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Geomagnetic Virtual Observatories: 10 years of Swarm and 25 years of GVO

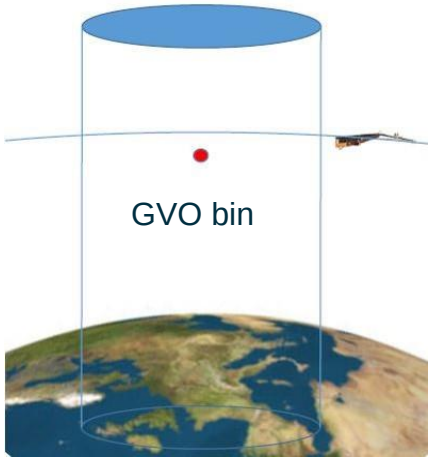
Swarm 10 Year Anniversary & Science Conference 2024
8th-12th April 2024, Copenhagen, Denmark

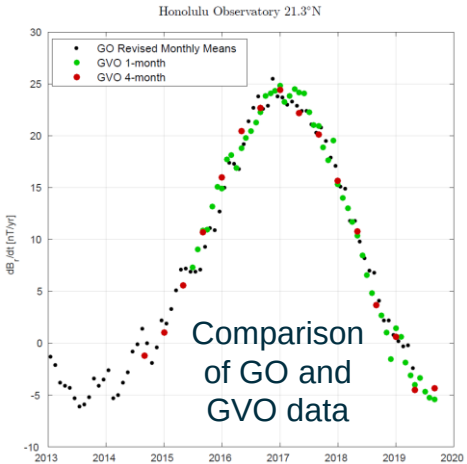
BGS British Geological Survey

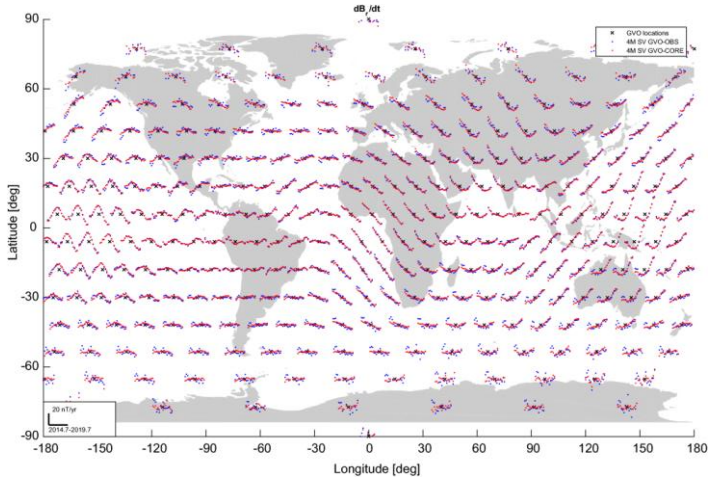
Geomagnetic Virtual Observatories (GVO)

DTU Space
National Space Institute

- A method to collect satellite data in spatial bins and calculate point estimates to construct timeseries for each bin
- Allow “direct” observation of secular variation (**SV**) from satellite data



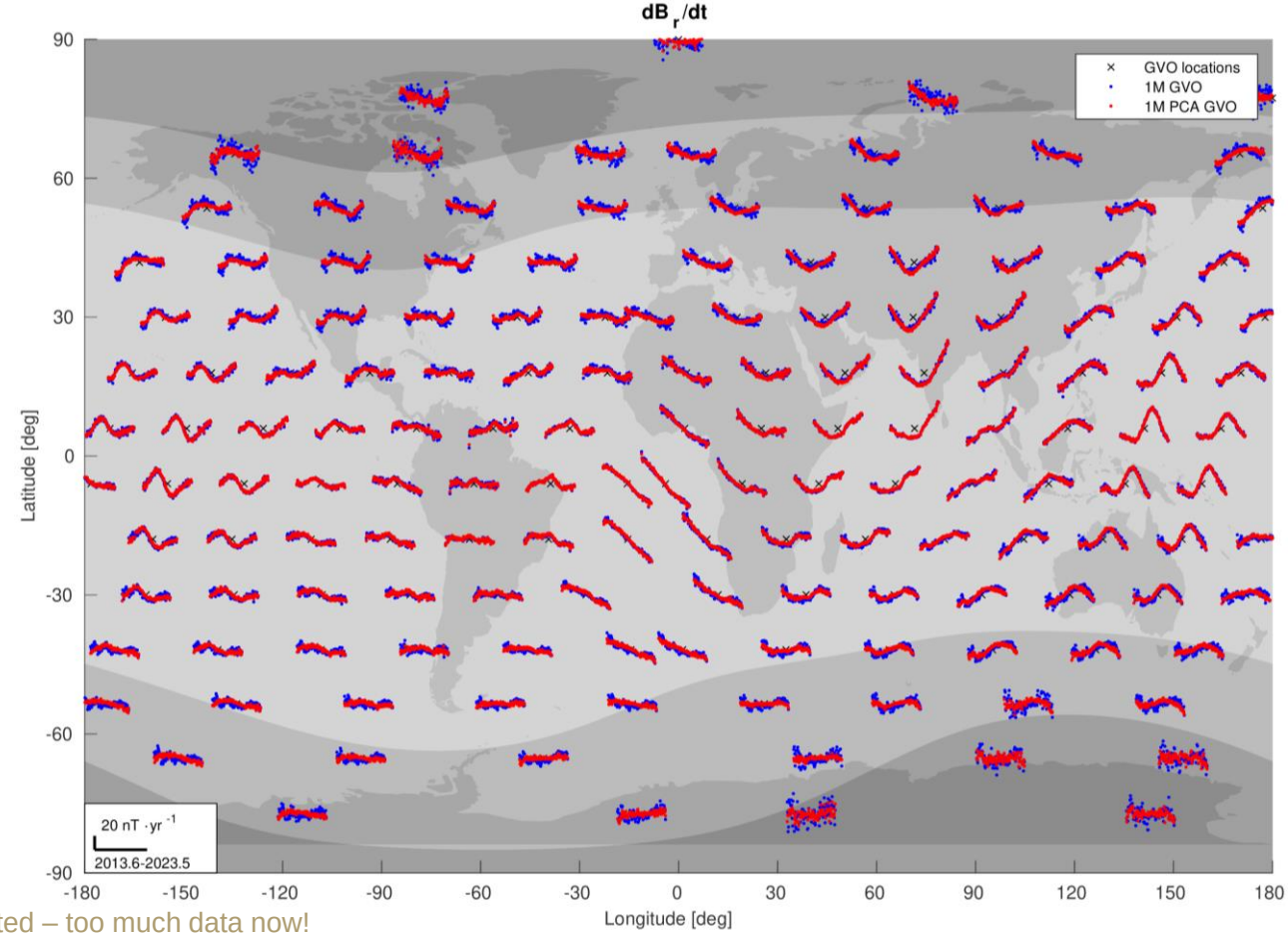




Hammer et al, 2021, EPS, https://doi.org/10.1186/s40623-021-01357-9

BGS

10 years of Swarm GVO



NB: Only half GVO plotted – too much data now!

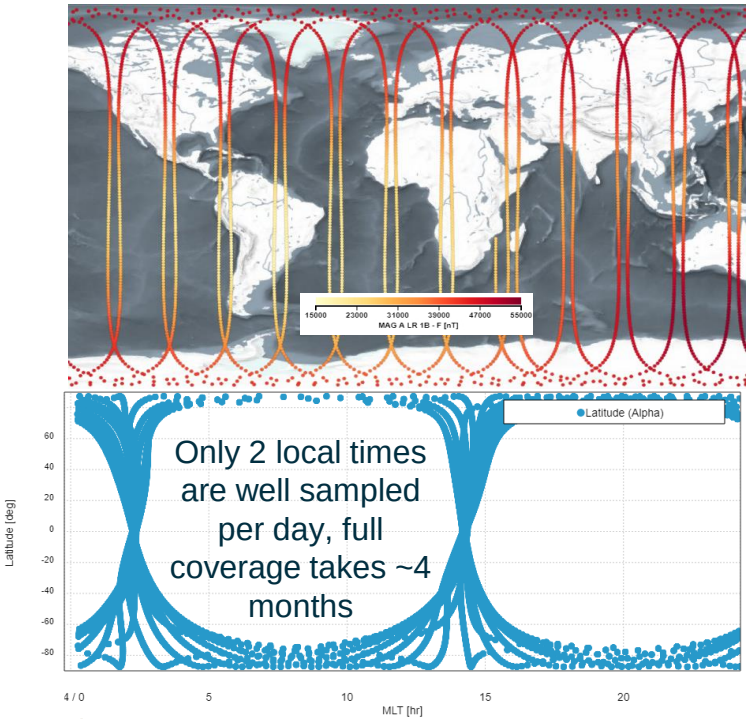
Isolating core field from GVO with Principal Component Analysis

- To isolate core field from GVO: use dark, quiet time selection
  - few data if active, or bins are too small or short
- To counter slow LT drift of satellite: longer time bin
  - time resolution depends on orbit

- Principal Component Analysis (**PCA**) approach retains data density and allows reduction of LT sampling bias
  - Detrend GVO with core field model
  - Calculate eigenvectors (PC) of covariance of GVO residuals

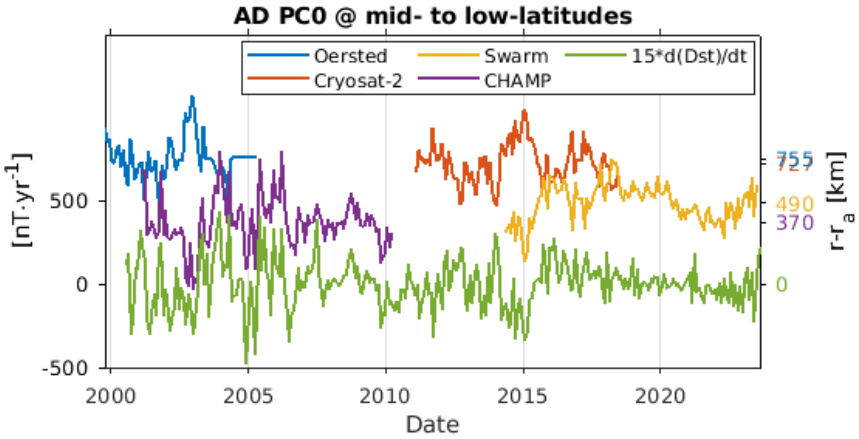
- PCA can be applied for satellite missions with long LT procession rates (e.g. Ørsted, CryoSat-2), to maintain resolution in time or space

1 day Swarm A data



VirES

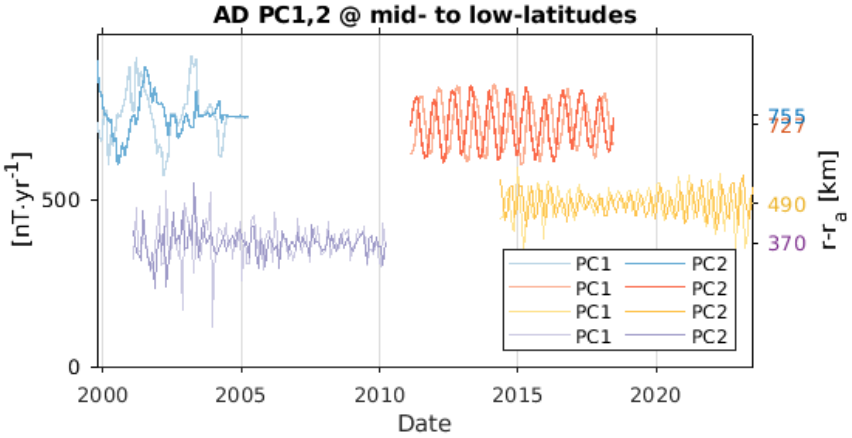
25 years of GVO from multiple missions



- GVO from Ørsted, CHAMP, CryoSat-2, Swarm from 1999 to 2024
- Principle Component Analysis (**PCA**) of GVO residuals highlights common non-core signals across GVO
- Prevalence of magnetospheric ring current seen across all data sets

Hammer et al, 2021a,b, EPS
Swarm: https://doi.org/10.1186/s40623-021-01357-9
CryoSat-2: https://doi.org/10.1186/s40623-021-01365-9

25 years of GVO from multiple missions

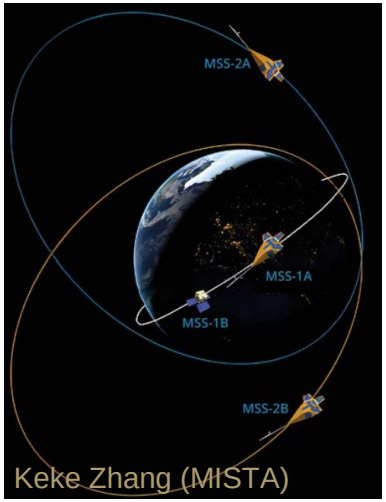


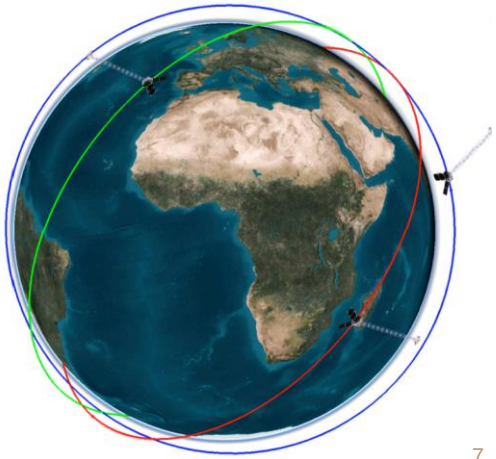
- GVO from Ørsted, CHAMP, CryoSat-2, Swarm from 1999 to 2024
- Principle Component Analysis (**PCA**) of GVO residuals highlights common non-core signals across GVO
- Aliasing of Local Time (**LT**) varying external fields at orbit LT precession rate

Future GVO datasets

- MSS-1A launched on 23 May 2023 @ 450km, 40° inclined orbit
- NanoMagSat planned @ 575km, 60° inclined orbit
  - End-to-end simulation data available for GVO testing

- Both:
  - Have inclined orbits, sampling mid-latitudes
  - Cover longitudes more rapidly than polar orbits
  - Precess through all Local Time (**LT**) in weeks
  - Have potential for higher resolution GVO



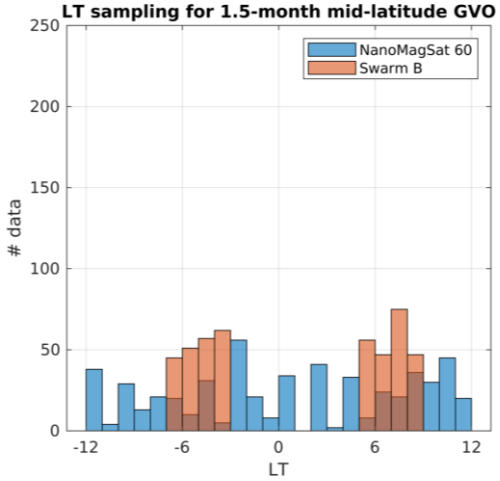


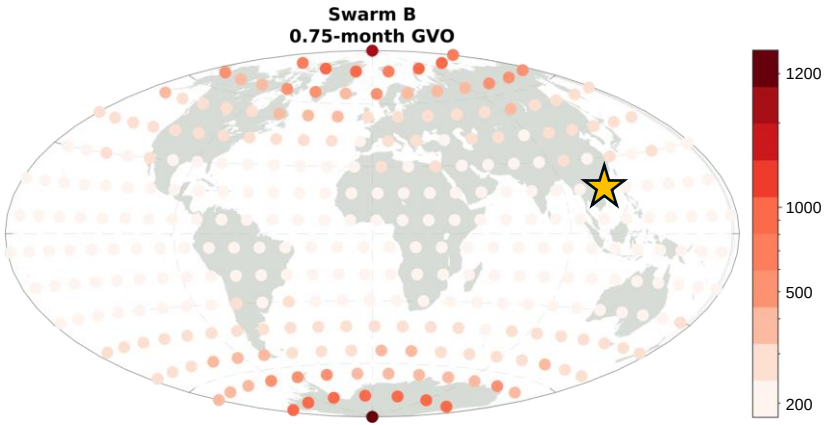
Hulot et al, 2021, EGU21-14660

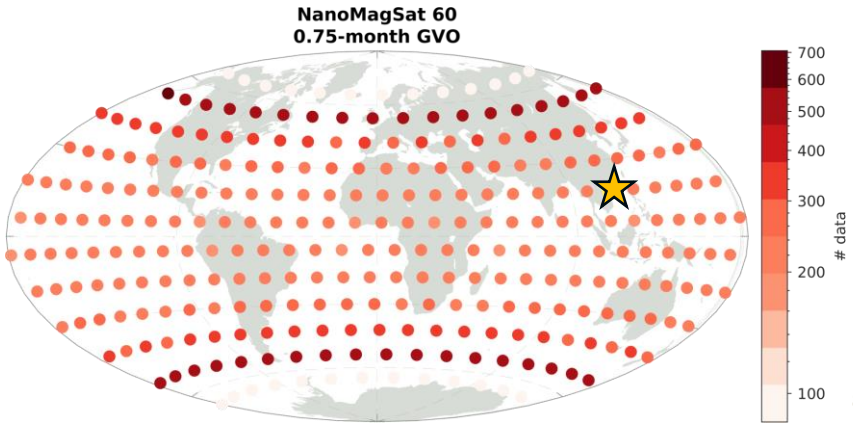
Geographic and Local Time sampling of GVO

- Inclined orbit has advantages over polar orbit:
  - More dense geographic sampling in shorter time
  - Wider LT sampling in shorter time

=> finer temporal and spatial sampling of GVO possible

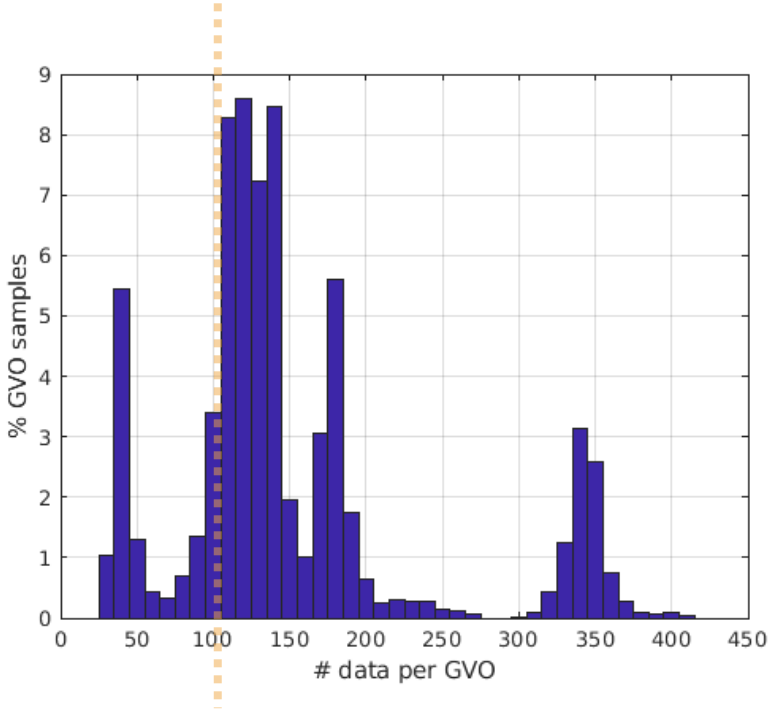






Can one inclined orbit satellite produce high-res GVO?

- Swarm sized bins: 300x with 700km radius
- <100 samples can produce unstable GVO solution
- Single inclined NanoMagSat can populate ~75% mid-latitude GVO in 3 weeks
- 6-week sampling rate likely more reliable, or multiple satellites' data combined,
- *but* LT biases are **additive (i.e. not averaged out)**



Summary

- Swarm GVO L2 product is available from 2013 to 2024 and ongoing
- DTU GVO datasets available covering 1999 to present
- PCA shows that magnetosphere and LT effects can still be present

- 1 inclined orbit satellite can produce similar quality of GVO over shorter time but:

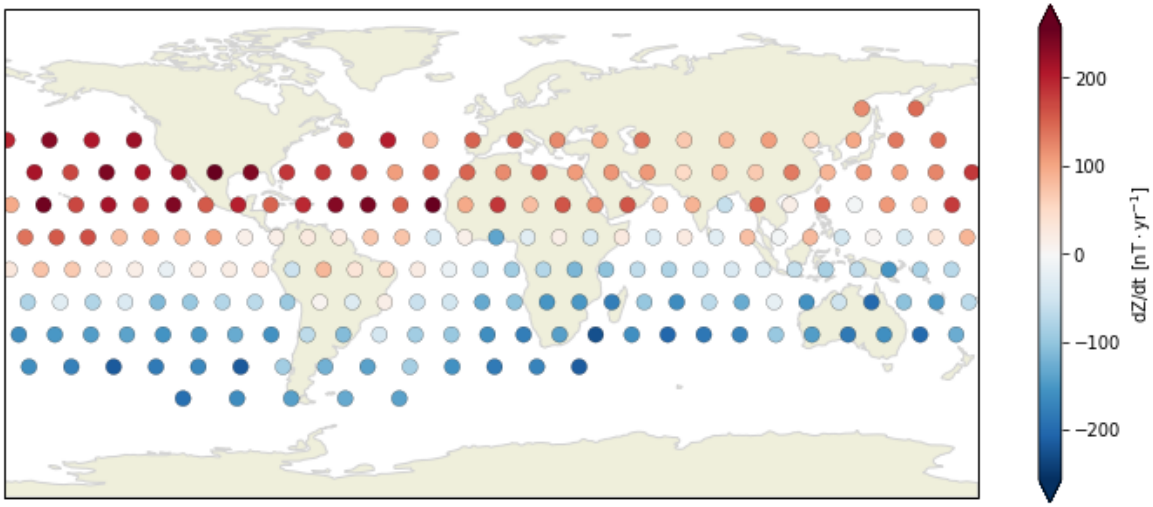
- “Best” solution is processing GVO from each orbit type independently to handle varying sampling optimally for each orbit type

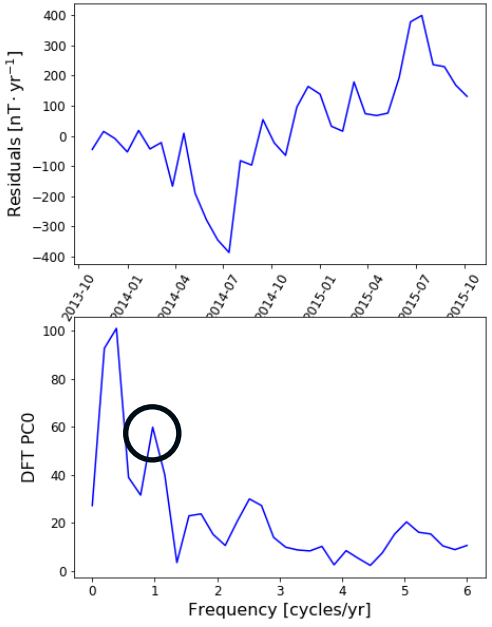
- Practical solution is combined GVO of data from different orbits with varying LT sampling, cognisant of LT sampling periods involved. Potentially sub-sample data for even LT coverage.


DTU
esa
Thank you to ESA and DTU
SWARM
10
YEAR ANNIVERSARY
SCIENCE CONFERENCE
Swarm 10 Year Anniversary & Science Conference 2024

Can one inclined orbit satellite produce high-res GVO?`

- 1 x 60° orbit satellite produces 3-week GVO with same signal captured as for combined 2 x 60° orbit satellites' data, and is comparable to 4-month Swarm GVO





1st PC from residuals to a core field model using a synthetic orbit with 60° inclination