High-latitude Neutral Density Maxima

CEDAR Grand Challenge B
High Latitude IT Coupling
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100 YEARS OF U.S. AIR FORCE SCIENCE & TECHNOLOGY

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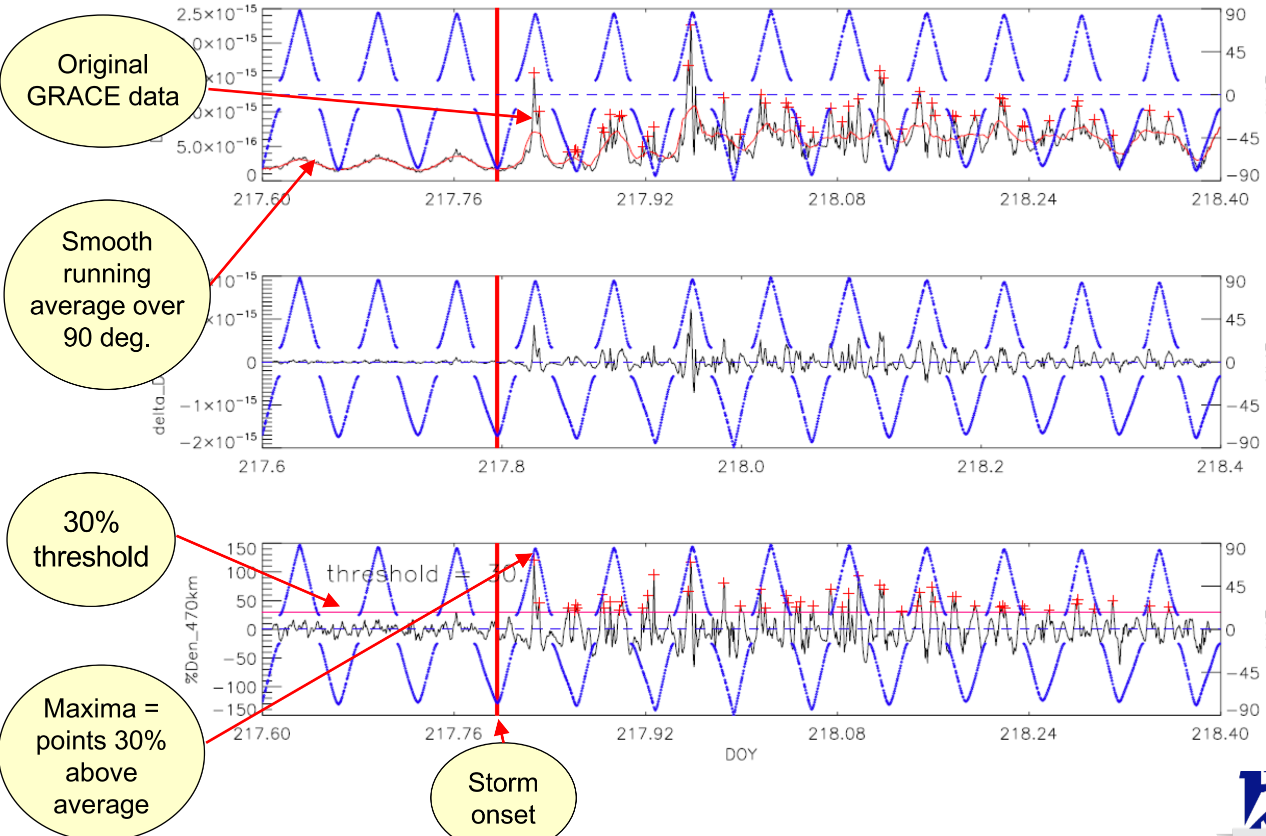
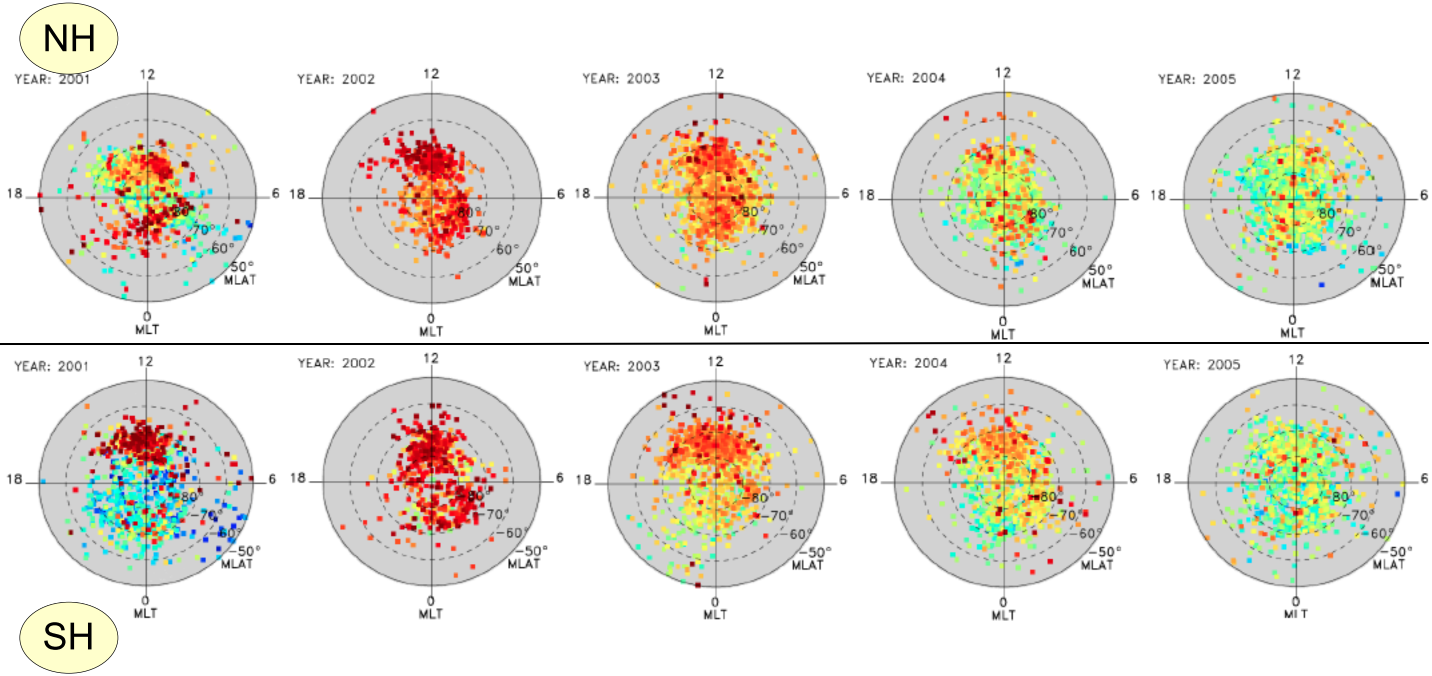
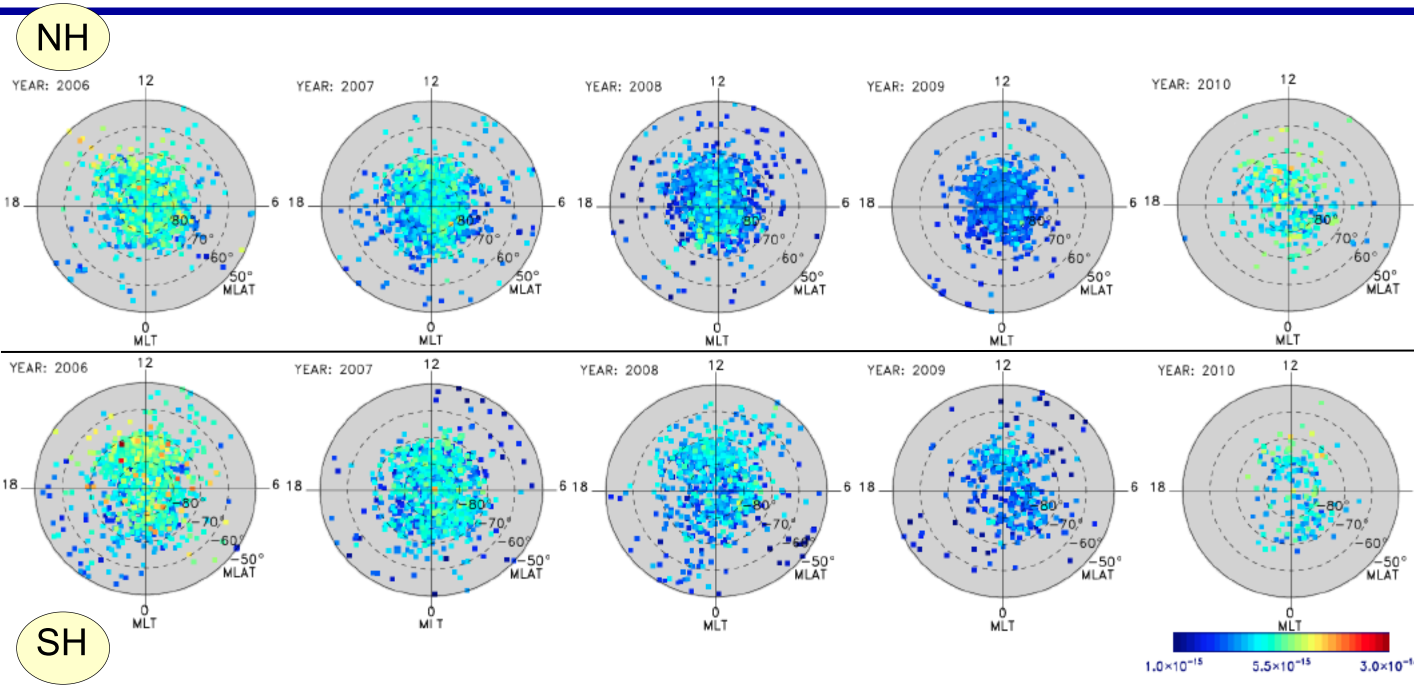
Neutral Density Maxima Selection
GRACE neutral density, 5-6 August 2011



CHAMP Density Maxima 2001-2005

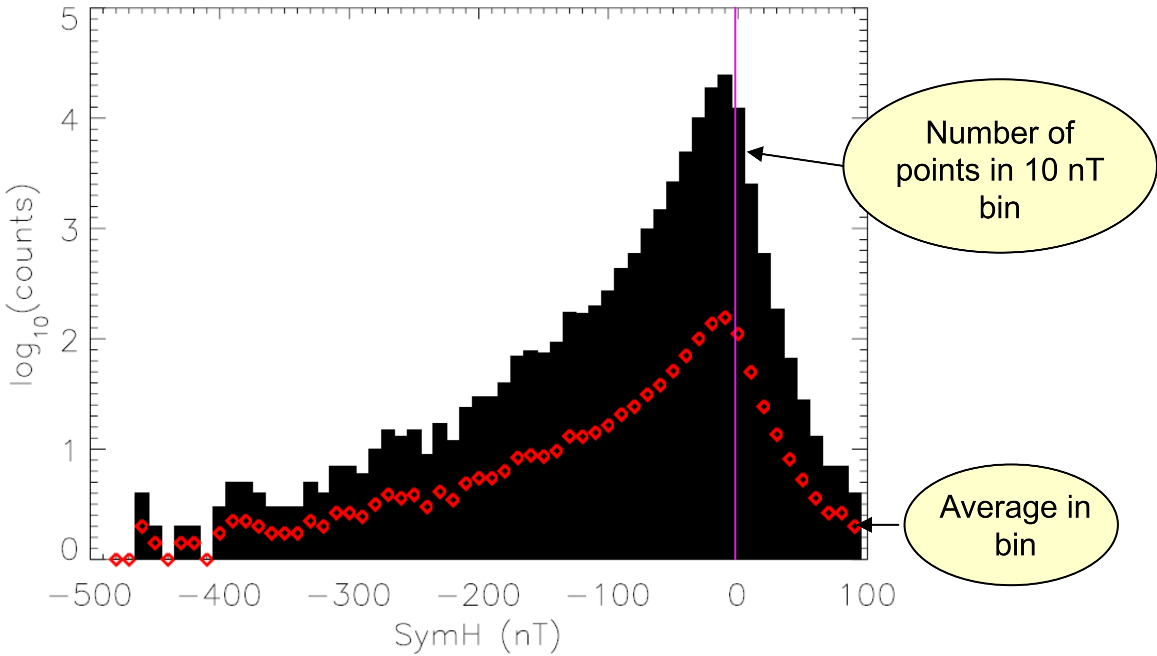


CHAMP Density Maxima 2006-2010



Maxima are restricted to polar latitudes, and are seen under all levels of solar activity. Spatial distributions of CHAMP and GRACE maxima are nearly identical. Where magnitudes of density maxima not important, treat the two satellite databases as one.

Distribution of Sym H for all Density Maxima



Density maxima occur for all levels of activity, but peak occurrence is during low activity

What creates neutral density maxima at polar latitudes?

There are 3 possible mechanisms:

1. Localized Joule heating by *J x B* forcing causes neutral expansion, creating local maxima.

2. Gravity waves (Traveling Atmospheric Disturbances, TADs) which are generated by Joule heating. Wave perturbations appear at maxima.

3. Advection or ion drag or co-rotation which moves density maxima from the auroral zone into the polar cap. This is unlikely:
   - Ion drag from auroral zone source is slow, and co-rotation is even slower.
   - Advection is asymmetric in the dawn-dusk plane. Dawn-dusk asymmetry not seen in neutral density maxima.

Treat maxima as combination of localized heating and TADs

Bin-normalized Maxima

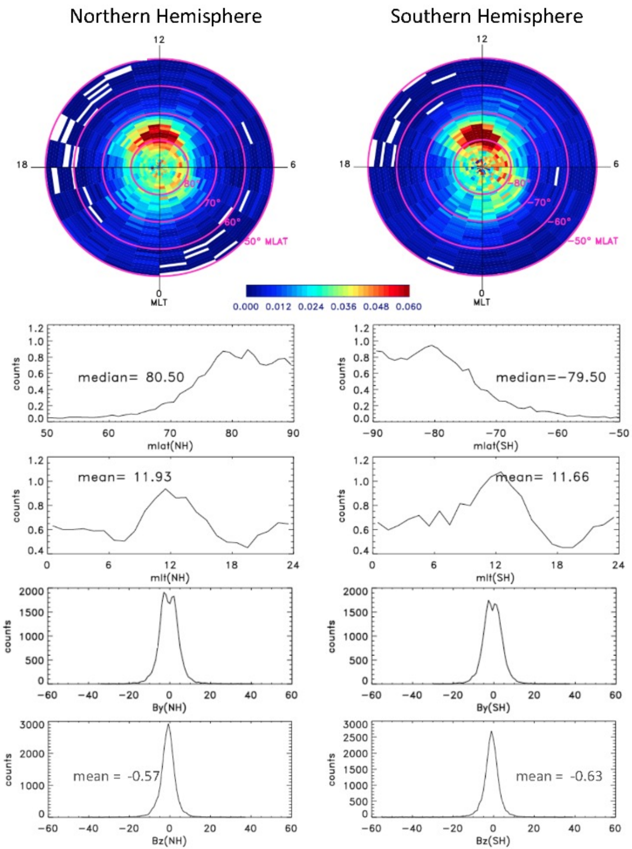
Remove orbital biases by normalizing counts of maxima:

1. Bin data into bins of 1° Mlat x 1 hour MLT

2. Count (1) data within bins; (2) number of orbital passes within bins

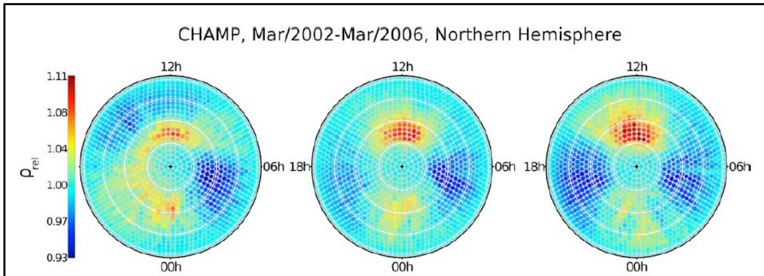
3. Divide (1) by (2) ➔ bin-normalized maxima counts

Distribution of bin-normalized GRACE neutral density maxima



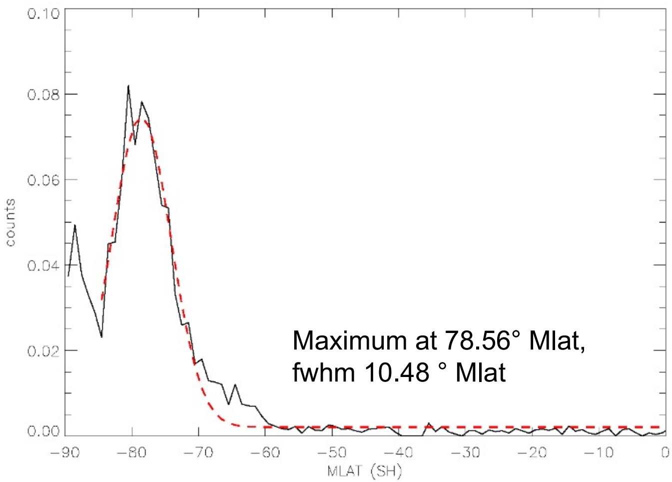
MLat, MLT distribution of GRACE neutral density maxima. Plot of CHAMP maxima nearly identical. Peaks at polar latitudes and noon, no auroral zone.

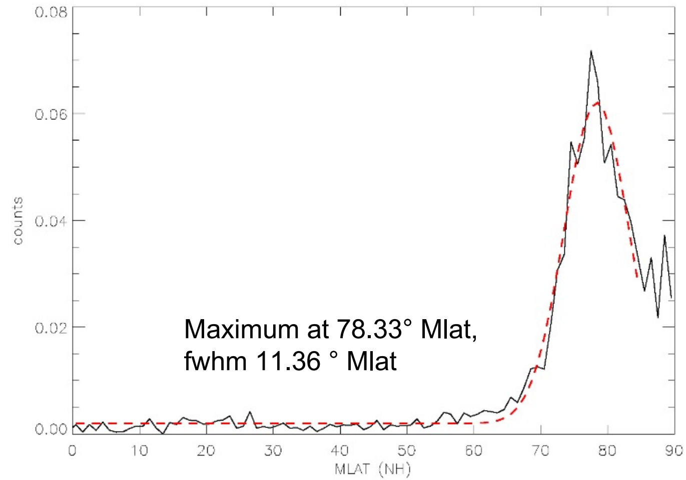
Figure very similar to Figure 3 of Kervalishvili and Luhr (2013), a study of bin-averaged neutral density anomalies in 4 years of CHAMP data.



[Kervalishvili and Luhr, 2013]

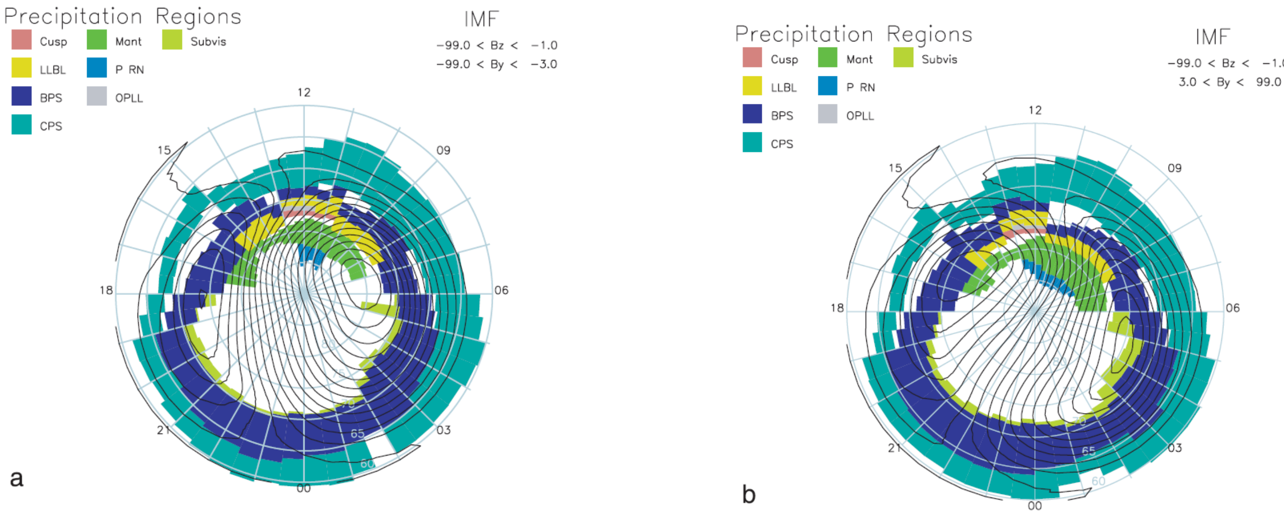
Distribution of GRACE bin-normalized maxima along 12 MLT





Location and width of peaks indicate this is not the cusp

The Low-Altitude Cusp



[Newell et al., 2004]

On average, the cusp is 0.8-1° wide and is located between 73° and 77° MLat [Newell et al., 1989]. Our results suggest heating of neutrals occurs in *__cusp and mantle__* which both exhibit IMF B_y dependence.

“Only ~ 25-35% of the dayside open-closed field line conversion occurs within the particle cusp….Merging is thus active throughout the frontside magnetosphere” [Newell et al., 2004]

Summary

- Analysis of maxima in neutral densities from CHAMP (2001-2010) and GRACE (2002-2012) show persistent peaks poleward of 70° MLat
- Bin-normalized maxima show large peak centered at 79-81° MLat, fwhm of 10-11° Mlat, approximately coincident with mantle average location
- When data are restricted to Sym H between -20 and -400 nT, peak location moves equatorward to 75-77° Mlat, with fwhm of 12-14° Mlat, approximately coincident with cusp average location but considerably wider in MLat (not shown)
- Additional peaks occur polewards of 80° MLat, possibly in flow channels (not shown)
- There is little evidence of auroral zone heating in analysis of spatial distribution of maxima
- Results suggest that the cusp and mantle are the primary locus of neutral heating during quiet and active times

Data in study

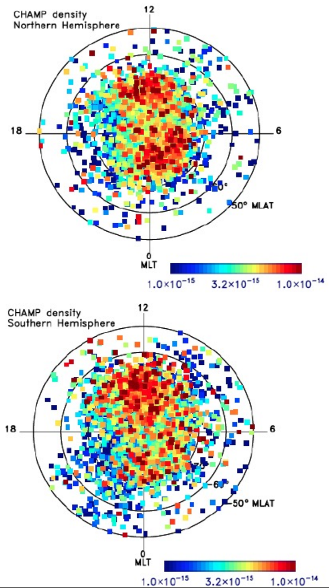
Table 1: Number of neutral data points in study; number of neutral data maxima selected

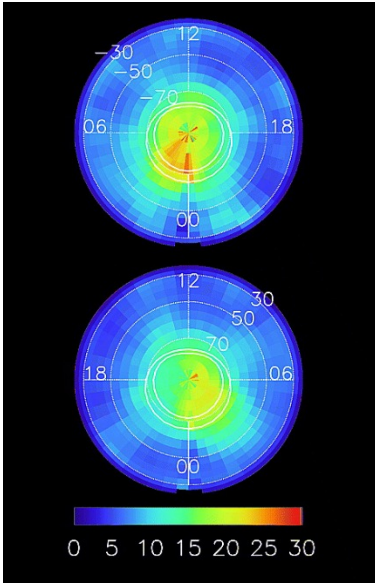
Year	CHAMP	CHAMP maxima	GRACE	GRACE maxima
2001	395718	2715		
2002	656340	1097	281387	1036
2003	669567	2662	675447	4731
2004	570631	2142	677384	4433
2005	667970	2445	680889	6486
2006	641853	3006	678216	5918
2007	676261	3099	678770	8018
2008	664755	3628	673734	9019
2009	656474	2077	679840	8307
2010	461964	546	680441	5959
2011			573631	3459
2012			272057	1018
Totals	6061533	23417	6551796	58384

CHAMP Maxima and DE-2 Gravity Waves

NH

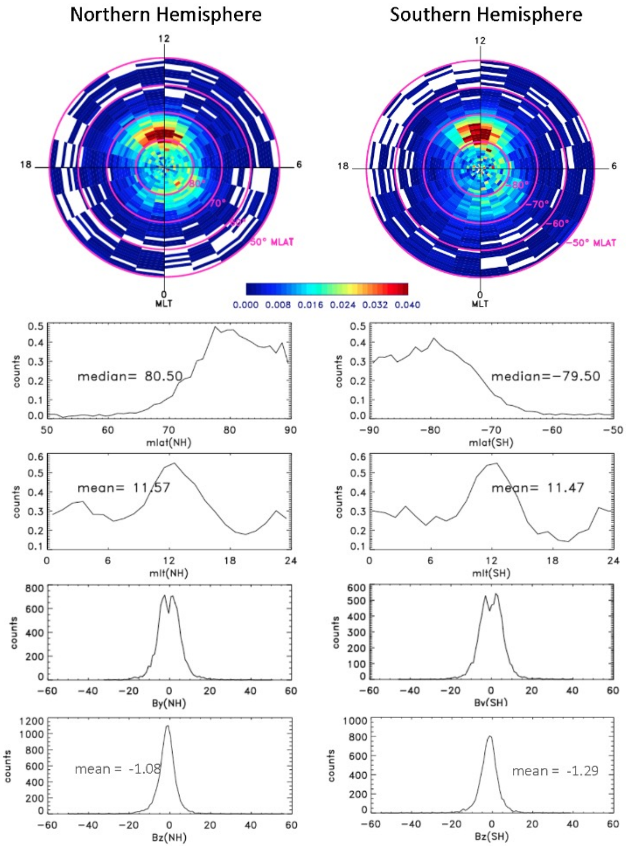
SH



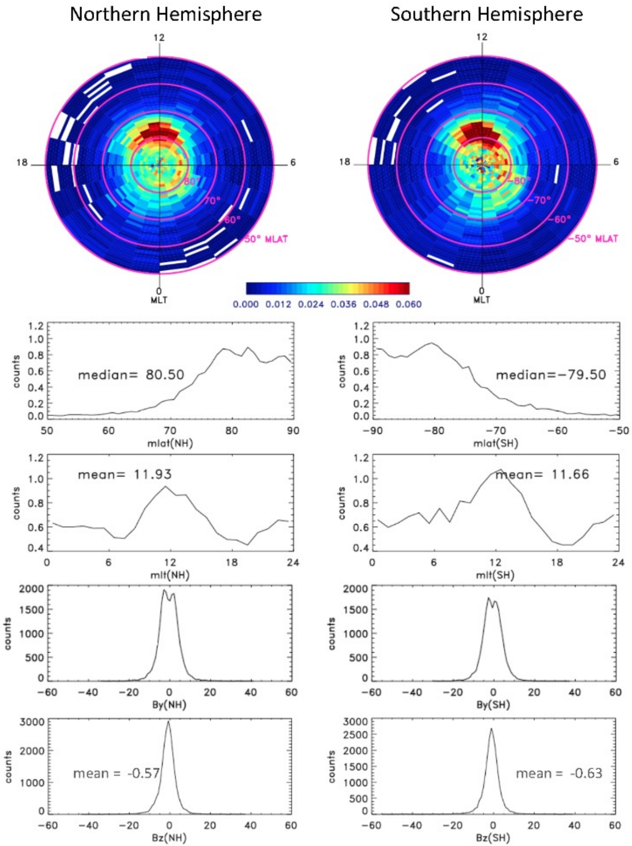


Striking similarity between neutral density maxima and gravity waves based on DE-2 neutral wind residuals (Innis and Conde, 2002) in the “hot polar cap” (Hays et al., 1984).
Both show: (1) concentration at polar latitudes; (2) no apparent auroral zone; (3) correlation between amplitude and activity level.
Major difference between density and neutral wind residuals: no apparent cusp in neutral wind analysis.

Champ bin-normalized maxima



GRACE bin-normalized maxima



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What is the source of energy for thermospheric heating at polar latitudes?

Quiet conditions:

DMSP observations of DC Poynting flux show values close to zero during non-storm periods, but density maxima occur most frequently under quiet conditions.

Possible explanations:

- AC Poynting flux which can be high (Neubert and Christiansen, 2003).
- Alfvénic fluctuations in solar wind (Tsurutani et al., 2011) which can enter the polar cap directly.

Storm conditions:

Measured DC Poynting flux can be high at all latitudes, but this is not captured in modeling.

- Physics-based models rely on empirical drivers which do not capture true high-latitude energy input and dissipation.
- Effect of dynamic small-scale fluctuations which are not captured in most DC measurements and are not considered in physics-based modeling.