Determination of the True Ionospheric Currents and Conductances from Combined Ground- and Space-Based Observations

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Background

- Ionospheric electrodynamics one major controlling factor of the geospace dynamics.
- Ground-based or space-based magnetic field observations alone cannot provide the true full (field-aligned and horizontal) ionospheric electric currents.
- Combined usage of ground-based and space-based magnetic field observations required for direct derivation of the the true ionospheric currents.
- When combined further with ionospheric electric field observations, the true currents facilitate direct characterization of the full ionospheric electrodynamics.

Background

- Our goal is to use combined unprecedented global data sets to derive, for the first time, directly the full electrodynamic properties of the global ionosphere.
- Work supported by the NSF grant # AGS-1003513.

Methodology

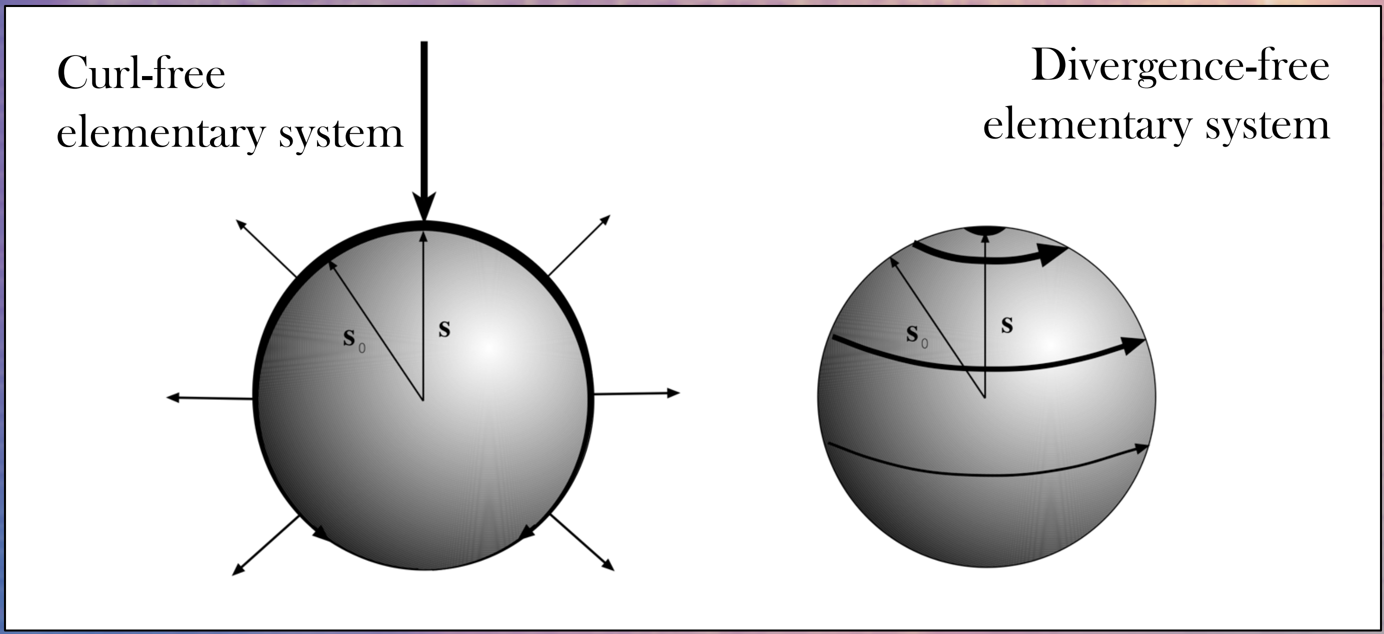
- We apply Spherical Elementary Currents Systems (SECS) to represent the divergence-free and curl-free parts of the system:

$$\bar{j} = \bar{j}_{df} + \bar{j}_{cf} = \int_V \overline{G}_{df} \times \bar{u}\, dV + \int_V \overline{G}_{cf}\, v\, dV \qquad (1)$$

$$\begin{aligned} \nabla \cdot \bar{j}_{df} &= 0 & \qquad \nabla \times \bar{j}_{df} &= \bar{u} \\ \nabla \times \bar{j}_{cf} &= 0 & \qquad \nabla \cdot \bar{j}_{cf} &= v \end{aligned} \qquad (2)$$

Methodology

- In SECS $\overline{G}_{df}, \overline{G}_{cf}$ in Eq. (1) are constructed using discrete elementary systems:



Methodology

- The amplitudes J_0^{df}, J_0^{cf} of the discrete elementary systems are solved using information about ground magnetic field fluctuations and field-aligned current densities, respectively. For details, see *Amm* (JGR, 2001) and *Pulkkinen et al.* (Earth, Planets, Space, 2003).

Methodology

- Finally, conductances can be solved from:

$$\Sigma_H = \frac{\left(\bar{j} \times \bar{E}\right)_r}{\left|\bar{E}\right|^2}$$

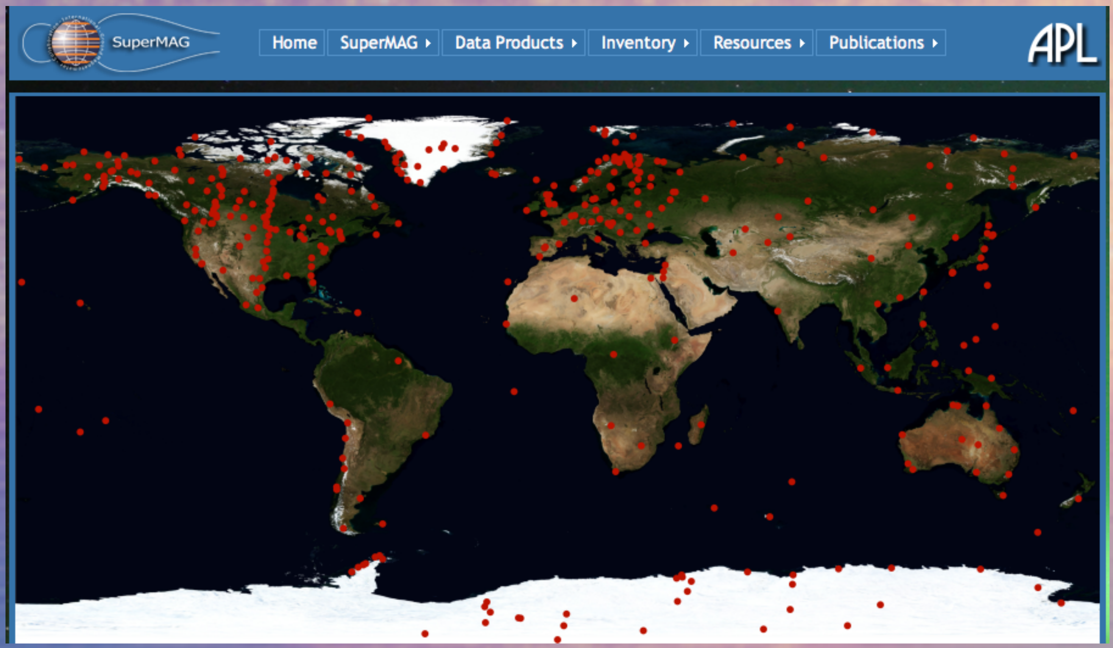
$$\Sigma_P = \frac{\bar{j} \cdot \bar{E}}{\left|\bar{E}\right|^2} \qquad (3)$$

Fields need to "line up" well

Need to be careful with small electric field amplitudes

Global observations I

- The ground magnetic field observations provided by SuperMag:



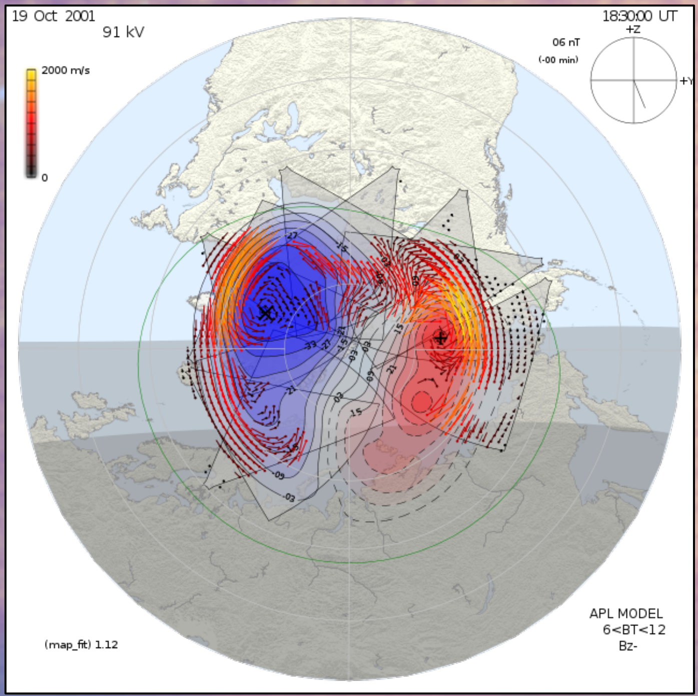
Global observations II

- The field-aligned current densities provided by the Iridium constellation:

>70 spacecraft in six orbit planes

Global observations III

- Ionospheric electric field provided by SuperDARN:



Progress

- We have identified a set of steady state periods for which initially lower temporal resolution Iridium data can be applied.
- Software interfaces between SuperMAG, SuperDARN and Iridium data and SECS software generated.
- SECS software package extended to include treatment of divergence-free systems.

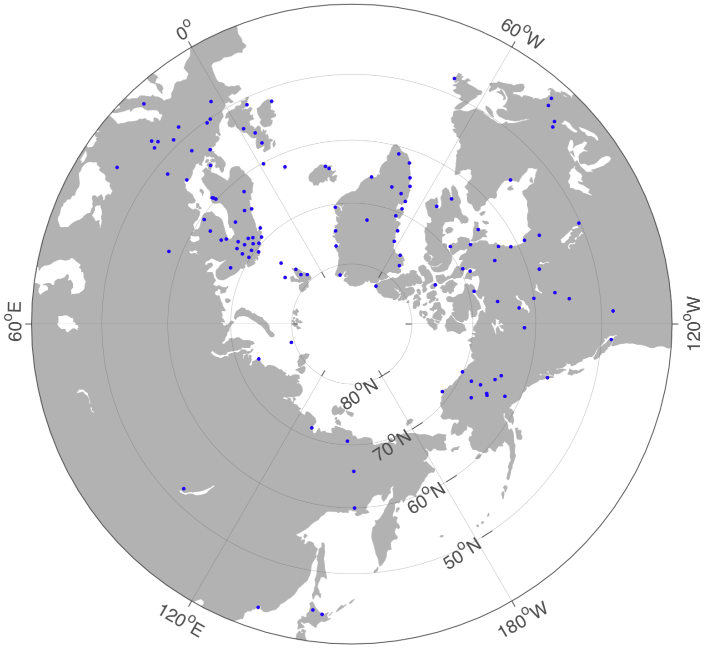
Progress

- Coordinate transformations and mappings between 780 and 110 km required:
  - IDL package for Altitude Adjusted Corrected Geomagnetic (AACGM) coordinates converted to Matlab.
  - New Matlab AACGM package freely available (email antti.a.pulkkinen@nasa.gov).
- DataMap reader for MatLab generated.

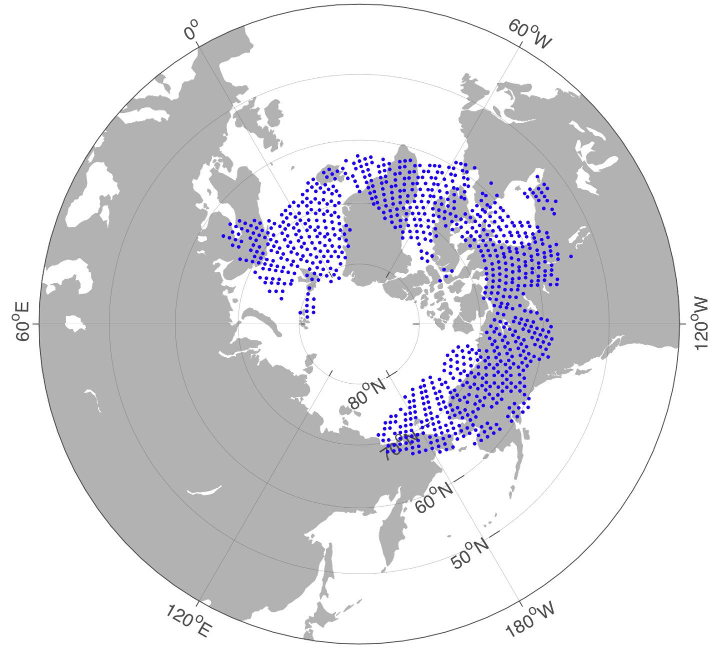
Initial results: 2001-10-09 14:00-15:00Z

In the following 1-min SuperMAG and 2-min SuperDARN data averaged over the given 60-min periods

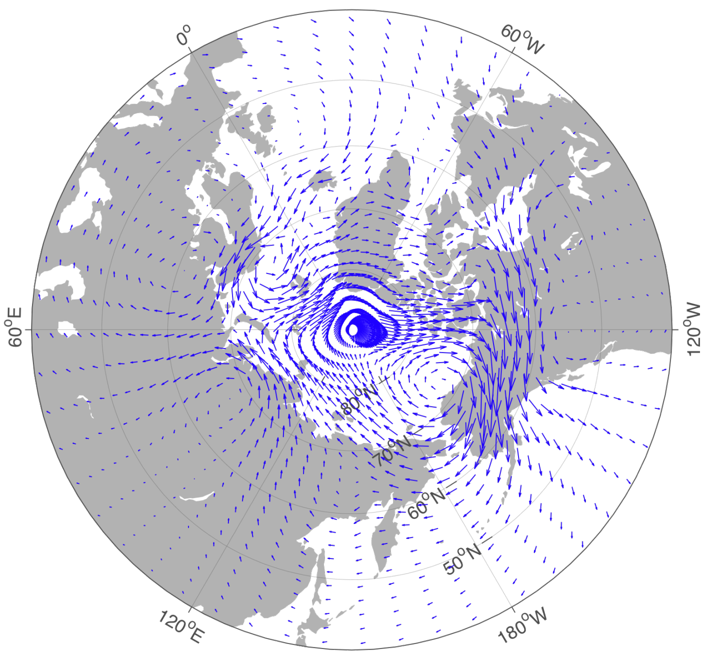
Supermag stations.



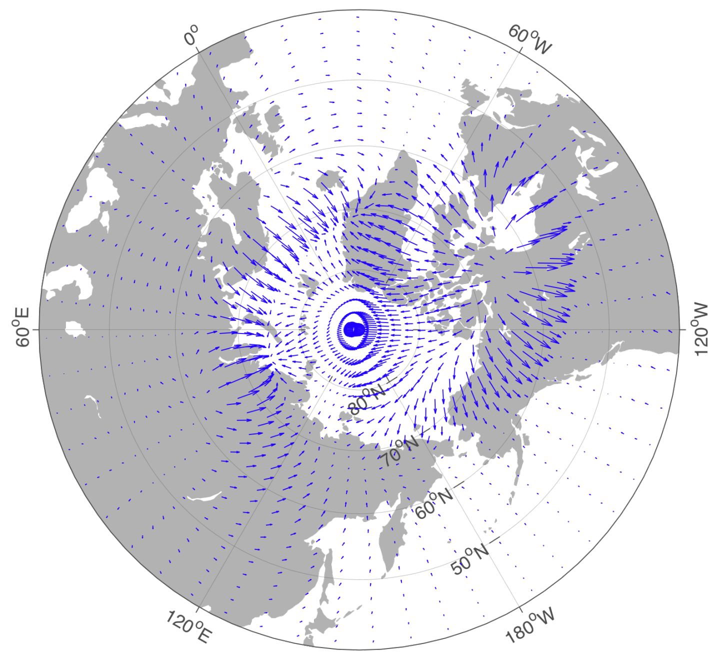
SuperDARN locations with good coverage.



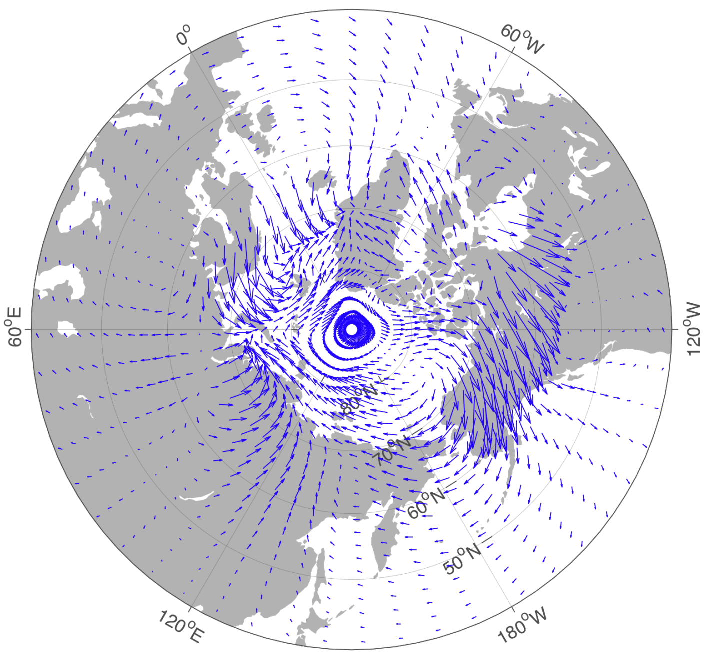
Supermag divergence−free horizontal currents. Max. |j|: 0.82 A/m.



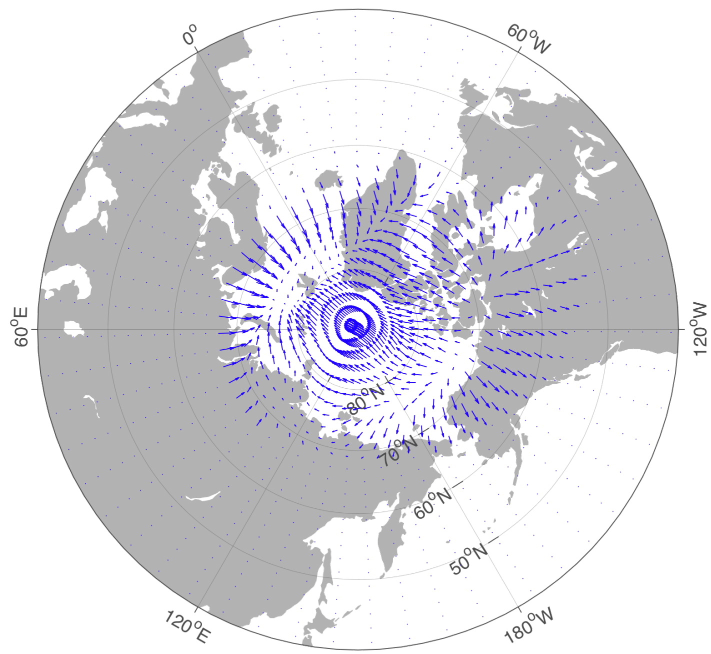
Iridium curl−free horizontal currents. Max. |j|: 0.57 A/m.



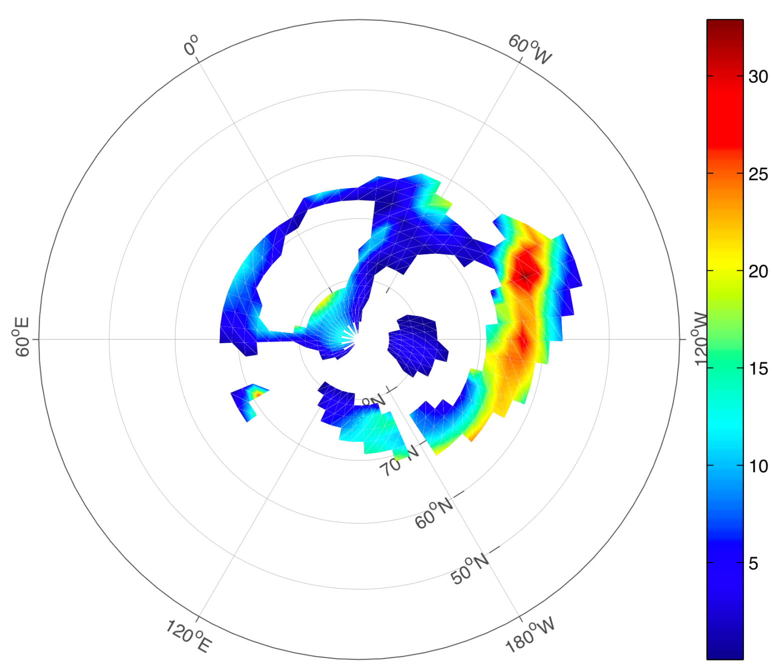
Total horizontal currents. Max. IjI: 1.04 A/m.



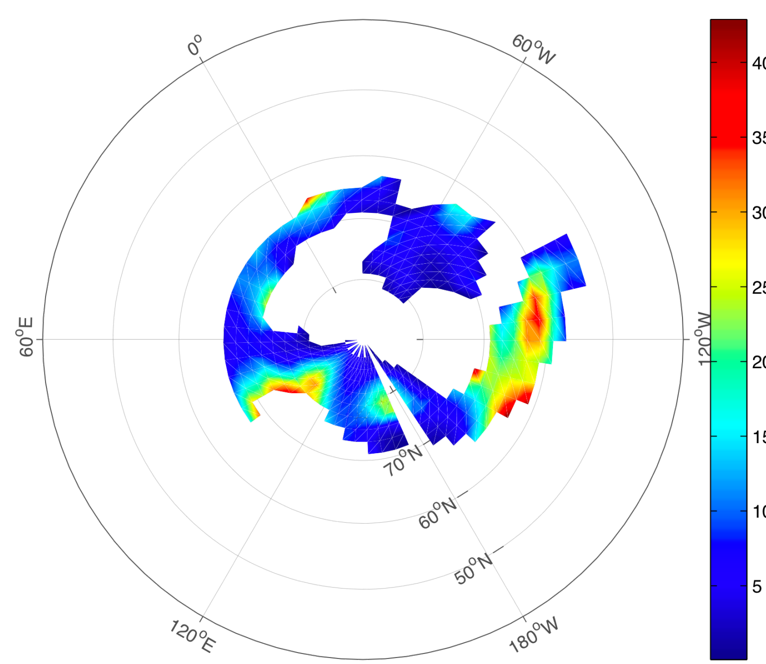
Electric field. Max. IEI: 0.05 V/m.



Hall conductance. Max SigmaH: 32.90 Siemens.



Pedersen conductance. Max SigmaP: 42.87 Siemens.



Next steps

- Analysis of all 20 quasi-steady state one-hour periods.
- Carry out detailed sciences analyses.
- Use the derived global ionospheric maps in the global geospace model validation.
- Apply the methodology and the generated software with the new AMPERE data.

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