

# ASSESSMENT OF THE NON GRAVITATIONAL FORCES ACTING ON THE LAGEOS SATELLITES, AND IMPACTS ON GRAVITATIONAL PARAMETERS

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**Journées de la sf2a 2011**

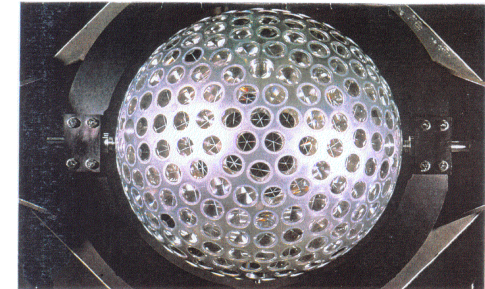


Observatoire  
de la CÔTE d'AZUR



# NON GRAVITATIONAL FORCES ACTING ON THE LAGEOS SATELLITES

- 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  $a$ ,  $e \cdot \cos \omega$  and  $e \cdot \sin \omega$
- This was the case up to 1996...
- After 25 years (2001), 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- After 33 years (2009) , the BI model is no longer valid : 1 to 1 resonance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).
- We try to draw an assessment of the present situation
  - Long orbital arc of LA1 AND LA2
  - Analysis of the empirical coefficients time series
  - Impact of GF time series estimation



# 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)along – track component :  $\Delta T(t) = BT + BTC \cos(\omega + M) + BTS \sin(\omega + M)$   
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 :

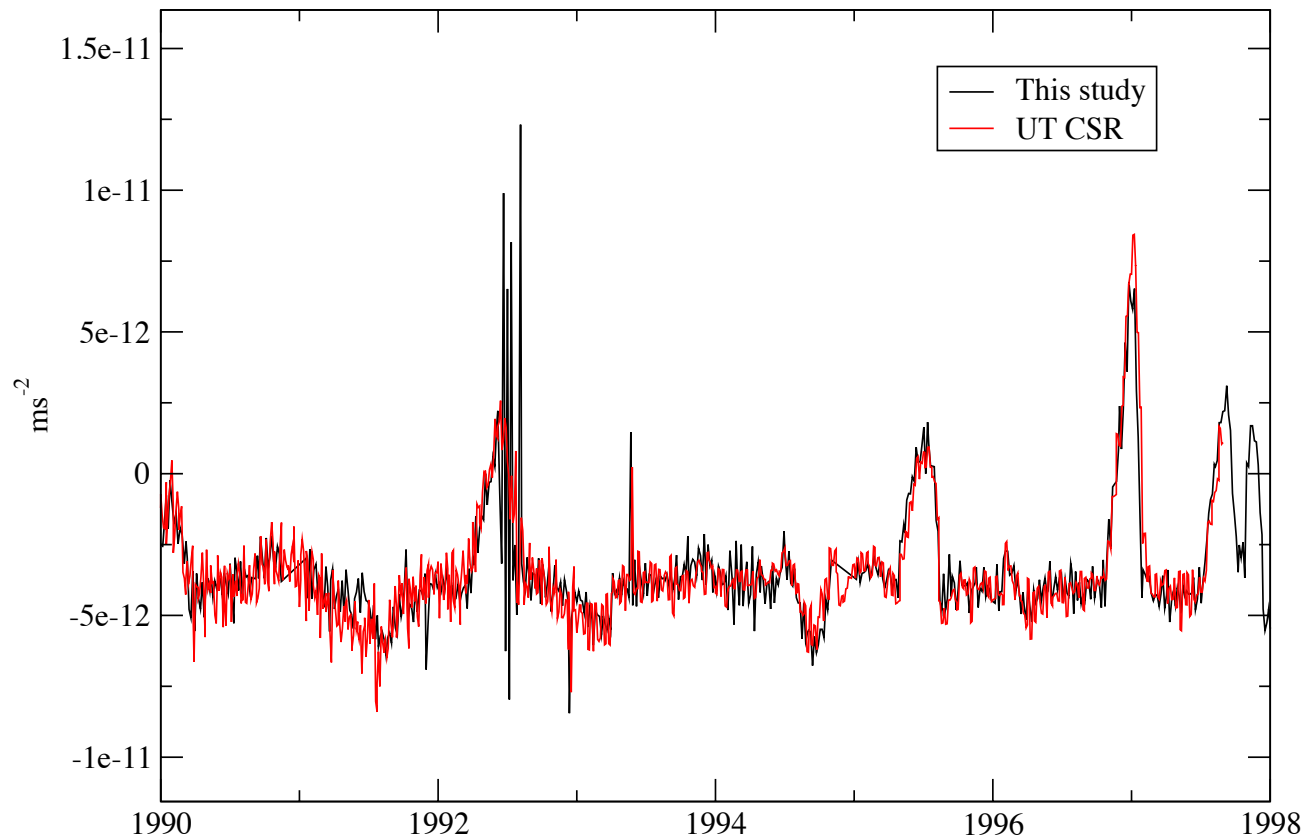
$$\frac{\Delta \dot{a}}{a} \approx \frac{2}{na} BT$$

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

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

# CHECKING THE APPROACH (1/2)

## COMPARISON OF RESIDUAL ACCELERATIONS



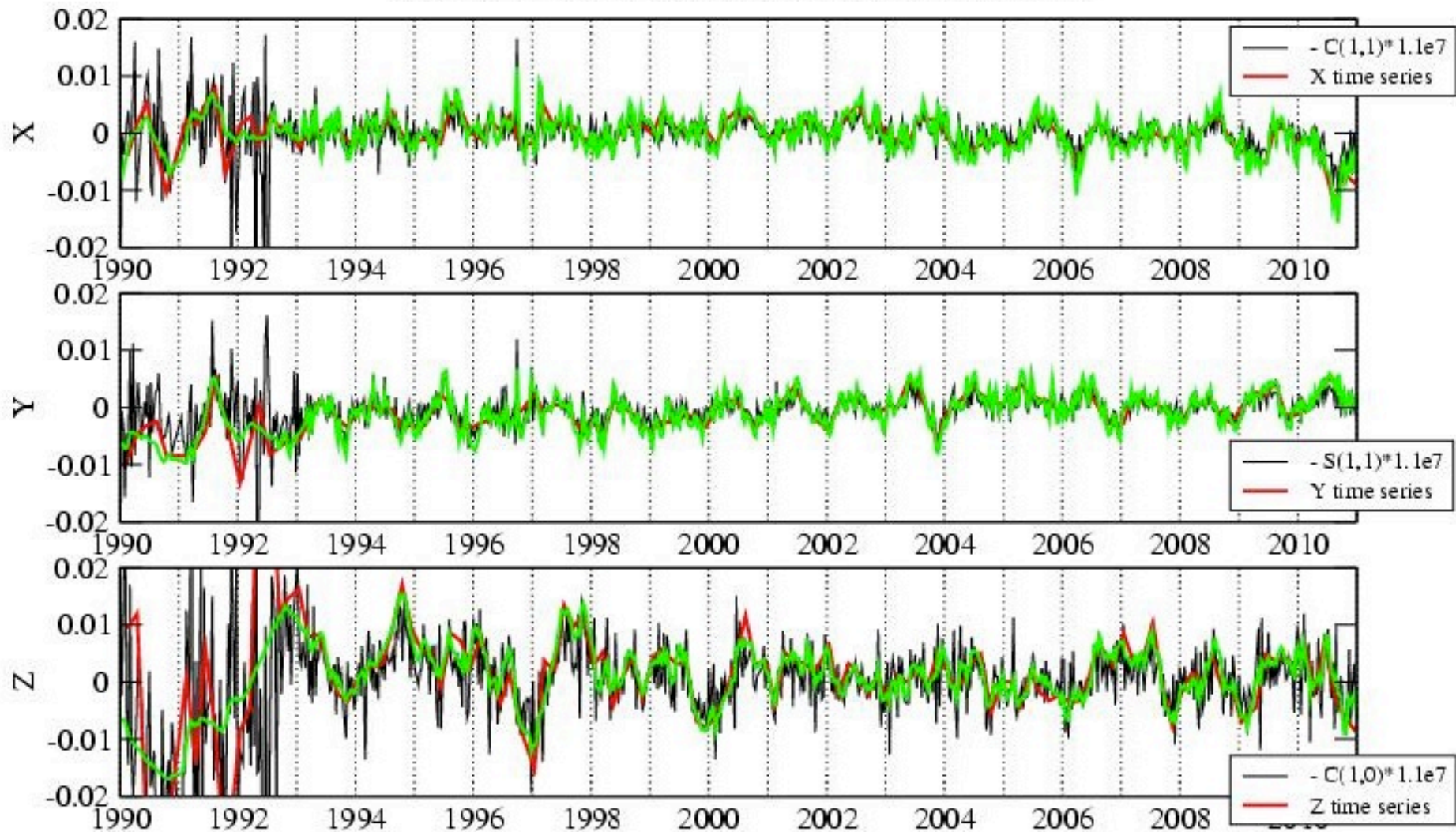
*Comparison of residual acceleration (BT) computed by UT CSR (1980-1997) and in this study (1990-2011) over the common period.*

# CHECKING THE APPROACH (2/2)

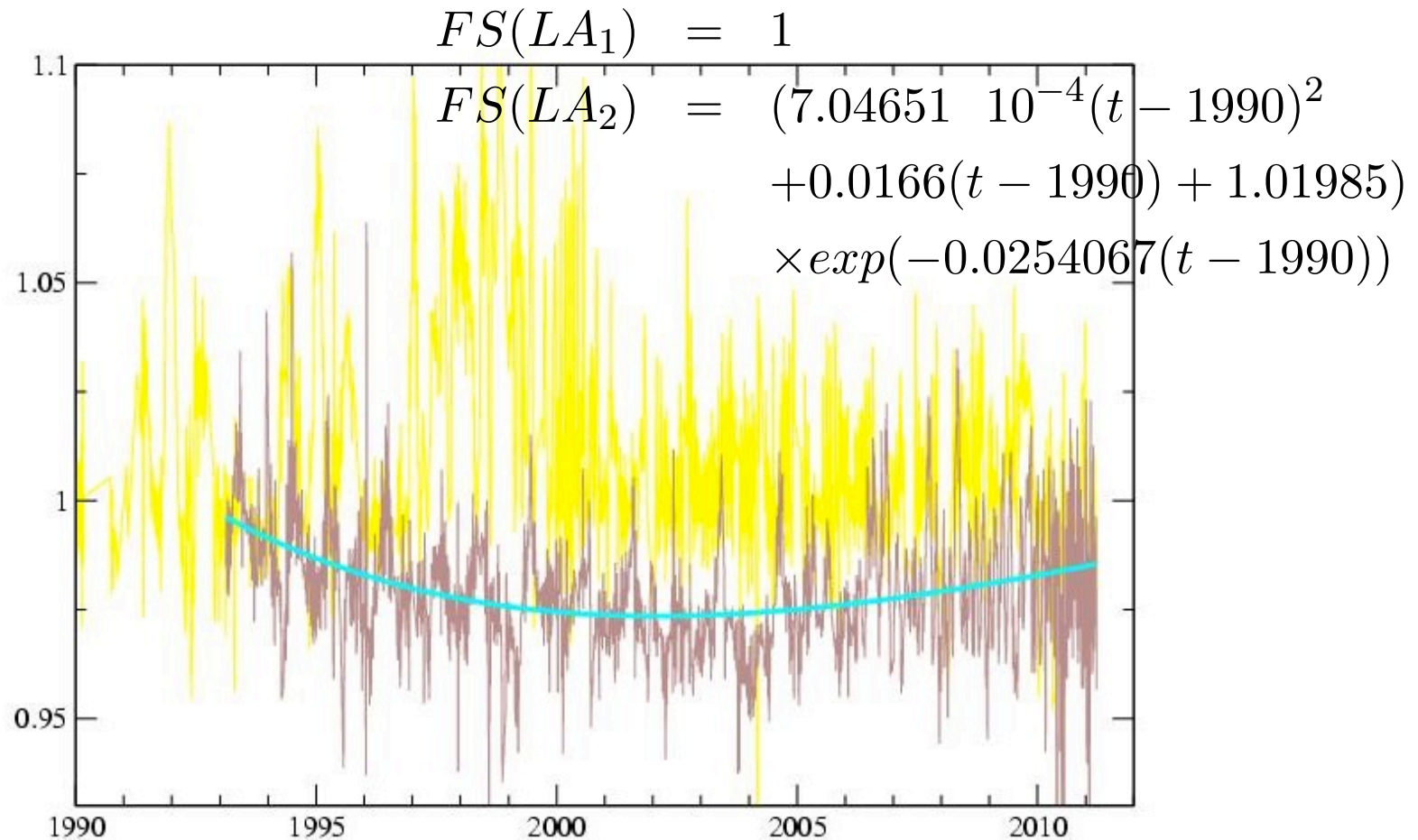
## GEOCENTER MOTION

Geocenter coordinates / Degree 1 solutions

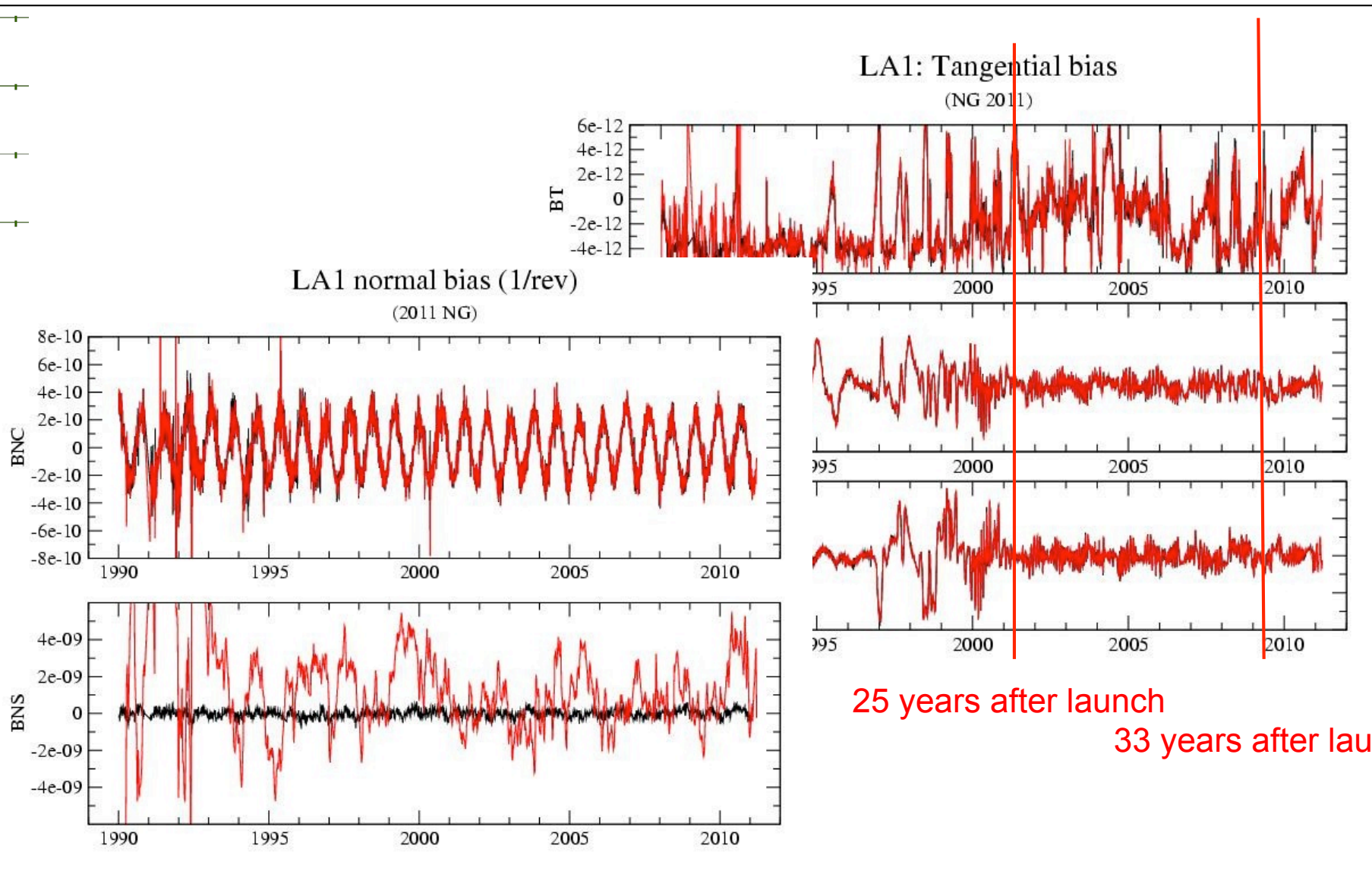
(in green: Degree 1 solution with continuity constraints)



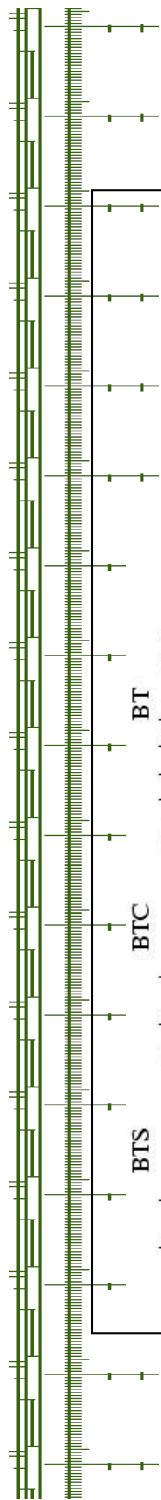
# *SRP TIME SERIES, AND MODELLING*



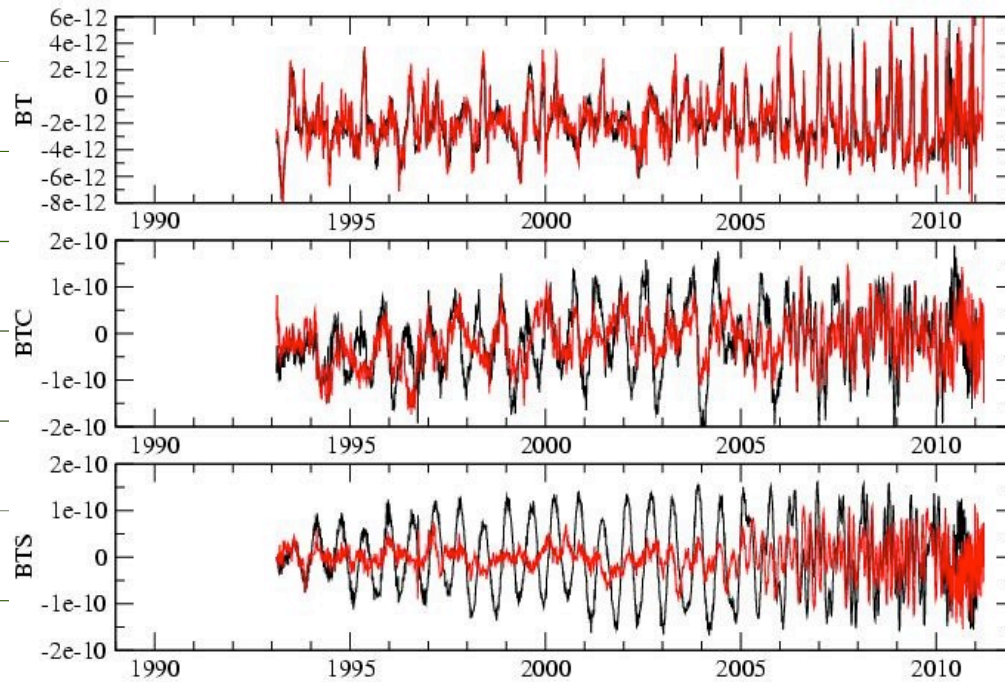
# LA1: EMPIRICAL COEFFICIENTS



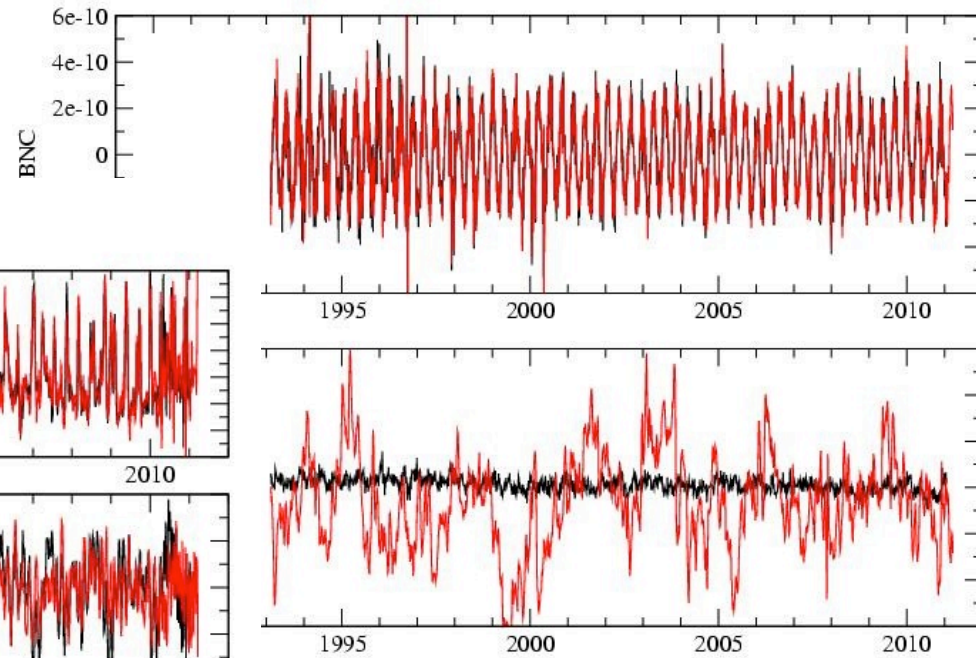
# LA2: EMPIRICAL COEFFICIENTS



LA2: Tangential bias  
(NG 2011)



LA2 normal bias (1/rev)  
(2011 NG)

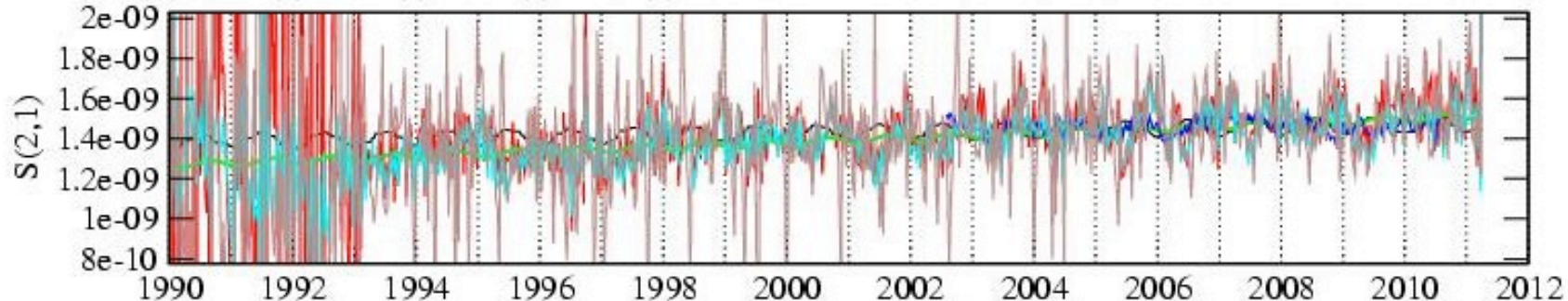
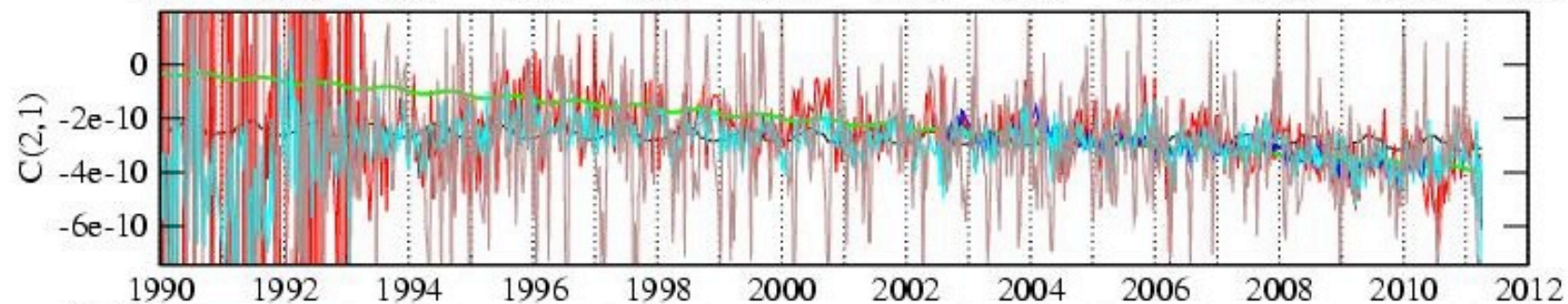
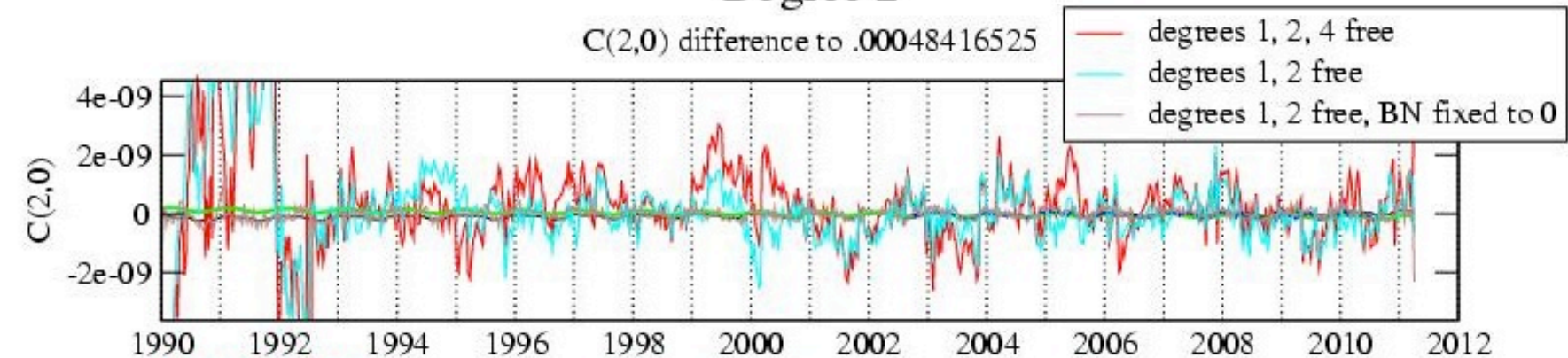




# GF DEGREE 2 ESTIMATION STRATEGY.

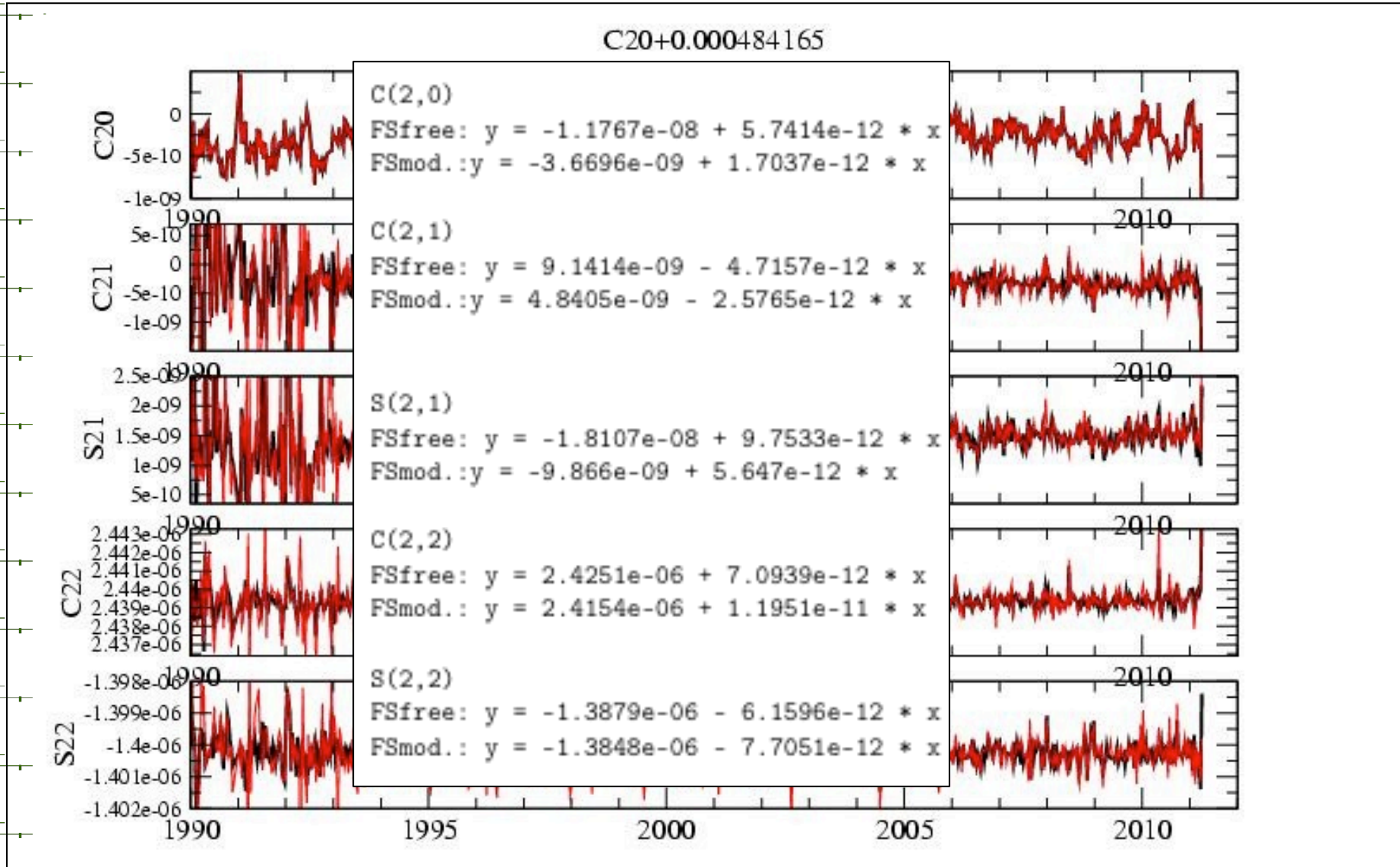
## Degree 2

$C(2,0)$  difference to .00048416525

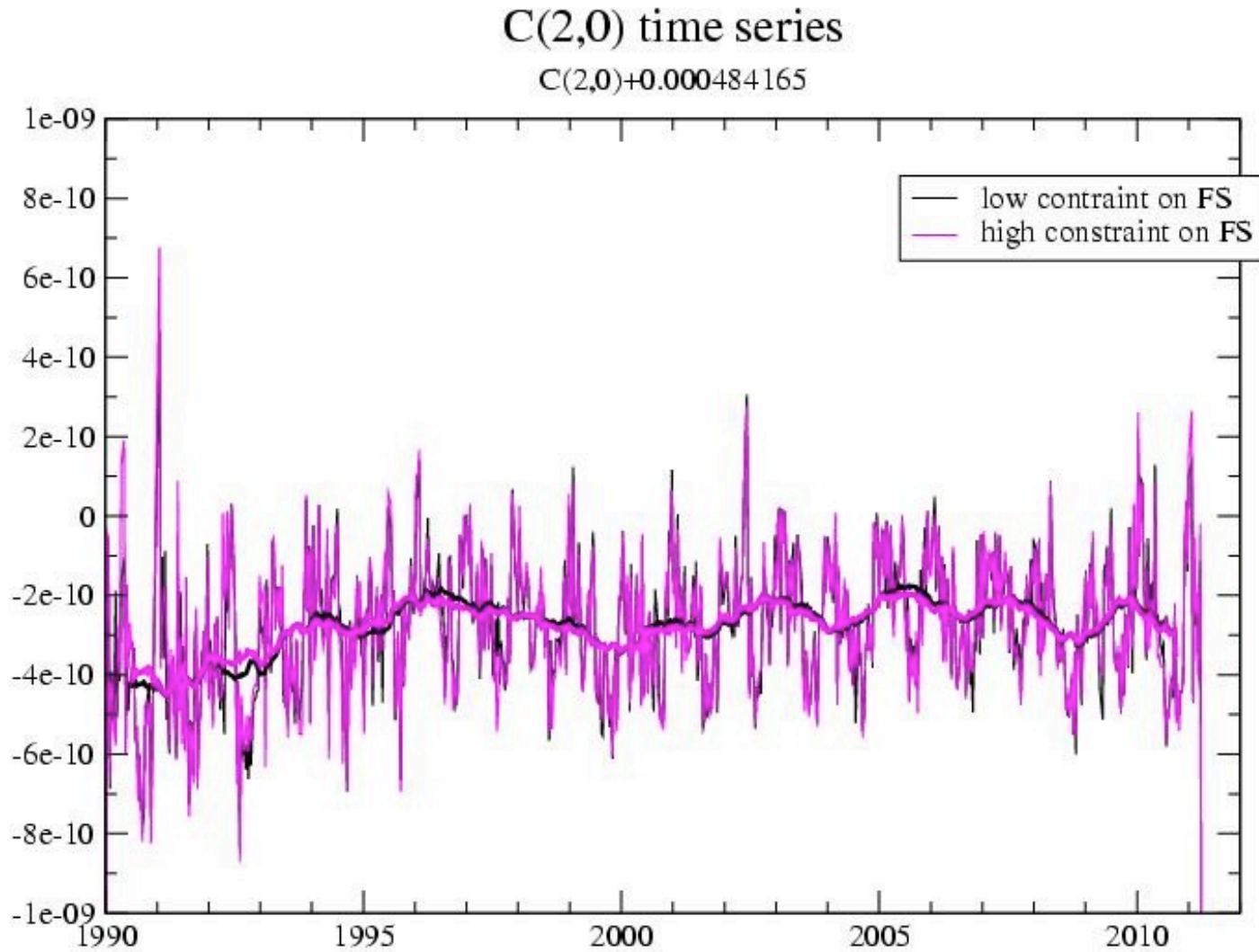


— GRACE+LAGEOS EIGEN-GRGS RL02bis Mean Field (2003-2010.5)  
— GRACE+LAGEOS EIGEN-GRGS RL02bis 10-day time series

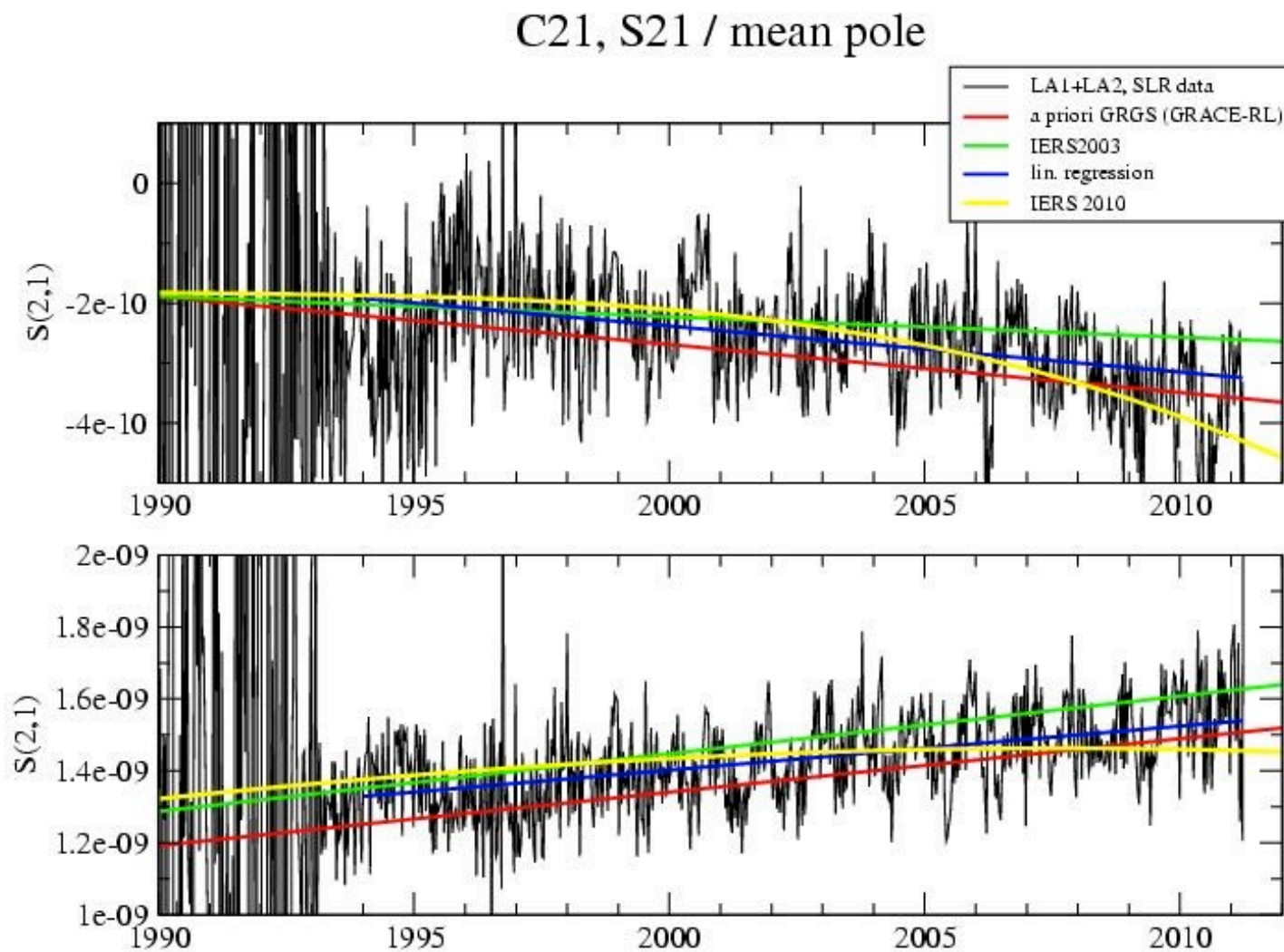
# GF DEGREE 2 TIME SERIES WITH/ WITHOUT CONSTRAINING THE SRP COEFF.



# $C(2,0)$ 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

$$FS(LA_1) = 1$$

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

- 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**

- Impact on GF coeff. of the **reduction strategy** of empirical parameters

- FS free or modelled

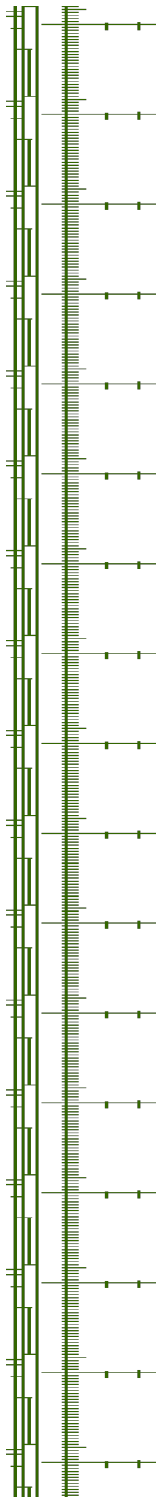
- Normal coefficients highly constrained or not

- Changes on C(2,0) times series:

- Up to a few  $10^{-10}$

- Impact on the secular variation

- **To be continued...**



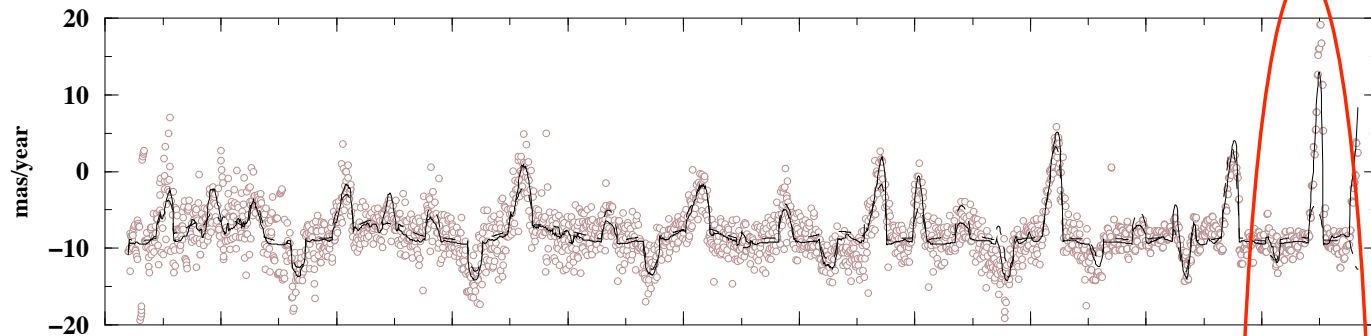
*THANK YOU !*

# 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

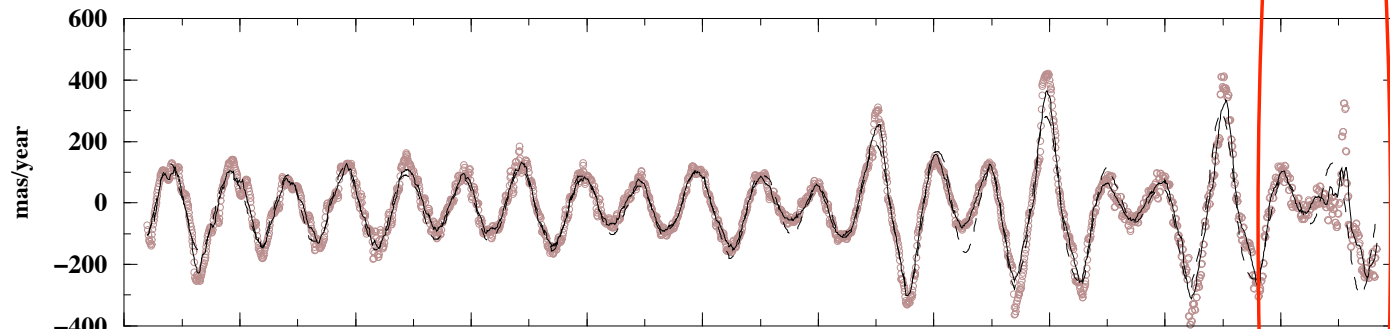
# NON GRAVITATIONAL FORCES ACTING ON THE LAGEOS SATELLITES

semi-major axis excitation



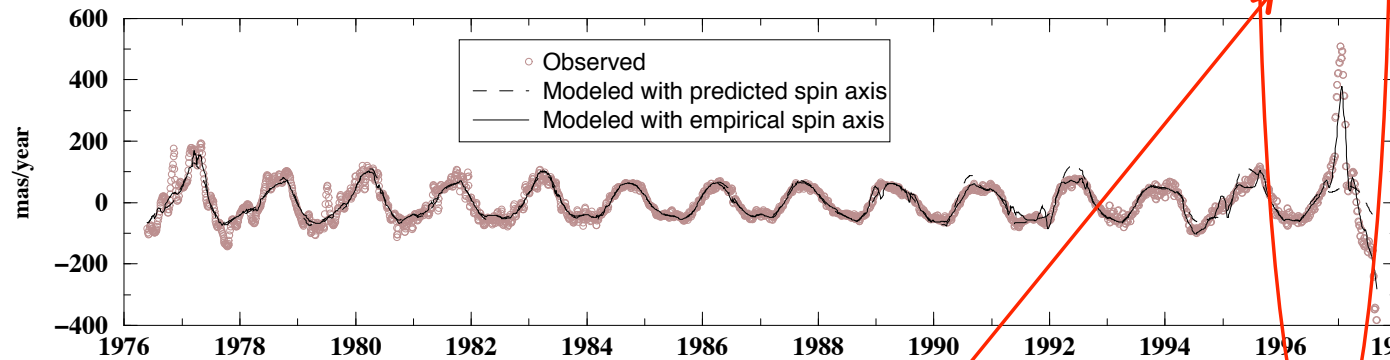
(a)

Eccentricity vector excitation (real part)



( $e^* \cos \omega$ )

Eccentricity vector excitation (imaginary part)



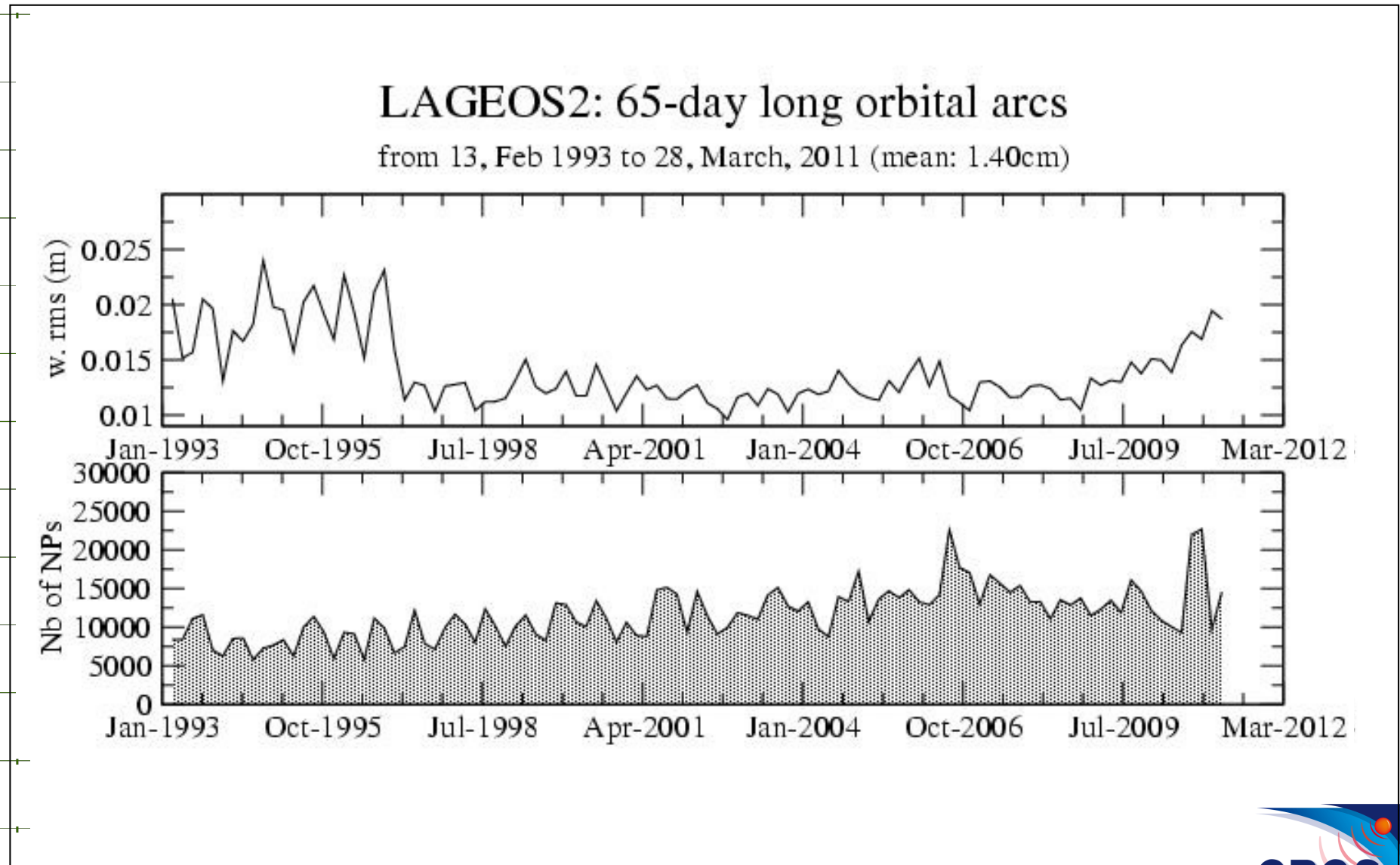
( $e^* \sin \omega$ )

1997 « anomalies »



# CHECKING THE APPROACH (1 / 3)

## POST-FIT WEEKLY ARCS RESIDUALS



# NON GRAVITATIONAL FORCES ACTING ON THE LAGEOS SATELLITES

- After 25 years (2001), 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)
- Effects to be considered:
  - Magnetic torque
  - Gravitational torque
  - Thermal effect
  - Anisotropy
  - ...

Measured values  
of the period

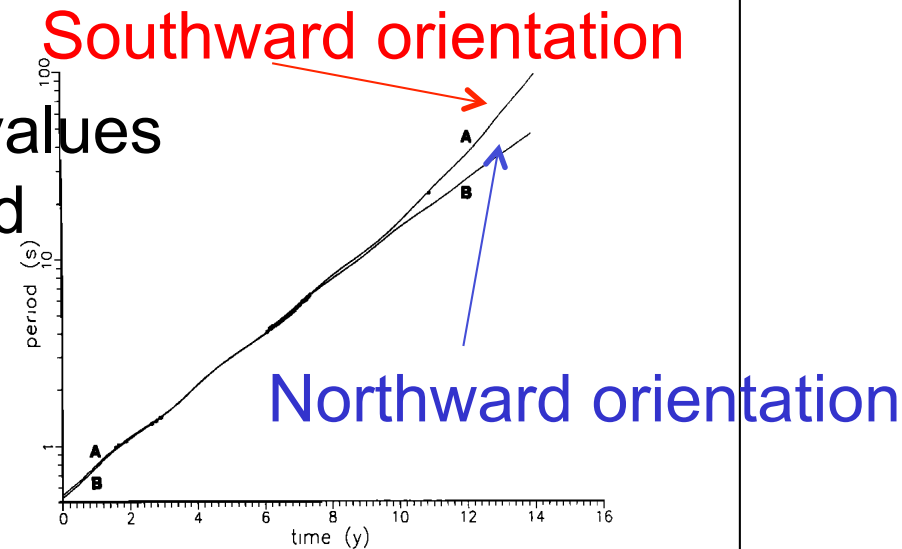


Fig. 4. Predicted evolution of the LAGEOS spin period as a function of time (years), under the action of magnetic and gravitational torques. The dots represent the measured values of the period. Curve A refers to a southward orientation of  $\omega(0)$ , while curve B, which shows a poorer agreement,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