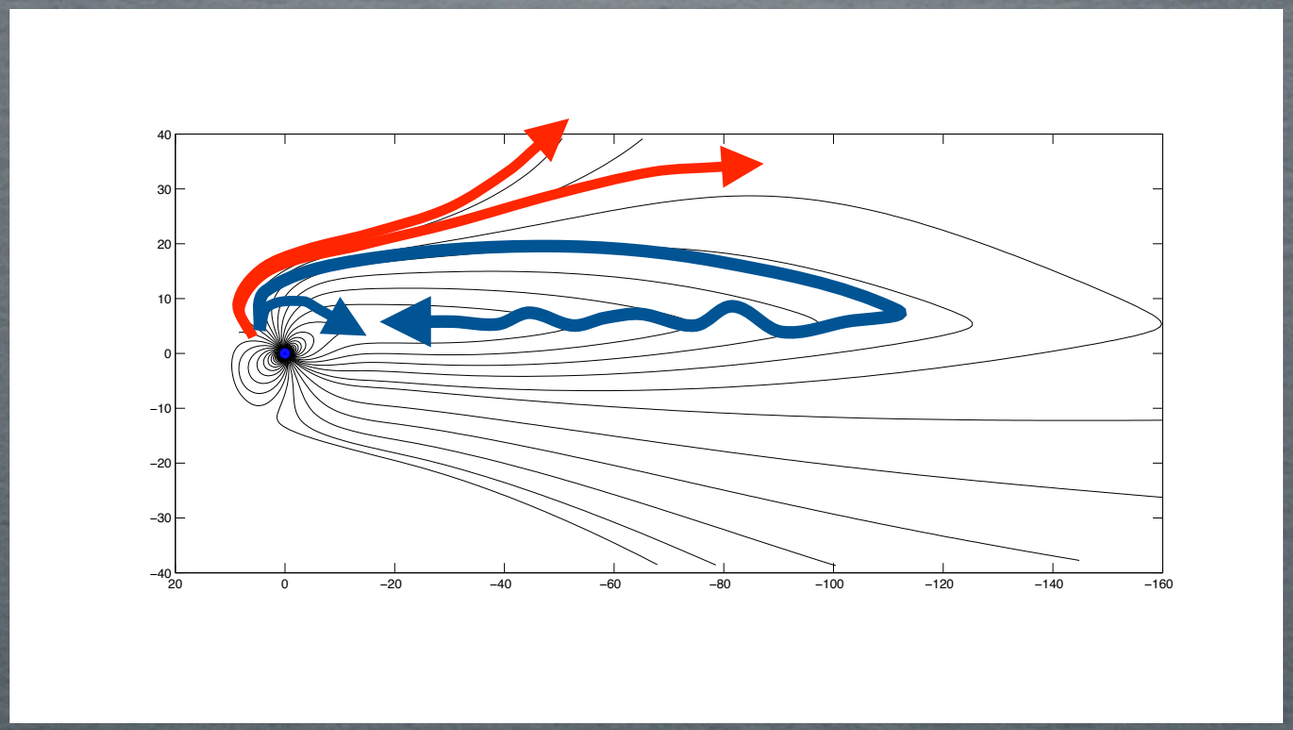
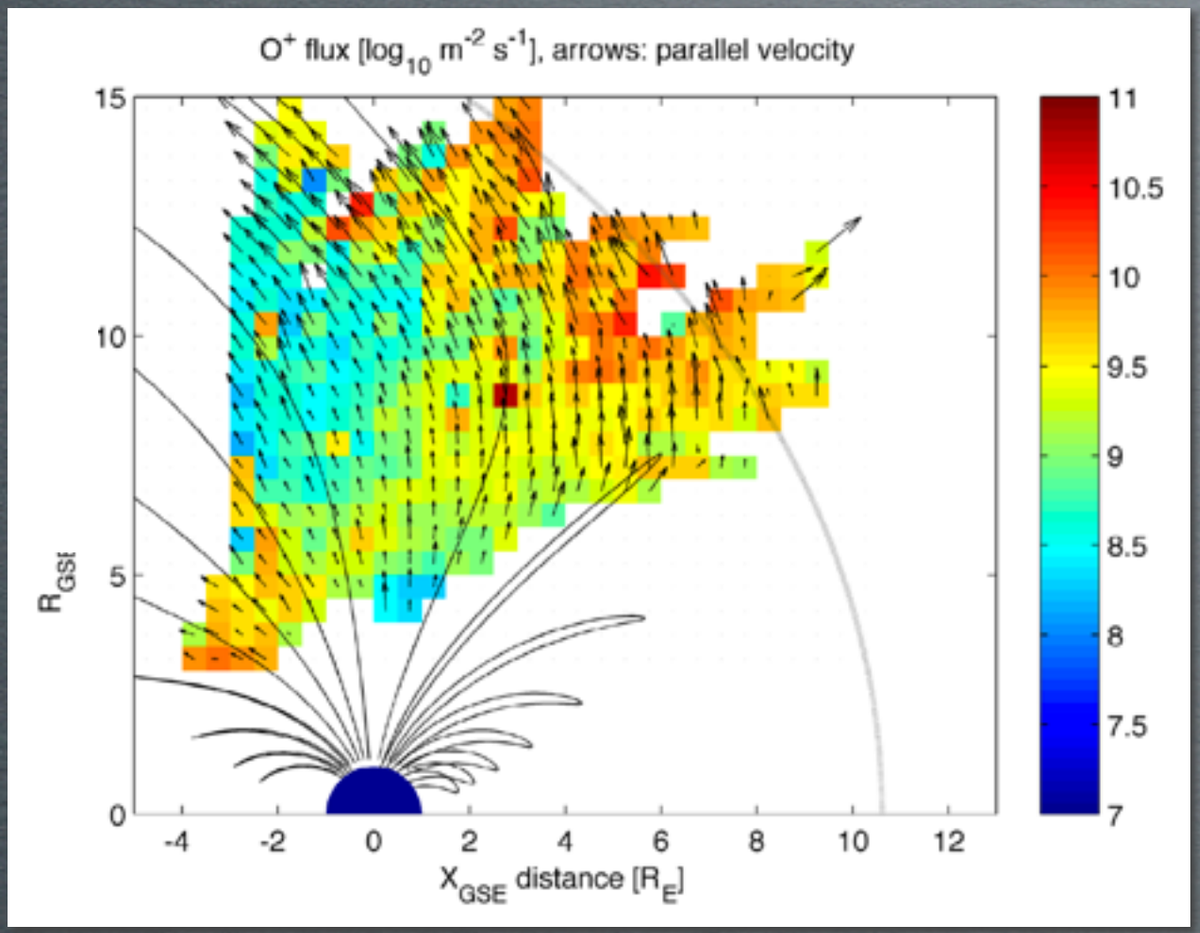
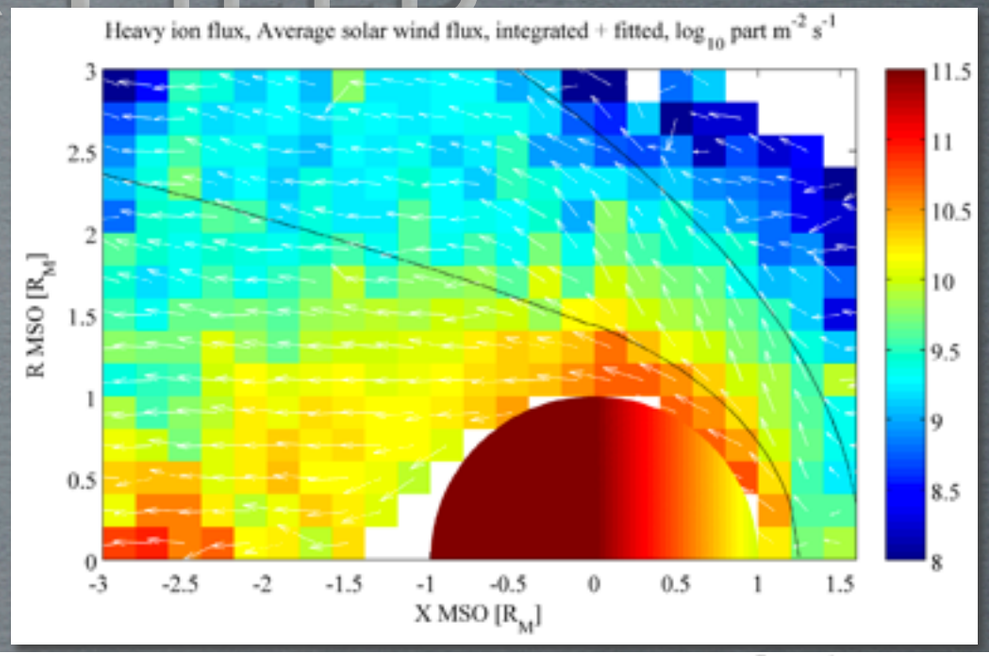
Hot and cold ion outflow, from the ionosphere to the plasma sheet and back

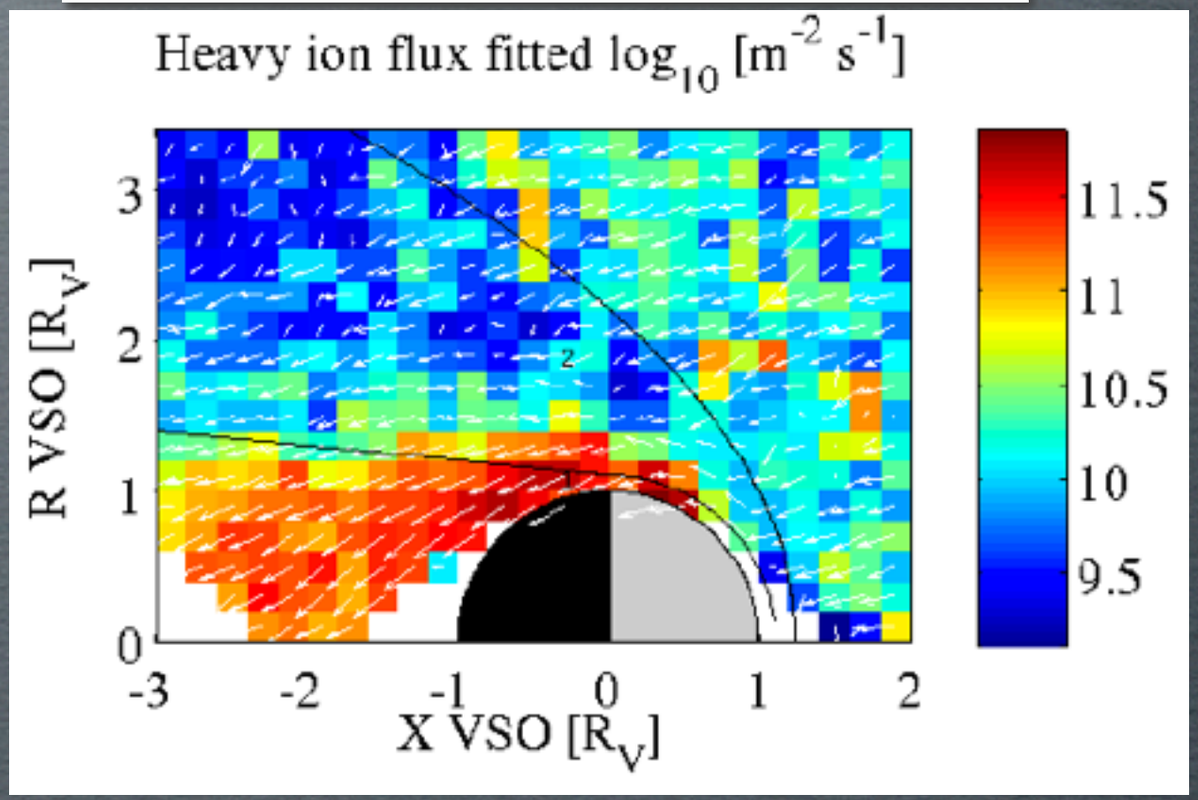


Hans Nilsson
Swedish Institute of Space Physics

Role of a Planetary Magnetic Field

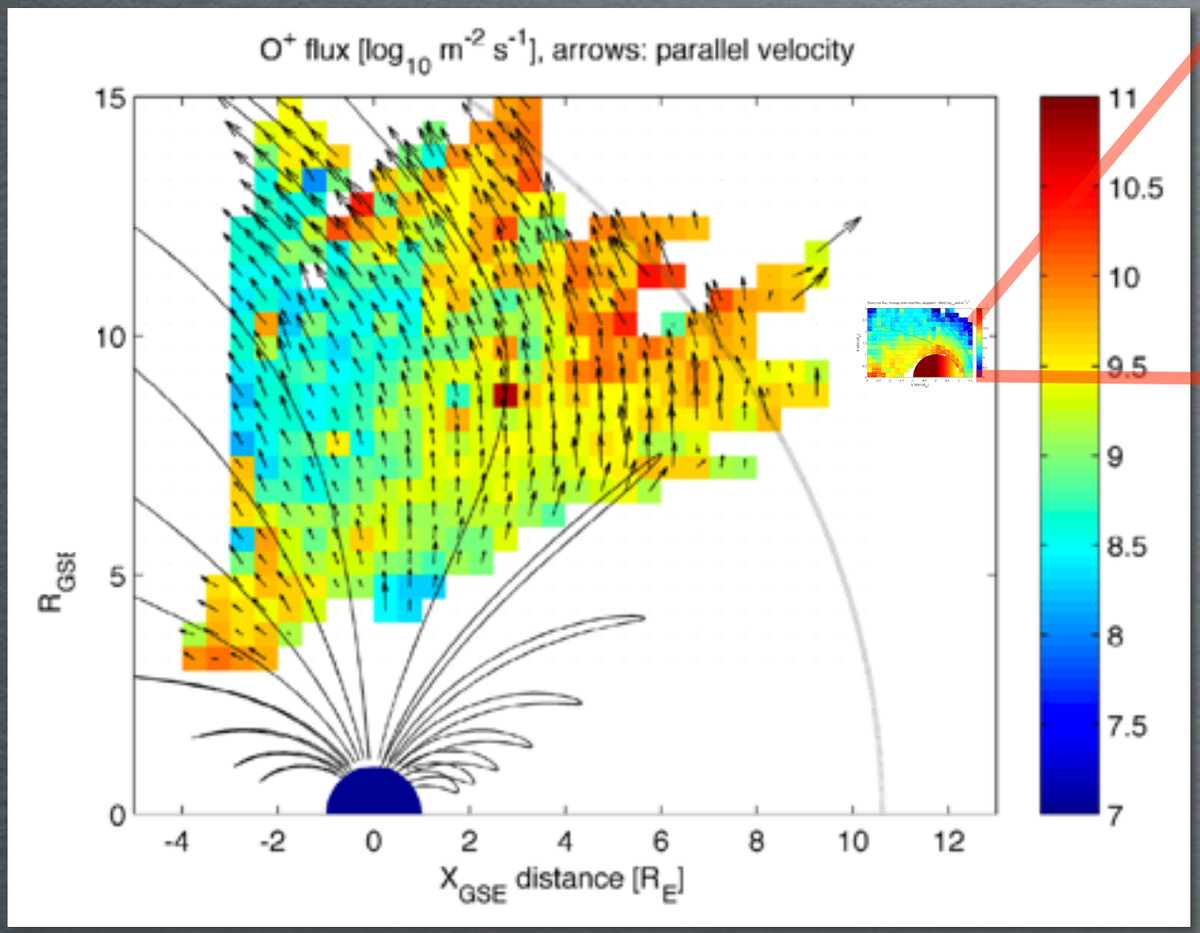


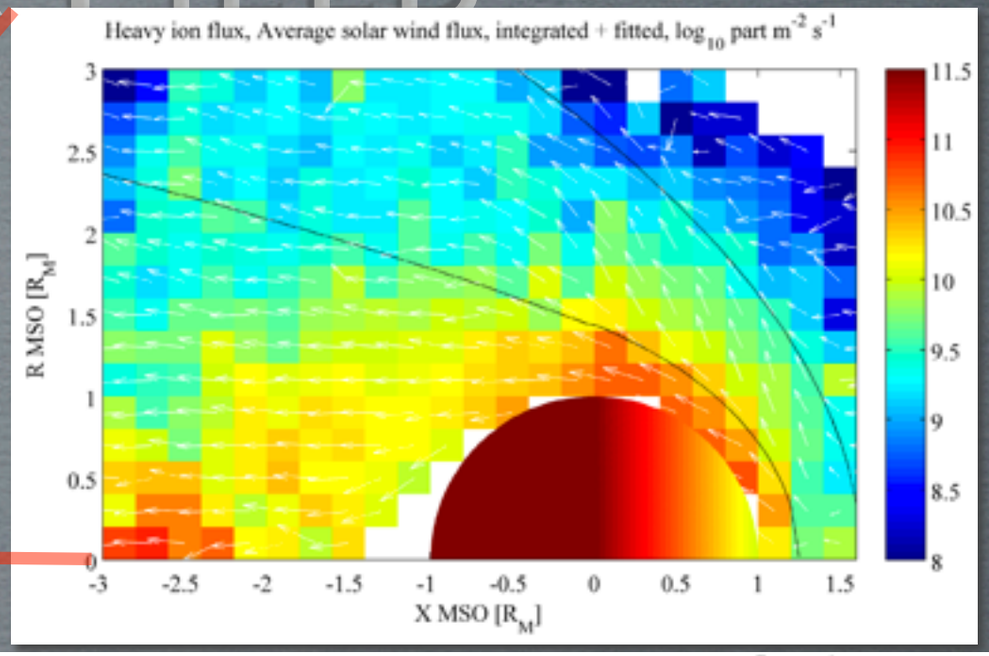


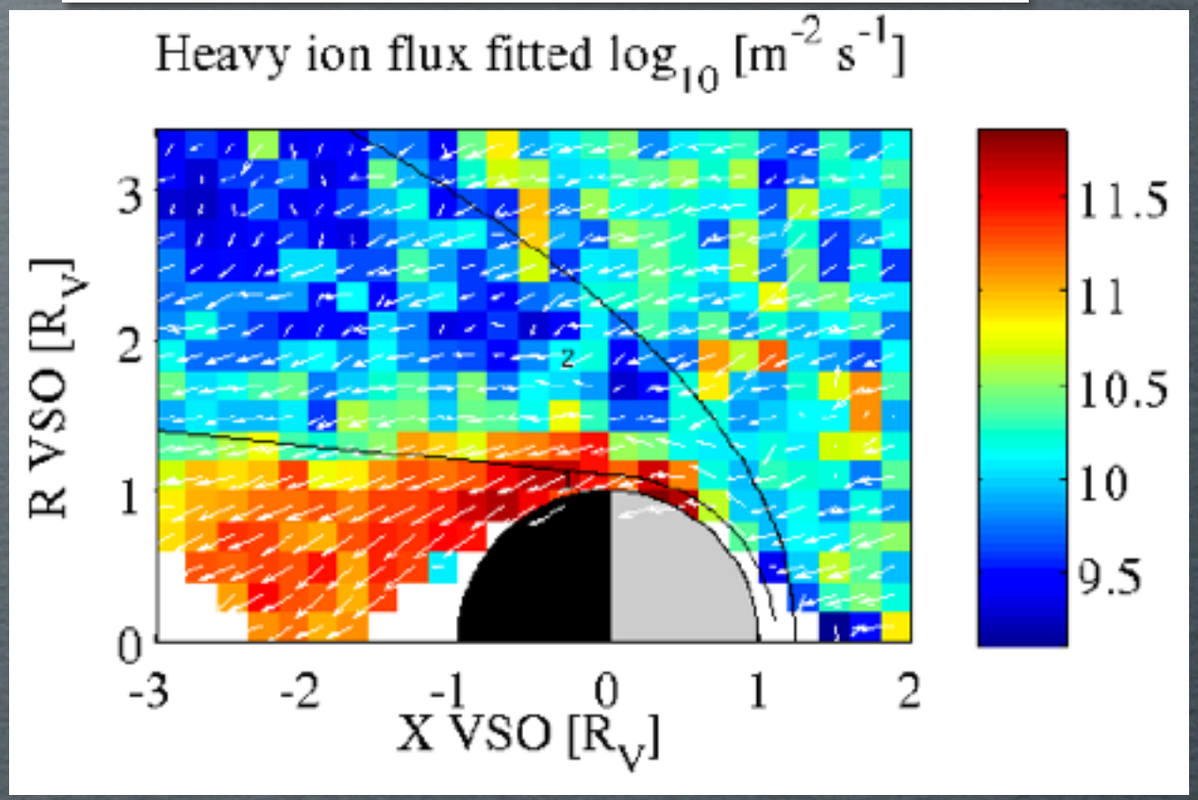


A Changing Paradigm?

Role of a Planetary Magnetic Field







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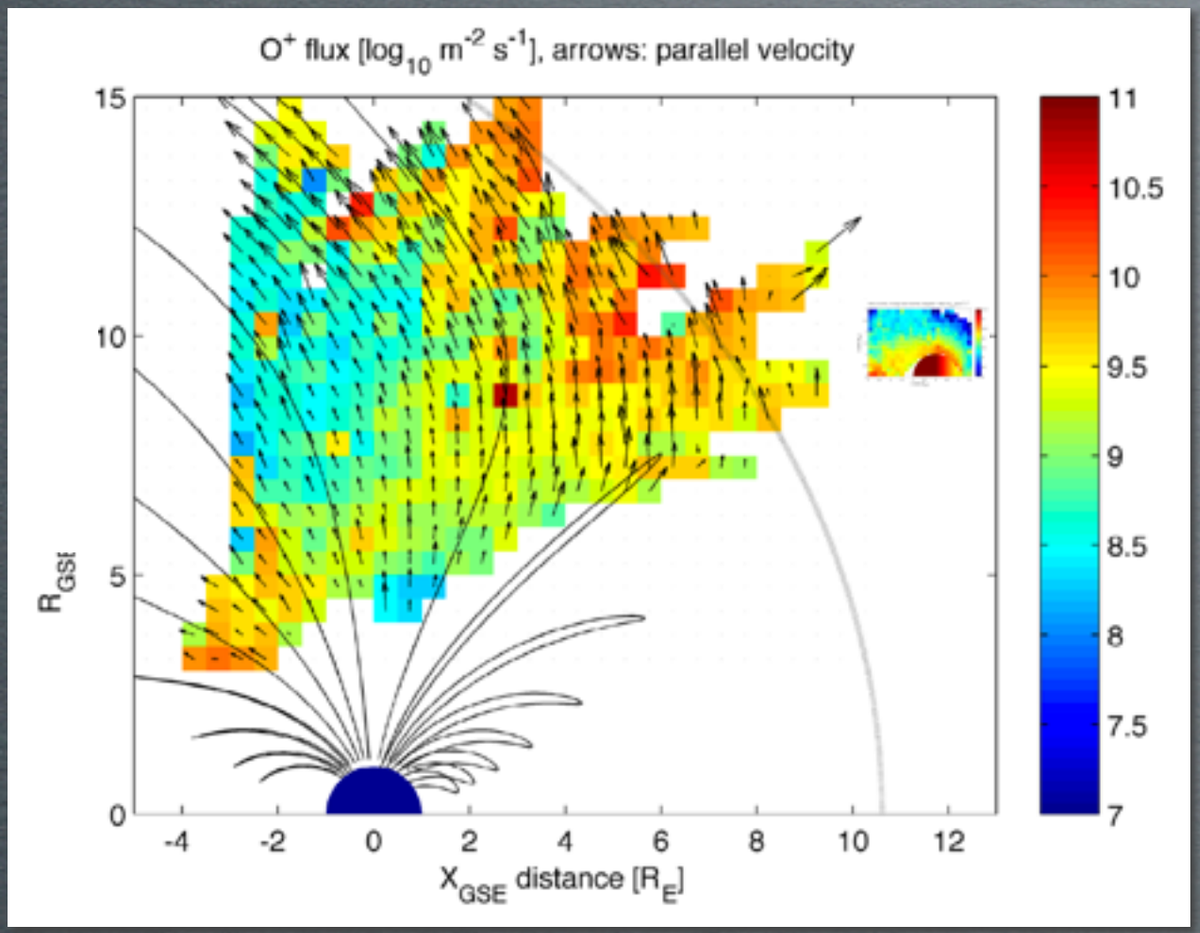
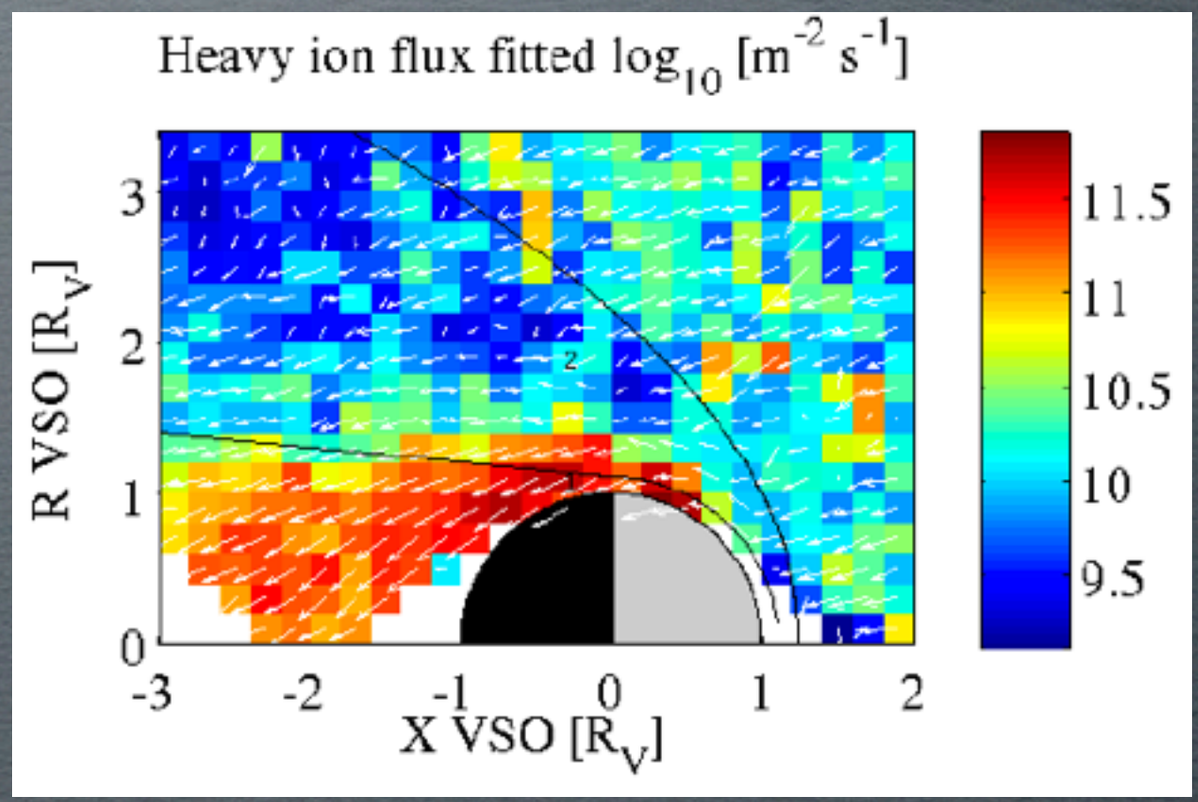
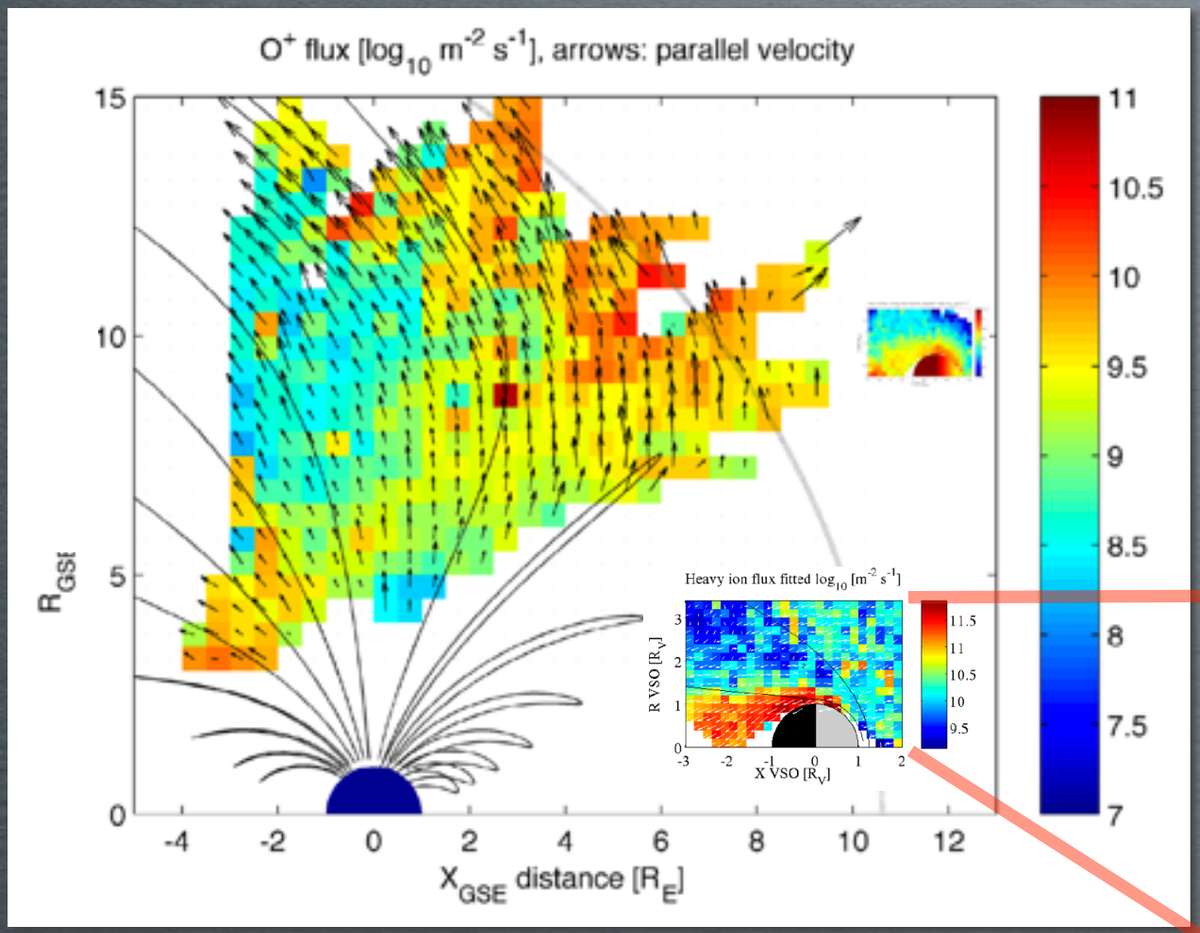
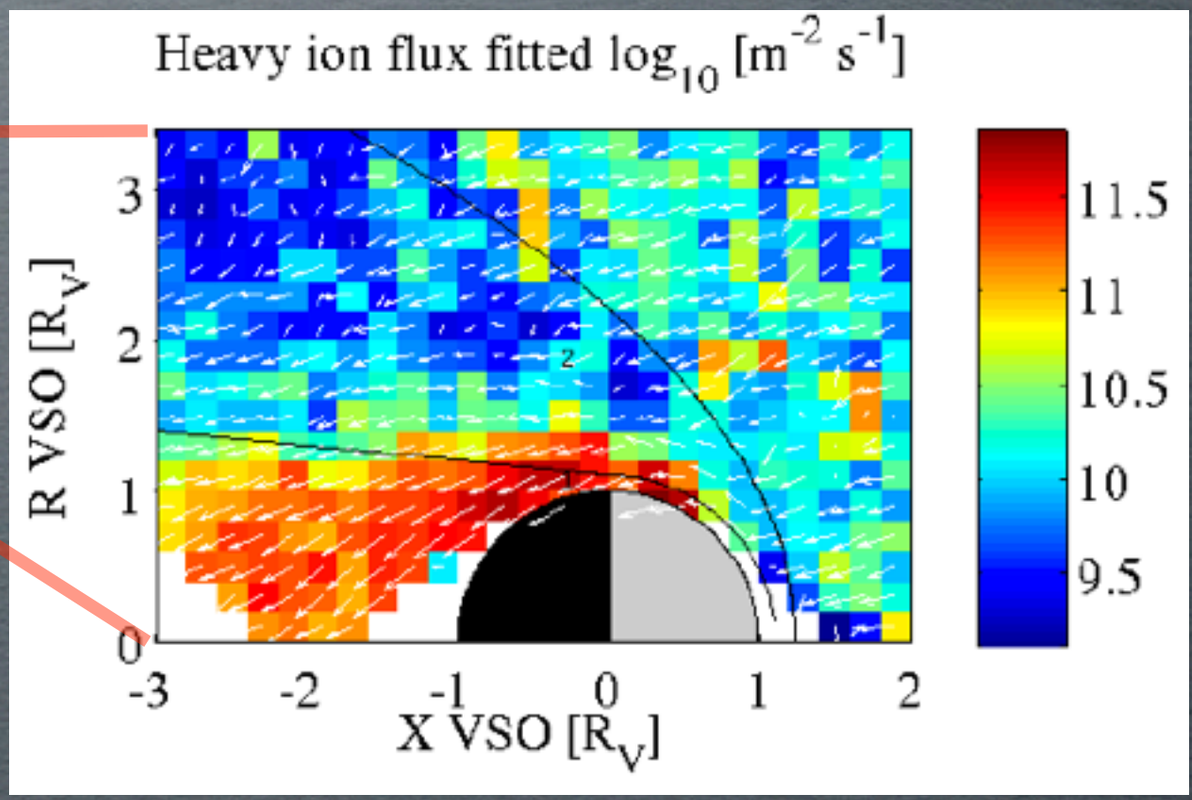




A Changing Paradigm?

Role of a Planetary Magnetic Field





A Changing Paradigm?

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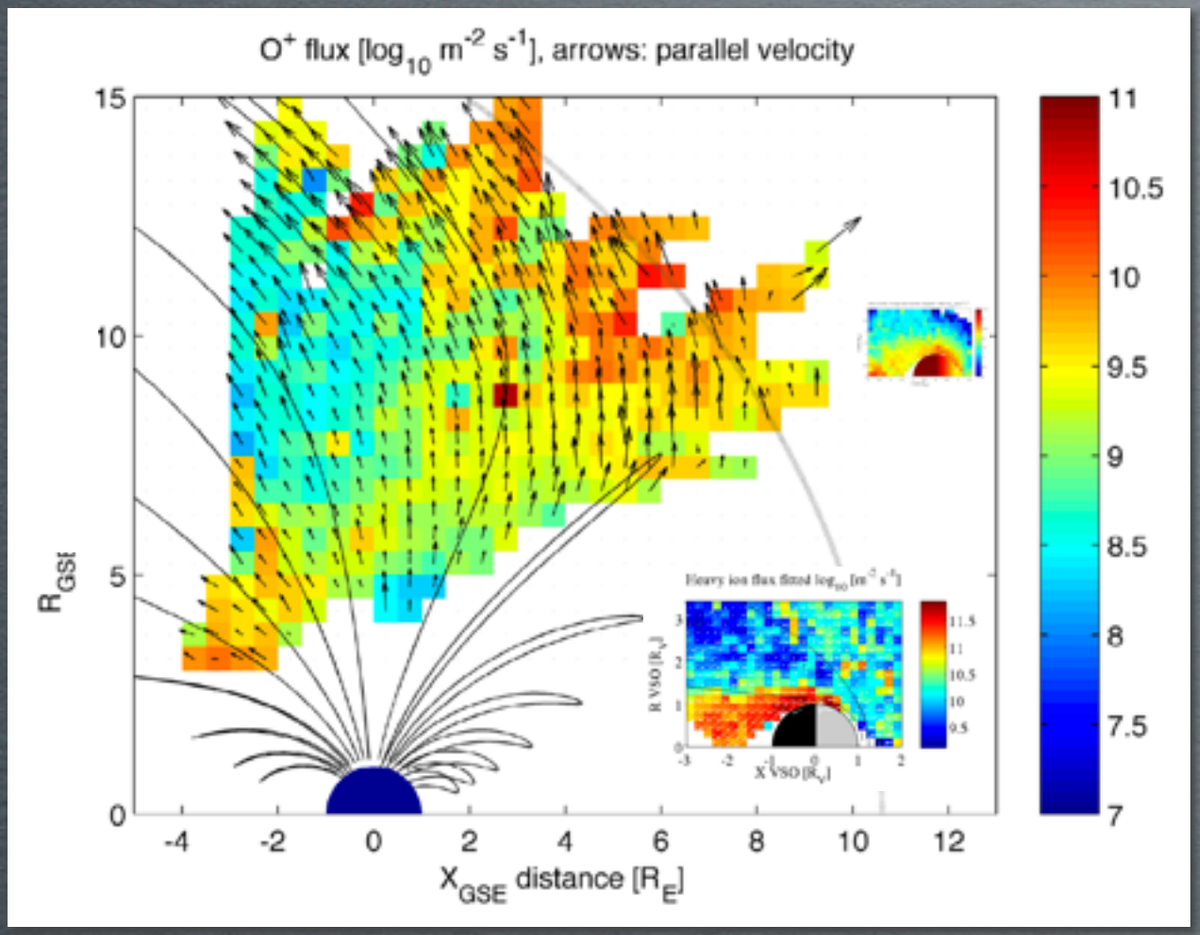
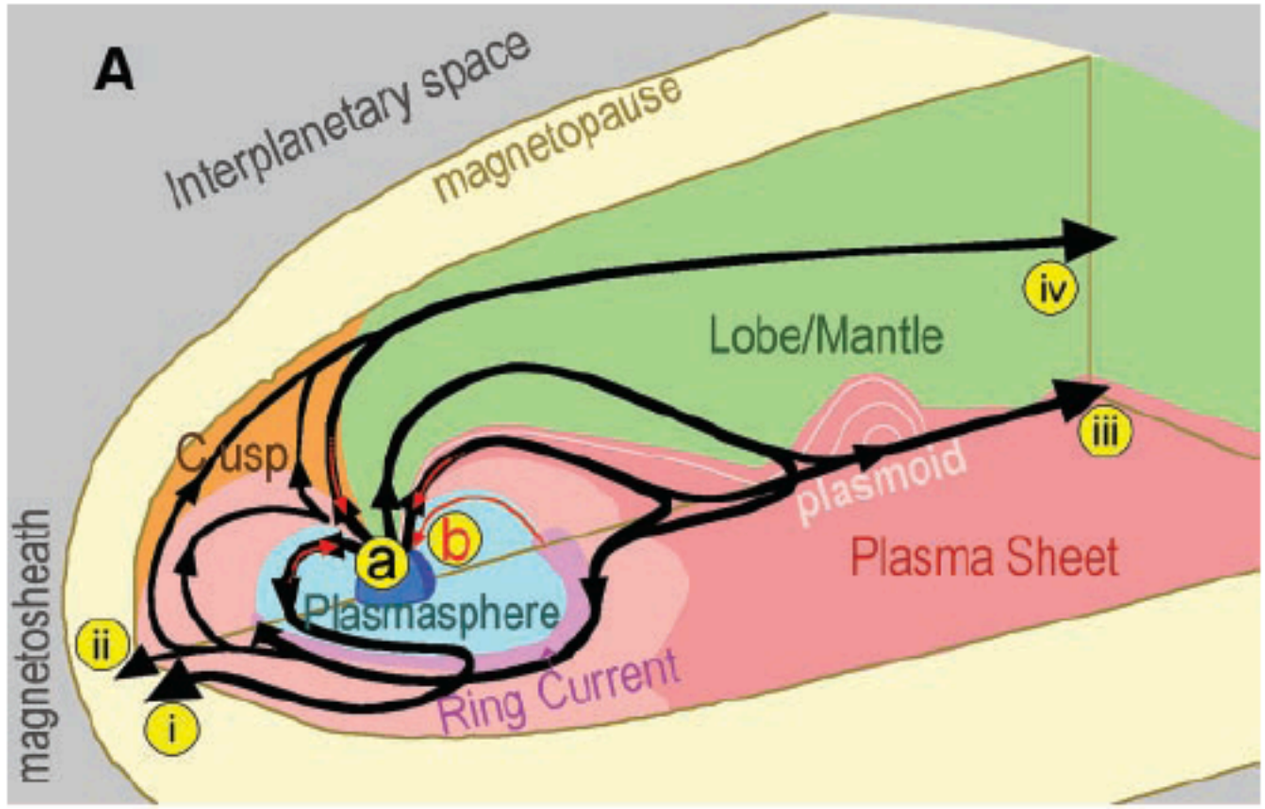
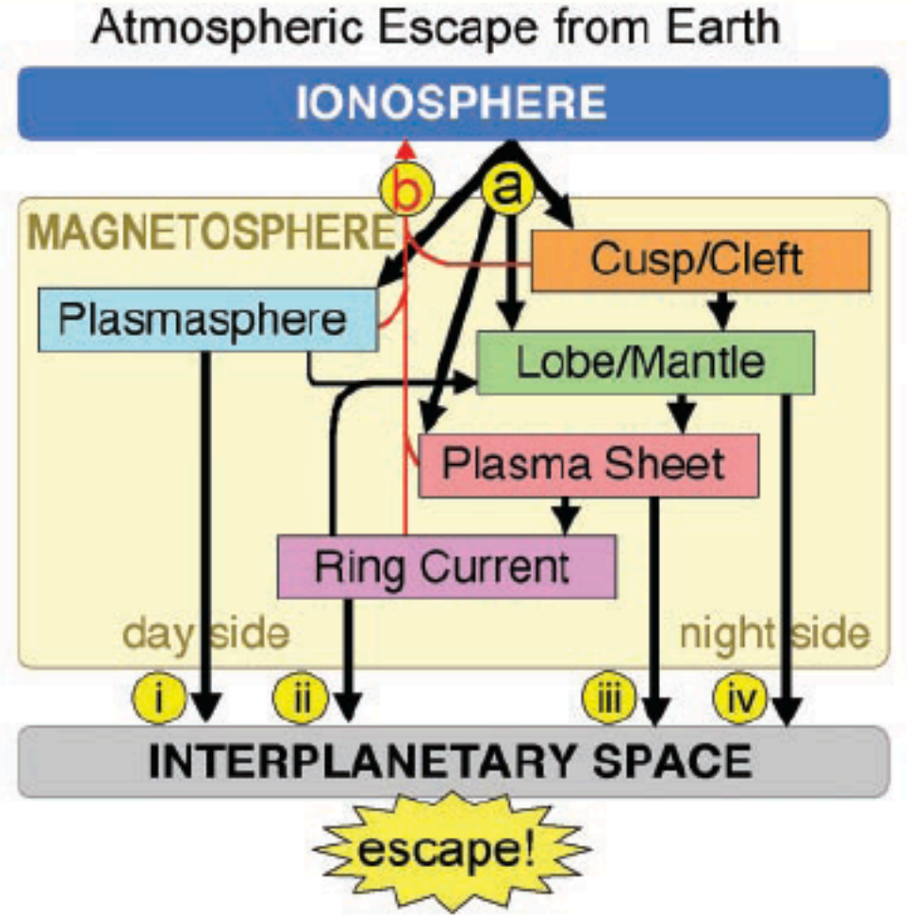


A Changing Paradigm?

Seki et al., Science, 2001

- Ion outflow of order 10^{25} / s
- Return flow dominates
- Less escape from magnetized planet
- Escape of order 10^{24} / s





Geospace Revisited,

9 MARCH 2001 VOL 291 SCIENCE www.sciencer

Seki et al., Science, 2001

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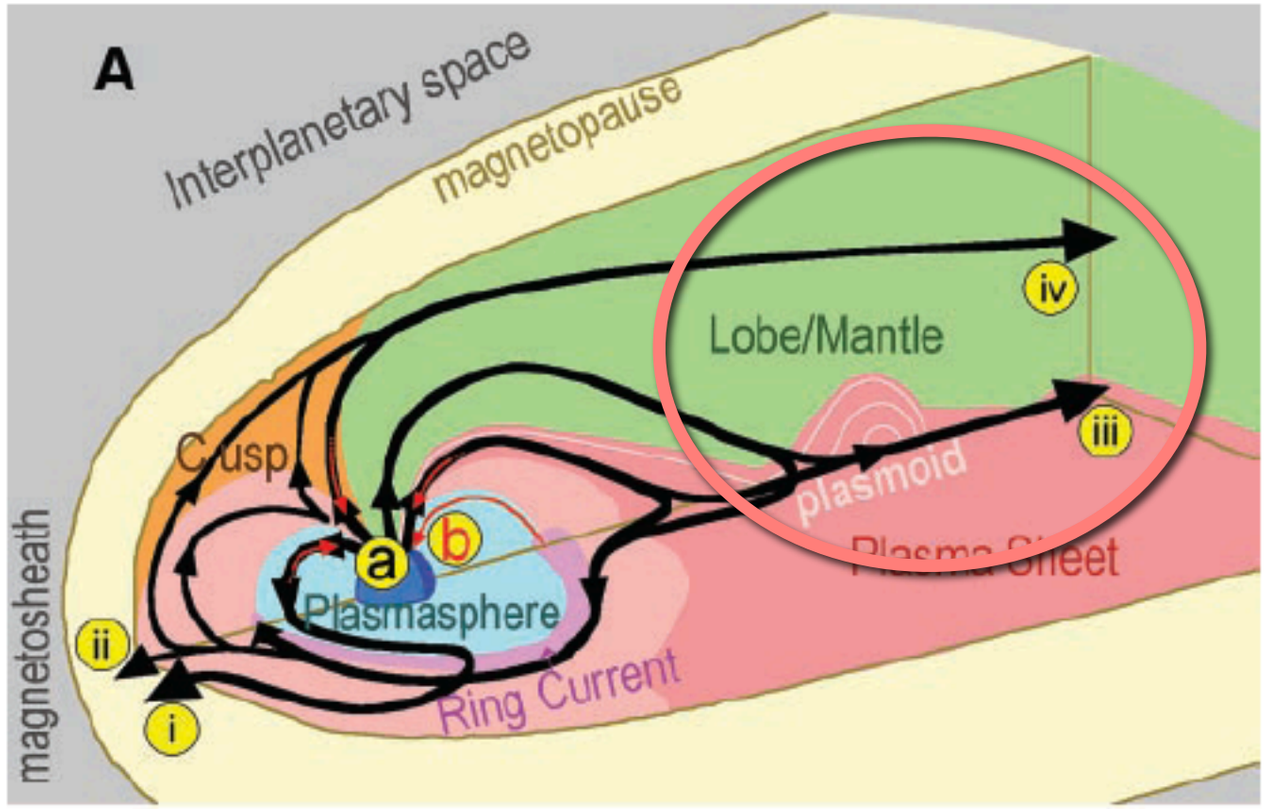

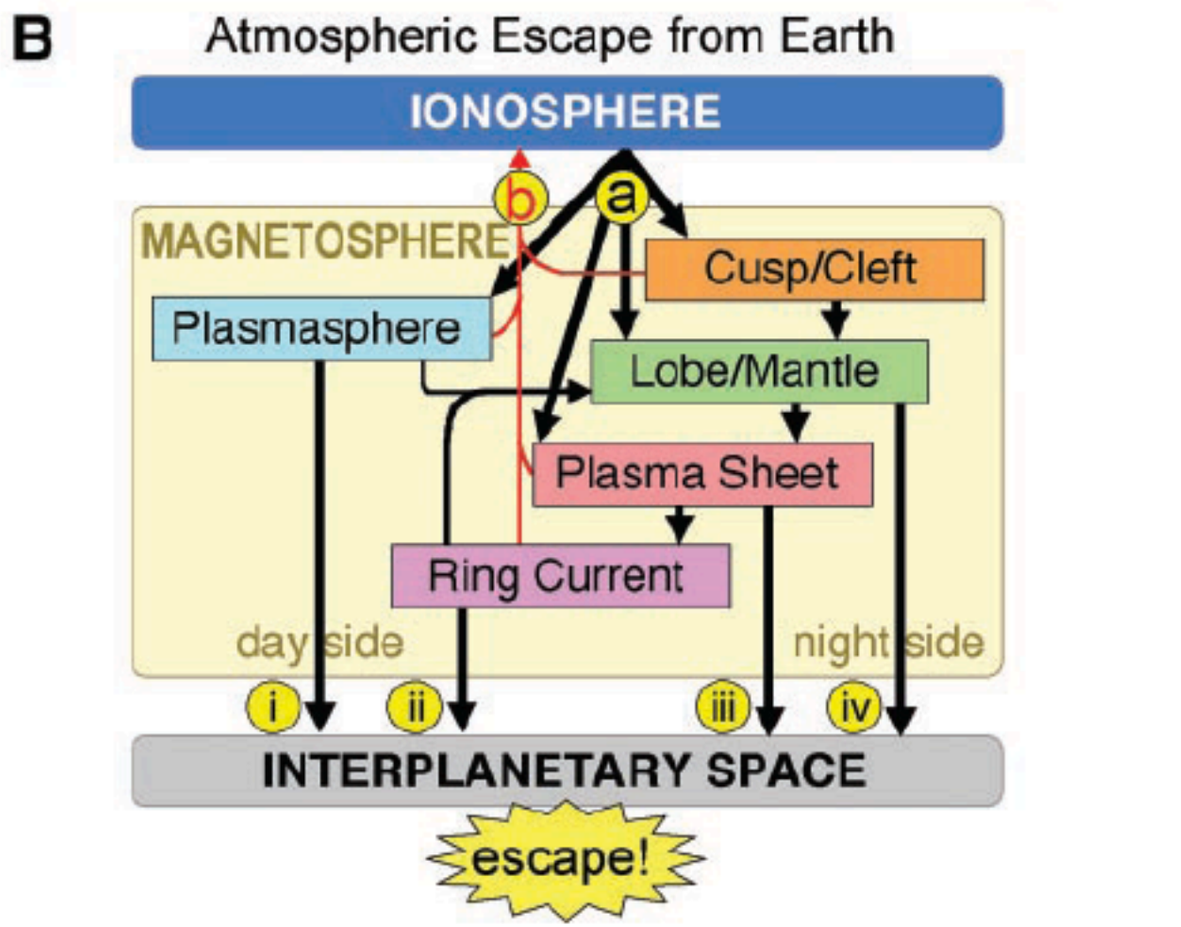

Seki et al., Science, 2001

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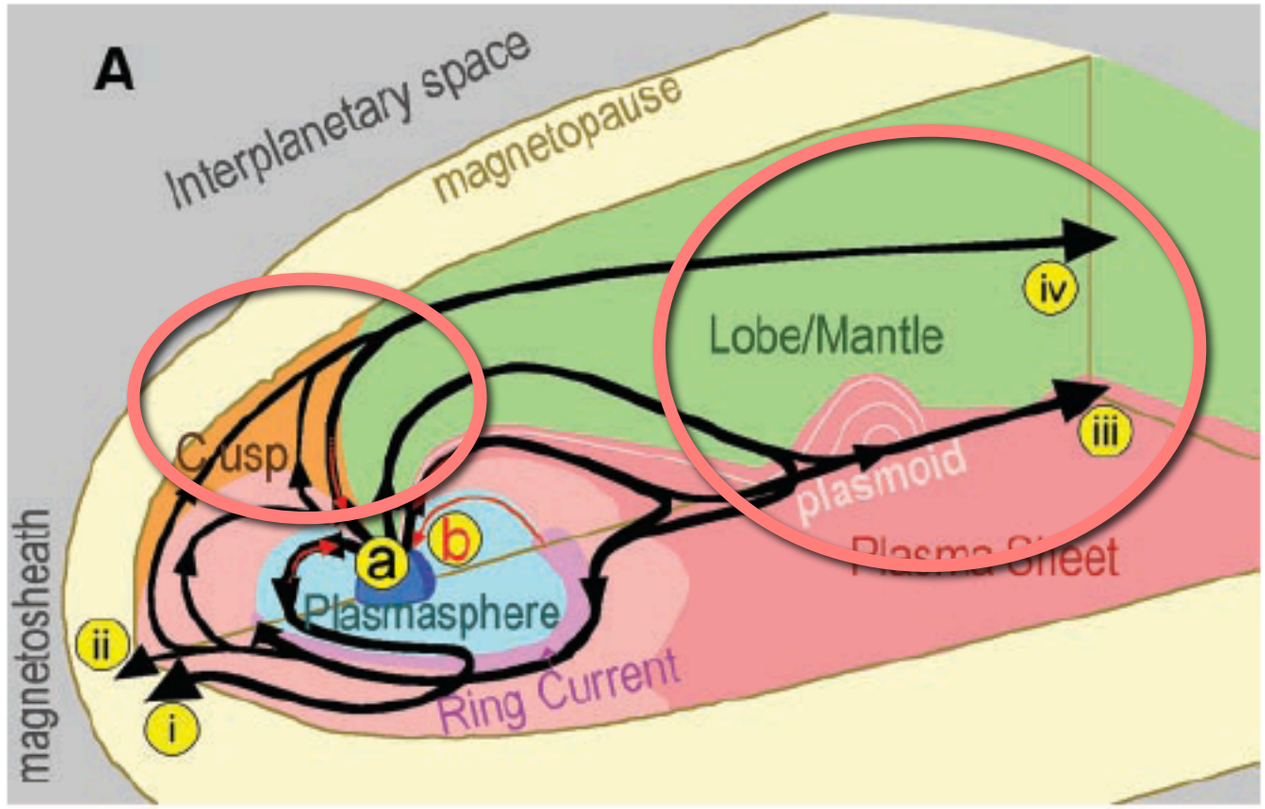

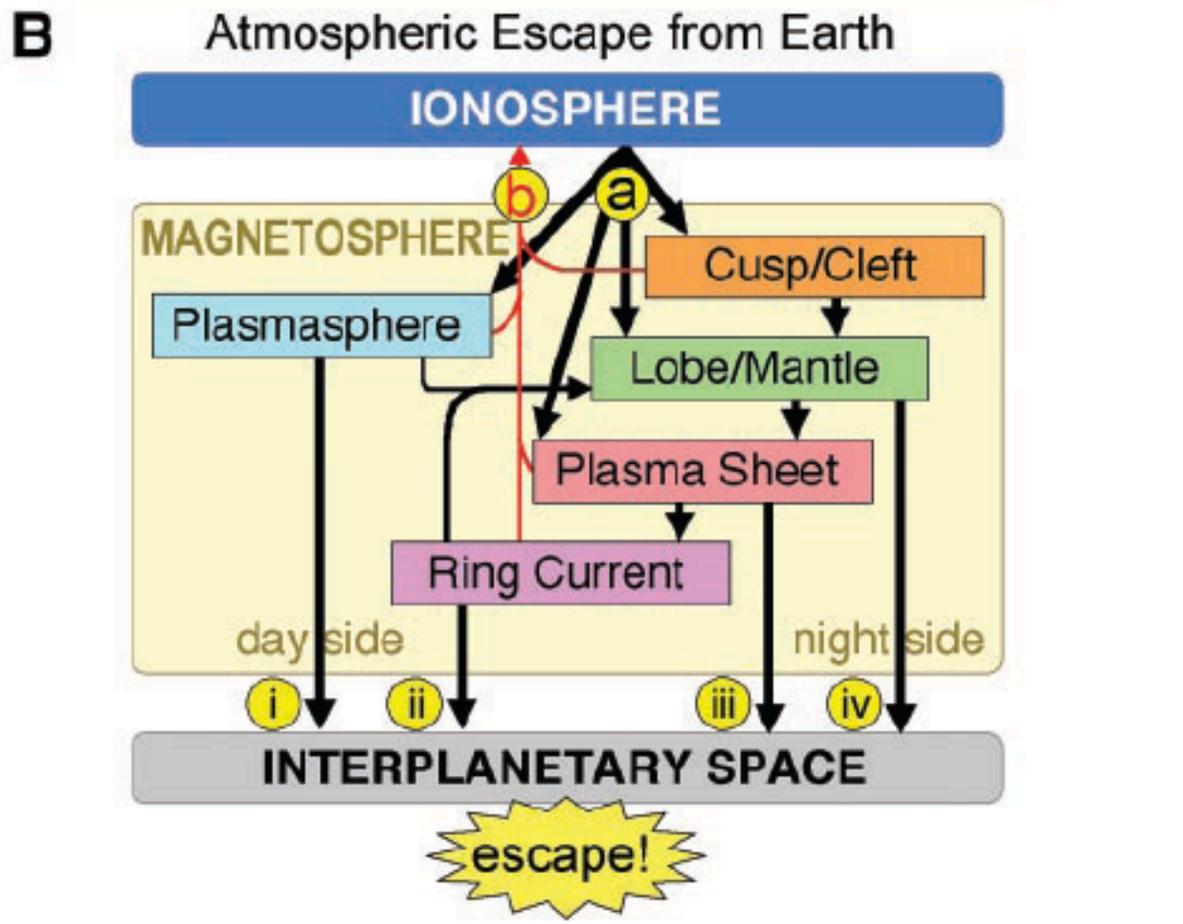

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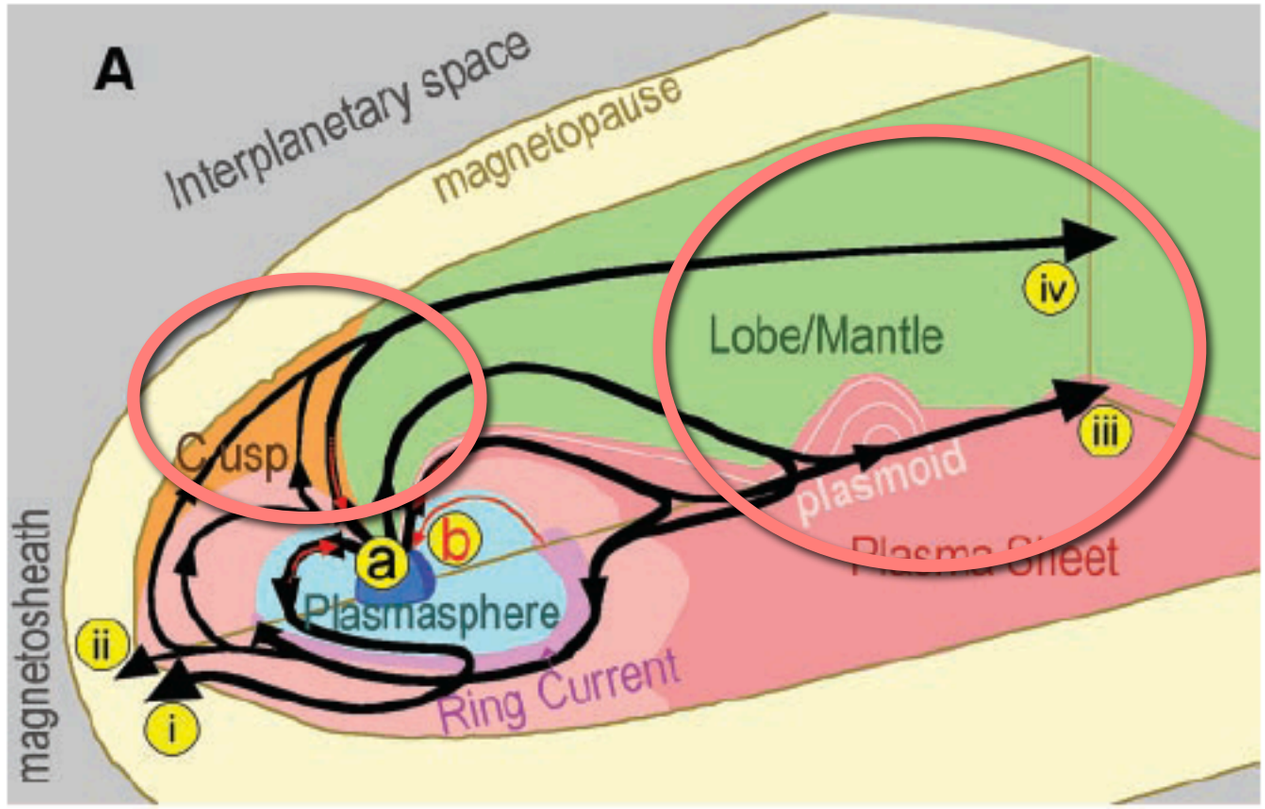

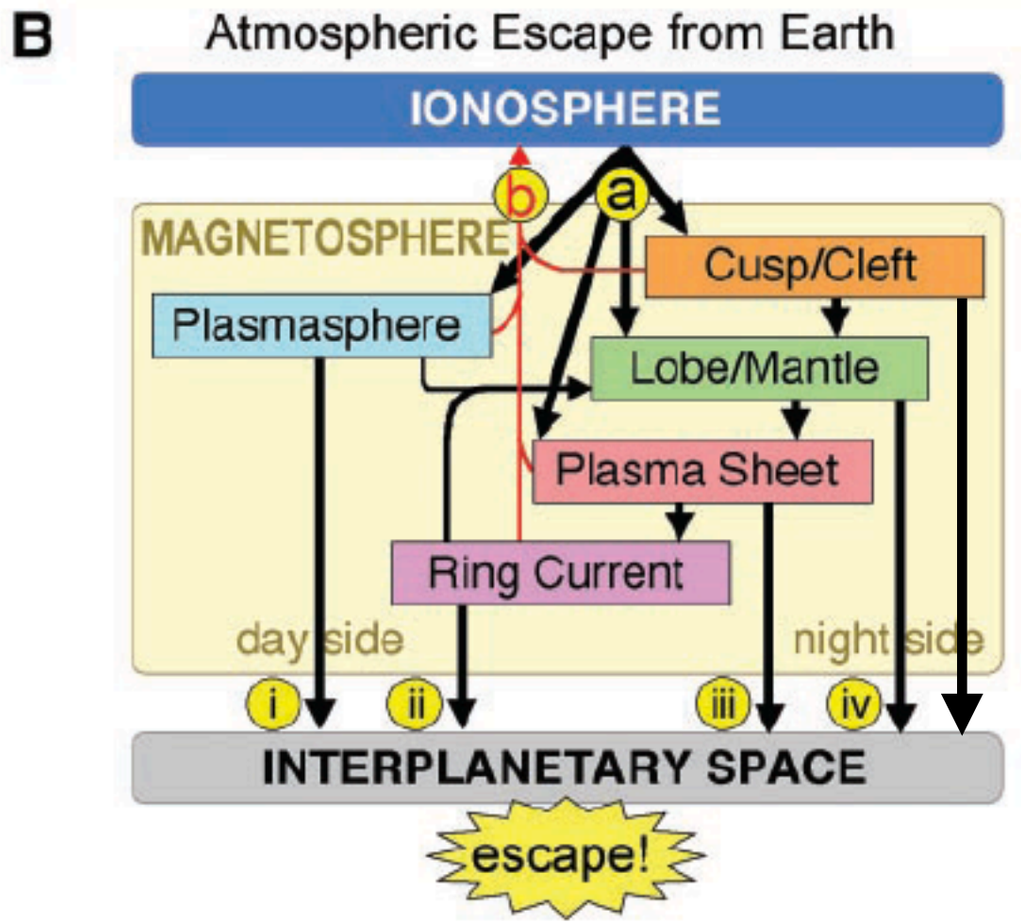

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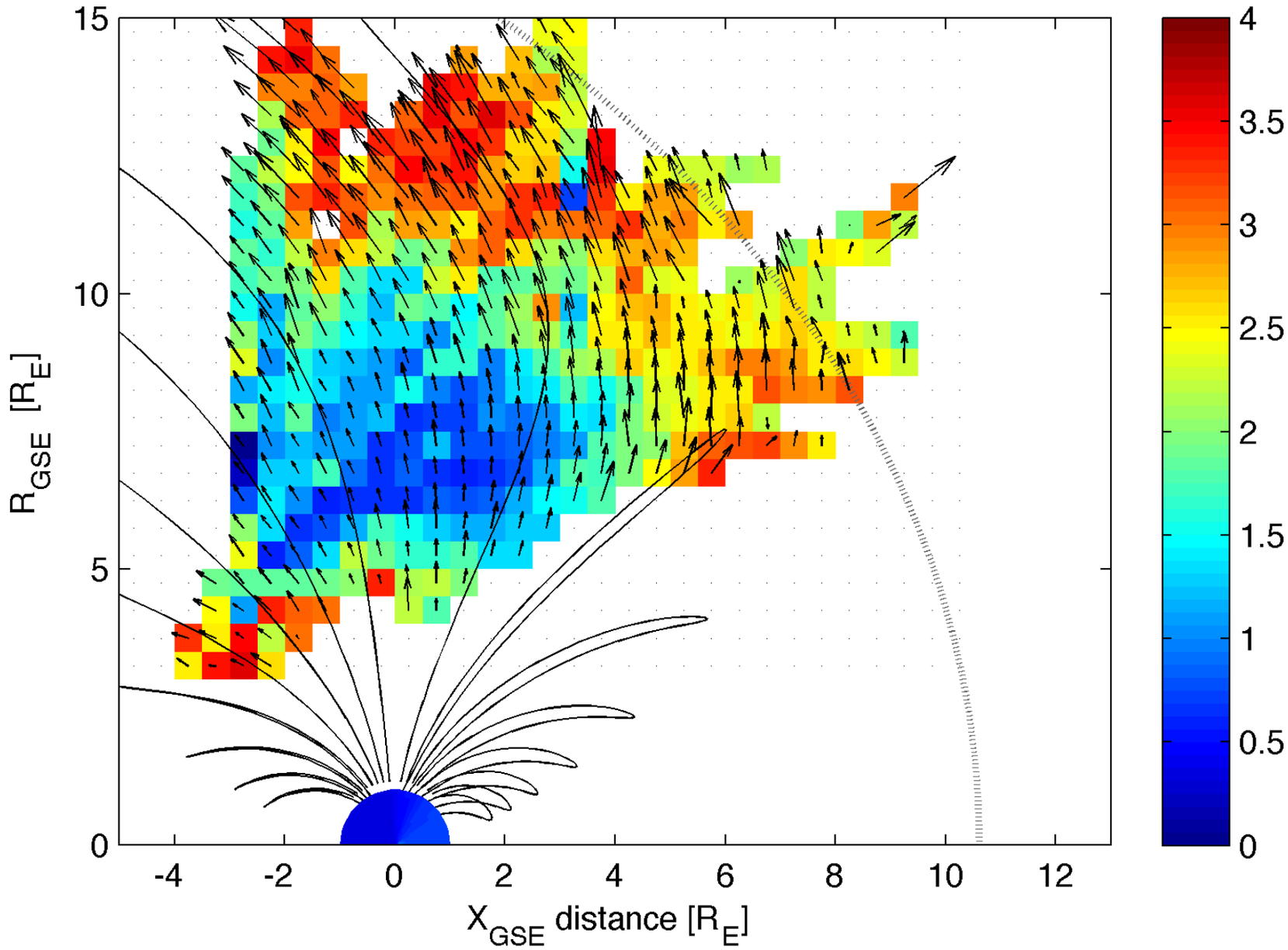


Strong Oxygen Ion Heating in the High Altitude Polar Cap Region

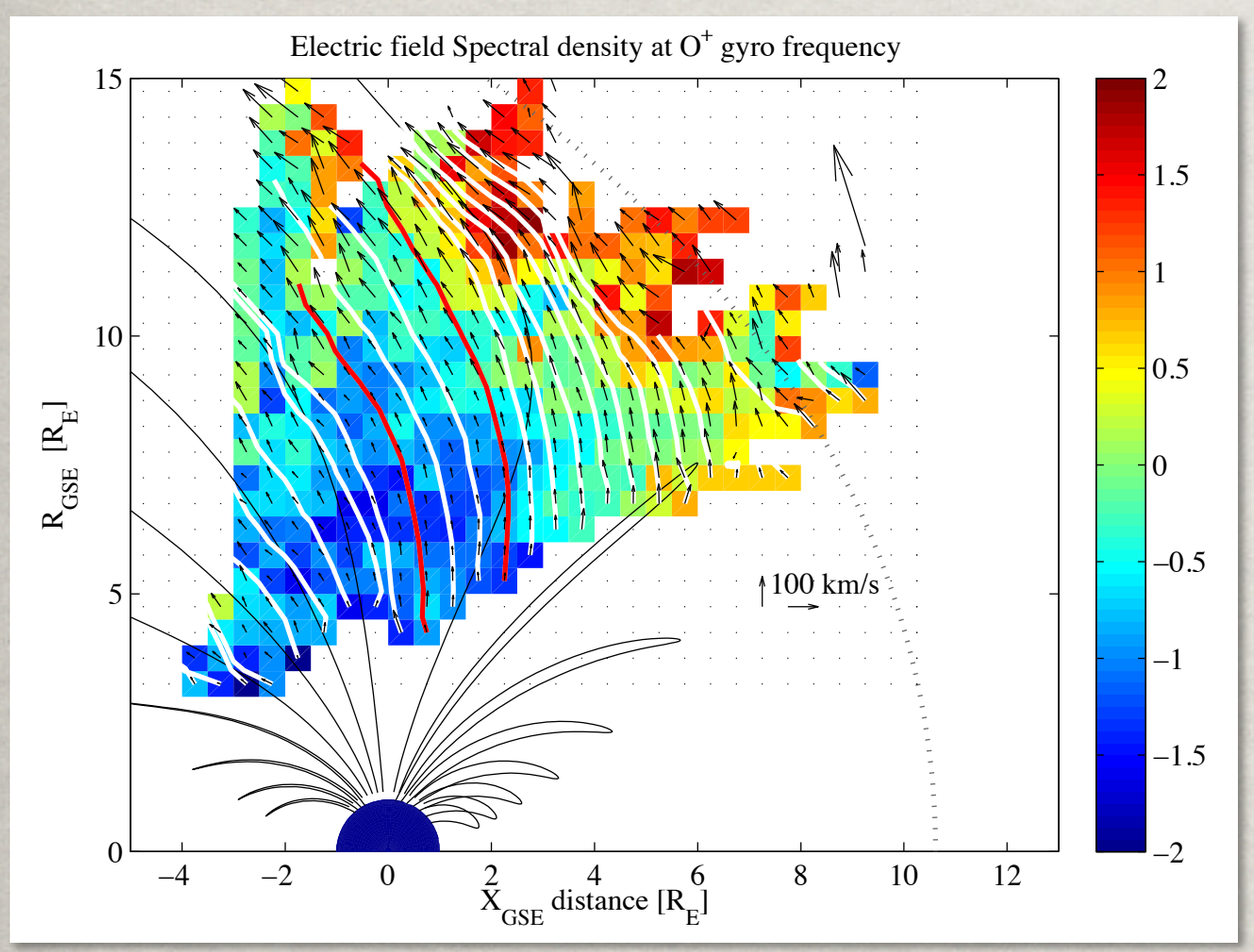
Is there a contradiction between reports of hot and cold plasma?

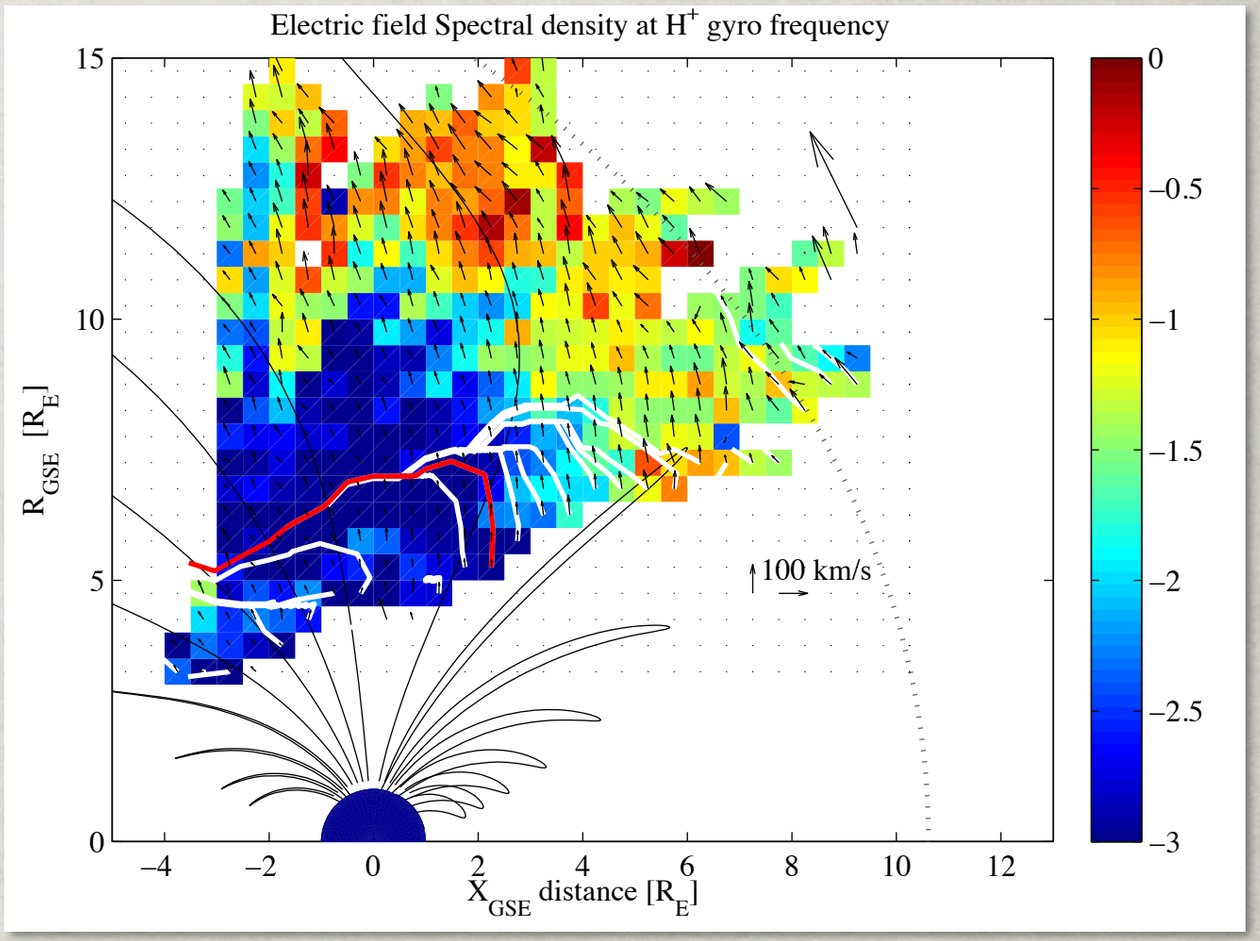
- Nilsson et al. (2006,2012,2013), Slapak et al. (2012,2013), strong heating at high altitude

- Liao et al. (2012), no heating of cold oxygen ion beams in the polar cap and lobes

- Engwall et al. (2009), André and Cully (2012), cold ion beams in the lobes (protons)

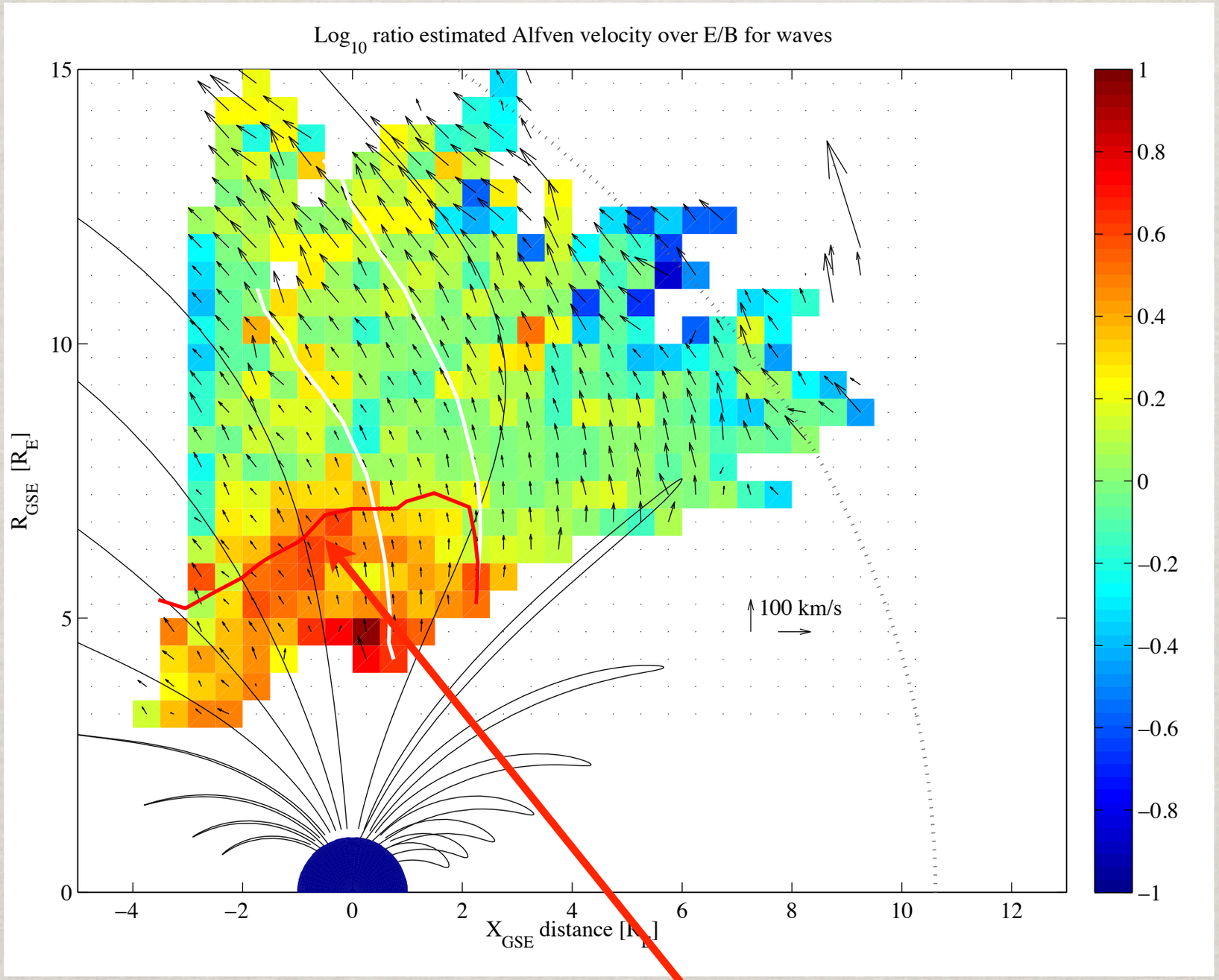
Electric Field Spectral Density





The Flight Path Determines High or Low Degree of Heating of the Outflowing Ions

Cold Plasma?



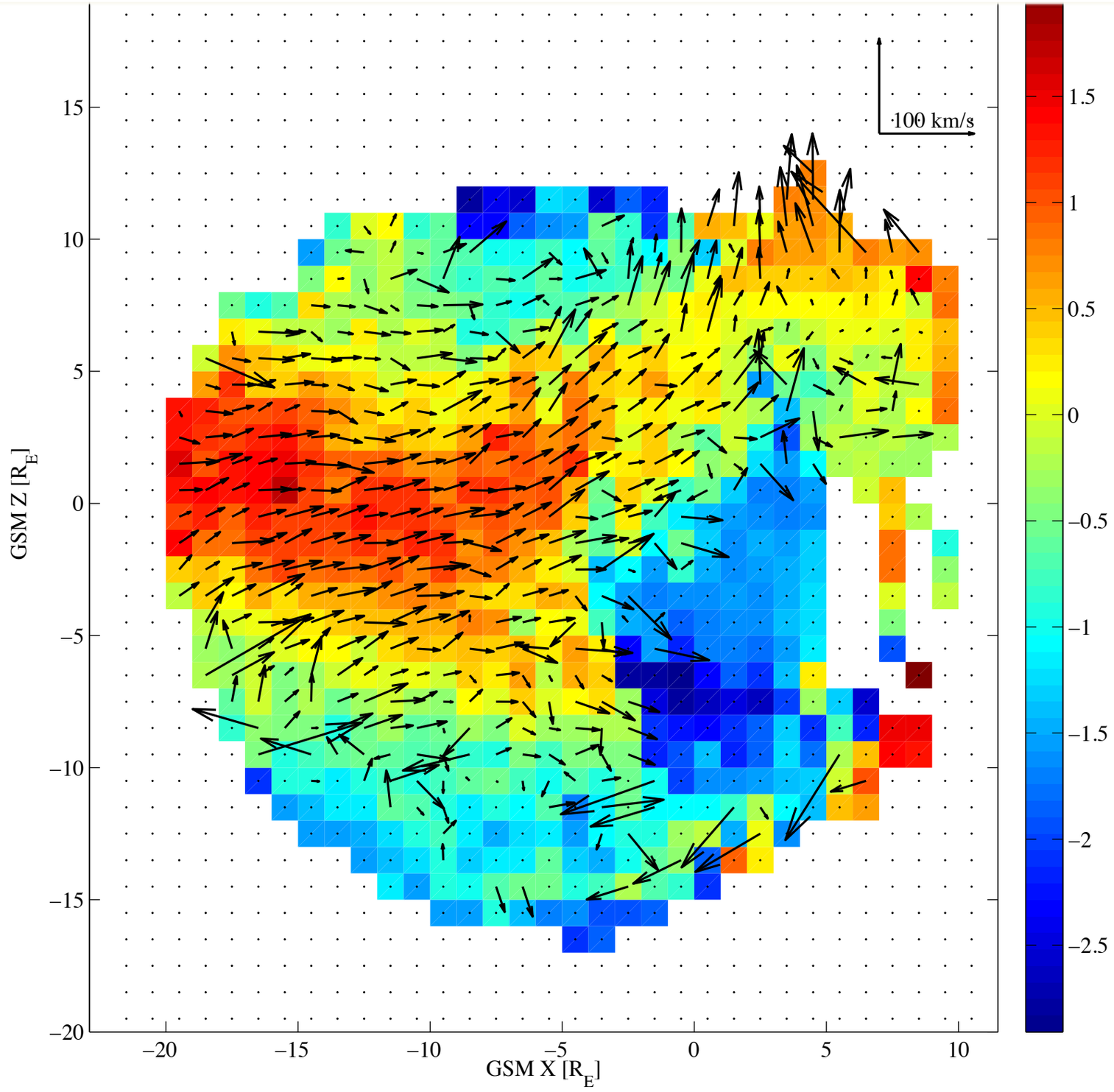
Nilsson et al. 2012

Cold ion flight trajectory

Extension to the Tail

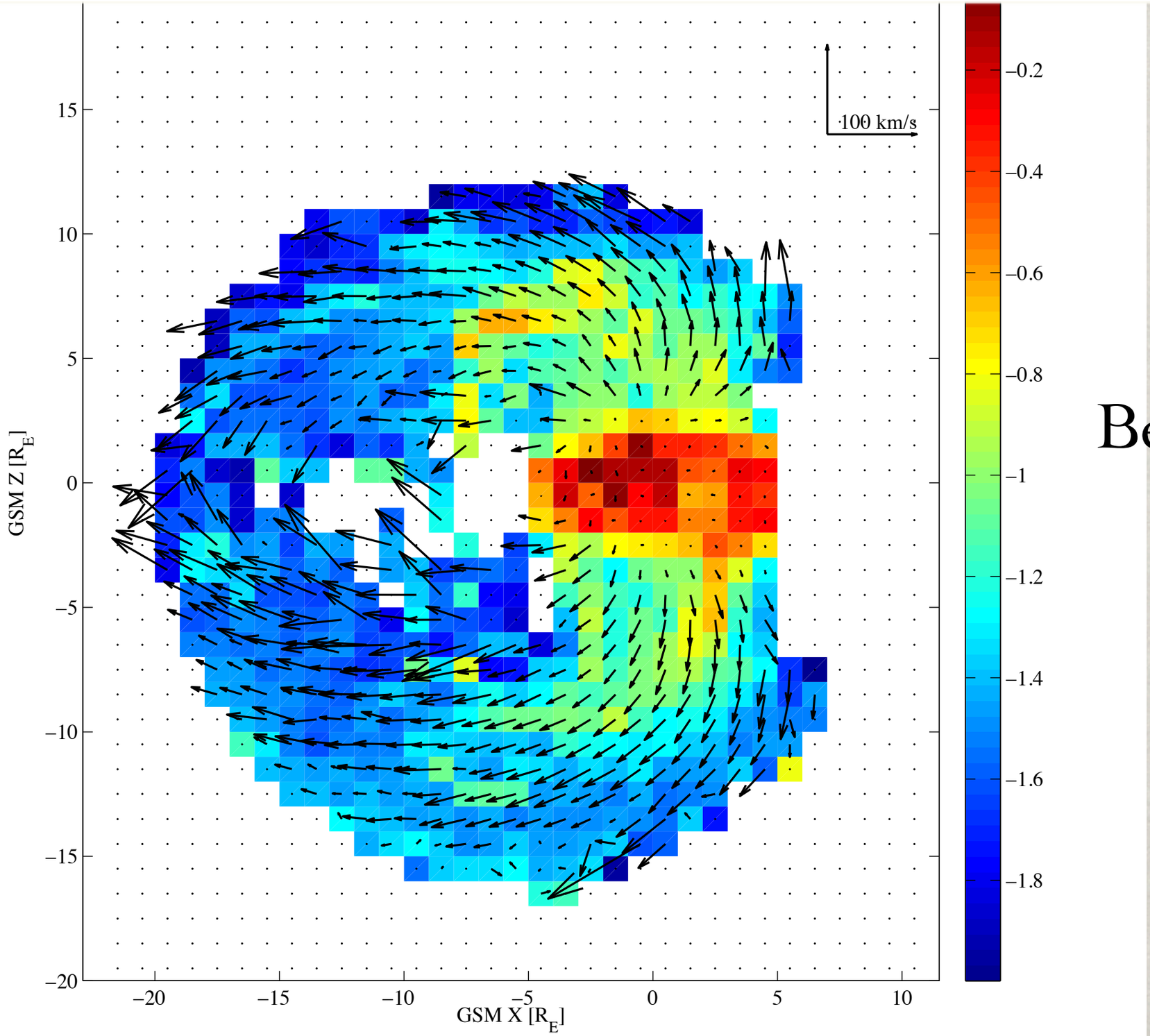
- Previous data set manually identified
- In the tail, plasma beta is a useful way to distinguish lobes from plasma sheet
- Try plasma beta combined with a "Magnetosheath like plasma" parameter
- In what follows only X-Z projections will be shown

Use Plasma Beta to Distinguish Region



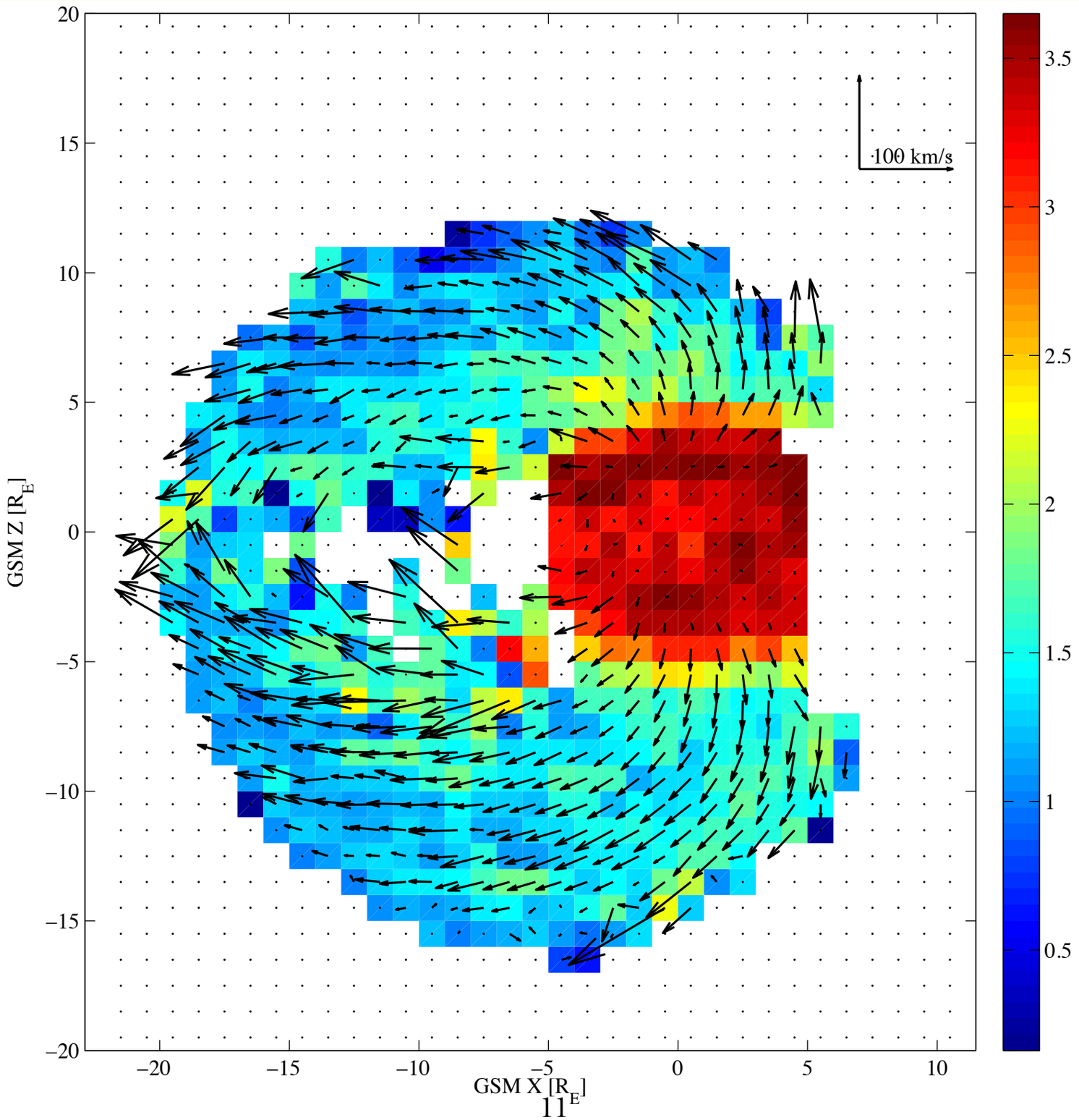
Beta > 1

Low Beta, Oxygen Density and Velocity



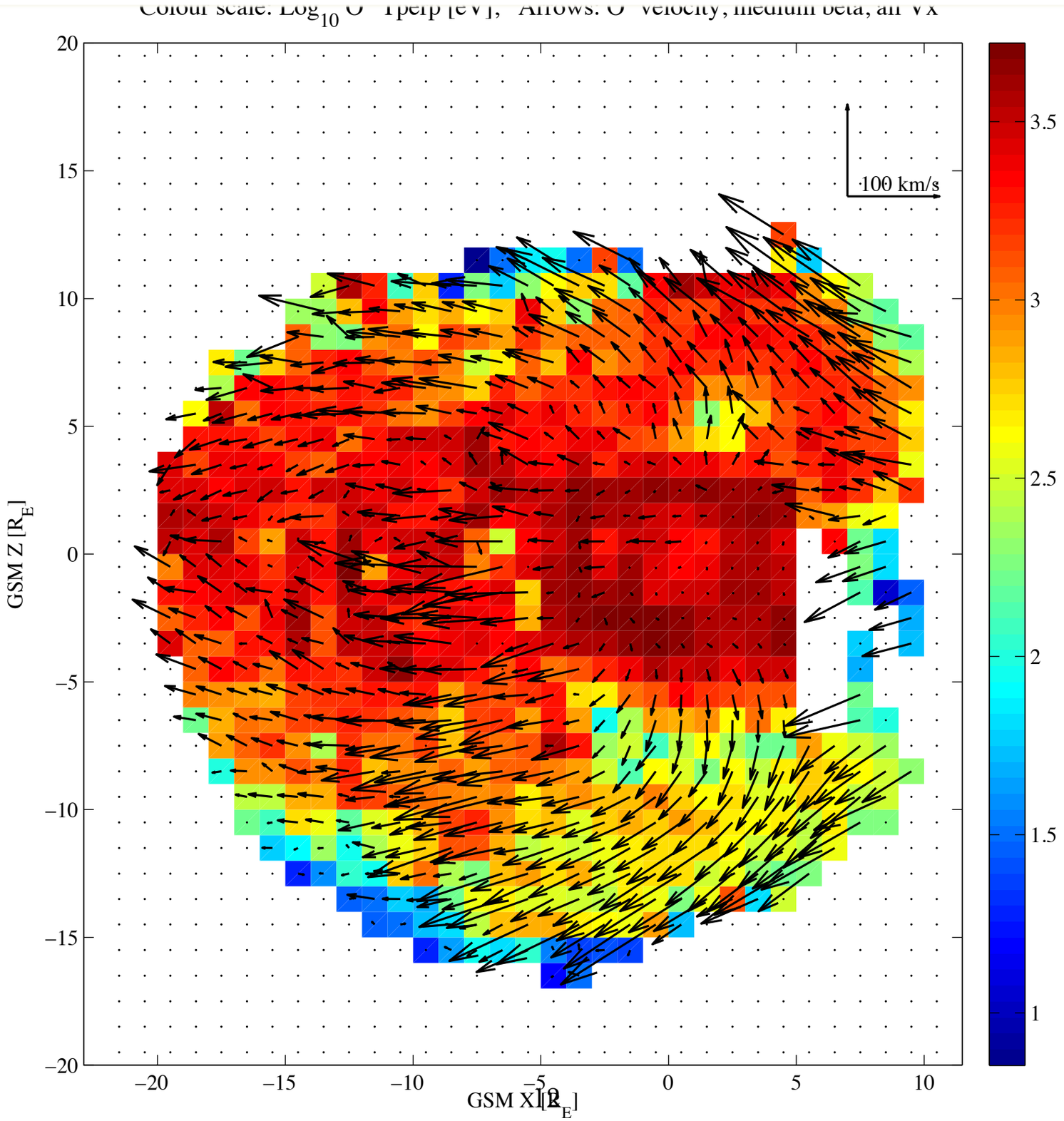
Beta < 0.01

Temperature in Low Beta Region Consistent with no or Very Low Heating Rate



Log10 O+ Tperp

Medium Beta (0.01 - 1), and magnetosheath-like

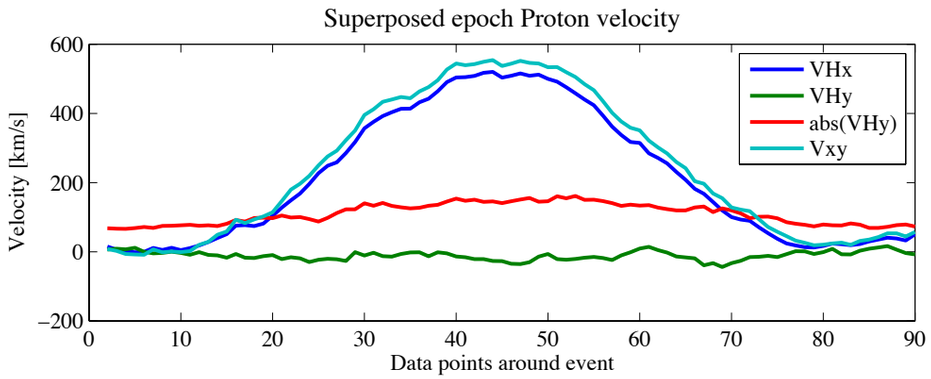


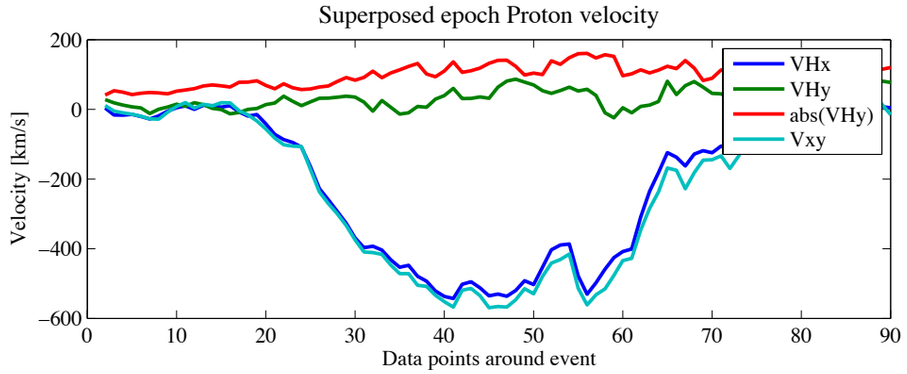
Log10 O+ Tperp

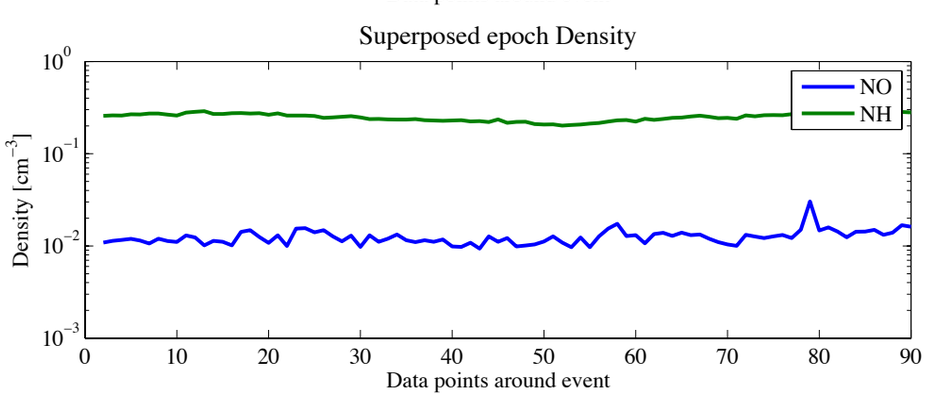
Let Us Now Look at the Plasma Sheet

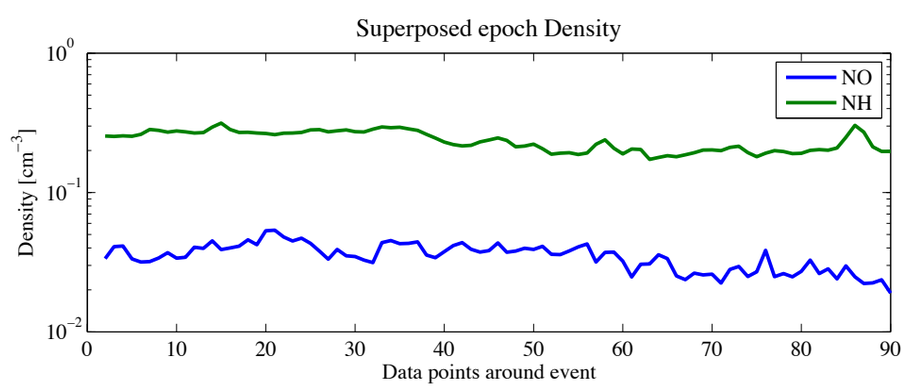
- H+ Bursty Bulk Flows
- O+ Affected by Much Larger Gyro Radius?
- Look at Superposed Epoch Analysis

H+ and O+ Transport in Plasma Sheet

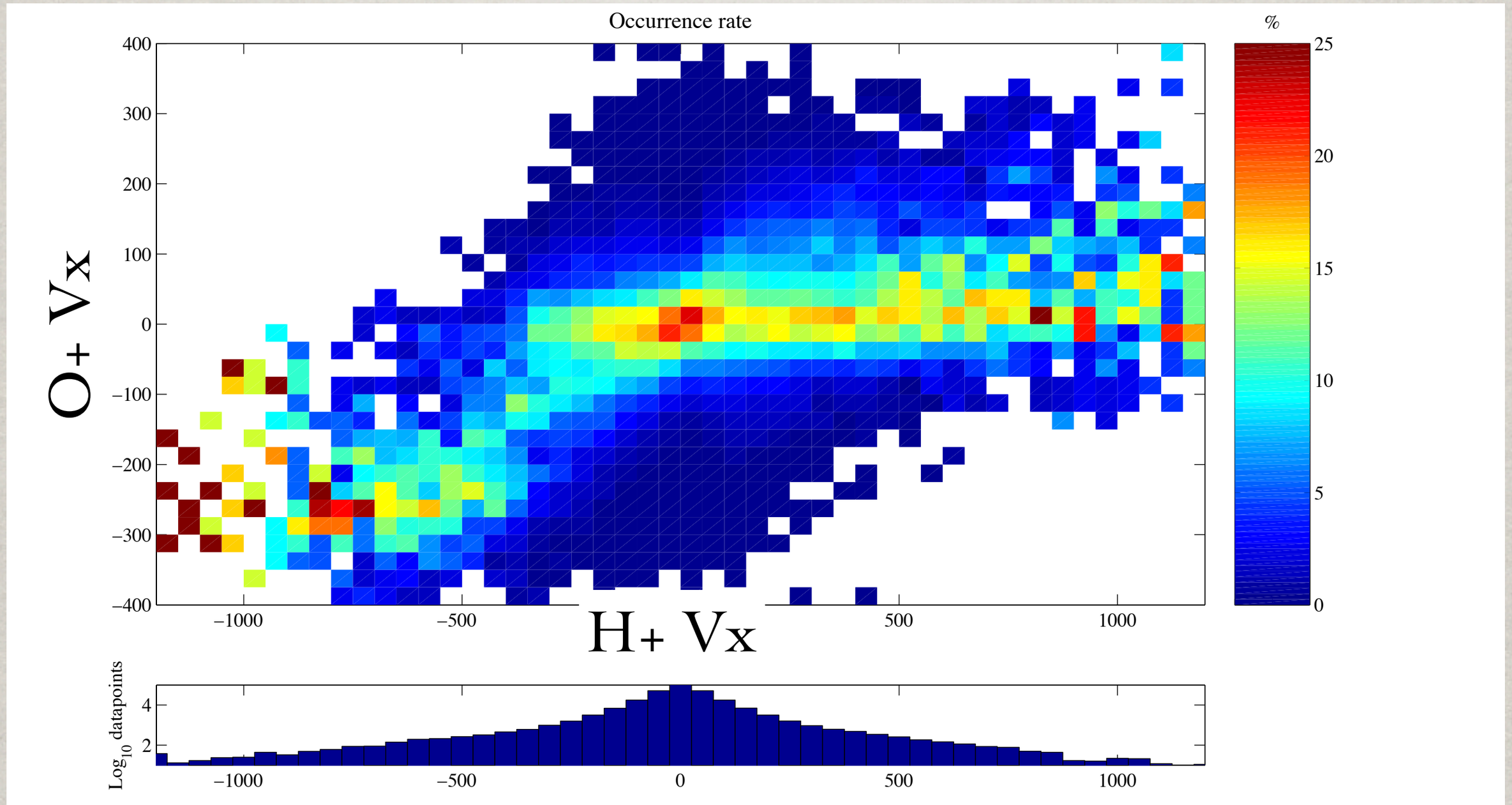




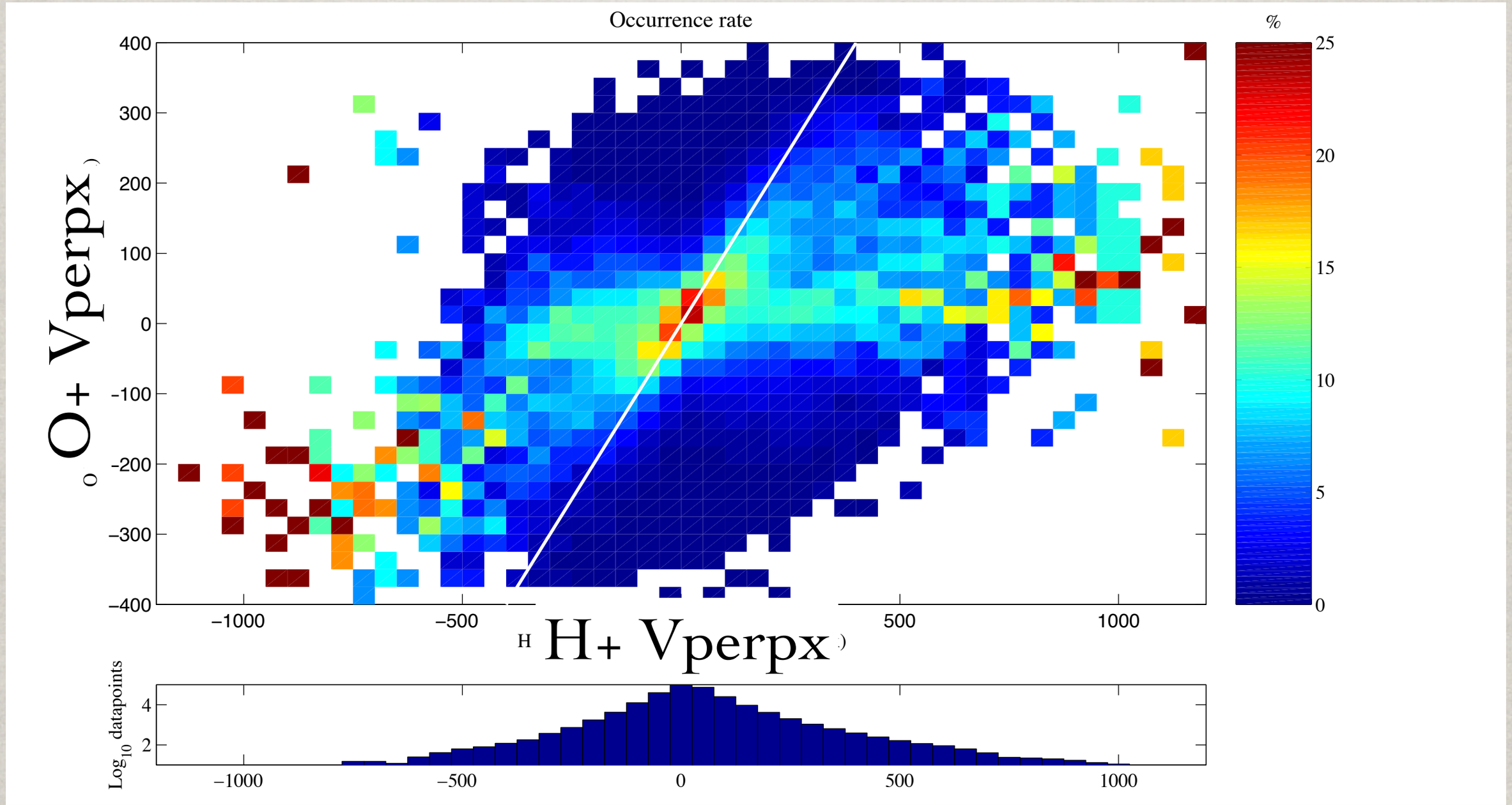




Oxygen Ions do not Follow Protons in Bursty Bulk Flows



Perpendicular Velocity



What is the Fate of Returning Plasma?

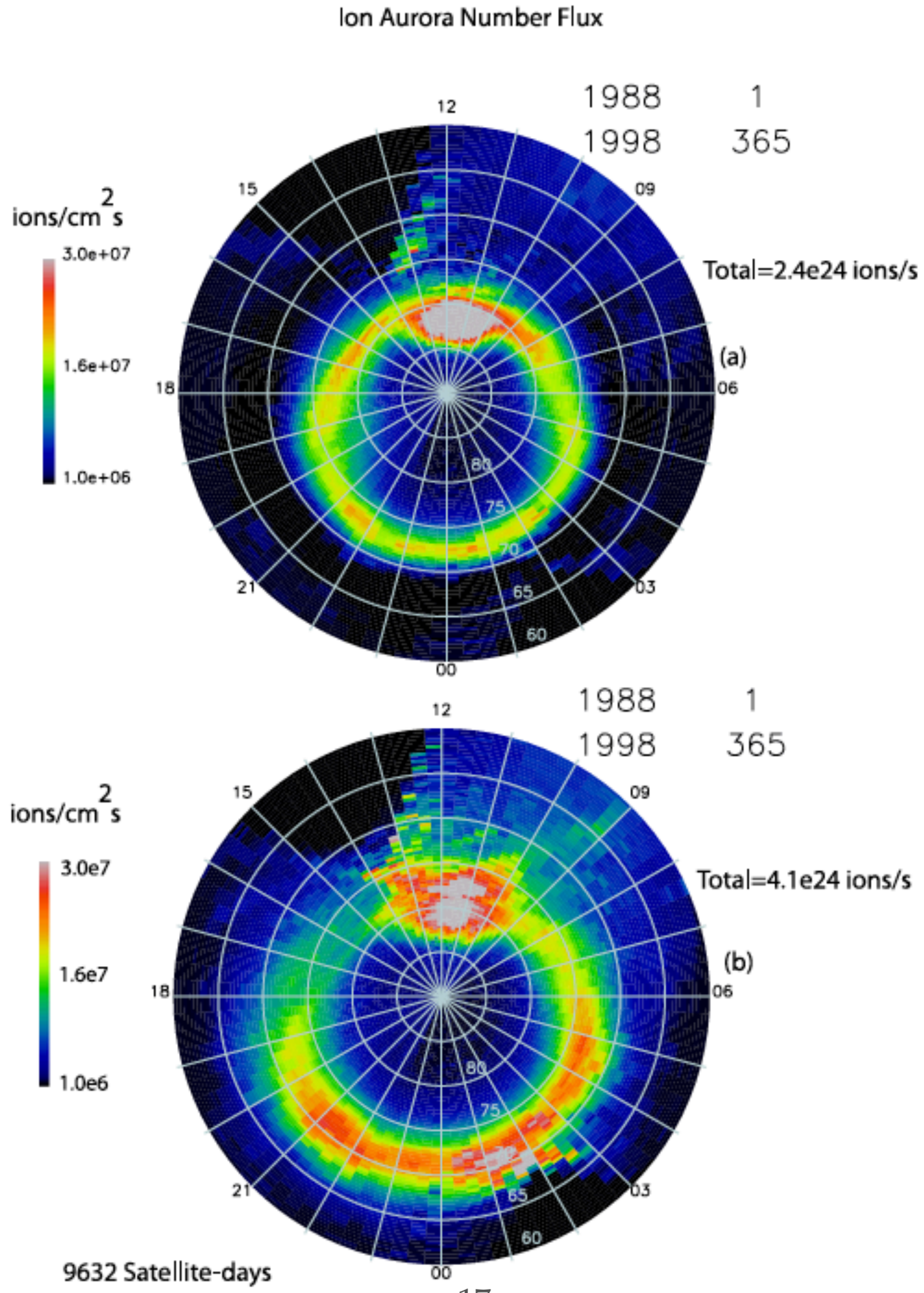


Figure 10. Ion aurora for (a) low and (b) high solar wind driving.

Further return to the atmosphere?

Further return to the atmosphere?

- Outside DMSP energy range

Further return to the atmosphere?

- Outside DMSP energy range
- Energetic Neutral Atoms

Further return to the atmosphere?

- Outside DMSP energy range
- Energetic Neutral Atoms
- Only fraction of ENA enter atmosphere

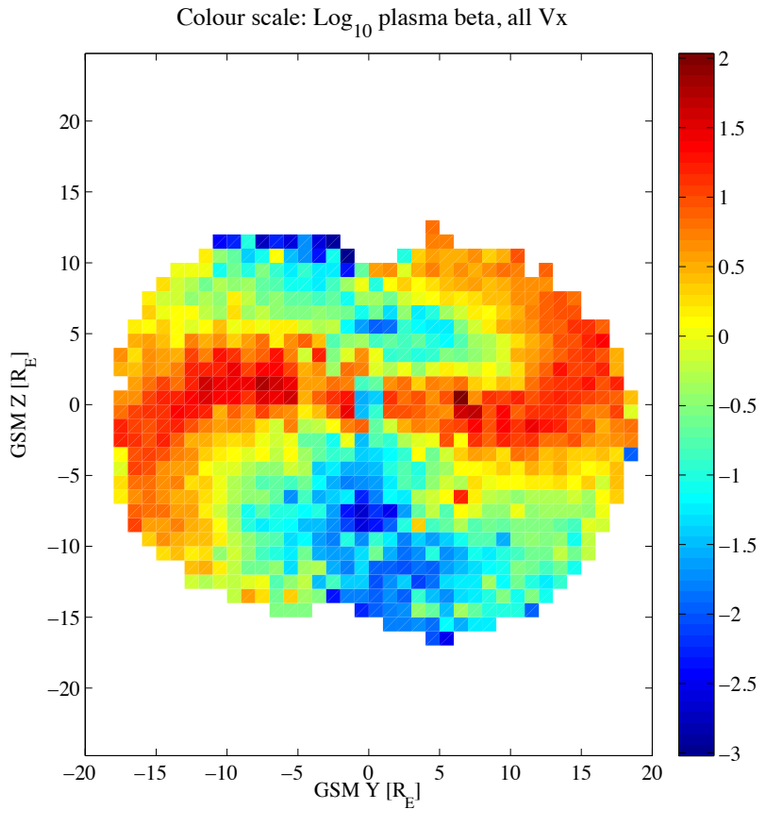
Further return to the atmosphere?

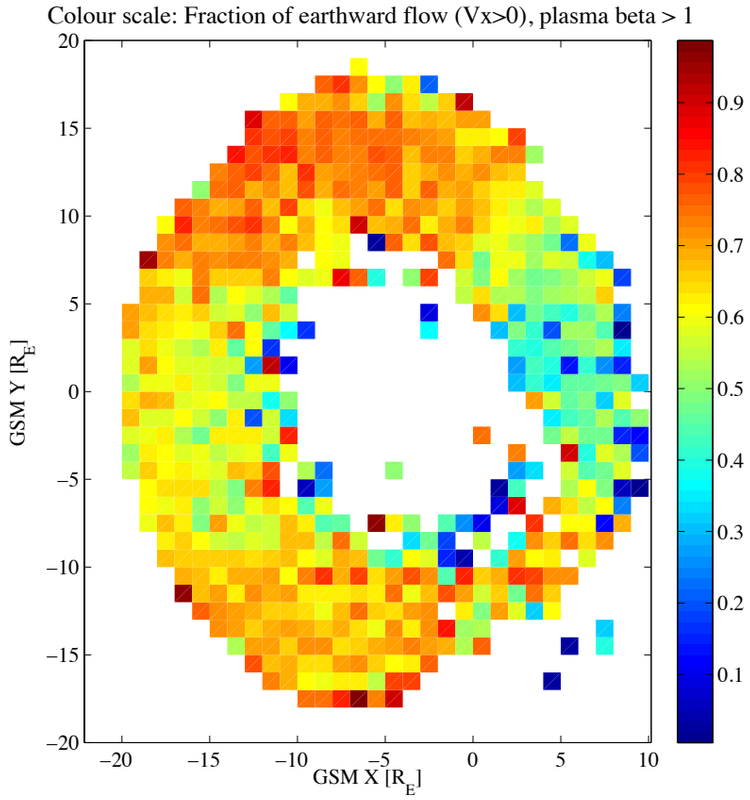
- Outside DMSP energy range
- Energetic Neutral Atoms
- Only fraction of ENA enter atmosphere
- A significant fraction of returning ions transported to the magnetopause

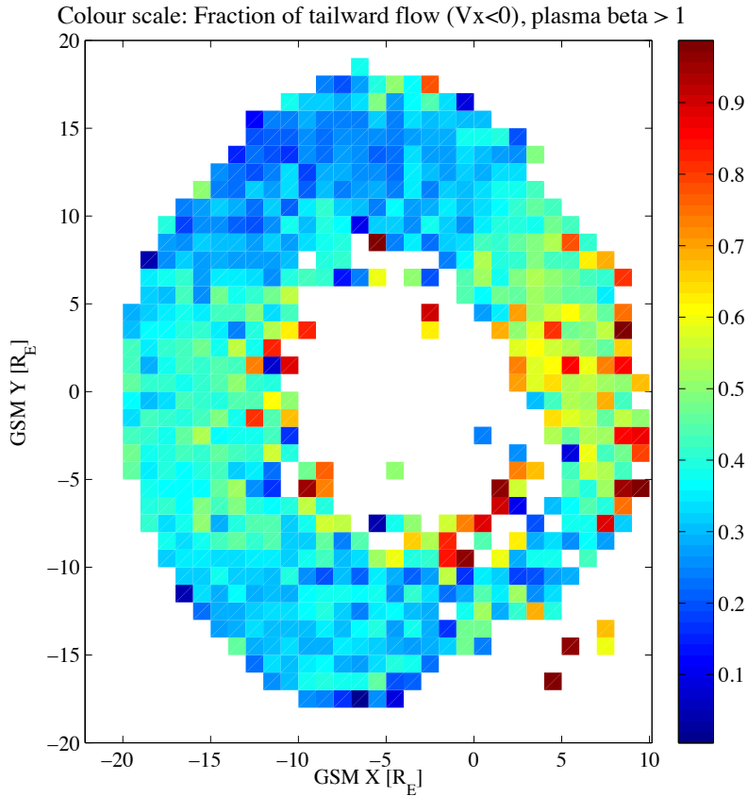
Conclusions

- Both hot and cold ions simultaneously present, ion temperature a function of ion flight trajectories
- Strong heating for high beta: O+ heating determined by properties of major ion species - magnetosheath like fluxes or cold proton beams
- Oxygen transport in the plasma sheet is different from the proton transport
- Oxygen ions do not follow protons in BBF:s, Likely an ion gyro radius effect
- Most of the return flow is also lost from the atmosphere

Other views


Colour scale: Log10 plasma beta, all Vx
GSM Z [RE]
GSM Y [RE]


Colour scale: Fraction of earthward flow (Vx>0), plasma beta > 1
GSM Y [RE]
GSM X [RE]


Colour scale: Fraction of tailward flow (Vx<0), plasma beta > 1
GSM Y [RE]
GSM X [RE]

H velocity, NO / NH ratio