Characteristics of Large Scale Travelling Ionospheric Disturbances Exploiting Ground-Based Ionograms, GPS-TEC and 3D Electron Density Distribution Maps

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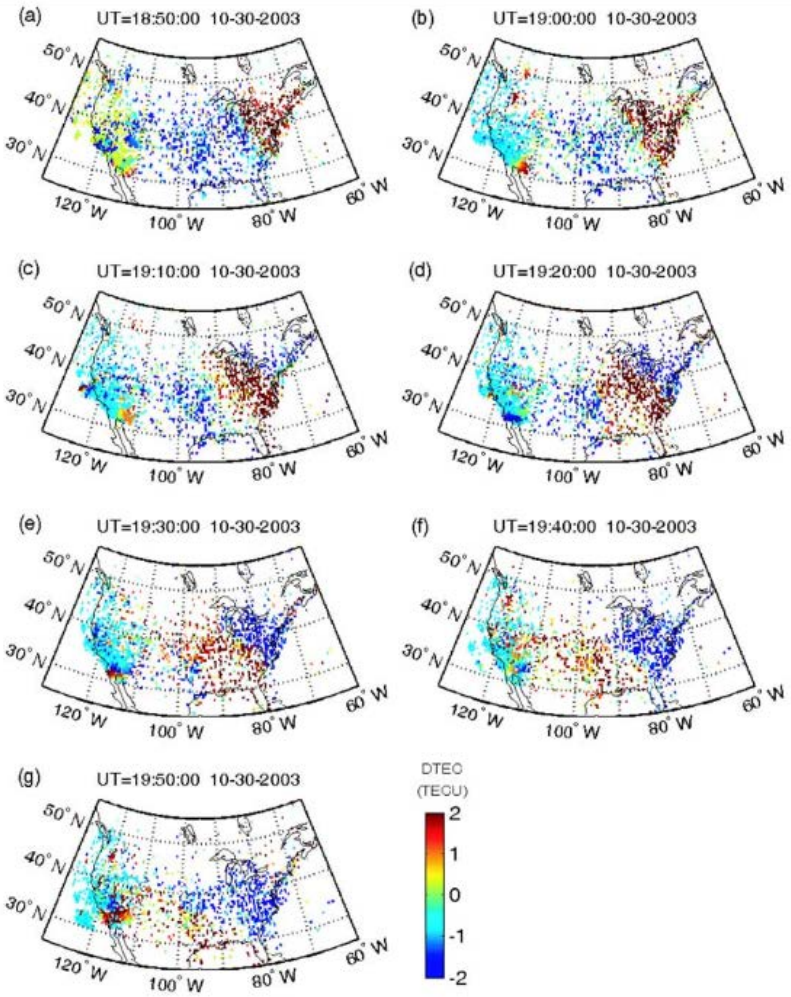
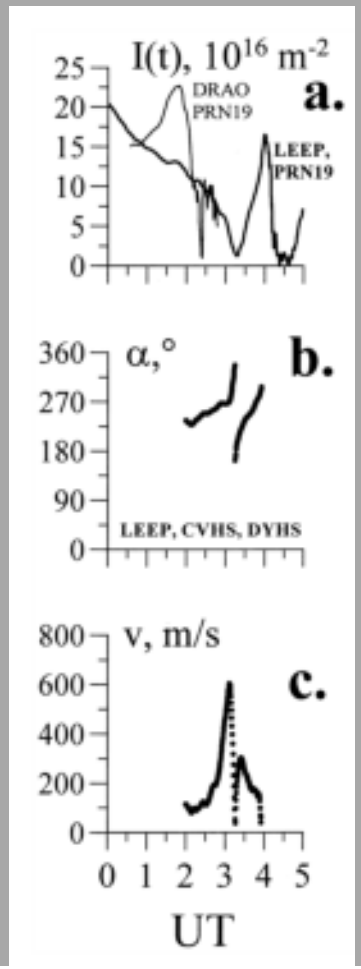
Large Scale Travelling Ionospheric Disturbances (LSTIDs) are recognized as ionospheric manifestations of the passage of AGWs that are generated at high latitudes by the energy input from the magnetosphere to the auroral ionosphere. (Hunsucker, 1982; Hocke and Schlegel, 1996)

- Horizontal scale > 1000 to 3500 km
- Period ~ 30 to 180 min
- Mean horizontal velocity ~ 300 to 1000 m/s (Afraimovich et al., 1998; 2002; Tsugawa et al., 2004; Ding et al., 2007)
- Damping and growth rates of LSTIDs are correlated with upward and downward propagating AGWs (Tsugawa et al., 2004)

Identification and tracking of TIDs



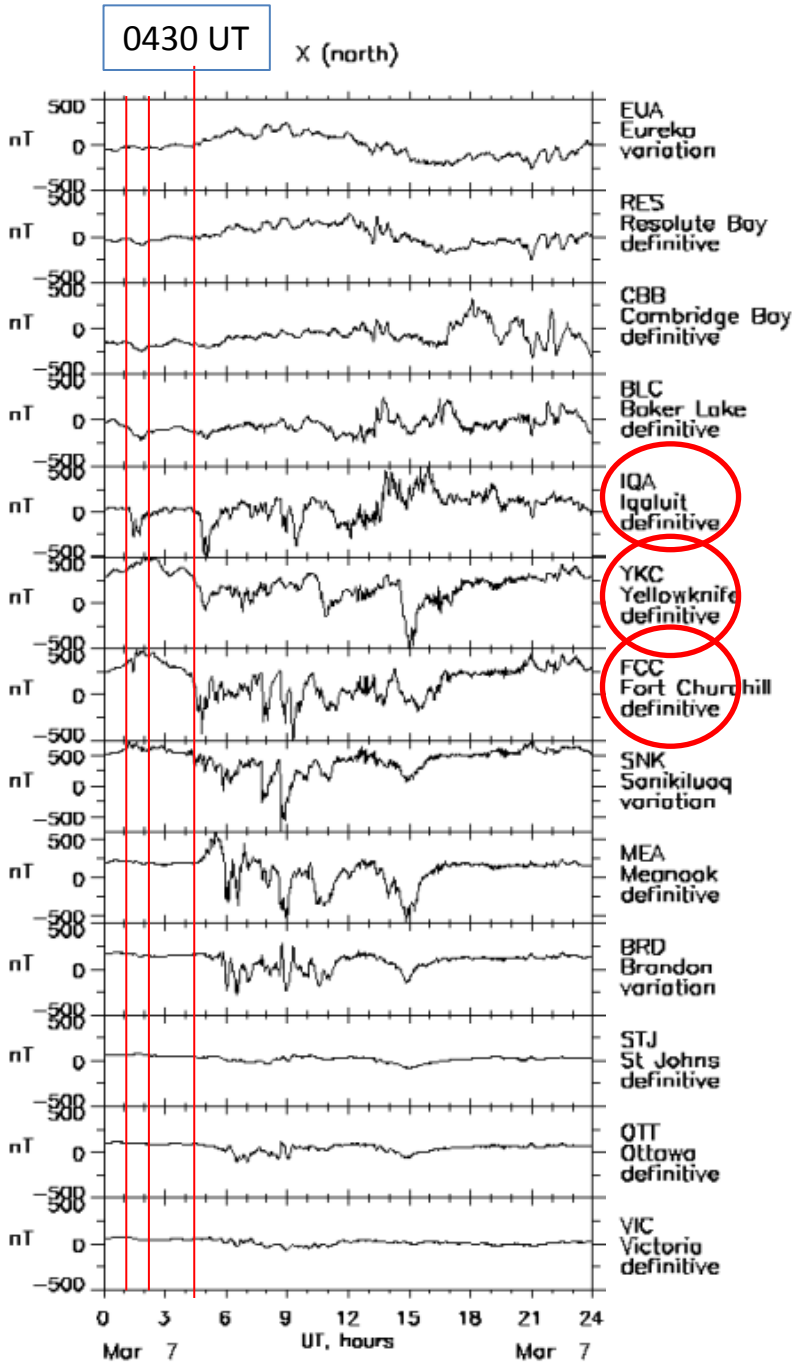
Method based on 2D maps of TEC perturbation (ex. Ding et al., 2007)

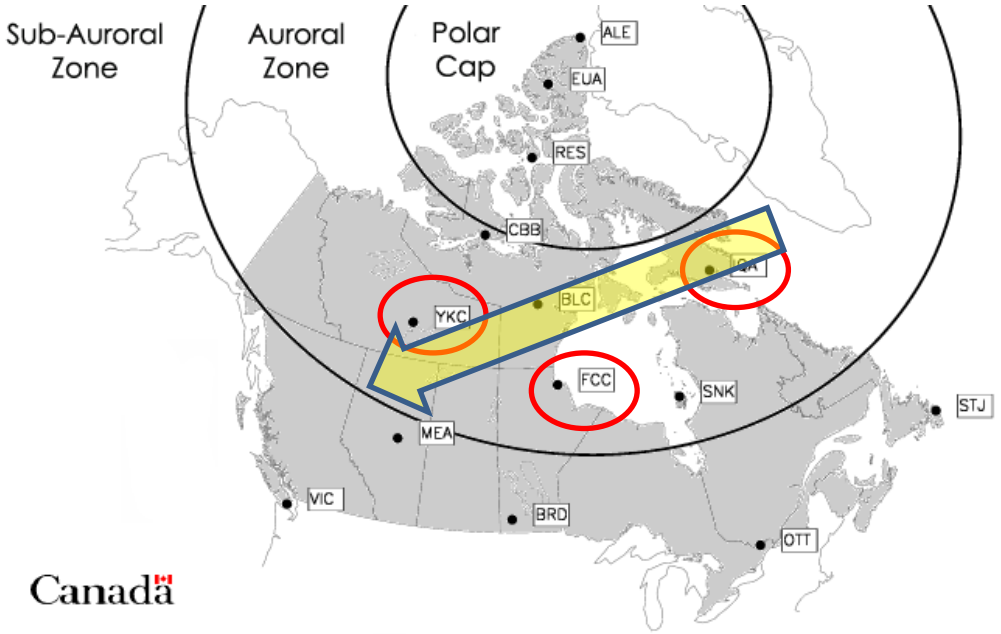


Afraimovich method: calculations of spatial and temporal variations of TEC measured at three spaced GPS receivers

Methodology

- Identification of the onset time, polar and auroral magnetograms inspection
- Indications from Digisondes: ionograms + electron density variation with height
- Indications from the slant TEC (STEC) variation extracted from GPS receivers
- Analysis of the electron density model output (TaD model)

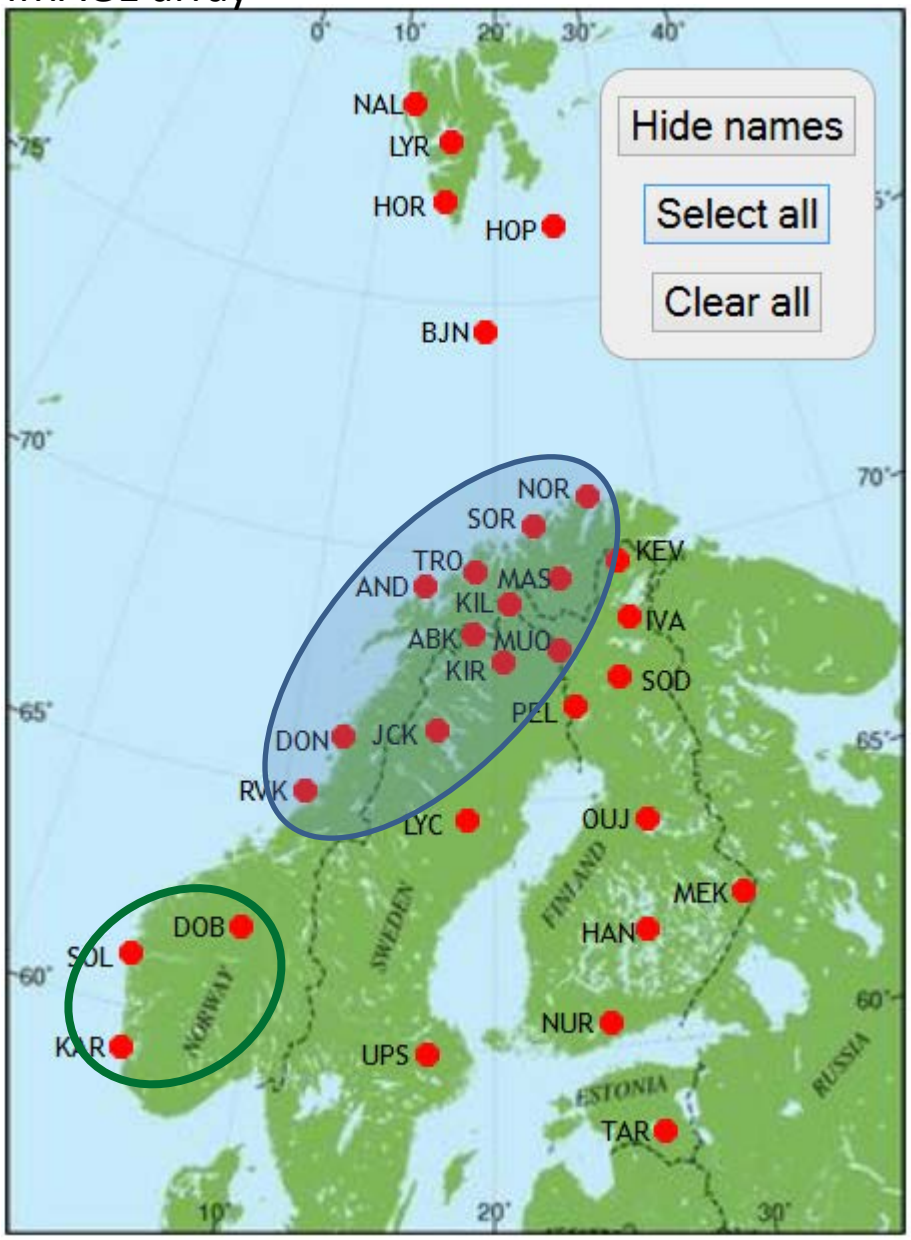




Main onsets:

0200 @ IQA
0220 @ FCC
0300 @ YKC
0430 @ IQA

IMAGE array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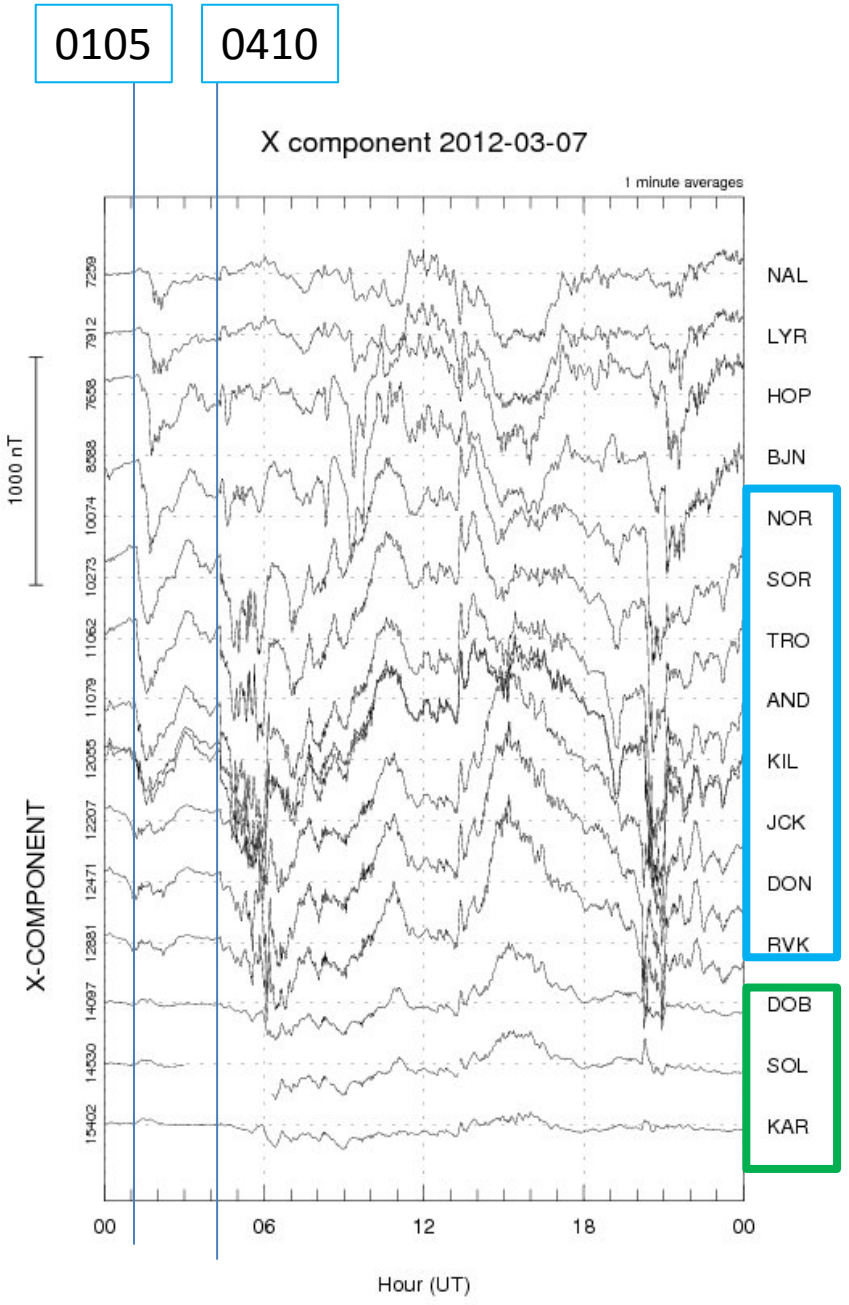
SWEDEN
FINLAND
NORWAY
ESTONIA
RUSSIA


0105
0410
X component 2012-03-07
1 minute averages
1000 nT
X-COMPONENT
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7658
8588
10074
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11062
11079
12055
12207
12471
12881
14097
14530
15402
NAL
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NOR
SOR
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AND
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DON
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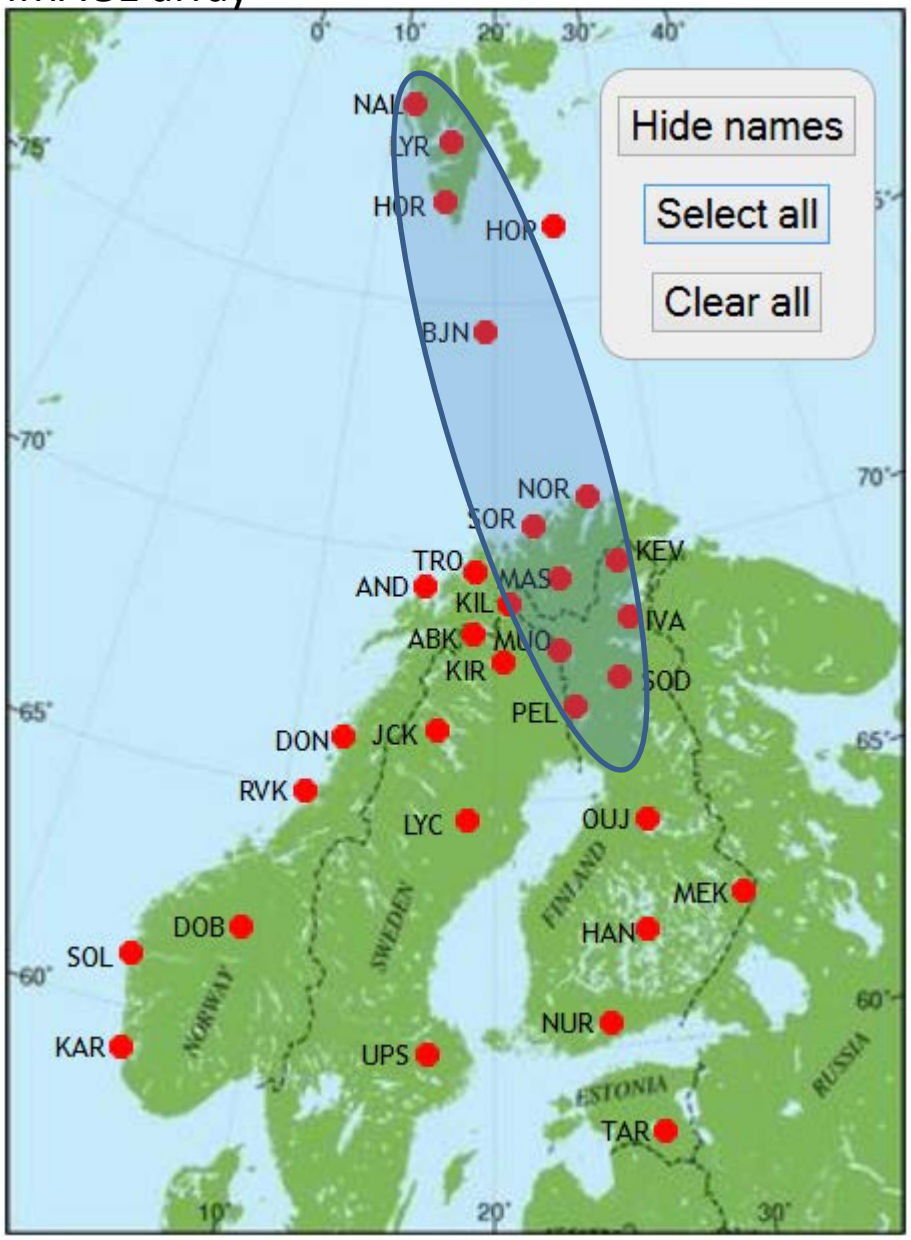
DOB
SOL
KAR
00
06
12
18
00
Hour (UT)

IMAGE array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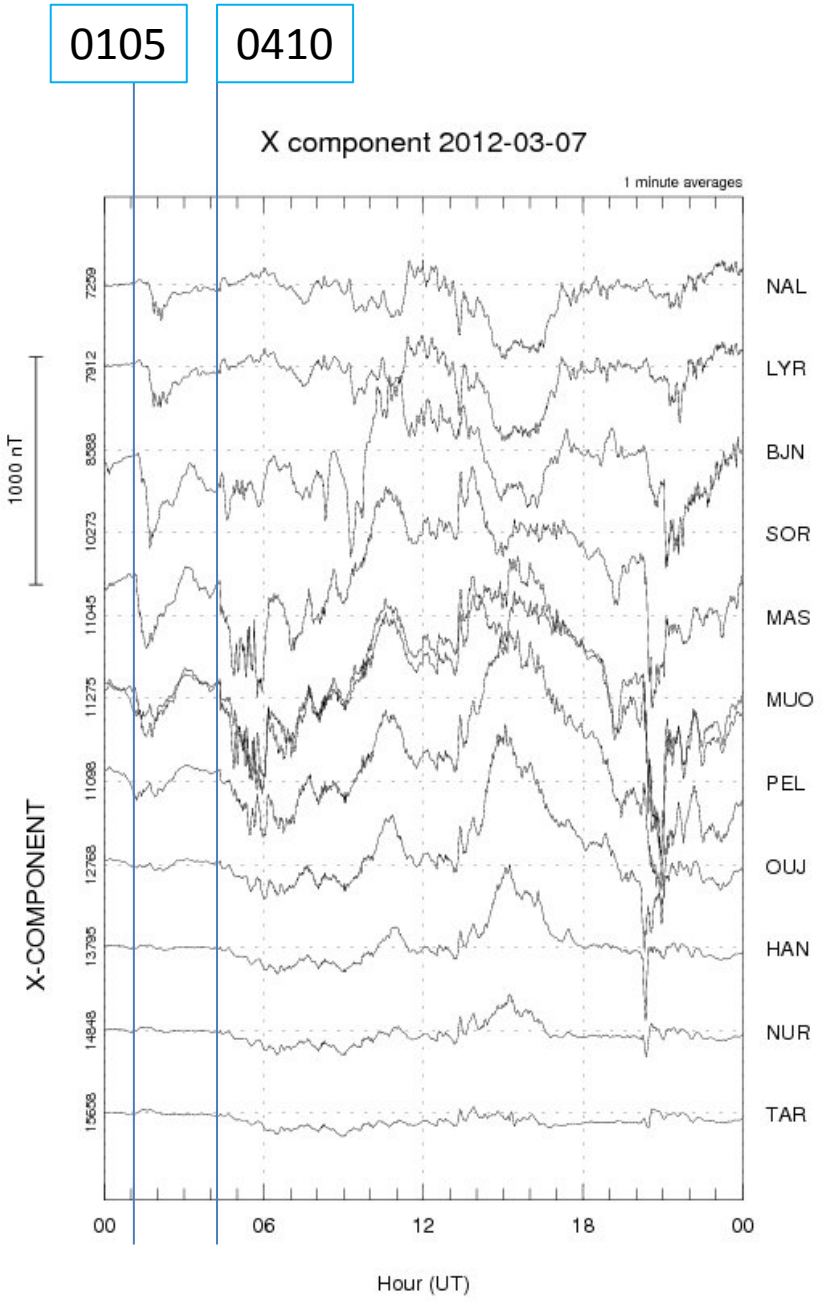
0105
0410
X component 2012-03-07
1 minute averages
1000 nT
X-COMPONENT
NAL
LYR
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MAS
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OUJ
HAN
NUR
TAR
00
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Hour (UT)

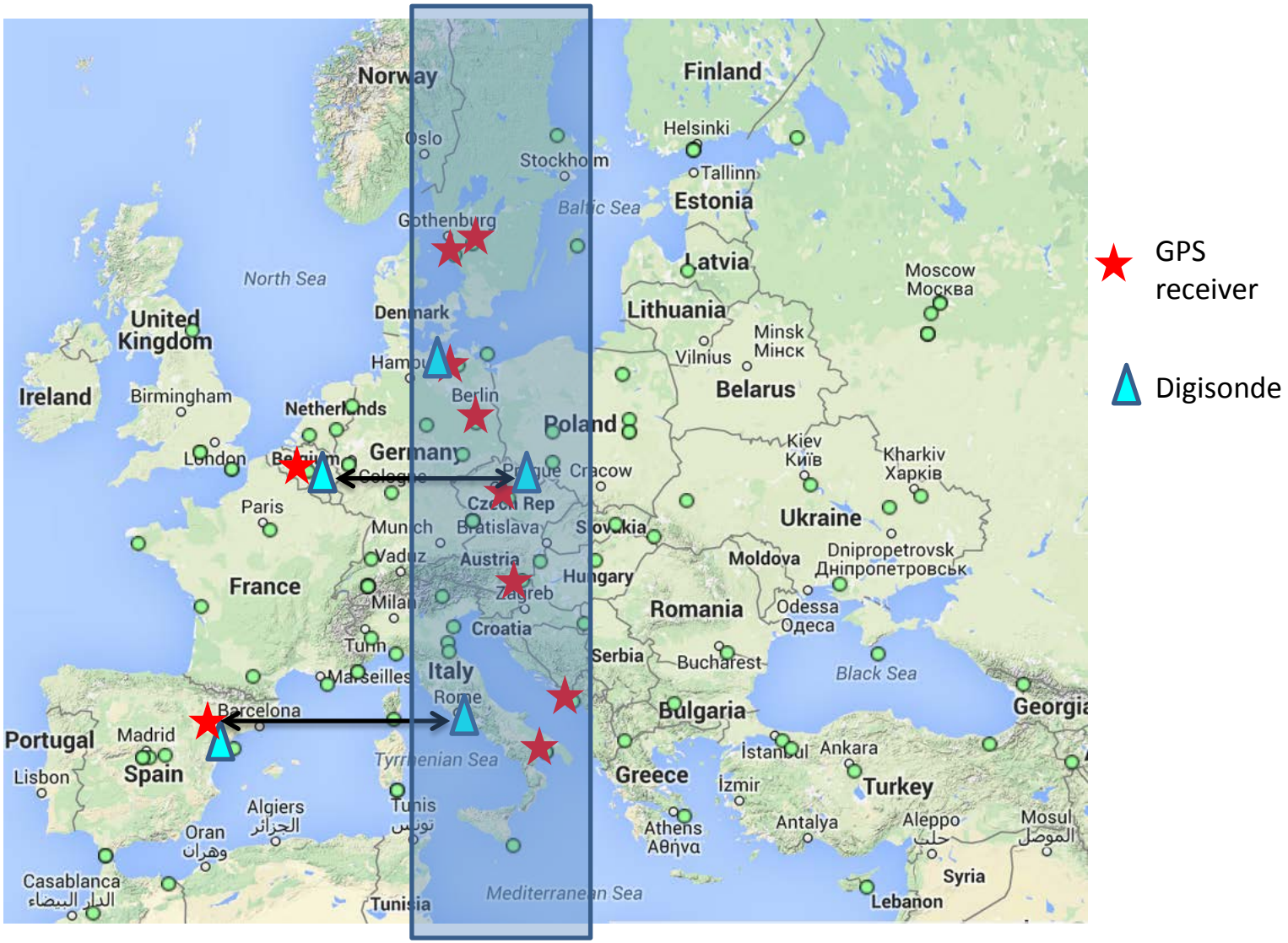
Onset time

Two main indications of westward electrojet intensification were observed:

- at 0200UT and 0430 from the Canadian magnetometers
- at 0105UT and 0410 from the Scandinavian magnetometers (local time in Europe is close to midnight)

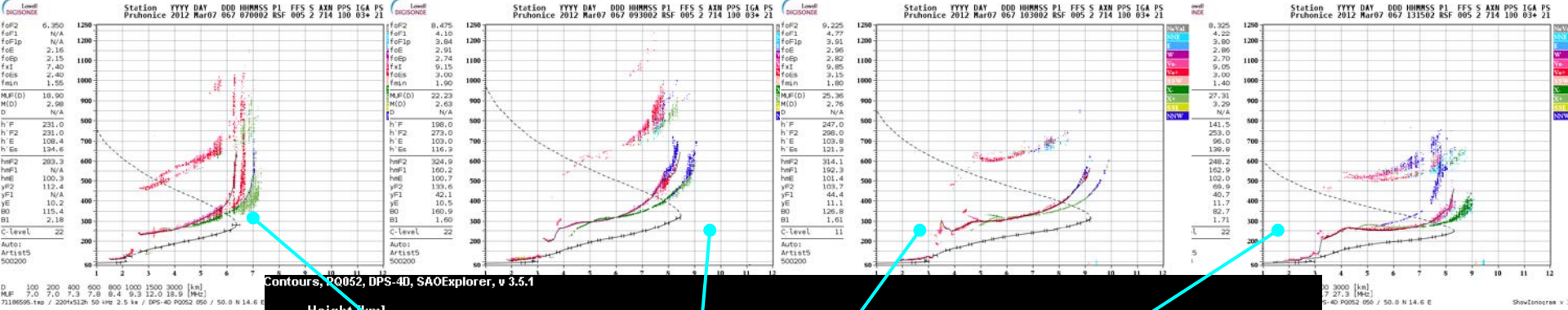
Conclusion: The European chain of Digisondes should see first the disturbance (high probability of spread-F, the nighttime indication of TID)

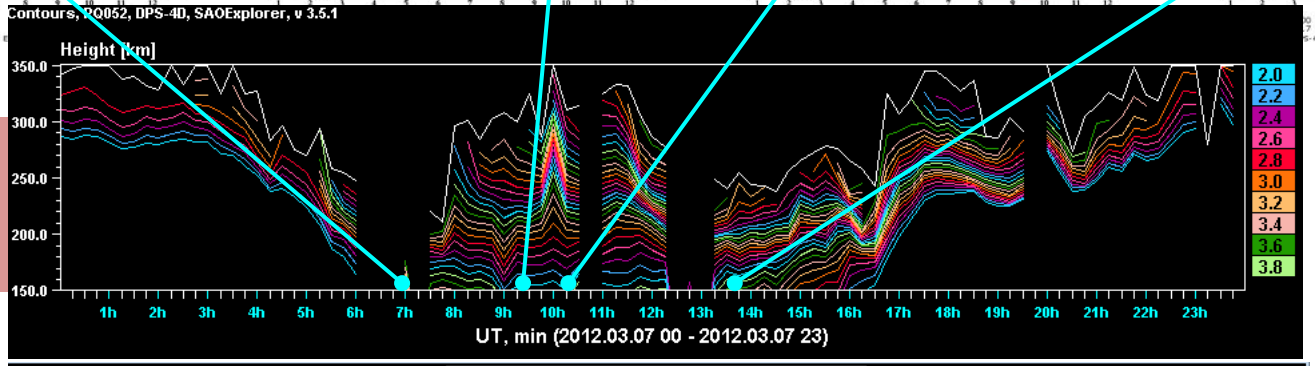
Monitoring network at the 12°-15° meridian



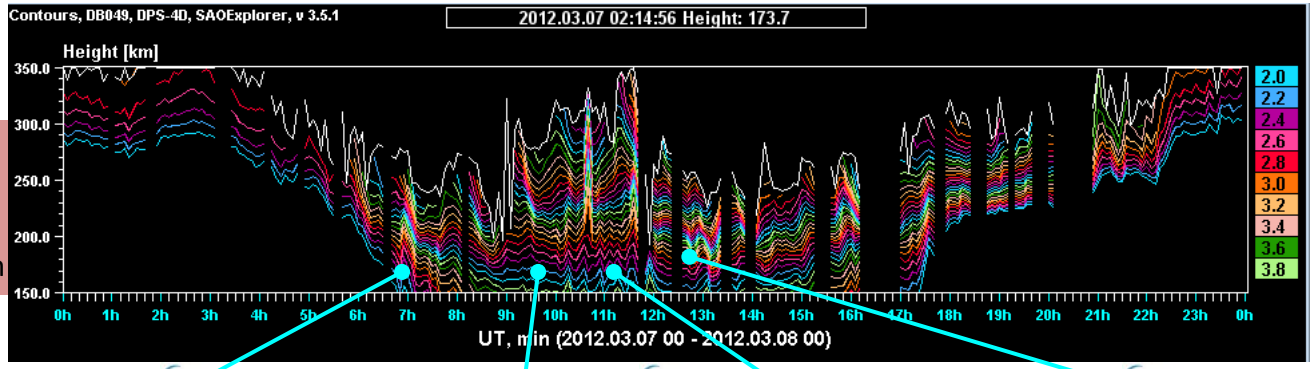
GPS receiver

Digisonde

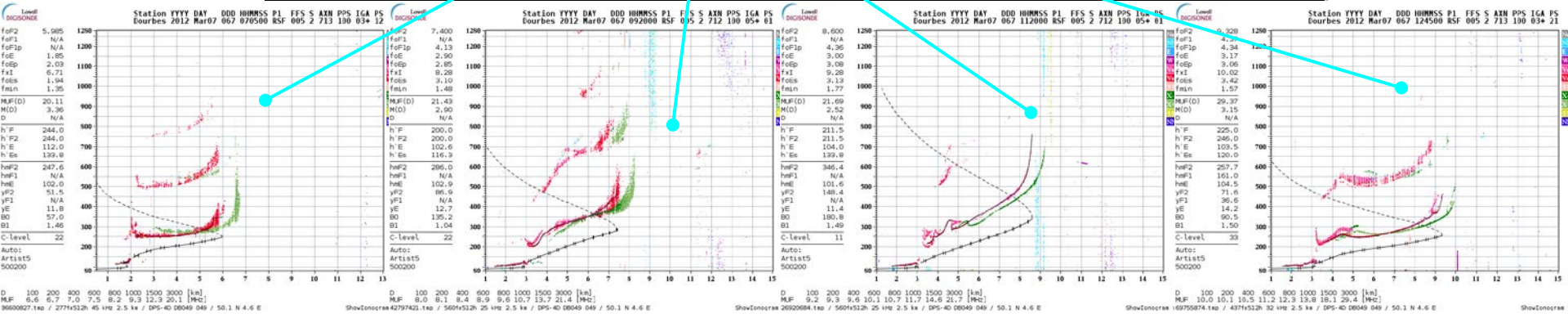


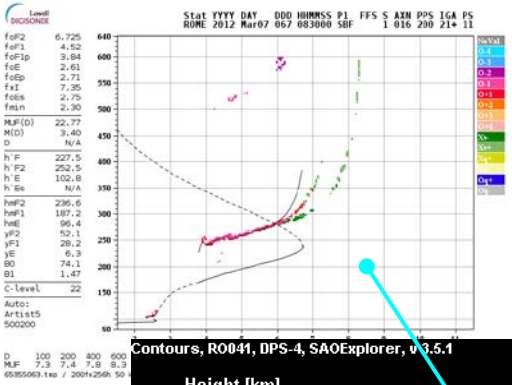


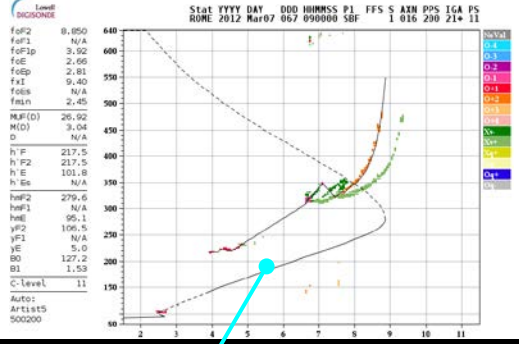
Pruhonice, 50°N
15 min sampling
Sounder: DPS4D
Settings: 50kHz, 2.5km

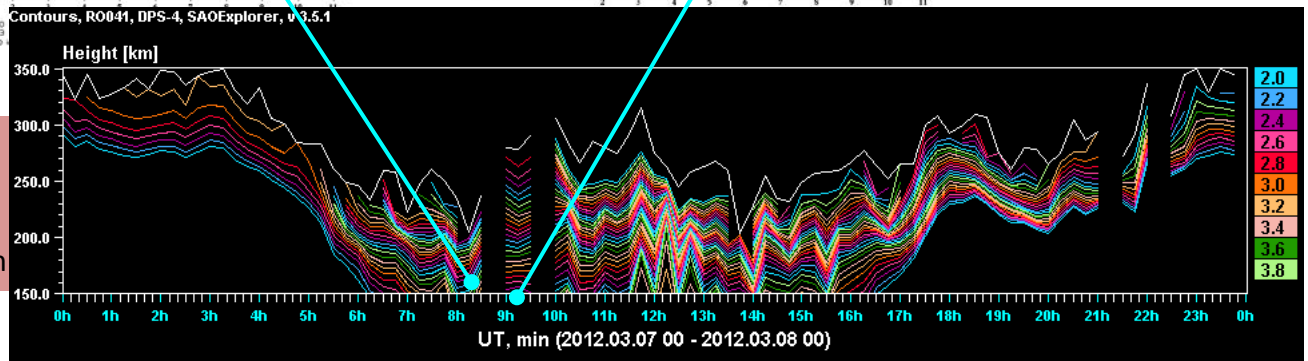


Dourbes, 50.1°N
5 min sampling
Sounder: DPS4D
Settings: 45kHz, 2.5 km

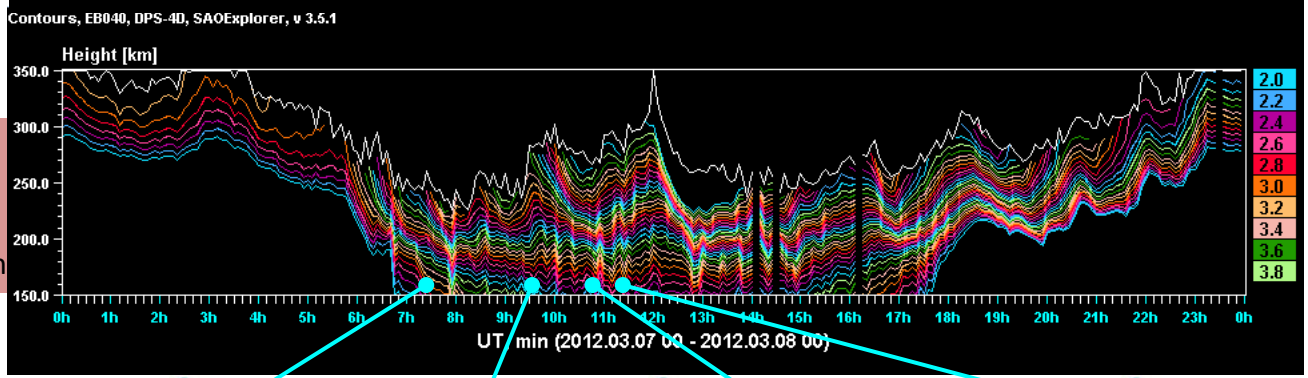




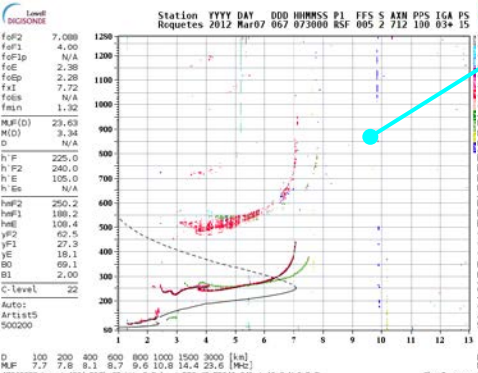


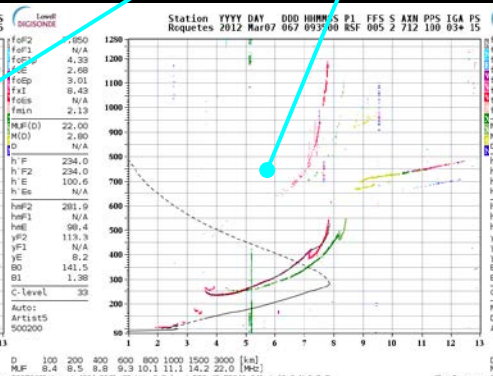


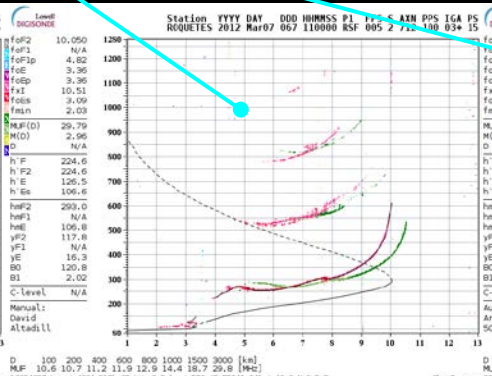
Rome, 50°N
15 min sampling
Sounder: DPS4
Settings: 50kHz, 2.5km

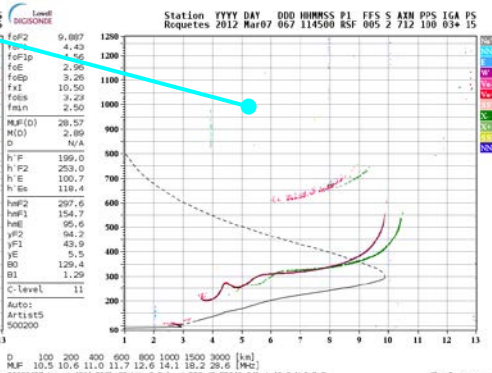


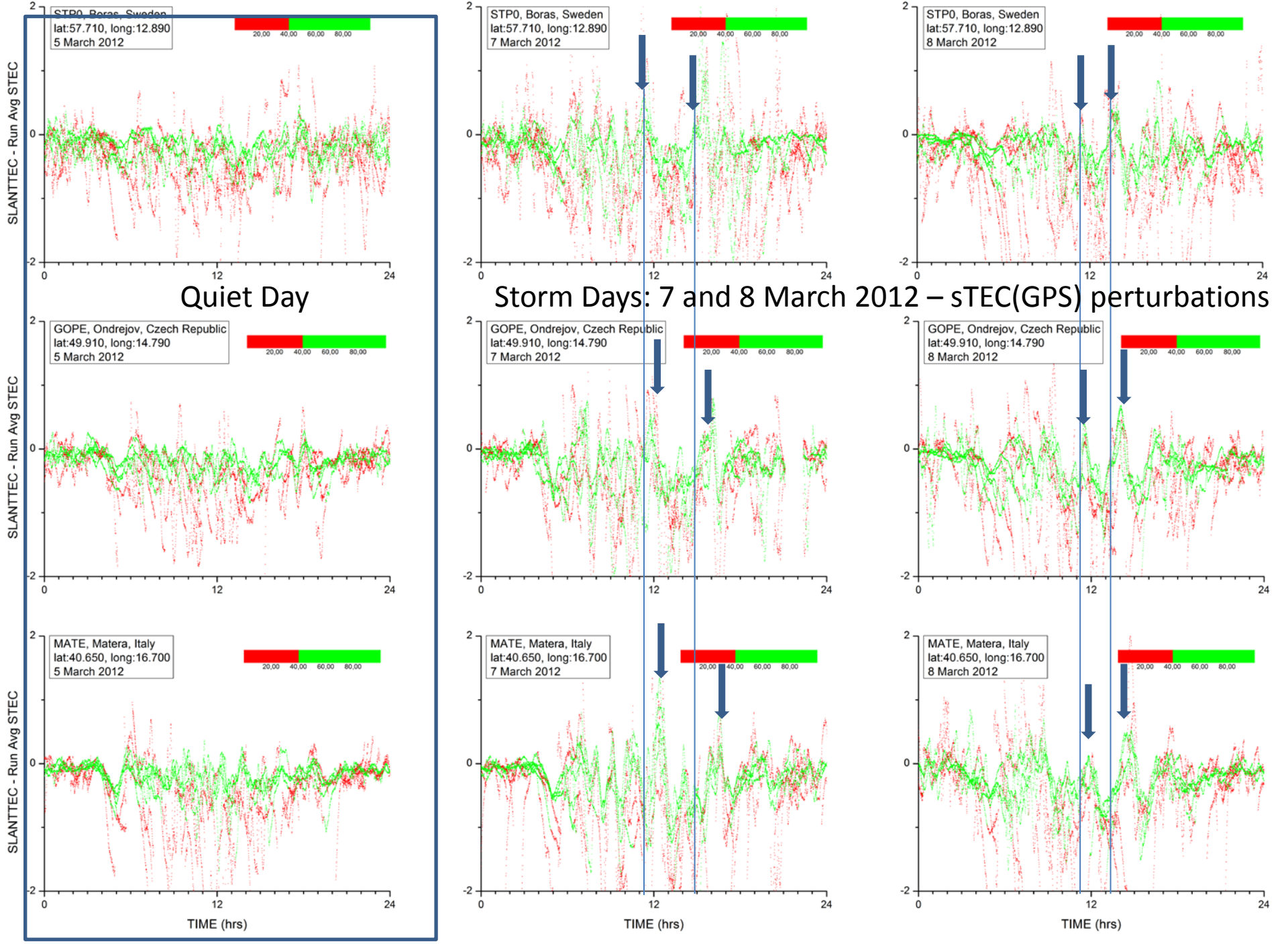
Ebro, 50.1°N
5 min sampling
Sounder: DPS4D
Settings: 25kHz, 2.5km





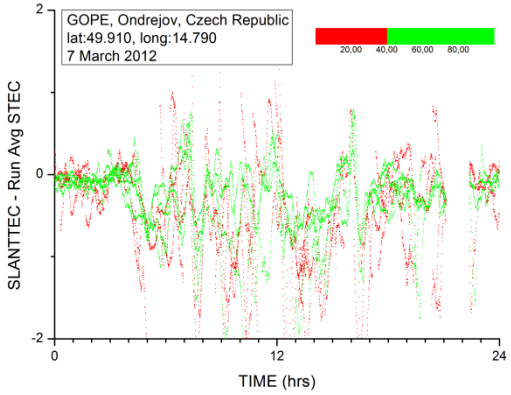


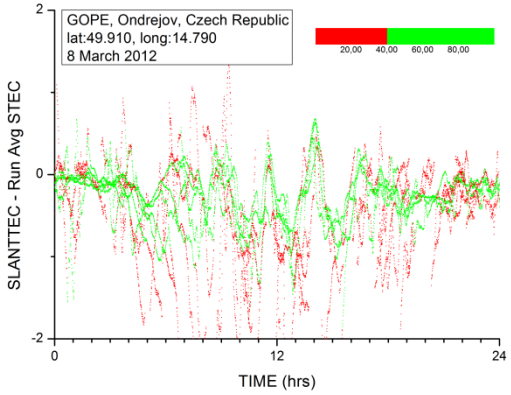



STP0, Boras, Sweden
lat:57.710, long:12.890
5 March 2012
STP0, Boras, Sweden
lat:57.710, long:12.890
7 March 2012
STP0, Boras, Sweden
lat:57.710, long:12.890
8 March 2012
GOPE, Ondrejov, Czech Republic
lat:49.910, long:14.790
5 March 2012
GOPE, Ondrejov, Czech Republic
lat:49.910, long:14.790
7 March 2012
GOPE, Ondrejov, Czech Republic
lat:49.910, long:14.790
8 March 2012
MATE, Matera, Italy
lat:40.650, long:16.700
5 March 2012
MATE, Matera, Italy
lat:40.650, long:16.700
7 March 2012
MATE, Matera, Italy
lat:40.650, long:16.700
8 March 2012
20,00 40,00 60,00 80,00
SLANTTEC - Run Avg STEC
TIME (hrs)
Quiet Day
Storm Days: 7 and 8 March 2012 – sTEC(GPS) perturbations

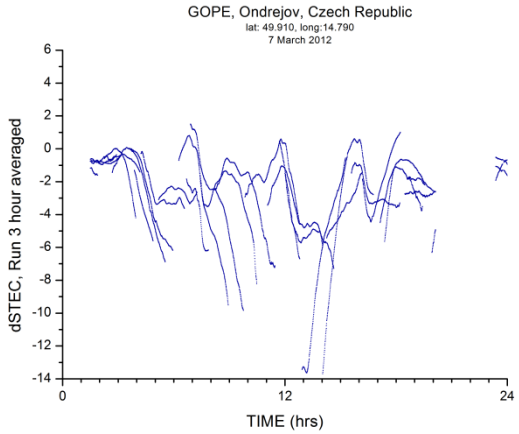
The LSTID amplitude depends on the STEC filtering method

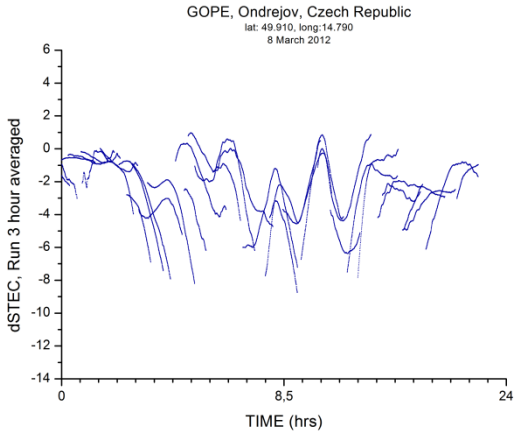
STEC Background:
1 hr avrg





STEC Background:
3 hr avrg

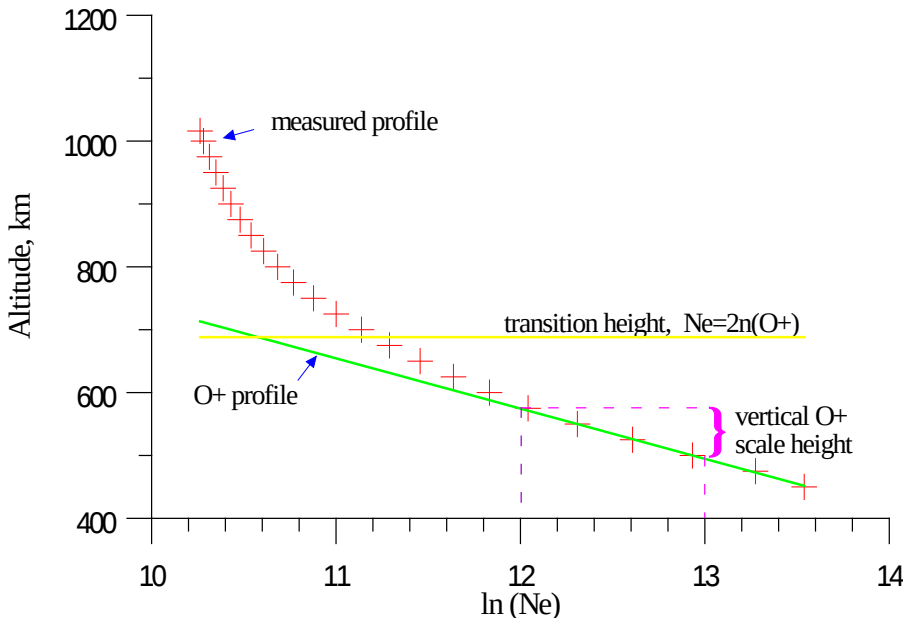




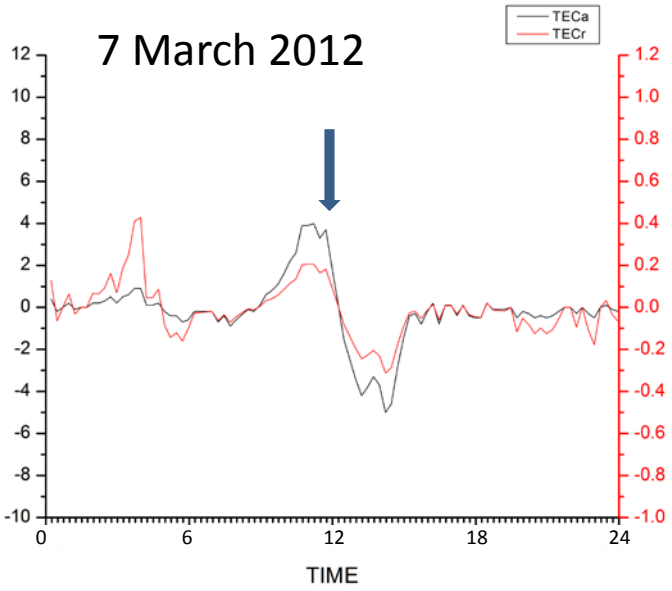
TaD: the Topside Sounders Model – assisted Digisonde

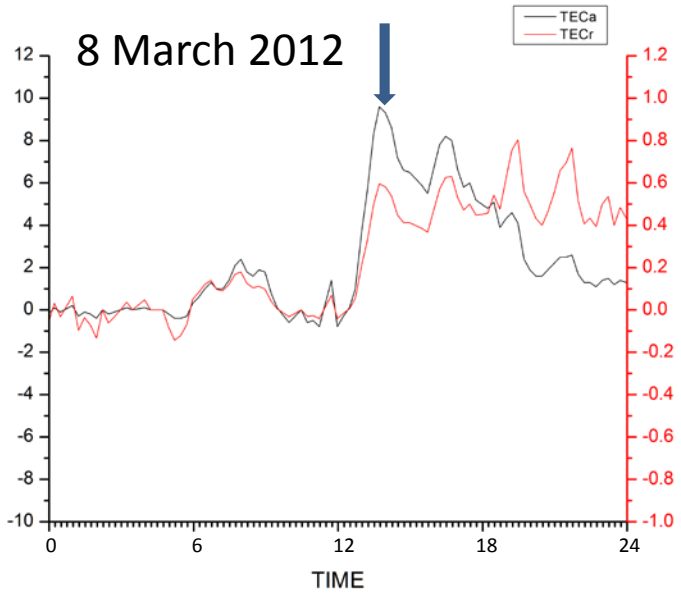
Present profiling technique combines:

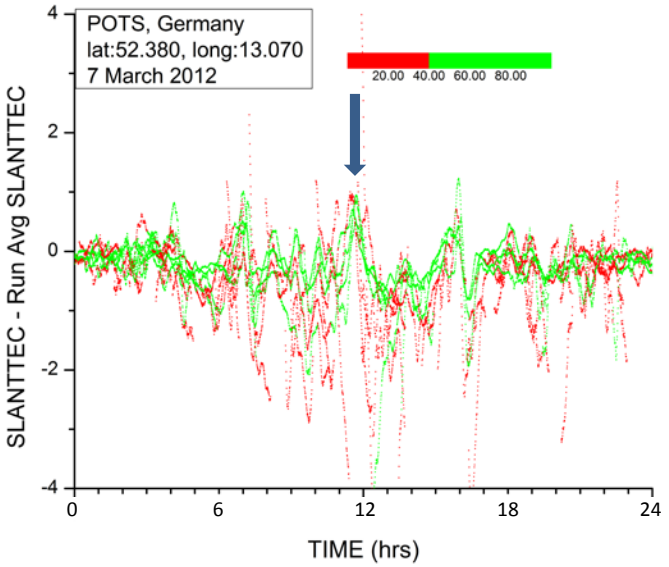
- **a core empirical model (TSM)** providing the topside scale height and upper transition (O^+- H^+) height,
- **a profiler (TSMP)** providing the shape of the vertical electron density profile in the topside and plasmasphere as a sum of O^+, H^+, and He^+ partial distributions,
- **a TSM-assisted Digisonde (TaD) profiler** ingesting Digisonde-derived parameters peak altitude, density, and topside scale height into TSMP, allowing real-time update of TSMP.

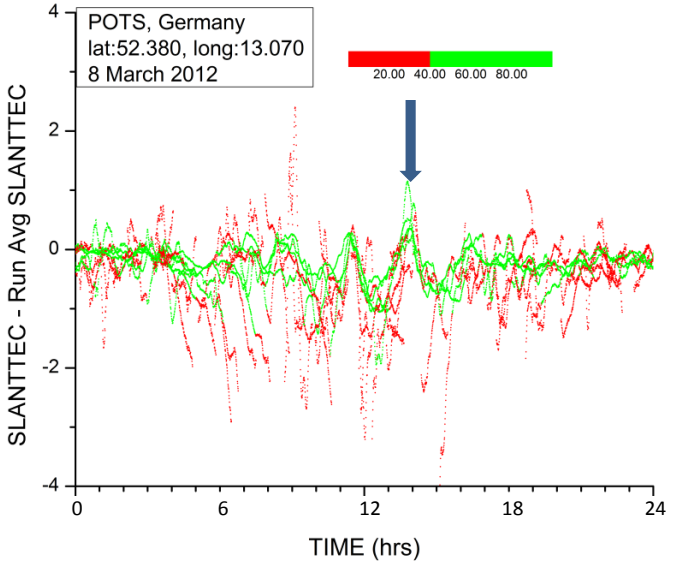


Juliusruh – TaD signatures

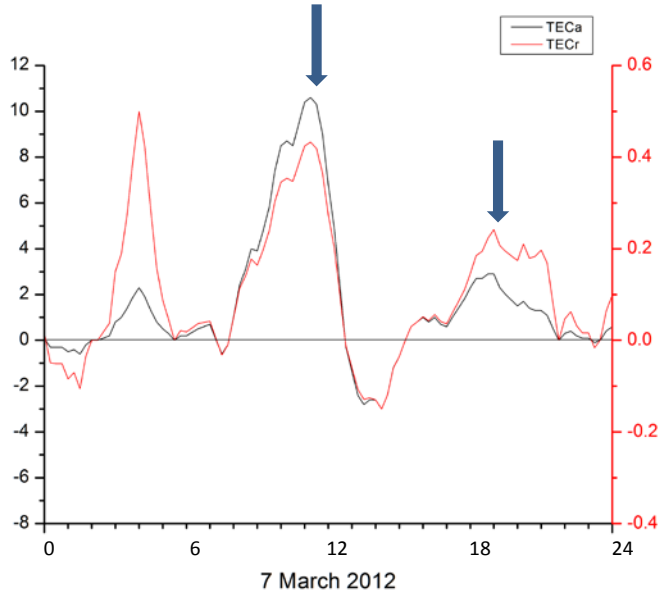


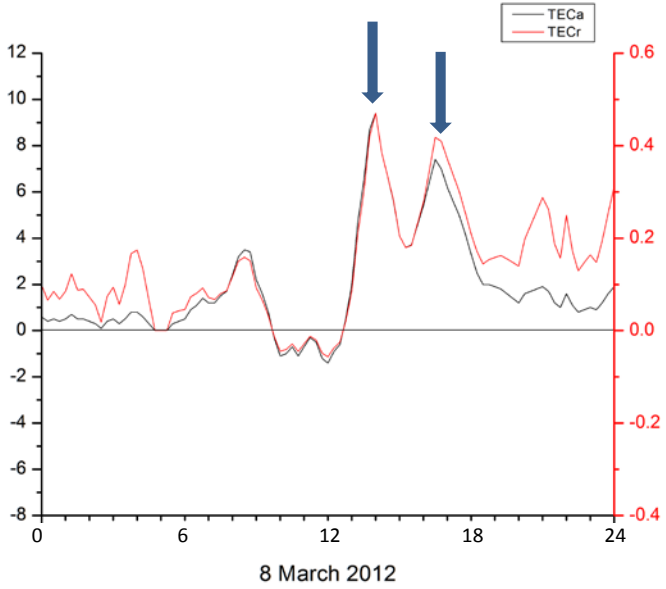


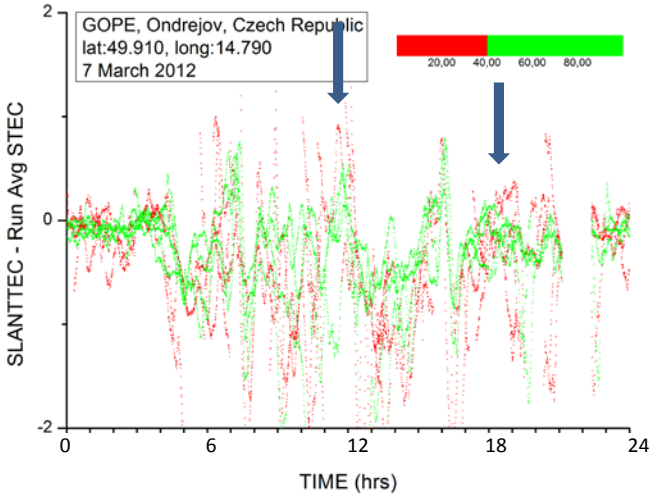


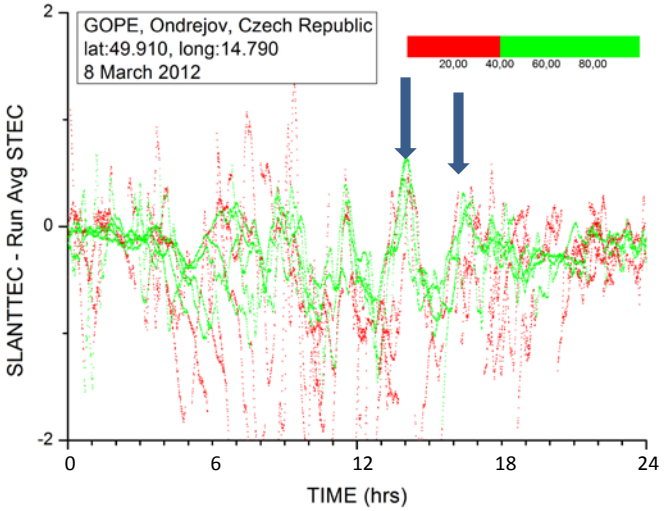


Pruhonice-TaD signatures

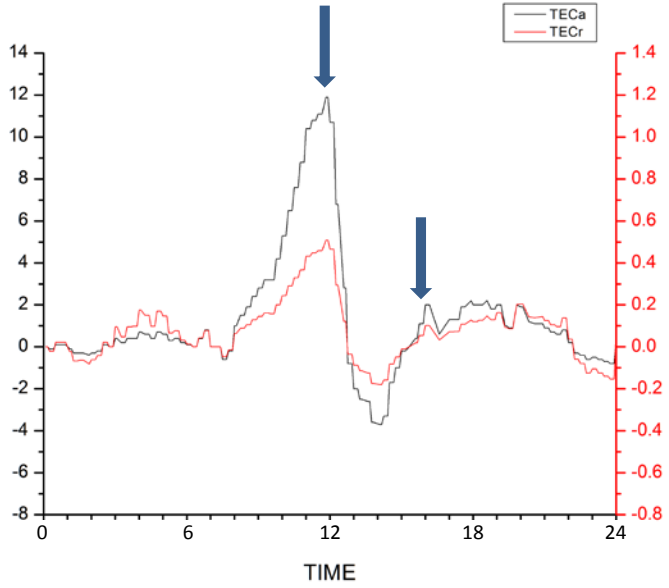


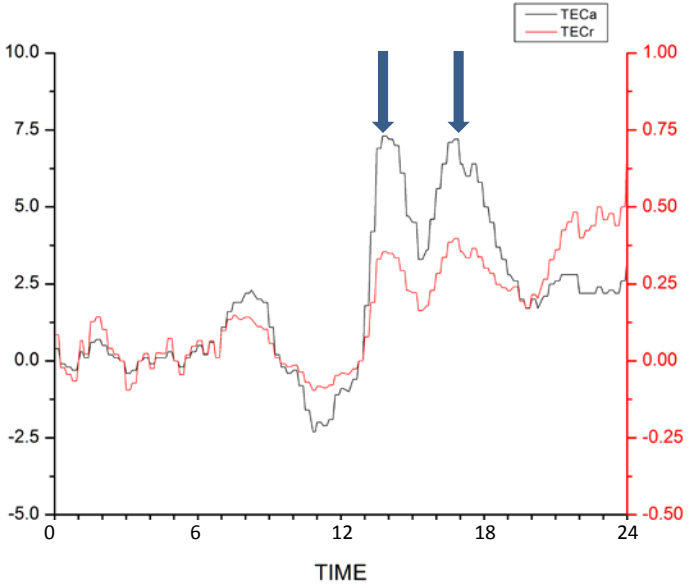


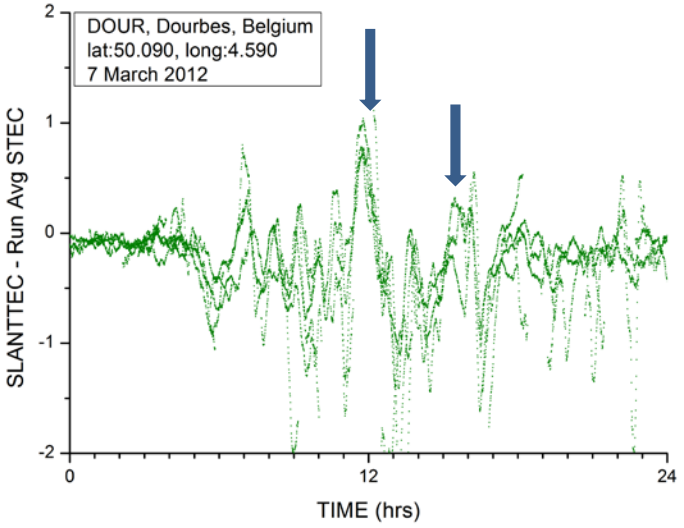


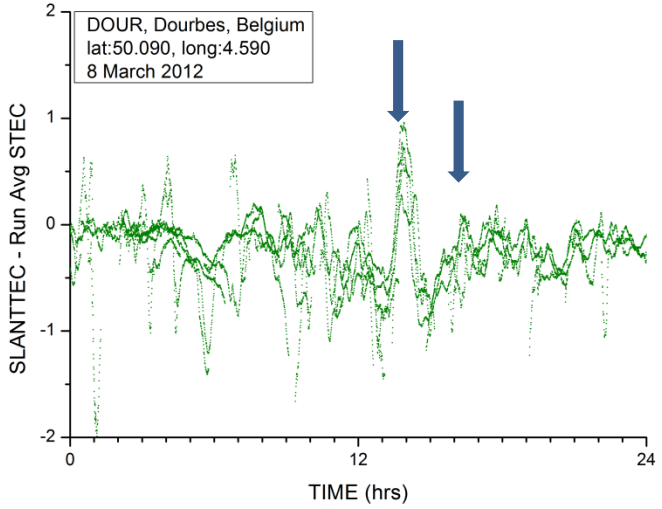


Dourbes-TaD signatures



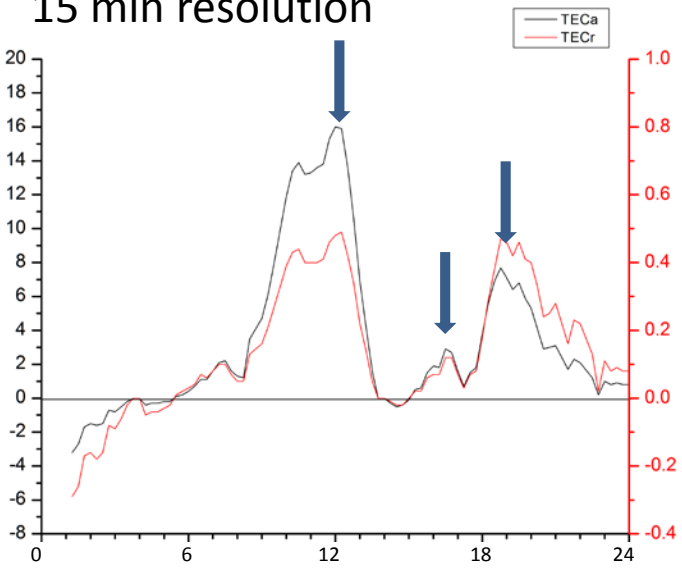


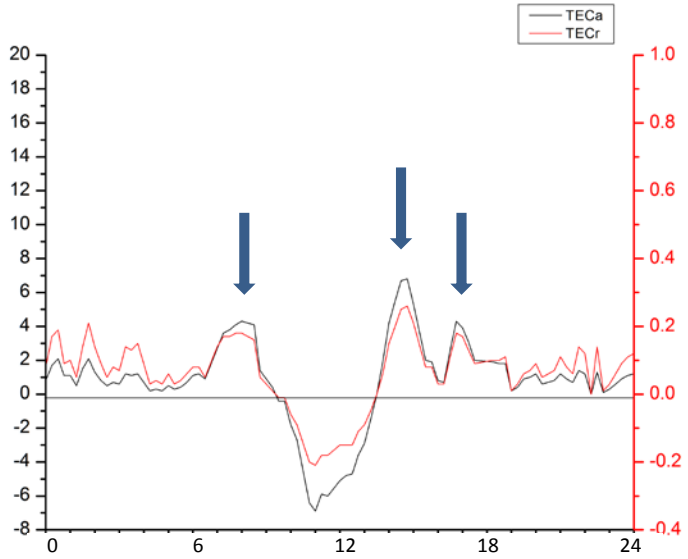




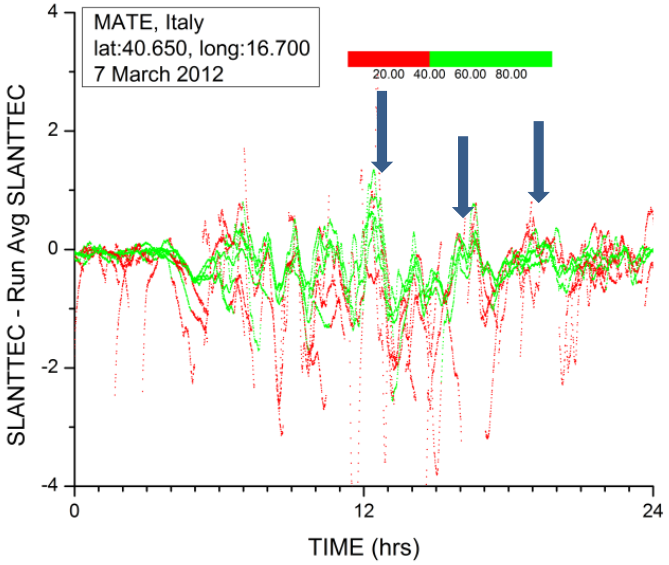
Rome-TaD signatures

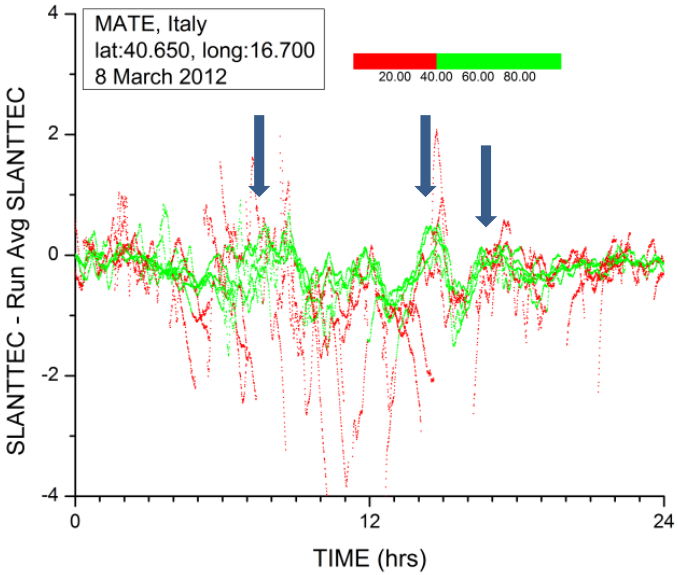
15 min resolution



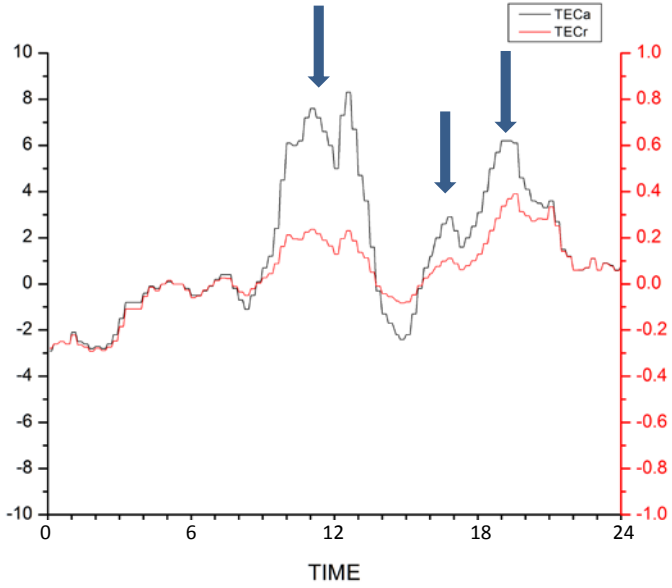


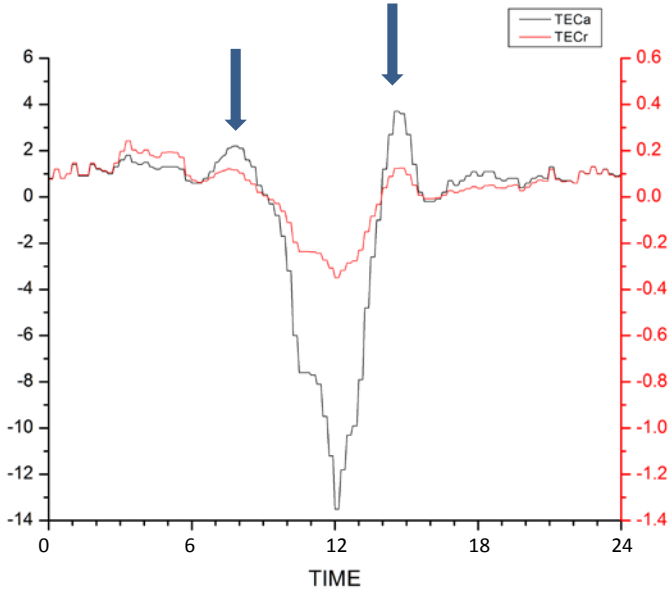
30 sec resolution

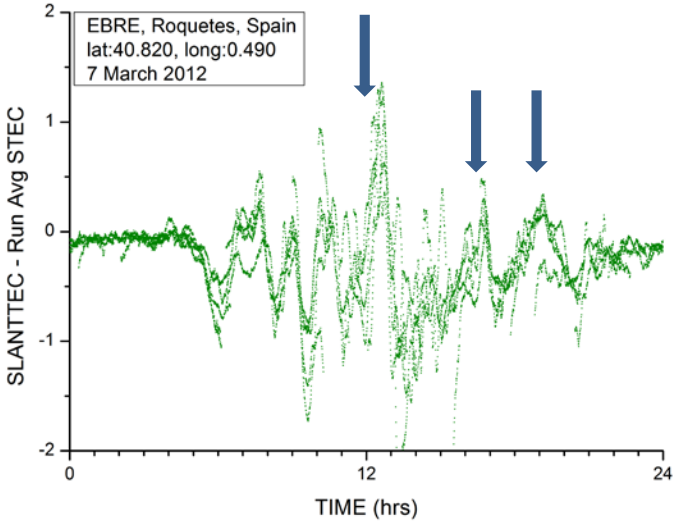


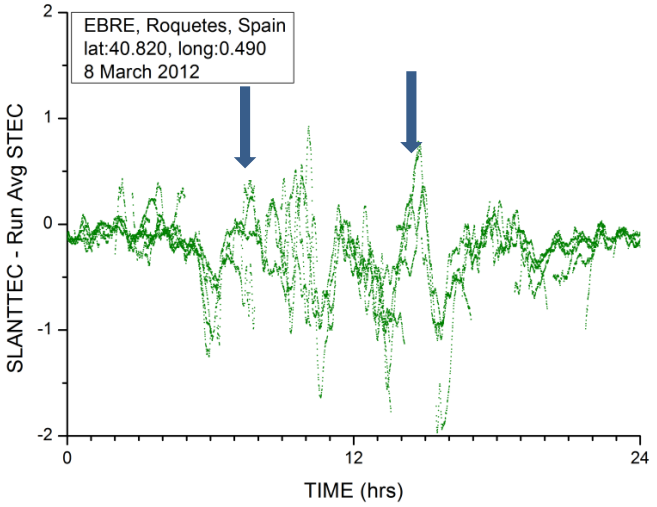


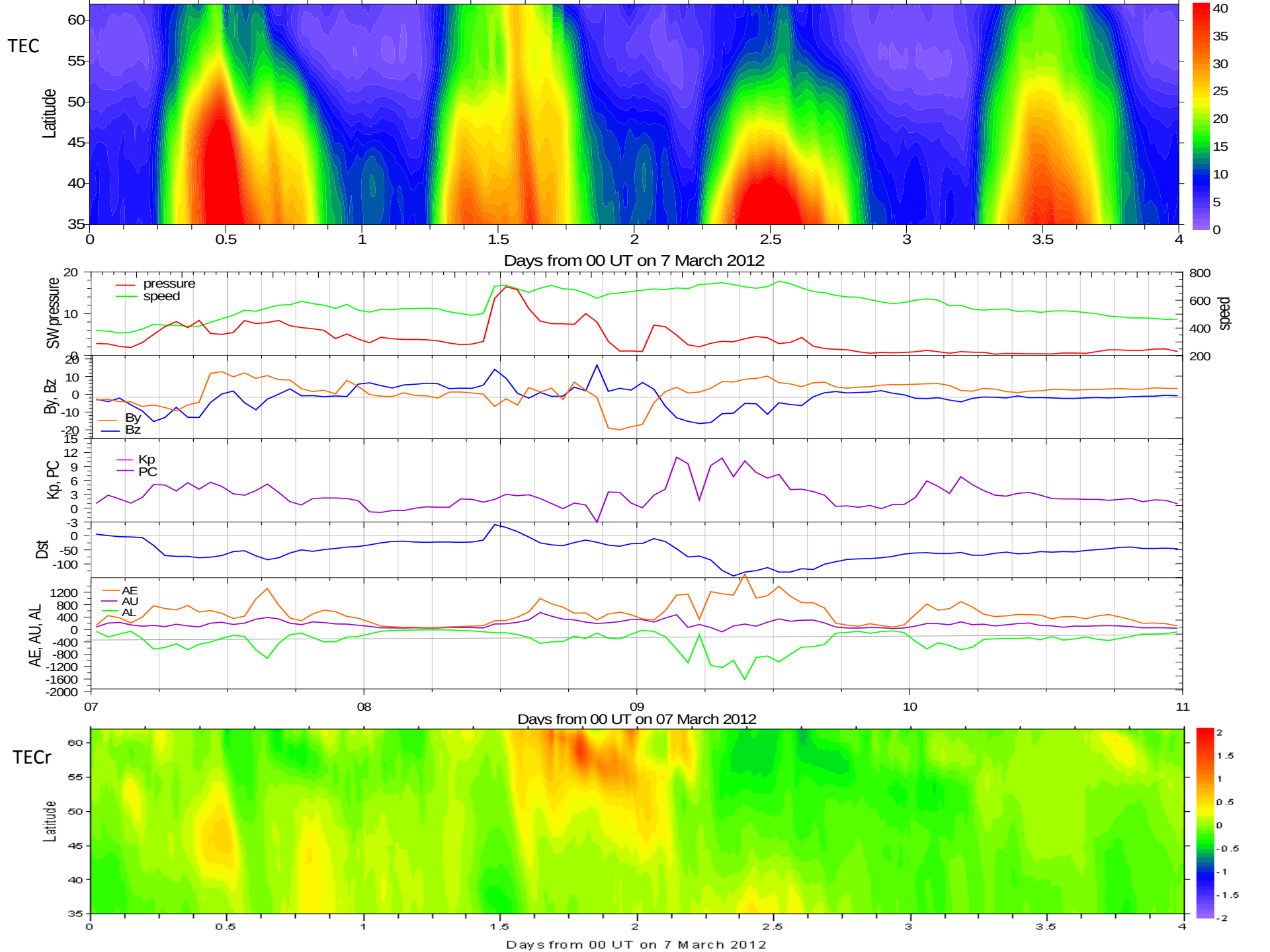
Ebro-TaD signatures










TEC
Latitude
Days from 00 UT on 7 March 2012
SW pressure
pressure
speed
speed
By, Bz
By
Bz
Kp, PC
Kp
PC
Dst
AE, AU, AL
AE
AU
AL
Days from 00 UT on 07 March 2012
TECr
Latitude
Days from 00 UT on 7 March 2012

Conclusions

Digisondes: the inspection of contour plots of true height, and of ionograms provide an indication of the **horizontal and vertical extent** of the area affected by the LSTIDs – DPS4Ds with high cadence (5min) of measurements provide observations of best quality

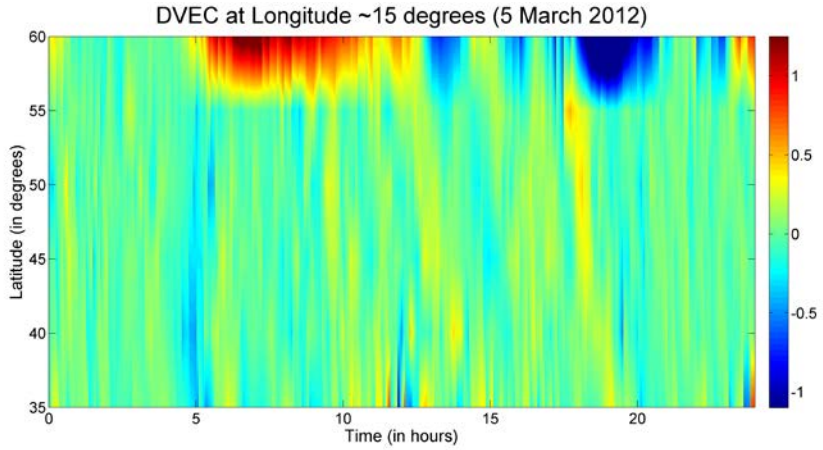
GPS receivers: the 30 sec analysis of dSTEC from a network of receivers provide information **the duration, the amplitude, the propagation direction, the growth and the damping of LSTIDs** – need to confirm how these are affected by the filtering

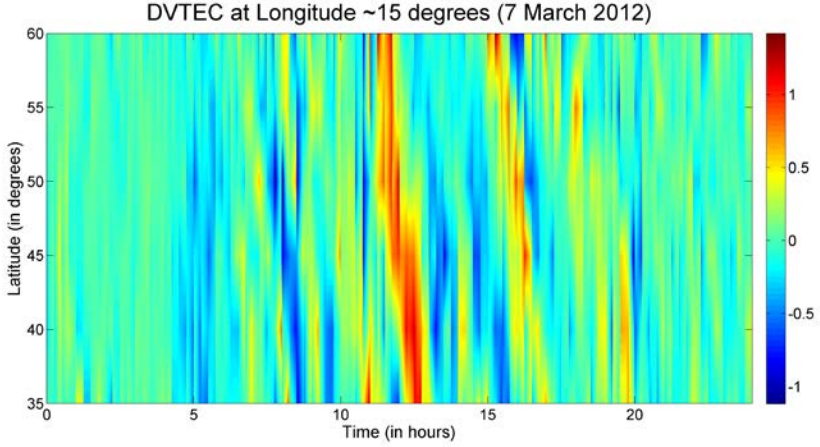
TaD reconstruction model: it runs operationally in DIAS and provides 3D EDD and TEC maps at 15 min sampling using Digisonde derived parameters at the peak height. This preliminary analysis shows that **the model is sensitive to LSTIDs**, with indications comparable to those obtained from GPS receivers even with 15 min measurements.

TaD model can reproduce the general pattern of ionospheric variations due to LSTIDs – although there are discrepancies in the amplitude calculations comparing to the dSTEC results and this needs to be carefully investigated.

Thank you for your attention!

Acknowledgements are due to: EOARD, GIRO network and to Luigi Ciraolo for making us available the software routine that converts RINEX to sTEC and vTEC


DVEC at Longitude ~15 degrees (5 March 2012)
Latitude (in degrees)
Time (in hours)
60
55
50
45
40
35
0
5
10
15
20
1
0.5
0
-0.5
-1


DVTEC at Longitude ~15 degrees (7 March 2012)
Latitude (in degrees)
Time (in hours)
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50
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5
10
15
20
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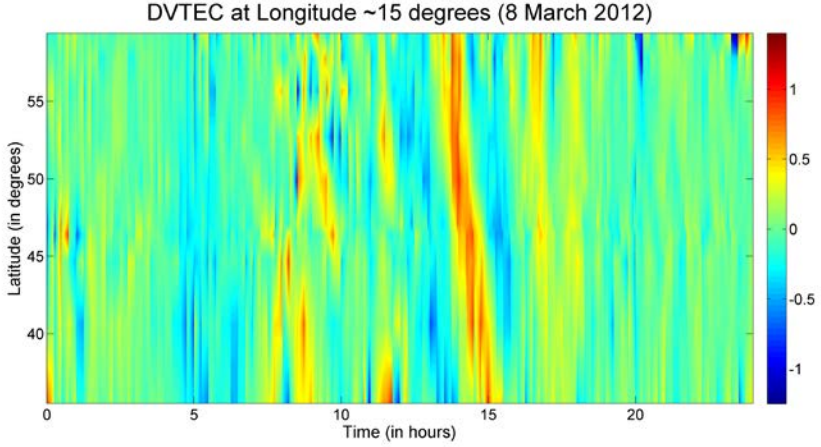
0
-0.5
-1


DVTEC at Longitude ~15 degrees (8 March 2012)
Latitude (in degrees)
Time (in hours)
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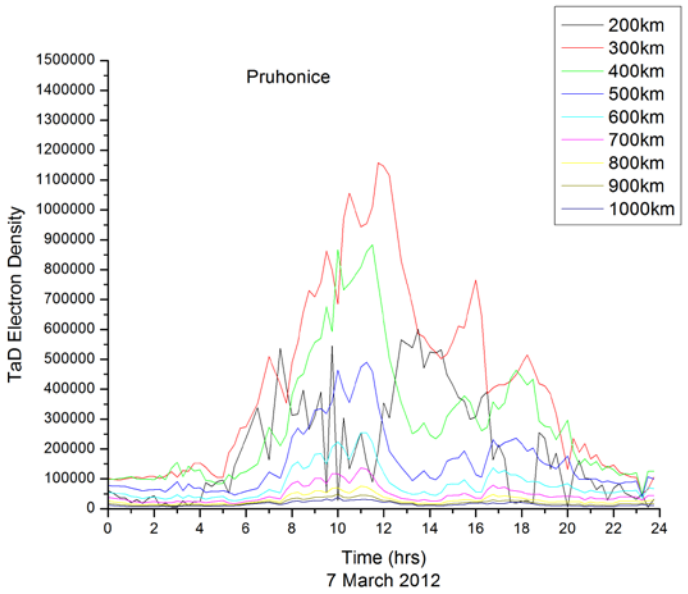
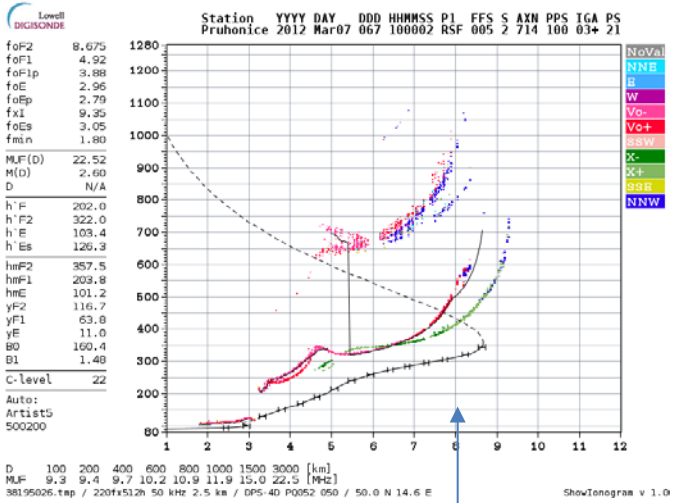
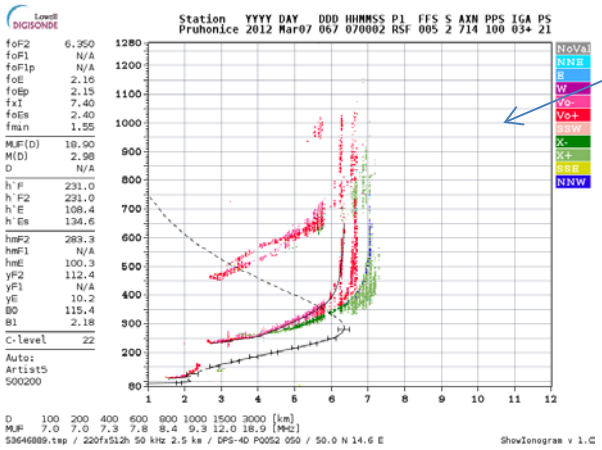
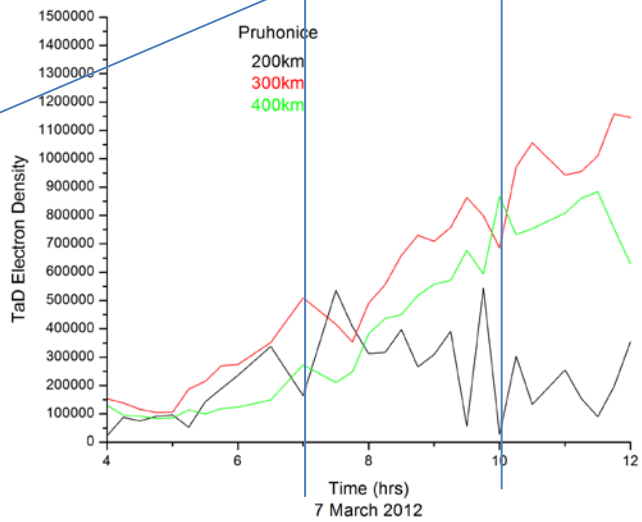
50
45
40
0
5
10
15
20
1
0.5
0
-0.5
-1

TaD model results: Pruhonice

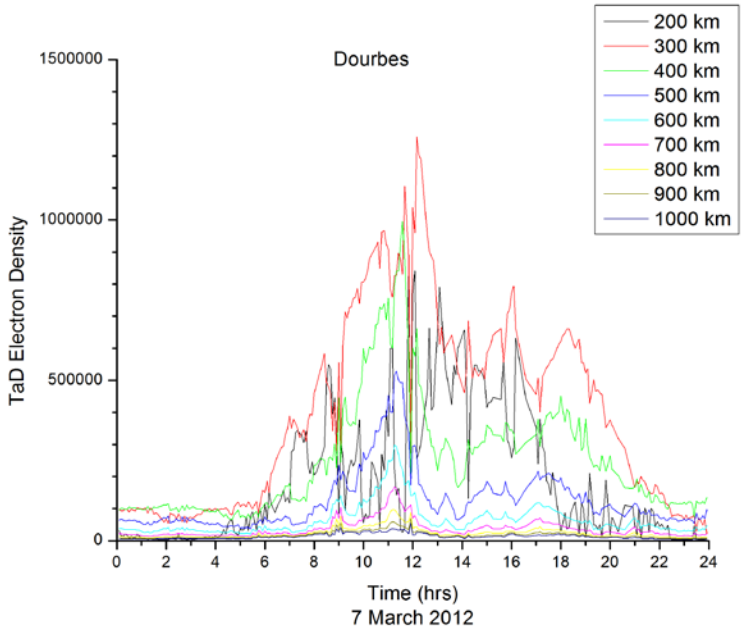


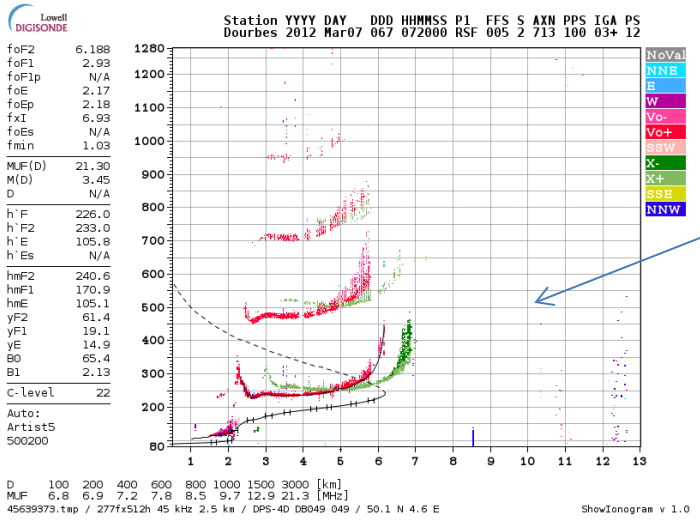


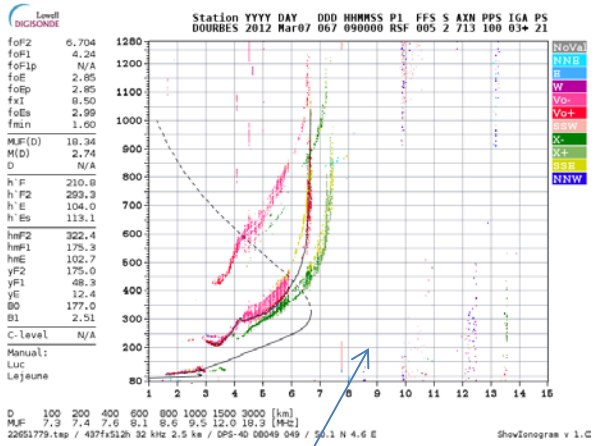


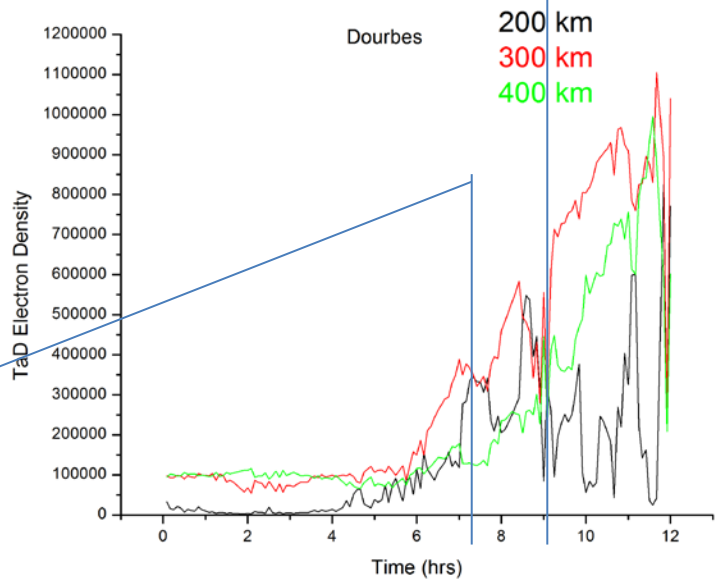


TaD model results: Dourbes

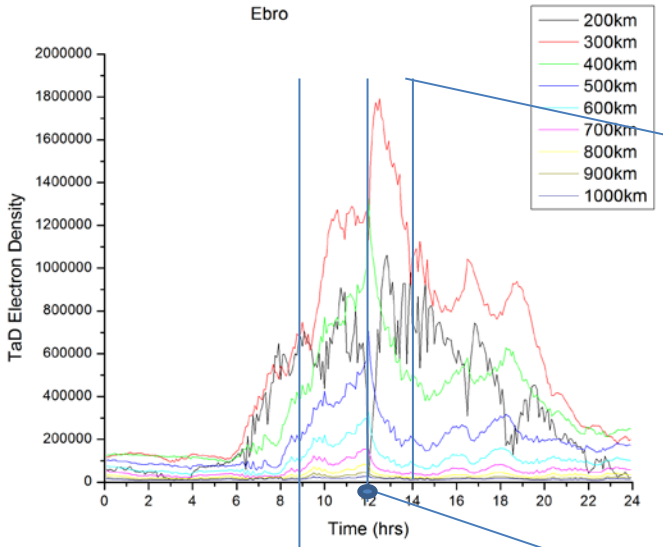


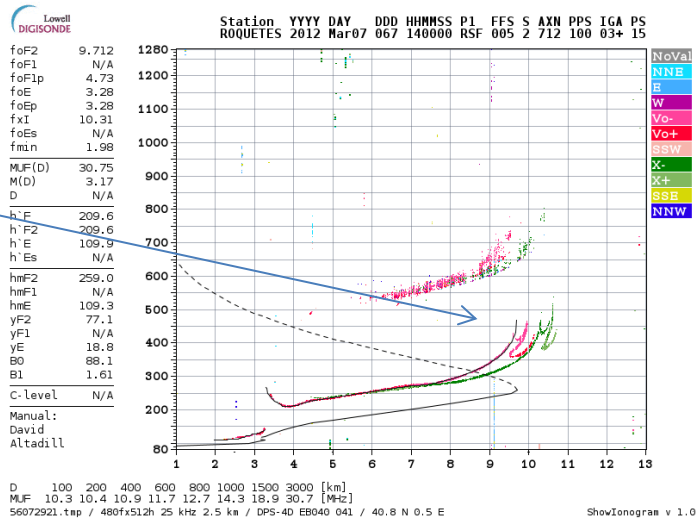


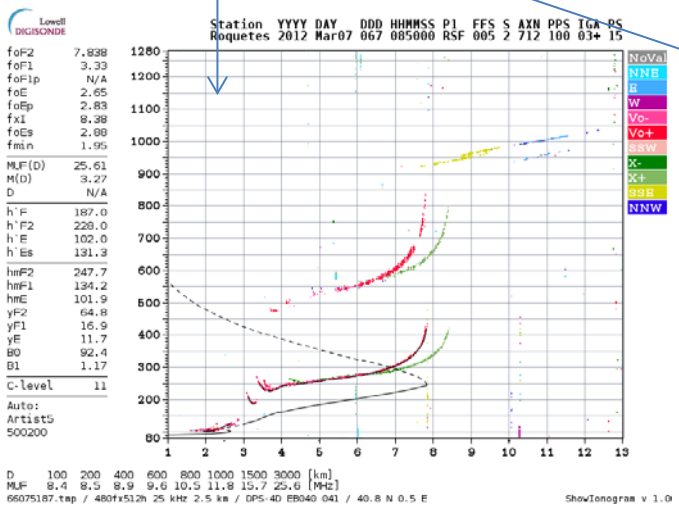


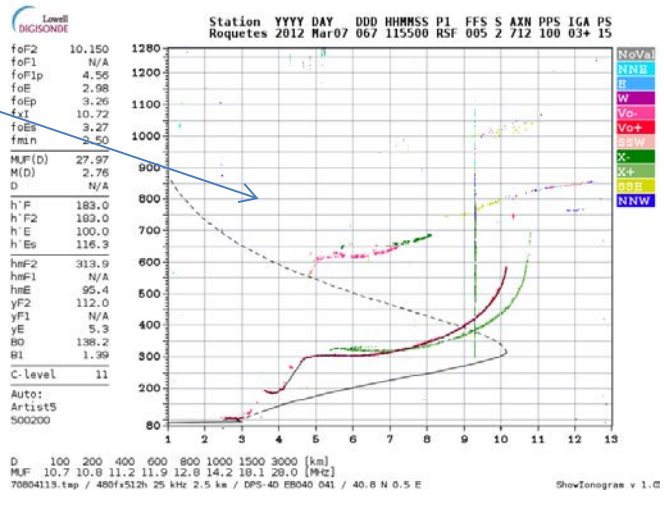


TaD model results: Ebro









Input Parameters	Code	Output
Month, LT, glat, f10.7, Kp	TSM: Topside Sounders Model Analytical approximation of Alouette, ISIS-1,-2 topside profiles (Bilitza, 2001)	Empirical functions of H_T: topside scale height h_T : transition height R_T: ratio H_T/h_T
H_T ($\equiv H_{O+}$), h_T, H_m, N_m and *glat*	TSMP: Topside Sounders Model Profiler Analytical approximation of ISIS-1 topside profiles to model plasmaspheric scale height	Empirical functions of H_P: plasmaspheric scale height ($\equiv H_{H+}$) $H_P=H_T(9cos^2 glat+4)$ *Ne*: electron density profile in the topside ionosphere and plasmasphere $Ne = N_O(h) + gN_O(h_T)\exp\left(-\frac{\lvert h-h_T\rvert}{Hp}\right) + (1-g)N_O(h_T)\exp\left(-\frac{\lvert h-h_T\rvert}{4H_T}\right)$ and $N_O(h) = Nm\exp\left\{-\frac{1}{2}\left[\frac{h-hm}{Hm}+1-\exp\left(\frac{h-hm}{Hm}\right)\right]\right\}$ g is the ratio N_H+ / N_O+ at h_T
Digisonde parameters at the height of maximum density (*hmF2*, *foF2*, H_m) and vTEC (GNSS) at the Digisonde location	TaD: TSM-assisted Digisonde Profiler Calculation of the actual profile over each Digisonde location to update TSMP with current Digisonde and TEC (GNSS) parameters	$Ne = N_O(h) + gN_O(h_T)\exp\left(-\frac{\lvert h-h_T\rvert}{Hp}\right) + (1-g)N_O(h_T)\exp\left(-\frac{\lvert h-h_T\rvert}{skH_m}\right)$ where $s=H_{He+}/kH_m$ k is the correction parameter that converts H_m (the neutral scale height) to make it compliant with H_T The integral of the Ne profile can be adjusted to the measured vTEC by varying solely the correction parameter k