Detecting Waves in Core Surface Flow Acceleration Derived from 26 Years of Secular Variation

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Background

• Since 1999: (Almost) continuous satellite monitoring of the magnetic field
• Satellites provide much improved spatio-temporal coverage
• Allows us to see rapid field changes world wide
• Allowed seeing signatures of hydromagnetic waves

Aim: See signatures of such waves in the core flow acceleration
Determining a flow from secular variation data

• Invert the radial magnetic induction equation, assuming frozen flux (negligible diffusion)

$$\dot{B}_r = -\nabla H \cdot (uB_r)$$

• Regularization in time and space: assume flow large scale, only little change in time

• Minimise second spatial derivative of the flow

• Minimise flow acceleration

• Main field treated as known, specified by the CHAOS-7 model
The Secular Variation Data

- Combination of Swarm data with other satellite and ground observatory data
- Satellite data is represented by geomagnetic virtual observatories
- Higher quality data chosen when overlapping
The resultant flow
Flow-predicted secular variation

Scatter dots: Observations, Dashed line: Flow predictions
Green: Ørsted, Blue: CHAMP, Orange: CryoSat-2, Red: Swarm
Calculating flow acceleration

\[ a_t = u_t - u_{t-1} \]

- No smoothing involved
- Temporal damping minimised the acceleration
  - Any acceleration seen must be included to fit the flows to the data
Azimuthal Acceleration Profile

2019.33

2019.67

2020.00

2020.33

2020.67

2021.00

$\dot{u}_\phi$ [km yr$^{-2}$]
Time-longitude section

1 – Left sloping features of alternating sign
2 – Weaker, right sloping features

Features travel westward at velocities on the order of 1700 km/yr
Power spectral density

2D Fourier Transform

Westward propagation

Eastward propagation
Spatial variations

- Focusing at low latitudes
- One order of magnitude smaller at 20°N
Repeat analysis on overlapping intervals of length 10 years.
Noisier start, but afterwards the signal persists through time.
Inverted a 26-year SV dataset of GVO satellite and ground observations for core surface flows.

Flow acceleration shows systematic periodic features travelling at velocities on the order of 1700 km/yr.

PSD shows both eastward and westward travelling modes at spatial wavenumbers -5, -2, and 2, with periods of ~6 and ~7 years.

Features are focussed on low latitudes.

Features appear robust in time.