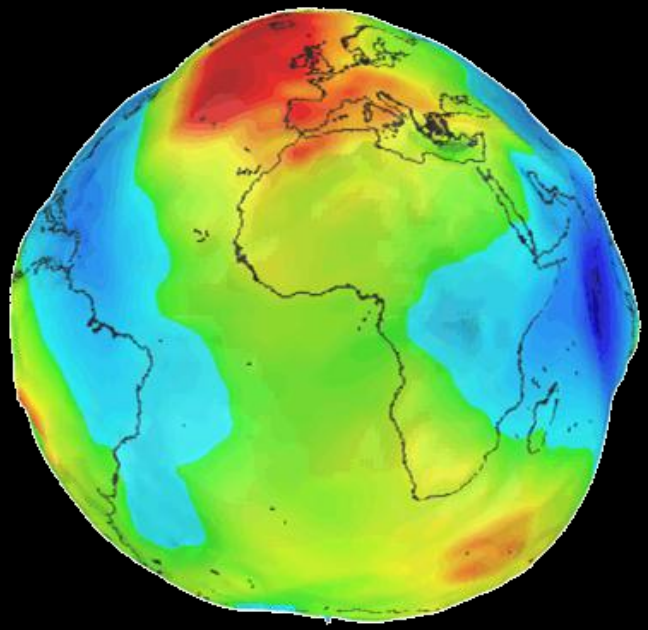
Earth's low degree gravitational variations from space geodetic data



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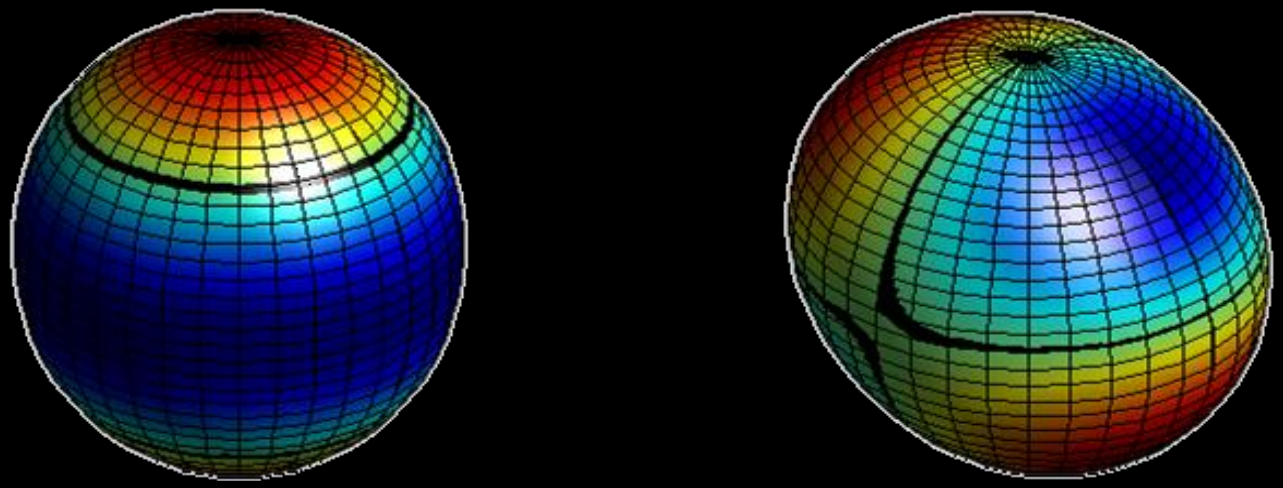
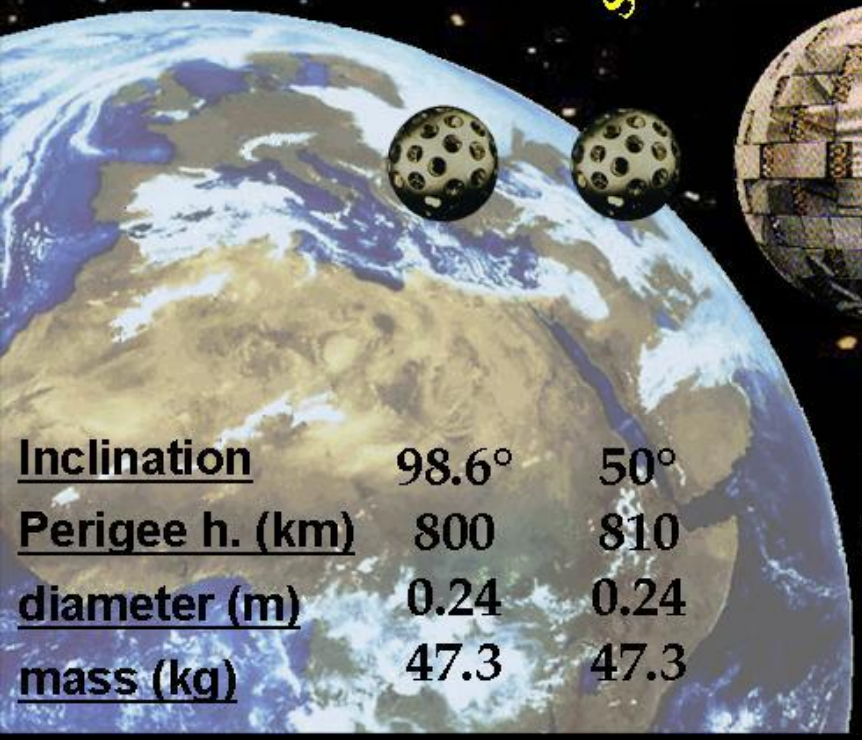
- The C21, S21 and C20 Stokes coefficients are related to the Earth's principal figure axis and oblateness
- The redistribution of the mass within the Earth system induces changes in the Earth's gravity field.
- Mass load variations induce excitations in the EOPs that are proportional to those second-degree coefficients.
- SLR data are used to retrieve time series of direct estimates of low degree geopotential coefficients
- Time series of 2-deg Stokes coefficients can be derived from the EOP excitation functions (SLR and VLBI EOP in this study)



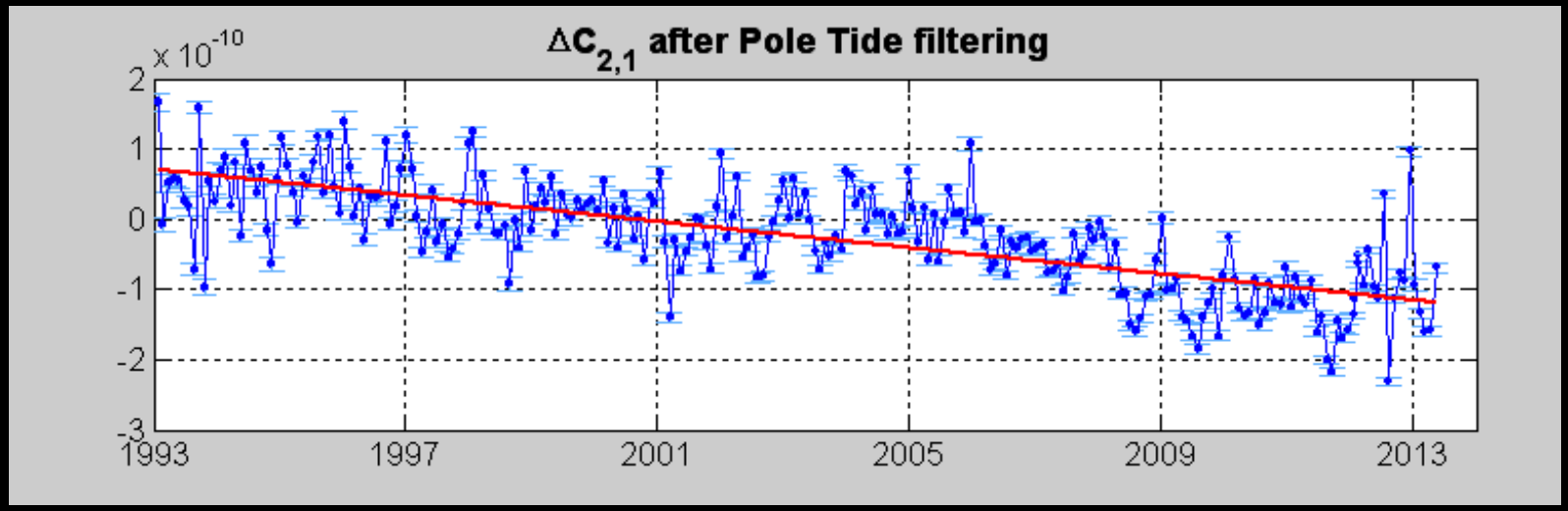
Geodetic Satellite Constellation

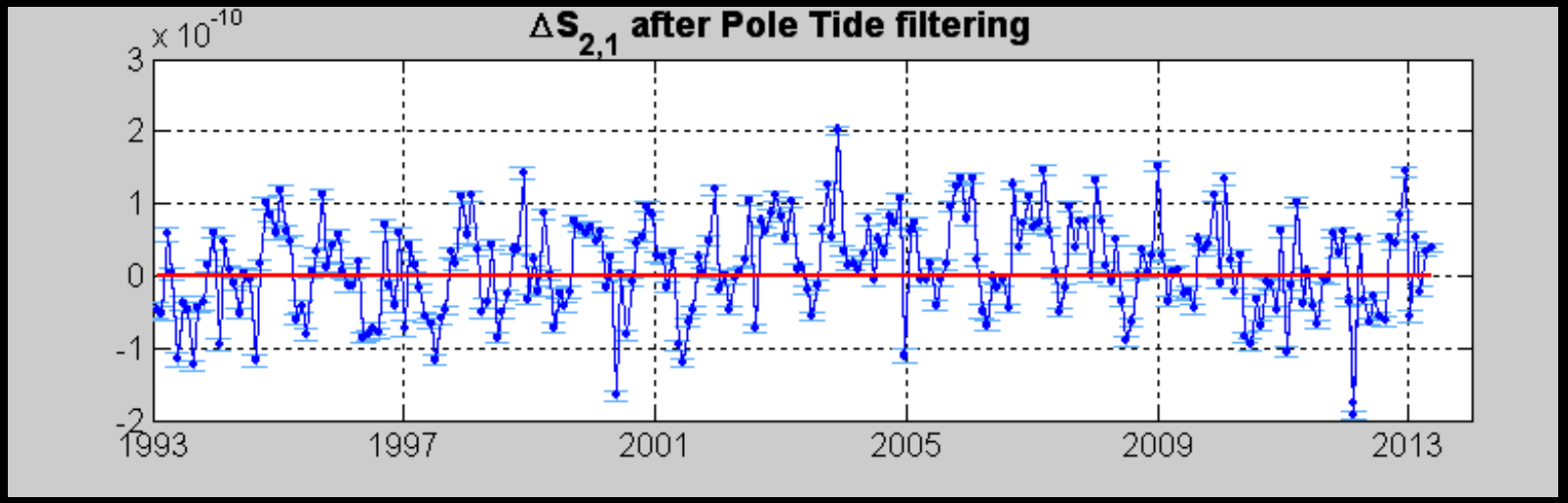


Inclination	98.6°	50°	50°	52.6°	109.8°	65.3°
Perigee h. (km)	800	810	1,485	5,620	5,860	19,105
diameter (m)	0.24	0.24	2.14	0.60	0.60	1.294
mass (kg)	47.3	47.3	685	405.4	407	1,415

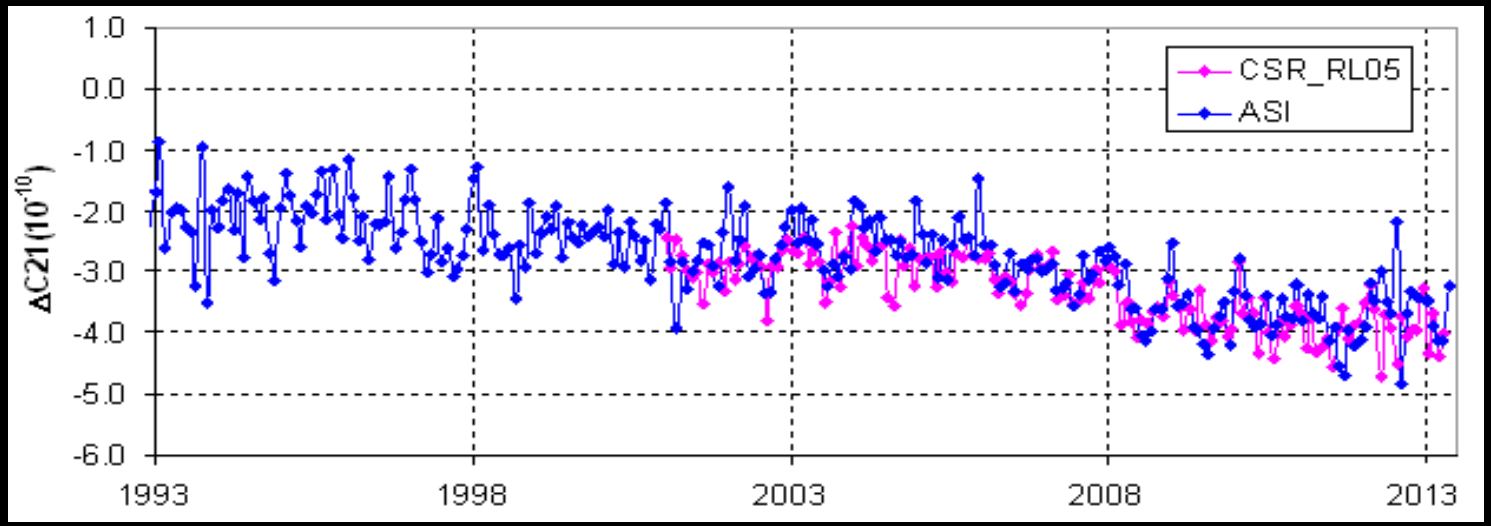
All the SLR data available from 1983 to June 2013

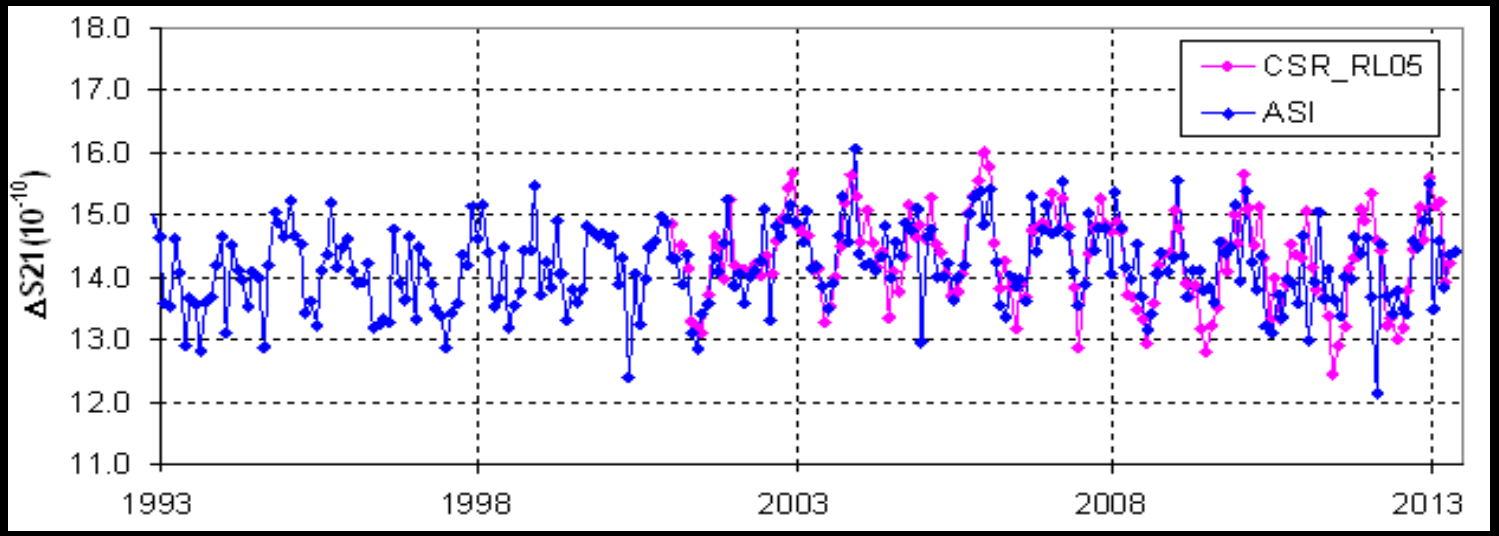
$\Delta C_{2,1}$ $\Delta S_{2,1}$ Full Time Series from SLR data





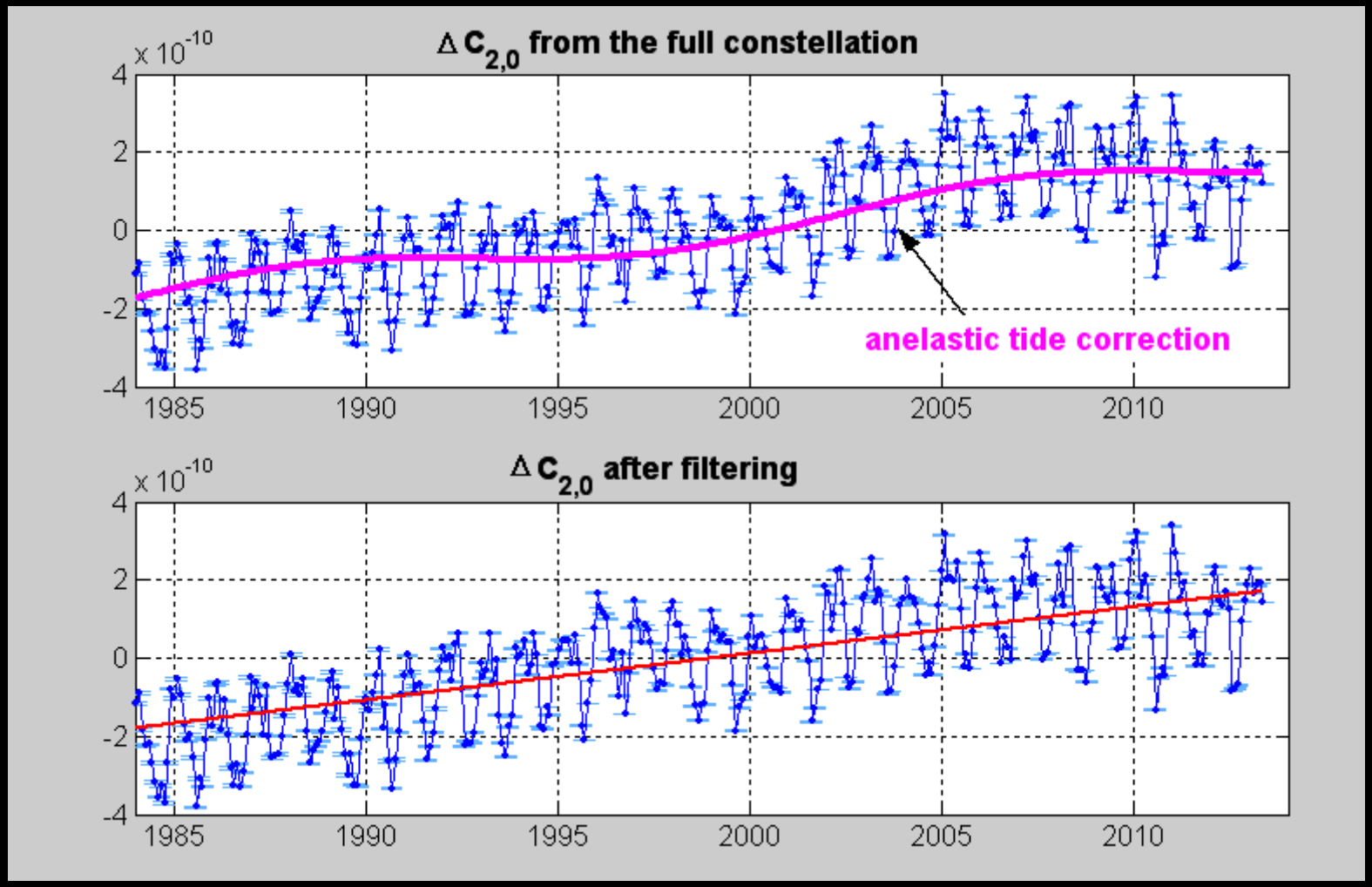
$\Delta C_{2,1}$ and $\Delta S_{2,1}$ external comparison



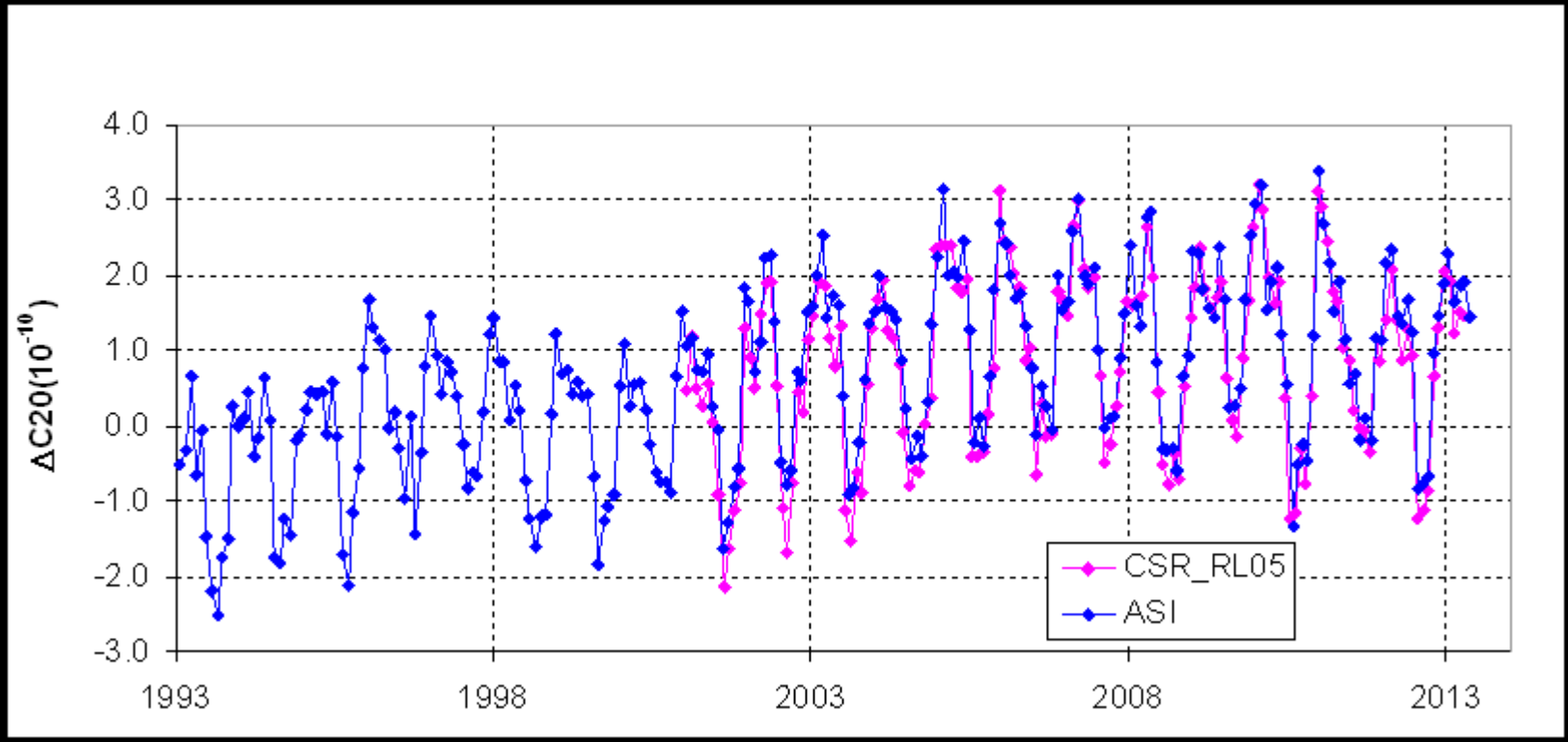


CSR solution: Cheng, M. K., J. C. Ries, and B. D. Tapley (2011) Variations of the Earth's Figure Axis from Satellite Laser Ranging and GRACE, J. Geophys. Res., 116, B01409, DOI:10.1029/2010JB000850.

$\Delta C_{2,0}$ Time Series from SLR data



$\Delta C_{2,0}$ external comparison



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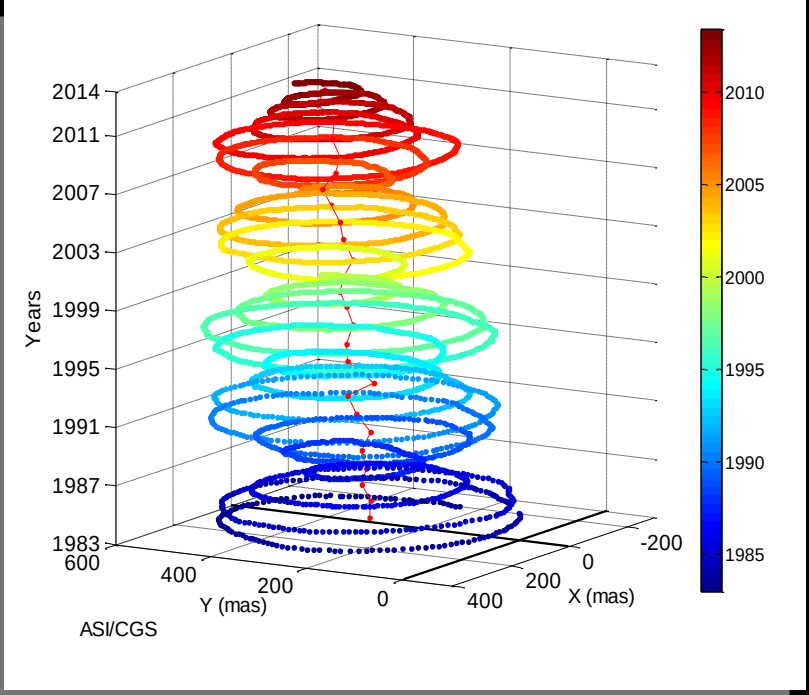
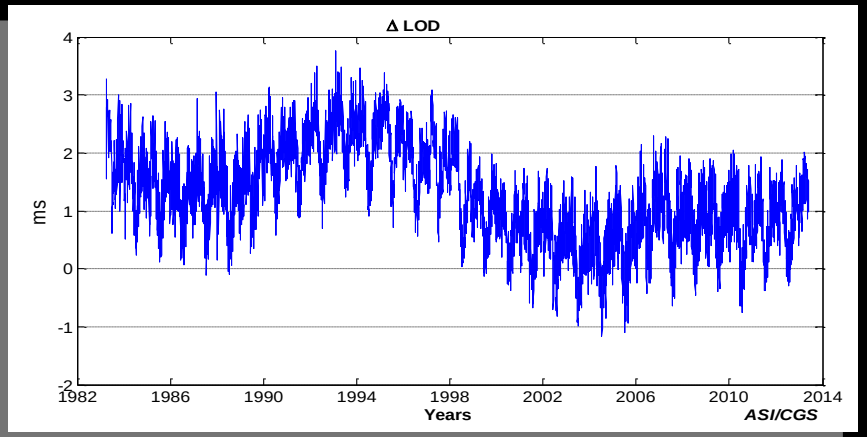
Cheng, M. K., J. C. Ries, and B. D. Tapley (2011) Variations of the Earth's Figure Axis from Satellite Laser Ranging and GRACE, J. Geophys. Res., 116, B01409, DOI:10.1029/2010JB000850.

Polar motion and LOD

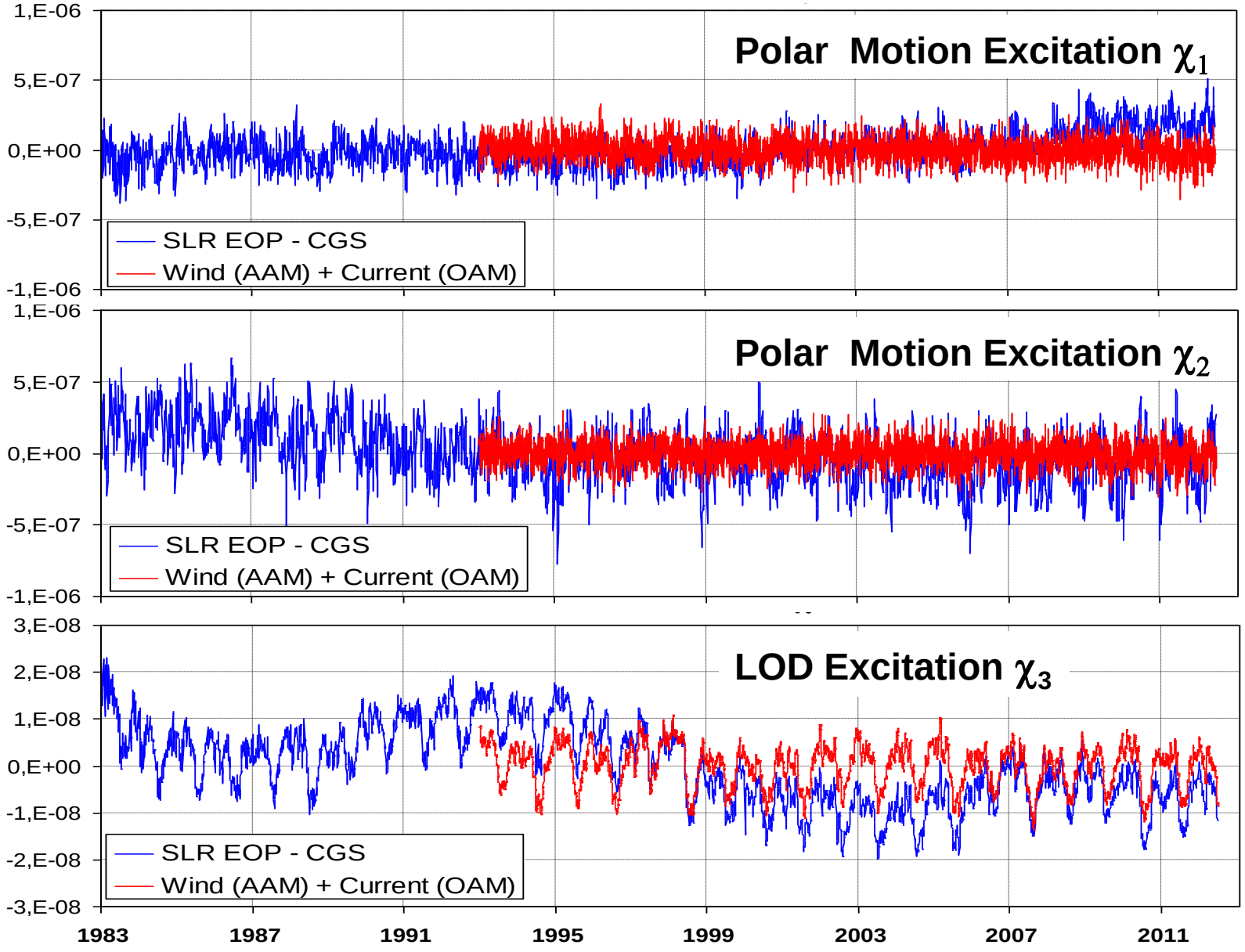
- Surface mass load variations induce excitations in the EOPs
- The excitation functions are proportional to the C_{21}, S_{21} and C_{20} coefficients
- Time series of excitation functions have been derived from the EOPs estimated at ASI/CGS from SLR (LAGEOS 1-2) and VLBI data and available at IERS as operational series

$$\Delta C_{21} + i\Delta S_{21} = -(1+k_2')\sqrt{\frac{3}{5}}\frac{(C-A)}{1.098R^2M}(\chi_1^{mass} + i\chi_2^{mass}); \qquad \Delta C_{20} = -(1+k_2')\frac{3}{2\sqrt{5}}\frac{C_m}{0.753R^2M}\chi_3^{mass}$$



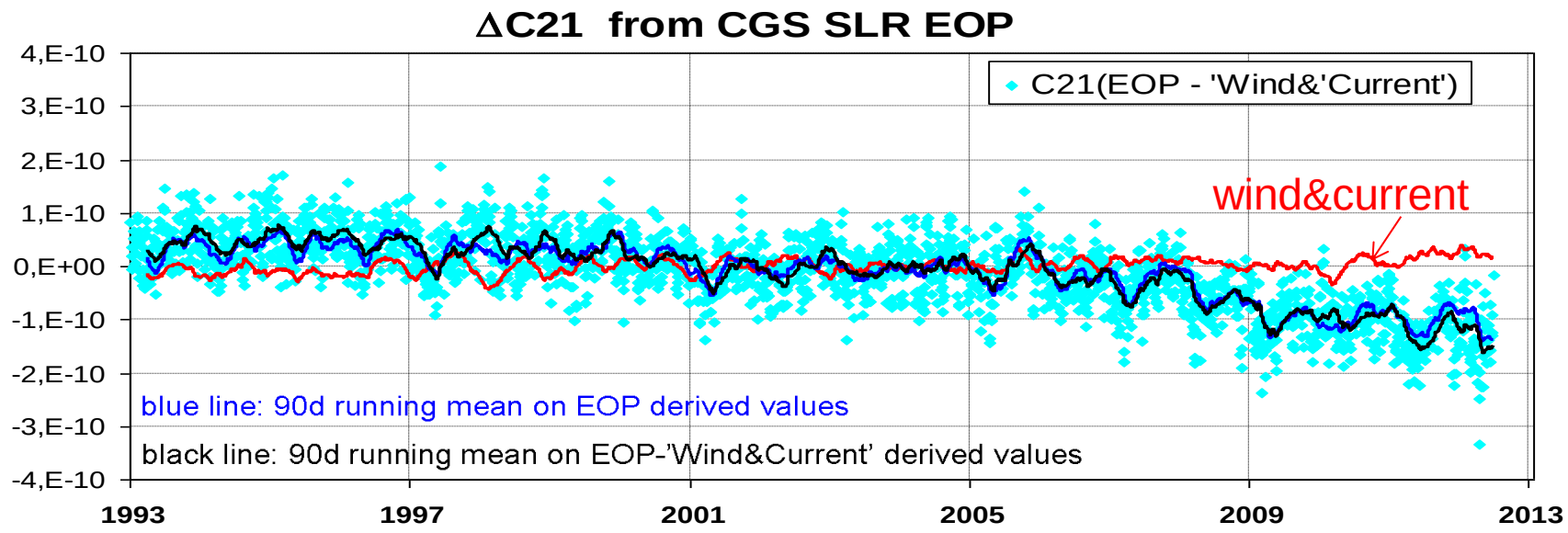


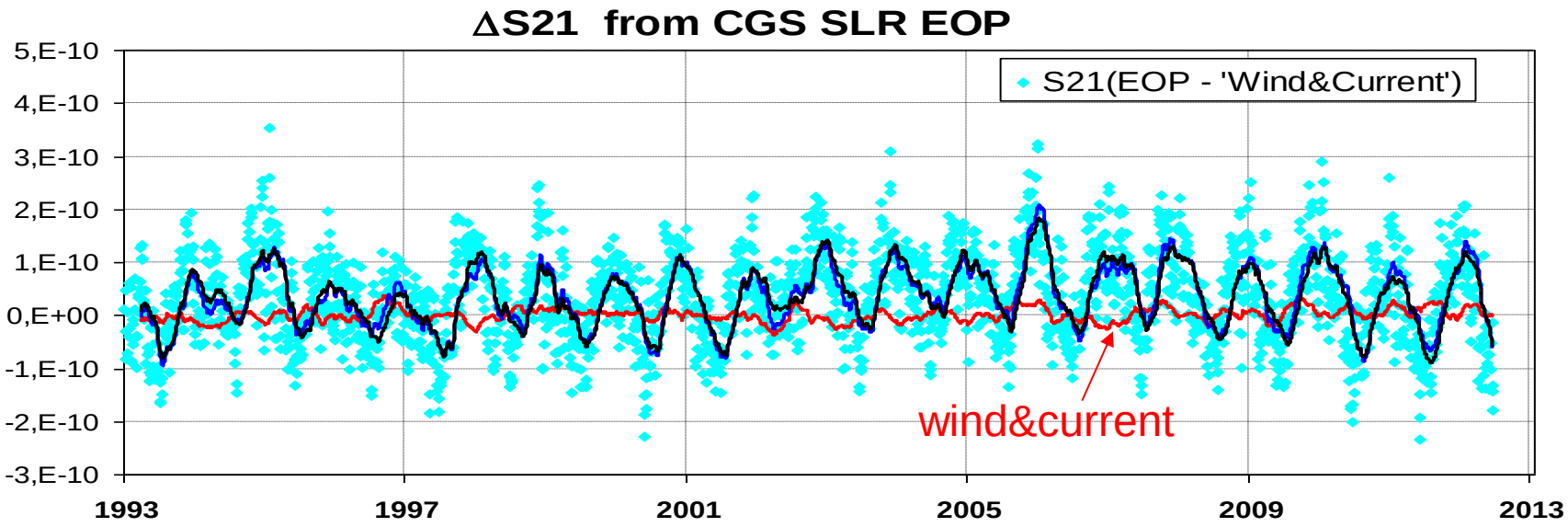
SLR Polar motion & LOD excitations



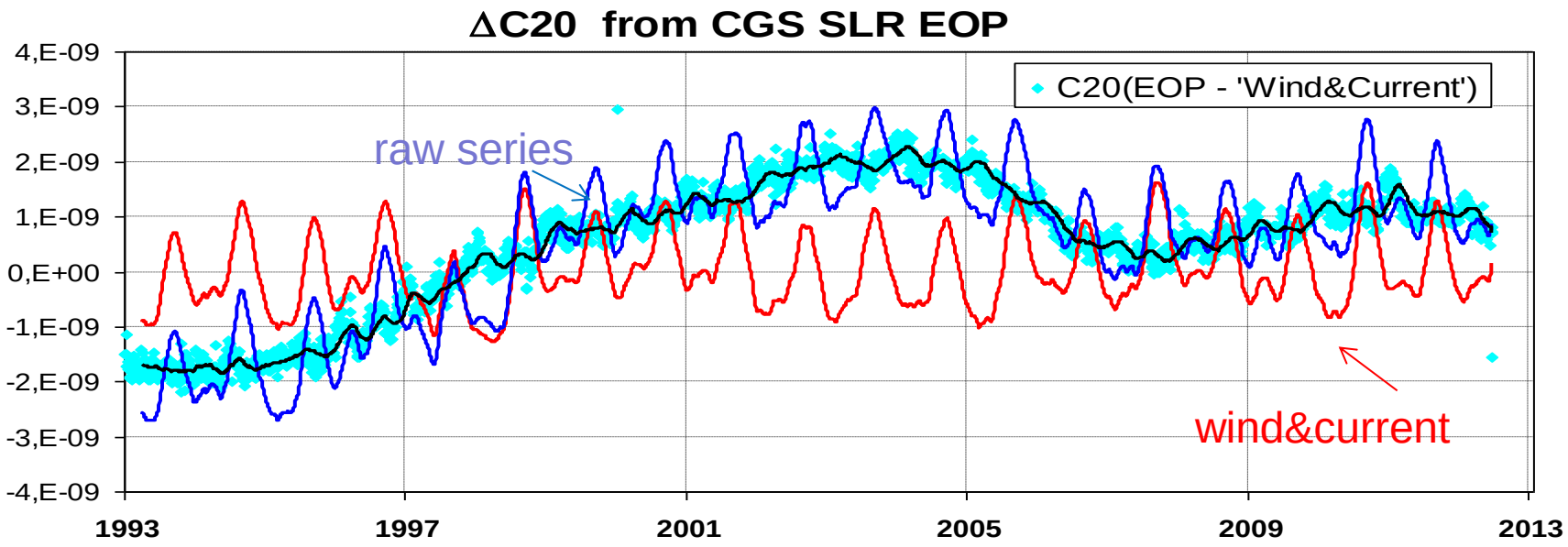
D. Salstein, aamf.ncep.reanalysis values, AER, IERS Special Bureau for the Atmosphere
R. Gross, ECCO_kf080.chi values, NASA/JPL, IERS Special Bureau for the Oceans

$\Delta C_{2,1}$ and $\Delta S_{2,1}$ from EOP





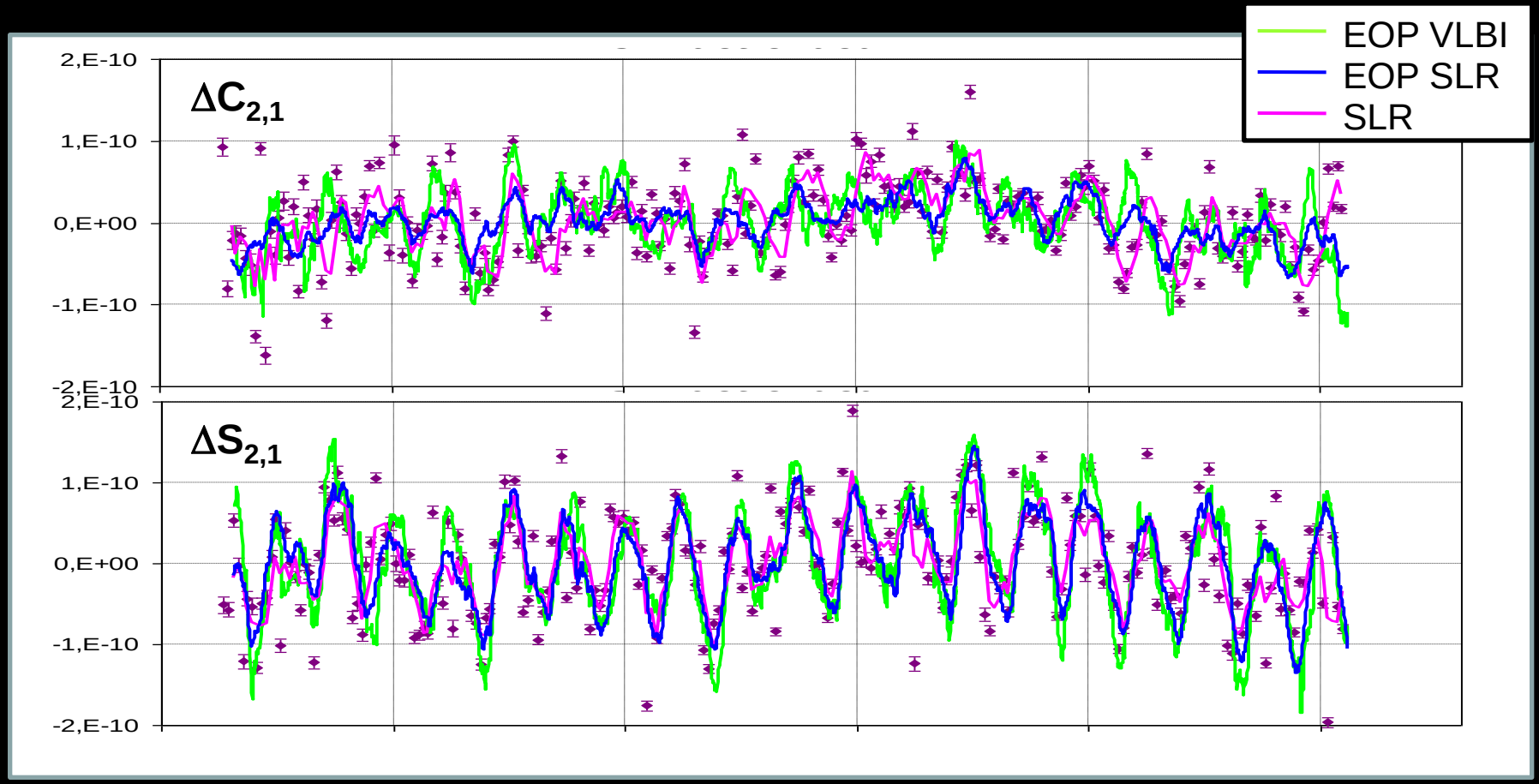
$\Delta C_{2,0}$ from EOP



blue line: 90d running mean on EOP derived values

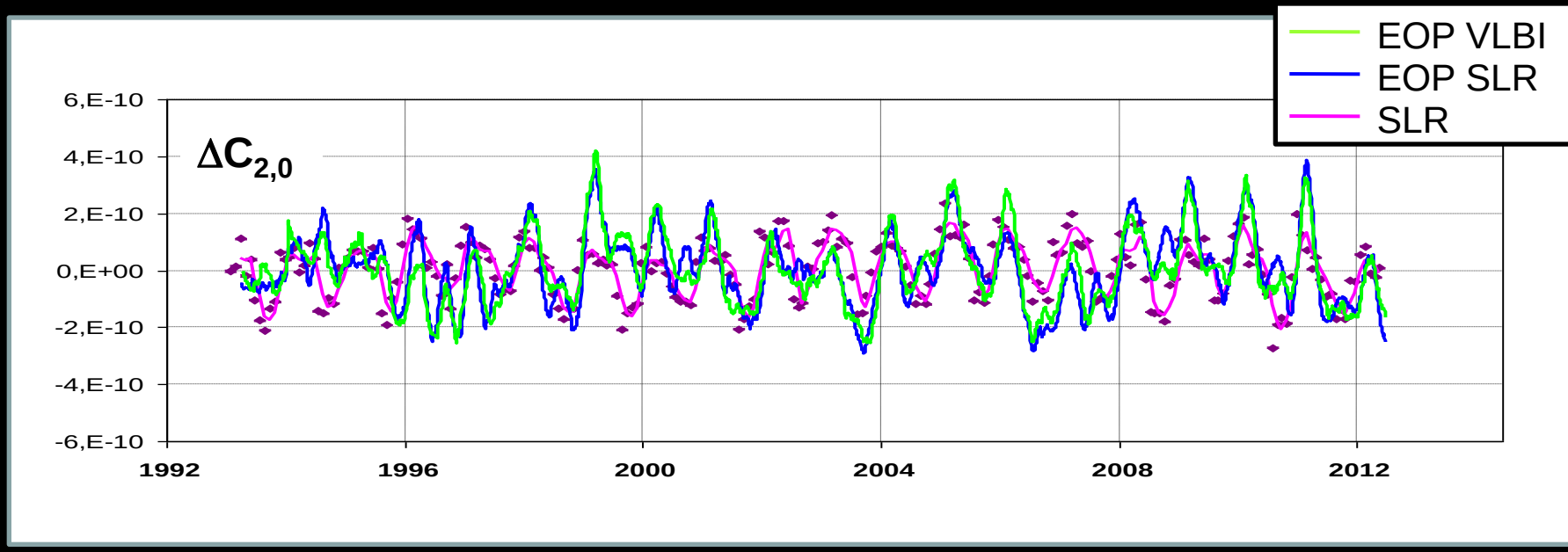
black line: 90d running mean on EOP-'Wind&Current' derived values

Comparison



- The residual behavior of C21, S21 from SLR dynamics and from SLR & VLBI EOP excitation functions are similar.
- An annual frequency is clearly visible in all the terms, with more significant amplitude for S21 term.

Comparison

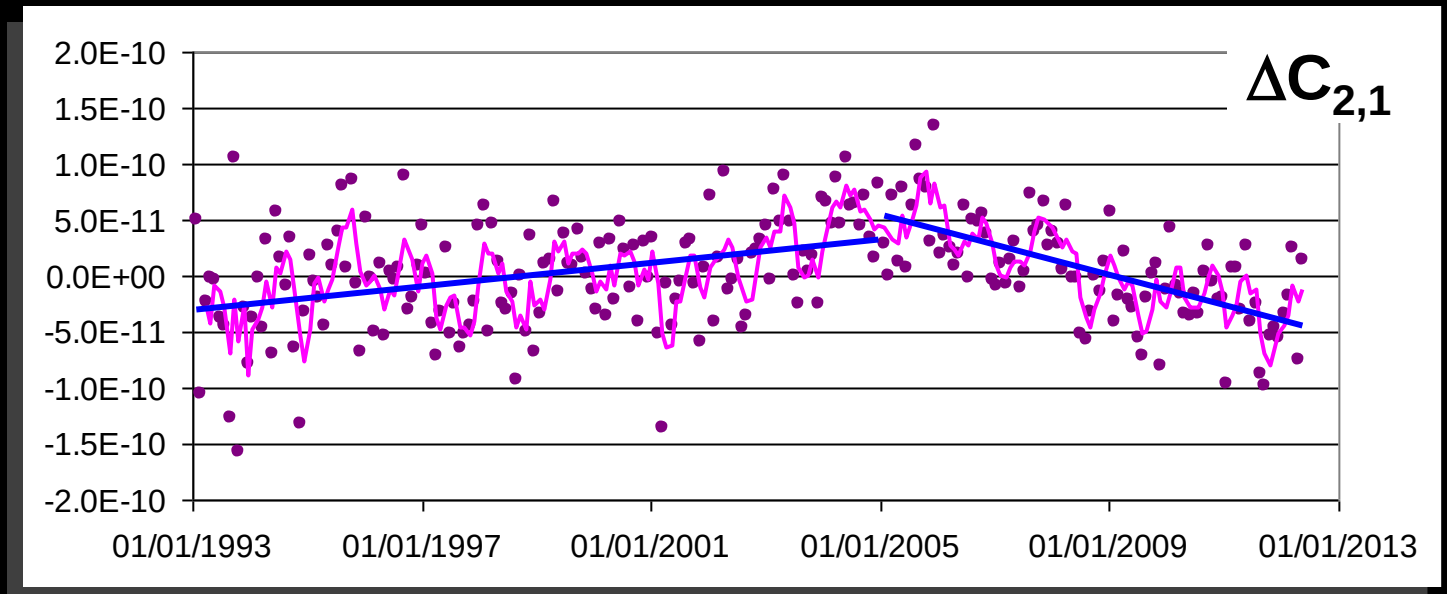


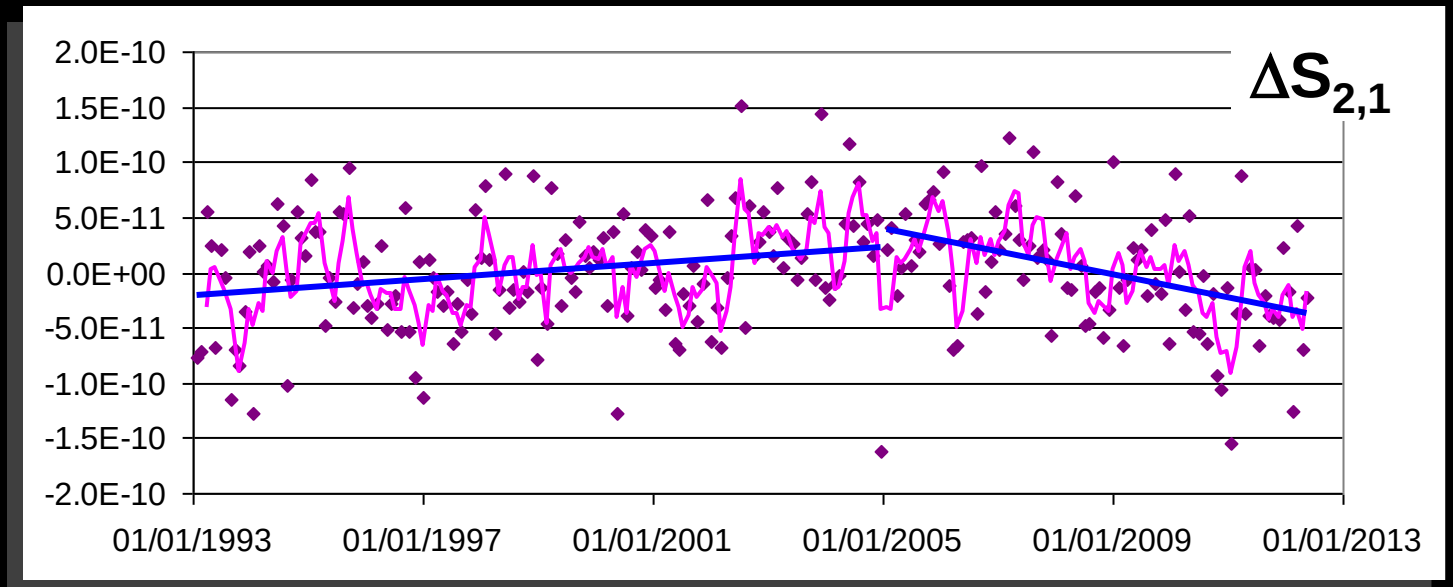
- The variations of C20 show similarities too, even if the interpretation of the direct comparison of the EOP derived series with the dynamics one is a bit more complicated: the LOD derived series, after the removal of the “motion” geophysical component, has been cleaned also from the low frequency terms (<1/4 y^{-1}) and compared with the detrended C20 from SLR dynamics. Also in this case, a residual annual signature is visible in all the series.

“Numerical” summary

	Rate (10^{-12})	Annual amp (10^{-10})	Semi-annual amp (10^{-10})
ΔC2,1 SLR	-9.8 ± 0.6	0.25 ± 0.04	0.13 ± 0.04
ΔC2,1 EOP_SLR	-9.0 ± 0.2	0.22 ± 0.01	0.07 ± 0.01
ΔC2,1 EOP_VLBI	-9.1 ± 0.2	0.30 ± 0.02	0.06 ± 0.02
IERS conventions	-3.3		
ΔS2,1 SLR	0.7 ± 0.6	0.48 ± 0.05	0.11 ± 0.05
ΔS2,1 EOP_SLR	1.3 ± 0.2	0.71 ± 0.02	0.21 ± 0.02
ΔS2,1 EOP_VLBI	2.4 ± 0.2	0.77 ± 0.02	0.22 ± 0.02
IERS conventions	16.1		
ΔC2,0 SLR	10.6 ± 1.2	1.15 ± 0.05	0.38 ± 0.05
ΔC2,0 EOP_SLR	-	1.10 ± 0.05	1.01 ± 0.05
ΔC2,0 EOP_VLBI	-	1.16 ± 0.05	0.99 ± 0.05
IERS conventions	11.6		

Variations of the figure axis





Mean pole since 1900

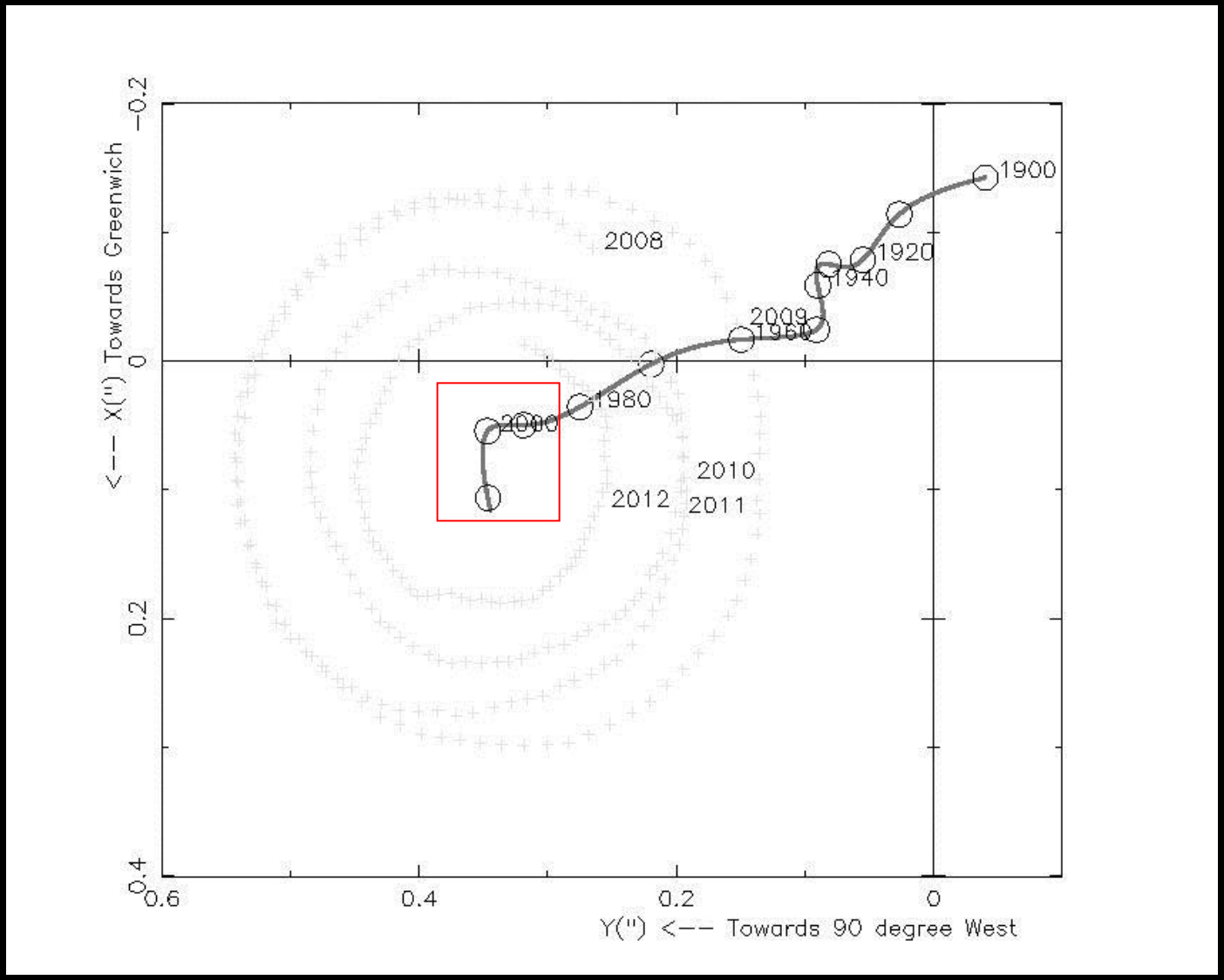


Figure from http://hpiers.obspm.fr