Statistical field-aligned current maps determined from SuperDARN HF radar measurements of ionospheric vorticity

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SuperDARN Workshop 2008

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Motivation

Measurements of ionospheric plasma vorticity have been used as a proxy for the magnetic field-aligned currents (FACs) that dynamically couple the magnetosphere to the ionosphere.

- How good a proxy is vorticity for field-aligned current?
- What can we learn from comparing statistical patterns of vorticity and field-aligned current?
- Does studying spatiotemporal variations in vorticity help understand magnetosphere-ionosphere coupling?

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Talk Outline

- Introduce new method for vorticity determination.
- Test validity of method by studying statistical variations of vorticity with AACGM latitude, magnetic local time, season and interplanetary magnetic field direction.
- Compare these results with previous field-aligned current measurements.

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Vorticity and Field-Aligned Current

- The field-aligned current $J_{||}$ can be written in terms of the **E×B** drift velocity **v** as,

$$J_{||} = \Sigma_P \mathbf{B} \cdot (\nabla \times \mathbf{v}) + (\mathbf{v} \times \mathbf{B}) \cdot \nabla \Sigma_P + |\mathbf{B}| \, \mathbf{v} \cdot \nabla \Sigma_H$$

- In the limit of uniform ionospheric conductances, the field-aligned current is proportional to the vorticity $\nabla \times \mathbf{v}$,

$$J_{||} = \Sigma_P \mathbf{B} \cdot (\nabla \times \mathbf{v})$$

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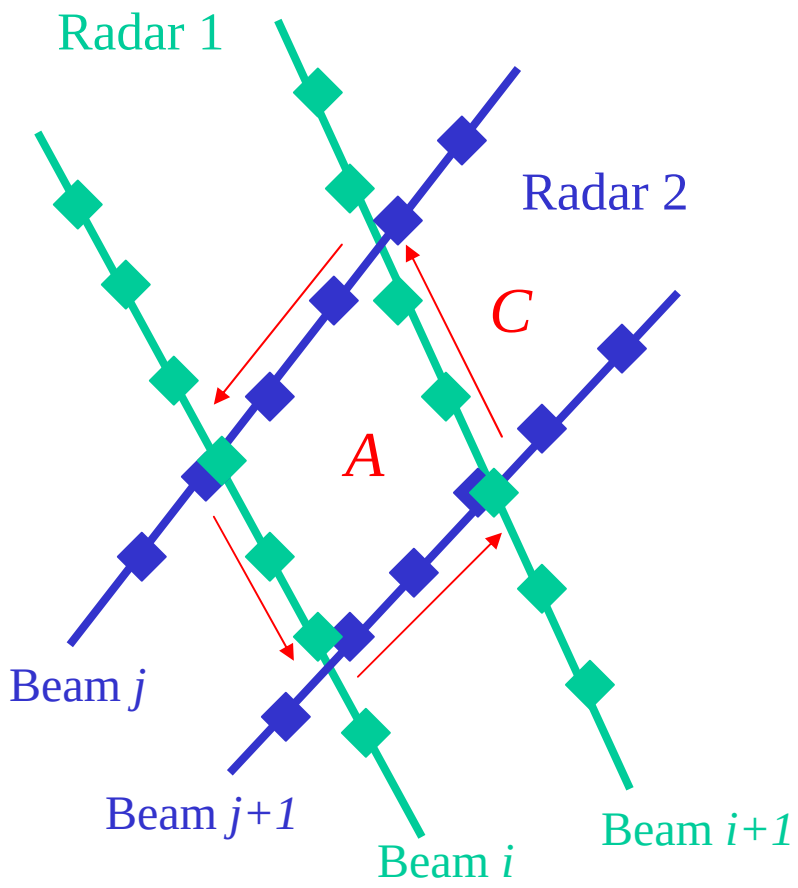
Vorticity Determination Technique



- We use Stokes theorem to estimate the vorticity (∇x**V**)

$$\oint_C \mathbf{V}.\mathbf{dl} = \int_S (\nabla \times \mathbf{V}).\mathbf{dS}$$

- The quadrilateral defined by overlapping beams from adjacent radars represents a closed loop *C*, enclosing surface *S*, of area *A*.

- Similar method to *Sofko et al. (1995)* but the use of line-of-sight velocities rather than MERGE or Map Potential velocity vectors means fewer assumptions and limitations.

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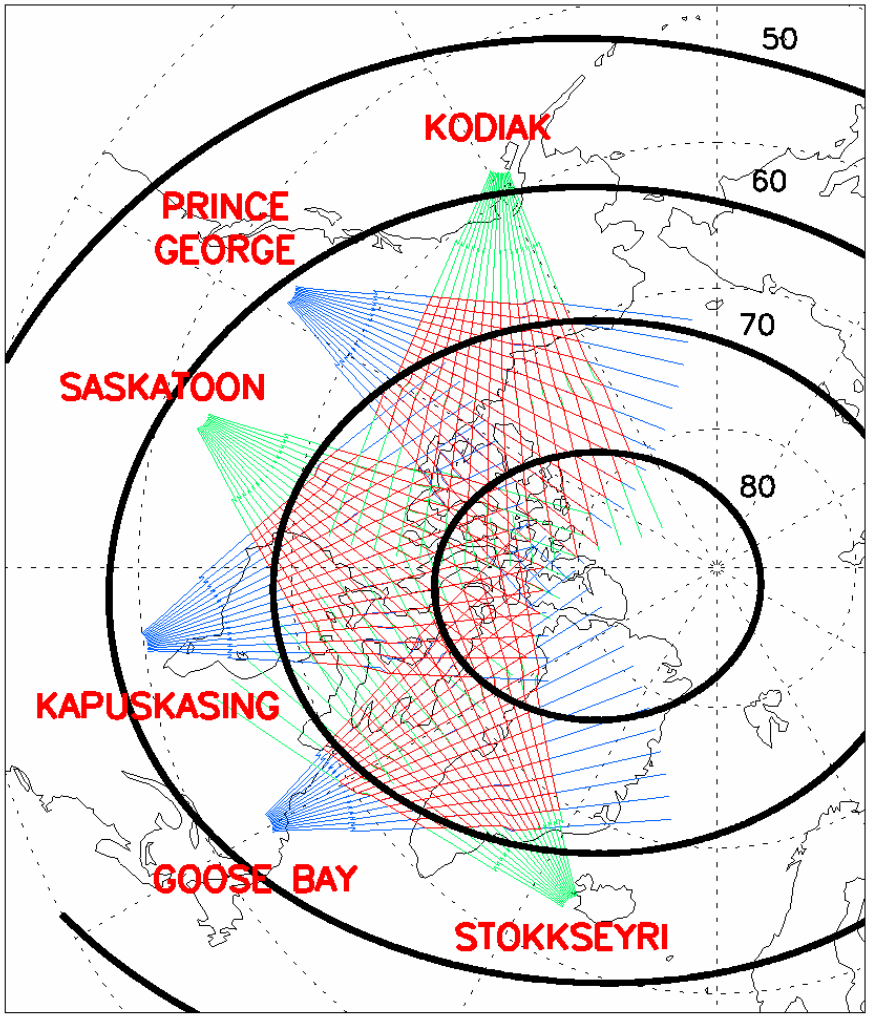
Compilation of Database

- Determined all vorticities for 6 years of common mode data (2000-2005) from three northern hemisphere SuperDARN radar pairs.
- Determined the average vorticity from this data set in 1° and 1-hr MLT bins.
- Negative (positive) vorticity is equivalent to an upward (downward) field-aligned current.



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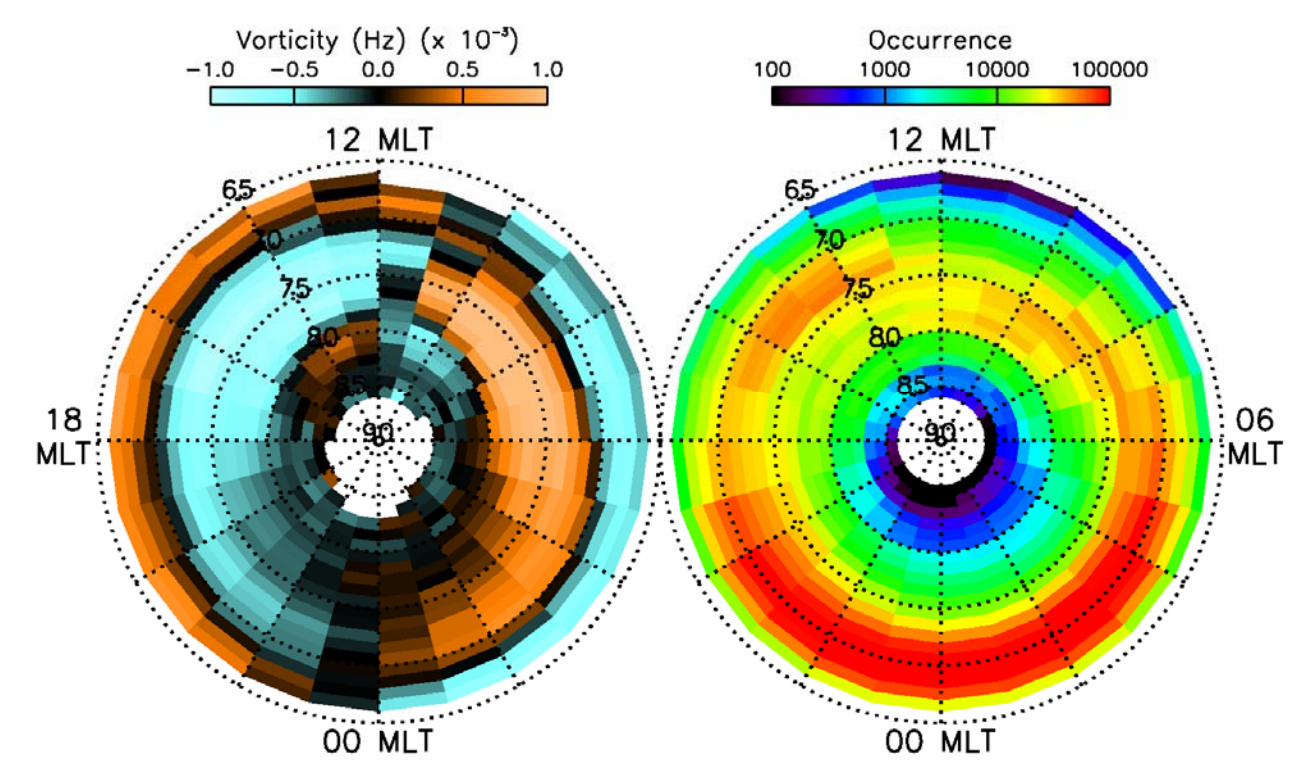
Global Average Vorticity Variation



- The statistical pattern of vorticity closely resembles the previously-reported average field-aligned current pattern.
- Region 2 currents at lowest latitudes (<70°).
- Region 1 currents at higher latitudes (~70°-80°).
- NBZ/Region 0 currents at highest latitudes (>80°).

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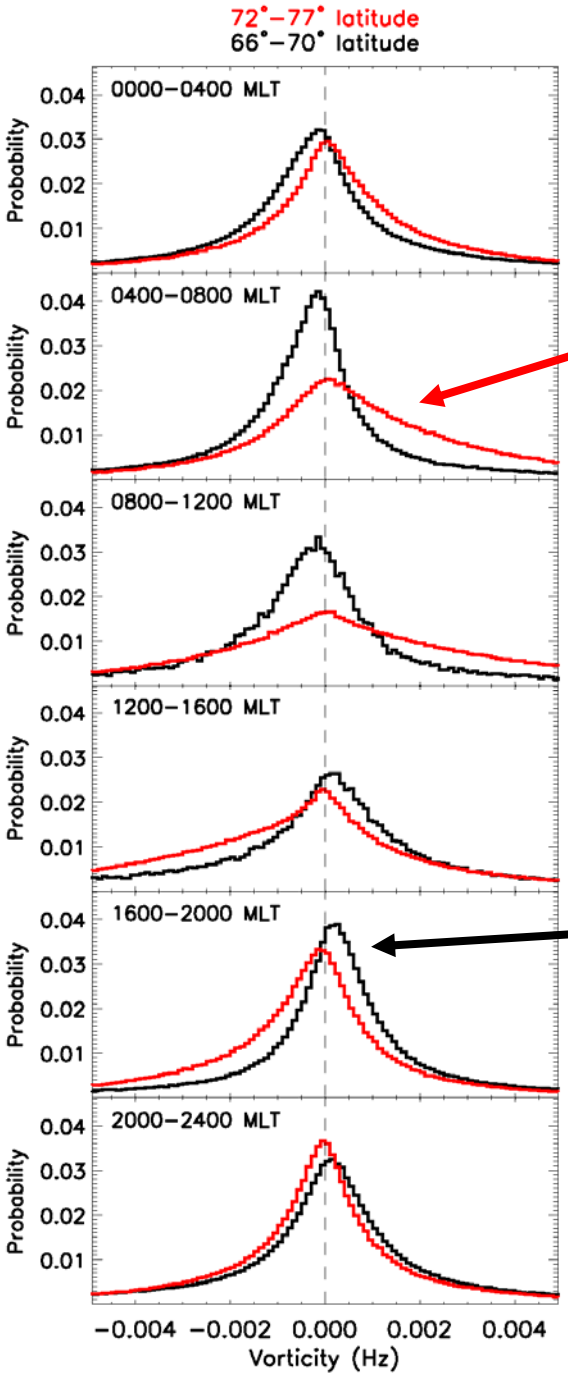
Vorticity Distribution Variation with AACGM Latitude and MLT

- The distributions of measured vorticity are very wide and non-Gaussian.
- The average vorticity maps don't portray the range of vorticity values observed in any one region.



Distributions of vorticity in the Region 1 current region

Distributions of vorticity in the Region 2 current region

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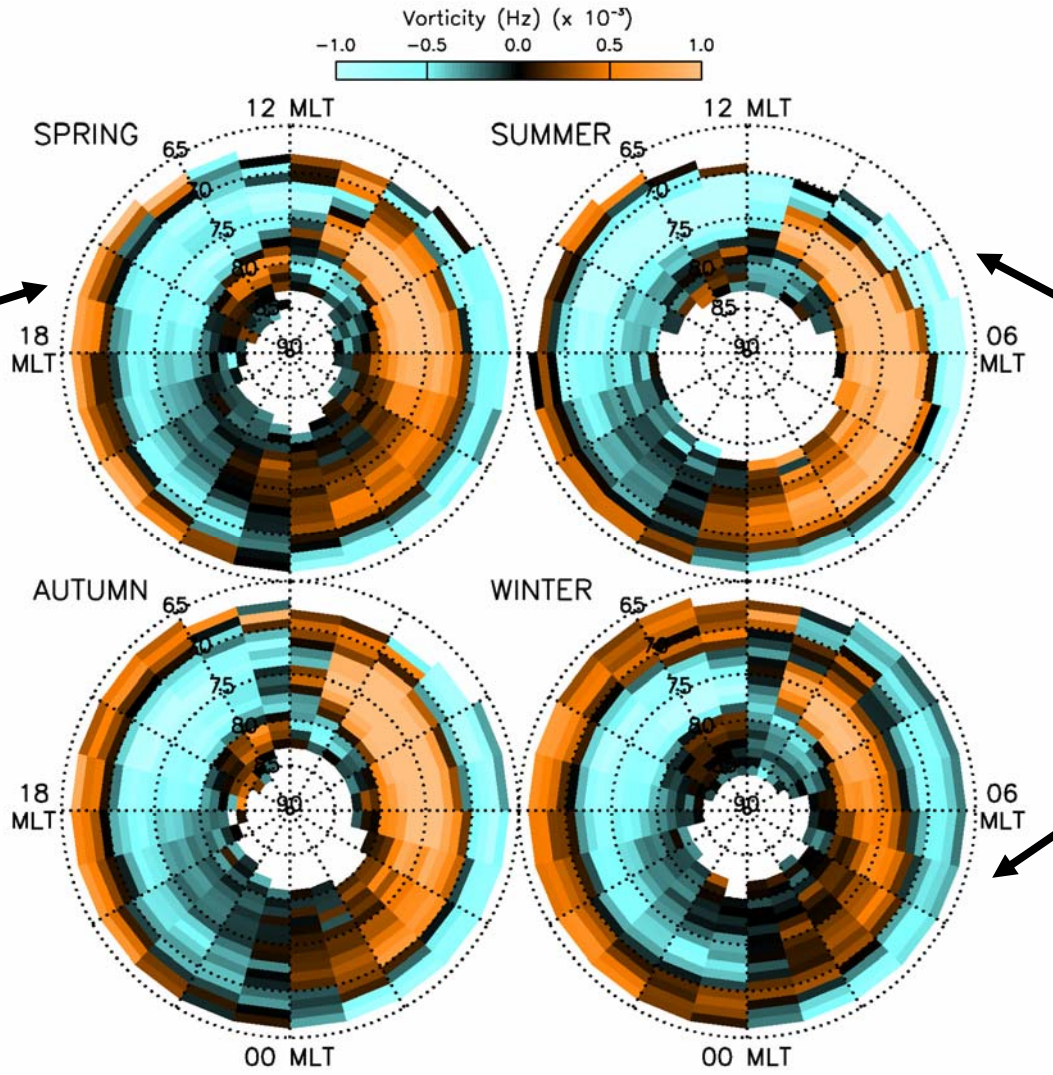
Average Vorticity Variation with Season



Equinoctal average vorticity patterns are very similar

Solstice average vorticity patterns have significant differences

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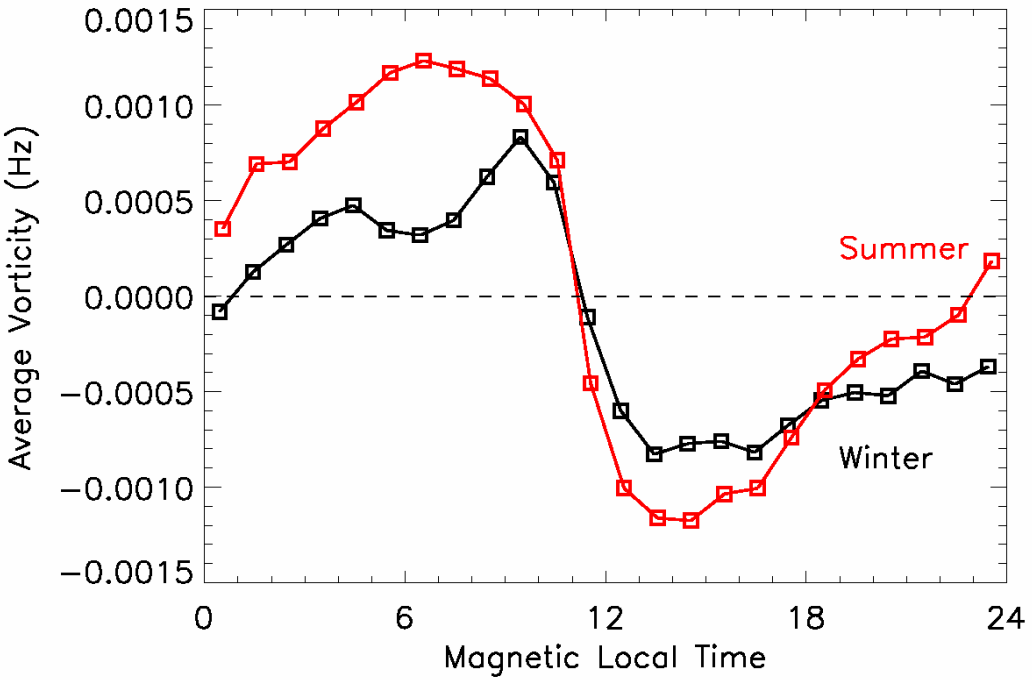
Average Vorticity Variation with Season

Average vorticity between 72° and 77° AACGM latitude – centre of region 1 current system



- Previous studies have concluded that the peak dayside region 1 FAC is ~2 times greater in the summer hemisphere than the winter hemisphere.
- The average vorticity measurements show a similar result suggesting that this difference is not solely a result of seasonal differences in the Pedersen conductance but that there are seasonal differences in the electric field intensity.

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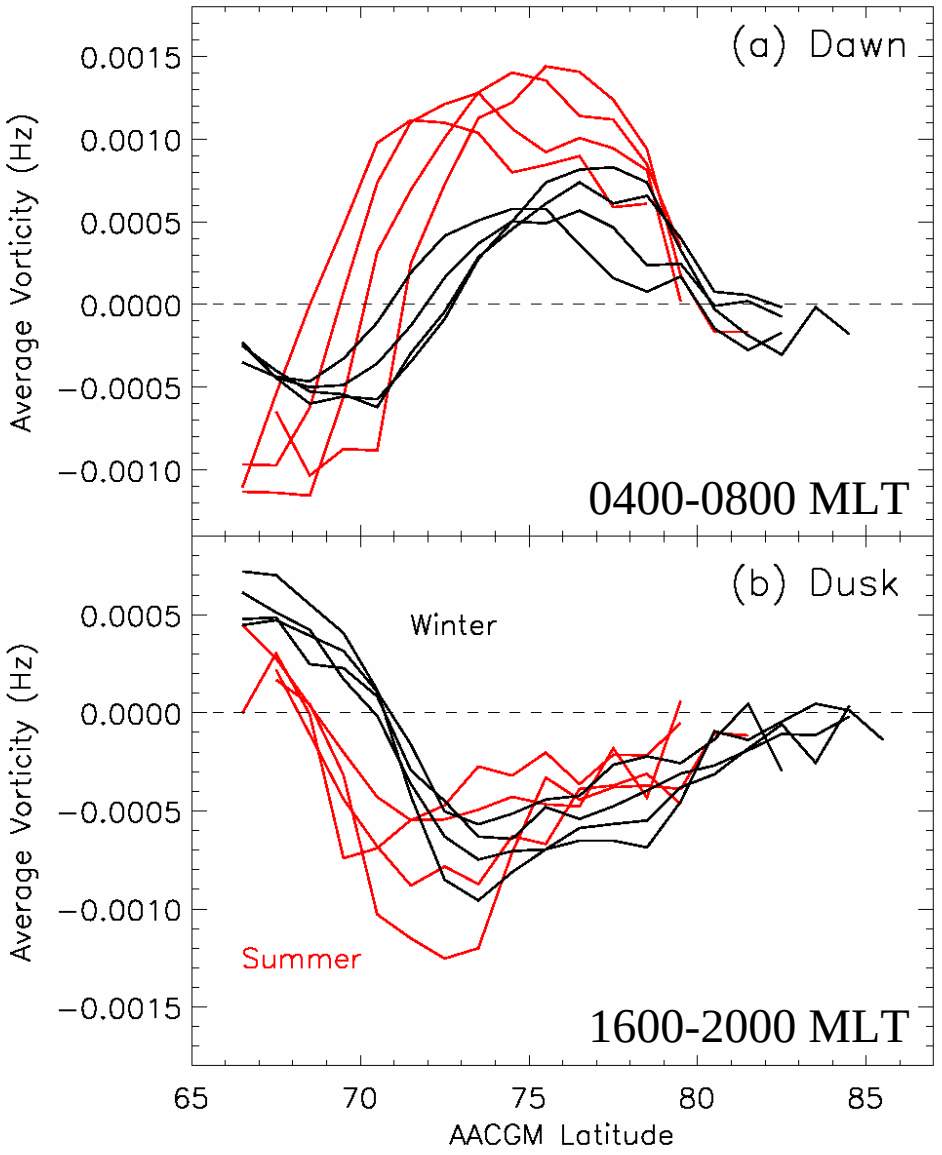
Average Vorticity Variation with Season

- Previous studies have reported that the dayside currents in the summer hemisphere are located at ~1º-3º higher latitude than in the winter hemisphere.
- Our peak average vorticity variations around dawn and dusk show the opposite variation with season.
- We presently have no explanation for these differences.



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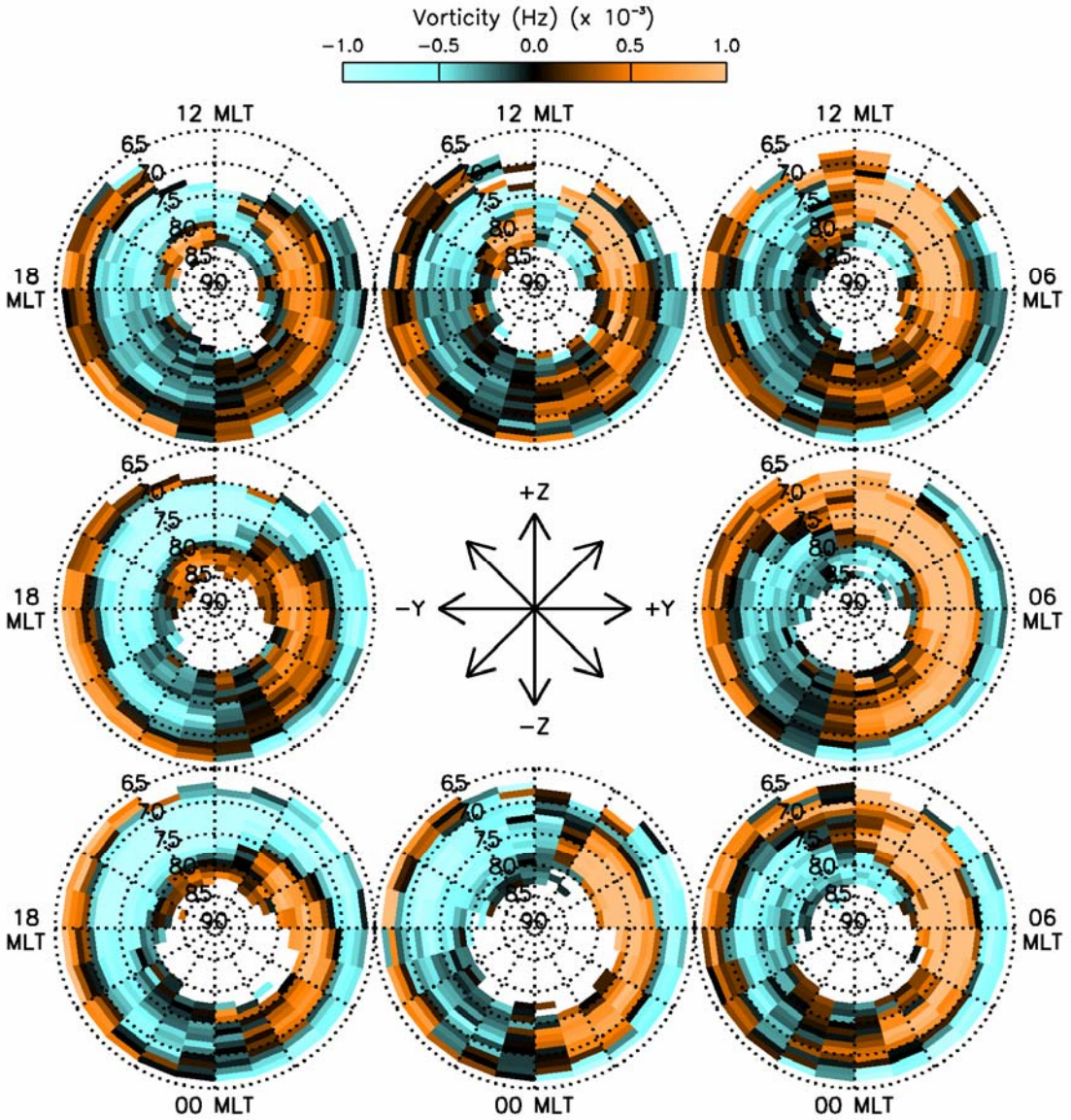
Average Vorticity Variation with IMF

- Only SuperDARN data from half-hour intervals within which 70% of Weimer-mapped IMF data from the ACE spacecraft falls within a certain IMF direction bin are used.
- The vorticity regions relating to the Region 1 and Region 2 currents (and the Region 1 and Region 0 currents) merge in the dayside ionosphere in the form of a spiral, but not in the nightside ionosphere.
- There is a clear high-latitude two-cell vorticity pattern in the dayside ionosphere for northward IMF



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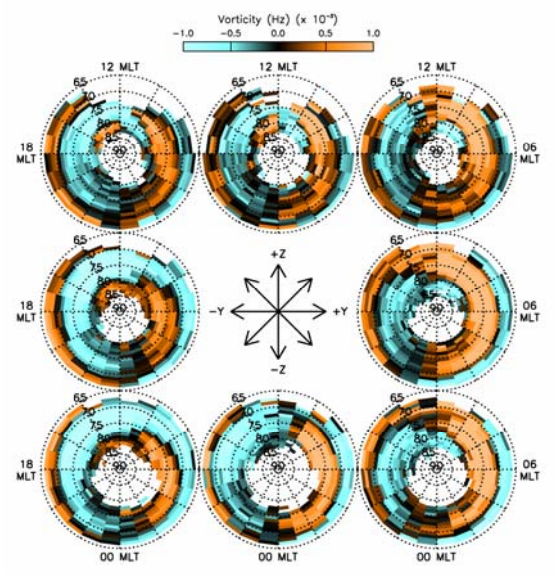
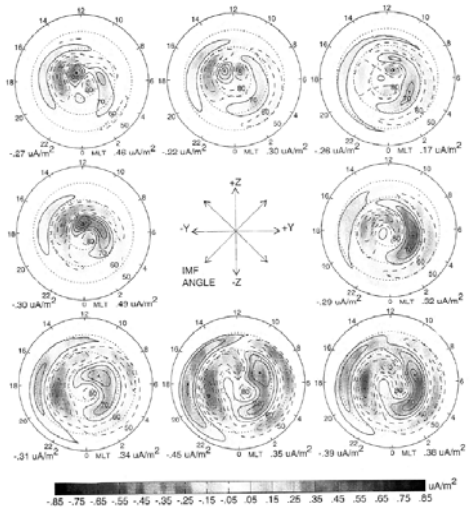
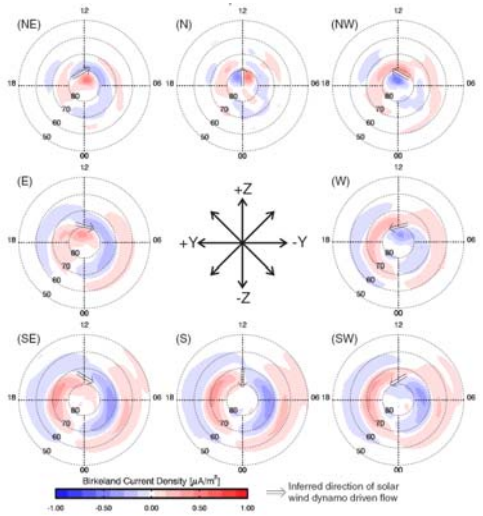
Average Vorticity Variation with IMF



Chisham et al.(2008)
SuperDARN vorticity



Weimer (2001)
DE-2 B-field data



Anderson et al.(2008)
Iridium B-field data

- The vorticity maps are almost identical to the statistical FAC maps measured by Anderson et al.(2008).
- All these maps show a clear symmetry with IMF *By* and reproduce all the expected current regions for different IMF directions.

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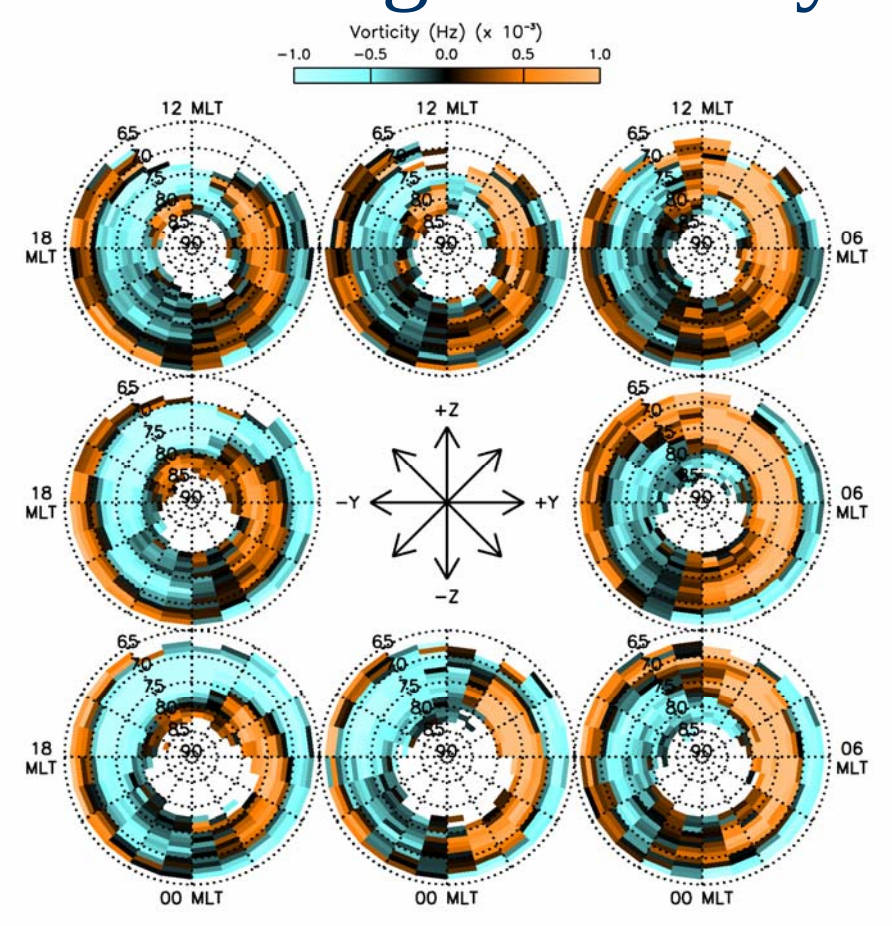
Average Vorticity Variation with IMF



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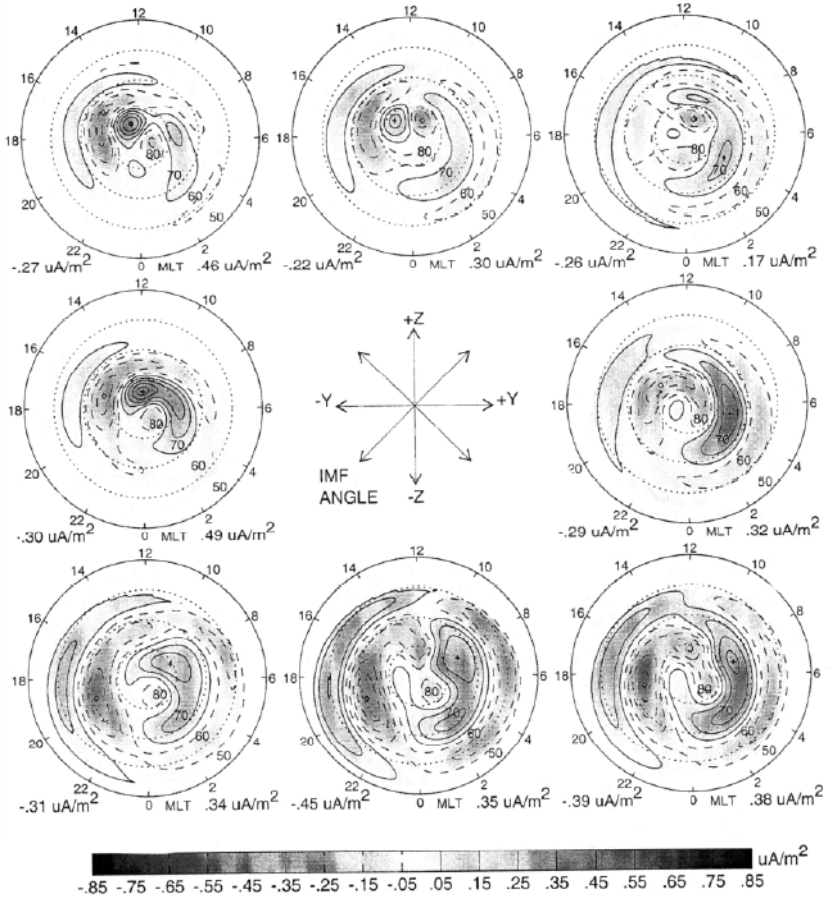

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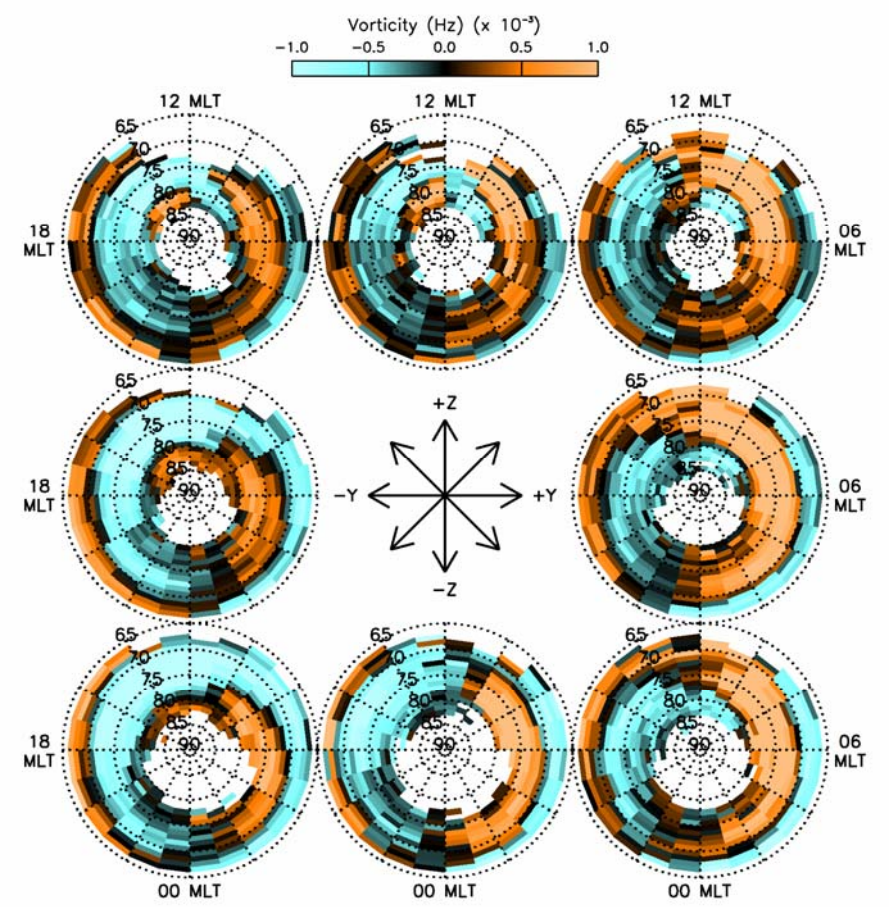
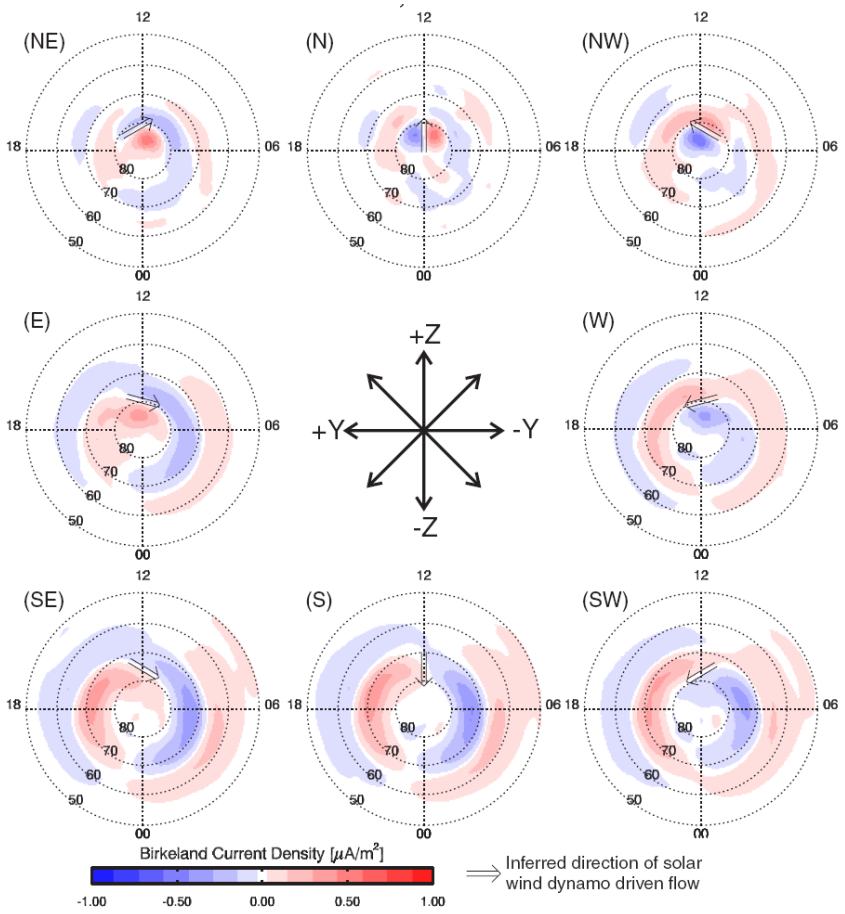
Average Vorticity Variation with IMF



Chisham et al.(2008)
SuperDARN vorticity



Anderson et al.(2008)
Iridium B-field data

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Summary

- Developed a new method for determining ionospheric vorticity from overlapping SuperDARN data.
- Average vorticity maps reproduce the average field-aligned current patterns.
- Larger average vorticities are measured in the dayside ionosphere in the summer hemisphere than in the winter hemisphere suggesting that this difference is not solely a result of seasonal differences in conductance.
- The vorticity maps show a clear symmetry with IMF B_y and reproduce all the expected current regions for different IMF directions.

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