British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Geomagnetic jerks during the Swarm era and impact on IGRF-12

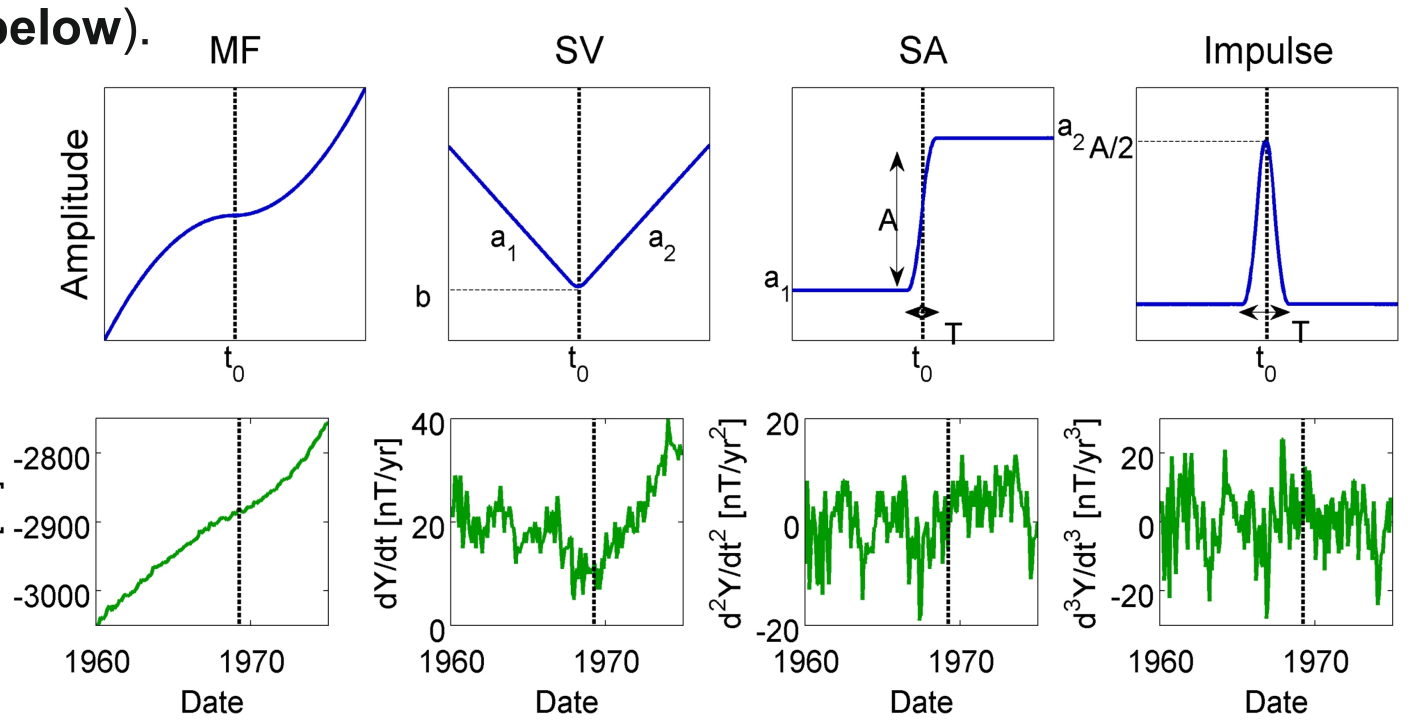
William Brown [wb@bgs.ac.uk], Susan Macmillan
British Geological Survey, The Lyell Centre, Edinburgh, United Kingdom.

The timely provision of geomagnetic observations as part of the ESA Swarm mission means analysis and modelling can be conducted rapidly and kept up-to-date in a manner not possible before. Observations from each of the three satellites in the Swarm constellation at 1Hz are available within 4 days and hourly mean ground observatory measurements (AUX_OBS_2) are updated every 3 months by the British Geological Survey (BGS). This makes it possible to study recent changes of the magnetic field. Here we investigate variations known as geomagnetic jerks, during the Swarm era.

Given that jerks represent (currently) unpredictable changes in the internal geomagnetic field, we ask what impact they might have on the accuracy of the International Geomagnetic Reference Field model (IGRF). The 12th generation IGRF was updated using observations up to mid-2014 and provides a snapshot of the geomagnetic field at 2015 and predictions until 2020.

1. Geomagnetic Jerks

The Earth's magnetic field is generated by the motion of electrically conductive, iron-rich fluid in the outer core. As this field passes through the mantle and crust it is filtered to give the generally large-scale and slowly varying field we observe at the surface and in space. The most rapid known features we observe in the core field are on the timescale of months – jerks (**Fig. below**).



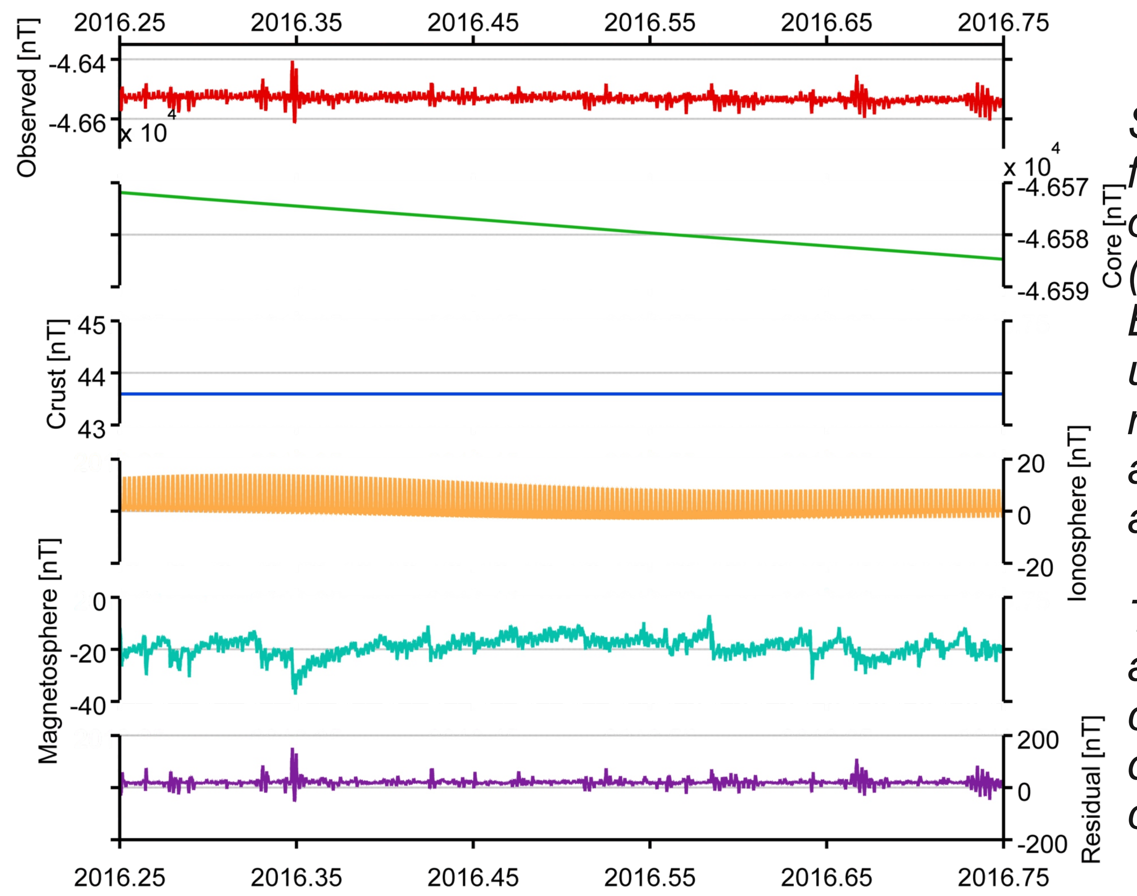
*Idealised form of a jerk (at dashed line) (top) and in observations from Eskdalemuir, Scotland (bottom). The **main field (MF)**, **secular variation (SV)**, **secular acceleration (SA)** and third time derivative (impulse) are shown.*

2. Data and Modelling

We use vector and scalar geomagnetic observations from Swarm and ground observatories. Geomagnetic observations capture many sources of magnetic fields (**Fig. top middle**) – in order to study the core field, we require a field model of the internal and external magnetic sources.

First we use a selection of data during periods of "quiet" magnetic activity. Second we use modelling techniques designed to distinguish field sources by physicsl, spatial, and temporal characteristics.

Here we use the MEME model of the core field derived by BGS using Swarm and AUX_OBS_2 [1] observatory data up to March 2016.



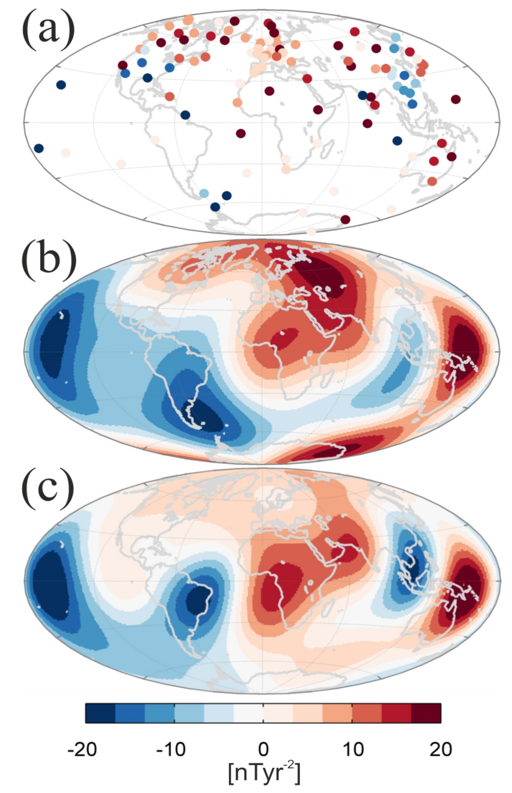
Separated field sources from an example observatory time series (radial component, Eskdalemuir, Scotland) using a BGS MEME field model created from Swarm and AUX_OBS_2 data, CM4 and CHAOS-6.

The range of magnitudes and time scales of features captured in geomagnetic data can be seen when by comparing the field sources.

3. Jerks During Swarm

Torta *et al.* (2015) [4] were first to point out the presence of a jerk around 2014 in observatory data which detailed SV to March 2015. Strong SA was seen particularly in the South Atlantic/Africa region, extending up into Europe and the North-Western Atlantic, and also in Australasia.

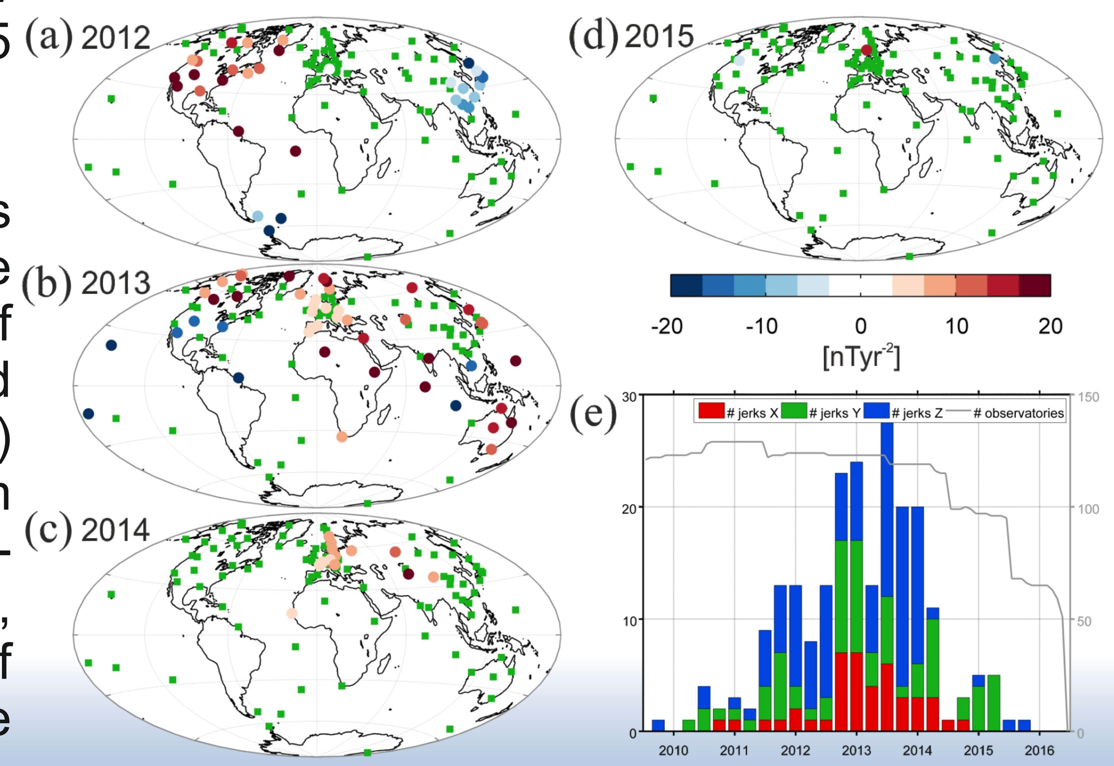
With AUX_OBS_2 data detailing SV to March 2016, we reassess the extent of the 2014 jerk and more recent developments (**Figs. right, below, top right**) using the technique of Brown *et al.* (2013) [5].



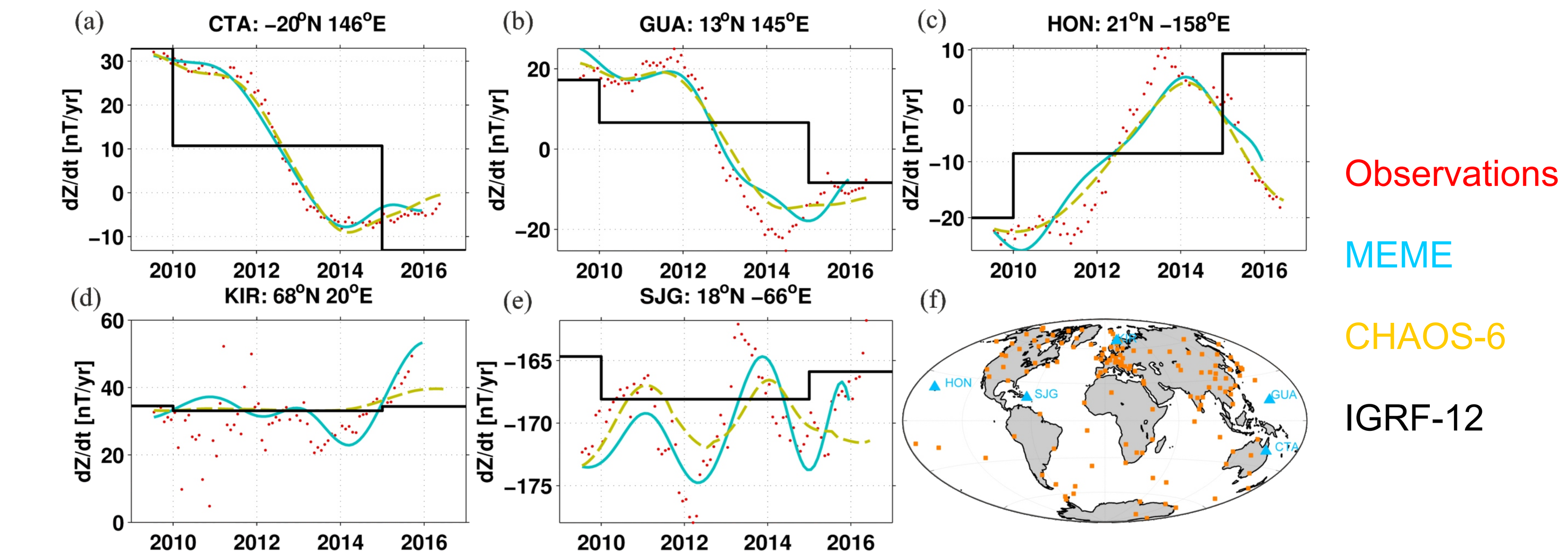
Detected (top) and modelled (middle) 2014 jerk amplitudes in Z, with estimated ΔSA from CHAOS-6 model (bottom).

In general we can confirm the presence of widespread jerks across much of the globe from late 2013 through to early 2015 (**Fig. below**). This includes jerks in some regions (e.g. Alaska) not highlighted by Torta *et al.* (2015) which appear in only the most recent observations, and in some locations, a new successive jerk in 2015 (**Figs. below, top right**).

The significance of this is seen by comparing the capture and prediction of SV by MEME (Swarm and obs. data to March 2016) and IGRF-12 [6] (Swarm and obs. data to mid-2014) (**Fig. top right**), although the limitations of spline end effects must be acknowledged.



Detected jerk amplitudes in Z (ΔSA) mapped by year, and in histogram in time by field component.

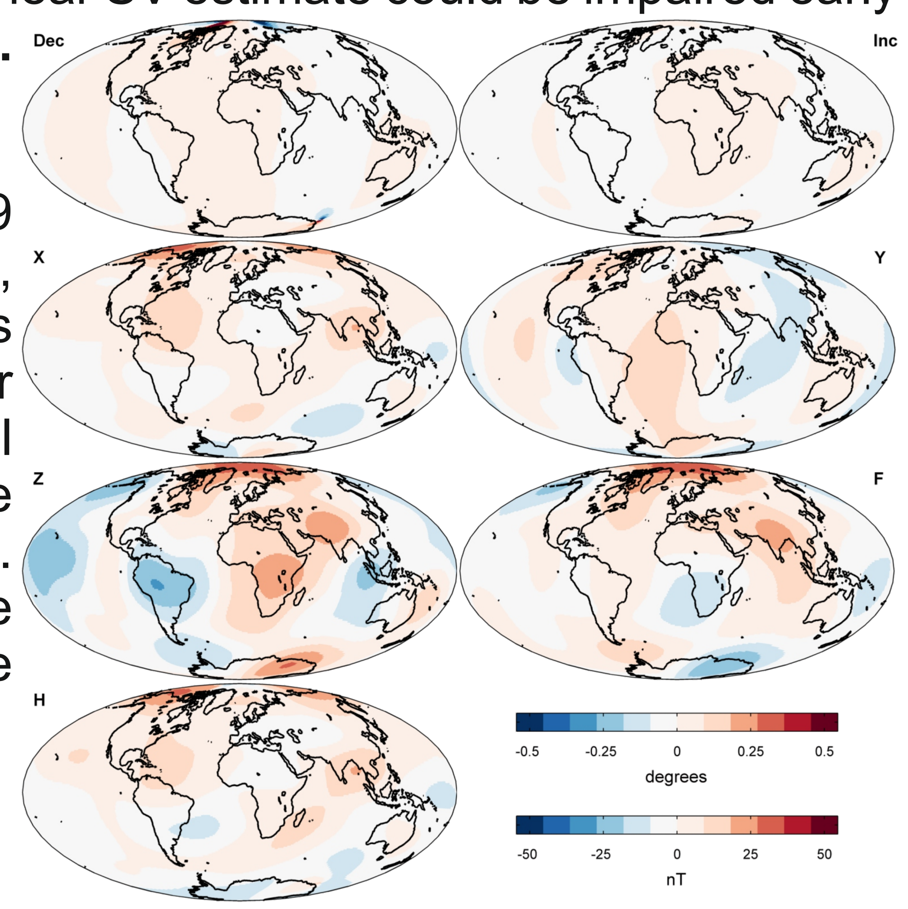


SV at selected observatories indicates that jerks occurred into 2015, further illustrating the unpredictable and rapid nature of such SV.

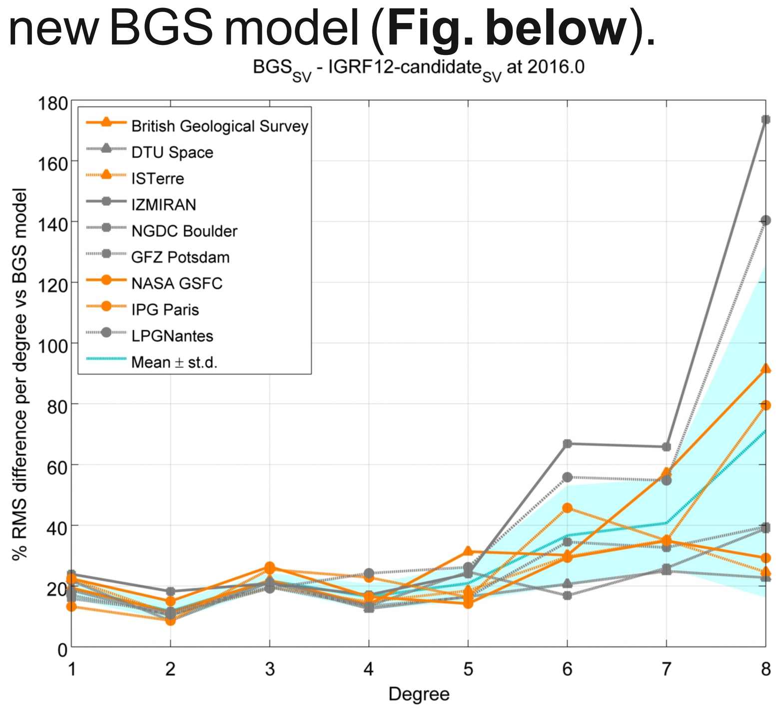
4. IGRF SV Predictions

The presence of unpredictable, non-linear SV such as jerks so close to the release of IGRF-12 means that its linear SV estimate could be impaired early in its 5 year life span to 2020 (**Fig. right**).

IGRF-12 SV is derived from 9 candidate models. Of these models, 4 use physical processes such as forward projection of core flow or data assimilation to a dynamo model to forecast the SV while the remaining 5 use linear extrapolation. We compare here the performance of each as of 2016.0 relative to the new BGS model (**Fig. below**).



Difference maps at 2016.0 between MEME, built with Oersted to March 2016, and IGRF-12 prediction from 2014.5 to 2016.0.



Percentage difference per degree for the IGRF-12 SV candidates and MEME, at 2016.0. Models with physically derived SV predictions in orange, mathematically extrapolated SV models in grey.

Our analysis indicates there is no clear discrepancy between the accuracy of physical and non-physical SV predictions, at least between 2015 and 2016. This is likely due to the occurrence of jerks immediately after the production of IGRF-12 and illustrates the difficulty of forecasting the geomagnetic field until such phenomena are better understood.

Acknowledgements and References

The Swarm mission and data centre are operated by ESA, CHAMP data is provided by GFZ, Oersted data by DTU. Many institutes and agencies are involved in the operation of geomagnetic observatories around the world. INTERMAGNET and the World Data Centre (WDC) for Geomagnetism (Edinburgh) assist in dissemination of these data from which AUX_OBS_2 are produced by BGS for ESA. The work here not have been produced without the efforts of all of these bodies.

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