Mass redistributions at the core mantle boundary from satellite gravity

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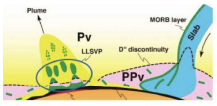
Motivations

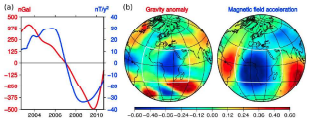
Measurements of the space-time variations of the gravity field from the GRACE & GRACE-FO missions (since 2002) → **new constraints on deep mass redistributions ?**

Mass redistributions due to variations of the CMB **topography**: coupling with sudden changes in core flows ?



(Hirose et al. 2008)

This could help to better understand sudden changes in the secular variation of the geomagnetic field, the **geomagnetic jerks**.

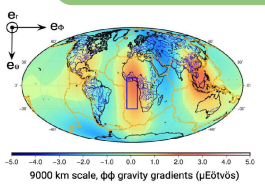


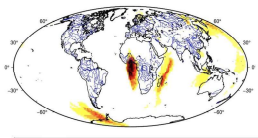
(Mandea et al. 2015)

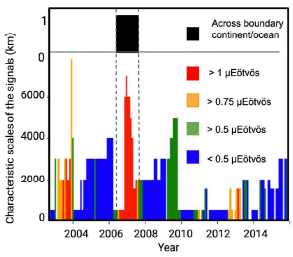
Objective: Search for **gravity signals** of mass redistributions at the CMB at timescales of **months up to a few years**

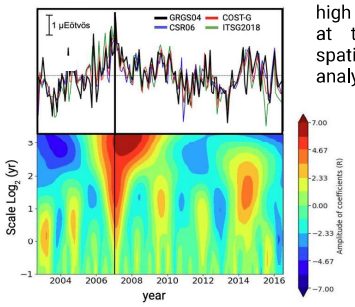
Gravity signal related to the **2007** magnetic jerk in the **Atlantic ocean** ?

Detection of signal









Anomalous North-South oriented signal **across** the boundary between the **Atlantic ocean** and the **African continent**, with a high intensity (≥1μEötvös) at the largest 9000-km spatial scales of the analysis in **January 2007**.

Detection of bump +/- 4 months around January 2007
→ **same spatial signature** over different timescales

Methods

- **GRACE/SLR** and pure SLR geoid models: GRGS04 compared with CSR06, ITSG2018, COST-G, SLR-AIUB
- We subtract a **mean**, **trend**, **annual** and **semi-annual** signals (2003-2015)

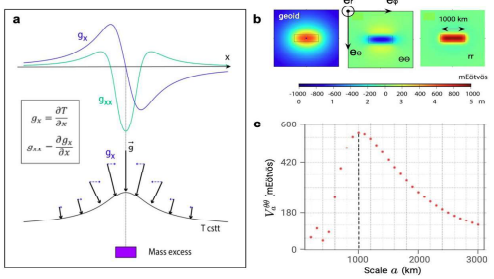


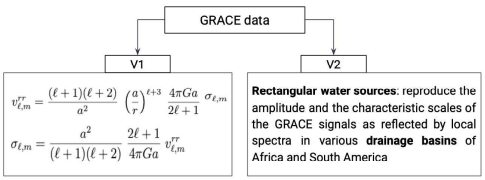
Figure 1 - Multi-scale gravity gradients (Panet et al. 2022)

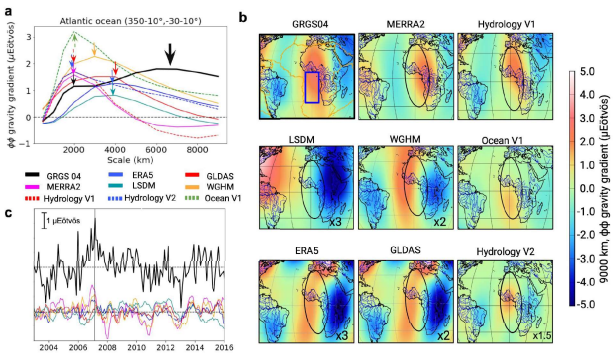
- **Gravity gradients** in the local spherical frame, at different spatial scales (no terms of degree 0 nor 1)
- **Rotations of the spherical frame** to align with the orientation of the signals → **separate** signals with different **characteristic scales** and **orientations** (Panet et al. 2018 ; Panet 2019)
- Wavelet transform of the gravity gradients time series at scales **28-32 months** : search for peaks in the period **September 2006 - April 2007**
- **Bump** in the time series ↔ **peak** in the wavelet-transformed coefficients

Water cycle

To investigate a potential origin of the 2007 Atlantic signal within the **fluid envelopes of the Earth**, we now compare its spatio-temporal fingerprint with those of **hydrological**, **oceanic** and **atmospheric** sources based on global circulation models, GRACE-based reconstructions (V1) and the geographic distribution of land and ocean (V2).

Hypothesis: observed gravity variations are solely **due to water**.





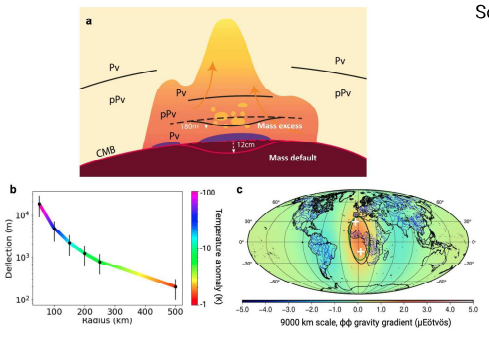
For continental hydrology and oceanic sources (modelled or reconstructed from GRACE), their combinations, and tests of coalescence of continental sources, the **characteristic scale** and **location** differ from those of the 2007 GRACE anomaly.

The 2007 Atlantic signal is not well explained by surface water sources.

These conclusions support the possibility of a **deeper origin within the solid Earth**.

Mass redistributions at the CMB / in the D" layer

Source from the core is expected to be to small to generate dynamic CMB topography, we focus on a **mantle side source**. Source at the top of the CMB can not explain both geomagnetic jerk and gravimetric magnitude anomaly.



Source in the mantle above CMB:

- Characteristics of Pv-pPv : **fast** (Langrand et al 2019), density contrast (**100 kg/m^3**), occur in the D" region
- African LLSVP : **Pv-pPv phase transition** deeper (7-14 K/m)
- **Scenario proposed:** Pv **cold** anomaly (T') passing through the phase transition and transform to pPv before other material at temperature T creating a **mass anomaly**.
- **Model parameters:** elastic D" layer of 350 km, phase transition at 50 km above CMB, 2 calottes (4°W,29°N and 5°E,15°S) modelling the transformed pPv of different size (radius from 50 km to 500 km)

Reproduce characteristic of the 2007 anomalous signal (spatial fingerprints)
Generate a dynamic CMB topography of at least **12 cm**.

Conclusion

The 2007 Atlantic signal is **not well explained by surface water sources**. This leads us to propose that part of this gravity signal could **reflect deep mass redistributions** from the **Pv-pPv** phase transition and generate a **dynamic CMB topography** notable. We next propose to do the same study on the magnetic field.

References

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