TEAMS Calibration and Nightside O$^+$ Ionospheric Outflow Flux during Isolated Substorms

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Motivation

Sawtooth events are repeated injections of energetic particles at geosynchronous orbit. 94% of sawtooth events occur during geomagnetic storms [Cai et al., 2011]. O+ in the tail has been suggested as a possible driver of sawtooth events. Simulations [Brambles et al., 2013] suggest that O+ from nightside ionosphere produces a feedback mechanism that drives subsequent injections in ICME-driven sawtooth events. Our first study [Lund et al., 2017] on an ICME sawtooth event did not verify the simulation claim. Our new work is a statistical study to further test this model.

The main question is whether or not the nightside outflow flux of O$^+$ ions is different during sawtooth events compared to isolated substorms. Firstly we test the validation of the used method via reproducing isolated substorm result [Wilson et al.2001, 2004], and then will perform the method over eleven years sawtooth list. We will use the data from two instruments of FAST space craft , ESA and TEAMS, over the years of 1996-2007. TEAMS measures the ion composition over the energy range of 1 eve^{-1} to 12keve^{-1}. Because the efficiencies of some of the positions in the instrument have declined significantly with time due to exposure to ram plasma, we will use the full 3D data of the TEAMS instrument, rather than the 2D data based only on the spacecraft spin-plane positions. To do this, , it is necessary to cross-calibrate the instrument positions before performing the final superposed epoch analysis. The method of this calibration is similar to CLUSTER/CODIF calibration [Kistler et al., 2013].

Two Methods for Auroral Outflow Flux

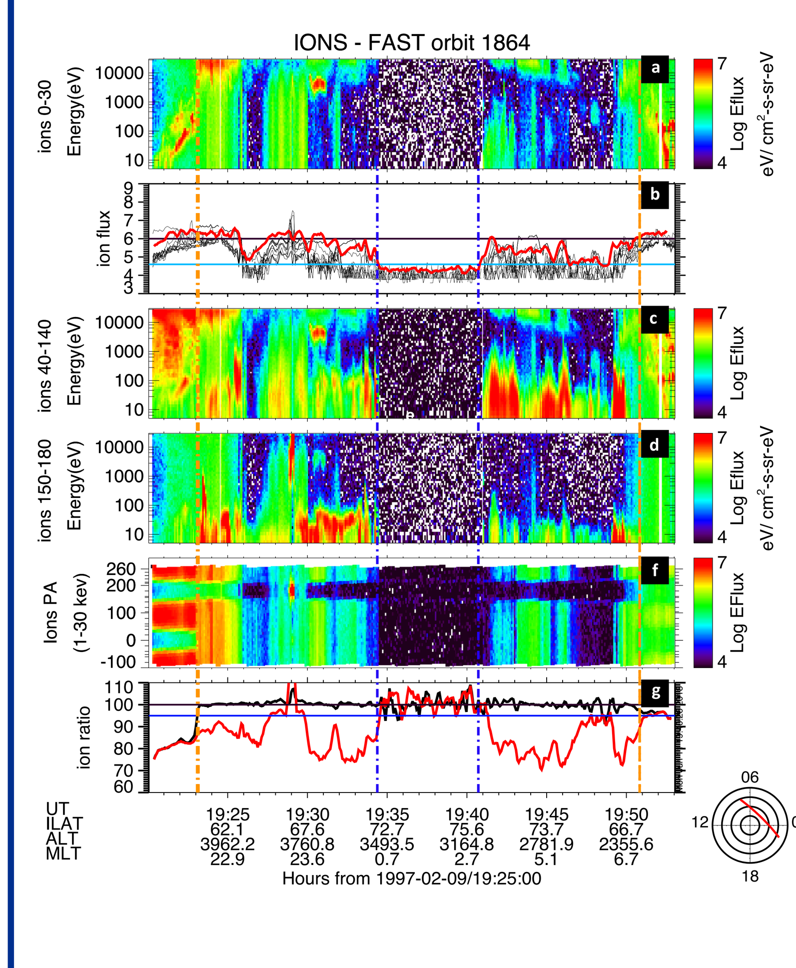

Figure1. The overview plots of FAST orbit 1864, the Energy flux is shown as a function of energy and pitch on different panels.

Auroral oval boundaries

Andersson Method:

- Equatorial edge of the auroral oval is the location of the transition from double loss cone to single loss cone.
- Poleward edge of the auroral oval is associated with a significant decrease in the intensity(flux) of particles.

Wilson's Method:

- The region with the luminosity higher than 0.1 kR. (Figure2.b.

Outflow Flux

- The outflow flux is the flux with the pitch angle greater than loss cone, with the energy from 8 eV to 6keV

- Wilson studied the substorm outflow flux from February 1997 to March 1998, when the TEAMS data was reliable.
- To test the validation our future study method we reproduce the Wilson's result with Anderson's boundary. But to use the data of later years we firstly need to calibrate the TEAMS data.

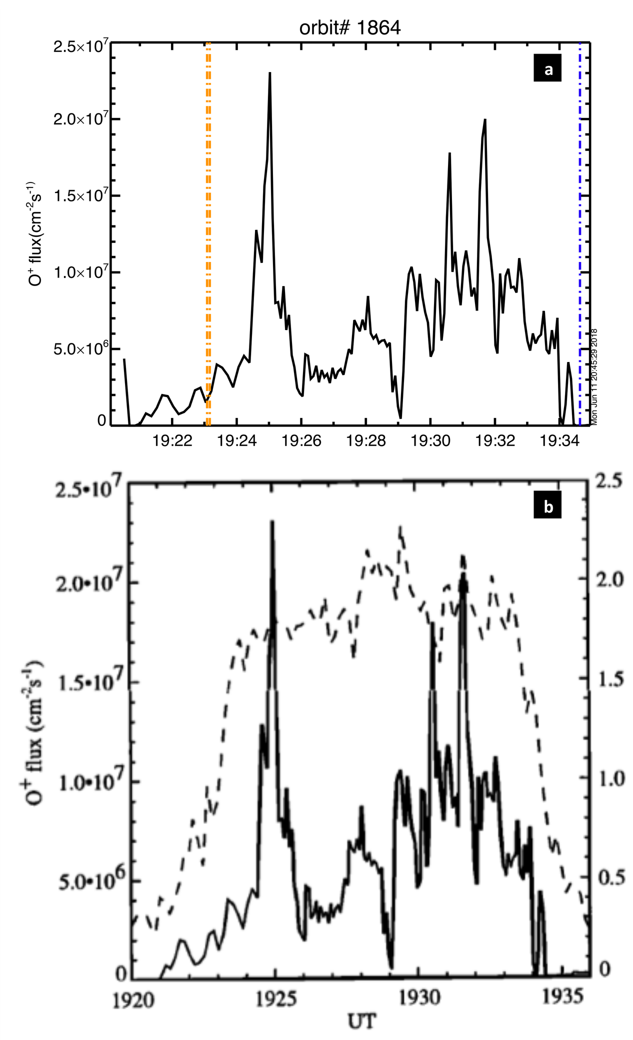

Figure2. Outflow flux during a substorm and inside the auroral oval

TEAMS Calibration

Before Calibration

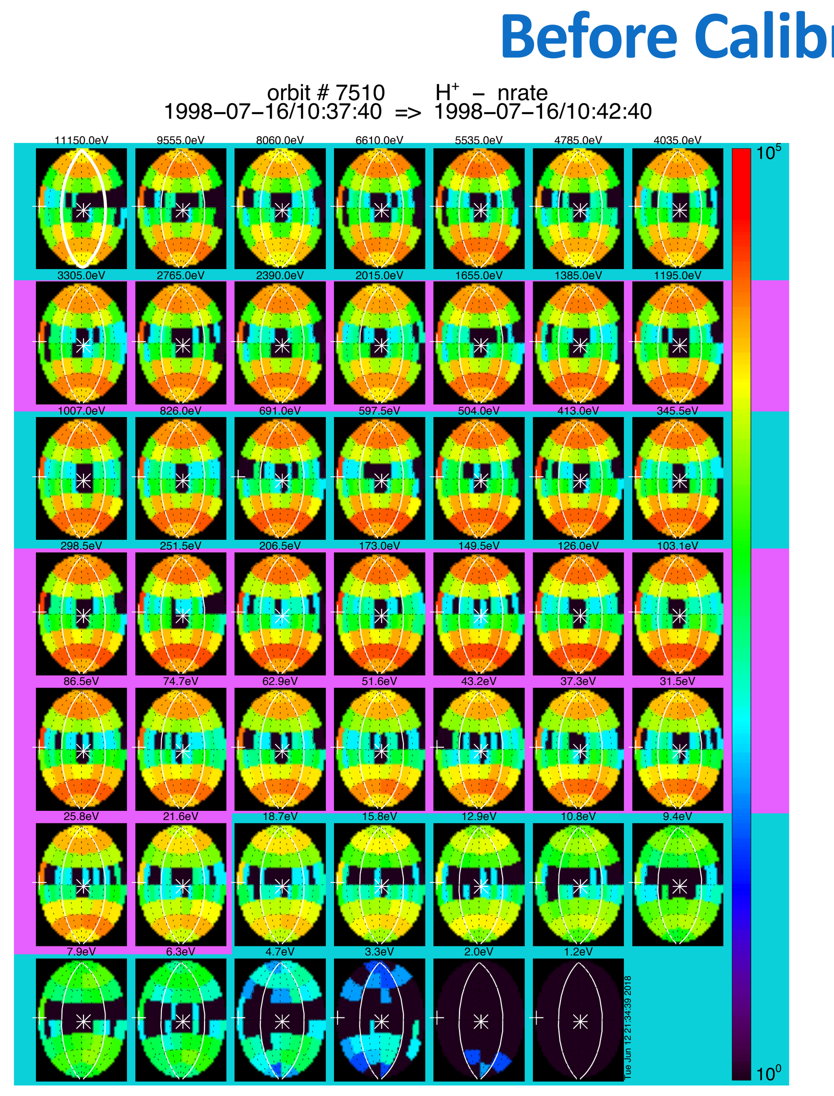

Figure3. A globe plot of 3-D data nrate over 48 energy channels.

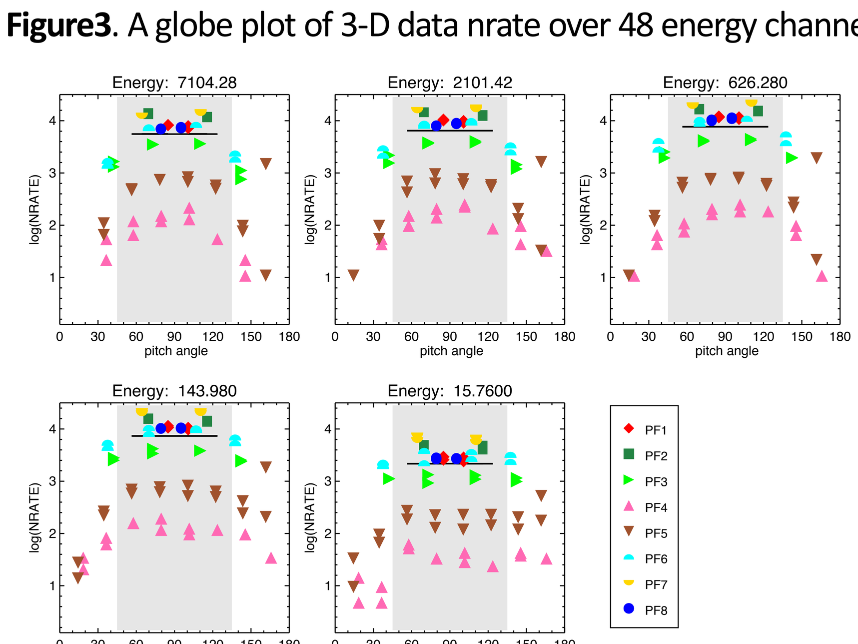

Figure4. nrate as a function of pitch angle for eight different anodes and over five energy channels.

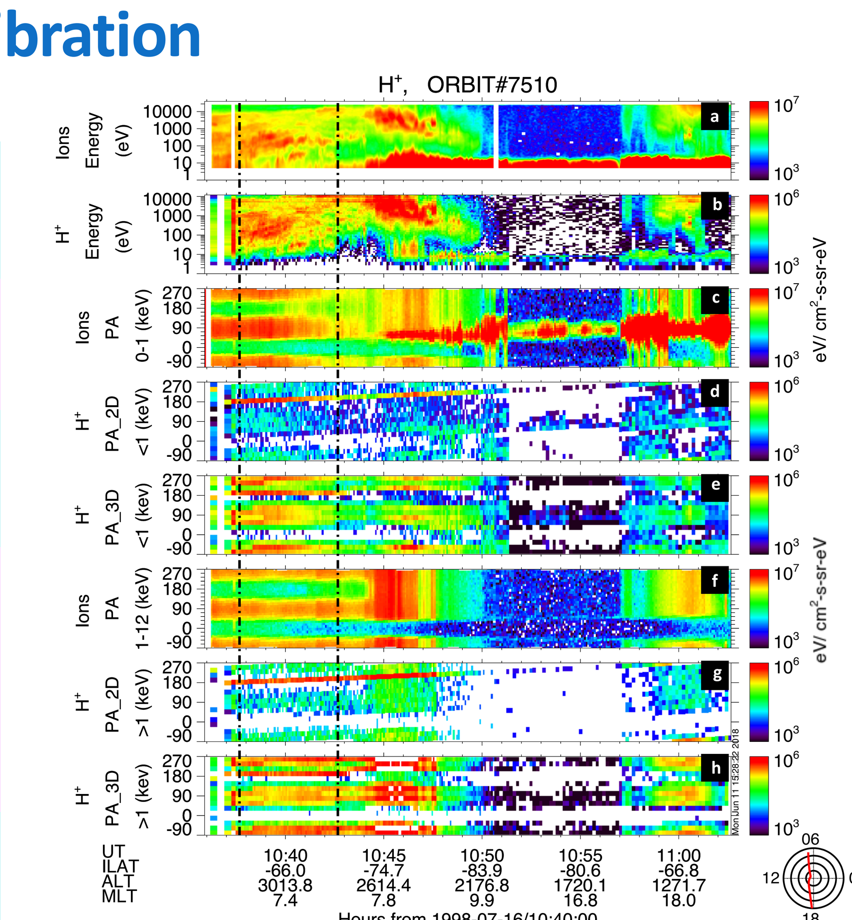

Figure5. The H$^+$ overview spectrogram plots of ion data from ESA and H$^+$ data from TEAMS instrument.

- Survey data of TEAMS instrument is a 3-D data set consists of 4 mass groups, 48 energies, and 64 solid angles segments organized over 8 anodes. **Figure3.**
- 2-D survey data is a subset of the 64 solid angles segments and accumulates the data from anodes PF4 and PF5
- Because of the gyrotropy, it is expected to see the same data for those pixels with an individual pitch angle.
- A comparison of 2-D and 3-D distributions is shown in the pitch angle spectrogram data of **Figure.5.**
- Bad data line is corresponded to bin zero appears on the **Figure5.d** and **Figure5.g .**

Calibration Method

- The relative efficiencies are the efficiencies of different anodes
- The method for calculating the relative efficiencies is to normalize the efficiencies at different anodes in the instrument during a selected time.

1- eliminate the bad data of bin zero.

2- group the energy channels into 5 groups and get average of each bin in an individual energy group.

3- .Now we have a data set with 64 angle bins and 5 energy channels. **Figure.4**

5- For each energy, **n**ormalization factor of an individual anode is the ratio of the averaged value of all the data which has a pitch angle between 45° to 135 ° (solid black lines in **Figure.4**) to the averaged value of the data of that individual anode.

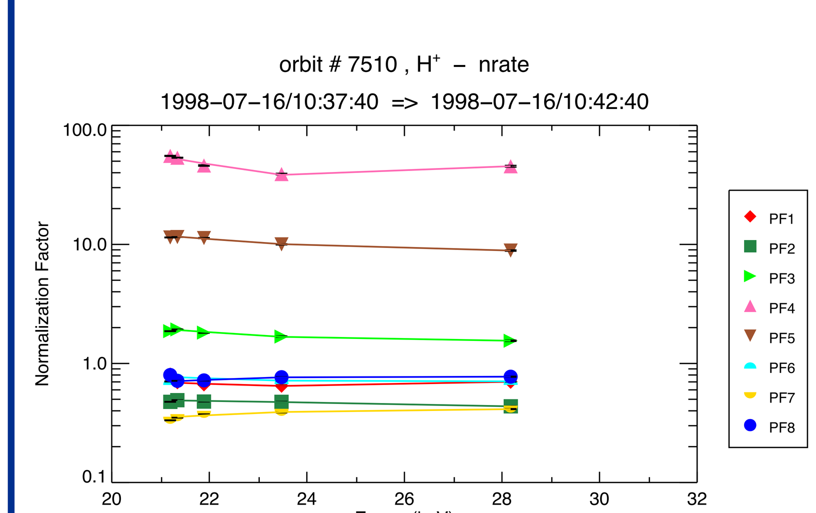

Figure6. Normalization factor for different anodes and at four different energy groups. Solid line is the closest fitted function to relevant four points.

After Calibration

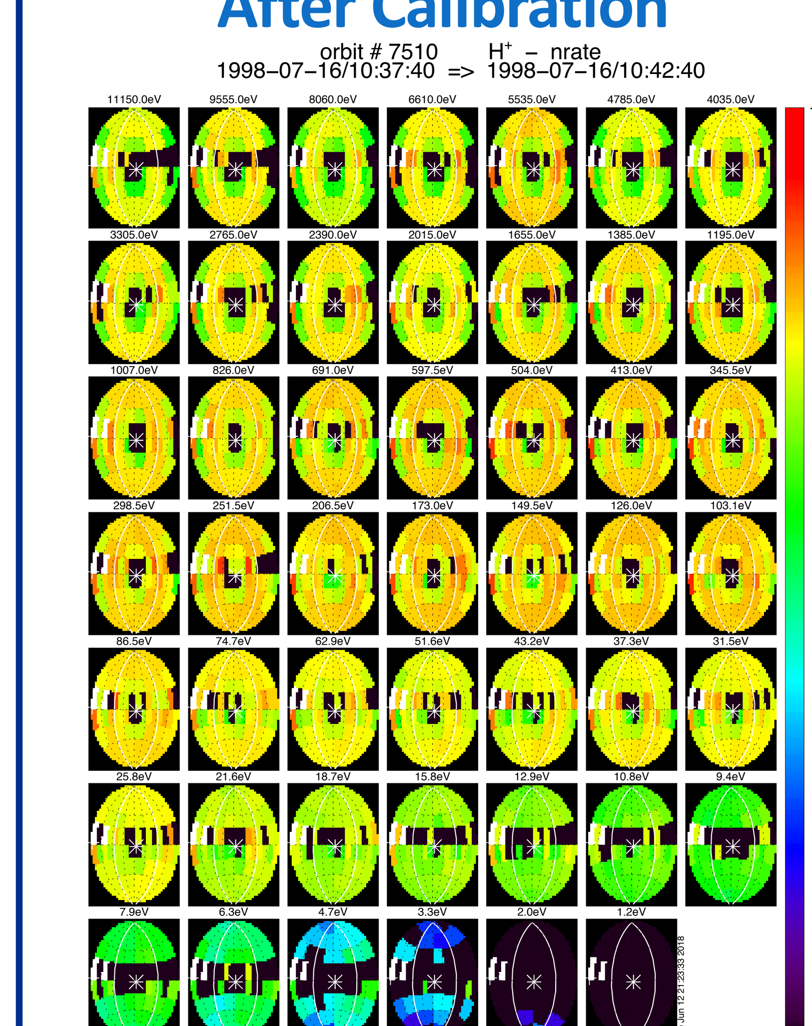

Figure7. A globe plot of 3-D data nrate over 48 energy channels.

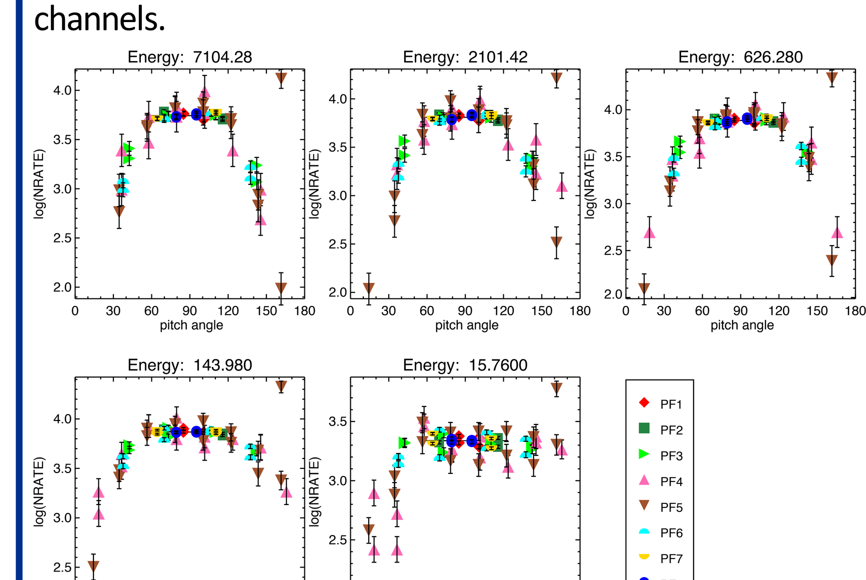

Figure8. nrate as a function of pitch angle for eight different anodes and over five energy channels.

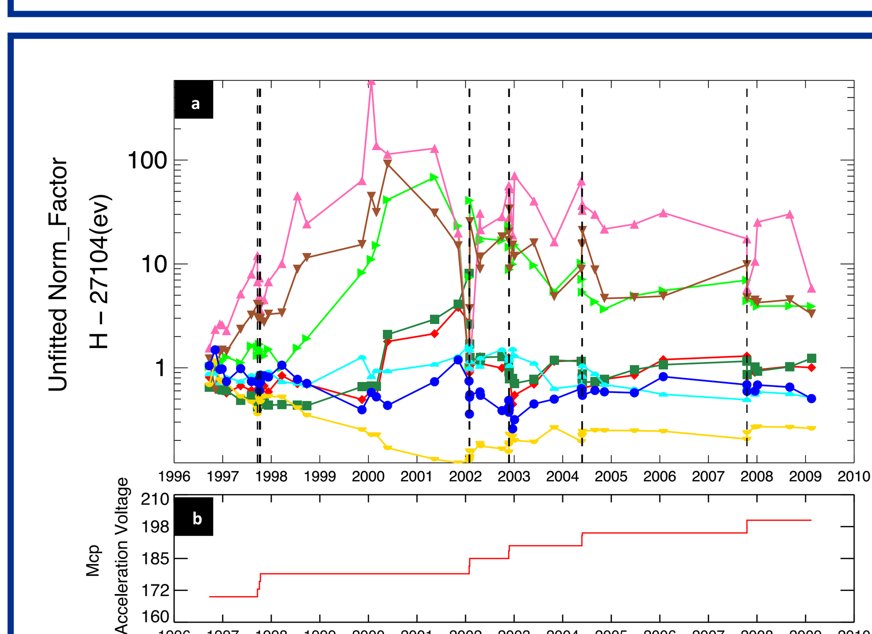

Figure 9. (a) Normalization factor for eight anodes over the years of 1996 to 2009, (b) MCP acceleration voltage over the eleven years.

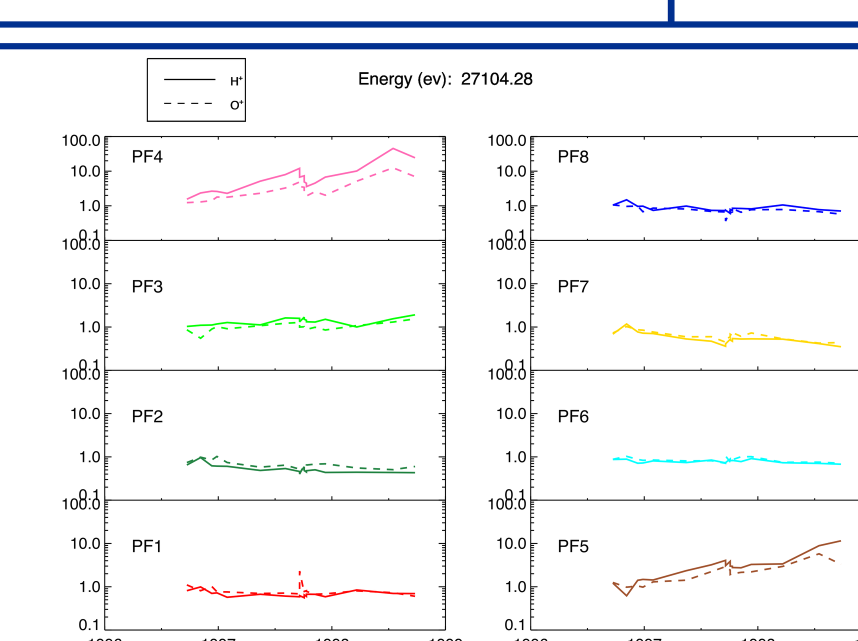

Figure 10. Solid and dashed lines show the change of normalization factor for eight anodes over the first four years of the mission for H$^+$ and O$^+$ respectively.

Conclusion

- Our outflow flux has a good agreement with Wilson's result. And the auroral boundary in both methods are close quite the same region.
- Our 3D- distribution function data consents with in common 2-D data so we can use this data for later years when there is lack of data in anodes PF4 and PF5 .
- We calculated the normalization factor of the eight anodes over the eleven years.
- The data from first four years of mission shows that the normalization factor of O$^+$ and H$^+$ are consistent with each other.
- Because of the lack of good statistics for O$^+$ we decided to use the H$^+$ normalization factor for both H$^+$ and O$^+$ data.

Reference

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Future work

- Implementing of recent calculation of calibration into the TEAMS data set and using the corrected data to measure the O$^+$ and H$^+$ outflow fluxes inside the auroral zone for sawtooth events between the year of 1996 – 2007.
- Comparing the average O+ outflow flux for isolated substorms and for sawtooth to know whether the O+ is a driver for subsequent teeth in the ICME sawtooth or not.