

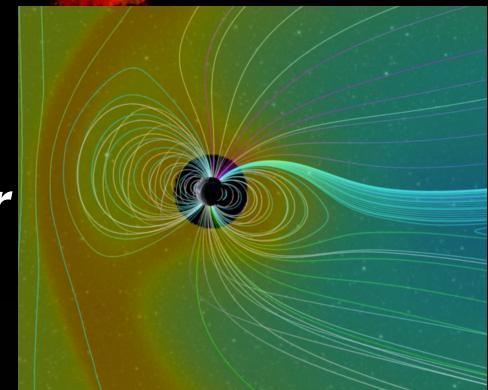
Recent Space Weather Efforts in Sweden

Hermann Opgenoorth

*Professor Emeritus
University of Umeå*

*and also
Dept. of Astronomy
Leicester University
Leicester UK*

***Chair: European Space Weather
Assessment and Consolidation
Committee of the ESSC/ESF***



Ongoing activities in Sweden:

ISES Regional Warning Center - IRF-Lund

SMHI: SWx warning system contracted out to METOFFICE UK

MSB Project: Research into Extreme Space Weather - SU, IRF- Uppsala, FOI

Paper on Arlanda radio-burst incident published:

Solar radio emission as a disturbance of aeronautical radionavigation

Christophe Marqué^{1*}, Karl-Ludwig Klein², Christian Monstein³,
Hermann Opgenoorth⁴, Antti Pulkkinen⁵, Stephan Buchert⁴,
Säm Krucker⁶, Rudiger Van Hoof⁷ and Peter Thulesen⁸, SWSC 2018

MSB activities: National Risk Register, SWx upgraded to risk no 1 !
Workshops and outreach to “end-user community”
Recent Leaflet to public on SWx risks to society



Myndigheten för
samhällsskydd
och beredskap

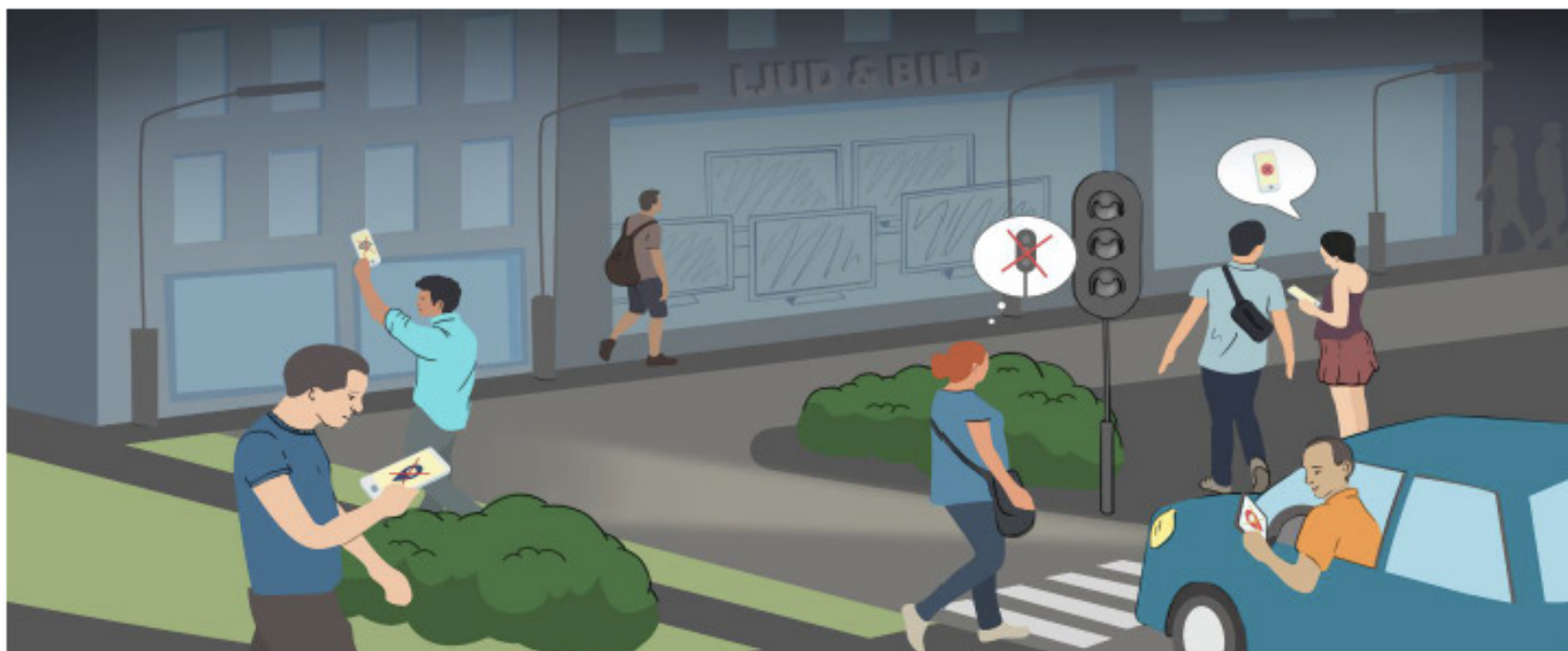
FAKTA

JANUARI 2019

MSB1318

Extrema solstormar

Konsekvenser för samhällsviktig verksamhet



En solstorm är ett utbrott på solen där strålning och elektriskt laddade partiklar slungas ut. I sällsynta fall sker extrema solstormar som kan leda till mycket allvarliga

Solfläckscykeln

Solens aktivitet kan följas genom

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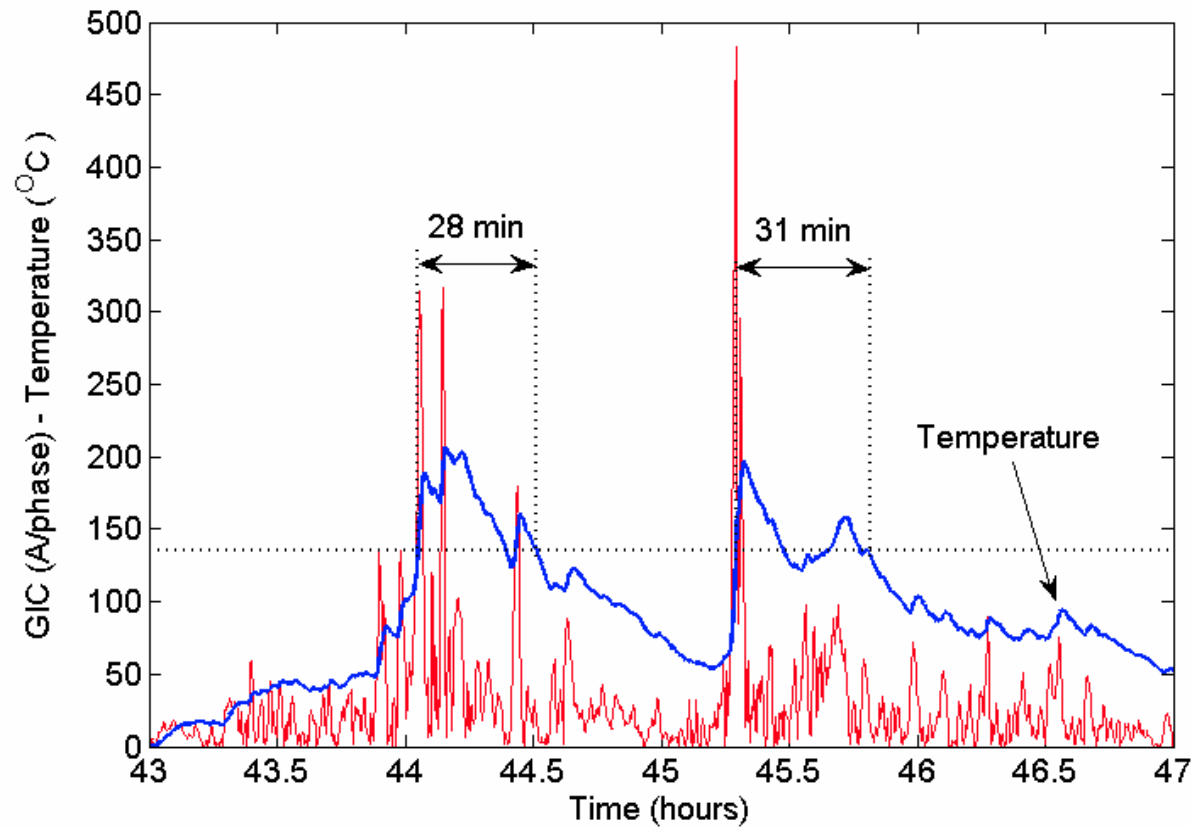
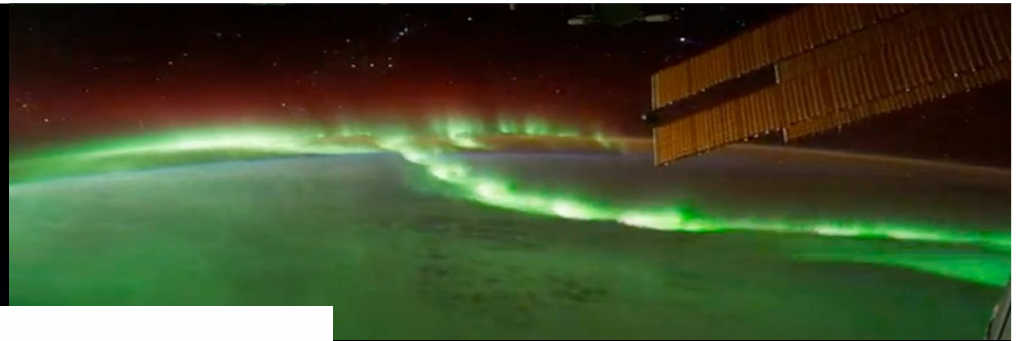
Recent Leaflet to public on SWx risks to society

Sweden Partner in ESA-SSA EXPERT SERVICE CENTER – GEOMAGNETISM

Consortium: Norway, Denmark, Sweden, Finland, UK, Germany

NEW magnetometer network Sweden Denmark: MAGSWEDAN (see below)

Space Weather Damage



“The Beauty
and the Beast
”

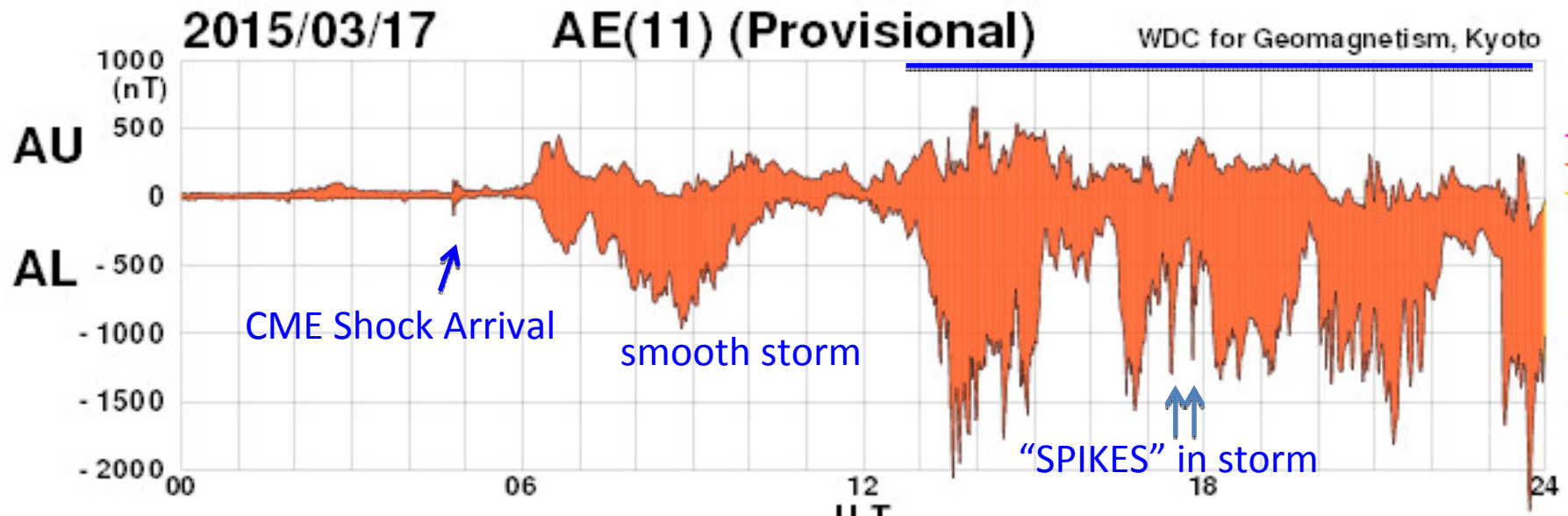
Internal
Damage due
to one storm

Sample tie plate temperature calculation for a transformer exposed to multiple events of Geomagnetically Induced Currents (GICs) during a magnetic storm.

Blue trace is incremental temperature and
Red trace is the magnitude of the GIC/phase.

From NERC report



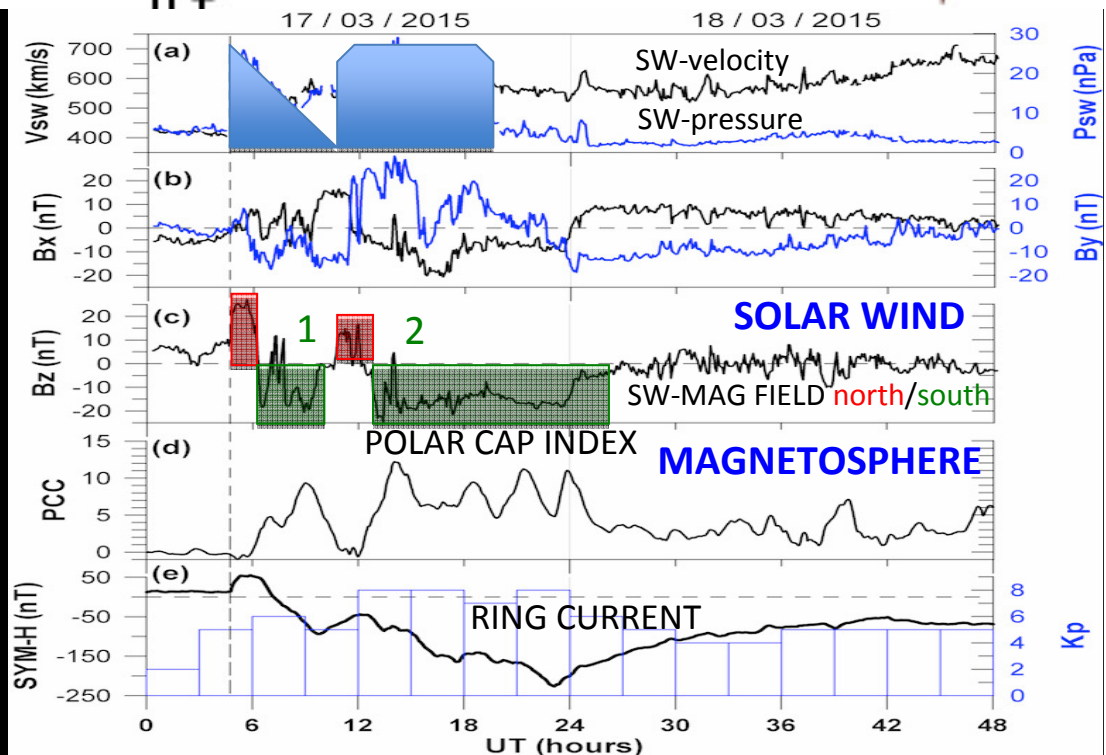


Pilot study on B "spikes" in storms, or dB/dt peaks ?

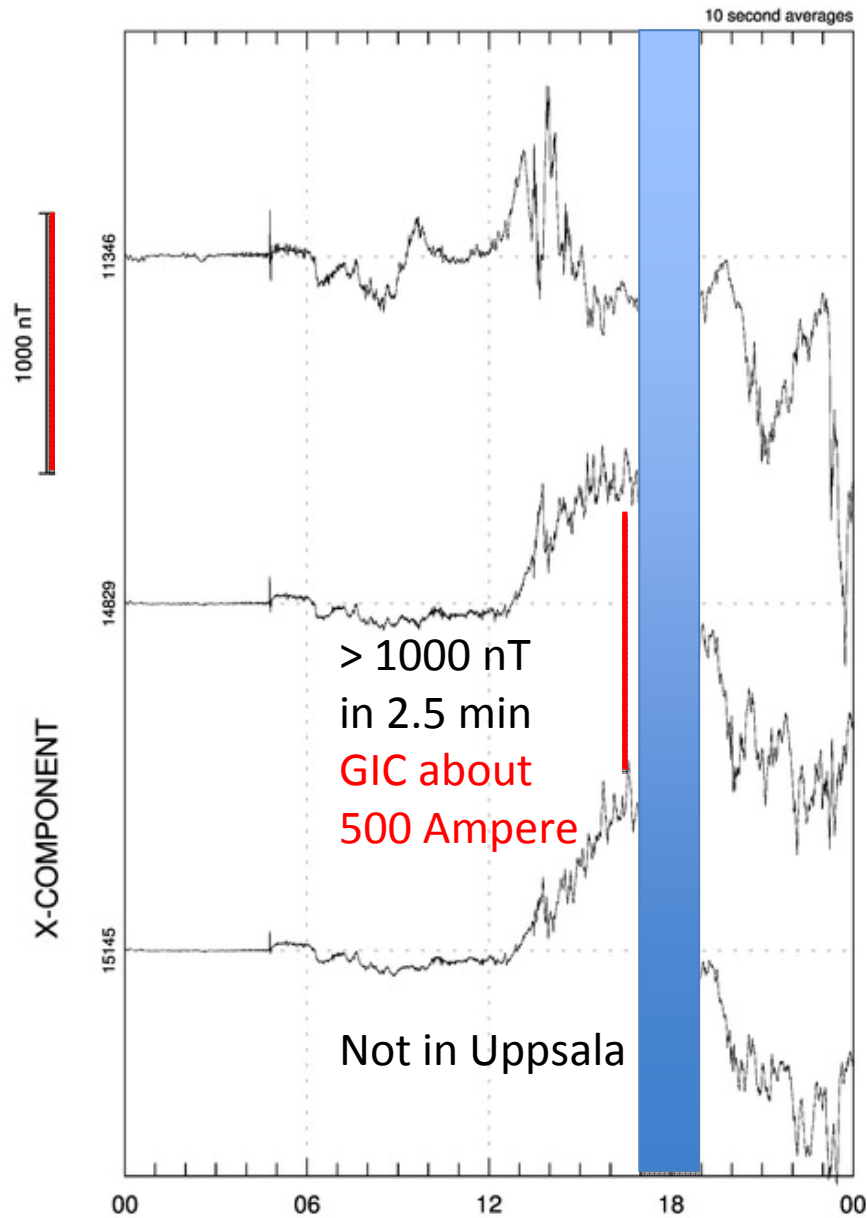
... looked at 2015-03-17: s.c. "St. Patrik's Day" Storm

TOP: Auroral Electrojet Indices (AE = AU+AL)

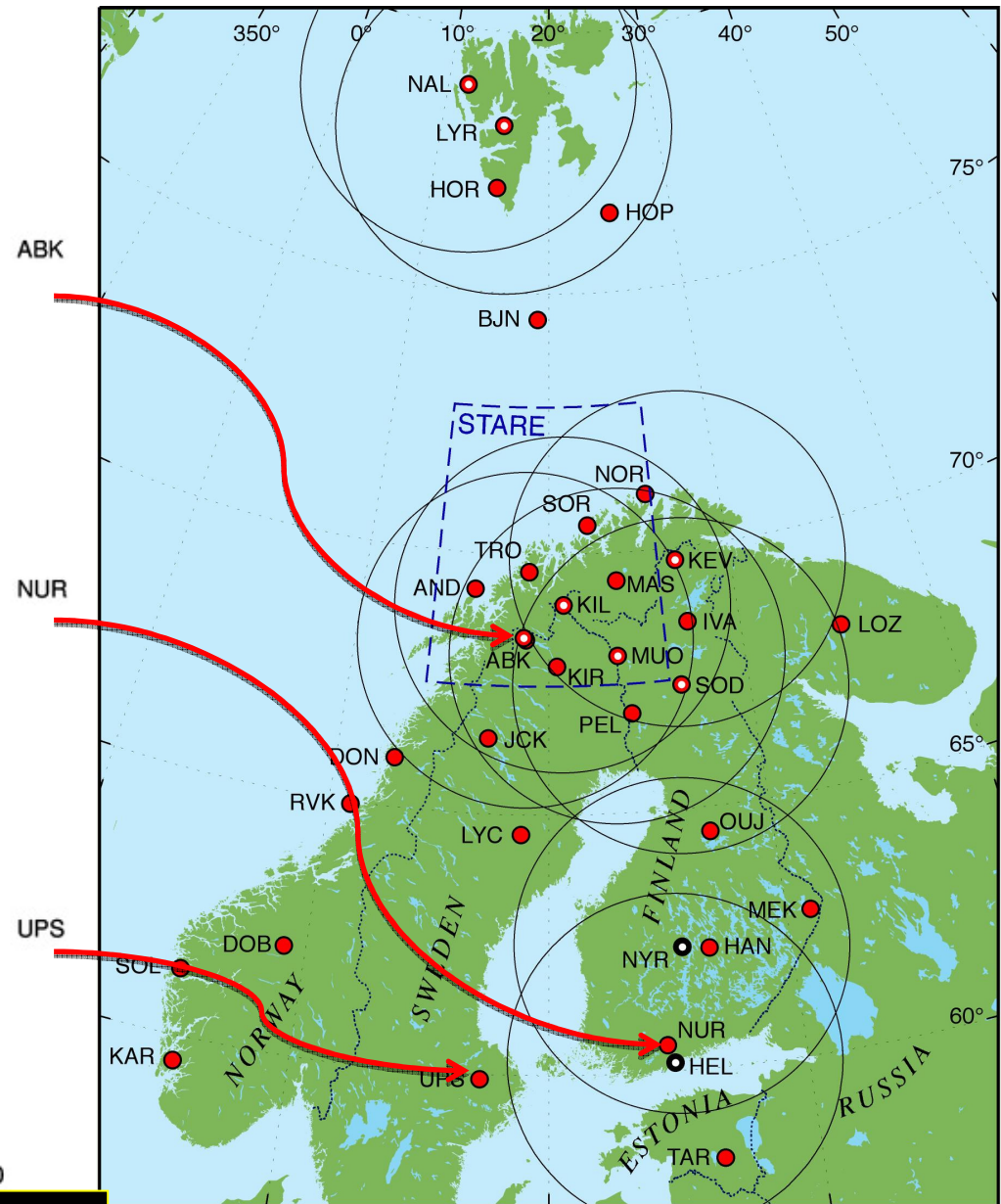
RIGHT: Solar Wind Data ...and Pc - Dst /SymH indices



X component 2015-03-17



MIRACLE NETWORK: FMI, IRF, Univ. of Tromsø

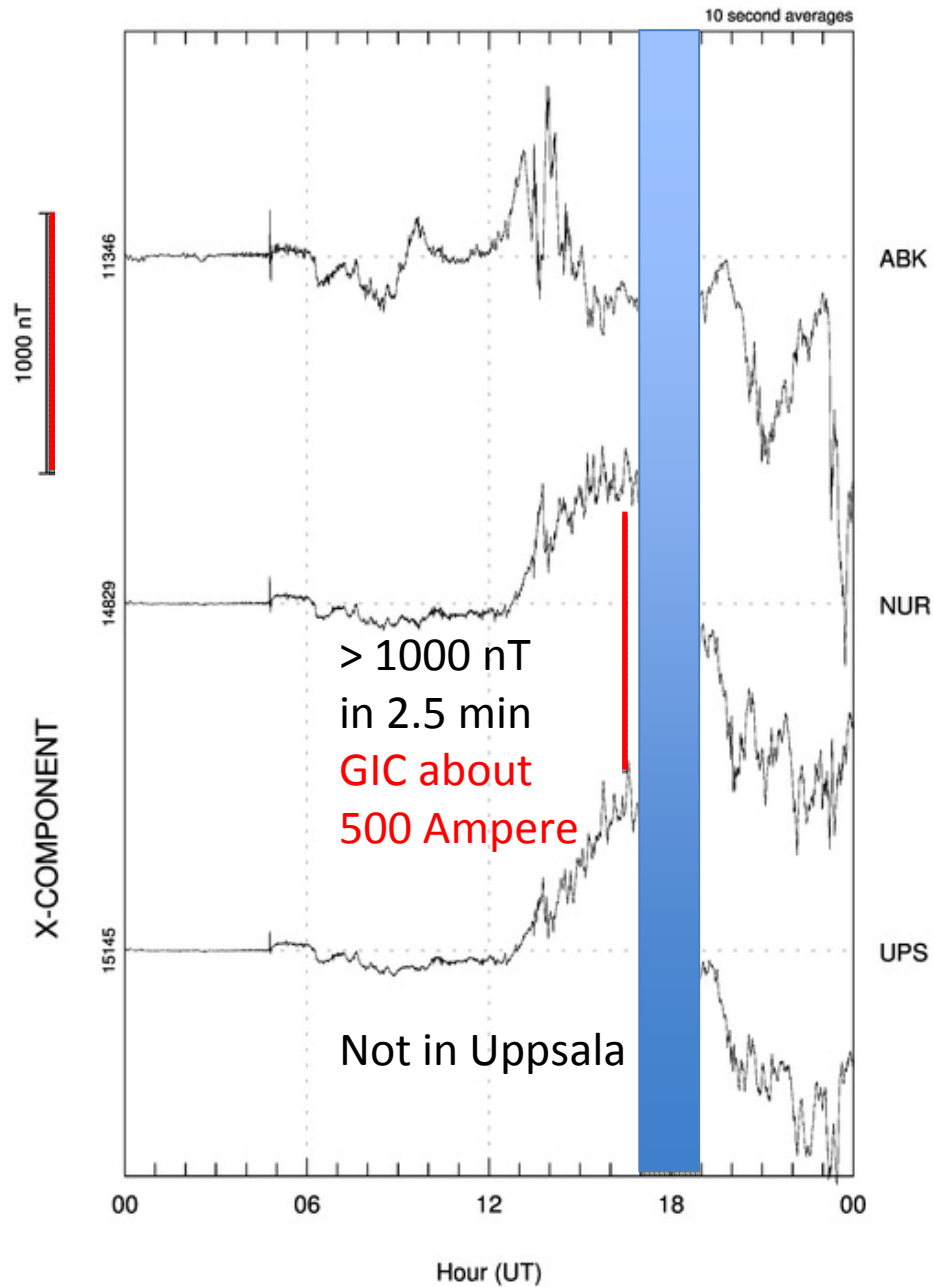


- Magnetometer
- All-sky camera
- Magnetometer and all-sky camera

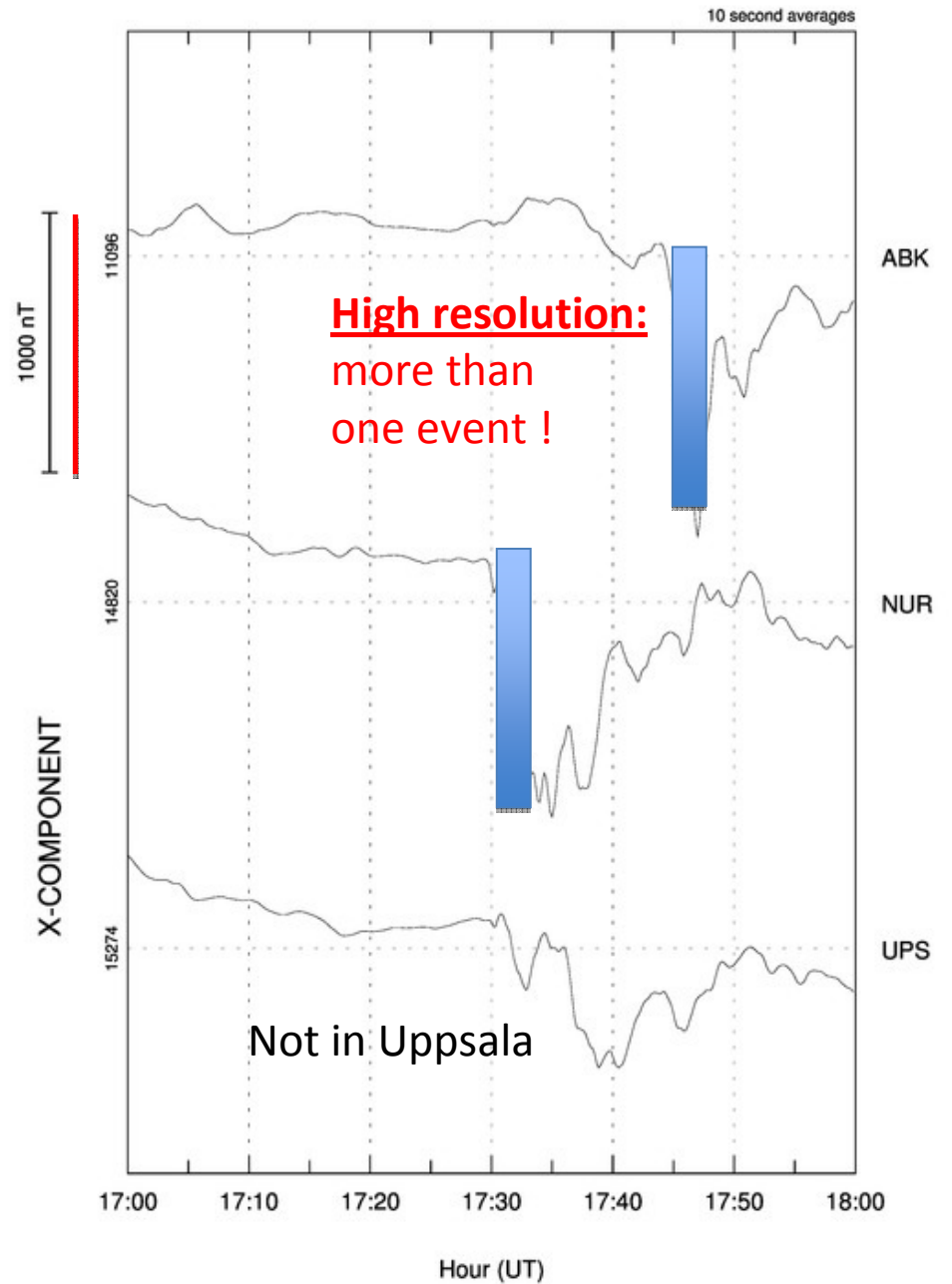
February 2013

Note: B-spikes during Halloween storm 2003 were similar: 2000 nT in 5 min over Malmö !!

X component 2015-03-17

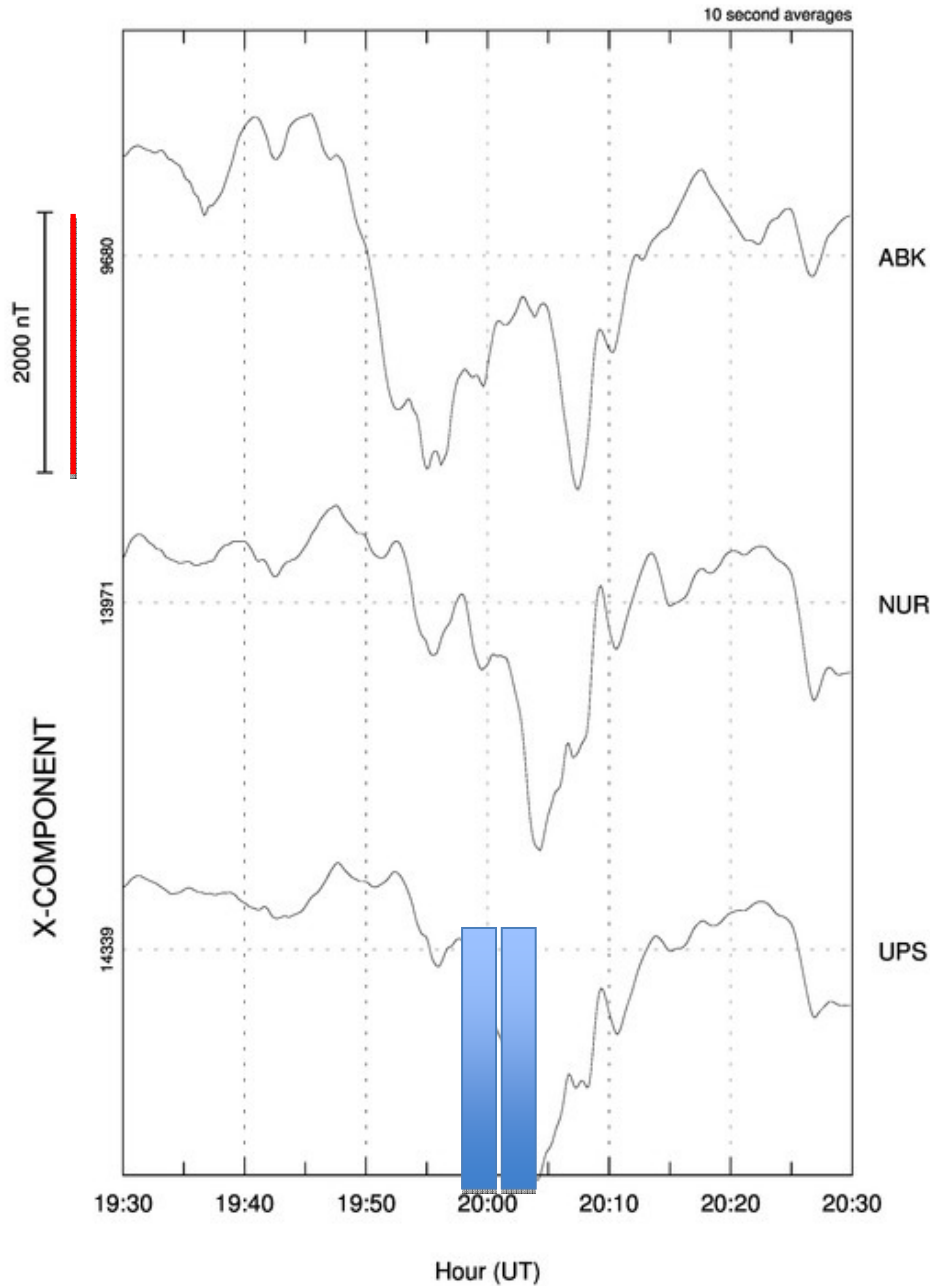


X component 2015-03-17



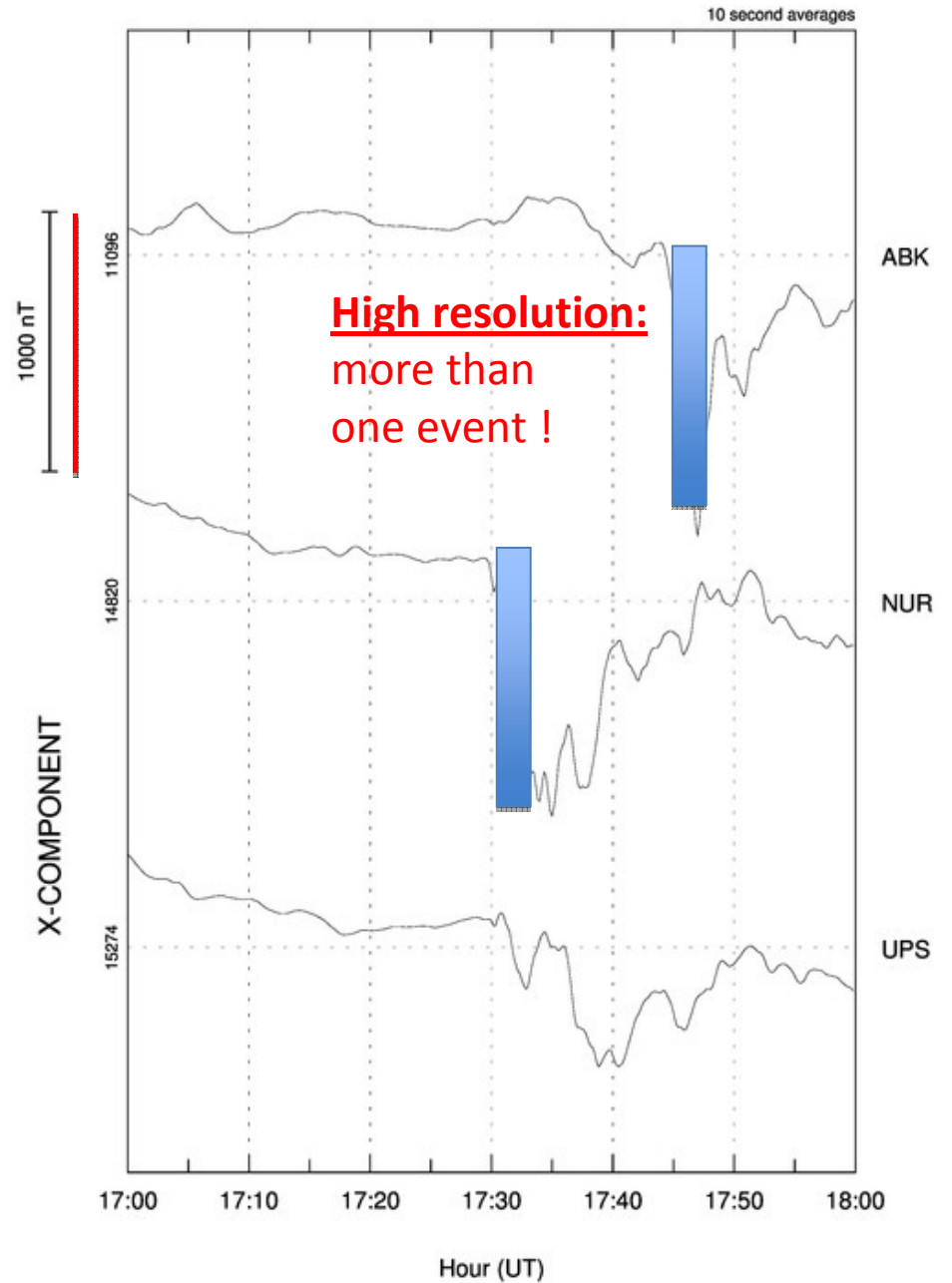
ST PATRICK'S Storm NOTE: scale 1000 nT

X component 2003-10-30



HALLOWEEN storm NOTE: scale 2000 nT

X component 2015-03-17



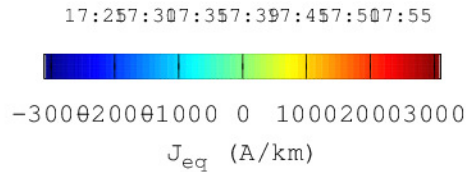
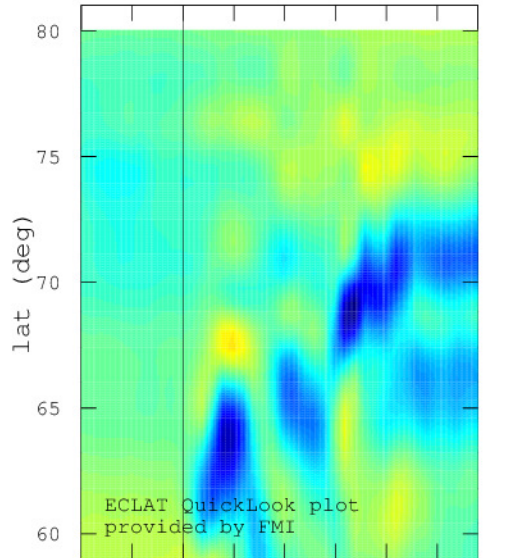
ST PATRICK'S Storm NOTE: scale 1000 nT



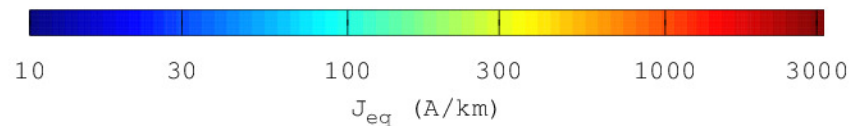
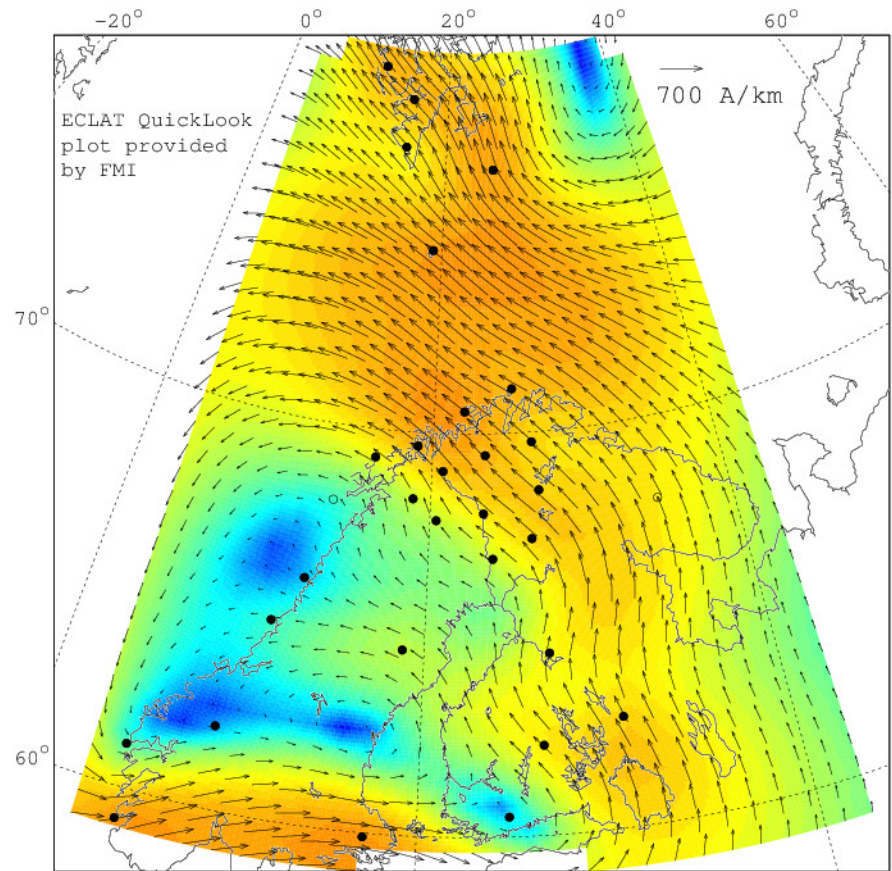
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:30:00 UT

Eastward current at 22.061° long.



“KEO-gram” W-jet **BLUE**



2D-pattern total equiv. current **RED**

FMI MIRACLE Quicklook Equivalent Current flows
MOVIE WITH 1 MIN TIME RES.

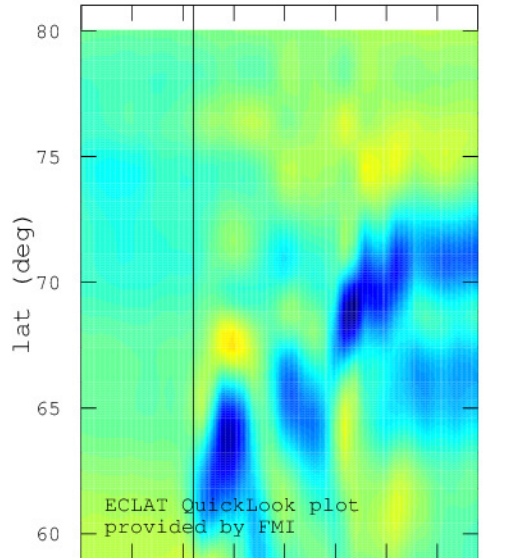
(SECs method – after O.Amm
- note different colour code)



FINNISH METEOROLOGICAL INSTITUTE

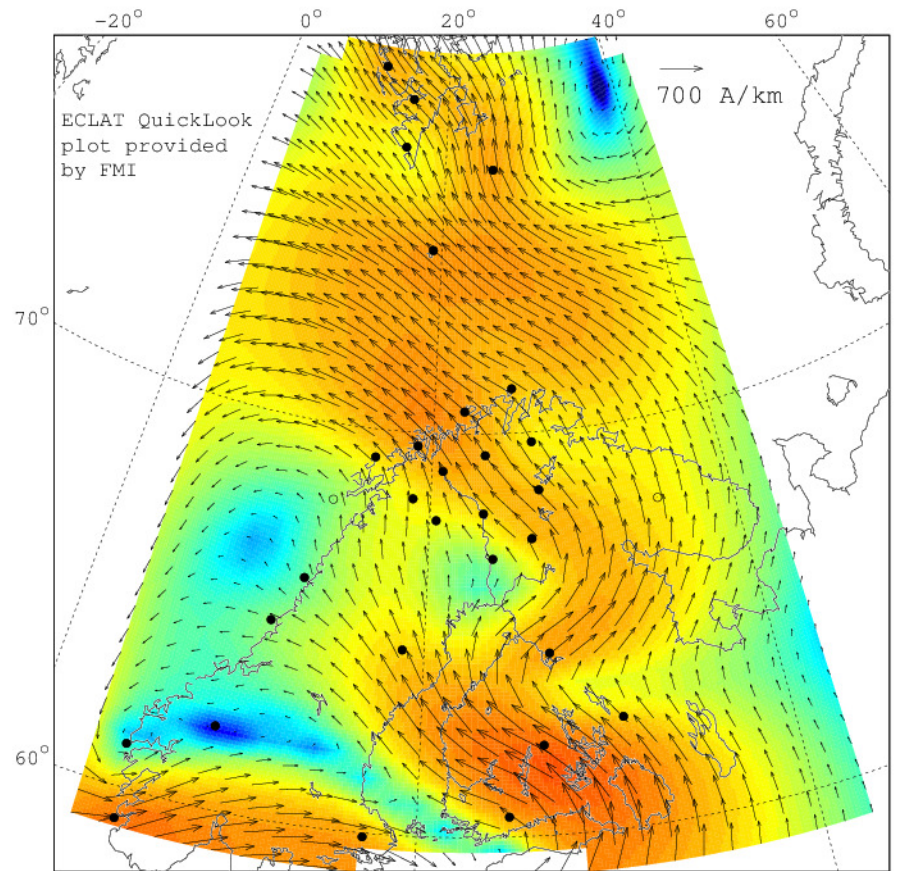
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Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

J_{eq} (A/km)



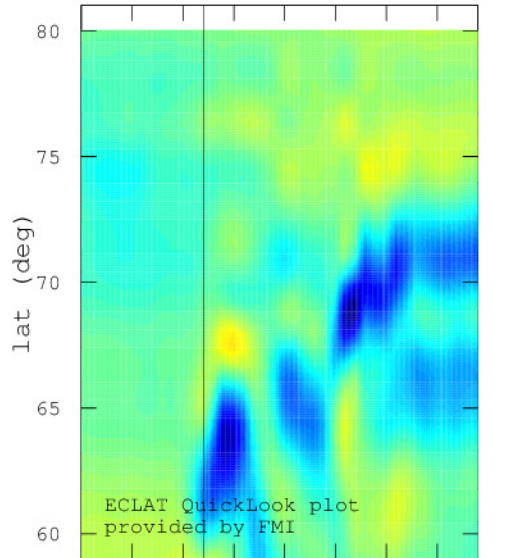
J_{eq} (A/km)



FINNISH METEOROLOGICAL INSTITUTE

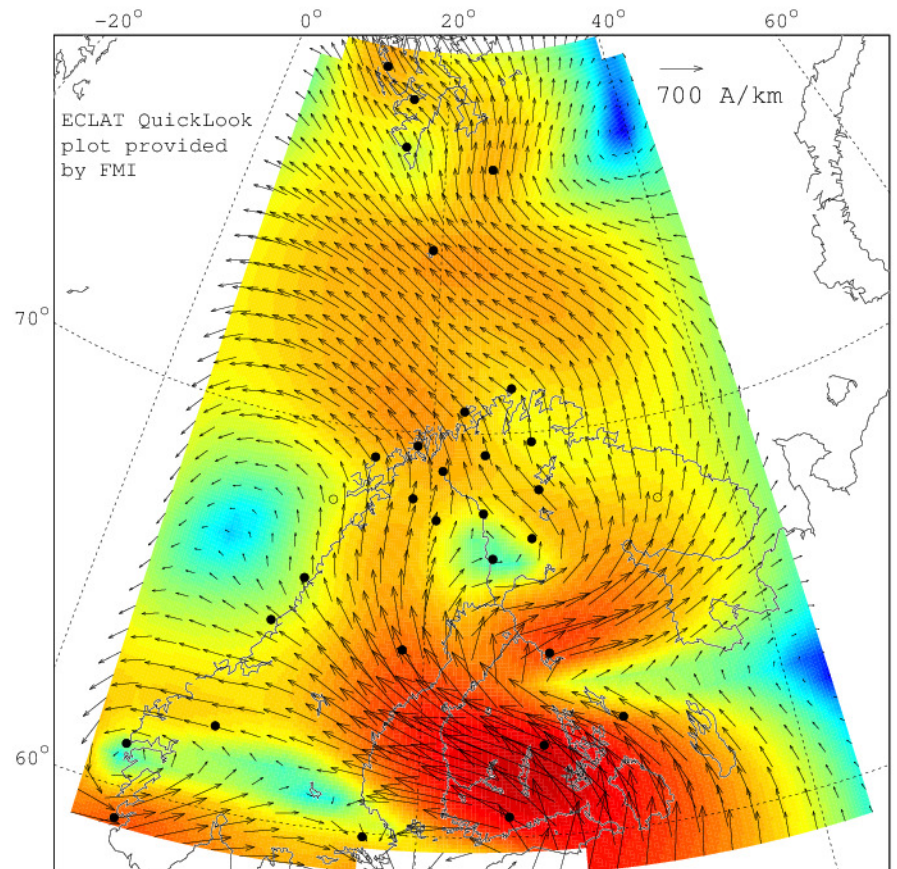
Date/time: 17-03-2015; 17:32:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

-3000 0 2000 1000 0 1000 2000 3000
 J_{eq} (A/km)



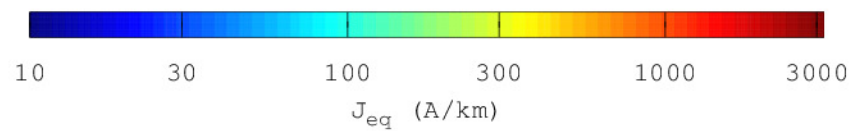
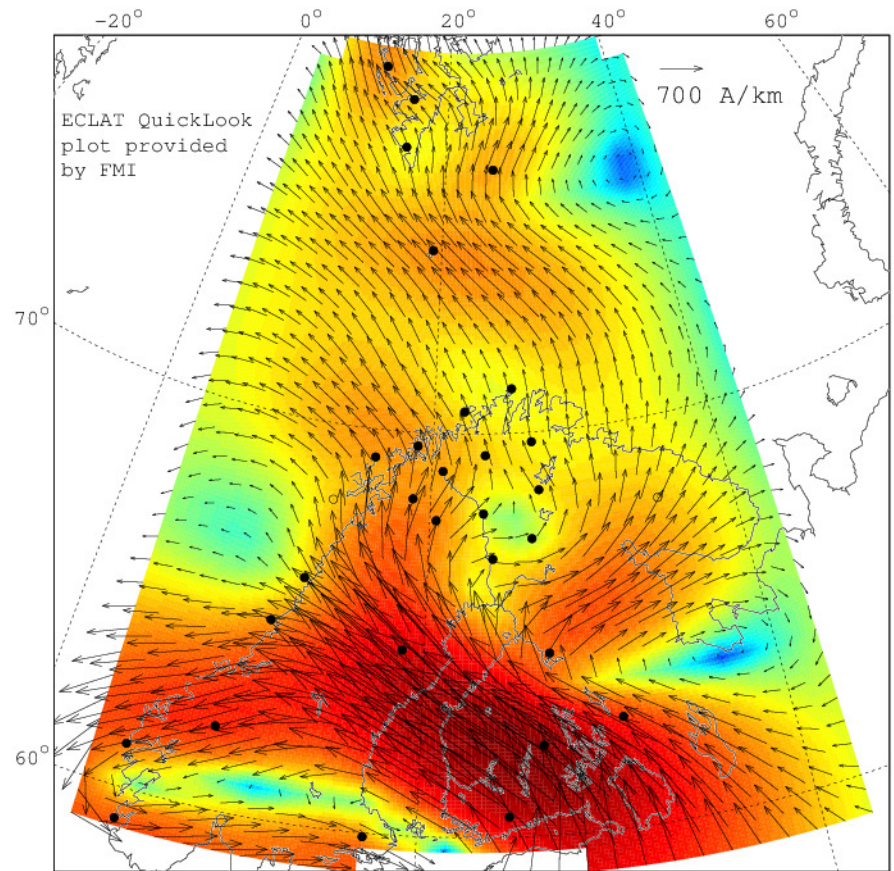
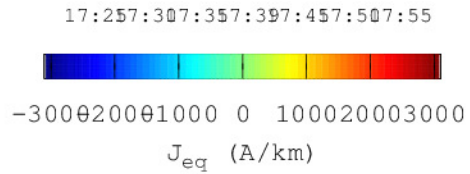
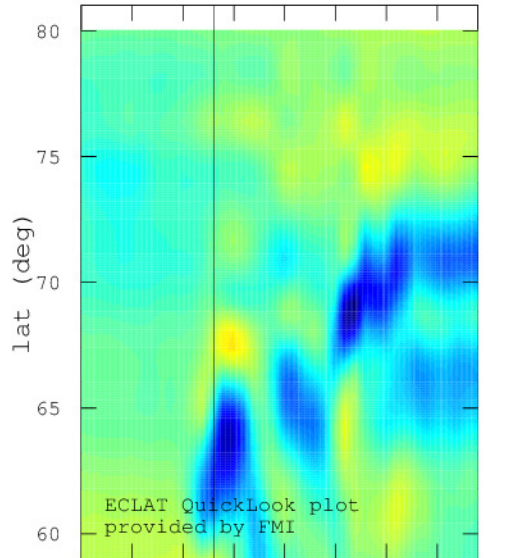
10 30 100 300 1000 3000
 J_{eq} (A/km)



FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:33:00 UT

Eastward current at 22.061° long.

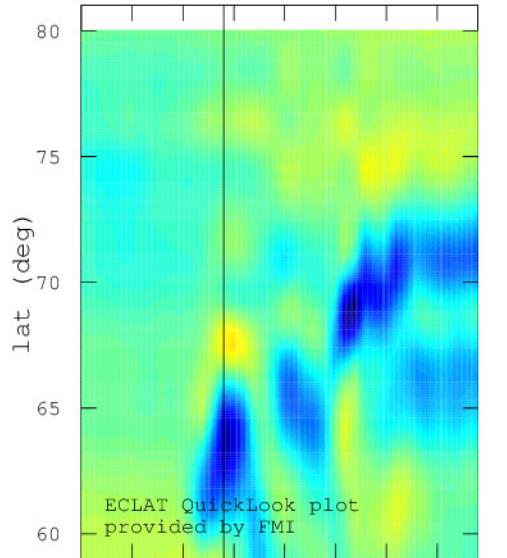




FINNISH METEOROLOGICAL INSTITUTE

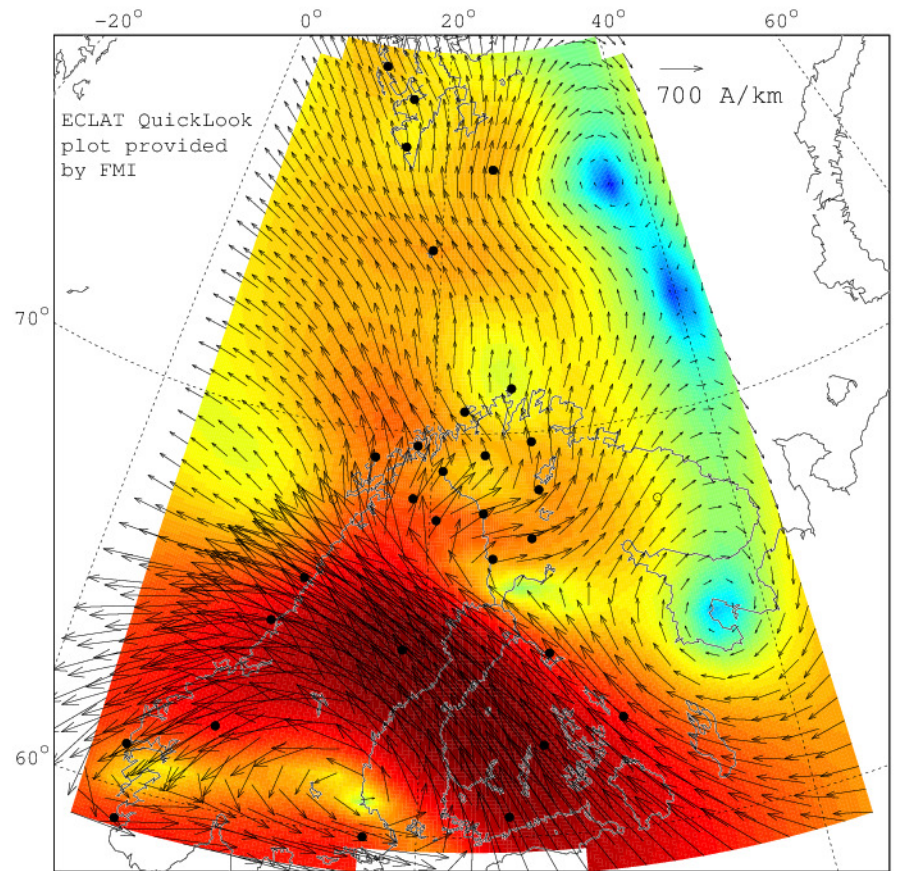
Date/time: 17-03-2015; 17:34:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

J_{eq} (A/km)



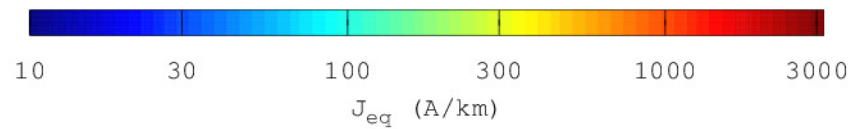
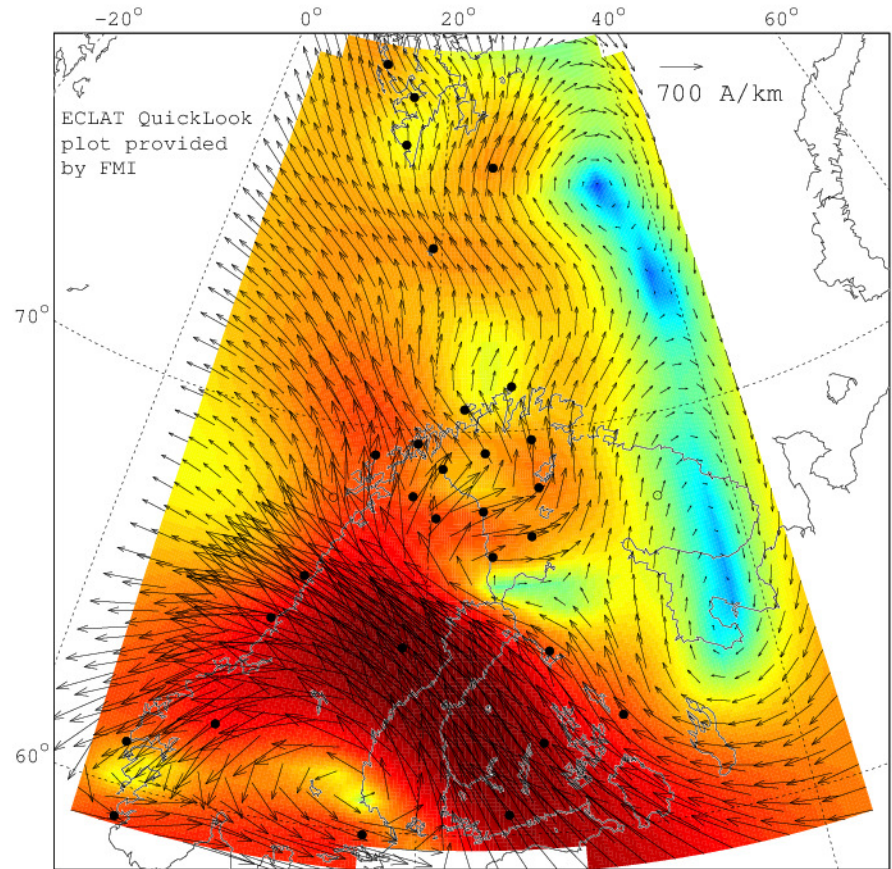
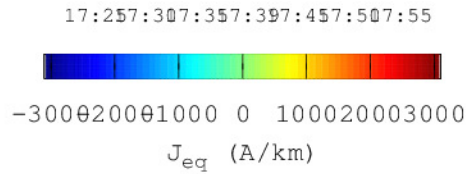
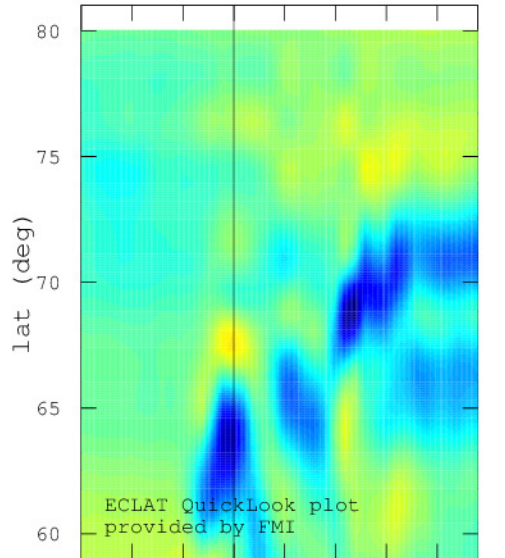
J_{eq} (A/km)



FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:35:00 UT

Eastward current at 22.061° long.



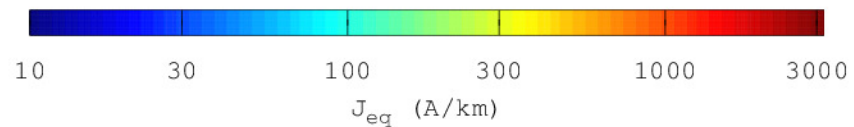
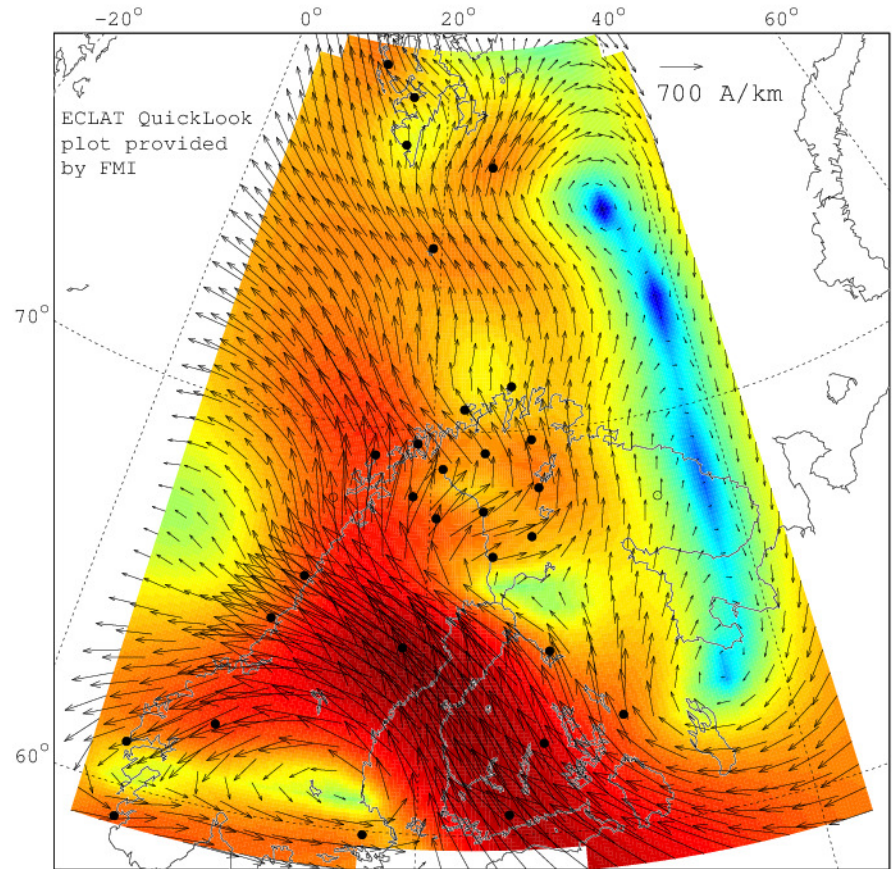
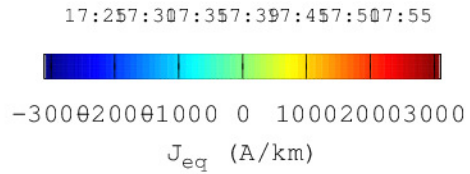
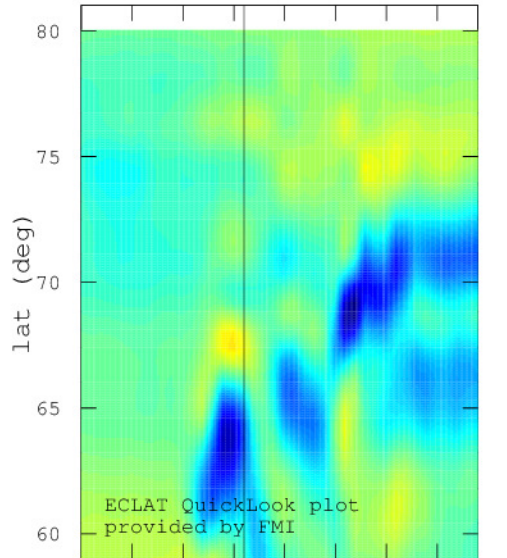
Note edge effects in top right zone – central data OK



FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:36:00 UT

Eastward current at 22.061° long.



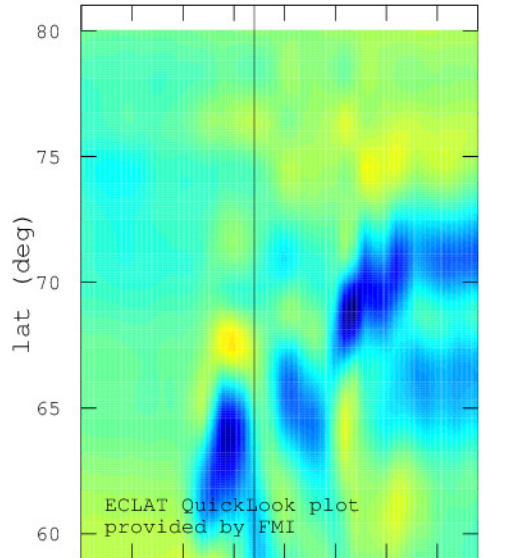
Note edge effects in top right zone – central data OK



FINNISH METEOROLOGICAL INSTITUTE

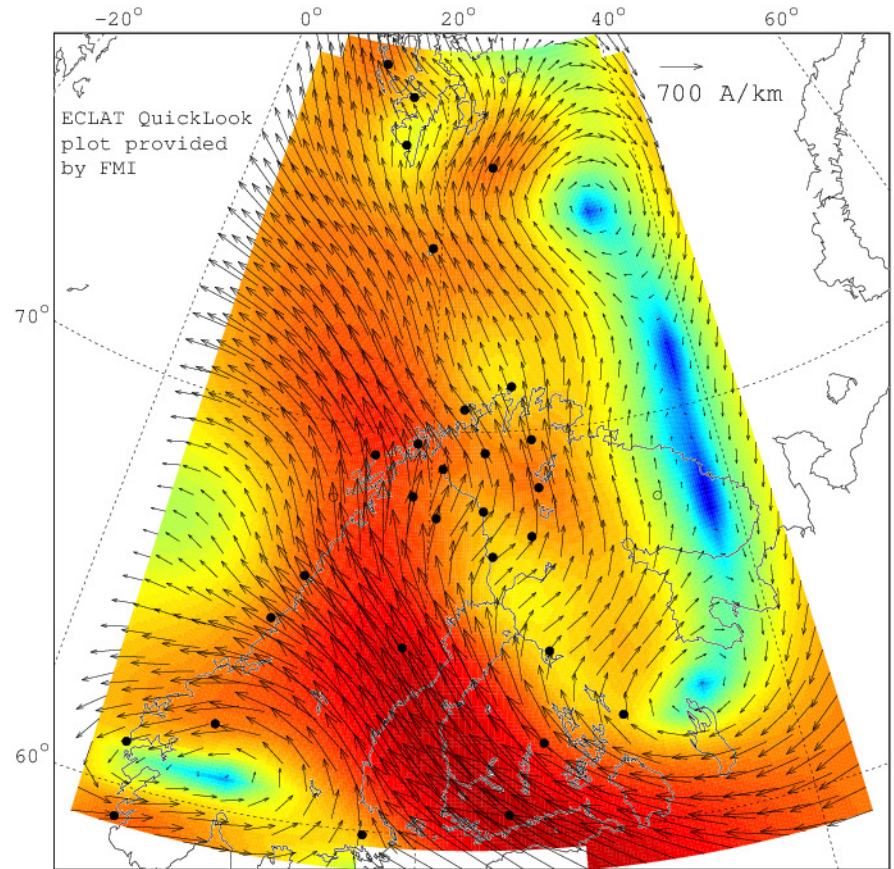
Date/time: 17-03-2015; 17:37:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

J_{eq} (A/km)



J_{eq} (A/km)

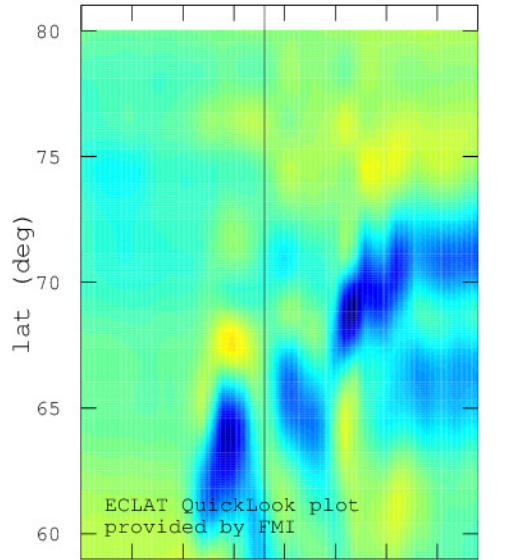
Note edge effects in top right zone – central data OK



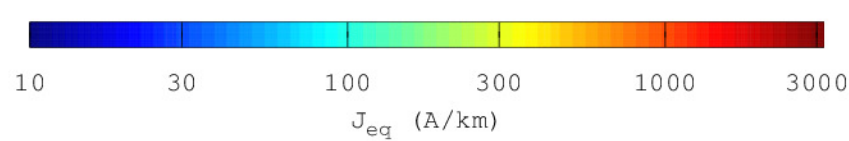
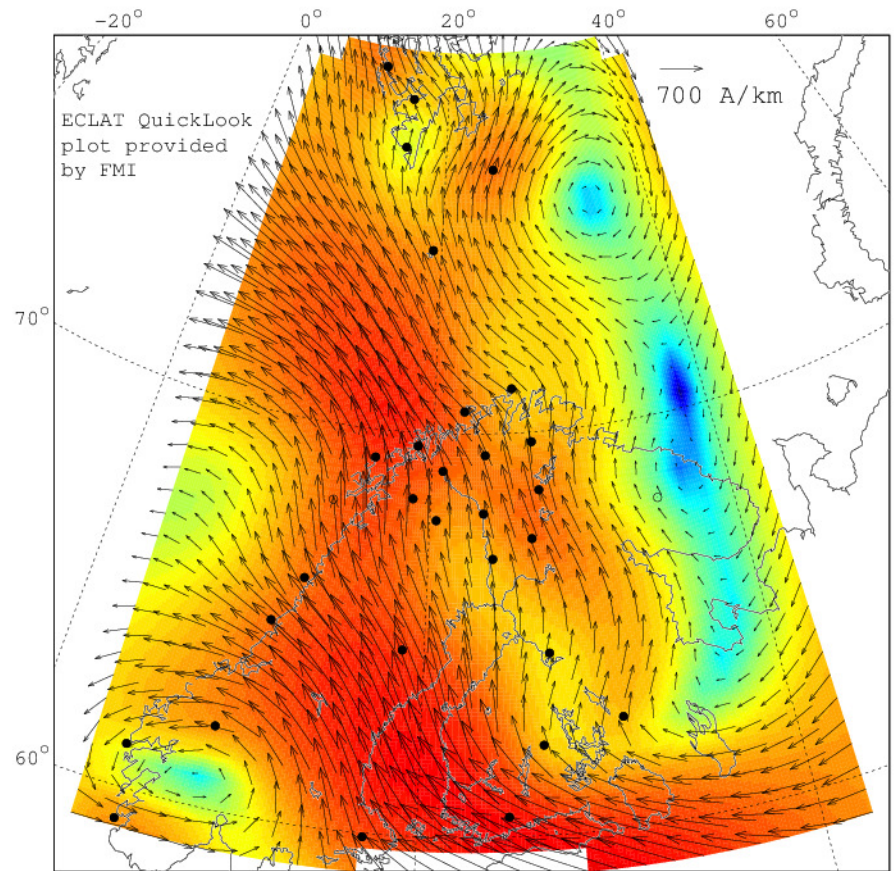
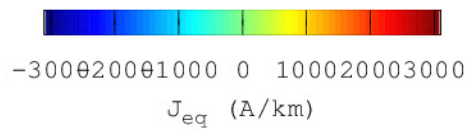
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:38:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

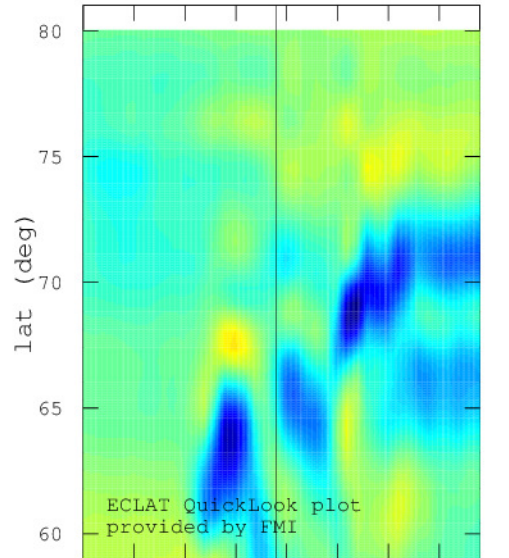




FINNISH METEOROLOGICAL INSTITUTE

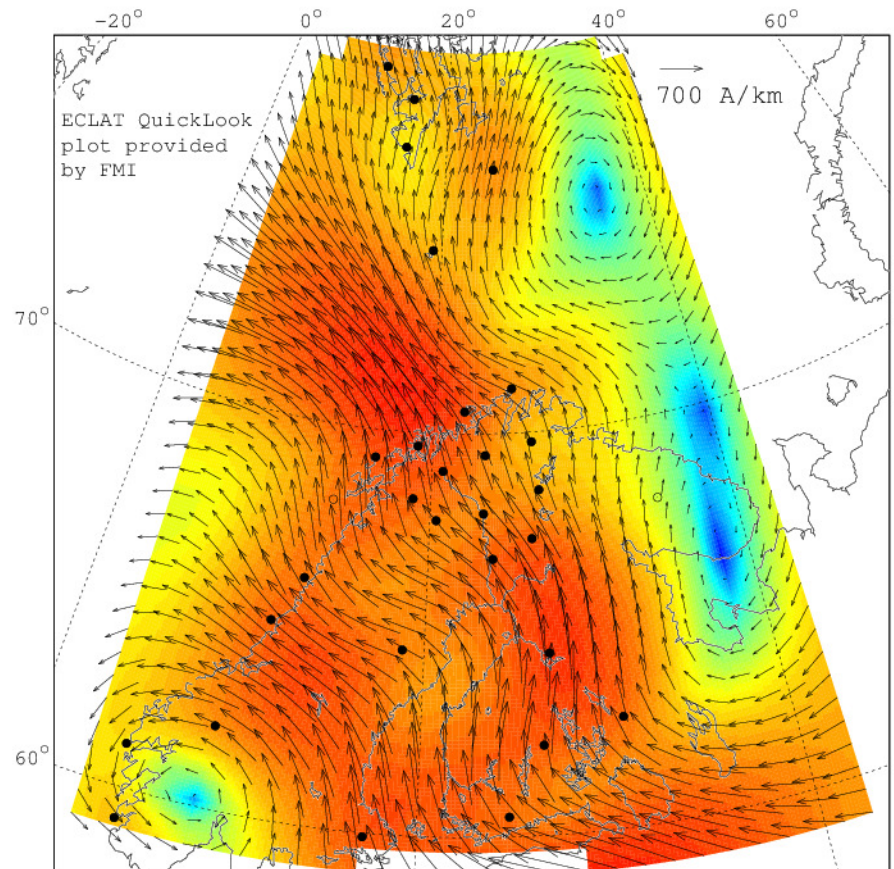
Date/time: 17-03-2015; 17:39:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

-3000 2000 1000 0 1000 2000 3000
 J_{eq} (A/km)



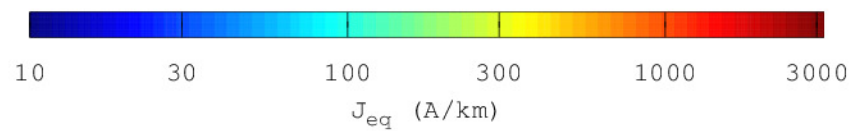
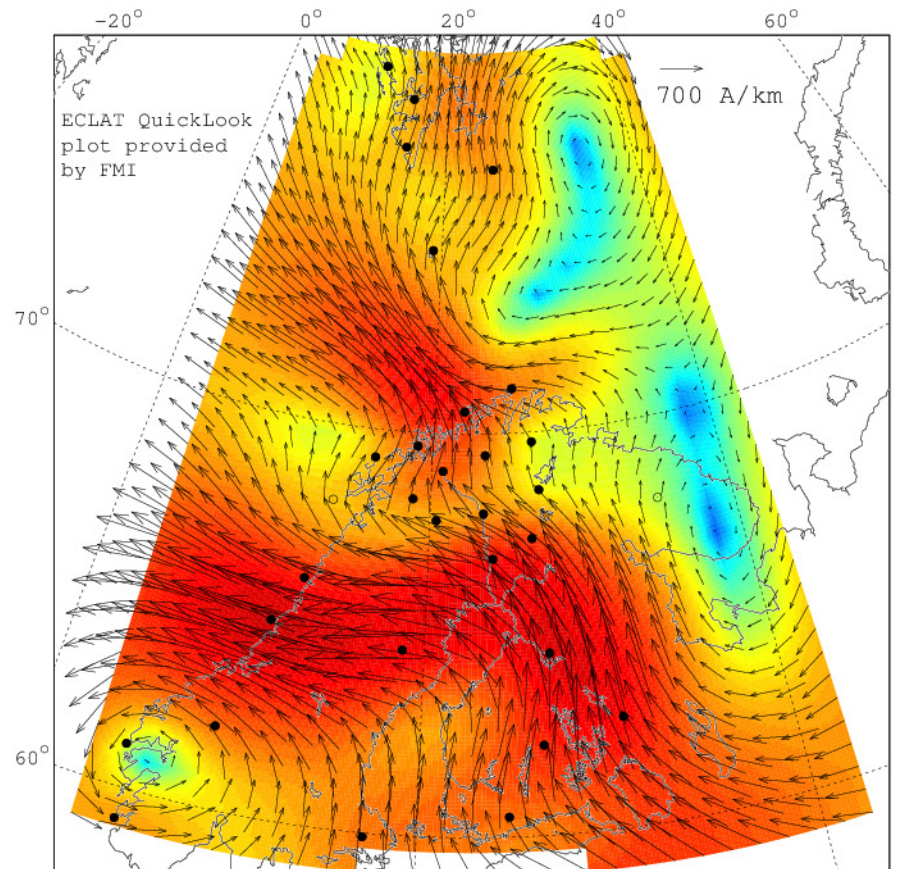
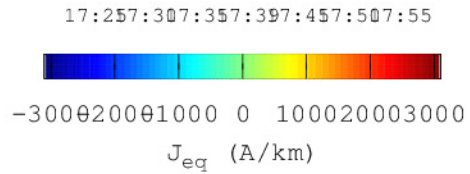
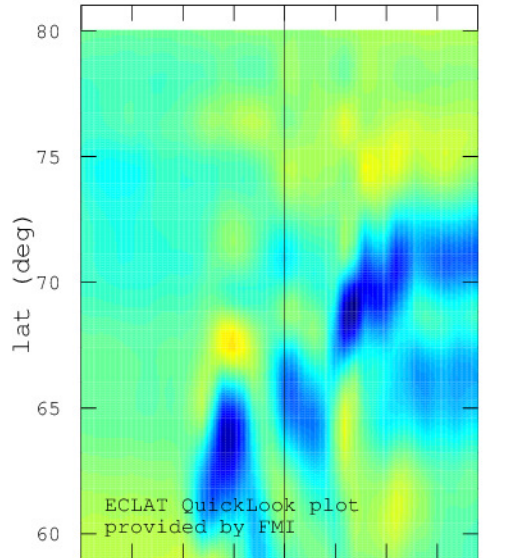
10 30 100 300 1000 3000
 J_{eq} (A/km)



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Date/time: 17-03-2015; 17:40:00 UT

Eastward current at 22.061° long.

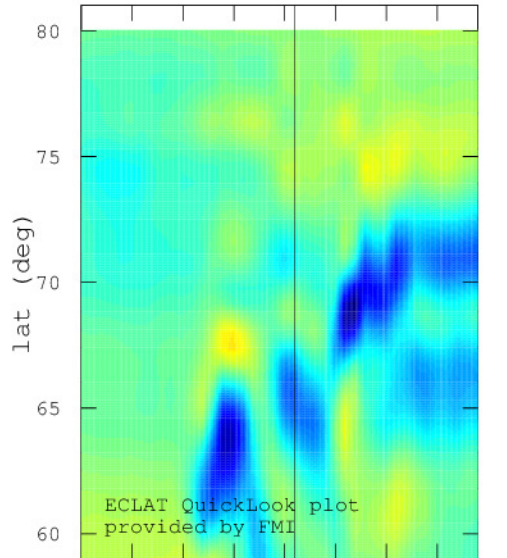




FINNISH METEOROLOGICAL INSTITUTE

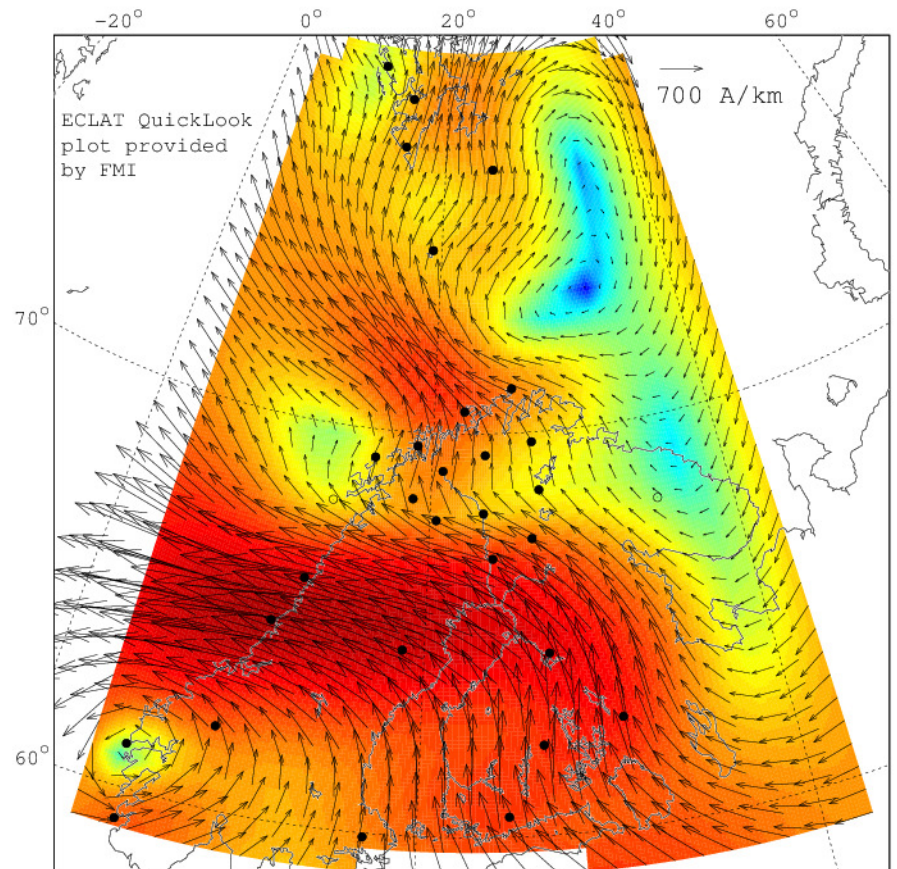
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Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

J_{eq} (A/km)



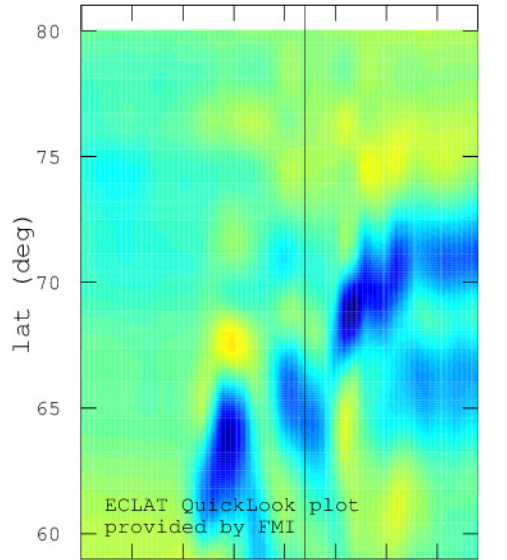
J_{eq} (A/km)



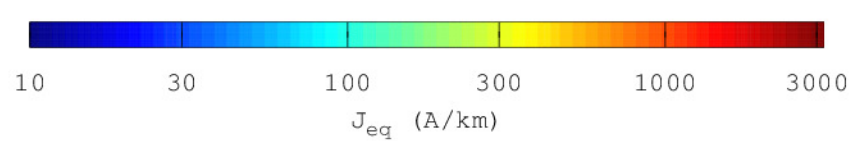
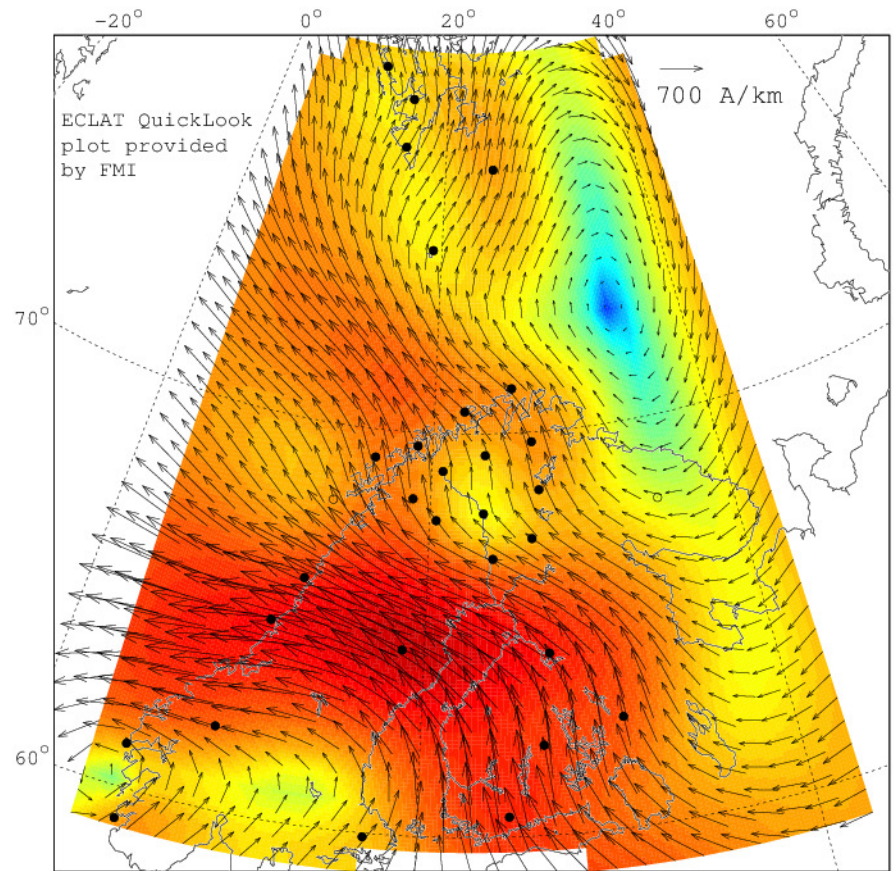
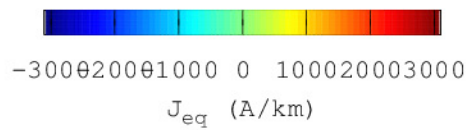
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:42:00 UT

Eastward current at 22.061° long.



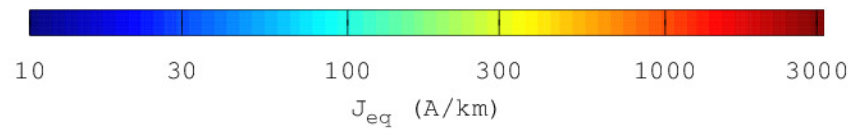
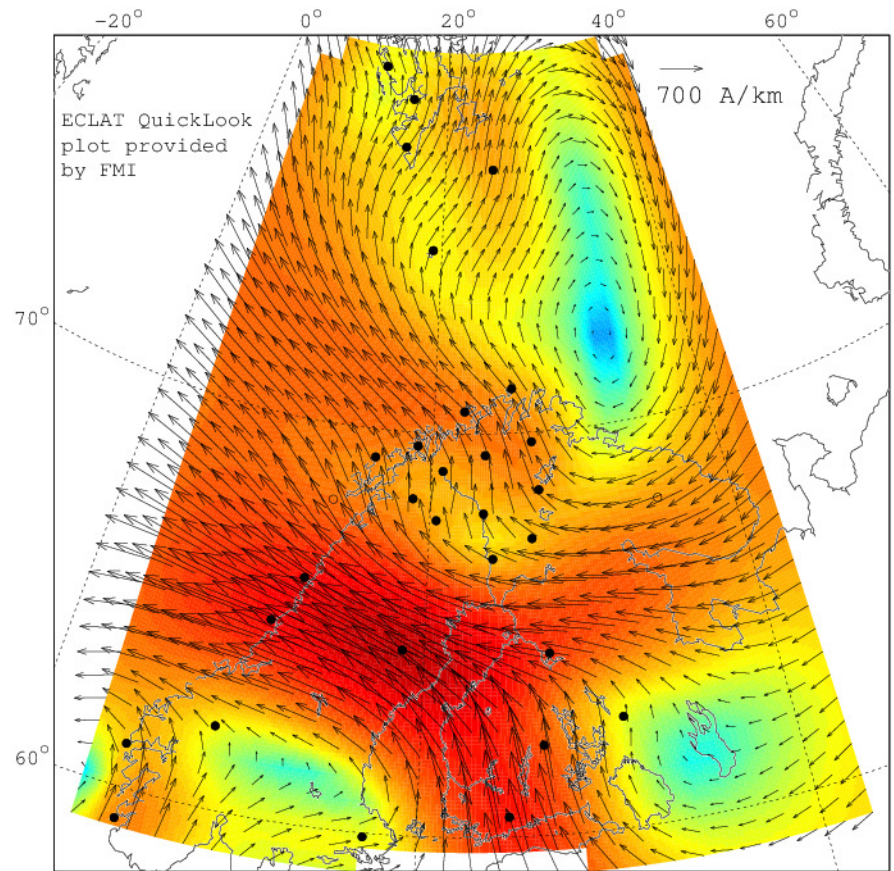
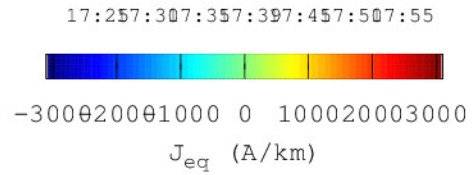
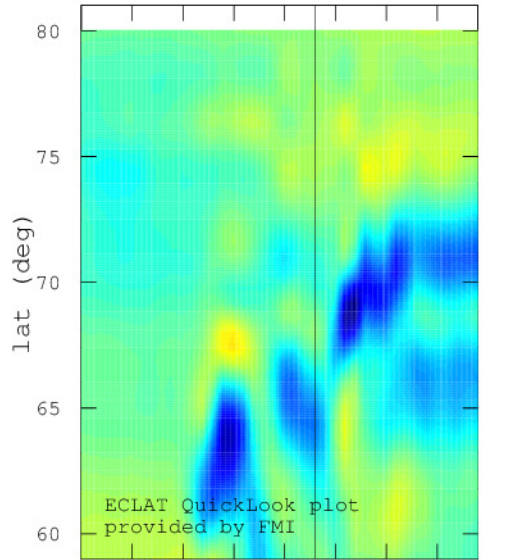
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Date/time: 17-03-2015; 17:43:00 UT

Eastward current at 22.061° long.

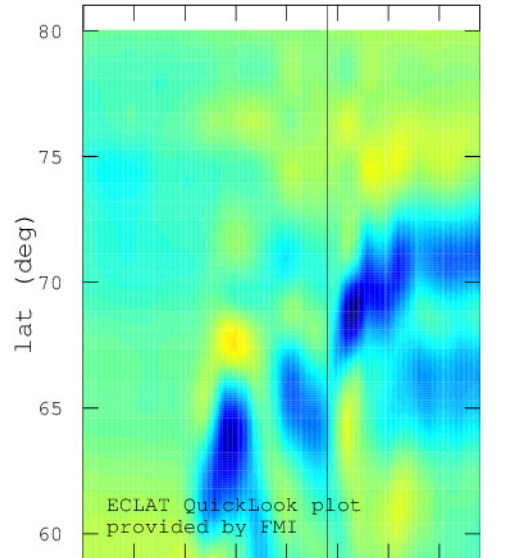




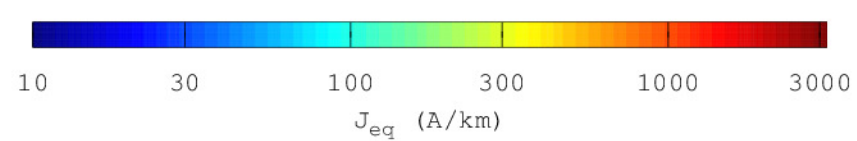
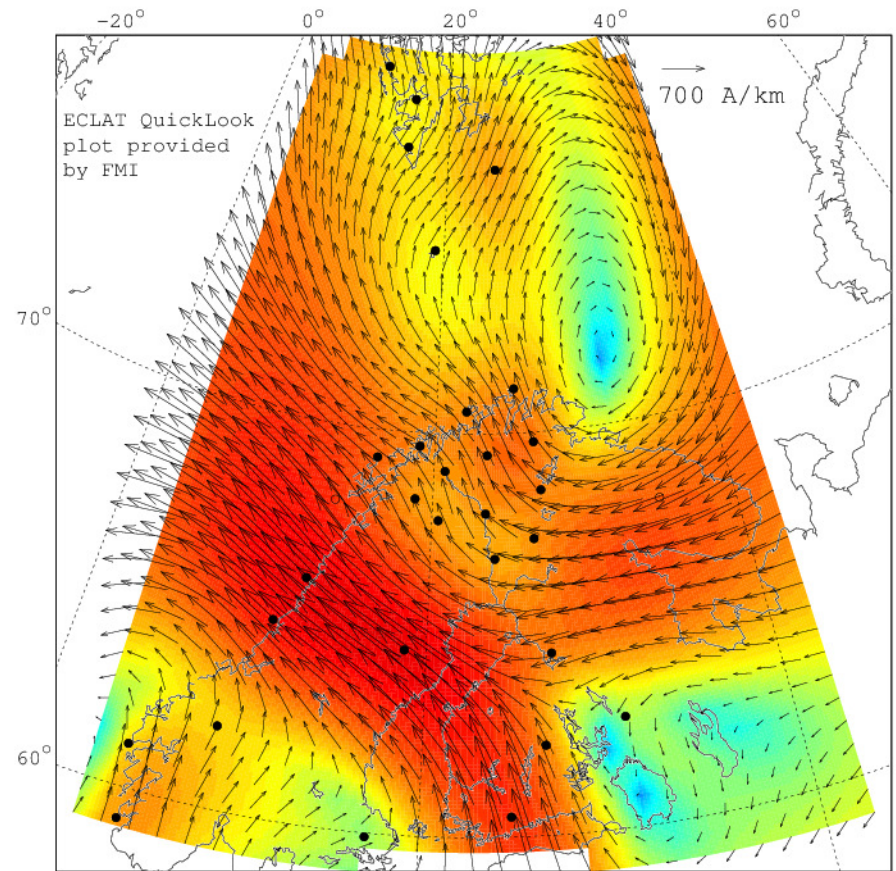
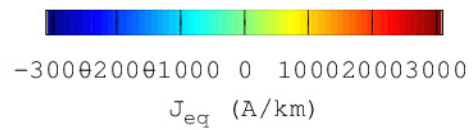
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:44:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

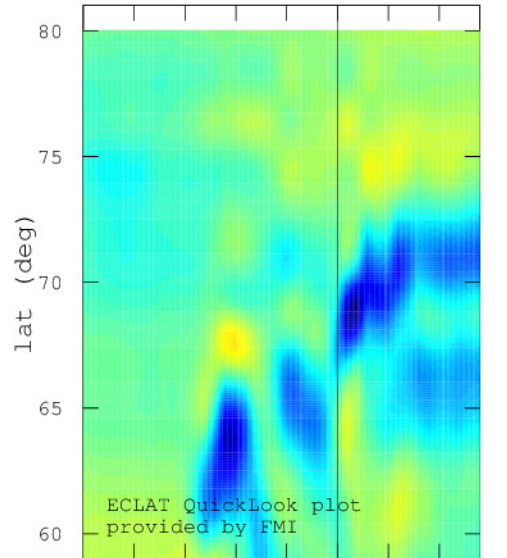




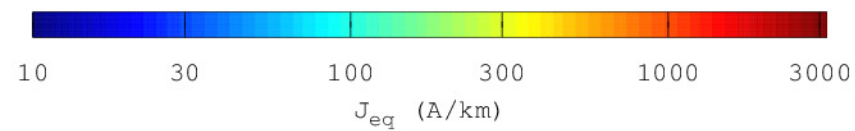
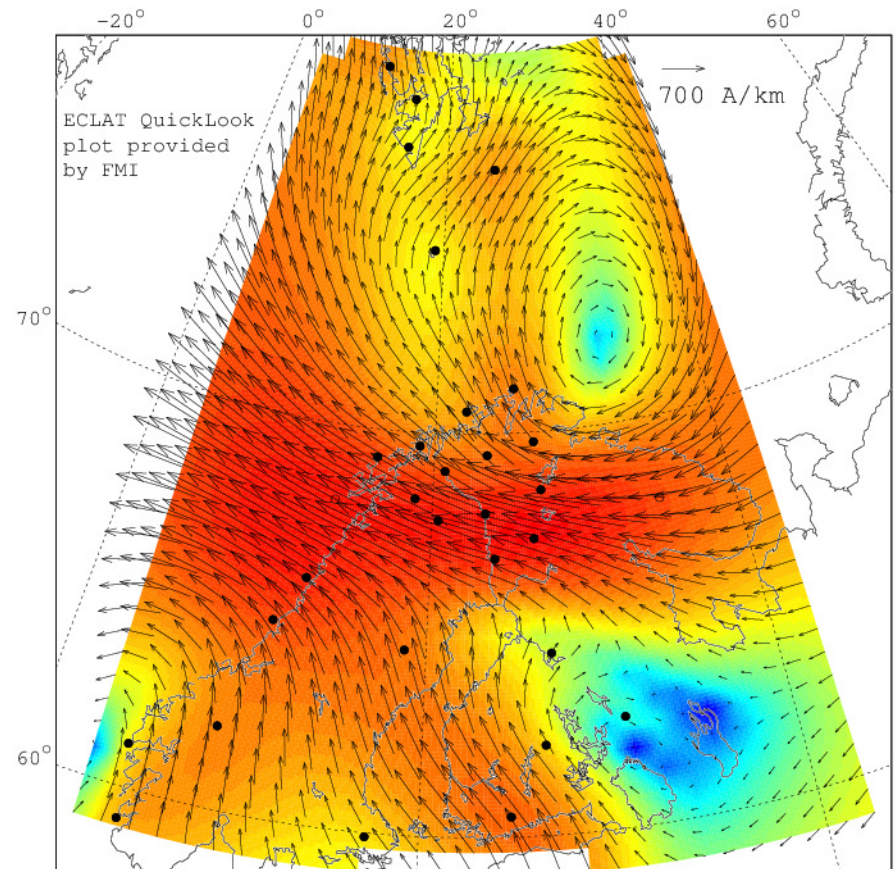
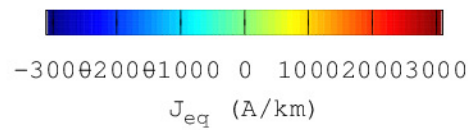
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:45:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

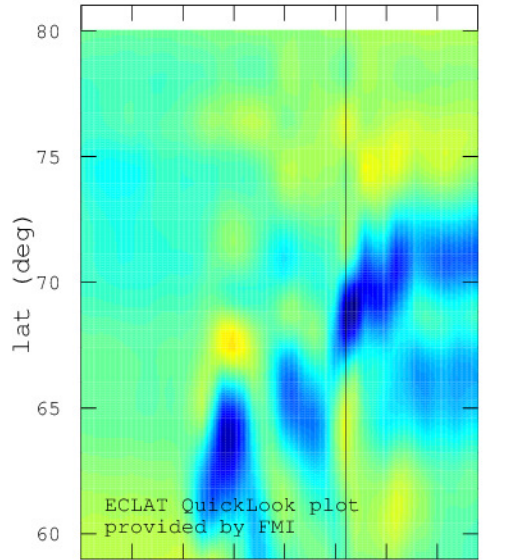




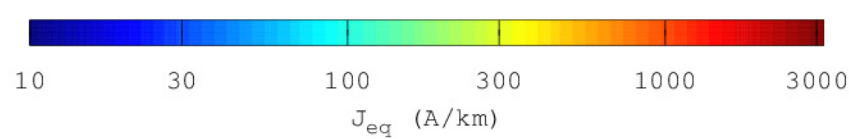
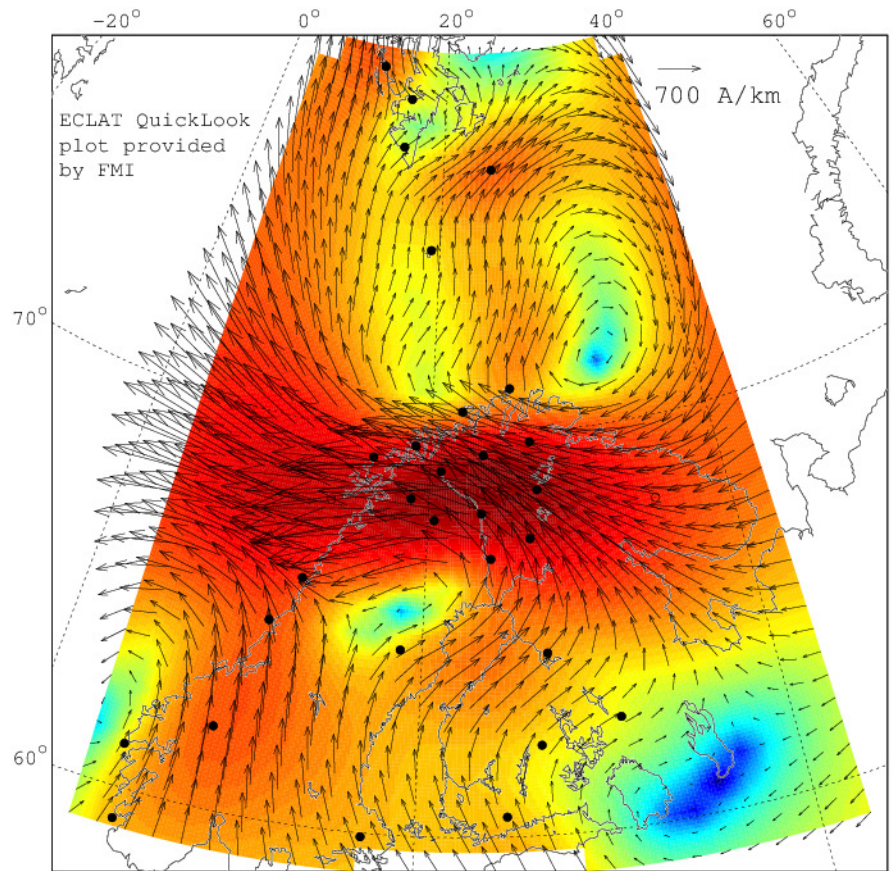
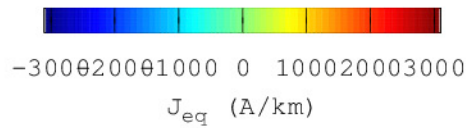
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:46:00 UT

Eastward current at 22.061° long.



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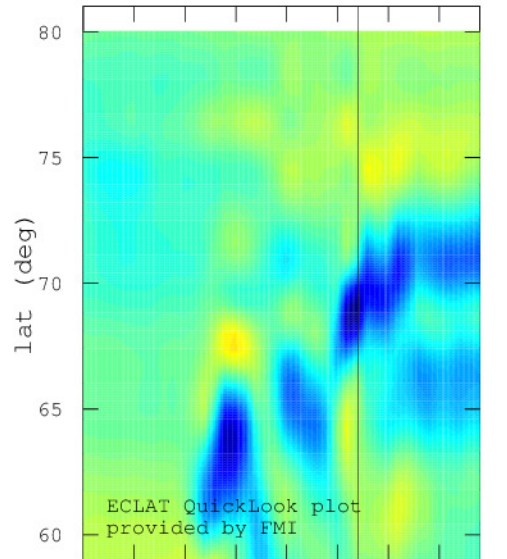




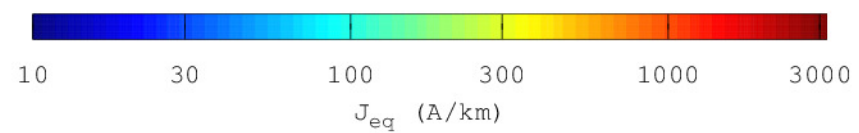
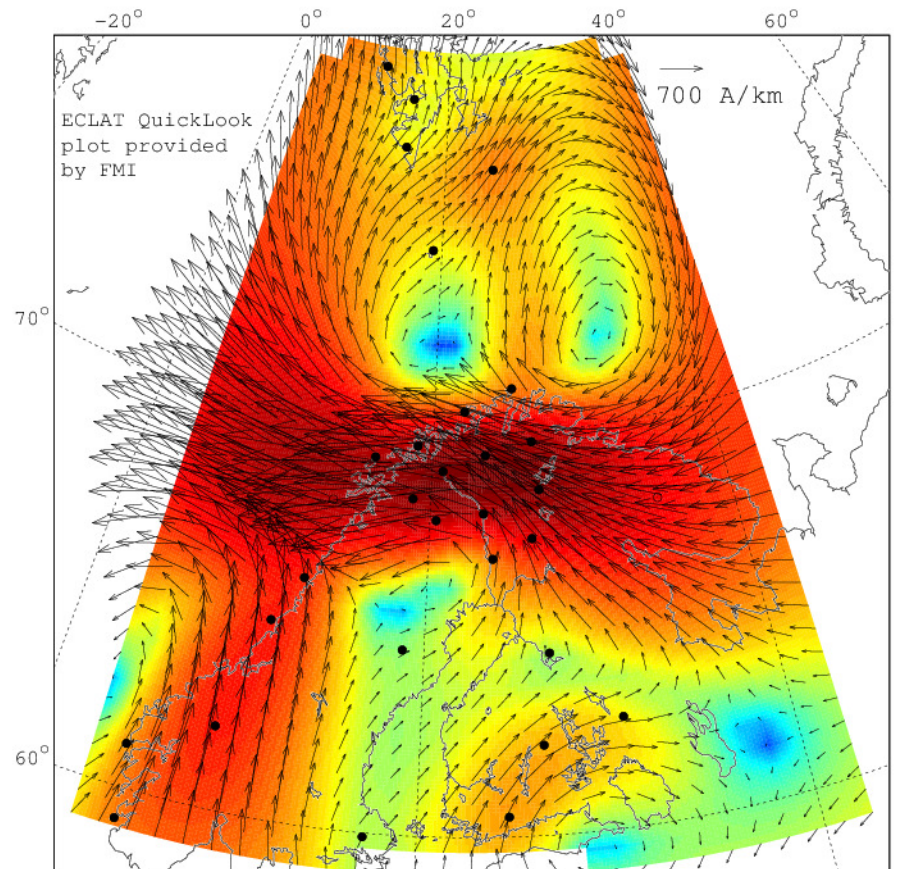
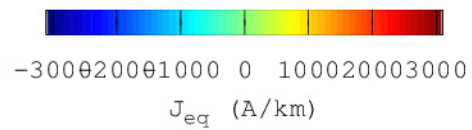
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:47:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

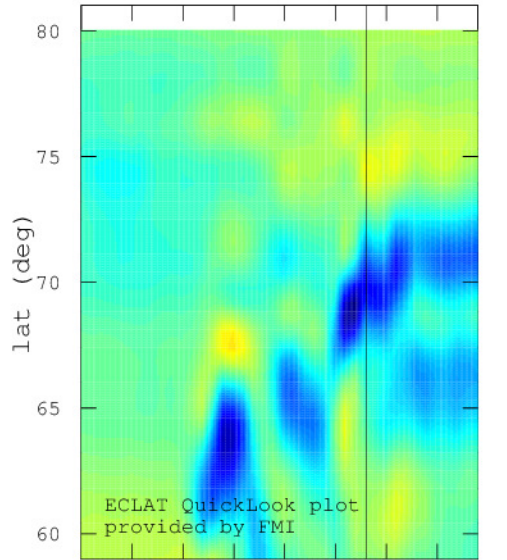




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Date/time: 17-03-2015; 17:48:00 UT

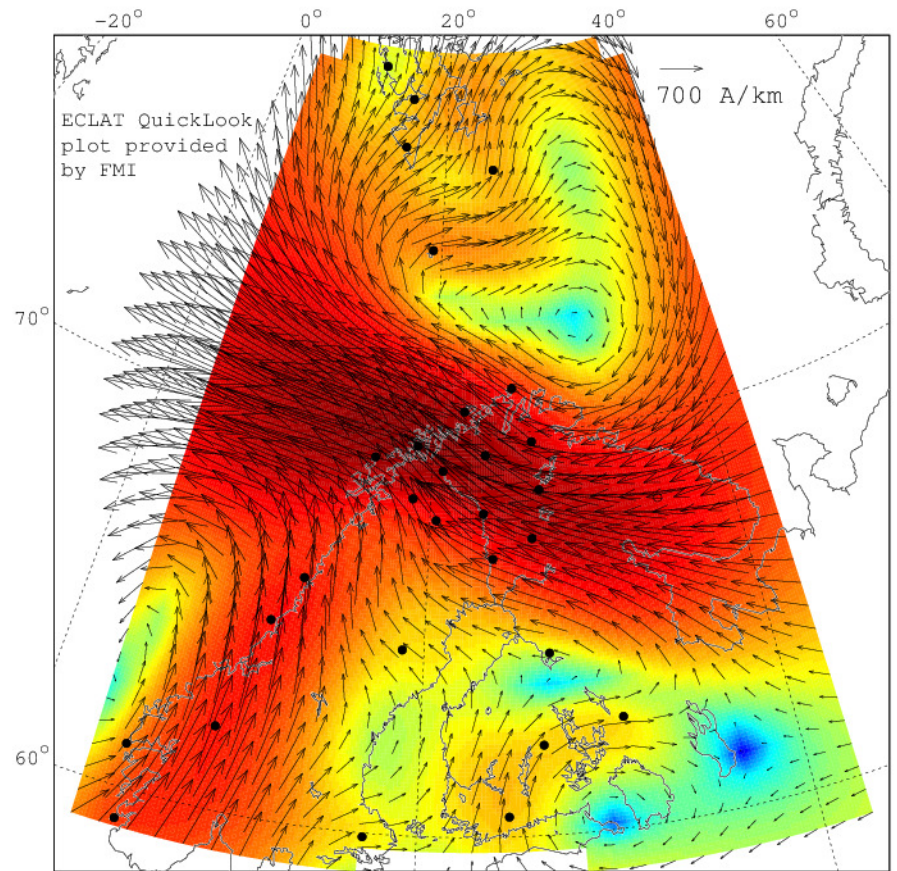
Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

-3000 2000 1000 0 1000 2000 3000

J_{eq} (A/km)



10 30 100 300 1000 3000

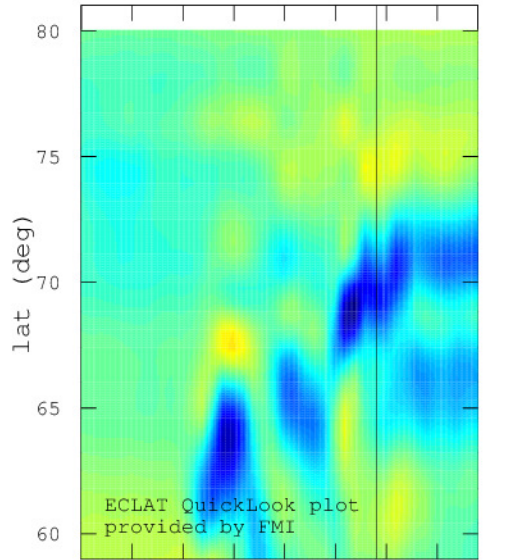
J_{eq} (A/km)



FINNISH METEOROLOGICAL INSTITUTE

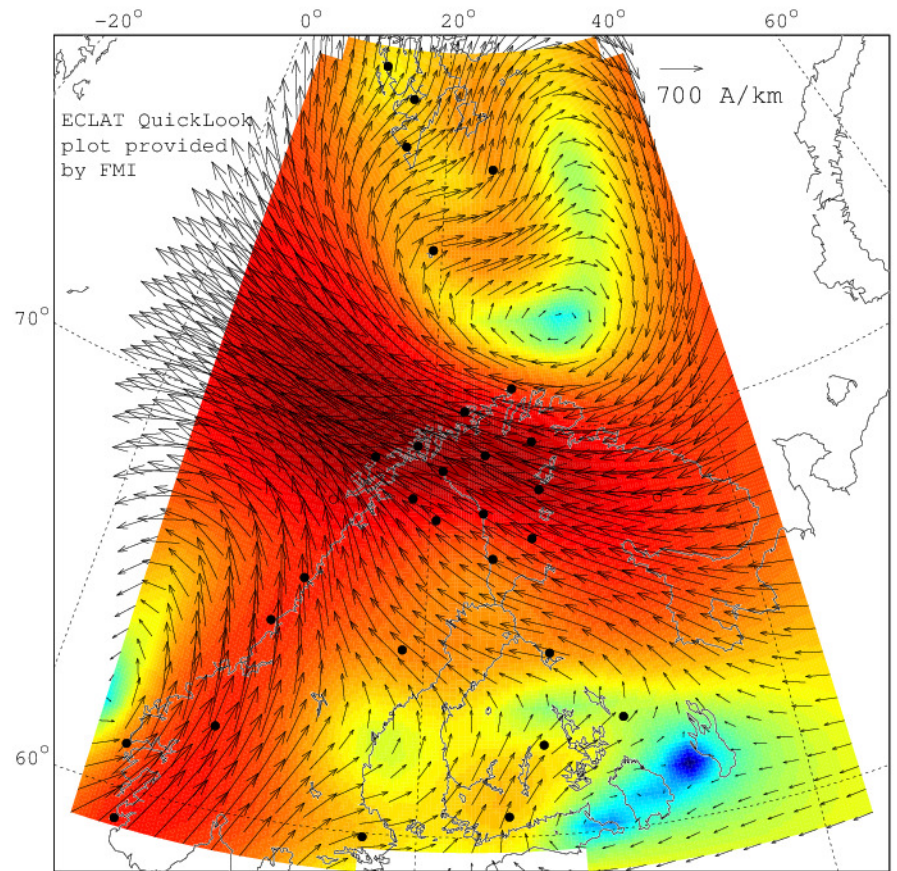
Date/time: 17-03-2015; 17:49:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

-3000 2000 1000 0 1000 2000 3000
 J_{eq} (A/km)



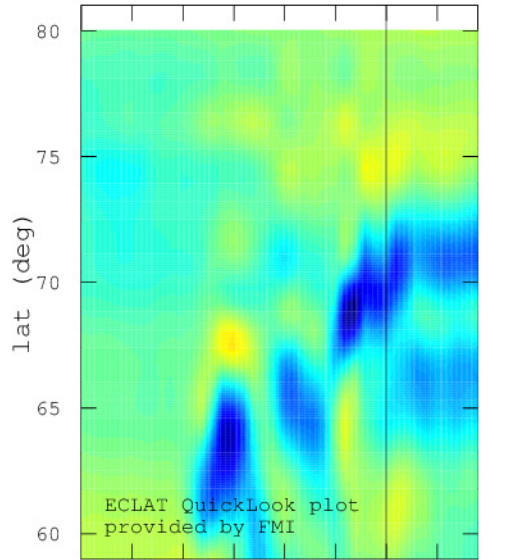
10 30 100 300 1000 3000
 J_{eq} (A/km)



FINNISH METEOROLOGICAL INSTITUTE

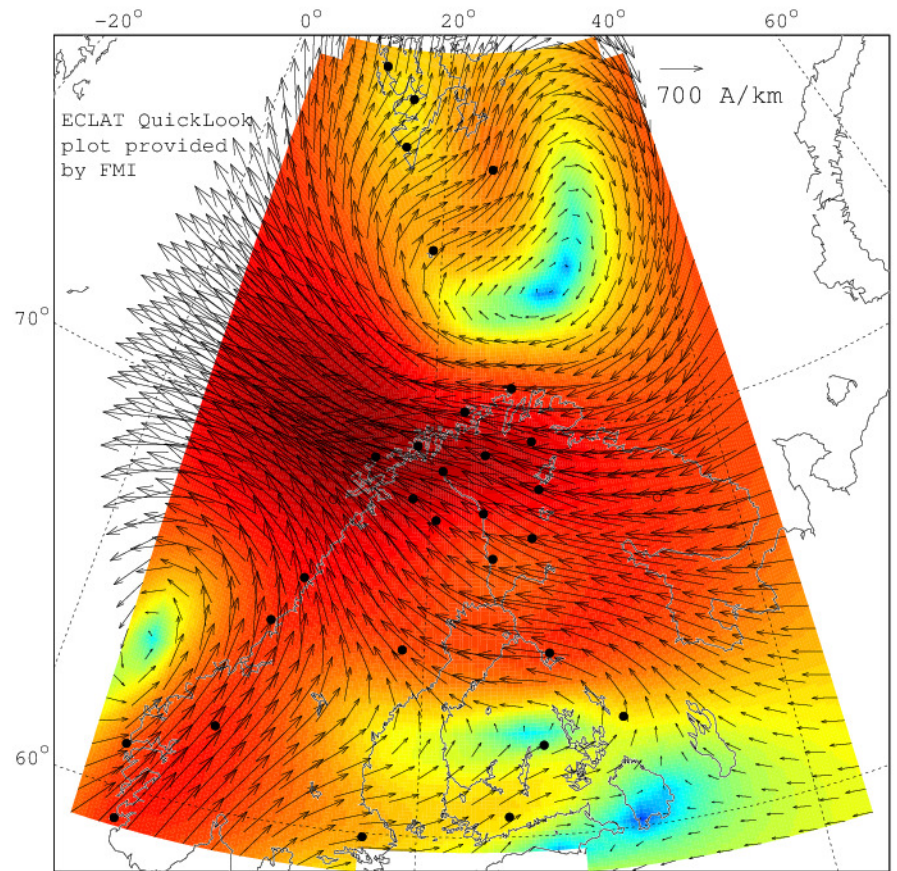
Date/time: 17-03-2015; 17:50:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

-3000 2000 1000 0 1000 2000 3000
 J_{eq} (A/km)



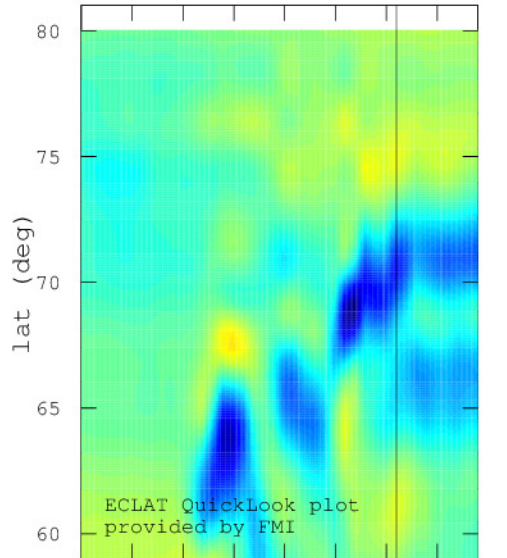
10 30 100 300 1000 3000
 J_{eq} (A/km)



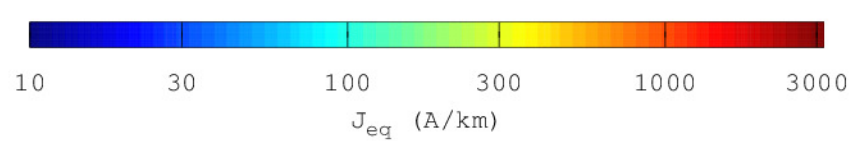
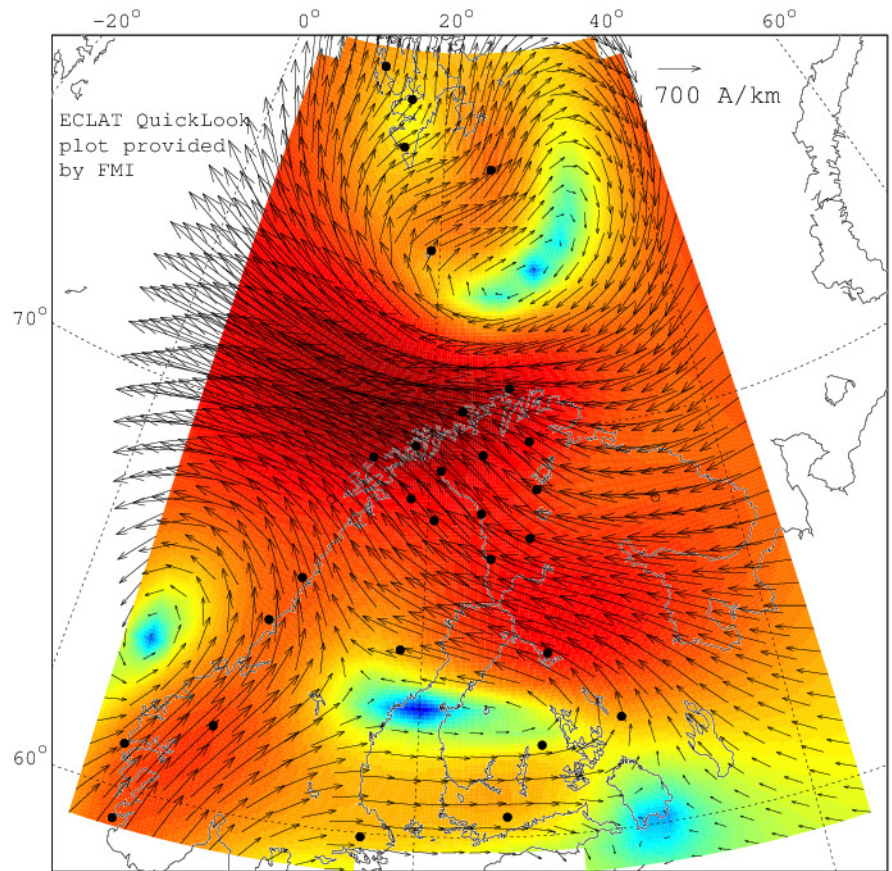
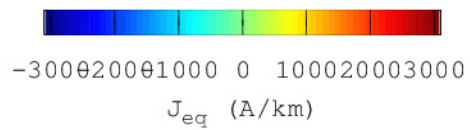
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:51:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

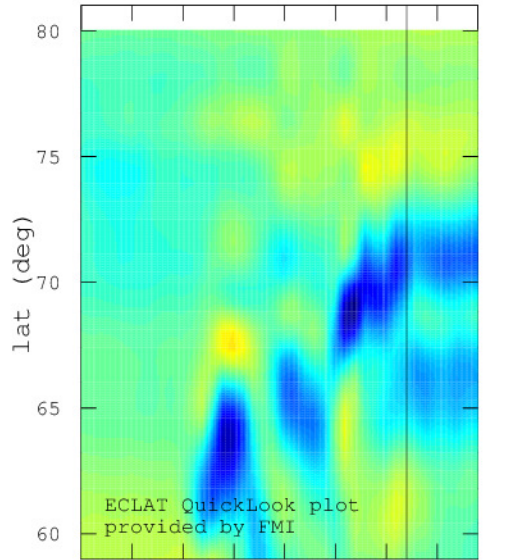




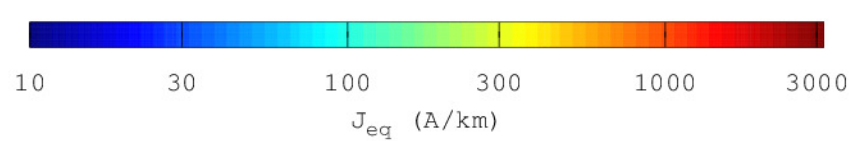
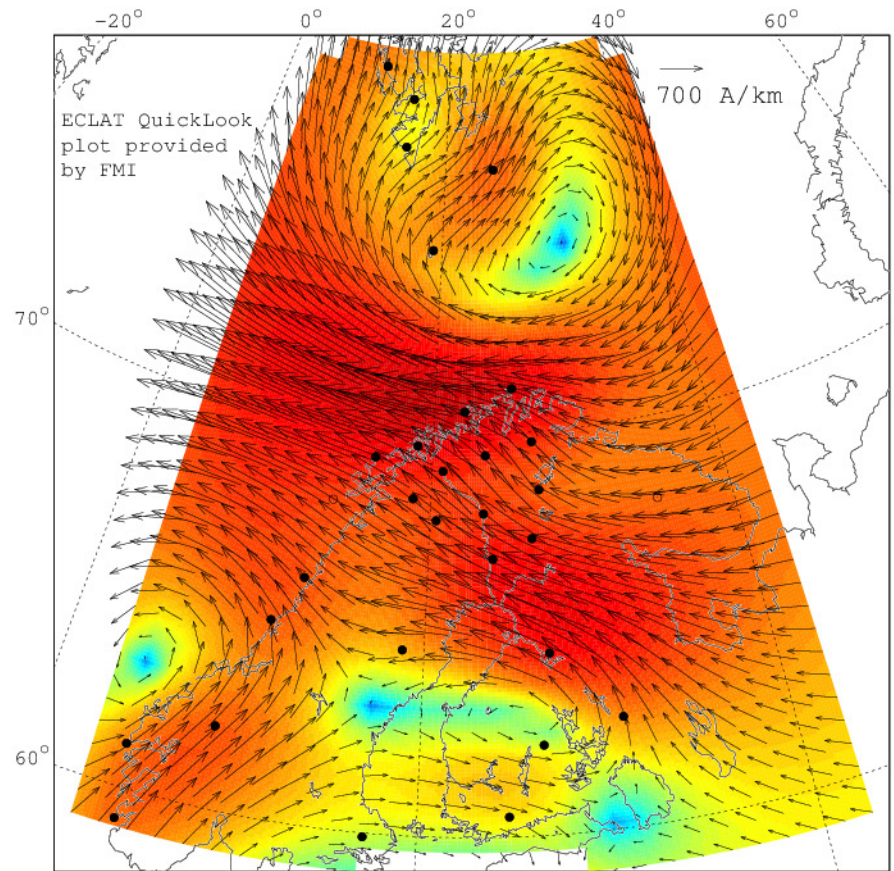
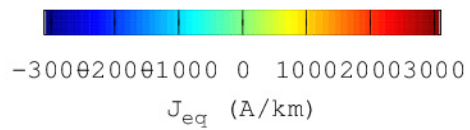
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:52:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

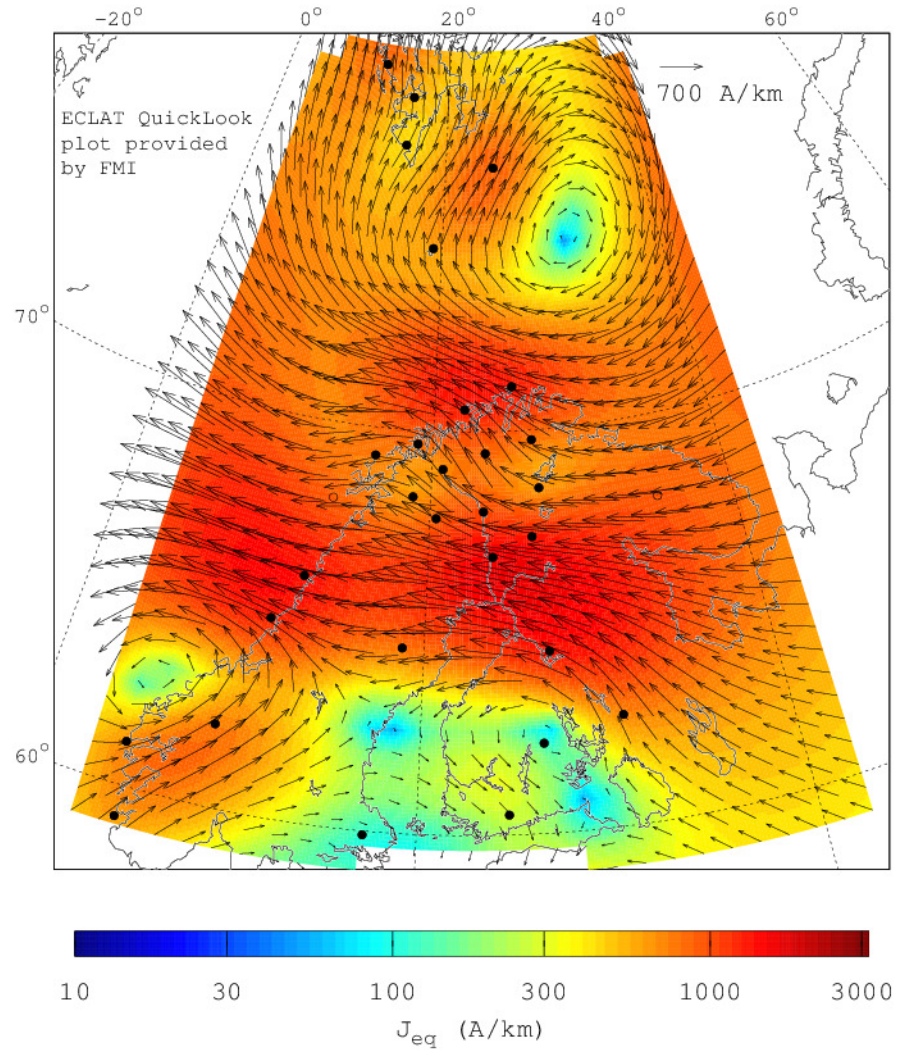
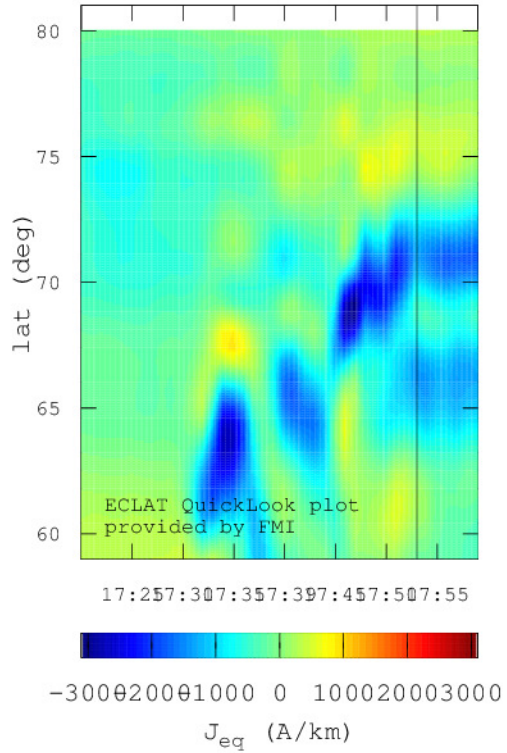




FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:53:00 UT

Eastward current at 22.061° long.

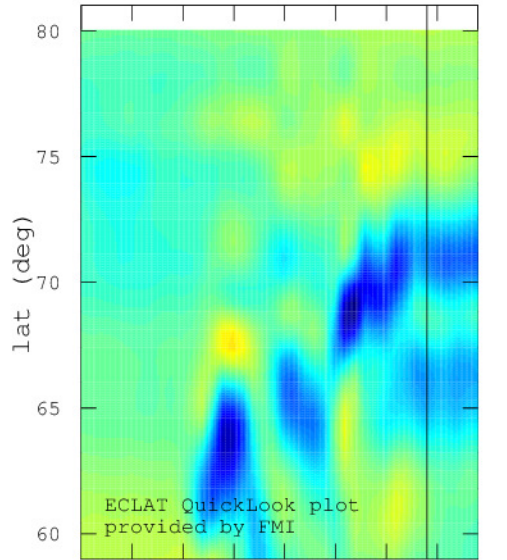




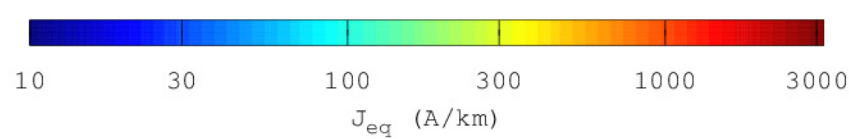
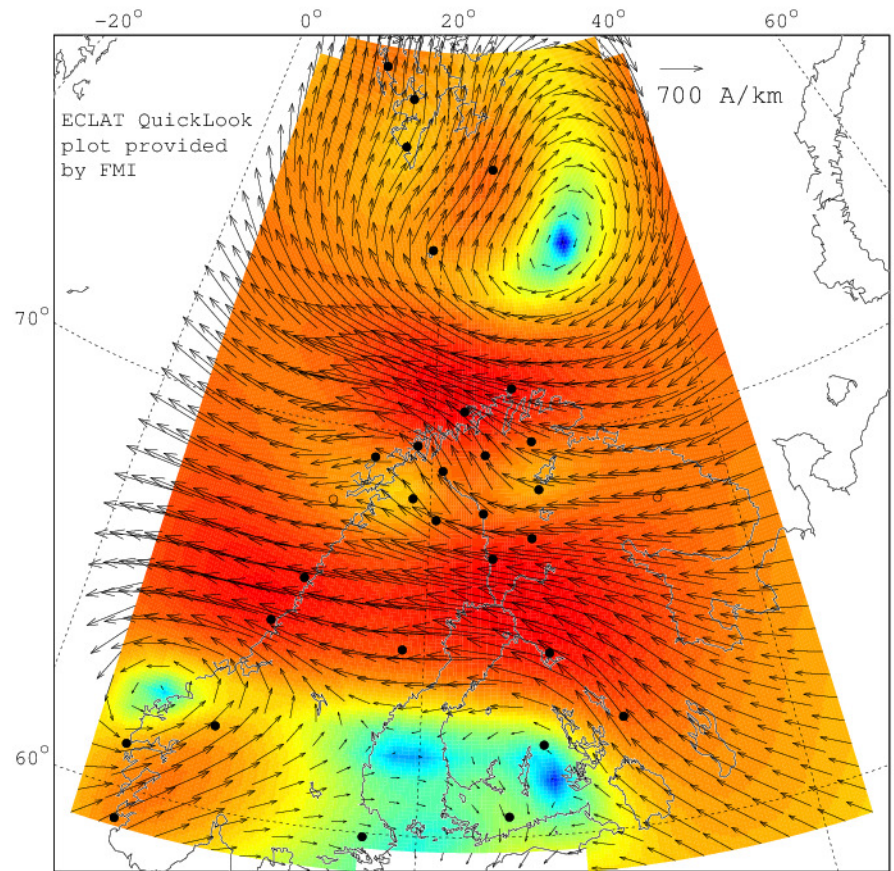
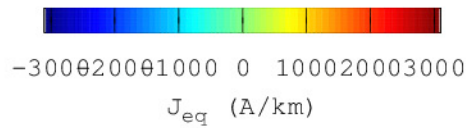
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:54:00 UT

Eastward current at 22.061° long.



17:257:307:357:397:457:507:55

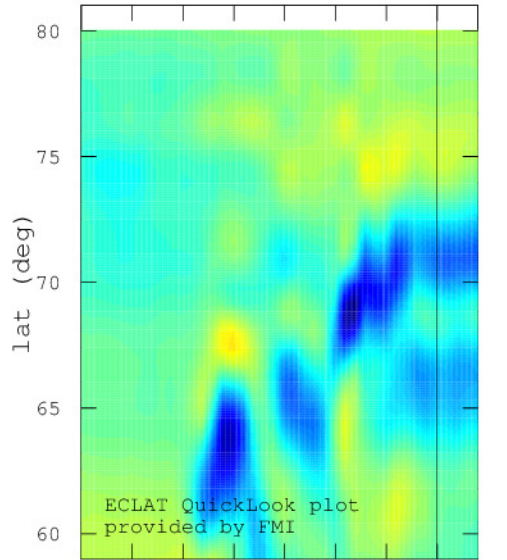




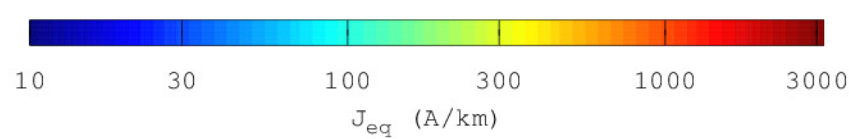
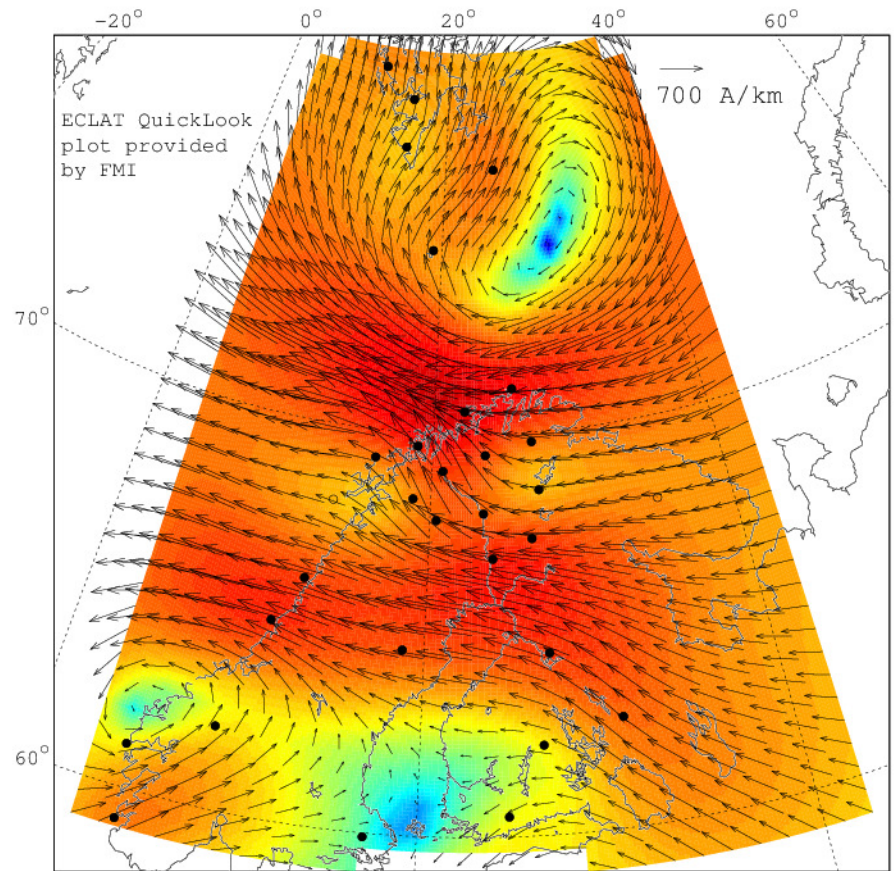
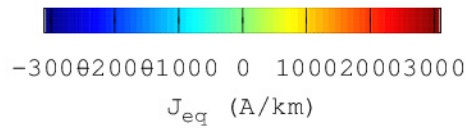
FINNISH METEOROLOGICAL INSTITUTE

Date/time: 17-03-2015; 17:55:00 UT

Eastward current at 22.061° long.

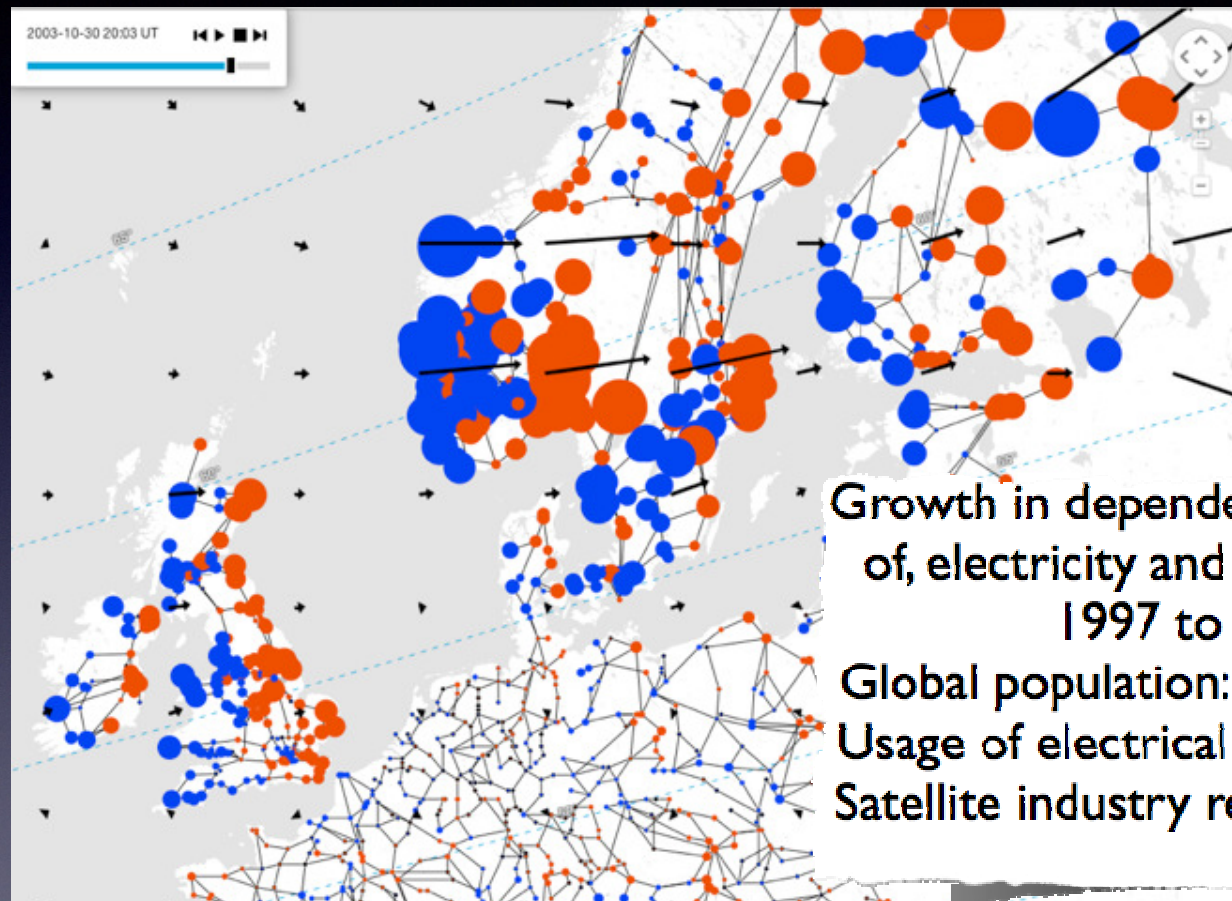


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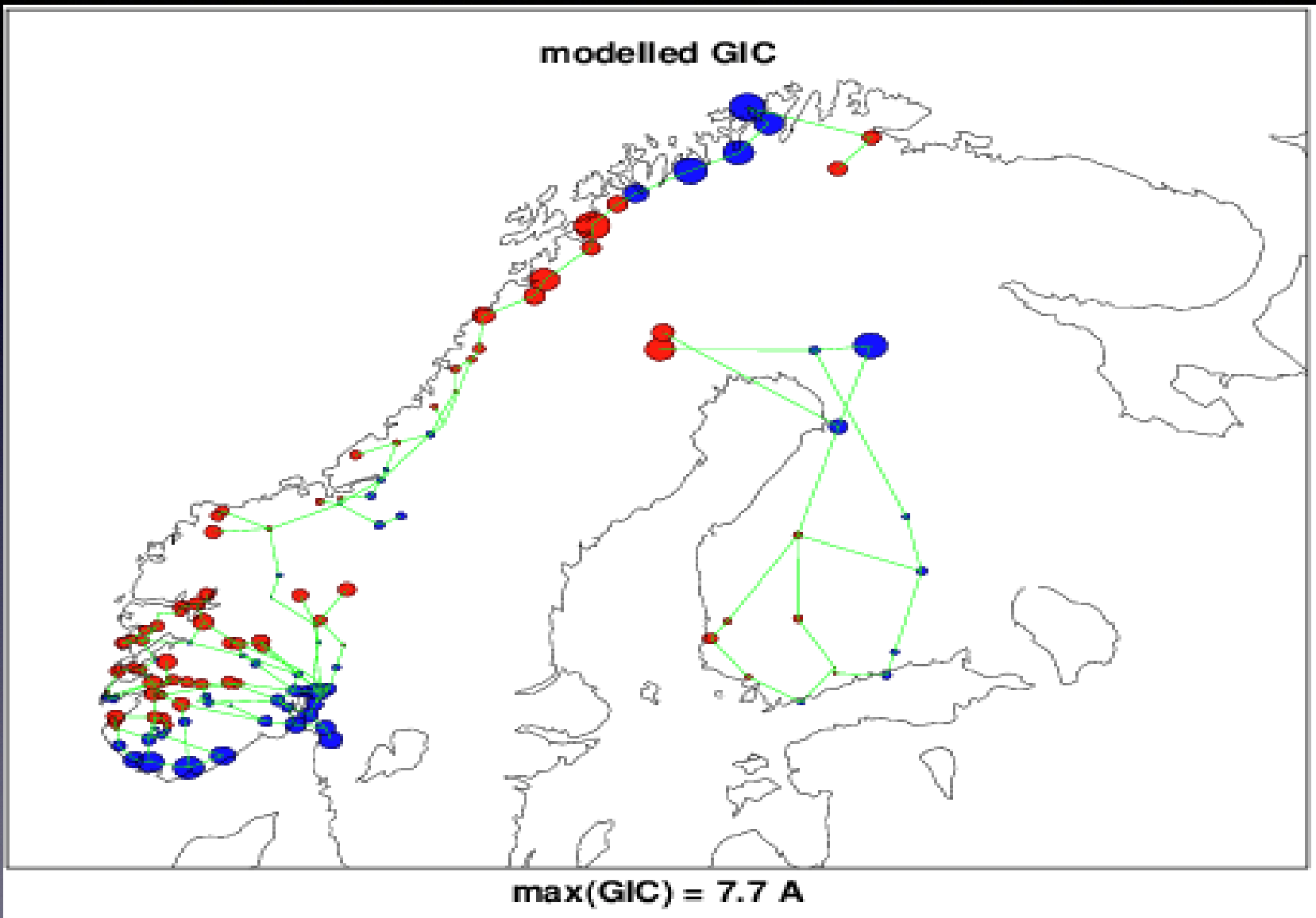
EXAMPLE FOR NETWORK RISK ANALYSIS & USER-NEED CONSOLIDATION

Geomagnetic variability and grid disturbances



Electric field (arrows) and GIC connecting ground and grid (circles; blue and red for opposite directions), computed from dB/dt and a model grid configuration, for the 2003/10/30 Halloween storm a few minutes before the failure in power delivery in Southern Sweden (Malmö).
Courtesy Ari Viljanen.

Present ESA SSA-SWE product - Geomagnetic Services



GIC Now-Casting

in Norway
and Finland

...during the large
September 2017
Magnetic Storms

**INSUFFICIENT
DATA FROM
SWEDEN
IN THIS ESA-
SWE PRODUCT !**

**Needs
Improvement**

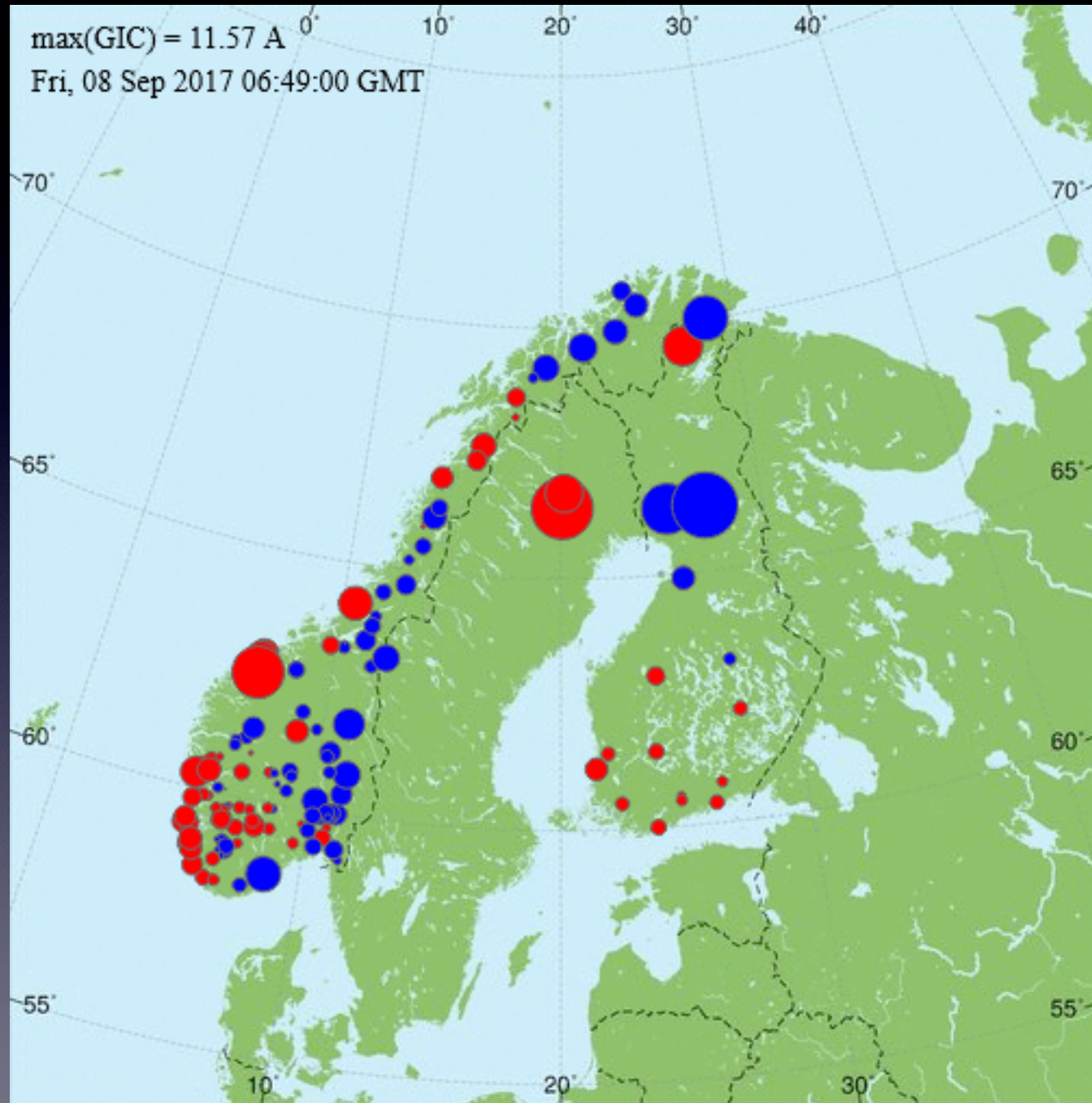
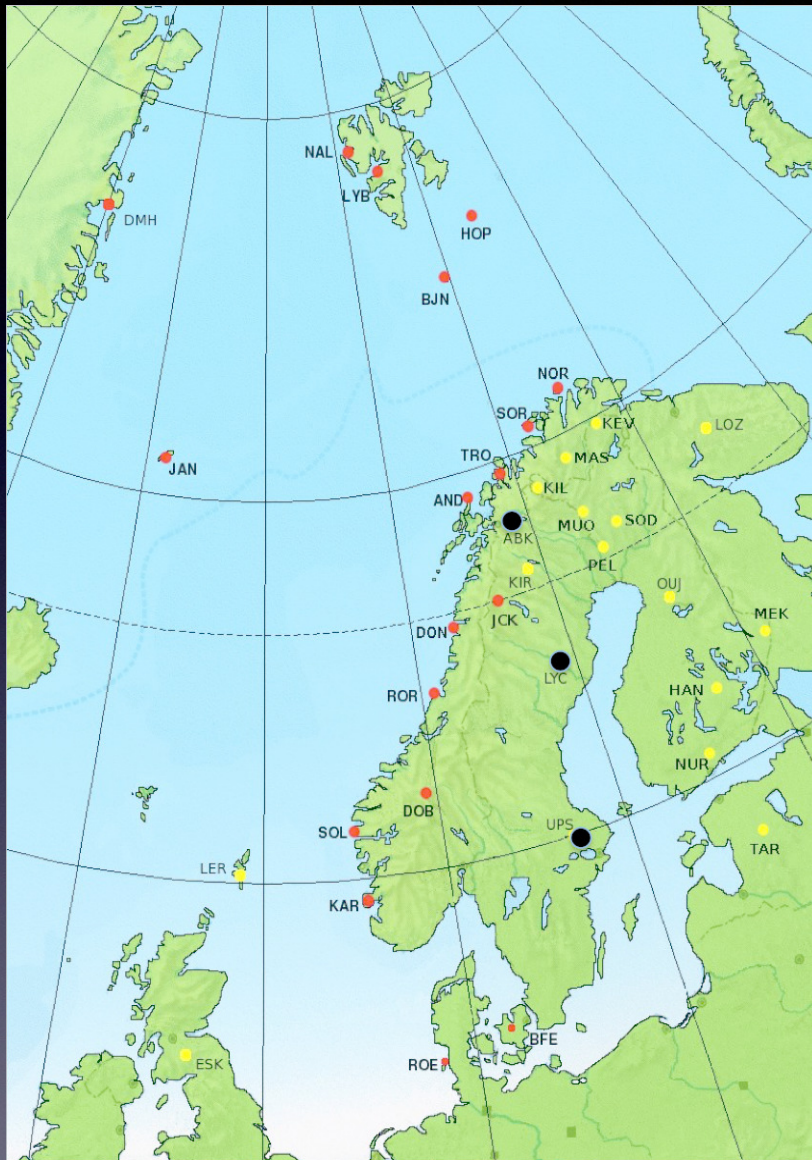
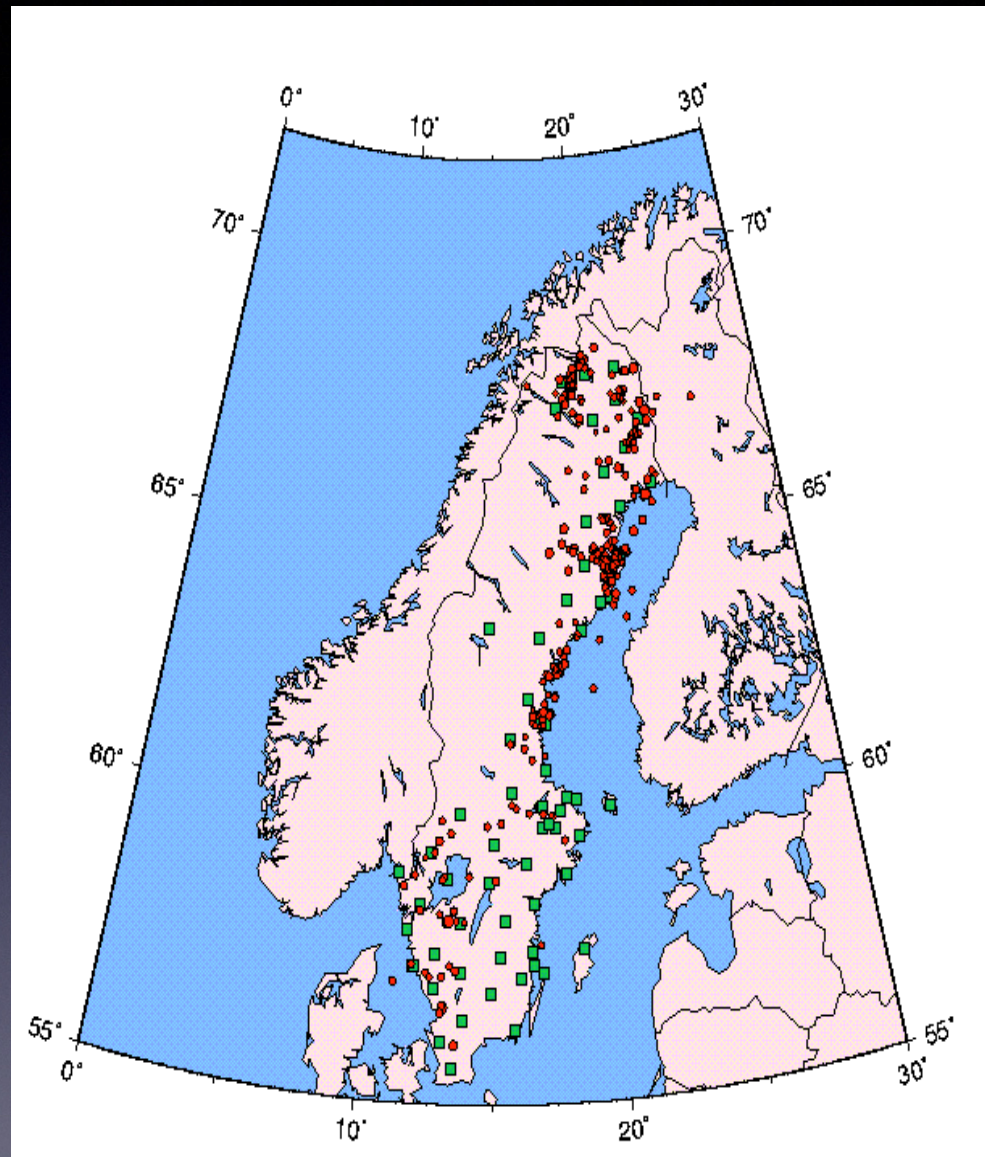


IMAGE stations

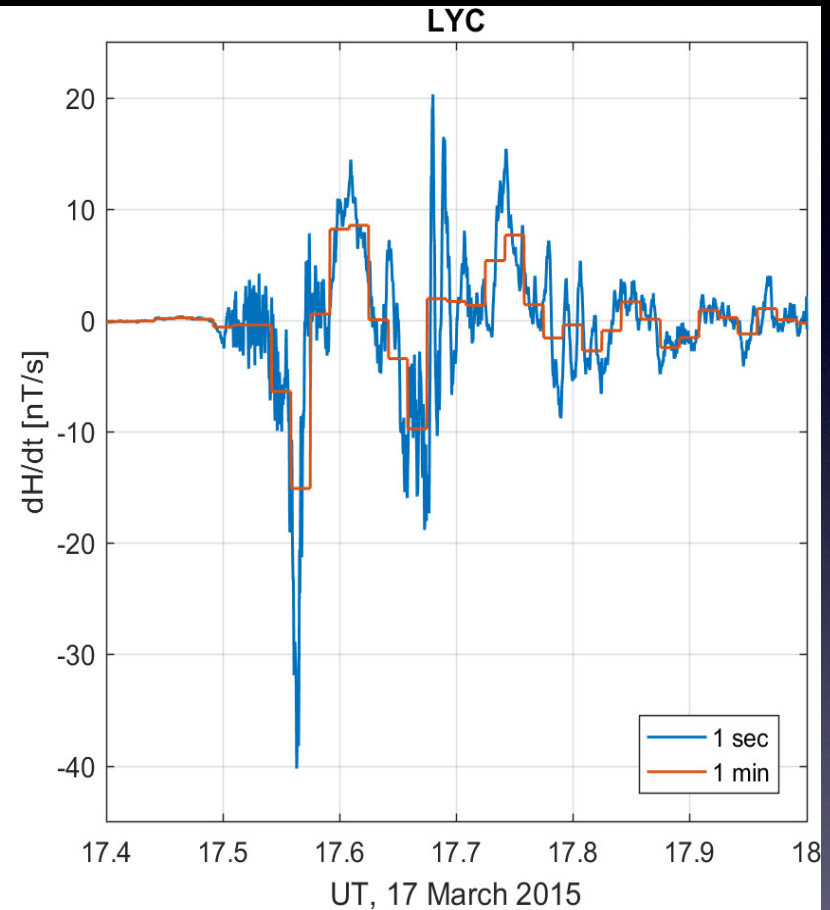
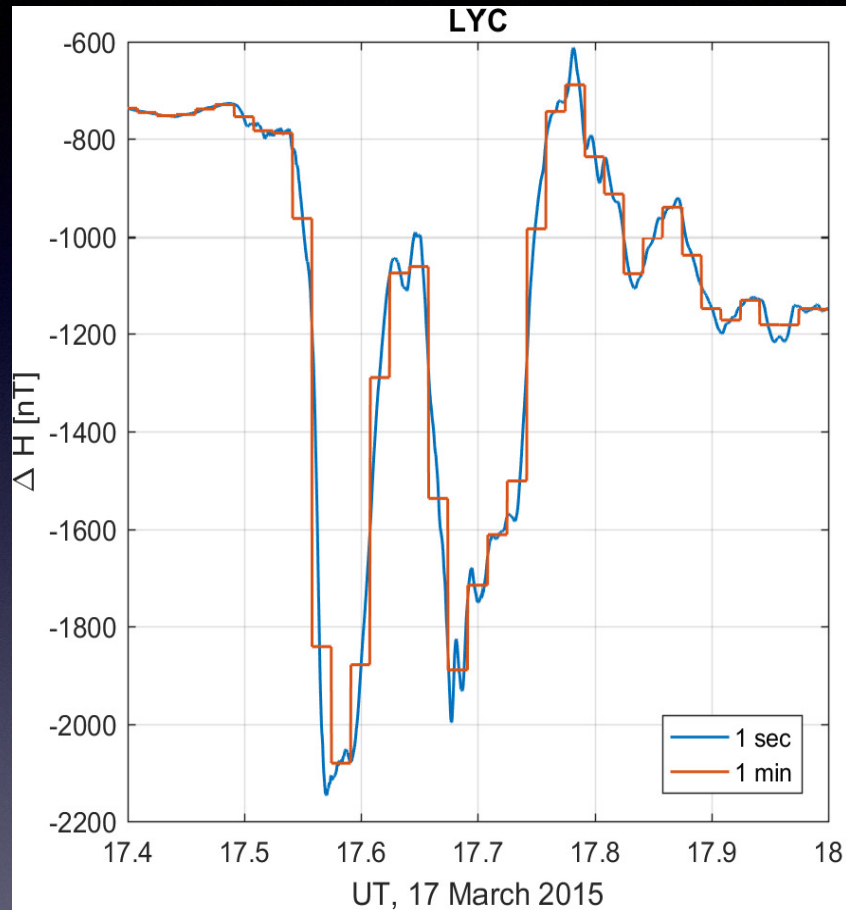


Seismometers # SNSN Univ. Uppsala



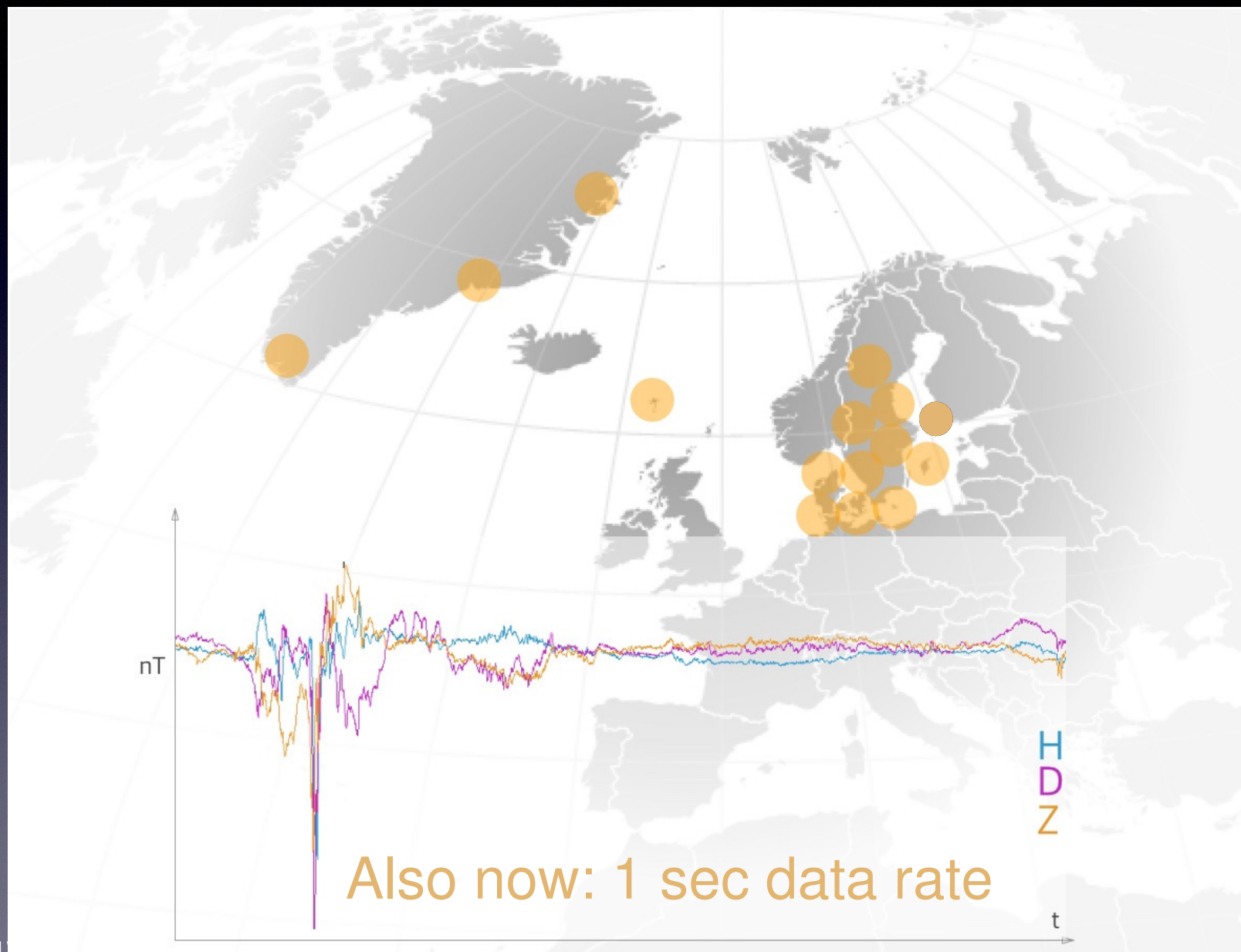
Present Swedish magnetometer network is insufficient

WE NEED 1 SEC RESOLUTION DATA FOR LARGE dB/dt!



Insufficiency is not restricted to instrument coverage, and station density, but even in temporal resolution !

The New MAGSWEDAN Magnetometer Network



Also now: 1 sec data rate

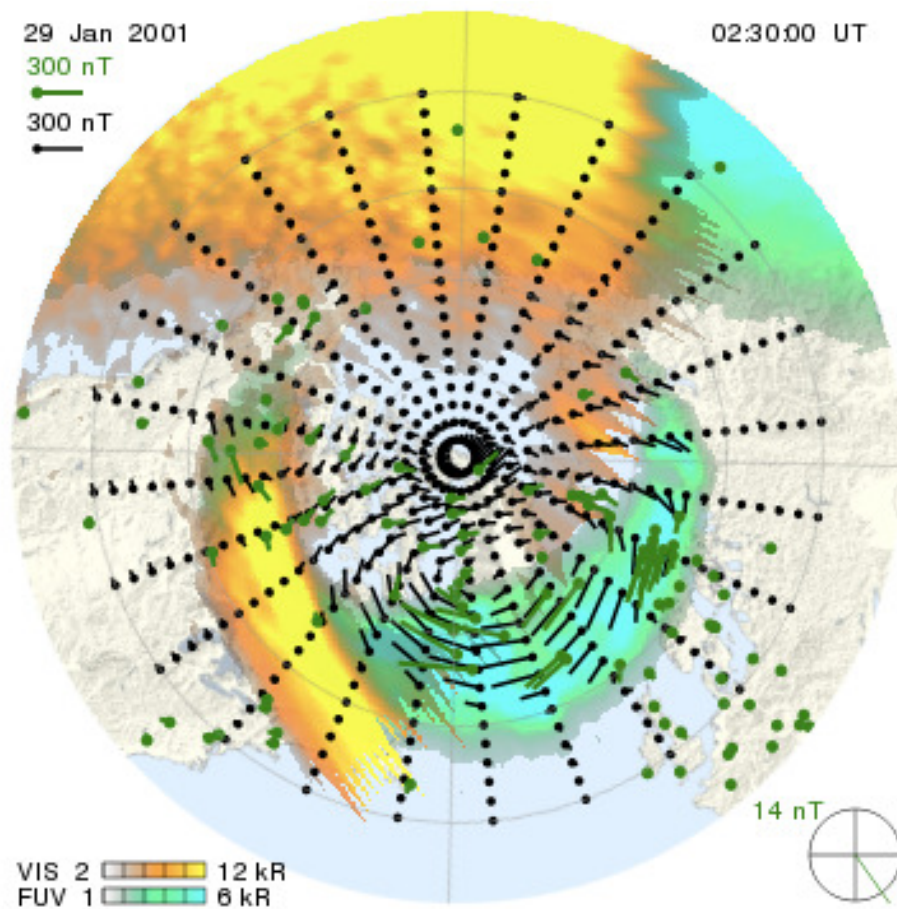
29 Jan 2001

300 nT

300 nT

300 nT

02:30:00 UT



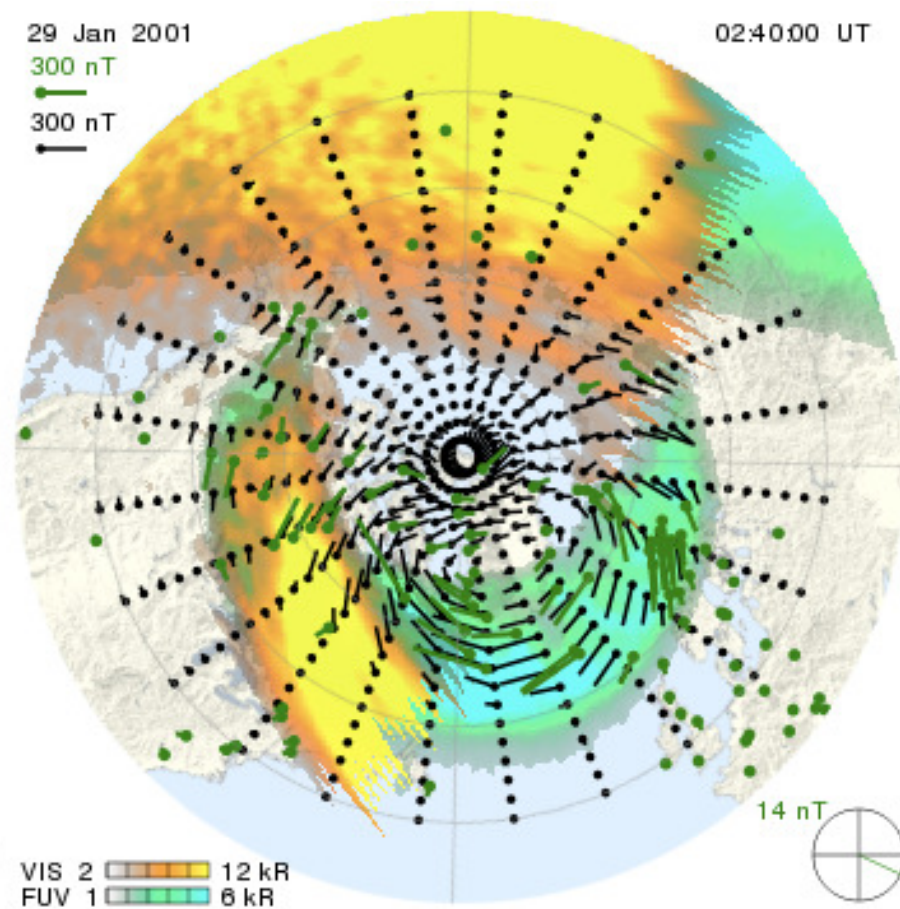
29 Jan 2001

300 nT

300 nT

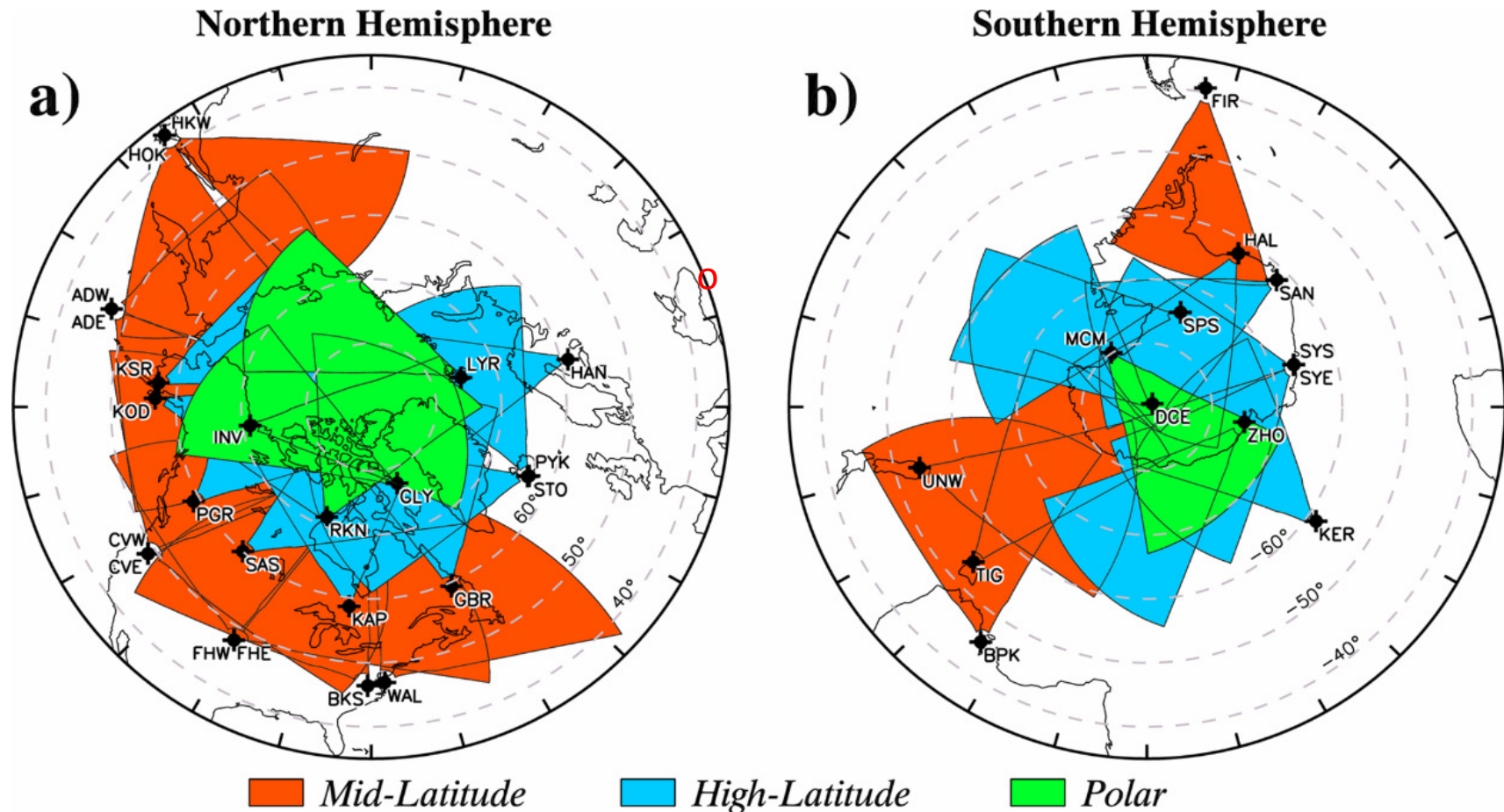
300 nT

02:40:00 UT



OTHER NEWS: the SuperDARN Radars' present day fields-of-view

Lack of subauroral coverage in Europe



New idea of CyprioDARN supporting the new magnetometer network

