Processing 18.6 years of Lageos data

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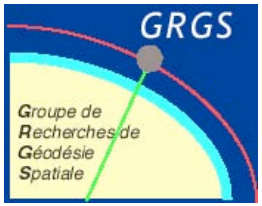


Processing of **18.9 years** of **Lageos** data : from May 9th, 1985 to April 9th, 2004

and of **11.5 years** of **Lageos2** data : from October 10th, 1992 to April 9th, 2004

Per arc of **10 days**

With following **adjusted parameters during orbit computation**:

- 6 orbital elements (a, e, I, _, _+M, _-M) per arc
- one radiation factor per year
- one empirical tangential bias per arc
- 2 empirical biases (in the orbit plane) per arc
- some range biases (constrained to zero for core stations)

With following additional **adjusted parameters over the full period**:

- spherical harmonic coefficients of the **gravity field** up to degree 30
  with degree 2 coefficients (C_{20},C_{21},S_{21},C_{22},S_{22}) distinct per 10 days
- C_{20} terms of **tidal constituents**: $_1$ (18.6 y), $_2$ (9.3 y), Sa (1 y), Ssa (6 m)
- **stations** coordinates and velocities + **geocentre** annual motion per year

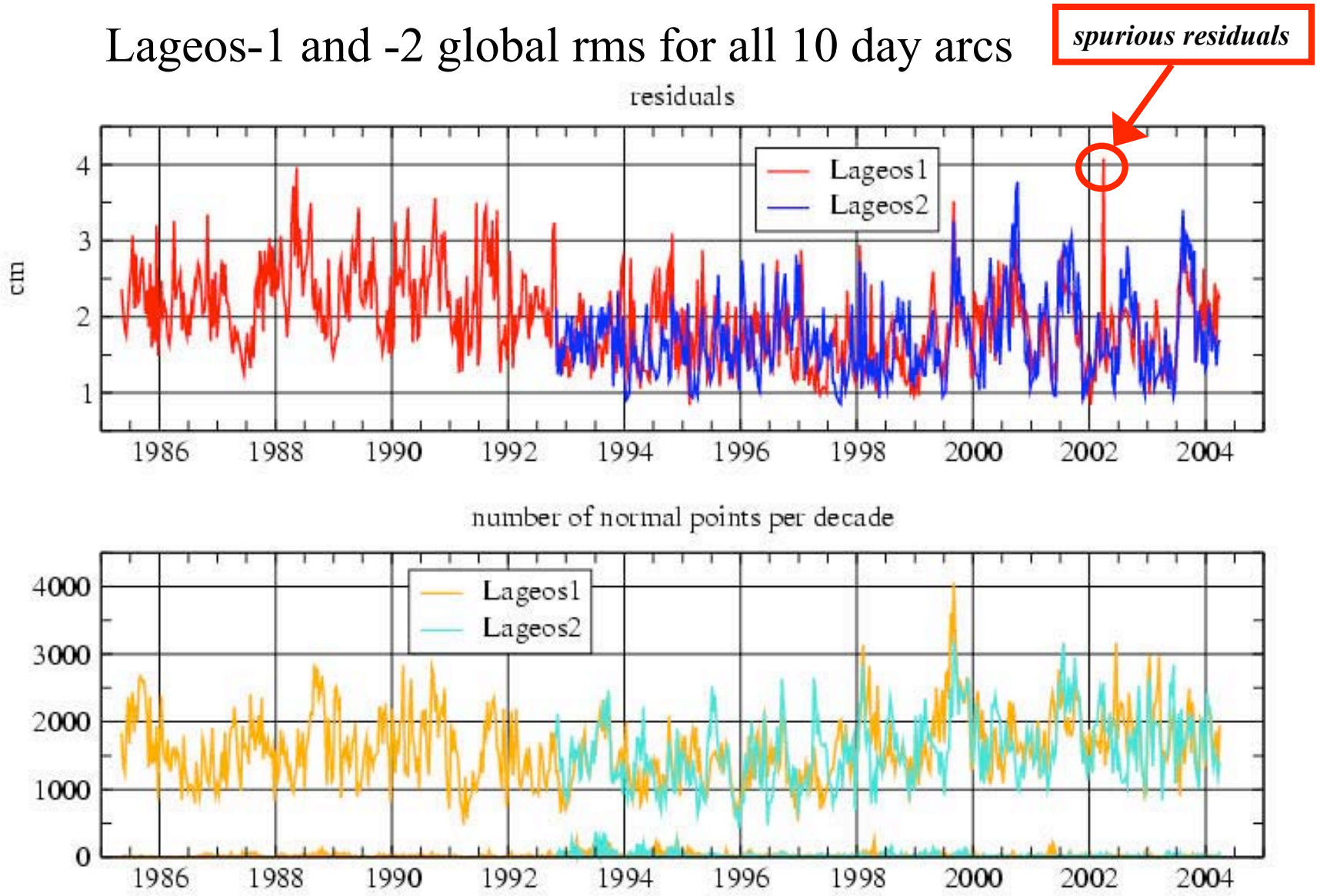
Initial dynamical models (GRACE standards) :

- EIGEN-GRACE02S gravity field model (up to degree 40)
- Sun, Moon and planets point mass attraction + indirect Moon/J2 effect
- Earth tides and pole tide according to IERS Conventions 2000
- FES-2004 ocean tide model (8 waves up to degree 20) + 7 long period waves + 62 waves through admittance theory
- atmospheric tide model (S1 and S2) deduced from ECMWF pressure data
- atmospheric gravitational variability from ECMWF continental atmospheric pressure (each 6 h up to degree 20)
- ECMWF Earth radiations (albedo and emissivity per day by 9 deg. means)

Geometrical models :

- ITRF-2000 station coordinates and velocities
- Earth tides and pole tide according to IERS Conventions 2000
- 3D loading effects from the FES-2002 ocean tide model
- 3D loading effects from ECMWF continental pressure grids (each 6h)

Lageos-1 and -2 global rms for all 10 day arcs



Impact detection

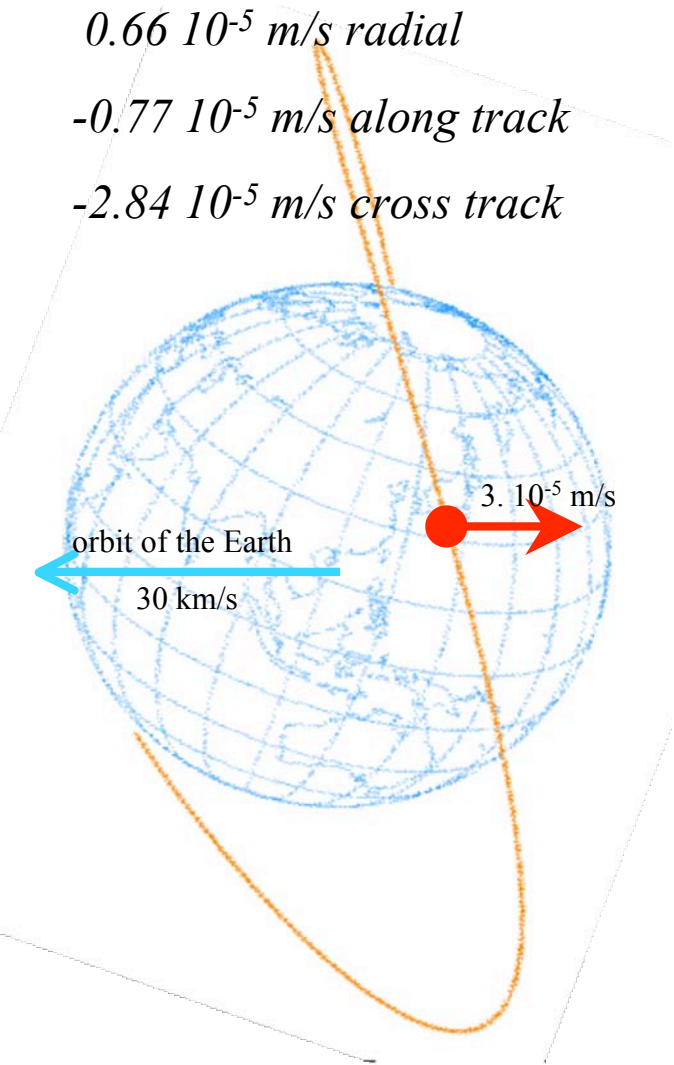
on April 5th, 2002, at 3:19:11 IAT above the Pacific ocean; lat. : 23°, long : 141°

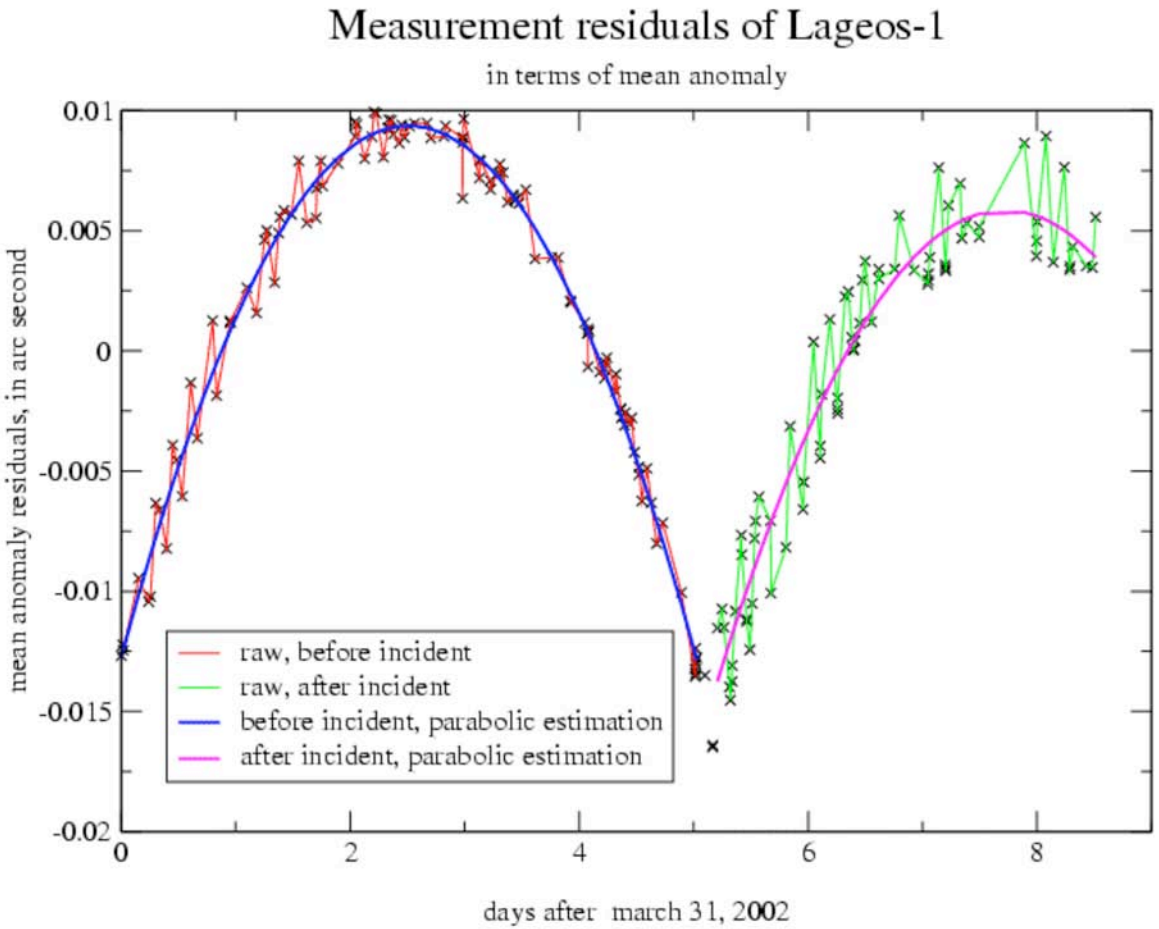
Impulse (given by some mg space particle ???):

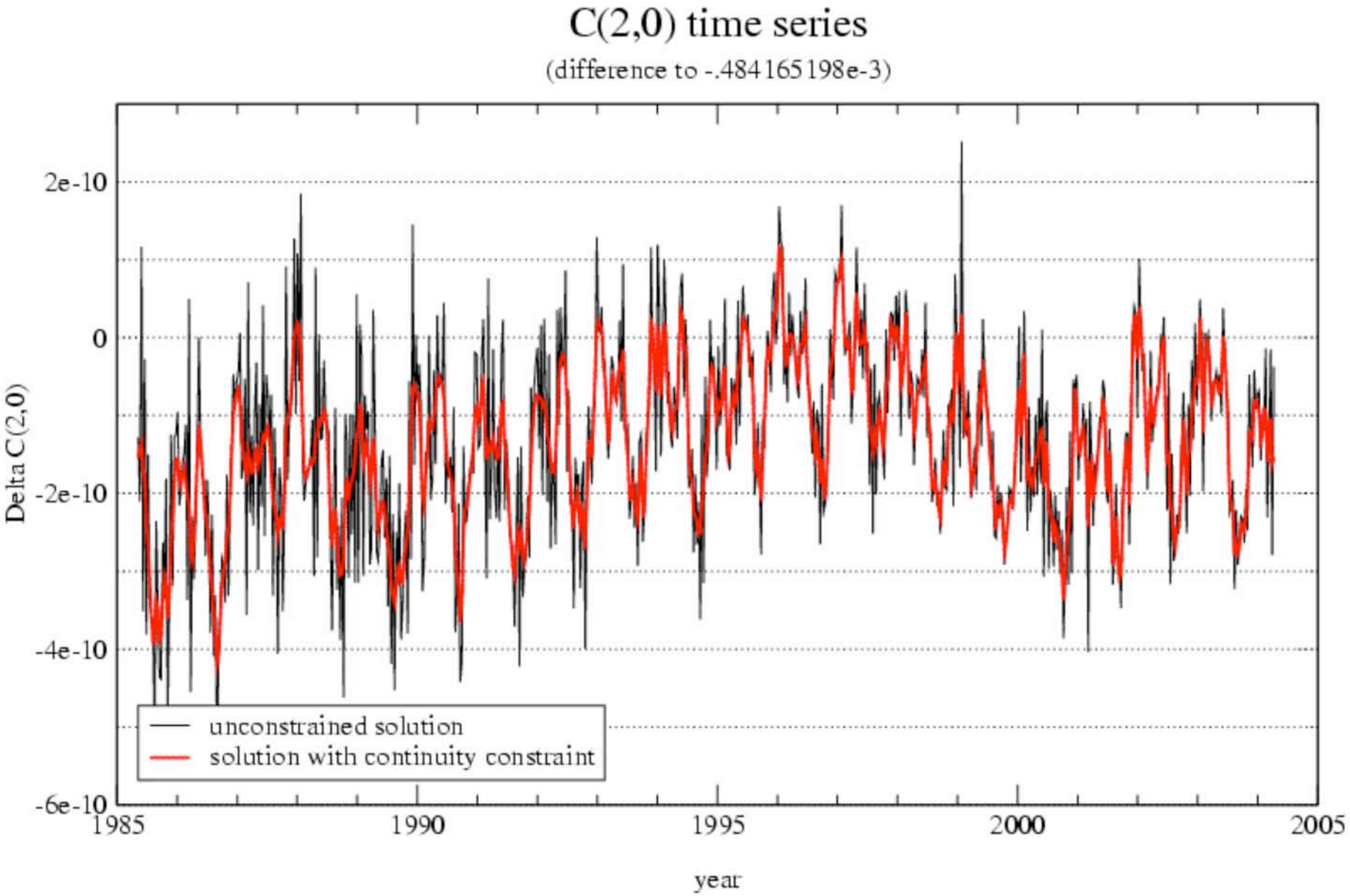
0.66 10^{-5} m/s radial

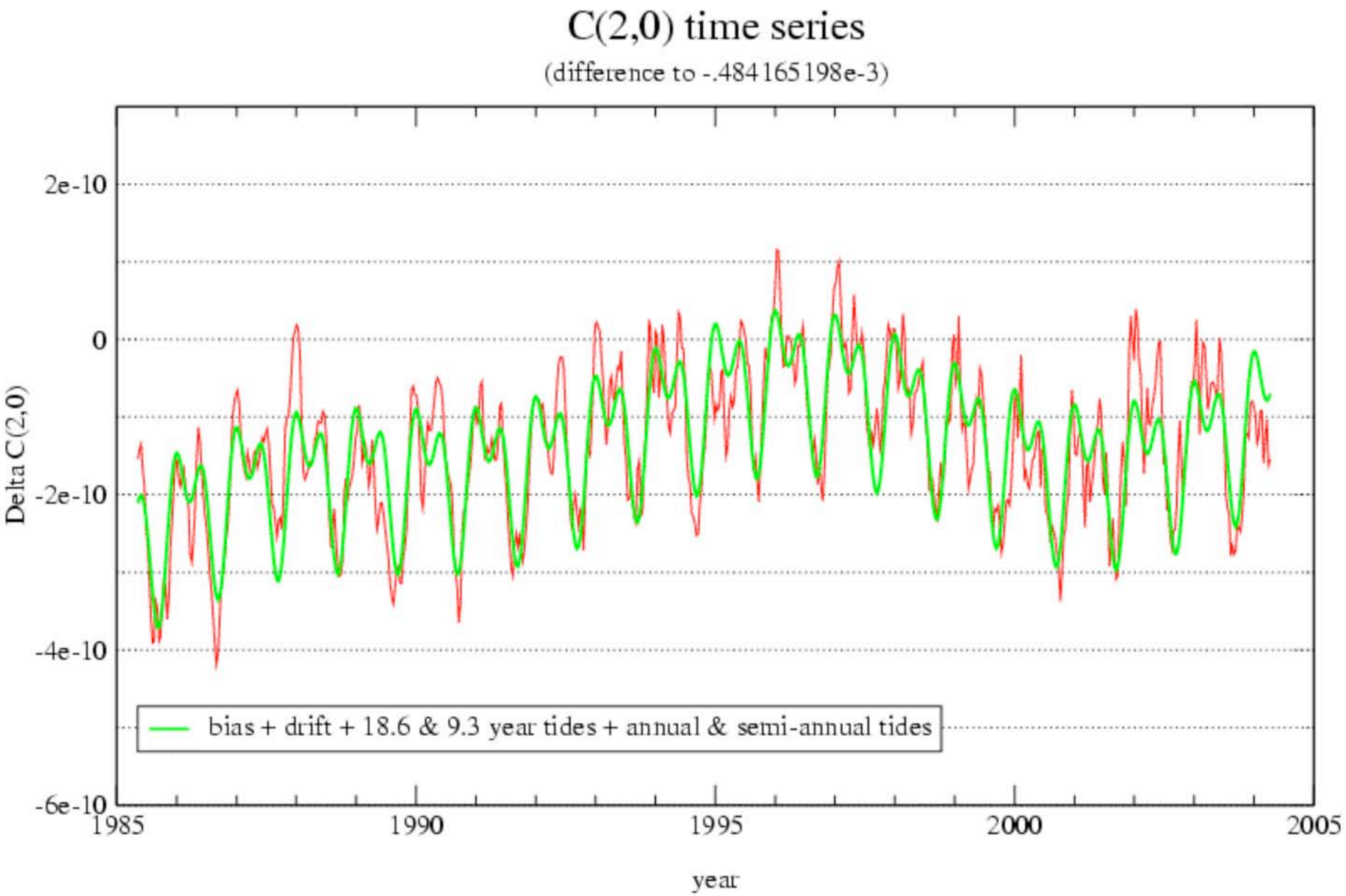
-0.77 10^{-5} m/s along track

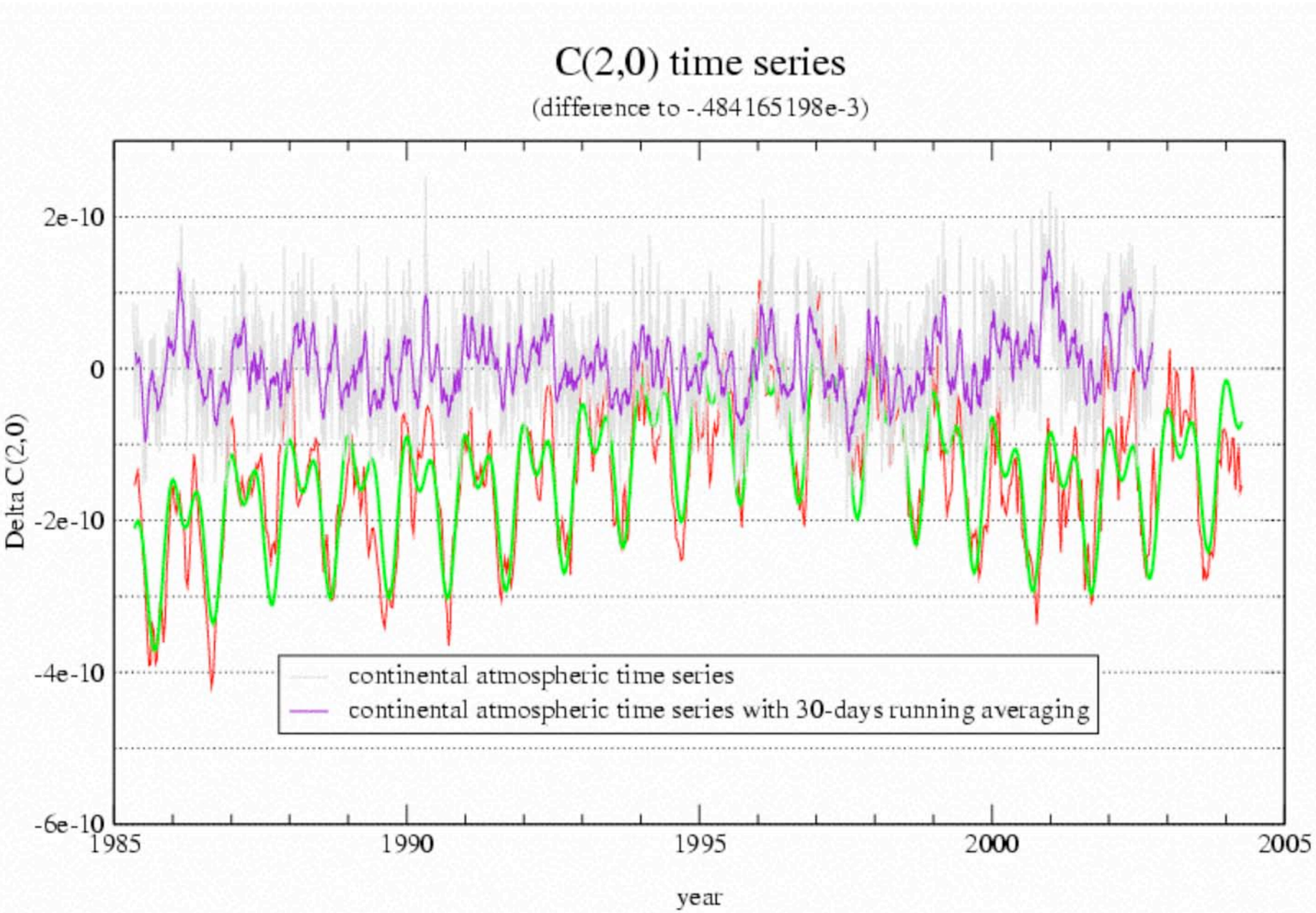
-2.84 10^{-5} m/s cross track

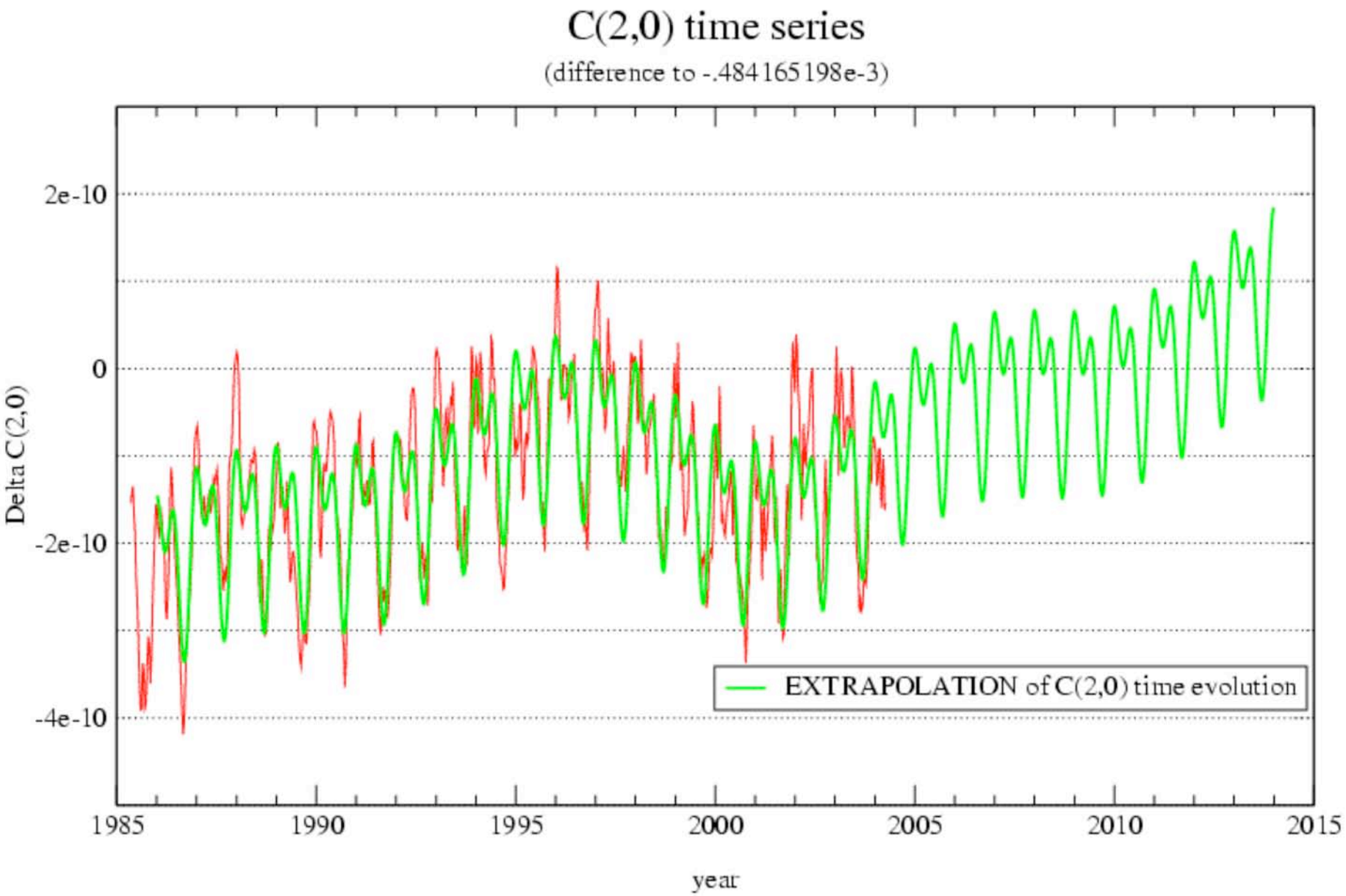


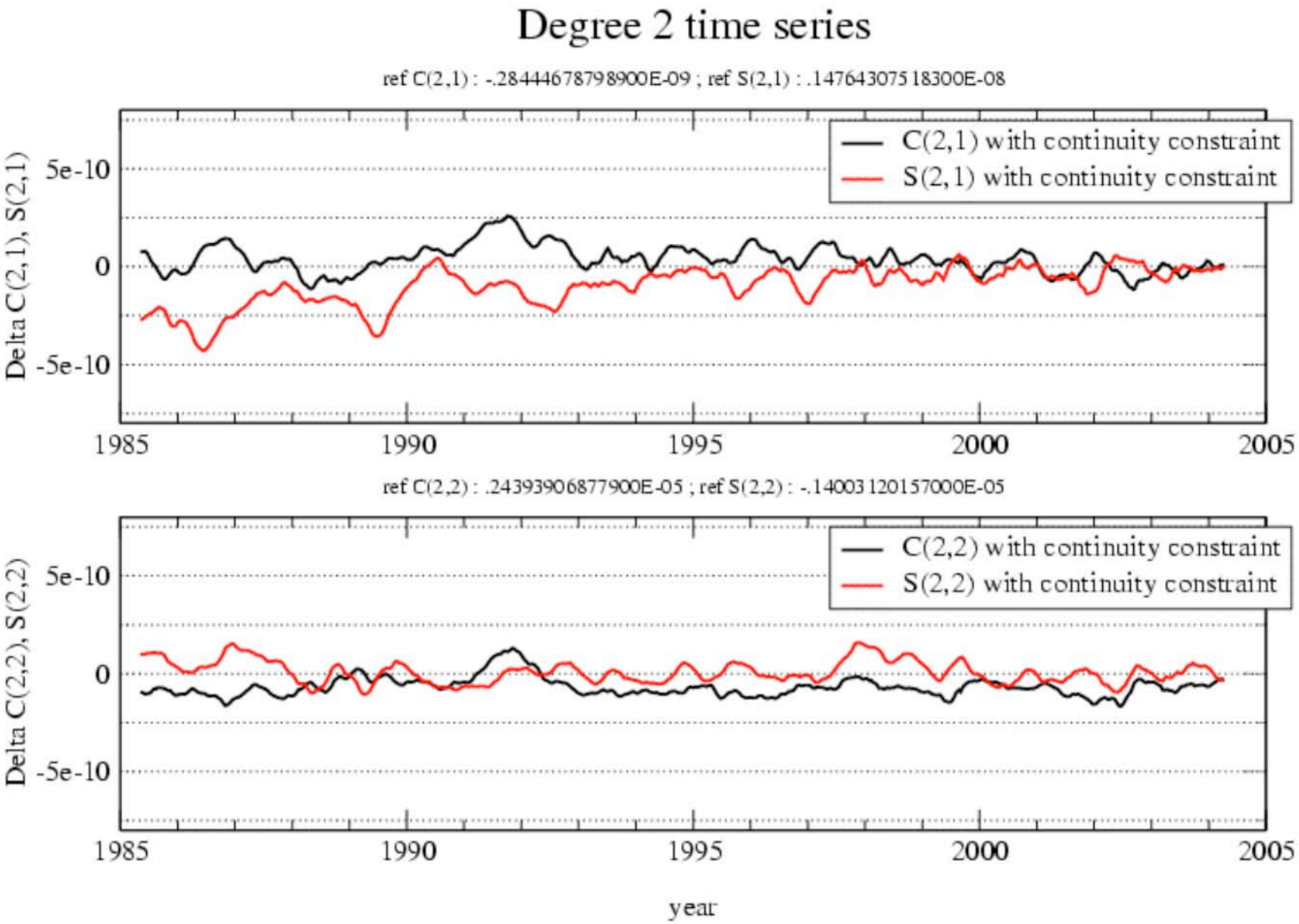


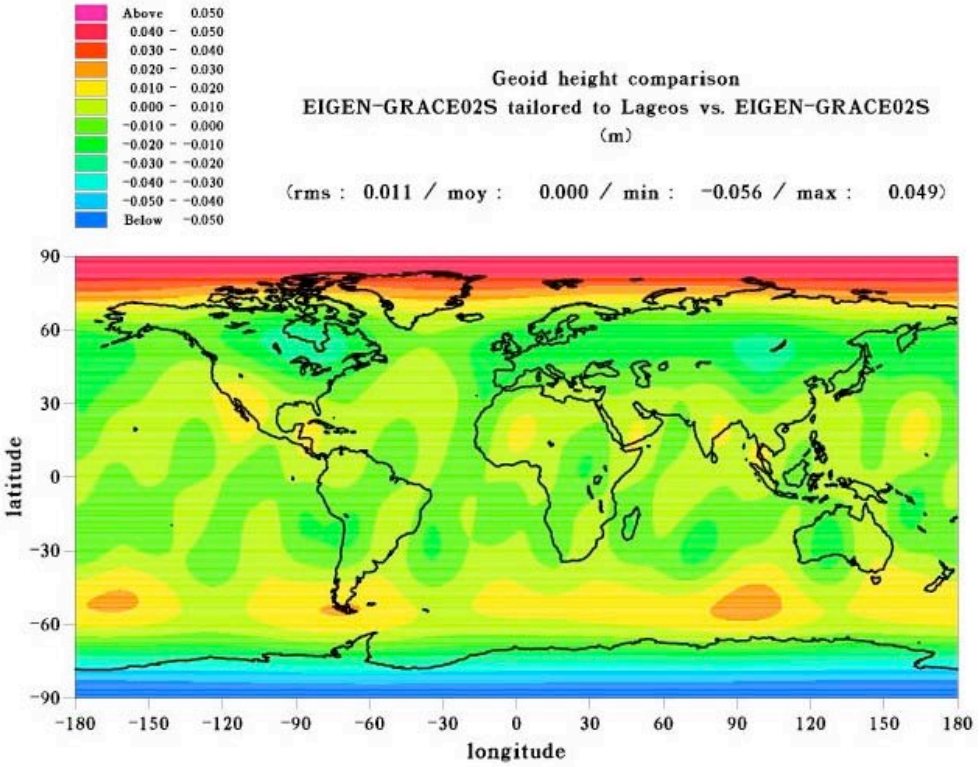

C(2,0) time series
(difference to -.484165198e-3)
2e-10
0
-2e-10
-4e-10
-6e-10
Delta C(2,0)
1985
1990
1995
2000
2005
year
unconstrained solution
solution with continuity constraint

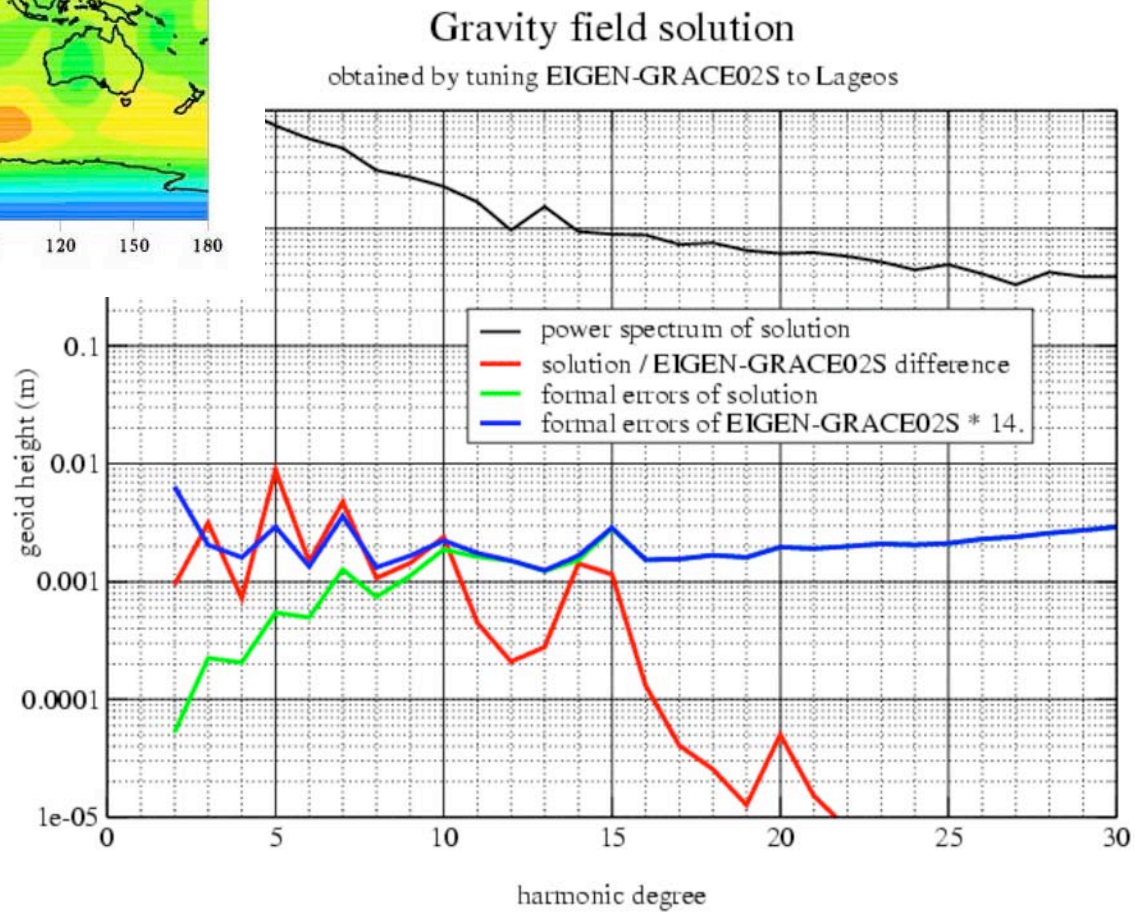

C(2,0) time series
(difference to -.484165198e-3)
2e-10
0
-2e-10
-4e-10
-6e-10
Delta C(2,0)
1985
1990
1995
2000
2005
year
bias + drift + 18.6 & 9.3 year tides + annual & semi-annual tides


C(2,0) time series
(difference to -.484165198e-3)
2e-10
0
-2e-10
-4e-10
-6e-10
Delta C(2,0)
1985
1990
1995
2000
2005
year
continental atmospheric time series
continental atmospheric time series with 30-days running averaging


C(2,0) time series
(difference to -.484165198e-3)
2e-10
0
-2e-10
-4e-10
Delta C(2,0)
1985
1990
1995
2000
2005
2010
2015
year
EXTRAPOLATION of C(2,0) time evolution


Degree 2 time series
ref C(2,1) : -.28444678798900E-09 ; ref S(2,1) : .14764307518300E-08
C(2,1) with continuity constraint
S(2,1) with continuity constraint
Delta C(2,1), S(2,1)
5e-10
0
-5e-10
1985
1990
1995
2000
2005
ref C(2,2) : .24393906877900E-05 ; ref S(2,2) : -.14003120157000E-05
C(2,2) with continuity constraint
S(2,2) with continuity constraint
Delta C(2,2), S(2,2)
5e-10
0
-5e-10
1985
1990
1995
2000
2005
year

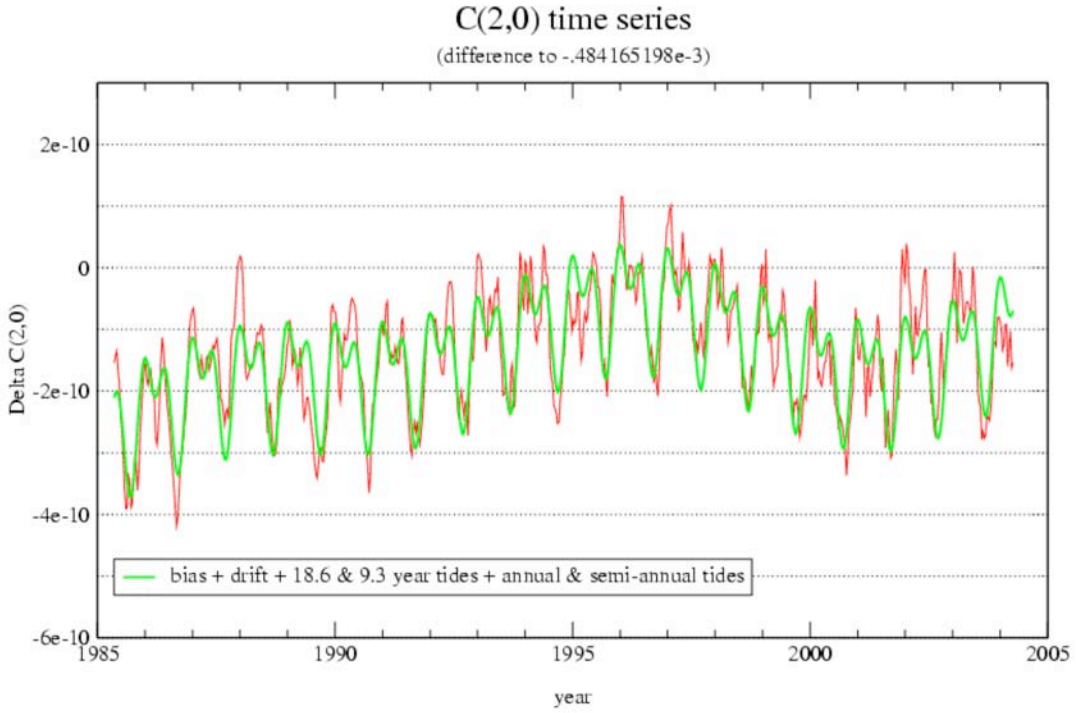

Above 0.050
0.040 - 0.050
0.030 - 0.040
0.020 - 0.030
0.010 - 0.020
0.000 - 0.010
-0.010 - 0.000
-0.020 - -0.010
-0.030 - -0.020
-0.040 - -0.030
-0.050 - -0.040
Below -0.050
Geoid height comparison
EIGEN-GRACE02S tailored to Lageos vs. EIGEN-GRACE02S
(m)
(rms : 0.011 / moy : 0.000 / min : -0.056 / max : 0.049)
latitude
longitude
90
60
30
0
-30
-60
-90
-180 -150 -120 -90 -60 -30 0 30 60 90 120 150 180

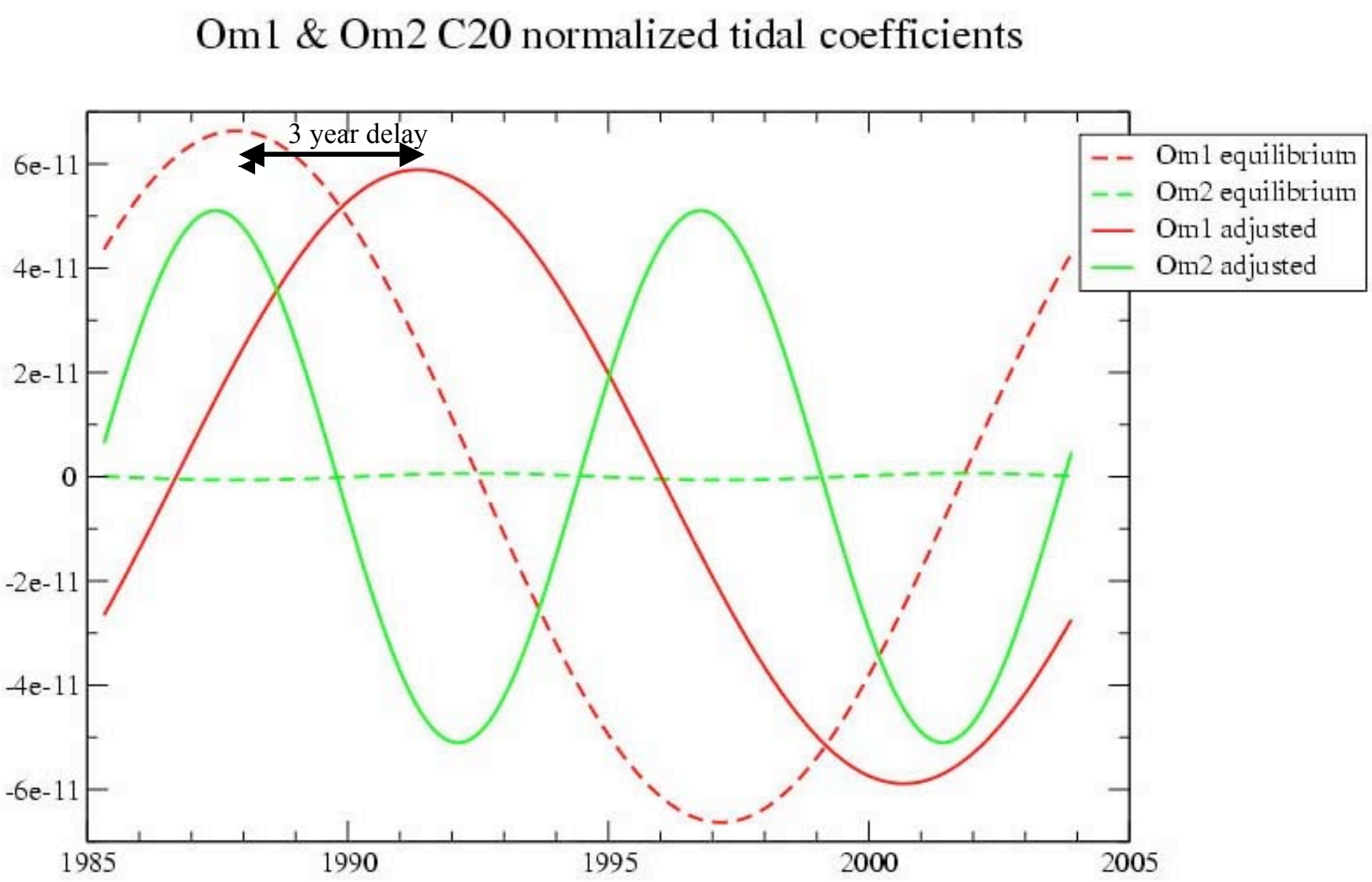

Gravity field solution
obtained by tuning EIGEN-GRACE02S to Lageos
power spectrum of solution
solution / EIGEN-GRACE02S difference
formal errors of solution
formal errors of EIGEN-GRACE02S * 14.
geoid height (m)
0.1
0.01
0.001
0.0001
1e-05
0 5 10 15 20 25 30
harmonic degree

Ocean tides comparison (normalized coefficients) **:**

				solution		FES-2004		difference	
doodson	**darw**	**l**	**m**	**C^+(cm)**	**$\_^+$(deg)**	**C^+(cm)**	**$\_^+$(deg)**	**$\_C^+$(%)**	**$\_\_^+$(%)**
55.565	**$\__1$**	**2**	**0**	**0.4387**	**223.72**	**0.5406**	**270.00**	**19.**	**26.**
55.575	**$\__2$**	**2**	**0**	**0.3206**	**125.05**	**0.0052**	**270.00**	**6044.**	**80.**
56.554	**Sa**	**2**	**0**	**0.5800**	**26.61**	**0.0466**	**268.89**	**1144.**	**65.**
57.555	**Ssa**	**2**	**0**	**0.7390**	**277.17**	**0.2966**	**267.91**	**149.**	**5.**

$\__2$, Sa and Ssa results are not to be considered in terms of tides but more probably in terms of mass displacement




Om1 & Om2 C20 normalized tidal coefficients
3 year delay
6e-11
4e-11
2e-11
0
-2e-11
-4e-11
-6e-11
1985
1990
1995
2000
2005
Om1 equilibrium
Om2 equilibrium
Om1 adjusted
Om2 adjusted

Station positions :

- 88 stations
- mean formal error : 2 mm
- rms difference to ITRF-2000 : 11 mm
- Helmert's transformation in translation : 0, -2, -8 mm

  in rotation : 0, 0, .2 mas ($\Leftrightarrow$ 6 mm)

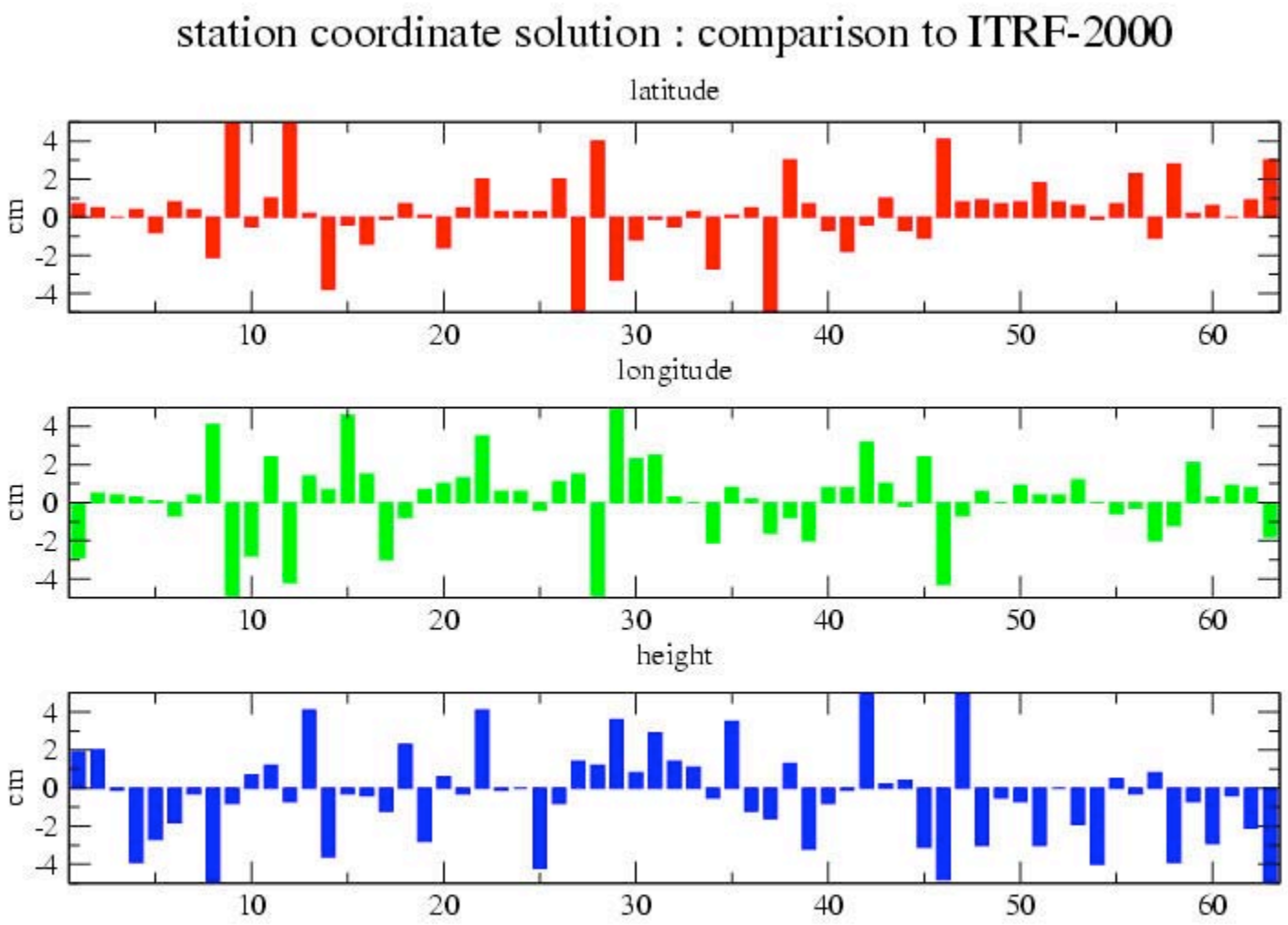
  in scale : 1.6 10^{-9} ($\Leftrightarrow$ 10 mm)

Station velocities :

- 63 sites
- mean formal error : .2 mm/y
- rms difference to ITRF-2000 : 1.6 mm/y
- Helmert's transformation in translation : .2, .5, 1.8 mm/y

  in rotation : 0, 0, 0 mas/y

  in scale : -1.5 10^{-3}

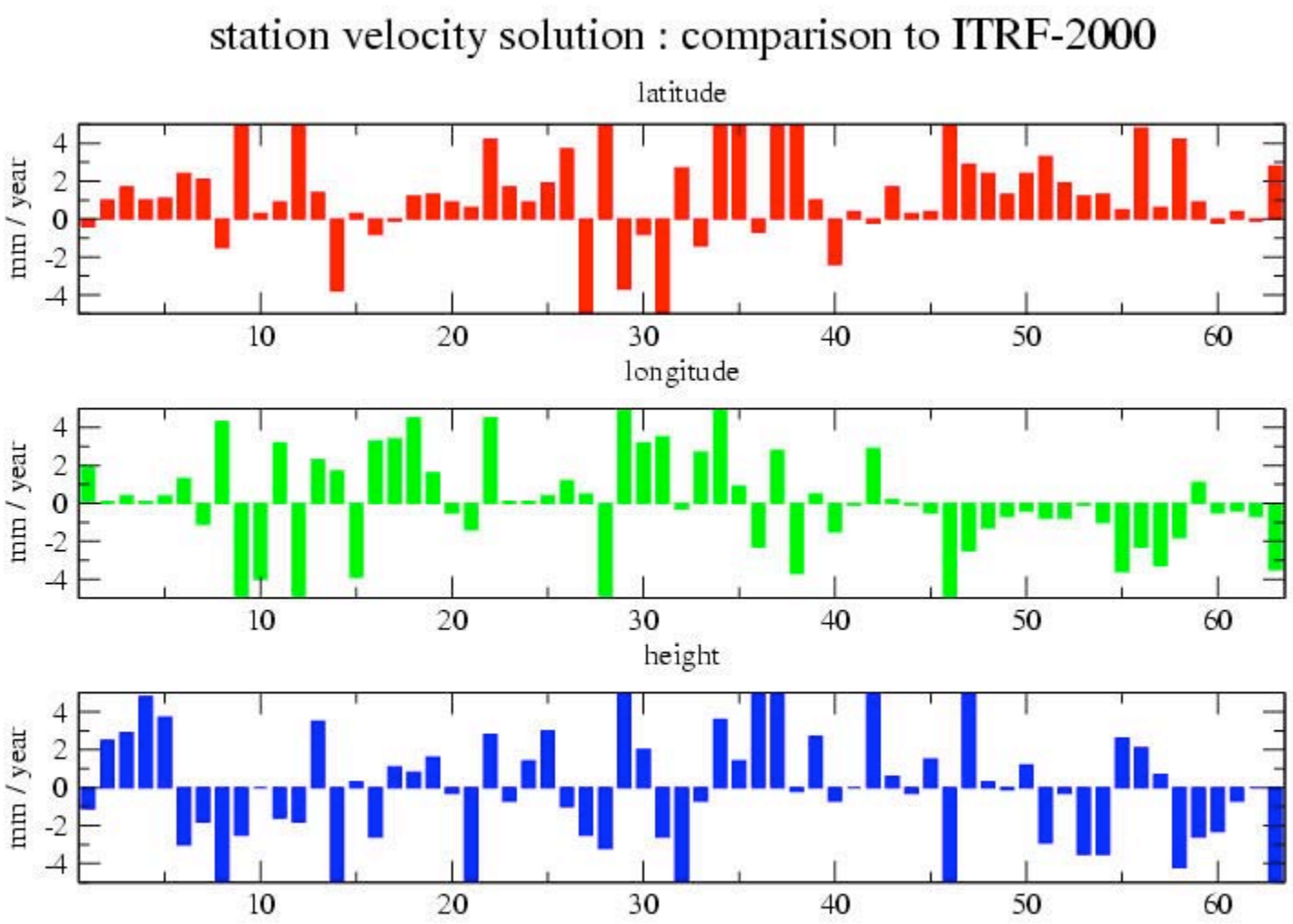


After adjustment :

brut mean (lat., lon., height) : -3, -4, 5 mm, brut rms : 20, 24, 35 mm

weighted mean : (lat., lon., height) : -1, 0, 0 mm, weighted rms : 6, 6, 15 mm

1 10302 M002 Tromsoe
10503 S014 Metsahovi
11101 M001 Sofia
12205 S001 Borowiec
12302 M001 Riga
12337 M001 Simeiz
12340 S002 Maidanak
12602 M002 Dionysos
12612 M001 Askites
10 12613 M001 Roumelli
12615 M001 Katavia
12616 M001 Xrisokalaria
12706 M001 Lampedusa
12711 M002 Medicina
12717 M001 Noto
12718 M002 Trieste
12725 S013 Cagliari
12734 S001 Matera
12749 M001 Monte Venda
20 13402 S004 San Fernando
13504 M002 Kootwijk
14001 S007 Zimmerwald
14106 S001 Potsdam
14106 S009 Potsdam
14201 M200 Wettzell
20702 M001 Bar Giyyora
20801 M001 Diyarbakir
20802 M001 Yozgat
20803 M001 Melengiclick
30 20804 M001 Yigilca
21602 S003 Wuhan
21609 S002 Kunming
21611 S001 Changchun
21701 M002 Kashima
21704 S002 Koganei
21739 M001 Miura
21740 M001 Tateyama
30101 S001 Helwan
30302 M003 Hartebeesthoek
40 40104 M003 Algonquin
40132 M001 La Grande
40405 M013 Goldstone
40433 M002 Quincy
40436 M003 San Diego - Otay
40438 M002 Bear Lake
40439 M004 Owens Valley
40440 M001 Westford
40442 M008 Fort Davis
40445 M001 Maui
50 40451 M120 Washington
40496 M001 Platteville
40497 M001 Monument Peak
40499 M002 Richmond
40504 M001 Mazatlan
40505 M001 Cabo San Lucas
40506 M001 Ensenada
40701 S001 Santiago de Cuba
41703 M002 Easter Island
42202 S001 Arequipa
60 50103 S007 Canberra
50107 S009 Yarragadee
50119 S001 Mount Stromlo
92202 M004 Huahine



After adjustment :

brut mean (lat., lon., height) : 0, -.1, -.9 mm/y, brut rms : 2.5, 2.6, 3.9 mm/y

weighted mean : (lat., lon., height) : 0, 0, 0 mm/y, weighted rms : .7, .9, 1.5 mm/y

1 10302 M002 Tromsoe
10503 S014 Metsahovi
11101 M001 Sofia
12205 S001 Borowiec
12302 M001 Riga
12337 M001 Simeiz
12340 S002 Maidanak
12602 M002 Dionysos
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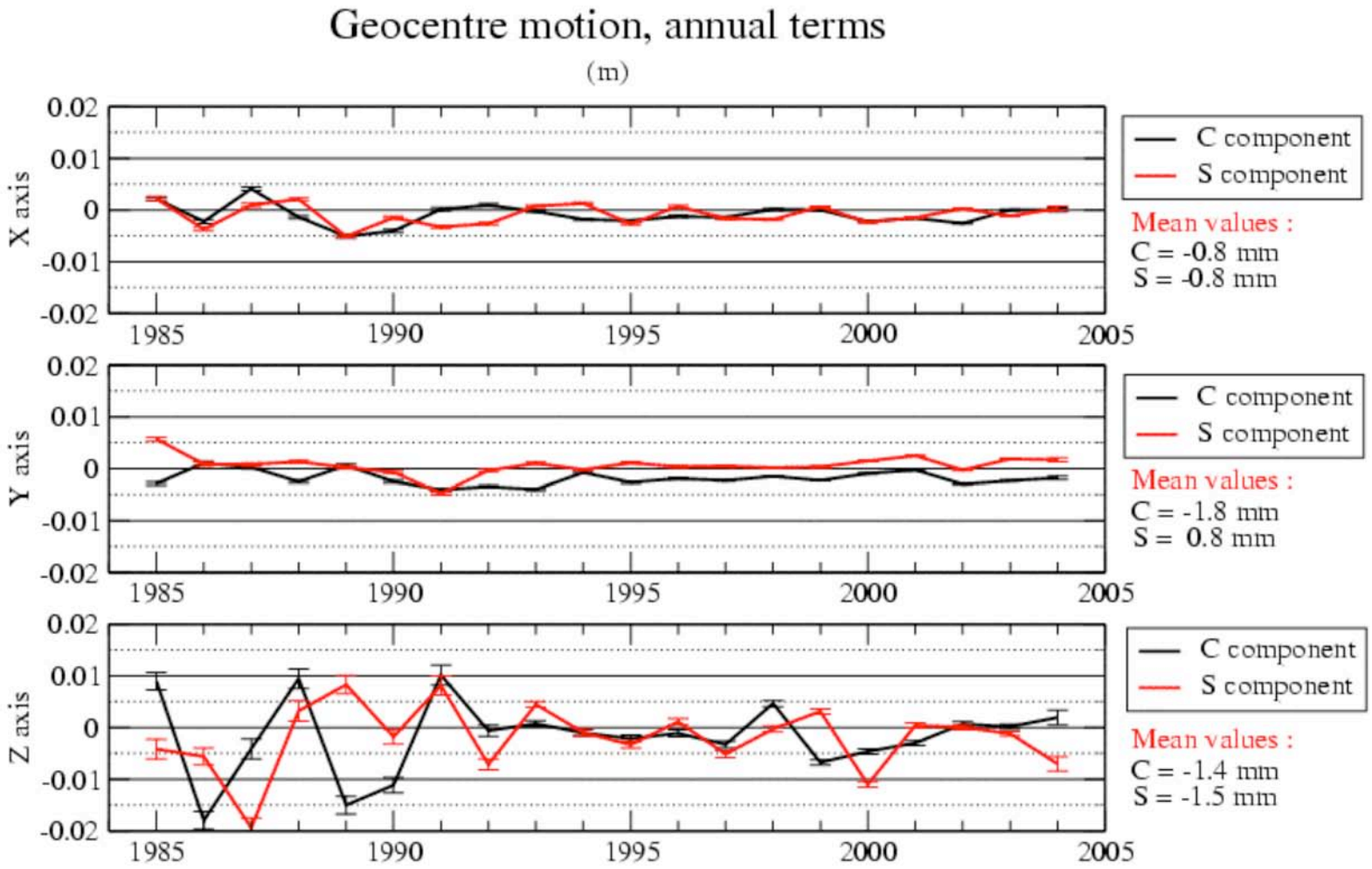
14001 S007 Zimmerwald
14106 S001 Potsdam
14106 S009 Potsdam
14201 M200 Wettzell
20702 M001 Bar Giyyora
20801 M001 Diyarbakir
20802 M001 Yozgat
20803 M001 Melengiclick
30 20804 M001 Yigilca
21602 S003 Wuhan
21609 S002 Kunming
21611 S001 Changchun
21701 M002 Kashima
21704 S002 Koganei
21739 M001 Miura
21740 M001 Tateyama
30101 S001 Helwan
30302 M003 Hartebeesthoek
40 40104 M003 Algonquin
40132 M001 La Grande
40405 M013 Goldstone
40433 M002 Quincy
40436 M003 San Diego - Otay
40438 M002 Bear Lake
40439 M004 Owens Valley
40440 M001 Westford
40442 M008 Fort Davis
40445 M001 Maui
50 40451 M120 Washington
40496 M001 Platteville
40497 M001 Monument Peak
40499 M002 Richmond
40504 M001 Mazatlan
40505 M001 Cabo San Lucas
40506 M001 Ensenada
40701 S001 Santiago de Cuba
41703 M002 Easter Island
42202 S001 Arequipa
60 50103 S007 Canberra
50107 S009 Yarragadee
50119 S001 Mount Stromlo
92202 M004 Huahine



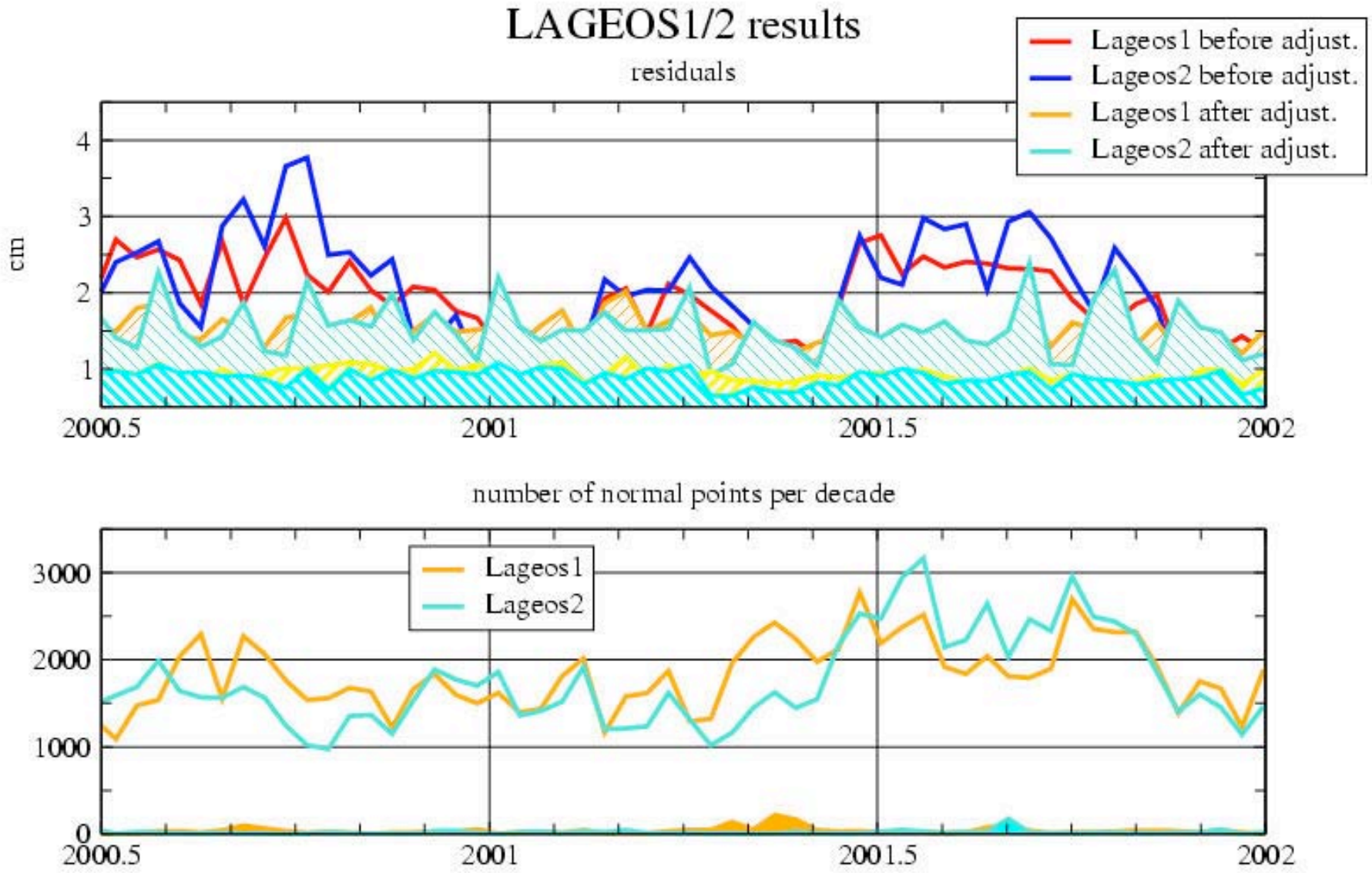
Mean annual terms amount to :

1.2 mm in X, with a minimum in February

2.0 mm in Y, with a minimum in December

1.8 mm in Z, with a minimum in February

} **corresponding to a winter loading centred on Siberia**


LAGEOS1/2 results
residuals
Lageos1 before adjust.
Lageos2 before adjust.
Lageos1 after adjust.
Lageos2 after adjust.
cm
4
3
2
1
2000.5
2001
2001.5
2002
number of normal points per decade
Lageos1
Lageos2
3000
2000
1000
0
2000.5
2001
2001.5
2002

In conclusion :

- more than 18.6 y of Lageos SLR data were successfully processed with upgraded orbit computation standards

- GRACE gravity field models are not yet fully adequate for orbit computation

- residual level is still very depending on number of empirical parameters and data editing

- Lageos-1/-2 SLR data give pertinent information about time varying degree 2 terms (particularly C20) at 18.6 y, 9.3 y, annual and semi annual scales

- this study provides moreover an homogeneous reference for all SLR stations in terms of position, velocities and geocentre at a 2 mm global level (.2 mm/y for velocities)

- the impact of a tuned Lageos gravity field adjustment seems to be positive in orbit computation

- impact of space dust was shown up on Lageos-1 in 2002