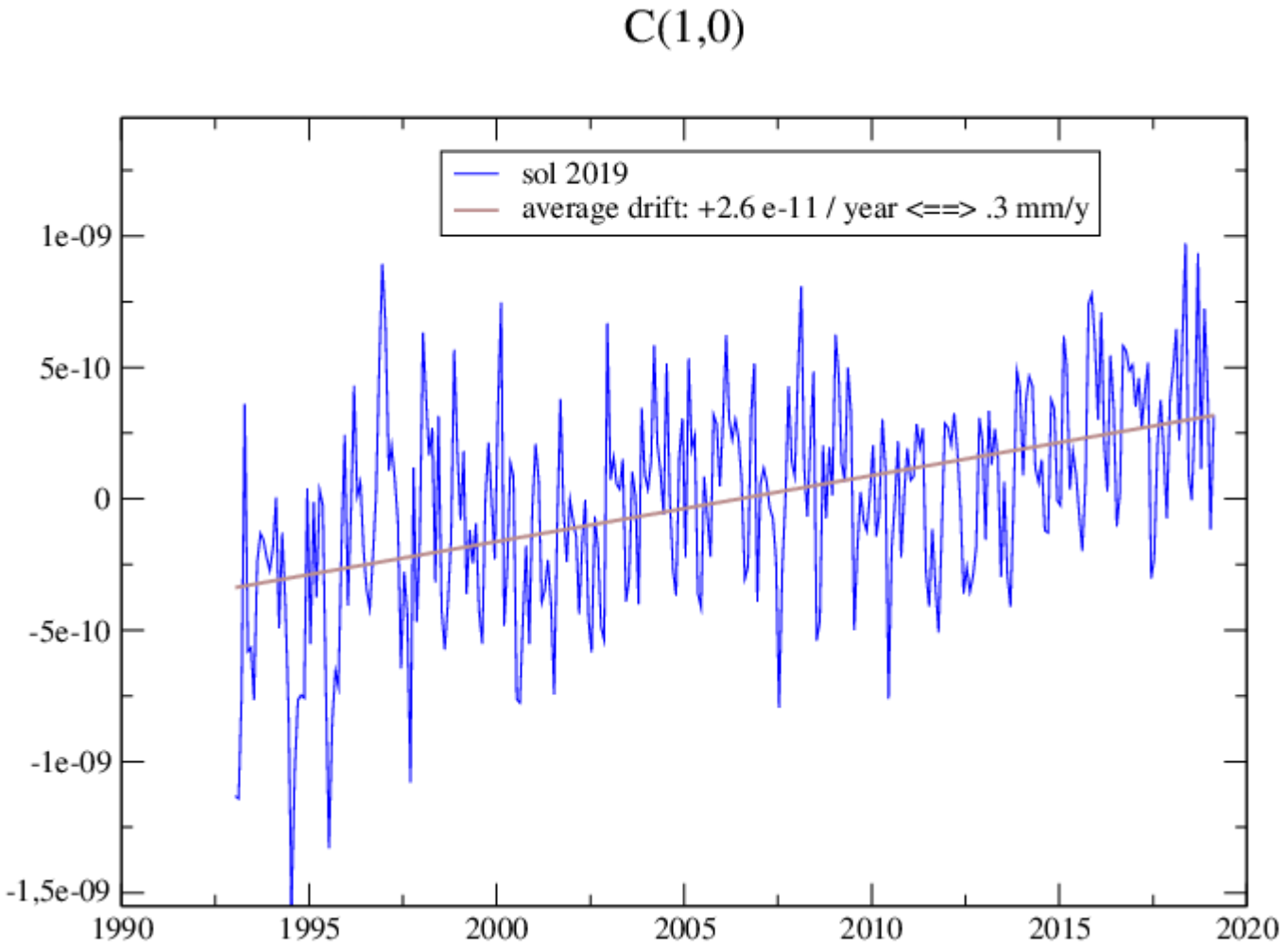
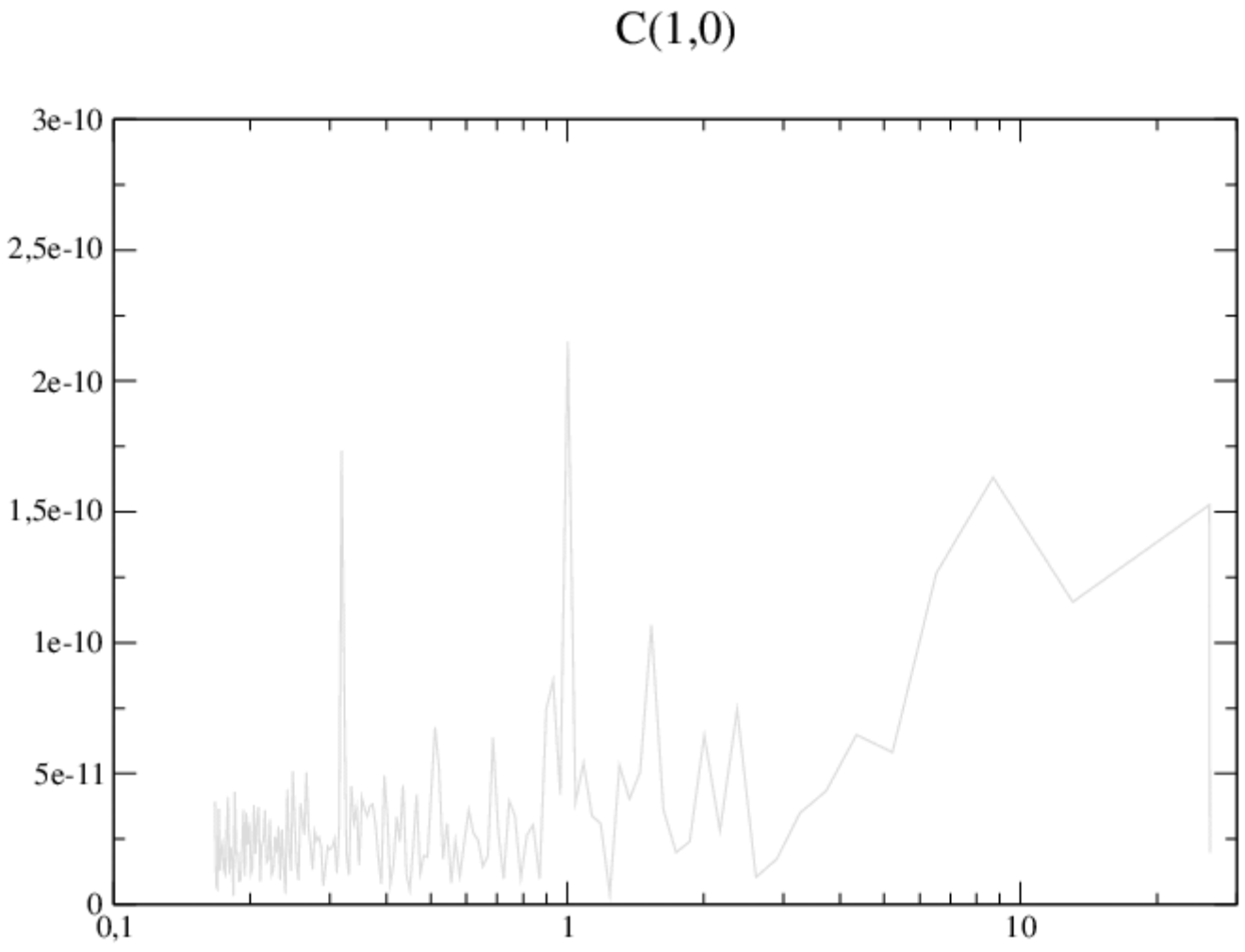
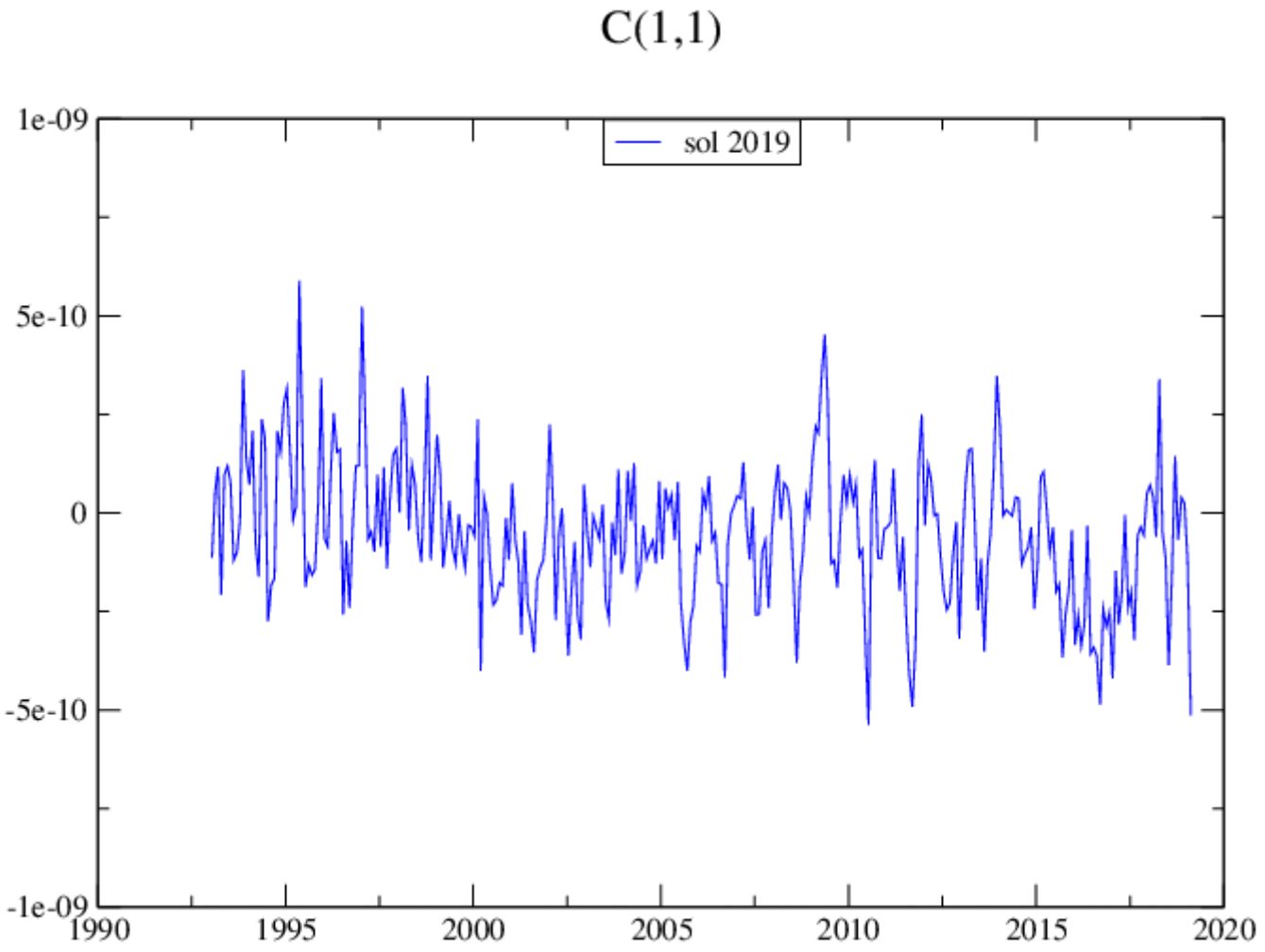
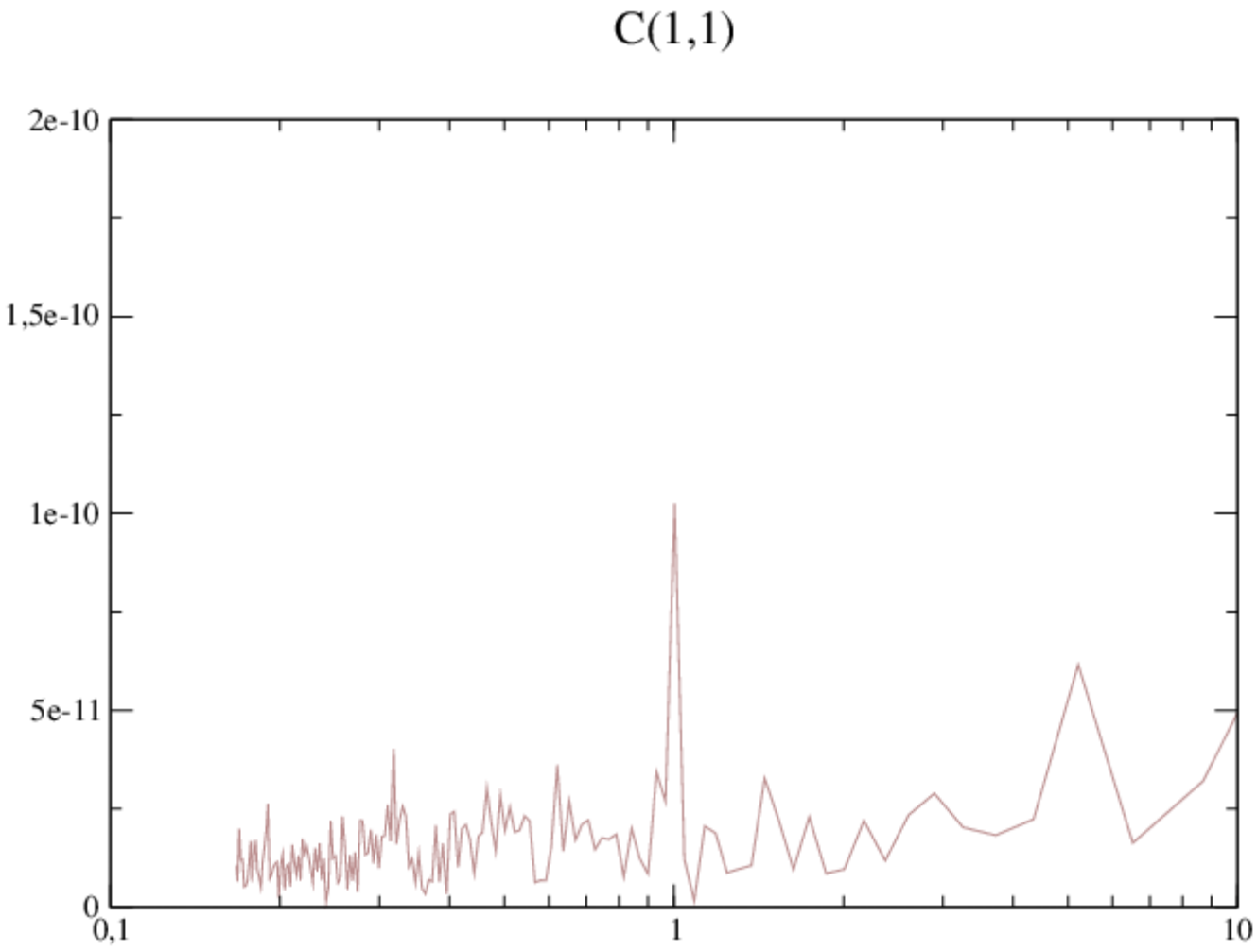
Low degrees

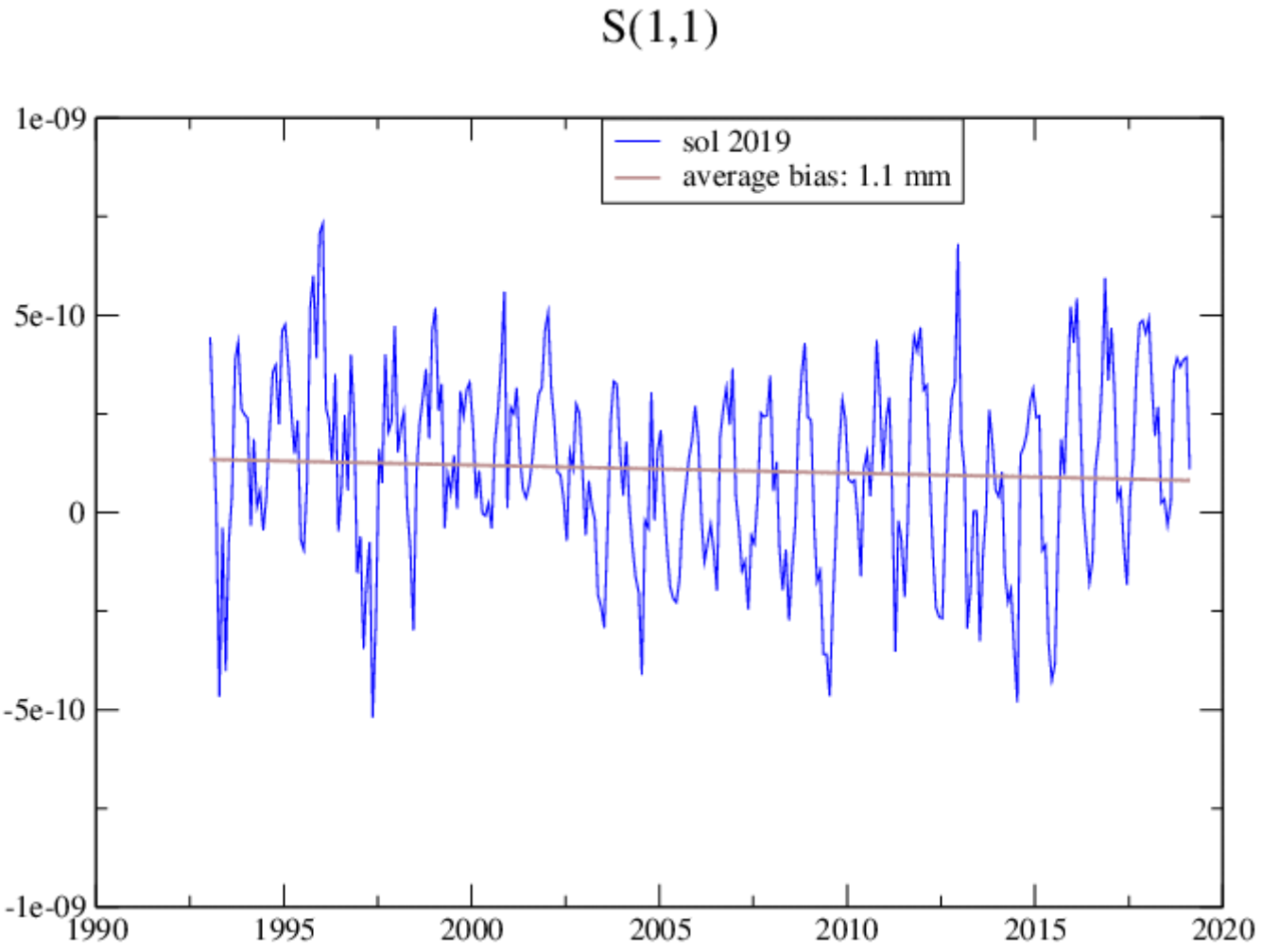
- For POD it is important that the low degrees of the gravity model be very accurate.
- A complete reprocessing of the SLR data from 5 satellites (Lageos, Lageos-2, Starlette, Stella, Ajisai) has been done from 1993/01 to 2019/02 using the latest standards.
- SLR data contribution to EIGEN-GRGS.RL04.MEAN-FIELD:
  - 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 **2.4 mm in Z, 1.1 mm in X and 2.5 mm in Y**
  - There is a second peak in Z at 0.318 y: 1.9 mm

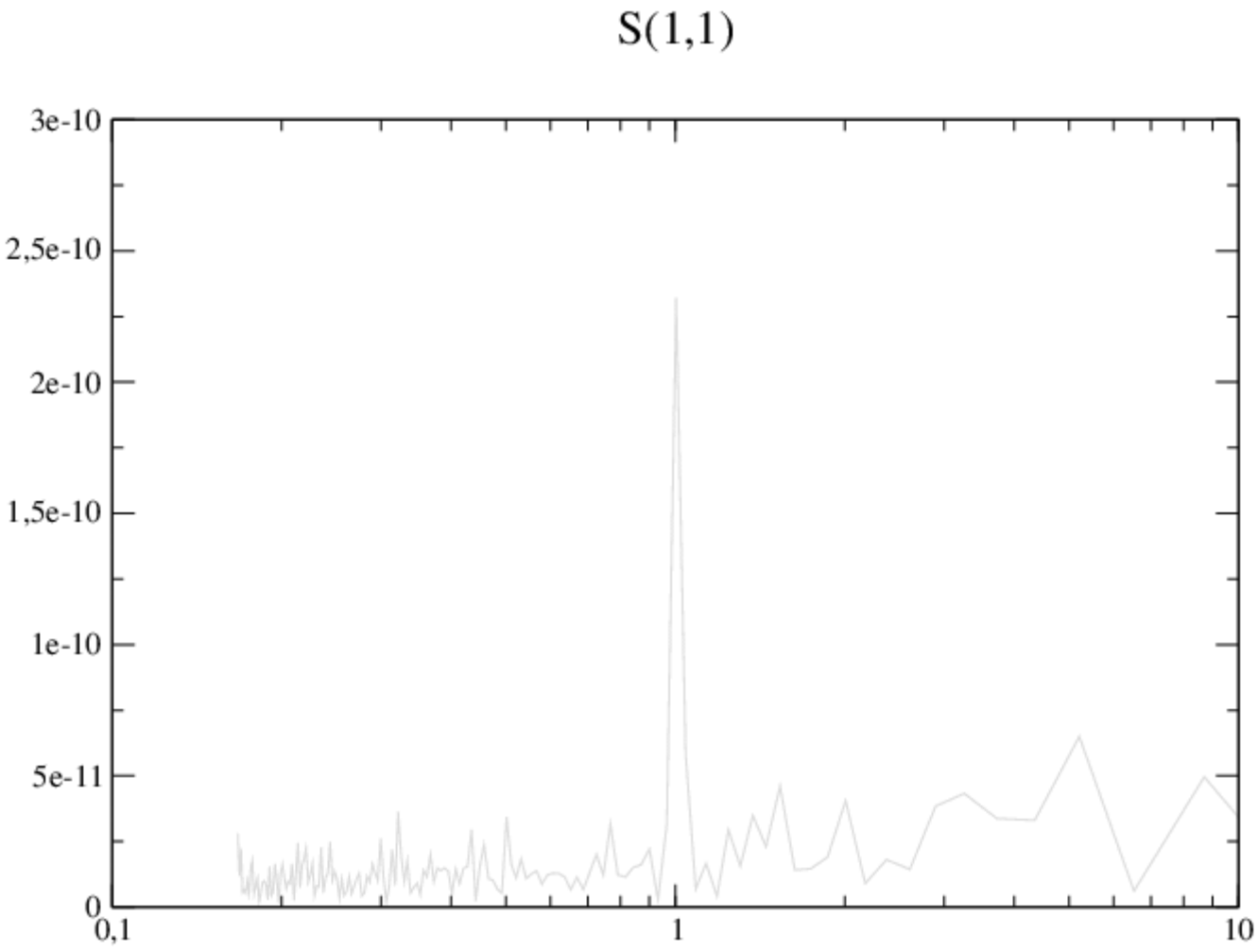

C(1,0)
sol 2019
average drift: +2.6 e-11 / year <==> .3 mm/y
1e-09
5e-10
0
-5e-10
-1e-09
-1,5e-09
1990
1995
2000
2005
2010
2015
2020


C(1,0)
3e-10
2,5e-10
2e-10
1,5e-10
1e-10
5e-11
0
0,1
1
10


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

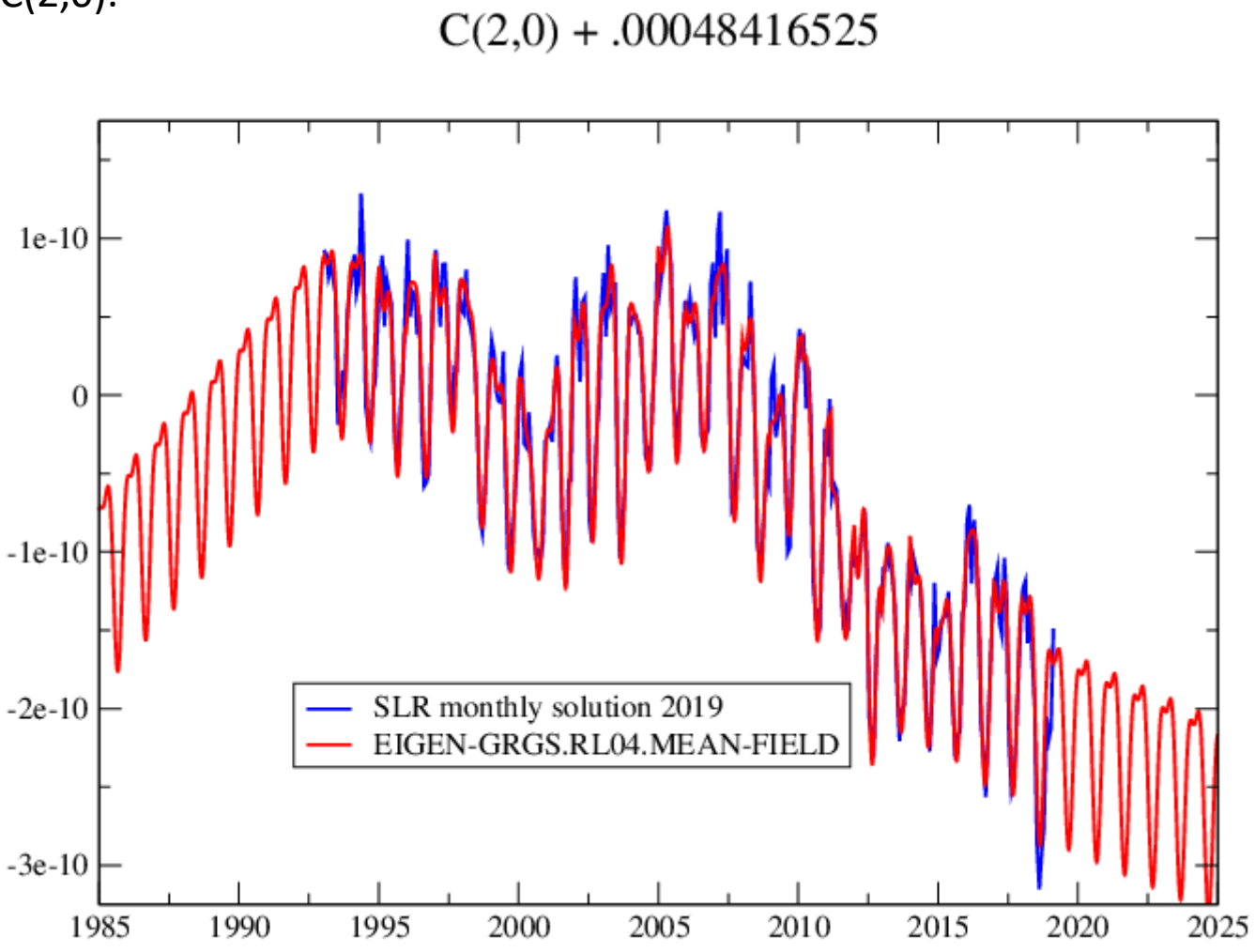

C(1,1)
2e-10
1,5e-10
1e-10
5e-11
0
0,1
1
10

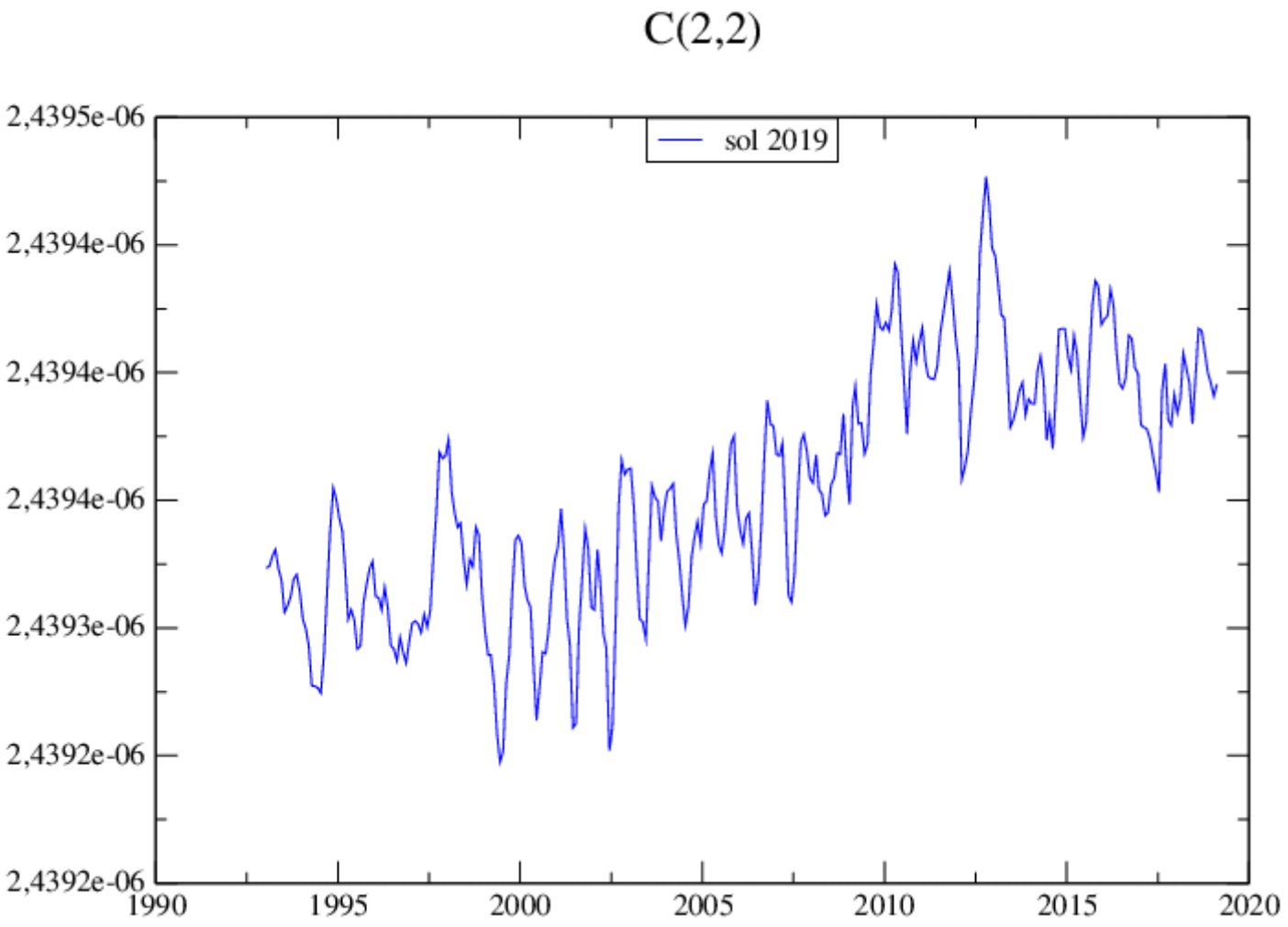

S(1,1)
sol 2019
average bias: 1.1 mm
1e-09
5e-10
0
-5e-10
-1e-09
1990
1995
2000
2005
2010
2015
2020

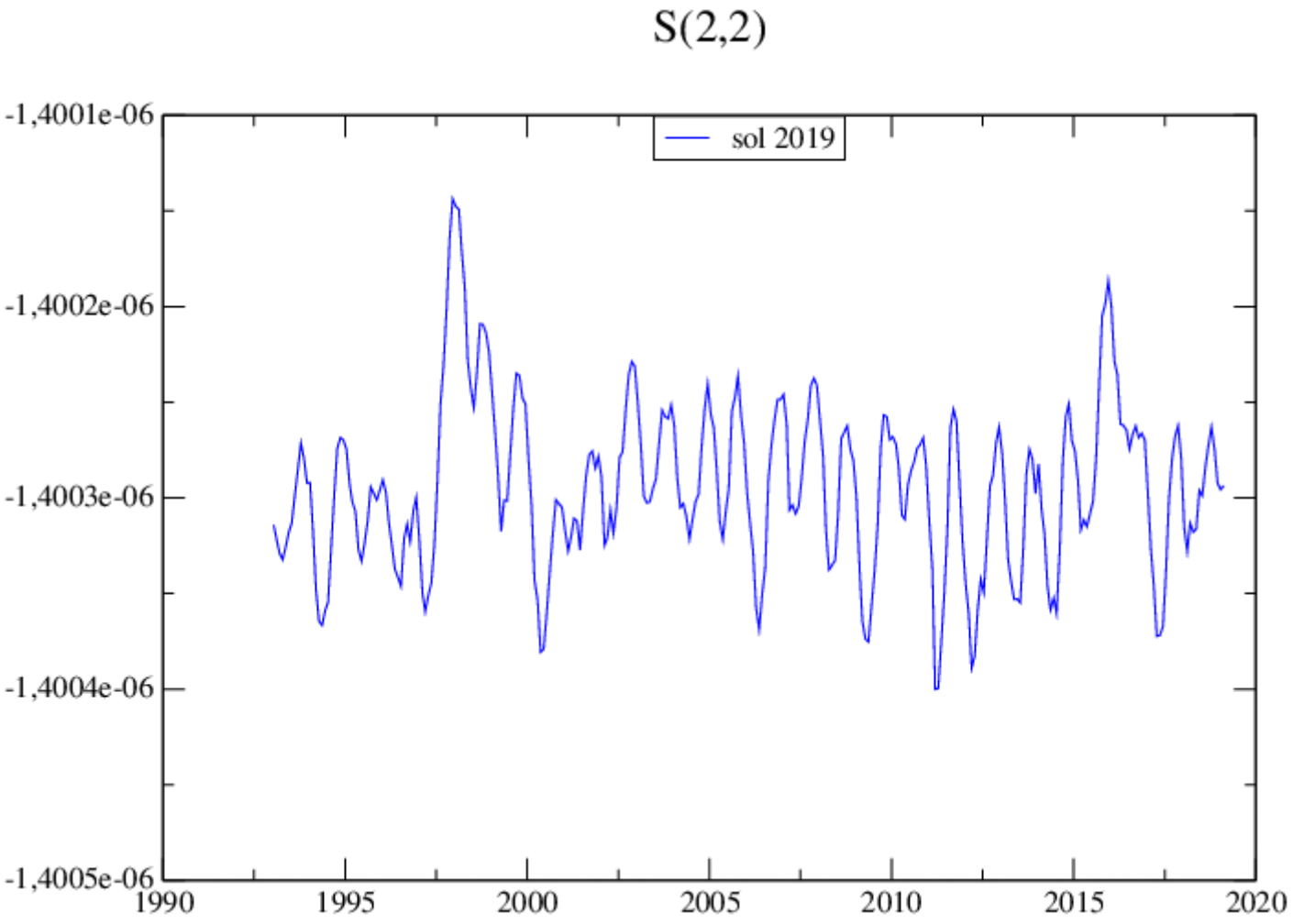

S(1,1)
3e-10
2,5e-10
2e-10
1,5e-10
1e-10
5e-11
0
0,1
1
10

❖ **Degree 2:**

➢ The **slope** of the C(2,0) coefficient **before 1993** is based on earlier determinations of C(2,0).




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


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

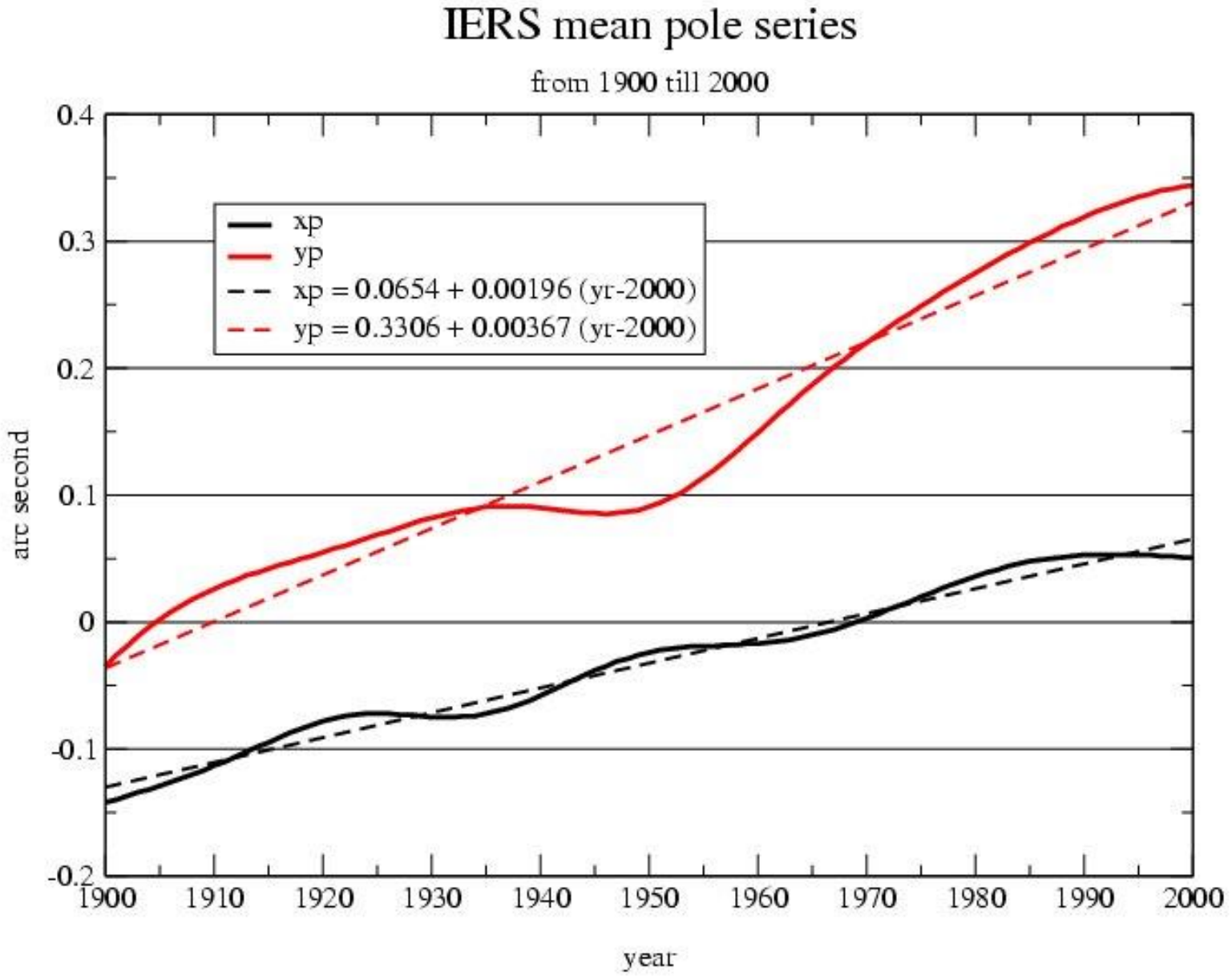
- Specific case of the **C(2,1) / S(2,1)** coefficients: the change of IERS conventions on the mean pole implies to provide 2 different solutions, one in each convention. On Feb 1st, 2018, the IERS convention for the mean pole motion changed from quadratic to linear.
  - There **has to be** a coherence 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

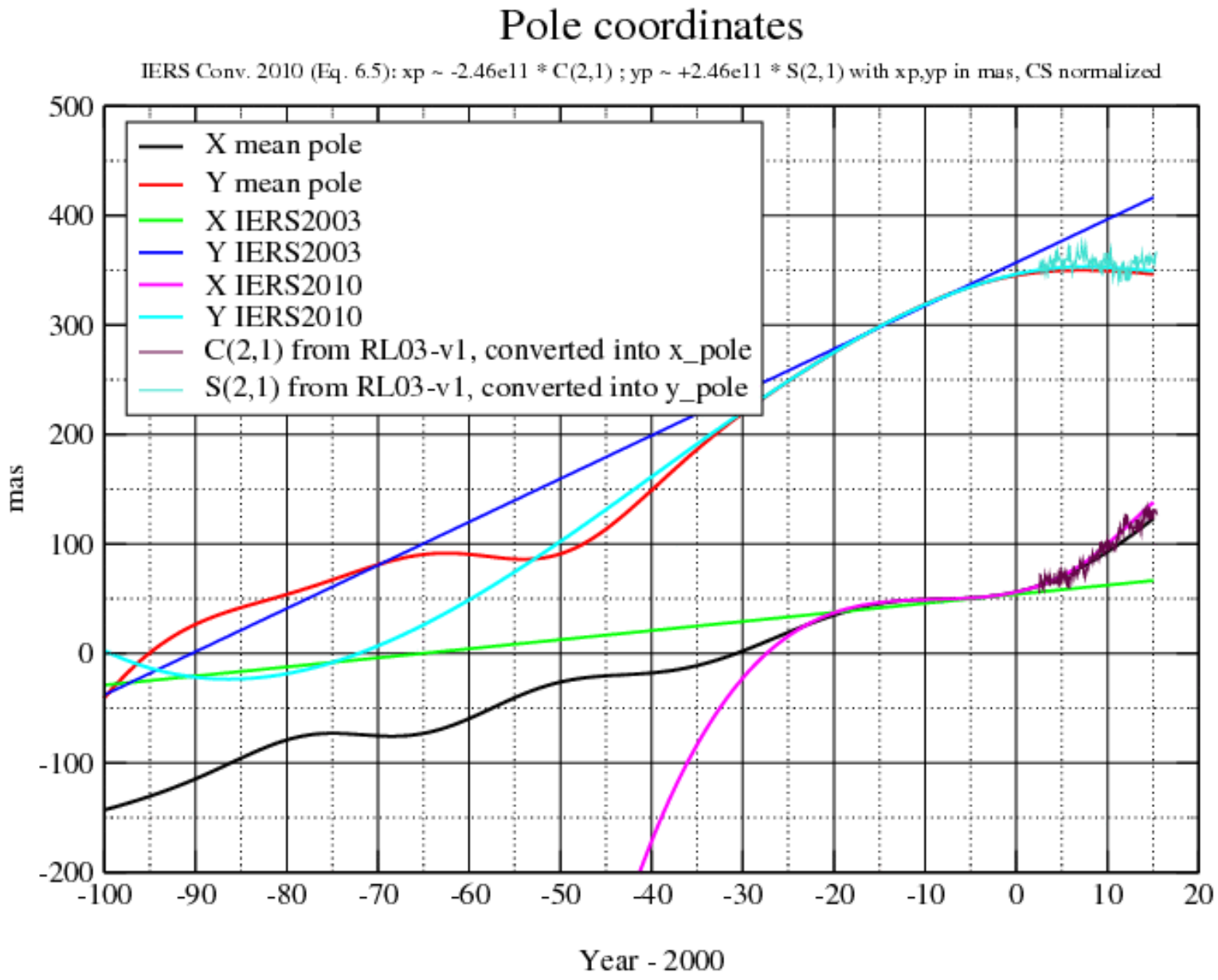
or

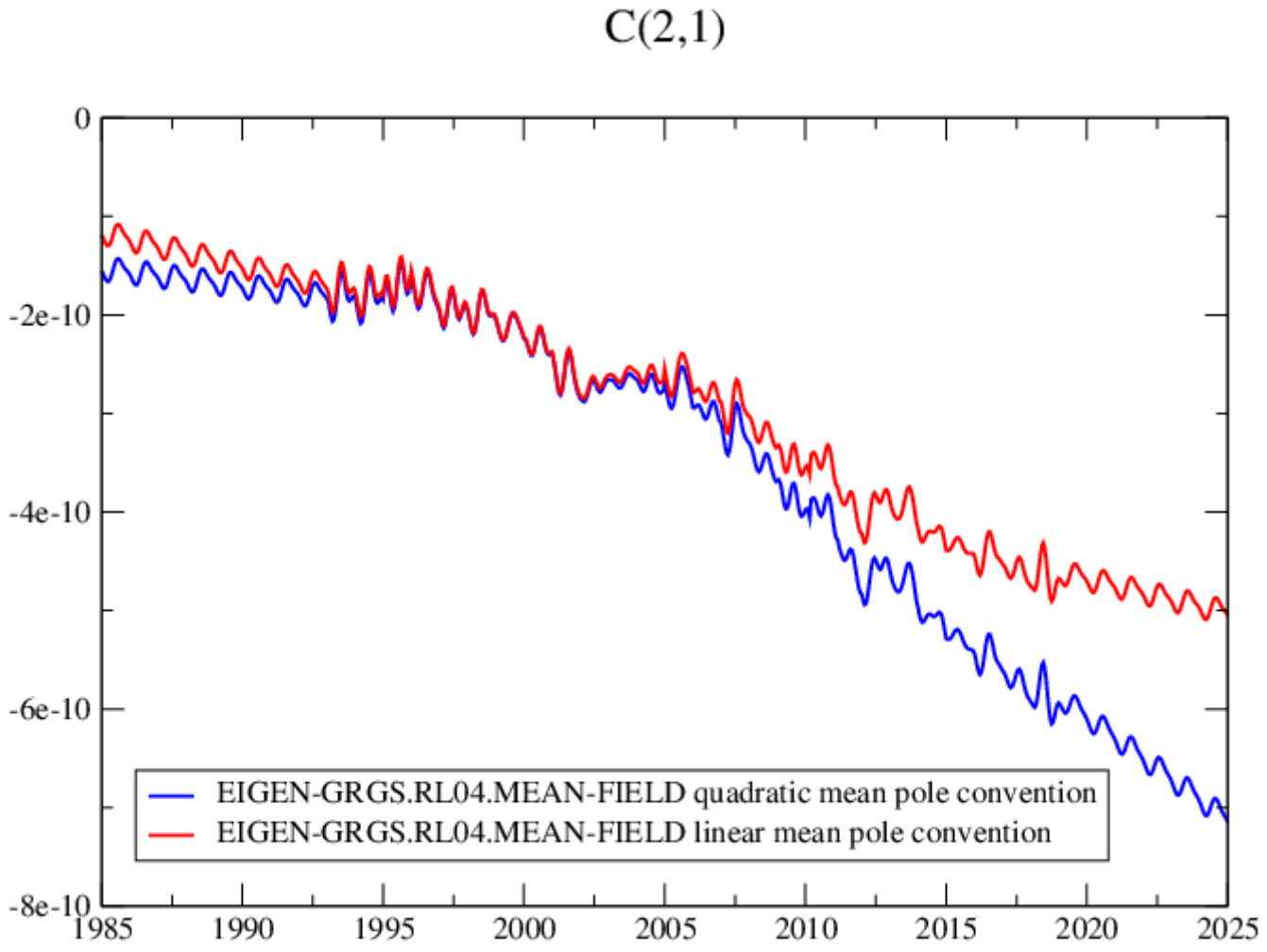
CMMNT Mean pole convention: linear

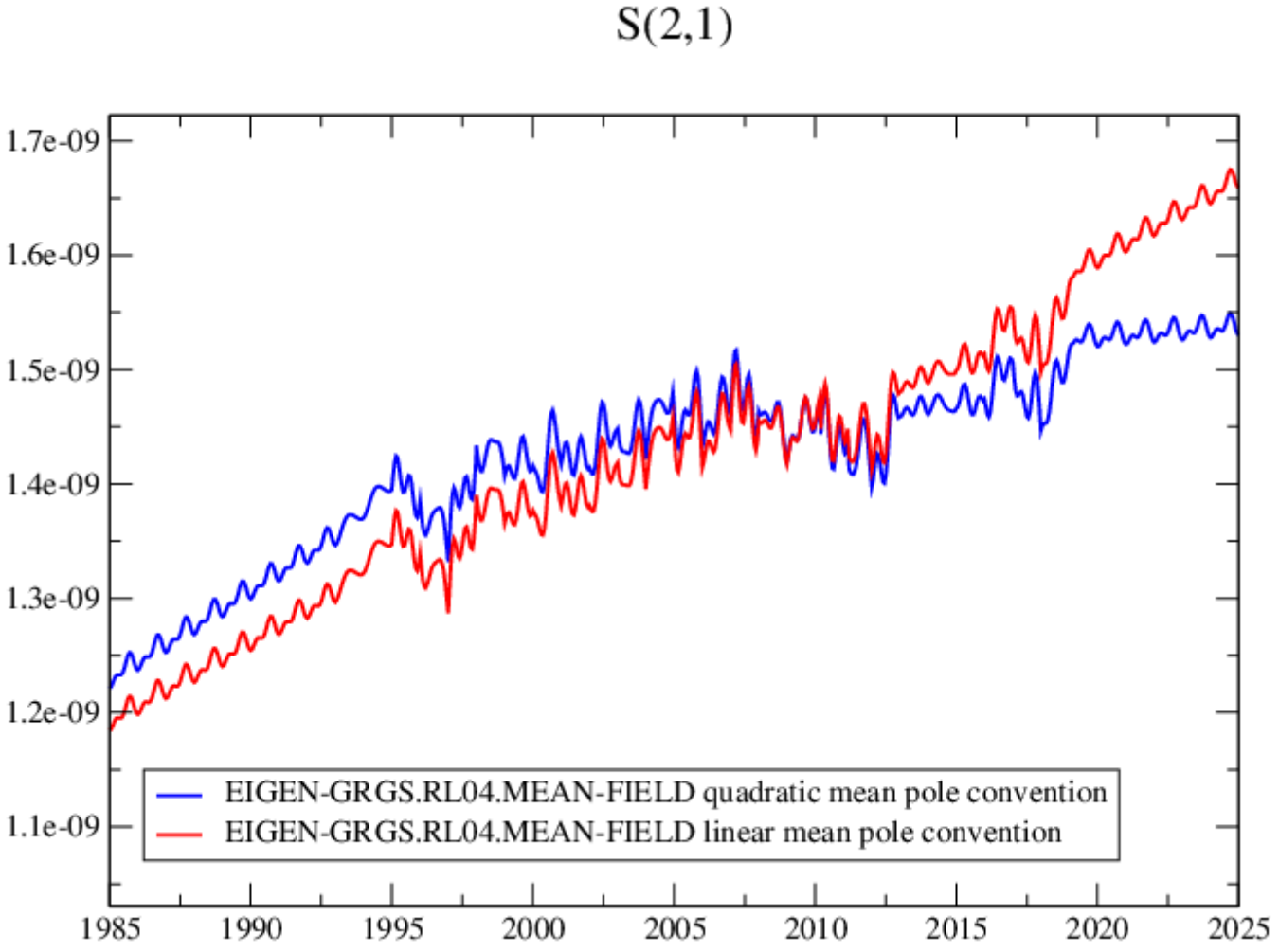
“M100Y mean pole”



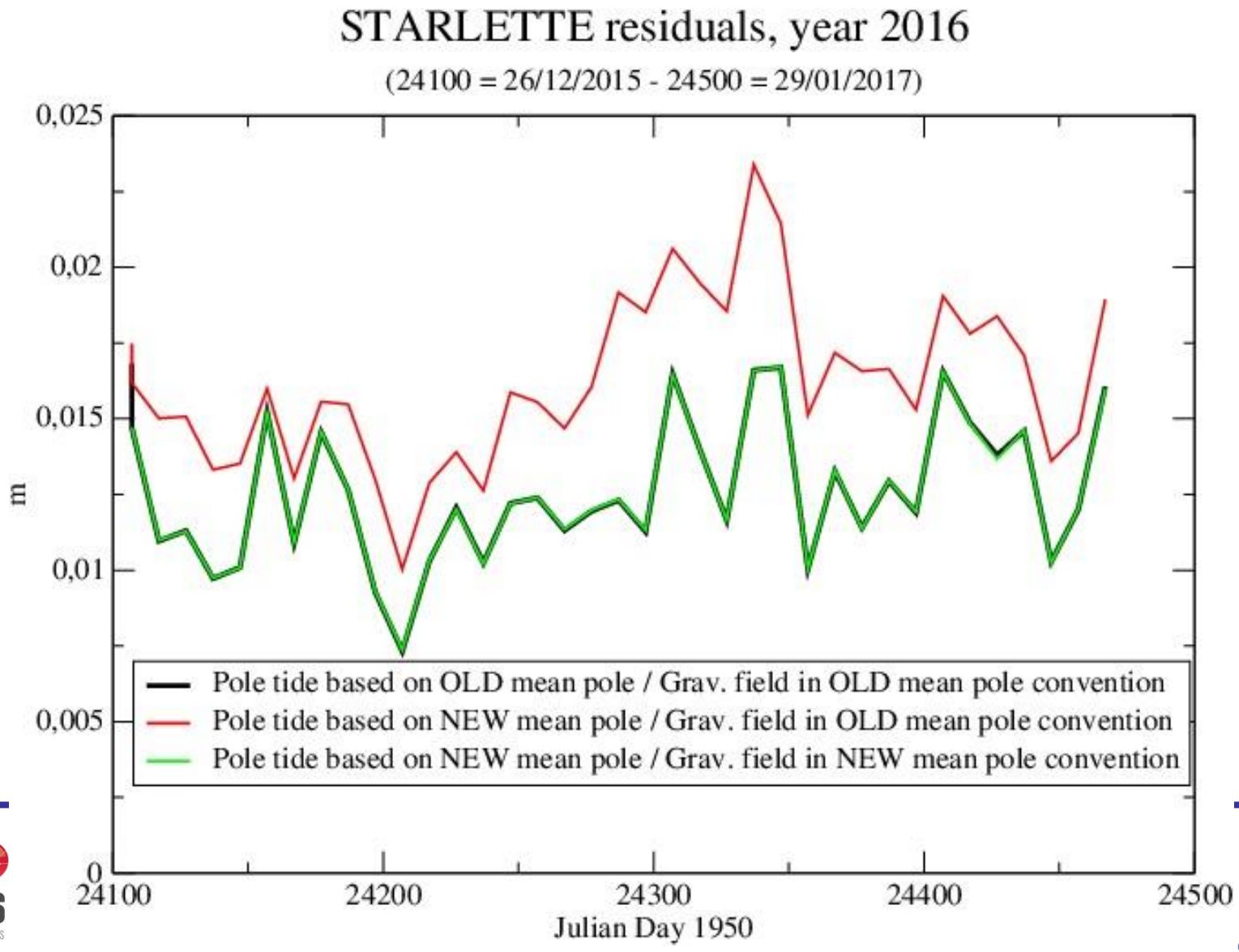
“IERS2010 mean pole”




C(2,1)
0
-2e-10
-4e-10
-6e-10
-8e-10
1985
1990
1995
2000
2005
2010
2015
2020
2025
EIGEN-GRGS.RL04.MEAN-FIELD quadratic mean pole convention
EIGEN-GRGS.RL04.MEAN-FIELD linear mean pole convention


S(2,1)
1.7e-09
1.6e-09
1.5e-09
1.4e-09
1.3e-09
1.2e-09
1.1e-09
1985
1990
1995
2000
2005
2010
2015
2020
2025
EIGEN-GRGS.RL04.MEAN-FIELD quadratic mean pole convention
EIGEN-GRGS.RL04.MEAN-FIELD linear mean pole convention

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



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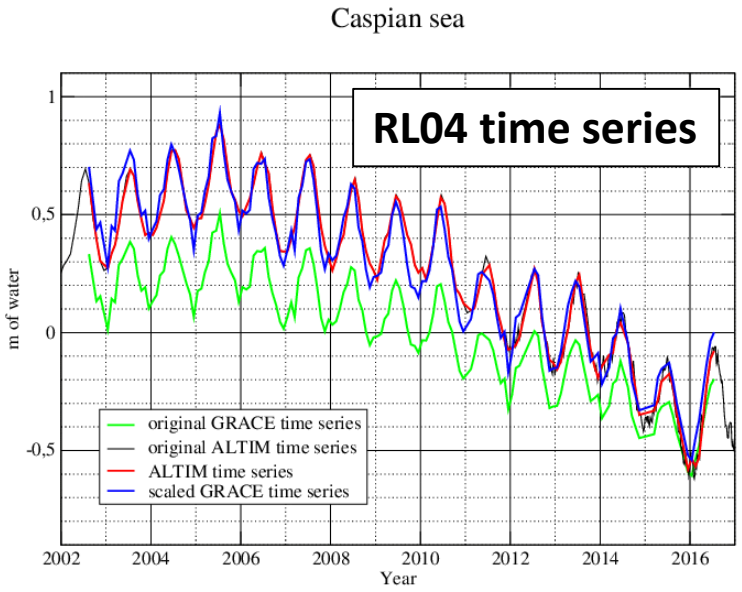
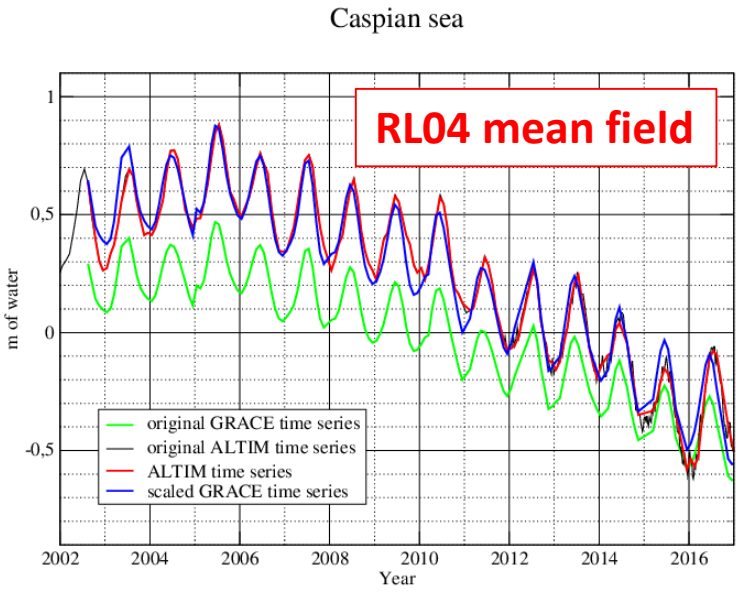
Quality control on RL04

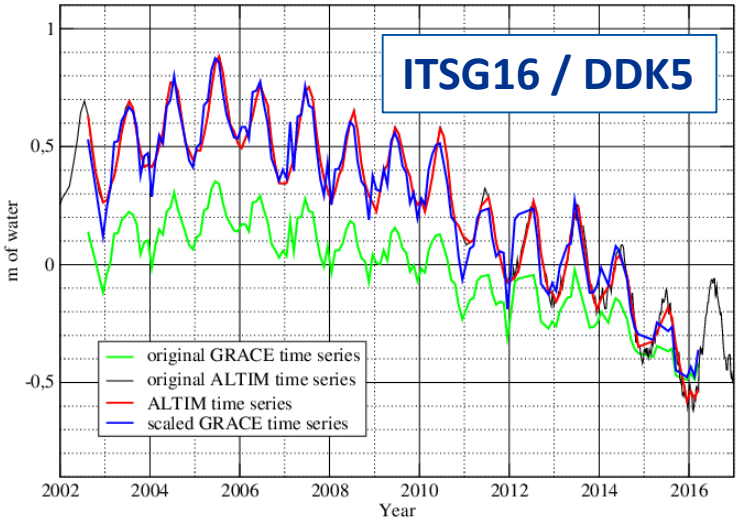
A- RL04 time series

Signal assessment by comparison to altimetry (Caspian Sea)



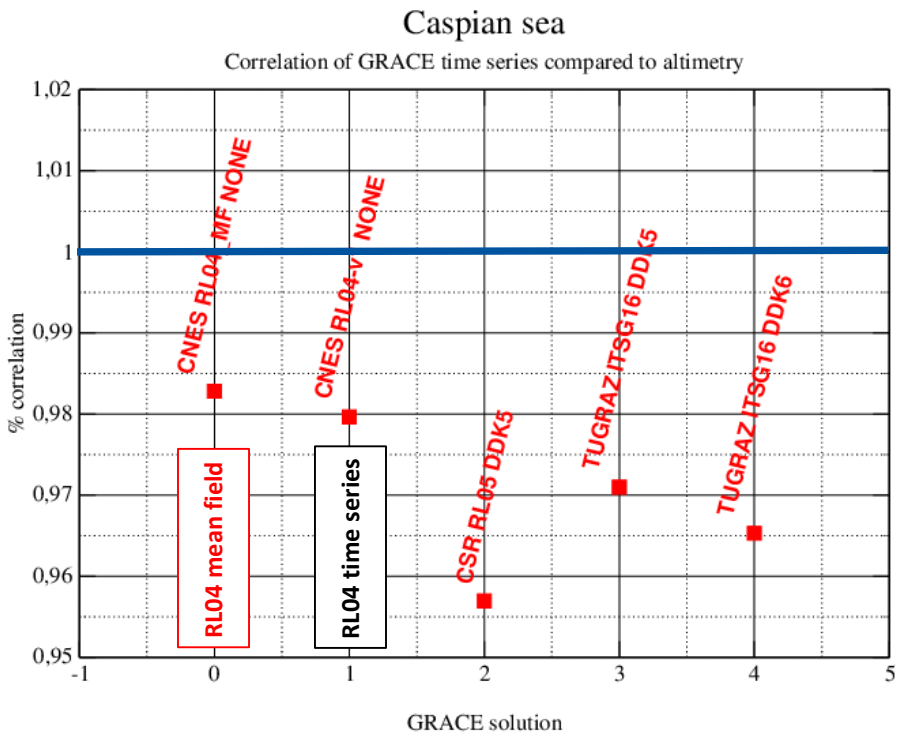


Altimeter time series from Hydroweb (https://sso.theia-land.fr)

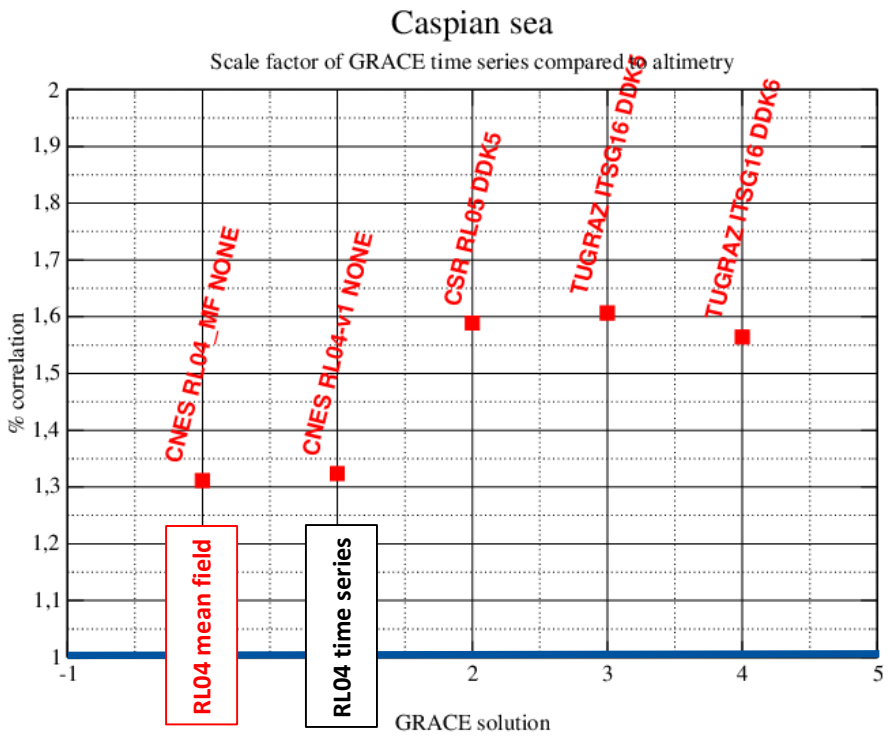


Signal assessment by comparison to altimetry
(Caspian Sea)

CORRELATION

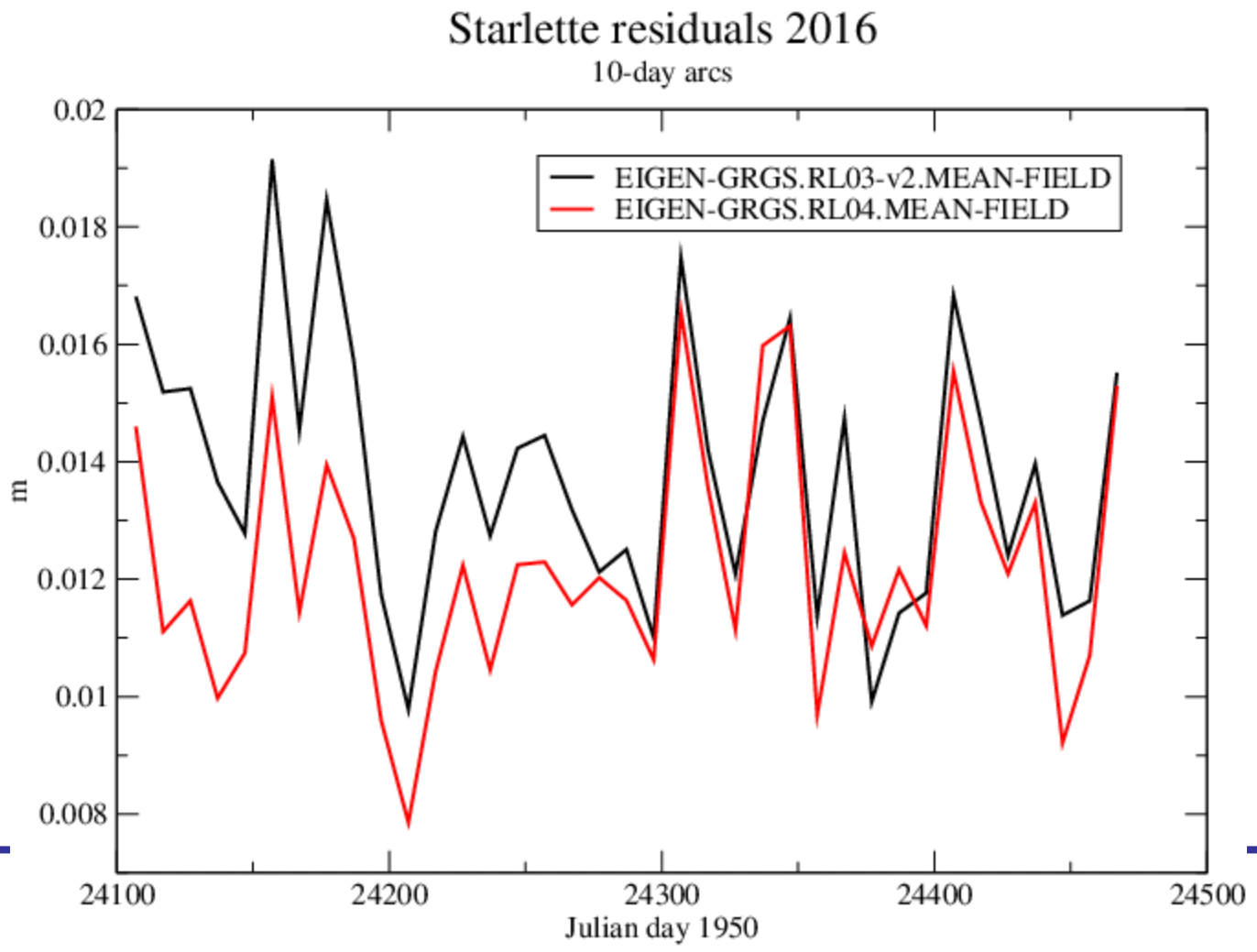


SCALE FACTOR



Quality control on RL04

B- POD with new mean field



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 model.

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. Alternative options for the POD gravity model: GOCO05S. But…contains GRACE data only until 2014 & extrapolation of low degrees maybe not as careful as for EIGEN-GRGS.RL04.MEAN-FIELD.

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

New FES2014c ocean tides model