living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

Observed sub-decadal changes in Earth's core magnetic field

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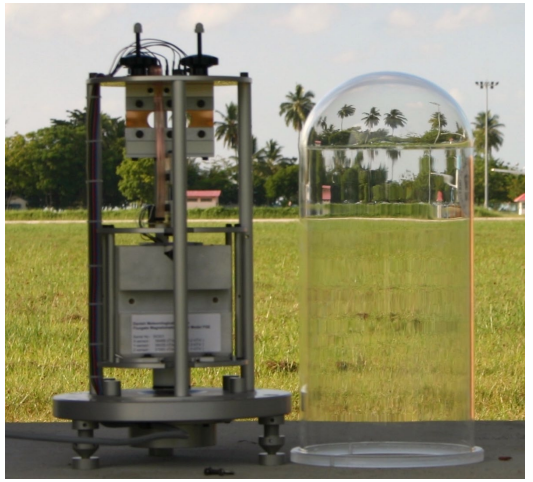
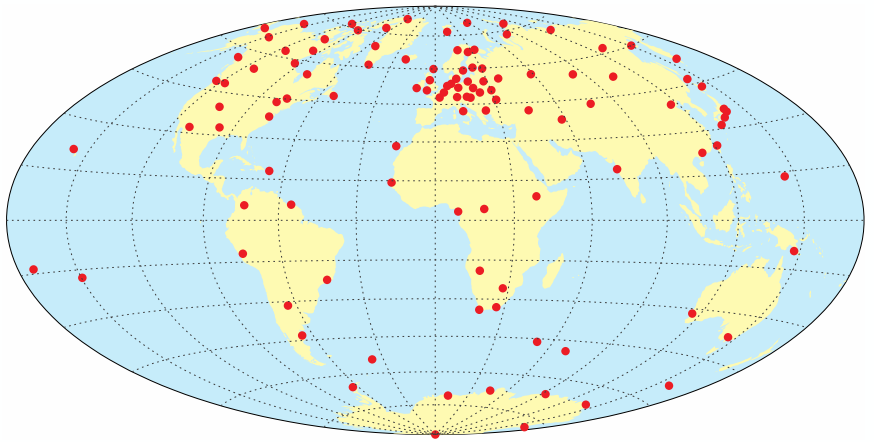
National Space Institute

Mon 23rd May 2022

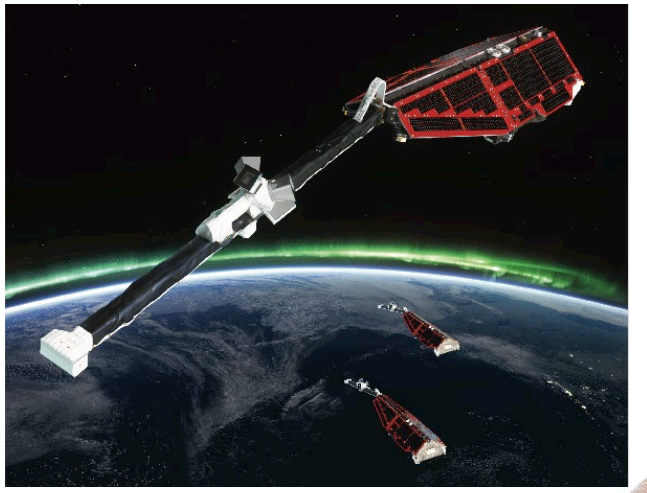
Measurements of Earth's core-generated magnetic field

Ground observatories

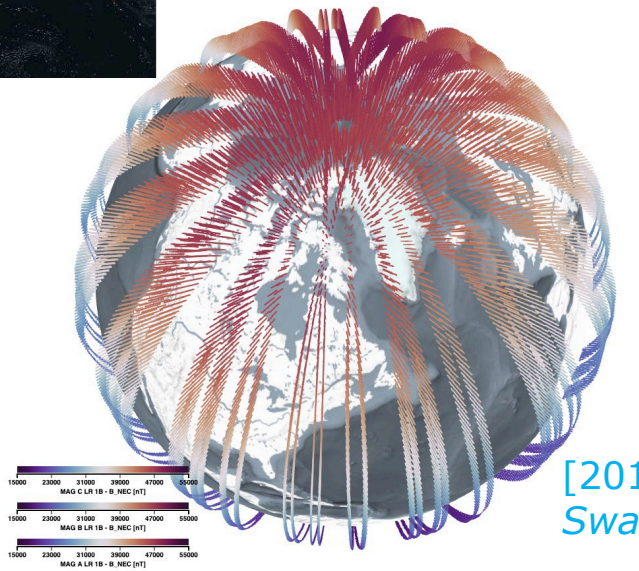




Magnetic survey satellites



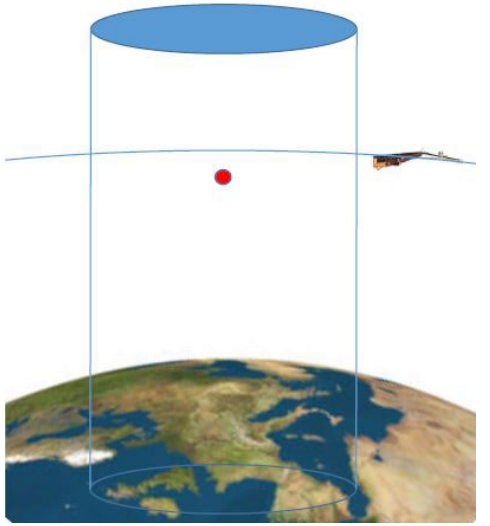
(*Swarm* since Nov 2013)



[2018.10.19 *Swarm* VirES]

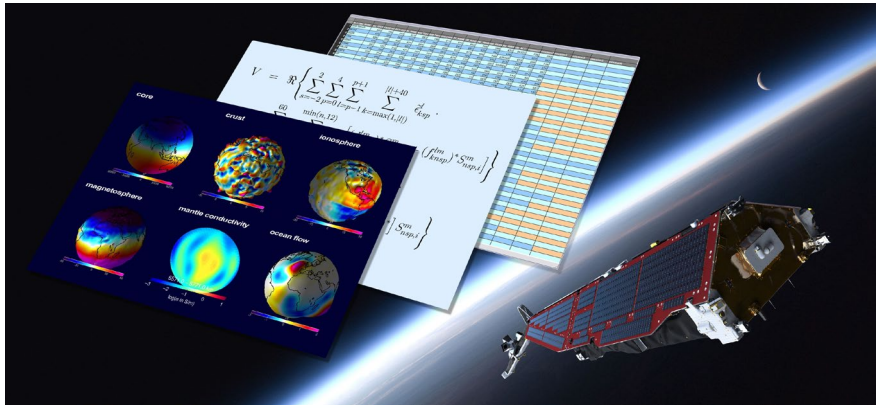
Derived data products/models

1. **Ground Observatory Revised Monthly Means**



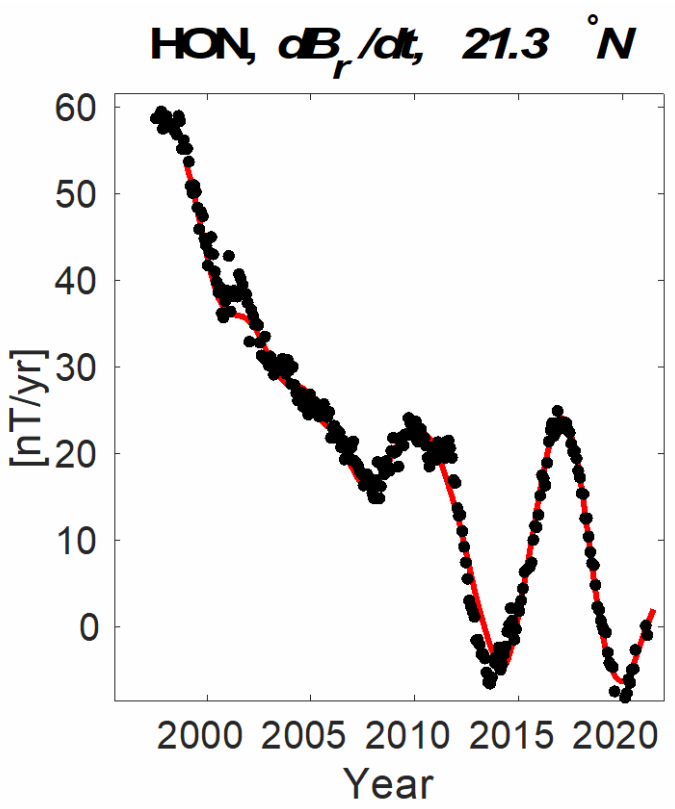
2. **Geomagnetic Virtual Observatories (GVOs)**
   - Local estimates derived from nearby satellite data
   - 300 sites at satellite altitude
   - Times series of Secular Variation (SV)
   - Convenient for data assimilation

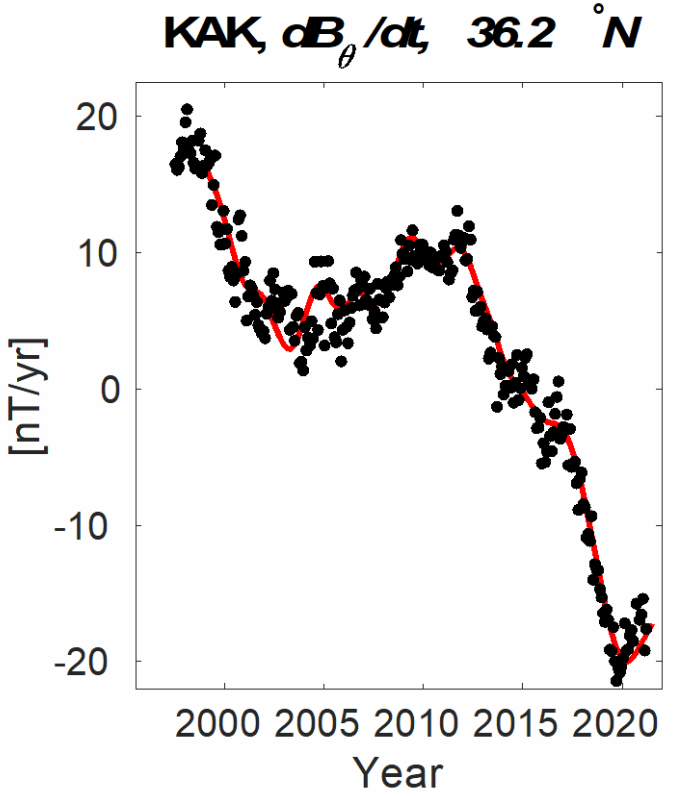
3. **Geomagnetic field models**
   - Global, spherical harmonics
   - Allows source separation
   - Downward continuation to CMB

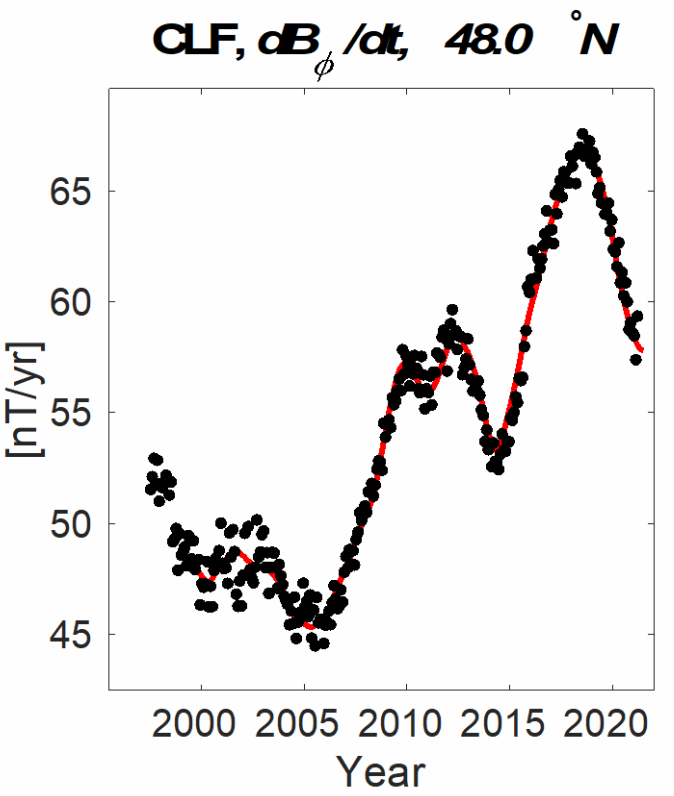


e.g. CHAOS field model [Olsen et al. 2006; Finlay et al. 2020]

Sub-decadal field change : Secular variation (SV) dynamics at ground observatories



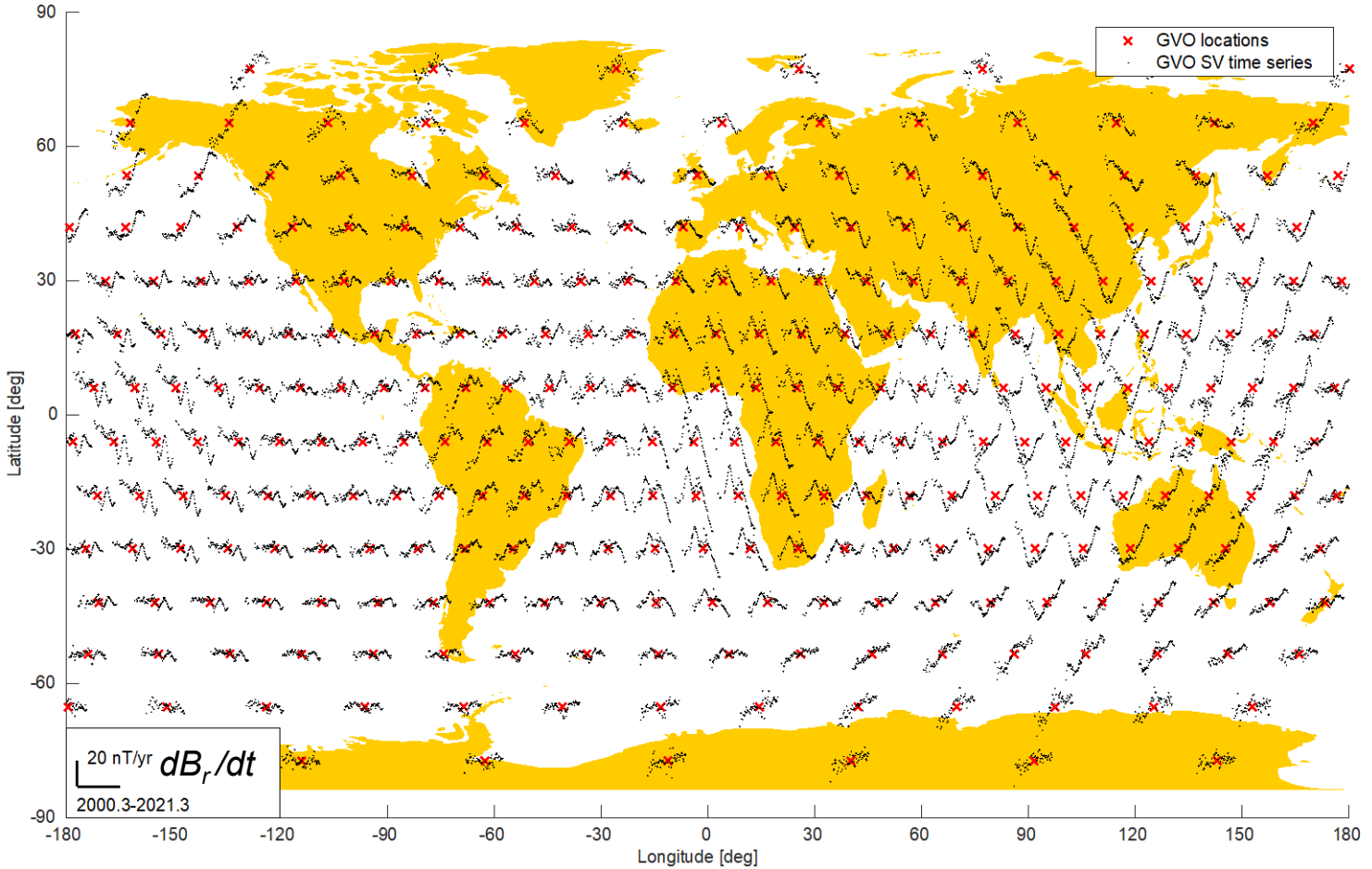




- Wave-like oscillations in the radial field since 2008 at Honolulu in the central Pacific
- Sharp change in slope of SV around 2017 in the Pacific – well covered by *Swarm* data
- Another obvious change in slope of SV in 2020 but in the Eastward field component in Europe

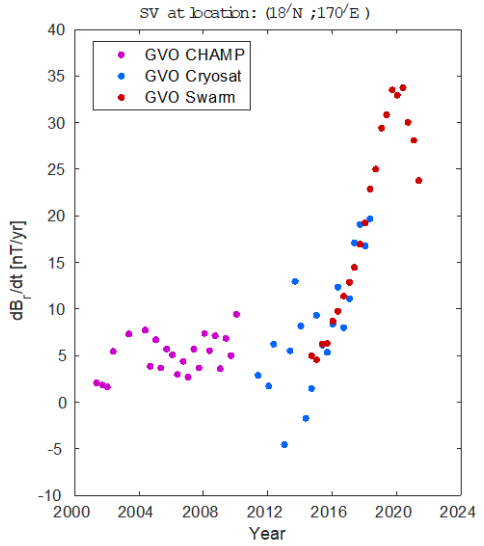
GVO datasets for monitoring SV dynamics
Consistent processing for *Swarm* and previous missions

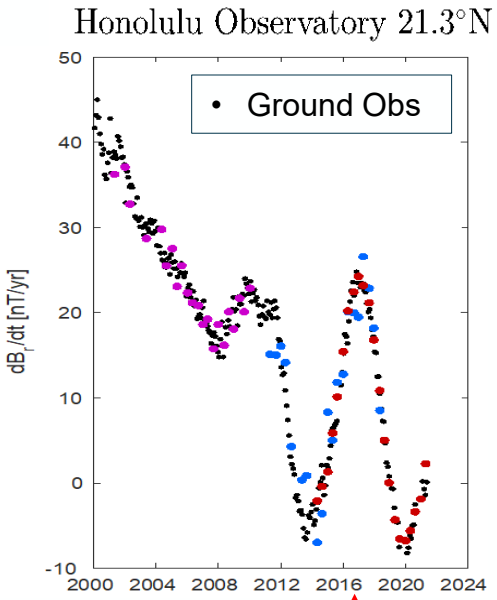
- GVO series at 300 locations from *Swarm* , CHAMP, Cryosat-2, Ørsted; same processing and cdf file format.
- Available online at: http://www.spacecenter.dk/files/magnetic-models/GVO/

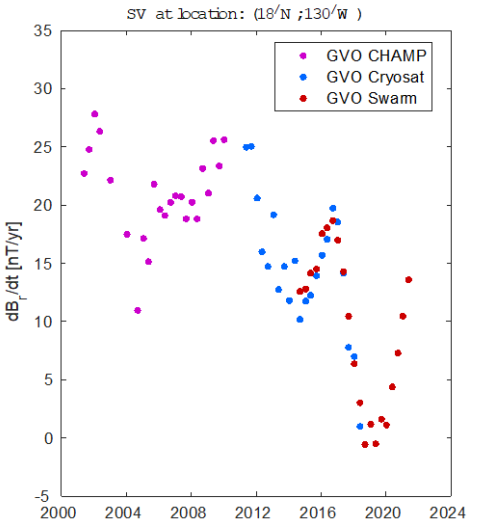


[See poster by M. Hammer today for more on GVOs and an extension to field gradient elements]

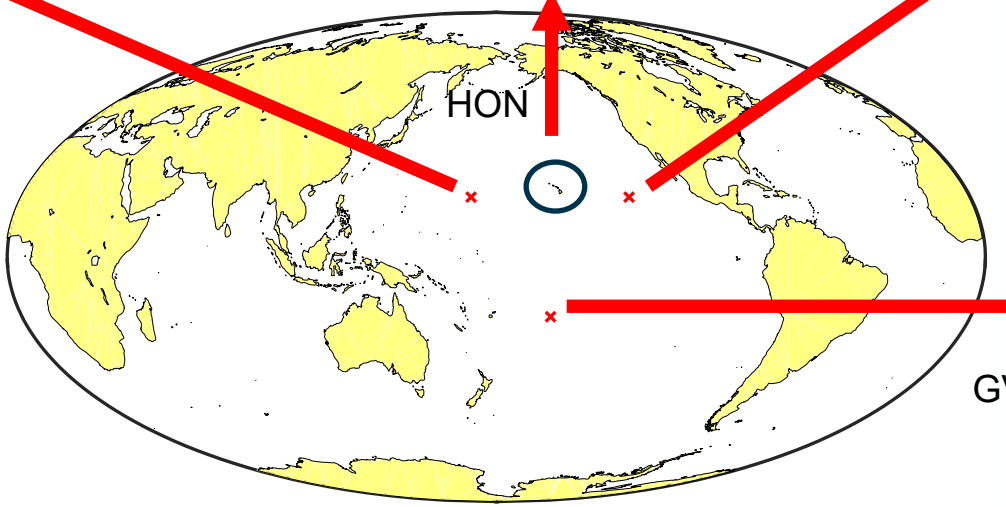
SV dynamics in the radial field component GVO series from the Pacific hemisphere

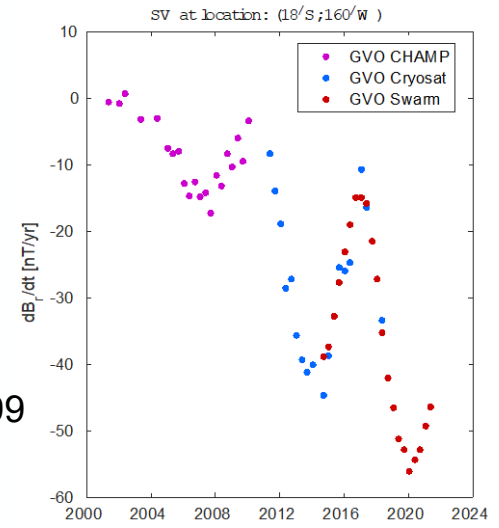




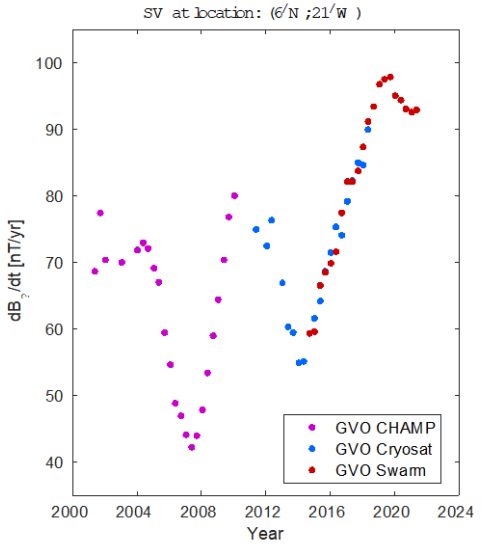


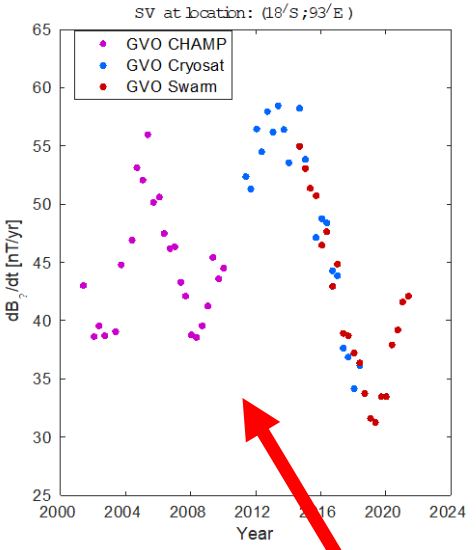
- Change of slope (jerk?) in SV in central Pacific in 2017
- Part of wave-like disturbance pattern with period 7 yrs
- Disturbance has travelled rapidly westward across Pacific in 4 yrs





SV dynamics in Eastward component observed by GVOs

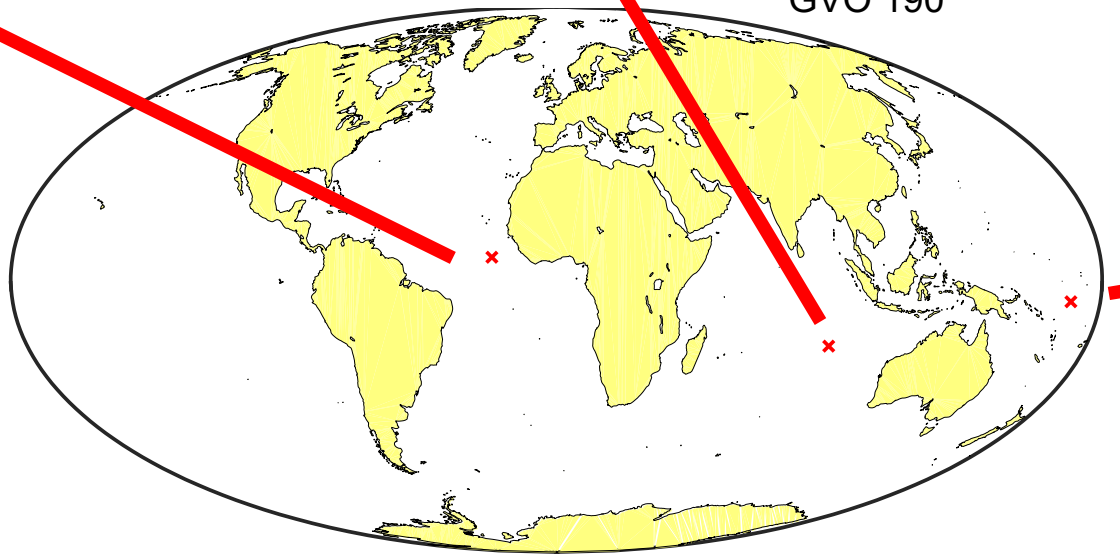




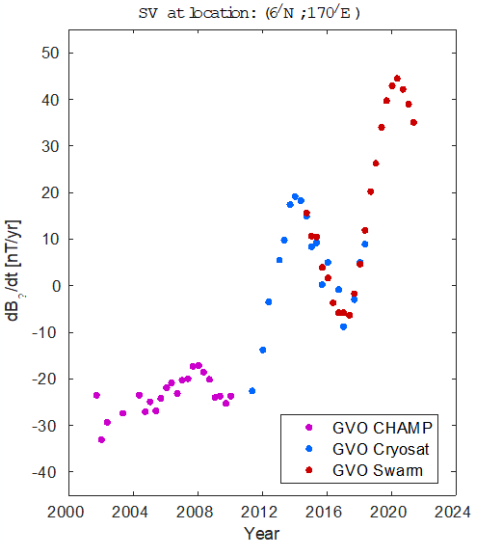
- Wave-like disturbance patterns with periods 6-7 years also seen in eastward component
- Change in slope of eastward (Y) component of SV at many locations in 2020

GVO 150

GVO 190



GVO 166

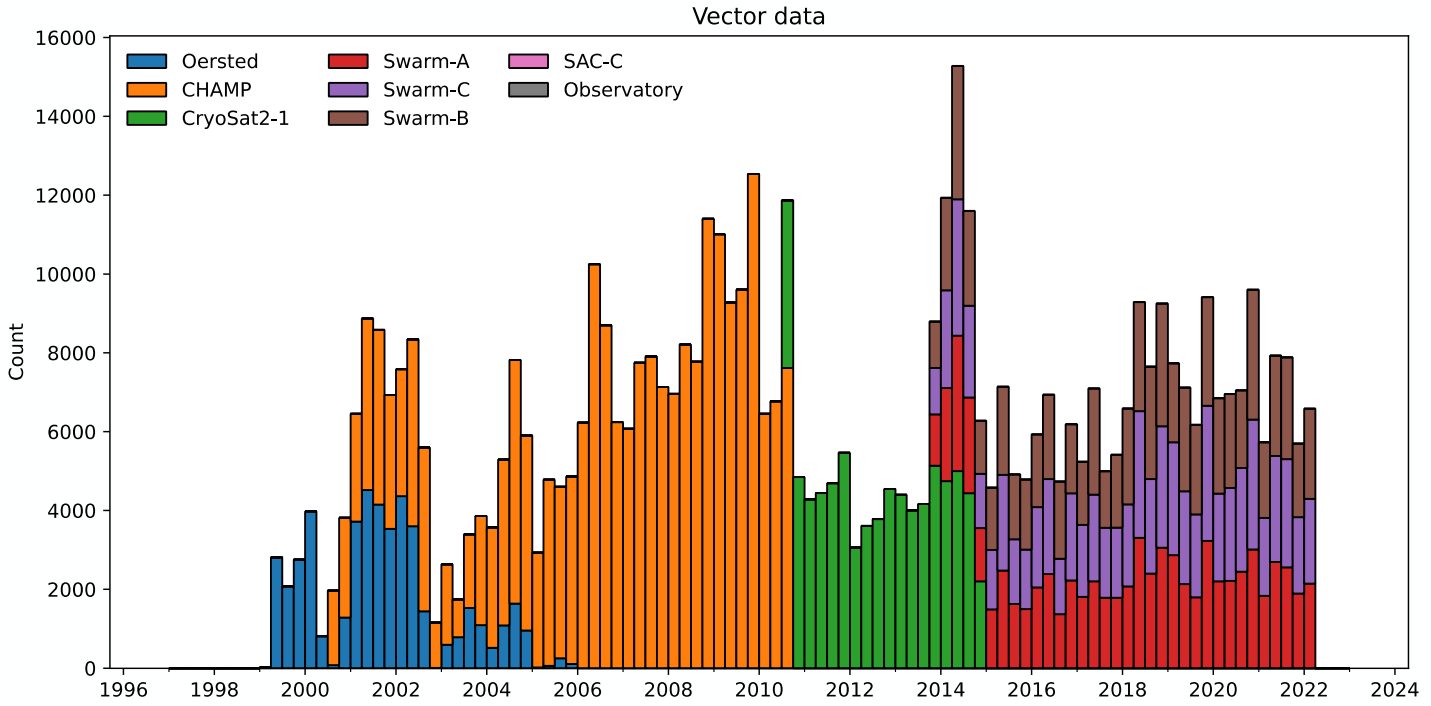


CHAOS-7 field model

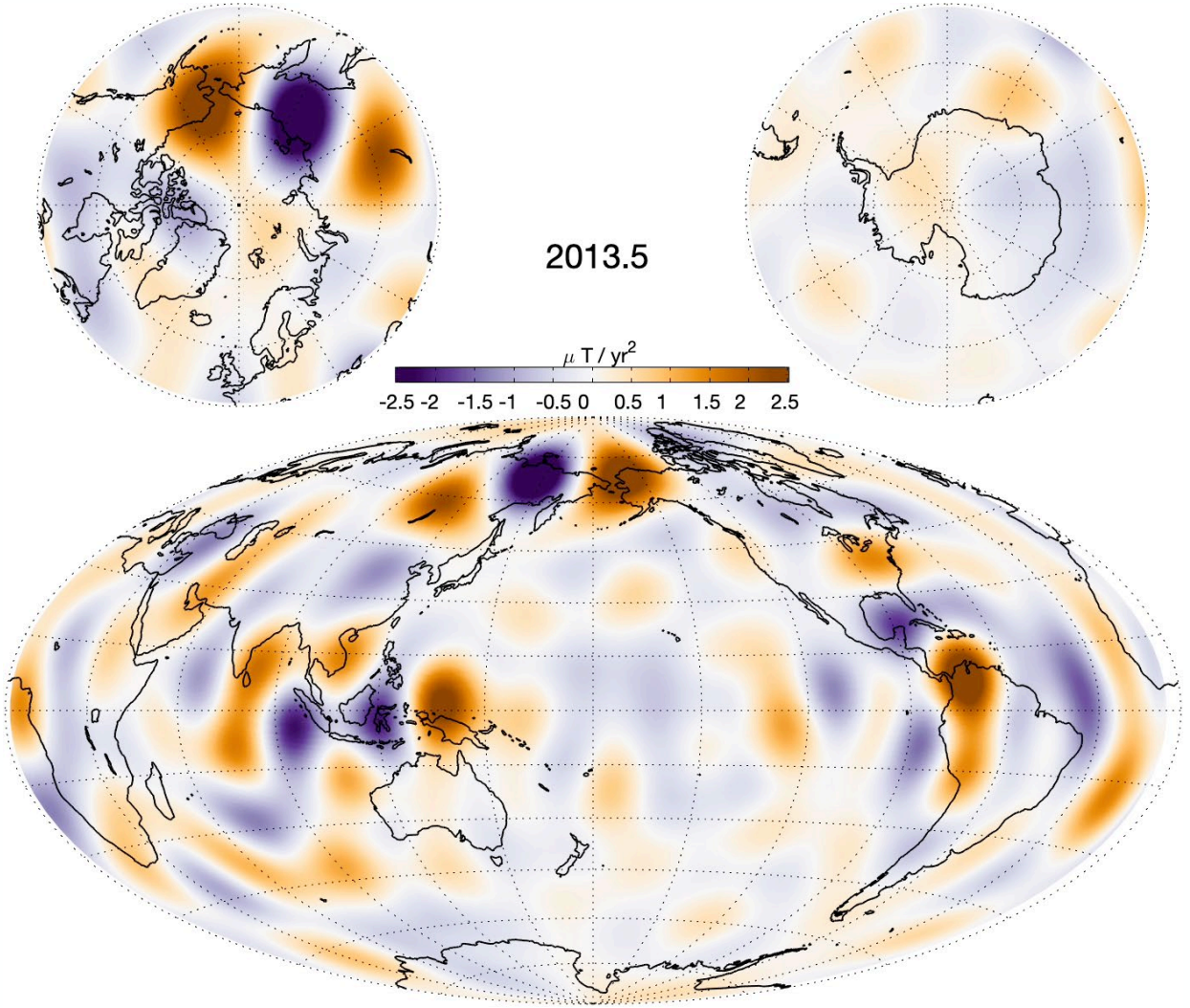
- **CHAOS-7** [Finlay et al., 2020] Regularly updated (3 times per year). Latest release 7.10.
- Uses *Swarm* and ground observatory data to March 2022
- Also data from CHAMP, Ørsted and SAC-C missions and platform magnetometer data from CryoSat-2

- Strict data selection criteria related to solar wind driving parameters, relaxed temporal smoothing at high degree

http://www.spacecenter.dk/files/magnetic-models/CHAOS-7/



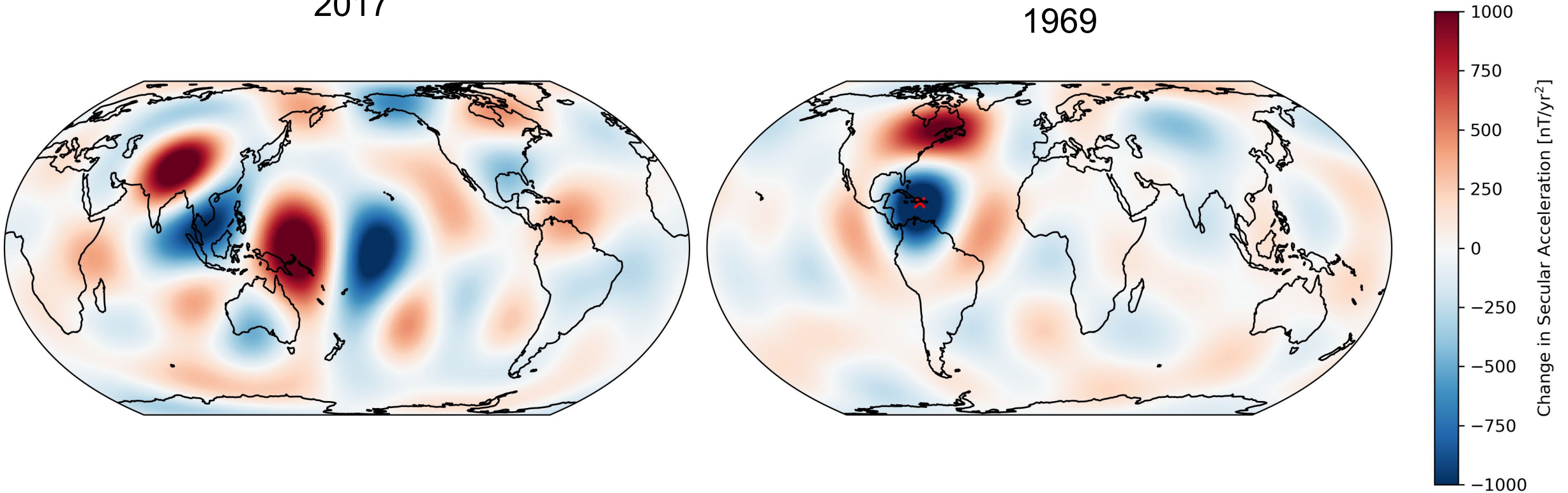
CHAOS-7.10 Core surface radial field: SA 2013-2021



SA change in 2017 compared with the 1969 jerk event

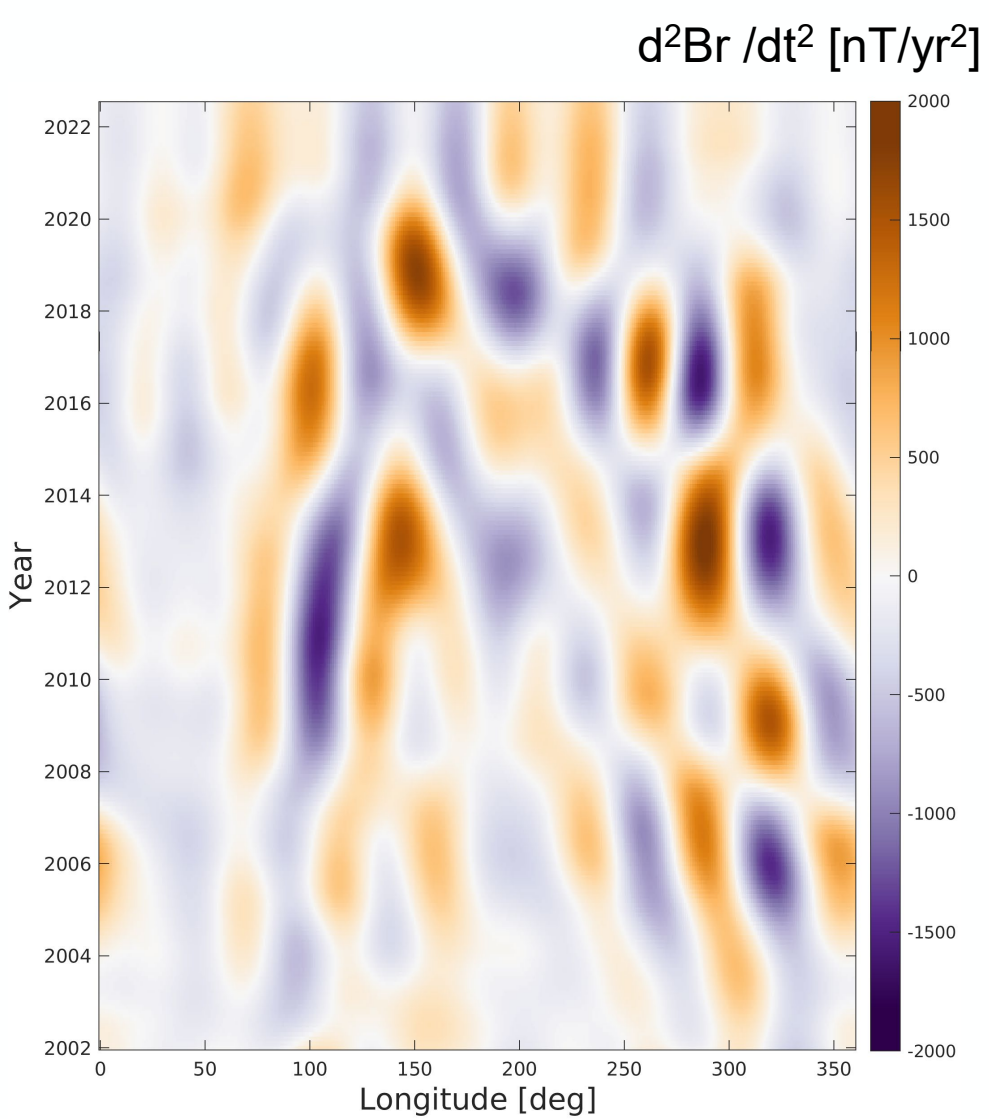
2017

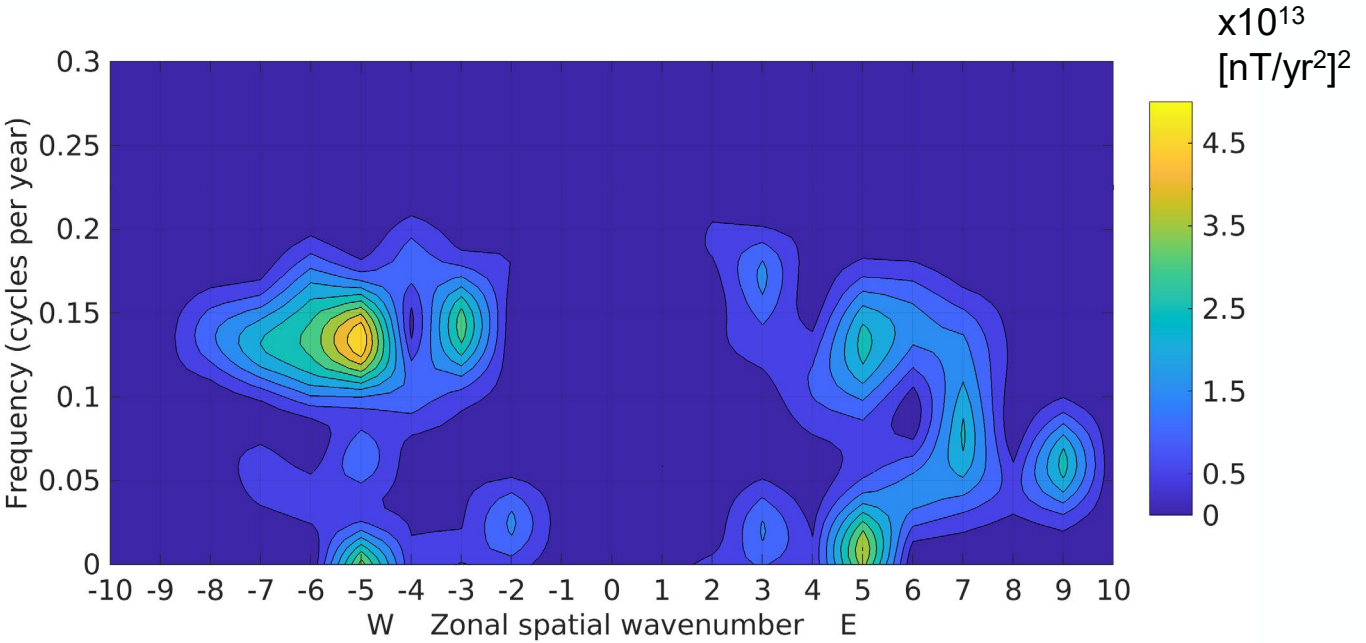
1969



[See poster by Rasmus Blangsbøll et al., today at 5pm]

Evolution of field acceleration in the equatorial region





- Rapid azimuthal drift of alternating patterns (500-1000 km/yr)
- Frequency-wavenumber spectra dominated by m=5, T=7yrs
- Predominantly westwards but also some eastwards signal
- Difficult to explain by advection, likely due to phase propagation of hydromagnetic waves [Gillet et al., 2022]:
- Similar patterns found in dynamo simulations [Aubert and Finlay, 2019; Aubert et al., 2022]

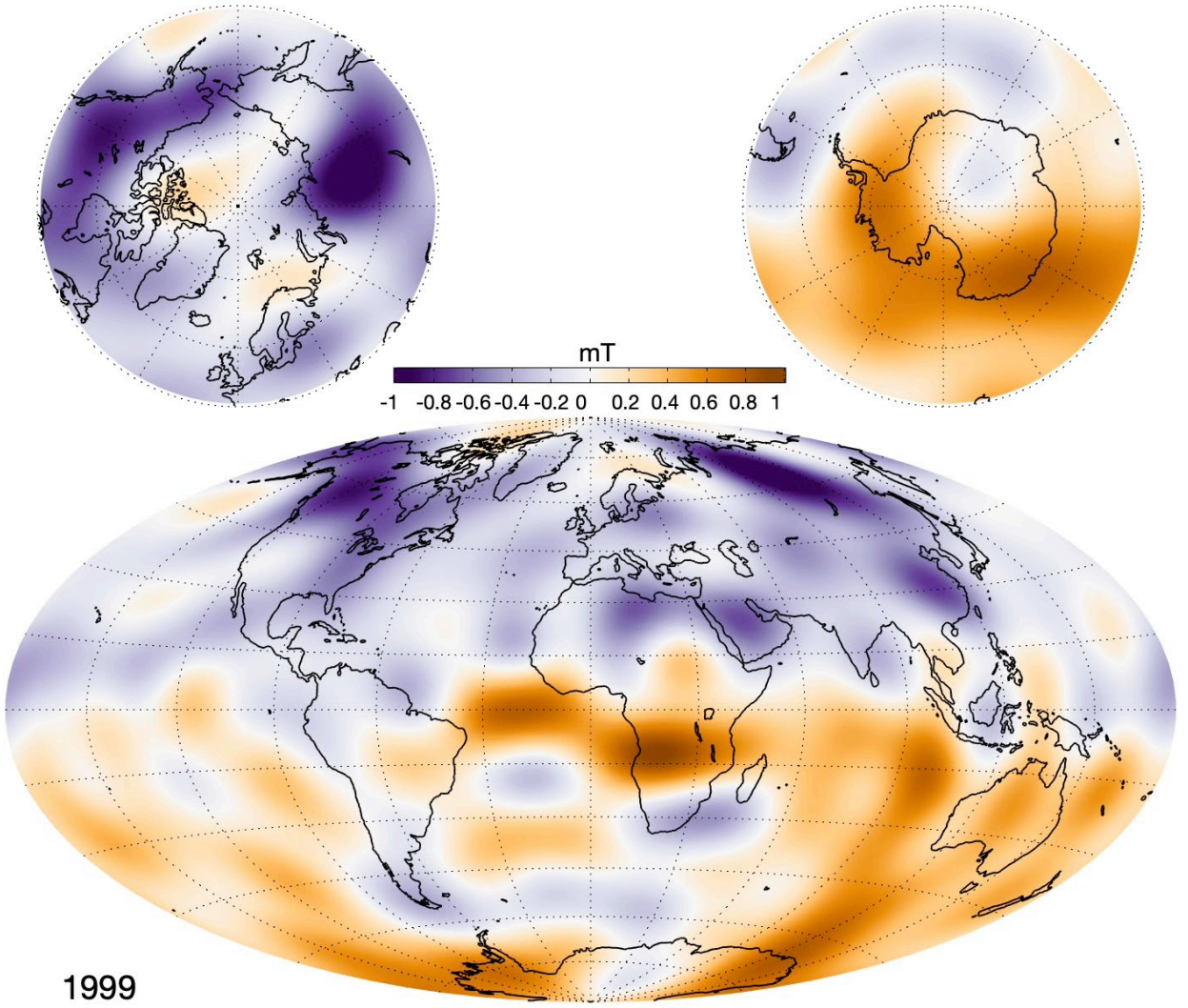
Summary and Outlook

- **Rich sub-decadal core dynamics** have been revealed by the lengthening time series from *Swarm*,
- **Evidence for wave propagation** e.g. in the equatorial Pacific
- Such waves provide a **new means of probing properties of the core and deep mantle**

- Fundamental wave periods in the core are long (e.g. 7 years) – long lifetime of *Swarm* mission is essential
- To isolate faster core signals better local time coverage is also needed – NanoMagSat

- **Improved data products are under development:**
- **GVOs**: improved error models describing error correlations between stations and components
- **CHAOS field model:** better accounting for polar ionospheric signal [poster of C. Kloss, thursday]
  and considering correlated satellite data errors during inversion process

CHAOS-7.10 Core surface radial field, 1999-2022



CHAOS-7.10 Core surface radial field SV, 1999-2022