Three-Dimensional Modeling of High-Latitude Scintillation

Alex T. Chartier[1], Biagio Forte[2], Kshitija B. Deshpande[3], Gary S. Bust[1]

[1] Johns Hopkins University Applied Physics Laboratory
[2] University of Bath
[3] Virginia Tech

Outline

- Observations
- Modeling
- Conclusions

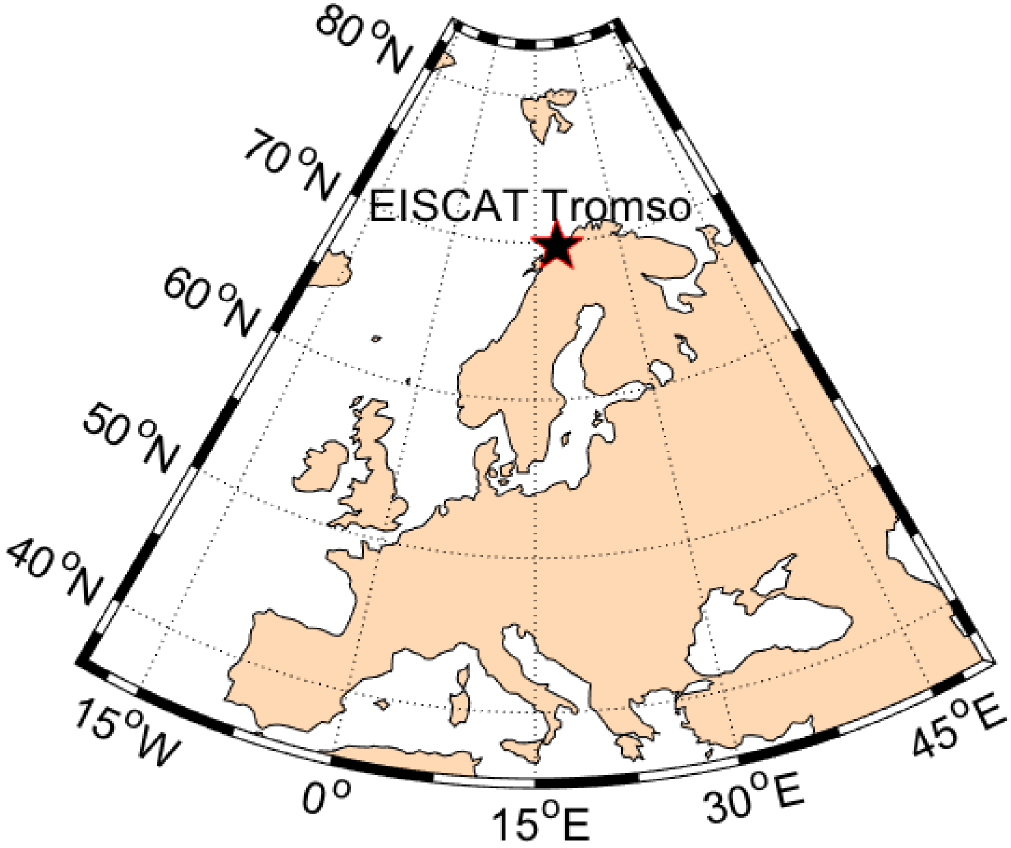
Observations

- Electron density profiles: EISCAT ISR Tromso
- Small-scale structures: 50hz GPS receiver Tromso
- Aurora: All-sky camera Ramfjordmoen (just south of Tromso)
- Field-aligned currents: SuperMAG
- Magnetosphere: THEMIS satellites

Observations

Date: 17 October 2013,
Time: 18:00 – 21:00 UT

Radar Location

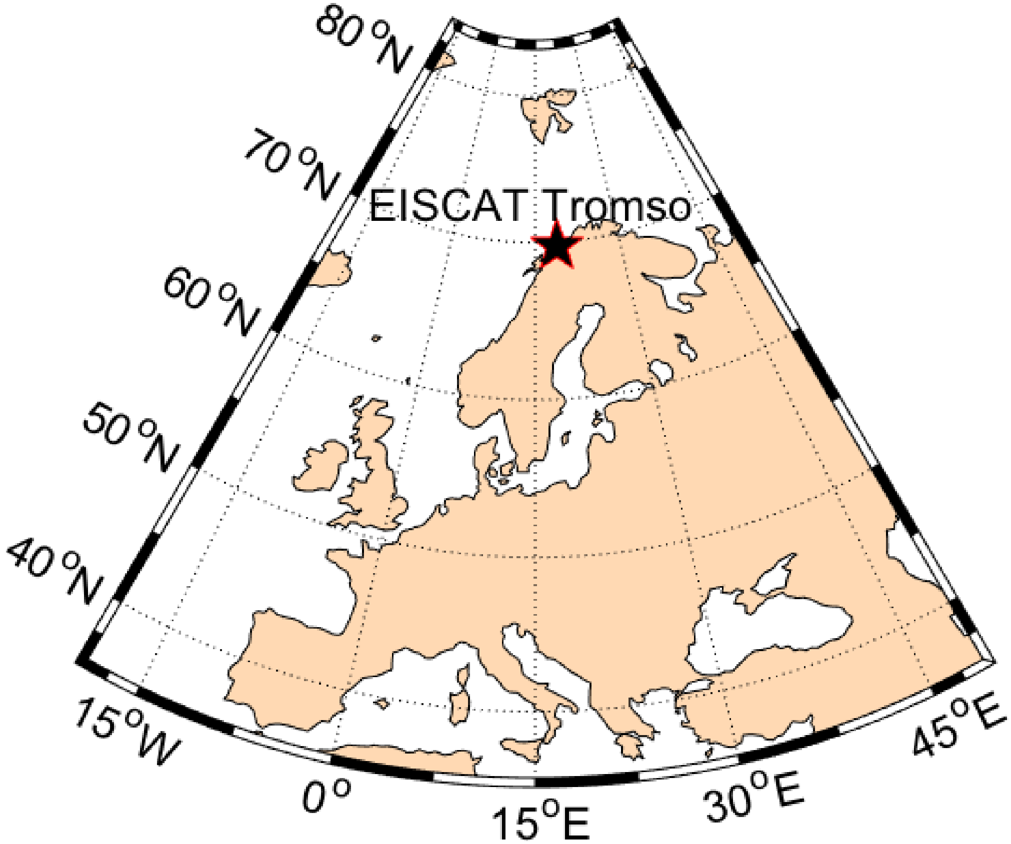


Observations

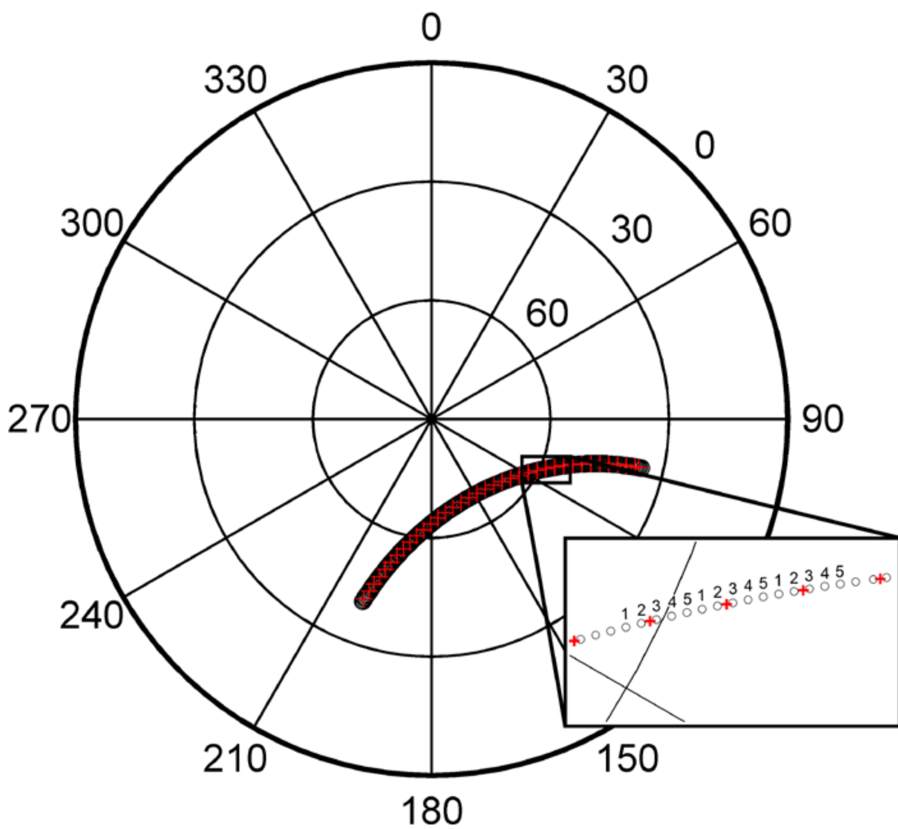
Date: 17 October 2013,
Time: 18:00 – 21:00 UT

EISCAT tracks GPS satellite (**PRN 23**)

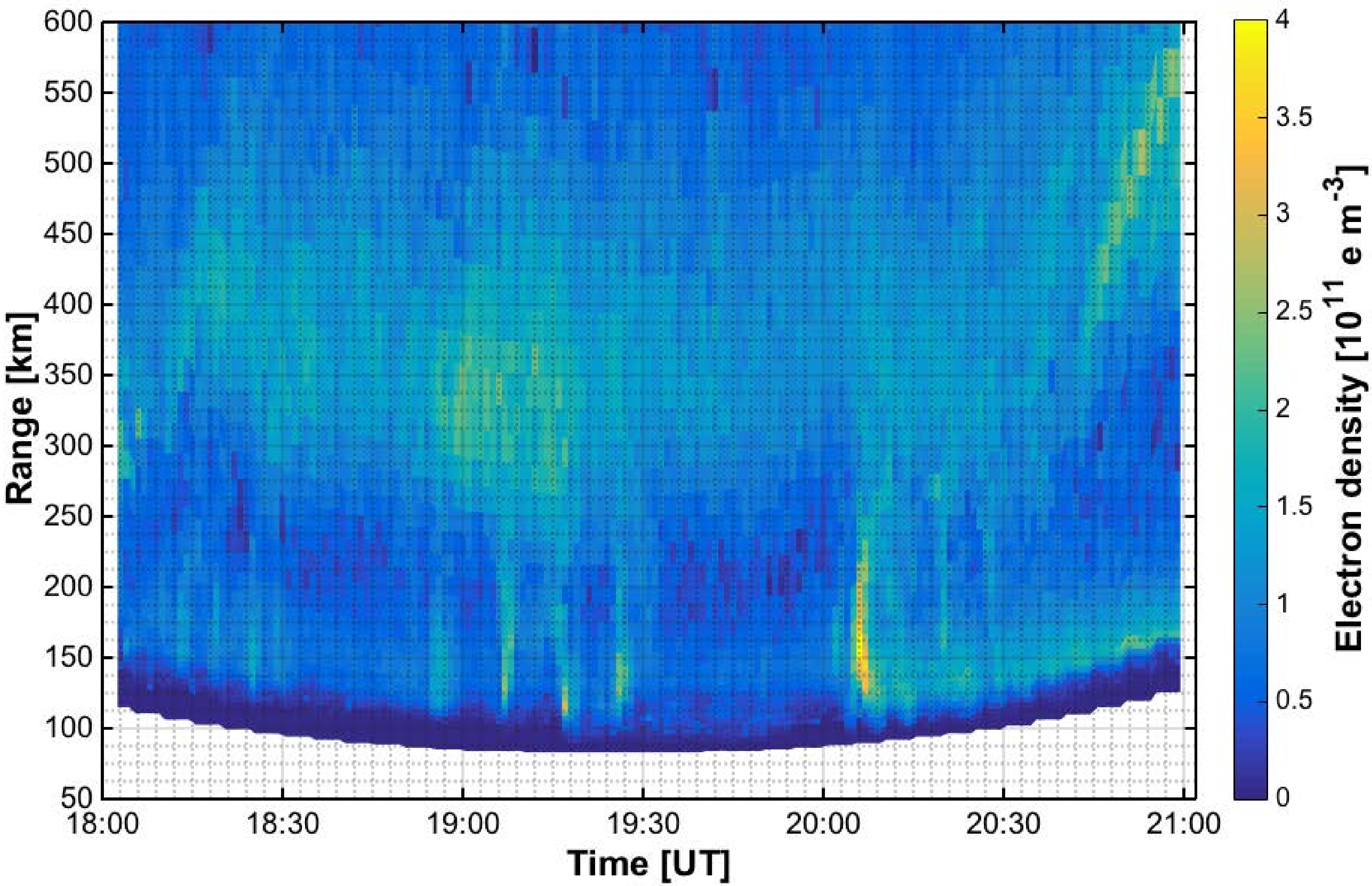
Radar Location



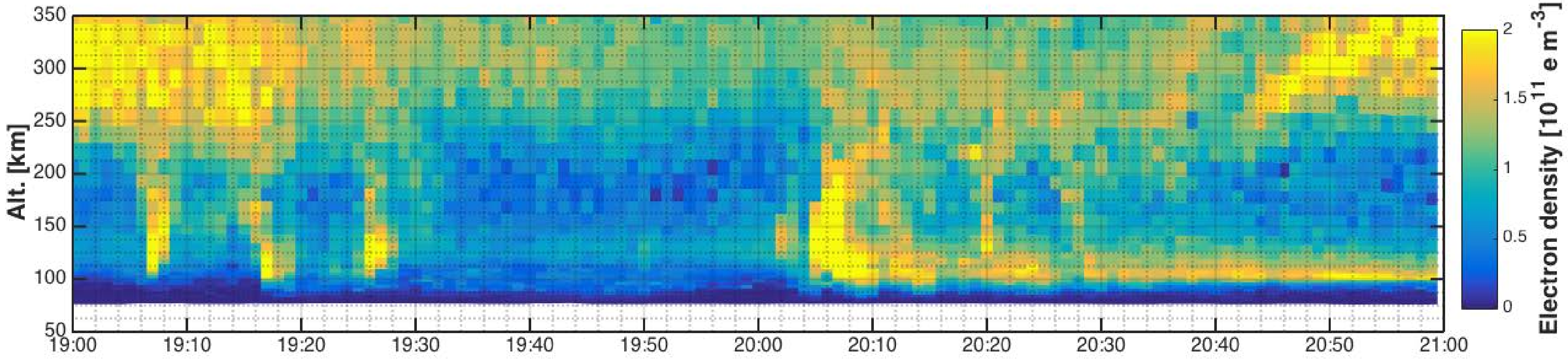
Beam Direction



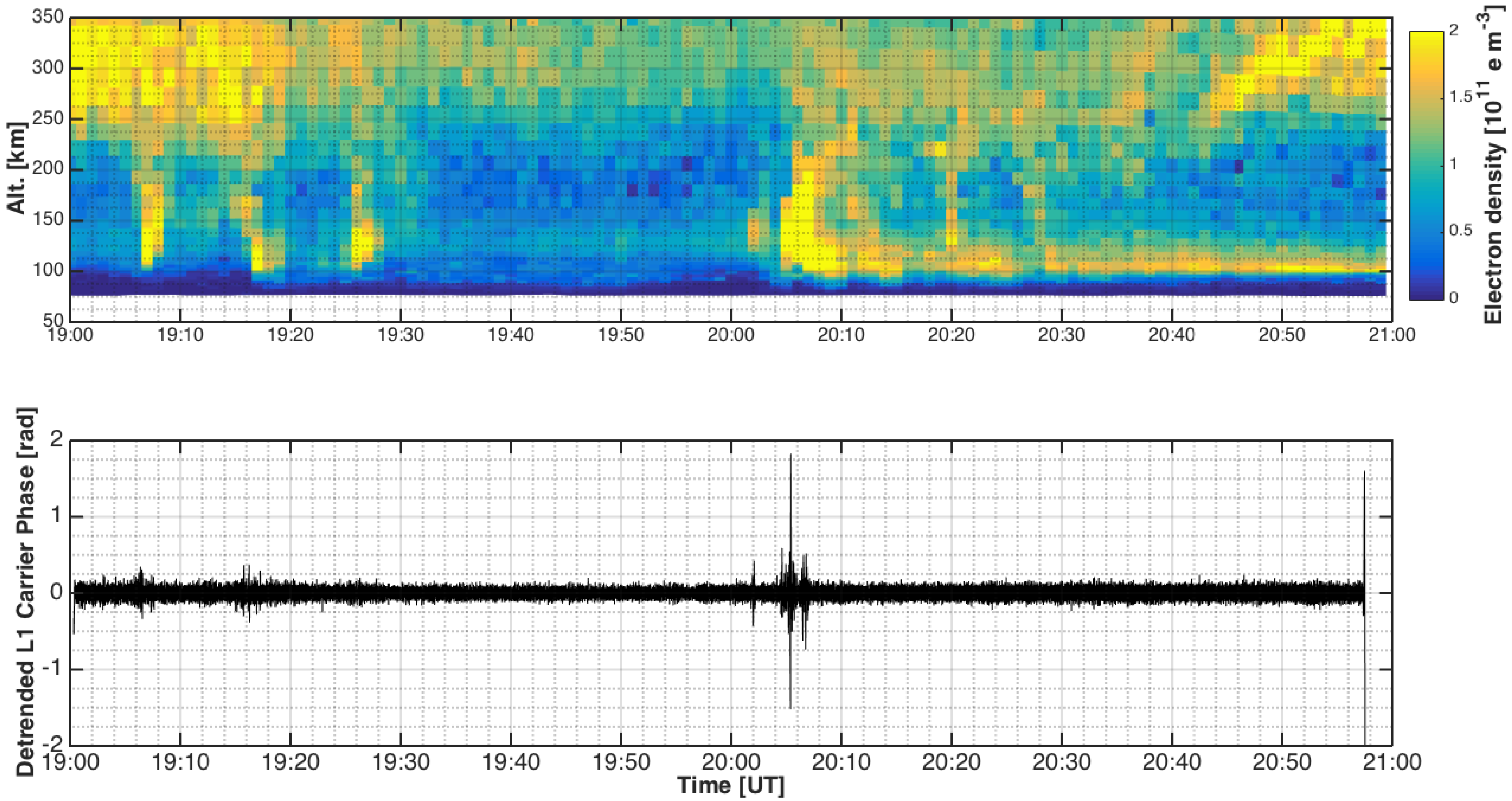
Observations: EISCAT



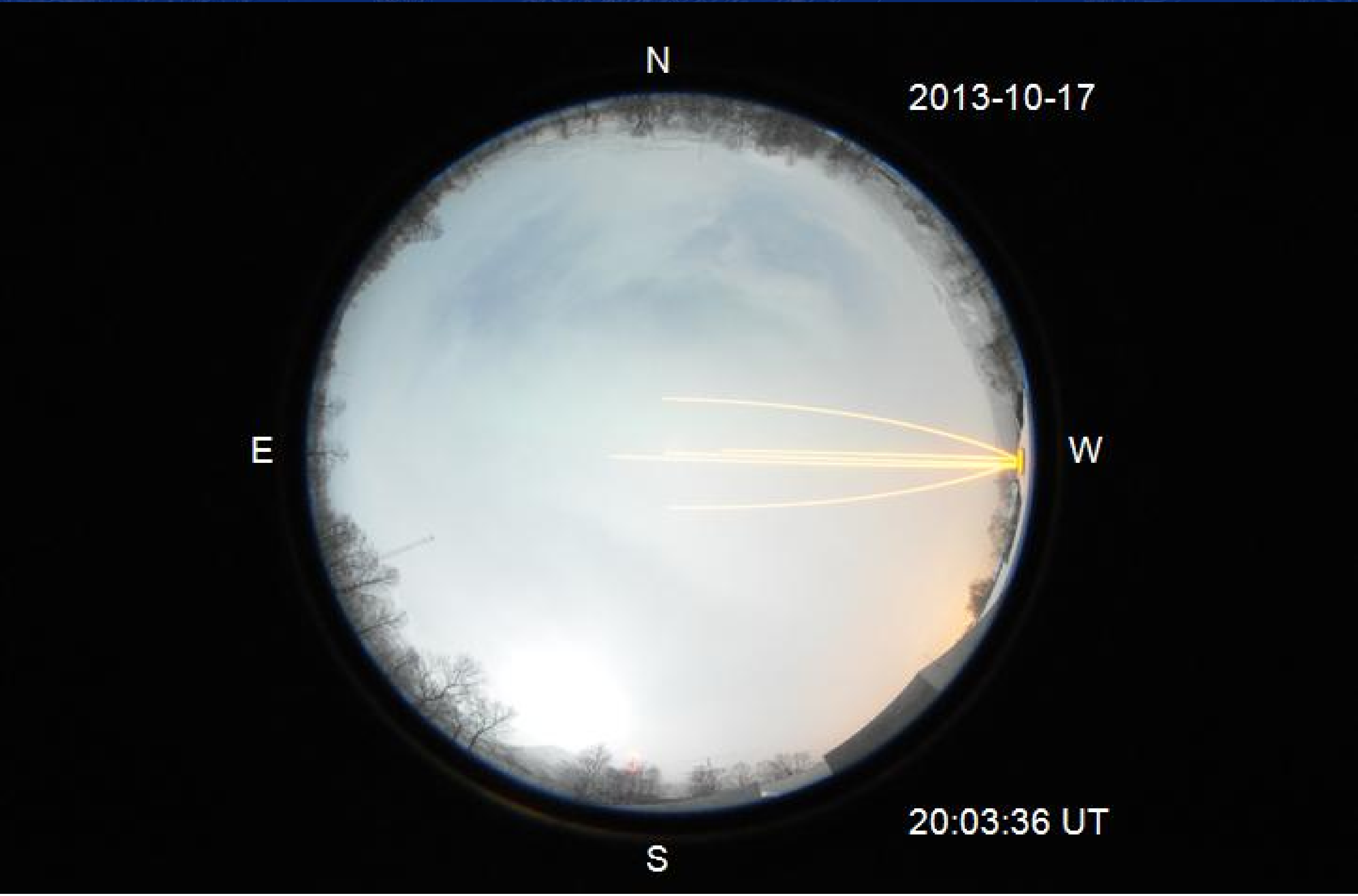
Observations: EISCAT



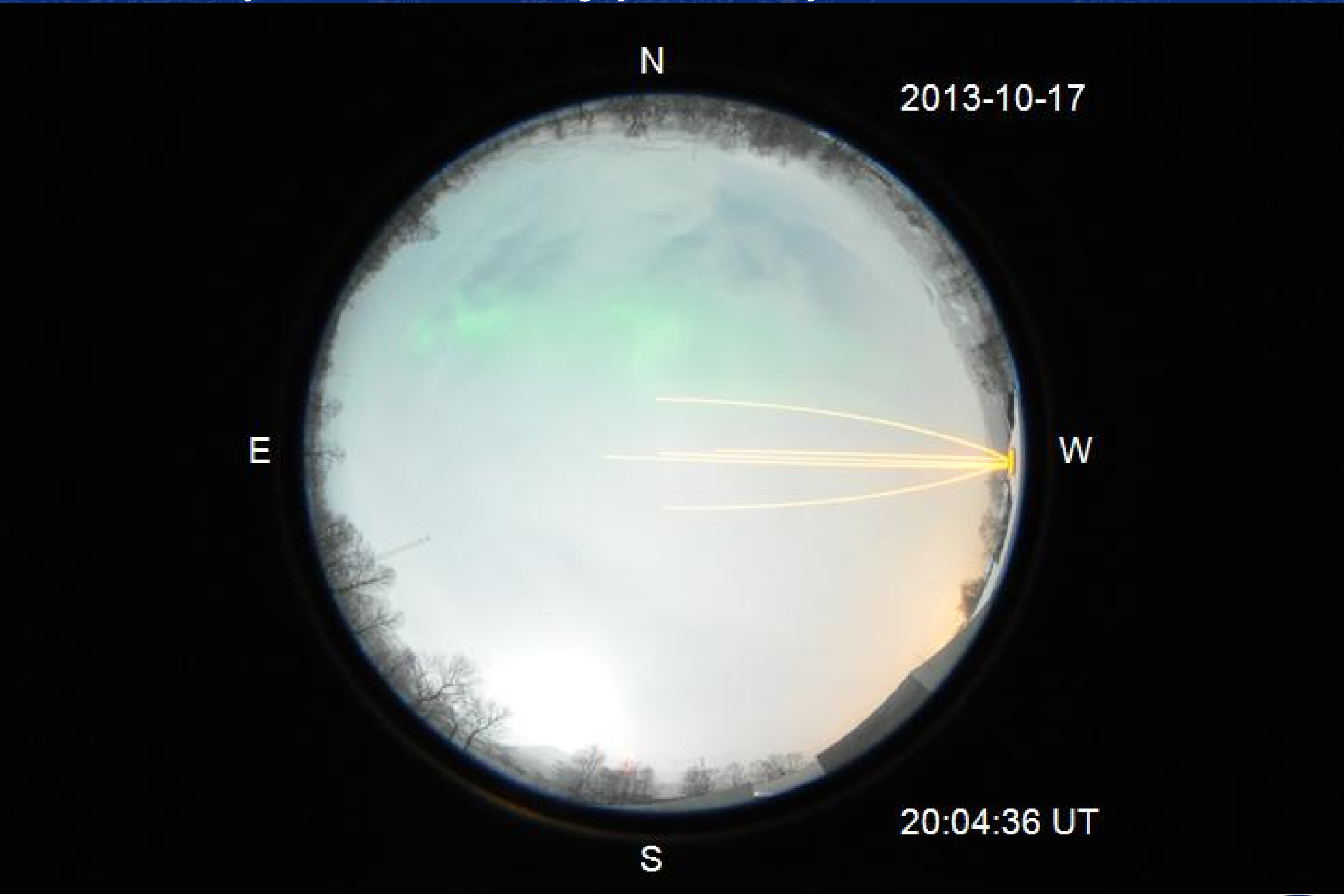
Observations: EISCAT + 50hz GPS



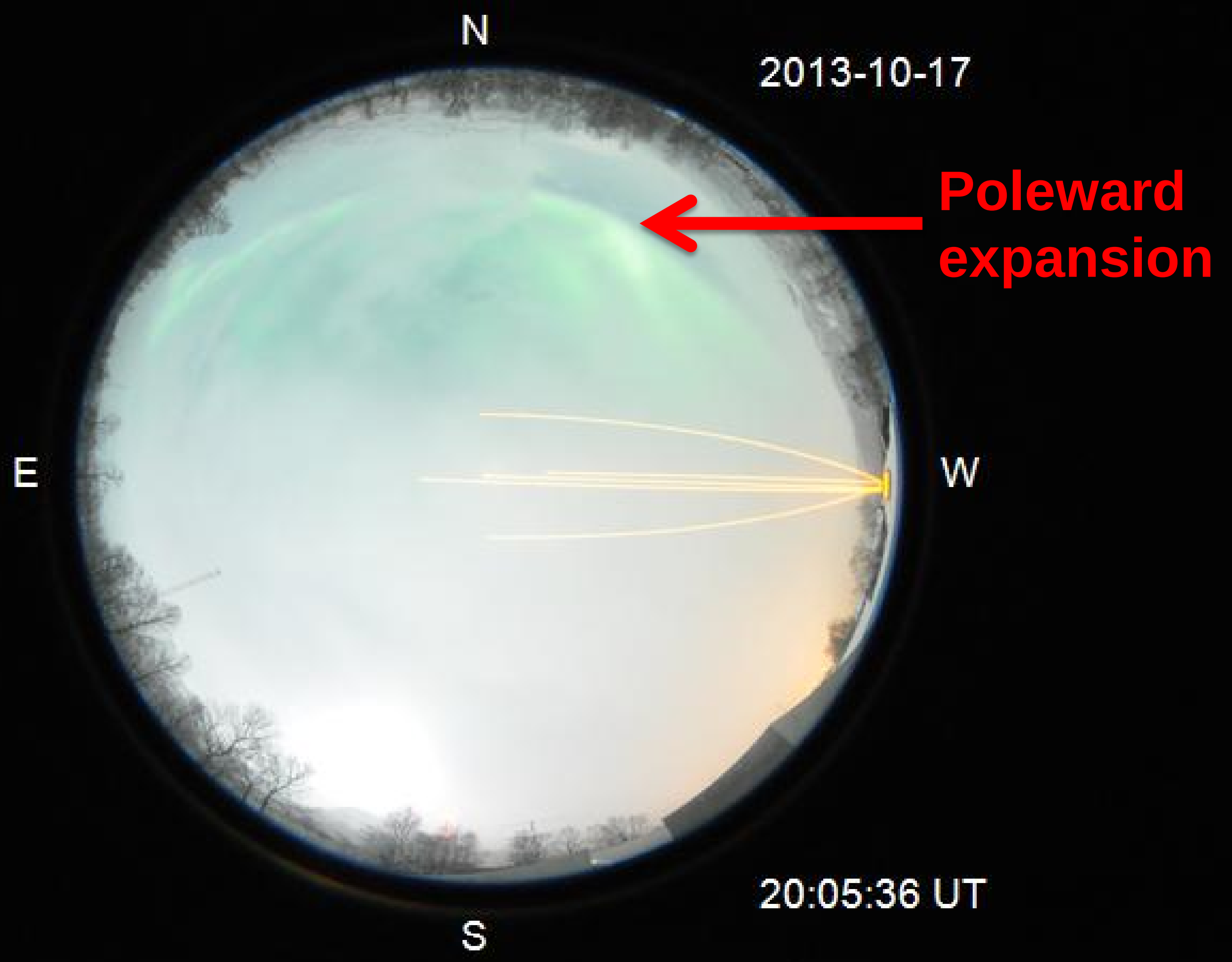
Tromso all-sky camera STELab Nagoya University



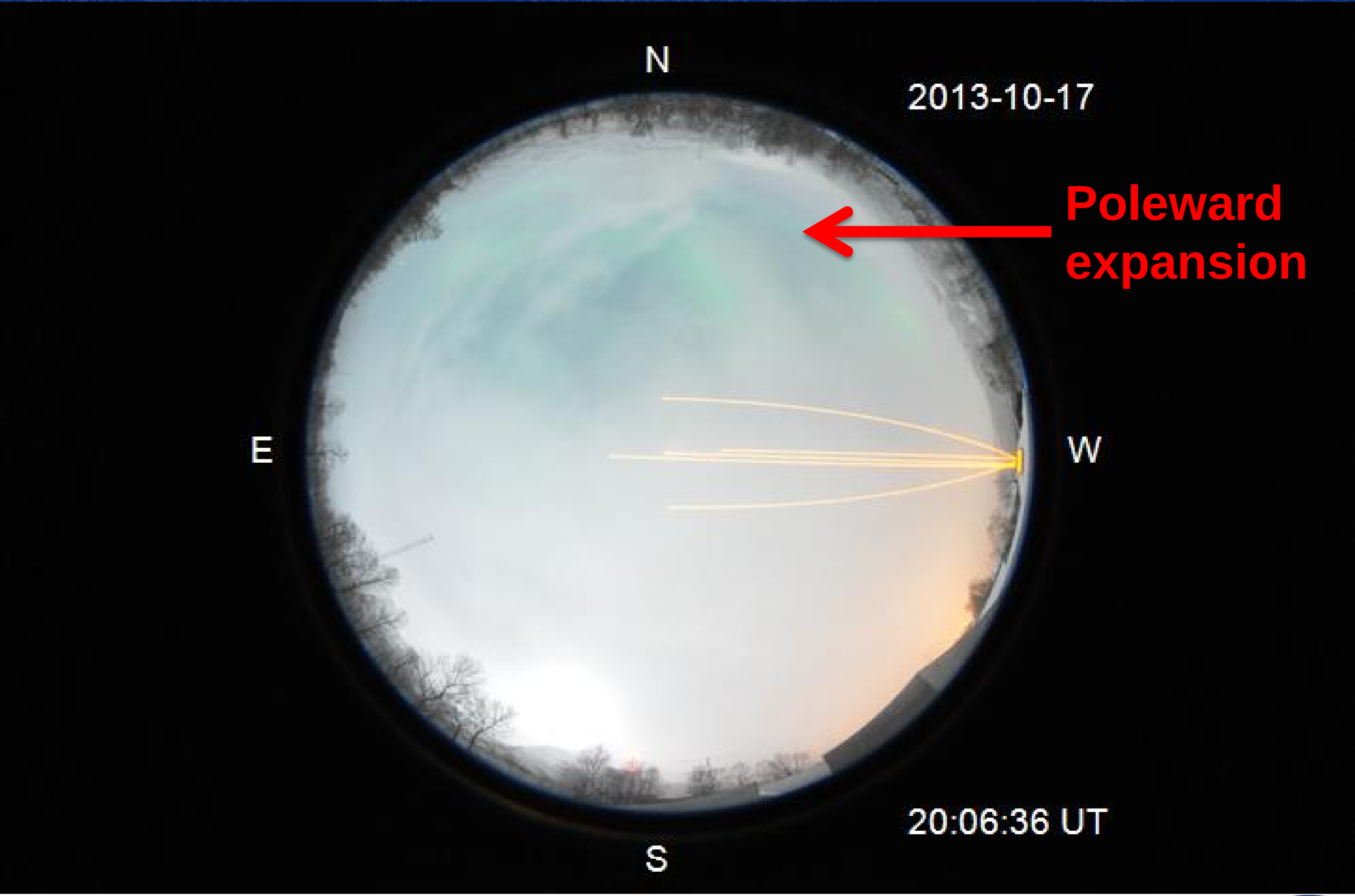
Tromso all-sky camera STELab Nagoya University



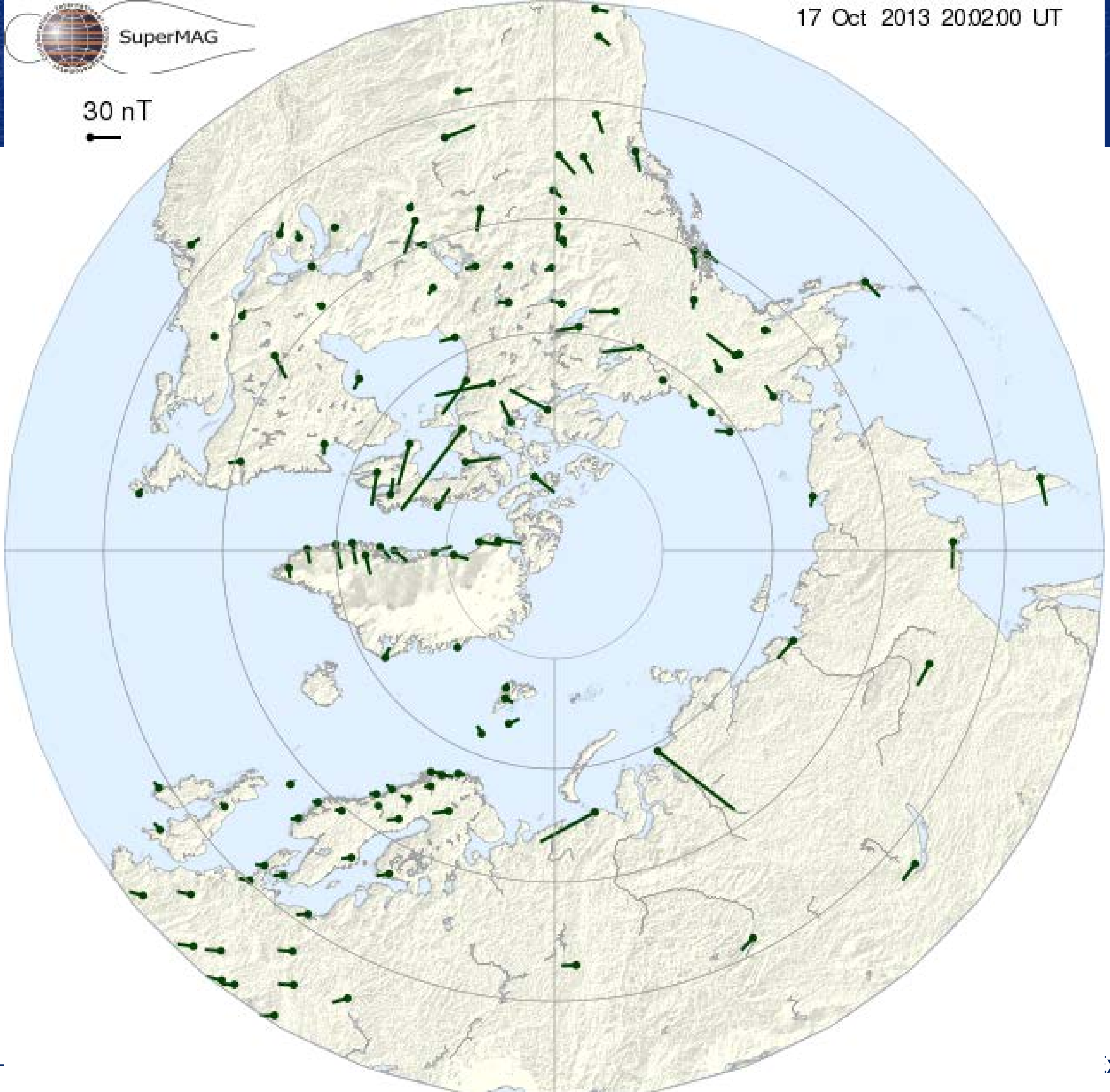
Tromso all-sky camera STELab Nagoya University



Tromso all-sky camera STELab Nagoya University

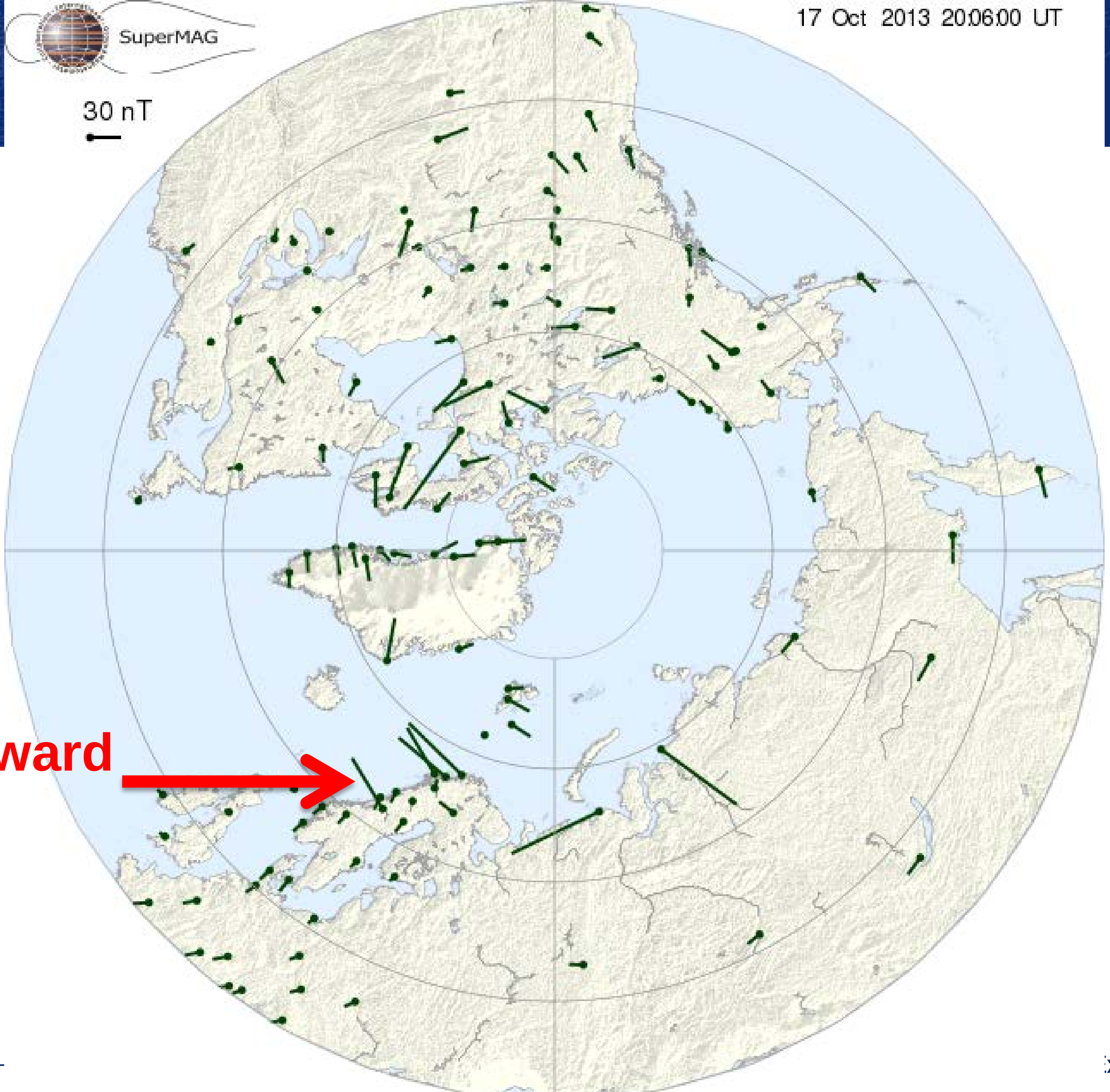



SuperMAG
30 nT
17 Oct 2013 20:00:00 UT

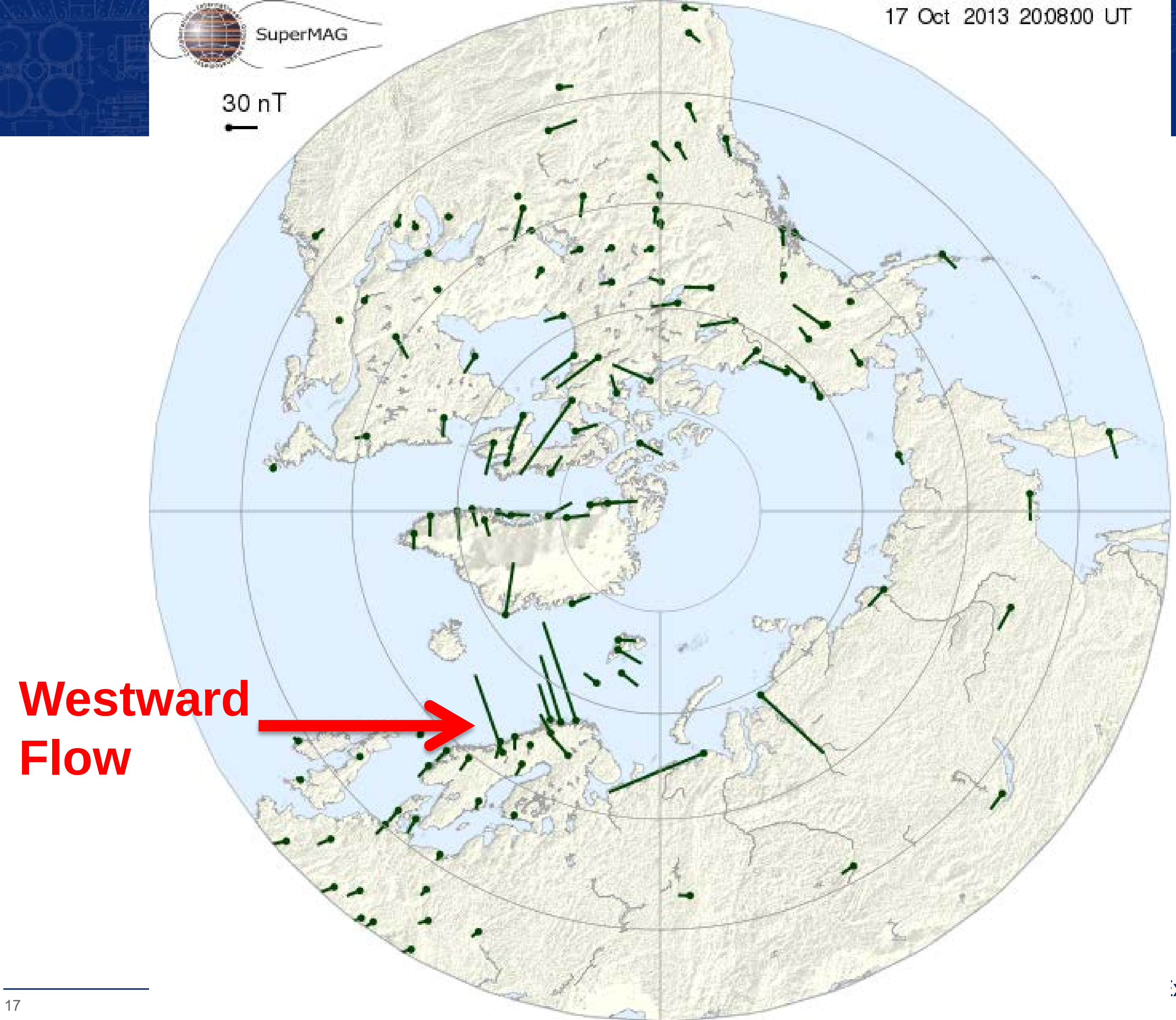


Exploration

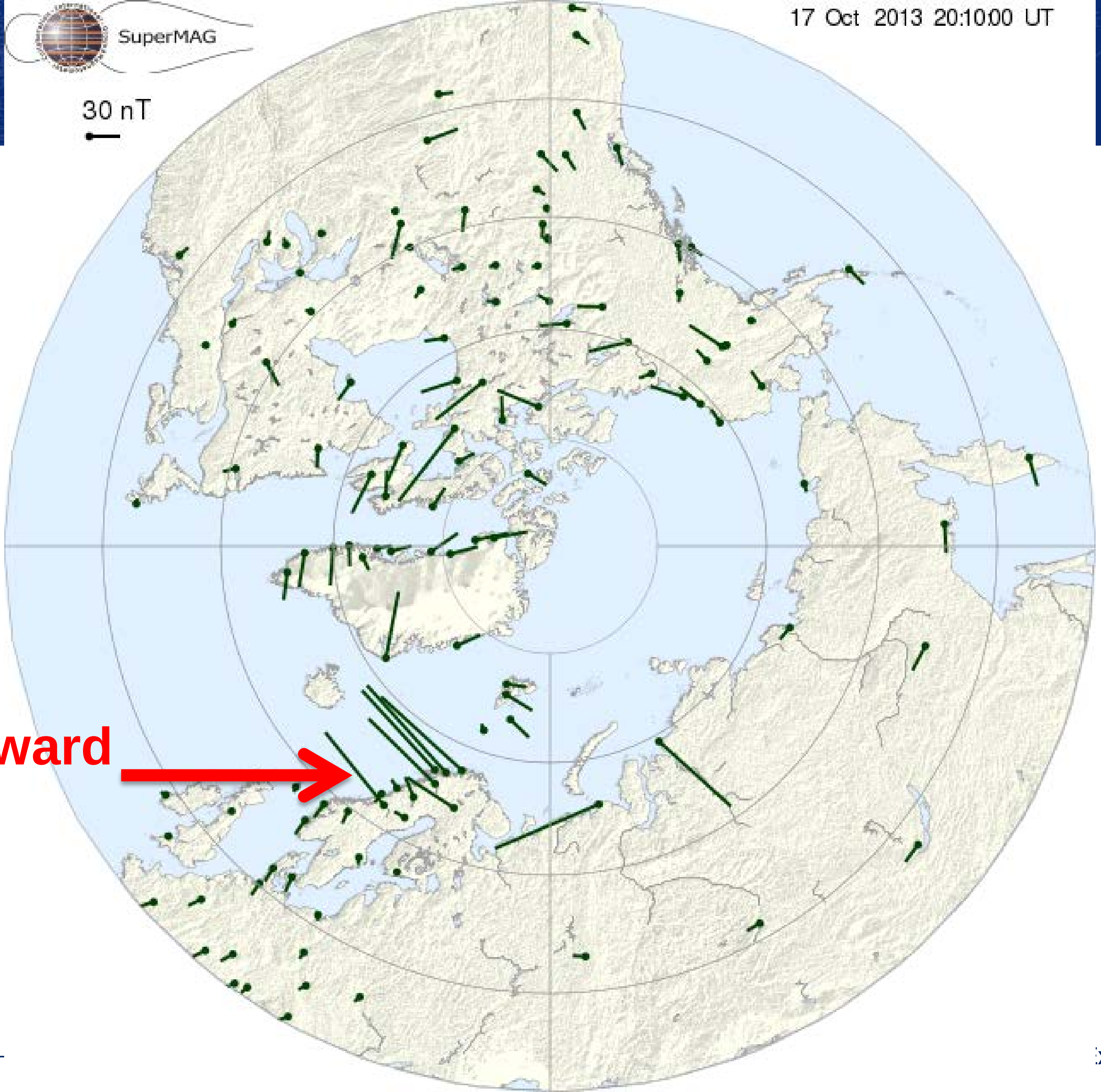
Westward Flow



Westward Flow

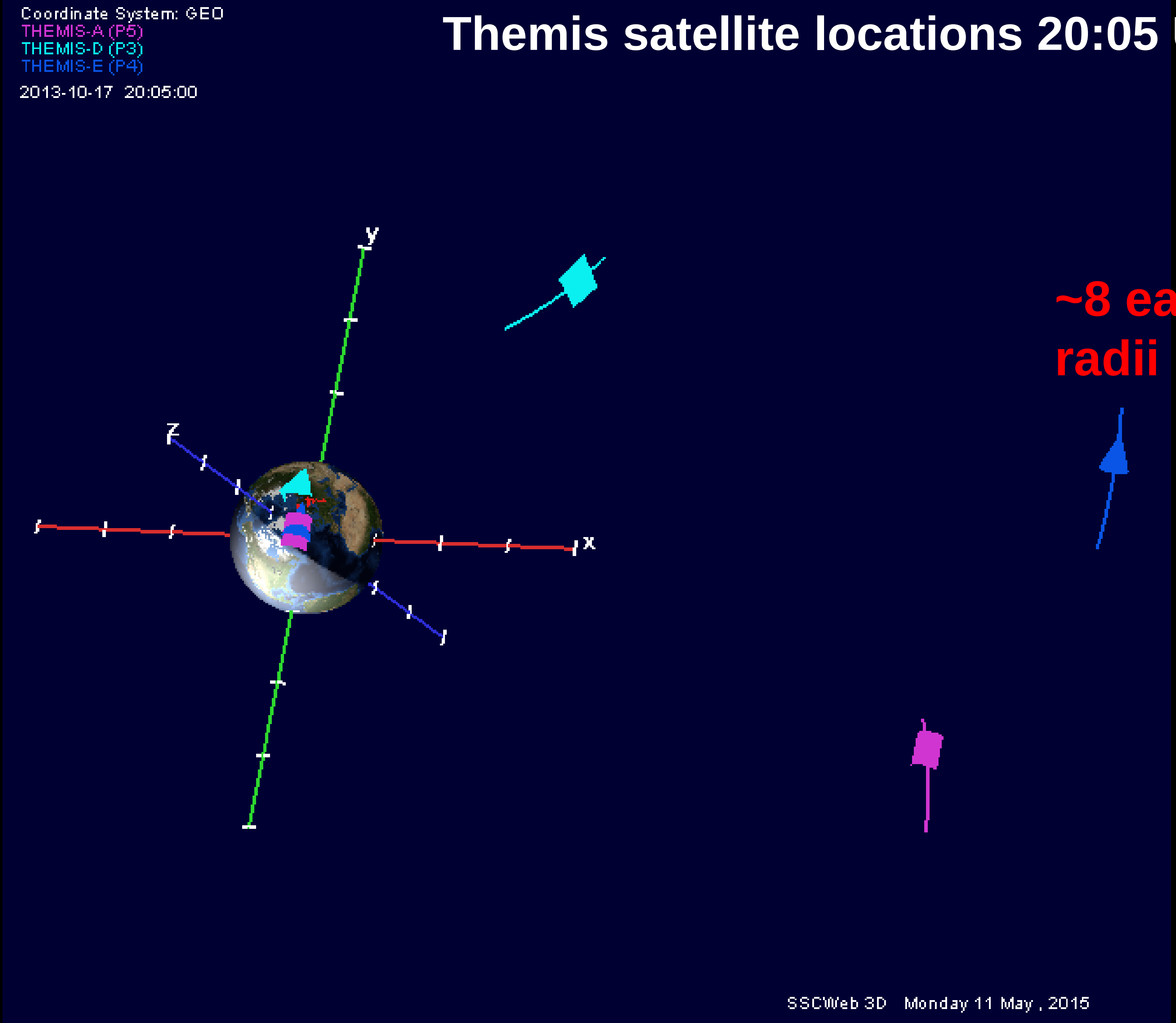


SuperMAG
30 nT
17 Oct 2013 20:08:00 UT
Westward
Flow

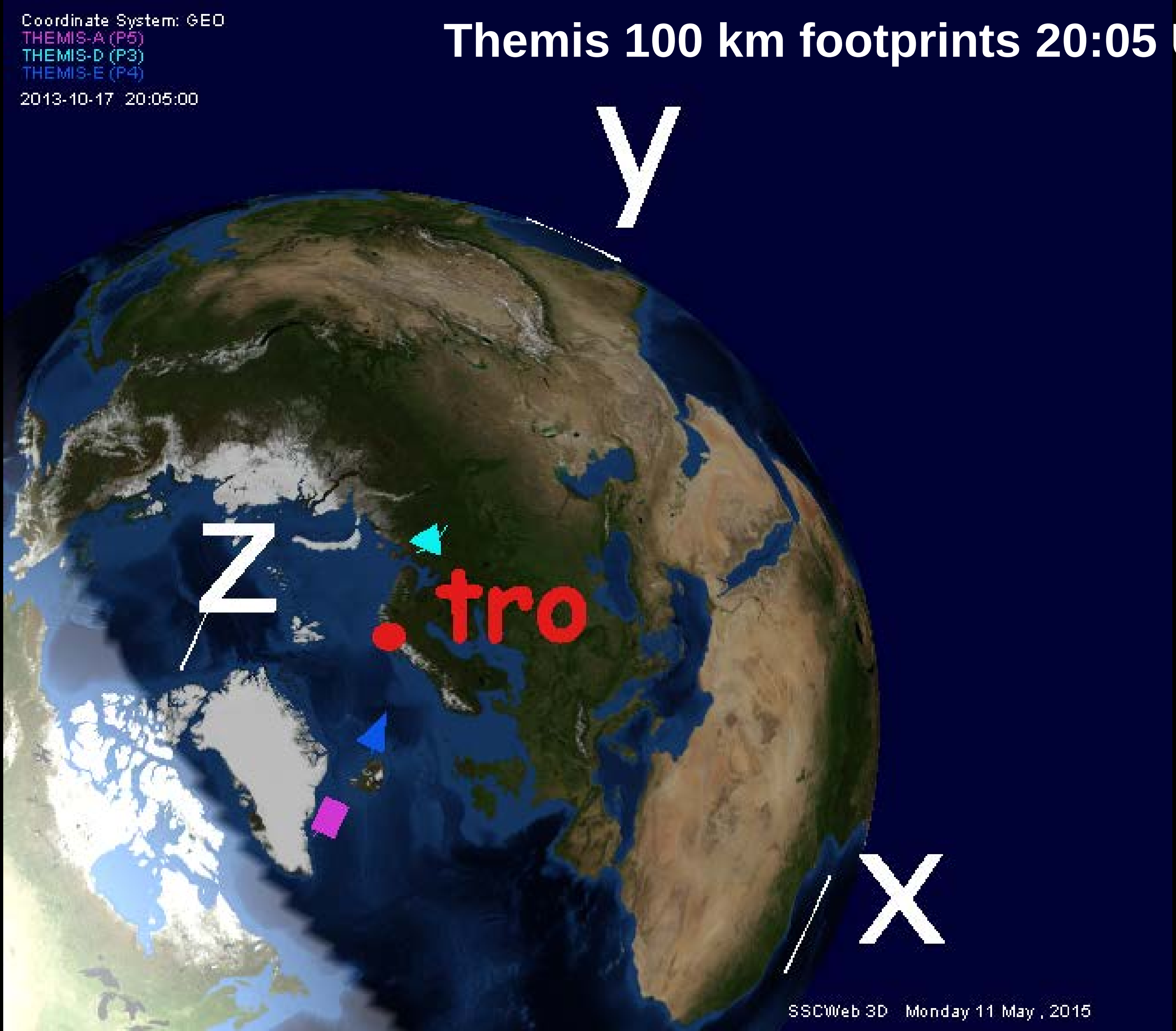


Westward Flow

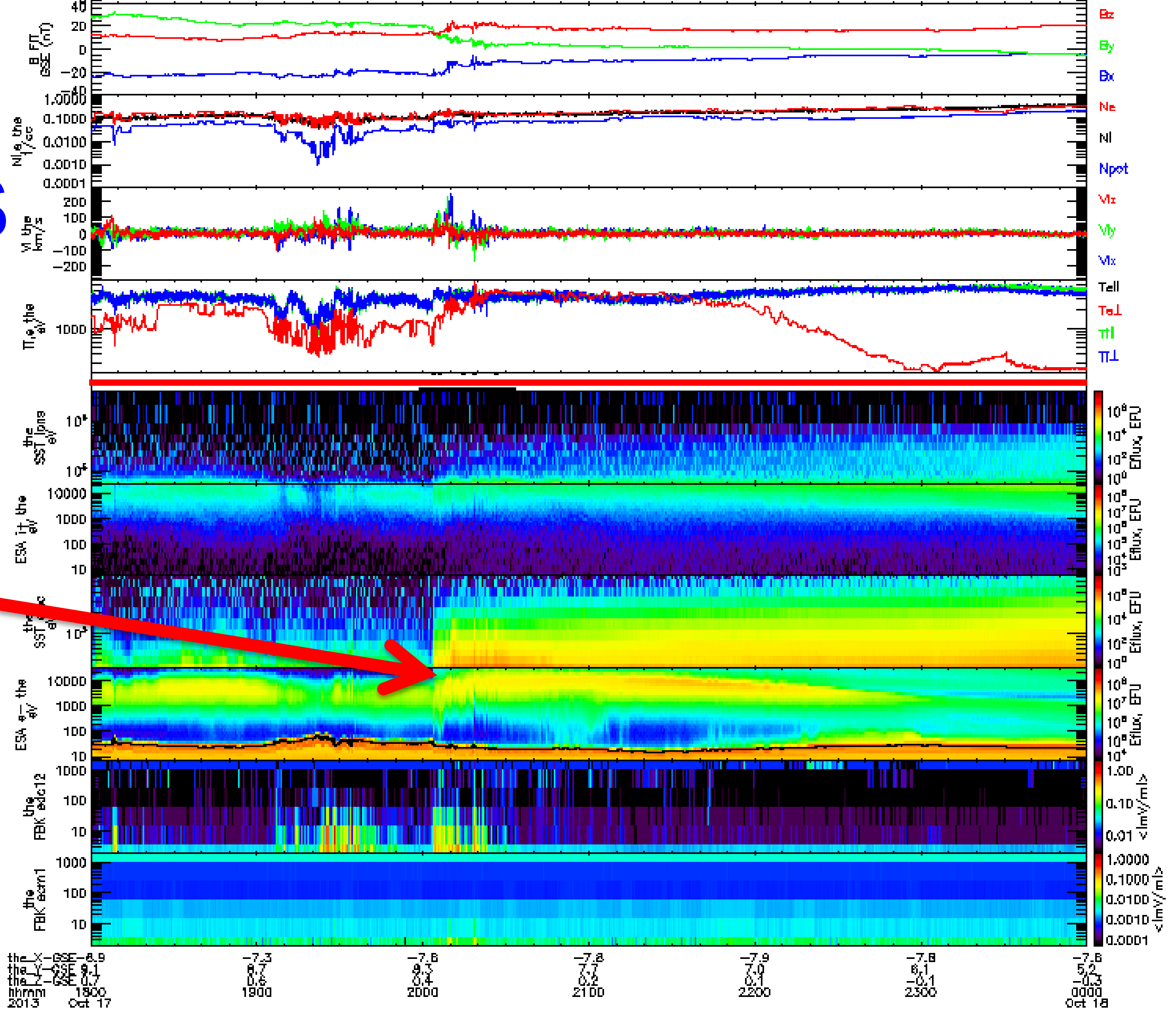
Themis satellite locations 20:05 UT



Themis 100 km footprints 20:05 UT



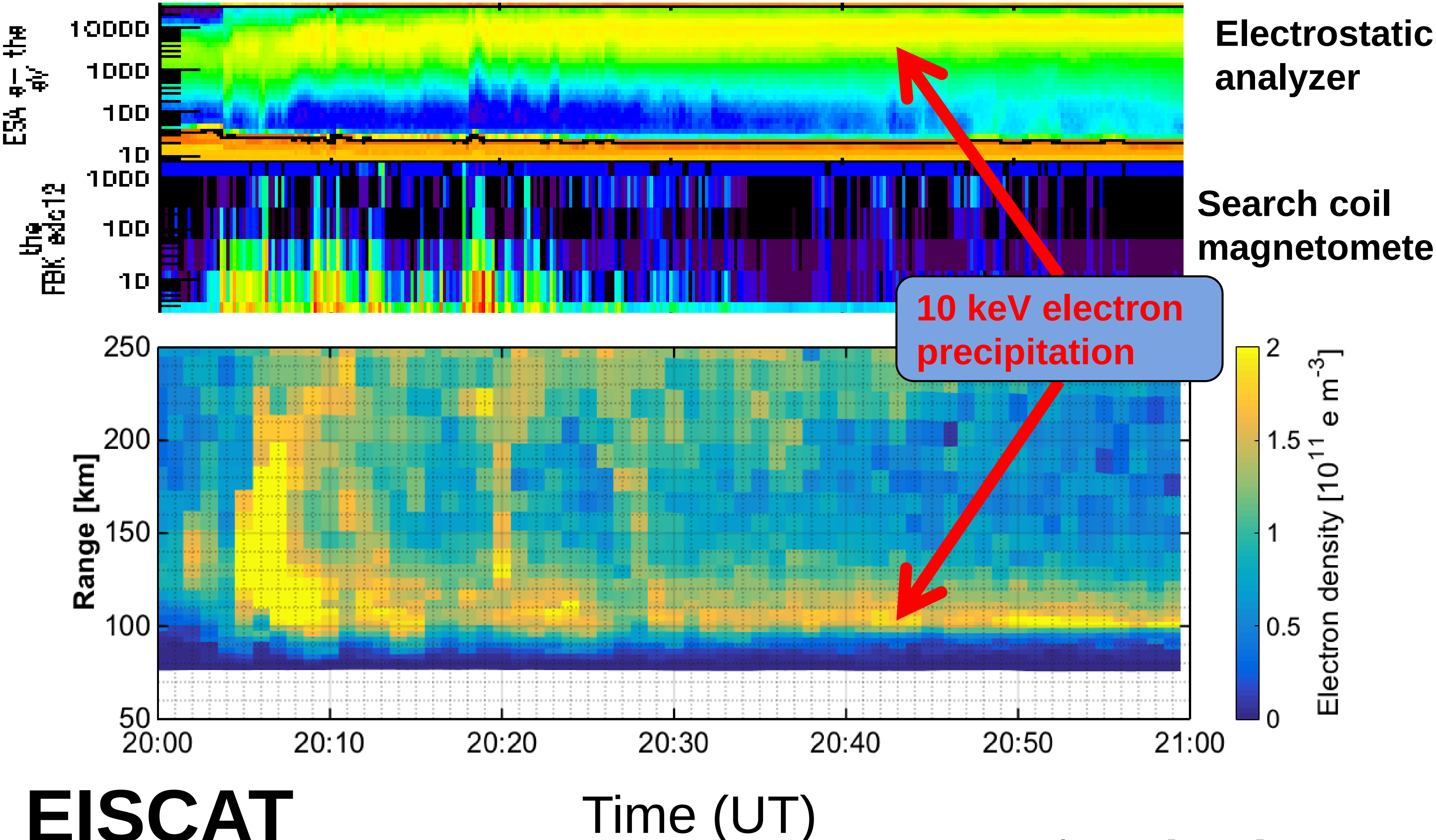
THEMIS P4



Electron Precipitation ~20:04 UT

18:00 UT 20:00 UT 22:00 UT 24:00 UT

THEMIS P4



Solomon [2001]

Modeling

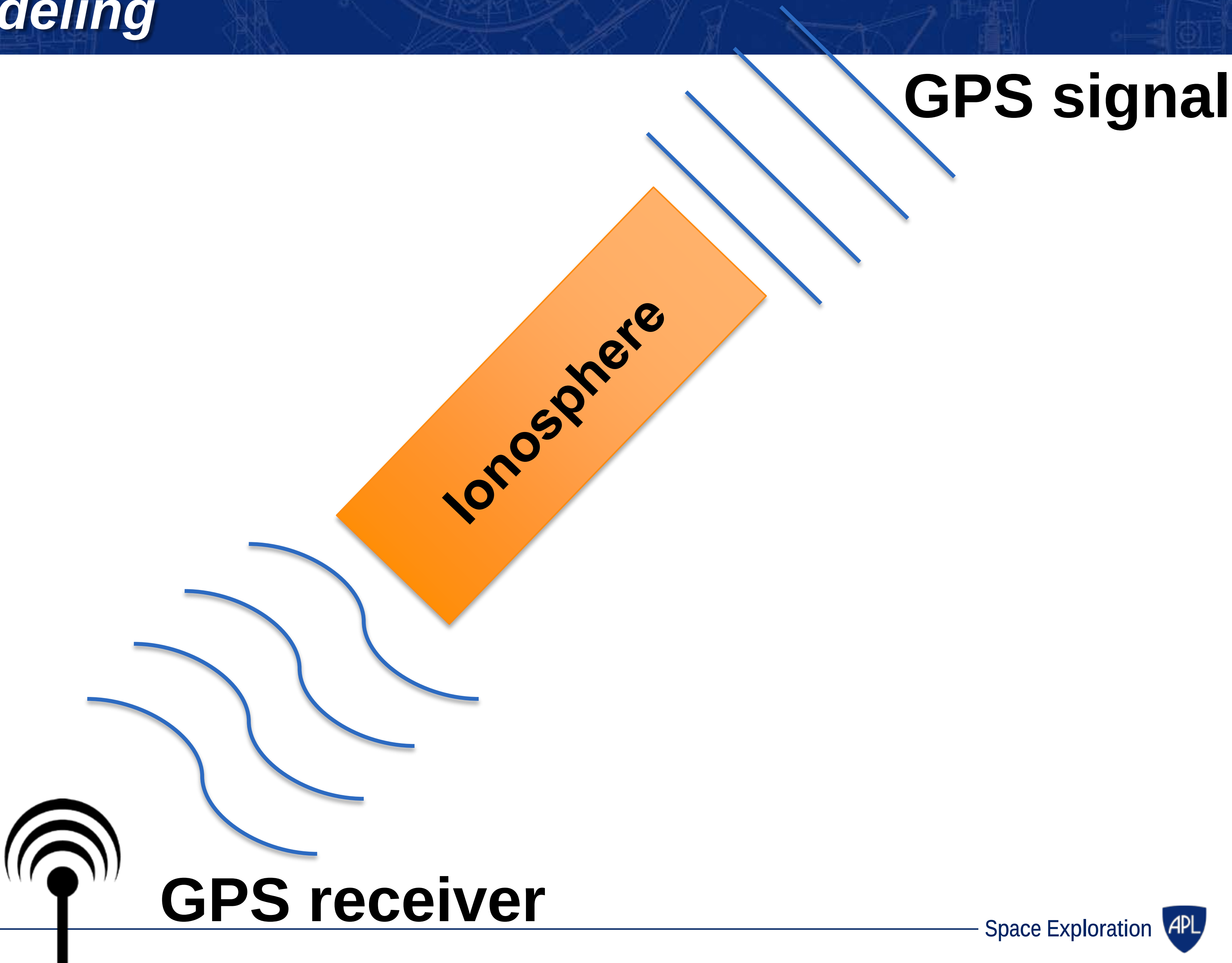
- 3D multiple phase screen signal propagation [*Rino,* 1979]. 60 phase screens, 5 x 5 x 400 km volume

- 2 km cross-track gradient. 330 m/s drifts

- Thick, anisotropic ionospheric irregularity layer [*Costa & Kelley,* 1977]
  - Axial ratio: 5
  - Spectral index: 3
  - Outer scale: 5 km

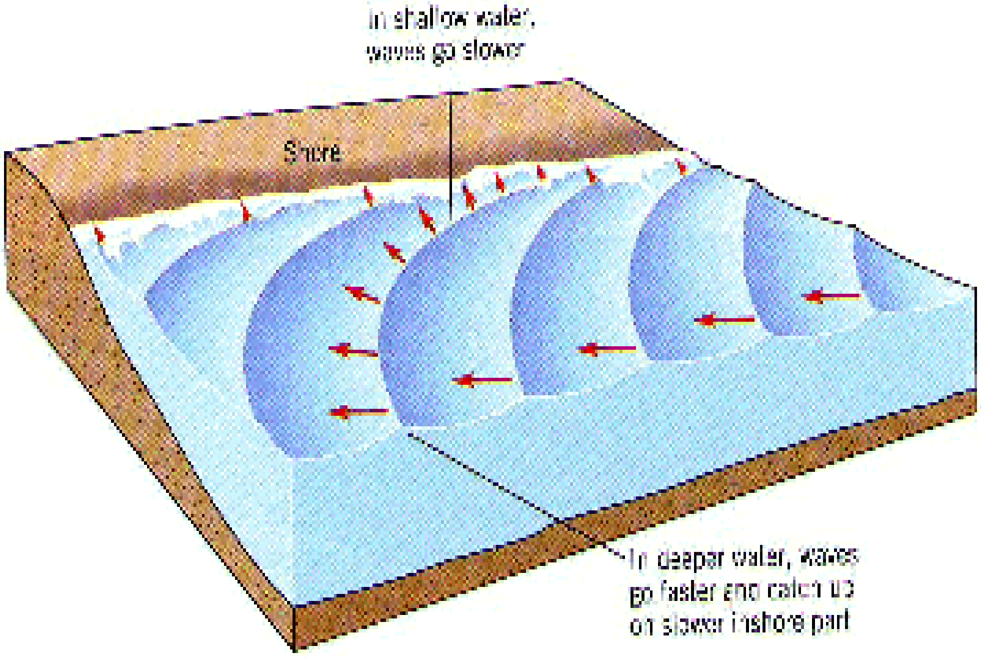
- SIGMA model implemented by *Deshpande et al.* [2014], geometry modified here

Modeling



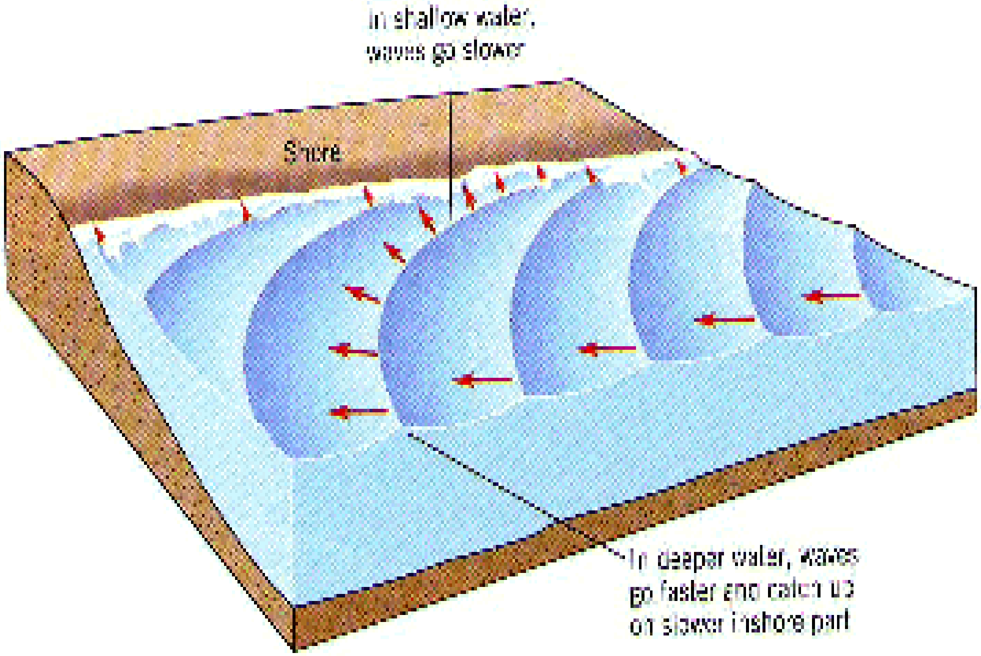
Modeling

Refraction

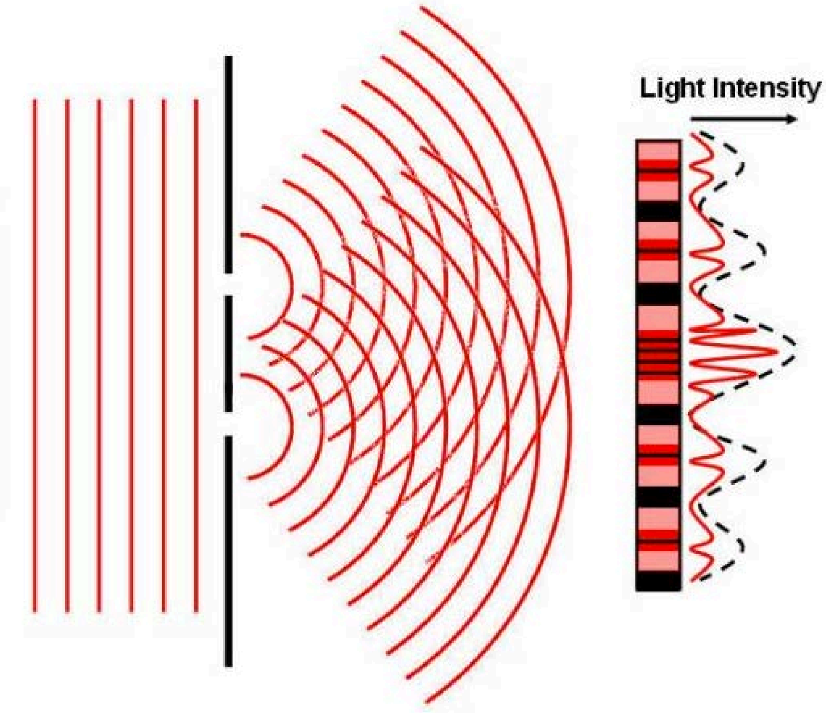


Modeling

Refraction



Diffraction



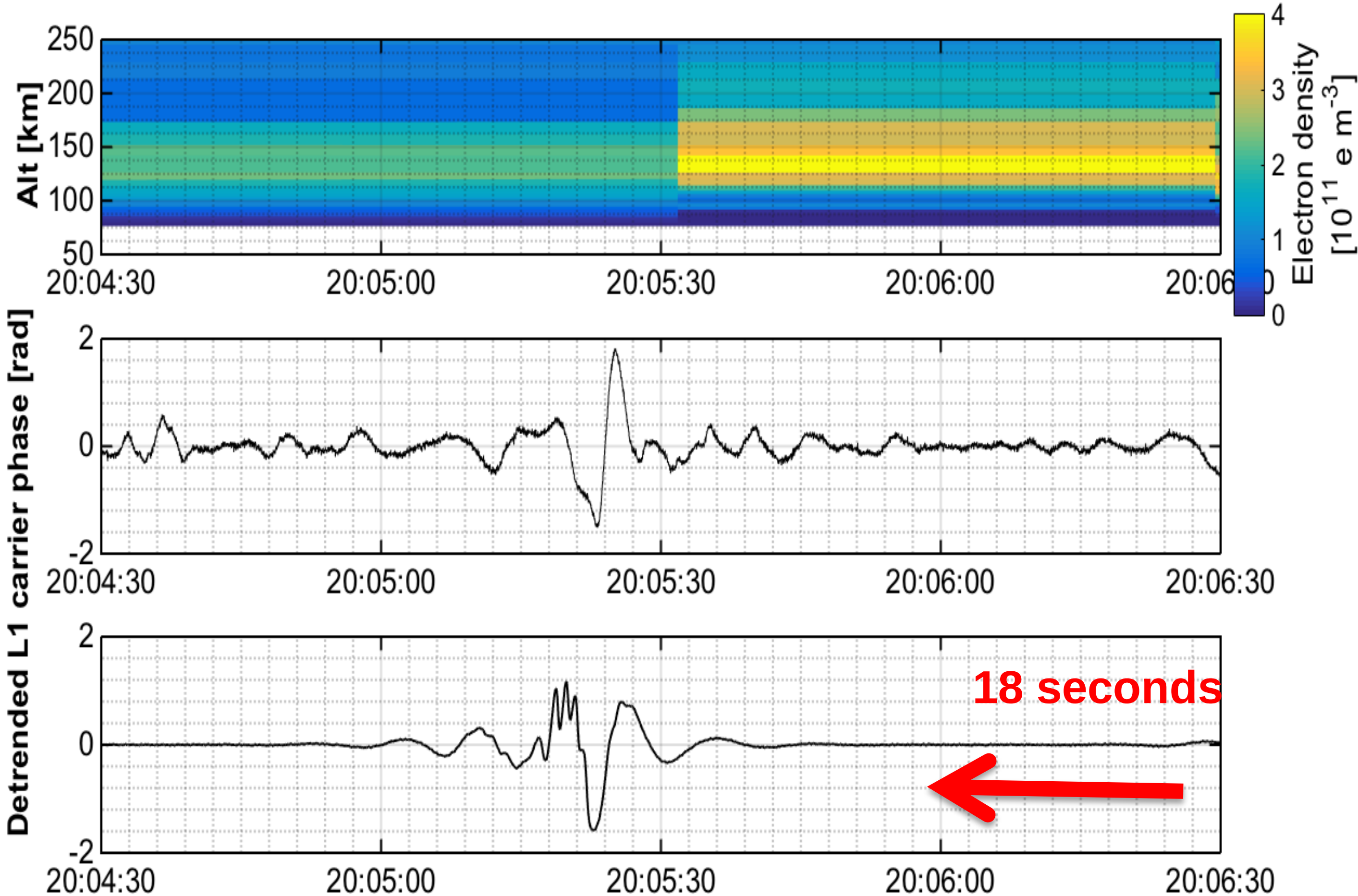
Modeling

Parameter	Value
Cross-track velocity	330 m/s
Gradient size	2 km
Irregularities	**None**
Sample rate	10 Hz

EISCAT

Observed

Refractive Model



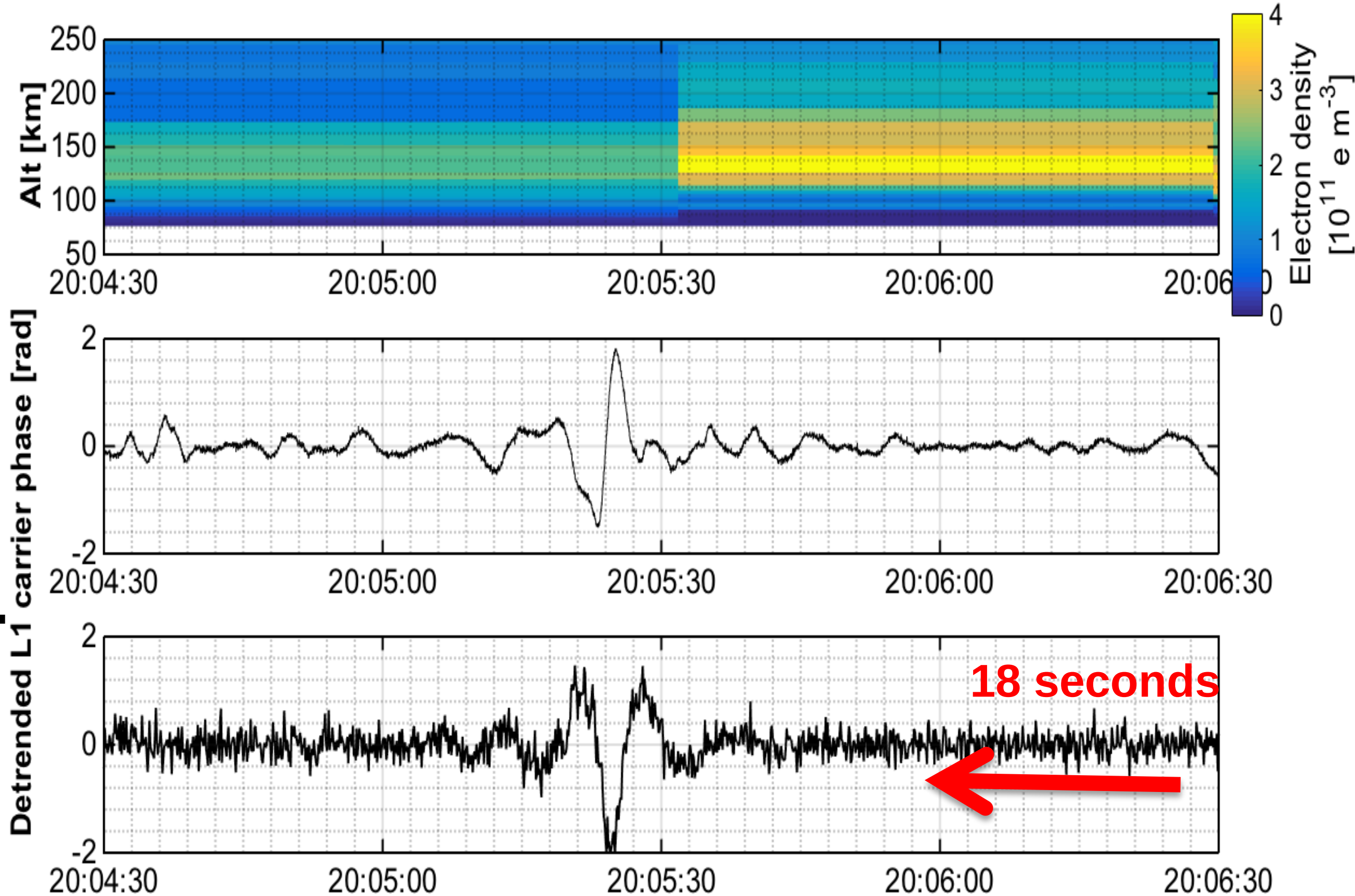
Modeling

Parameter	Value
Cross-track velocity	330 m/s
Gradient size	2 km
Irregularities	**0.5 %**
Sample rate	10 Hz

EISCAT

Observed

Refractive + Diffractive Model



Summary

Substorm onset identified using GPS scintillation

Three-dimensional modeling approach developed

Refractive effects shown to be important

References

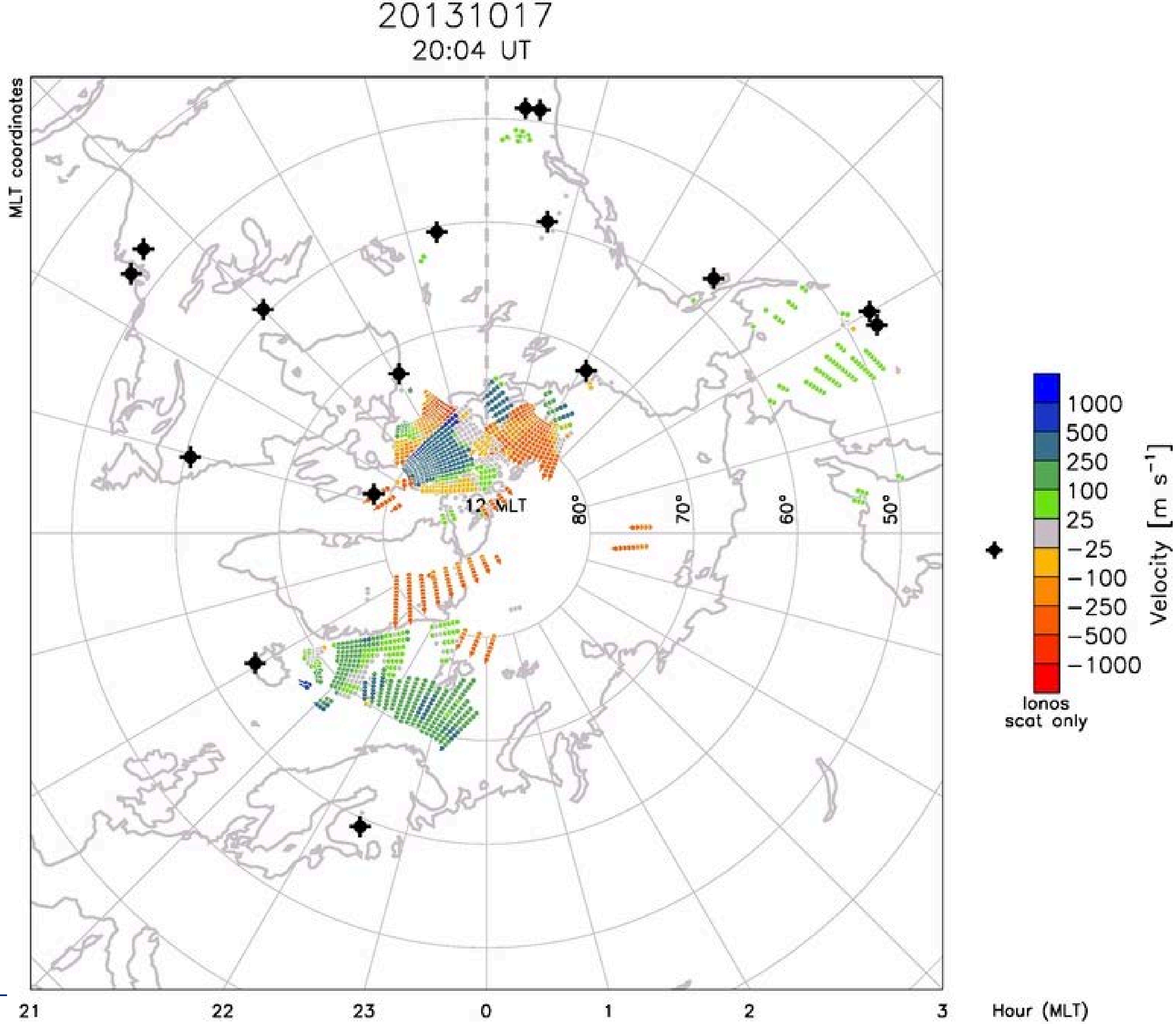
Costa, E., & Kelley, M. C. (1977). Ionospheric scintillation calculations based on in situ irregularity spectra. *Radio Science*, *12*(5), 797-809.

Deshpande, K. B., Bust, G. S., Clauer, C. R., Rino, C. L., & Carrano, C. S. (2014). Satellite-beacon Ionospheric-scintillation Global Model of the upper Atmosphere (SIGMA) I: High-latitude sensitivity study of the model parameters.*Journal of Geophysical Research: Space Physics*, *119*(5), 4026-4043.

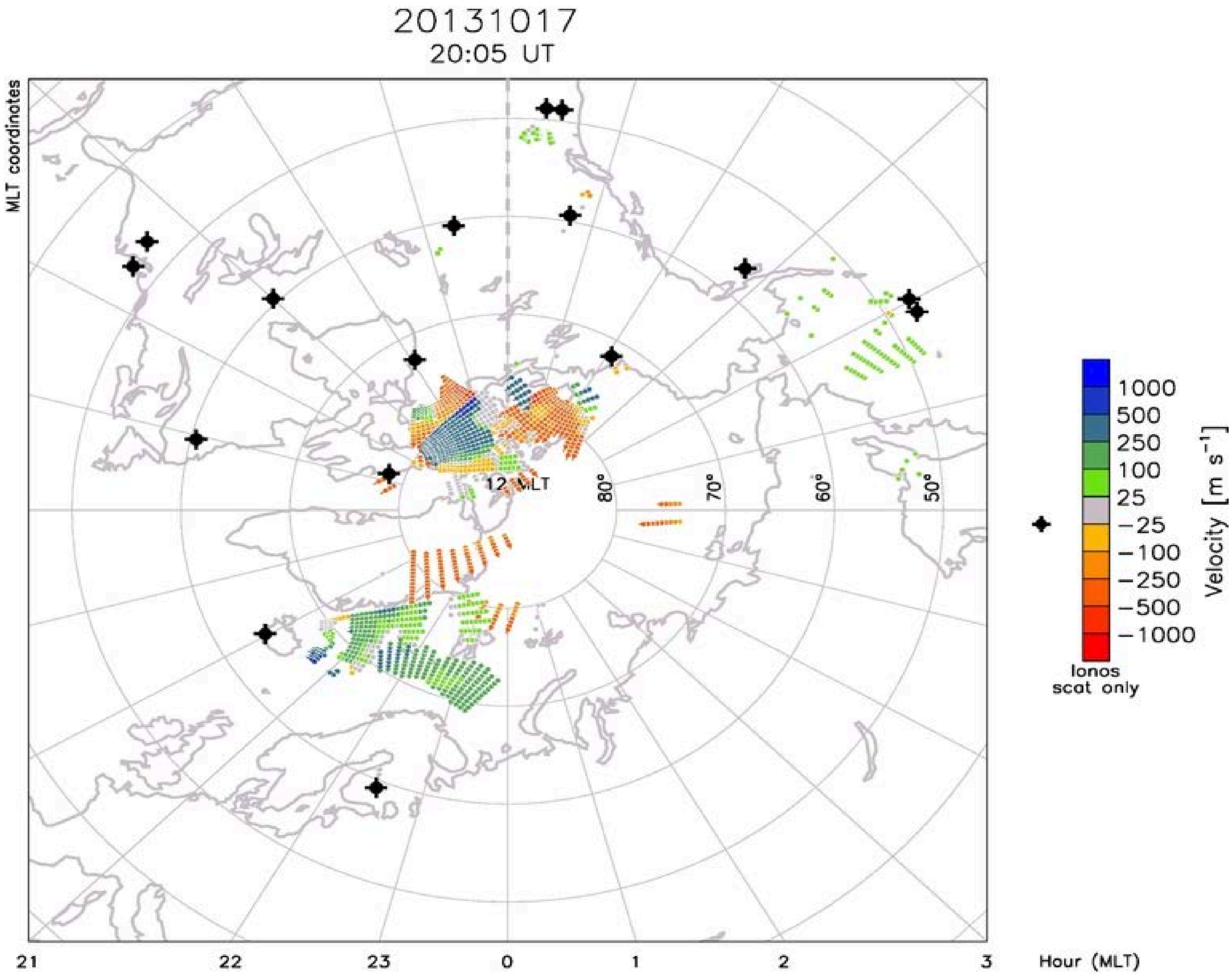
Rino, C. L. (1979). A power law phase screen model for ionospheric scintillation: 1. Weak scatter. *Radio Science*, *14*(6), 1135-1145.

Solomon, S. C. (2001), Auroral particle transport using Monte Carlo and hybrid methods, J. Geophys. Res., 106(A1), 107–116, doi:10.1029/2000JA002011.

SuperDARN

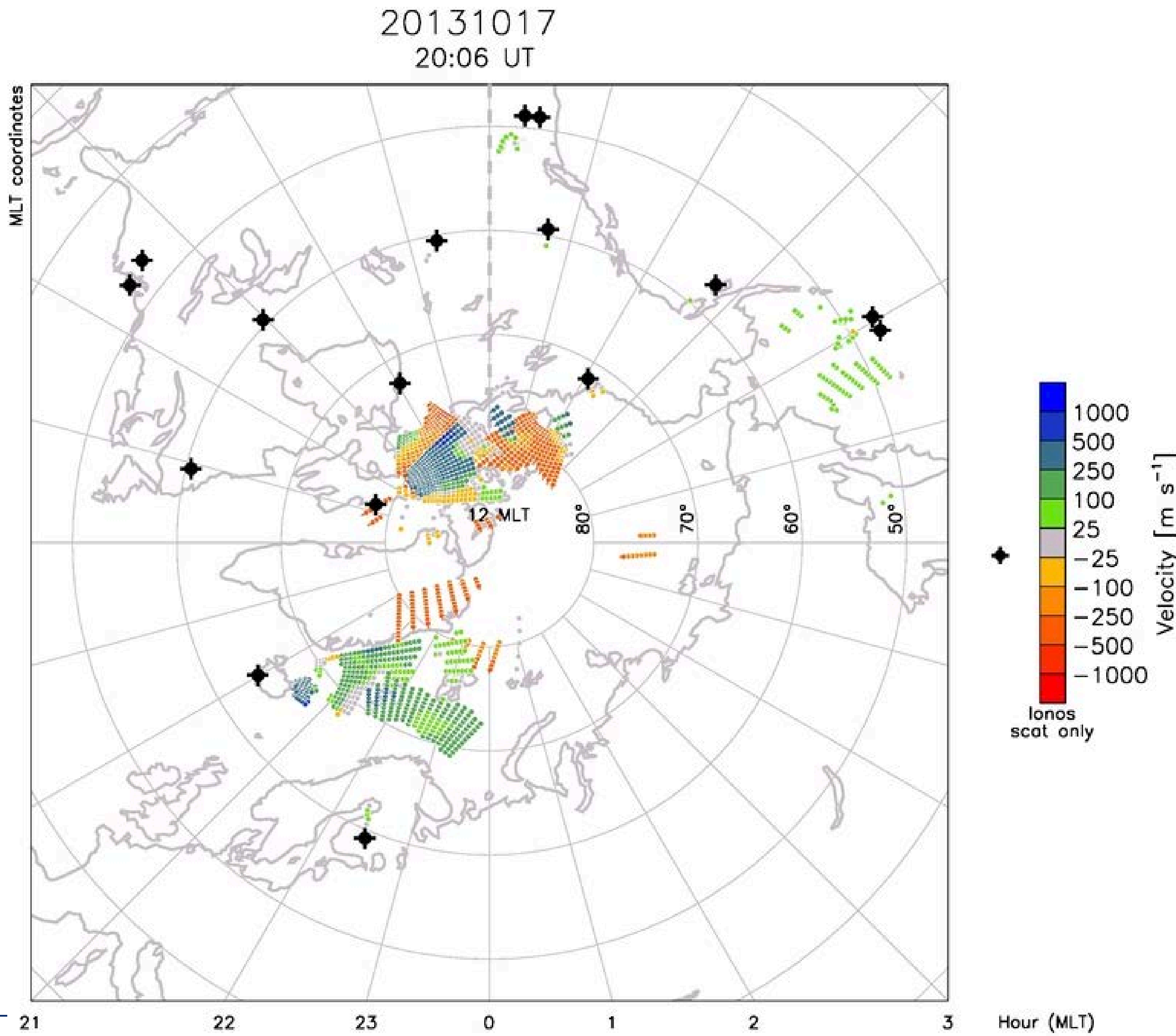

20131017
20:04 UT
MLT coordinates
12 MLT
80°
70°
60°
50°
21
22
23
0
1
2
3
Hour (MLT)
1000
500
250
100
25
−25
−100
−250
−500
−1000
Velocity [m s^{-1}]
Ionos scat only

SuperDARN



20131017
20:05 UT
MLT coordinates
12 MLT
80°
70°
60°
50°
1000
500
250
100
25
−25
−100
−250
−500
−1000
Velocity [m s^{-1}]
Ionos scat only
21
22
23
0
1
2
3
Hour (MLT)

SuperDARN



20131017
20:06 UT
MLT coordinates
12 MLT
80°
70°
60°
50°
1000
500
250
100
25
−25
−100
−250
−500
−1000
Velocity [m s^{-1}]
Ionos
scat only
21
22
23
0
1
2
3
Hour (MLT)

TEC modeling