The H^+ and O^+ Spectra of Inner Magnetosphere vs. MLT, L-Shell

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Abstract

The low energy (~40 eV-40 keV) plasma in the inner magnetosphere provides a sensitive measure of the important processes in this region. The ions in this energy range are predominantly drifting in from the plasma sheet, but their ultimate source can be from both the solar wind and the ionosphere. The amount of ionospheric plasma in the magnetosphere depends on both the UV input to the ionosphere, indicated by the F10.7 index and on magnetospheric activity. In this paper we use Cluster/CODIF data, accumulated over 10 years, to show how the H+ and O+ in the inner magnetosphere depend on F10.7 and Kp indices.

Project Goals / Motivation

To characterize the inner magnetosphere plasma population:

1. To show how the inner magnetosphere has changed over the course of the solar cycle, as a function of energy and local time
2. To show how the inner magnetosphere composition changes as a function of solar activity (F10.7 index) and Kp
3. Current inner magnetosphere models (e.g. RAM, RCM) use the empirical formula of Young et al, 1982 to specify the O+/H+ boundary condition to the model.
   - Geosynchronous orbit (6.6 Re)
   - Data from 1977-1981 (GEOS 1 and 2)
   - averaged over local time
   - 0.9 – 15.9 keV/e ions
4. We are developing an empirical model using Cluster/CODIF data
   - Use Cluster/CODIF perigee passes
   - Includes H+, O+ and He+ over the energy range 40 eV- 40 keV.
   - Includes all perigee passes - L-values from 4-10. Organize by L, MLT, Kp, F10.7, and Year.
   - So far, cover years from 2001-2010 – Extends into the deep solar minimum.
5. With this we can test the dependences found by Young et al. 1982

Methodology

- Use Cluster/CODIF perigee passes to determine a baseline for the inner magnetosphere particle populations
- Include H+, O+ and He+ over the energy range 40 eV- 40 keV.
- Collect all perigee passes - L-values from 4-10 Re. Organize by L, MLT, Kp and Year.
- So far, cover years from 2001-2010 - solar cycle dependence.

To build empirical dataset, need to:

- Automate radiation belt background subtraction for lower L-values
- Implement mapping of measurements to the equator.
- In this presentation we will concentrate on the L=6-7 Re results, to compare with the Young et al. 1982 data set.

1 Charge Exchange Effects

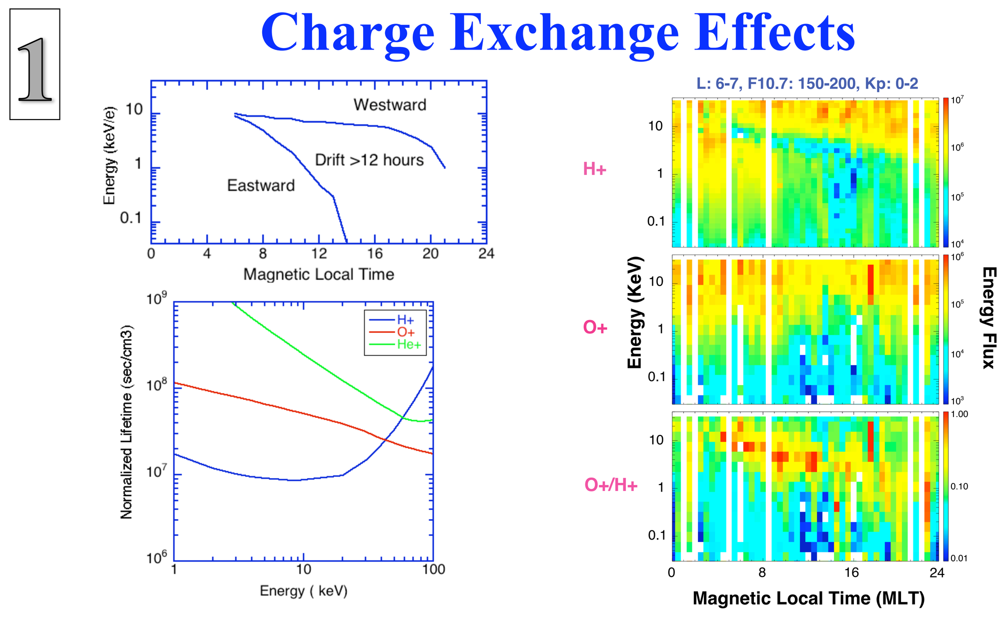

Figure 1: Due to their higher charge exchange rate, H+ ions drifting westward are lost at a higher rate compared to the O+ ions resulting in the differences in the energy spectra as a function of MLT

2 Yearly/Solar cycle Change – L: 6-7 – Kp: 0-2

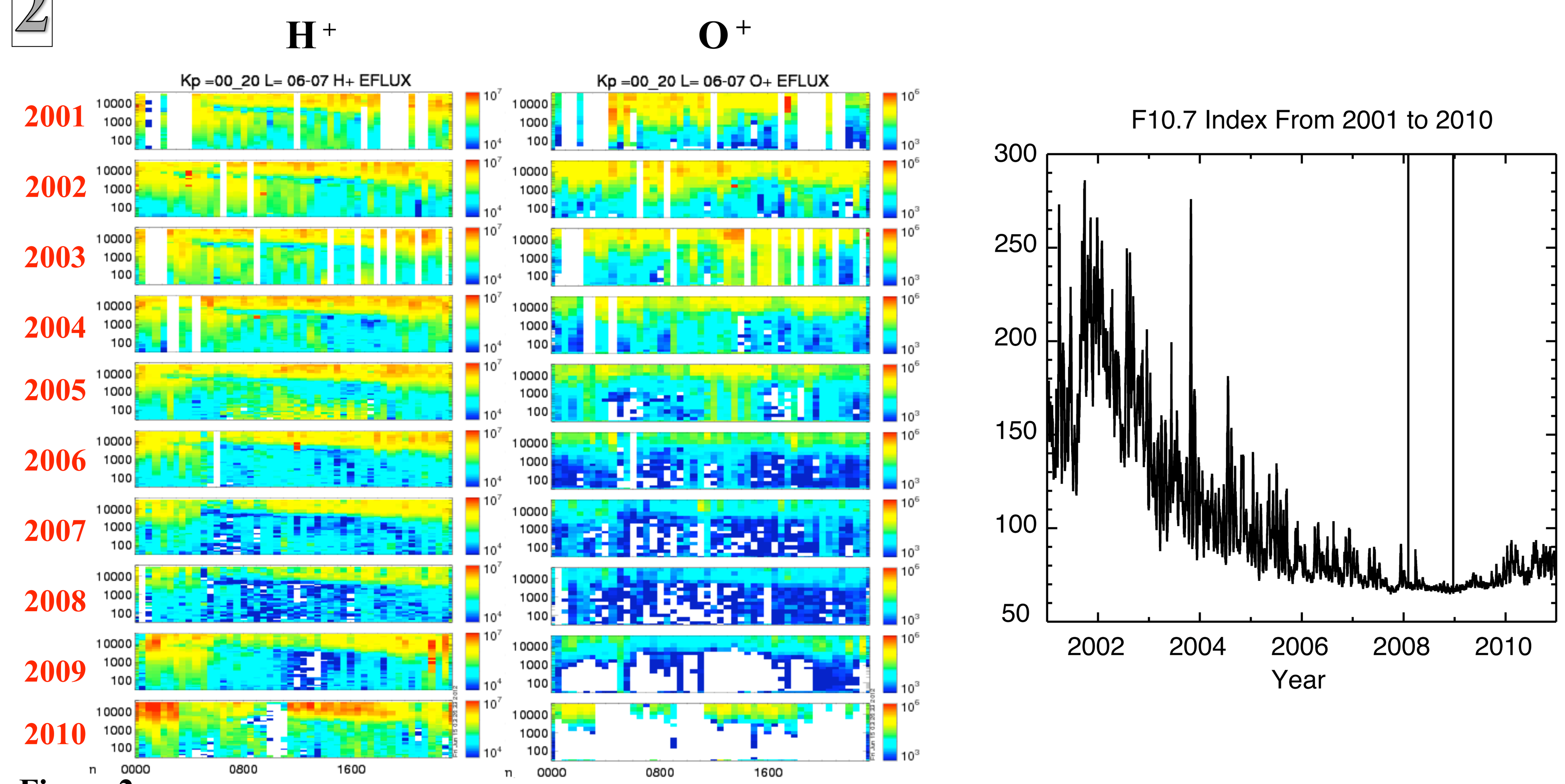

Figure 2:
•Strong decrease in flux with solar cycle, particularly for E< 1 keV
•Spectral minimum observed in H+ spectrum at ~10 keV
•Inner magnetosphere H+ and O+ spectra over the 10 years of the solar cycle. The decline of the fluxes over the whole energy range for both species towards the solar minimum is evident (Yau et al., 1985). Data for each panel are accumulated over a Year.

3 O^+ H^+ Densities and Ratio / F10.7 Dependence

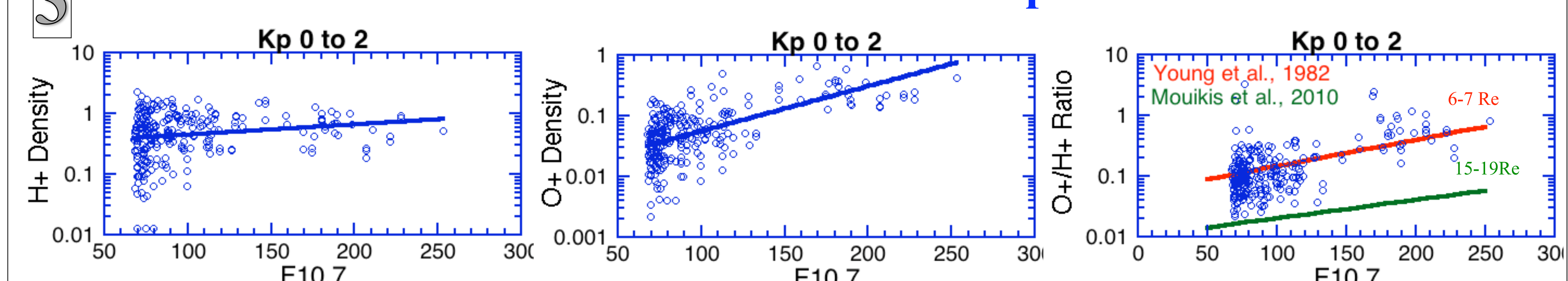

Figure 3:
•Change of H+ with F10.7 is small
•The O+ increases strongly with F10.7
•The Young et al., 1982 F10.7 dependence agrees well with the Cluster results
•There is a factor of ~10 increase in the O+/H+ density ratio from 15-19 Re to 6-7 Re. This implies that there is significant additional entry of O+ inside 15 Re

4 O^+ H^+ Densities and Ratio / Kp Dependence

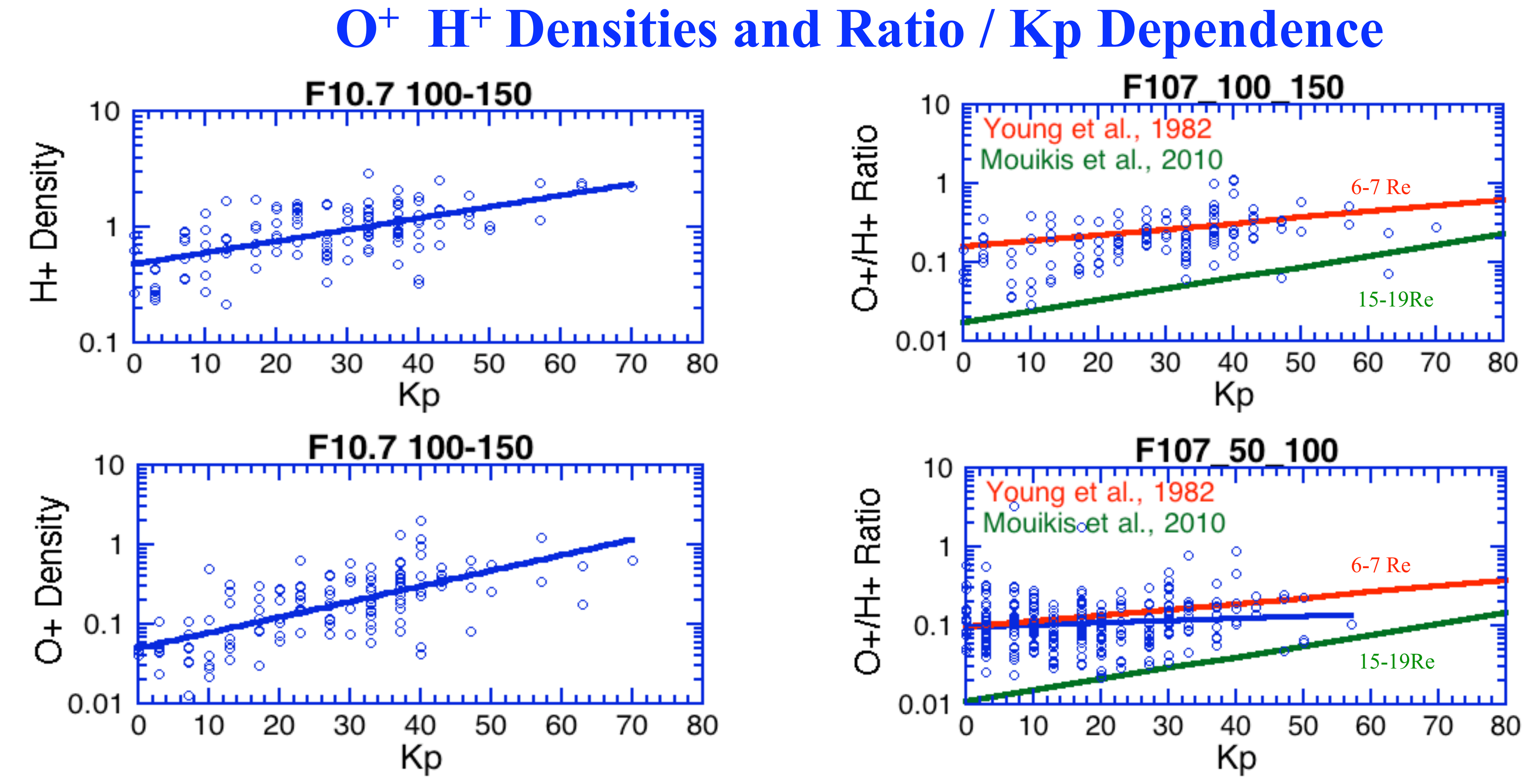

Figure 4 (left):

- The H+ density increases with Kp
- The O+ density increases by a factor of ~15 over the full Kp range

Figure 4 (right)

- Because the H+ density increases with Kp, the O+/H+ ratio does not increase as much as O+ alone
- For low F10.7, there is almost no increase with Kp
- Again, we see the radial dependence, with higher O+/H+ at 6-7 Re than 15-19 Re

Equatorial Projection of Pitch Angle Distribution

5

$$J = A \sin^n \theta$$

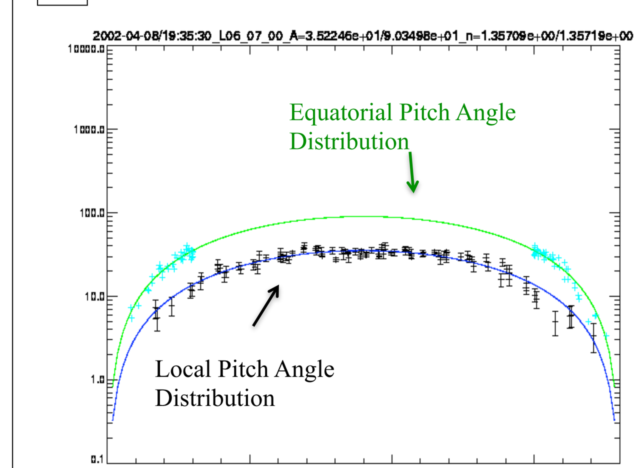

Figure 5:

1. Cluster is in a polar orbit, so many measurements are off the equator. The Young et al., 1982 measurements are from the equator.
2. To determine the equatorial distribution, we map each point to the pitch angle it would have at the equator, and then fit the distribution to n =anisotropy factor A=flux at 90°
3. By Liouville's theorem, for this functional form, n for the local distribution is the same as n at the equator.

6

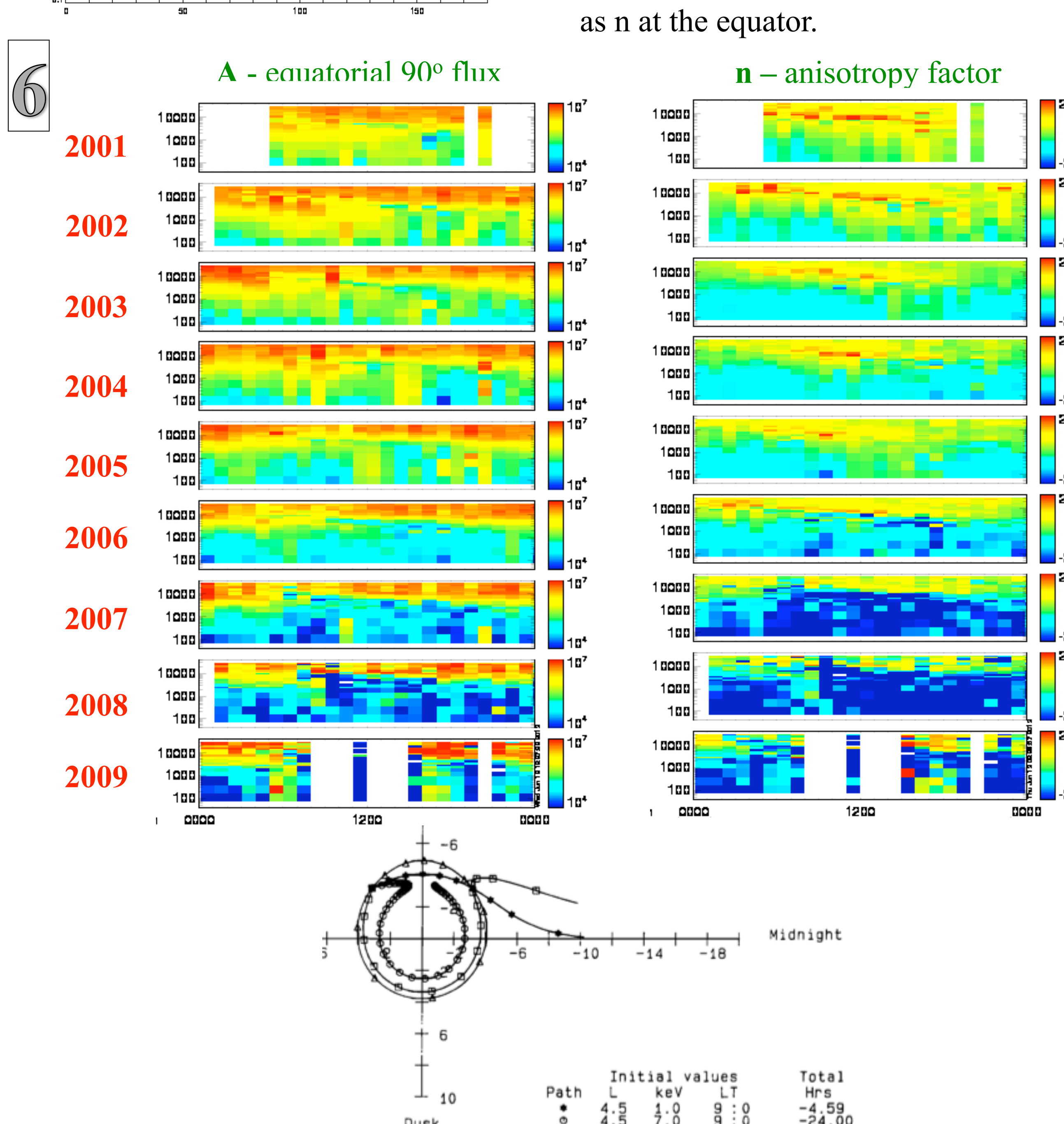

Figure 6:
• The deep minimum observed at ~10 keV corresponds with a high anisotropy.
• This is consistent with the minimum resulting from long slow drift paths, with charge exchange.
• In the deep solar minimum, the <1 keV distributions become more field aligned.

Summary & Discussion

➢We have used the ion composition data from the CLUSTER/CODIF instrument to investigate how the H+ and O+ energy spectra change during the solar cycle, and to determine how the changes relate to solar UV and geomagnetic activity.

➢We find that there is a dramatic change in the energy spectra of both H+ and O+ from solar maximum to solar minimum. The flux of both species decrease significantly over the full energy range, and the minimum in the energy spectrum becomes broader and deeper.

➢In addition to the change in flux and composition we also see evidence for the change in convection patterns with increased activity.

➢The Young et al., 1982 formulas for O+/H+, agree with the Kp and F10.7 dependencies observed during this deep solar minimum. This indicates that the affects on ion composition in the inner magnetosphere were not more dramatic during this solar minimum.

Acknowledgements

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