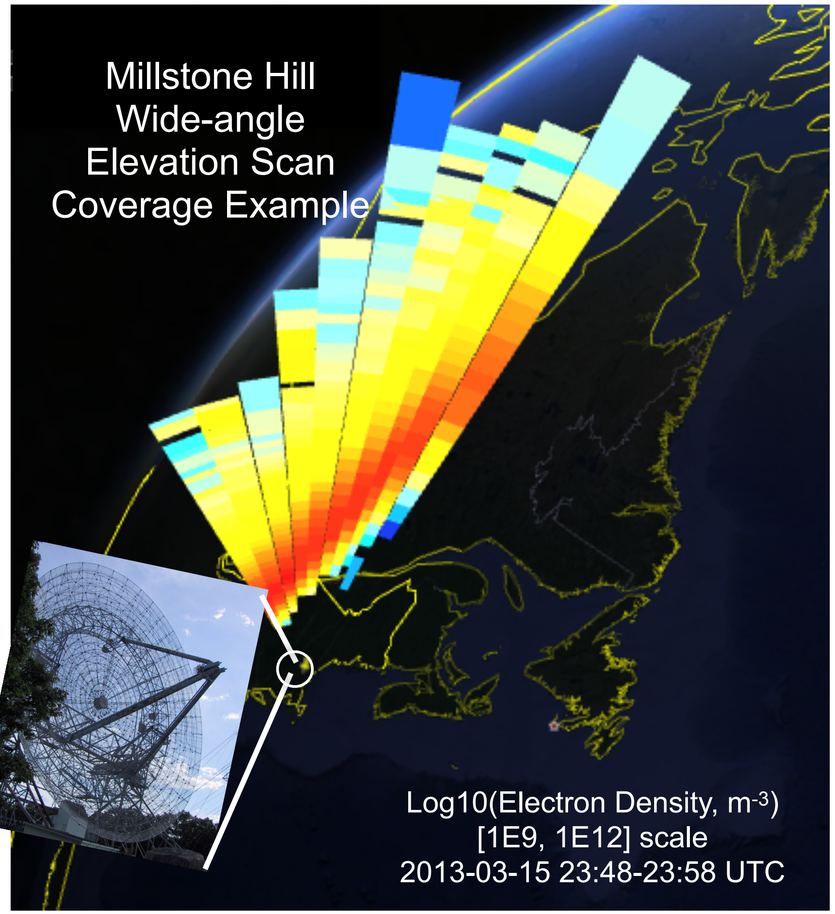
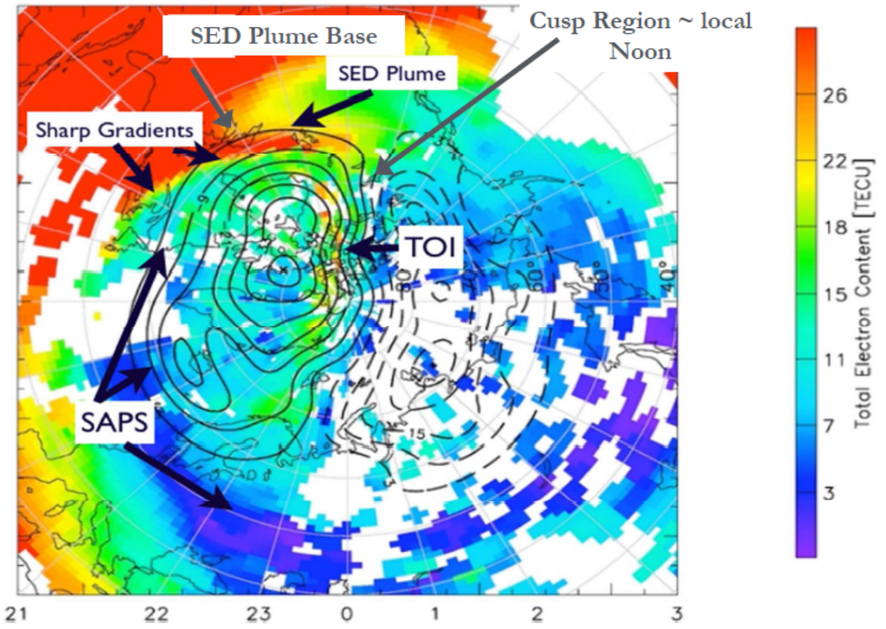
Ground Based Observational Studies of M-I Coupling / Stormtime Electrodynamic Forcing: Essential for Future Progress

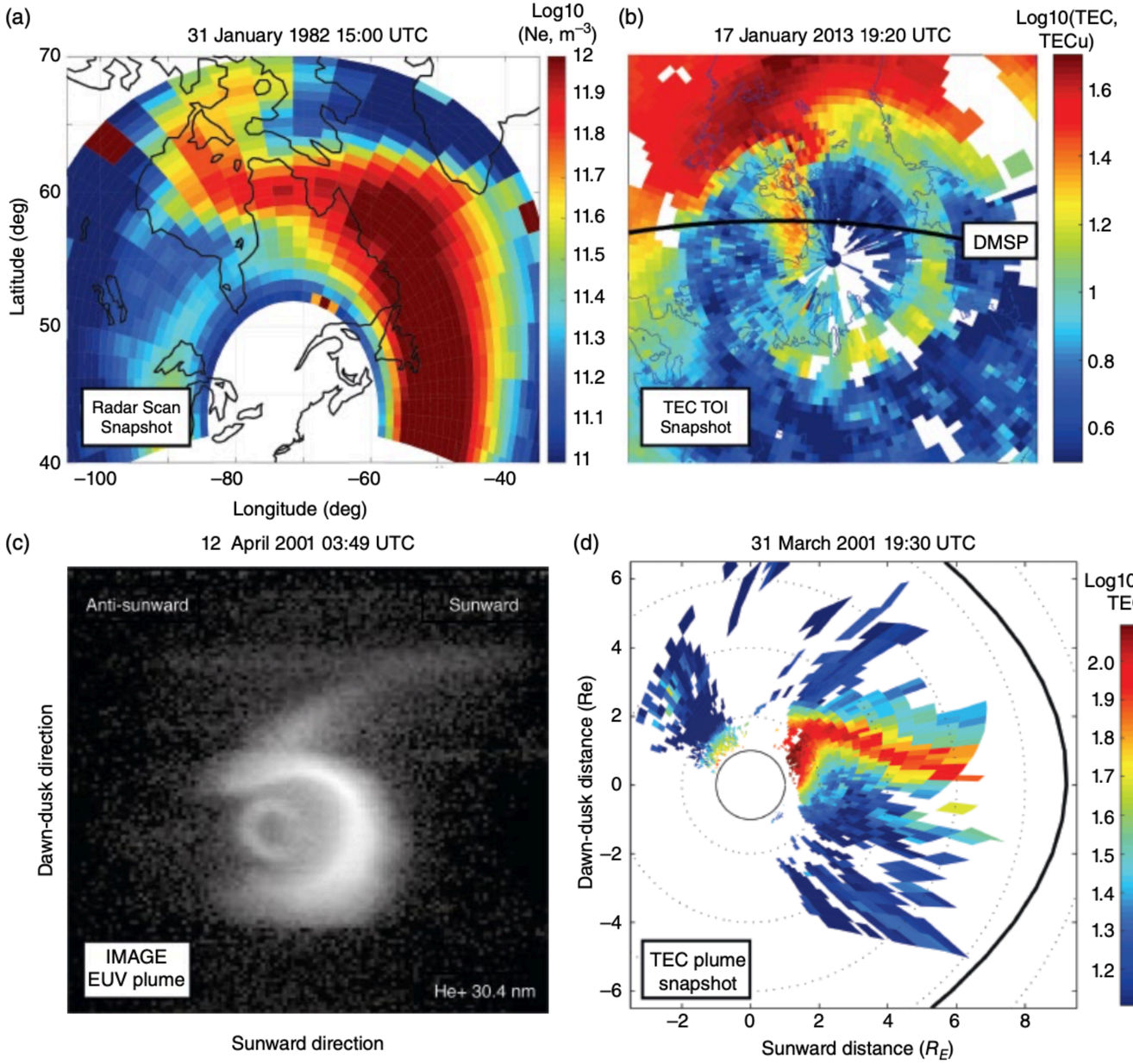


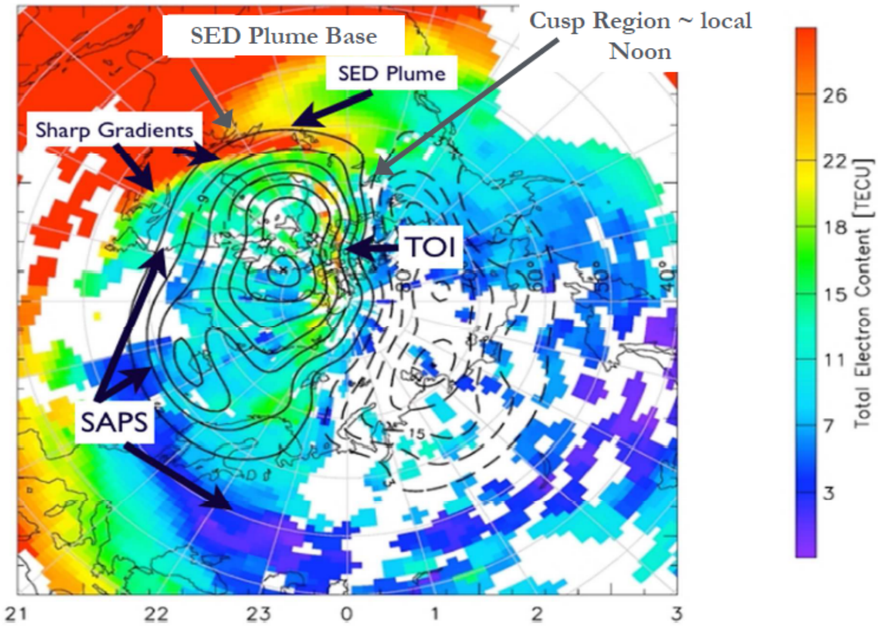
P. J. Erickson
MIT Haystack Observatory

Future of Ground Based Magnetosphere/ITM Research Workshop

2022-03-14

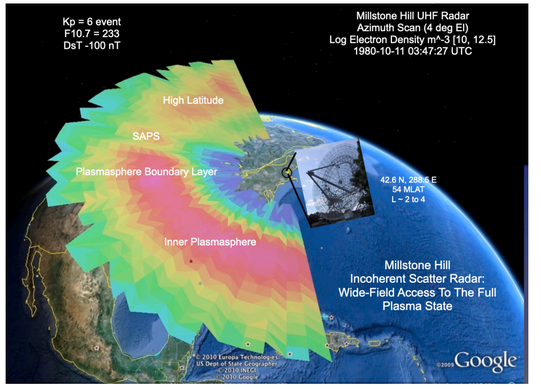






Ground Based Observations at Stormtimes Are ***Essential*** for Multi-Scale Physics

- < 1 eV Plasma
- EM driven mass transport (> 1E24 ions/s; cold heavy O+)
- Tight connection to plasmasphere / inner magnetosphere
- **Subauroral energy transfer** as a function of altitude



Foster et al (2020) doi:10.1002/9781119509592

Stormtime SAPS Frictional Heating Drives Supersonic O+ Outflow

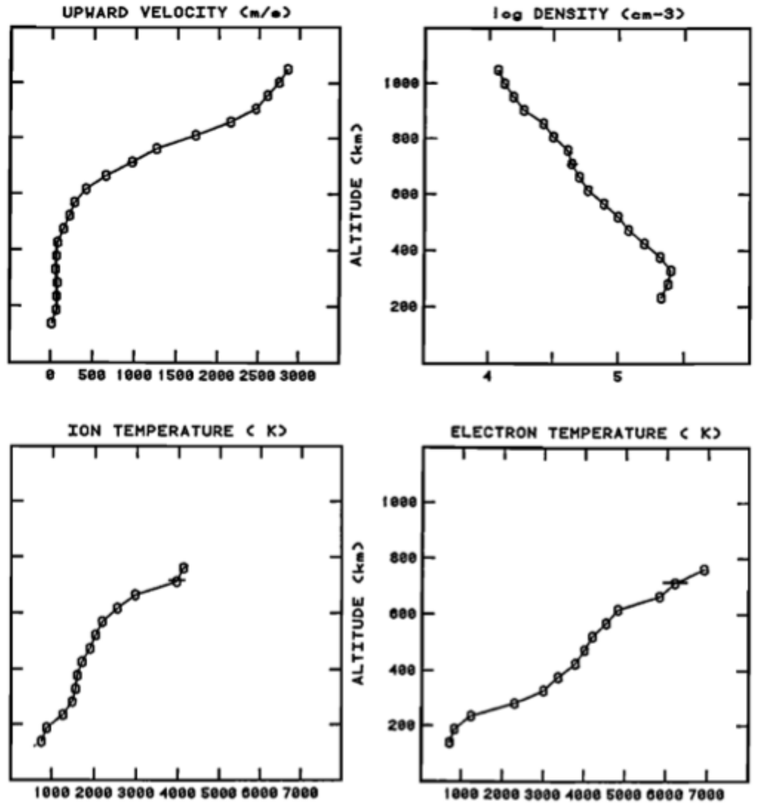
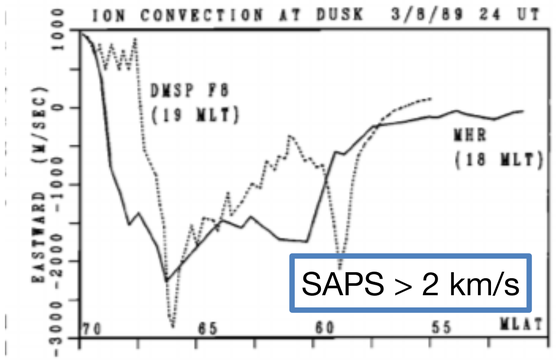


Fig. 2. Altitude profiles of the principal plasma parameters derived from the spectra of Figure 1: Doppler velocity, log plasma density, ion temperature, and electron temperature. Error bars at ~700 km illustrate the typical uncertainty associated with the parameters. Between 600 km and 800 km altitude the upward directed velocity increases from 500 m s^{-1} to 2000 m s^{-1}, and the ion and electron temperatures exceed 4000 °K and 7000 °K, respectively.

Yeh & Foster (1990), JGR, doi: 10.1029/JA095iA06p07881
Yeh et al. (1991), JGR, doi: 10.1029/90JA02751
Loranc & St. Maurice (1994), JGR, doi: 10.1029/93JA01852

Feb 8, 1986 Great Storm



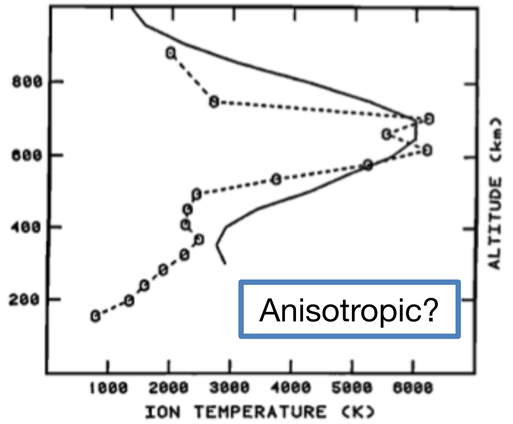
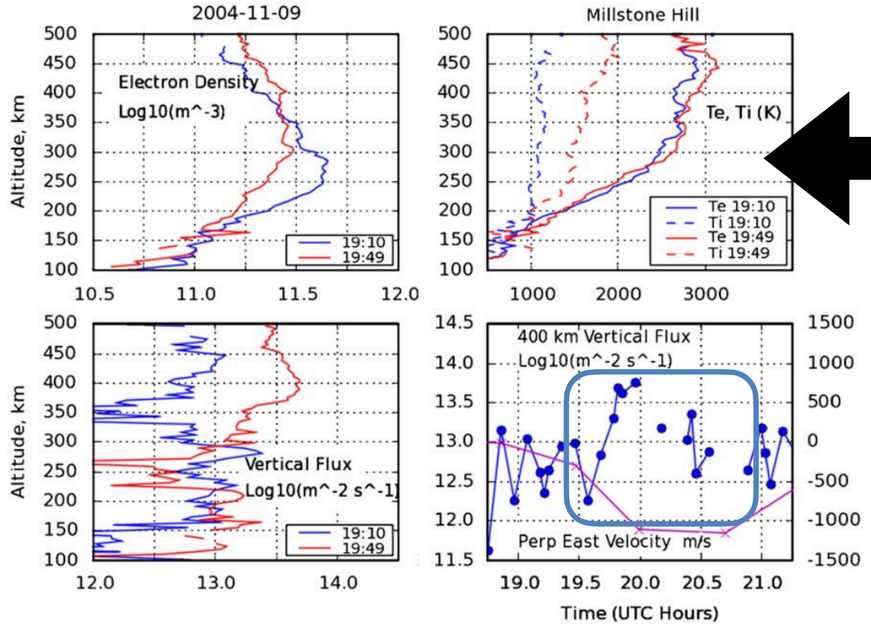
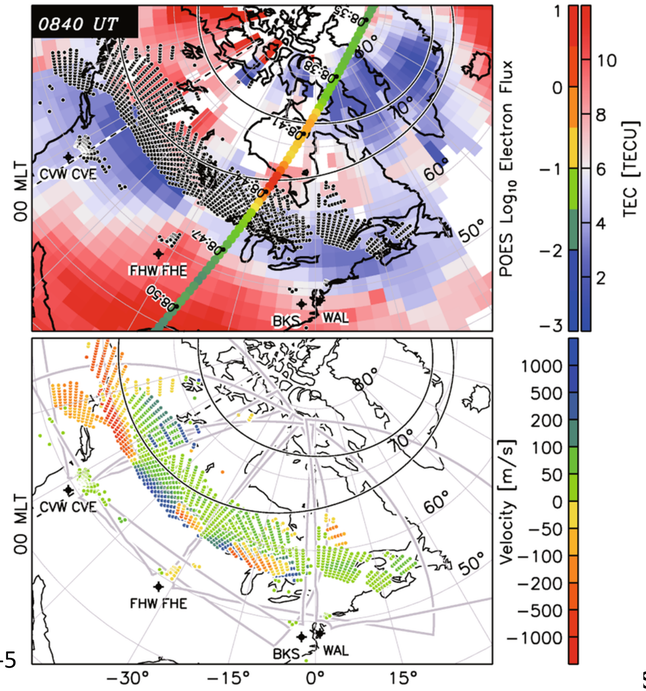


Fig. 9. The altitude profile of ion temperature observed with the radar at 2054 UT on February 8, 1986 (dashed curve) shows an enhancement to 6000°K localized in altitude between 600 km and 700 km. The profile independently predicted by the modeling work of J.-P. St.-Maurice et al. (private communication, 1989) (solid curve) for the temperature perturbation some 100 s after the onset of strong frictional heating at 400 km altitude is in close agreement with the observations.

P.J. Erickson et al. / Journal of Atmospheric and Solar-Terrestrial Physics 72 (2010) 292–301



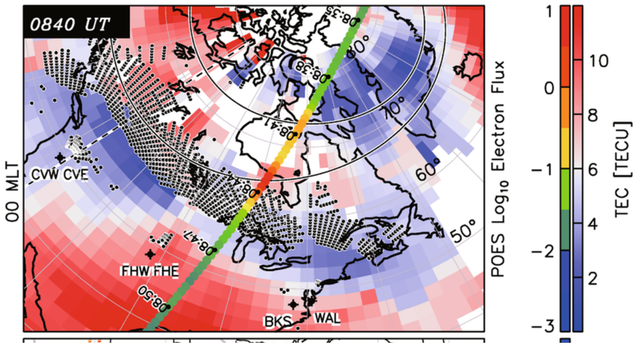


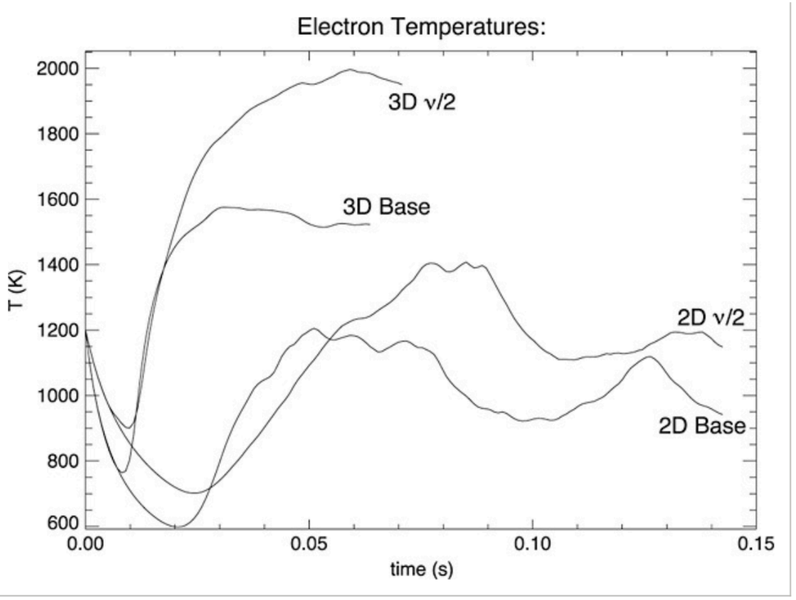
Nishitani et al (2019)
doi:10.1186/s40645-019-0270-5

Longitudinal / MLT
SAPS variation:
IM coupling
In the Plasmasphere
Boundary Layer

(SuperDARN)

Under strongly driven conditions..
Everything matters: <m scales to >1000s km (and larger).
It's not one OR the other.





Oppenheim and Dimant (2013) doi:10.1002/jgra.50196

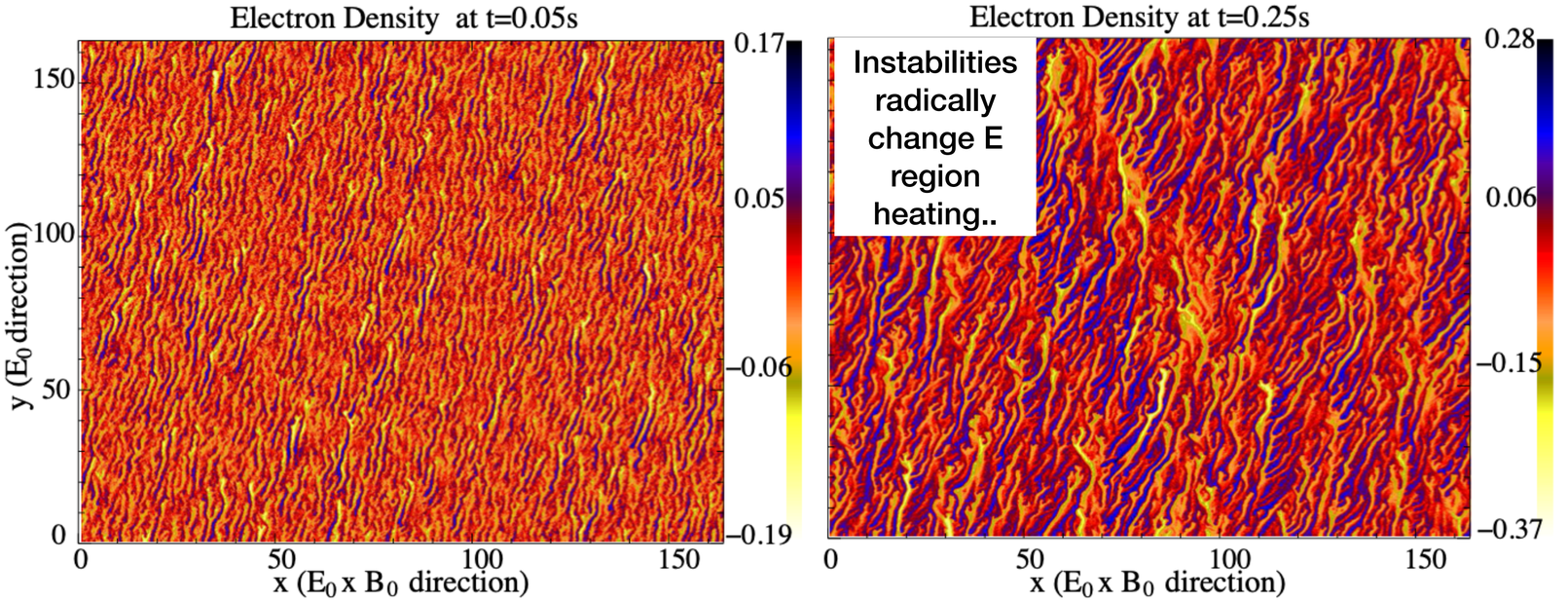
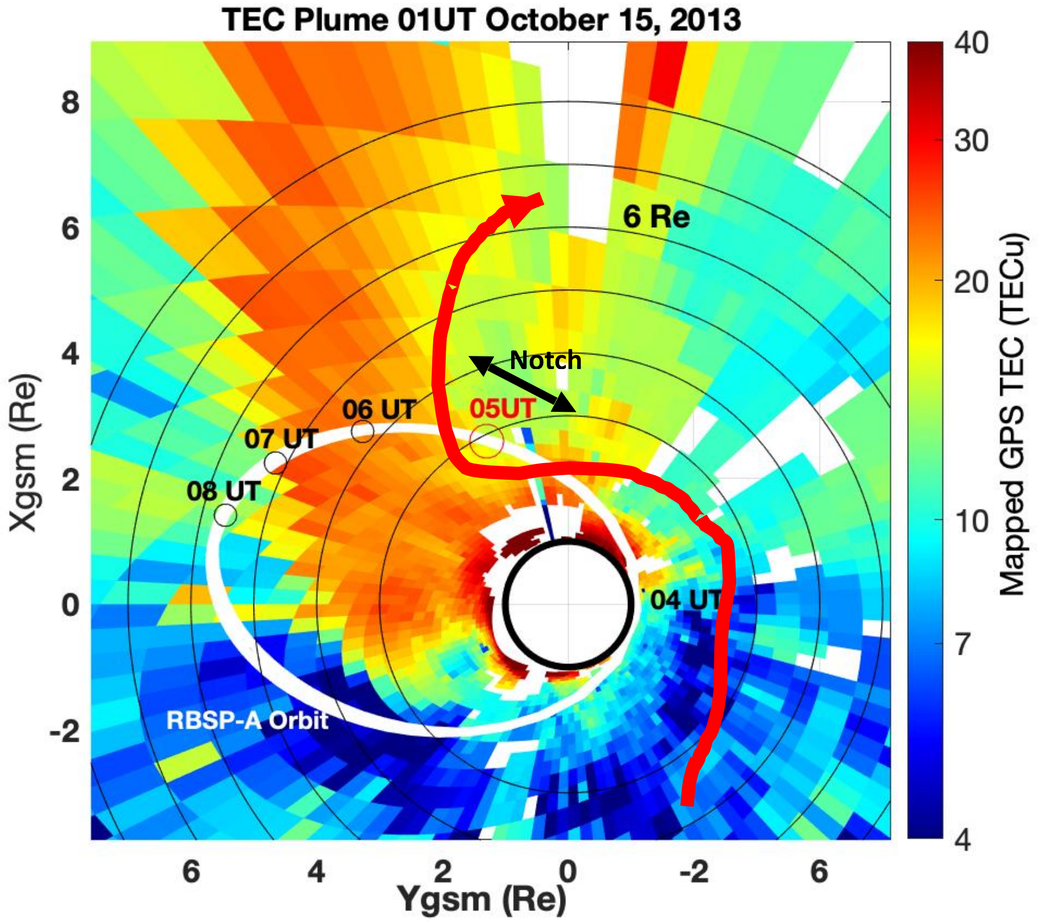


Fig. 1. Plasma density as a function of position at two different times. The color bar to the right indicates the ion density perturbation amplitude. Note that the maximum values of the density perturbation, δn_i reflect approximately four times the RMS value of δn_i because of statistical variations on large meshes.

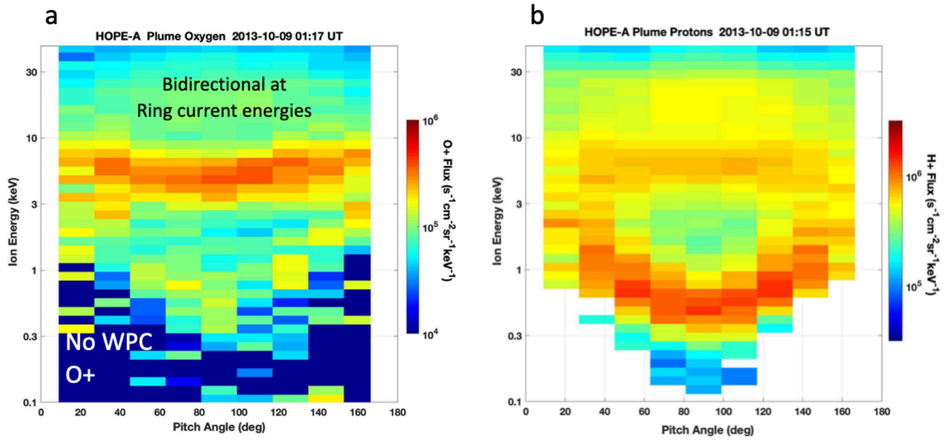
Oppenheim et al (2008) doi:10.1186/s40645-019-0270-5

IM Implications of IT Origin Cold Plasma

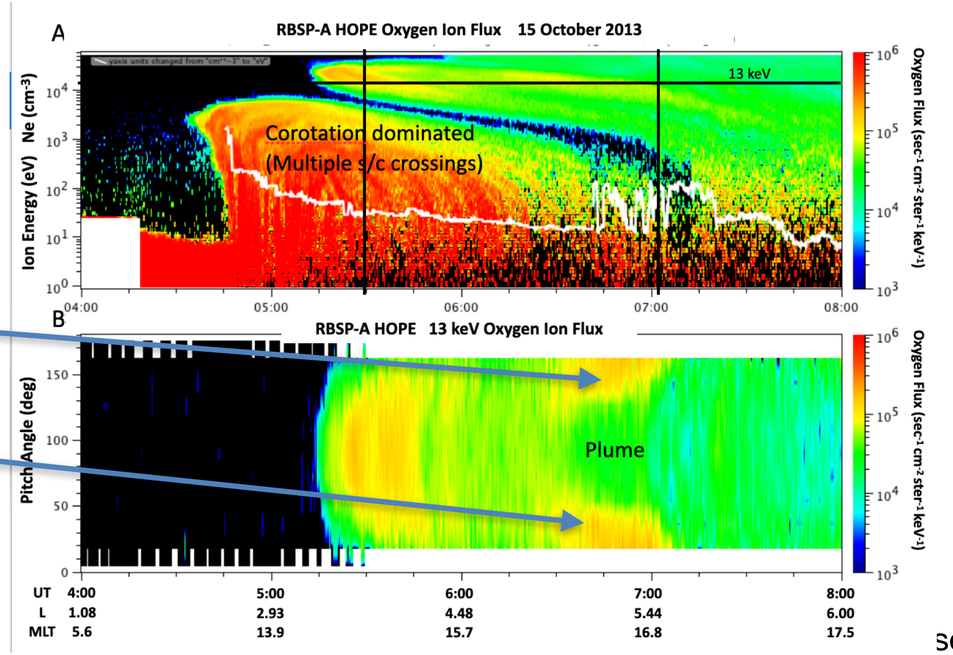


Plume O+

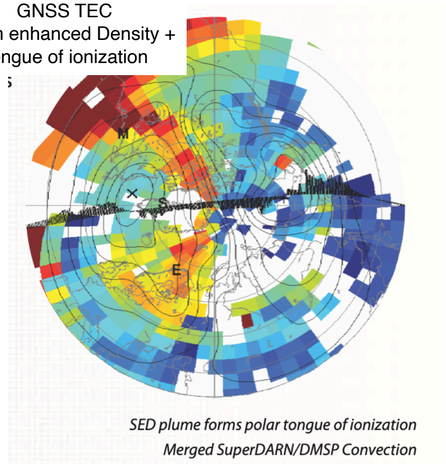
Plume H+

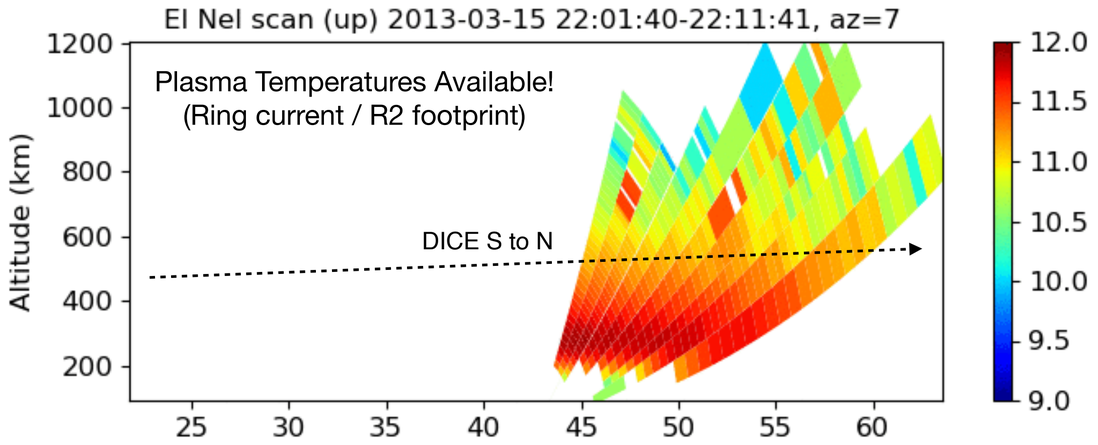


Increasing bidirectionally with
increasing energy (< 1 keV)
Butterfly PAD main ring current (3-10 keV)



Localized ionospheric O+ outflow
Subsequent accel to >= 50 keV in 30 min
(Suppression of EMIC Waves in strong O+ fluxes outside plume)

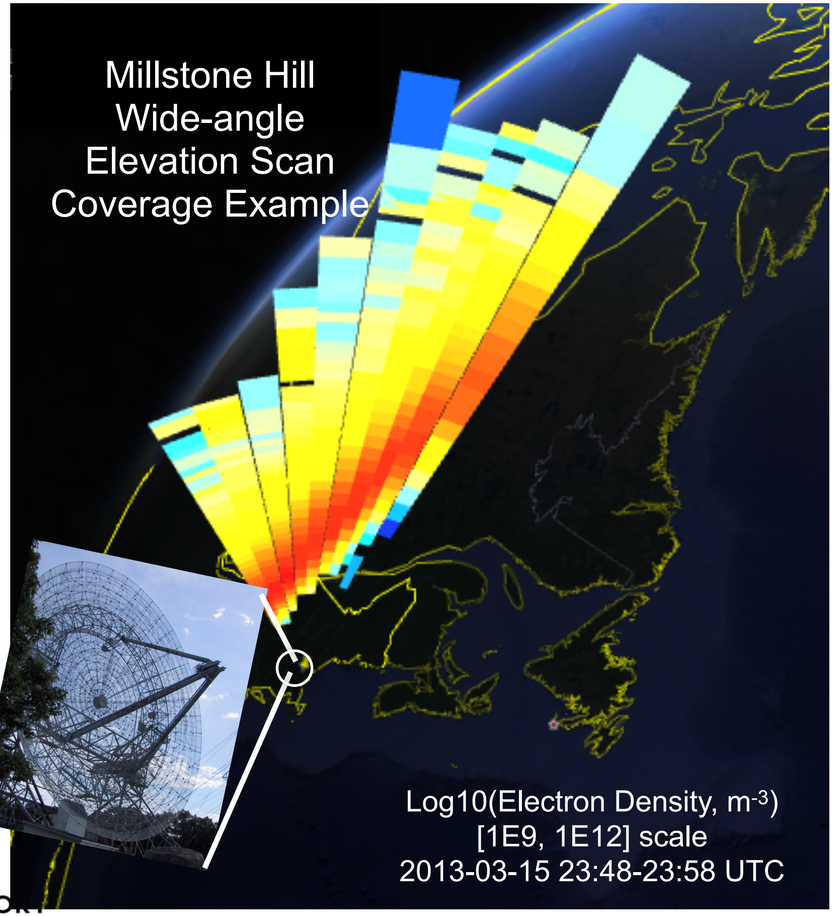




Ground-Based Plasma Diagnostics, Multi-Scale Physics Processes:

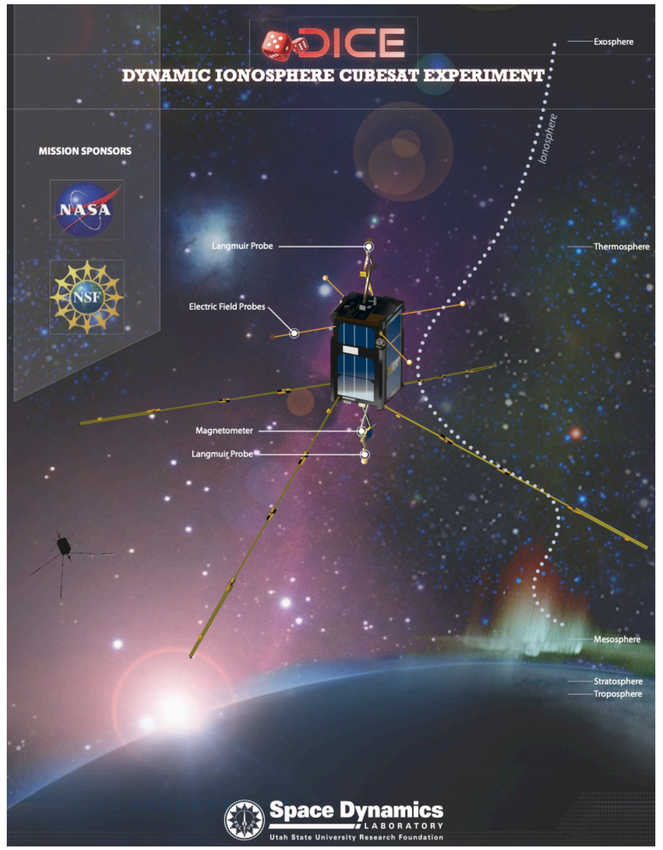
Cubesat Science 'Force Multipliers'

Also true for major missions *especially* at the planning stage!



DICE Cube Sat
[Utah State SDL]
Mid-latitude
overflight through
Millstone Hill
elevation scan

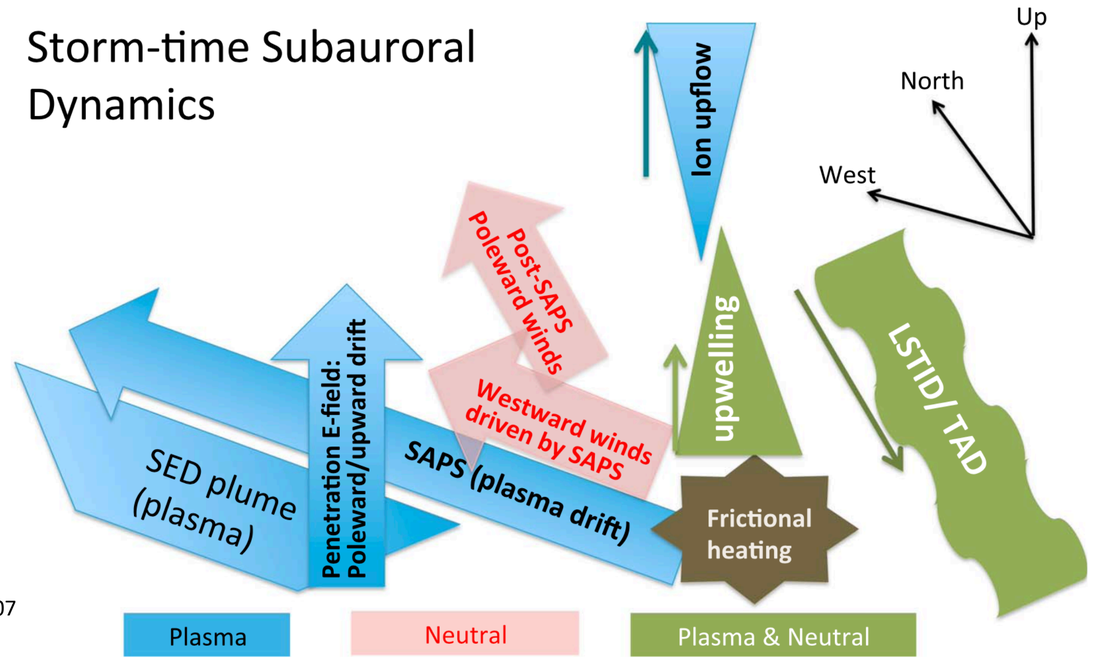
Subauroral
Physics
[Storm enhanced
density,
Sub-auroral
polarization stream]



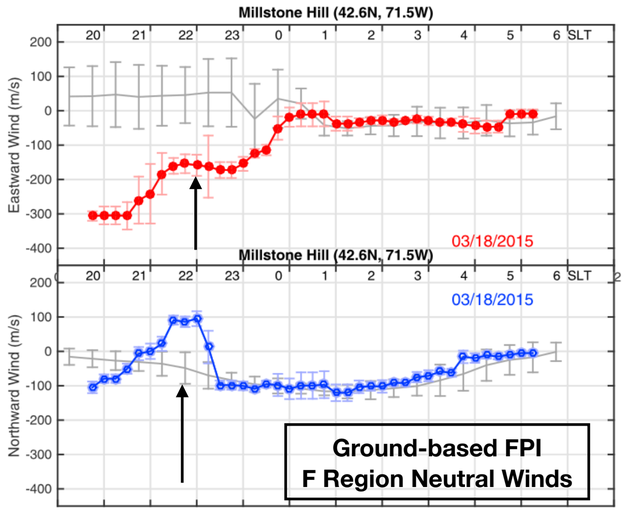
MIT HAYSTACK OBSERVATORY

Takeaways for the Future

- Ground based views are <u>essential</u> at all scales of M-I coupling physics
- Wide field / synoptic views must be combined with local / regional views for modern era progress (due to e.g. long distance EM forcing action)
- Mass, energy transfer information from ground sensors are at the heart of frontier questions in atmosphere-ionosphere-plasmasphere-magnetosphere dynamics, especially under significant EM forcing
- Altitude dependent plasma temperature information is ***vastly under-utilized***
- Hard to understand **UxB** without **E -** or vice versa
- Space missions can ***GREATLY*** benefit from synergistic ground based observations; earlier planning = more capability



Zhang et al 2017
doi:10.1002/2016JA023307



Thermosphere neutral wind surge: Coriolis force effects after ion velocity spin-up

Zhang et al 2015
doi:10.1002/2015GL064836

Figure 17. Schematic summary representation of primary storm time subauroral ionosphere and thermosphere dynamics observed during the 17–18 March 2015 St. Patrick's Day great geomagnetic storm.