Sensitivity of Auroral Zones to the Global Internally Generated Magnetic Field

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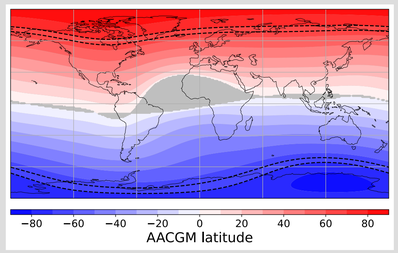
DEFINITIONS

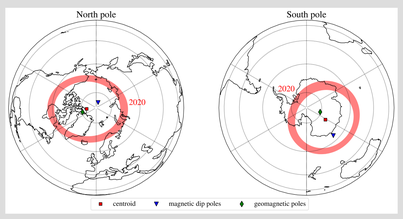
Auroral oval ⇒ influenced by solar activity (*space weather*)

Auroral zone ⇒ time-averaged auroral oval: controlled by the internal magnetic field (*space climate*)

How do we obtain them

1. Calculate AACGM latitudes from IGRF-13 model (up to L=13)
2. Isolate 65-to-70 latitudinal bands at Earth's surface
3. Calculate centroid as additional measure for location



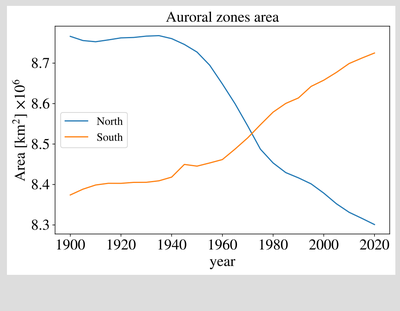


See *Maffei et al., 2023* for more details

MOTIVATIONS

Observation:

- Northern Zone: shrinking
- Southern Zone: expanding
- Dipole-based scaling laws predict expansion for both



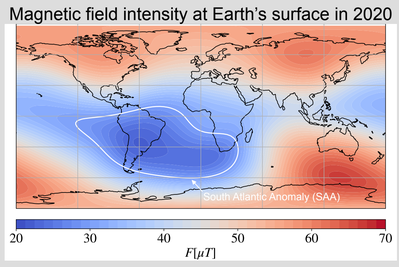
Current explanation:

- The asymmetric evolution of the geomagnetic field in the two polar regions.

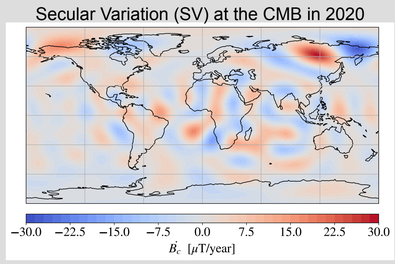
Open questions:

- **Effect of global SV?** *Typically, equatorial effects are neglected (e.g. Zossi et al., 2020).*
- **Effect of non-dipolar SV?** *Currently poorly quantified.*

Magnetic field intensity at Earth's surface in 2020



Secular Variation (SV) at the CMB in 2020



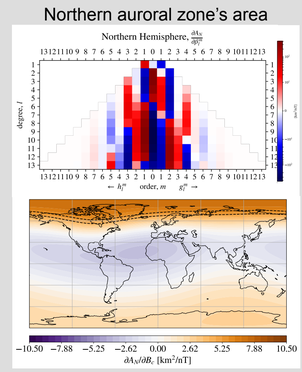
METHODOLOGY

Green's function's approach

Q = zones area or centroids latitude: functions of the Gauss coefficients, β_l^m.

Sensitivity to Gauss coefficients, obtained numerically:

$$\frac{\partial Q}{\partial \beta_l^m} = \frac{Q(\beta_l^m + \delta\beta_l^m) - Q(\beta_l^m)}{\delta\beta_l^m}$$



Sensitivity to CMB field, B_c:

$$\frac{\partial Q}{\partial B_c} = \sum_{l=1}^{L} \sum_{m=0}^{l} \frac{\partial Q}{\partial \beta_l^m} \frac{\partial \beta_l^m}{\partial B_c}$$

Sources of time variation, from the secular variation:

1. as a function of degree, l: $\frac{\partial Q}{\partial t}(l) = \sum_{m=0}^{l} \frac{\partial Q}{\partial \beta_l^m} \frac{\partial \beta_l^m}{\partial t}$

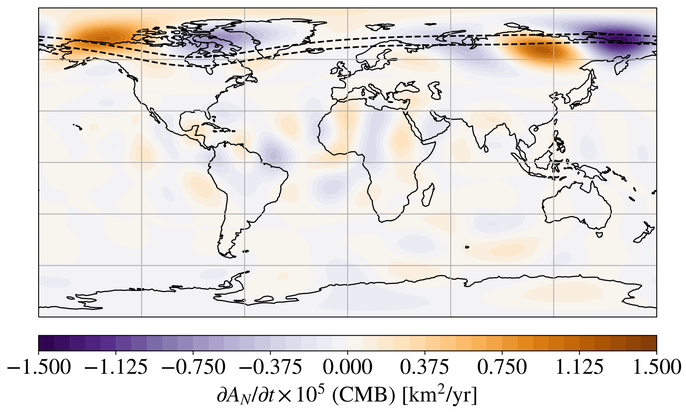
2. or geographical location: $\frac{\partial Q}{\partial t}(\theta, \phi) = \frac{\partial Q}{\partial B_c} \frac{\partial B_c}{\partial t}$

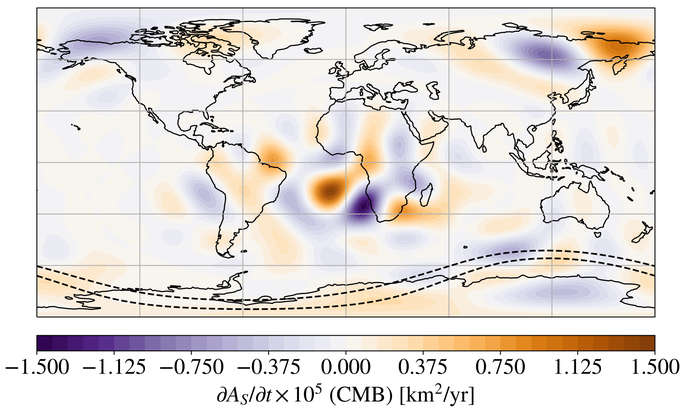
RESULTS: Sources of time variation

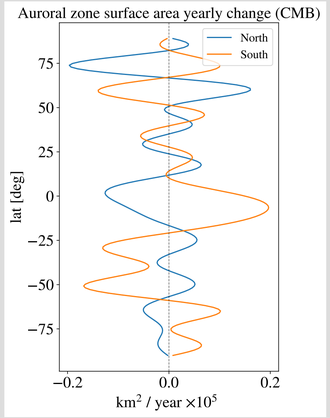
Geographical distribution at the CMB

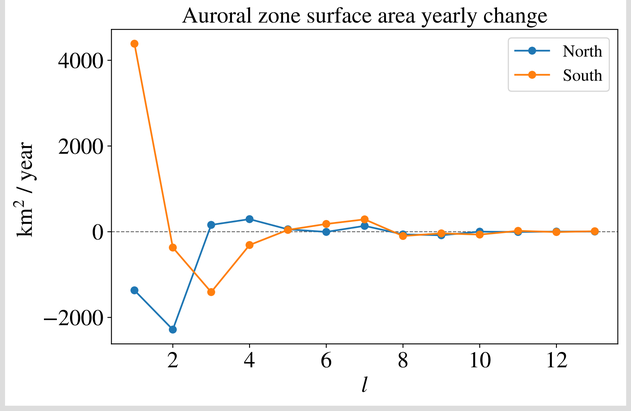
Spectral distribution

Surface area

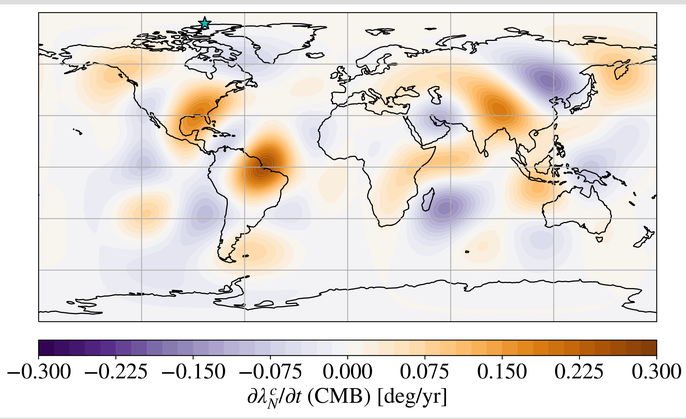


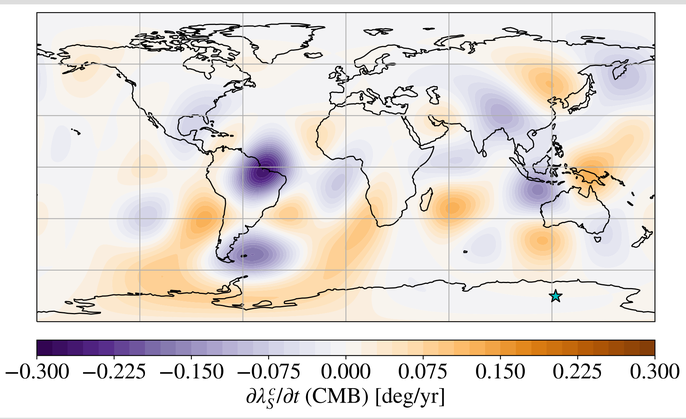


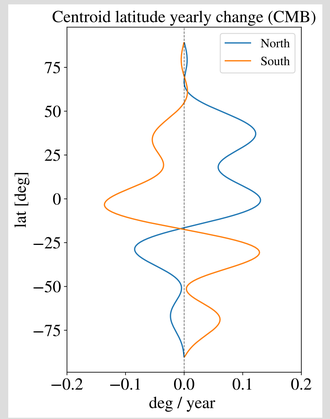


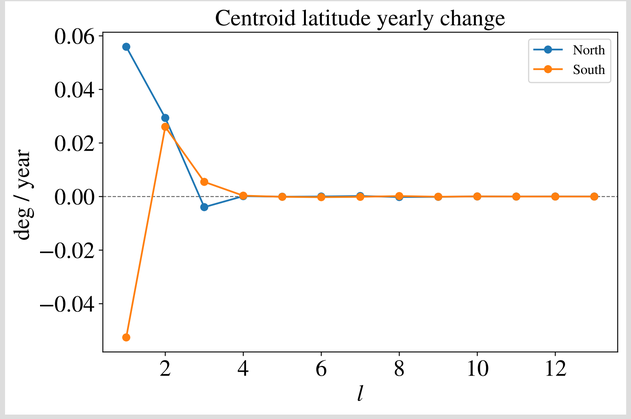


Centroid latitude

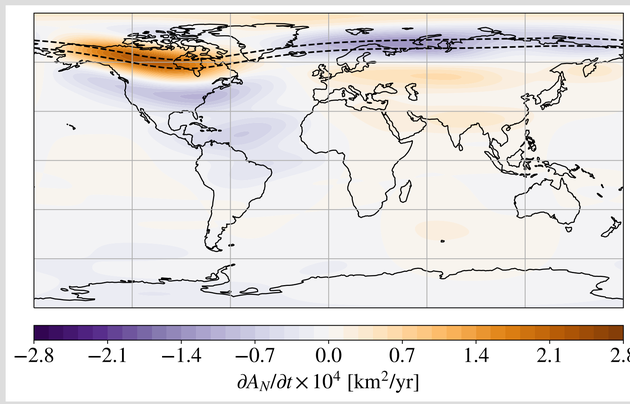


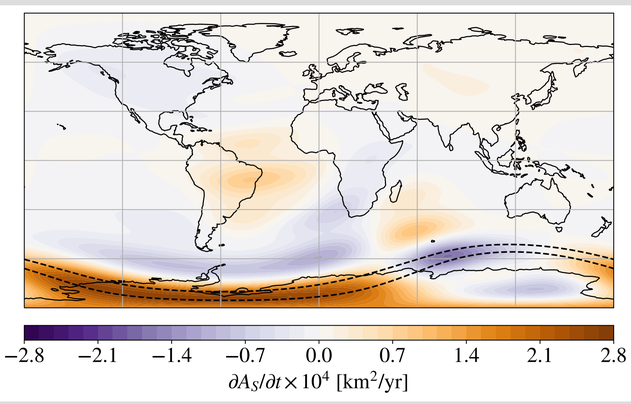


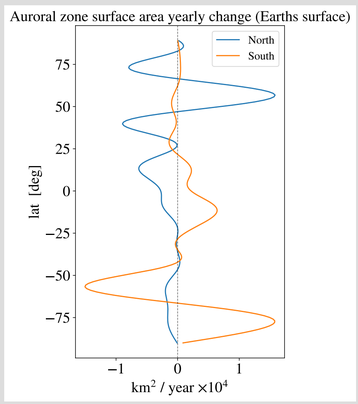




RESULTS: Sources of time variation at Earth's surface







Conclusions

- The auroral zones location and geometry is heavily affected by non-dipolar field components
- Northern zone area shrinking: caused by dipolar and quadrupolar contributions
- Geographical sources of time-variation are distributed globally
- Secular Variation in the SAA region strongly affects the auroral zones.

References

aacgmv2 Github repository: https://github.com/aburrell/aacgmv2

Laundal, Karl Magnus, and Arthur D. Richmond. "Magnetic coordinate systems." *Space Science Reviews* 206, no. 1 (2017): 27-59.

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