Study of ionospheric perturbations using GNSS ground station and AWESOME VLF data

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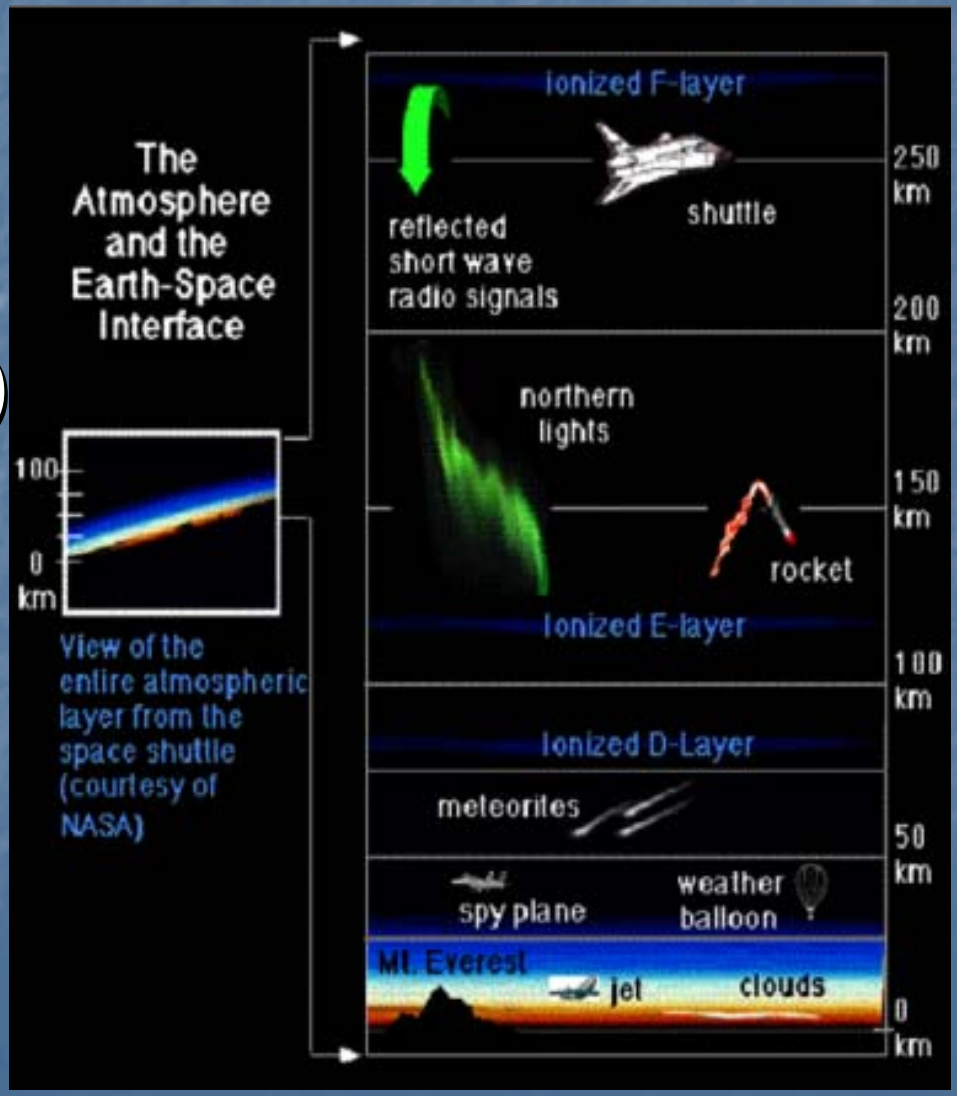
Outline

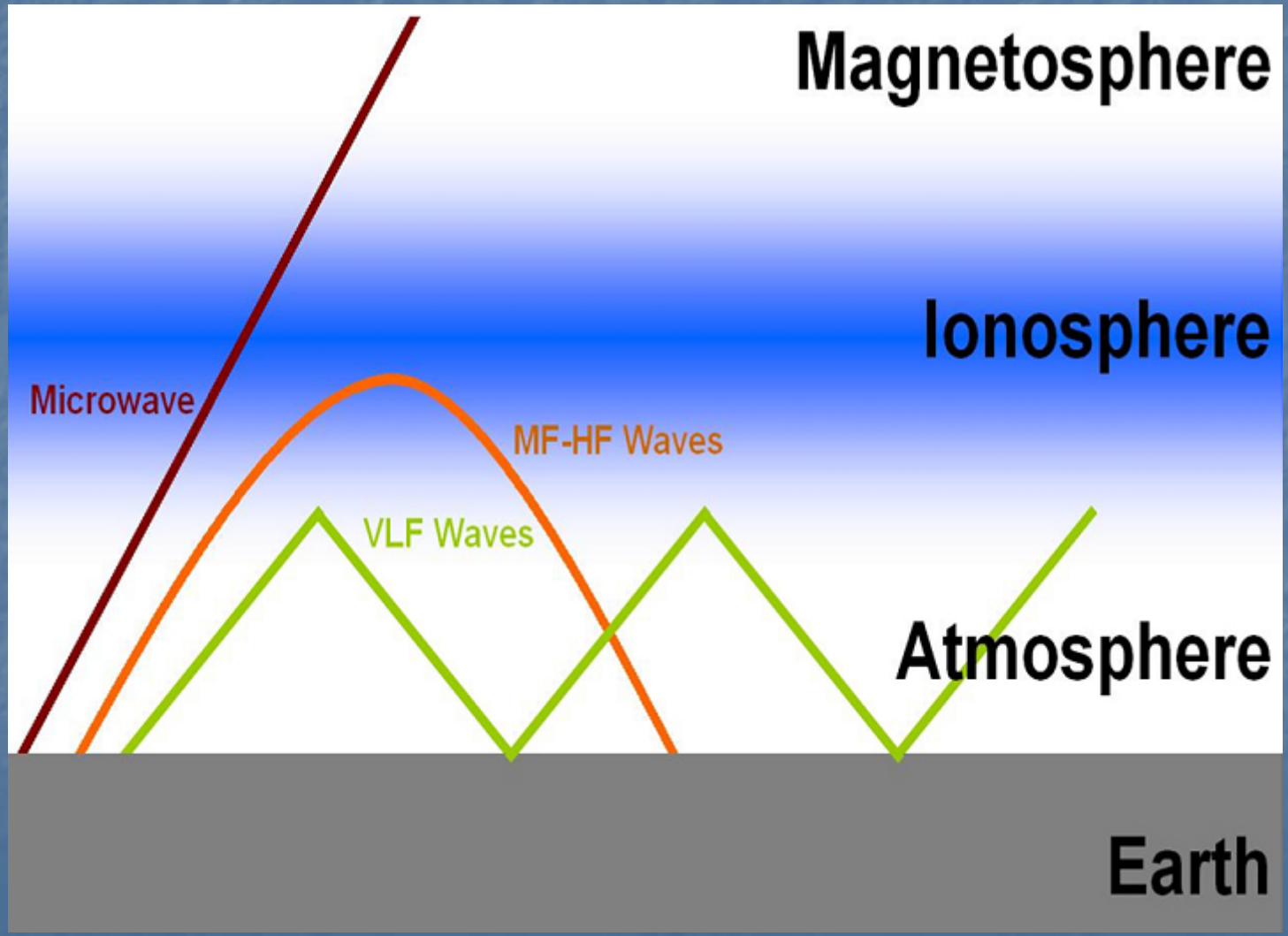
- Introduction
  - Ionospheric layers
  - TEC
- Uzbekistan permanent GNSS ground stations
- TEC variations
- AWESOME project
- Tashkent AWESOME station
- Monitoring of space weather
- Conclusion

Ionosphere

- D-layer (60-90 km) $n \sim 10^2$ e/cc
- E-layer (90-120 km) $n \sim 10^5$ e/cc
- F-layer (130-1000) $n \sim 10^6$ e/cc



Earth-ionosphere waveguide



Ionosphere and total electron content

GPS measurements use time delay between radio signals at two frequencies

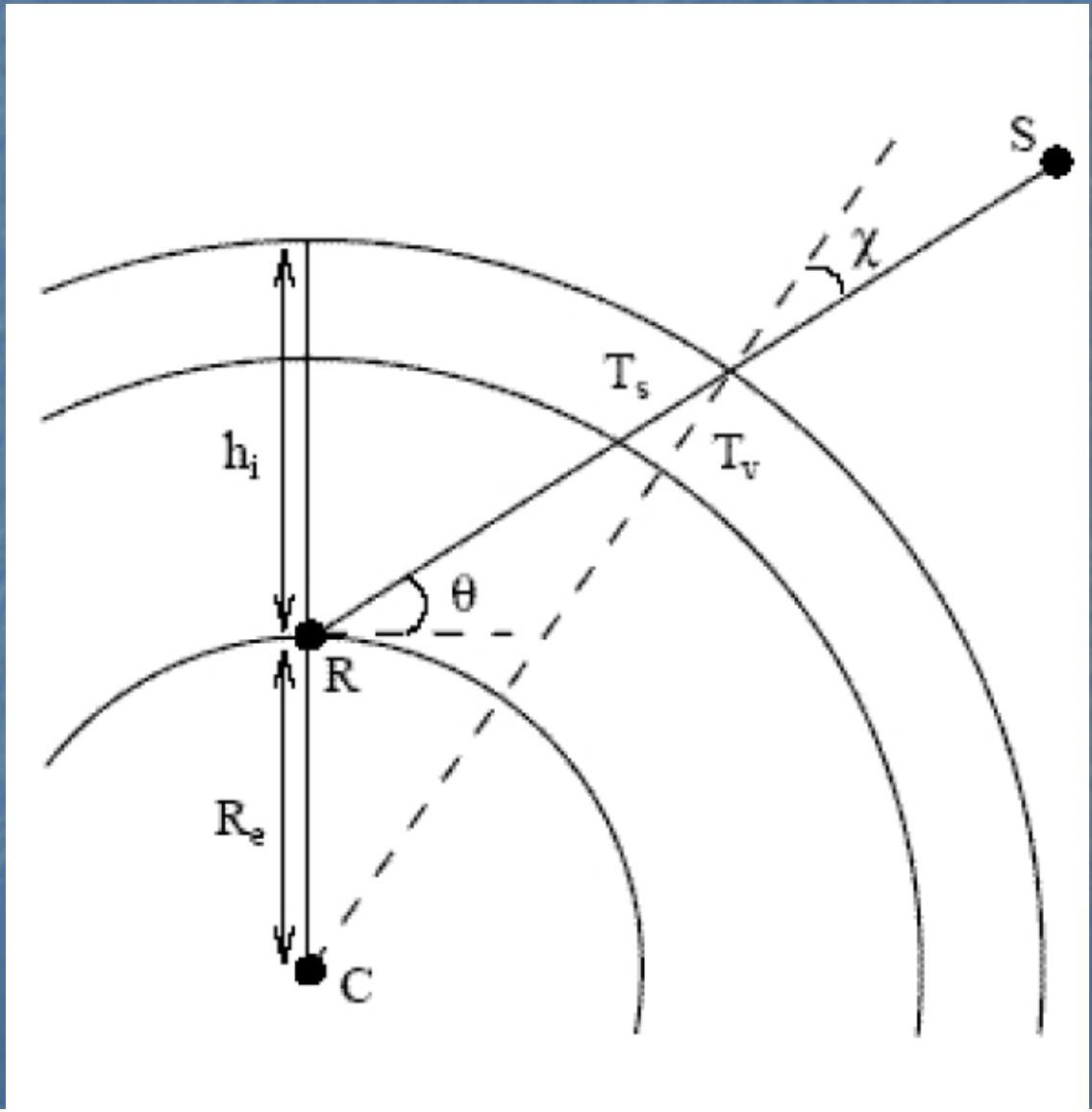
$$L_1 = 1575.42\text{MHz} \quad \text{and} \quad L_2 = 1227.6\text{MHz}$$

Pseudorange

$$P_i = \rho + c\,(dT - dt) + \Delta_i^{iono} + \Delta^{trop}$$

- Layers cause delay of incoming signals
- Signals carry information about the state of the ionosphere
- Thus, signals can be used for remote sensing

sTEC and vTEC



GNSS permanent stations in Uzbekistan

1996 Kitab station (KIT3)

- 2001 Tashkent (TASH)

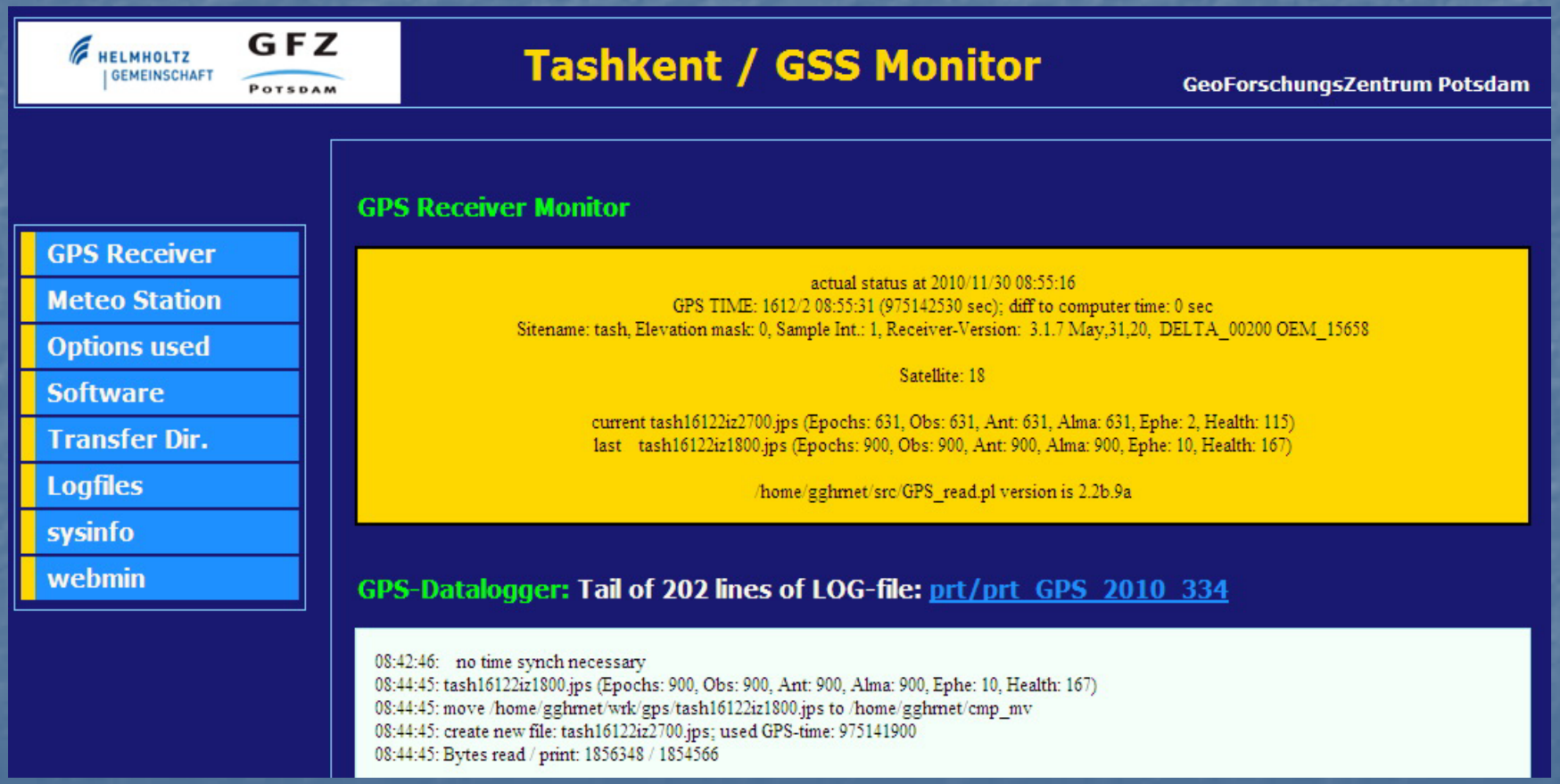
Installed by German Research Center GeoForschungsZentrum (GFZ), Potsdam

Tashkent station

Receiver: Javad Delta

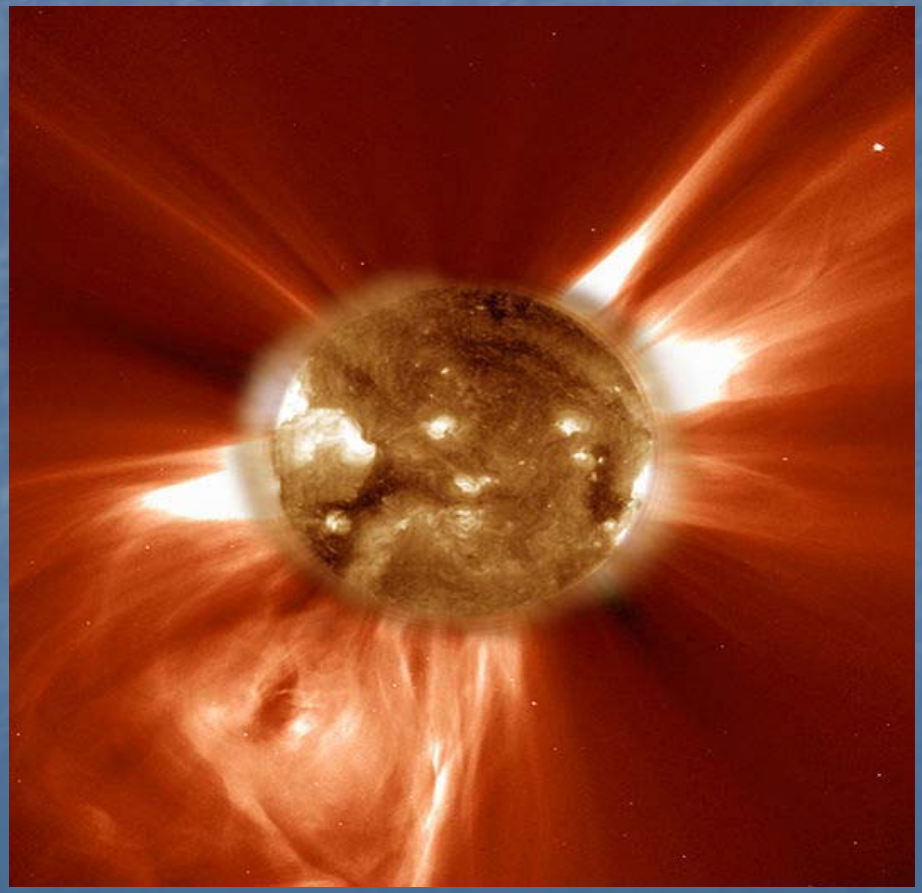
Antenna: Javad

Web-interface



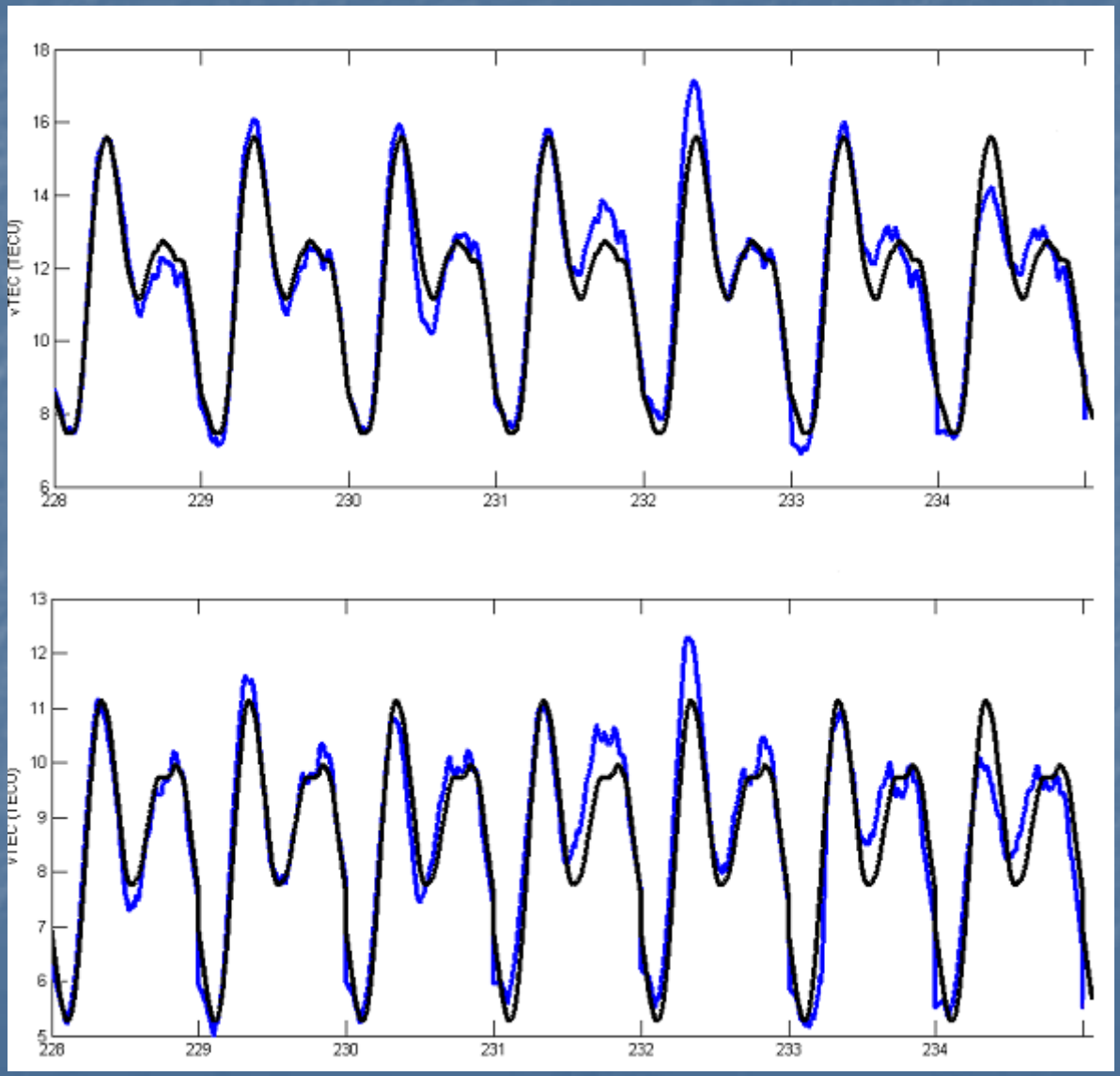
Solar Flares

Classification of X-Ray Solar Flare: A, B, C, M, X



Analysis method

- Monthly mean of TEC around the day of interest is taken as a reference


18
16
14
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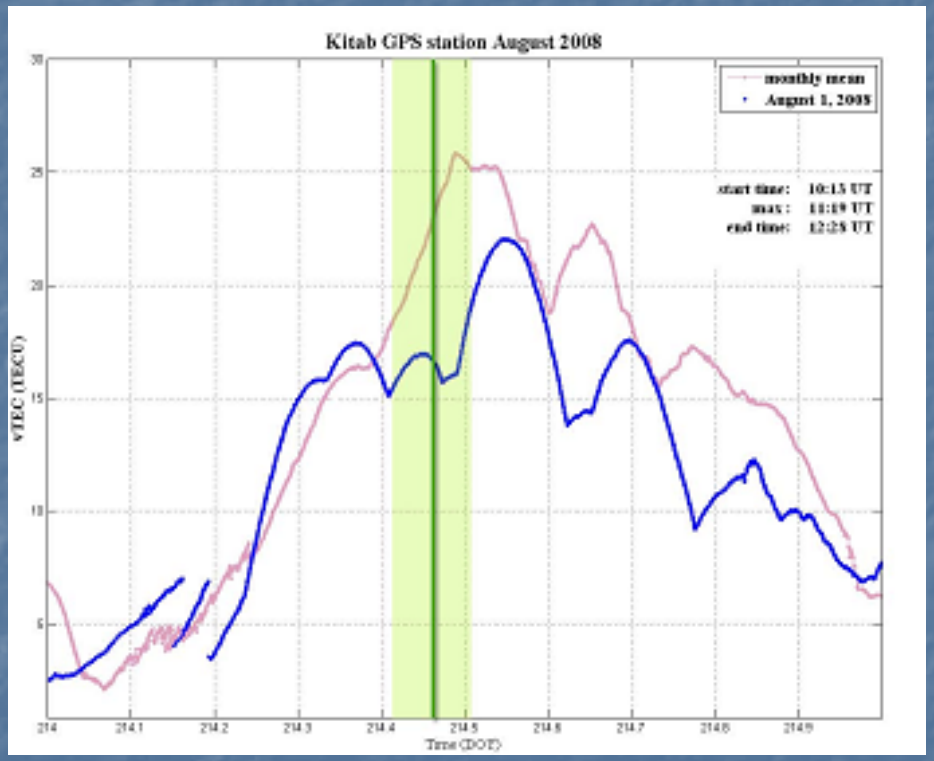
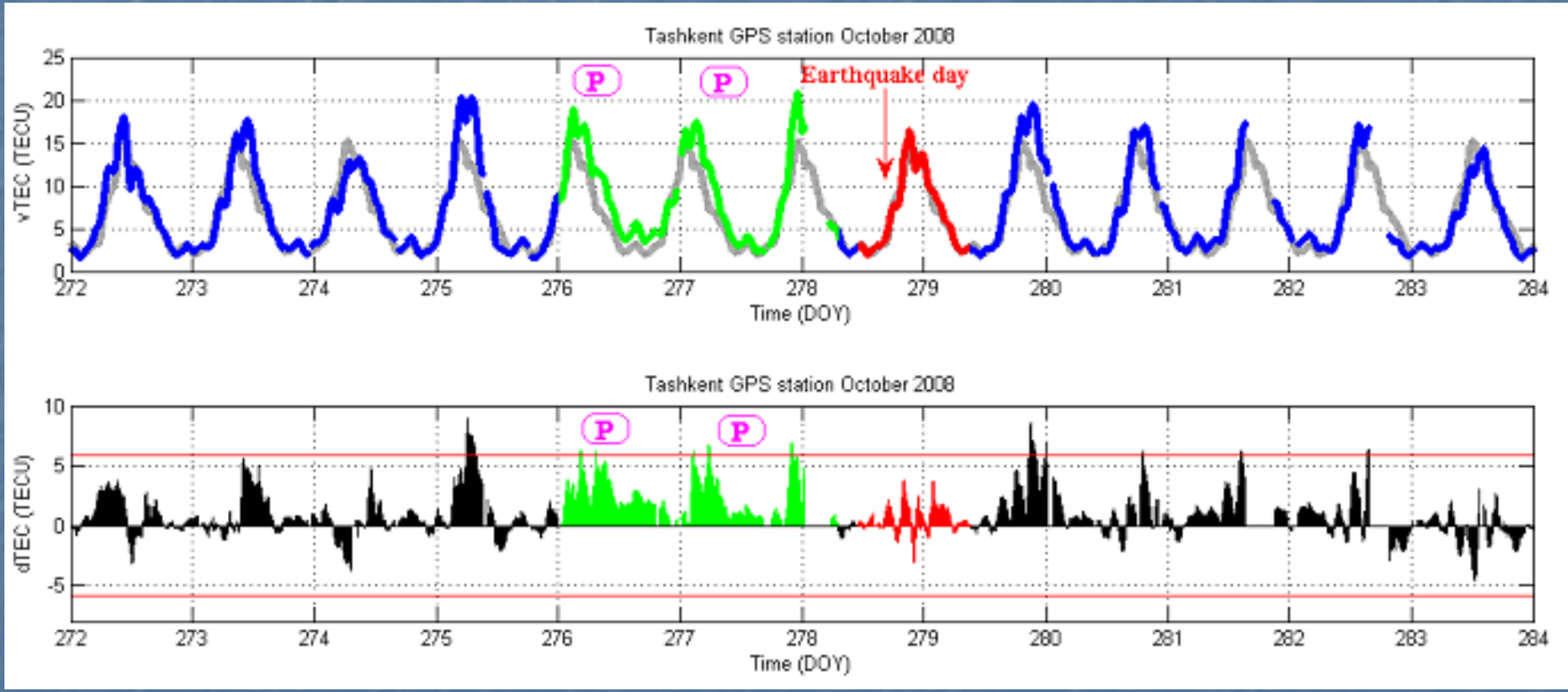
Solar eclipse



Anomalies of TEC



Space weather monitors

VLF AWESOME project

A tmospheric

W eather

E lectromagnetic

S ystem for

O bservation

M odeling and

E ducation

World SID & AWESOME Sites

Space Weather Monitor Sites

IHY Distribution 2007-2009


USA


Mexico


Germany


Nigeria


Ethiopia


China

● AWESOME research monitors ● SID student monitors

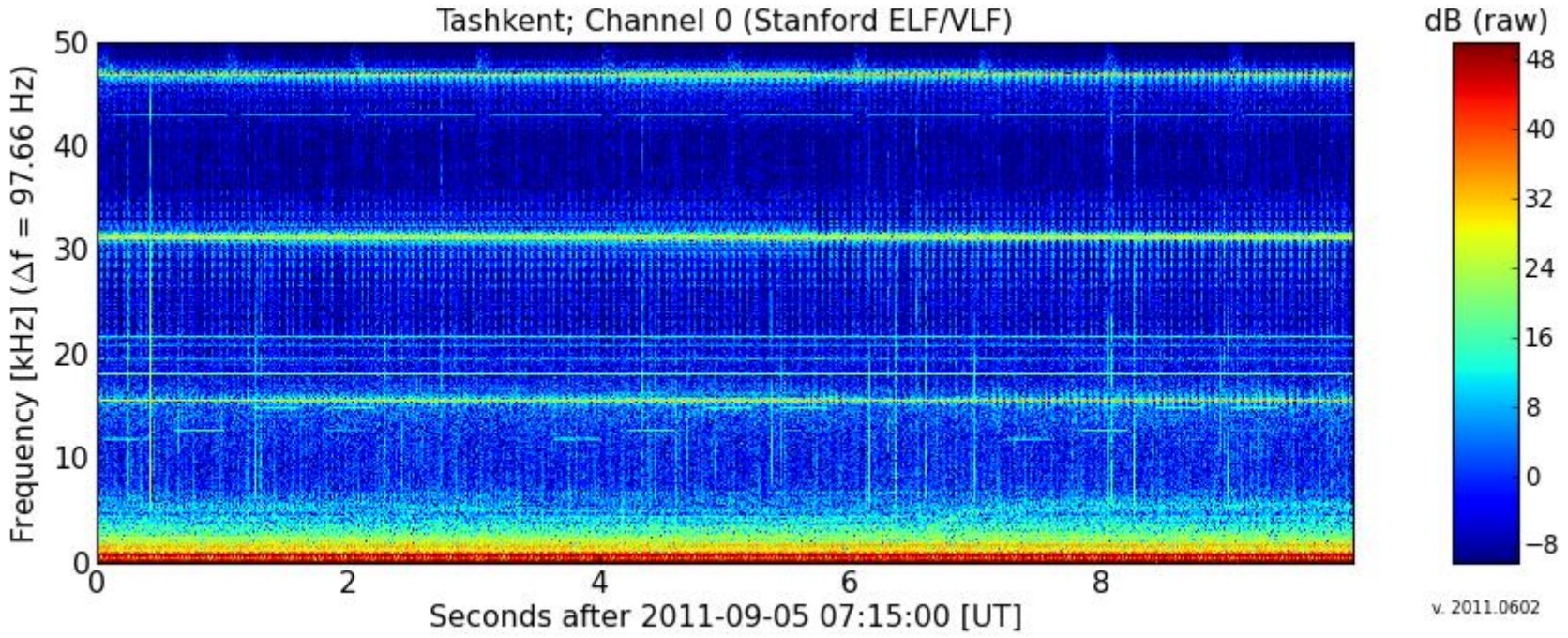

USA

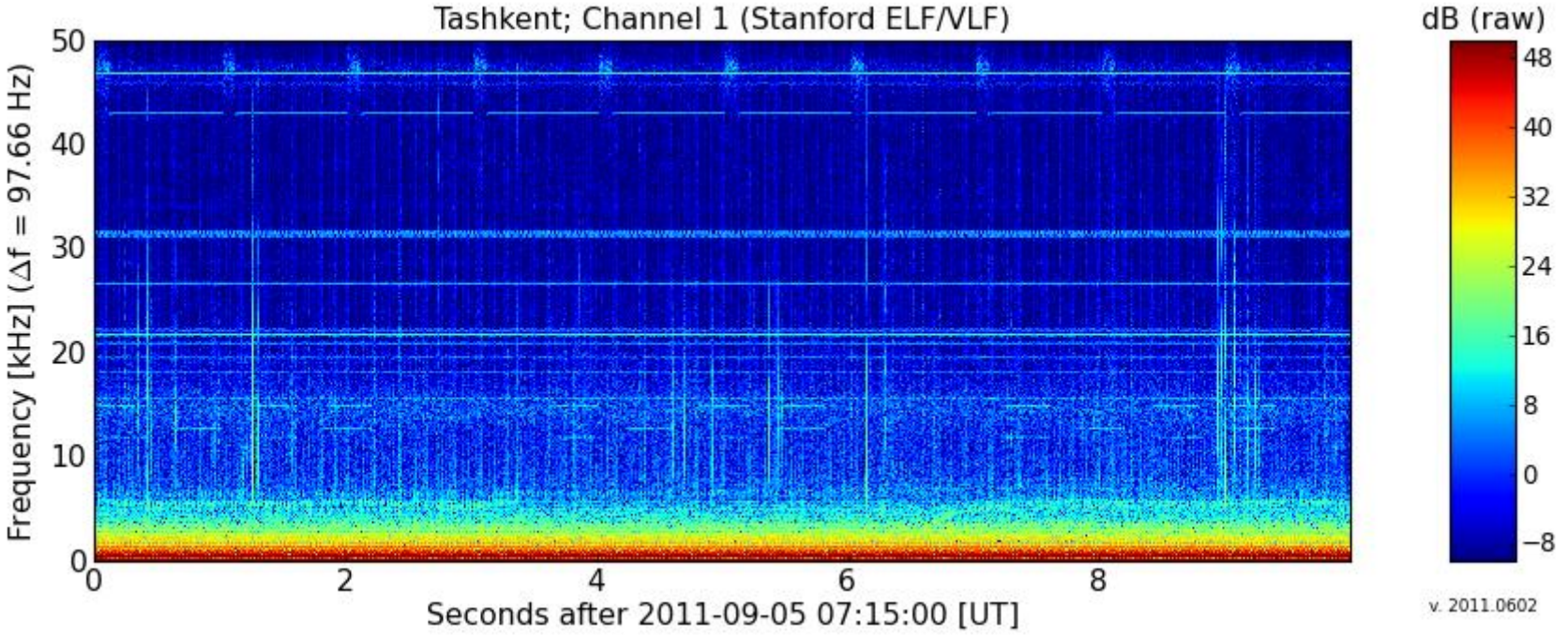

Romania


Lebanon

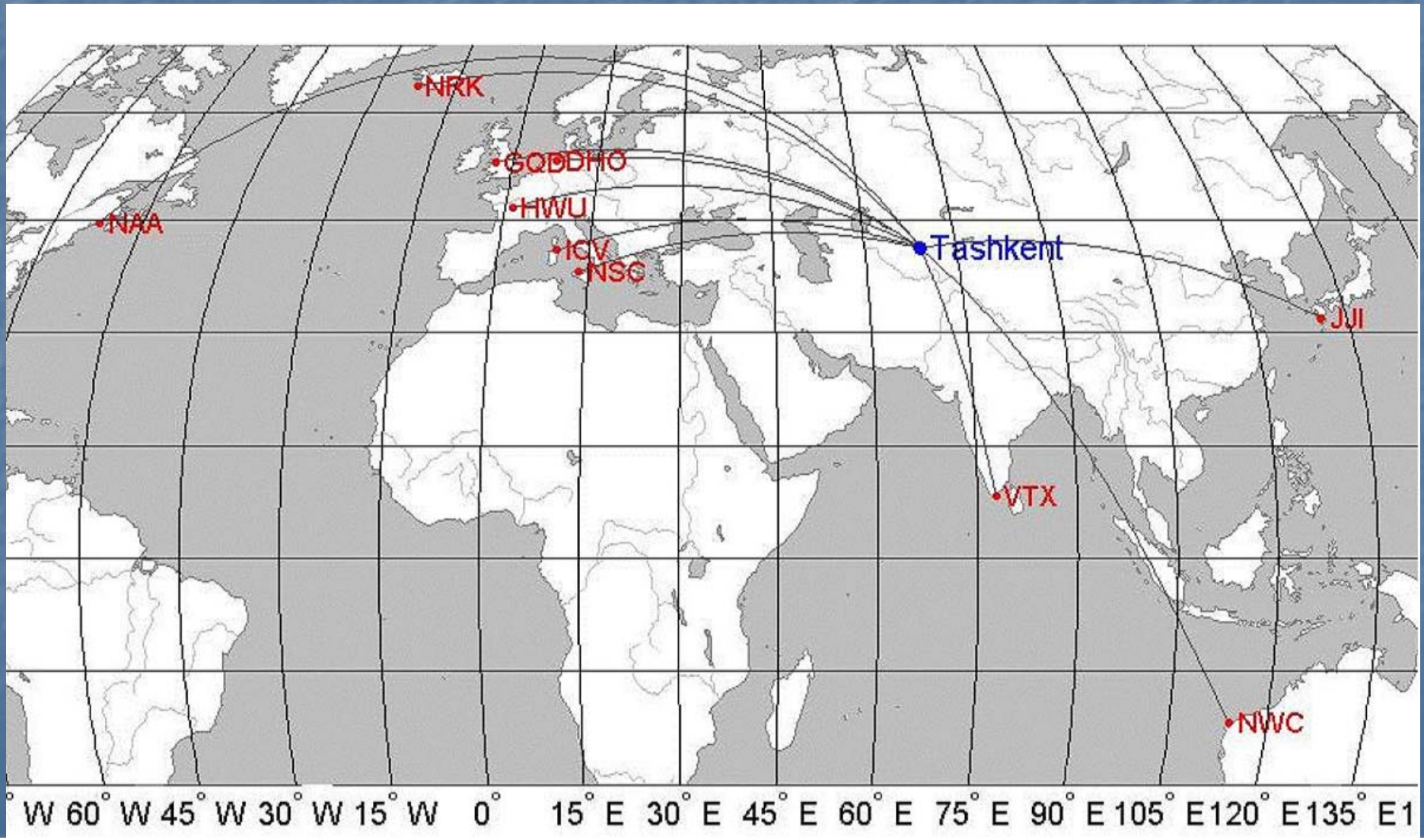
Thailand

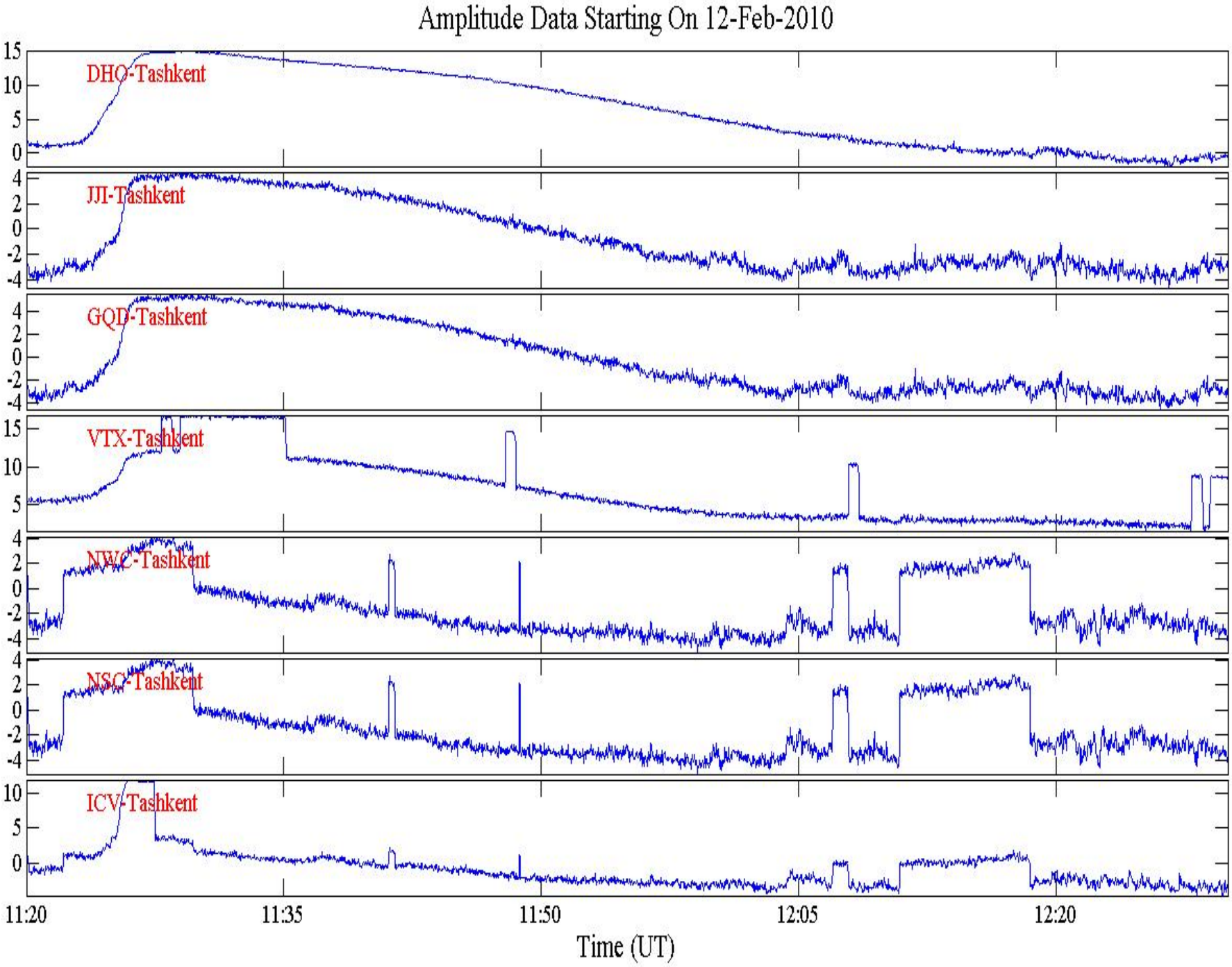
Tashkent AWESOME station


Tashkent; Channel 0 (Stanford ELF/VLF)
dB (raw)
Frequency [kHz] (Δf = 97.66 Hz)
Seconds after 2011-09-05 07:15:00 [UT]
v. 2011.0602

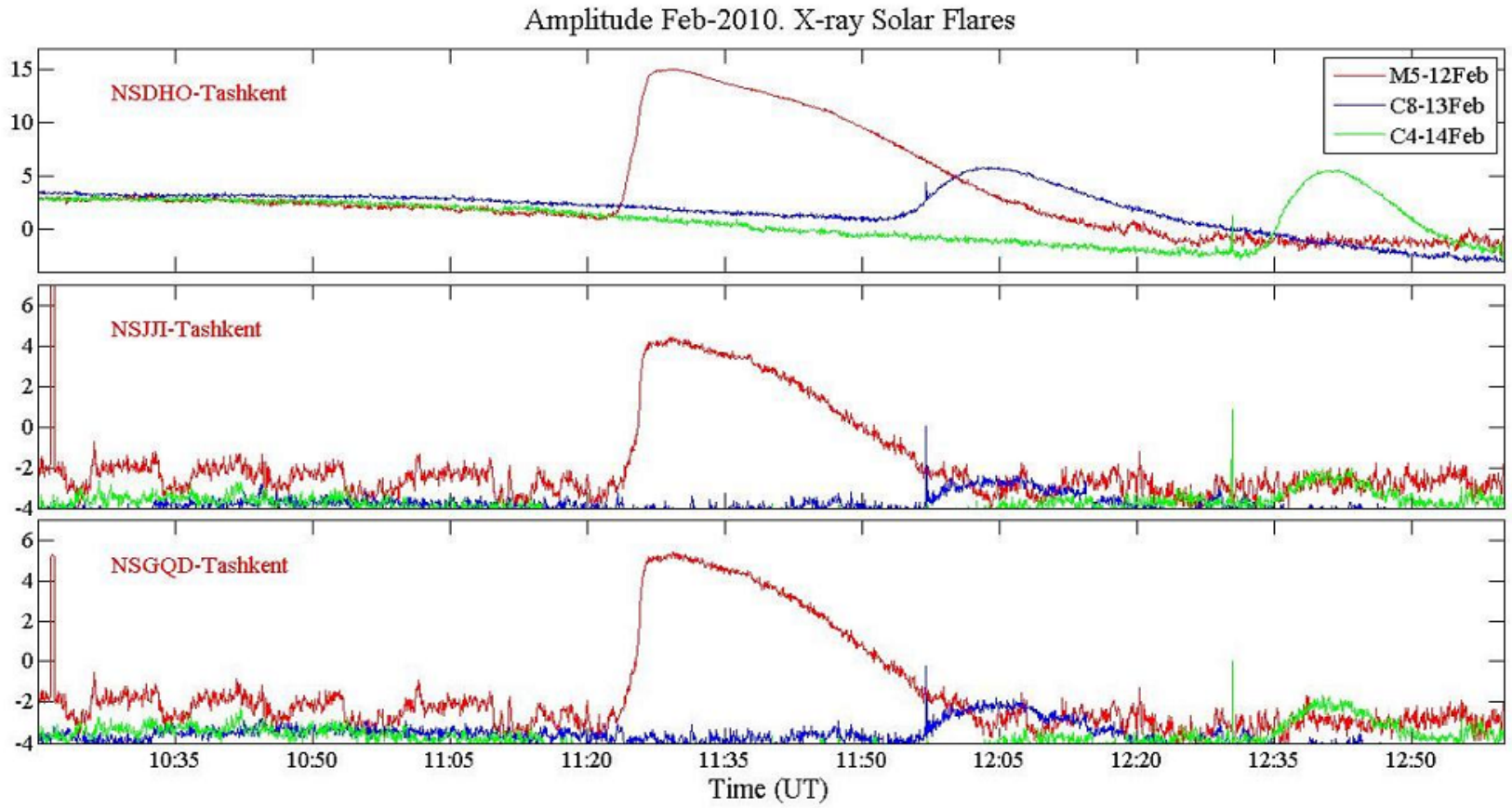

Tashkent; Channel 1 (Stanford ELF/VLF)
dB (raw)
Frequency [kHz] (Δf = 97.66 Hz)
Seconds after 2011-09-05 07:15:00 [UT]
v. 2011.0602

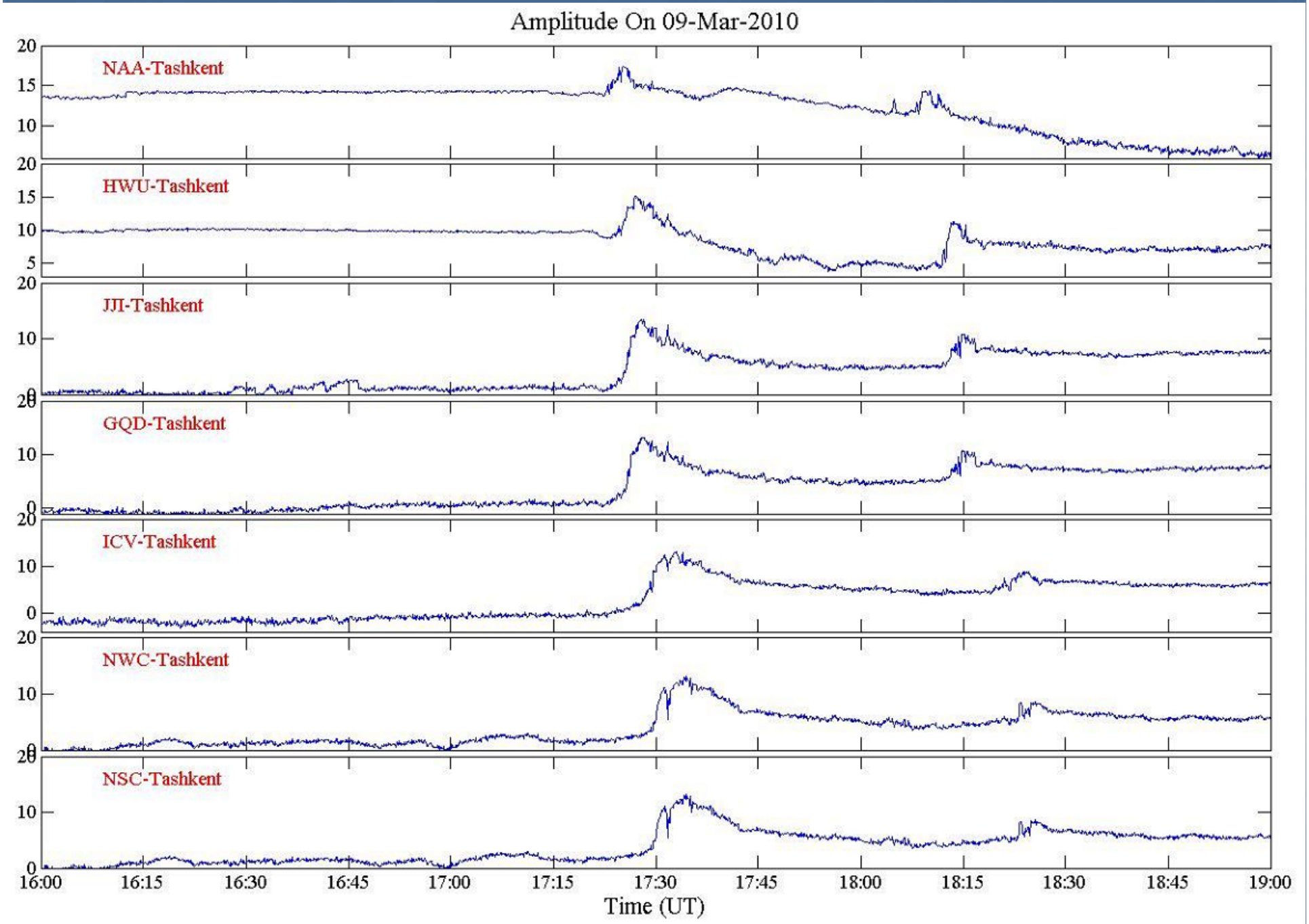
Transceivers



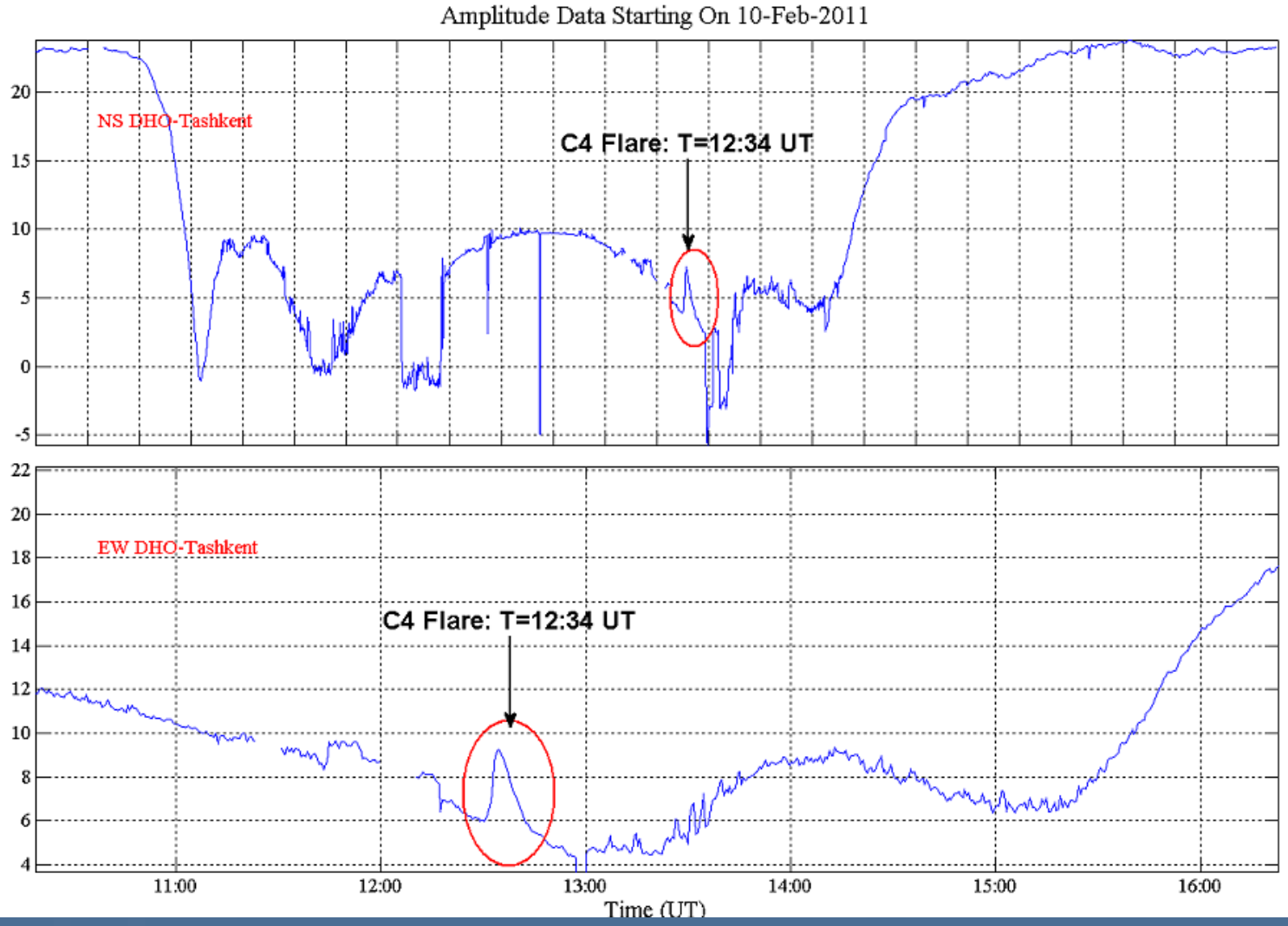

Amplitude Data Starting On 12-Feb-2010
DHO-Tashkent
JJI-Tashkent
GQD-Tashkent
VTX-Tashkent
NWC-Tashkent
NSC-Tashkent
ICV-Tashkent
11:20
11:35
11:50
12:05
12:20
Time (UT)

X-ray Solar Flare are observed during February 12-14, 2010




Amplitude On 09-Mar-2010
NAA-Tashkent
HWU-Tashkent
JJI-Tashkent
GQD-Tashkent
ICV-Tashkent
NWC-Tashkent
NSC-Tashkent
16:00
16:15
16:30
16:45
17:00
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
Time (UT)

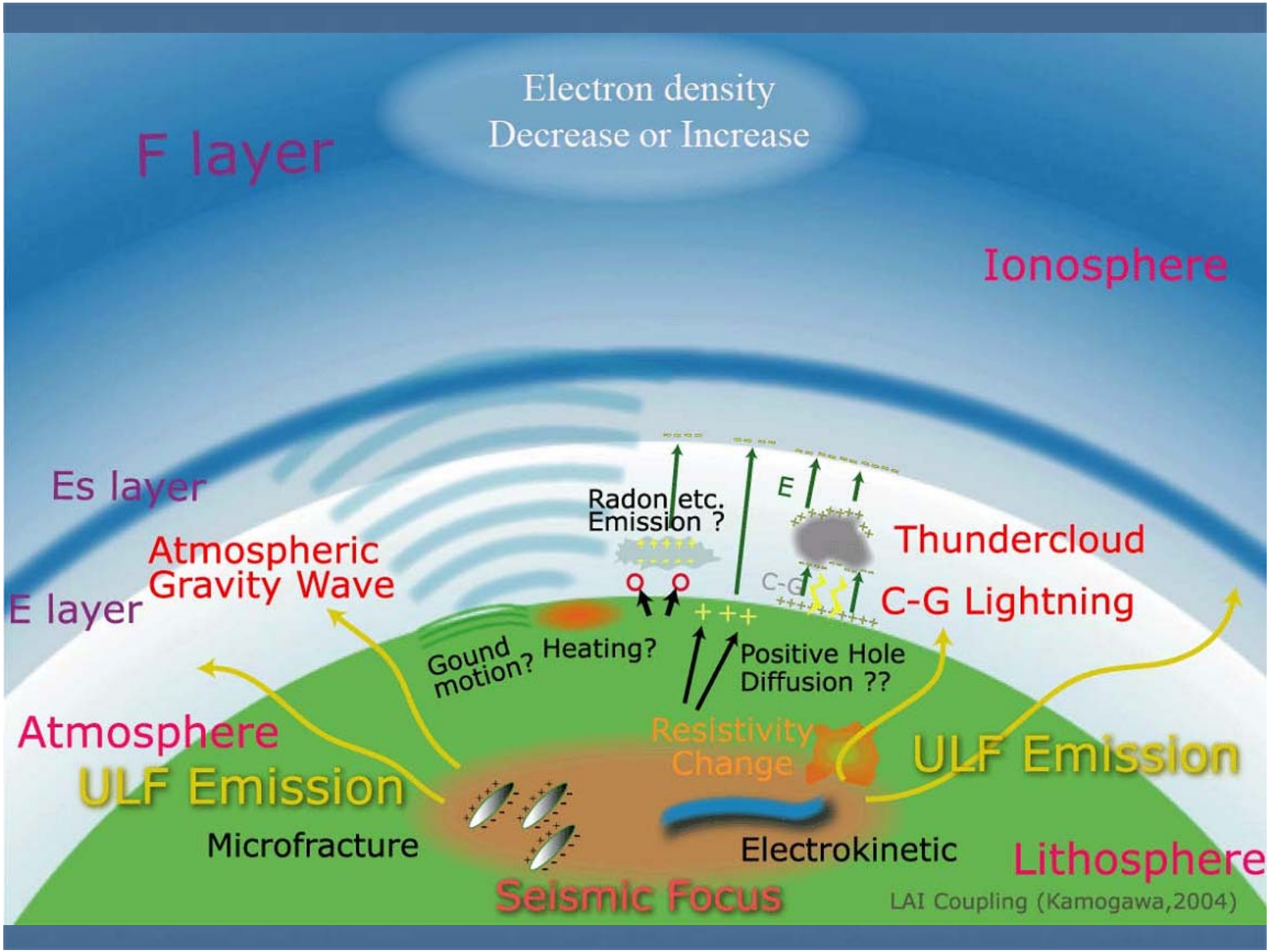
X-ray Solar Flare are observed on February 10, 2011



Conclusion

- Ionospheric TEC variations can be used as a monitor of space weather
- Two independent sensors of the ionosphere can complement each other in better understanding
- Construction of a web-based online near real time space weather monitor is in progress


Thank you


Electron density
Decrease or Increase
F layer
Ionosphere
Es layer
Atmospheric
Gravity Wave
E layer
Radon etc.
Emission ?
E
Thundercloud
C-G
C-G Lightning
Gound
motion?
Heating?
Positive Hole
Diffusion ??
Atmosphere
ULF Emission
Resistivity
Change
ULF Emission
Microfracture
Electrokinetic
Lithosphere
Seismic Focus
LAI Coupling (Kamogawa,2004)

Lithosphere-Atmosphere-Ionosphere Coupling - Types

- **Electromagnetic Coupling**: Connected with the direct penetration of DC electric field induced due to the appearance of Seismic-related electric charges on the EarthŸs surface. It can lead to substantial modifications of ionospheric properties.
- **Chemical Coupling**: Determined by the variation of the fair weather electric field in the lower ionosphere due to the enhancement of conductivity of lower atmospheric layer ionized by radon emanating from Seismic faults.
- **Dynamic Coupling**: Implies influence of atmospheric wave processes originating near the Earth surface on the lower ionosphere.

Ionospheric Precursors: For different ionospheric layers

- **F-Layer**: Critical frequency of F layer ($f_o\mathrm{F}_2$) and **TEC**
- **E-Layer**: Critical frequency of Sporadic E-Layer ($f_o\mathrm{E}_s$)
- **D-Layer**: Phase and Amplitude of **ELF/VLF signals** from navigational transmitters

  Out of these three types lot of work have been done by Japanese and Russian group on D-region precursors studies. (Pulinets et al 1991, Lipervosky et al 2000, Hayakawa 1996, Gokhberg et al., 1982; Gufeld et al., 1992)