The non-Gaussian nature of ionospheric vorticity fluctuations

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Motivation

Complex Ionosphere

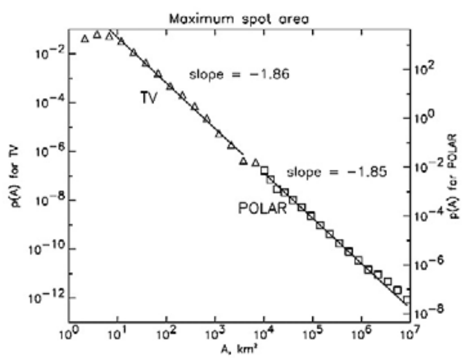
Complex Magnetosphere

Complex Field-Aligned Currents?

(rather than simple large-scale currents)

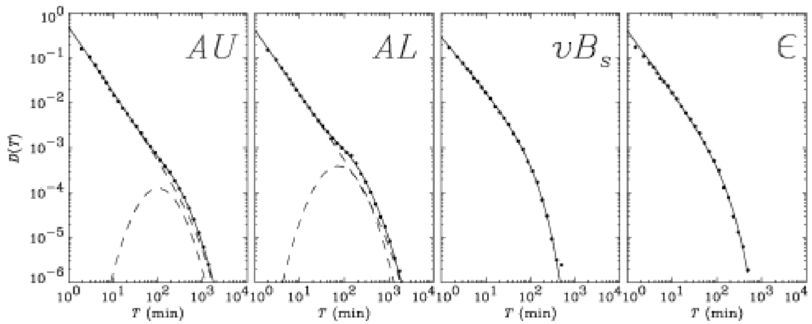
Complex Ionospheric Vorticity?

e.g., Scale-free aurora, scale-free ionospheric velocity fluctuations



Kozelov et al. (2004)

e.g., multi-scale magnetotail reconnection, scale-free FTE structure, scale-free magnetospheric currents.



Freeman et al. (2000)

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Talk Outline

- Outline the vorticity determination method.
- Determine global vorticity distribution.
- Investigate the variation of the vorticity distribution with measurement cell size.
- Illustrate how we can deconvolve the effects of latitudinal and cell size variations in the distributions.

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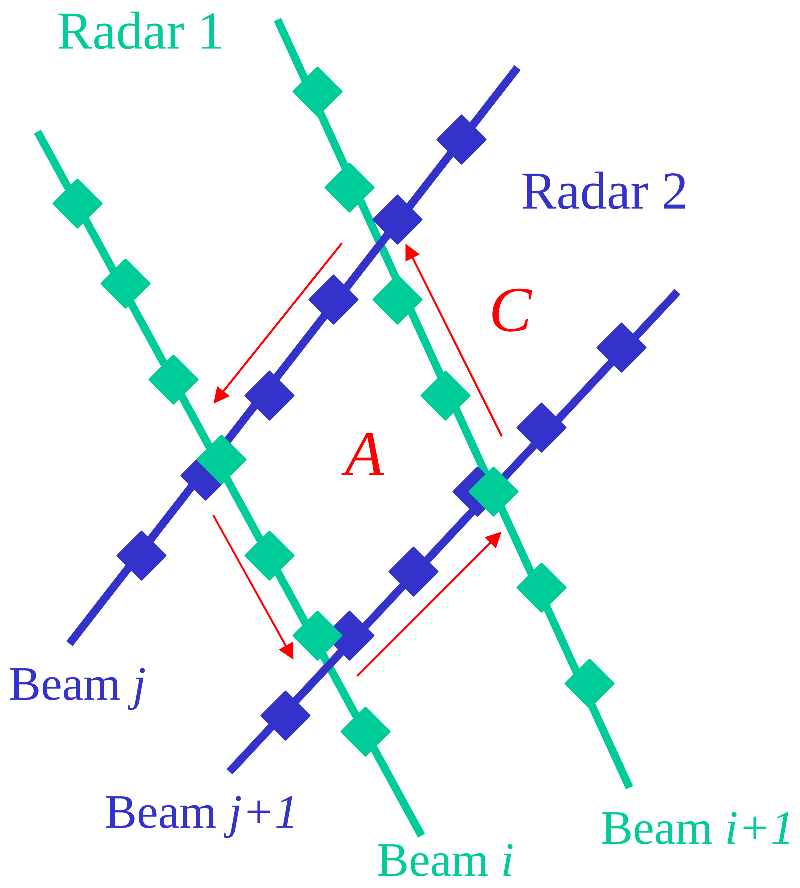
Vorticity Determination Technique



- 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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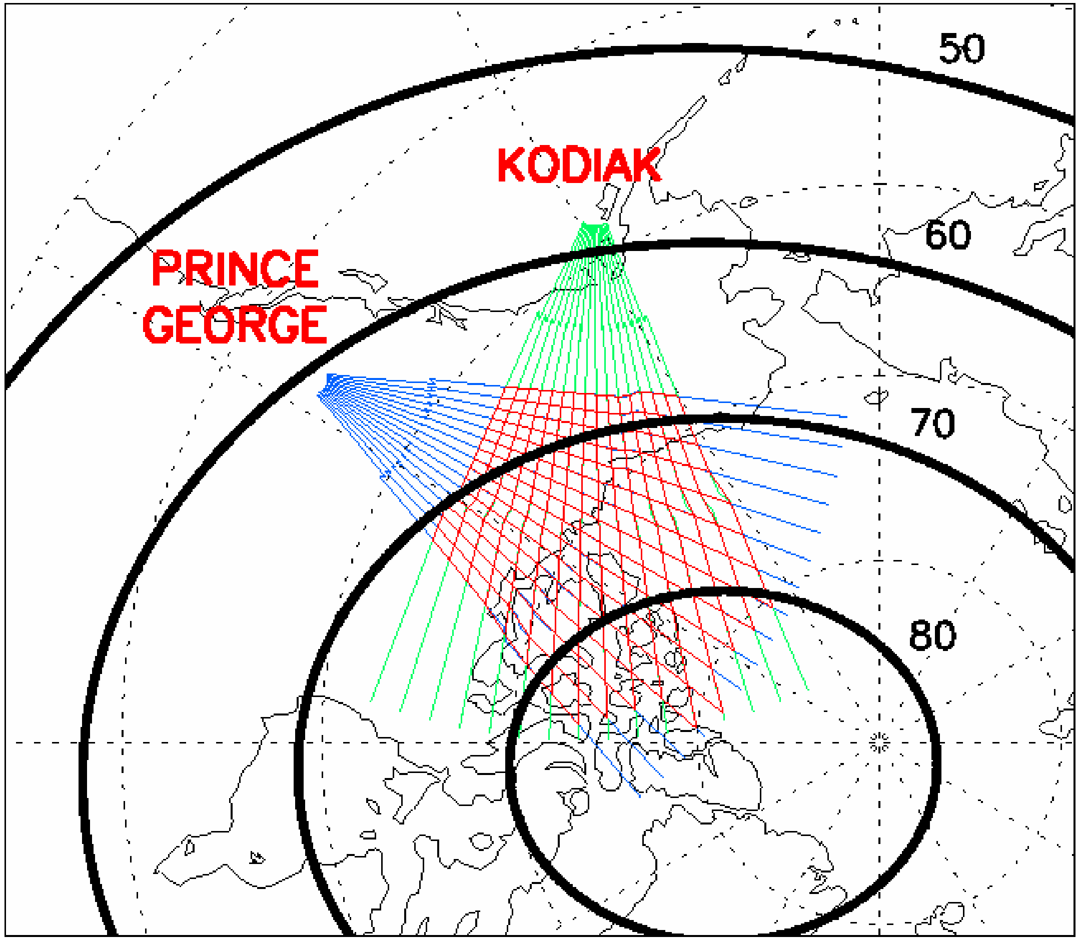
Compilation of Database

- Determined all vorticities for 6 years of common mode data (2000-2005) from the Prince George-Kodiak SuperDARN radar pair.

- Determined distributions of vorticity for all measurement cells.

- Negative (positive) vorticity is equivalent to an upward (downward) field-aligned current.



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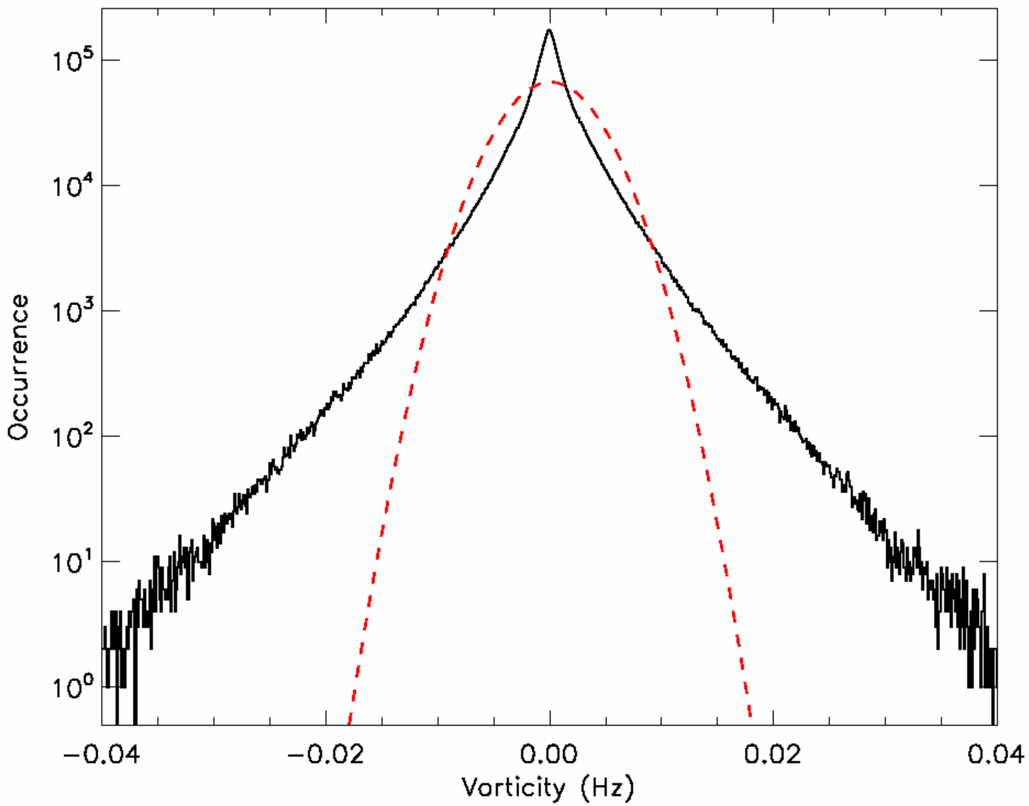
Global Vorticity Distribution

- Vorticity distribution combining all vorticity measurements from all measurement cells, covering all AACGM latitudes and magnetic local times.

- The distribution of vorticities is distinctly non-Gaussian with very heavy tails.

- Red dashed line shows a Gaussian distribution with the same mean and standard deviation as the observed distribution.



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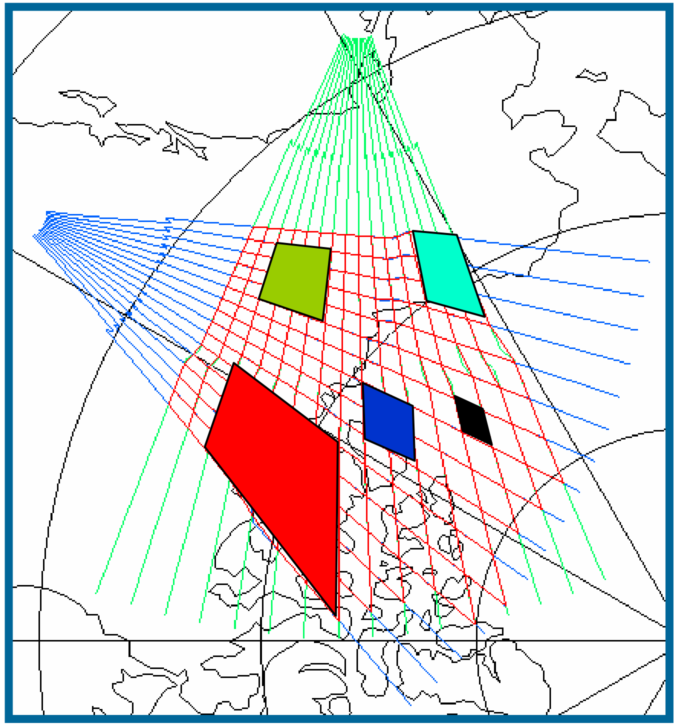
Variation with Measurement Cell Size

- Make vorticity measurements for a larger range of measurement cell sizes by increasing the beam separation of the edges of the quadrilateral measurement cells.

- Determine vorticity distributions for cell sizes ranging from a 1x1 beam separation to a 5x5 beam separation.



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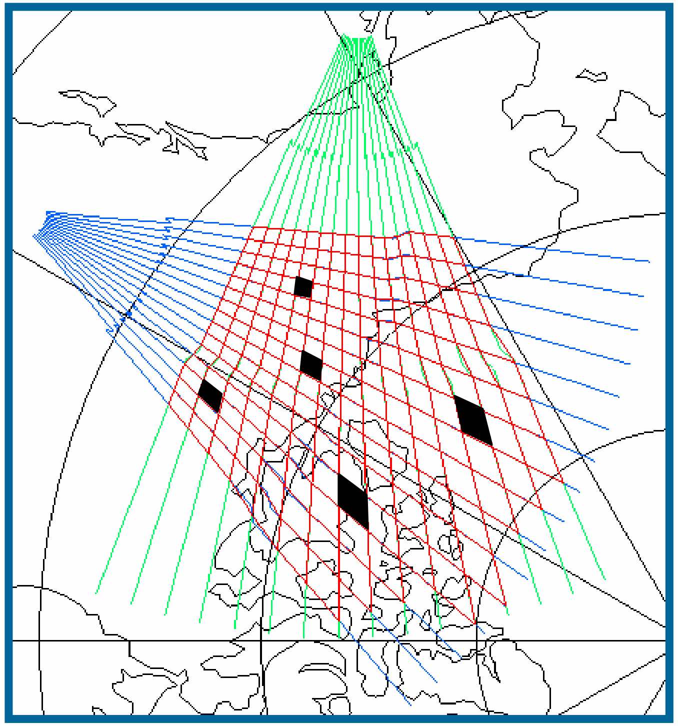
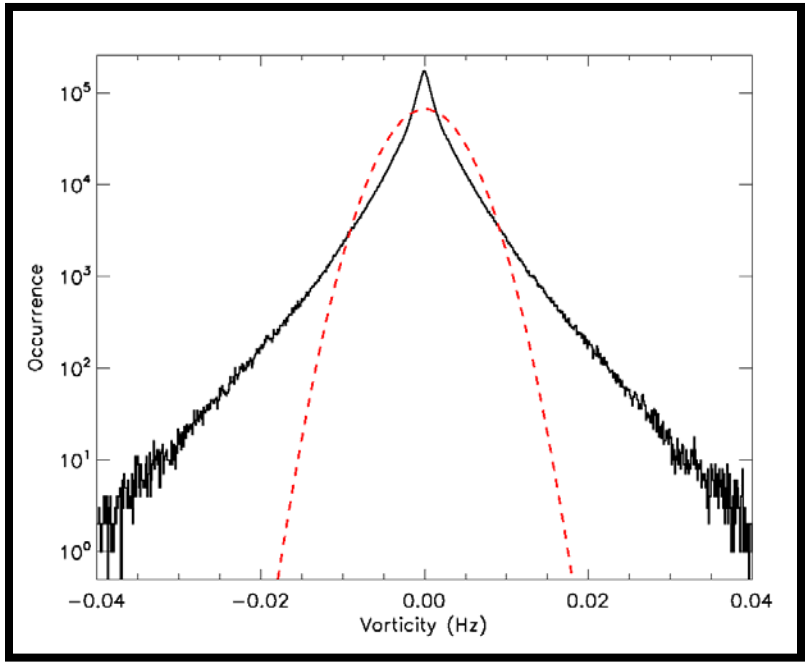
Variation with Measurement Cell Size

Example cells within the Kodiak – Prince George field of view





Cell size 1x1
191 cells
$5.4 \times 10^3 – 4.7 \times 10^4$ km^2

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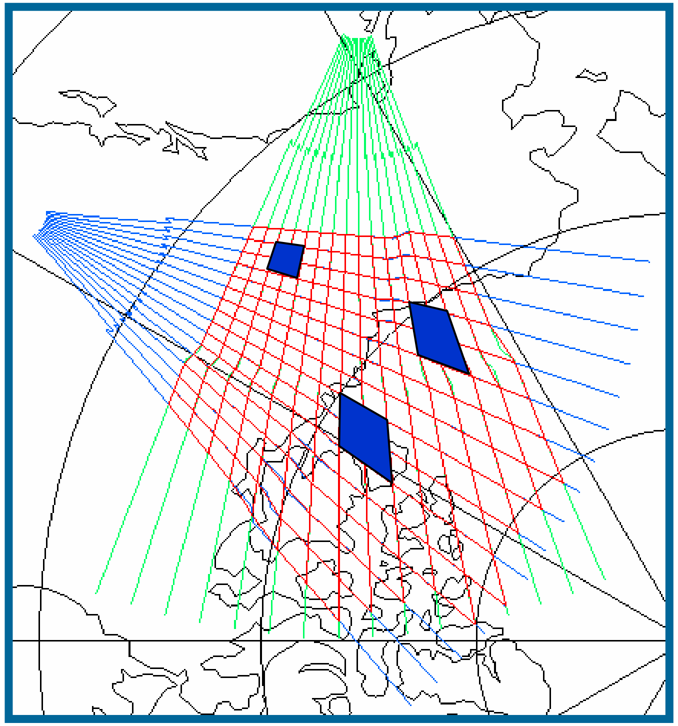
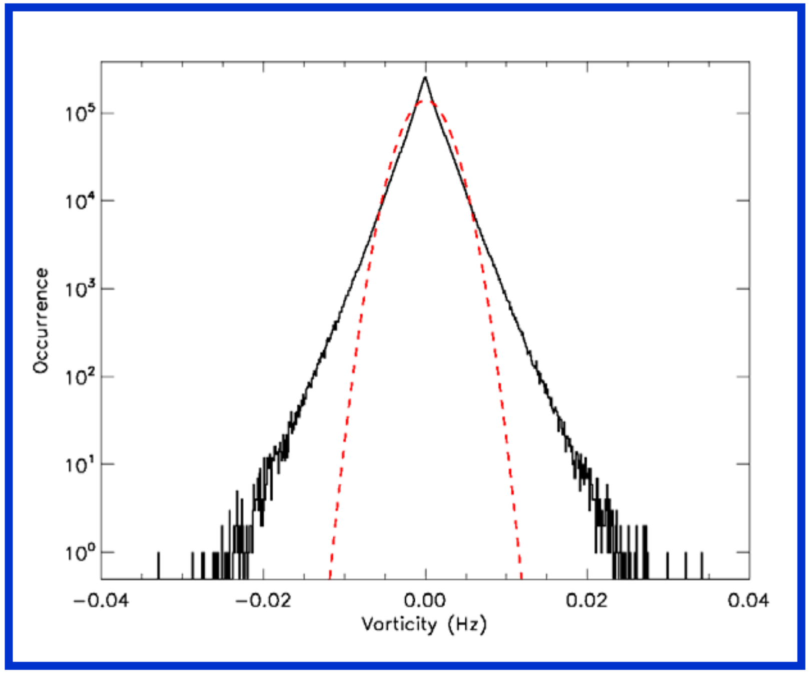
Variation with Measurement Cell Size

Example cells within the Kodiak – Prince George field of view





Cell size 2x2
162 cells
$2.2\text{x}10^4 – 1.5\text{x}10^5$ km^2

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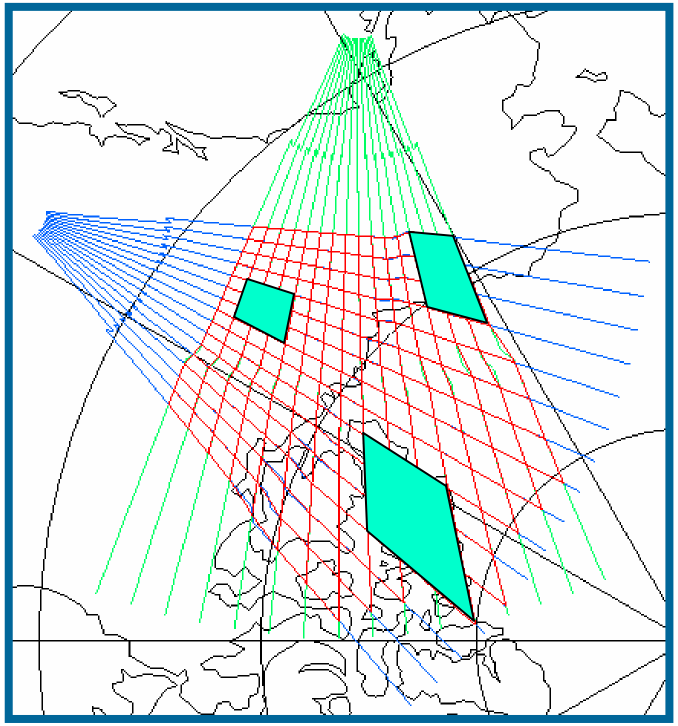
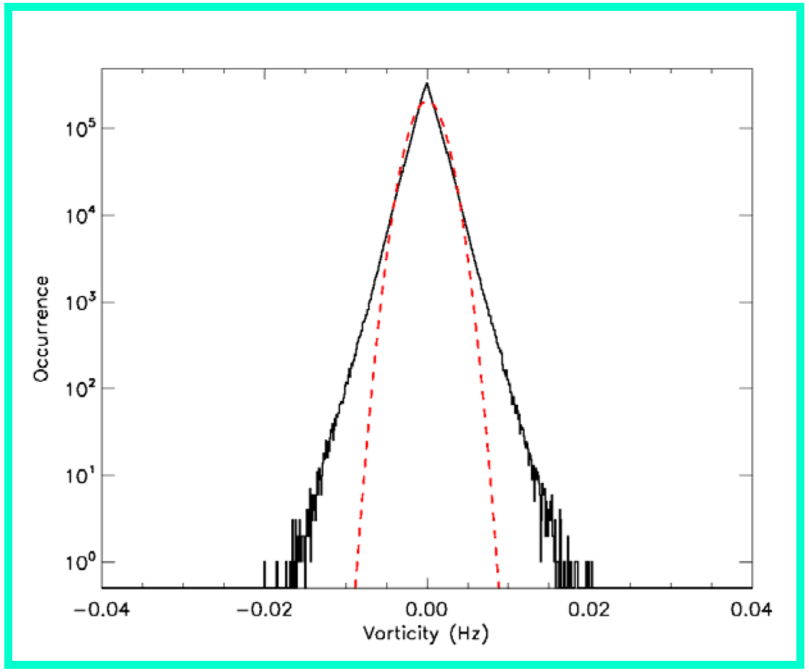
Variation with Measurement Cell Size

Example cells within the Kodiak – Prince George field of view

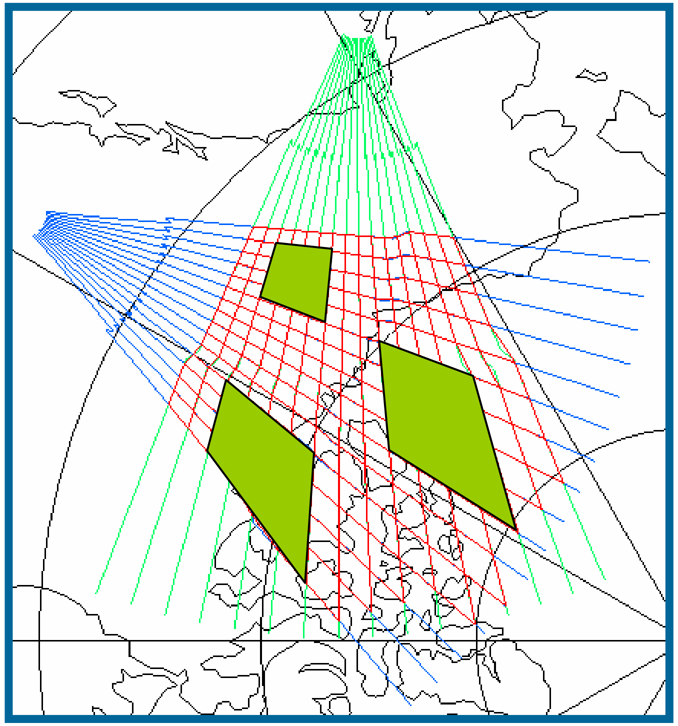


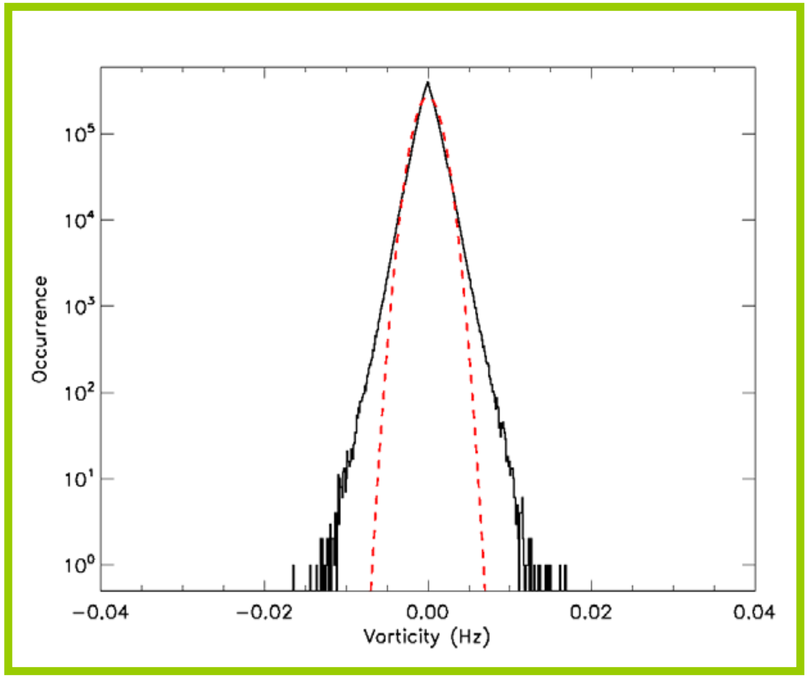


Cell size 3x3
135 cells
$5.2 \times 10^4 – 3.0 \times 10^5$ km^2

Variation with Measurement Cell Size

Example cells within the Kodiak – Prince George field of view





Cell size 4x4
110 cells
$9.5\times10^4 – 4.6\times10^5$ km^2

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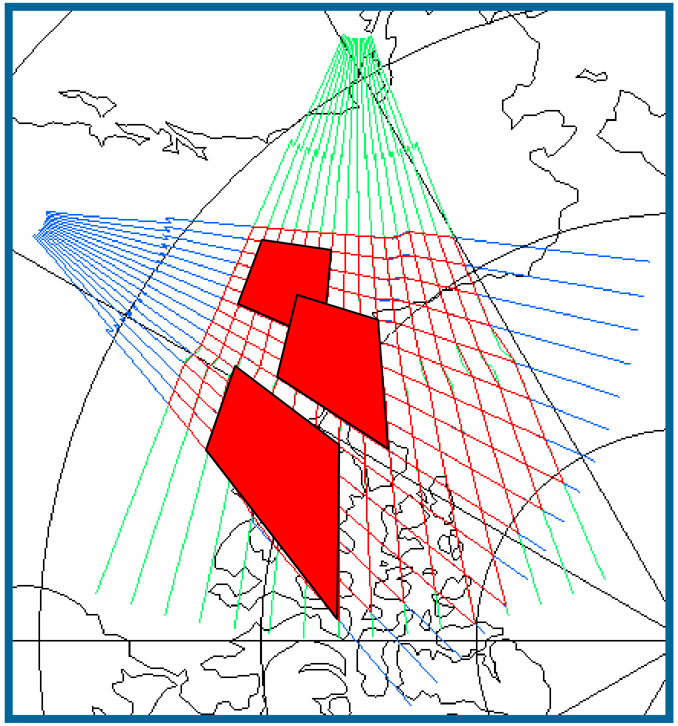
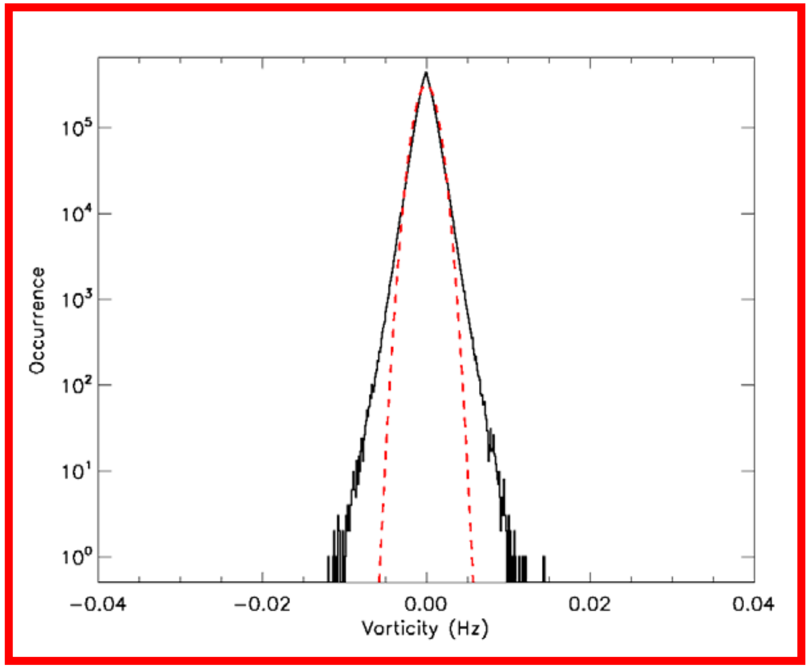
Variation with Measurement Cell Size

Example cells within the Kodiak – Prince George field of view





Cell size 5x5
87 cells
$1.6 \times 10^5 – 6.2 \times 10^5$ km^2

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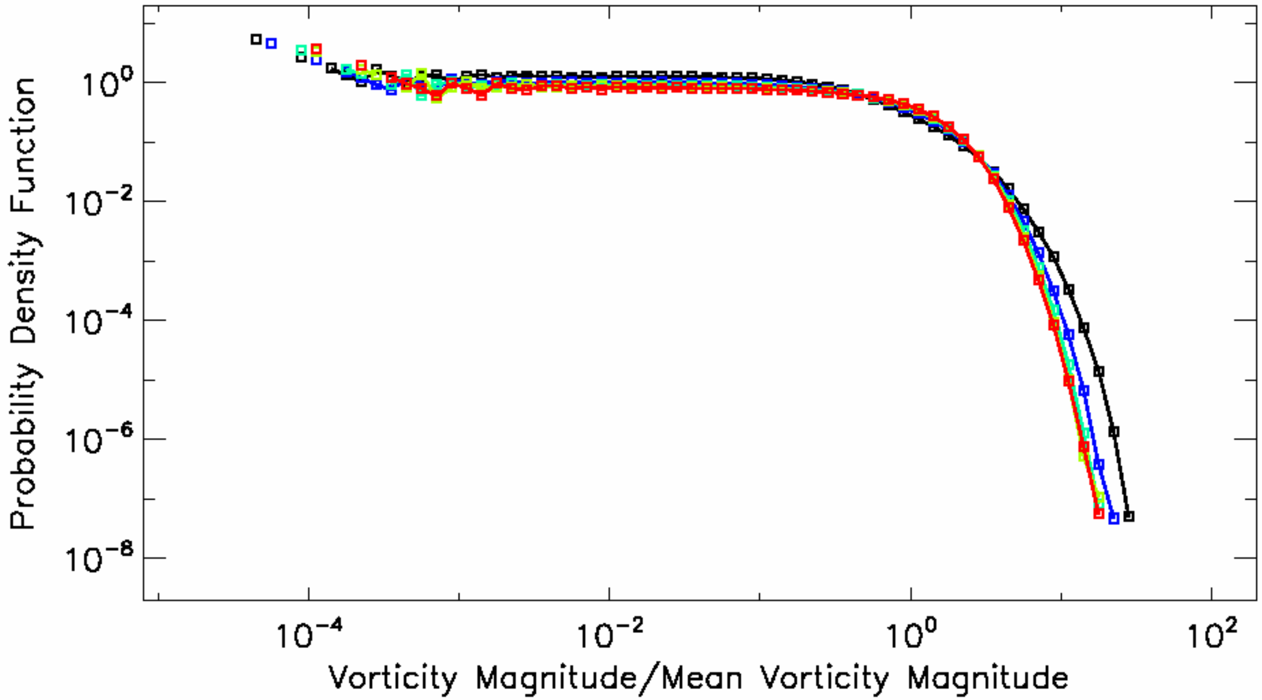
Variation with Measurement Cell Size

- The vorticity distributions become narrower and more Gaussian with increasing cell size.

- Smaller-scale current structures are averaged out when measuring on larger scale sizes.

Variation with Measurement Cell Size



- Distributions of vorticity magnitude for the five sets of measurement cell sizes. The vorticity magnitude in each case has been rescaled by dividing by the mean vorticity magnitude.

- The distributions, although similar, do not collapse onto a single functional form.

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Deconvolving Latitude and Cell Size Variations

- Vorticity distributions have been determined for each and every individual measurement cell within the field of view, for the five sets of cell sizes described on previous slides.

- The moments of all these distributions have been measured and plotted against both the cell size and AACGM latitude.

- The five different colours represent the five cell-size groups used on previous slides.

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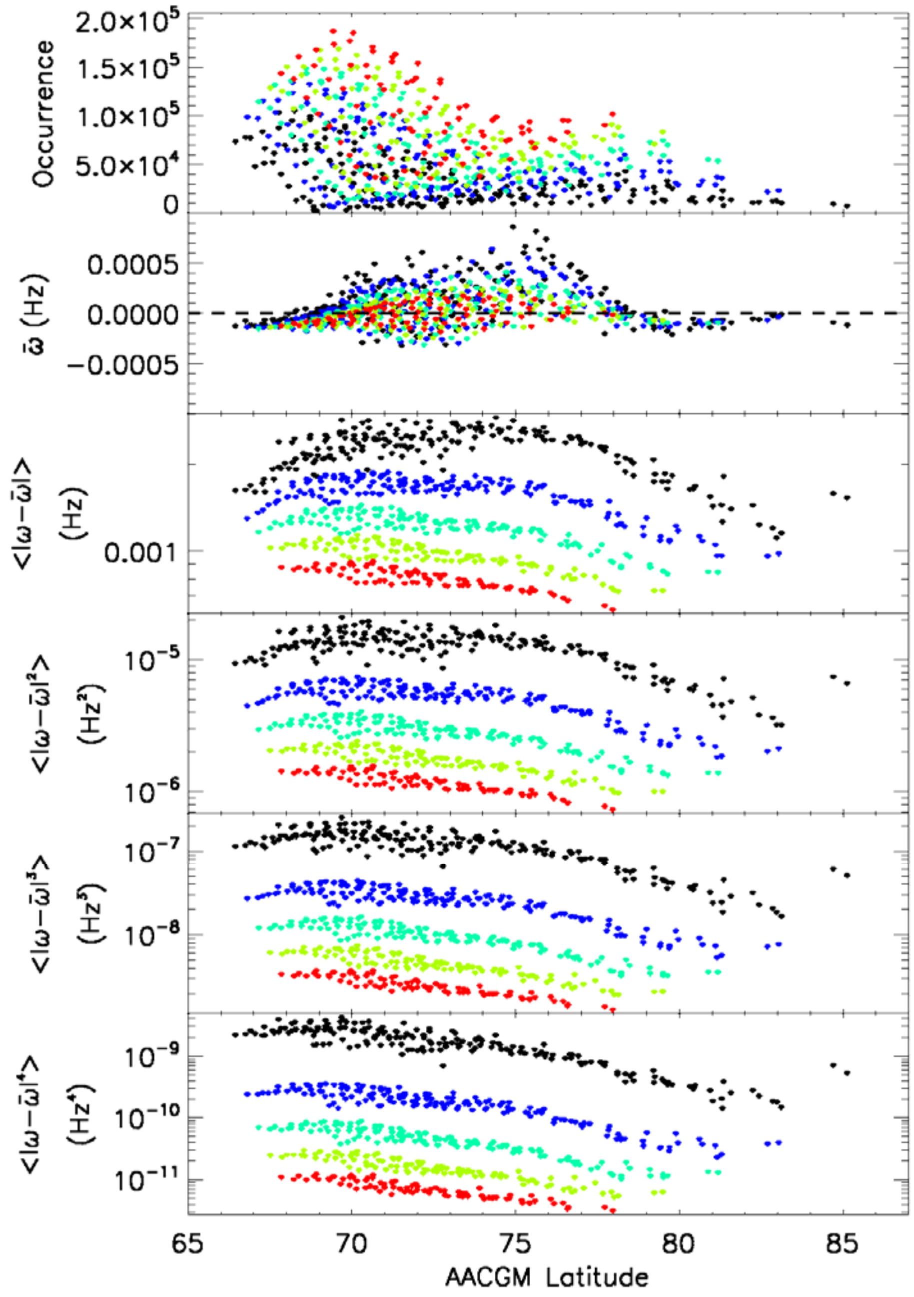
Deconvolving Latitude and Cell Size Variations

- The moments of the distributions are clearly different in the 5 cell size groups.
- The moments in each group also show a clear variation with latitude with reductions at both high and low latitude.



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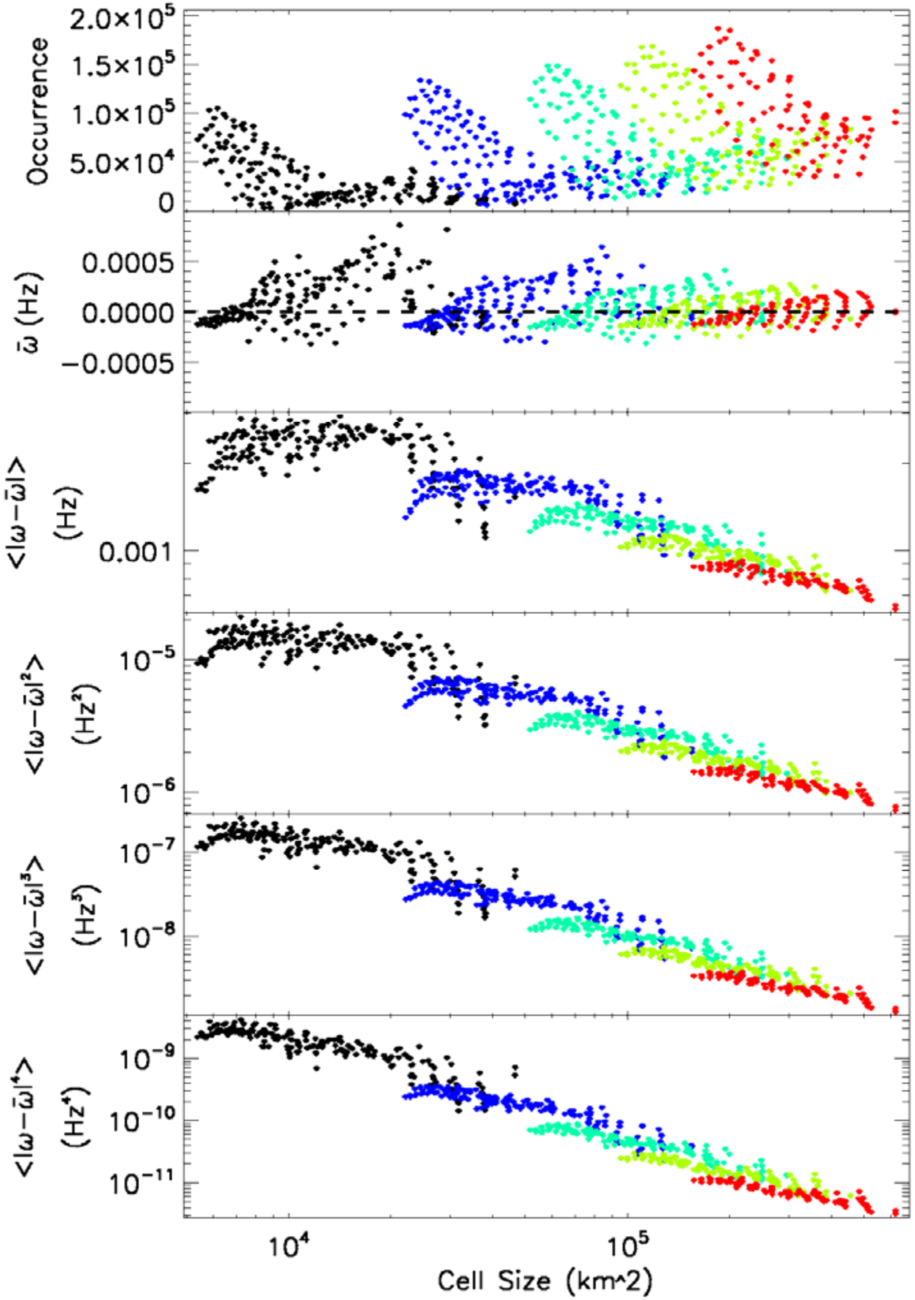
Deconvolving Latitude and Cell Size Variations

- The approximate power-law variation of the moments with cell size is suggestive that the vorticity scales with the measurement cell size.



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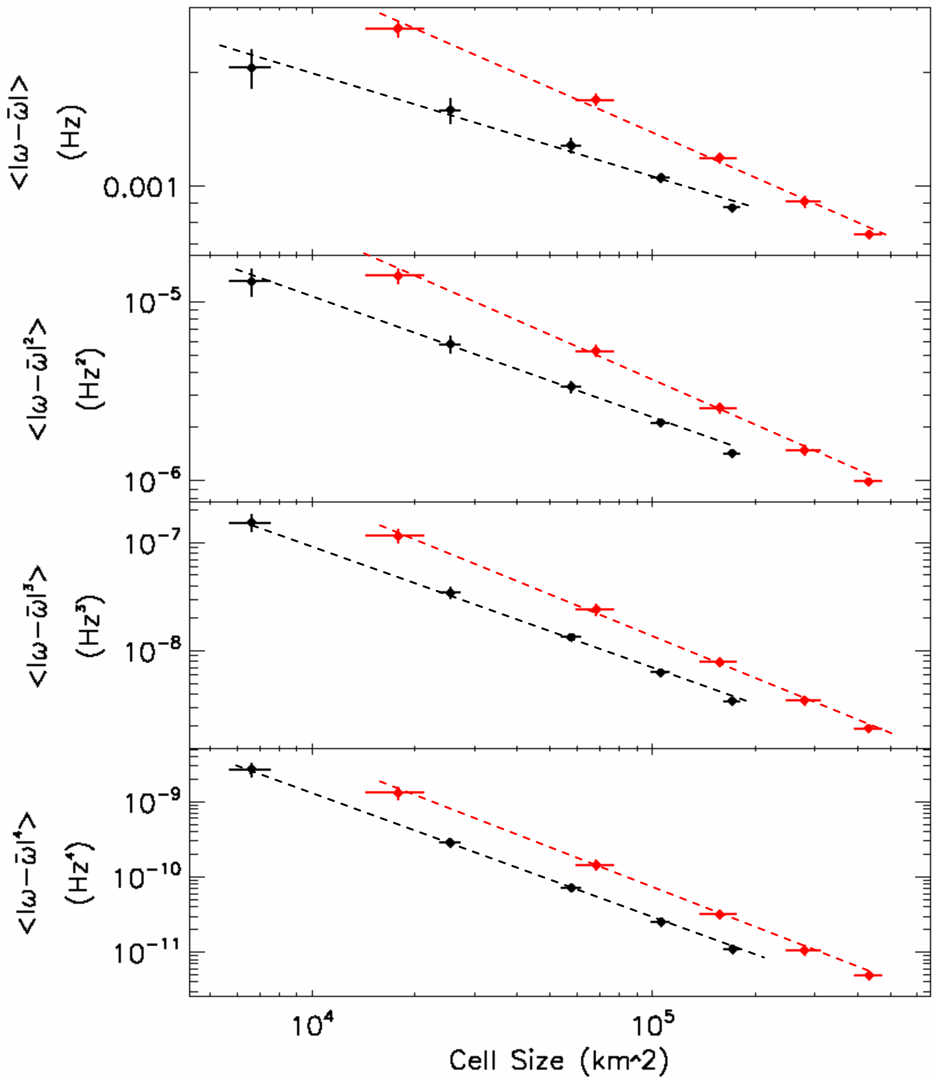
Deconvolving Latitude and Cell Size Variations

- Results show a roughly similar scaling to that observed for ionospheric velocities by *Abel et al. (2007).*

- On closer inspection it is not clear if the moments scale with cell size at all.



Black – Average moments in Region 2 current region (67°-69°)

Red – Average moments in Region 1 current region (74°-76°)

Summary

- The distributions of ionospheric vorticity are distinctly non-Gaussian – this has implications for understanding average patterns of field-aligned current as the ‘average’ patterns will not represent ‘typical’ patterns.

- Understanding the nature of the fluctuations is important if the current systems are to be fully understood.

- Future work will involve combining this work with the studies of the turbulent structure of ionospheric convection velocities (e.g., *Abel et al., 2007*), and the scaling of auroral emissions (e.g., *Uritsky et al., 2002; Kozelov et al., 2004*). This will help in achieving the ultimate goal of a unified model of multi-scale auroral dynamics.