THE UNIVERSITY of EDINBURGH

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**

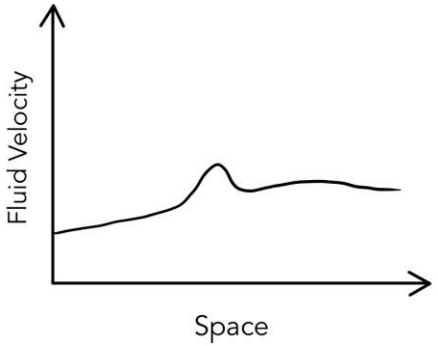
Aim: See signatures of such waves in the core flow acceleration

Determining a flow from secular variation data

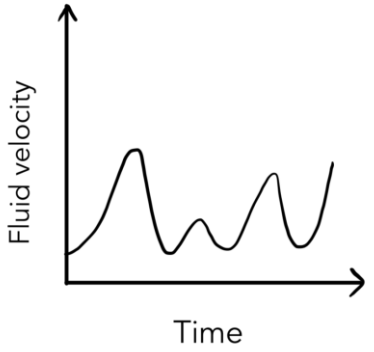
- Invert the radial magnetic induction equation, assuming frozen flux (negligible diffusion)

$$\dot{B}_r = -\nabla_H \cdot (\boldsymbol{u} B_r)$$

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



Minimise second spatial derivative of the flow

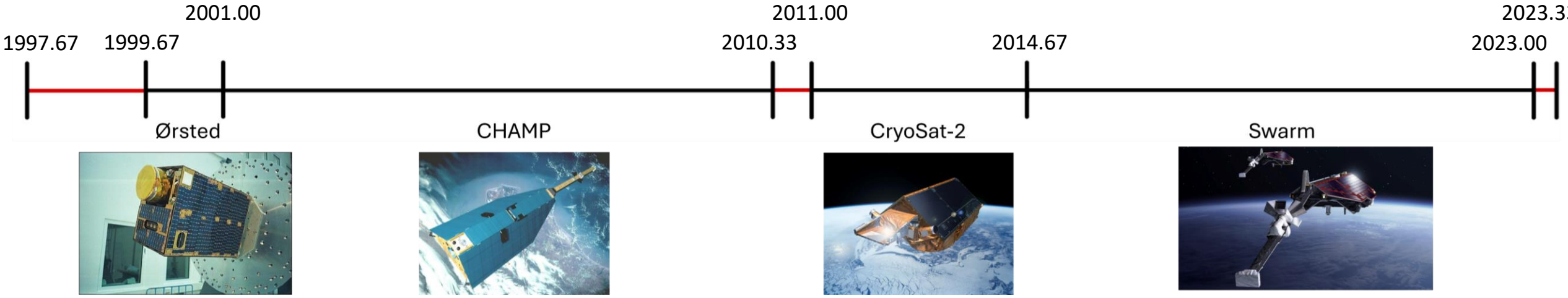


Minimise flow acceleration

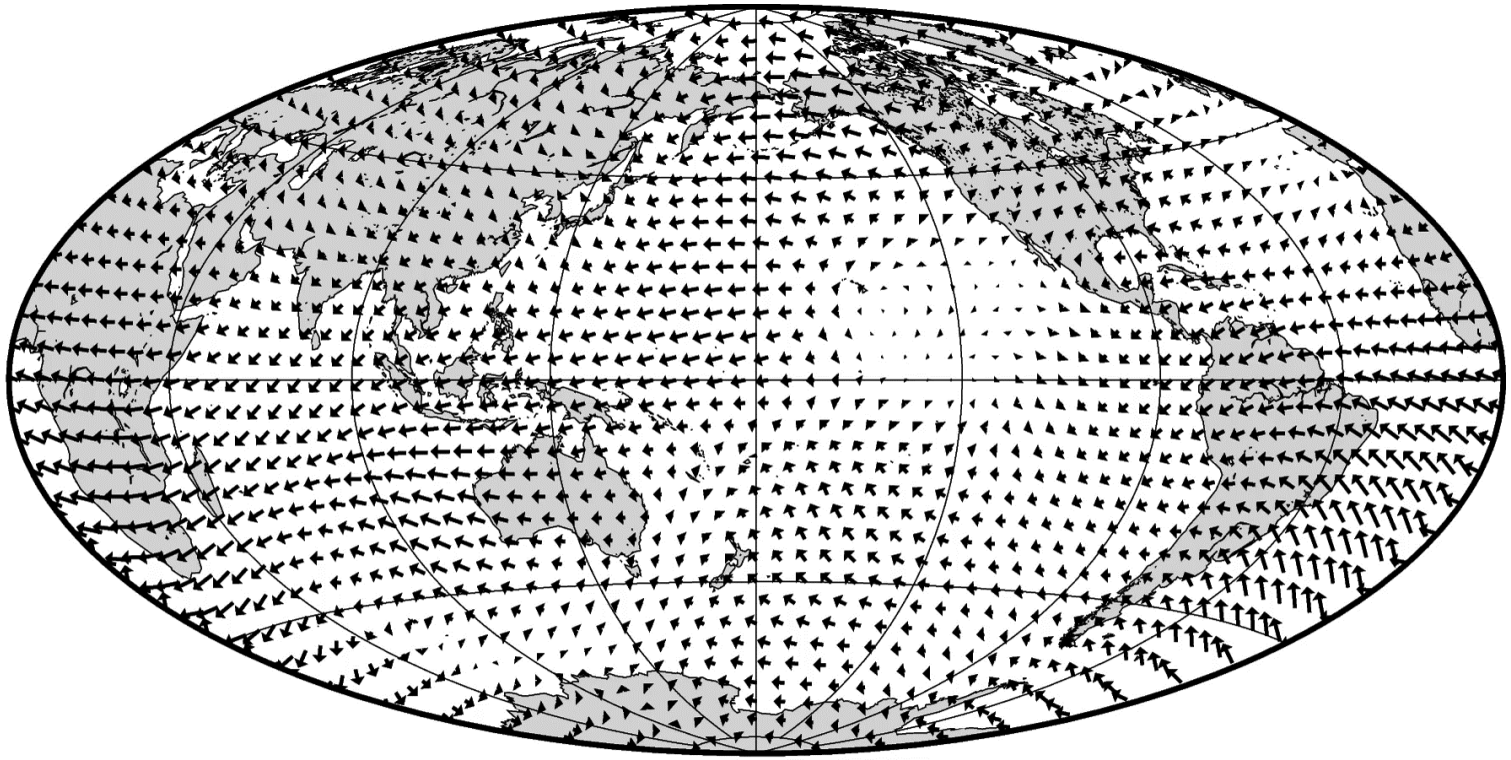
- Main field treated as known, specified by the CHAOS-7 model

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

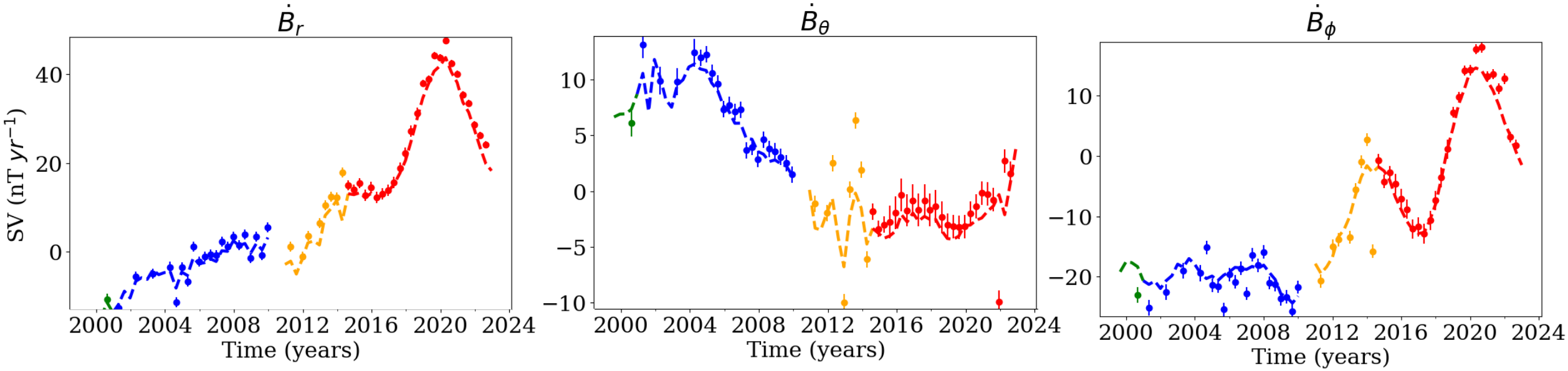


The resultant flow



(Note: Continents for reference only)

Flow-predicted secular variation



Scatter dots: Observations, Dashed line: Flow predictions

Green: Ørsted, Blue: CHAMP, Orange: CryoSat-2, Red: Swarm

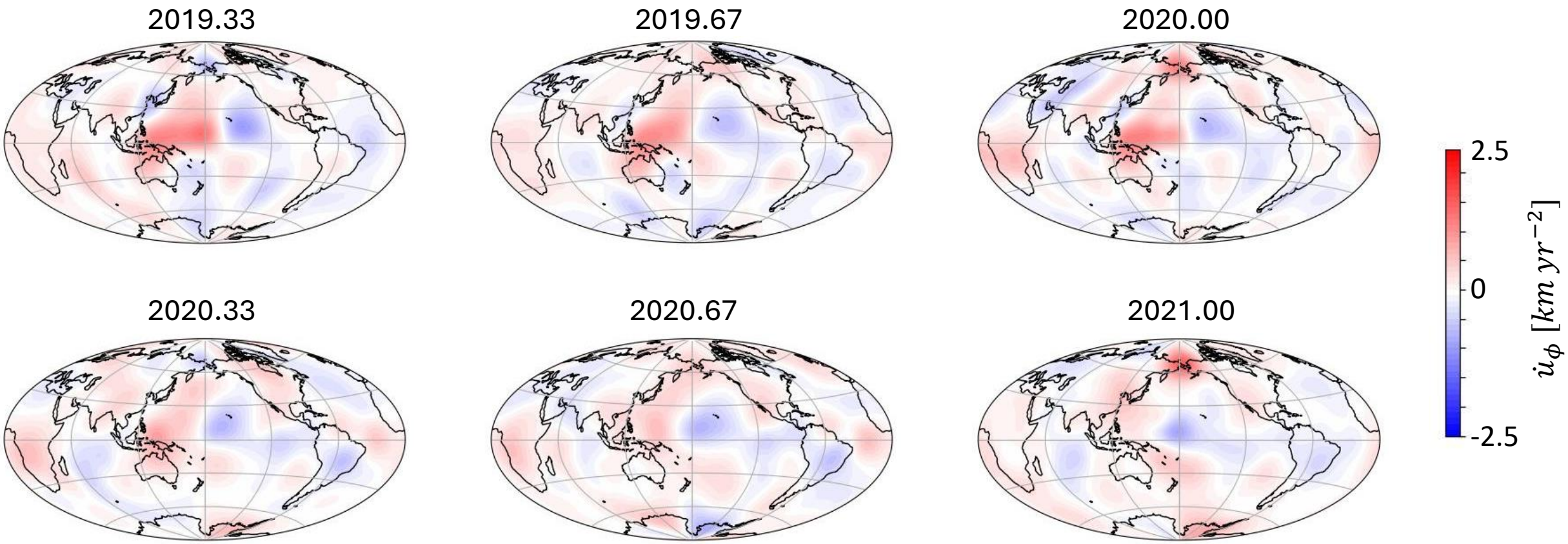
Calculating flow acceleration

$$a_t = u_t - u_{t-1}$$

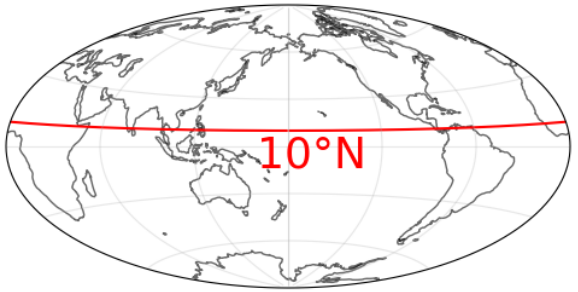
Acceleration at time t Velocity at time t Velocity at time $t-1$

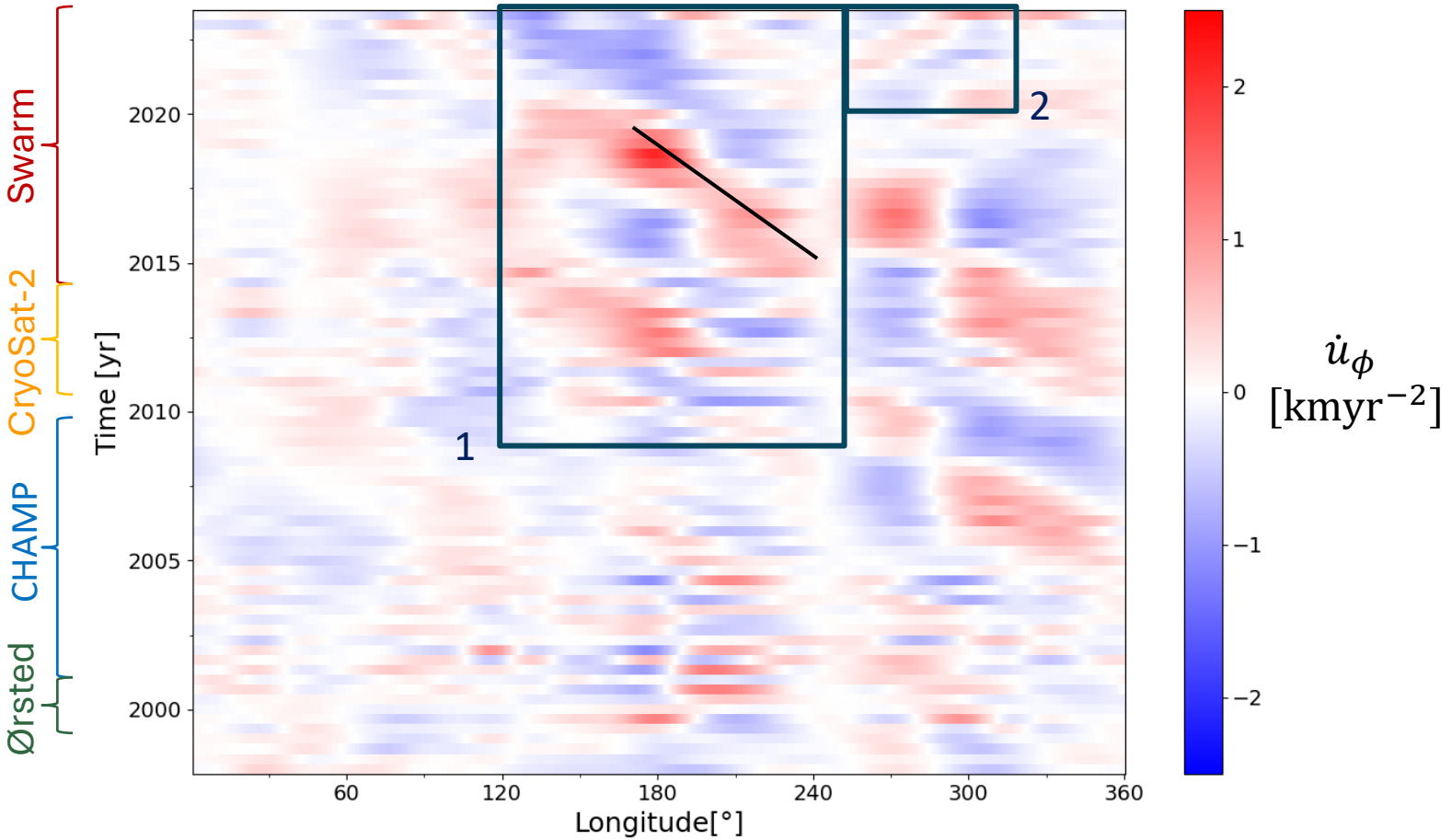
- No smoothing involved
- Temporal damping minimised the acceleration
  - Any acceleration seen must be included to fit the flows to the data

Azimuthal Acceleration Profile



Time-longitude section



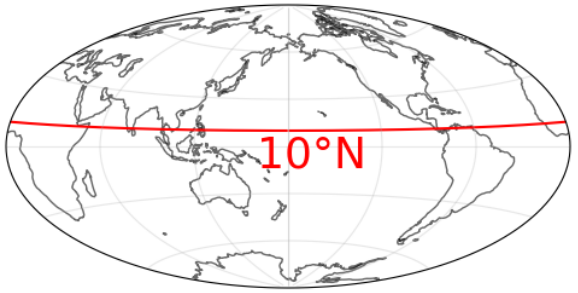


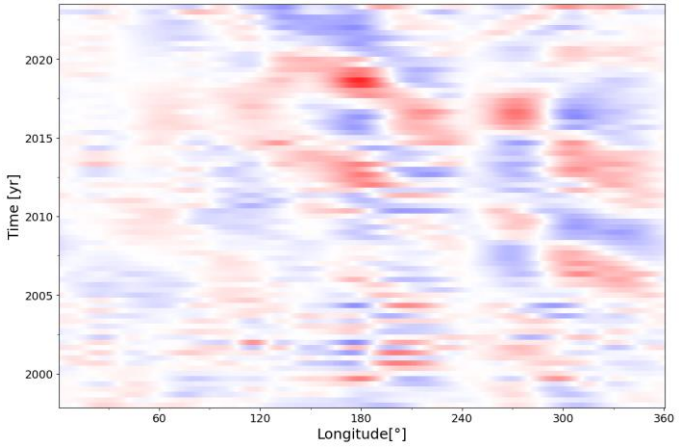
1 – Left sloping features of alternating sign

2 – Weaker, right sloping features

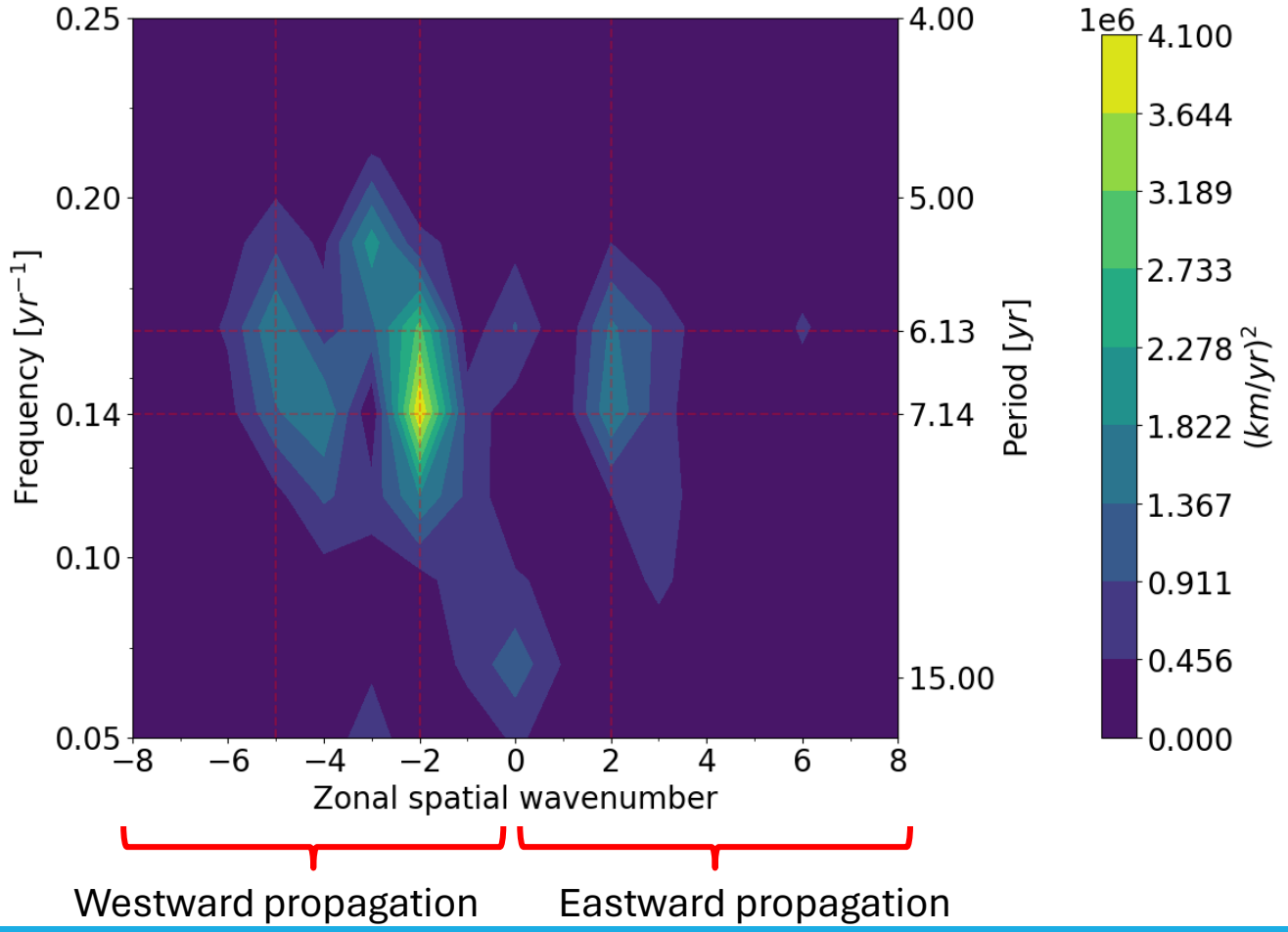
Features travel westward at velocities on the order of 1700km/yr

Power spectral density

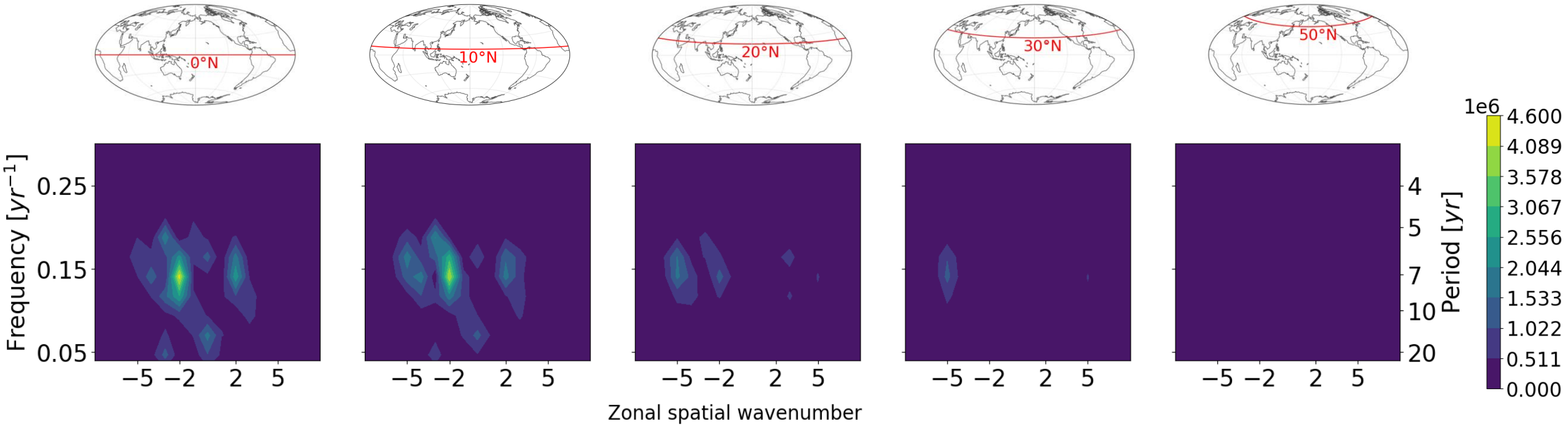




2D Fourier Transform

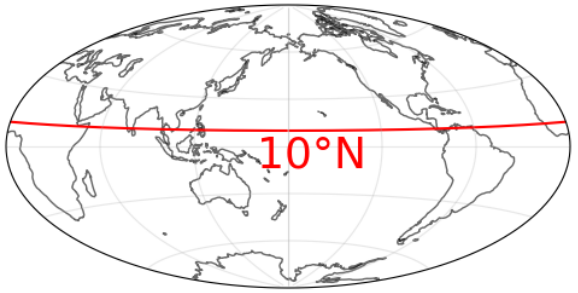


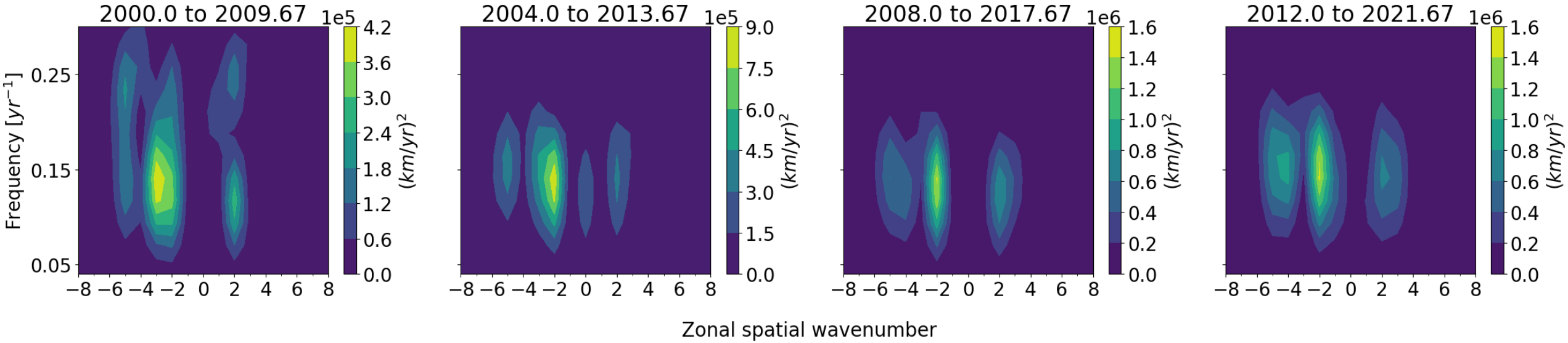
Spatial variations



- Focusing at low latitudes
- One order of magnitude smaller at 20°N

Time variations





- Repeat analysis on overlapping intervals of length 10 years
- Noisier start, but afterwards the signal persists through time

Summary

- Inverted a 26-year SV dataset of GVO satellite and ground observations for core surface flows.
- Flow acceleration shows systematic periodic features travelling at velocites on the order of 1700km/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.