

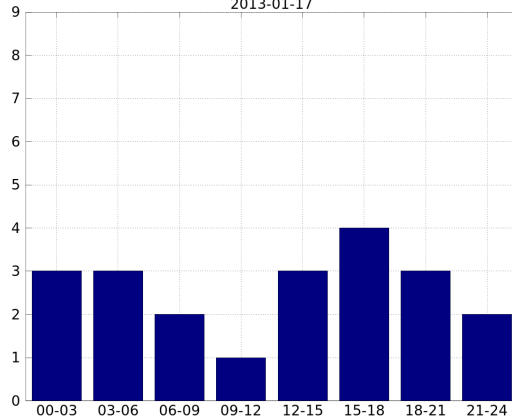


Kartverket

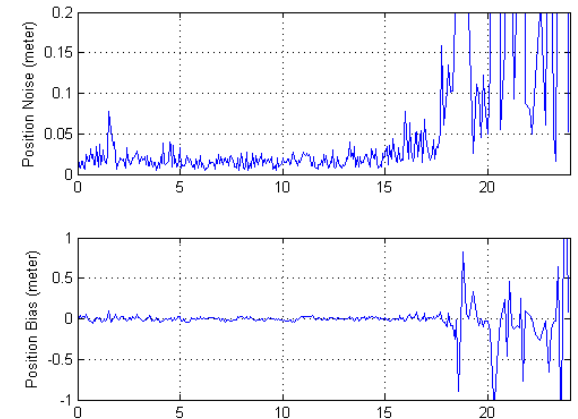
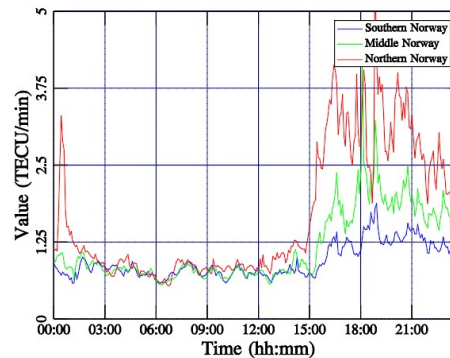
Observed high-latitude GNSS disturbances during a less-than-minor geomagnetic storm

Knut Stanley Jacobsen and Yngvild Linnea Andalsvik
Norwegian Mapping Authority

Kp index from NOAA/SWPC
2013-01-17

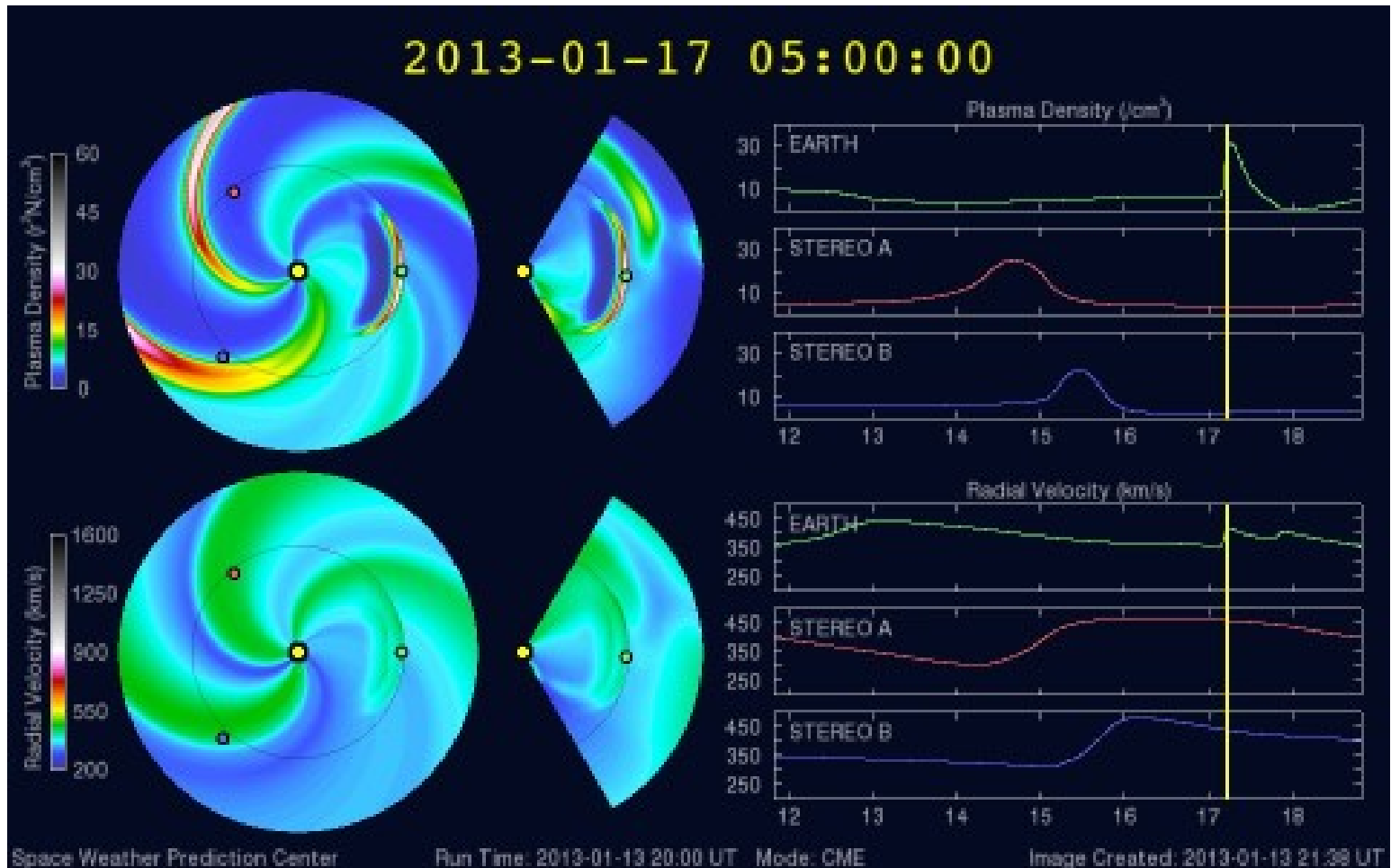


2013-01-17 00:00 to 2013-01-17 23:59 UTC
Rate of TEC Index at ground



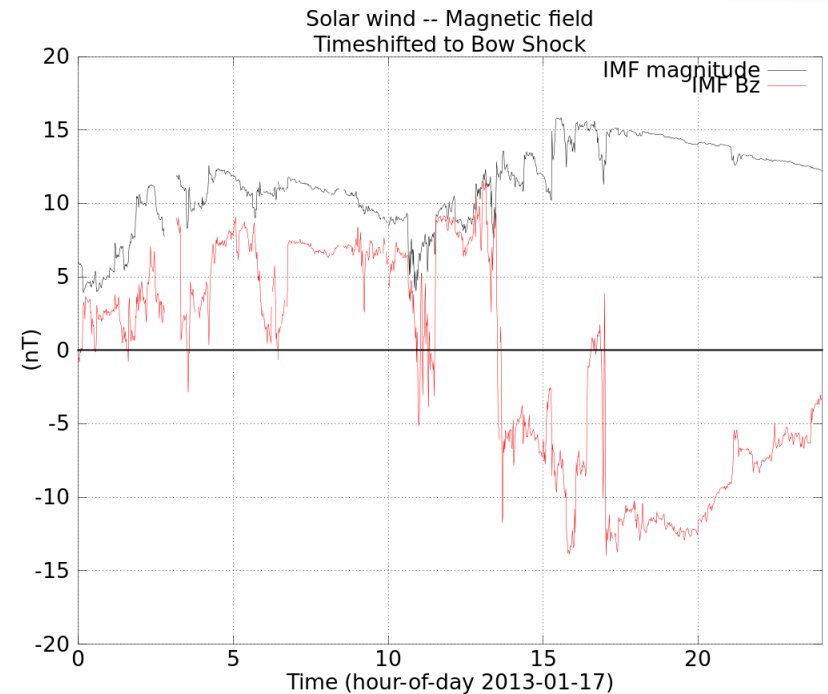
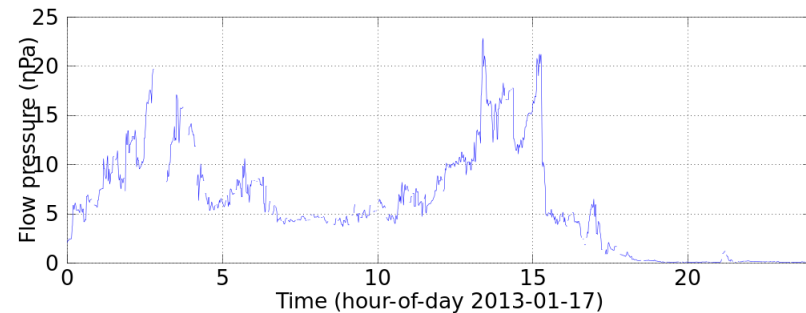
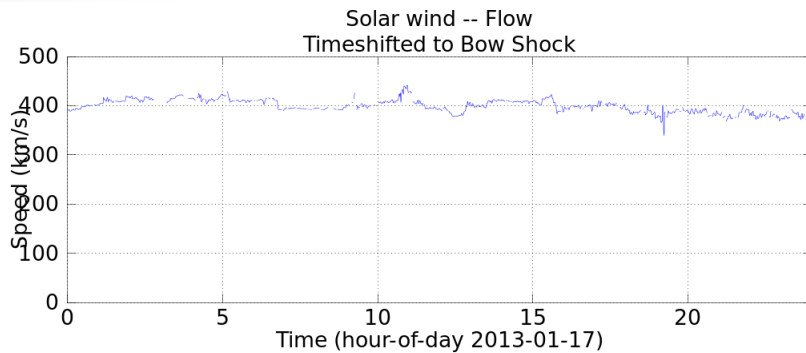
17 January 2013

A CME impacted Earth's magnetosphere



Solar wind

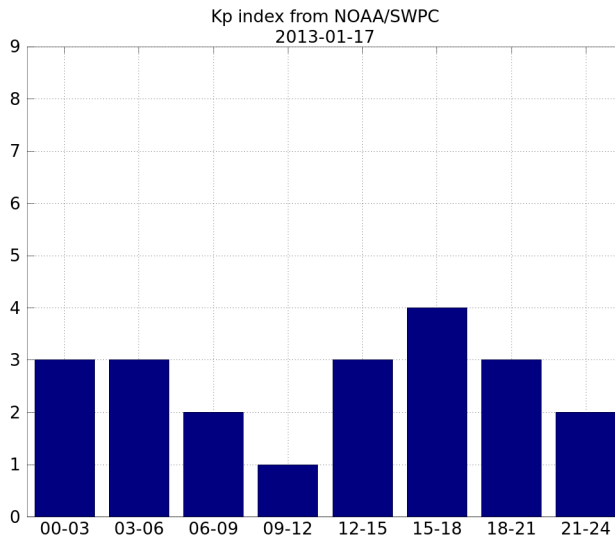
- Southward turning when the CME hits
- Increased pressure, transient ejecta, smooth CME



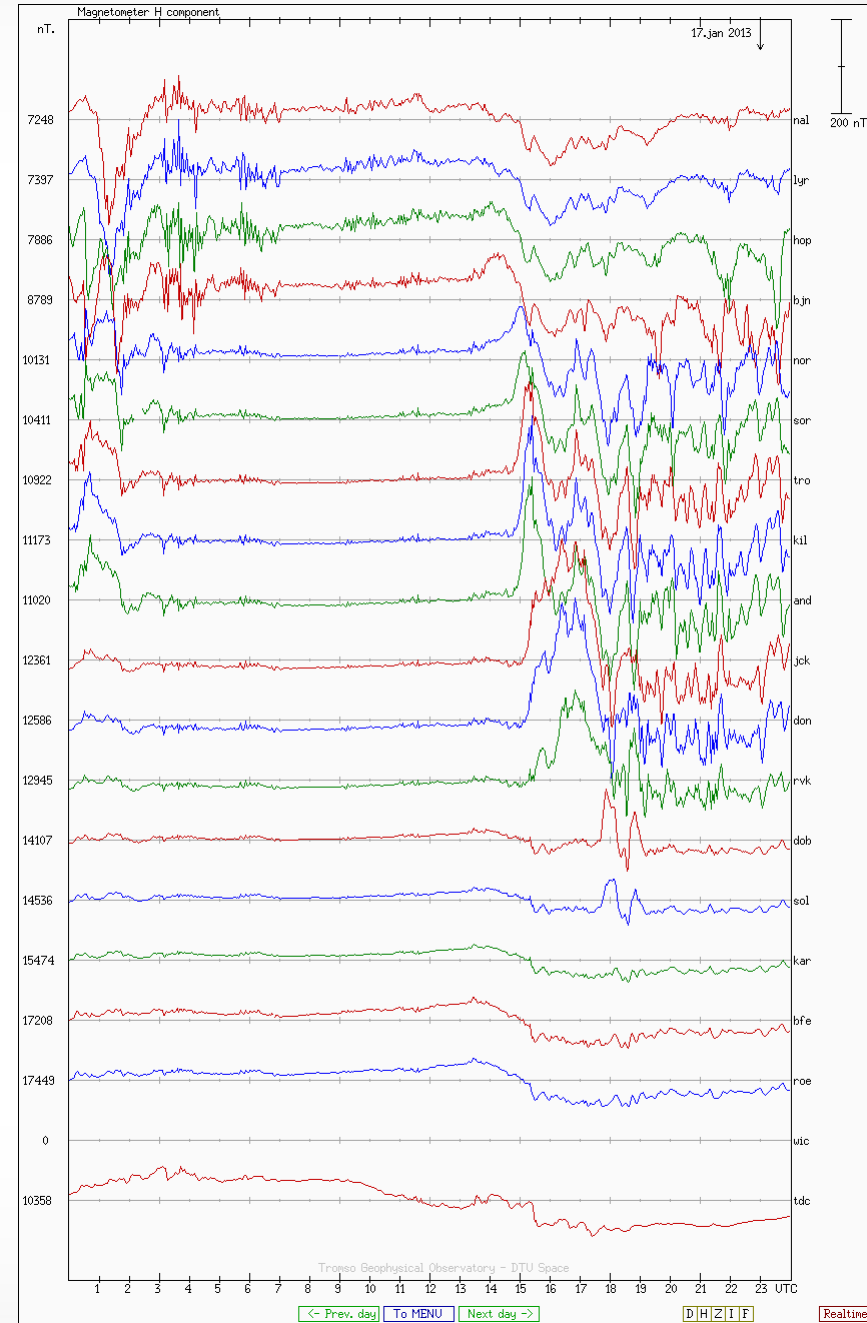
17 January 2013

Onset of geomagnetic activity around 14 - 15 UT

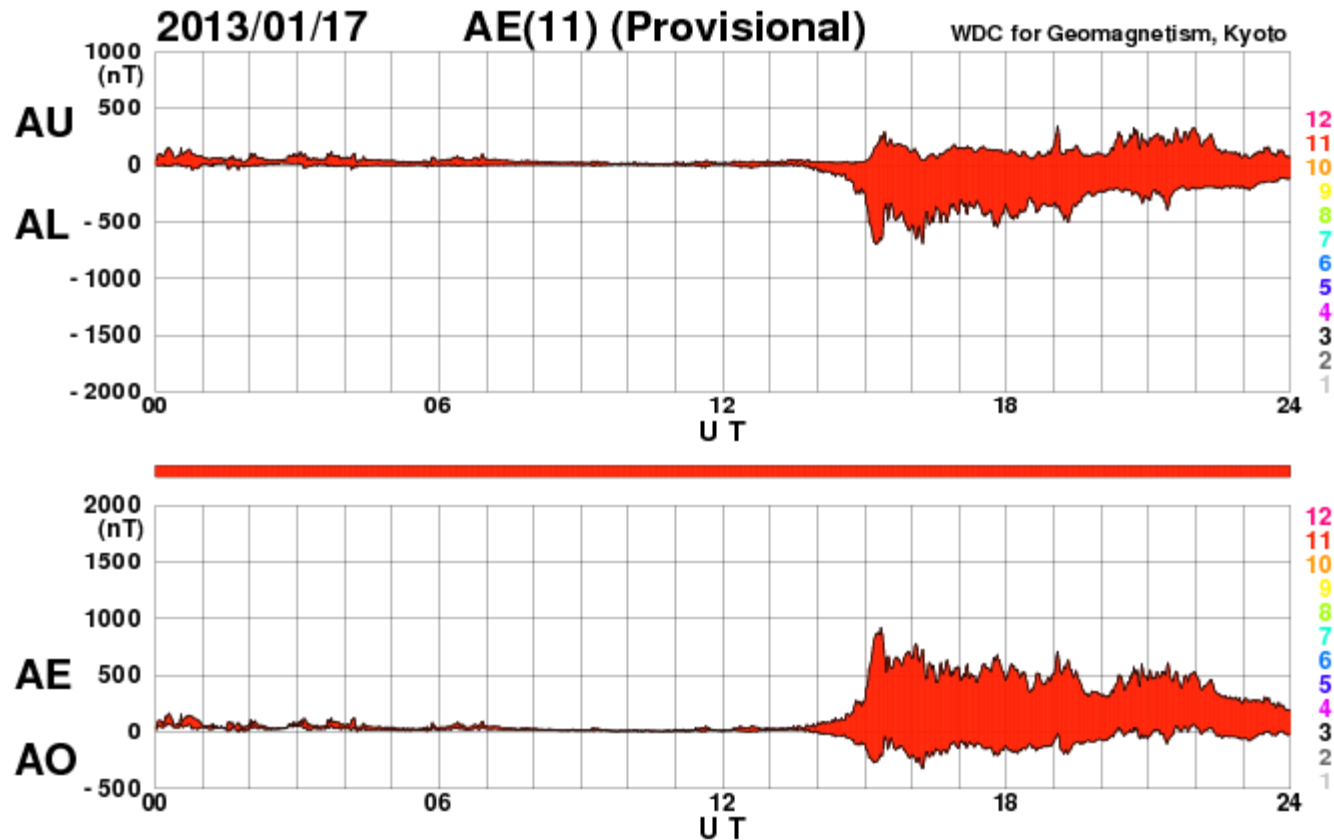
3-hour planetary Kp:



Magnetometer stackplot from TGO:

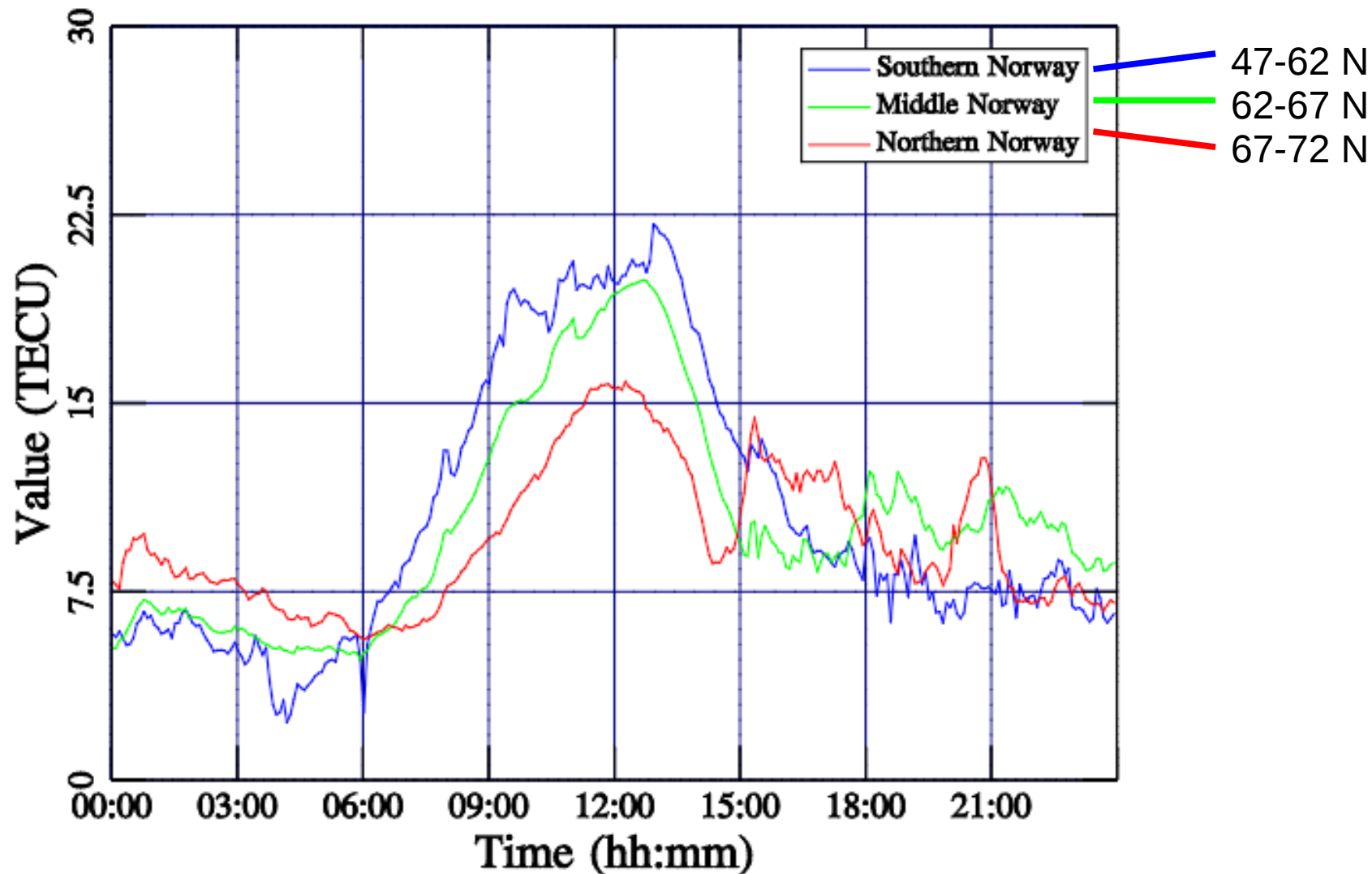


AE and AL indicies



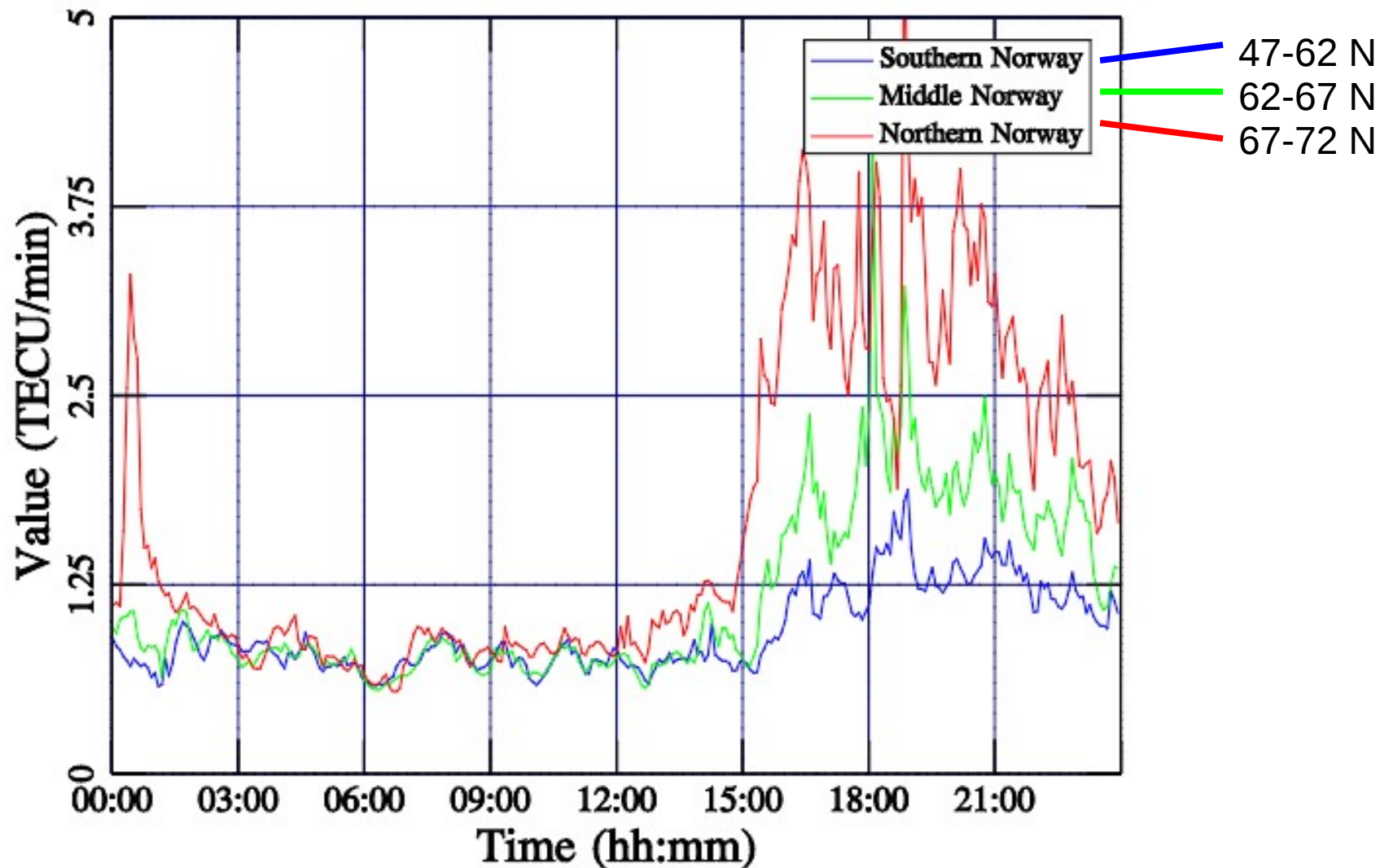
[Created at 2013-05-13 09:07UT]

2013-01-17 00:00 to 2013-01-17 23:59 UTC Vertical Total Electron Content

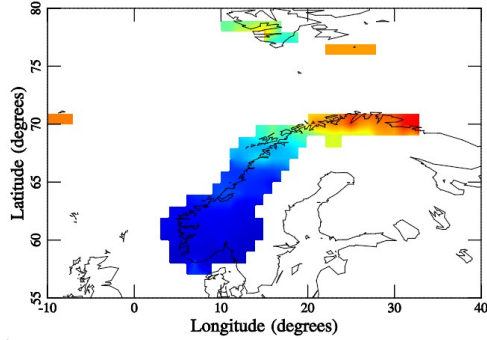


2013-01-17 00:00 to 2013-01-17 23:59 UTC

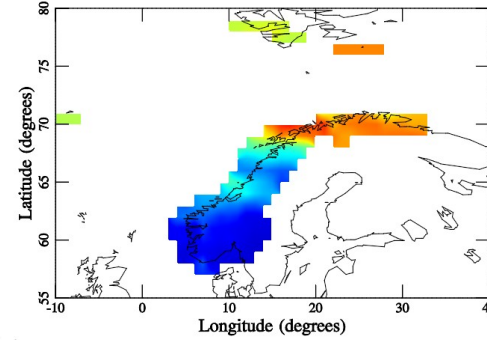
Rate of TEC Index at ground



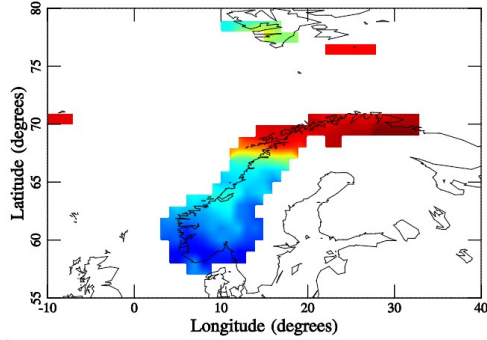
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 15:25 UTC



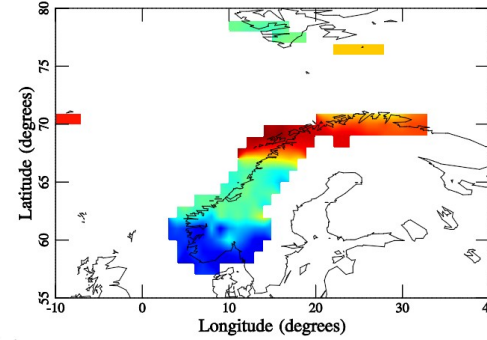
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 15:55 UTC



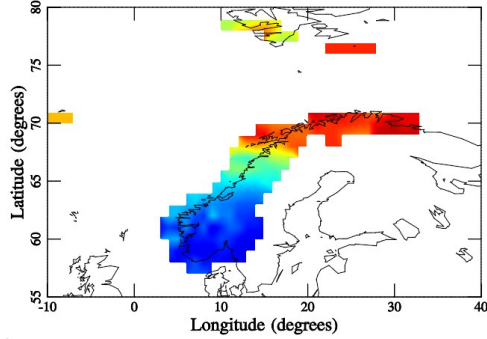
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 16:25 UTC



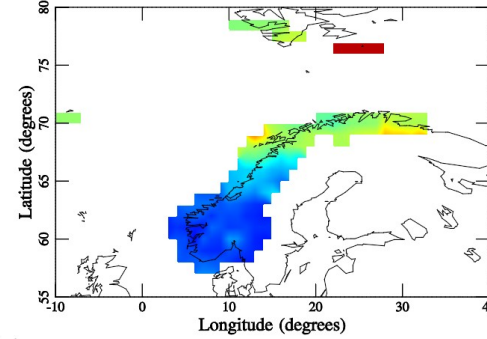
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 16:35 UTC



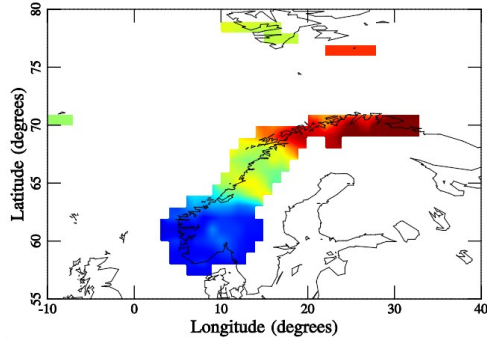
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 16:55 UTC



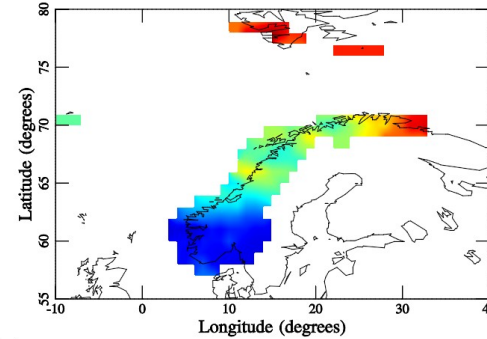
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 17:25 UTC



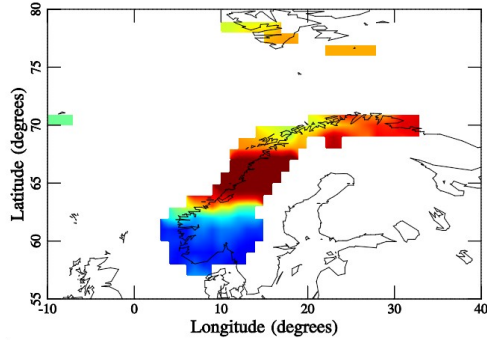
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 17:45 UTC



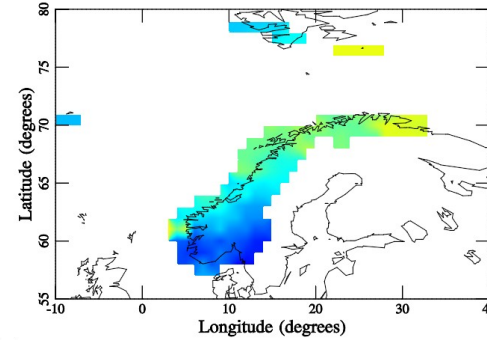
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 17:55 UTC



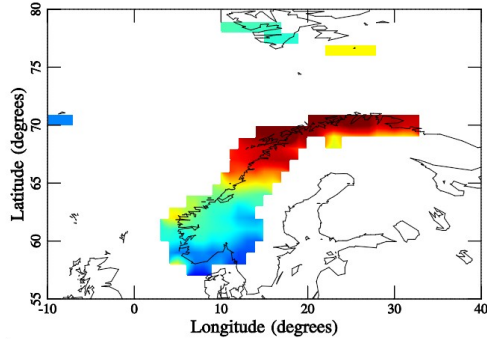
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 18:05 UTC



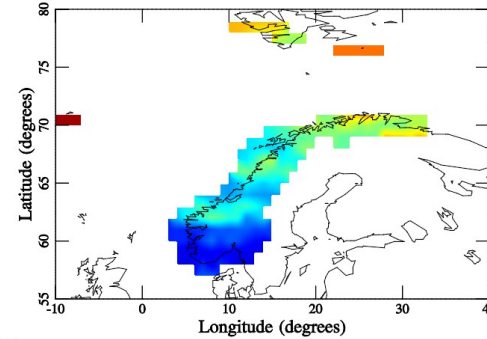
Mean ROTI observed at ground locations [TECU/min]
2013-01-17 18:25 UTC



Mean ROTI observed at ground locations [TECU/min]
2013-01-17 18:55 UTC



Mean ROTI observed at ground locations [TECU/min]
2013-01-17 19:25 UTC



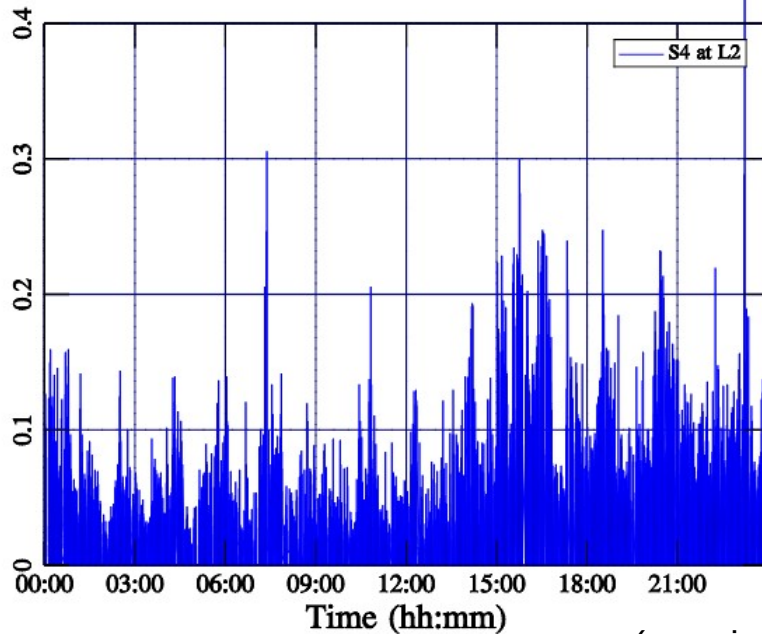
Scintillations

- S4 and σ_ϕ show higher values from ~14 UT
- The scintillations were stronger in Tromsø than on Vega

S4 scintillation index:

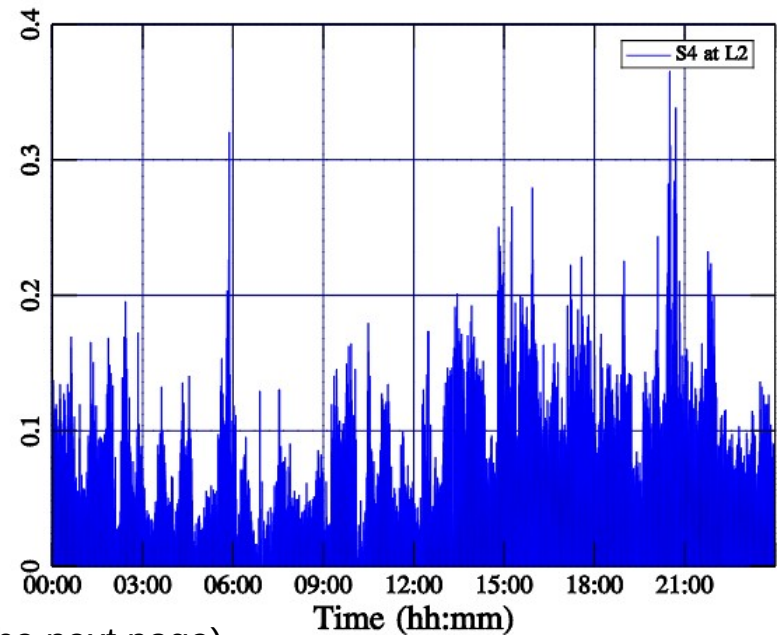
Vega:

2013-01-17 00:00 to 2013-01-17 23:59 UTC
Station Id: veg2



Tromsø:

2013-01-17 00:00 to 2013-01-17 23:59 UTC
Station Id: tro2



(σ_ϕ scintillation index is on the next page)

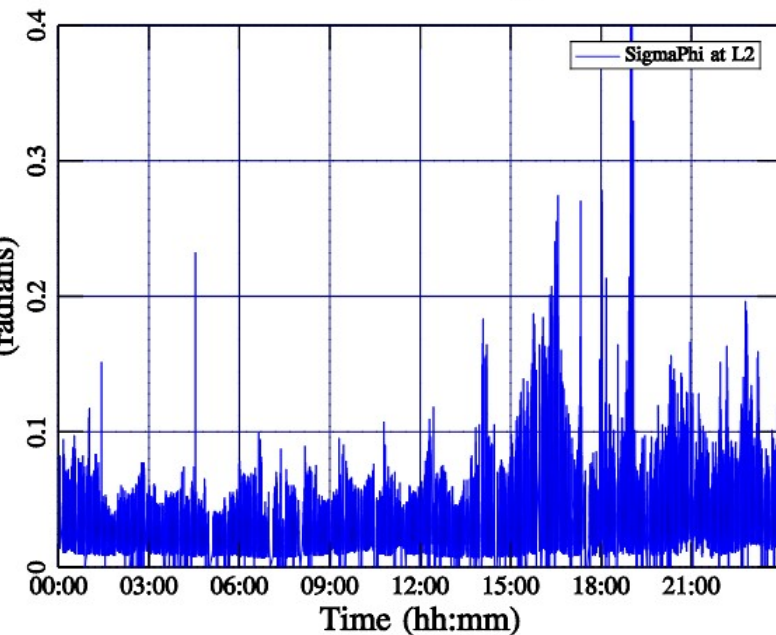
Scintillations

- S4 and σ_ϕ show higher values from ~14 UT
- The scintillations were stronger in Tromsø than on Vega

σ_ϕ scintillation index:

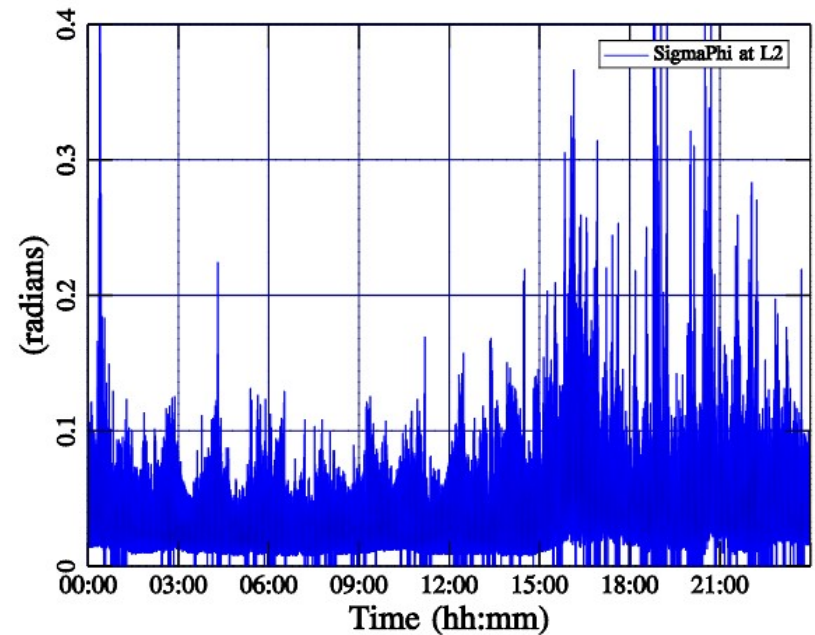
Vega:

2013-01-17 00:00 to 2013-01-17 23:59 UTC
Station Id: veg2



Tromsø:

2013-01-17 00:00 to 2013-01-17 23:59 UTC
Station Id: tro2



CPOS network disruptions

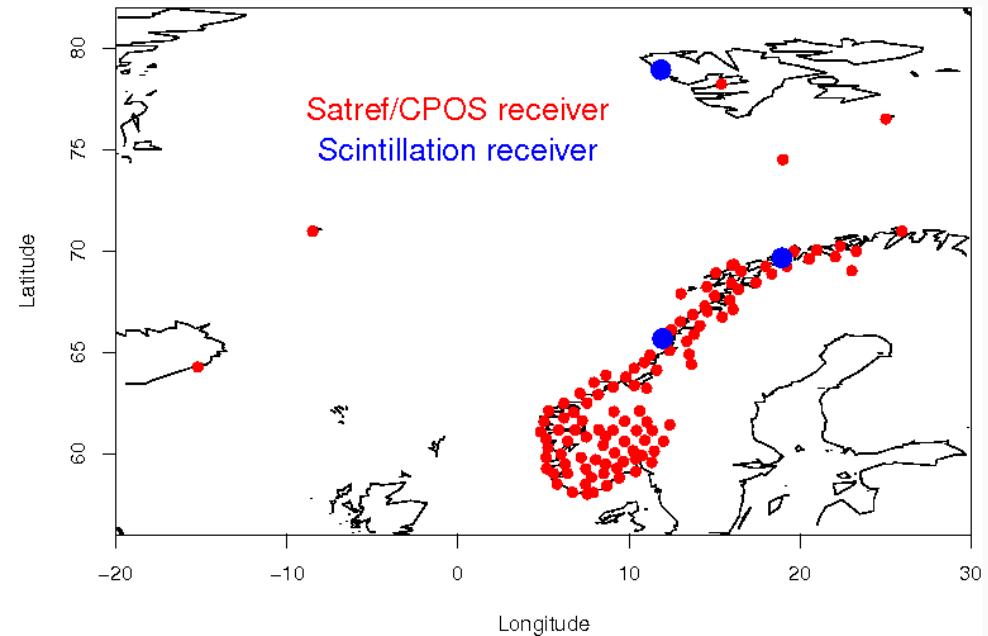
(CPOS is a Network RTK
positioning service)

North Norway:

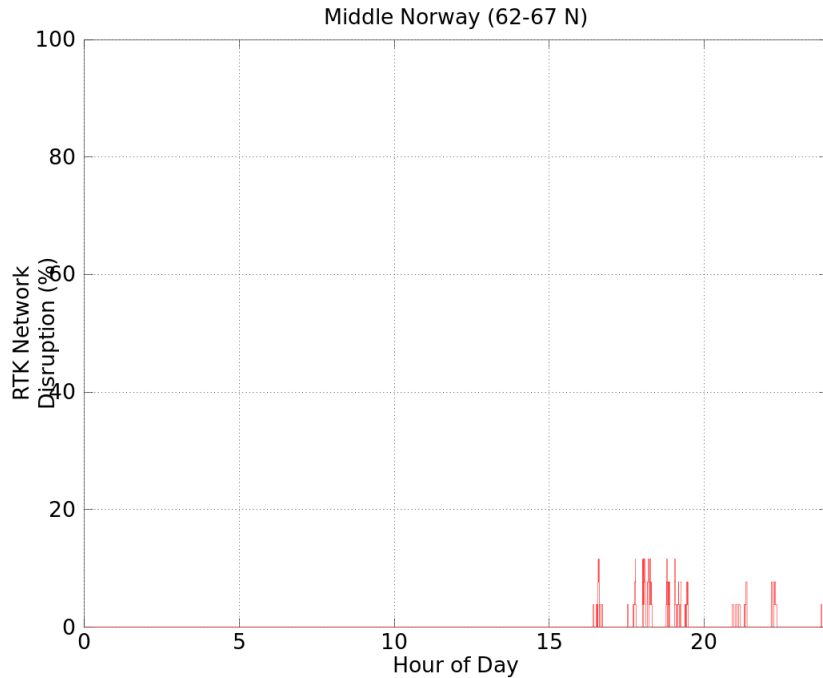
- Scintillation monitor, CPOS station, and GNSS monitor in Tromsø (~70 deg. N)

Middle Norway:

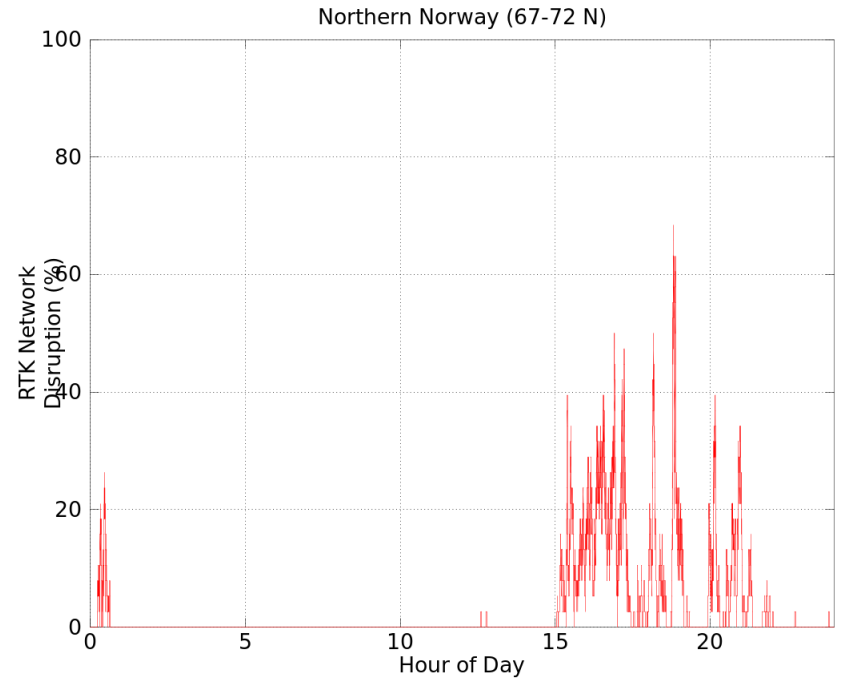
- Scintillation monitor at Vega (65.5 deg N)
- GNSS monitor station in Steinkjer, approximately 14 km from the closest CPOS station



CPOS network disruptions



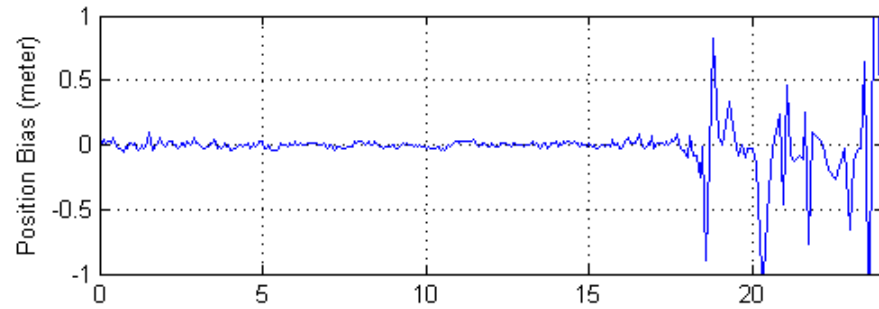
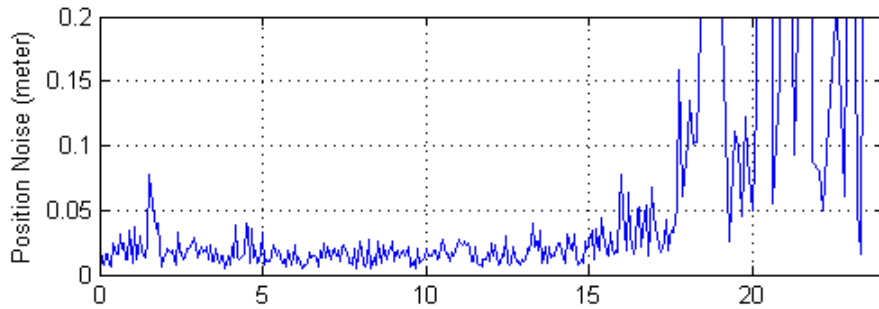
Middle Norway: RTK network suffers small disruptions



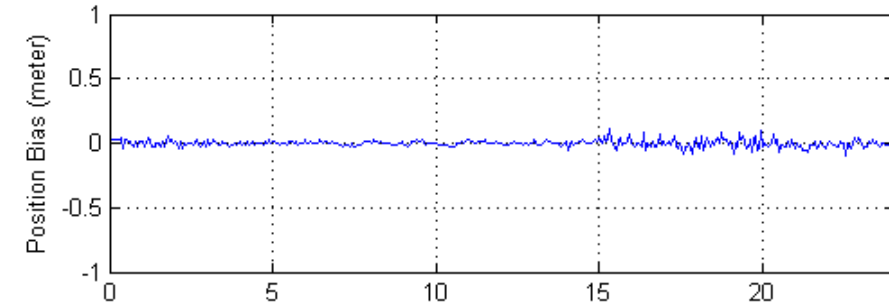
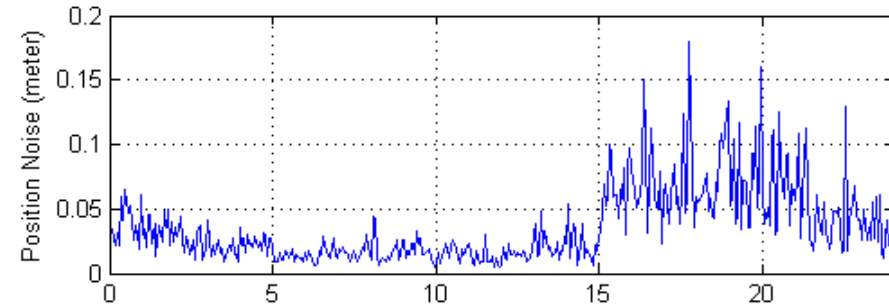
Northern Norway: Strongly disrupted for several hours

Disruption is measured as the percentage of stations for which less than 10 percent of the satellites in view can be used by the RTK software

Position noise and bias

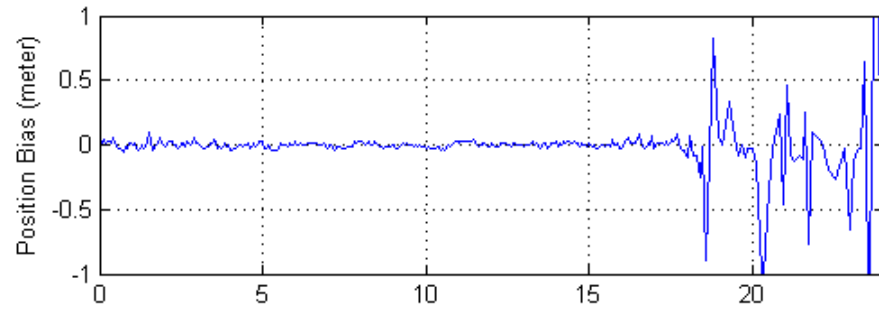
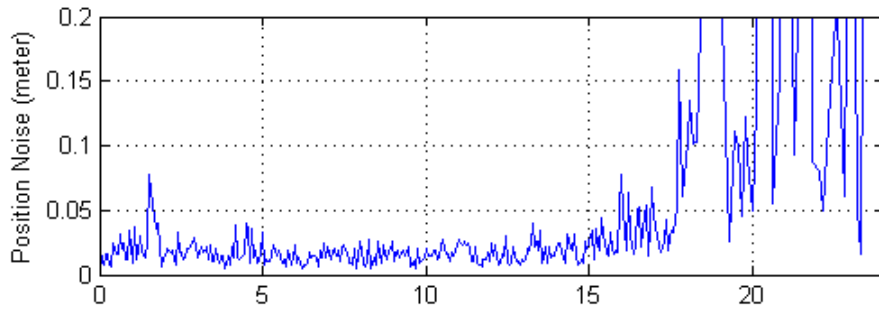


Steinkjær: increased noise and large position bias values up to 1m in magnitude

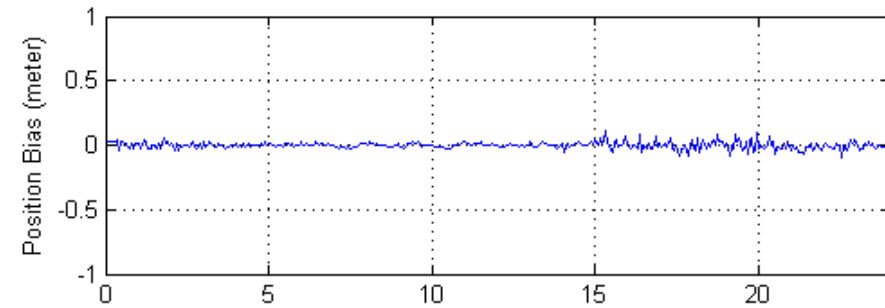
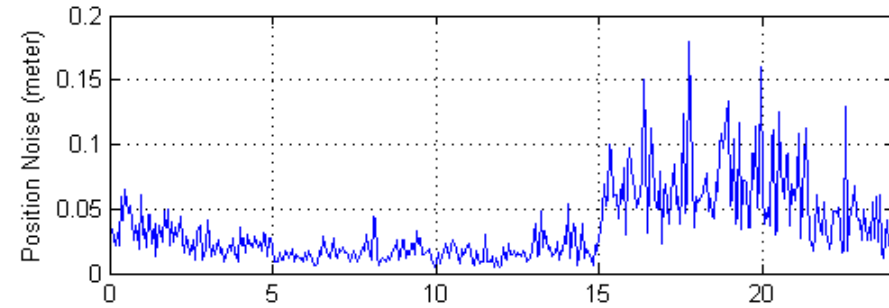


Tromsø: increase in position noise from $\sim 1\text{cm}$ to $\sim 1\text{dm}$ -correlated with ROTI

Position noise and bias



Steinkjær: increased noise and large position bias values up to 1m in magnitude

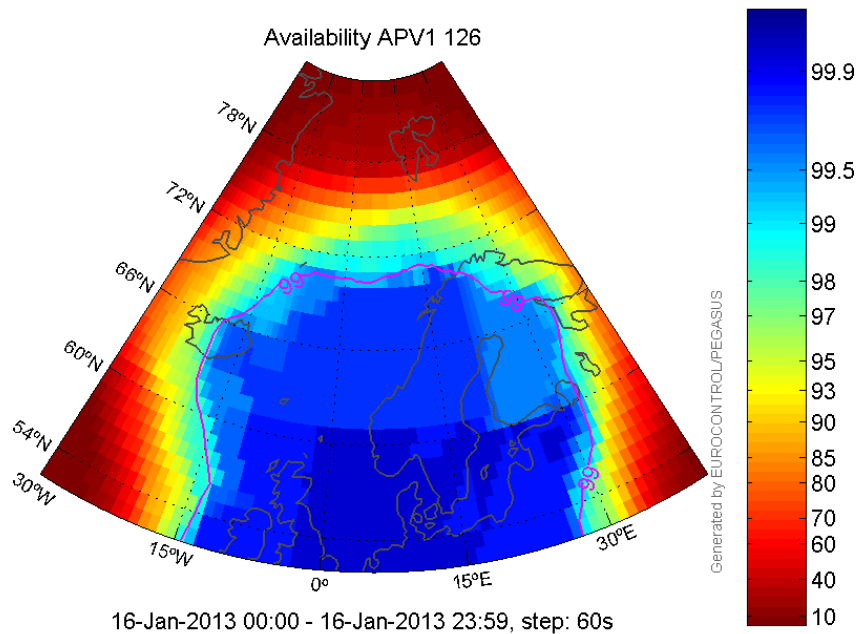


Tromsø: increase in position noise from ~1cm to ~1dm -correlated with ROTI

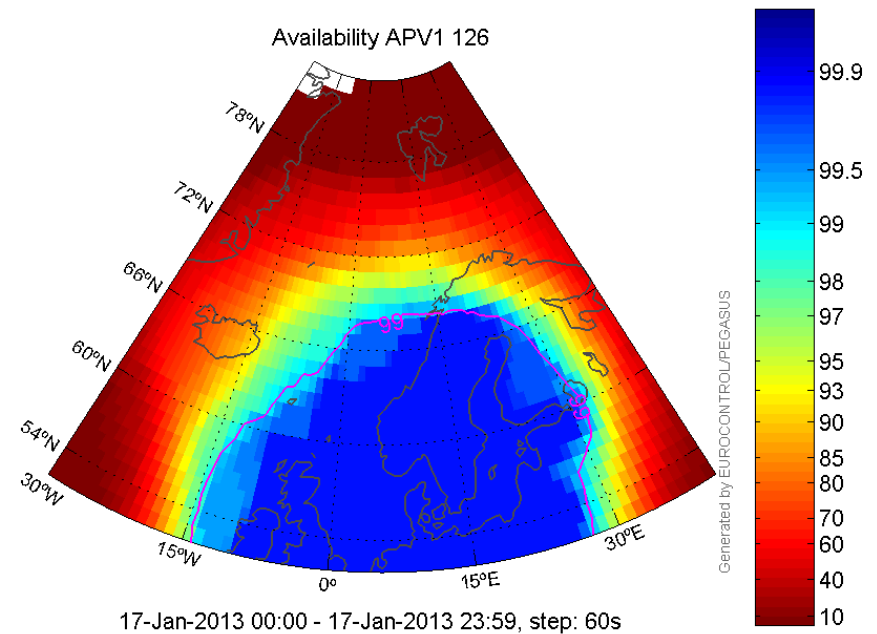
Steinkjær is far from nearest CPOS station - end effect of disturbances is larger because the RTK network fail to model the spatial variability in the ionosphere

EGNOS availability

The day before the storm:



The day of the storm:



- Some reduction in availability
- No RIMS stations down

Summary

- Small space weather events can have a large local impact at high latitudes.
- The effects are amplified for users that receive corrections from a support network which has no receivers close to the user.

(presumably because of a decreased spatial correlation distance in the ionosphere)

Steinkjer/Vega (65 N)

Tromso (70 N)

