OBSERVATIONS IN THE AURORAL ZONE USING SONDRESTROM INCOHERENT SCATTER RADAR

ISR Summer school 2016

Group 4

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The Original Experiment

- Map boundary of auroral oval
- UHF Radar in Tromsø
- Meridian scan (CP3)
- Beata (50-700 km)
- Comparison with external data sources for validation
  - DMSP SSUSI
  - TEC monitors
  - Magnetometers

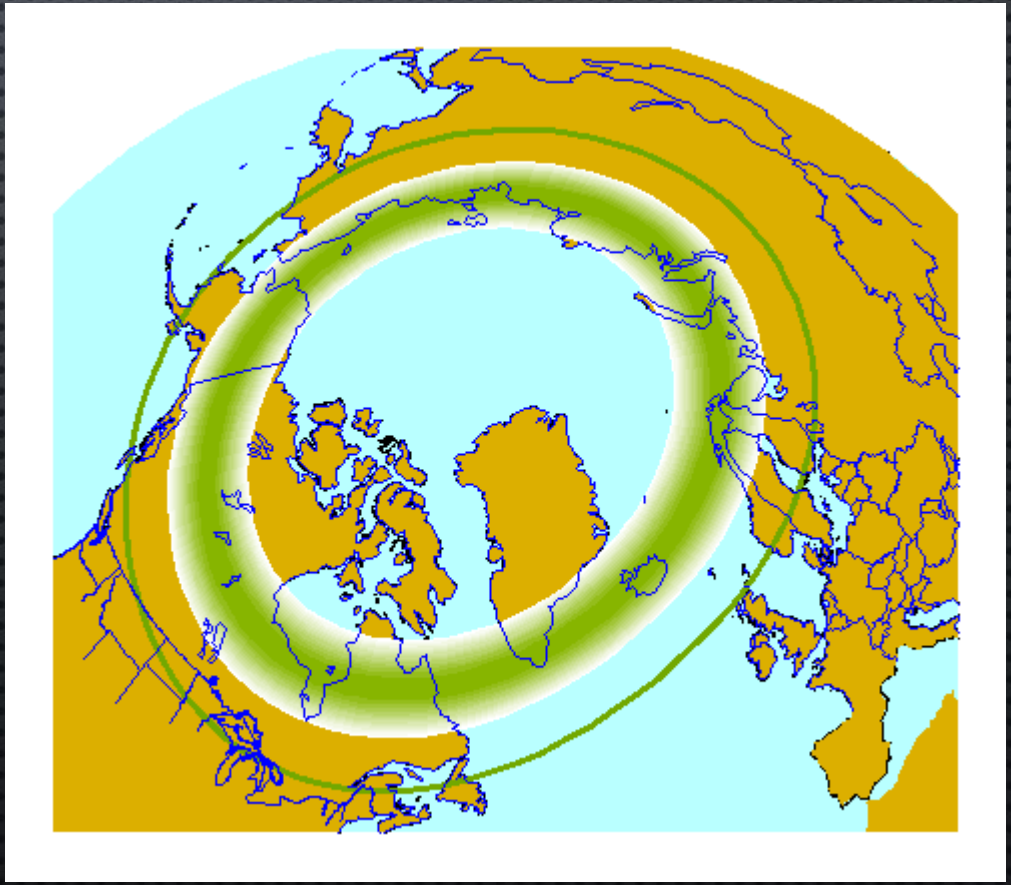
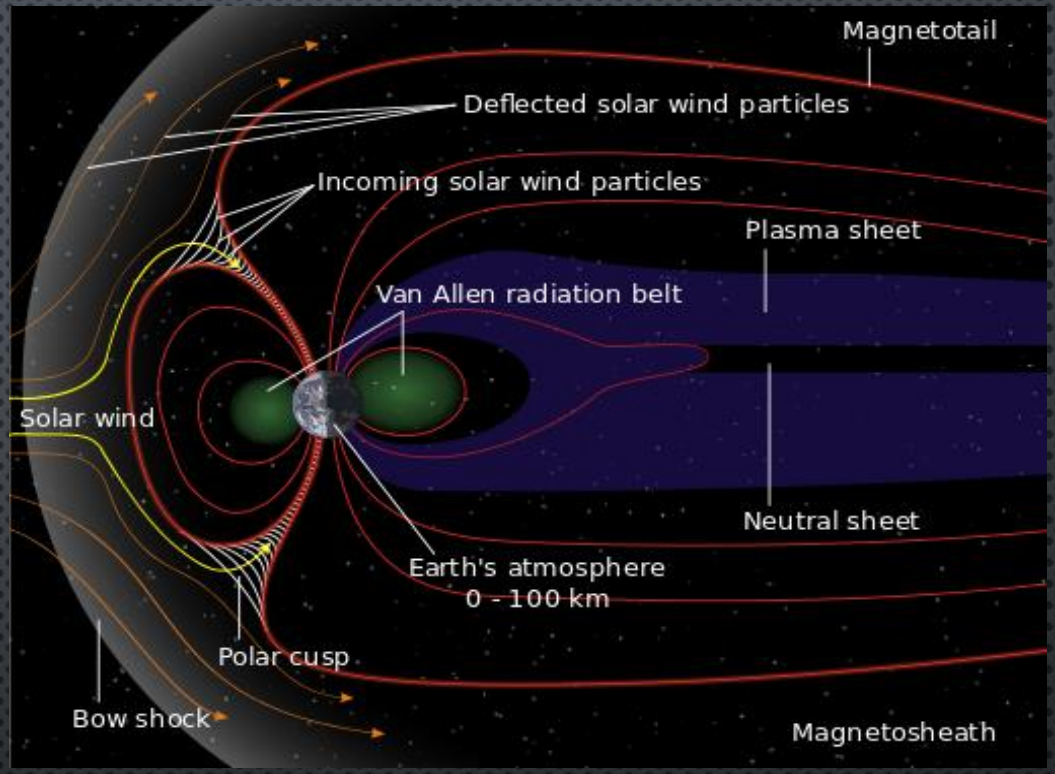
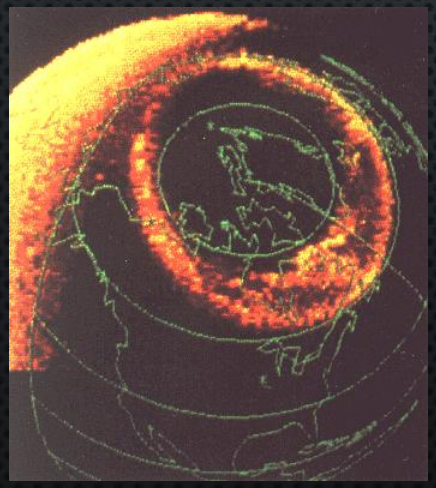


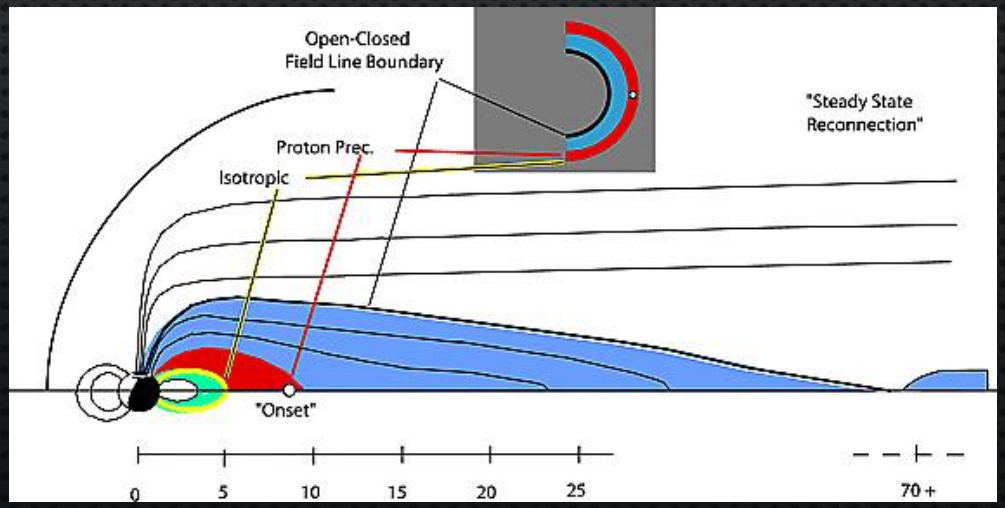
Image: UAF Geophysical Institute Aurora Forecast for 7/26/2016

WHY MAP THE BOUNDARY?

- MONITOR MAGNETOSPHERIC PROCESSES
  - SUBSTORMS
  - RECONNECTION

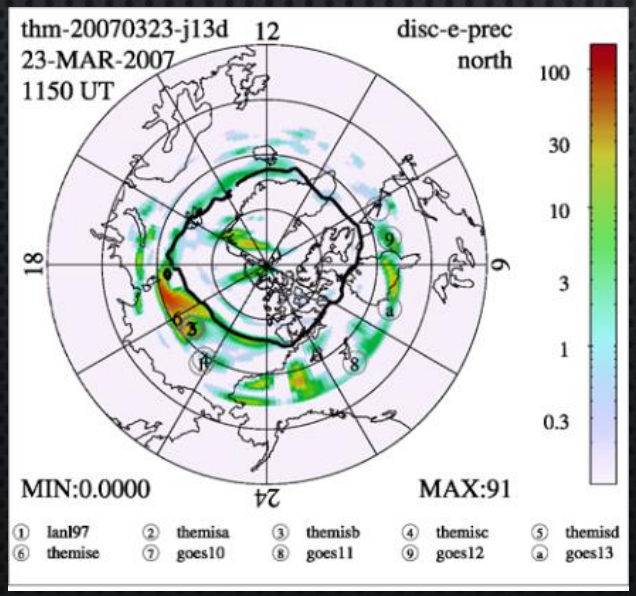


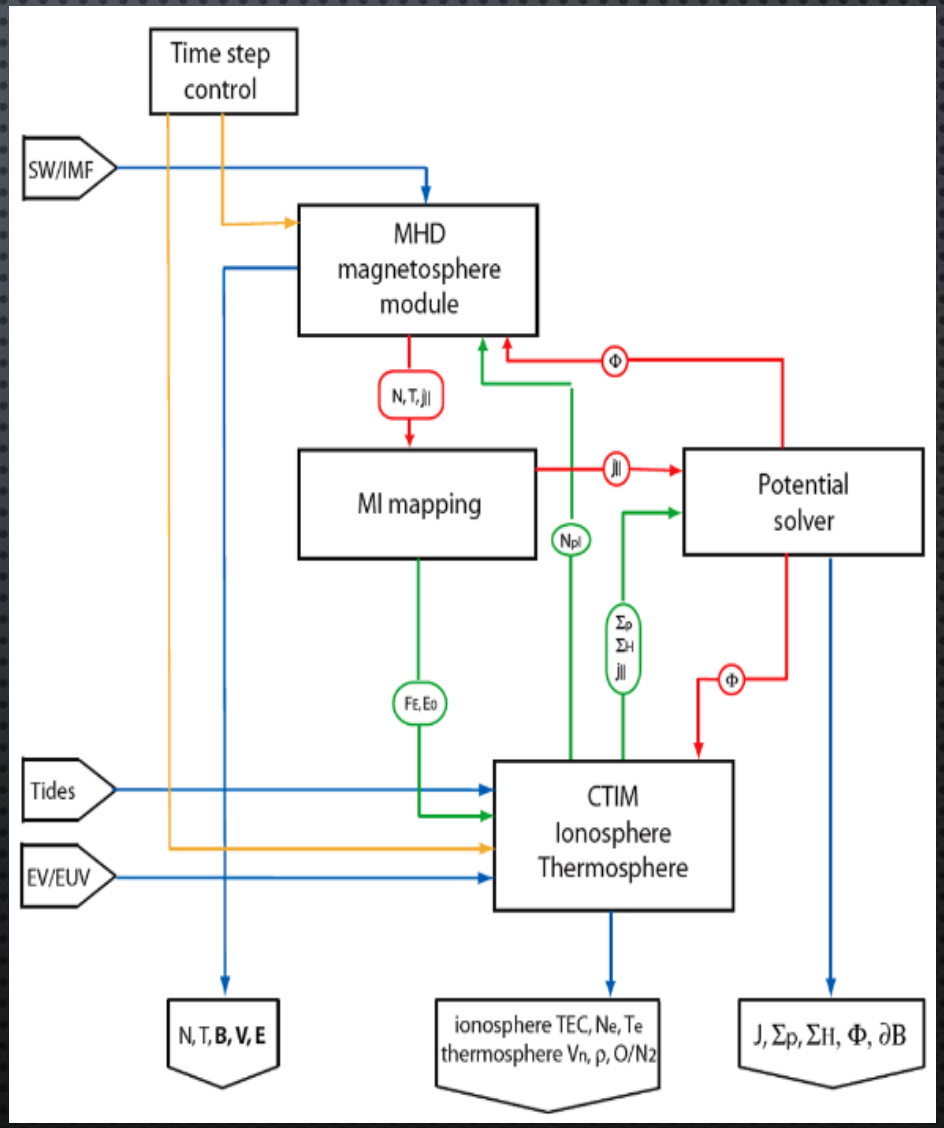




WHY MAP THE BOUNDARY?

- Monitor magnetospheric processes
- Validate magnetospheric models
  - e.g. OpenGGCM, LFM, CRCM
  - N, T, $J_{\parallel}$, Σ_P, Σ_H, Φ

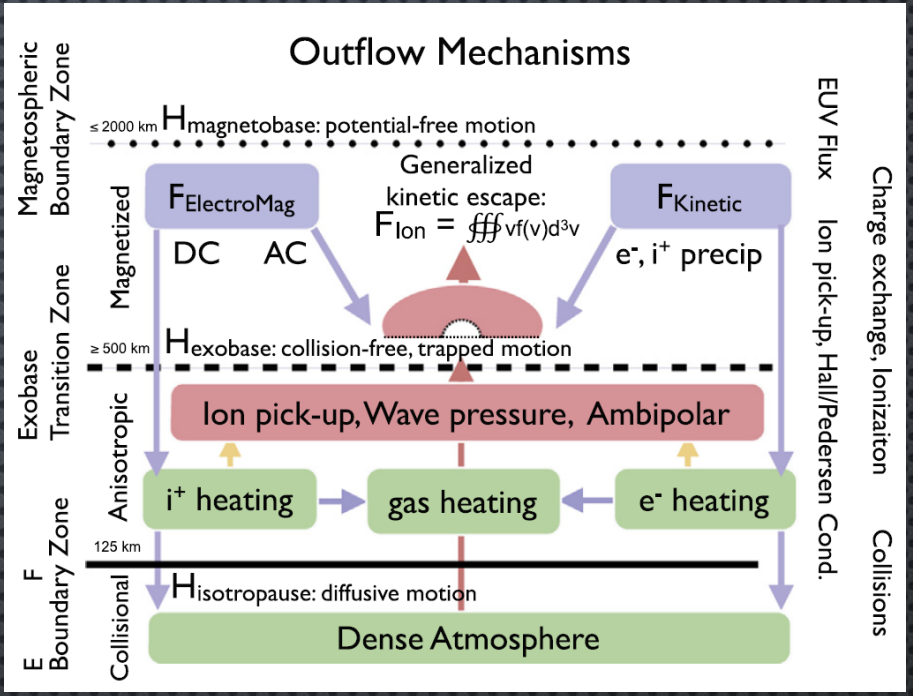


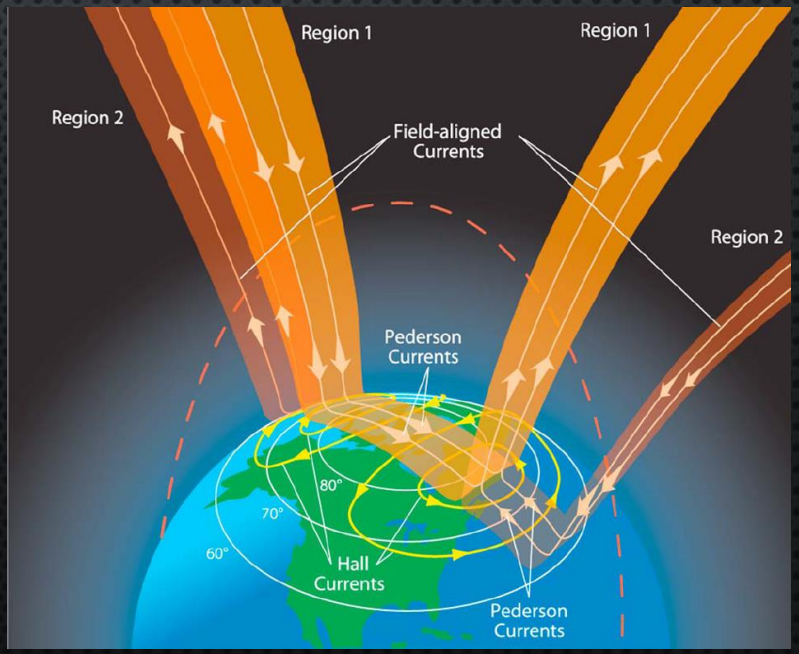


Raeder et al [2008]

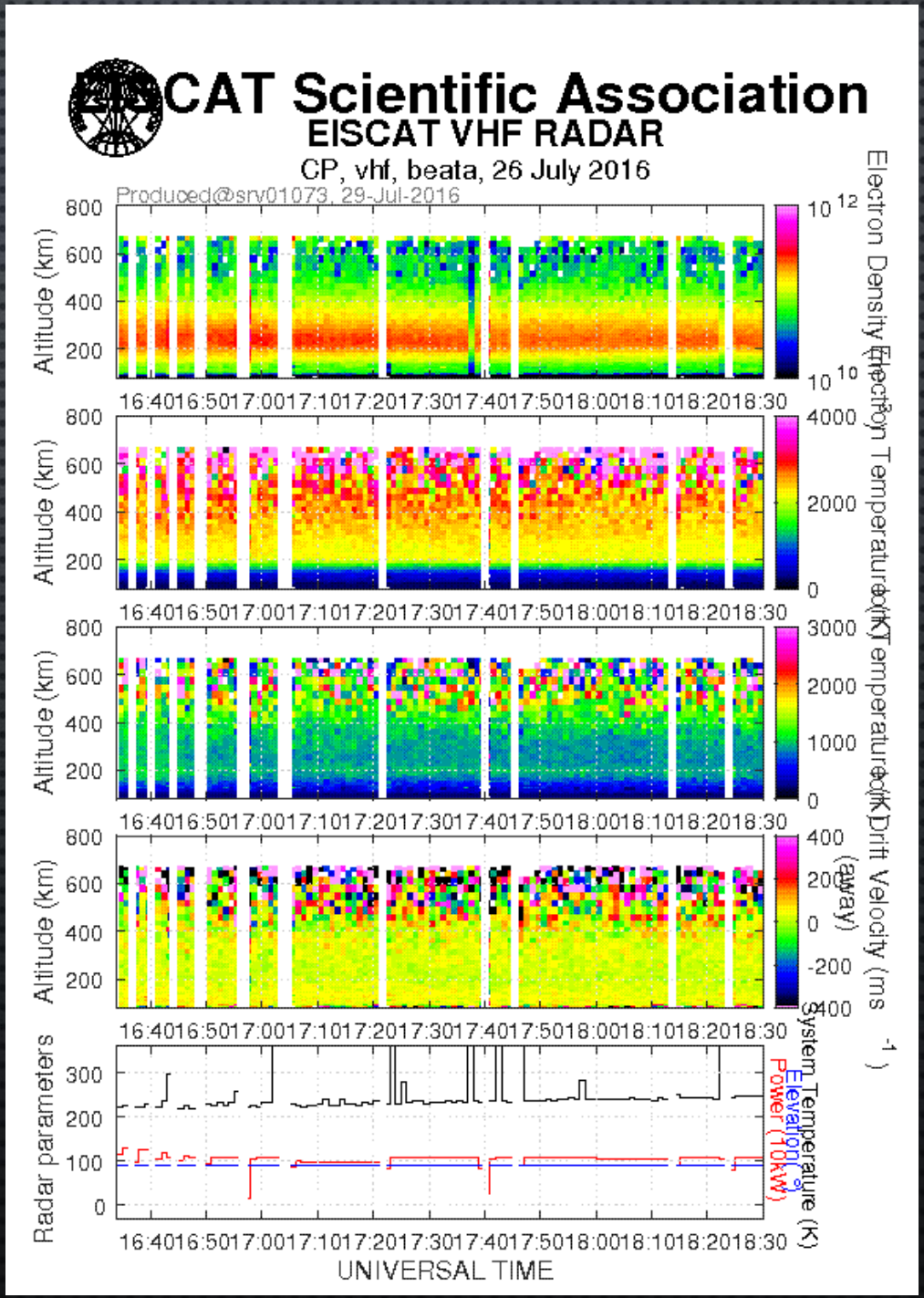
WHY MAP THE BOUNDARY?

- MONITOR MAGNETOSPHERIC PROCESSES
- VALIDATE MAGNETOSPHERIC MODELS
- UNDERSTAND M-I COUPLING PROCESSES
  - ION OUTFLOW
  - FIELD-ALIGNED CURRENTS





WHAT ACTUALLY HAPPENED…



THE NEW EXPERIMENT

- SAME SCIENCE GOAL
- SONDRESTROM RADAR

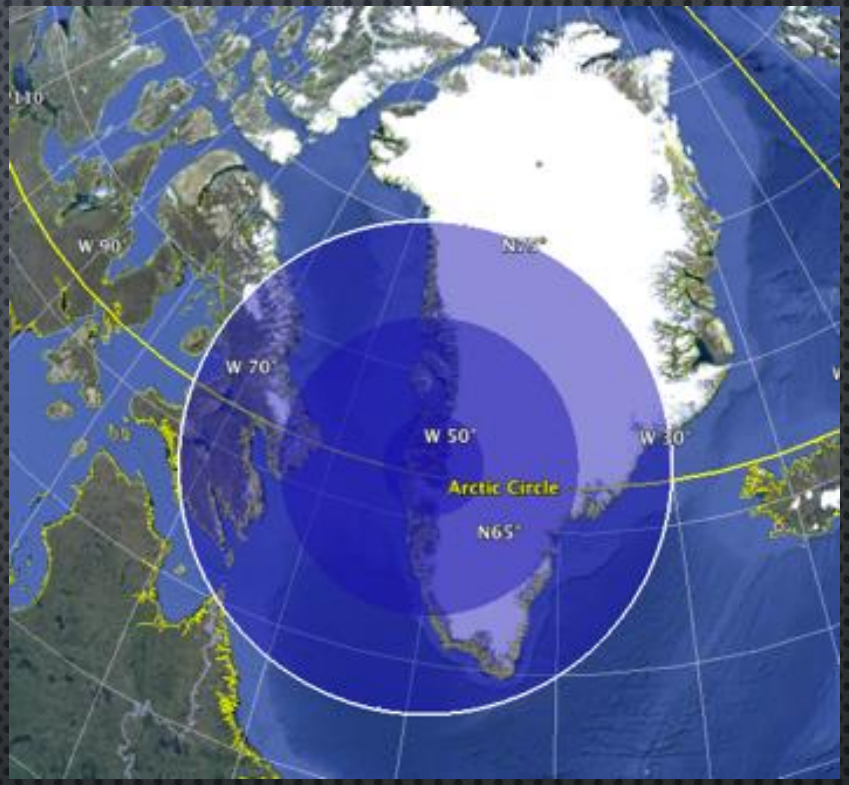


Image: http://isr.sri.com

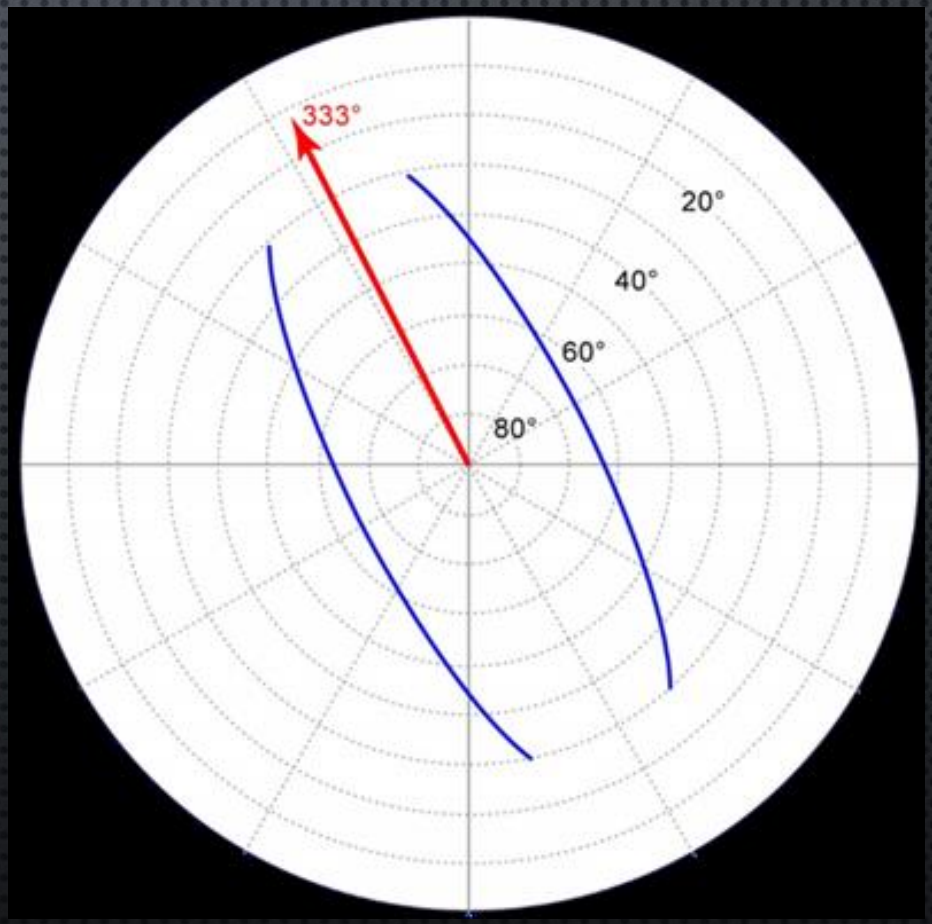
Sondrestrom

Geographic coord.	66° 59'12" N 309° 03'02" E
Geomag. dip angle	80° 24'
Invariant latitude	74° 11'24" N
Local time	UT – 3 (UT – 2 summer)
Magnetic time	UT – 1:58
Elevation	177 m
Coverage	360° az., above 25°–30° elev.*

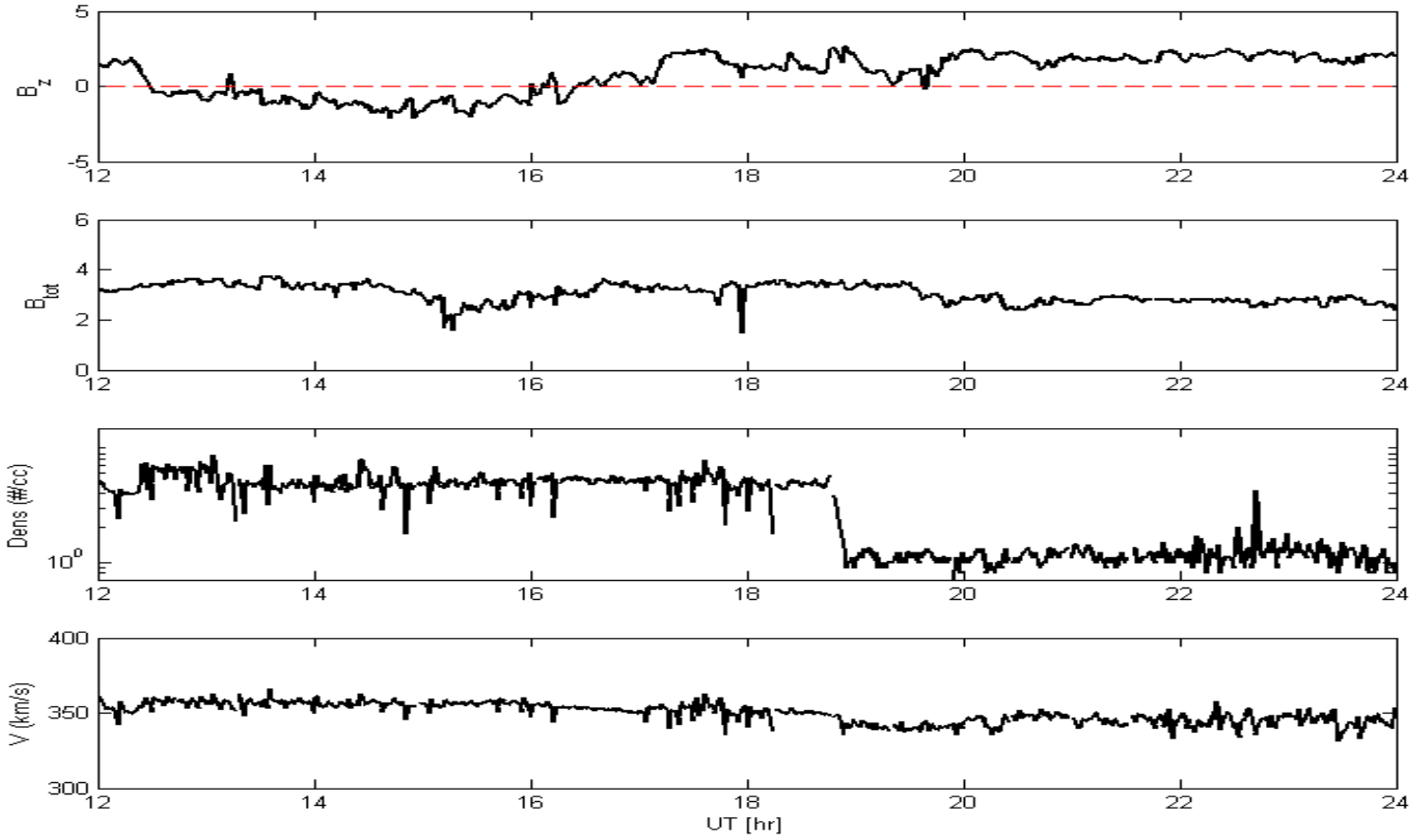
*Dependent on azimuth. No transmission below this elevation.

EXPERIMENT MODE

- SCAN AZIMUTH/ELEVATION SIMULTANEOUSLY
- PLANE PARALLEL TO MAGNETIC MERIDIAN, TIPPED 25° FROM ZENITH



26 JULY 2016 EVENT



ACE Solar Wind Data

26 JULY 2016 EVENT

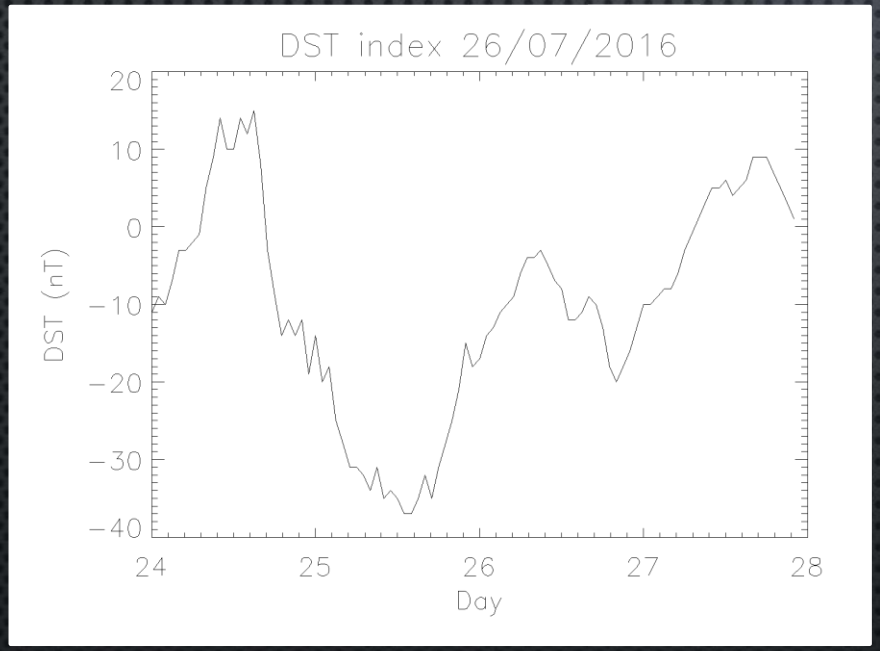


Image: http://wdc.kugi.kyoto-u.ac.jp/dst_realtime/presentmonth/index.html

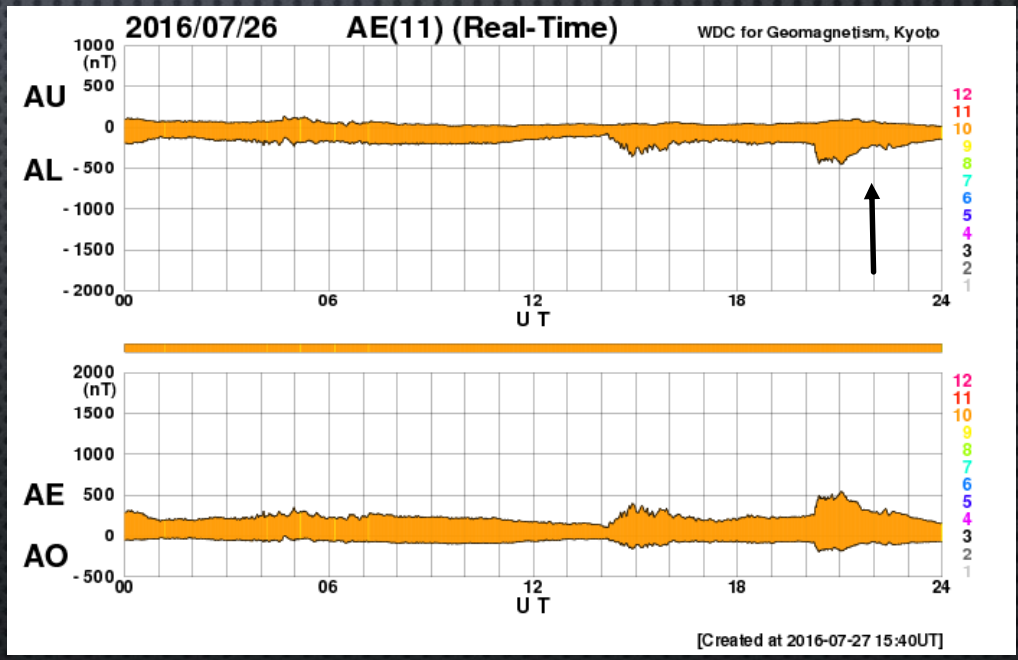
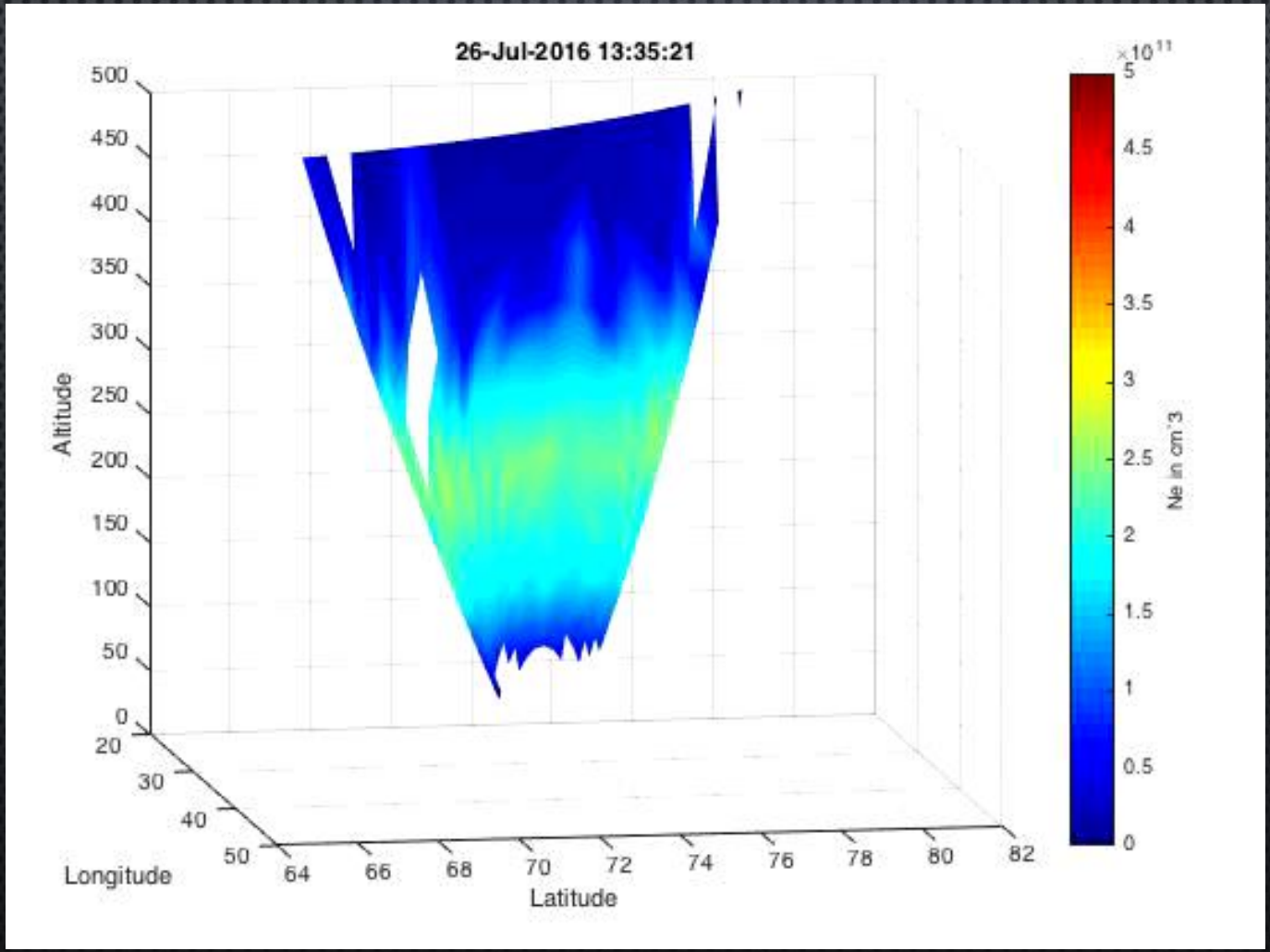
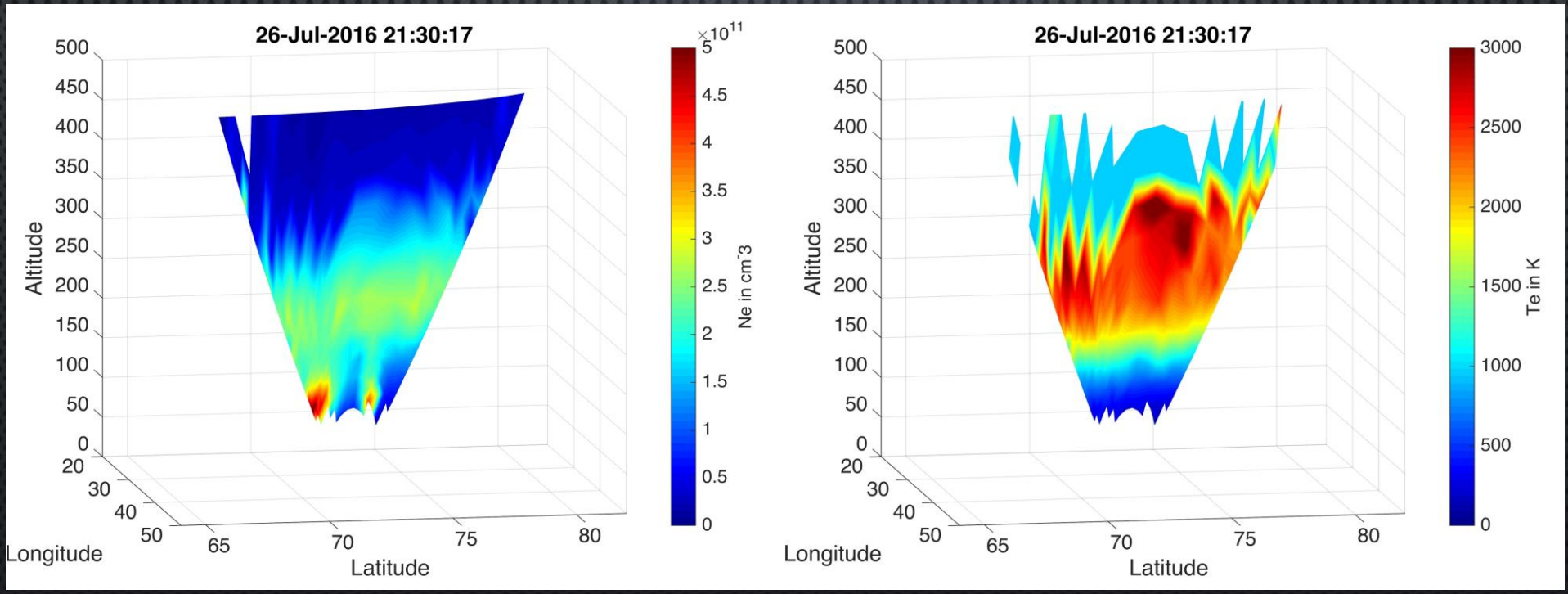


Image: http://wdc.kugi.kyoto-u.ac.jp/ae_realtime/lastday/lastday.html

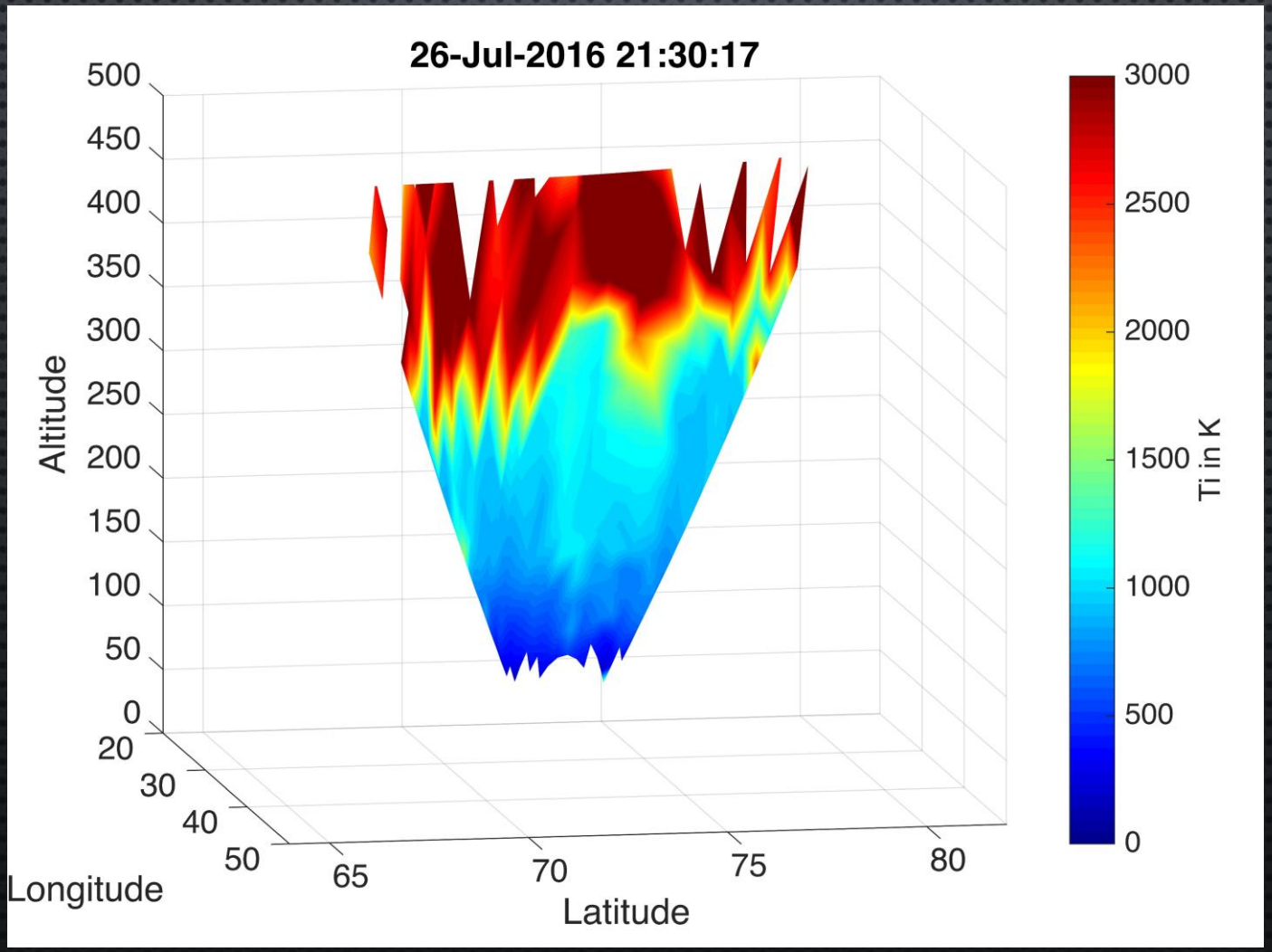
SAMPLE FITTED DATA - N_E



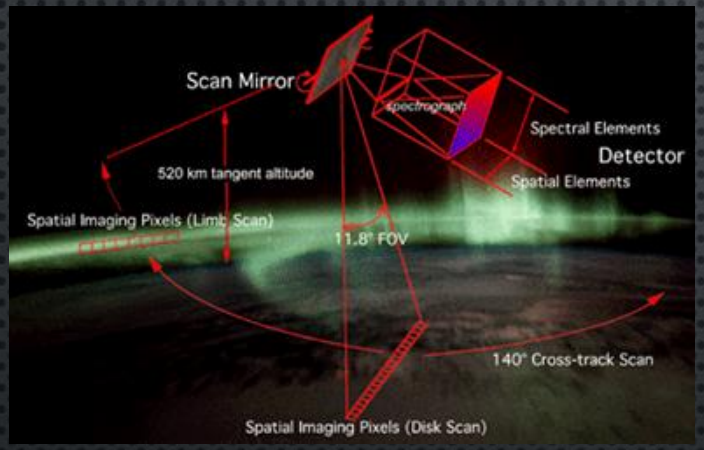
SAMPLE FITTED DATA – N_E, T_E



FITTED DATA - T_i



SSUSI (SPECIAL SENSOR ULTRAVIOLET SPECTROGRAPHIC IMAGER)

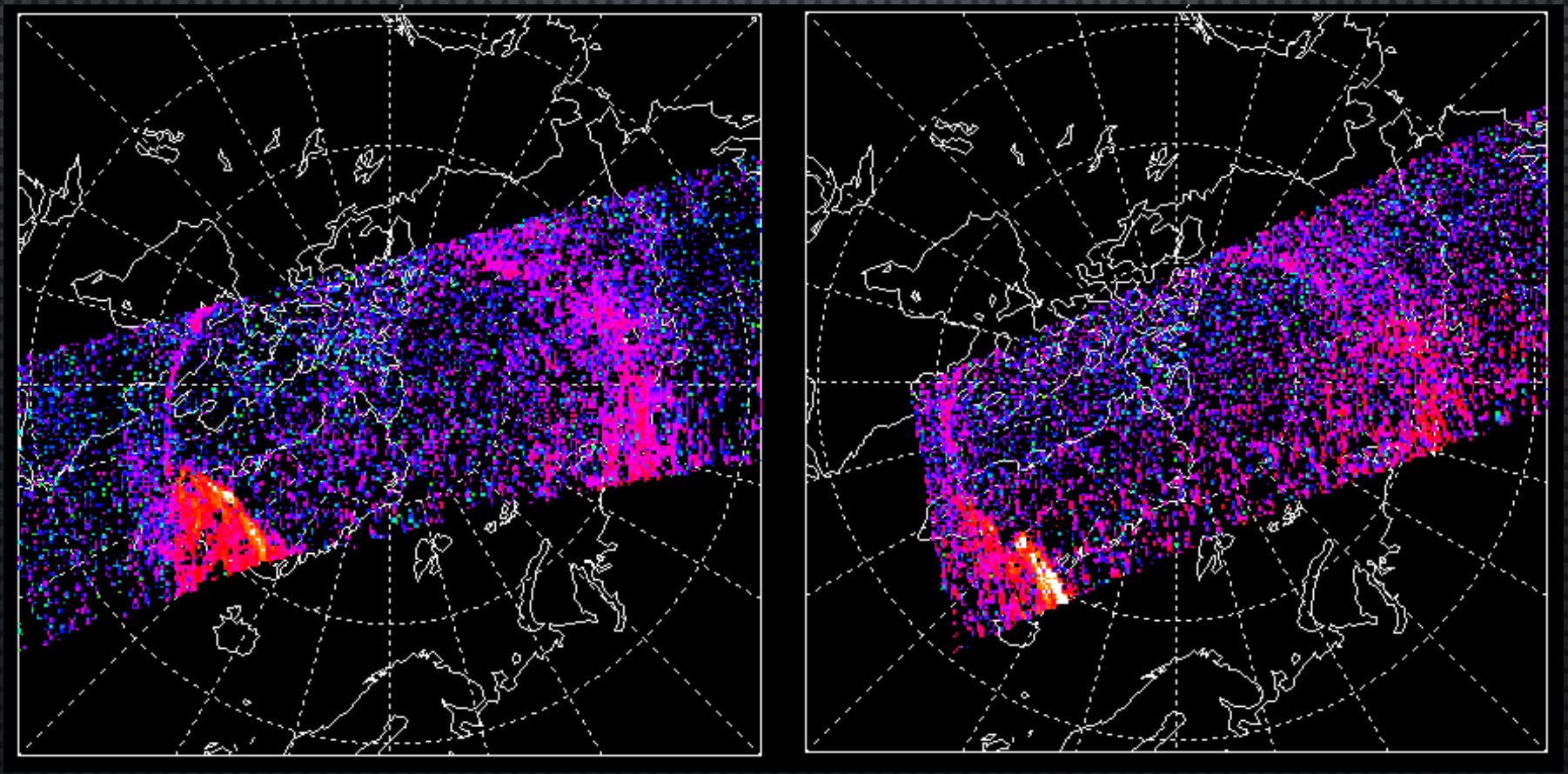


- Onboard DMSP satellites in polar orbits ~97 mins
- Scans a section of the poles building up brushstroke-like images of the aurora using line scanning imaging spectrograph (SIS)
- Takes around 20 mins to complete scan
- Images produced in 5 FUV wavelengths
- N2: Lyman- Birge Hopfield long (LBHL) band between 165-180nm
- Also available O (130.4nm, 135.6nm), H (121.4 nm), N2 (LBHS)

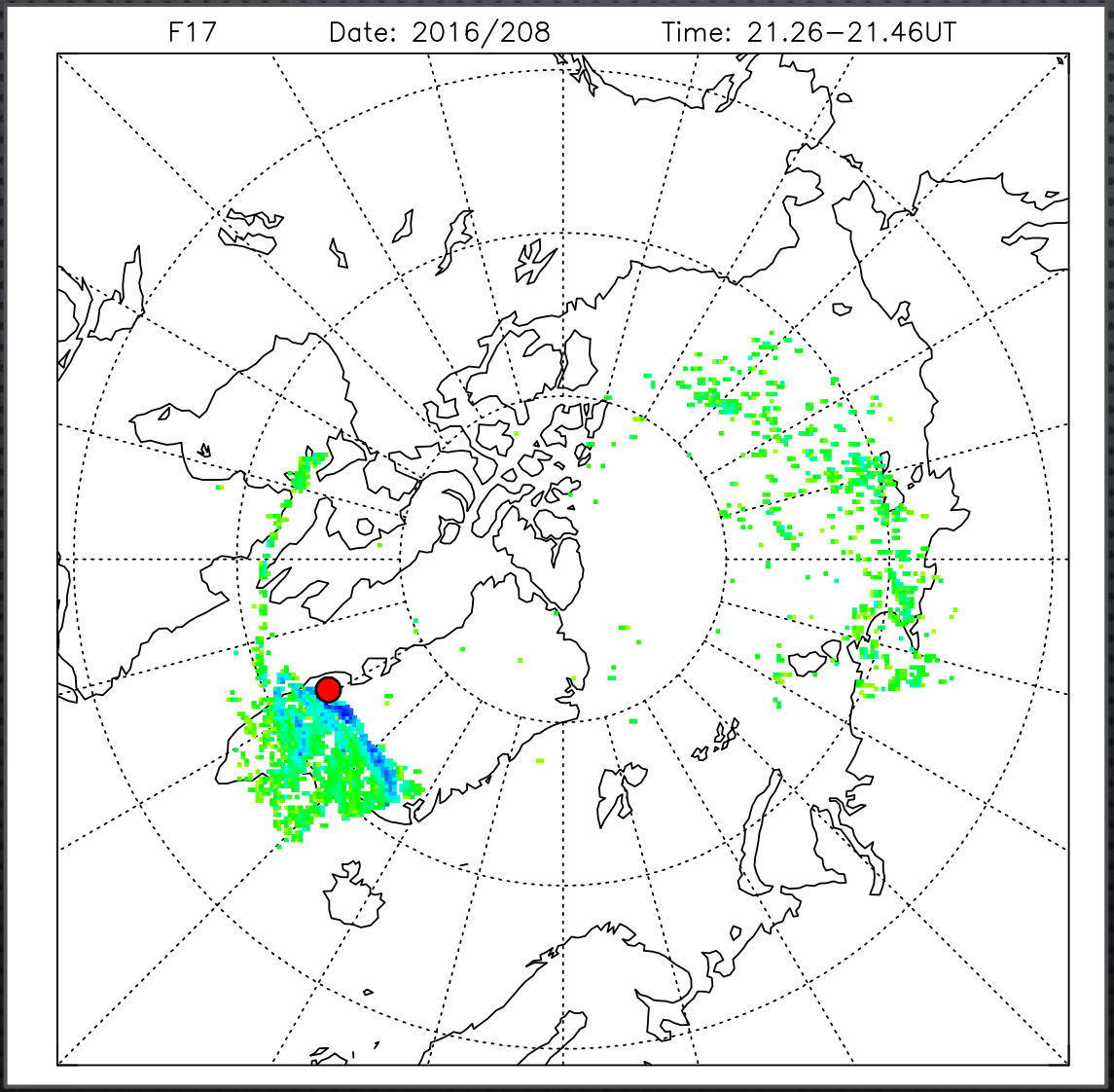
COMPARISON TO SSUSI IMAGES

F17 Time: 21:26-21:46UT

F18 Time: 21:23 – 21:40UT

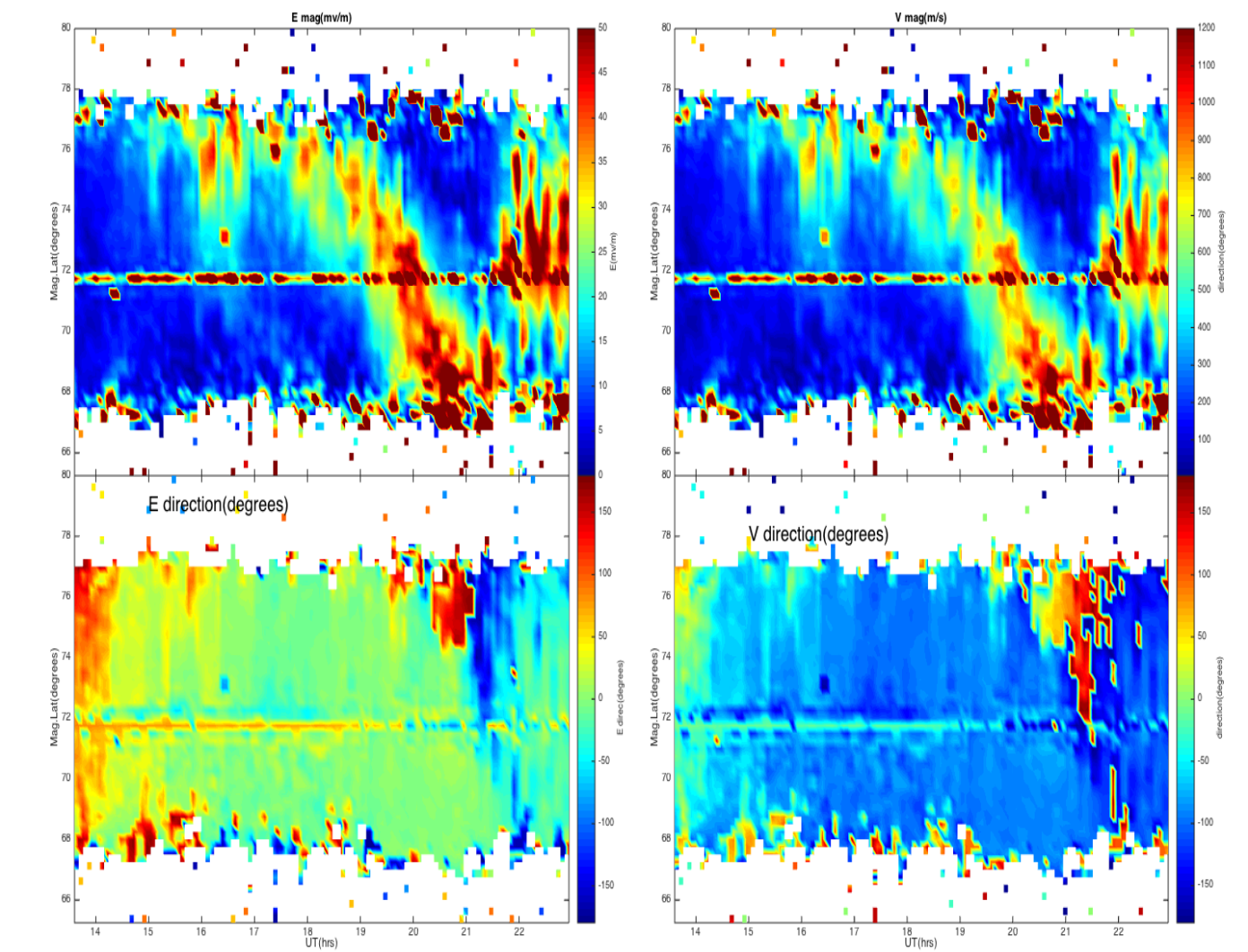


COMPARE ELECTRON ENERGY FLUX OF SSUSI TO SONDRESTROM DATA….



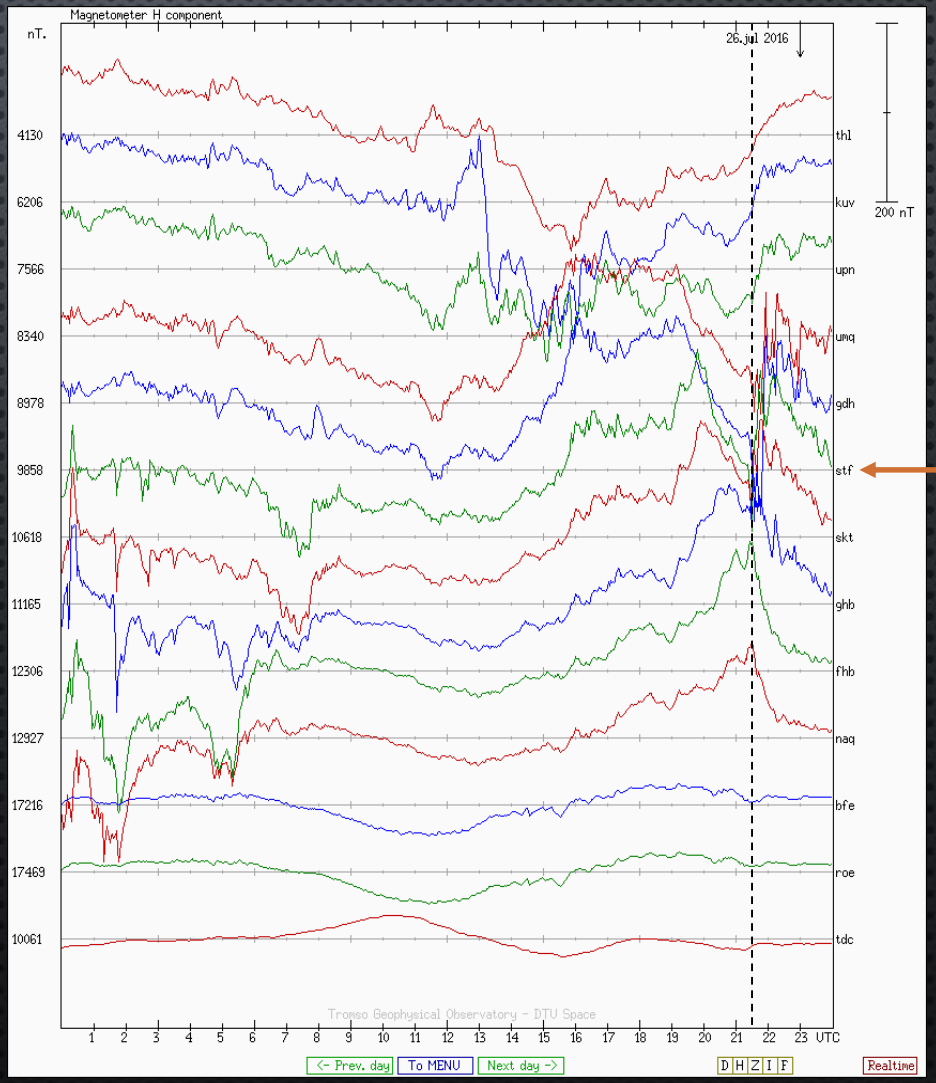
DERIVED PARAMETERS – E, V

- VELOCITY MAGNITUDE
- ELECTRIC FIELD MAGNITUDE
  - AVERAGE OF VALUES FROM ~200+ KM, WEIGHTED BY RANGE GATE FOR STRENGTH OF SIGNAL



GROUND MAGNETOMETER CHAIN

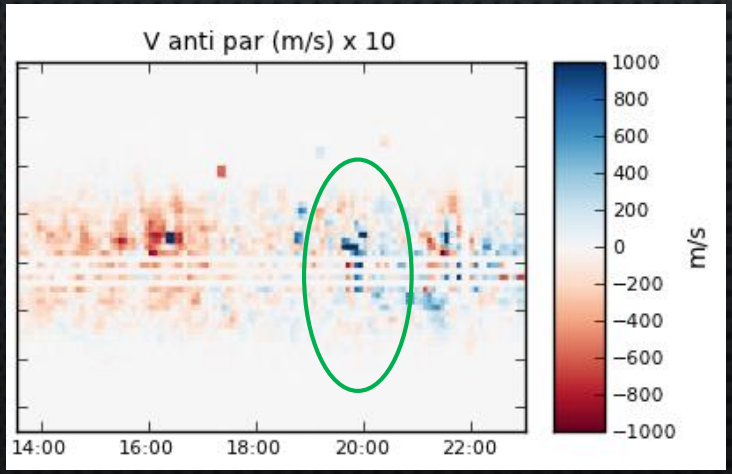
- H COMPONENT OF B
- TROMSØ GEOPHYSICAL OBSERVATORY
- STATIONS ALONG COAST OF GREENLAND, INCLUDING @ SONDRESTROM

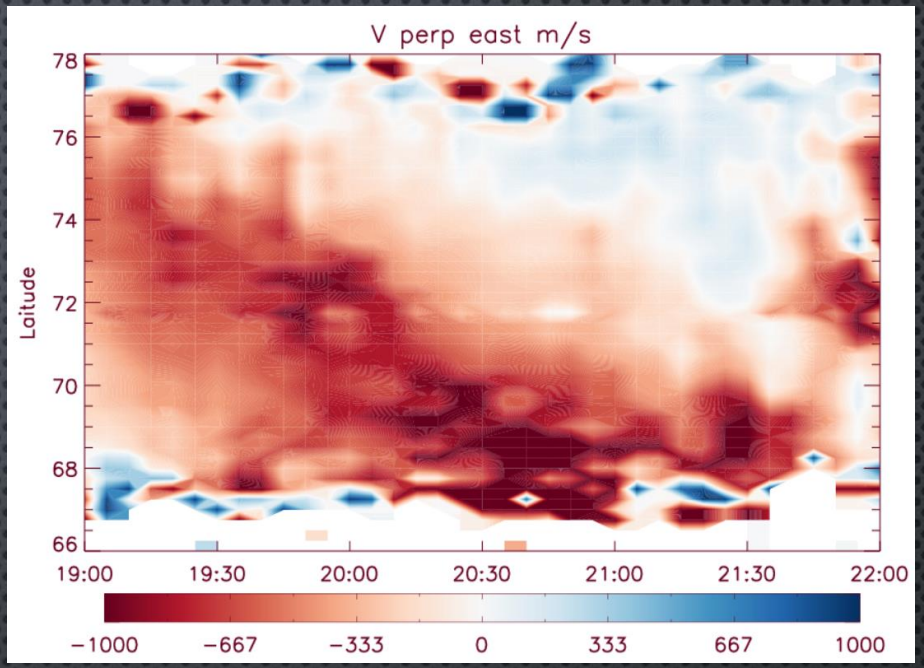


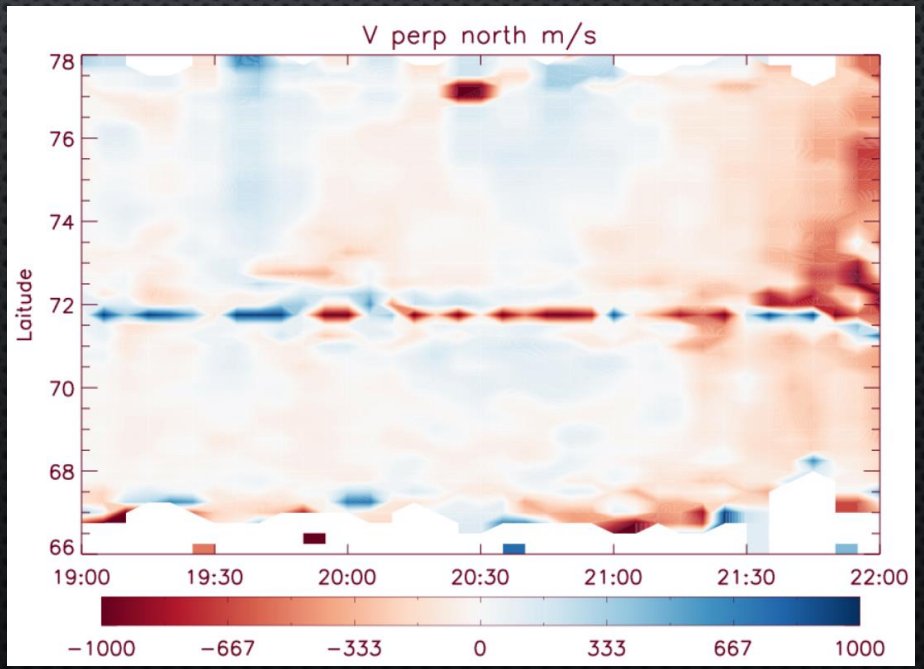
http://flux.phys.uit.no/stackplot/

DERIVED PARAMETERS – VELOCITY VECTORS

- Strong westward flows
- Flow channel moves north to south over time
- Weak upflow along field line as flow channel passes overhead ~20:00

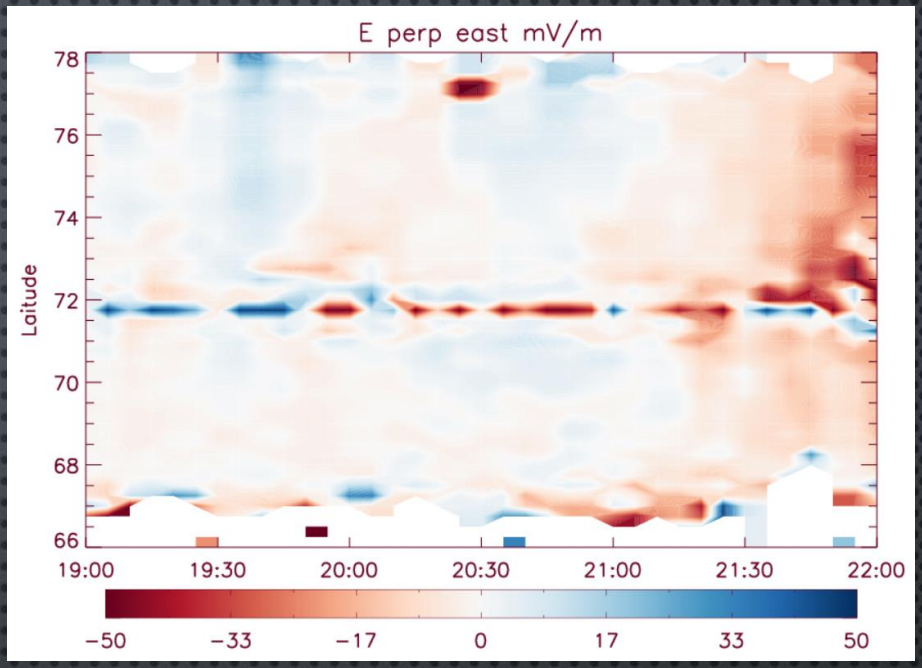


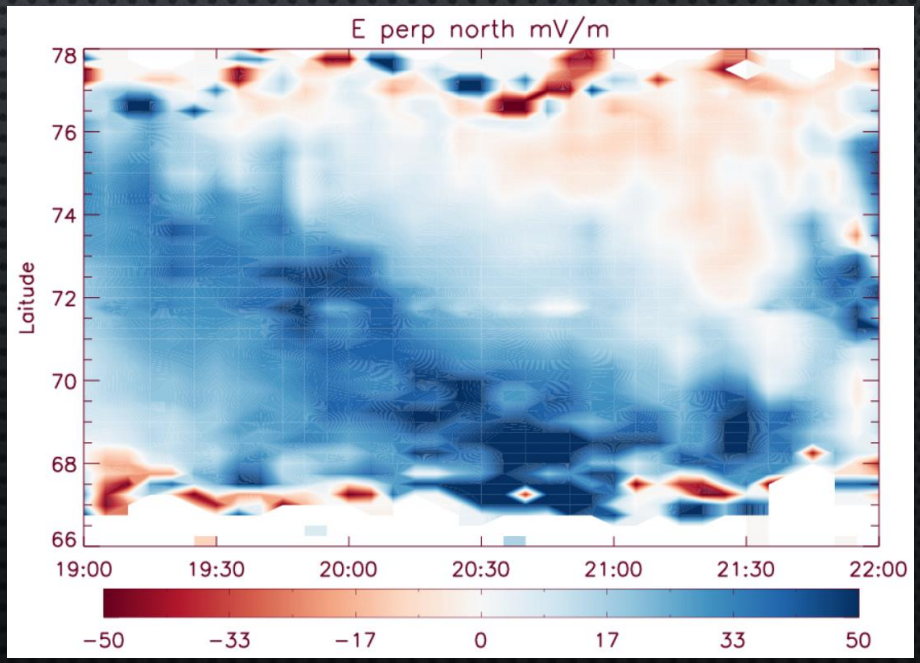




DERIVED PARAMETERS – ELECTRIC FIELD VECTORS

- Electric Field vector
- Strong northward Electric field
- V = E x B
  - collisionless F region





1. Plasma instabilities in the linear regime can be described by a specific relationship between frequency and wave number, known as dispersion relation:

$$\frac{k^2}{w^2} = \frac{\left(1 - \frac{n_e q^2}{e m_e w^2}\right)}{c^2} \qquad \text{Eq.(1)}$$

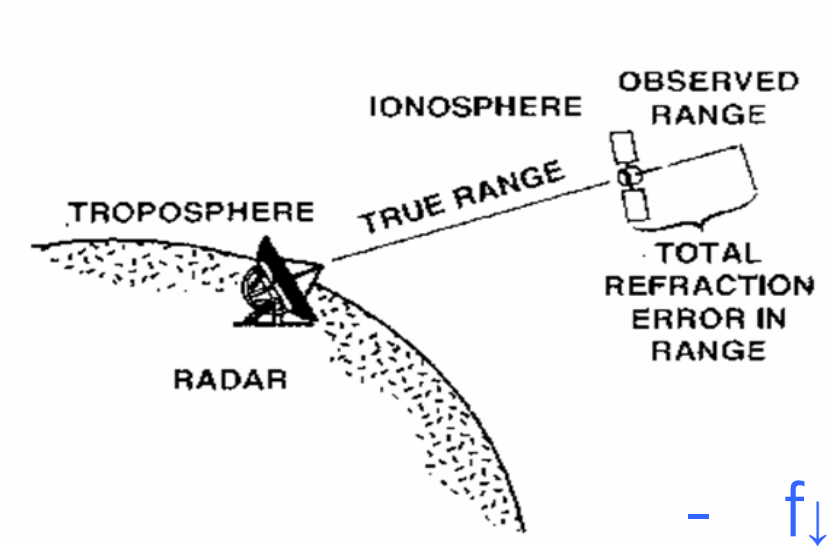
2. The phase velocity and the group velocity could be obtained from the dispersion relation

- The carrier signal travel in phase speed, while the modulated signal travels in group velocity. So the information content is transported in group speed.
- Recalling the dispersion relation Eq. (1), we can derive the group velocity as:

$$v_g = \frac{\P w}{\P k} = c\sqrt{1 - \frac{n_c q^2}{e m_e w^2}} \qquad \text{Eq.(2)}$$

(f↑ → Vg↑)

3. Ionospheric delay as a function of frequency and TEC



$$\Delta R_{ion}(meters) = \frac{40.3}{f^2}\underbrace{\int_0^R N_e\, dr}_{\textbf{TEC}}$$

Eq. (3)

- $f\downarrow$ or TEC $\uparrow \rightarrow$ Delay $\uparrow$

4. Consider ionospheric delay is a function of frequency and TEC from Eq. (3), and GPS satellites transmit in two frequencies (L1 & L2), we can get the difference in arrival time for two codes transmitted at identical times but at different frequencies:

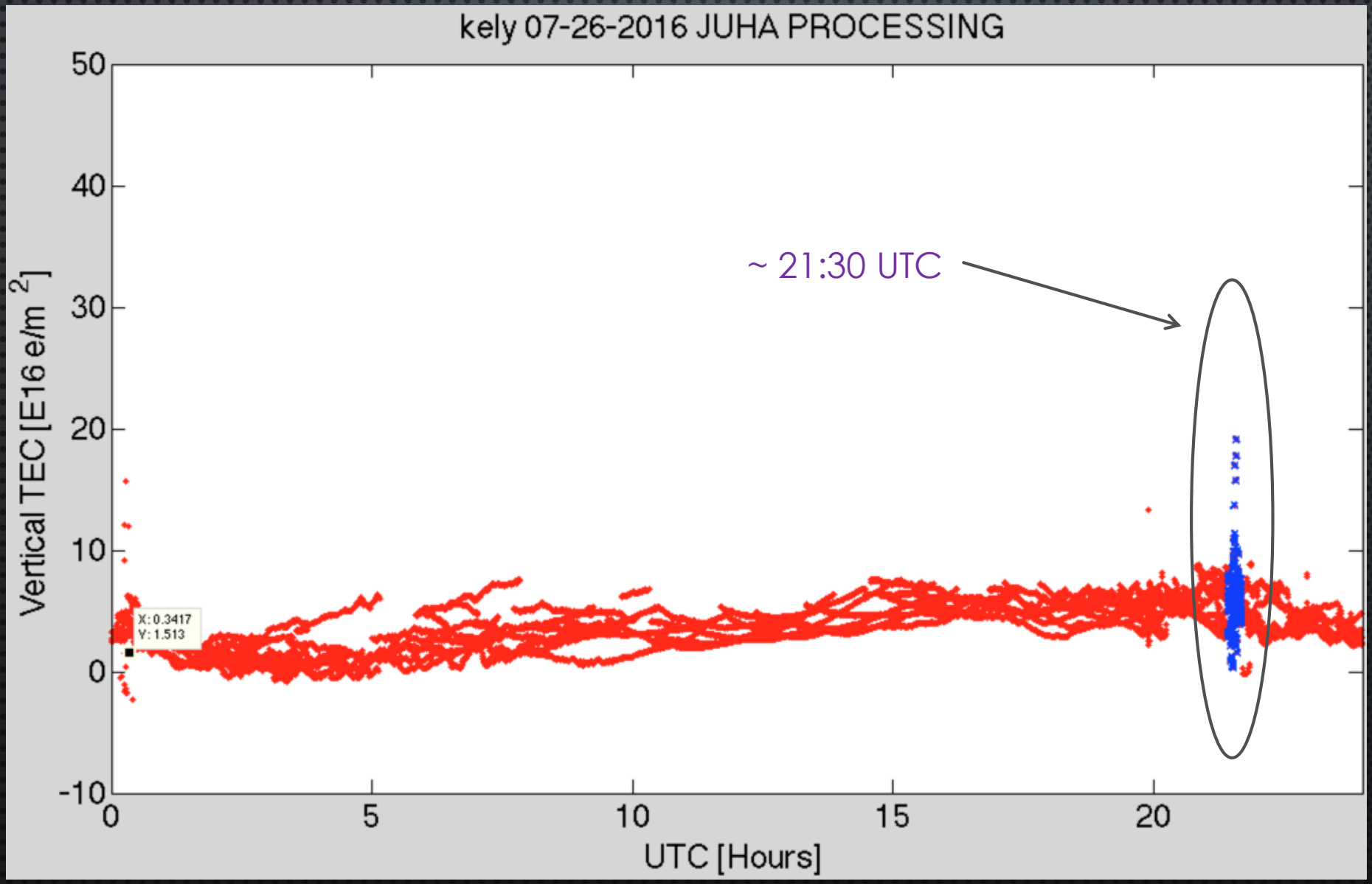
$$\Delta(dt) = \frac{40.3 \times TEC}{c}\left(\frac{f_{L1}^2 - f_{L2}^2}{f_{L1}^2 f_{L2}^2}\right)$$

Because pseudorange $P = c \times dt$, then:

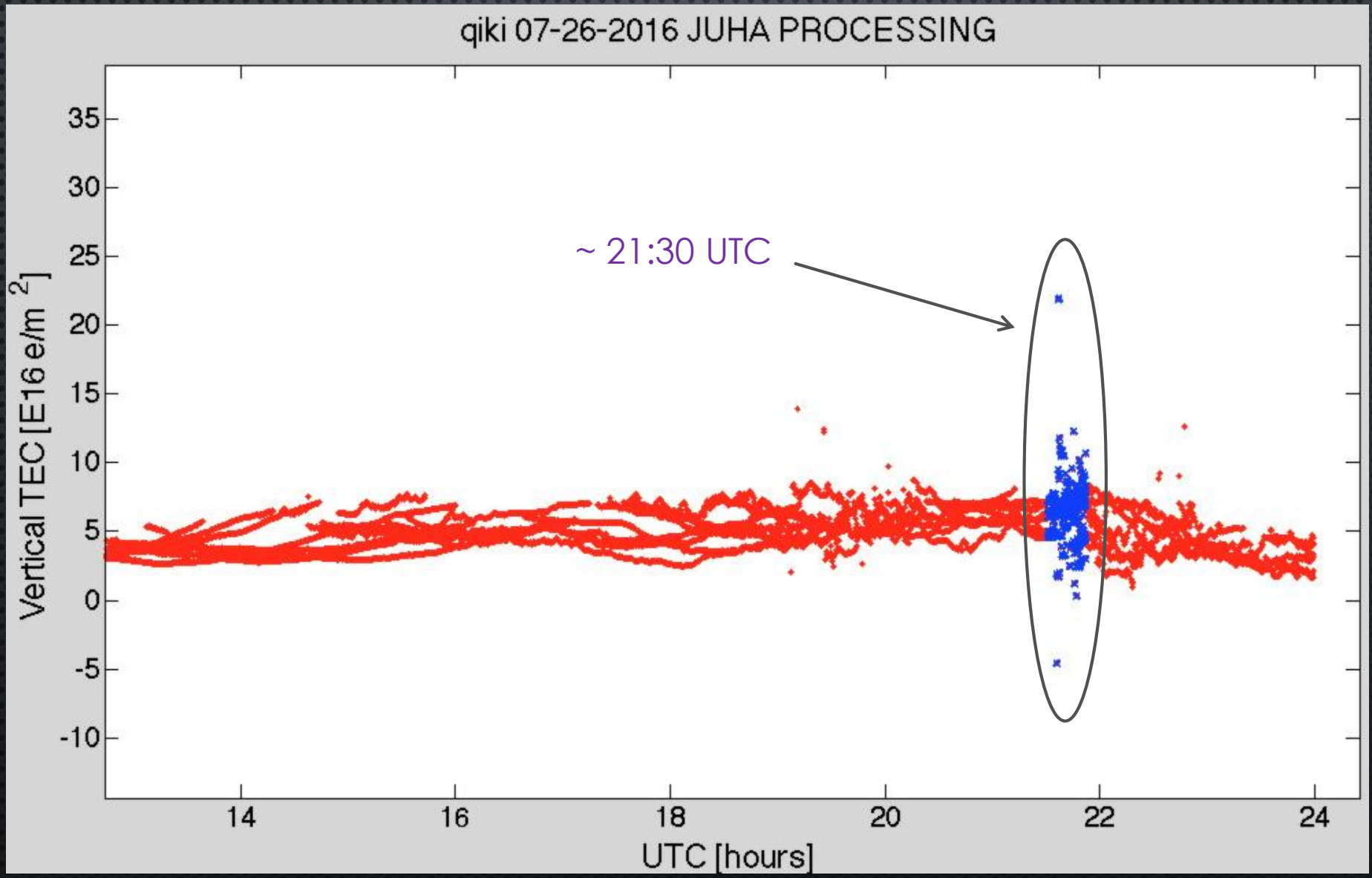
$$TEC = \frac{|P_{L1} - P_{L2}|}{40.3}\left(\frac{f_{L1}^2 f_{L2}^2}{f_{L1}^2 - f_{L2}^2}\right)$$

Where f_{L1}= 1575.42 MHz , f_{L2}= 1227.6 MHz

GPS TEC DATA [66.99° N 50.93° W]



GPS TEC DATA [67.56°N 64.03° W]



Conclusions

- Sondrestrom measured strong N_E enhancements in the auroral zone
  - Likely due to precipitation
  - Not enough coverage to see both boundaries
  - Correlates well with other observations
    - SSUSI
    - GPS TEC
    - Magnetometers
- Small upflow above the radar signature of ionospheric feedback
  - Only first step of outflow process

Acknowledgements

- Mary McCready (Sondrestrom data and all her help interpreting the data)
- Anthea Coster (TEC data)
- JHU/APL (SSUSI)
- ACE, Kyoto WDC
- UiT (Mag data)
- EISCAT

Questions?