STATUS ON GRAVITY FIELD MODELLING

GLOBAL MODELS AND TEMPORAL VARIATIONS

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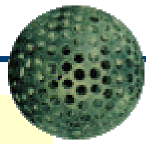
in cooperation with

Colloque G2 2004, ESGT, Le Mans

Processing of Lageos SLR data



- **18.9 years** of **Lageos** data : from May 9th, 1985 to April 9th, 2004 and
- **11.5 years** of **Lageos2** data : from October 10th, 1992 to April 9th, 2004

Per arc of **10 days**

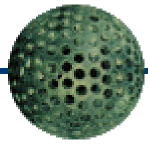
With following **adjusted parameters during orbit computation**:

- 6 orbital elements (a, e, I, O, ? +M, ? -M) per arc
- one radiation factor per year
- 2 empirical tangential biases per arc (one per 5 days)
- 2 empirical biases in the orbit plane per arc
- some laser 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**: O_1 (18.6 y), O_2 (9.3 y), Sa (1 y), Ssa (6 m)
- **stations** coordinates and velocities + **geocentre** annual motion per year

Processing of Lageos data : 1985-2003



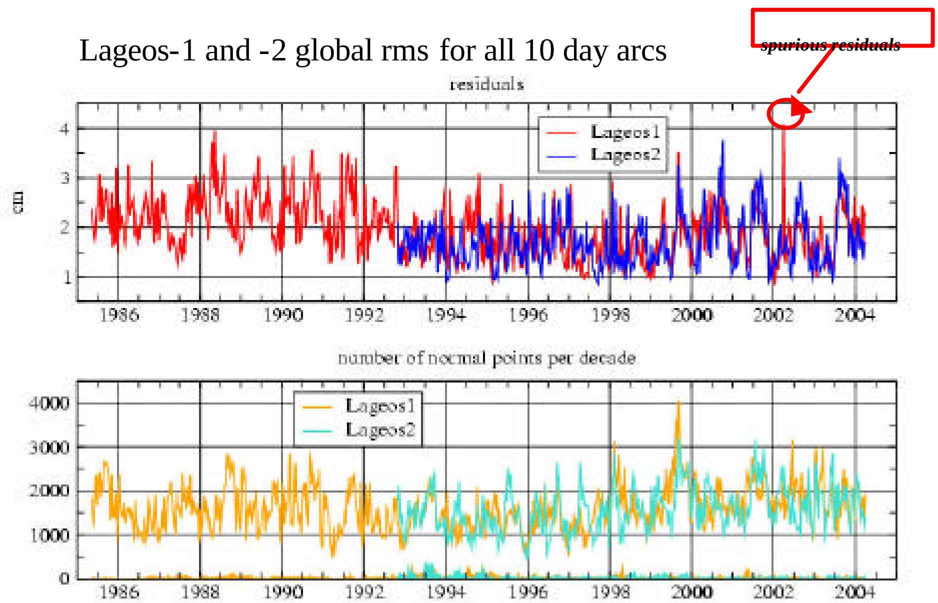
A priori dynamical models:

- <u>Gravity</u>: EIGEN-GRACE02S up to degree 40
- <u>Third body attraction</u>: according to IERS conventions 2000 and DE403 JPL ephemeris
- <u>Earth tides</u>: according to IERS conventions 2000
- <u>Ocean tides</u>: FES-2004 for diurnal and semi-diurnal waves + FES-2002 for long period waves + 62 admittance waves up to degree 20
- <u>Atmospheric tide</u> model (S1 and S2) deduced from ECMWF pressure data
- <u>Atmospheric gravity variations</u>: from continental ECMWF 6h pressure fields
- <u>Earth radiations</u> from ECMWF albedo and emissivity fields per day by 9 deg. means

A priori geometrical models:

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

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



Impact detection

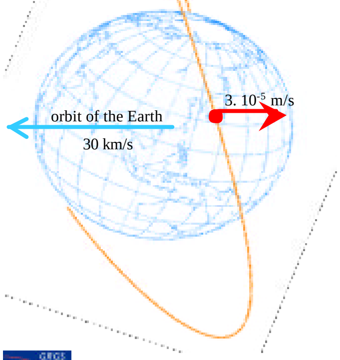
on April 5th, 2002, at 3:19:11 IAT above the Pacific ocean; lat. : 23°, long : 141°

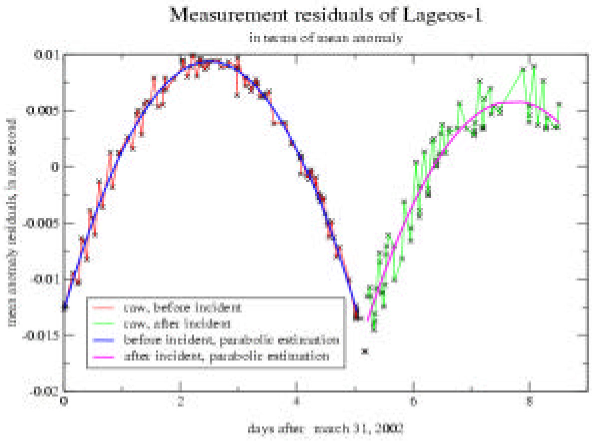
Impulse (given by some mg space particle ???):

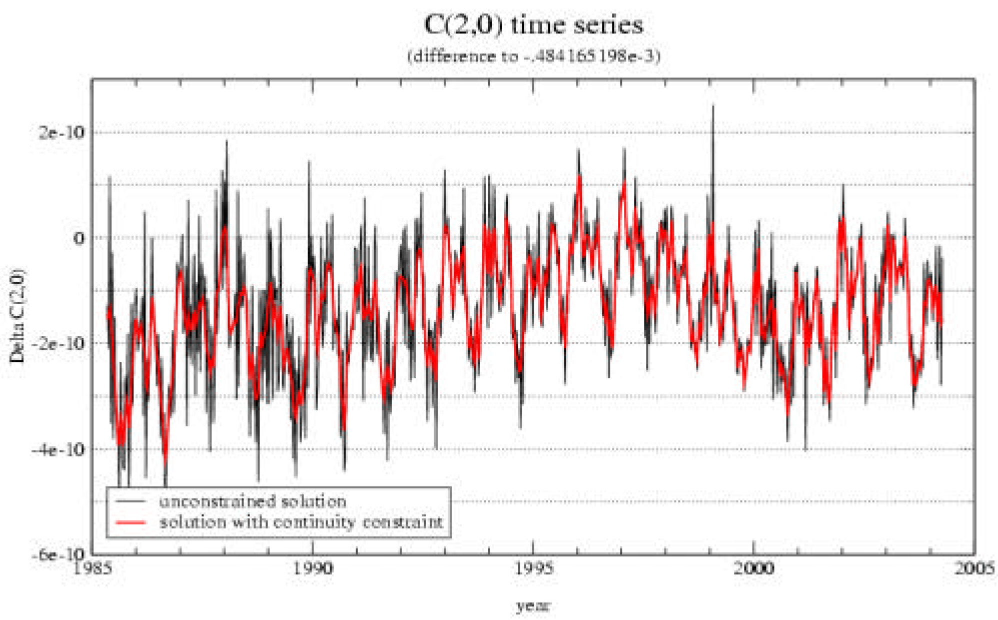
0.66 10^{-5} m/s radial

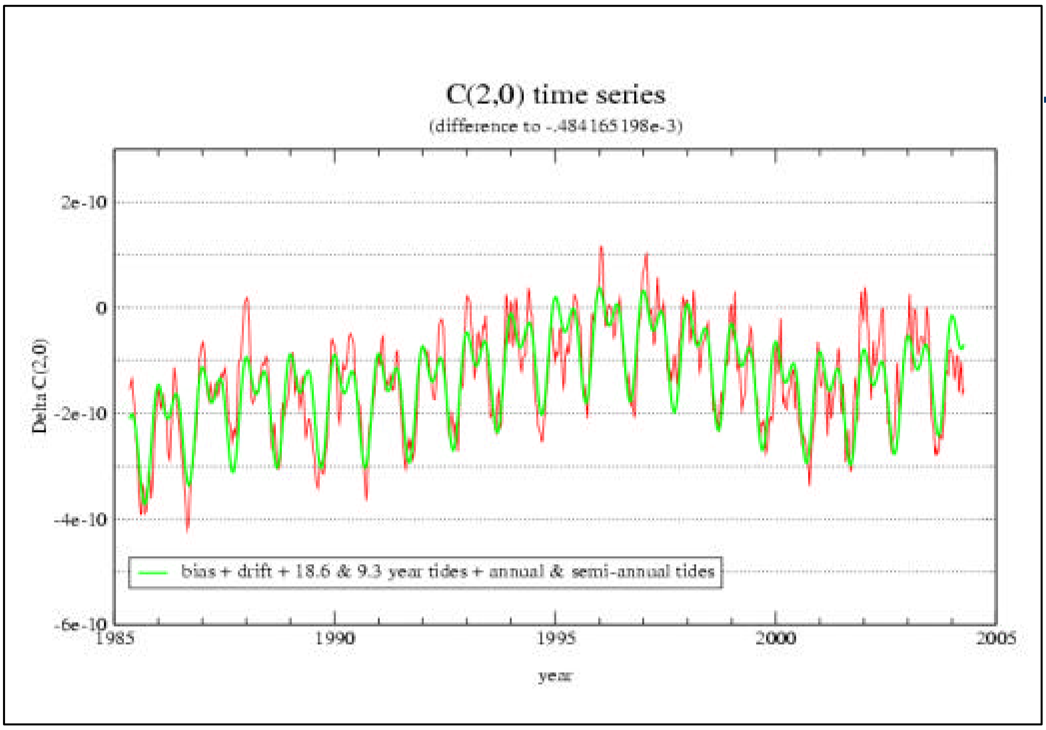
-0.77 10^{-5} m/s along track

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

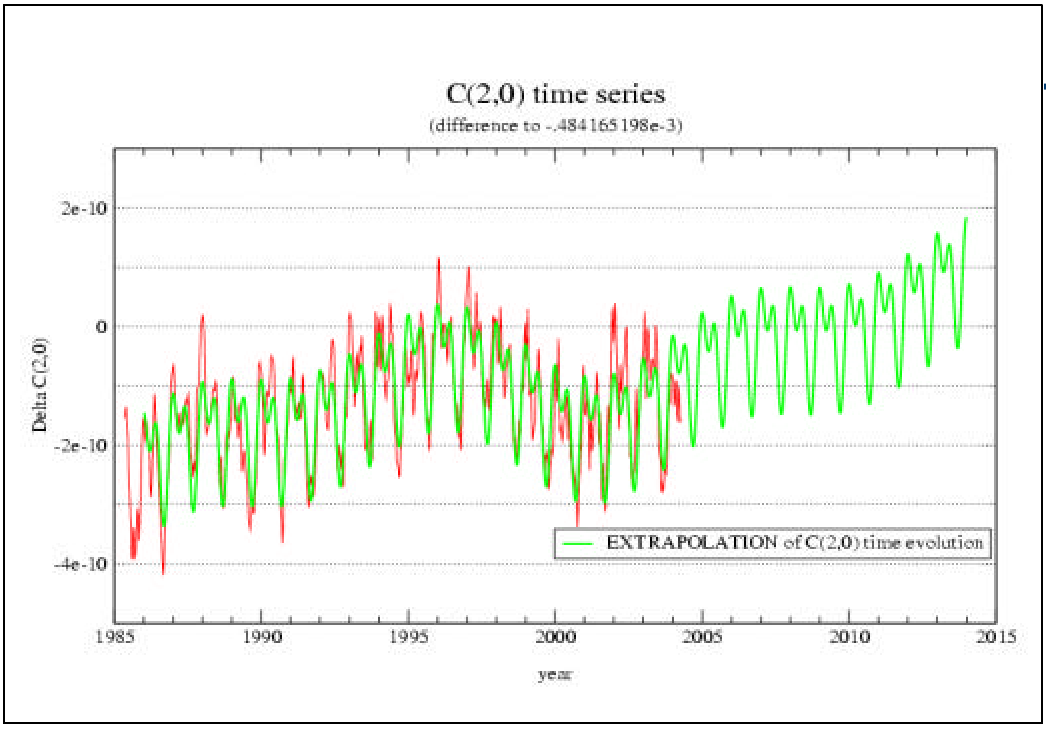






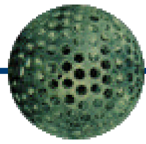


C(2,0) time series
(difference to -.484165198e-3)
2e-10
0
-2e-10
-4e-10
-6e-10
Delta C(2,0)
bias + drift + 18.6 & 9.3 year tides + annual & semi-annual tides
1985
1990
1995
2000
2005
year



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

C20 coefficients from Lageos laser data



Tide normalized coefficient				**Lageos**		FES-2004		difference	
doodson	**darw.**	**l**	**m**	**C^+(cm)**	**e^+(deg)**	C^+(cm)	e^+(deg)	? C^+(%)	? e^+(%)
55.565	**O_1**	**2**	**0**	**0.4387**	**223.72**	0.5406	270.00	19.	26.
55.575	**O_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.

(O2, Sa and Ssa results are not to be considered in terms of tides, but more probably in terms of mass displacement)

Gravity normalized coefficients:

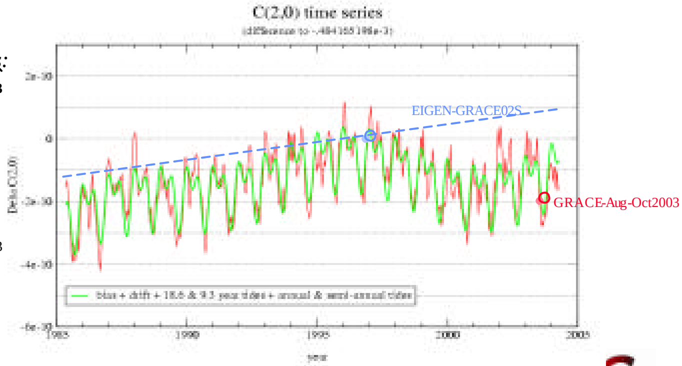
$C20_{1997}$ = -.484 165 316 58 10^{-3}

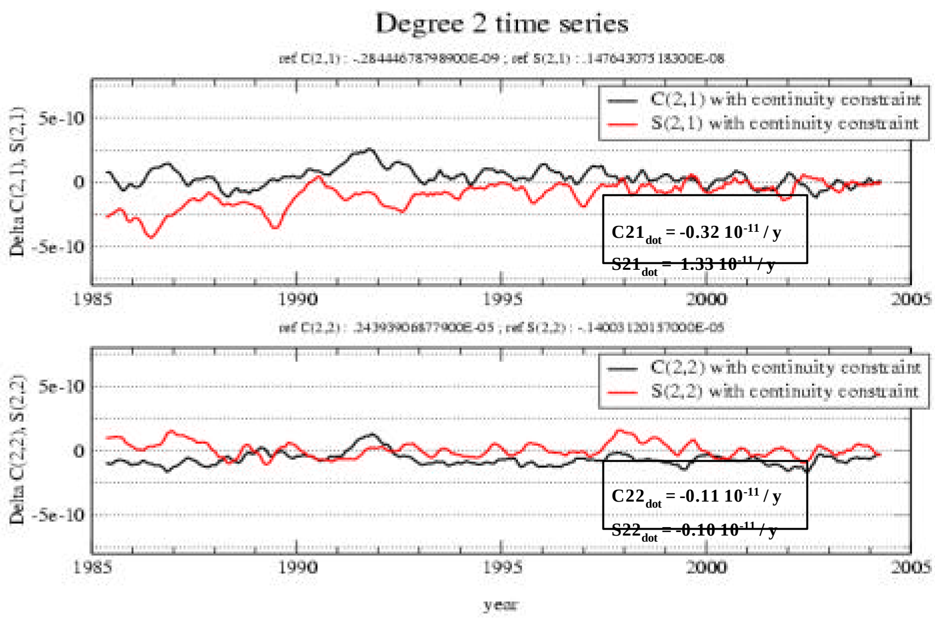
$C20_{dot}$ = 0.83 10^{-11} / y

a priori (EIGEN-GRACE02S) in blue:

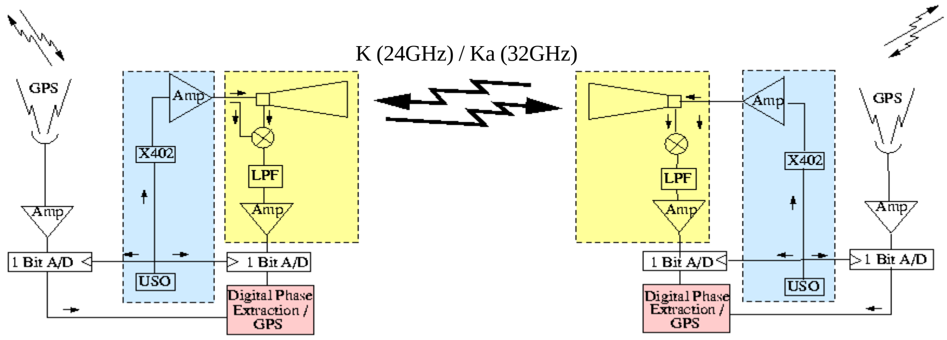
$C20_{1997}$ = -.484 165 197 88 10^{-3}

$C20_{dot}$ = 1.163 10^{-11} / y



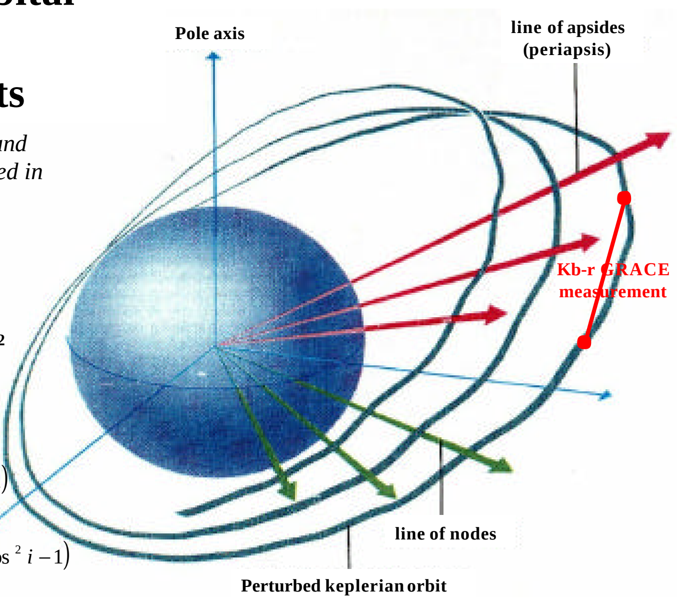


GRACE microwave ranging system



Description of orbital perturbations in keplerian elements

using the Lagrange's equations and the perturbated potential expanded in keplerian elements

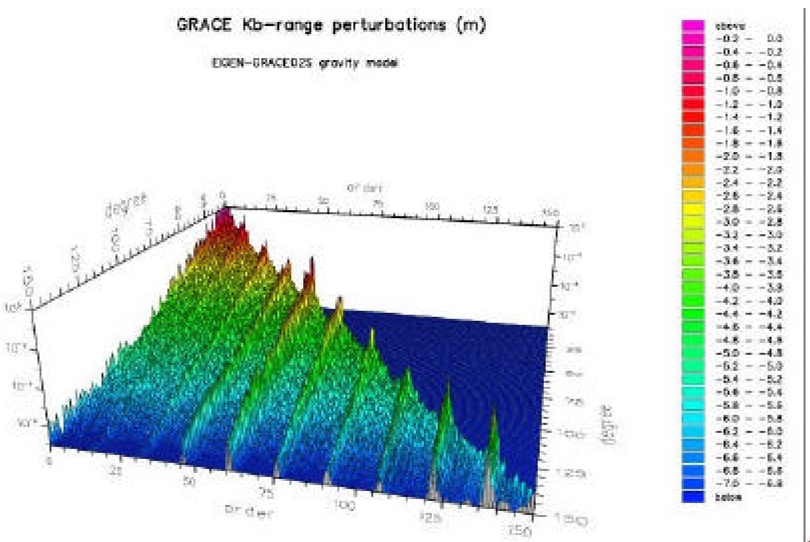


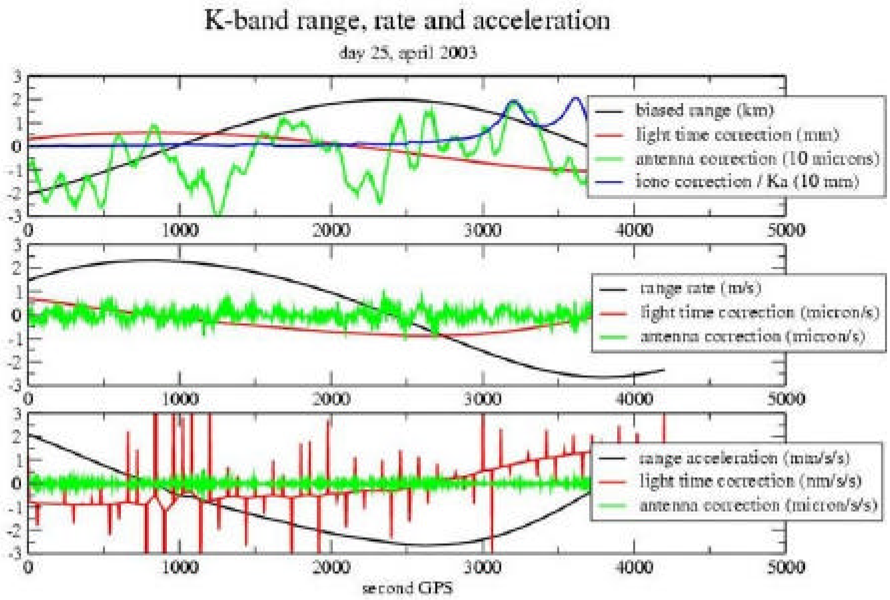
Secular perturbations due to J_2

$$\dot{\Omega} = -\frac{3}{2} n J_2 \left(\frac{a_e}{a}\right)^2 \frac{1}{(1-e^2)^2} \cos i$$

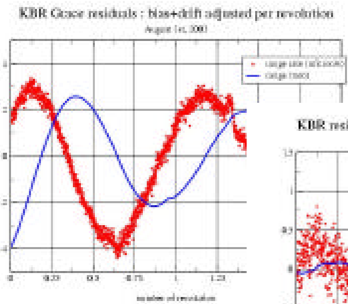
$$\dot{w} = \frac{3}{4} n J_2 \left(\frac{a_e}{a}\right)^2 \frac{1}{(1-e^2)^2} (5\cos^2 i - 1)$$

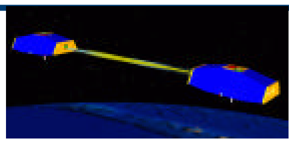
$$\dot{M} = n + \frac{3}{4} n J_2 \left(\frac{a_e}{a}\right)^2 \frac{1}{(1-e^2)^{3/2}} (3\cos^2 i - 1)$$

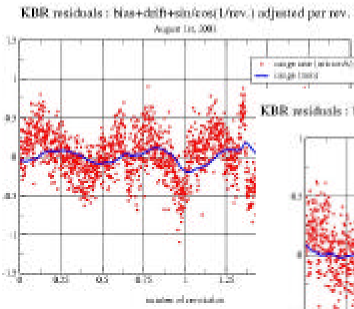


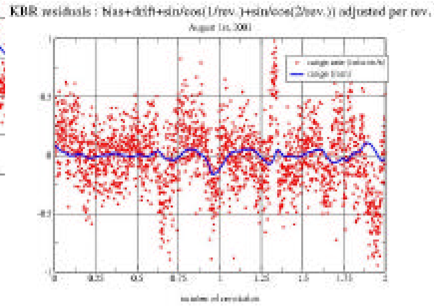


Processing of GRACE data : August-October 2003

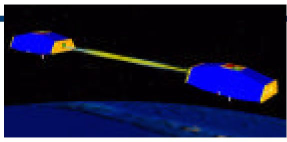








Processing of GRACE data : August-October 2003



A priori models:

• <u>Gravity</u>: EIGEN-GRACE02S up to degree 150

• <u>Third body attraction</u>: according to IERS conventions 2000 and DE403 JPL ephemeris

• <u>Earth tides</u>: according to IERS conventions 2000

• <u>Ocean tides</u>: FES-2004 for diurnal and semi-diurnal waves + FES-2002 for long period waves + 62 admittance waves up to degree 50

• <u>Atmospheric tide</u> model (S1 and S2) deduced from ECMWF pressure data

• <u>Atmospheric gravity variations</u>: from 3D-ECMWF 6h pressure models

• <u>Oceanic gravity variations</u>: MOG2D barotropic model (LEGOS)

Specific adjusted parameters:

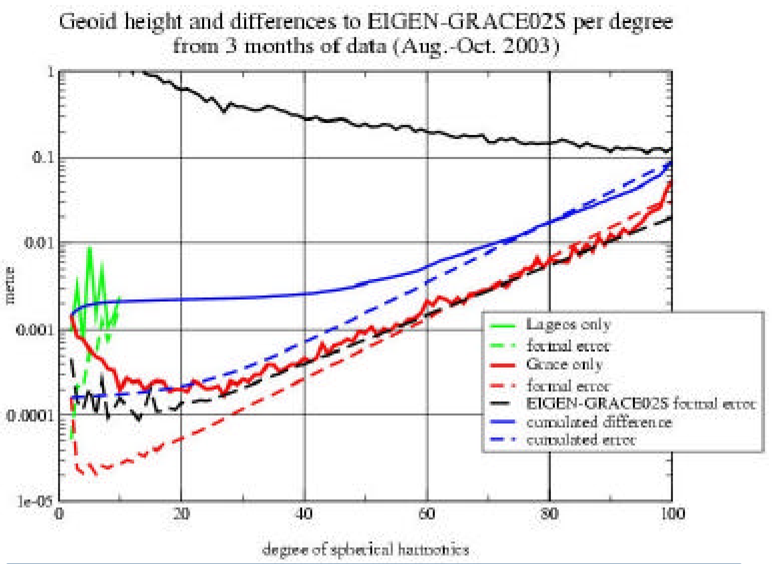
• <u>GPS data:</u>
one clock parameter per measure date (each 60s)
around 500 ambiguities per day

• <u>Accelerometer data:</u>
3 biases per day (one in each direction: X, Y, Z in satellite reference frame)
3 scale factors per day

• <u>K-band range data:</u>
16 (bias + drift + once and twice per rev. terms) per day and after phase break

• GPS/IGS orbits and clock/AIUB fixed

Power spectrum



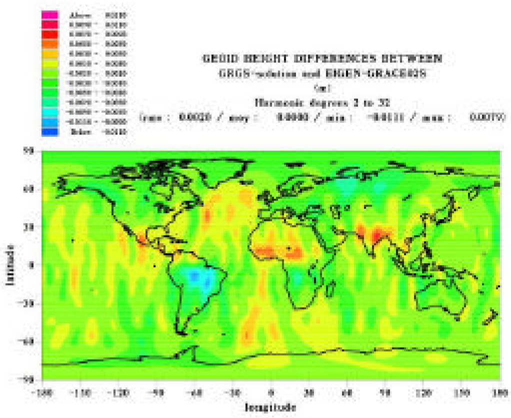
Comparison of gravity field models on GRACE orbit

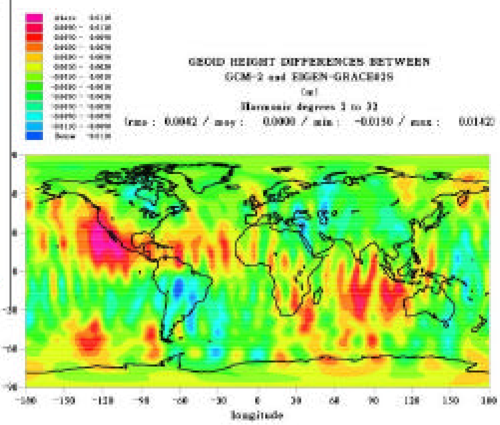
models / data (Aug.2003)	EIGEN-Aug-Oct03 MOG2D	EIGEN-GRACE02S MOG2D	EIGEN-GRACE02S +J2 Sep03	EIGEN-GRACE02S AODOC	GCM2 AODOC	GGM01S AODOC
SLR (mm)	86.3	88.5	88.7	90.2	91.7	88.6
GPS phase (mm)	6.1	6.2	6.1	6.3	8.3	7.4
Kb range (µm)	82	89	89	96	133	123
Kb range-rate (µm/s)	.72	.77	.77	.85	1.10	1.15

MOG2D: ECMWF 3-D atmospheric pressure + LEGOS barotropic model

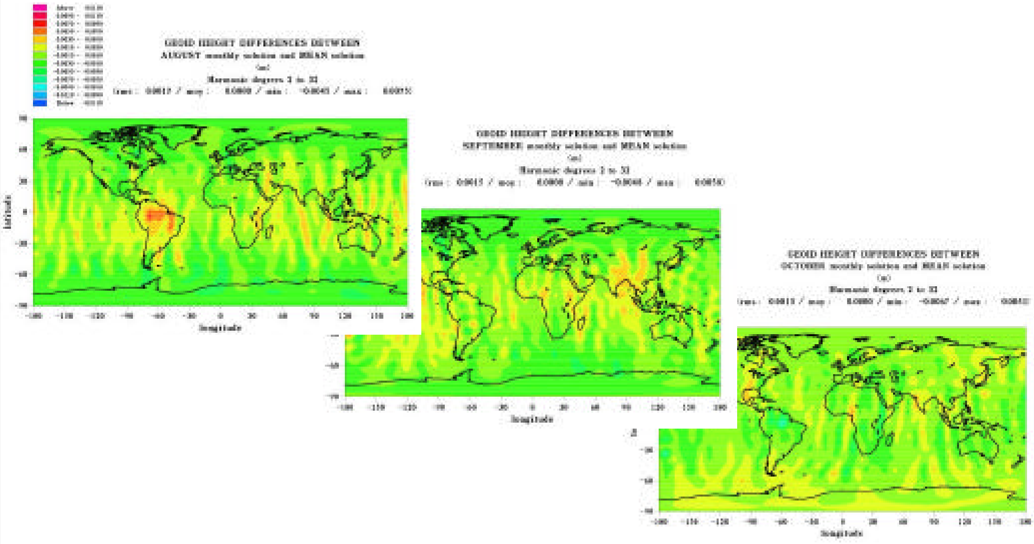
AODOC: ECMWF 3-D atmospheric pressure + JPL barotropic model

Geoid comparison

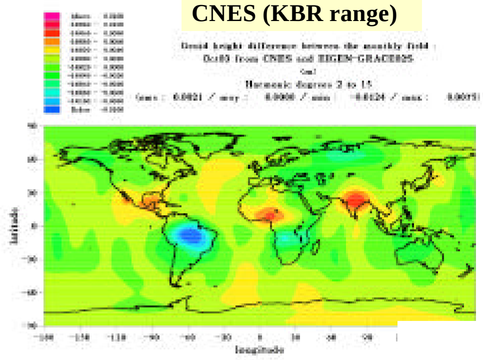




Geoid evolution from Aug. to Oct. 2003

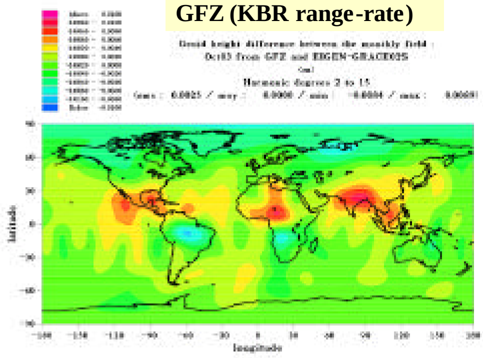


CNES (KBR range)



The monthly variability resulting from the difference 'monthly - reference model' (*degree 2 to 15*)

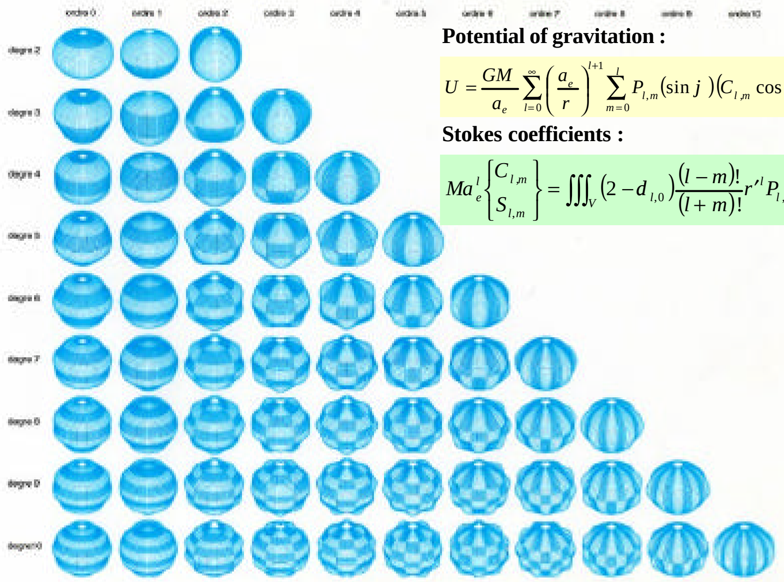
GFZ (KBR range-rate)



Month of **October 2003**
⇒ very similar results

Reference model= EIGEN-GRACE02S

Laplace's spherical harmonics : $P_{lm}(sin j\,)\ cos\ m l$



Potential of gravitation :

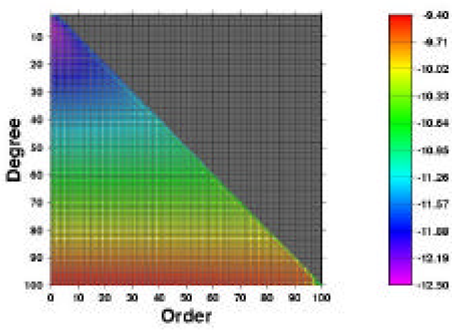
$$U = \frac{GM}{a_e}\sum_{l=0}^{\infty}\left(\frac{a_e}{r}\right)^{l+1}\sum_{m=0}^{l} P_{l,m}(\sin j\,)\left(C_{l,m}\cos m\,l + S_{l,m}\sin m\,l\,\right)$$

Stokes coefficients :

$$M a_e^{l}\begin{Bmatrix} C_{l,m} \\ S_{l,m}\end{Bmatrix} = \iiint_V (2-d_{l,0})\frac{(l-m)!}{(l+m)!} r'^{l} P_{l,m}(\sin j\,')\begin{Bmatrix}\cos m\,l\,' \\ \sin m\,l\,'\end{Bmatrix} dm$$

Formal errors and correlations

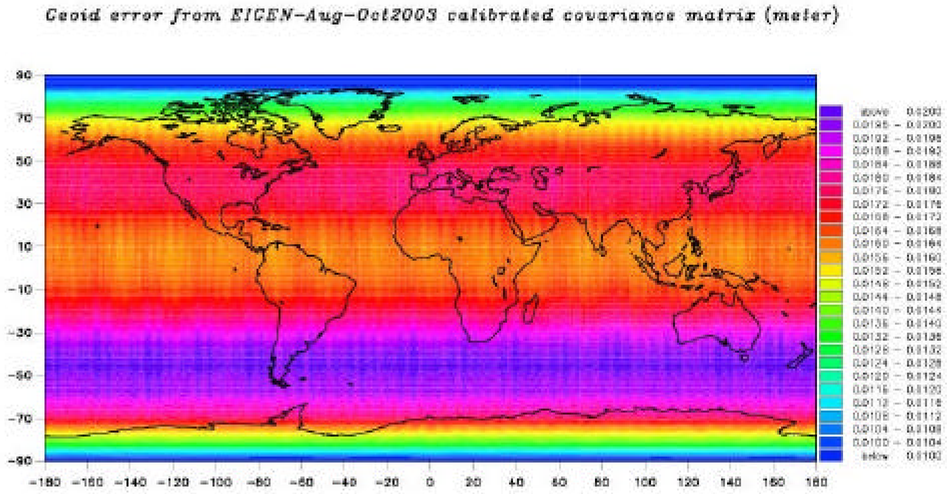
Gravity coefficients formal error (decimal exponent)



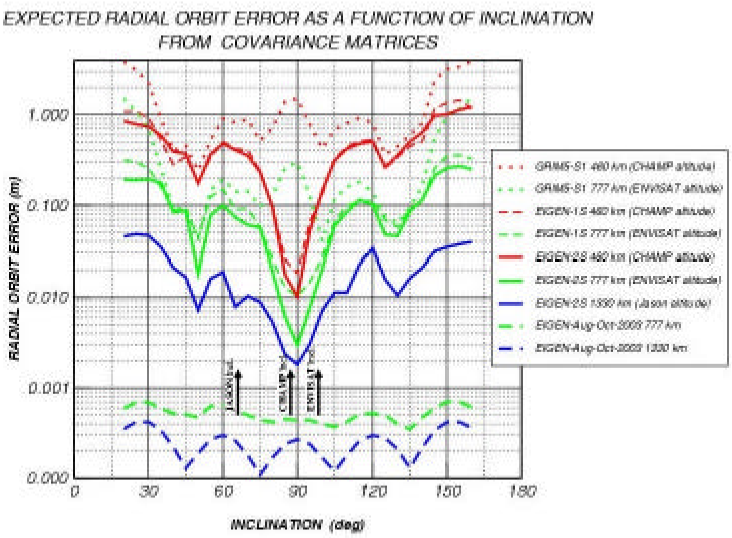
MAXIMUM CORRELATION OF THE SPHERICAL HARMONICS

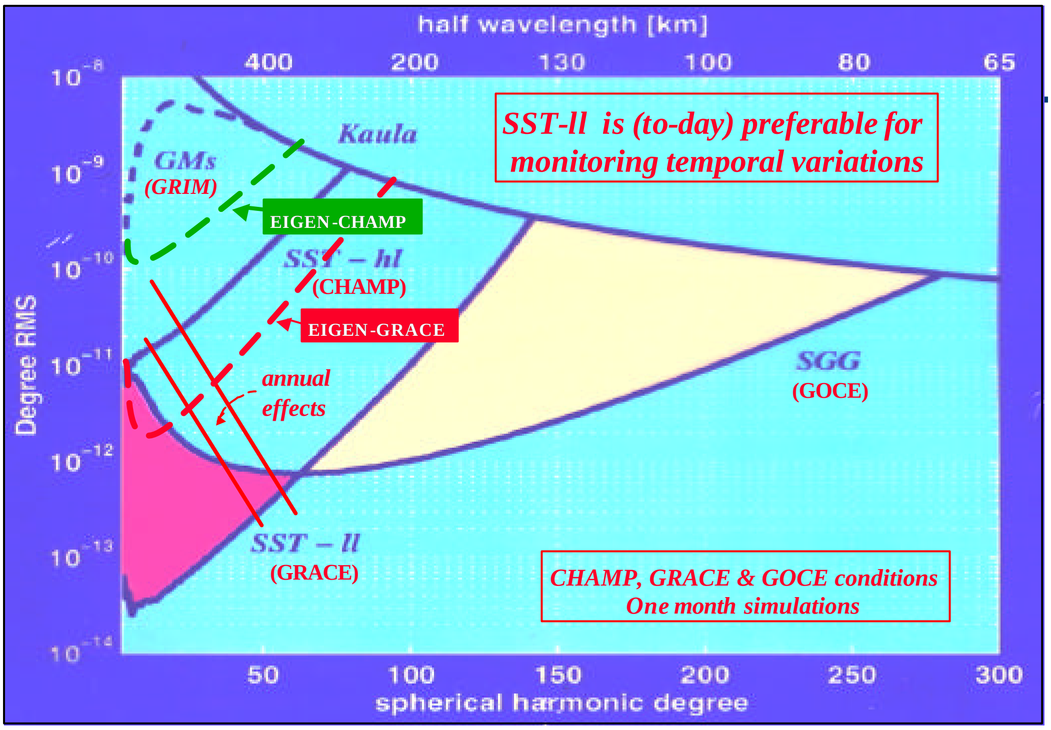
SH maximal degree : 100

Geoid error from covariance matrix



Radial orbit error from EIGEN covariance matrices




half wavelength [km]
400
200
130
100
80
65
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
Degree RMS
Kaula
GMs
(GRIM)
EIGEN-CHAMP
SST – hl
(CHAMP)
EIGEN-GRACE
annual
effects
SST – ll
(GRACE)
SGG
(GOCE)
SST-ll is (to-day) preferable for
monitoring temporal variations
CHAMP, GRACE & GOCE conditions
One month simulations
50
100
150
200
250
300
spherical harmonic degree