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

spurious residuals
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 ???):

- $0.66 \times 10^{-5}$ m/s radial
- $-0.77 \times 10^{-5}$ m/s along track
- $-2.84 \times 10^{-5}$ m/s cross track

30 km/s orbit of the Earth

Mean anomaly residuals, in arc second

Days after March 31, 2002
C(2,0) time series

(difference to -.484165198e-3)

-6e-10 to 2e-10

year


unconstrained solution

solution with continuity constraint
C(2,0) time series
(difference to -4.84165198e-3)

bias + drift + 18.6 & 9.3 year tides + annual & semi-annual tides
C(2,0) time series
(difference to -484165198e-3)

Delta C(2,0)

year

-6e-10  -4e-10  -2e-10  0  2e-10

continental atmospheric time series
continental atmospheric time series with 30-days running averaging
C(2,0) time series

(difference to -4.84165198e-3)
Degree 2 time series

ref \( C(2,1) : -2.8444678798900E-09 \); ref \( S(2,1) : 1.4764307518300E-08 \)

Delta \( C(2,1), S(2,1) \), \( C(2,1) \) with continuity constraint

Delta \( C(2,2), S(2,2) \), \( C(2,2) \) with continuity constraint
Geoid height comparison
EIGEN-GRACE02S tailored to Lageos vs. EIGEN-GRACE02S
(m)

(rms: 0.011 / moy: 0.000 / min: -0.056 / max: 0.049)

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

Latitude
Longitude
Geoid height (m)

 harmonic degree
Ocean tides comparison (normalized coefficients):

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<th>Solution</th>
<th>FES-2004</th>
<th>Difference</th>
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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

- 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 (≈ 6 mm)
  in scale: 1.6 10^{-9} (≈ 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}
station coordinate solution: comparison to ITRF-2000

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
station velocity solution: comparison to ITRF-2000

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
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

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**Geocentre motion, annual terms**

![Graph showing annual terms in X, Y, and Z axes with mean values and trend lines.]

**Mean values:**
- **X axis:**
  - C component: -0.8 mm
  - S component: -0.8 mm
- **Y axis:**
  - C component: -1.8 mm
  - S component: 0.8 mm
- **Z axis:**
  - C component: -1.4 mm
  - S component: -1.5 mm

Corresponding to a winter loading centered on Siberia.
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