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Polar Cap Heating During Magnetic Storms

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The Dynamic Polar Cap

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Joule Heating During Magnetic Storms



- Estimates of energy budget for magnetic storm on 5-6 August 2011 show that there is “missing” energy, energy not accounted for in Weimer 05 model [*Huang et al., JGR, 2014*].
- Postulate – missing energy enters polar cap and is not captured by empirical models.
- Evidence of energy entering thermosphere at polar cap latitudes.
- Evidence of Joule heating of ions in the polar cap at DMSP altitudes.
- Analyze T_i from DMSP during storm occurring in August 2011. Similar results obtained for additional 4 storms.
- Note that T_i measured by DMSP is not simply Joule heat from incoming Poynting flux. Effects of solar radiation, convection, neutral winds all influence T_i measured at DMSP locations.



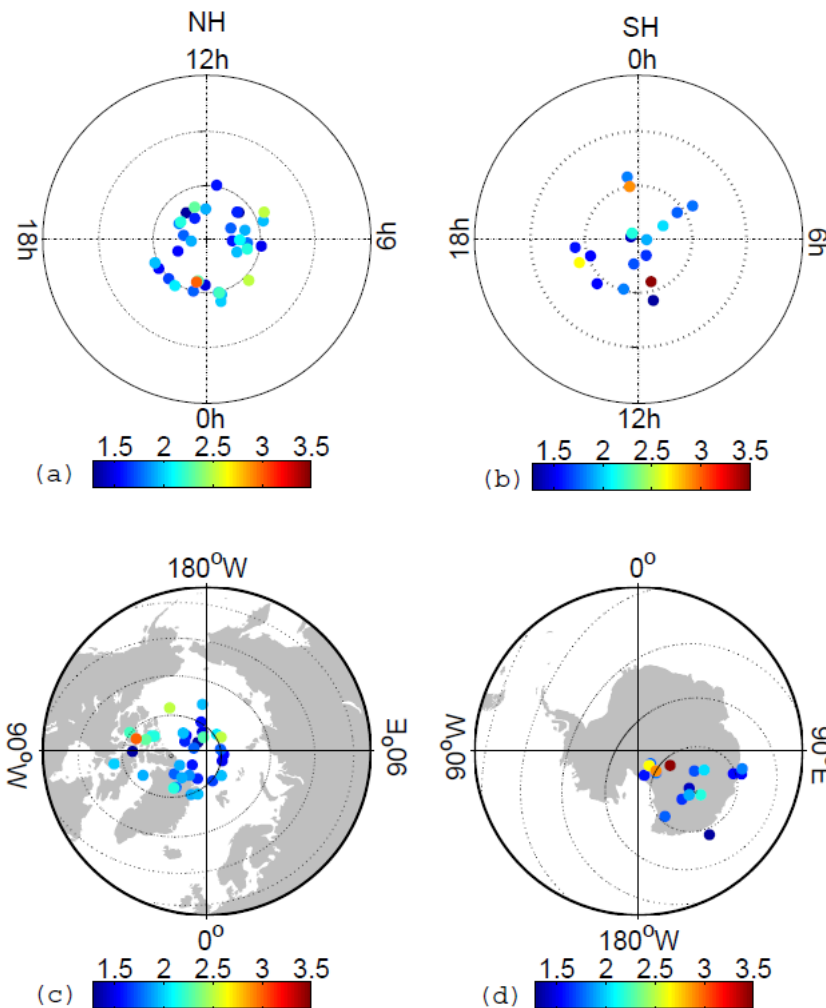
Polar Cap as a Source of Missing Energy?



R. Liu et al.: Storm-time related mass density anomalies in the polar cap

Mass densities on CHAMP analyzed for storms when Dst ≤ -100 nT between 2002-2005.

In 90% of storms analyzed, anomalously high mass densities were detected poleward of 78° MLat.



Magnetic Coordinates

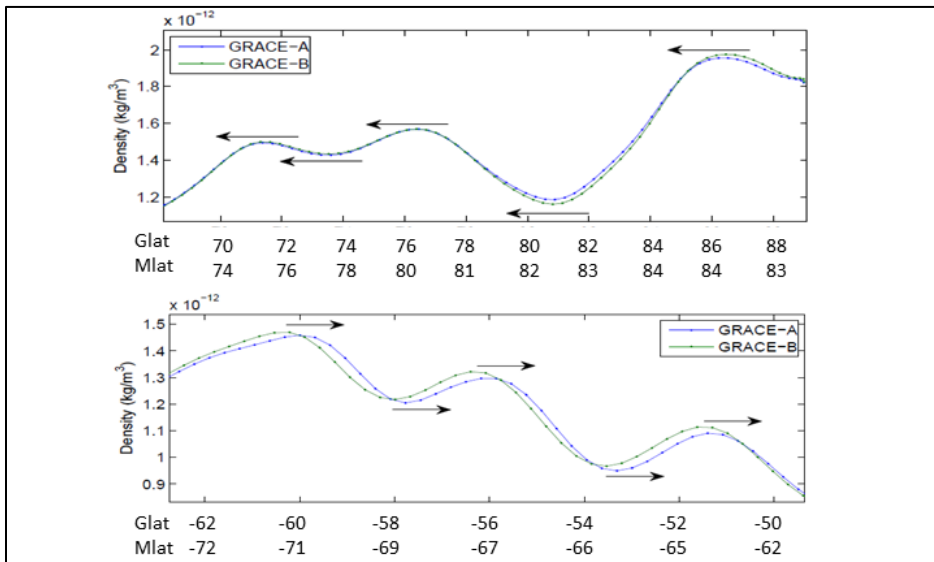
Geographic Coordinates

[Liu et al., *Ann. Geophys.* 2010]

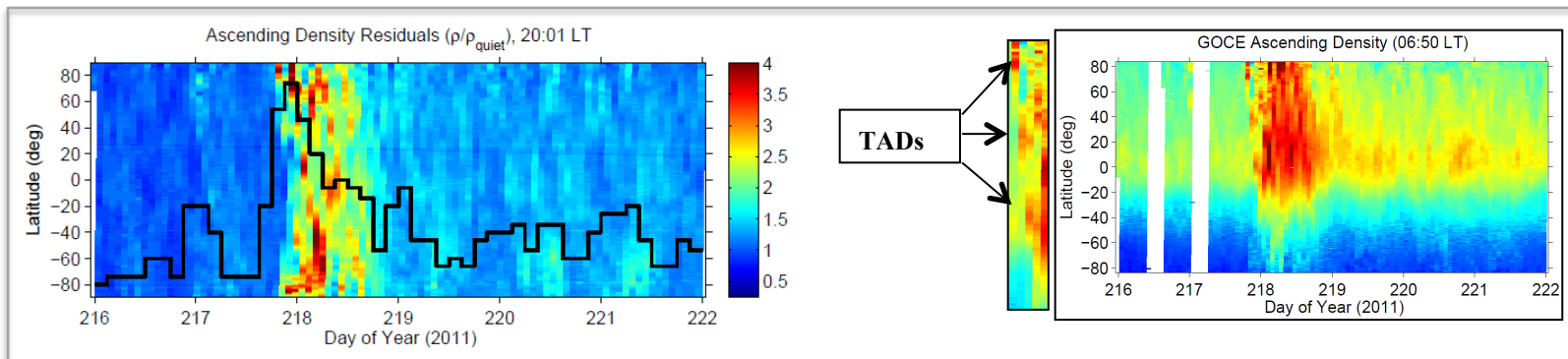


Polar Cap as a Source for Missing Energy?

GRACE and GOCE Observations During August 2011 Storm



Traveling Atmospheric Disturbances (TADs) on GRACE in both hemispheres indicate a source of Joule heating poleward of 83° Mlat (NH) and -72° Mlat (SH).



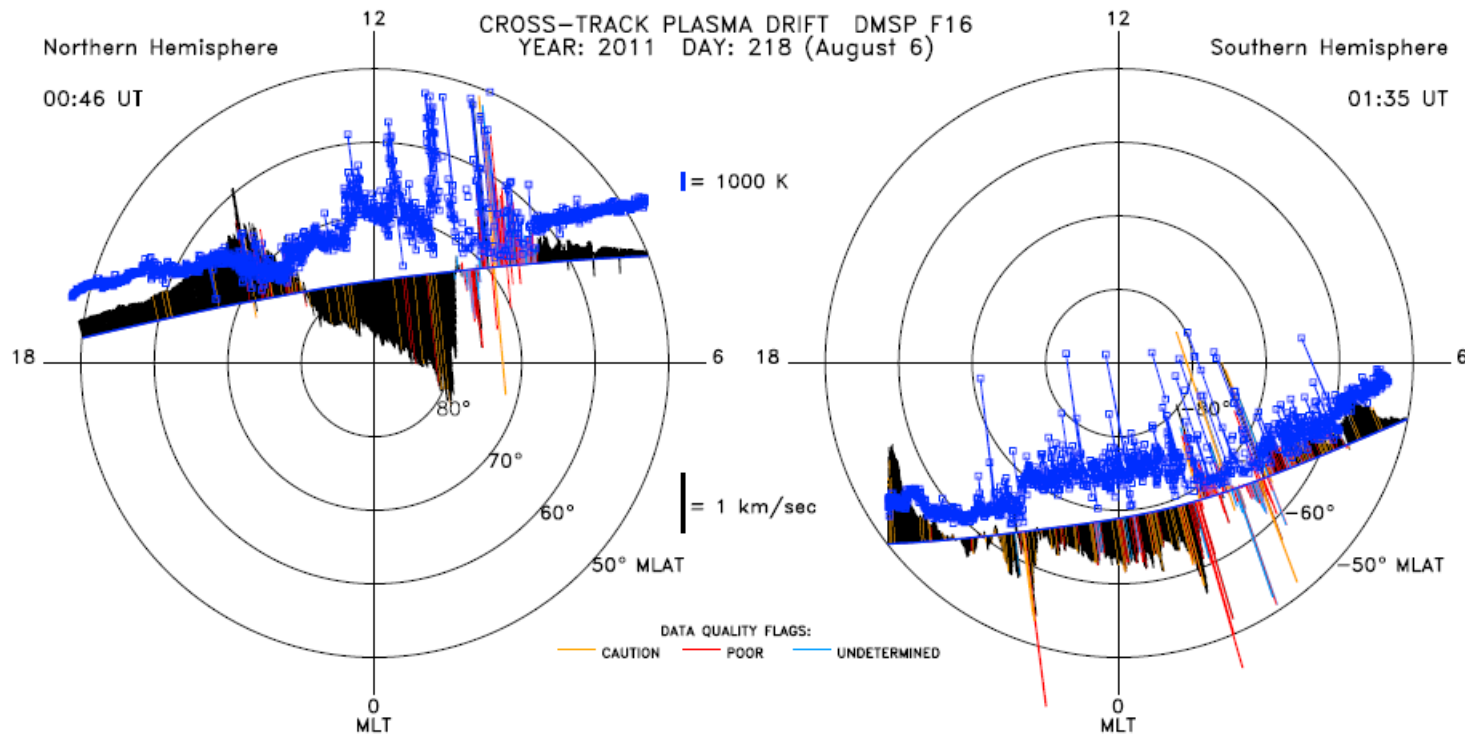
TADs detected simultaneously at GRACE at 2001 LT (left) and GOCE at 0650 LT (right). Source of Joule heating must be poleward of 83° (GRACE) and 80° (GOCE).



August 2011 storm



Ion Temperatures, Horizontal Velocities from DMSP F16



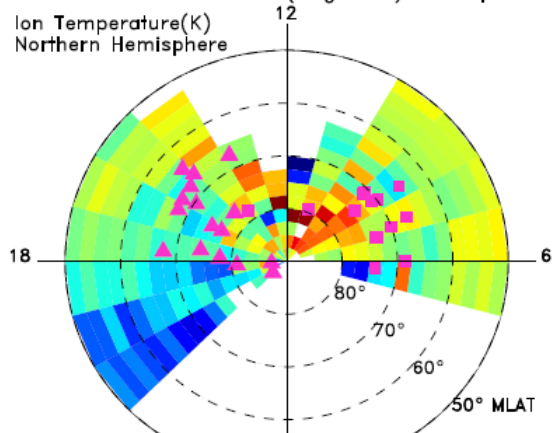
Ion temperatures increase mainly in polar cap and not in the auroral zone



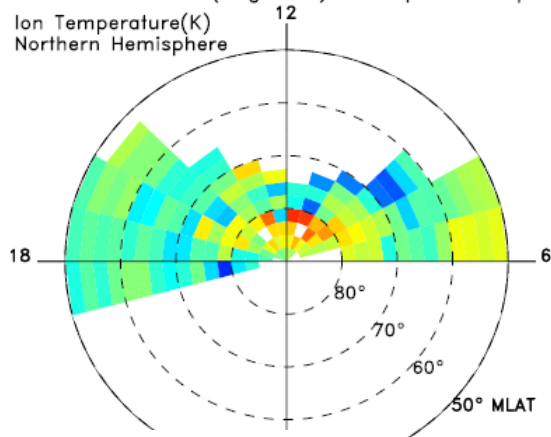
Average Ti in Polar Cap, Auroral Zones 5-6 August 2011, Northern Hemisphere



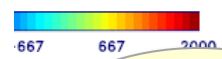
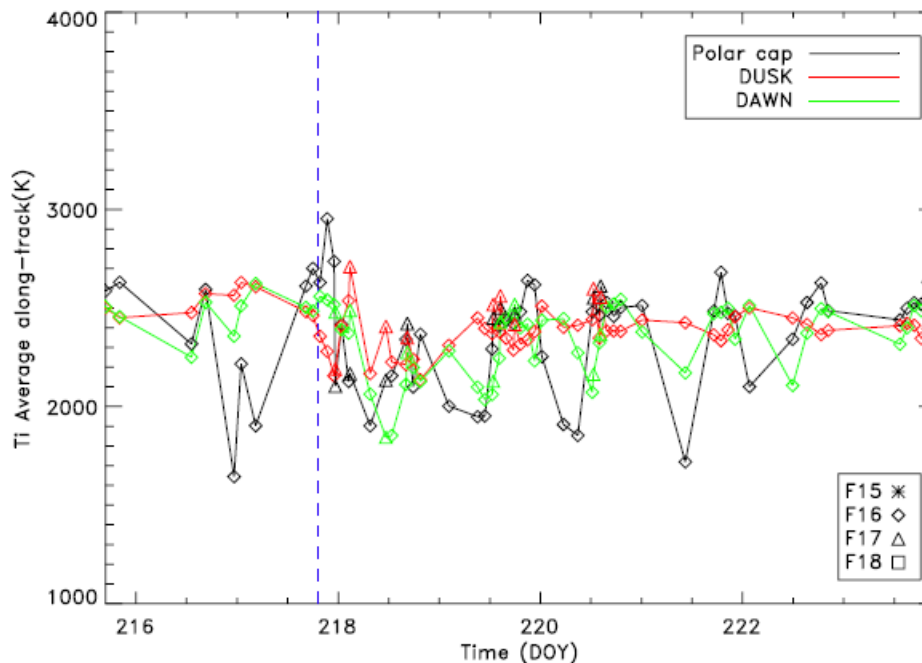
YEAR: 2011 DAY: 215 (August 3) main phase
Ion Temperature(K)
Northern Hemisphere



YEAR: 2011 DAY: 215 (August 3) main phase – quiet time



min: 962
max:416



Measured Ti along DMSP satellite track averaged for polar cap, dusk and dawn zones

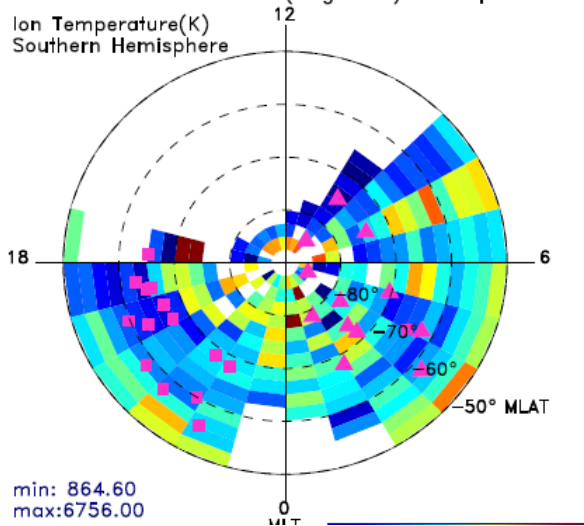


Average Ti in Polar Cap, Auroral Zones

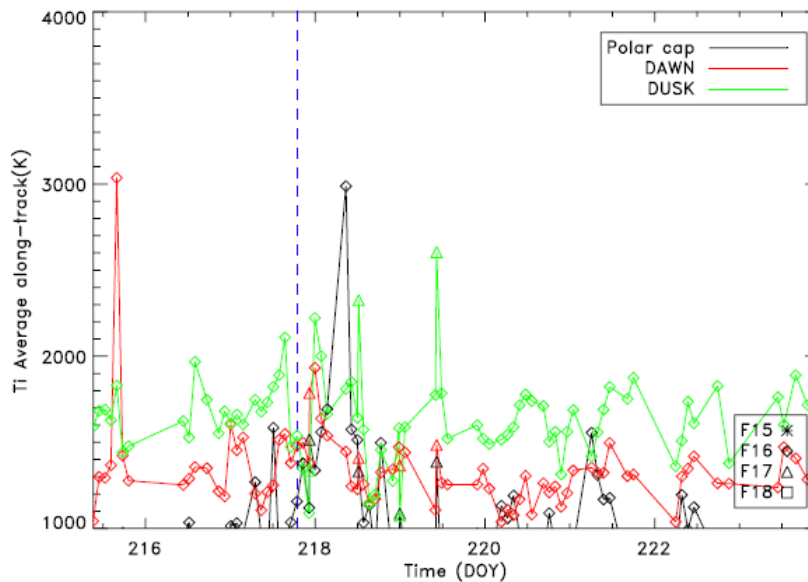
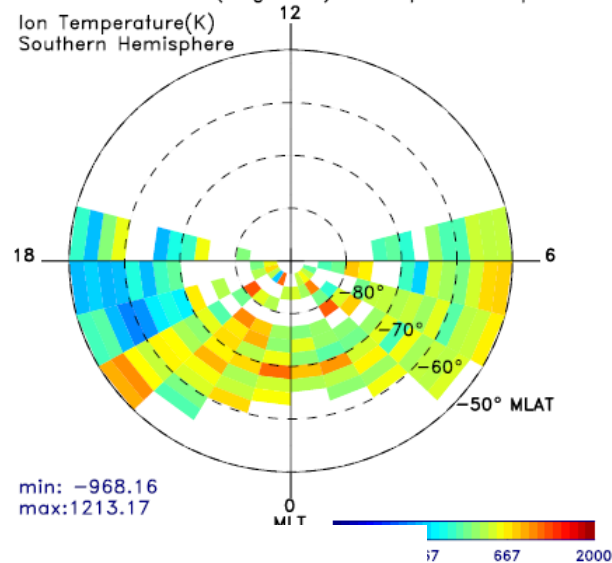
5-6 August 2011, Southern Hemisphere



YEAR: 2011 DAY: 215 (August 3) main phase
Ion Temperature(K)
Southern Hemisphere



YEAR: 2011 DAY: 215 (August 3) main phase – quiet time
Ion Temperature(K)
Southern Hemisphere





Summary



- GRACE and GOCE measurements show Joule heating in the polar cap during the August 2011 storm, in agreement with Liu et al (2010).
- TADs observed on GRACE and GOCE during the August 2011 storm indicate that Joule heating must occur at polar latitudes, poleward of $\sim 80^\circ$, between 20 and 07 LT.
- DMSP measurements of plasma temperatures show increased T_i mainly in the polar cap, and not in the auroral zone, during magnetic storms in August , September, October 2011, January, March 2012.
- Do IT coupling and energy dissipation occur primarily within the polar cap? What are the mechanisms by which the polar cap heats?