Climatological study of the Nightside Magnetospheric models from SWARM measurements

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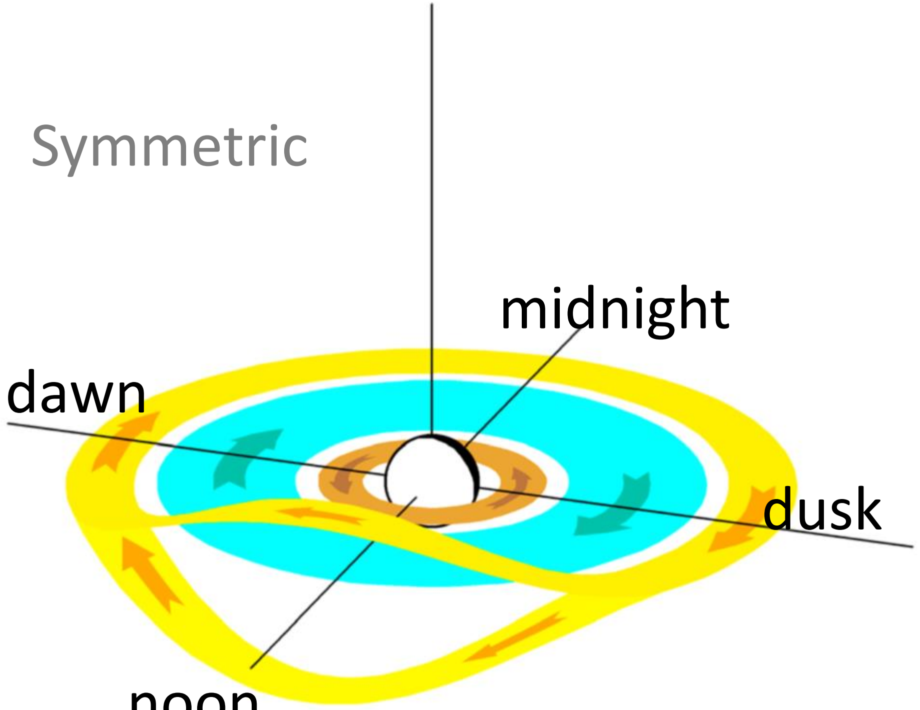
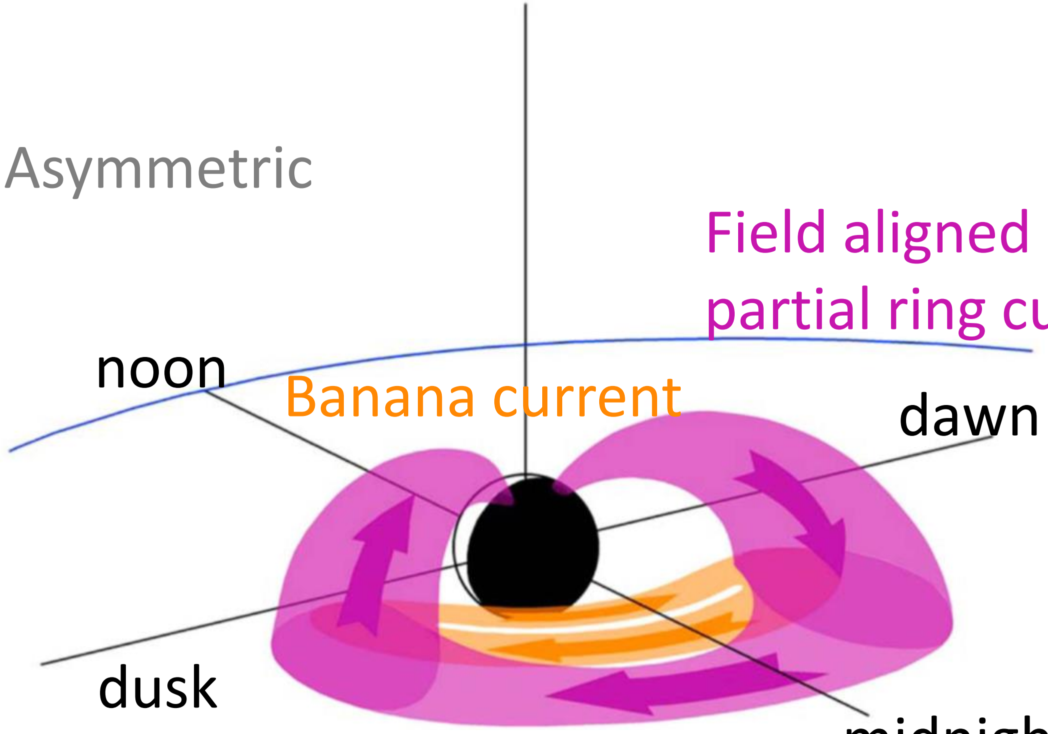
Swarm 10 Year Anniversary & Science Conference 2024

Magnetospheric currents

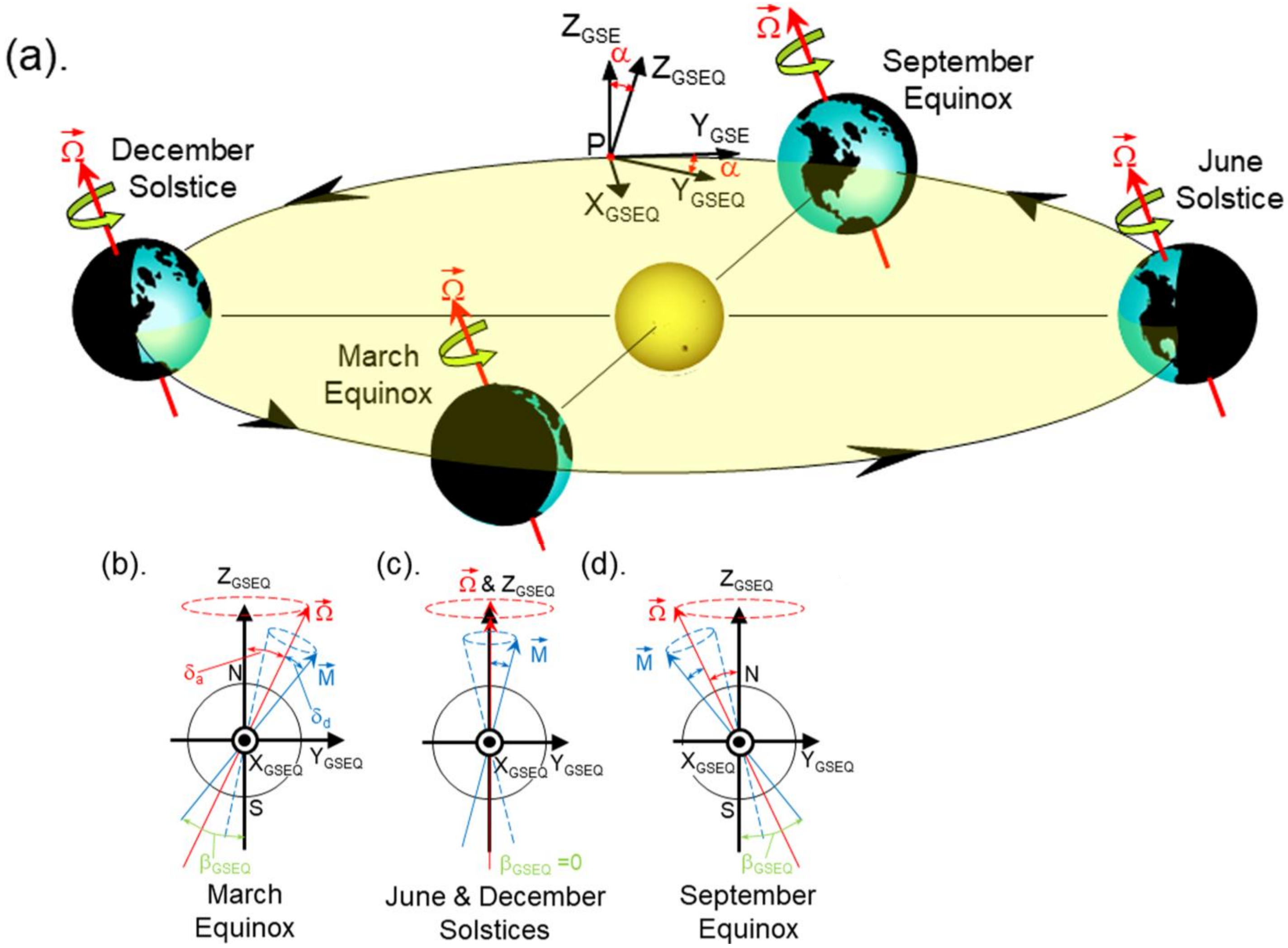




GANUSHKINA ET AL REV. GEOPHYS. (2018)

The Russell-McPherron effect

Lockwood et al. *J. Space Weather. Space Clim.* (2020)



Svalgaard et al. *Geophys. Res. Lett.* (2002)

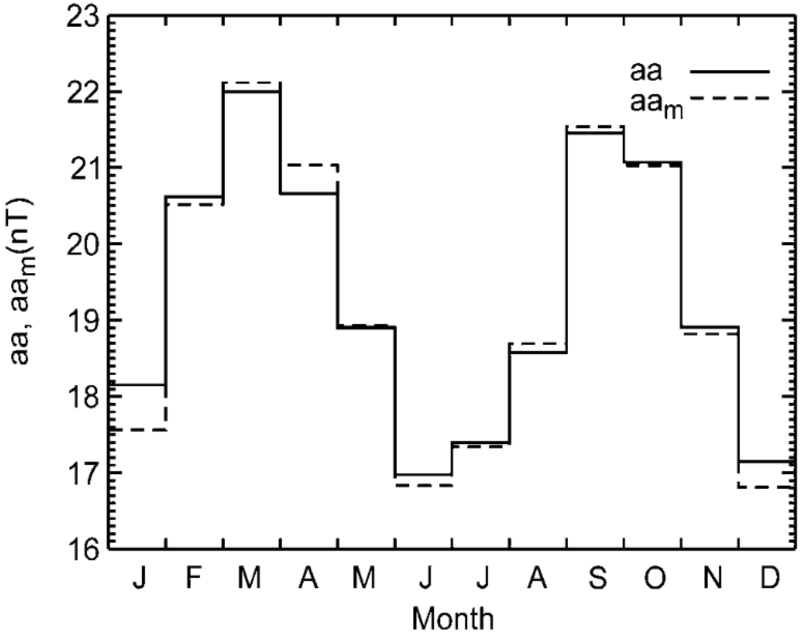
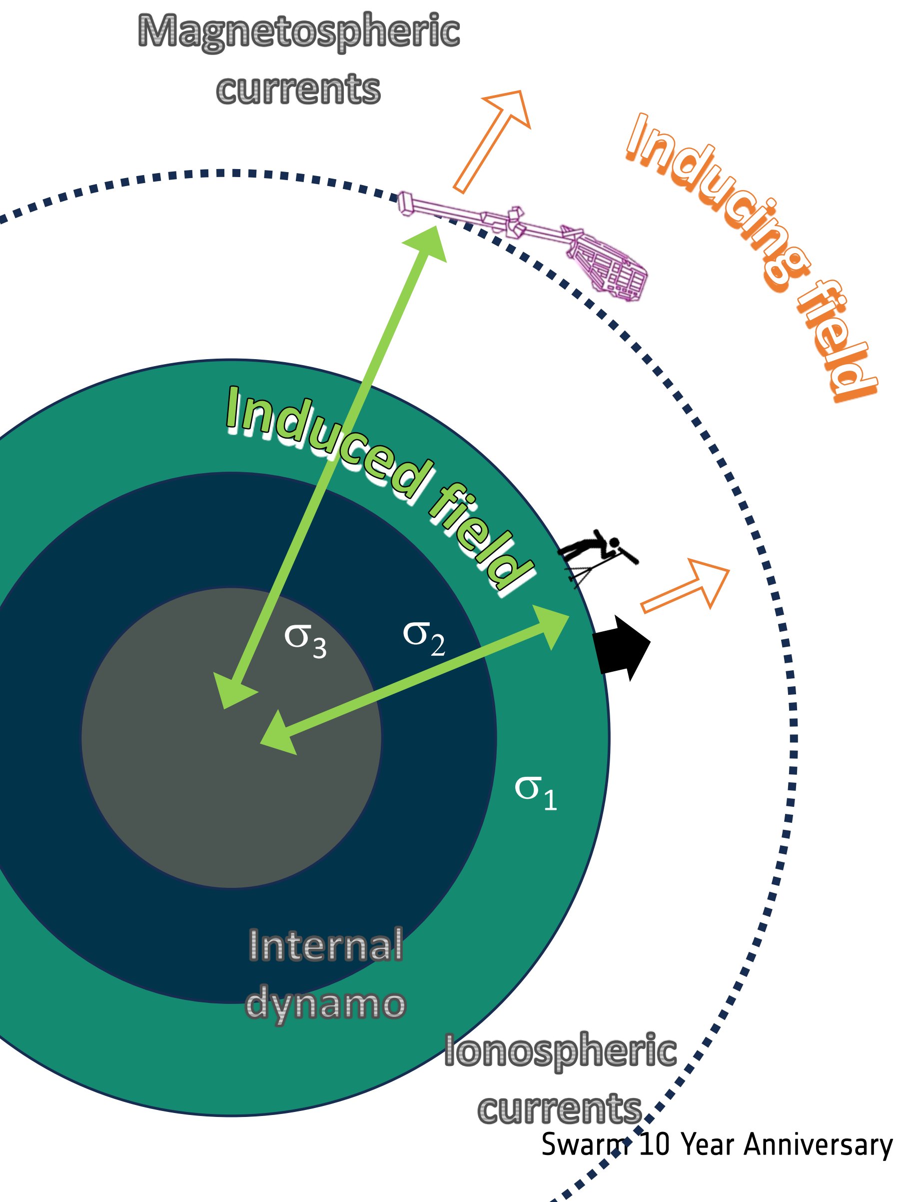


Figure 2. Seasonal variation of the geomagnetic *aa* and aa_m indices.

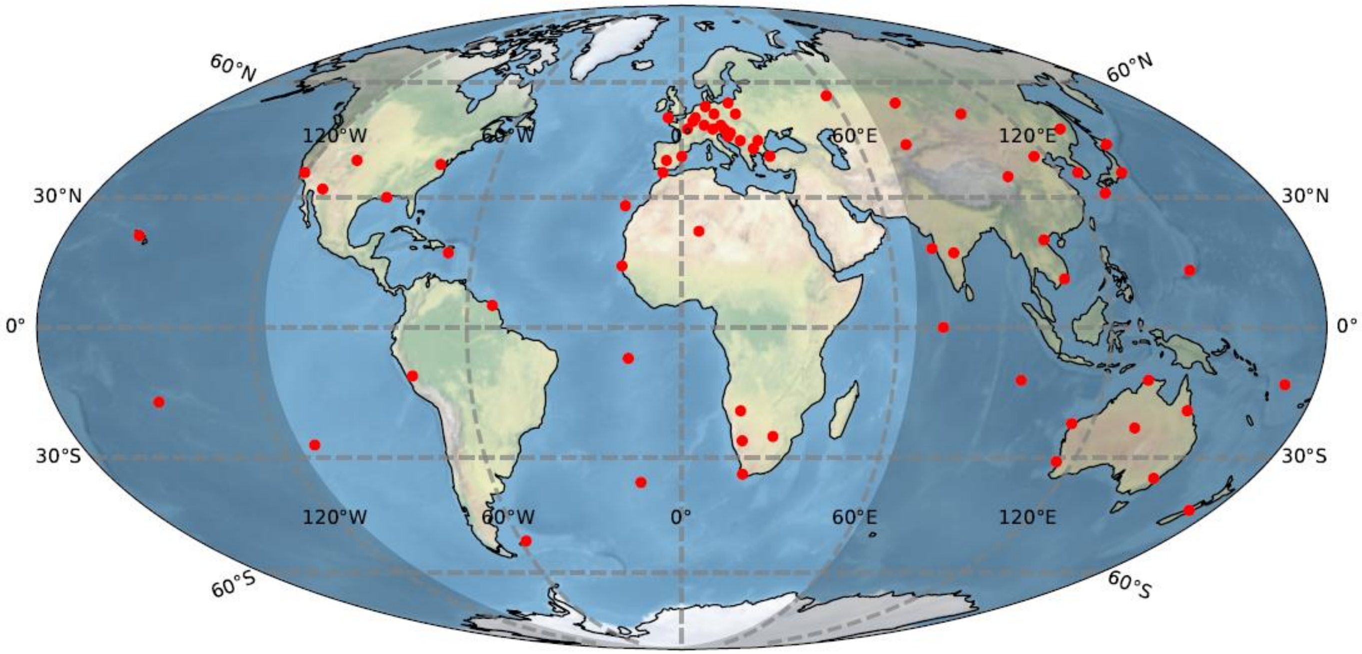
Methodology



- Using magnetic field measurements and assuming we have a good estimate of the Earth's 1D conductivity (i.e., radially dependent), we can separate the inducing fields from the induced fields (Grayver, et al. JGR 2021).
- We assume that during the integration time the source currents are constant. In our work we use 8h and 12h.
- We can use the decomposition for ground observatory measurements, as well as satellite.

Data selection

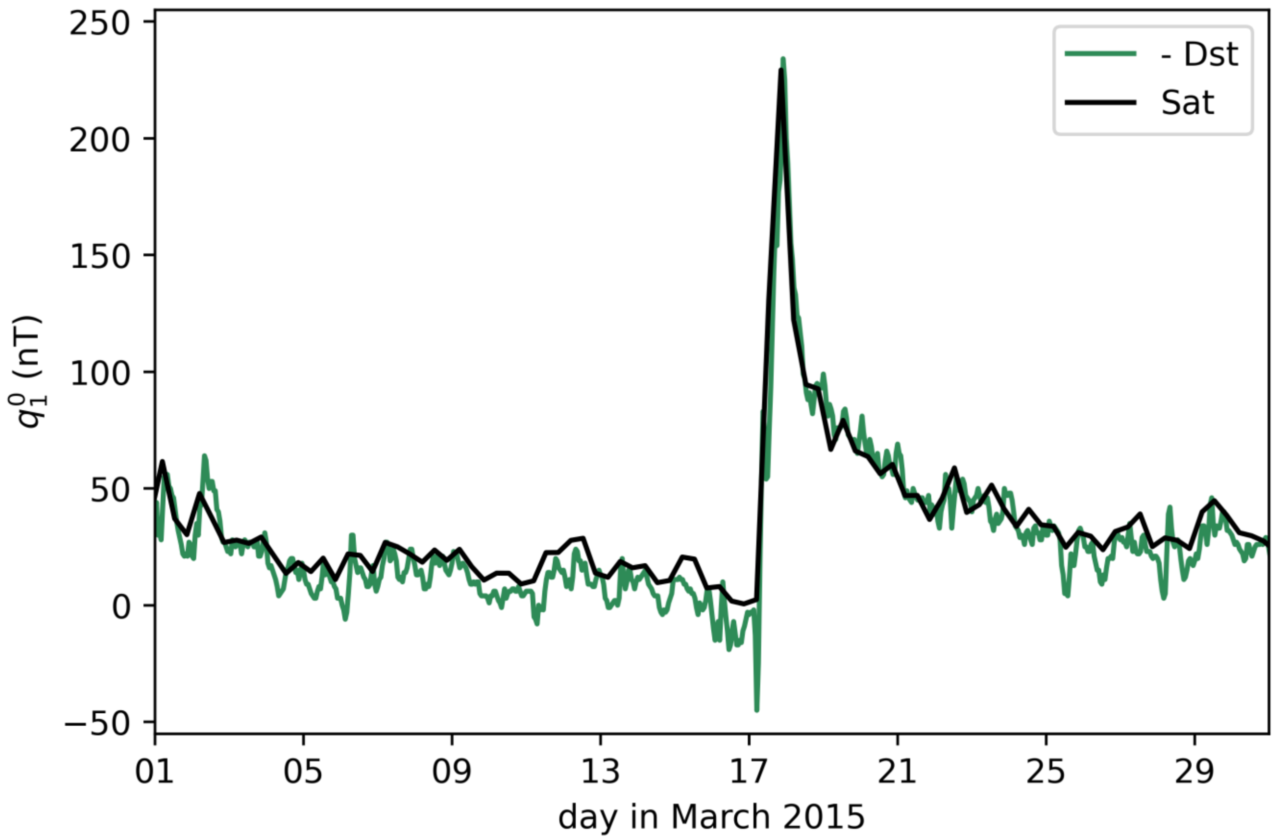
- We take the absolute magnetic field measured at ground observatories around the world or by Swarm Alpha and Bravo.
- We subtract the core field and ionospheric field from existent models (Swarm comprehensive models).
- We select these residuals and use the measurements at night-time (i.e, from 18h to 6h local time) and locations with magnetic latitude below 56°.



Map of the observatories used to estimate the external field during the month of March 2015

Observatory and satellite decomposition

§ World Data Center for Geomagnetism, Kyoto, M. Nose, T. Iyemori, M. Sugiura, T. Kamei (2015), Geomagnetic Dst index, doi:10.17593/14515-74000



- We obtain a spherical harmonic representation of the external field as a function of time (represented with the coefficients q_l^m and s_l^m). The q_1^0 coefficient is well correlated with the negative Dst index§.
- Shown here results for time windows of 8h for Swarm data (black).

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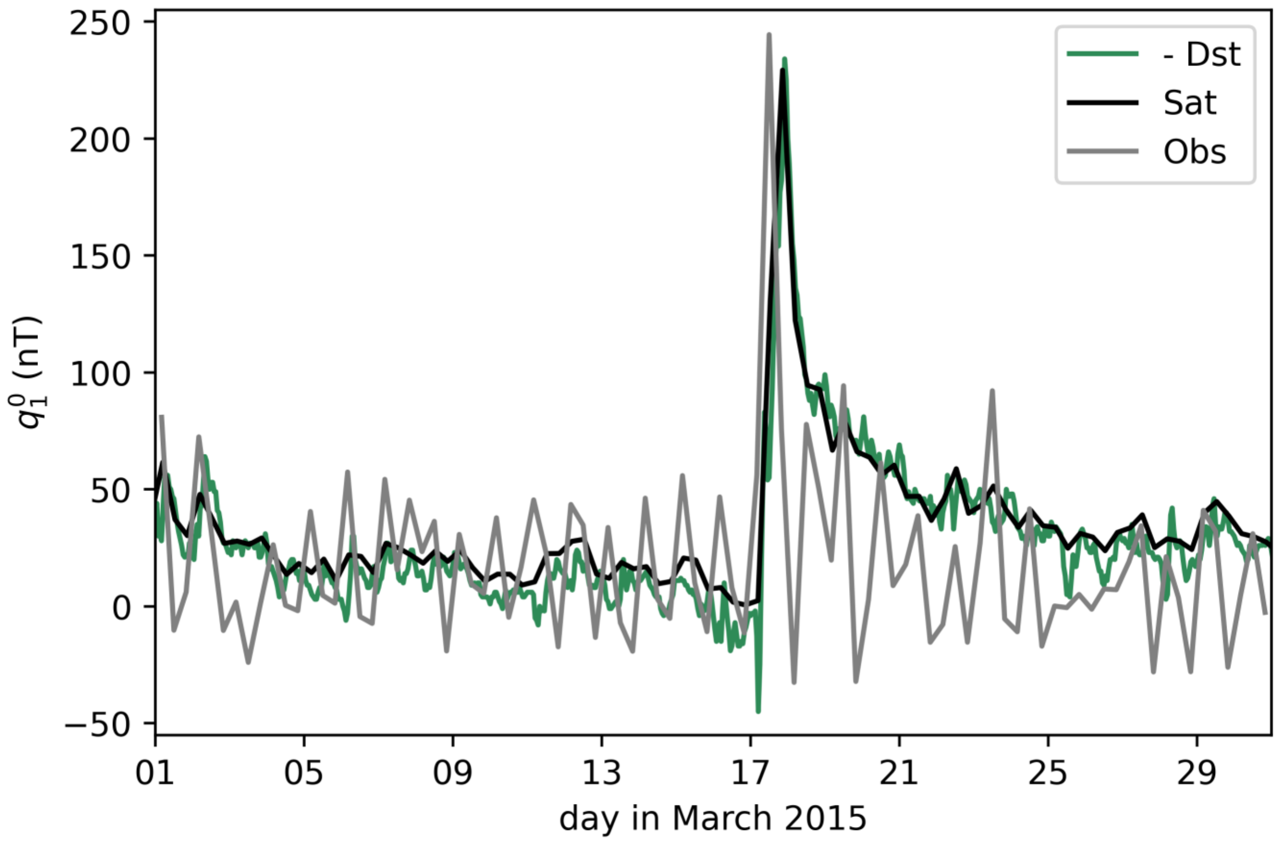

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- Same inversion using Ground Observatory data (grey).

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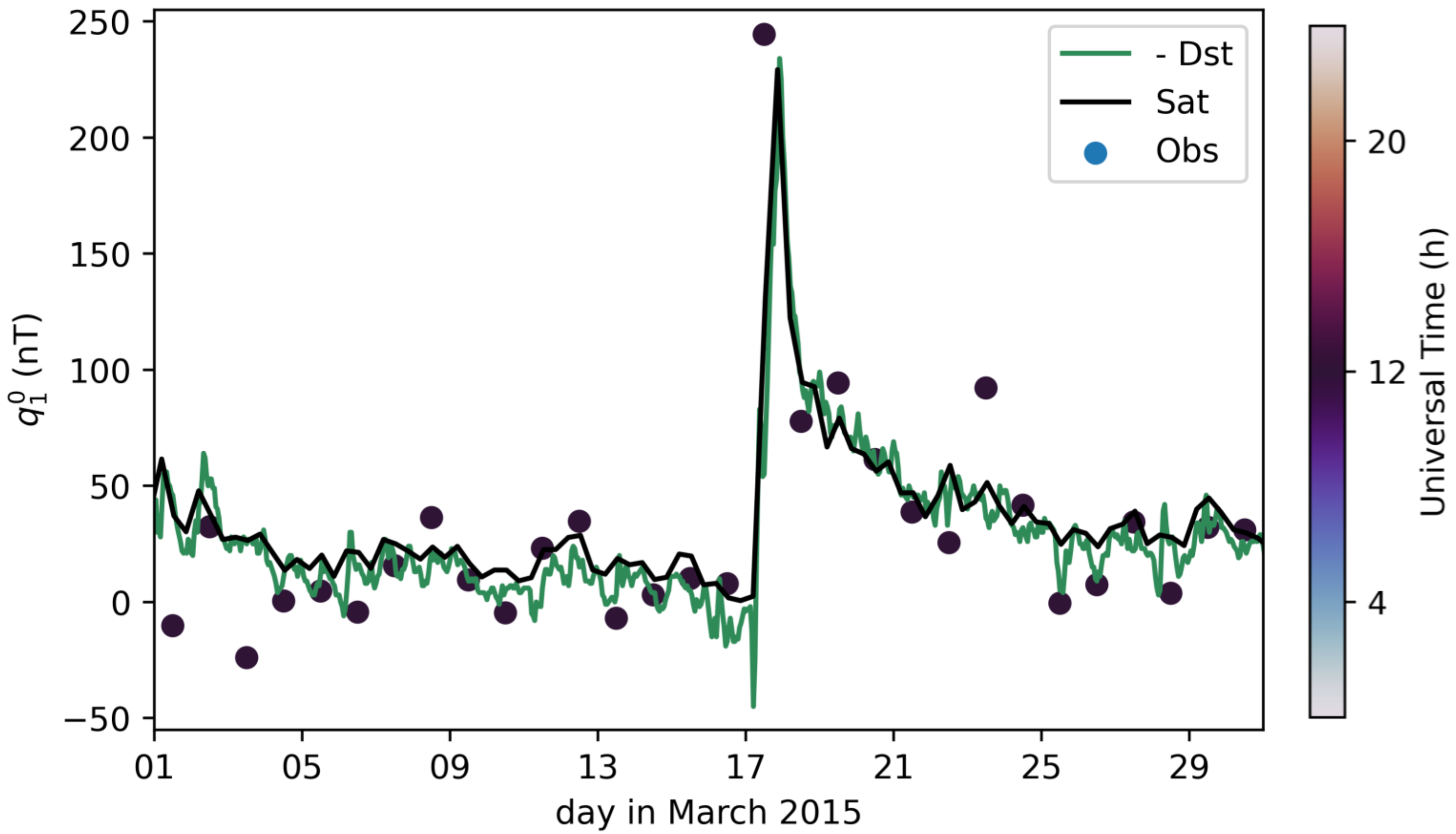

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- The inversion for Observatories is affected by the data distribution.

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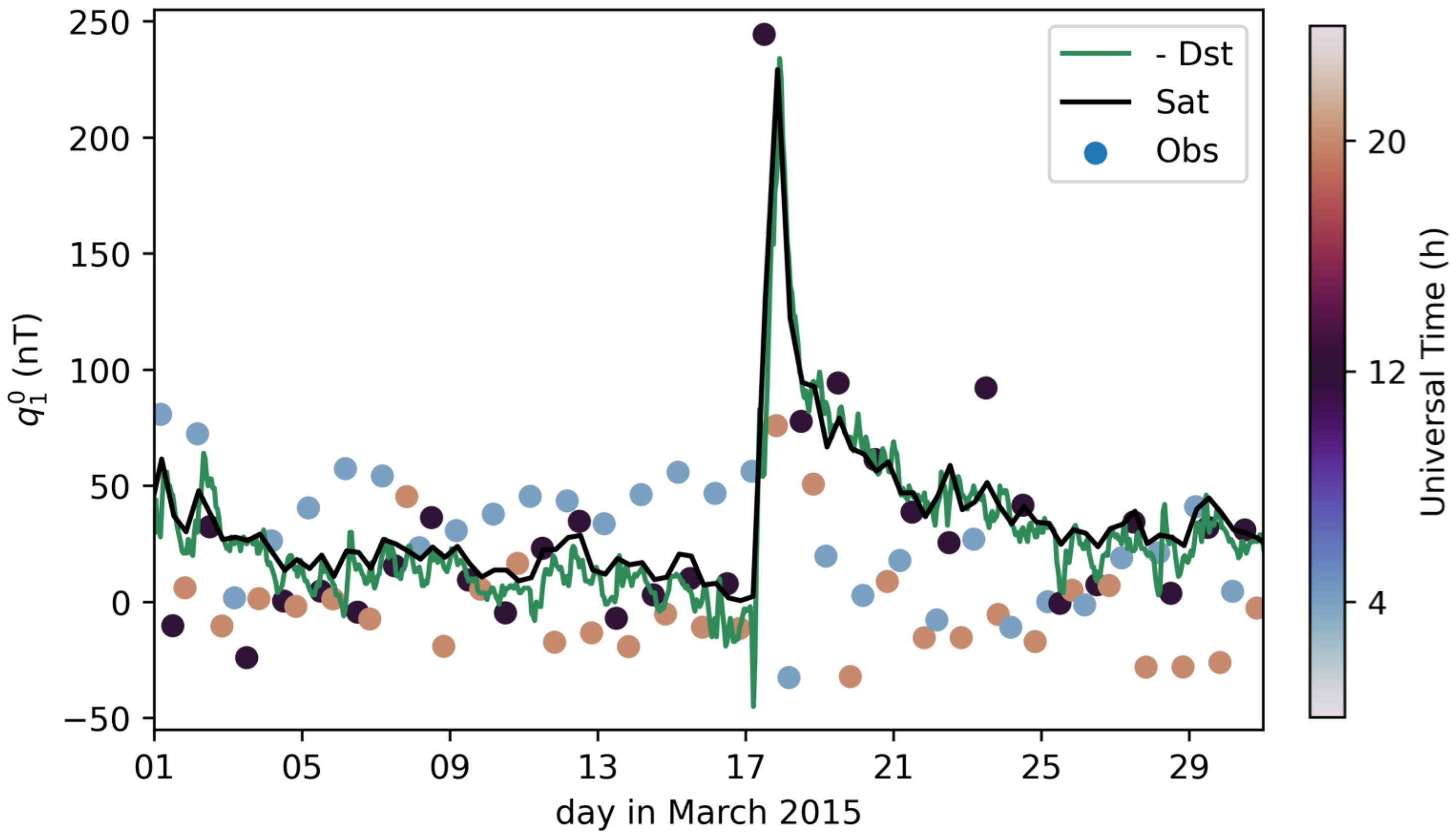

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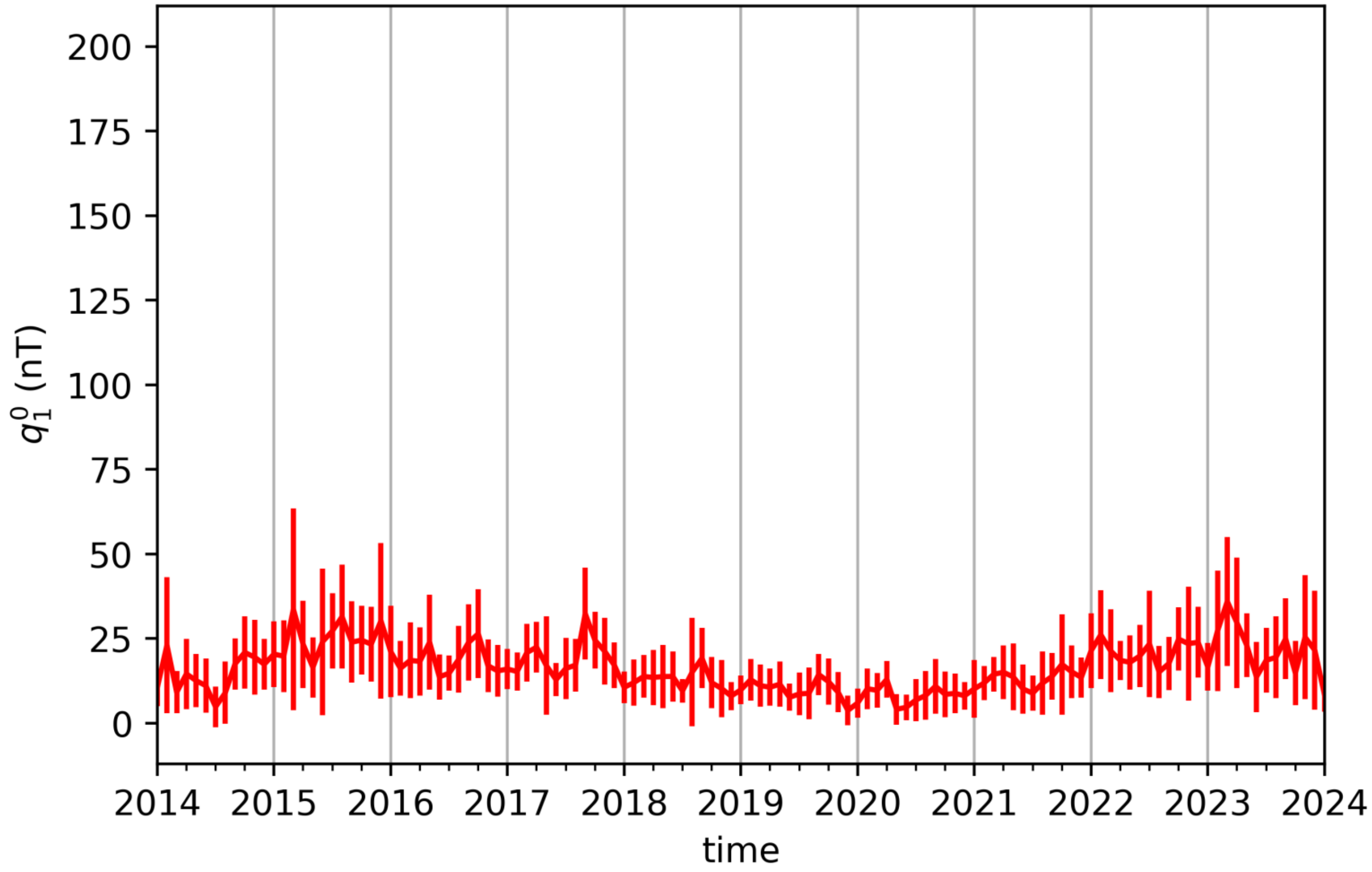
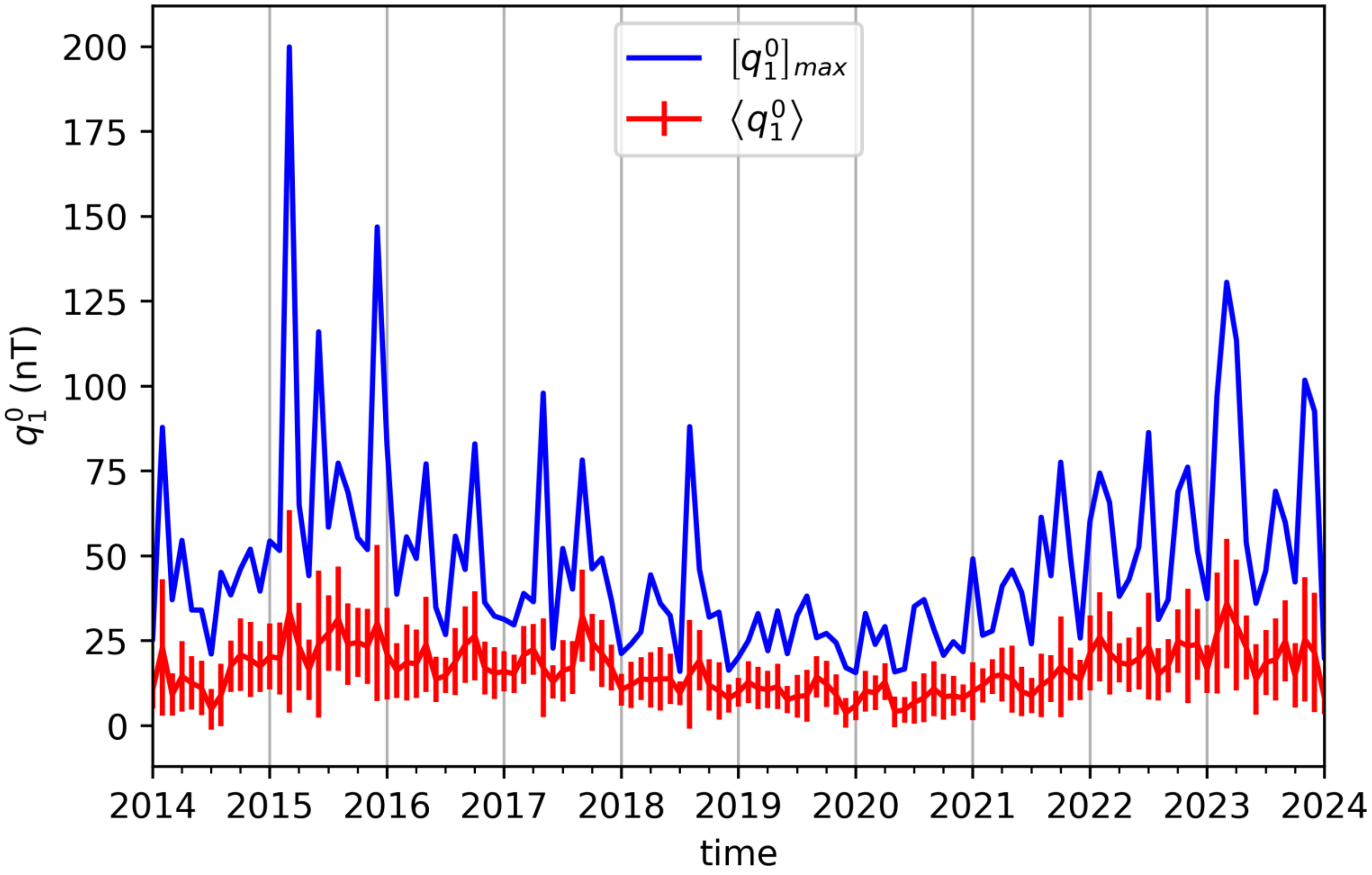
Solar cycle

- Using Swarm data only, we plot the monthly mean and standard deviation (red).



Solar cycle

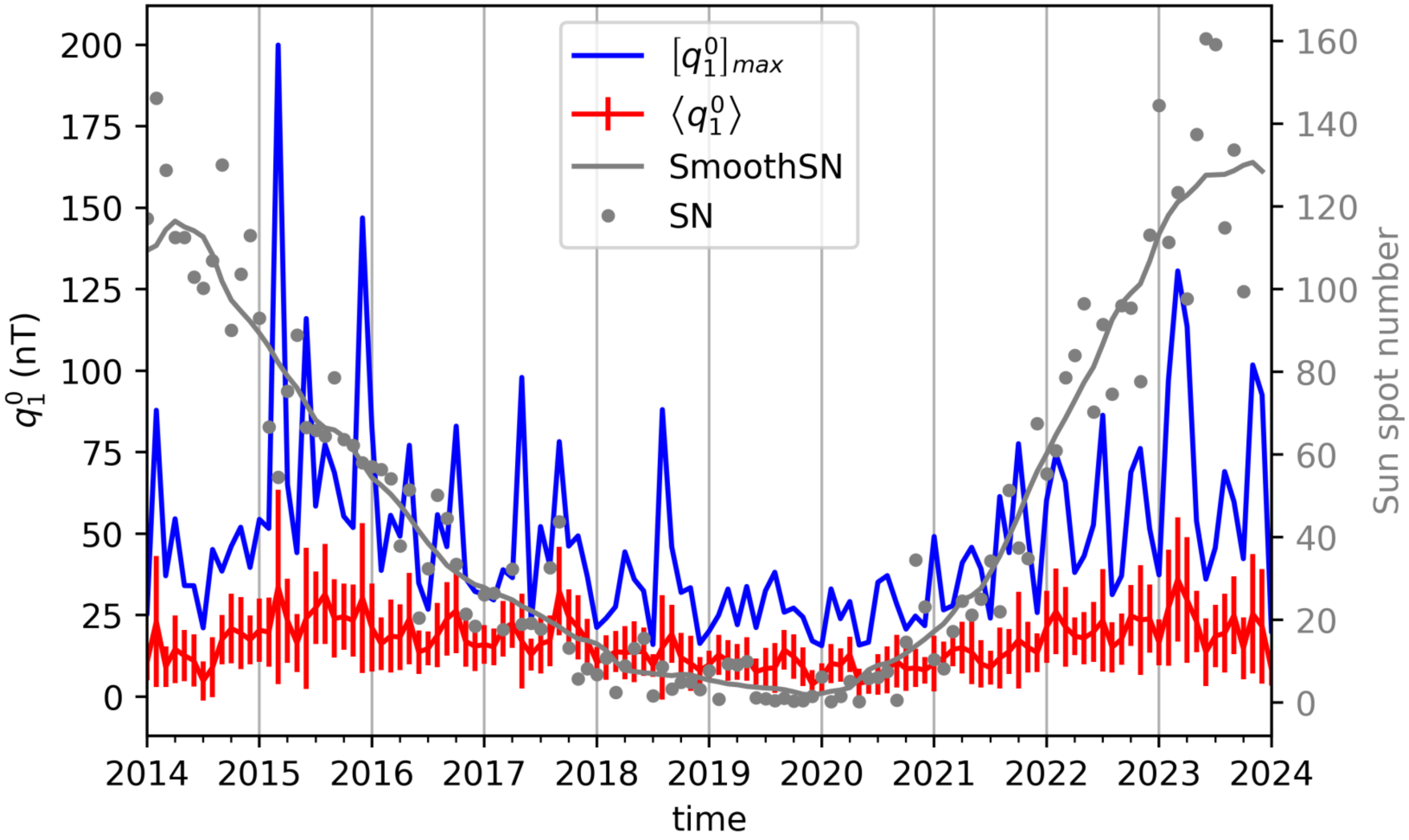
- Using Swarm data only, we plot the monthly mean and standard deviation (red).
- The monthly maximum value exhibits a larger variation (blue).



Solar cycle

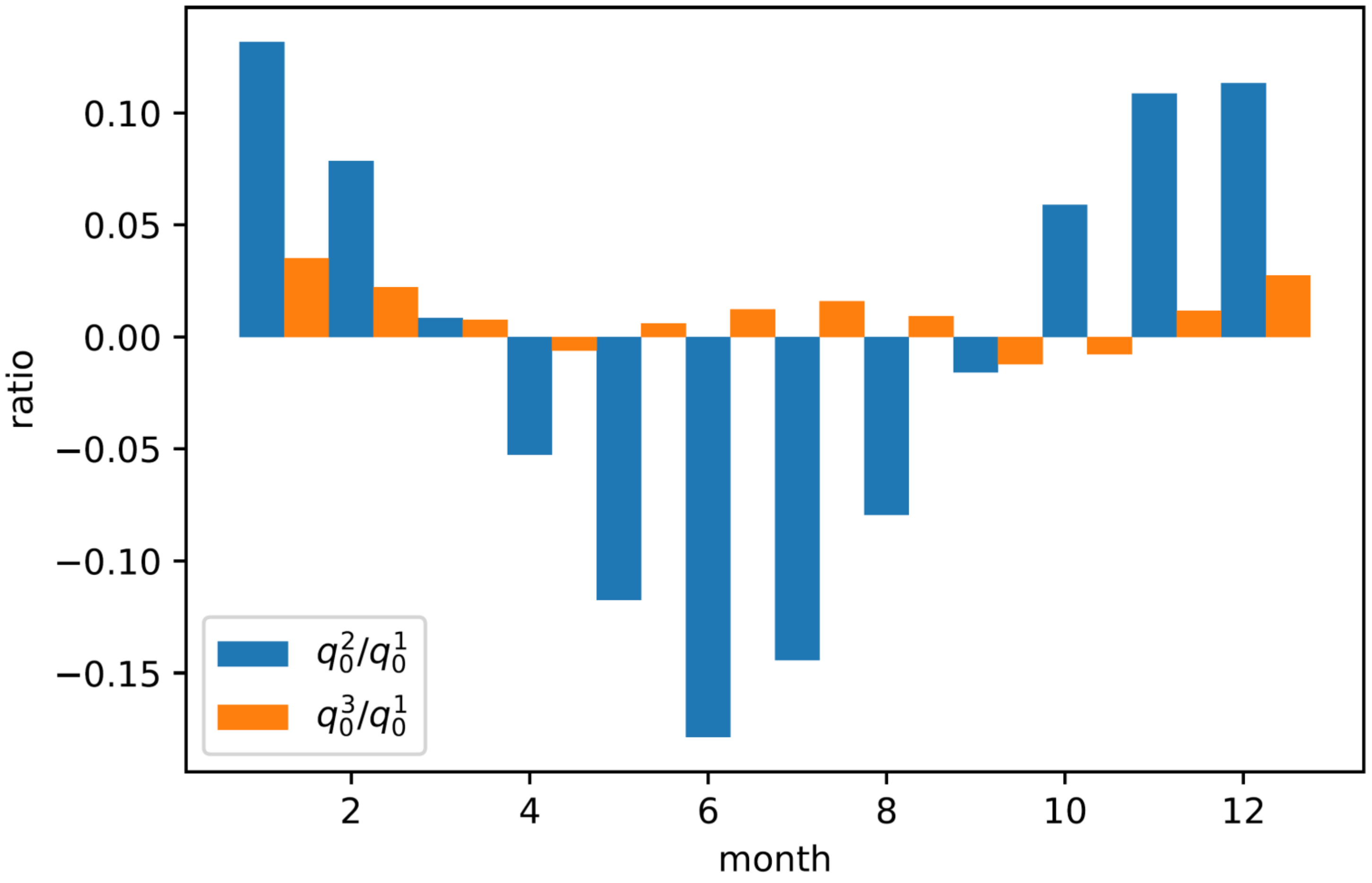
- Using Swarm data only, we plot the monthly mean and standard deviation (red) [steady ring current].
- The monthly maximum value exhibits a larger variation (blue).
- Energetic storms are more likely during solar maxima, when the Sunspot Number (SN) is large (see line and points in grey).

SILSO, World Data Center - Sunspot Number and Long-term Solar Observations, Royal Observatory of Belgium, on-line Sunspot Number catalogue: http://www.sidc.be/SILSO/, 2014 to 2024

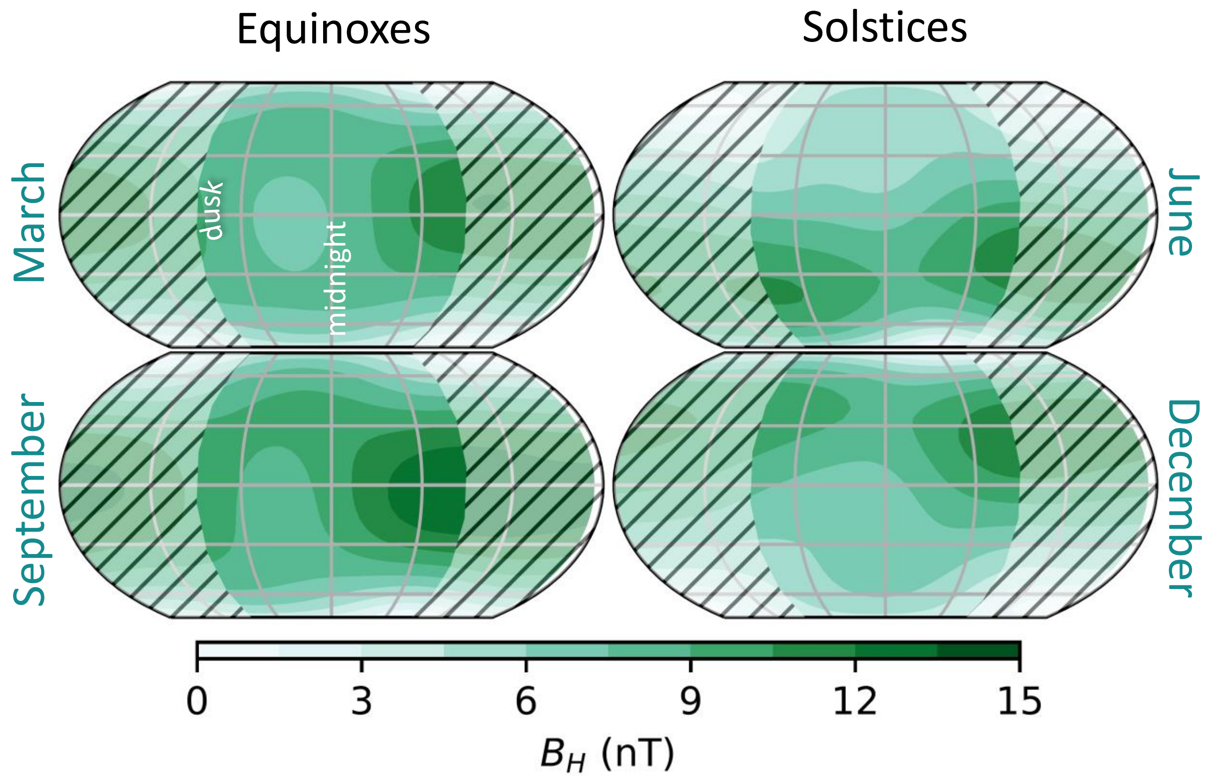


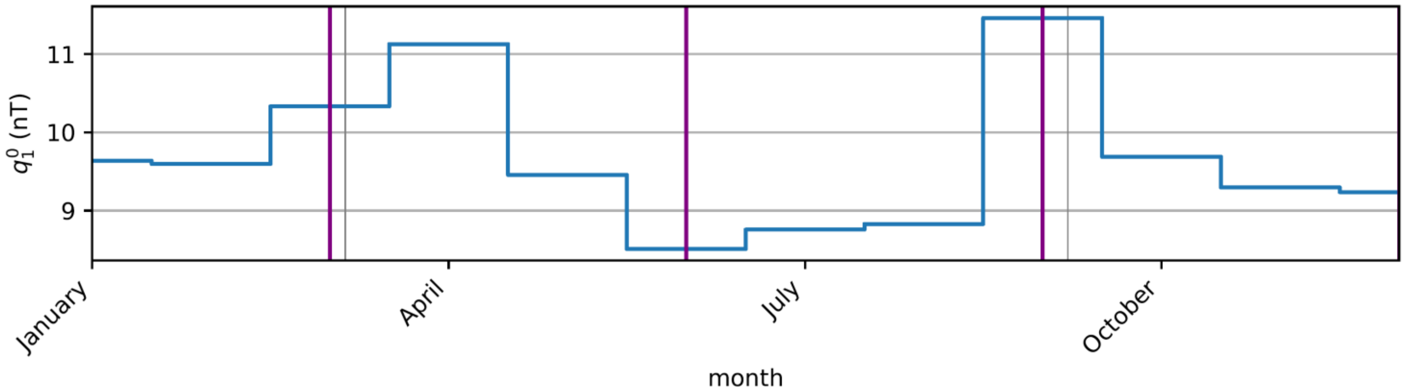
Seasonal variability

- The angle between the magnetic pole and the ecliptic plane varies seasonally. This can be observed by the location of the night-side ring current.
- During the June the night-side ring current moves south of the equator while it moves north in December.



Seasonal variability





Top: Color maps on Solar Magnetic (SM) coordinates.
On the center of the map is midnight. We use data only from the night side, so the day side is shaded.
Bottom: Value of the average inducing dipole per month, a value closely associated with the negative of the Dst-index.
Strong geomagnetic storms will result on large values of q_1^0

- We can also select the geomagnetically Quiet Days§ and study the behaviour of the night-side magnetosphere.
- We show here the mean Quiet magnetosphere for four months of the year, corresponding to the equinoxes and solstices. We see the Russell-McPherron effect as q_1^0 is larger during the equinoxes.

§ Matzka, et al., 2021. *The geomagnetic Kp index and derived indices of geomagnetic activity*.
Space Weather, https://doi.org/10.1029/2020SW002641

Conclusions

- Geomagnetic ground observatories provide long-term stable measurements. However, the inhomogeneous geographic coverage inhibits their usefulness for steady quiet-time magnetospheric currents.
- Thanks to Swarm 10-year high quality magnetic data we can study how the night-side magnetosphere has varied throughout the solar cycle.
- Even when combinations of other ESA satellites might provide a better resolution for specific events (storms), long-term study needs consistent and stable baseline that spans the whole solar cycle.
- Swarm is the only data set that can provide this!

Conclusions

- 10-Year variation controlled by the solar activity can be observed on Swarm measurements.
    - Magnetospheric field remains (relatively) unchanged during the solar cycle, but its variability increases during solar maxima.
    - Probability of occurrence of large storms (i.e., q_1^0 max) depends on the solar activity (and season, see also next point).
- We study the seasonal variation of the quiet night-side magnetosphere using the averaged 10-year data set.
    - As expected, we see a longitudinal displacement of the ring current (RC) plane.
    - We also observe an increase in the ring current intensity (mean q_1^0) during equinoxes (i.e., Russell-McPherron effect).
    - We observe an azimuthal asymmetry in the RC during equinoxes, where the RC is more intense at dawn local time.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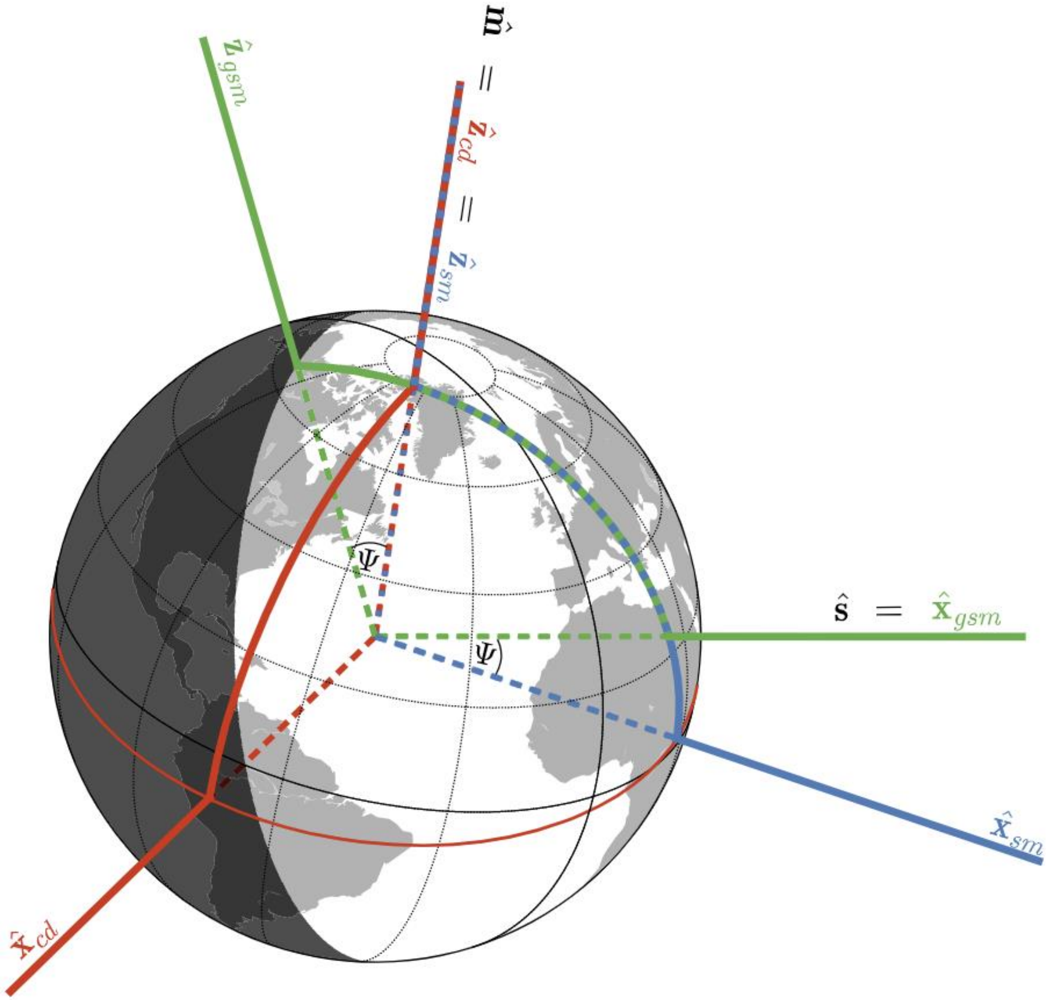
SM Coordinates

- The *z*-axis is aligned with the dipole axis
- The sun-Earth line is contained in the *xz*-plane



Laundal and Richmond Space Sci (2017)