Gravity field recovery of the MOCAST+ quantum mission proposal

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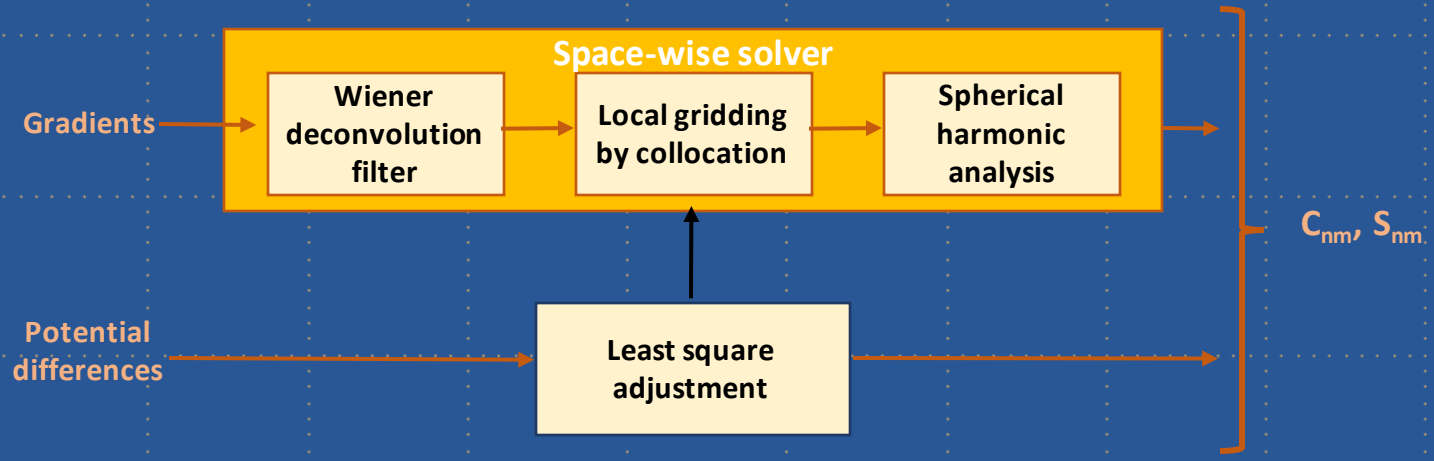
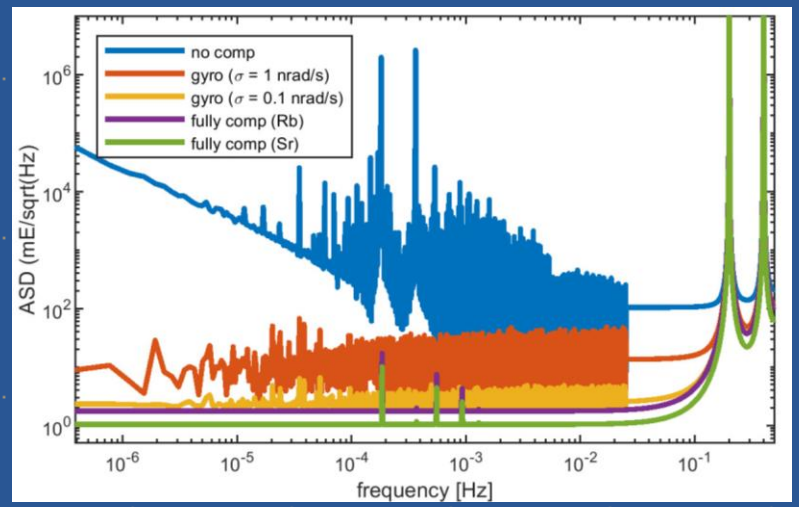


Dataset:

- Reference GGM: EGM2008
- Non-tidal mass variations (in AOHIS): ESA Earth System Model
- Orbits: provided by Thales Alenia Space



Simulation scenarios:

- Optical clock only
- Optical clock + CAI gradiometer
- Inclusion of non-tidal mass variations

For optical clock only:
clock observation sampling rates

Common parameters:

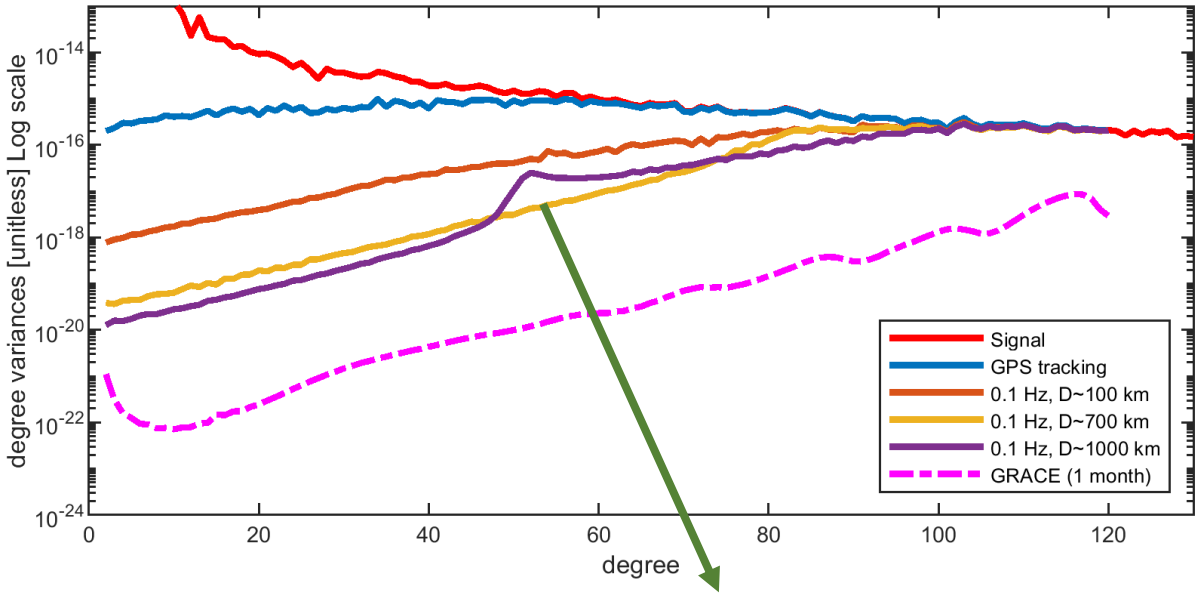
- inter-satellite distances
- orbital configuration (in-line configuration polar orbit only or Bender configuration)
- number of satellites in-line on the same orbit (two or three)

For CAI gradiometer only:
noise PSDs of the gradiometers, depending on the accuracy of the attitude control sensors and by considering different atomic species

Clock only simulations

In-line configuration: Polar orbit only

Case: inter-satellite distance and clock error

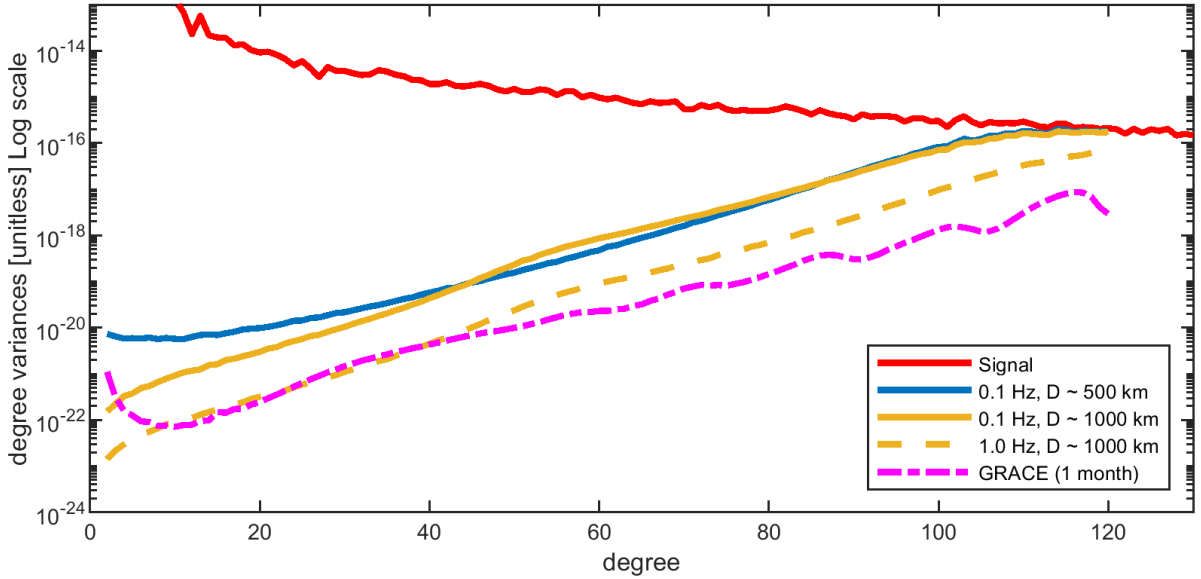


The reason behind jump in the error curve around d/o 85 (sc. 700 km distance) and d/o 55 (sc. 1000 km distance) is the ill-posed estimation of some coefficients due to the term $Y_{lm}(\vartheta_i, \lambda_i) - Y_{lm}(\vartheta_j, \lambda_j)$ in design matrix

the clock observation noise standard of $0.2\ {}^{m^2 s^{-2}}/_{\sqrt{Hz}}$, referred to the potential difference observations, was degraded to $1.35\ {}^{m^2 s^{-2}}/_{\sqrt{Hz}}$ for GOCE-like scenario

Bender configuration

Case: Bender configuration with three satellites



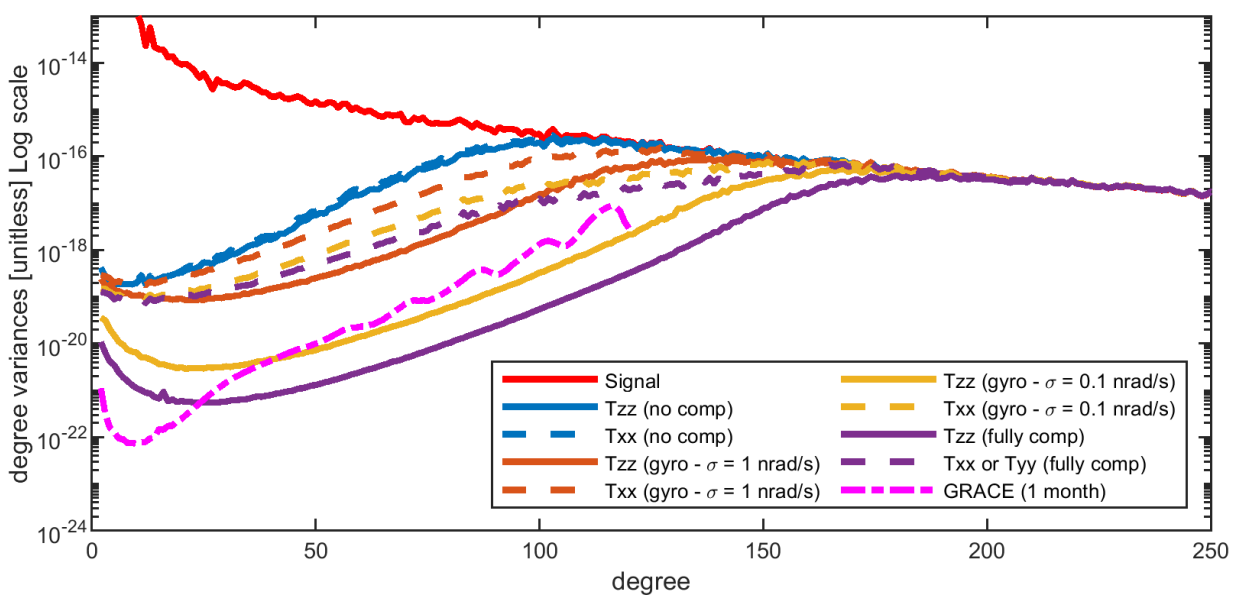
(i) adding the third satellite on an intermediate location between the leader follower satellites, e.g. an inter-satellite distance of 500 km between each pair (leader-middle, middle-follower)

(ii) adding the third satellite behind the follower satellite with a distance about 1000 km, thus having an inter-satellite distance of about 1000 km between each pair of satellites

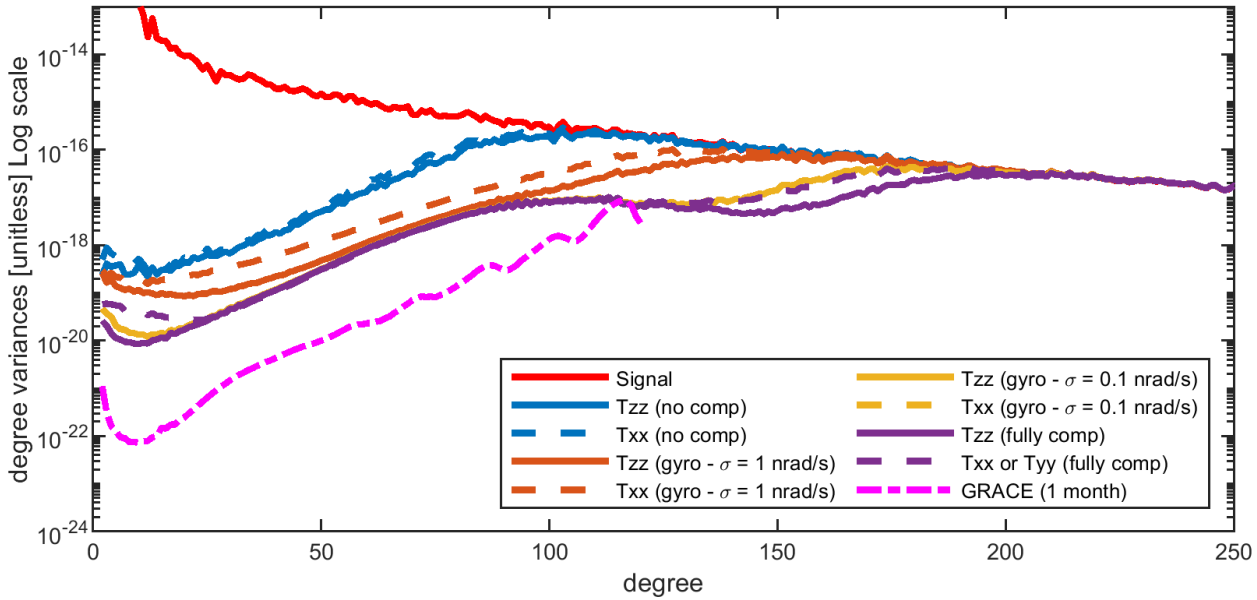
Clock + CAI gradiometer simulations

Single-satellite single-arm gradiometer

The effect of noise degradation on the polar and inclined orbits:



(a) Polar orbit



(b) Inclined orbit

*Colors represents possible noise PSDs.

The best solution: gradiometer arm directed along the radial direction (drag-free and compensation at the level of 0.1 nrad/s)

↓

BUT the current technologies cannot provide such an accuracy for attitude control system yet.

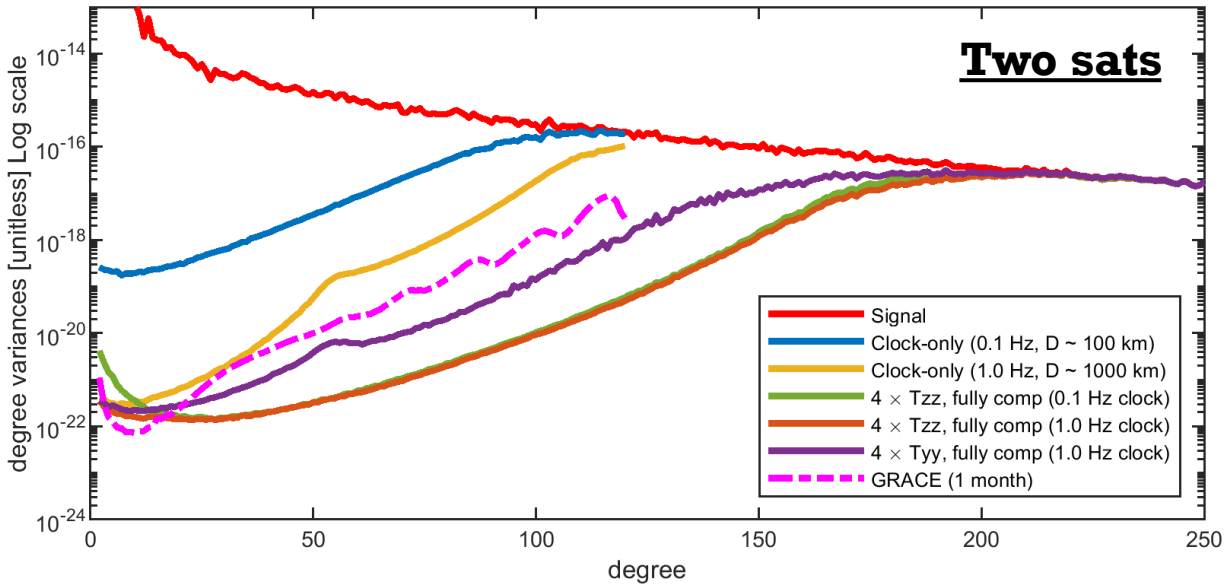
↓

The most realistic scenario: orienting the gradiometer arm along the out of plane axis (y)

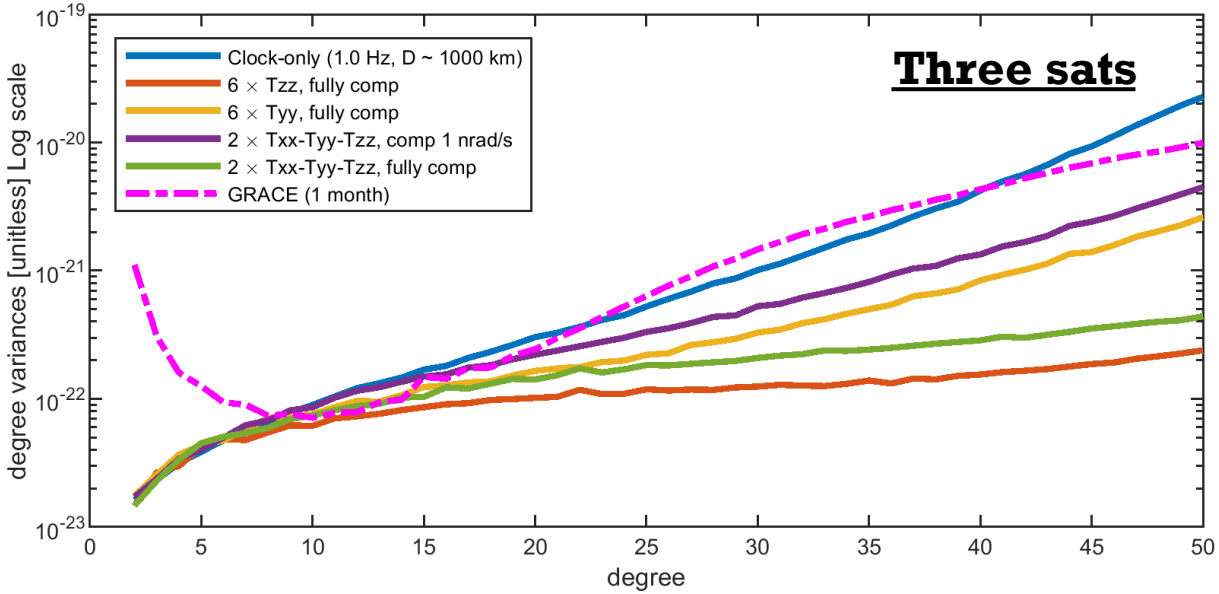
Clock + CAI gradiometer simulations

Bender configuration with two and three satellites

The effect of different gradiometer noise PSD and gradiometer orientation:



(a) different inter-satellite distances and optimal gradiometer noise PSD scenarios



(b) the optimal and degraded gradiometer noise PSD + different orientations of the gradiometer arm on board the satellites

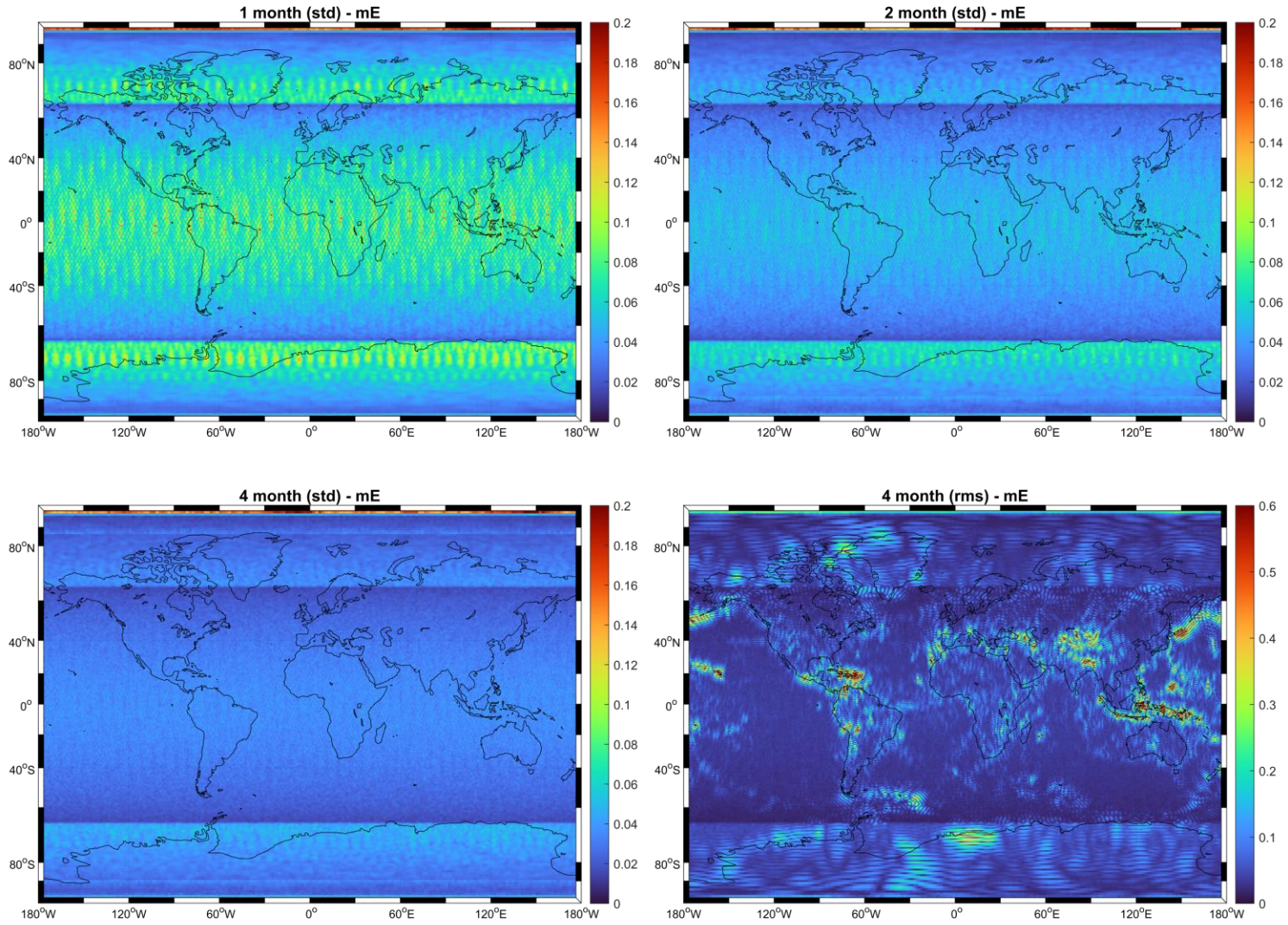
Gradient contribution

middle-high degrees: a better estimation of the spherical harmonic degrees up to about degree 200

low degrees: below degree 10 the solution is dominated by the clock information, while about above degree 30 the gradiometers only are playing a role.

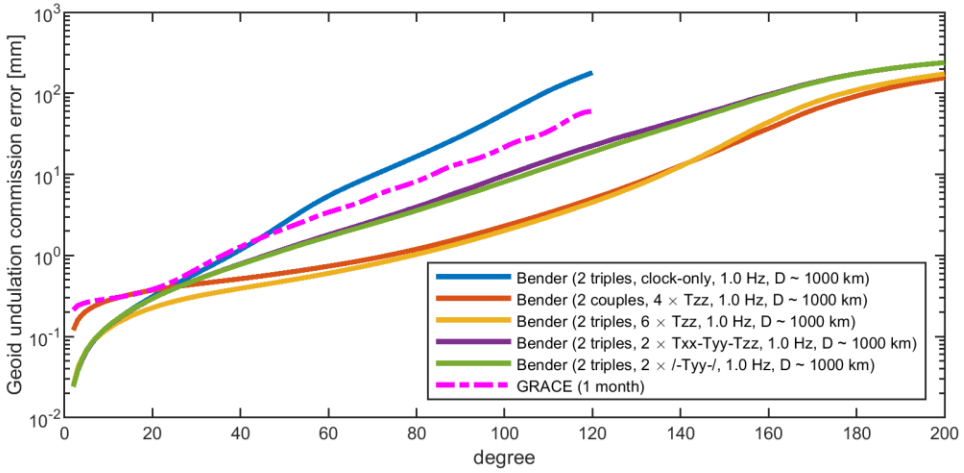
Longer simulation periods and cumulative comission errors

Grid estimation error in terms of standard deviation for different mission life-times:

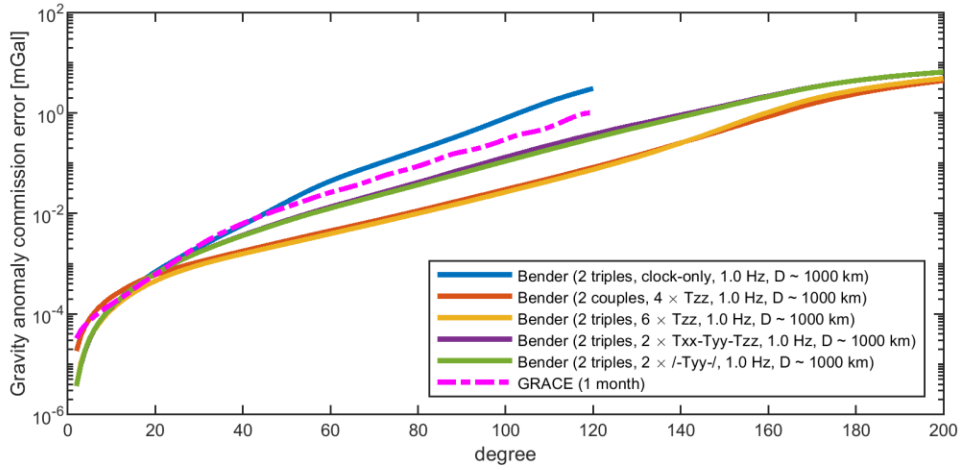


***The root mean square error for the 4-month scenario is given to quantify the omission error**

Cumulative commission errors:



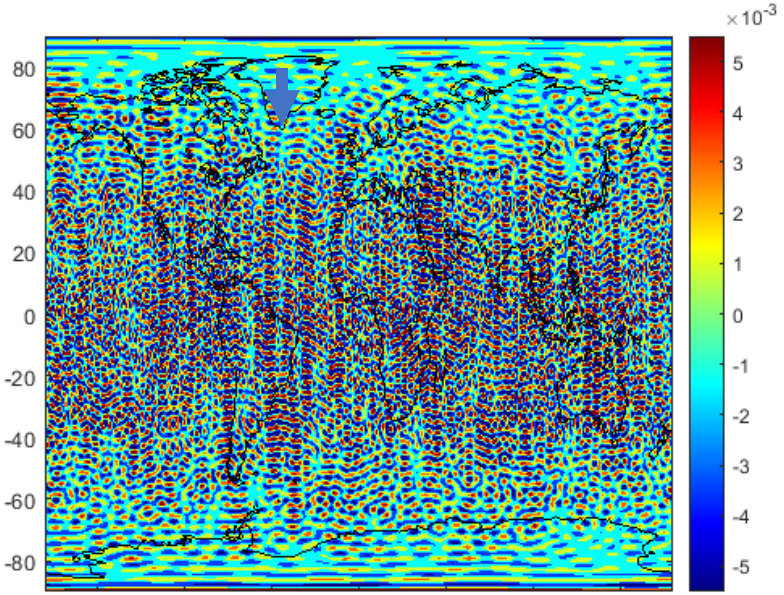
(a) Geoid undulations



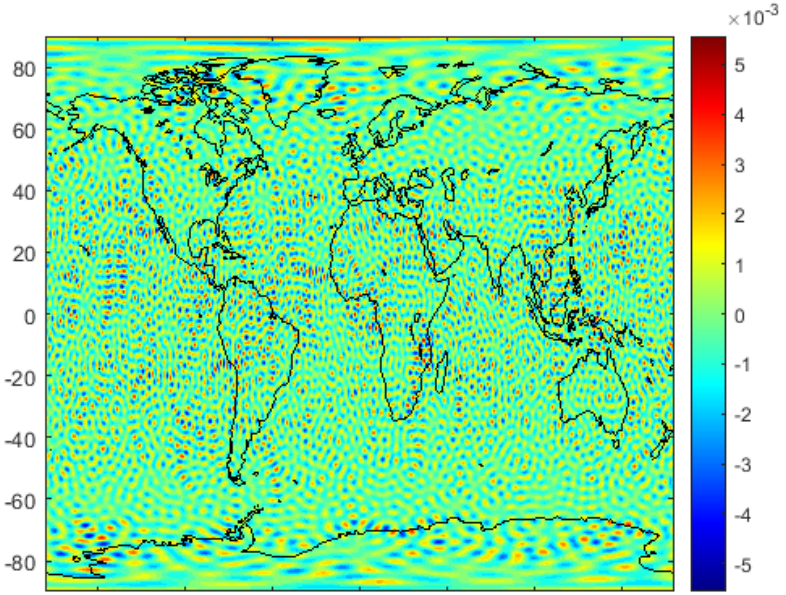
(b) Gravity anomalies

Inclusion of non-tidal mass variations

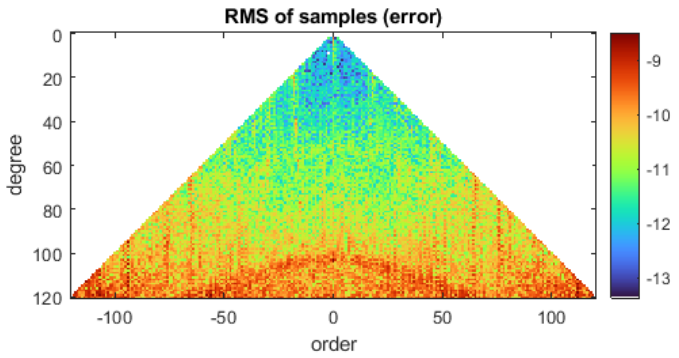
Aliasing over a geoid undulation grid [unit: m]

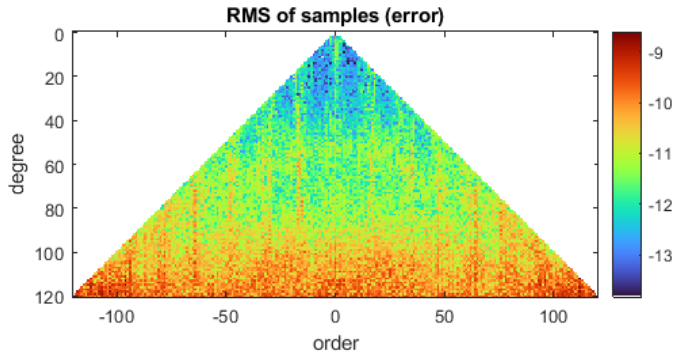


(a) Polar orbit only



(b) Bender configuration





Bender configration offers:

increase in the spatial resolution along the East-West direction

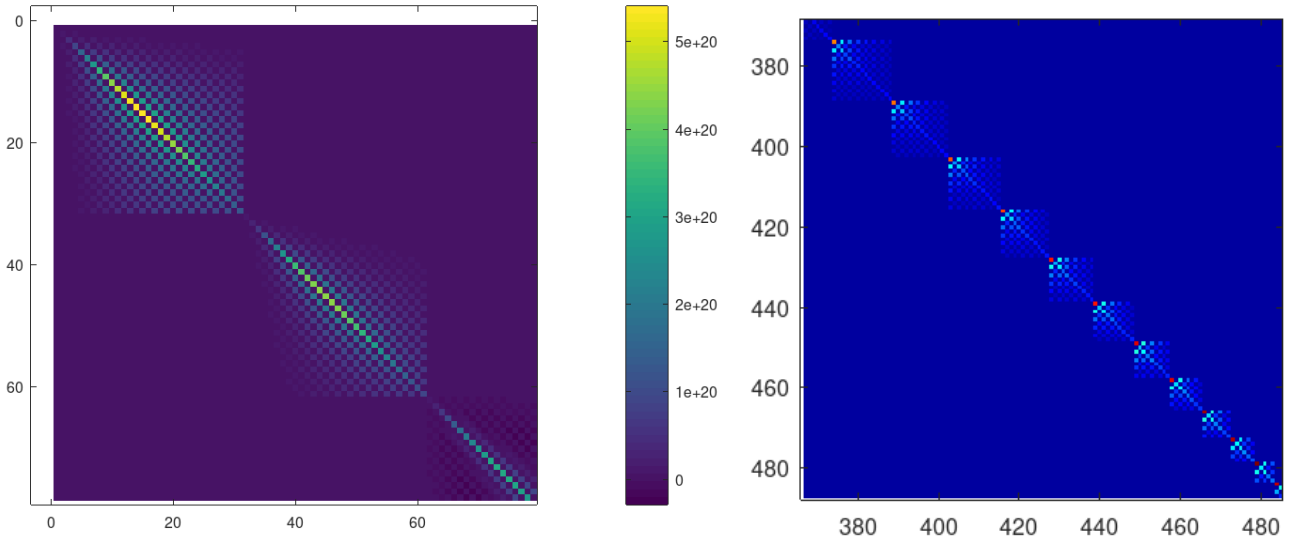
an increment in isotropy

Take away:

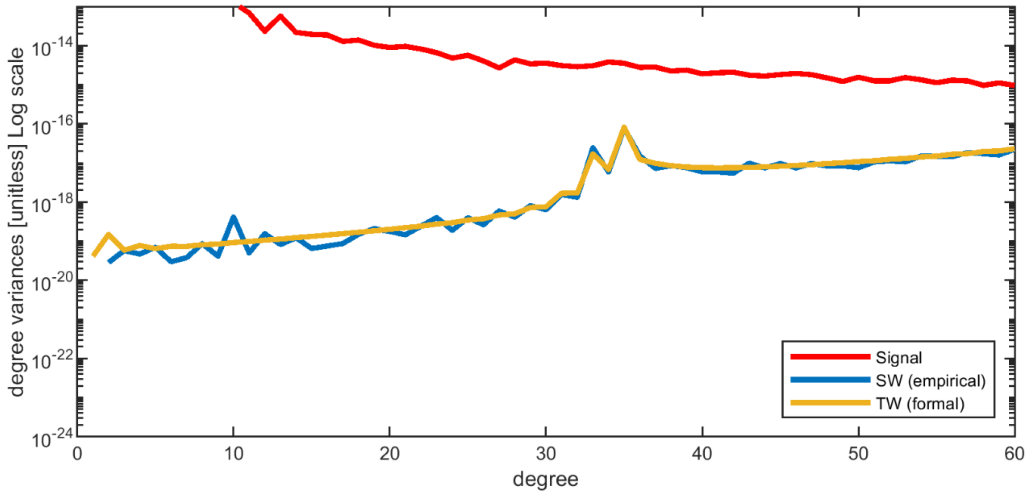
- The aliasing effect and the longitudinal striping are reduced significantly in the Bender configuration scenario.

- Having a polar pair coupled with an inclined pair provides a better and less degraded gravity field solution

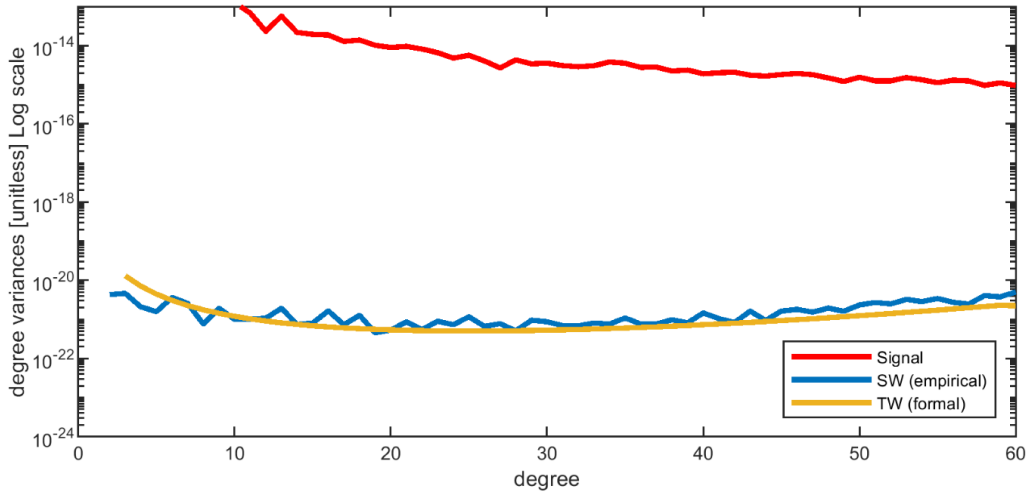
Comparison with time-wise approach



Block diagonal order-driven structure of the normal matrix (left) and its inverse (right) for a Bender configuration with a polar orbit and an orbit with an inclination of 67° (max harmonic degree = 30).



Comparison between space-wise and time-wise solutions based on potential differences in a simplified mission scenario.



Comparison between space-wise and time-wise solutions based on second radial derivatives of the potential in a simplified mission scenario.

Conclusions

Regarding the data:

- the direct observation of the gravitational potential differences can be an asset and its transfer function prevents the dampening of the spherical harmonic spectrum at the very low degrees (typical of GRACE)

Regarding the results:

- The mission configuration is made more complex than a "simple" GRACE-like scenario. This would imply considering 1 Hz (instead of 0.1 Hz) clock observations, longer inter-satellite distances (about 1000 km instead of 100 km) and a Bender formation with three satellites on each orbit. Without these "complications", the mission profile would not be really competitive with GRACE in the retrieval of the gravity field at low-medium degrees.

- As for the high harmonic degrees, the lower noise level of the cold atom gradiometer with respect to the electrostatic one gives the possibility of improving the GOCE performances in static gravity field determination around at least an order of magnitude, if the orbit altitude is not too high

For your questions, you can send an email to :
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