UNIVERSITÀ DEGLI STUDI DI MILANO

ThalesAlenia Space

On the Possibility to Monitor the Co- and Post-seismic Signal with the Next Generation Gravity Mission (NGGM)

K. Douch[1], G. Cambiotti[2], S. Cesare[3], N. Sneeuw[1], A. Anselmi[3], A.M. Marotta[2], R. Sabadini[2] .

[1]Universität Stuttgart, Geodätisches Institut, Stuttgart, Germany, [2]Università degli Studi di Milano, Department of Earth's Sciences, Milan, Italy, [3]Thales Alenia Space Italia, Domain Exploration and Science, Turin, Italy.

esa

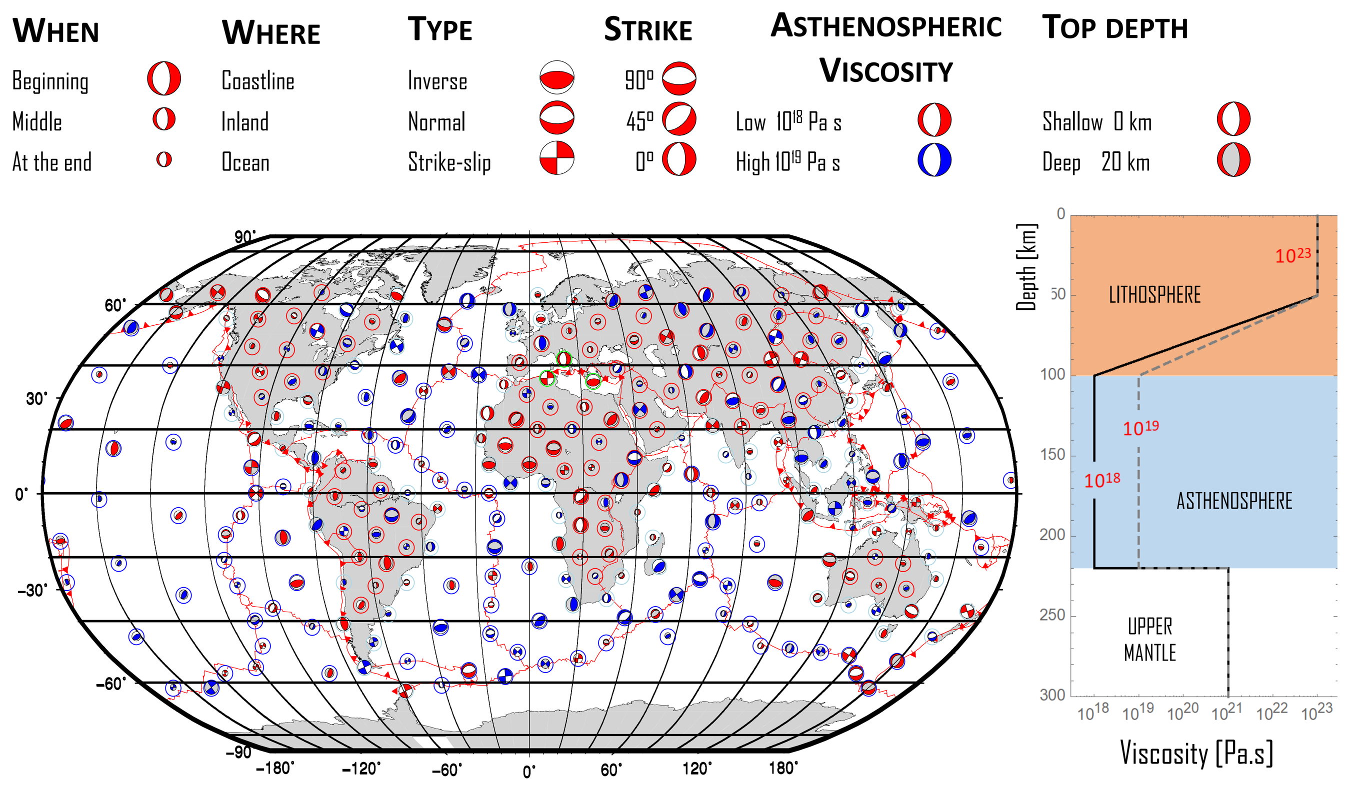
Universität Stuttgart

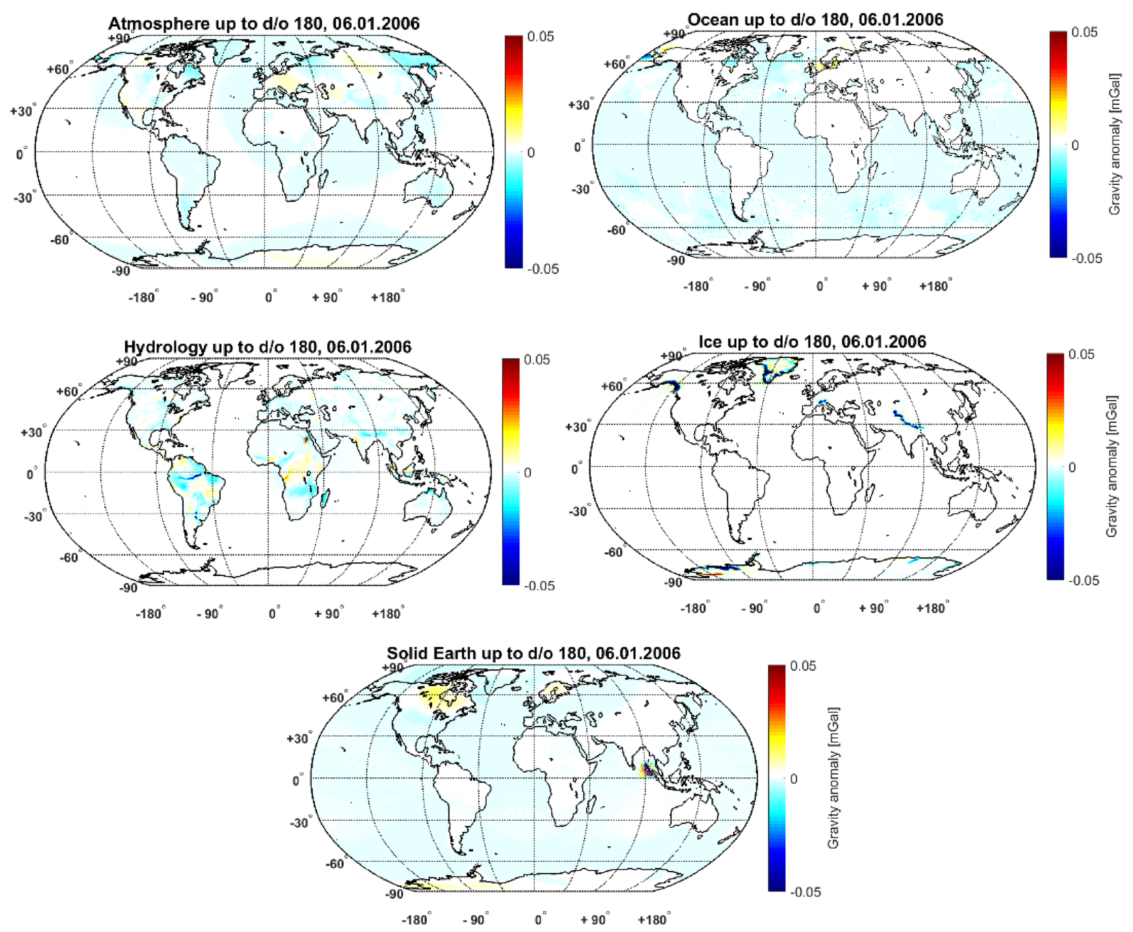
Sophisticated post-processing of GRACE data have made possible the detection of the time-variable gravity field signature of great earthquakes, opening the way to gravitational seismology. The latter method can provide relevant information about the co- and post-seismic phase, in particular in the case of epicentres located in the ocean. However, the range of earthquakes observable by GRACE is limited by the spatial resolution and error of the recovered gravity solutions. Until now, only earthquakes with magnitude > 8.3 have been detected with GRACE data. Here, we investigate and quantify via closed-loop simulations how the envisioned NGGM could extend the range of observable earthquakes.

I. Closed-loop simulation

Background model

- Static (EIGEN6c4) + (AOHIS - DEAL + AOerr x 0.5) (ESA ESM) + earthquake
- d/o Background model = 140
- No tides





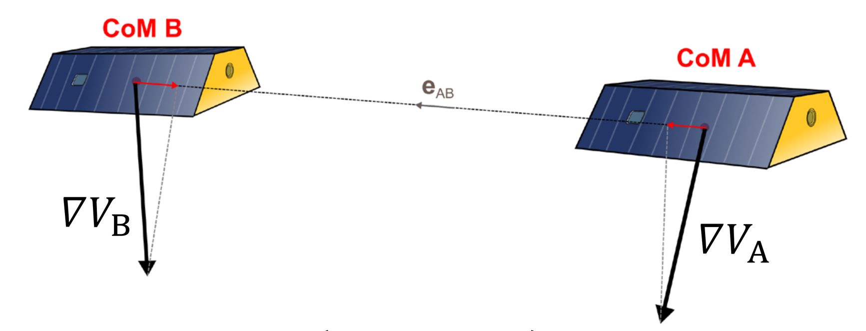
Total: 288 earthquakes + 3 in the Mediterranean Sea, all MW 7.

Simulation parameters

- $T_{sampling}$ = 10 s
- Period of 1 solution = 28 days
- 01.01.1995 to 31.12.2006
- Number of solutions = 156

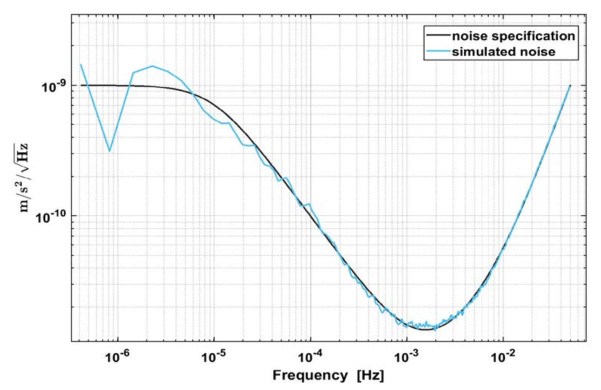
Orbit parameters

- Bender-type constellation (2 pairs of satellites)
- Inter-satellite range = 100 km
- Polar/inclined have a sub-cycle of 7 days
- Both 7-day ground-track patterns shift by the same angle.



$$\mathrm{Obs} = (\nabla V_B - \nabla V_A).\boldsymbol{e}_{AB}$$

Instrumental noise



- Includes accelerometer and laser interferometer noises

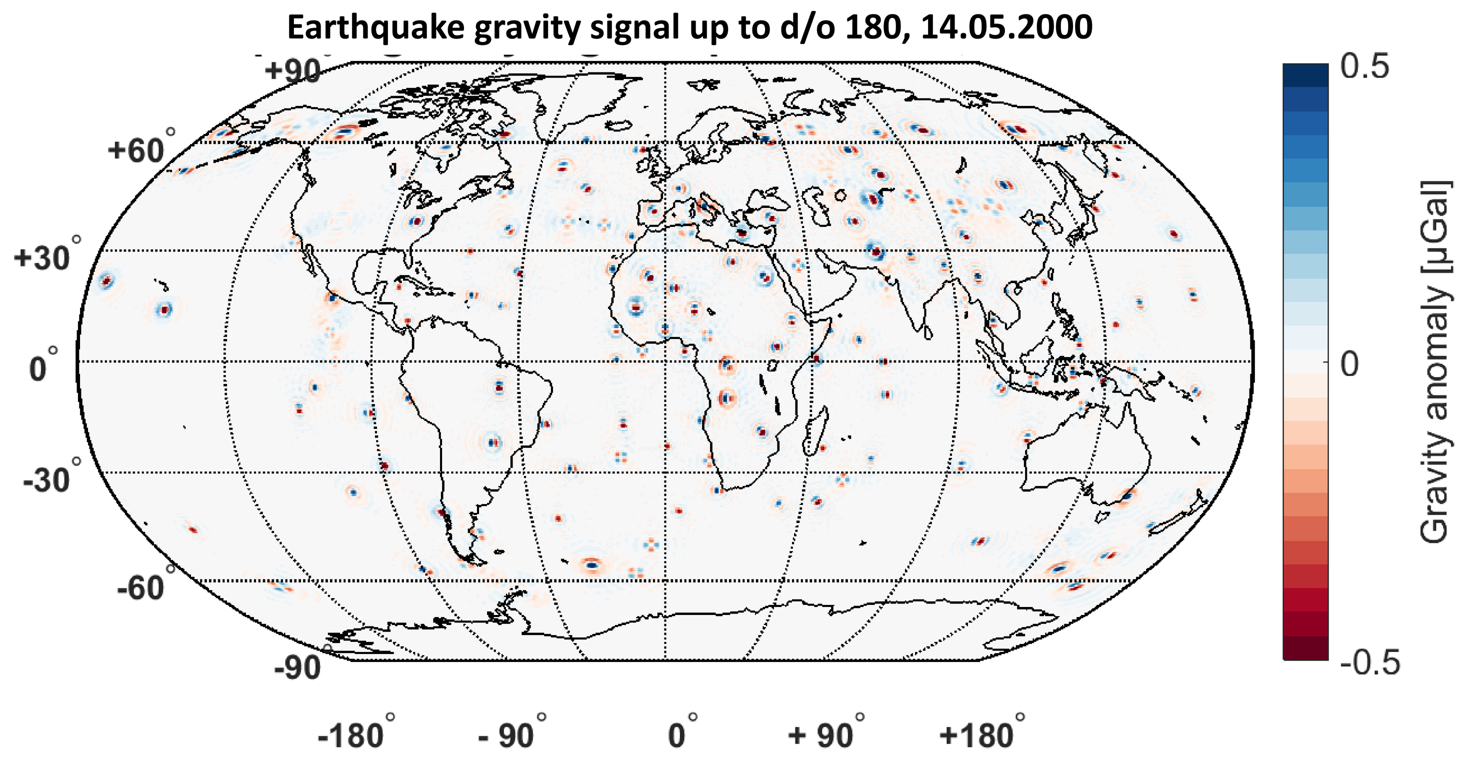
Gravity field recovery

- d/o of recovered sol. = 140

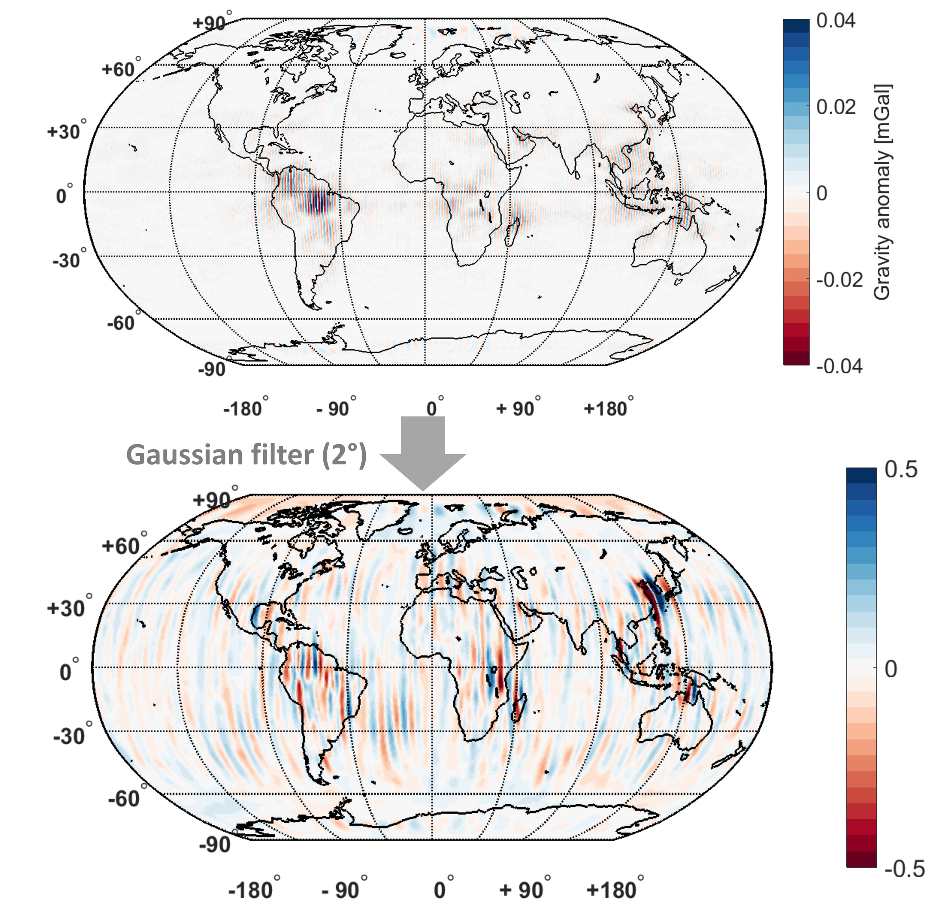
Comparison

II. Results

Orders of magnitude of the signal



Recovered earthquake signal (= recovered field – error-free static field – mean(AOHIS-DEAL)) up to d/o 140, sol.120



Detectability, inverse problem

The signal within a spherical cap centred on the epicentre is decomposed into a finite sum of Slepian functions associated with their respective amplitude time series of 156 points. We then assume that the **spatial and temporal pattern of the earthquake gravity signature is known**, and we fit this pattern to the synthetic gravity data by estimating a **scaling factor** and its uncertainty.

1st case: sensitivity study

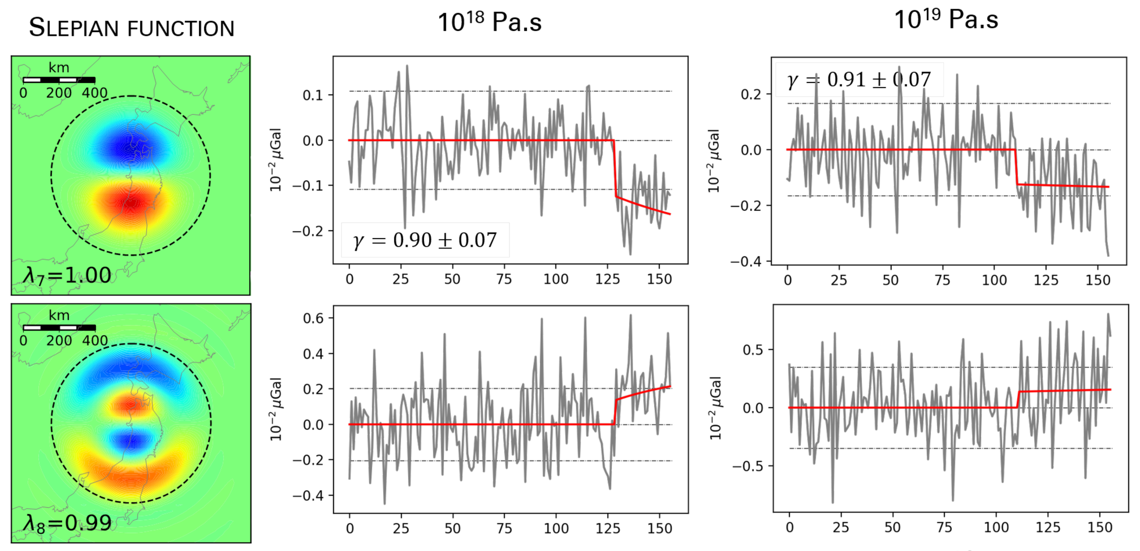
we assume we can remove exactly the AOHIS signal.

DATA = AOHIS – DEAL ESAESM = STATIC modelling + SCALING FACTOR × QUAKE signature + ERROR observational

$$\mathbf{g}_{\mathrm{obs}}(t) - \mathbf{g}_{\mathrm{aohis}}(t) = \boxed{\mathbf{s}} + \boxed{\gamma}\,\mathbf{q}(t) + \boxed{\boldsymbol{\epsilon}(t)} \longrightarrow N(\mathbf{0}, \alpha\,\mathbf{E})$$

$$\gamma = \langle\gamma\rangle \pm \sigma$$

By definition, the scaling factor should be 1.



Example: M=7, inland, normal, deep, perpendicular, end, 10^{18} Pa.s

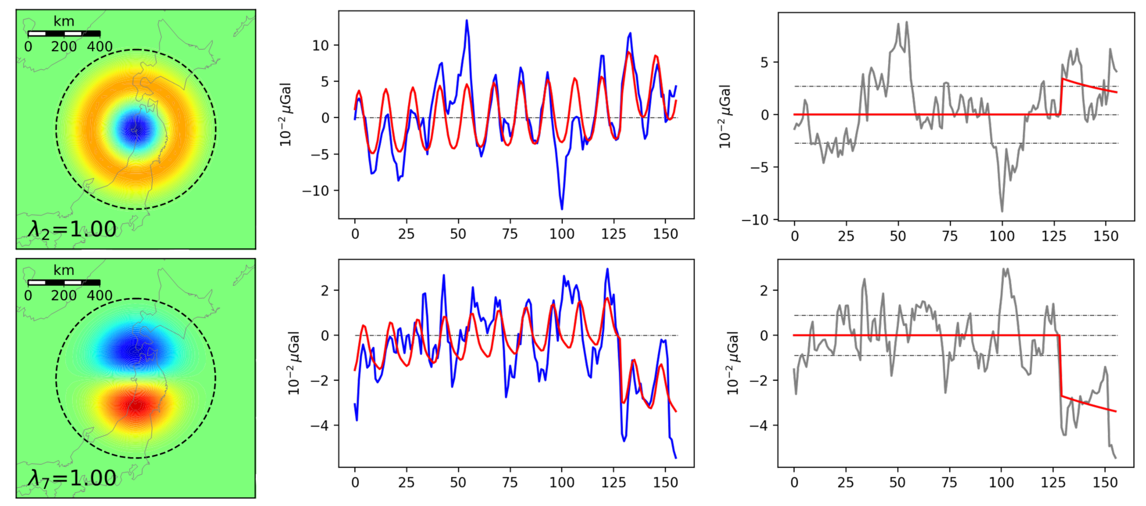
2nd case: discrimination study

the AOHIS signal is co-estimated by fitting a trend and annual and semi-annual oscillations.

DATA = STATIC modelling + AOHIS – DEAL modelling + SCALING FACTOR × QUAKE signature + ERROR observational + modelling

$$\mathbf{g}_{\mathrm{obs}}(t) = \boxed{\mathbf{s}} + \mathbf{K}(t)\boxed{\mathbf{m}} + \boxed{\gamma}\,\mathbf{q}(t) + \boxed{\boldsymbol{\epsilon}(t)} \longrightarrow N(\mathbf{0}, \alpha\,\mathbf{E})$$

$$\gamma = \langle\gamma\rangle \pm \sigma$$



Example: M=7.75, inland, normal, deep, perpendicular, end, 10^{18} Pa.s

Statistics

For each earthquake scenario we estimate the **scaling factor** and its uncertainty.

$$X = \frac{\langle\gamma\rangle - 1}{\sigma}$$

NORMALIZED SCALING FACTOR. It should follow a normal distribution with zero mean and unitary standard deviation.

1st case

X is normally distributed

	Total (in %)			**Where?**			**Type?**		
	M=6.75	M=7	M=7.25	Inland	Ocean	Coast.	Norm.	Inv.	Strike-s.
$\lvert\langle\gamma\rangle-1\rvert < 1$		99.3		100	100	99	100	100	98.6
$\lvert\langle\gamma\rangle-1\rvert < 0.5$		97.3		96.9	99	96.9	100	99.1	91.7
$\lvert\langle\gamma\rangle-1\rvert < 0.1$	35	65.7	91	72.9	67.7	57.3	71.3	73.1	47.2

2nd case

X is not normally distributed

	Total (in %)		
	M=7.5	M=7.75	M=8
$\lvert\langle\gamma\rangle-1\rvert < 1$	83,2	94,5	99.3
$\lvert\langle\gamma\rangle-1\rvert < 0.5$	70.4	85.2	95.9
$\lvert\langle\gamma\rangle-1\rvert < 0.1$	35	55.6	77.3

Discussion & outlook

- Statistics about the detectability of earthquakes have been computed based on the results of closed-loop simulations
- M=7 earthquakes can be distinguished from the NGGM errors. The possibility to reduce the unmodelled time-variable gravity field by considering 3 or 7-day solutions should be further investigated
- Difficulties in modelling the time-dependent background model (AOHIS) make only M=7.5/8 earthquakes detectable. A better modelling/separation of the other geophysical signal is required.