Estimating common signal of the spatial gravity and magnetic field related to the Earth's core field variation

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Context

The ERC SYNERGY GRACEFUL project aims at characterizing time-variable processes occurring at the core-mantle boundary and in the fluid core using a synergy of satellite data of the geomagnetic field, gravity field and Earth rotation.
While the observed geomagnetic field is assumed to reflect the convective dynamics of the Earth's fluid outer core, there is a question if the core field variation could be reflected in the gravity field observation also.

Research objectives:
Finding the **relationship** between the magnetic field and gravity field in the **spatial** and **temporal** domain using various spectral analysis and source separation methods. These will be applied to updated data sets with an extended observation period.

Data and Methods

Data:
Data time span: **Nov 1992 – Dec 2020**

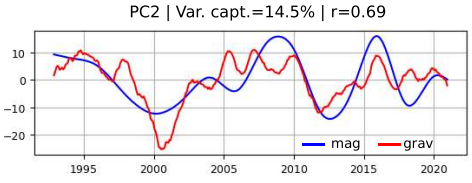
- Magnetic field of COV-OBS.x2 (Huder, et al., 2020)
  - Secular Acceleration (SA) of the magnetic field in the radial direction
- Gravity field of IGG-SLR (Löcher & Kusche, 2021)

Both fields are truncated at nmax=8 degree and the linear trend and seasonal signal are removed. The time series are standardized before being processed further.

Method:
Using **joint** Singular Value Decomposition (**SVD**), Principal Component Analysis (**PCA**) and Multivariate Singular Spectrum Analysis (**MSSA**) to separate distinct spatio-temporal patterns and to estimate common properties between two geopotential fields.

Results

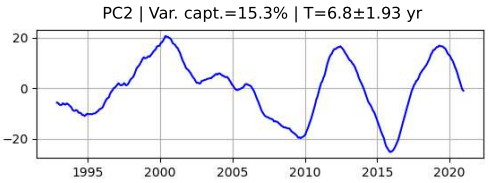
Joint SVD analysis



Spatial strucure of EOF-2 of joint SVD

- Joint SVD analysis can be used to study the coupling between 2 datasets.
- The dominant period of PC_{mag} = **~6.8±2.9 yr** and PC_{grav} = **~6.6±1.7 yr**
- The **variance captured of this signal is 14.5%** of the total variance
- The **correlation coefficient** between the obtained PCs of mag and grav is **0.69** (significant at the 95% level)

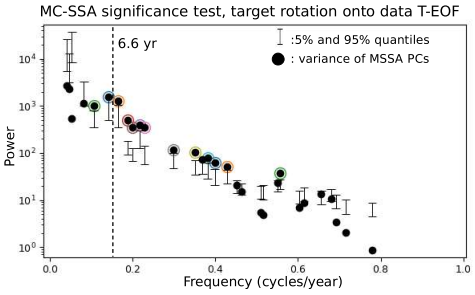
Joint PCA

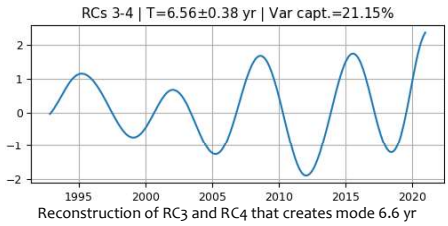


Spatial strucure of EOF-2 of joint PCA

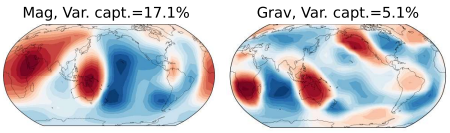
- PCA of joint data sets is used to find common signals of the combined field.
- **Oscillation period of ~6.8±1.9 yr** is obtained in PC2 from the joint PCA
- The **variance captured of this signal is 15.3%** of the total variance

Joint MSSA/Varimax





Reconstruction of RC3 and RC4 that creates mode 6.6 yr

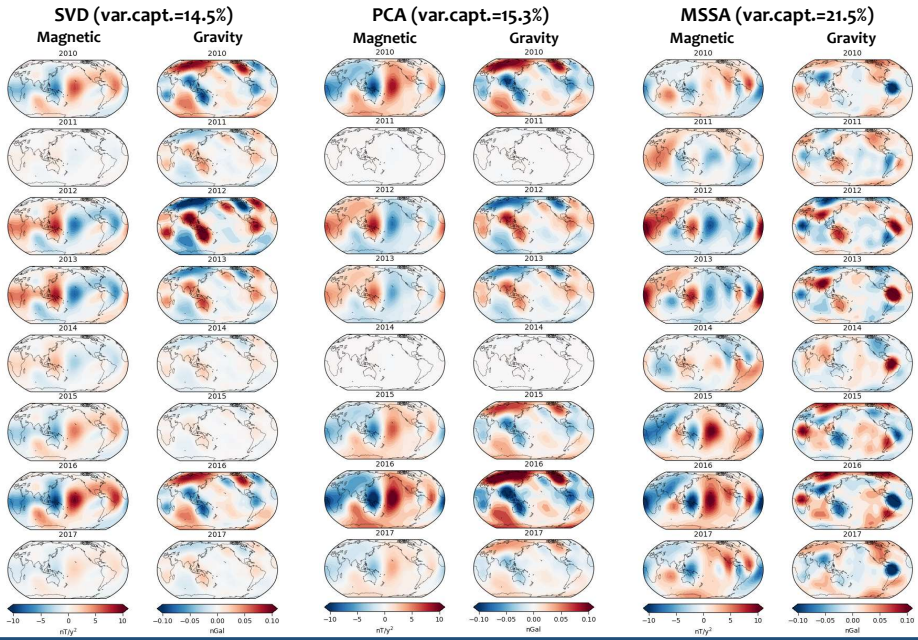


Spatial strucure of mode 6.6 yr

- (top) Spectral properties of joint datasets using MSSA with a window length of 9.2 yr (100 months). Monte Carlo test of MSSA modes with 1000 surrogates is used to test the data's eigenvalues against AR(1) process (Groth & Ghil, 2015).
- A pair of principal components (**RC3&4**) with an oscillation of **~6.6± 0.38 yr** is identified as **significant at the 95% level**.
- **21.15% of the total variance is captured** in this mode.

Spatial reconstruction of ~6-7 years signal

Annual geospatial patterns related to the ~6-7 years of oscillations, obtained from three methods used in this study.
The **6-7 yr oscillation signal is tested significant, found in three different methods** with **similar geospatial patterns**, hence **confirming the presence of this signal** in both magnetic and gravity field.



Discussion and Conclusion

- From three different methods, we detect a **common oscillation ~6-7 years** on the leading modes of the global temporal magnetic and gravity field with similar geospatial patterns, confirming the presence of the oscillation is above the noise level. This finding agrees with what has been presented in Mandea et al. (2012&2015).
- The **common area** where the ~6-7 yr oscillations present on the magnetic and gravity field occur around the **equator**.
- The physical interpretation of the temporal signals and their patterns is under investigation.
- Further study is envisaged to probe the relationship with the occurrence of geomagnetic jerks

Acknowledgments

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