Time variation of the lithospheric magnetic field between 2000 to 2017

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Abstract

The lithospheric field that is one of the main objectives of the ESA's mission Swarm is slowly varying in time due to the induced component. This variation is known to be small (and it is usually neglected in the lithospheric modelling) but recent advances in processing strategies and still growing amount of satellite data (longer time series) raise questions whether such an effect should be considered in the development of the lithospheric models, i.e. when exploiting data from missions like CHAMP and Swarm. We estimate this effect over the period of 17 years (since the launch of CHAMP) and discuss how the satellite measurements (the observable part of the spectrum) can be referenced to a single epoch. For this purpose, we have first inverted the magnetic field vector from CHAOS-6, which includes also Swarm data, into a vertically-integrated susceptibility map (with a remanent model removed). With the susceptibility distribution the core fields taken from CHAOS-6 can generate time varying lithospheric signal. Of course, the effect depends on the time span and the altitude considered, e.g., an altitude of 400 km and the span of 17 years can produce more than 0.5 nT with a peak-to-peak variation nearly 1 nT. The vertically-integrated quantities are found to be useful means to parameterize lithospheric time variations because the objective is to end up with data corrections at the satellite altitude. Studied is also the effect of the choice of the core field (employed in the inversion) on the lithospheric time variation. We show this choice is less important even for the core fields 20 years apart - however it is logical to select a core field that falls into the data span of themagnetic lithospheric model used.

References

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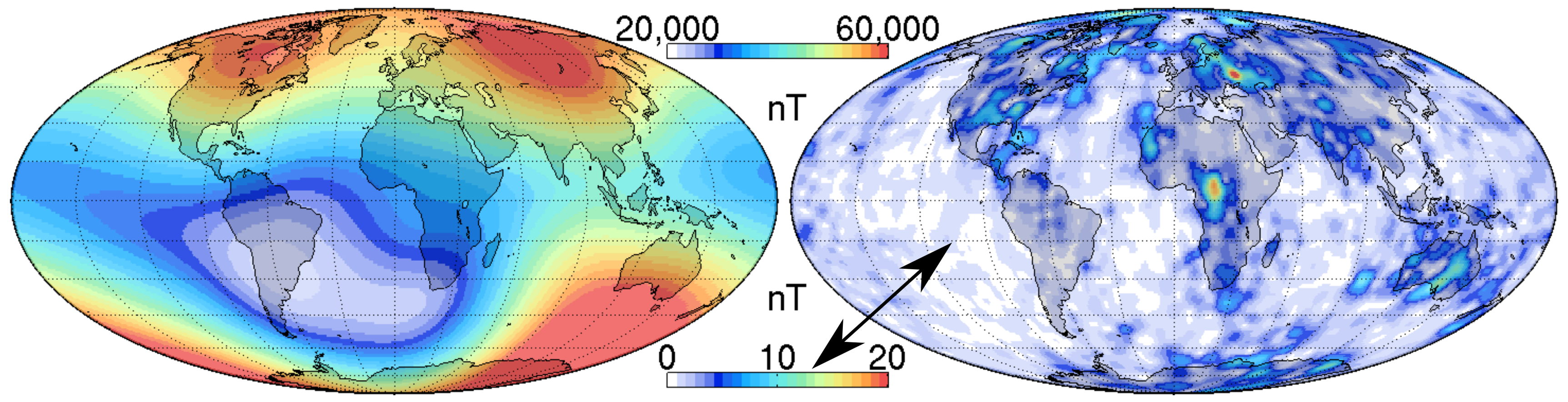
Motivation

* For how long time series of satellite magnetic data the induced lithospheric field can be considered constant (not varying in time)?
* How about exploting CHAMP data (from 2000) with Swarm data (ongoing)?

Data

CHAOS-6: both the time-dependent core fields (1-20) and the static lithospheric field (degrees 21-110)



Core signal in terms of |B| from CHAOS-6 over degrees 1–20 (left with the upper colorbar) and static |B| over degrees 21–120 calculated with V IS 2017 (right withthe bottom colorbar). The left and right panels are evaluated at r = 6, 371.2 km andr = 6, 771.2 km, respectively.

Approach

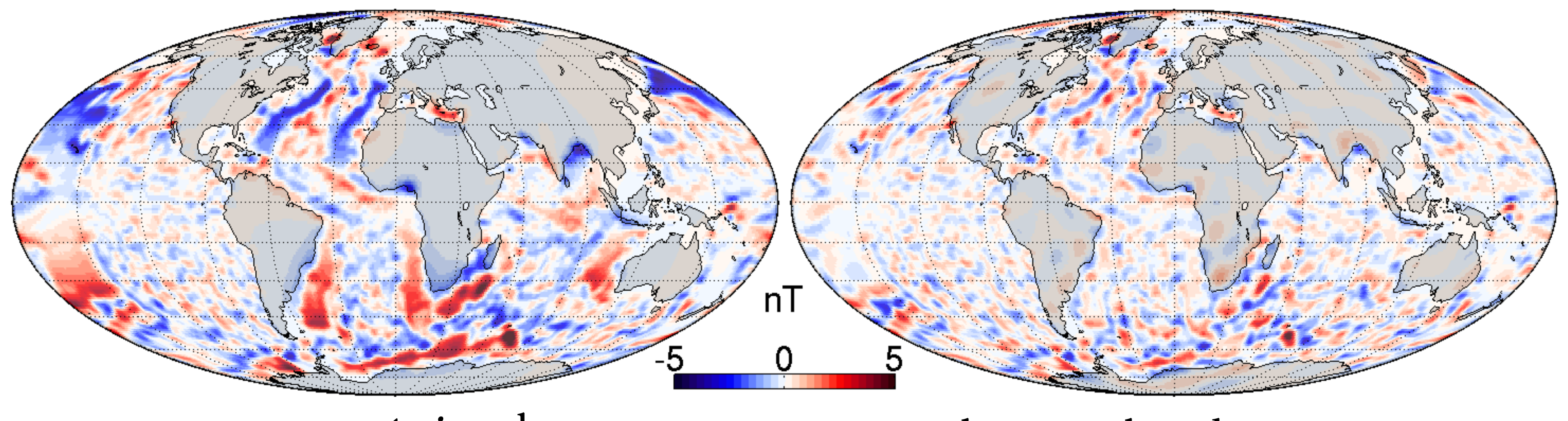
1. Consider a vertically-integrated approximation in which the lithospheric magnetization/susceptibility components are squeezed to thin shells

$$\phi_{\text{litho}}(t) = \underbrace{\frac{1}{4\pi}\int \left[\vec{B}^t_{\text{core}}\cdot\vec{G}\right] \text{VIS}\,\mathrm{d}S}_{\text{induced}} + \underbrace{\frac{1}{4\pi}\int \mu_0 I_0 \left[\vec{\nu}\cdot\vec{G}\right] \mathrm{d}S}_{\text{remanent}}$$

vertically-integrated susceptibility

2. Model remanent signal and subtract it from the lithospheric data (CHAOS-6 here)
3. Determine VIS (inverse problem)
4. Vary the core field with VIS => lithospheric time variation

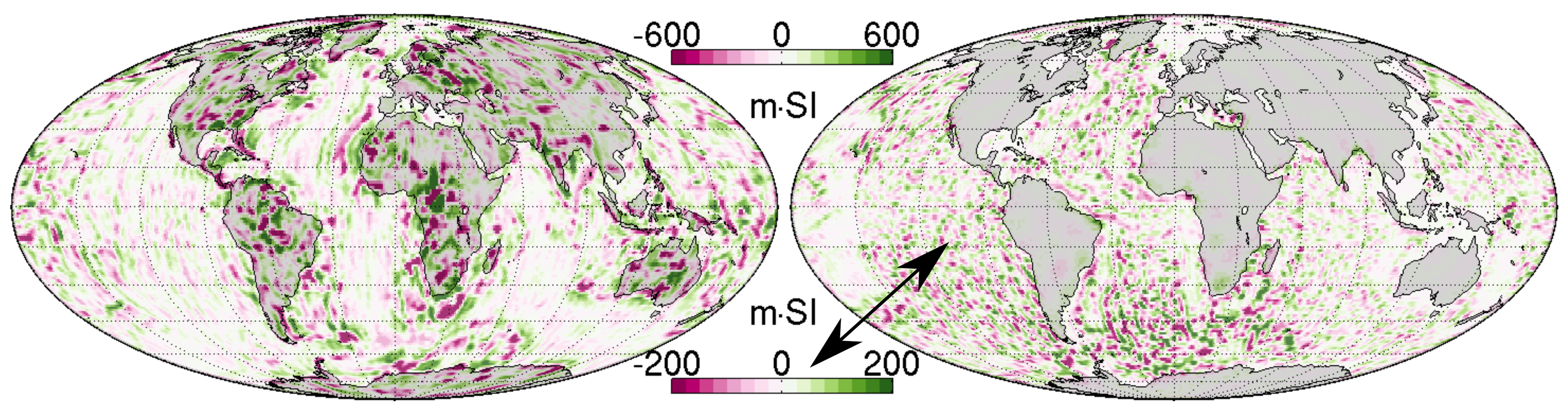
Modelling remanent signal



remanent signal full spectrum

the same but degrees 21-110

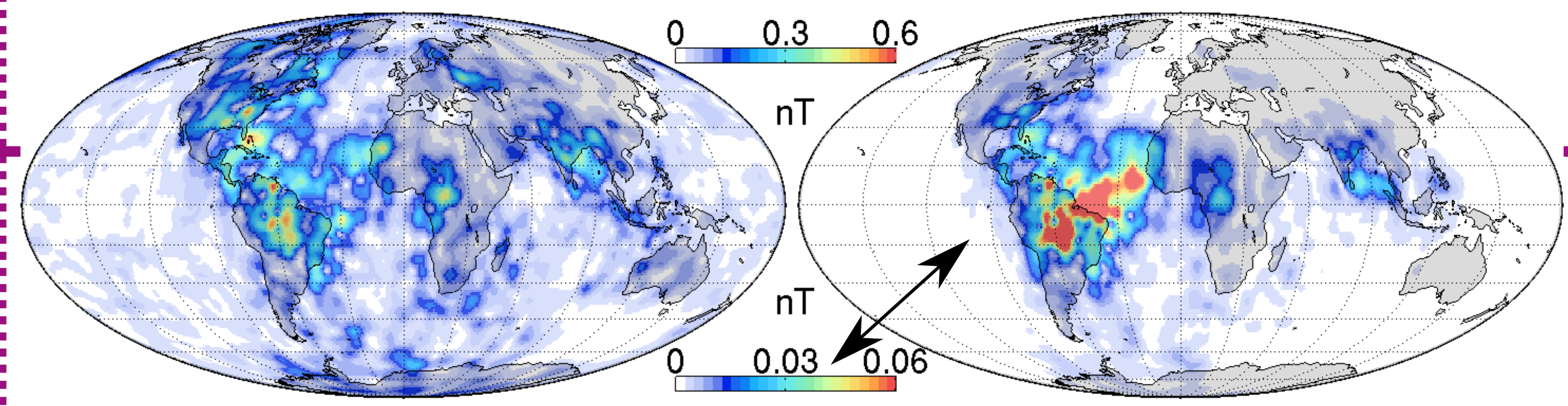
VIS determination & effect of the remanent model



final solution (VIS)

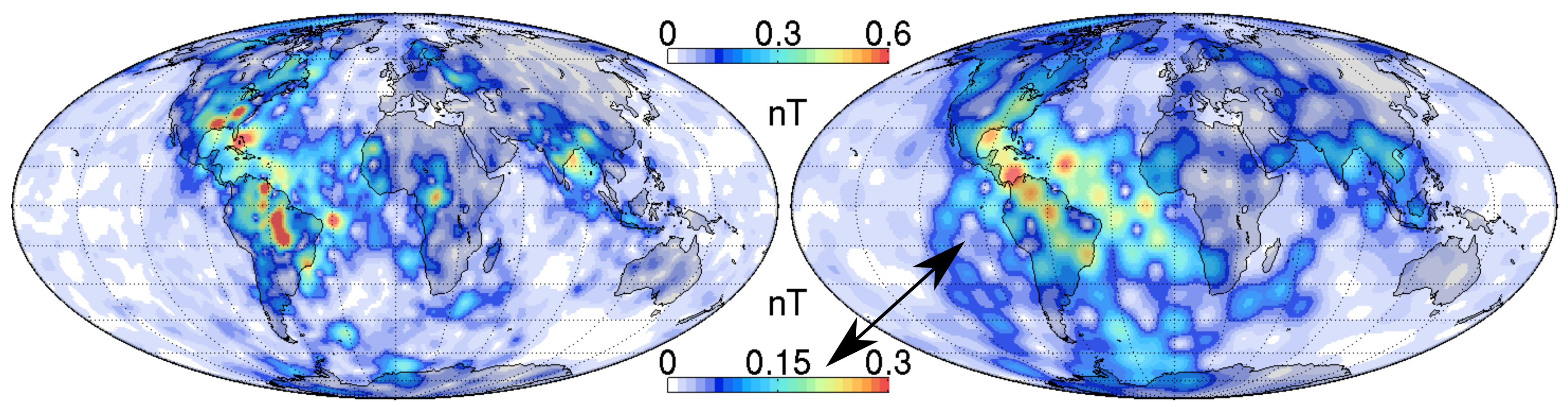
effect of remanent model on solution

Time variation in terms of intensity



time variation 2000-2017 over degrees 21-110

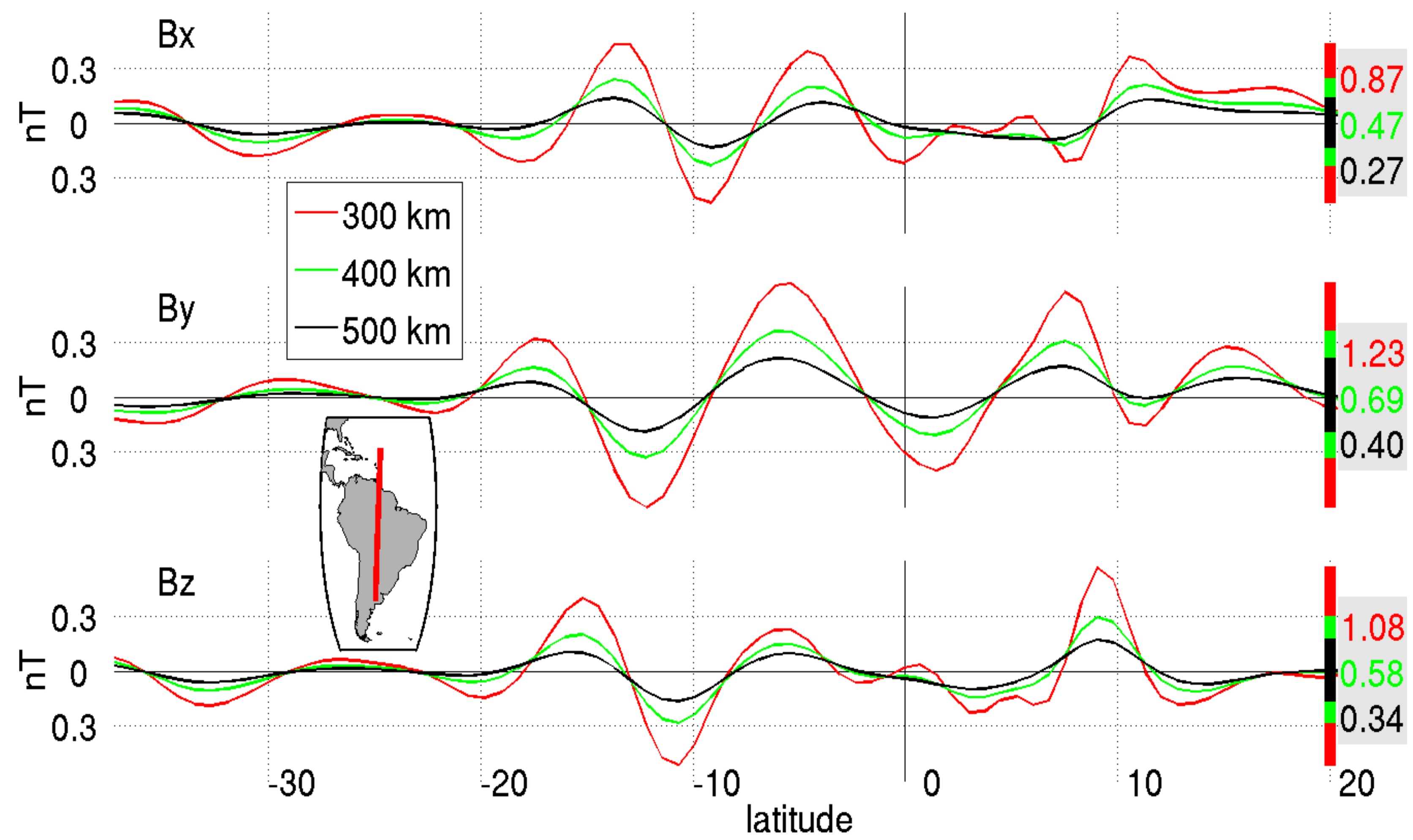
Effect of choice of the core field in the VIS inversion on the time variation



time variation 2000-2017 over degrees 16-90

Swarm model MLI_SHA_2C used for VIS determination

time variation 2000-2017 over degrees 16-20



Dependency of the time variation (vector) 2000-2017 along the satellite orbit on the height. Numbers in right show peak-to-peak values.

Summary

* Vertically-integrated susceptibility is handy means for modelling the crustal/lithospheric time variations (at satellite altitude)
* Time variations depend on the remanent model used and the target area - largest in the South America and over the Atlantic ocean
* Over 17 years the lithospheric time variation is small with peak-to-peak values up to 1 nT (height-dependent)
* However, 1 nT is at the level of magnetometry accuracy of instrumnets on Swarm spacecraft
* Determination of VIS slightly depends on the choice of the core field - effect contributes up to 5-10%
* Signal of degrees 16-20 of the time variation is much larger compared to the previous effect