DTU Space
National Space Institute

Core field accelerations from Swarm and ground observatory data

Christopher C. Finlay[1], Nils Olsen[1], Stavros Kotsiaros[1], Nicolas Gillet[2] & Lars Tøffner-Clausen[1]
1: DTU Space, Technical University of Denmark, 2: ISTerre, Université Grenoble 1, CNRS, Grenoble

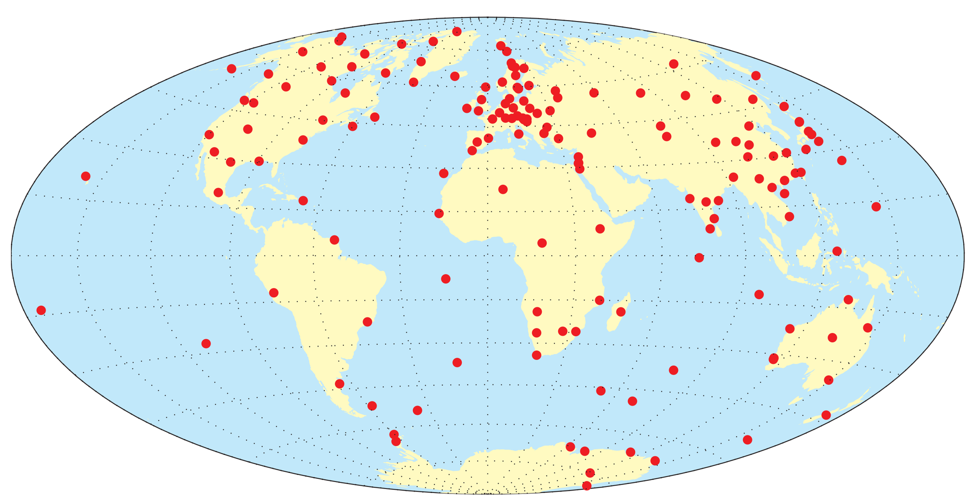
AGU
Fall Meeting 2015, San Francisco
Poster GP43C-1256

Summary

On sub-decadal timescales the evolution of the Earth's core-generated magnetic field is characterized by localized acceleration events, including oscillations. Our observational knowledge of these features, which are an important signature of the dynamics taking place within the core, is however still at a rudimentary stage. Here, we describe how observations from the *Swarm* multi-satellite mission, combined with data from ground observatories, can be used to study the most recent field accelerations.

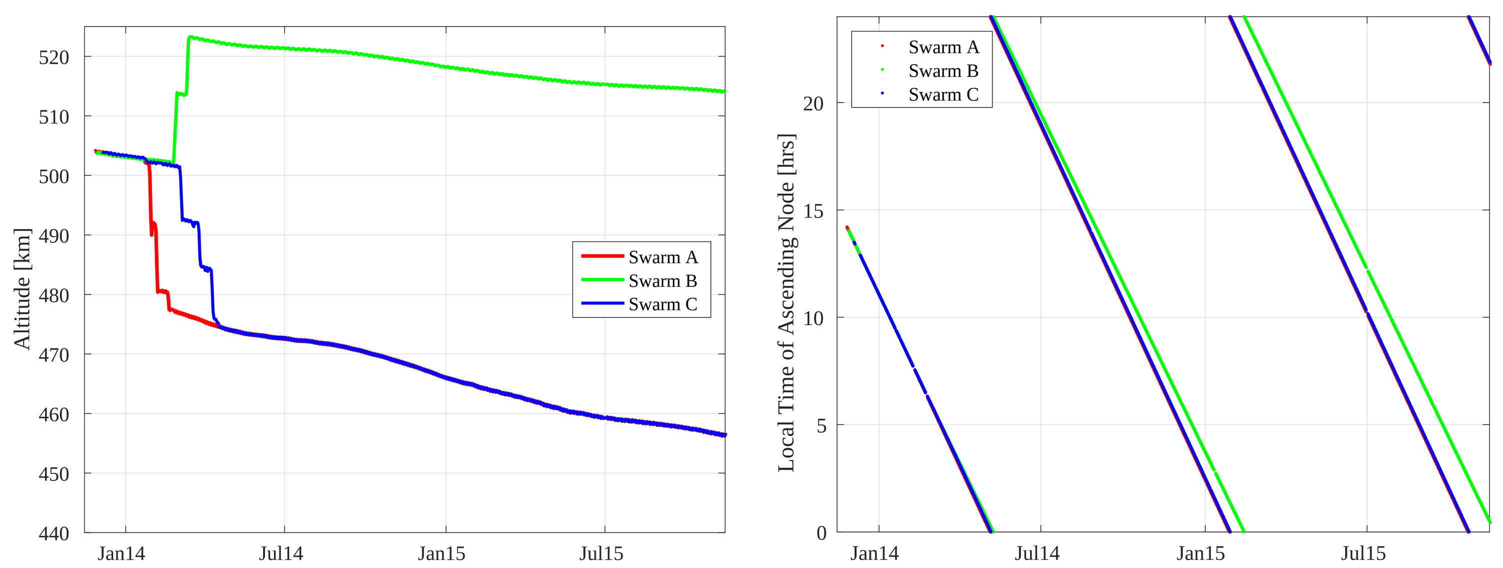
An updated version of the CHAOS time-dependent geomagnetic field model is presented, derived in part from the latest *Swarm* data. It accounts well for field accelerations observed at ground observatories during the past 16 years, including a new jerk event in 2014. In addition, it fits along-track and east-west field differences collected by *Swarm*. Resulting spectra of the field secular acceleration (SA) suggest that time-dependent information is available up to degree 15. Maps of the core surface SA with this resolution show intense features around 100E and at low latitudes in the Atlantic sector, especially at times of SA pulses. Furthermore, quasi-geostrophic core flow maps derived from the new field model show intense, fluctuating, equatorward flow around 100E as well as intriguing non-zonal, east-west, flow oscillations at low latitudes that appear to be related to the SA pulses.

Ground observatory network



Locations of ground observatories operating for at least 2 years between 1999 and 2015, from which revised monthly means are used to study rapid field changes.

Development of Swarm constellation



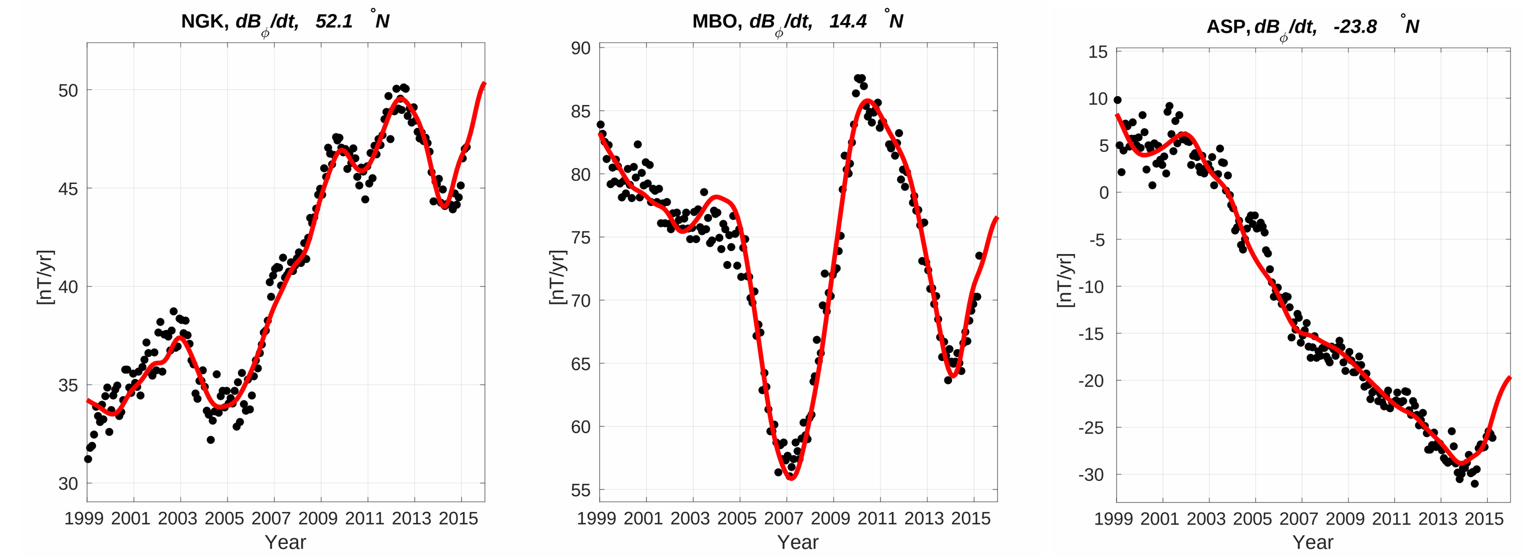
Evolution of Swarm constellation altitude (left) and local time (right) since launch in November 2013.

Data selection

- Quiet-time, night-side vector and scalar data, from Ørsted, CHAMP, SAC-C, *Swarm* and ground observatories as for CHAOS-5 (Finlay et al., 2015).
- No data from polar region when IMF B_z is positive
- Scalar field differences, along-track (CHAMP and *Swarm*) and east-west (*Swarm*), during dark and sunlit hours at all latitudes
- Vector field differences along-track (CHAMP and *Swarm*) and east-west (*Swarm*) at non-polar latitudes, only during dark times

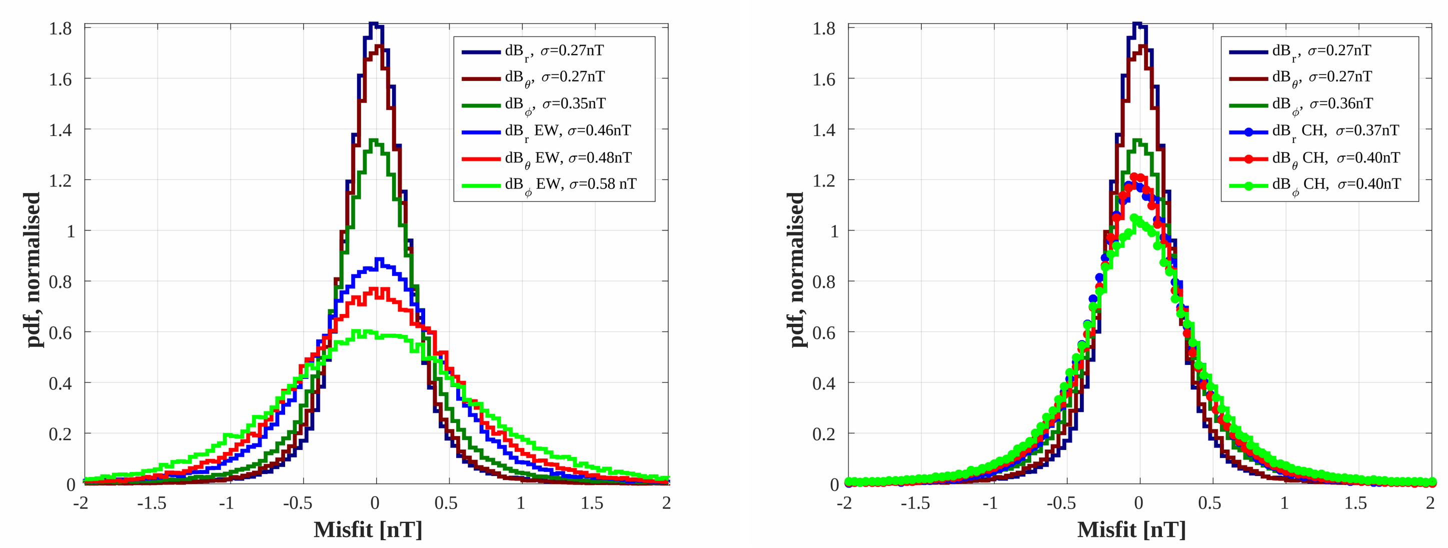
Results: latest CHAOS geomagnetic field model update

Fit to rapid secular variation changes at ground observatories



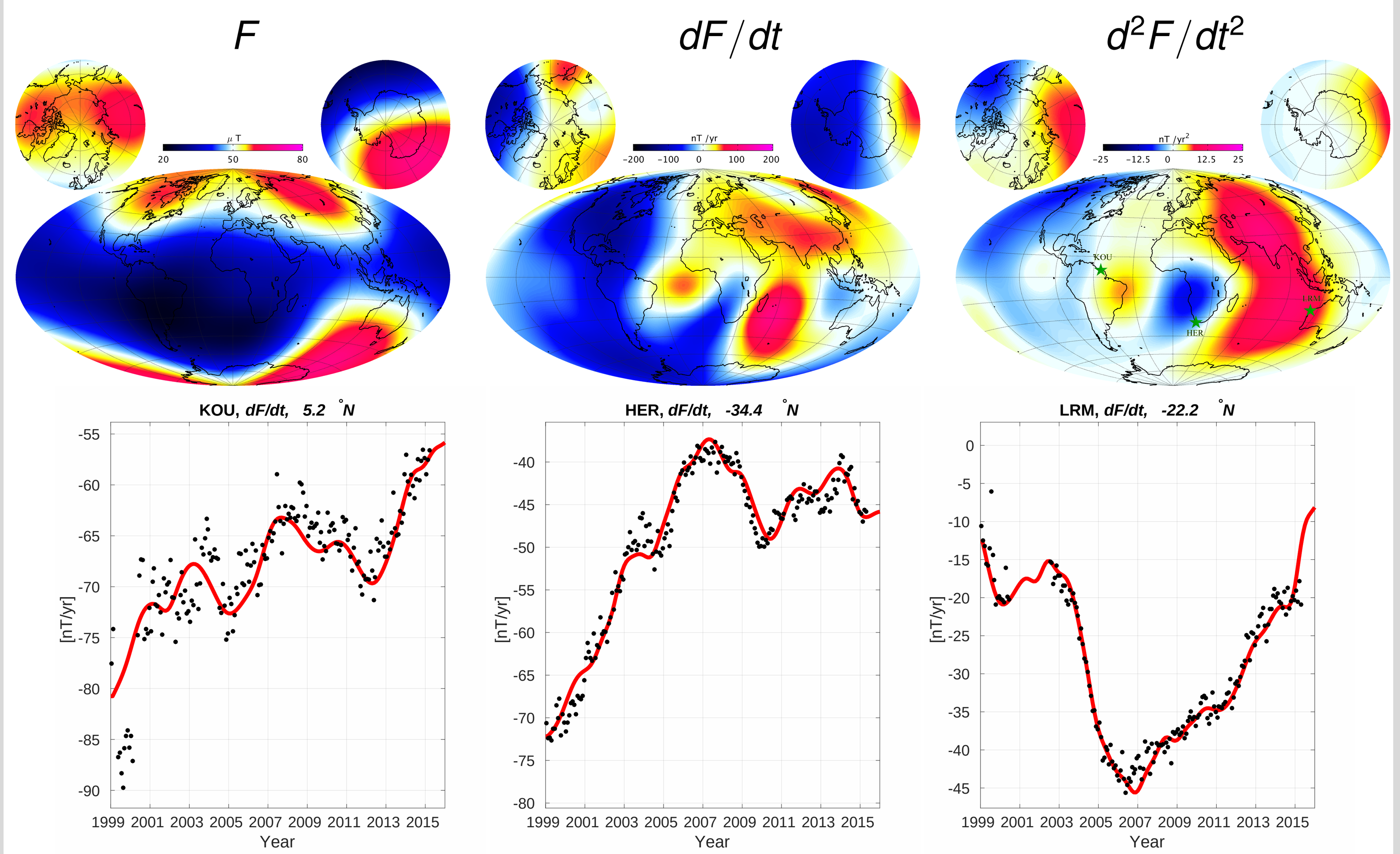
Black dots are annual differences of revised monthly means (c.f. Olsen et al., 2014) at Niemengk, Germany (left), M'Bour, Senegal (middle) and at Alice Springs, Austrialia (right). Red lines are predictions from the latest CHAOS field model. Note there has been a new *geomagnetic jerk* in 2014 - see also Pavon-Carrasco et al. (GP31A-1385).

Example residual distributions: Swarm and CHAMP field differences



Along-track and east-west vector field differences of Swarm data (left) are fit to within 0.3 nT and 0.5 nT respectively. Swarm along-track differences are fit approx 0.1nT better than CHAMP along-track differences, labelled CH in the above plot (right).

Field intensity: trends and accelerations at Earth's surface in 2015



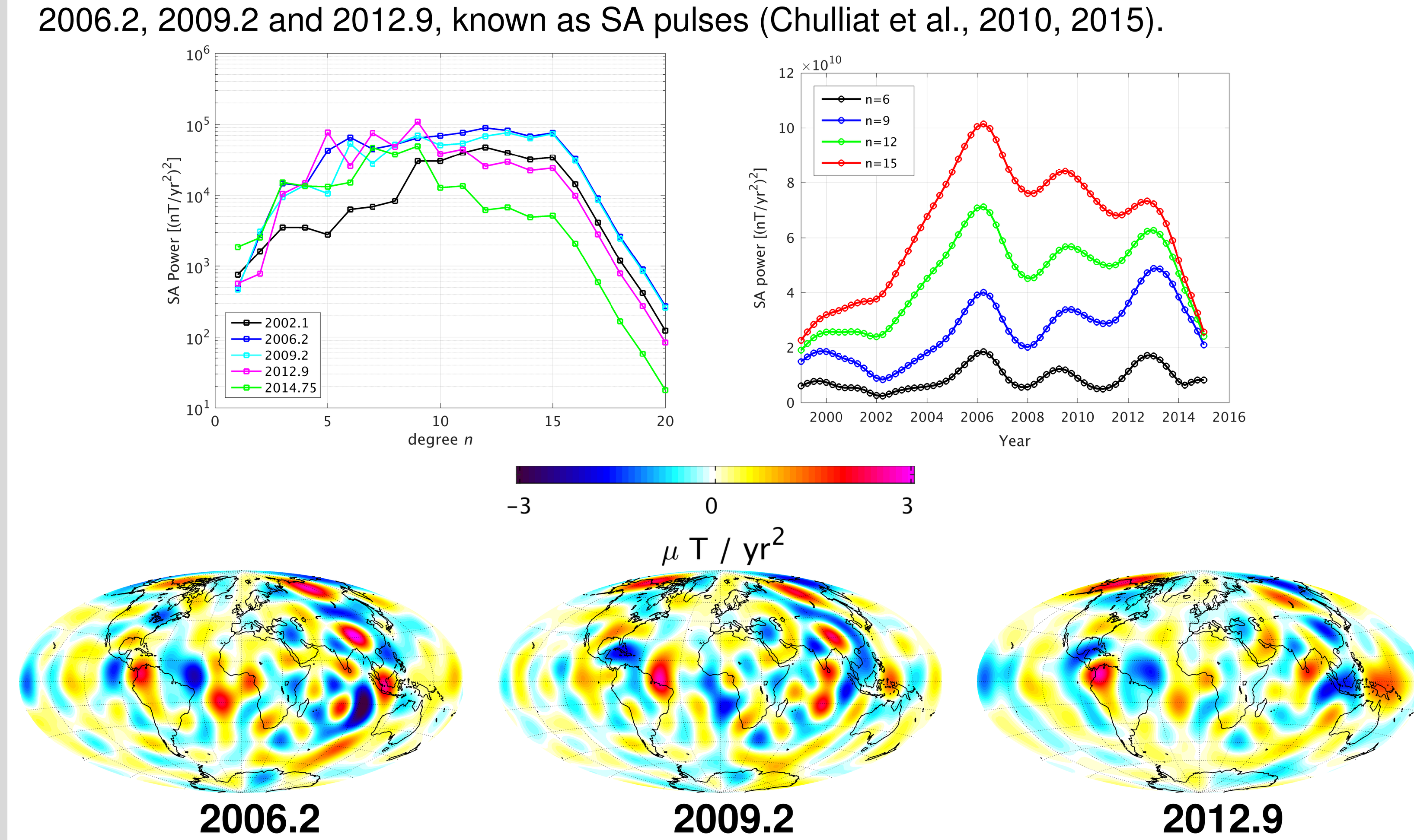
Field intensity variations derived from *Swarm* data agree with trends seen at ground observatories: KOU, French Guiana (left), HER, South Africa (middle) and LRM, Austrialia (right). There is presently a large positive acceleration in intensity in the eastern hemisphere.

References

Chulliat et al. (2010) Core field acceleration pulse as a common cause of the 2003 and 2007 geomagnetic jerks, *Geophys. Res. Lett.*, *37*, L07301.
Chulliat et al. (2015) Fast equatorial waves propagating at the top of the Earth's core, *Geophys. Res. Lett.*, *42*, 3321-3329.
Finlay et al., (2015) DTU candidate field models for IGRF-12 and the CHAOS-5 geomagnetic field model, *Earth, Planets, Space*, *67*, doi:10.1186/s40623-015-0274-3.
Gillet et al., (2015) Planetary gyre, time-dependent eddies, torsional waves, and equatorial jets at the Earth's core surface, *J. Geophys. Res.*, *120*, 3991-4013.
Olsen et al., (2014) The CHAOS-4 Geomagnetic Field Model, *Geophys. J. Int*, *197*, doi: 10.1093/gji/ggu033

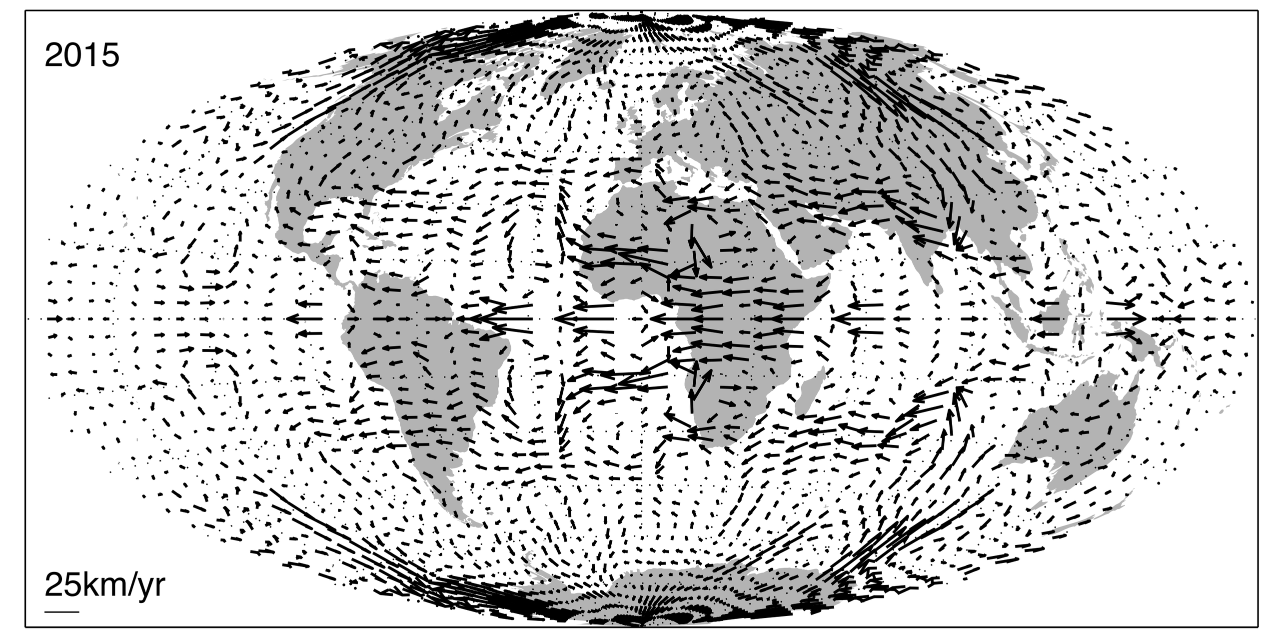
Pulses of acceleration at the core surface

Top left: Spherical harmonic power spectra of SA ($d^2\mathbf{B}/dt^2$) at the core surface for epochs 2002.1, 2006.2, 2009.2, 2012.9 and 2014.75; effect of regularization is visible above deg 15.
Top right: L2 norm of radial field SA (d^2B_r/dt^2), integrated over the core surface, vs time for difference spherical harmonic truncations of 6, 9, 12 and 15. Note the prominent peaks in 2006.2, 2009.2 and 2012.9, known as SA pulses (Chulliat et al., 2010, 2015).



Bottom: Estimated radial field SA (d^2B_r/dt^2), plotted to degree 15 at the core surface.

Preliminary map of quasi-geostrophic core flow in 2015



Time-dependent quasi-geostrophic (QG) core flow in 2015.0, to degree 28. This is an ensemble average flow (Gillet et al., 2015) deriving using the field to degree 13, SV to degree 16, and accounting for unresolved field to degree 30. Frozen-flux and AR-1 time-correlation are assumed. Note:

- Time-dependent, non-axisymmetric, east-west flow oscillations at low latitudes
- Intense meridional (equatorward) flow around longitude 100E
- A planetary-scale gyre is present, but is somewhat obscured by smaller scale eddies

Conclusions

- An updated version of the CHAOS field model (soon to be released as CHAOS-6) now spans 1999-2015
- It provides a good description of *Swarm* and CHAMP field difference data, while also following rapid field changes at ground observatories
- Field intensity is presently undergoing a strong positive acceleration in the eastern hemisphere
- Field acceleration shows time variations up to spherical harmonic degree 15 and can perhaps be mapped to this level at the core surface
- Maps of the quasi-geostrophic core flow in 2015, derived in part from *Swarm* data, displays intense equatorward flow in the eastern hemisphere and non-axisymmetric, east-west, flow oscillations at low latitudes