High latitude scintillation monitoring

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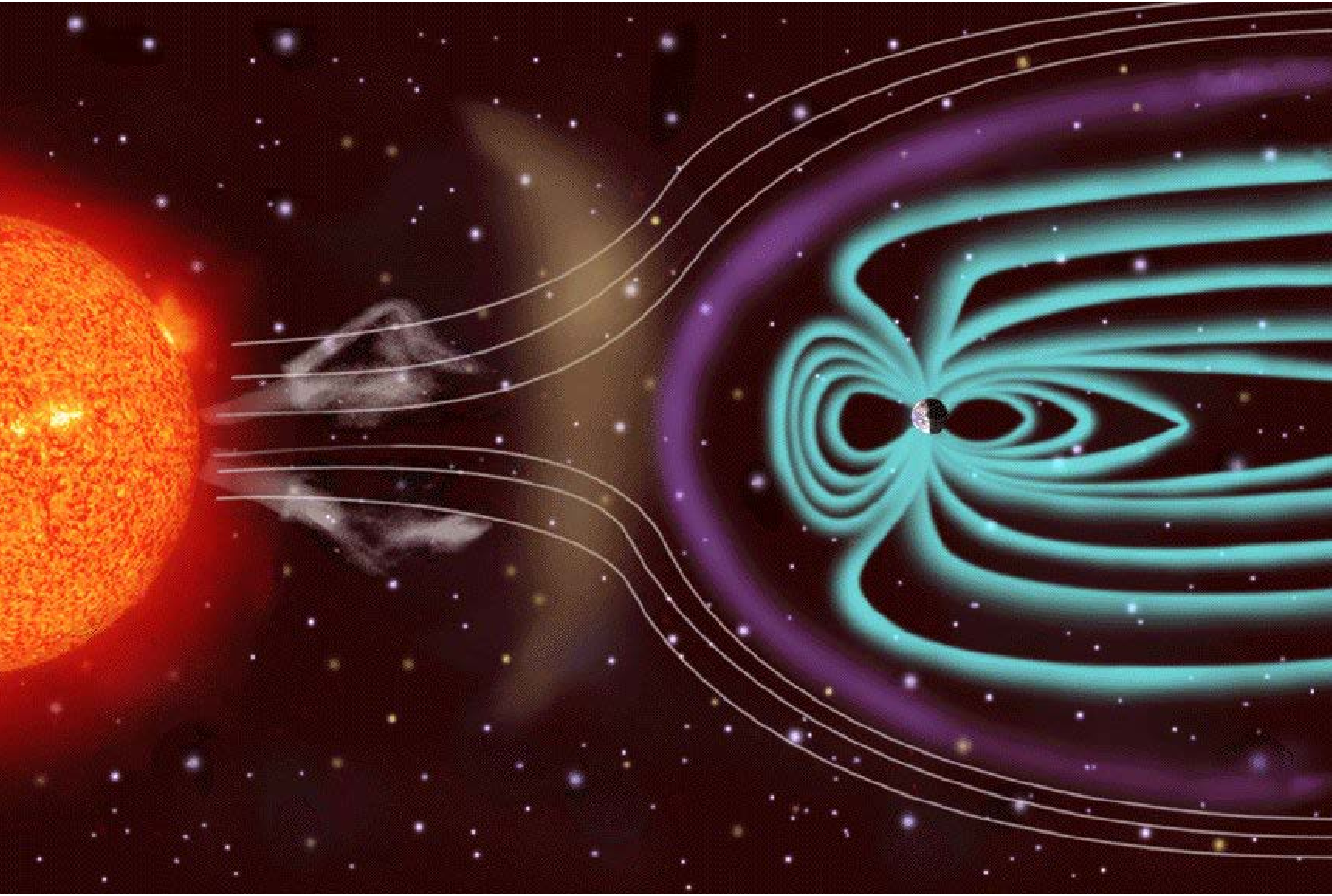
NKG 2014

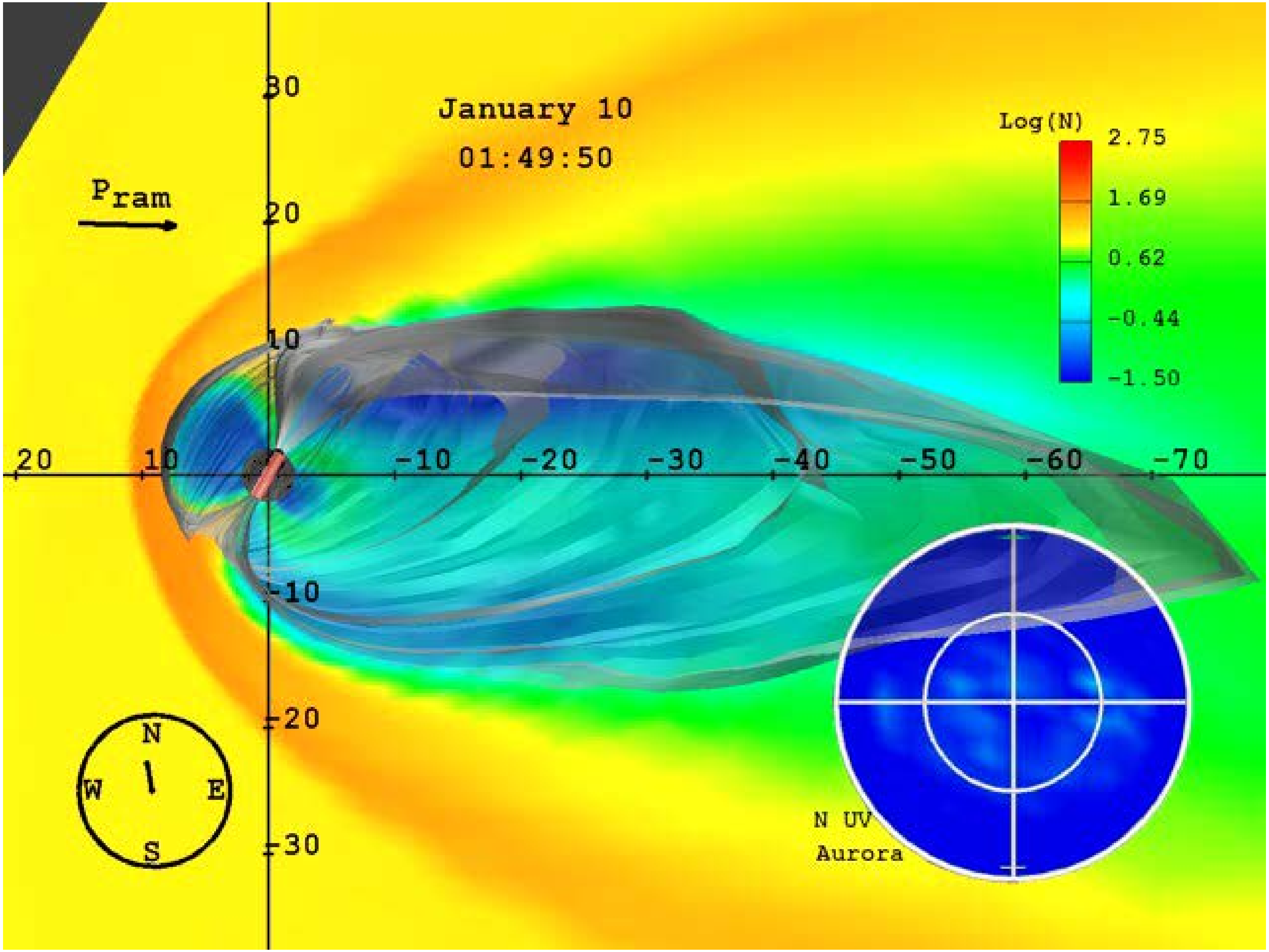
Kartverket

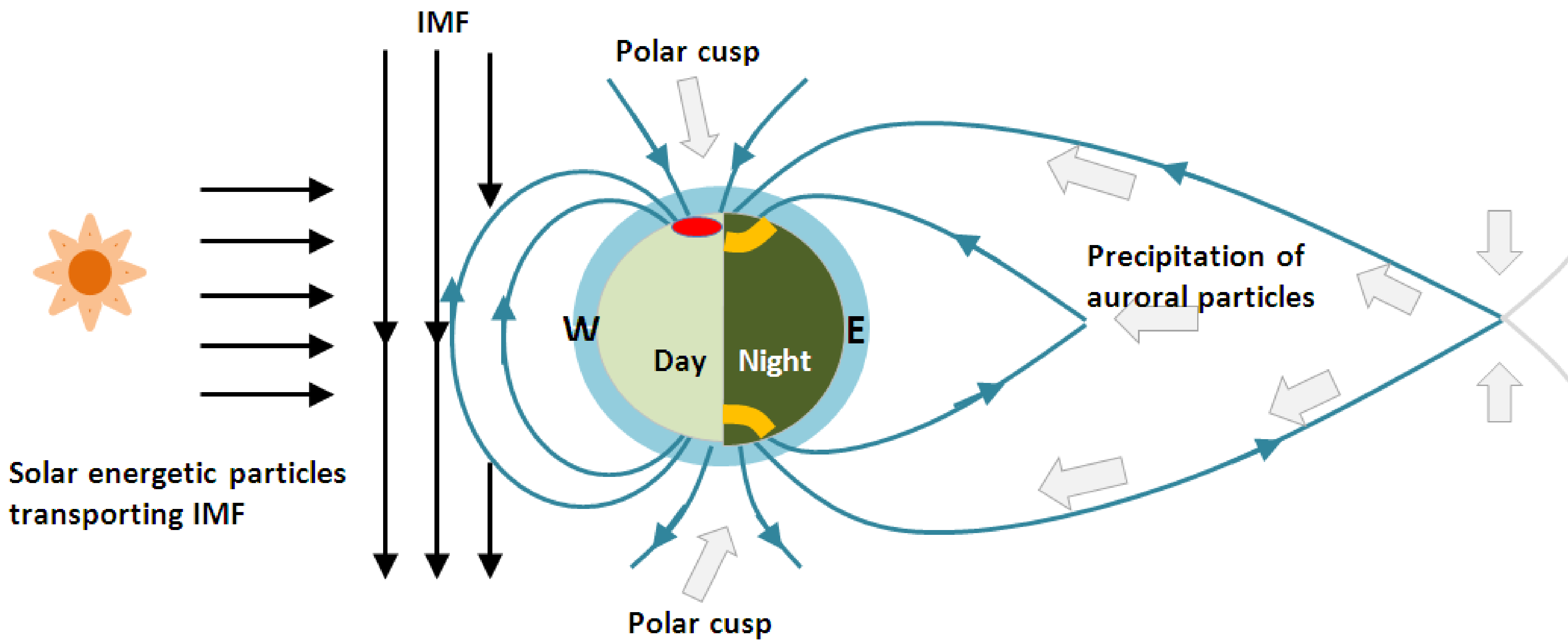
Outline

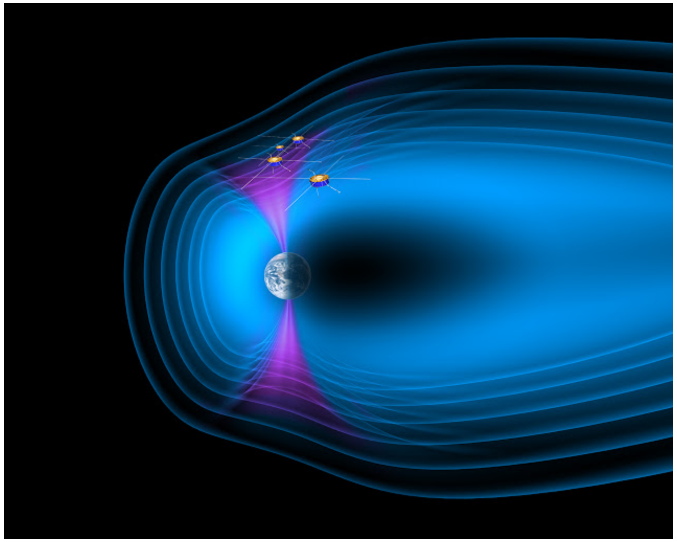
- What are scintillations and how do they occure
- NMA scintillation reciver network
- Examples

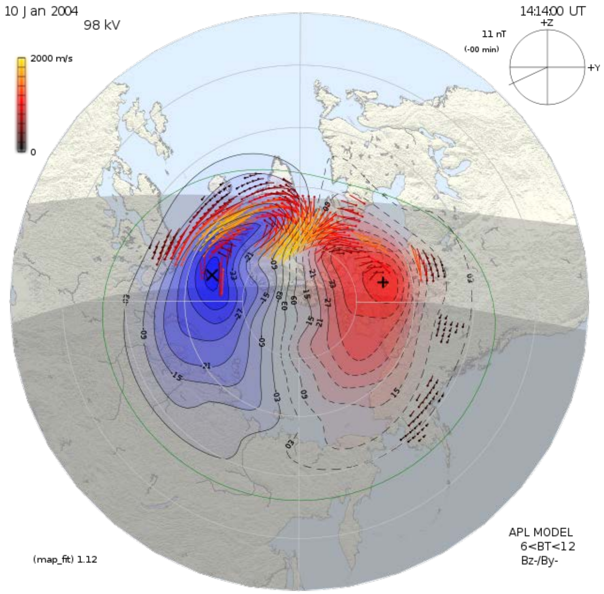
Kartverket




January 10
01:49:50
Log(N)
2.75
1.69
0.62
-0.44
-1.50
Pram
30
20
10
-10
-20
-30
20
10
-10
-20
-30
-40
-50
-60
-70
N
W
E
S
N UV
Aurora

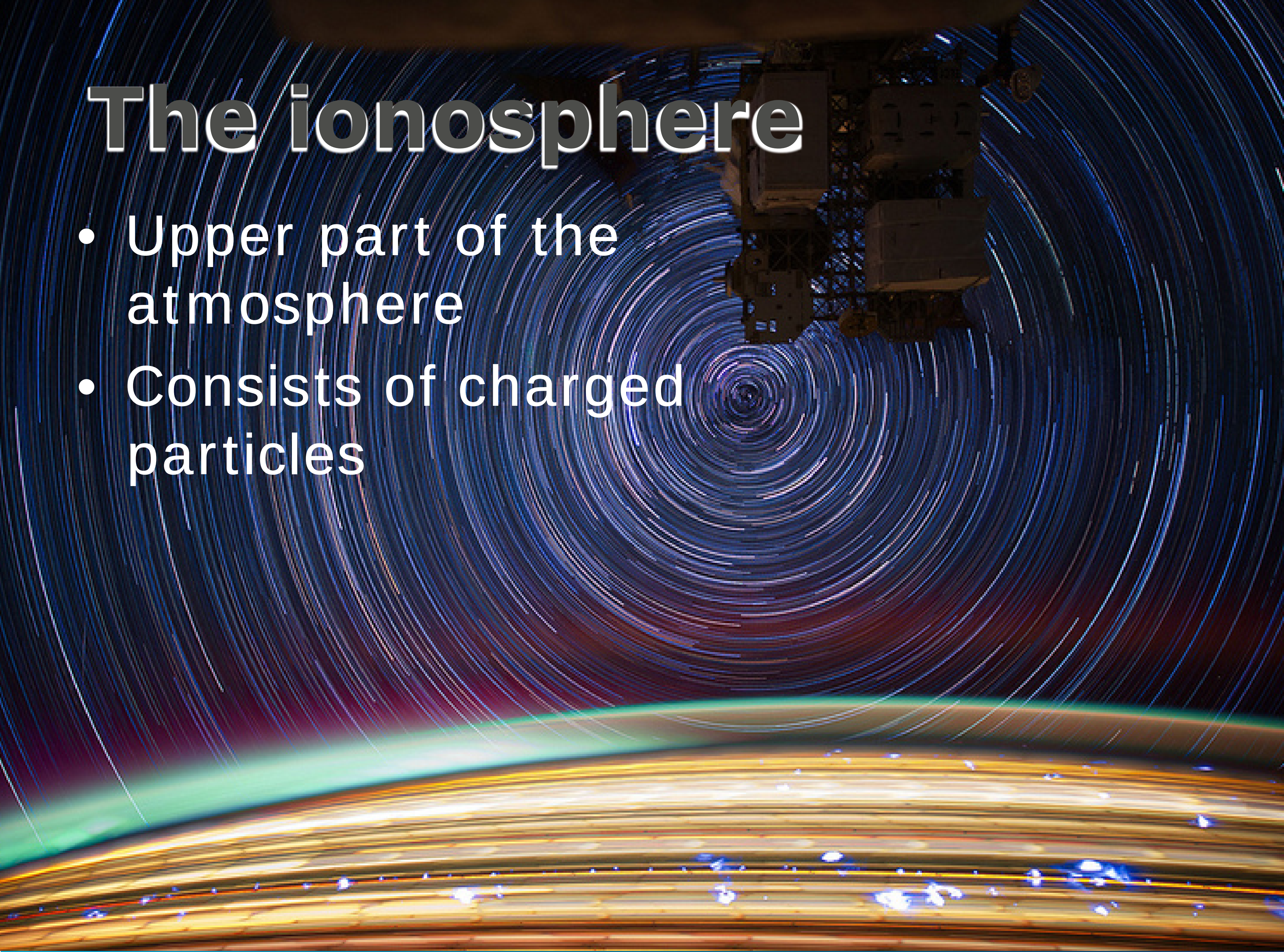

IMF
Polar cusp
Precipitation of auroral particles
W
E
Day
Night
Solar energetic particles transporting IMF
Polar cusp




10 Jan 2004
98 kV
14:14:00 UT
+Z
+Y
11 nT
2000 m/s
0
APL MODEL
6<BT<12
Bz-/By-
(map_fit) 1.12

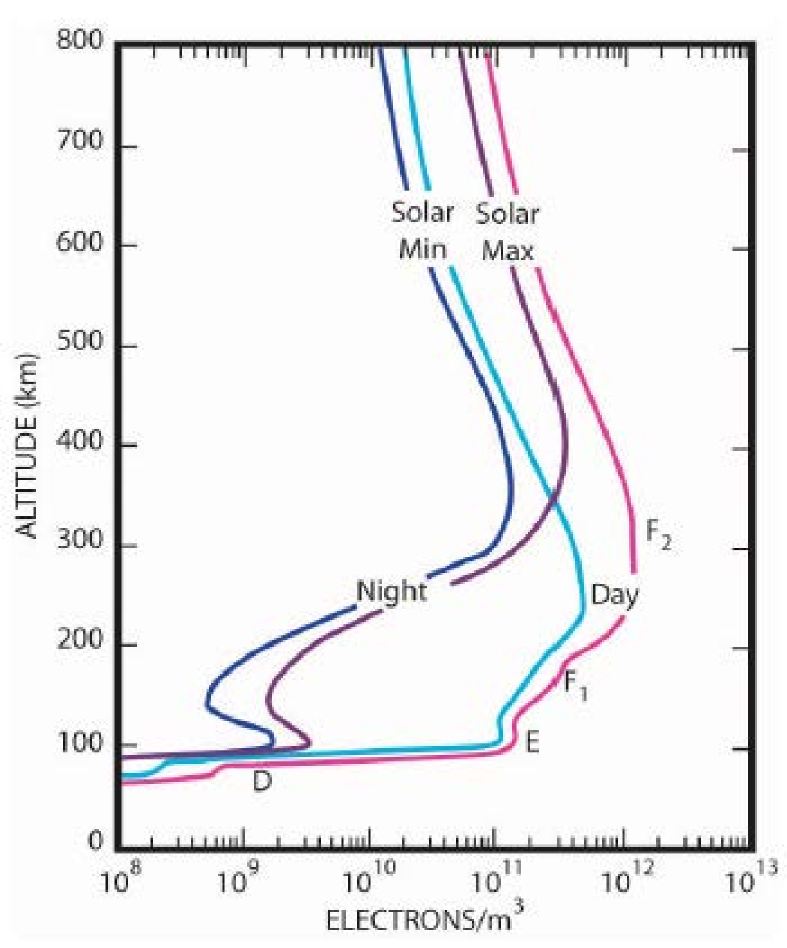
The ionosphere

- Upper part of the atmosphere
- Consists of charged particles



The ionosphere

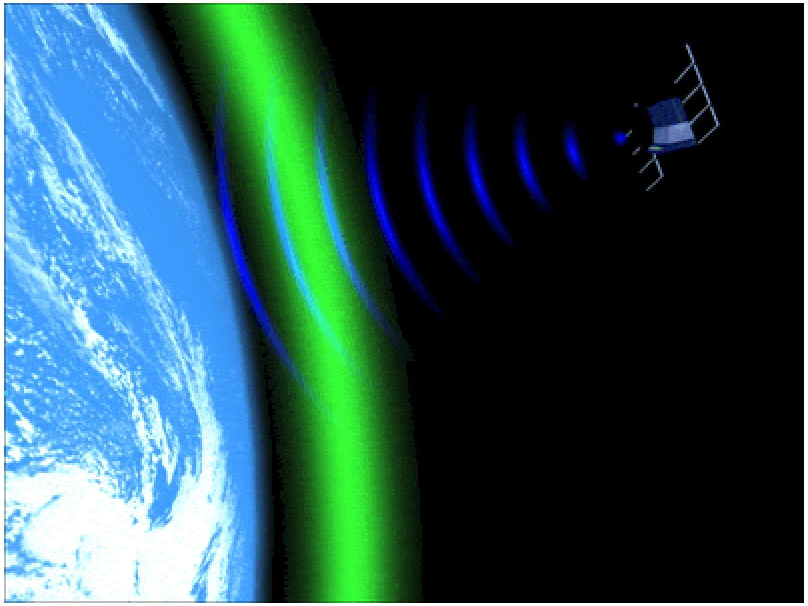
- Upper part of the atmosphere
- Consists of charged particles
- Ionization source:
  - Solar radiation
  - Particle precipitation



Two disturbing effects

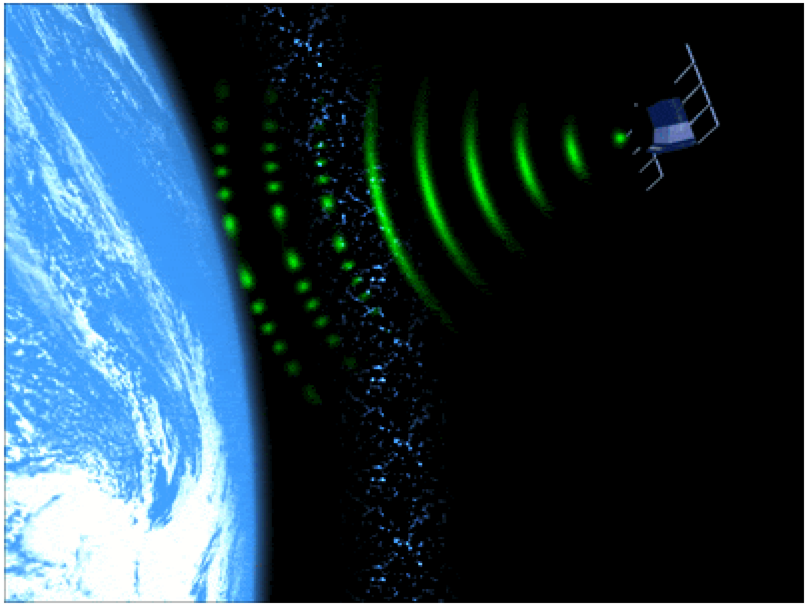
Delay

- Delay of the signal sent from the satellites



Scintillations

- Fluctuations in phase and amplitude

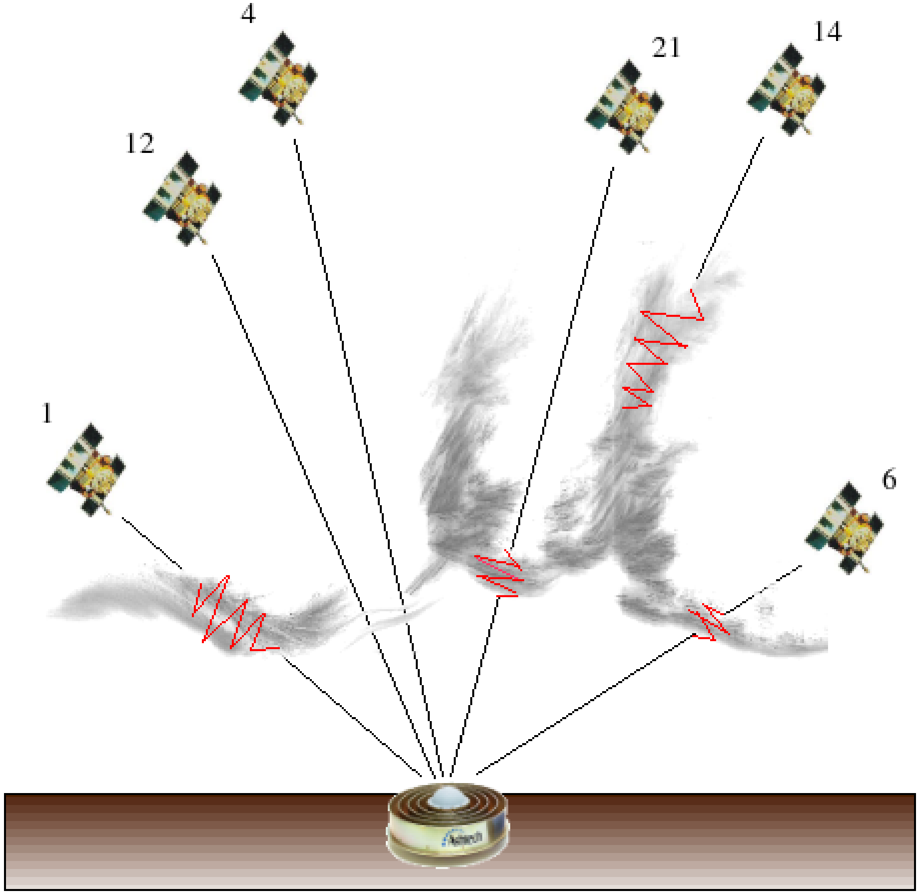


Kartverket

Credit: Pierre Cilliers/SANSA

Ionospheric scintillations

- Same effect as twinkling stars
- Fast fluctuations in the signal strength and frequency



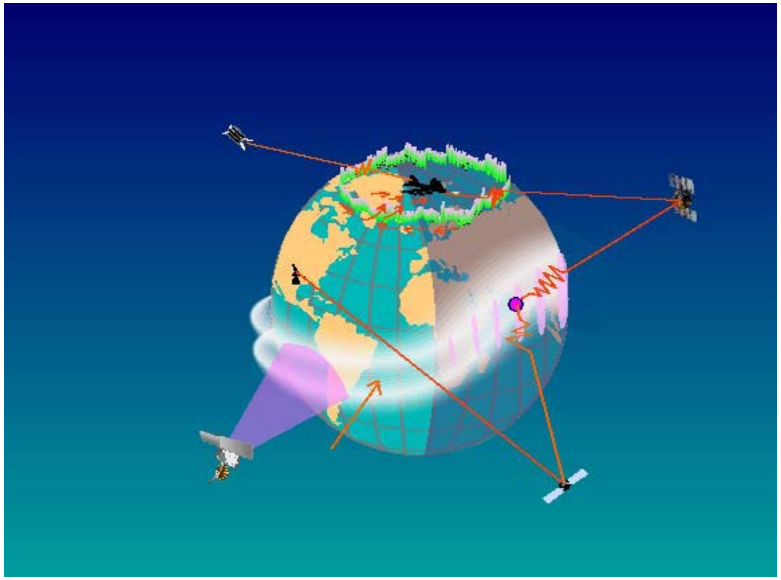
Credit: C. Carrano

Low latitudes:

- Stronger, but more predictable.
- Mainly amplitude scintillations
- Solar radiation ionization

High latitudes:

- More dependent on solar activity
- Mainly phase scintillations



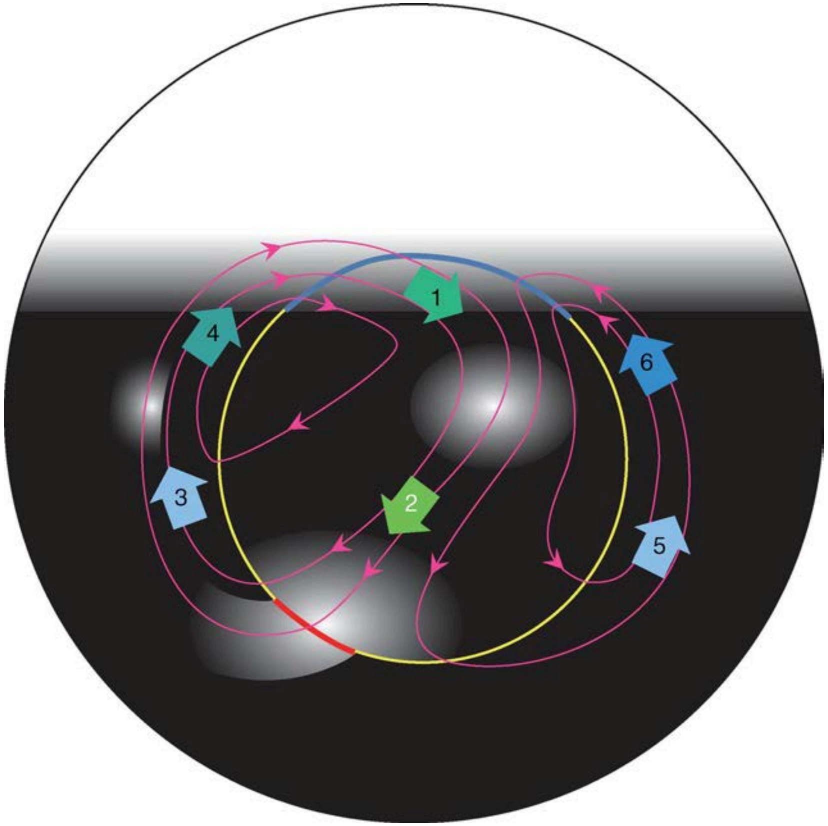
Patches

Enhanced electron density regions

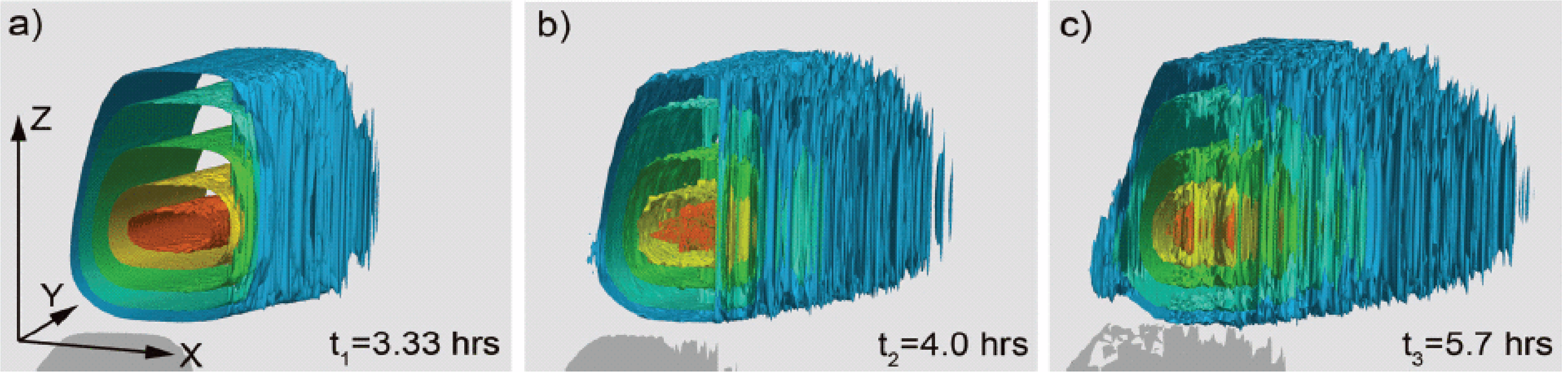
Size: 100-1000 km across

Drift velocity: 500-1000 m/s

Produced mainly by dayside solar ionized plasma (some by particle precipitation)

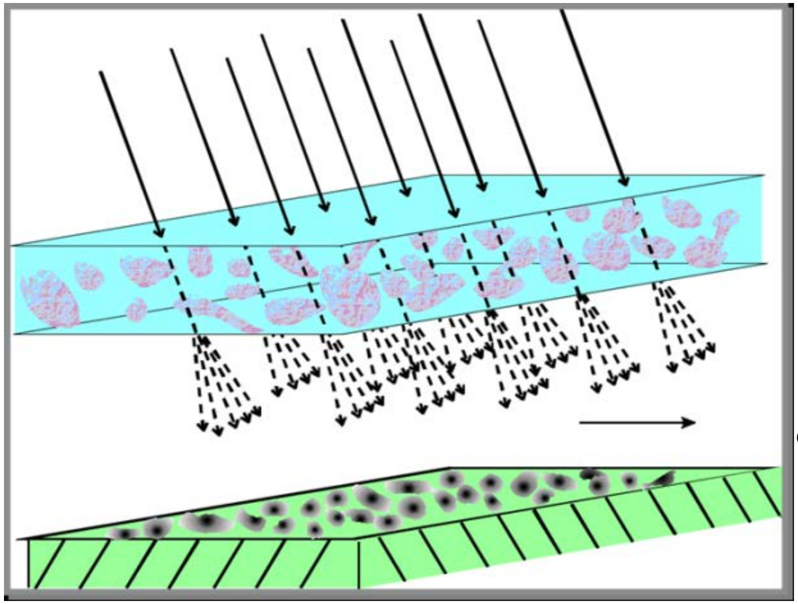


Structuring - tens of kilometers to tens of meters scale



Gondarenko and Guzdar, JGR 2006

- Gradient drift instability
- Kelvin Helmholtz instability



- Irregularities leading to variations in the index of refraction spreading the signal in random directions
- Small changes in the ray-path makes the signal interfere with itself.
- The interference pattern changes in time and space

➡ Amplitude fading and random phase fluctuations

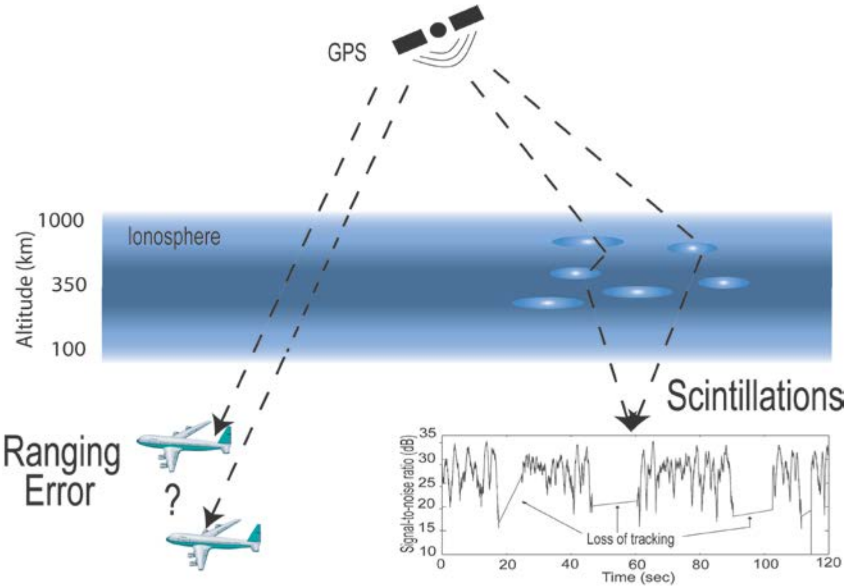
Scintillation indices

Amplitude scintillations

- S_4 – index: $S_4 = \sqrt{\frac{\langle I \rangle^2 - \langle I \rangle^2}{\langle I \rangle^2}}$
- *I* = signal strength

Phase scintillations

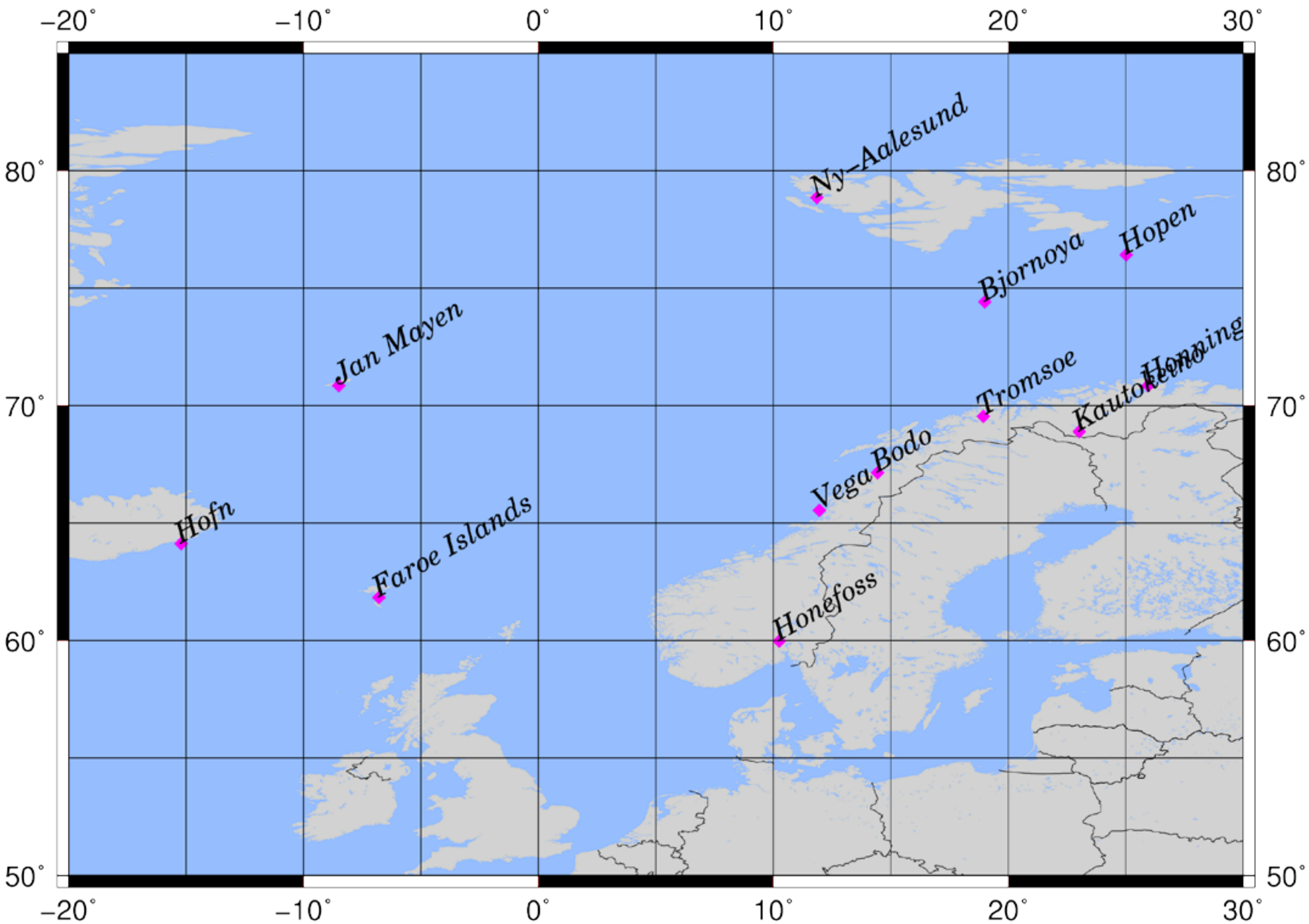
- Standard deviation of the phase in radians: $\sigma_\varphi = \sqrt{\langle \varphi^2 \rangle - \langle \varphi^2 \rangle}$



Amplitude og fase

Scintillation receivers

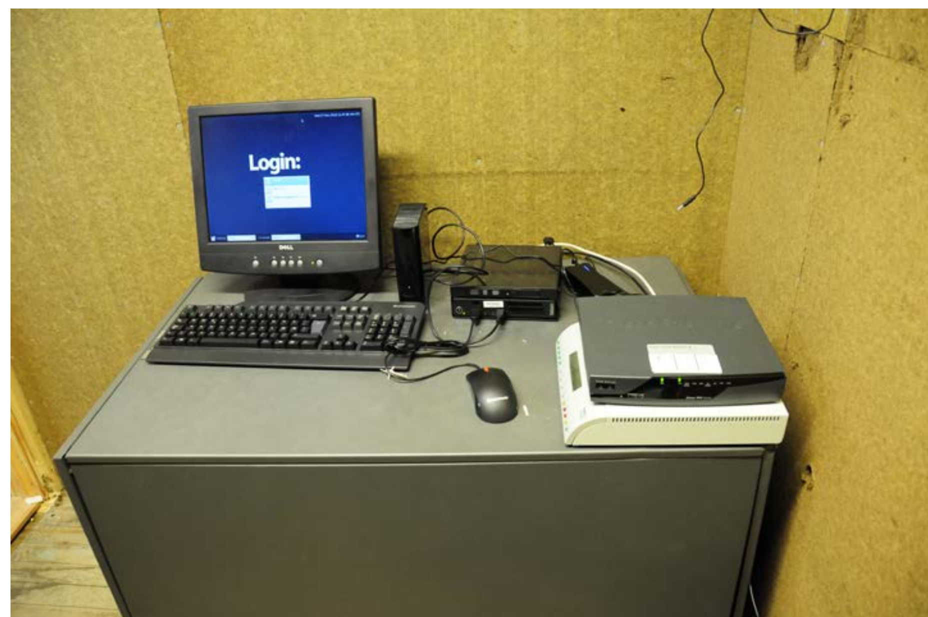
- Currently operating 10 (11) 100 Hz Septentrio recivers
- 2 belonging to CNES



Kartverket

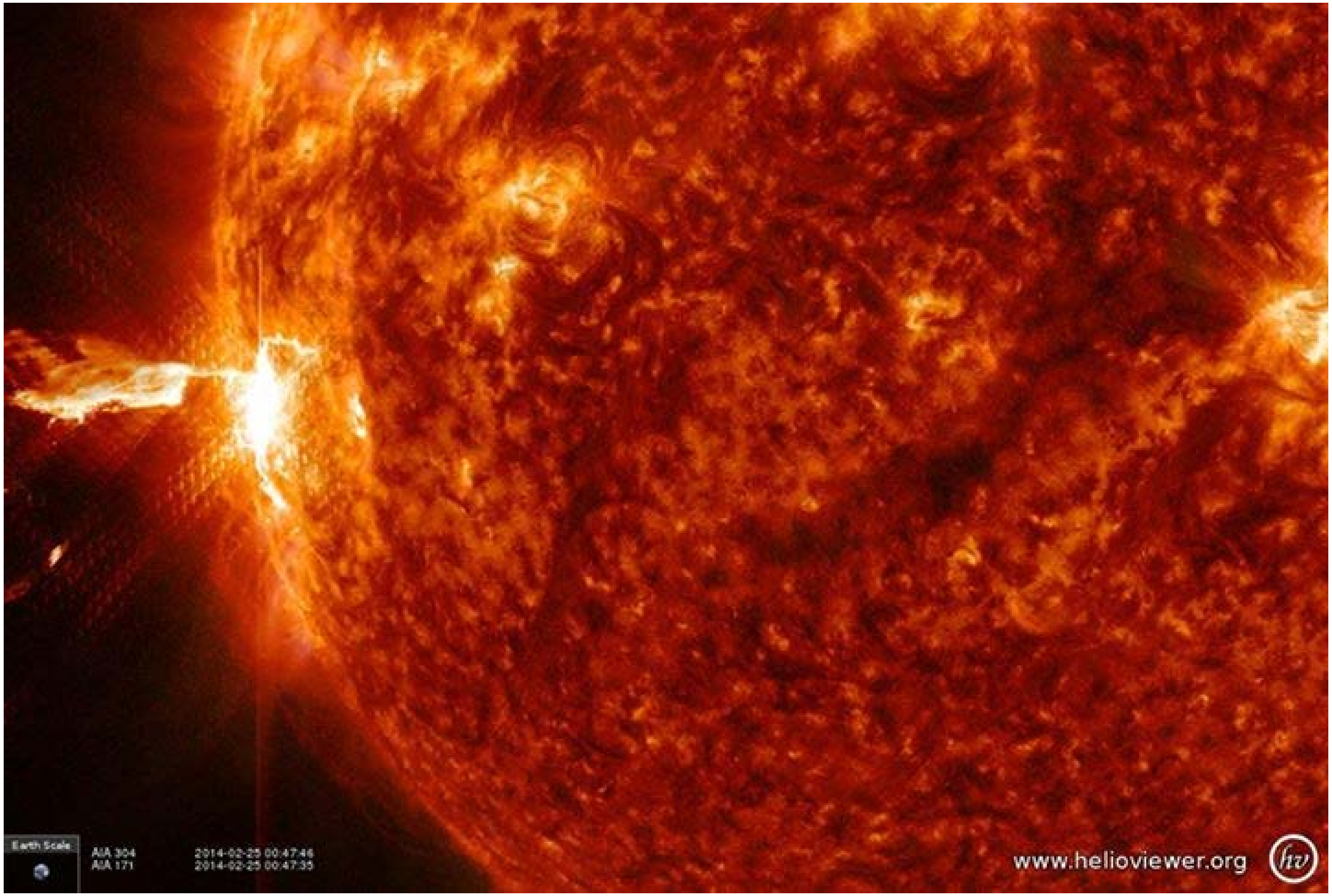
- Vega and Tromsø since February 2012
- Ny-Ålesund since December 2012
- 9 new received autumn of 2013
- All placed at existing NMA reference stations

- Calculates the S4 and Sigma Phi Scintillation indices in real time.
- The indices are sent to NMA at Høneføss every minute
- Raw data saved on external hard drives at the sites



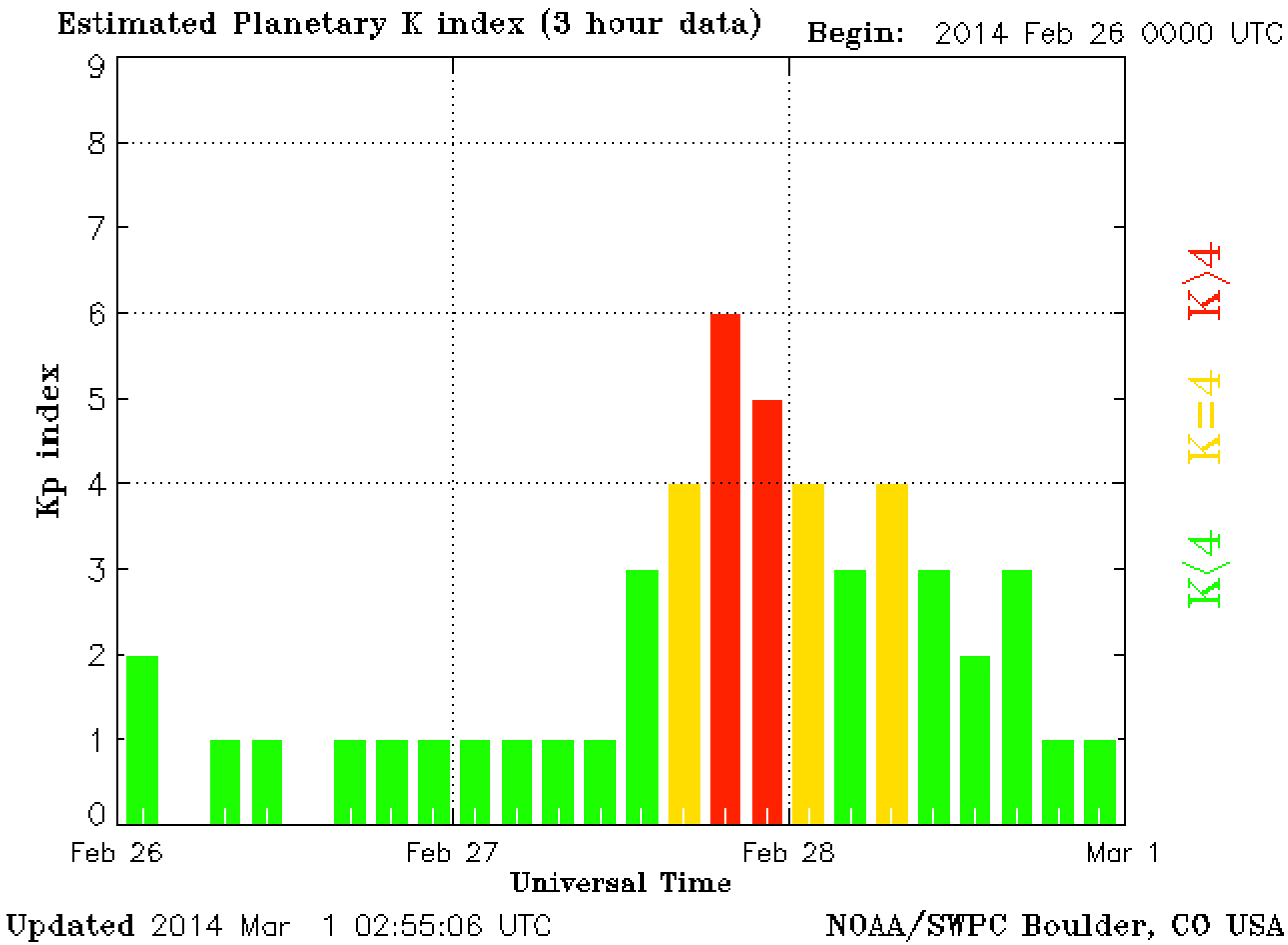
27-28 February 2014

CME erupting from the Sun 25th of February

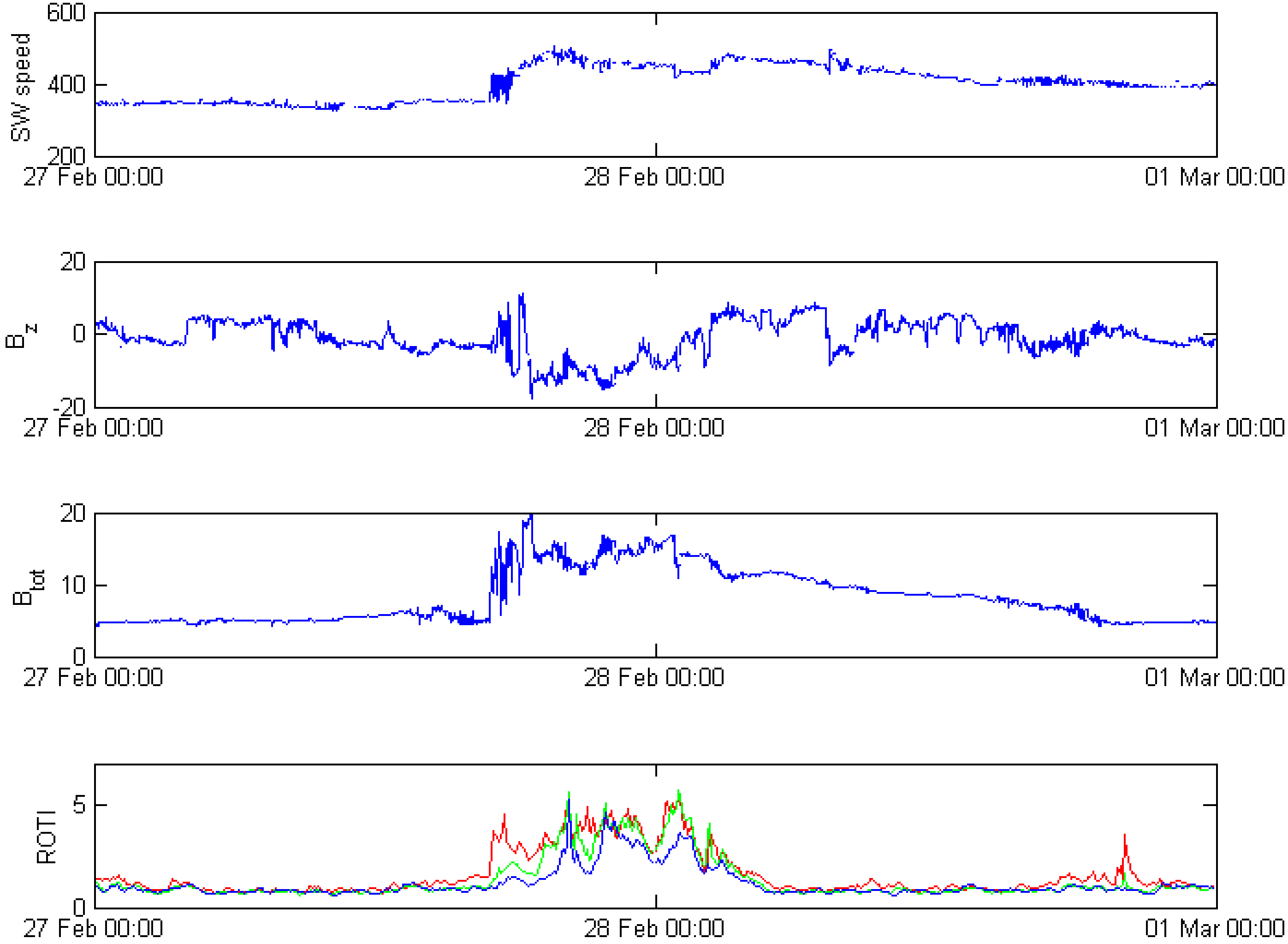


27-28 February 2014

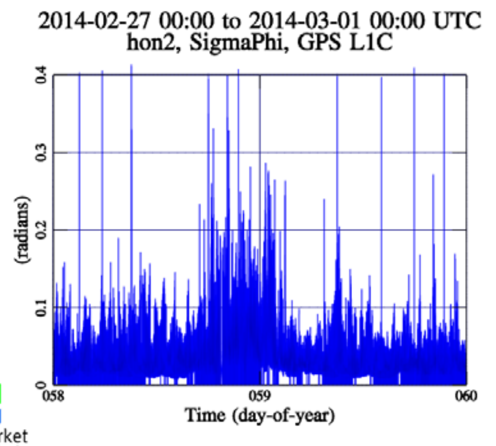
Moderate storm on the NOAA scale

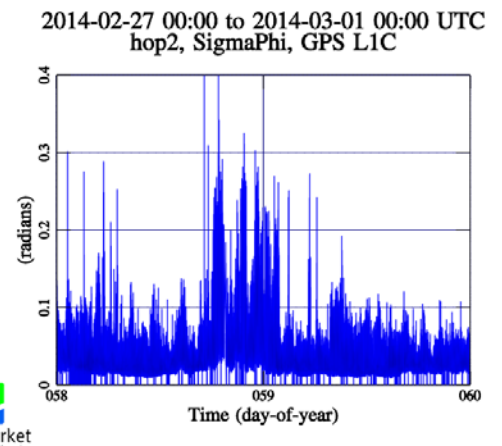


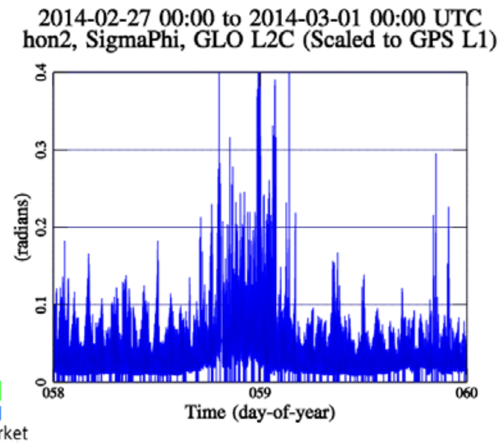
Kartverket

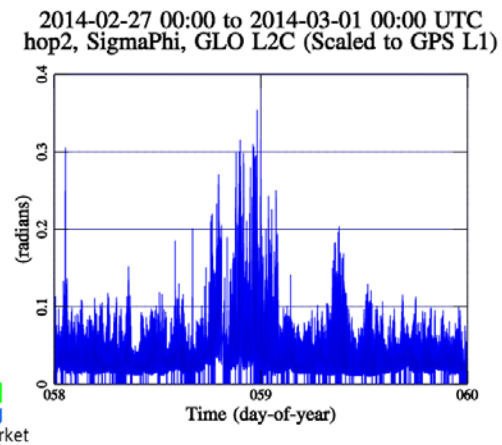

SW speed
600
400
200
B
z
20
0
-20
B
tot
20
10
0
ROTI
5
0
27 Feb 00:00
28 Feb 00:00
01 Mar 00:00

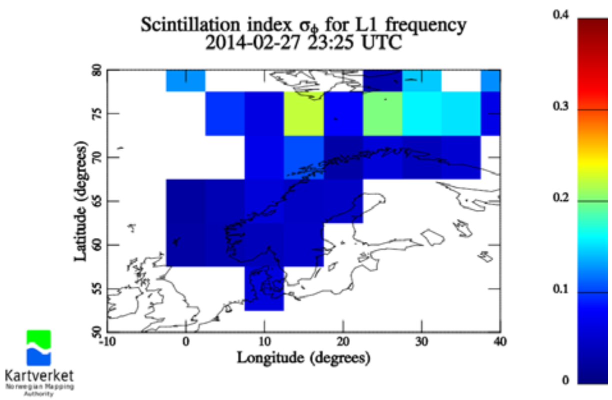
Sigma Phi time-series examples

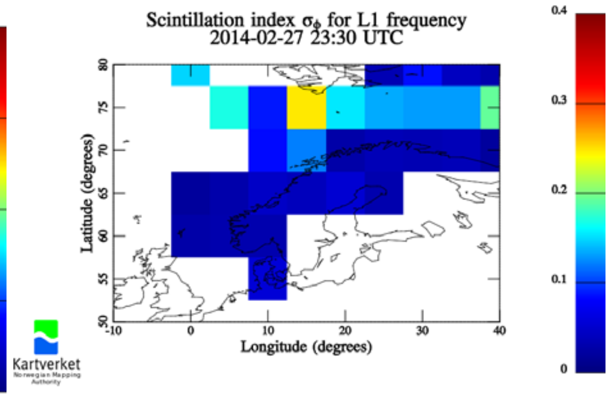









Scintillation index σϕ for L1 frequency
2014-02-27 23:25 UTC
Latitude (degrees)
Longitude (degrees)
0 0.1 0.2 0.3 0.4
Kartverket


Scintillation index σϕ for L1 frequency
2014-02-27 23:30 UTC
Latitude (degrees)
Longitude (degrees)
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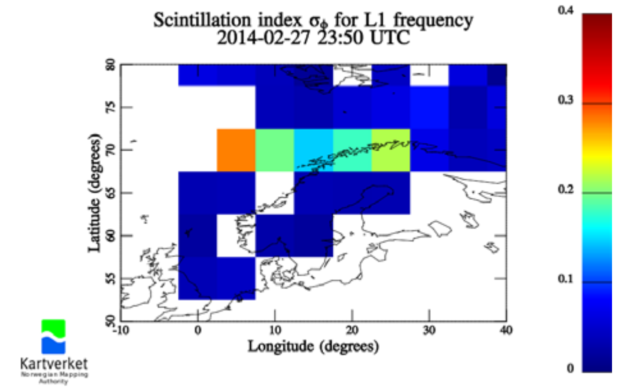
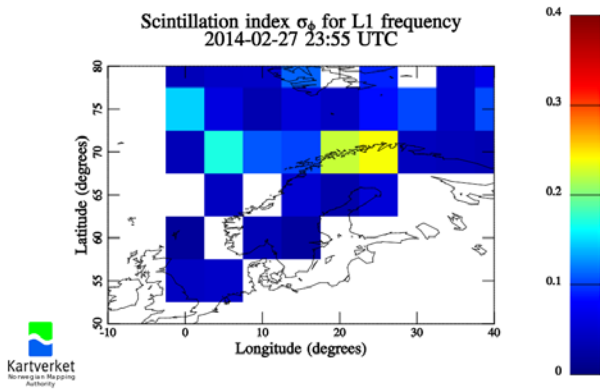
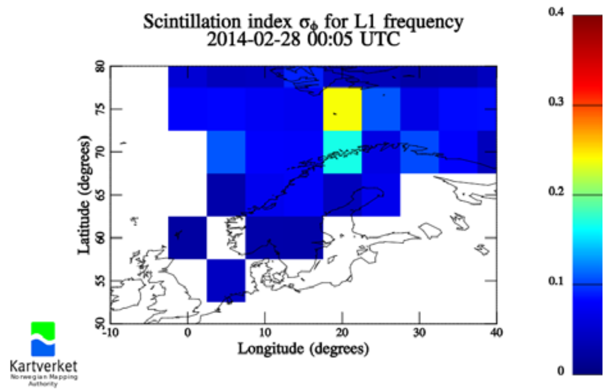
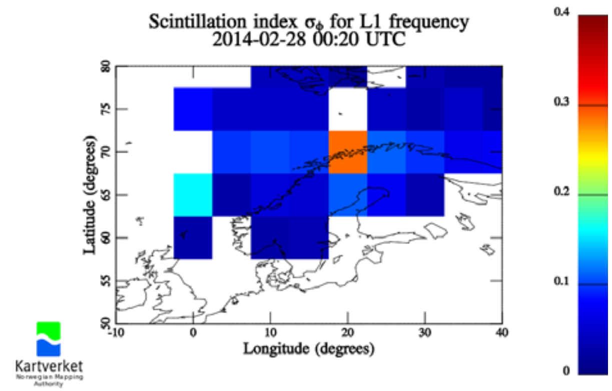
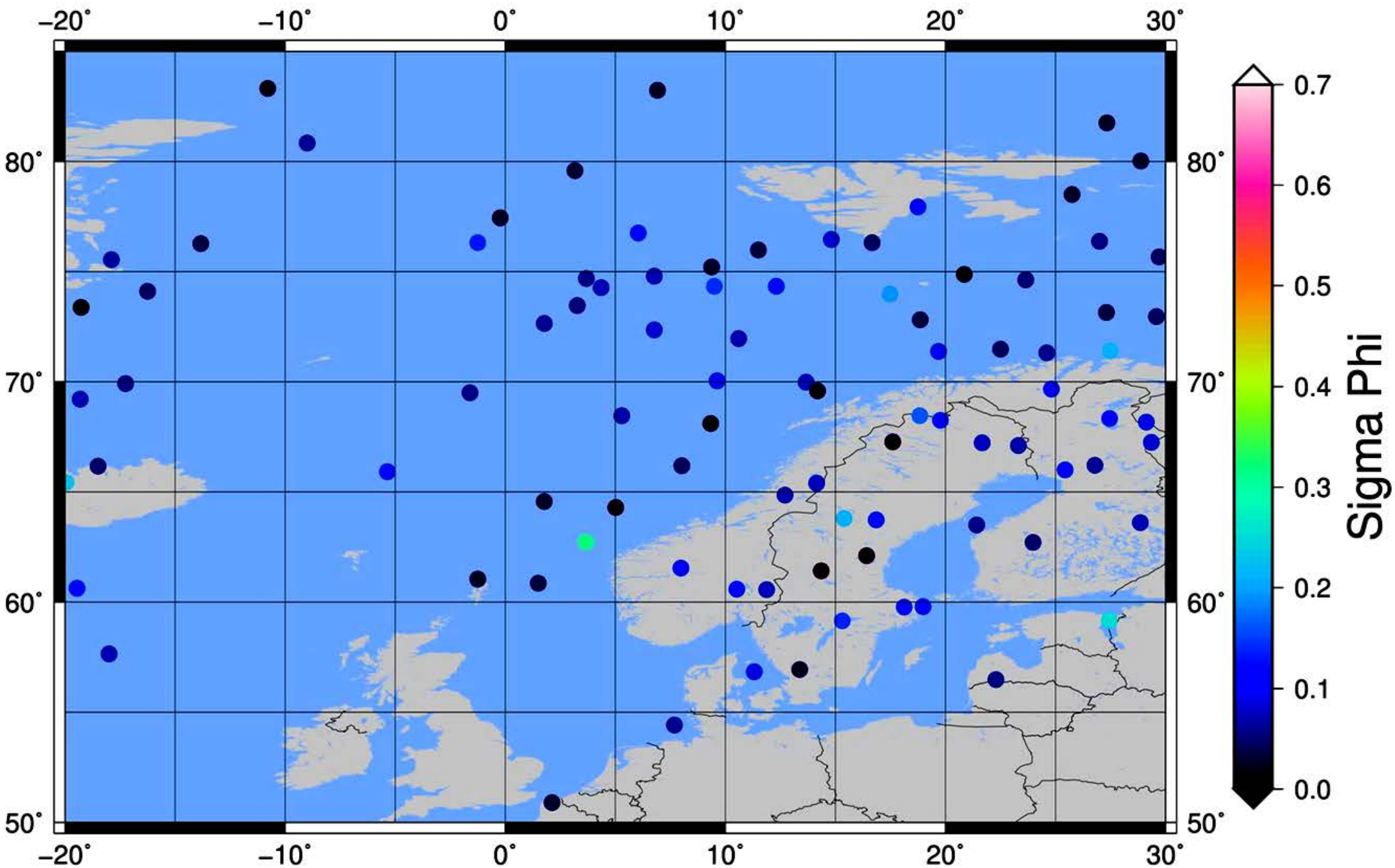
Kartverket


Scintillation index σϕ for L1 frequency
2014-02-27 23:50 UTC
Latitude (degrees)
Longitude (degrees)
0 0.1 0.2 0.3 0.4
Kartverket


Scintillation index σϕ for L1 frequency
2014-02-27 23:55 UTC
Latitude (degrees)
Longitude (degrees)
0 0.1 0.2 0.3 0.4
Kartverket

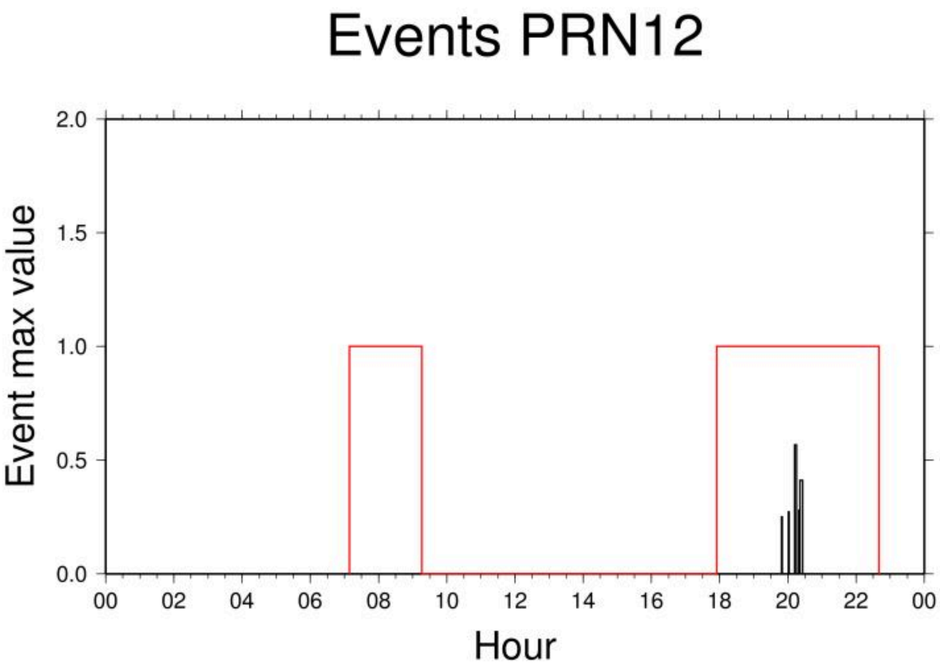

Scintillation index σϕ for L1 frequency
2014-02-28 00:05 UTC
Latitude (degrees)
Longitude (degrees)
0 0.1 0.2 0.3 0.4
Kartverket

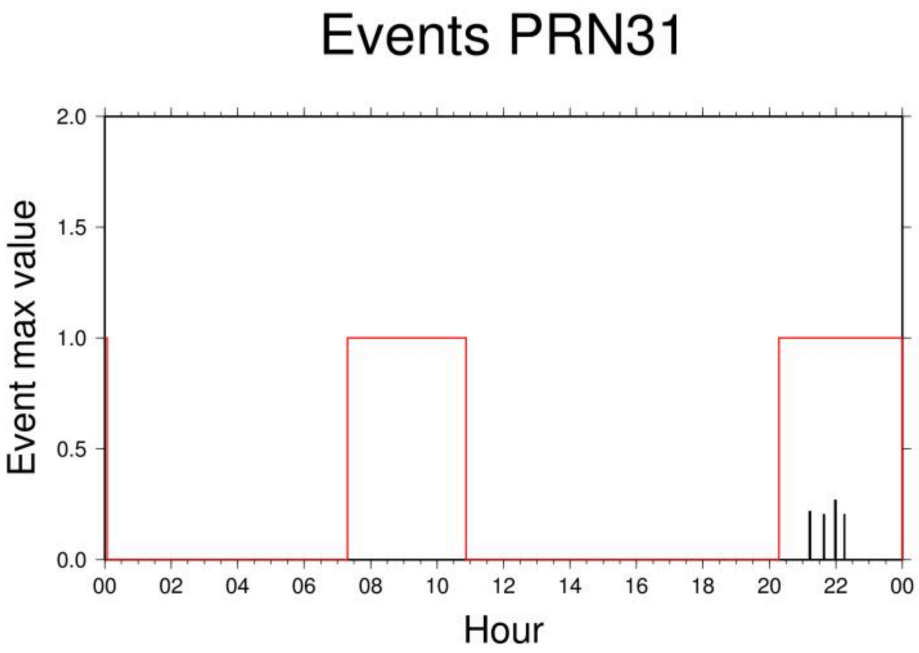

Scintillation index σϕ for L1 frequency
2014-02-28 00:20 UTC
Latitude (degrees)
Longitude (degrees)
0 0.1 0.2 0.3 0.4
Kartverket



−20˚
−10˚
0˚
10˚
20˚
30˚
80˚
70˚
60˚
50˚
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Sigma Phi

Per PRN, Honningsvåg

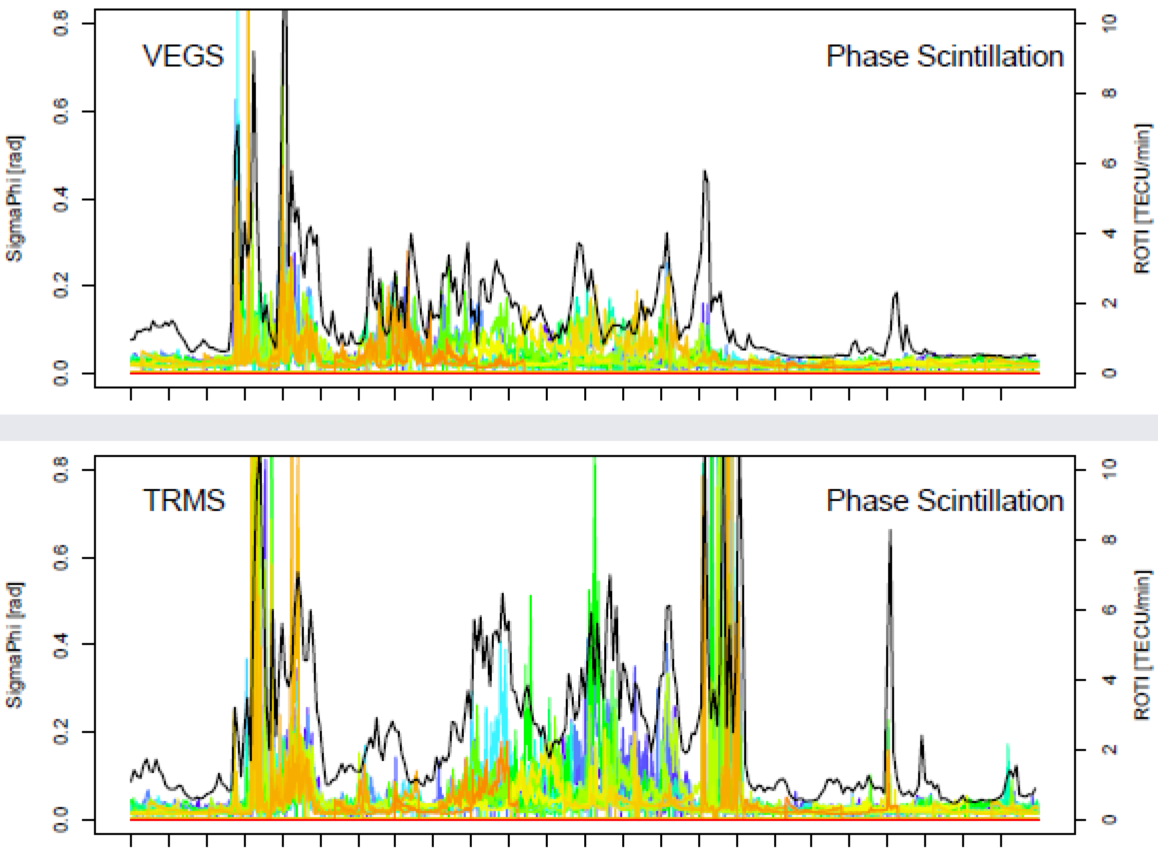


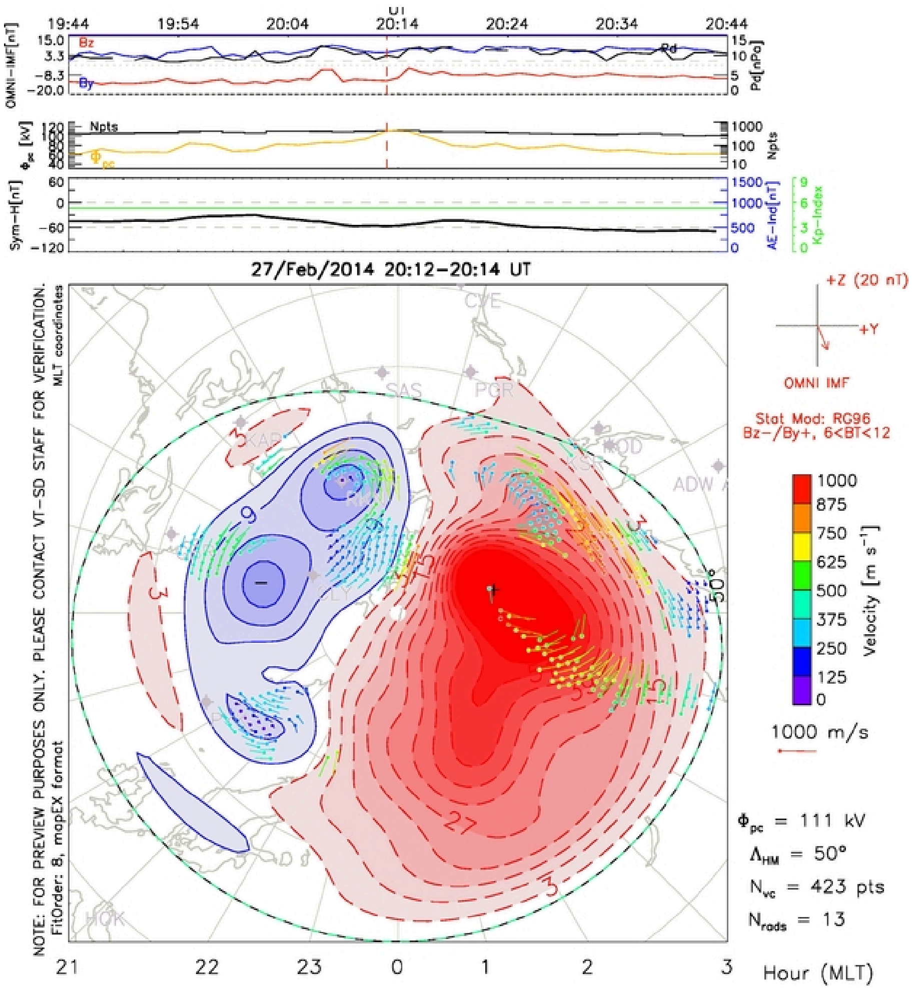


Kartverket

Thank you!

ROTI and Sigma Phi

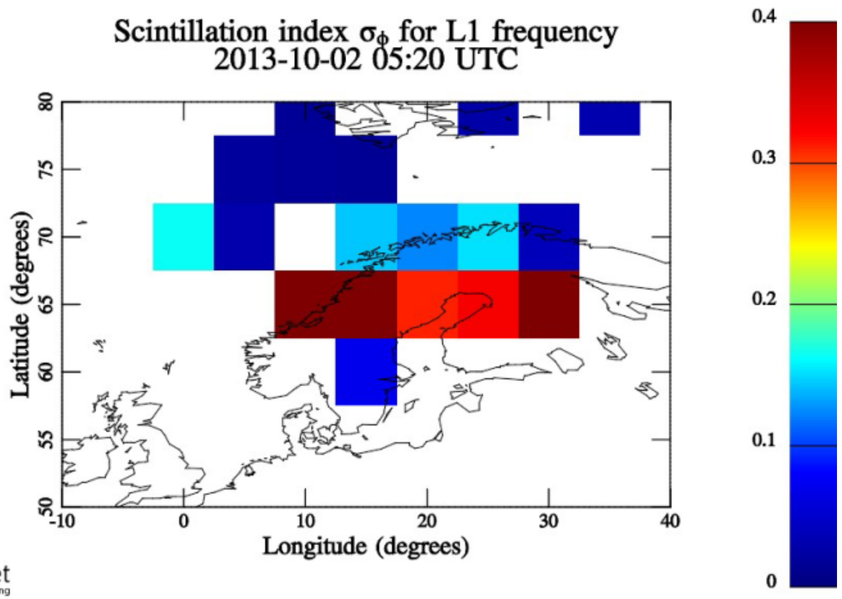


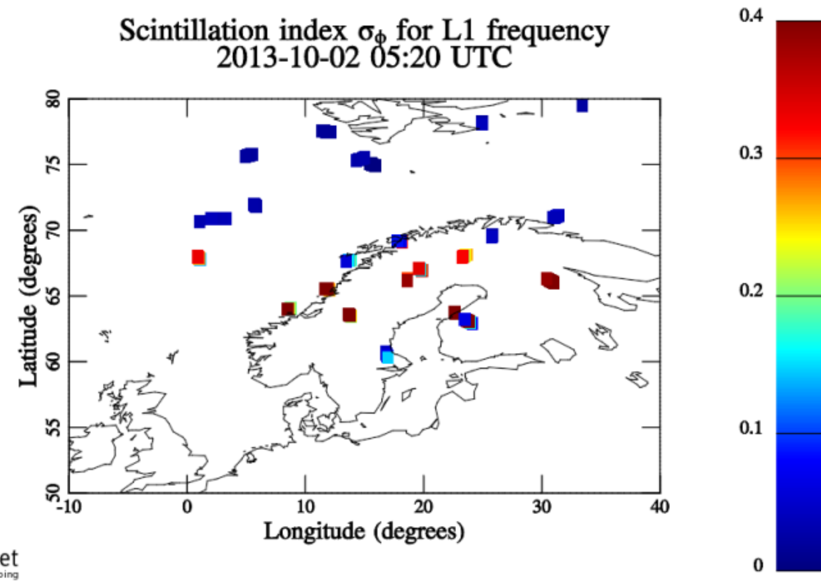


UT
19:44 19:54 20:04 20:14 20:24 20:34 20:44
OMNI-IMF[nT]
Bz
By
Pd
Pd[nPa]
Φpc [kV]
Npts
Sym-H[nT]
AE-Ind[nT]
Kp-Index
27/Feb/2014 20:12–20:14 UT
NOTE: FOR PREVIEW PURPOSES ONLY. PLEASE CONTACT VT-SD STAFF FOR VERIFICATION.
MLT coordinates
FitOrder: 8, mapEX format
+Z (20 nT)
+Y
OMNI IMF
Stat Mod: RG96
Bz–/By+, 6<BT<12
Velocity [m s⁻¹]
1000 m/s
Φpc = 111 kV
ΛHM = 50°
Nvc = 423 pts
Nrads = 13
21 22 23 0 1 2 3 Hour (MLT)

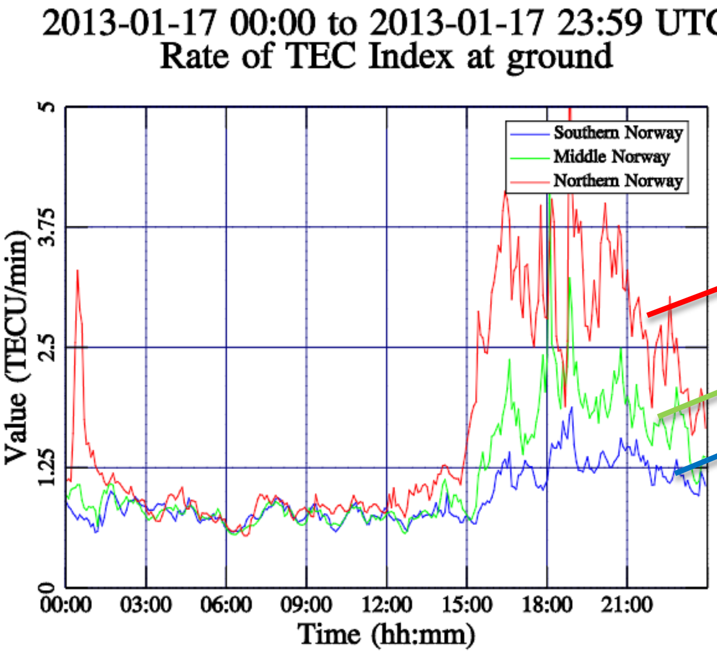
Kartverket

Scintillasjoner





Endringer i elektrontetthet



Nord-Norge: 67-72 N

Midt-Norge: 62-67 N

Sør-Norge: 57-62 N

Phase Scintillations

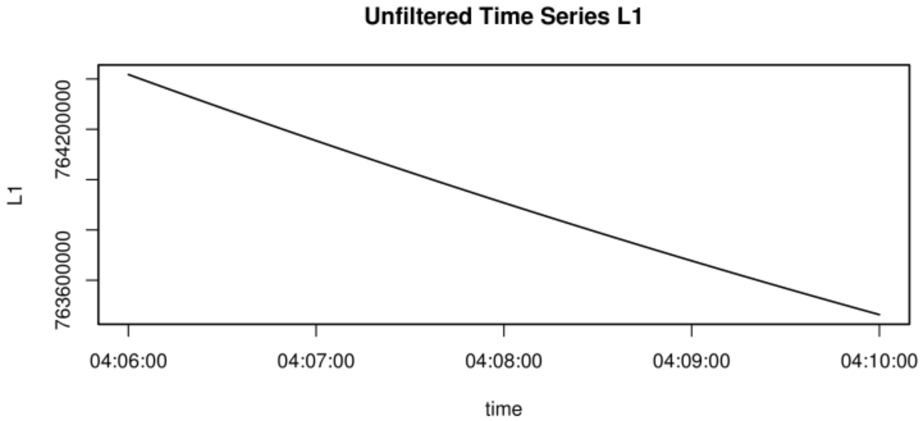
Sigma phi:

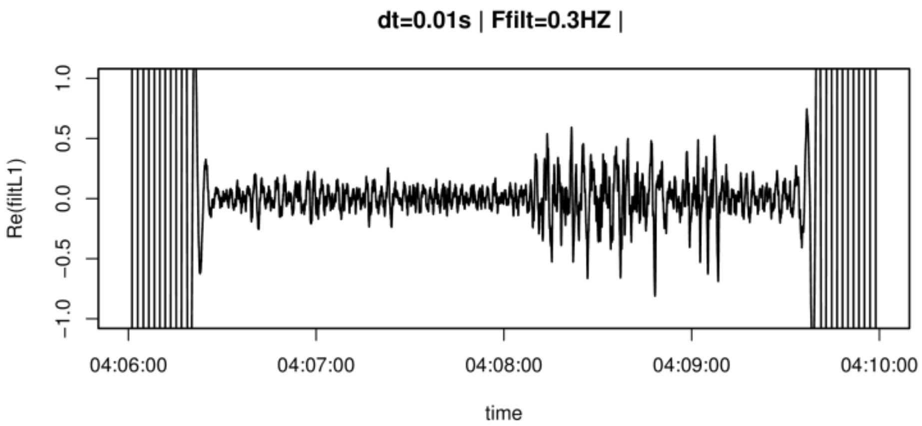
Std. dev. av detrended carrier phase

Sixth-order high-pass digital Butterworth filter (cutoff: 0.3 Hz)

Input a T=240s interval of raw phase measurements L(t)

Calculate standard deviation of $L_{filt(t)}$ considering the values between t=120s and t=180s of the complete T=240s => σ_{φ}





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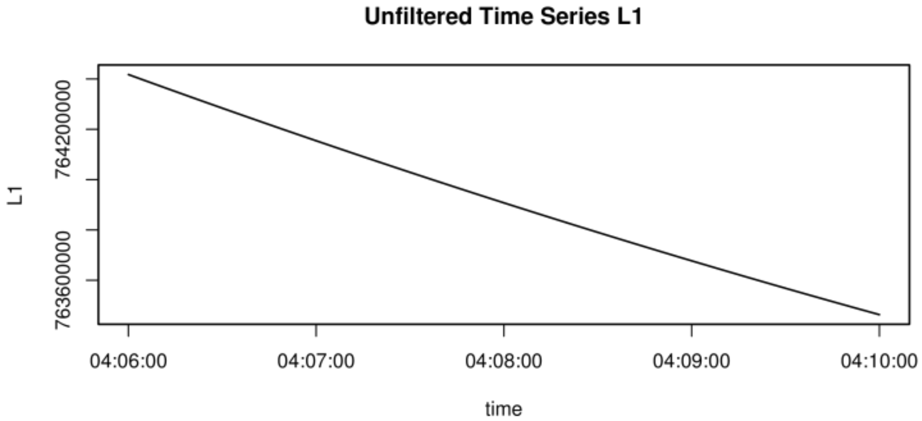
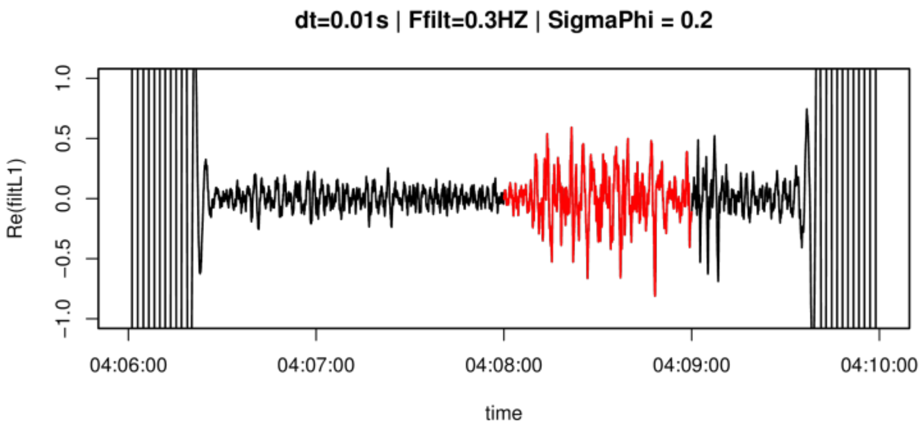
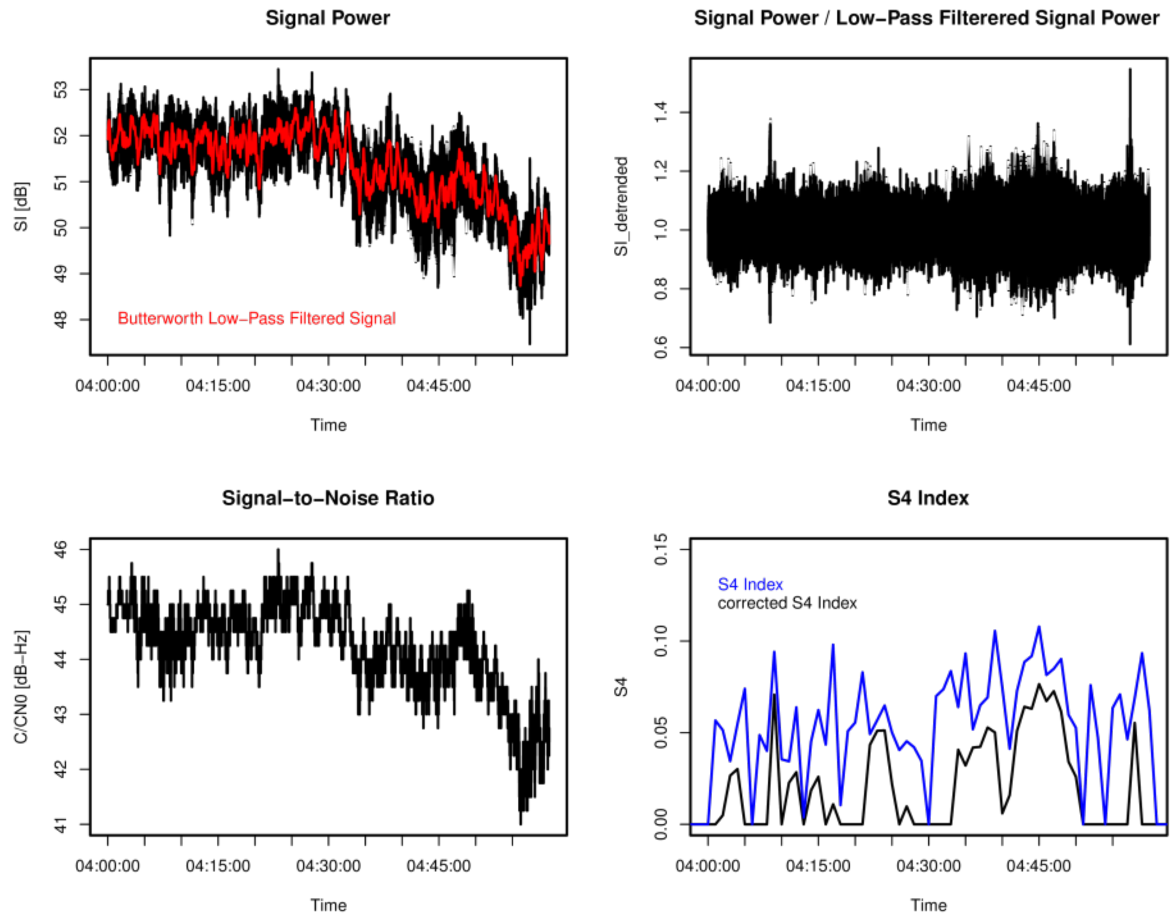




Amplitude scintillations

- S4: Strength of amplitude scintillations
- Ratio of the standard deviation of the signal power to the mean signal power
- Detrending: filtering the original intensity measurement time with a 6th order Butterworth low pass filter
- Correct for Signal to Noise Ratio



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