IONOSPHERIC TOTAL ELECTRON CONTENT DISTURBANCES OBSERVED BEFORE EARTHQUAKES: AT TASHKENT AND KITAB GNSS STATIONS

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Krasnoyarsk, Russian Federation, 18-22 May 2015

UNOOSA United Nations Office for Outer Space Affairs

Outline

1. Introduction

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2. TEC extraction from GNSS data at Tashkent and Kitab stations
3. Results obtained from GNSS data analysis

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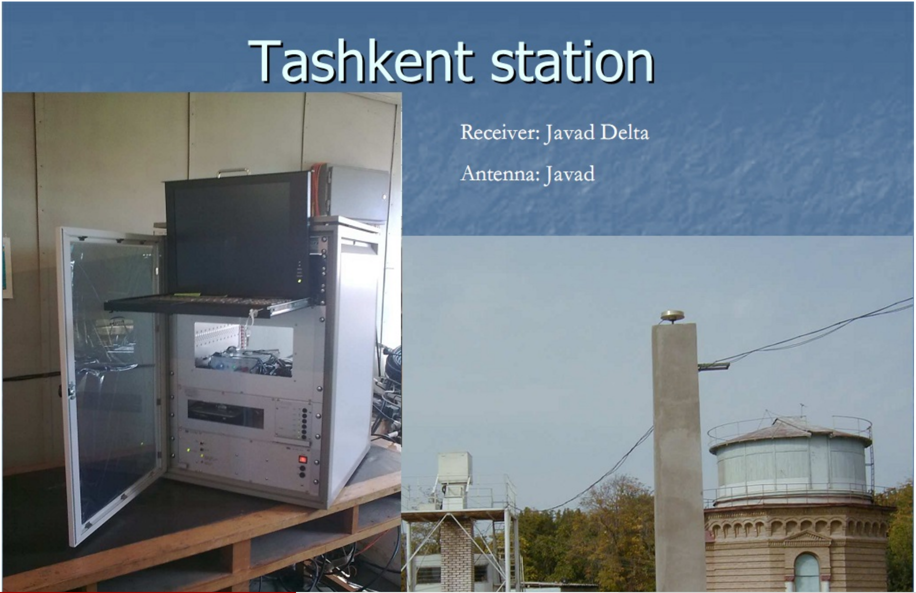
GNSS ground stations

Tashkent GNSS station



Kitab GNSS station

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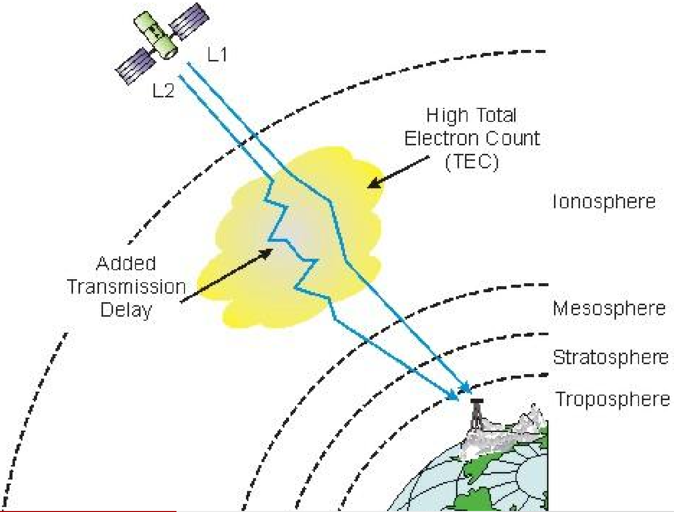
Satellite Ionospheric Delay

Effect of ionospheric refraction. GPS measurements use time delay between radio signals at two frequencies.



TEC extraction

Each satellite transmits two carrier electromagnetic waves with frequencies, both in the L-band.

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

Pseudorange.

$$P_i = \rho + c\left(dt_{rec} - dt^{sat}\right) + \Delta_i^{iono} + \Delta^{trop}$$

Effect of F-layer of ionosphere with thickness 870 km.

$$\Delta_i^{iono} = \frac{40.3}{L_i^2}\int_{z_{rec}}^{z_{sat}} N(z)dz = \frac{40.3}{L_i^2}\,TEC$$

Total Electron Content (TEC).

$$TEC = \frac{L_1^2 \cdot L_2^2}{40.3\left(L_1^2 - L_2^2\right)}\left(P_1 - P_2\right)$$

Receiver Independent EXchange (RINEX) FORMAT

observation file
kit31450a.13o

navigation file
kit31450a.13n

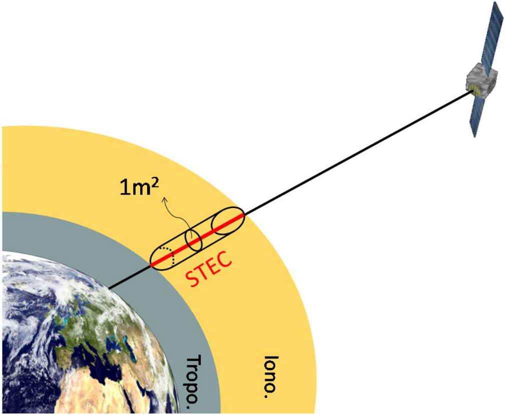
Kitab GNSS station

ftp://cddis.gsfc.nasa.gov/gps/data/daily/2013/145/00/kit31450a.13o
ftp://cddis.gsfc.nasa.gov/gps/data/daily/2013/145/00/kit31450a.13n

- Pseudo lengths P1 and P2 are extracted from observation file
- Ephemerides (coordinates & orbits of satellites) are extracted from navigation file

Slant Total Electron Content (STEC)

Slant TEC is extracted from pseudoranges P_1 and P_2



The STEC is expressed in Total Electron Content Units (TECU):

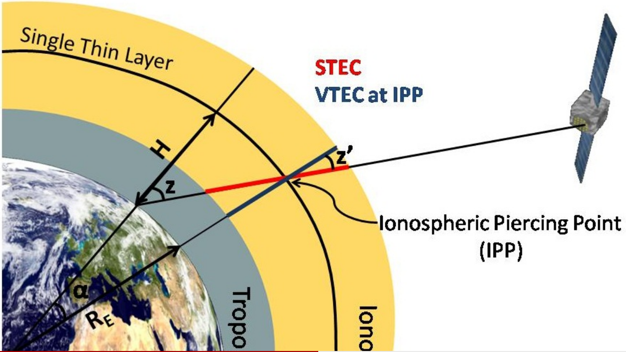
TECU=10^{16} electrons per m^2

How to Convert STEC in to VTEC ?

STEC vs VTEC

The VTEC is estimated at each Ionospheric Pierce Point (IPP) from the ionospheric mapping function $F(z')$ according to figure:

$$F(z') = \frac{STEC}{VTEC} = \frac{1}{\cos z'}, \quad \sin z' = \frac{R_E}{R_E + H} \sin z$$



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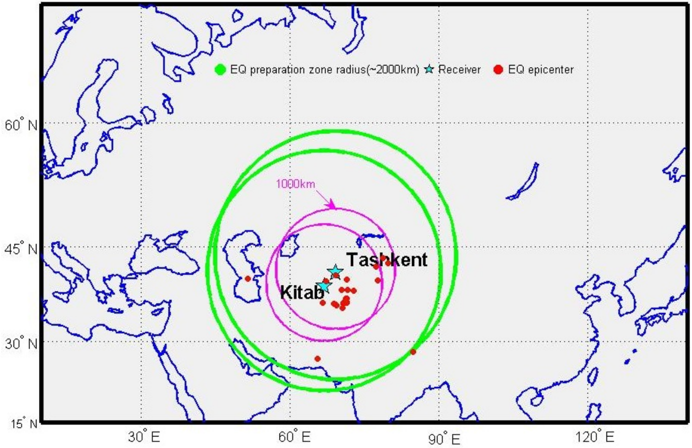
Recent Earthquake Observations

A map for Tashkent and Kitab GNSS stations during January 2011 and April 2015. Blue stars indicate positions of GNSS stations in Tashkent and Kitab. Red circle indicates the position of earthquake epicenter.

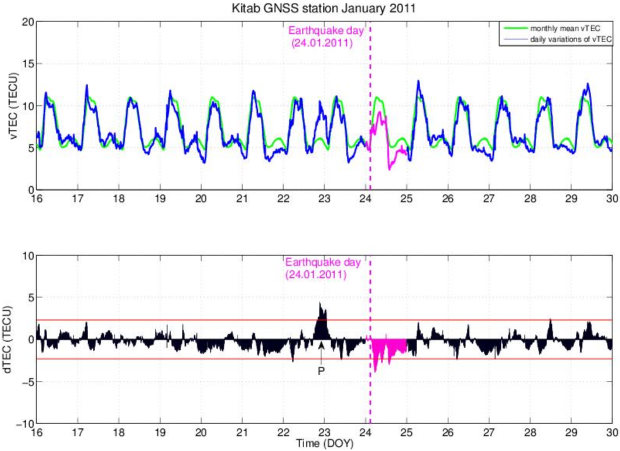


The parameters of M>5.0 earthquakes during 2011-2015 with identified Seismo-Ionospheric TEC precursors.

EQ	Y	M	D	Lat	Lon	M	Precursors
1	2011	01	24	38.432N	72.751E	6.1	D-2
2	2011	03	21	36.518N	70.920E	5.8	D-2,D-4
3	2011	07	19	40.151N	71.426E	6.1	D-4
4	2012	06	11	36.082N	69.316E	5.7	D-8
5	2012	07	12	36.502N	70.875E	5.7	D-2
6	2012	07	19	37.248N	71.368E	5.6	D-2,D-3
7	2012	09	25	36.279N	69.219E	5.2	D-8
8	2013	01	28	42.605N	79.708E	6.1	D-3,D-7
9	2013	03	11	40.119N	77.698E	5.4	X
10	2013	05	26	39.931N	67.345E	5.7	D-3
11	2013	09	24	26.951N	65.500E	7.7	D-6
12	2014	06	14	36.454N	70.717E	5.6	D-4,D-5
13	2014	11	14	42.105N	77.254E	5.2	D-2
14	2014	11	22	36.556N	66.581E	5.4	X
15	2015	04	25	28.147N	84.707E	7.8	D-1,D-3.D-5

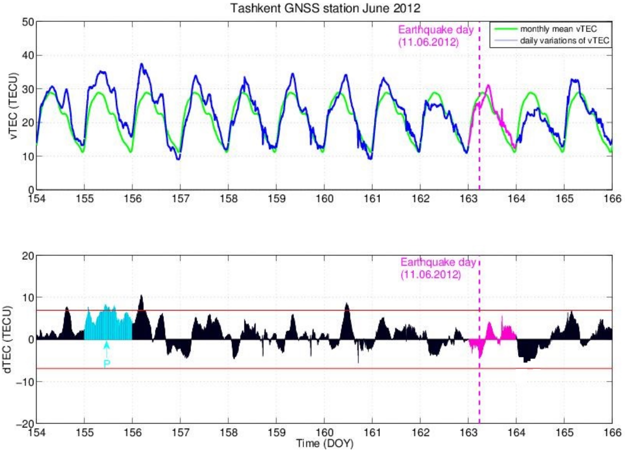
Kitab GNSS station: January 24, 2011

Vertical and Differential TEC variations above Kitab for Tajikistan M=6.1 EQ on 24-Jan-2011 in comparison with the monthly mean. P character denotes the precursor day.



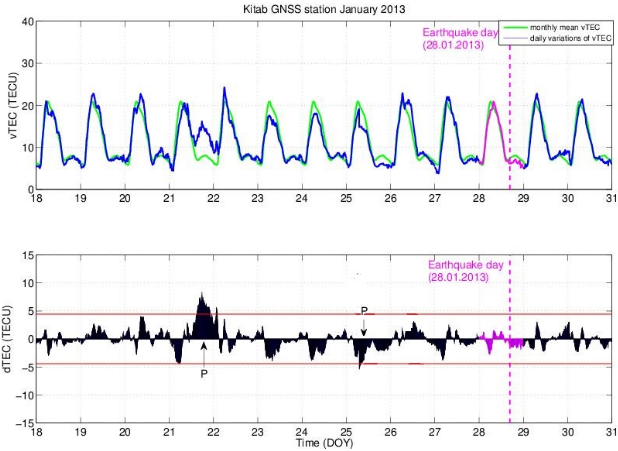
Tashkent GNSS station: June 11 , 2012

Vertical and Differential TEC variations above Tashkent for Afghanistan M=5.7 EQ on 11-June-2012 in comparison with the monthly mean. P character denotes the precursor day.



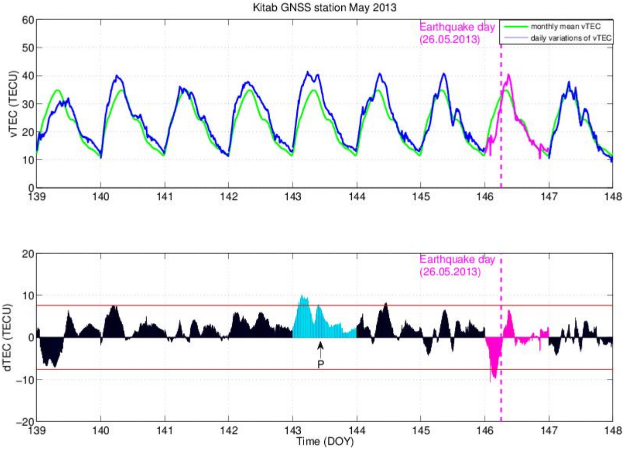
Kitab GNSS station: January 28 , 2013

Vertical and Differential TEC variations above Kitab for Kazakhstan M=6.1 EQ on 28-January-2013 in comparison with the monthly mean. P character denotes the precursor day.



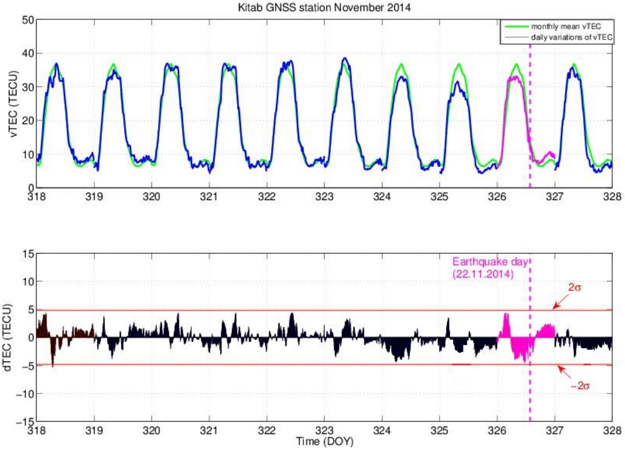
Kitab GNSS station: May 26, 2013

Vertical and Differential TEC variations above Kitab for Uzbekistan M=5.7 EQ on 26-May-2013 in comparison with the monthly mean. P character denotes the precursor day.



Kitab GNSS station: November 22 , 2014

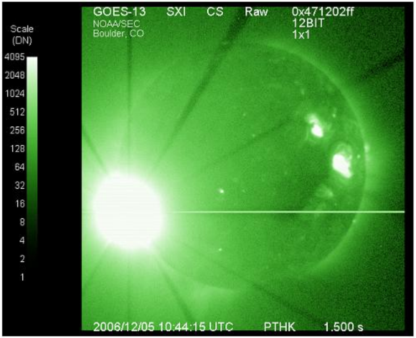
Vertical and Differential TEC variations above Kitab for EQ on 22-November-2014 in comparison with the monthly mean. P character denotes the precursor day.



Solar Flares

What is the Solar Flares?

- **Solar flare is a violent explosion in Sun's atmosphere**
- **Spans EM frequencies from radio to X-ray**
- **May be caused by release of energy stored in twisted magnetic field lines**
- **Large increase in X-ray flux can affect satellites**
- **Energy release accelerates protons in solar wind and cause disturbances in Earth's magnetic field.**



An X-ray image of an intense X9 flare taken from the GOES-13 satellite. The flare was actually intense enough to damage the imager.

X Solar Flare: March 29, 2014

Classification of Solar flare

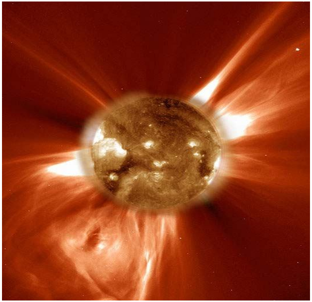
$A(1\text{-}9)=(1\text{-}9)\cdot 10^{-8}$ Wt/м^2

$B(1\text{-}9)=(1\text{-}9)\cdot 10^{-7}$ Wt/м^2

$C(1\text{-}9)=(1\text{-}9)\cdot 10^{-6}$ Wt/м^2

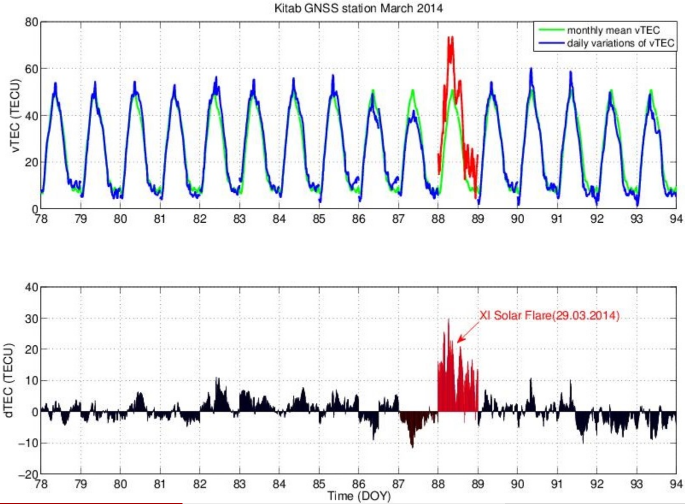
$M(1\text{-}9)=(1\text{-}9)\cdot 10^{-5}$ Wt/м^2

$X(1\text{-}n)=(1\text{-}n)\cdot 10^{-4}$ Wt/м^2



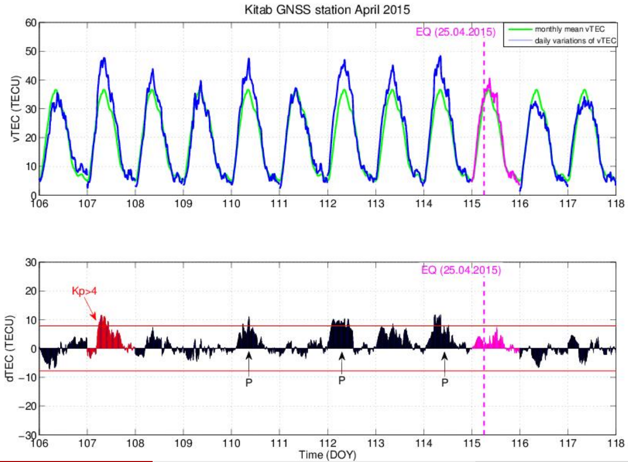
X Solar Flare: March 29, 2014

Vertical and Differential TEC variations above Kitab for 16 consecutive days, including Solar flare.



Kitab GNSS station: April 25 , 2015 (Nepal Earthquake)

Vertical and Differential TEC variations above Kitab for Nepal M=7.8 EQ on 25-April-2015 in comparison with the monthly mean. P character denotes the precursor day.



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- Ionospheric data in F-layer obtained on ground based navigation stations in Tashkent and Kitab are used for analysis of earthquake precursors.
- Monitoring of variation of F-layer of ionosphere over Tashkent and Kitab
- Preliminary data on effect of ionospheric disturbances caused by seismic activity on radio wave propagation in F-layer of ionosphere
- The correctness of applied method of TEC extraction from GNSS data is confirmed by the sharp increase of TEC during the Solar flare of 29-March-2014.
- Studied anomalous TEC signals and significant correlation in time between these TEC anomalies and the occurrence of the local earthquakes. In general the anomalies occurred 1-8 days before the earthquakes as precursors.

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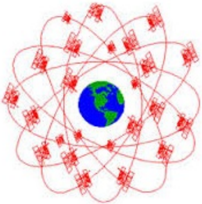

Thank you for your attention!

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