Assessment of the non gravitational forces acting on the Lageos satellites, and impacts on gravitational parameters

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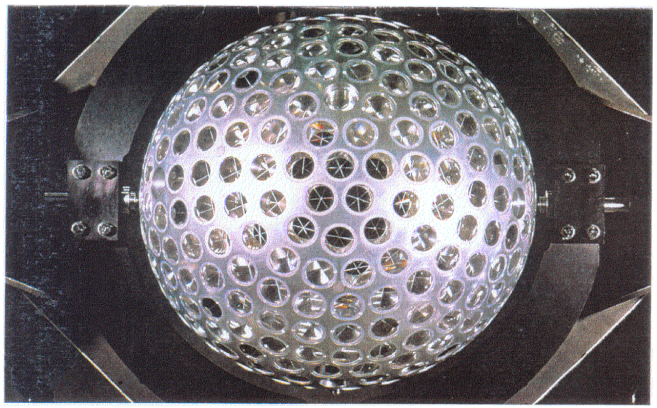
OVERVIEW

- In the mid 90'th, UT CSR group (J. Ries, R. Eanes) pointed out unexplained residual excitations on the Lageos eccentricity vector
- Metris et al (1996) demonstrated that a modified (empirically) thermal model using Farinella et al spin axis model, allowed to reconstruct the observed residual excitation both for a, e*cosω and e*sinω
- This was the case up to 1996…
- We try to draw an assessment of the present situation
  - Long orbital arc of LA1 AND LA2
  - Analysis of the empircial coefficients time series
  - Impact of GF time series estimation



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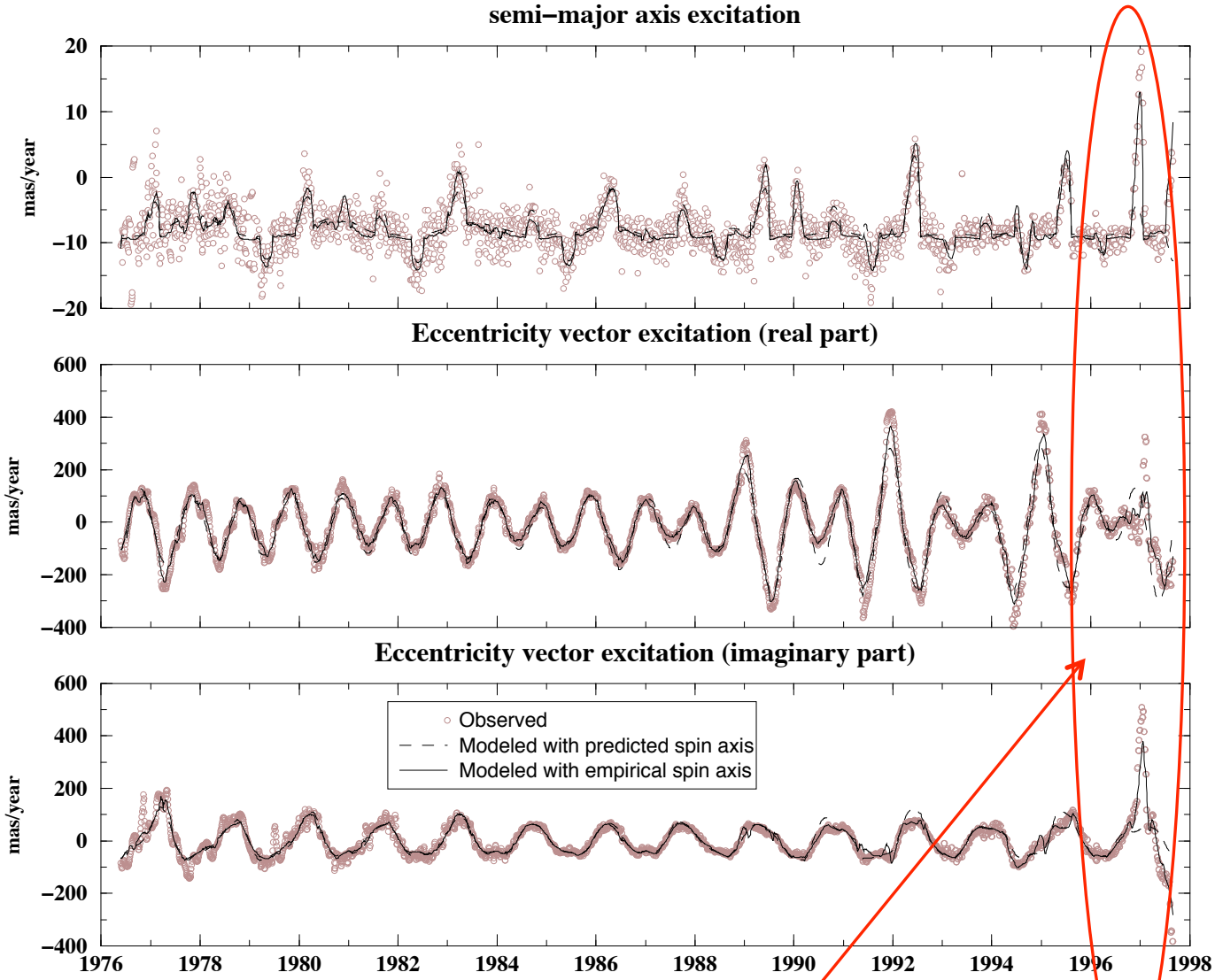
Non Gravitational forces acting on the LAGEOS satellites



(a)

(e*cosω)

(e*sinω)

1997 « anomalies »

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Non Gravitational forces acting on the LAGEOS satellites

- After 25 years (2001), The dashed circle is reached and implies a change in the behaviour of the spin axis motion. Its precession rate is increasing.

- After 33 years (2009) , the BI model is no longer valid : 1 to 1 resonance

- Bertotti, B., and L. Iess, The rotation of LAGEOS, J.Geoph. Res., 96, 2431 (1991).

Measured values of the period

Southward orientation

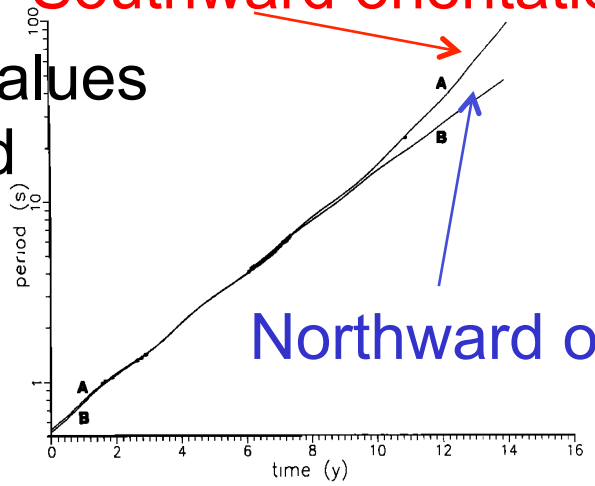

Fig. 4. Predicted evolution of the LAGEOS spin period as a function of time (years), under the action of magnetic and gravitational torques. The dots represent the measured values of the period. Curve A refers to a southward orientation of $\omega(0)$, while curve B, which shows a poorer agreement, refers to the opposite orientation.

- Effects to be considered:
  - Magnetic torque
  - Gravitational torque
  - Thermal effect
  - Anisotropy
  - …

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PARAMETERIZATION

- We have recomputed empirical accelerations for Lageos over [1990-2011] using GINS software
- Best known dynamical model but without thermal effects neither optical asymmetry
- 65 days arc with the following adjusted parameters :
  - 6 initial conditions
  - 1 set of bias (BT,BTC, BTS, BNC, BNS) every 5 days (13 sets / arc)

$$\text{along-track component} : \Delta T(t) = BT + BTC\cos(\omega + M) + BTS\sin(\omega + M)$$

$$\text{normal component} : \Delta N(t) = BNC\cos(\omega + M) + BNS\sin(\omega + M)$$

- The estimated biases absorb long period part of unmodeled accelerations
- The main unmodeled accelerations are due to non-gravitational effects such as thermal effects
- Interpretation of the estimated biases
  - effective BT, BTC, BTS are related to the so called along-track and eccentricity vector excitations :

$$\frac{\Delta \dot{a}}{a} \approx \frac{2}{na} BT$$

$$\Delta \frac{d}{dt}(e\cos\omega) \approx \frac{1}{na} BTC$$

$$\Delta \frac{d}{dt}(e\sin\omega) \approx \frac{1}{na} BTS$$

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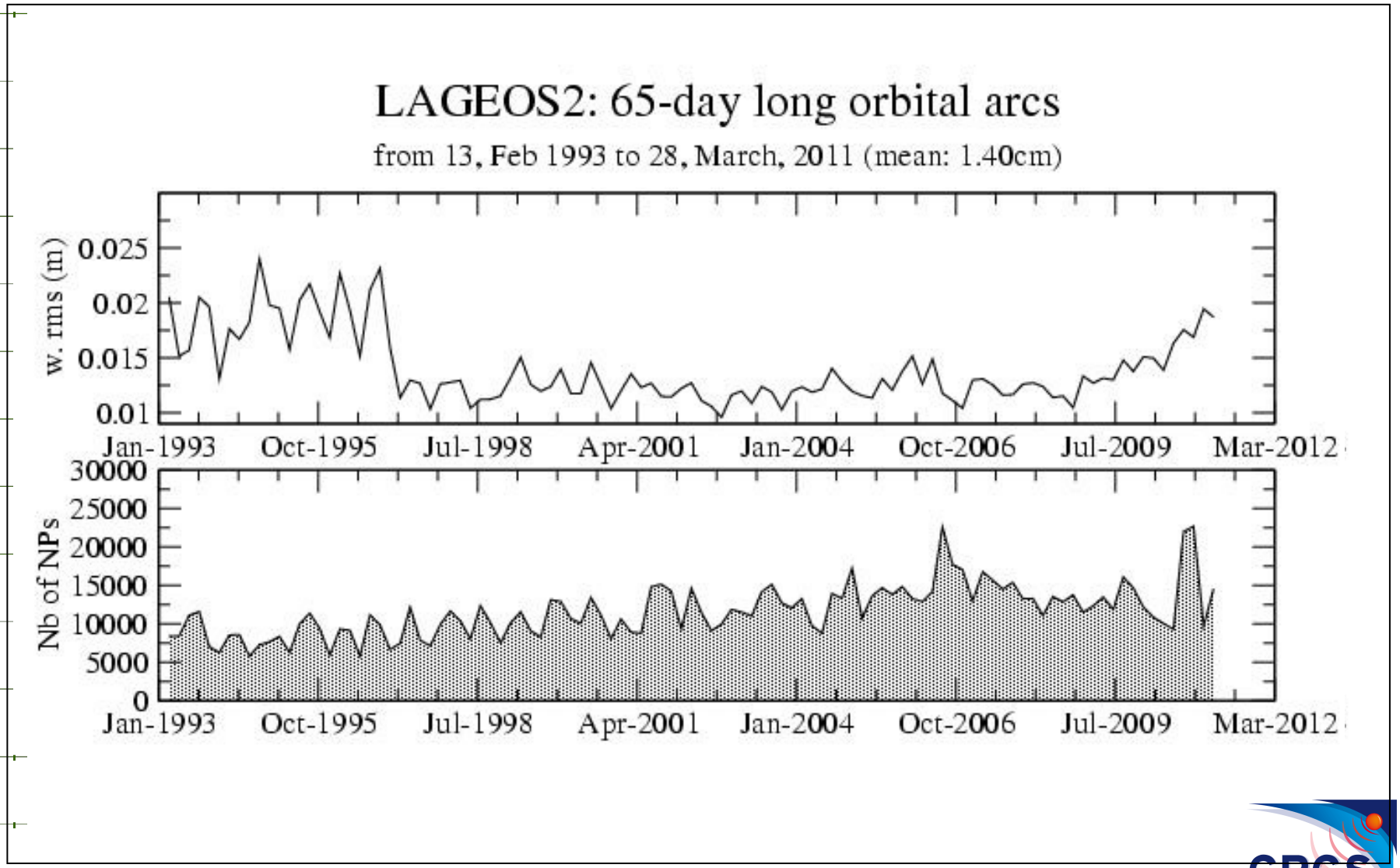
Checking the approach (1/3)
Post-fit weekly arcs residuals



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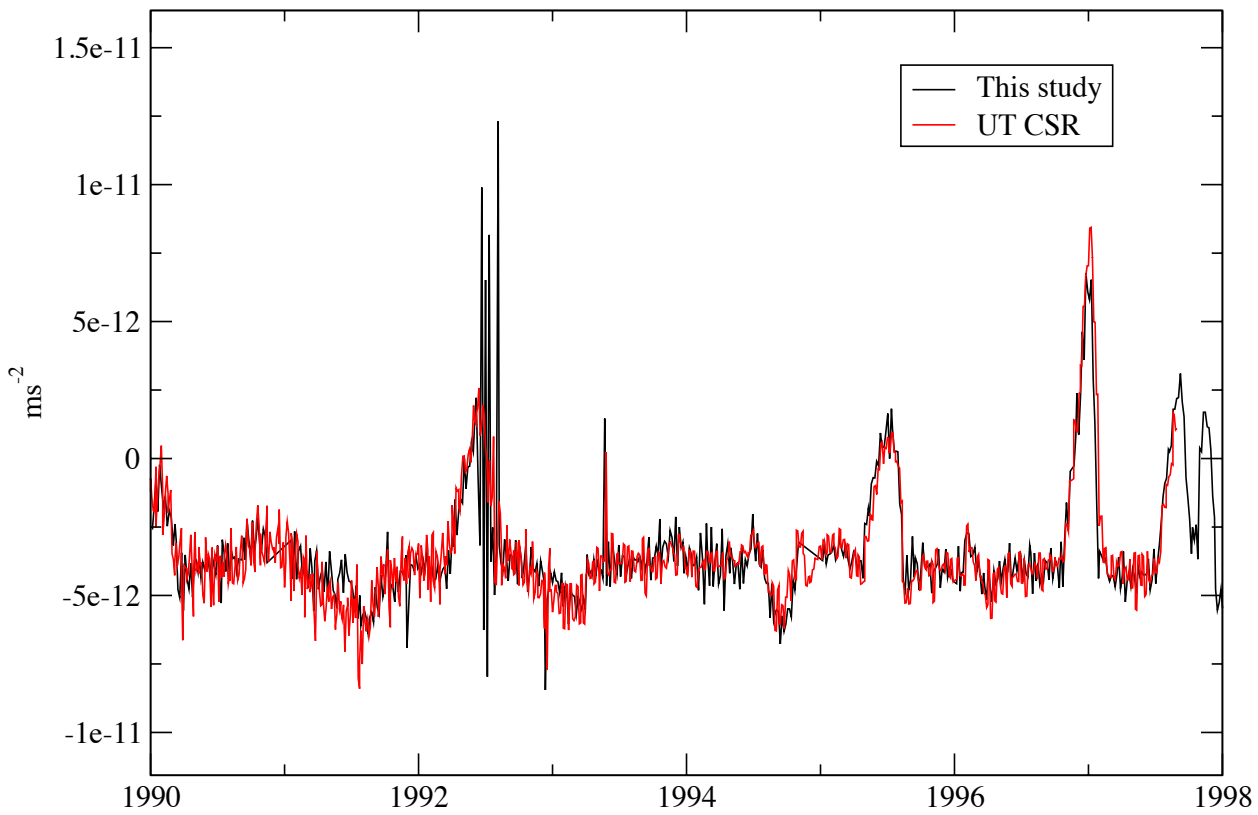
Checking the approach (2/3)
Comparison of Residual Accelerations



Comparison of residual acceleration (BT) computed by UT CSR (1980-1997) and in this study (1990-20101 over the common period.

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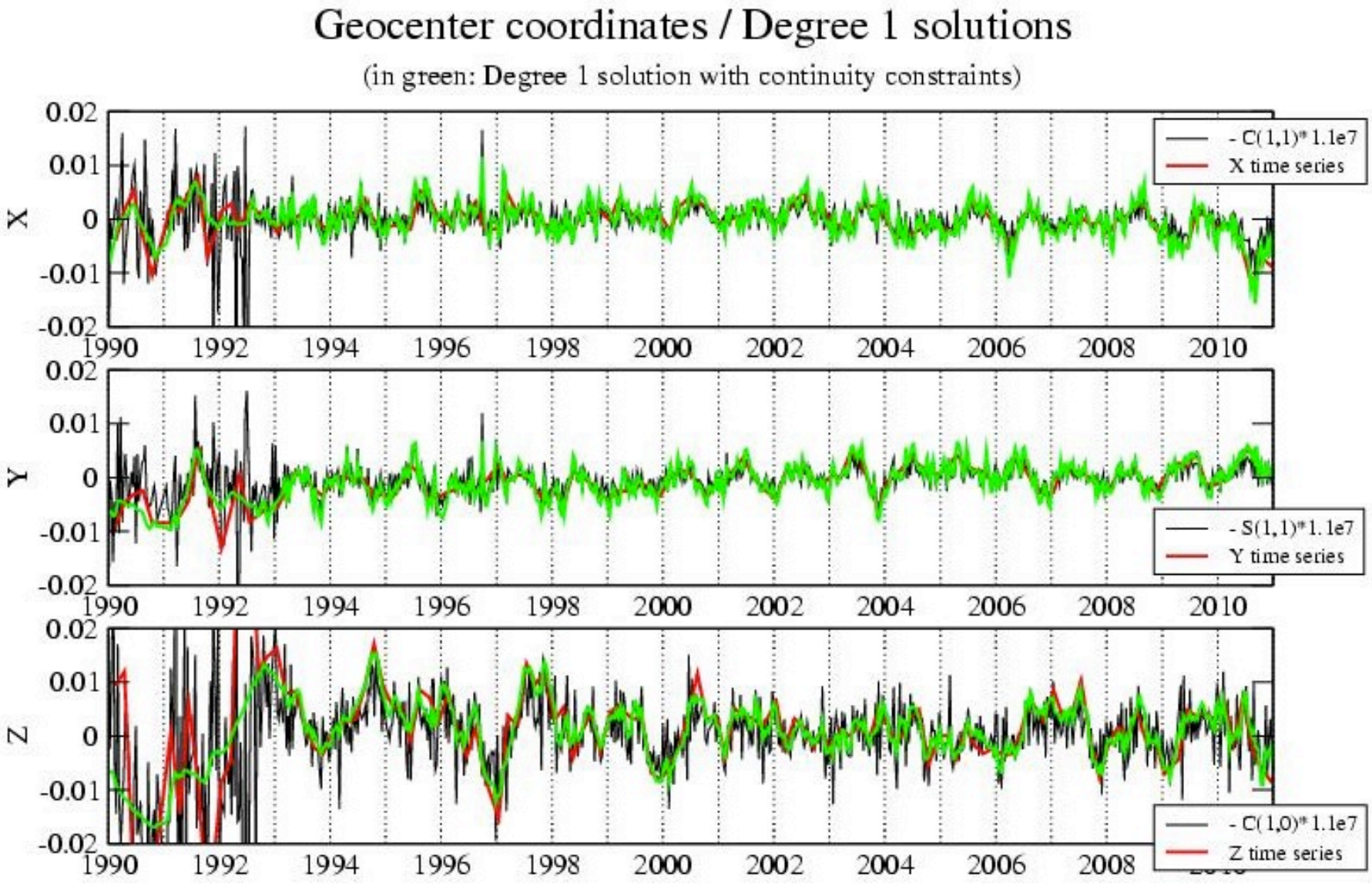
Checking the approach (3/3)
Geocenter motion



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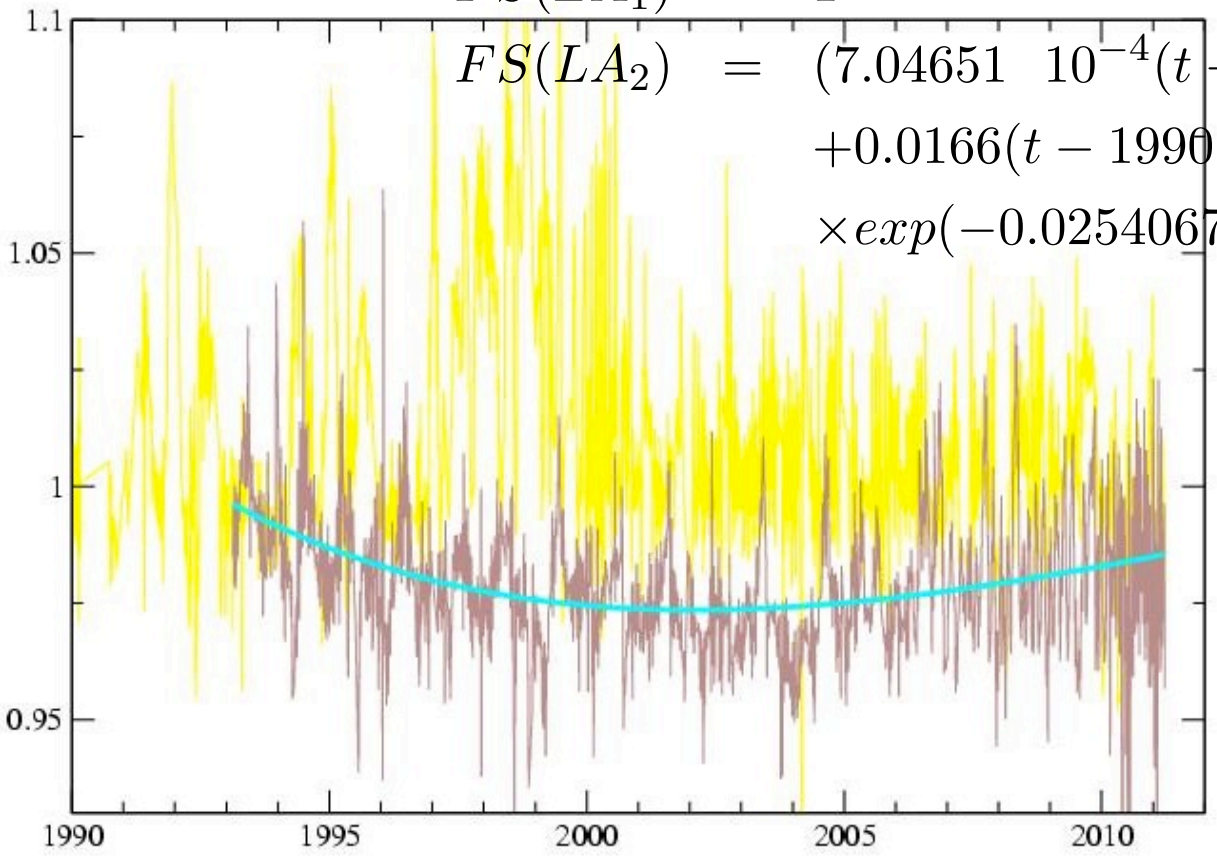
SRP TIME SERIES, AND MODELLING

$$FS(LA_1) = 1$$

$$FS(LA_2) = (7.04651\ \ 10^{-4}(t-1990)^2 + 0.0166(t-1990) + 1.01985) \times exp(-0.0254067(t-1990))$$



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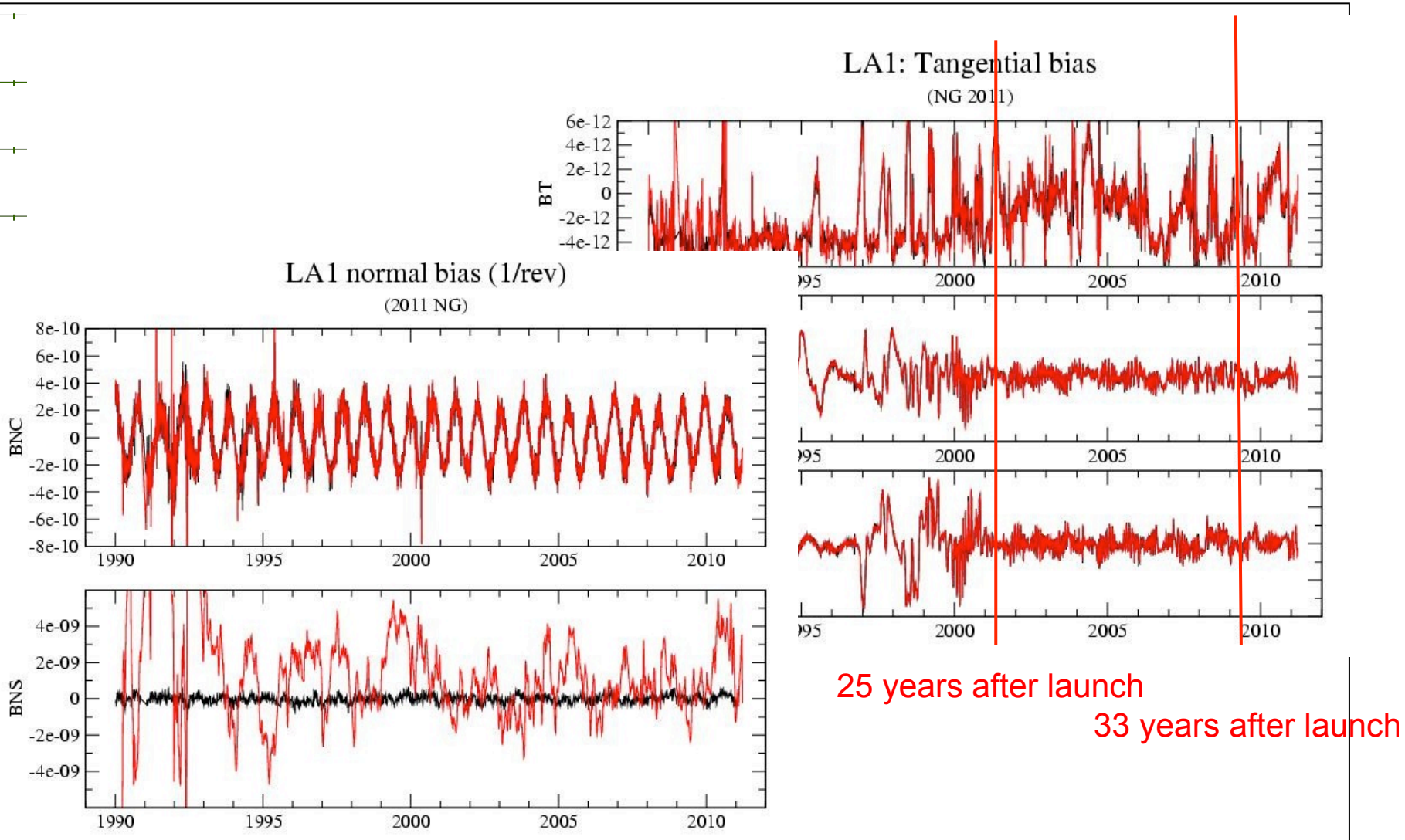
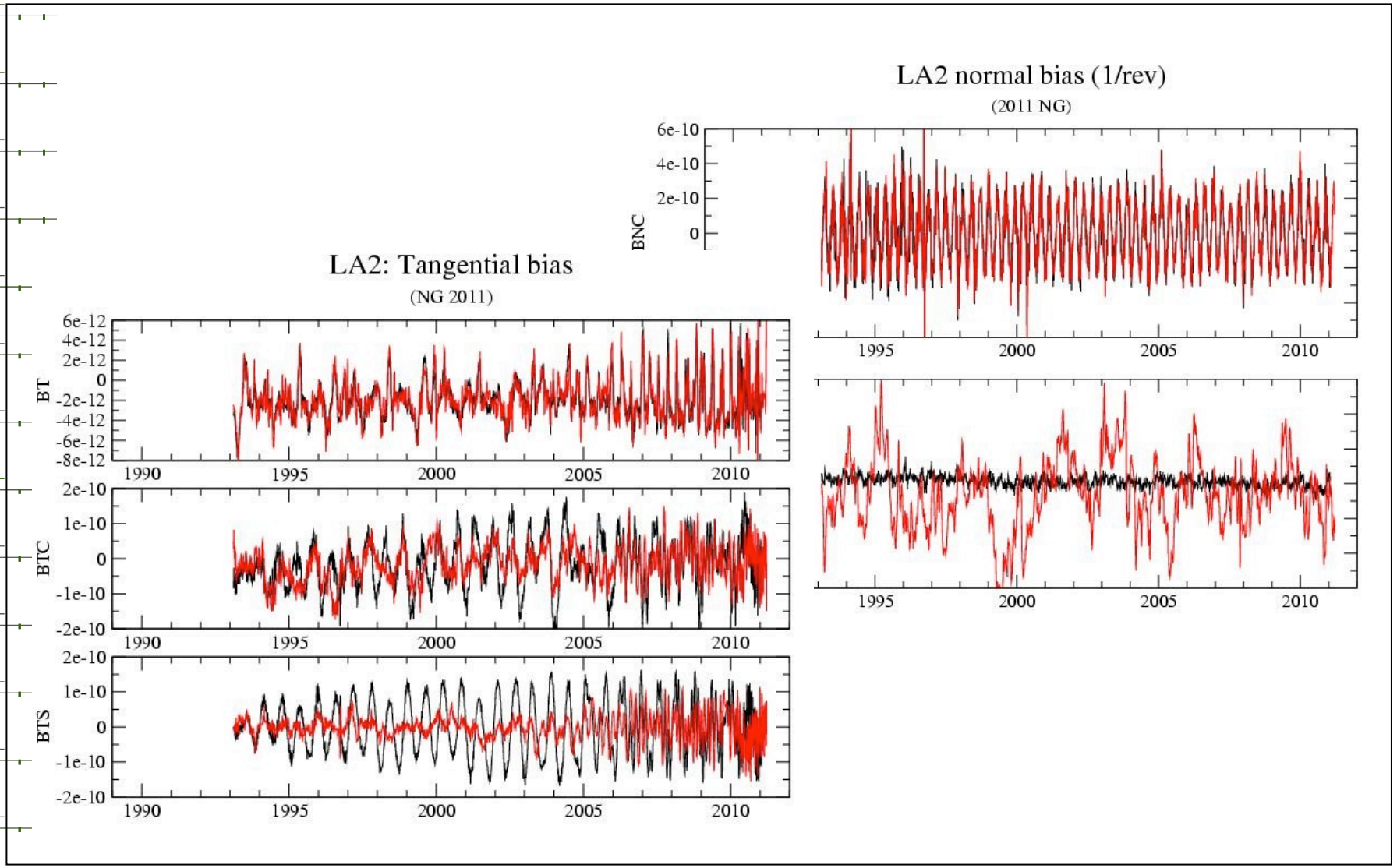
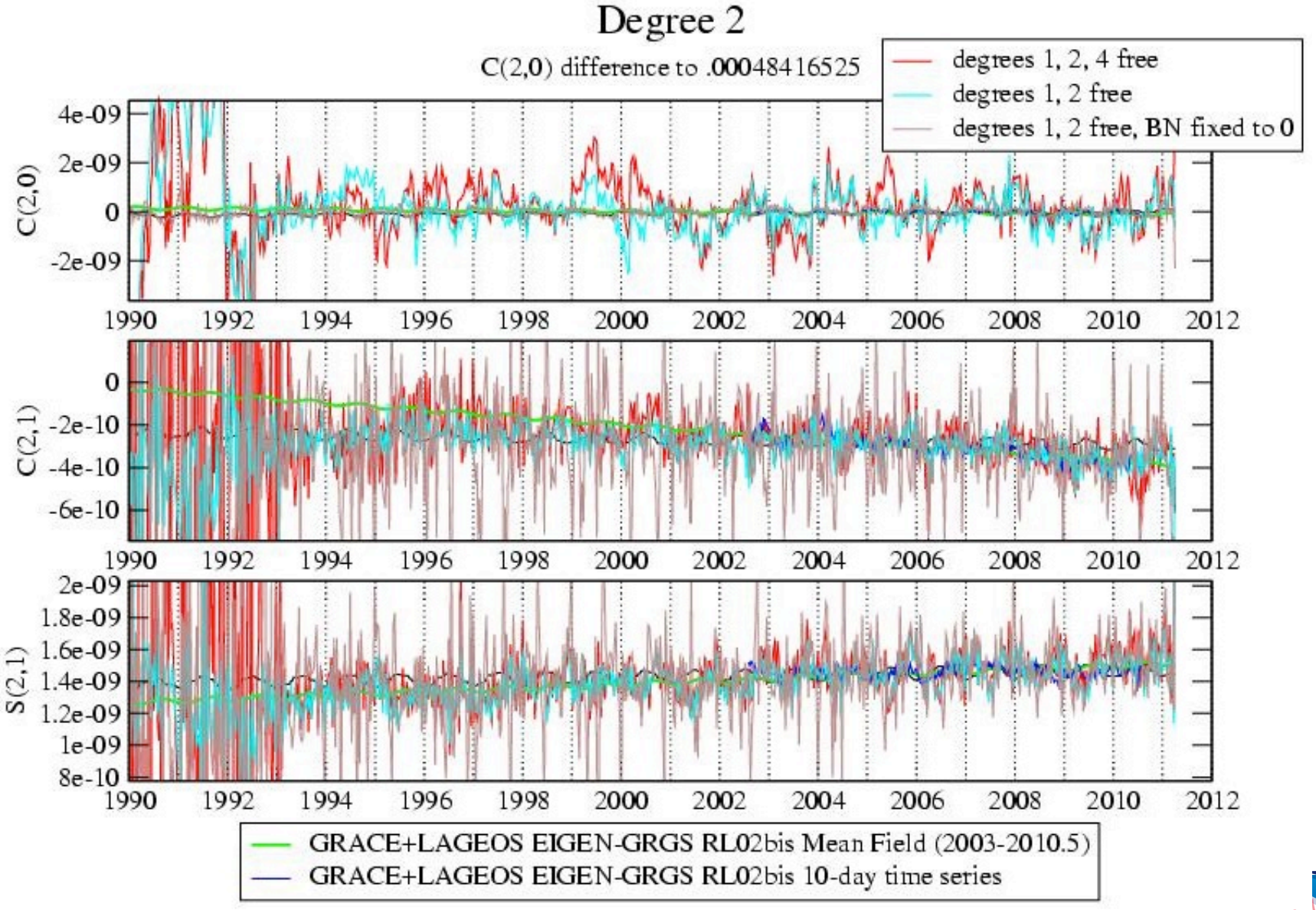
LA1: EMPIRICAL COEFFICIENTS



LA2: EMPIRICAL COEFFICIENTS



GF Degree 2 estimation strategy.



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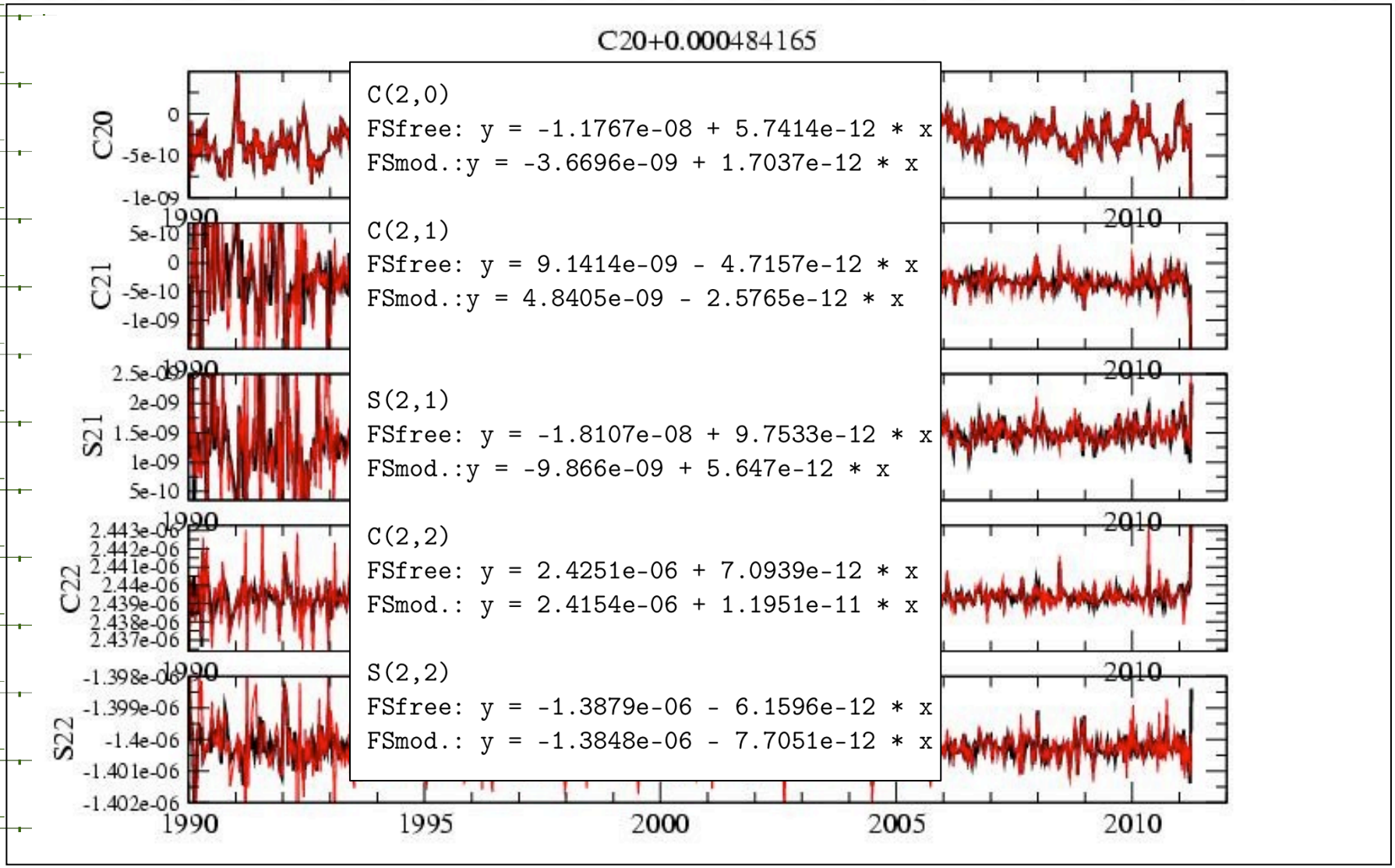
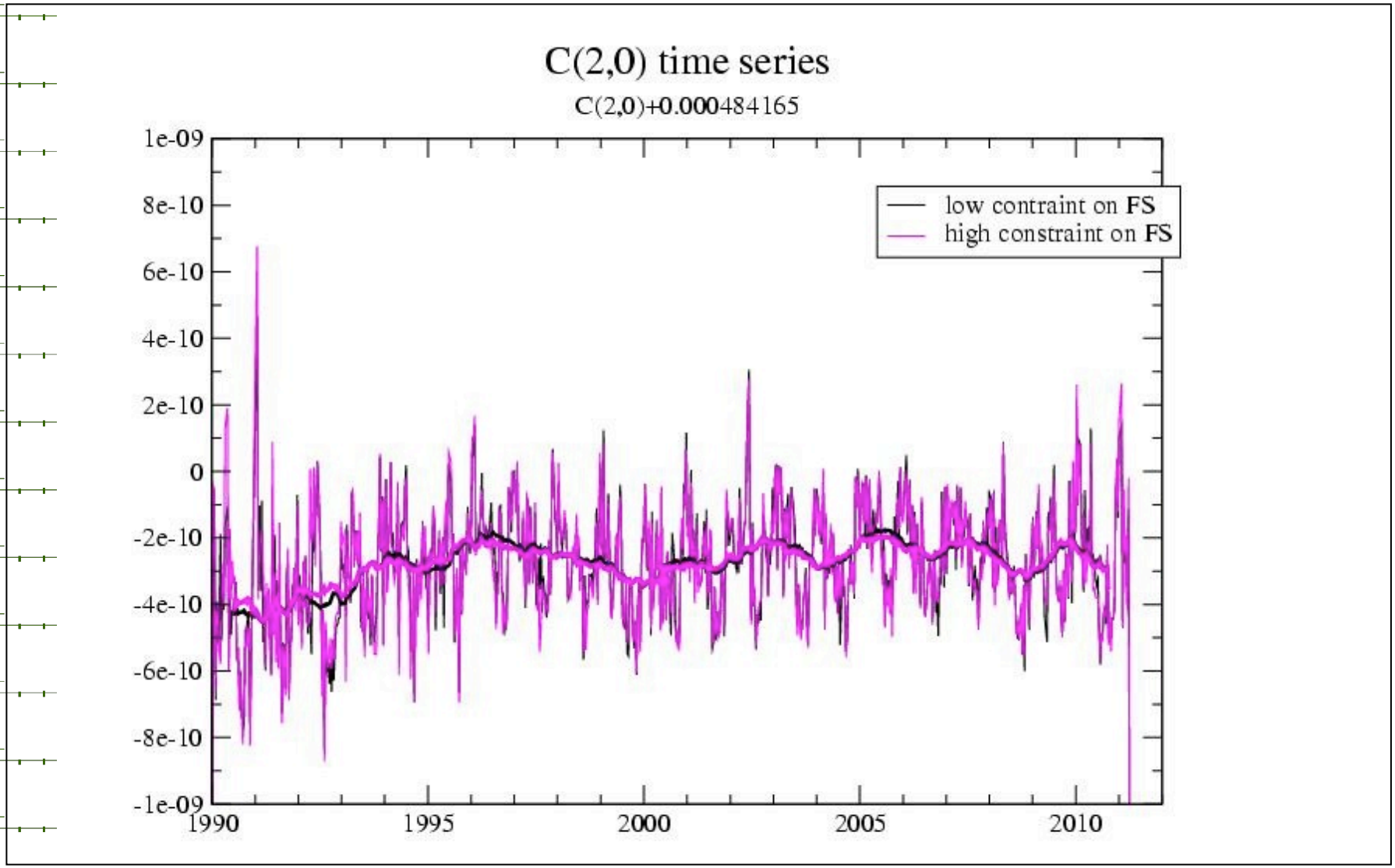
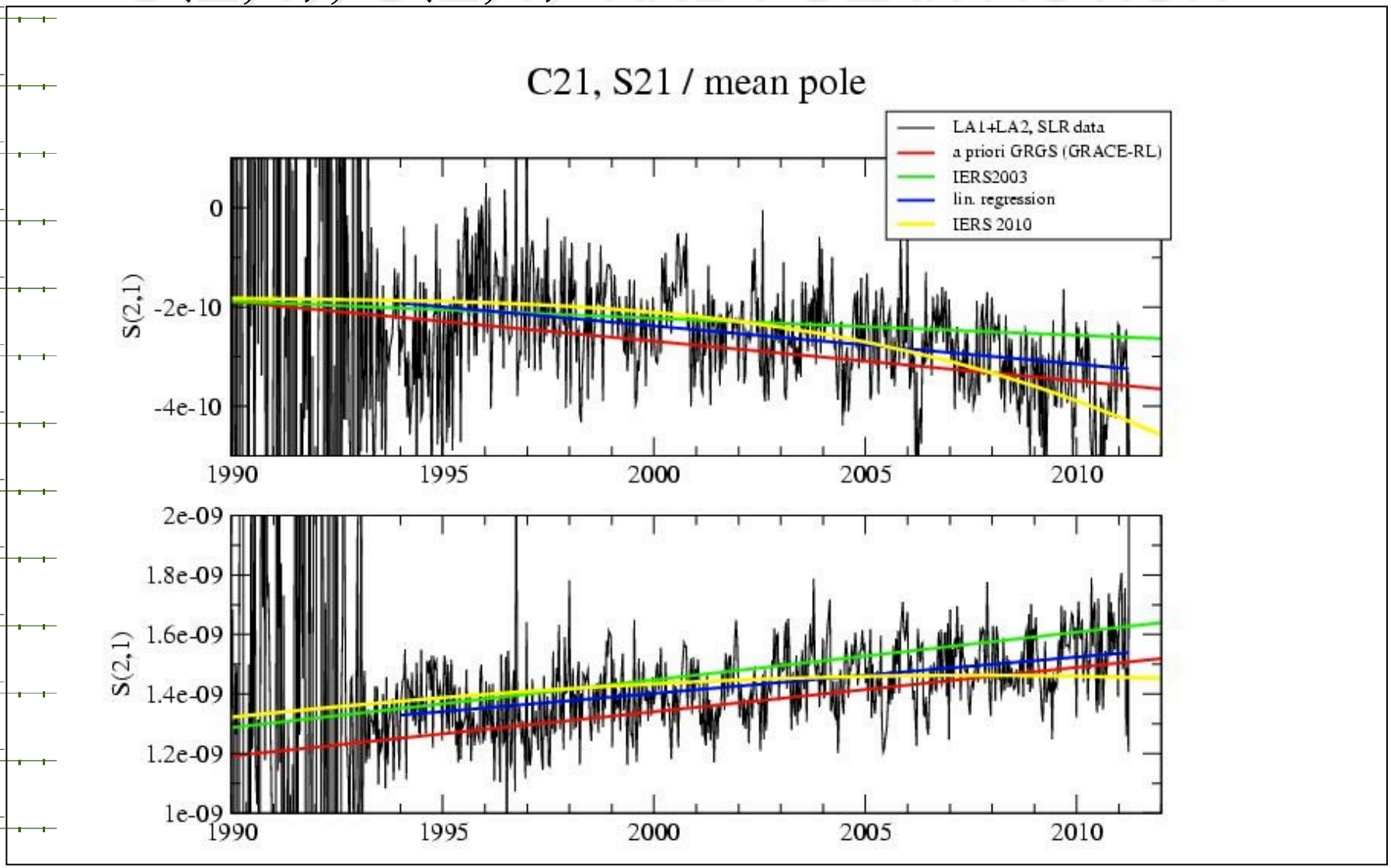
GF Degree 2 time series with/ without constraining the SRP coeff.



C(2,0) TIME SERIES.



To continue the discussion: C(2, 1), S(2, 1) and polar motion



CONCLUSIONS

- SRP coeff: no physical reason to be time dependent (roughly speaking)
  - Modelled

$$
\begin{aligned}
FS(LA_1) &= 1 \\
FS(LA_2) &= (7.04651 \;\; 10^{-4}(t-1990)^2 \\
&\quad +0.0166(t-1990)+1.01985) \\
&\quad \times exp(-0.0254067(t-1990))
\end{aligned}
$$

- Long Lageos orbital arcs suitable to describe NG forces:
  - LA1: chaotic behavior of empirical coefficients **confirmed**
  - LA2: change of regime on the tangential direction **detected**

- Impactson GF coeff. of the **reduction strategy** of empirical parameters
  - FS free or modelled
  - Normal coefficients highly constrained or not
- Changes on C(2,0) times series:
  - Up to a few 10^{-10}
  - Impact on the secular variation
- **To be continued**…

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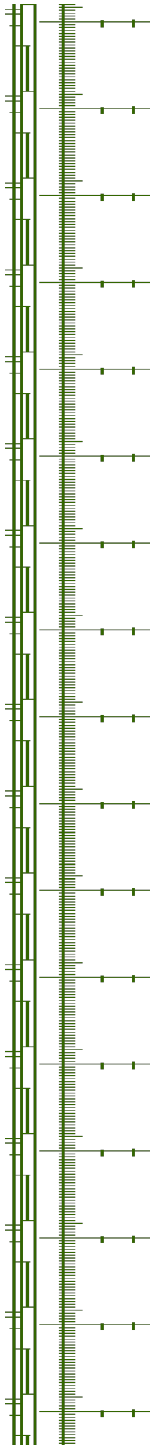

THANK YOU !

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GRGS ILRS Analysis center

- Staff:
  - OCA/Geoazur: F. Deleflie, O. Laurain, P. Exertier, B. de Saint-Jean
  - IGN/LAREG: D. Coulot
- Software:
  - GINS/DYNAMO (CNES/GRGS)
  - MATLO (IGN/LAREG/OCA/GRGS)
- Operational activities:
  - For ILRS: Weekly, and now daily, submissions
    - *pos+eop*
    - *based on LA1+LA2*
  - For GRGS internal validation and combinations: Weekly arcs
    - *Accounting as well for loading effects*
    - *Additionnaly: Gravity field time series*
- Other activities:
  - Reanalyses, over long periods of time
  - Specific projects: T2L2, calibration/validation altimetric measurements
  - Other satellites: STA, STE, AJI, ET1 & 2, *JAS1* and *JAS2*

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