Ionospheric total electron content variations observed during Tashkent earthquakes and Solar eclipses

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KAZAKSTAN
KAZAKSTAN
Aral Sea
Sariqamish Kuli
Nukus
Uzbekistan
Urganch
TASHKENT
KYRGYZSTA
Andijon
Farghona
Fergana Valley
Nawoiy
Bukhoro
Samarqand
Caspian Sea
TURKMENISTAN
TAJIKISTAN
CHI
Qarshi
Maidanak
Termiz
IRAN
AFGHANISTAN
PAKISTA
0 100 200 km
0 100 200

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Content

BASIC EQUATIONS

Dispersion measure

$$DM \equiv \int_0^{L_0} n_e dl \equiv < n_e > L_0$$

Arrival time of radio signal

$$t_a(\omega) = \int_0^L \frac{dl}{v_g} \simeq \frac{1}{c} \int_0^L \left(1 + \frac{\omega_p^2}{2\omega^2}\right) dl = \frac{L}{c} + \frac{2\pi e^2}{mc\omega^2} DM$$

Time delay

$$\frac{\Delta t_a}{\Delta \omega} = -\frac{4\pi e^2}{mc\omega^3} DM$$

TEC extraction

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

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

Effect of F-layer of ionosphere with thickness 870 km

$$\Delta_i^{iono} = -\frac{40.3}{f_i^2} TEC$$

Total Electron Content

$$TEC = \frac{f_1^2 \cdot f_2^2}{40.3\,(f_1^2 - f_2^2)}\,(P_1 - P_2)$$

GPS Station in Tashkent and Kitab

Receiver Independent EXchange (RINEX) FORMAT

observation file
tash1740a.08o

navigation file
tash1740a.08n

Tashkent GPS station

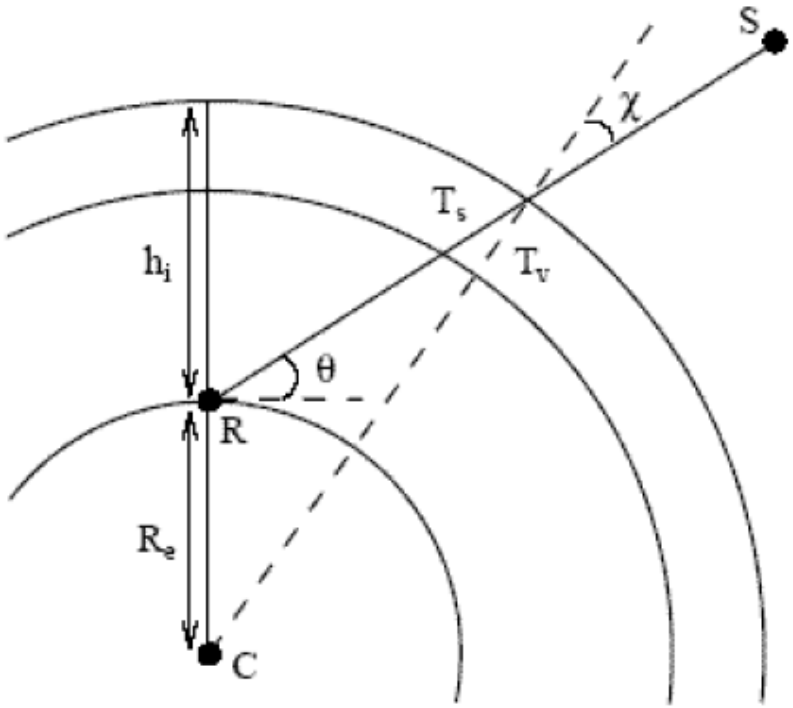
ftp://cddis.gsfc.nasa.gov/gps/data/daily/2008/174/00/tash1740a.08o

ftp://cddis.gsfc.nasa.gov/gps/data/daily/2008/174/00/tash1740a.08n

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

Slant and Vertical TEC

Slant TEC is extracted from pseudoranges P_1 and P_2

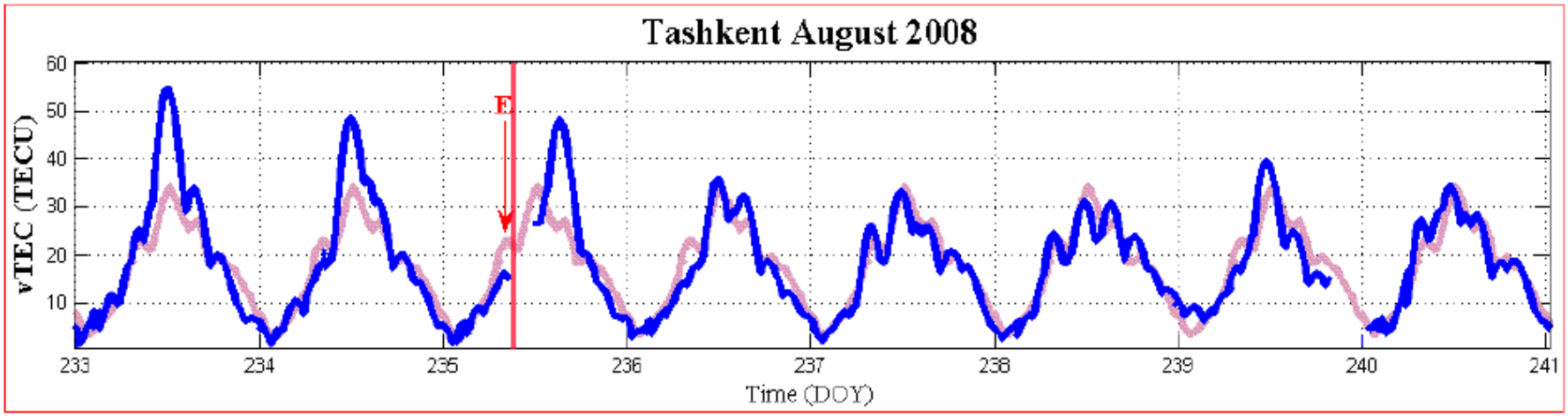


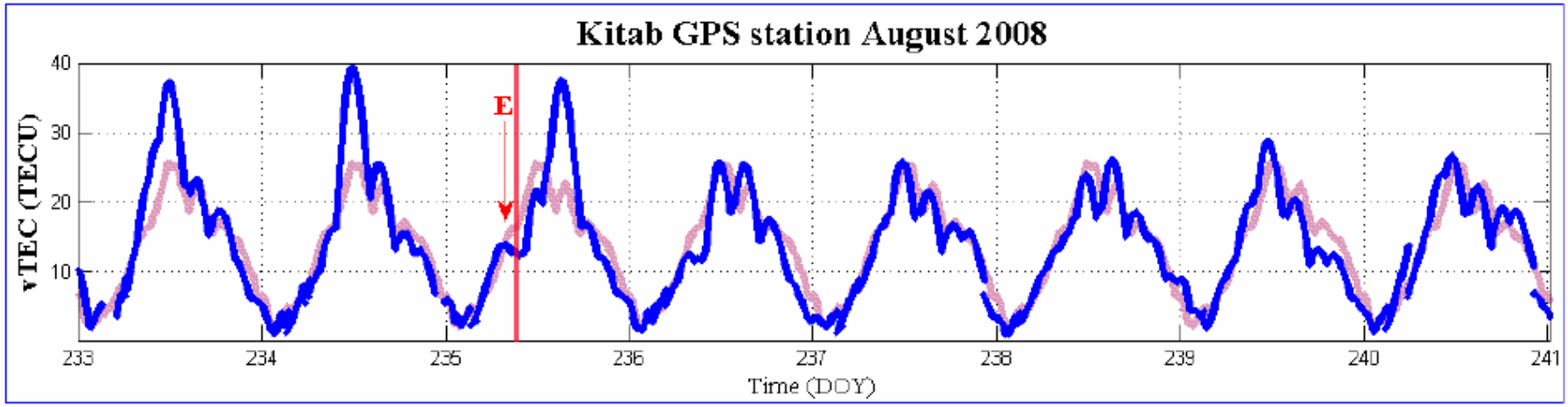
Vertical TEC

With help of navigation file containing 28 parameters being responsible for satellite coordinates vertical TEC is calculated in MatLab

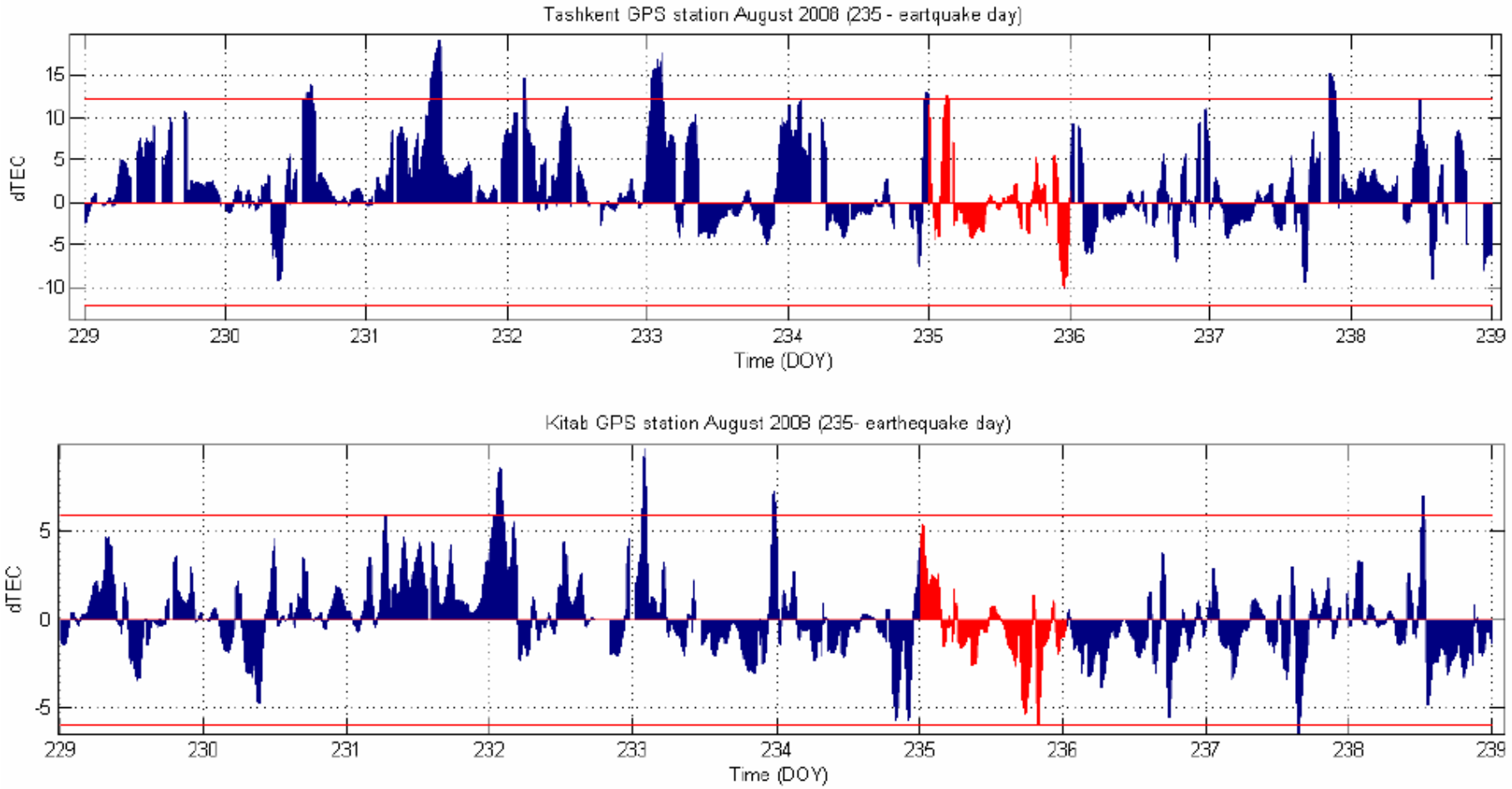
Green circles indicate positions of GPS stations in Tashkent and Kitab. Red circle indicates the position of Tashkent earthquake epicenter.

Daily Vertical Total Electron Content variations (blue line) above Kitab on top and Tashkent on bottom for 8 consecutive days, including earthquake date: August 22, 2008 (day 235) in comparison with the monthly mean (red line), E character denote the earthquake time (08:26:58 UT).

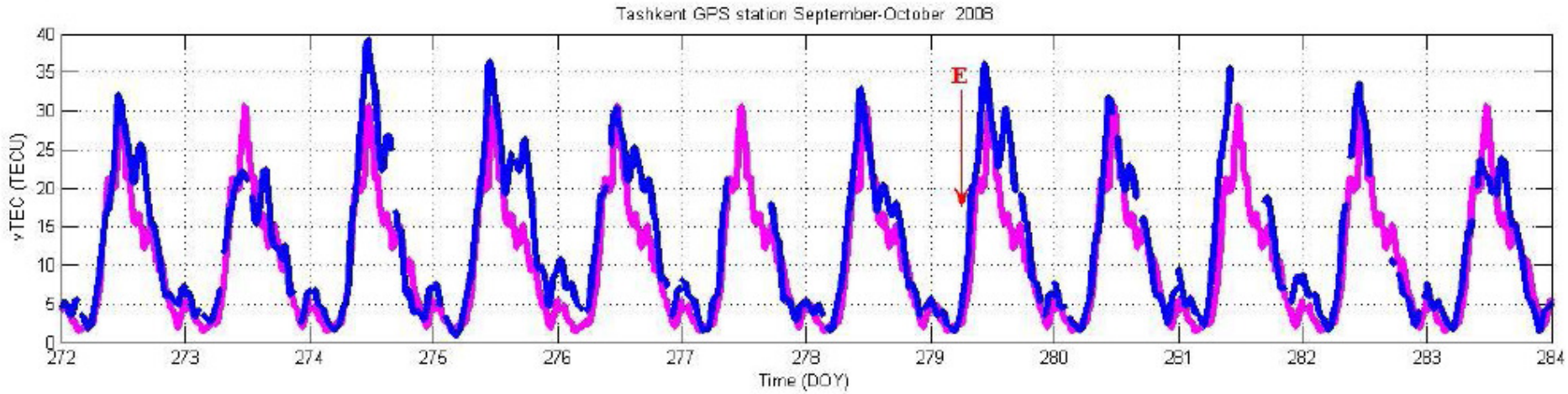




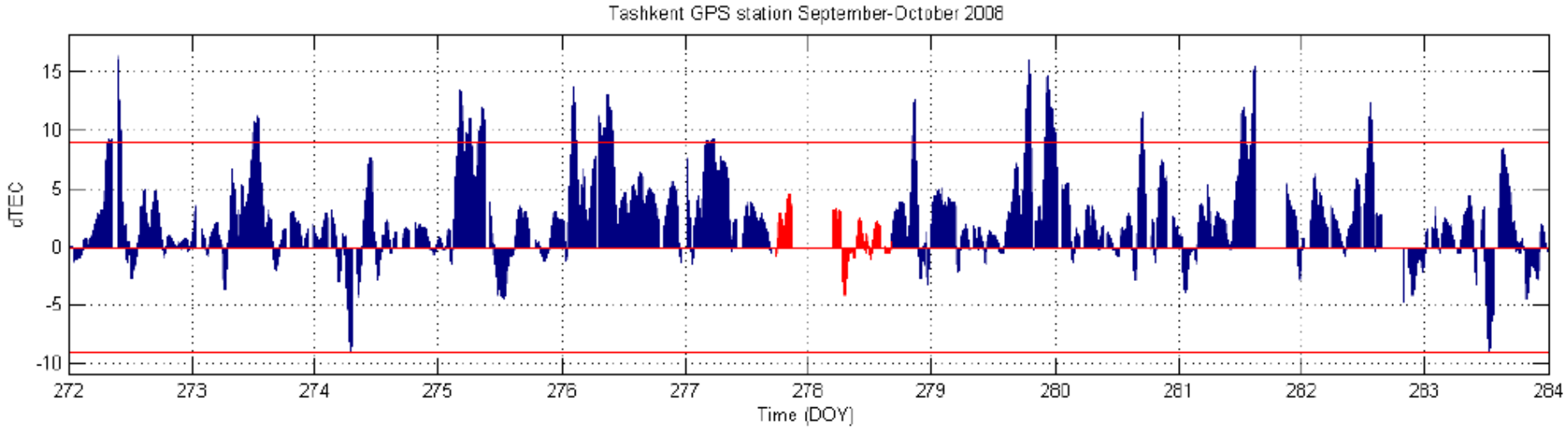
Differential TEC variations (blue line) above Kitab on top and Tashkent on bottom for 10 consecutive days, including earthquake date: August 22, 2008 (day 235).



Daily Vertical Total Electron Content variations (blue line) above Tashkent for 12 consecutive days, including KYRGYZSTAN earthquake (M=6.7) date: October 5, 2008 (day 278) in comparison with the monthly mean (red line), E character denote the earthquake day.



Differential TEC variations (blue line) above Tashkent for 12 consecutive days, including KYRGYZSTAN earthquake (M=6.7) date: October 5, 2008 (day 278).



CHINA earthquake (M=6.9) on April 14, 2010.

SIGNIFICANT EARTHQUAKES OF THE WORLD, 2010

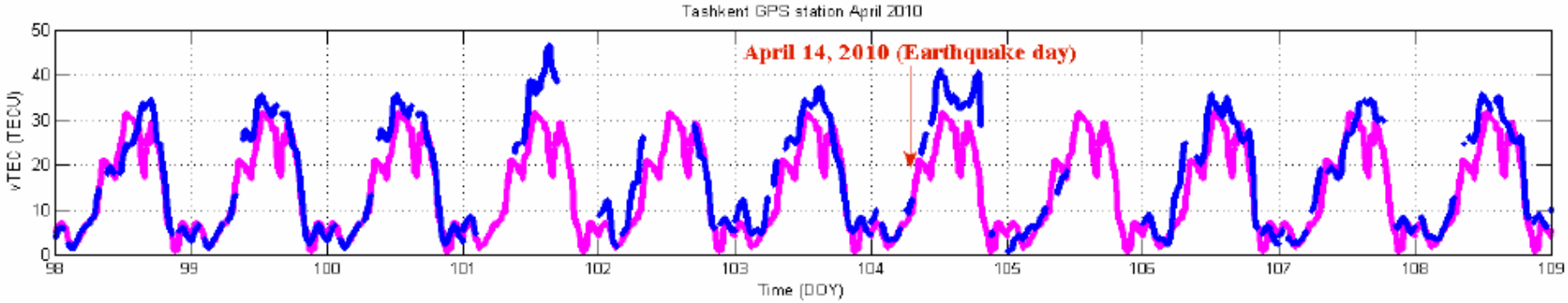
Earthquakes of magnitude 6.5 or greater or ones that caused fatalities, injuries or substantial damage.
BRK--Berkeley. PAS--Pasadena.

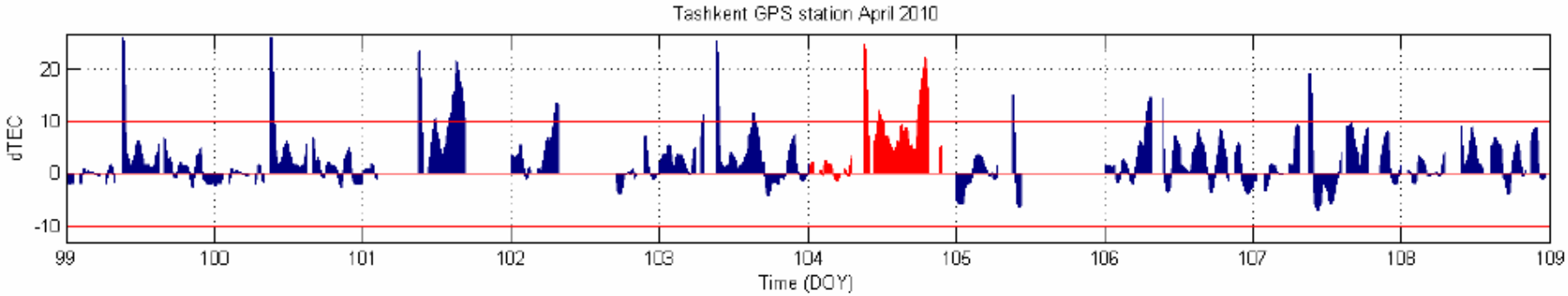
DATE UTC	ORIGIN TIME UTC HR MN SEC	GEOGRAPHIC COORDINATES LAT	LONG	DEPTH	MAG	SD	NO. STA USED	REGION, ADDITIONAL MAGNITUDES AND COMMENTS
APR 13	23 49 38.3	33.228 N	96.573 E	17 G	6.9	1.3	132	SOUTHERN QINGHAI, CHINA. MW 6.9 (UCMT), 6.9 (GCMT), 6.7 (GS), 6.8 (WCMT), 6.9 (UCMT). Mo 2.5*10**19 Nm (UCMT), 2.5*10**19 Nm (GCMT), 1.3*10**19 Nm (GS), 2.0*10**19 Nm (WCMT), 3.2*10**19 Nm (BPT). At least 2183 people killed, 84 missing, 12,135 injured and many buildings damaged in Yushu County.

NEIC

http://earthquake.usgs.gov/earthquakes/eqarchives/significant/sig_2010.php

Daily Vertical Total Electron Content & dTEC variations (blue line) above Tashkent, including CHINA earthquake (M=6.9) date: April 14, 2010 (day 104) in comparison with the monthly mean (red line).



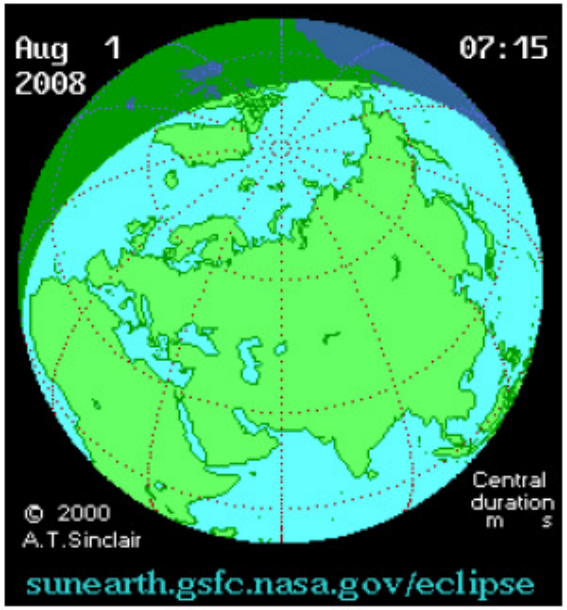


Solar eclipse on August 1, 2008.

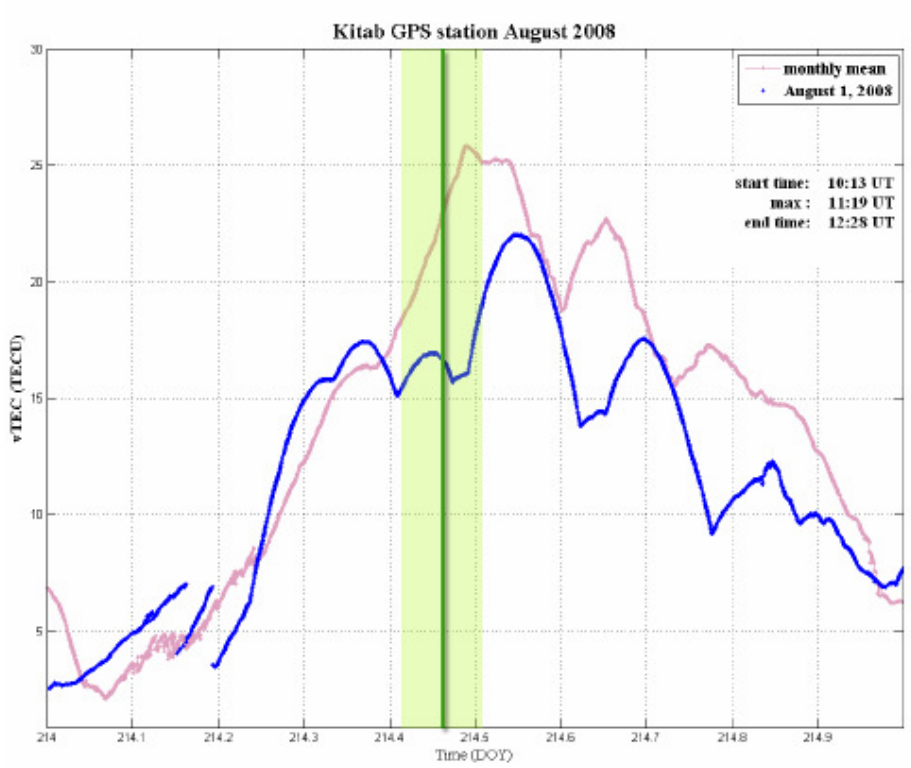
Solar Eclipse

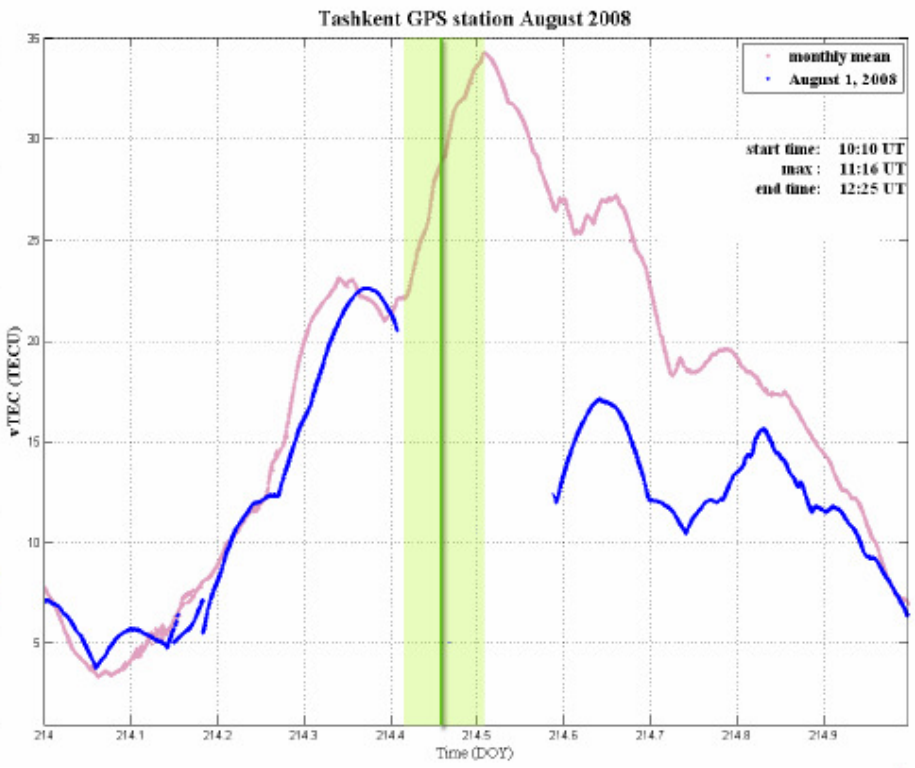
Day: 2008-08-01

Time: from ~10:00:00 to 12:00:00 UT

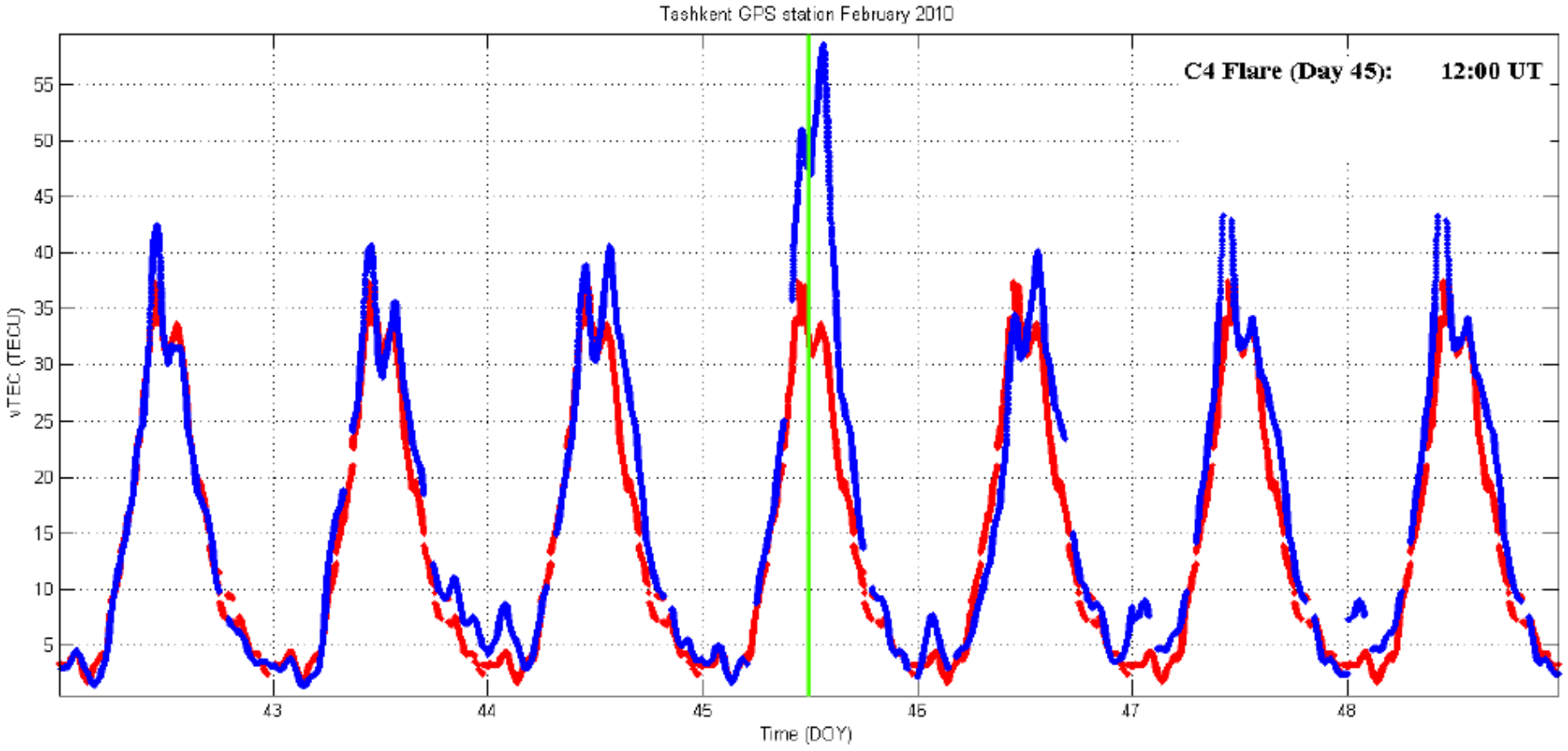


vTEC variations (blue line) above Tashkent and Kitab for August 1, 2008 comparison with the monthly mean (red line). There are no GPS data available for about several hours due to the EP shortcut in GPS station in Tashkent just at the time of the Solar eclipse.

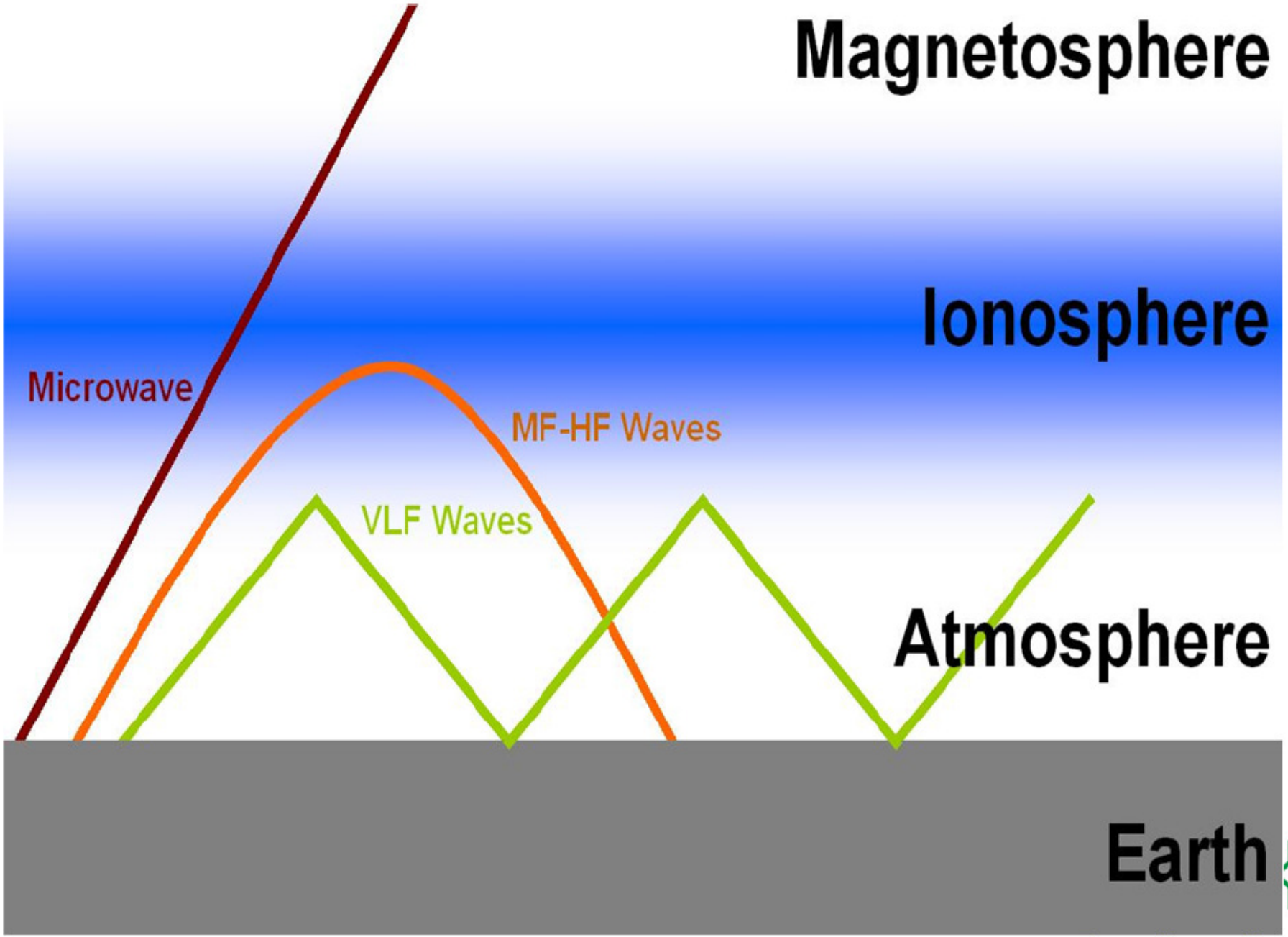




Daily vTEC variations (blue line) above Tashkent for 7 consecutive days, including solar flare date: February 14, 2010 (solar flare C4: day 45) in comparison with the monthly mean (red line)



Content


Magnetosphere
Ionosphere
Microwave
MF-HF Waves
VLF Waves
Atmosphere
Earth

UN


UN
UNITED NATIONS
AWESOME
INTERNATIONAL HELIOPHYSICAL YEAR
IHY
2007
SUPER SID
STANFORD
SOLAR
CENTER
Umran Inan
Deborah Scherrer
Prof. Hans J. Haubold
UN Office for Outer Space Affairs
Vienna International Centre

AWESOME

A tmospheric

W eather

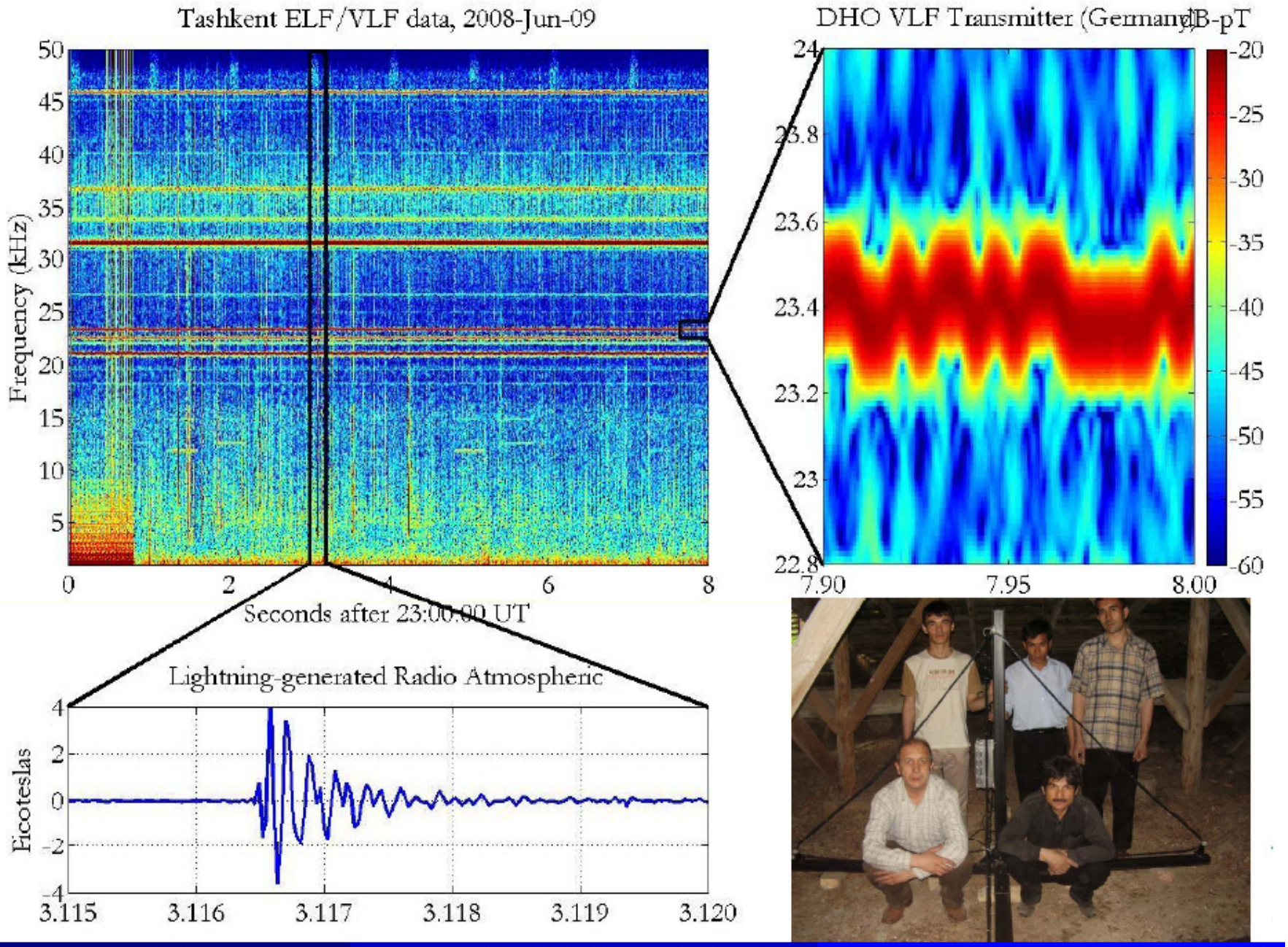
E lectromagnetic

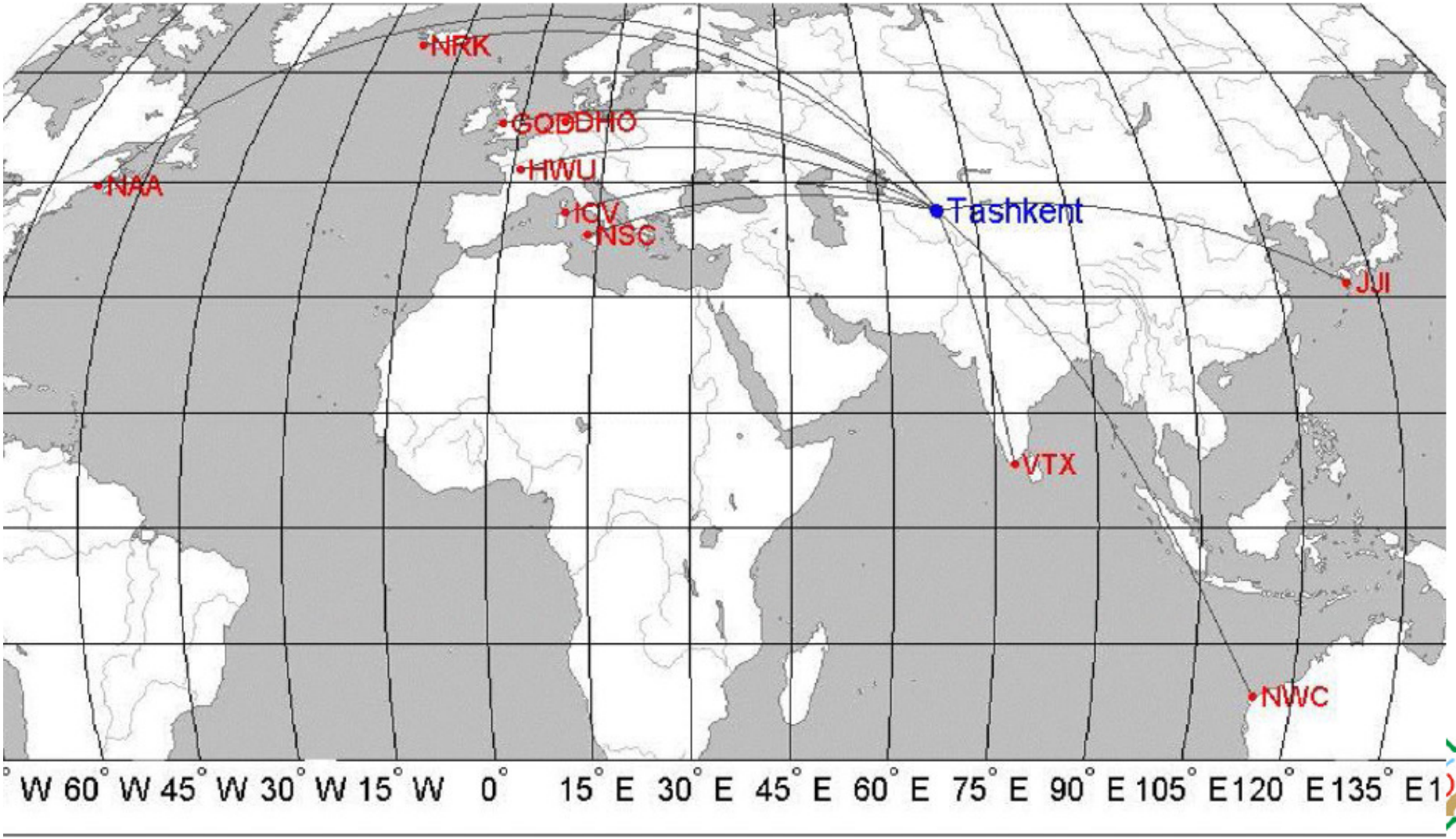
S ystem for

O bservation

M odeling and

E ducation


Tashkent ELF/VLF data, 2008-Jun-09
Frequency (kHz)
Seconds after 23:00:00 UT
DHO VLF Transmitter (Germany)
dB-pT
Lightning-generated Radio Atmospheric
Picoteslas


NRK
GQD
DHO
HWU
NAA
ICV
NSC
Tashkent
JJI
VTX
NWC
W 60° W 45° W 30° W 15° W 0° 15° E 30° E 45° E 60° E 75° E 90° E 105° E 120° E 135° E

NSs

- RADIO PULSARS: 2000 discovered to date
- Radiate covering most of the electromagnetic spectrum
- Rotate with periods that span five decades (ms to a few hours)
- Are powered by their own rotational energy, residual surface heat or accretion
- Live tens of millions of years

Magnetars (14 discovered to date)

- Magnetars are magnetically powered, rotating neutron stars
- Radiate almost entirely in X-rays, with luminosities 10^{33} to 10^{36} erg/s
- Emit typically brief (1-100 ms) bursts and very rarely, Giant Flares
- Rotate in a very narrow period interval (2-11 s) and slow down faster than any other object (10^{-10}-10^{-11} s/s^{-1})
- Powered by MF energy, which heats the NS and the surface glows persistently in X-rays, and fractures the crust inducing short, repeated bursts
- Die rather young; typical ages are 10 000 yrs

SGR and AXP

Soft Gamma-ray Repeaters

- Discovered in 1979 as transient sources of hard X-ray bursts and giant flares (GF)
- 5 confirmed SGRs (3 emitted a GF)

Anomalous X-ray Pulsars

- Identified in the 90s as a peculiar class of persistent X-ray pulsar with no signs of binary companions
- 9 confirmed AXPs: 3 in SNRs, 3 transients

Massive gamma-ray burst

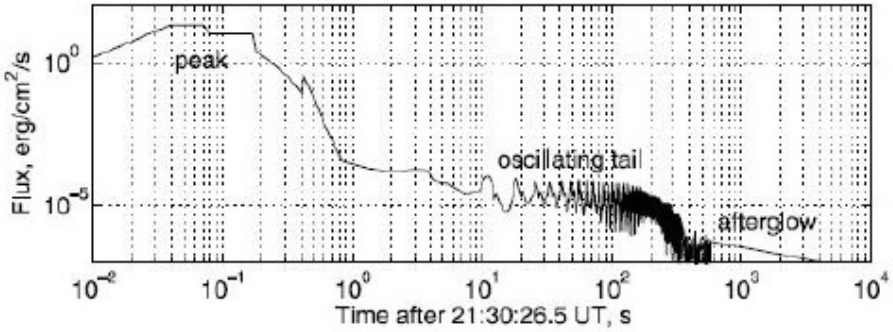
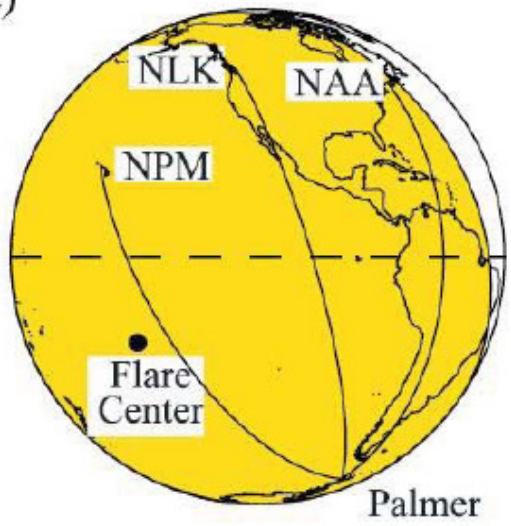
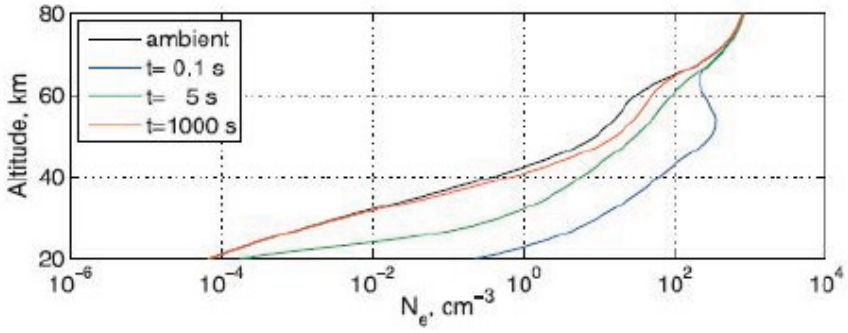


Figure 1. The γ-ray flux versus time, showing the peak [*Terasawa et al.*, 2005], oscillating tail [*Hurley et al.*, 2005] and the afterglow ($\propto t^{-0.85}$ [*Mereghetti et al.*, 2005]).

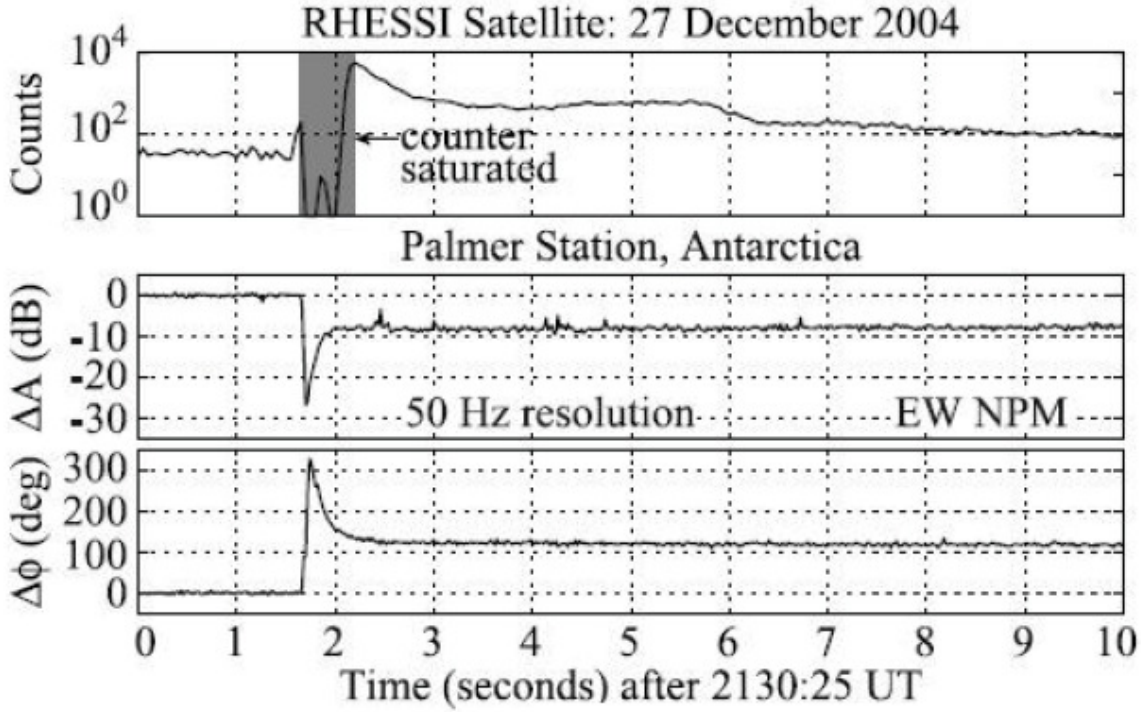
a)



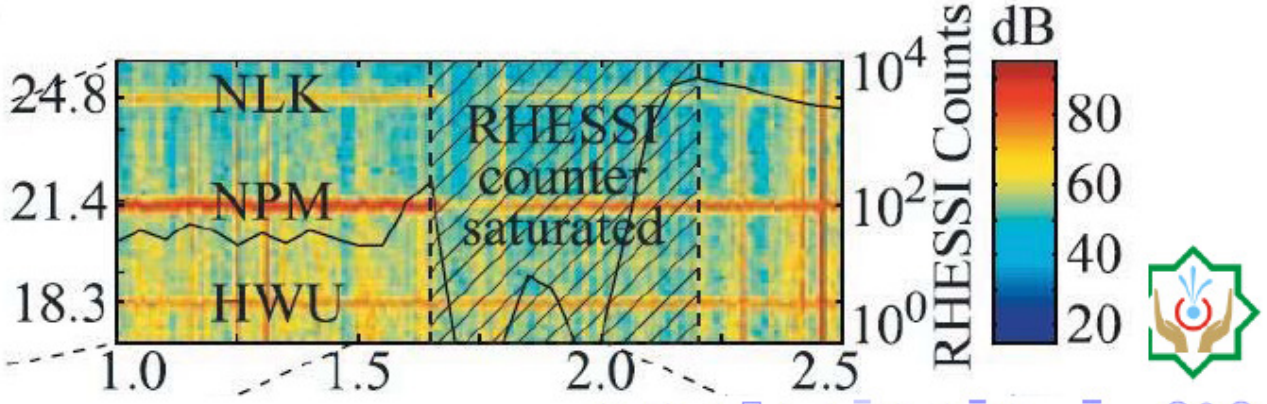


From *Inan et al.* 2007

Second timescale characteristics

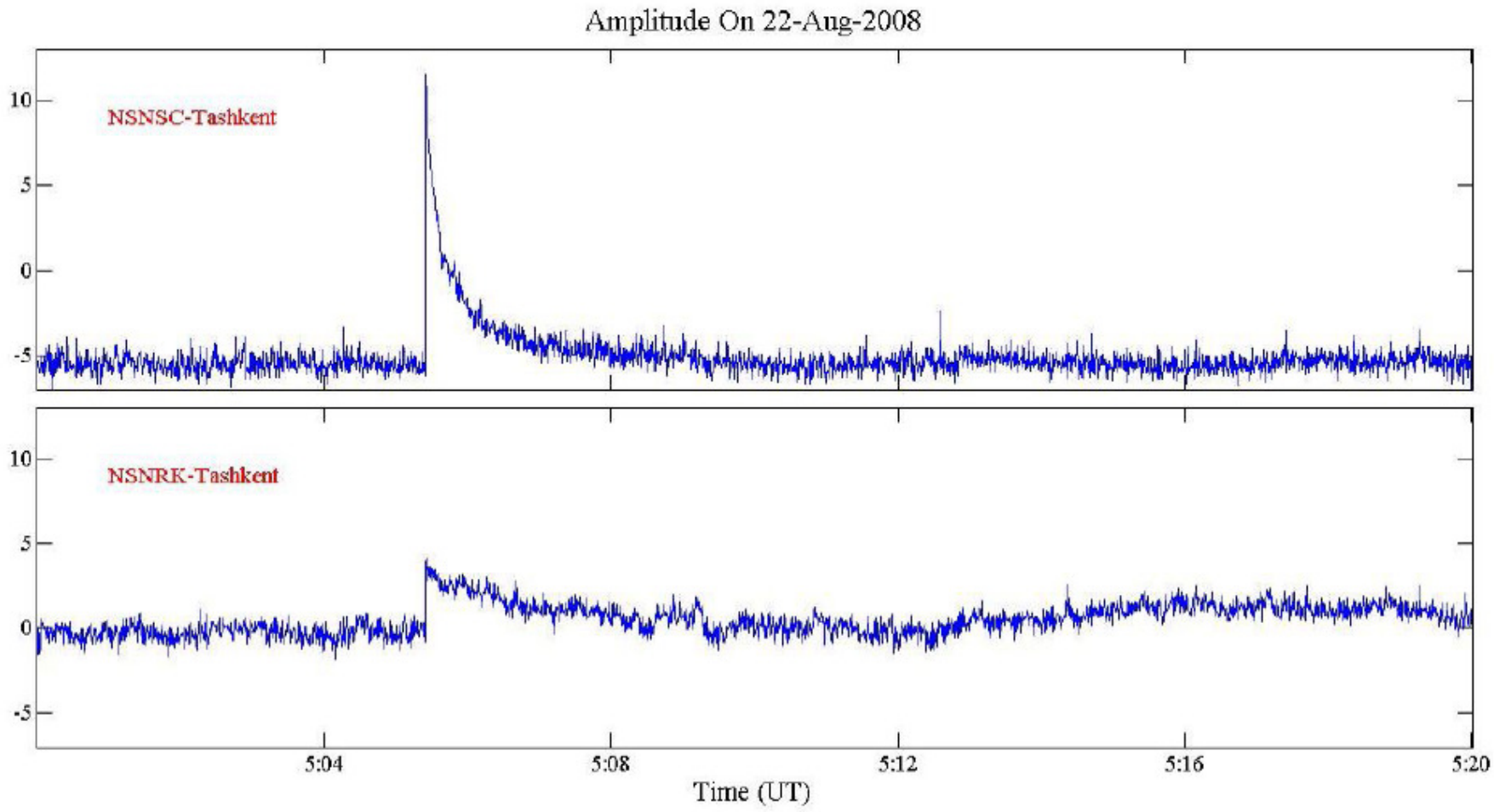


-25 dB disturbance!!

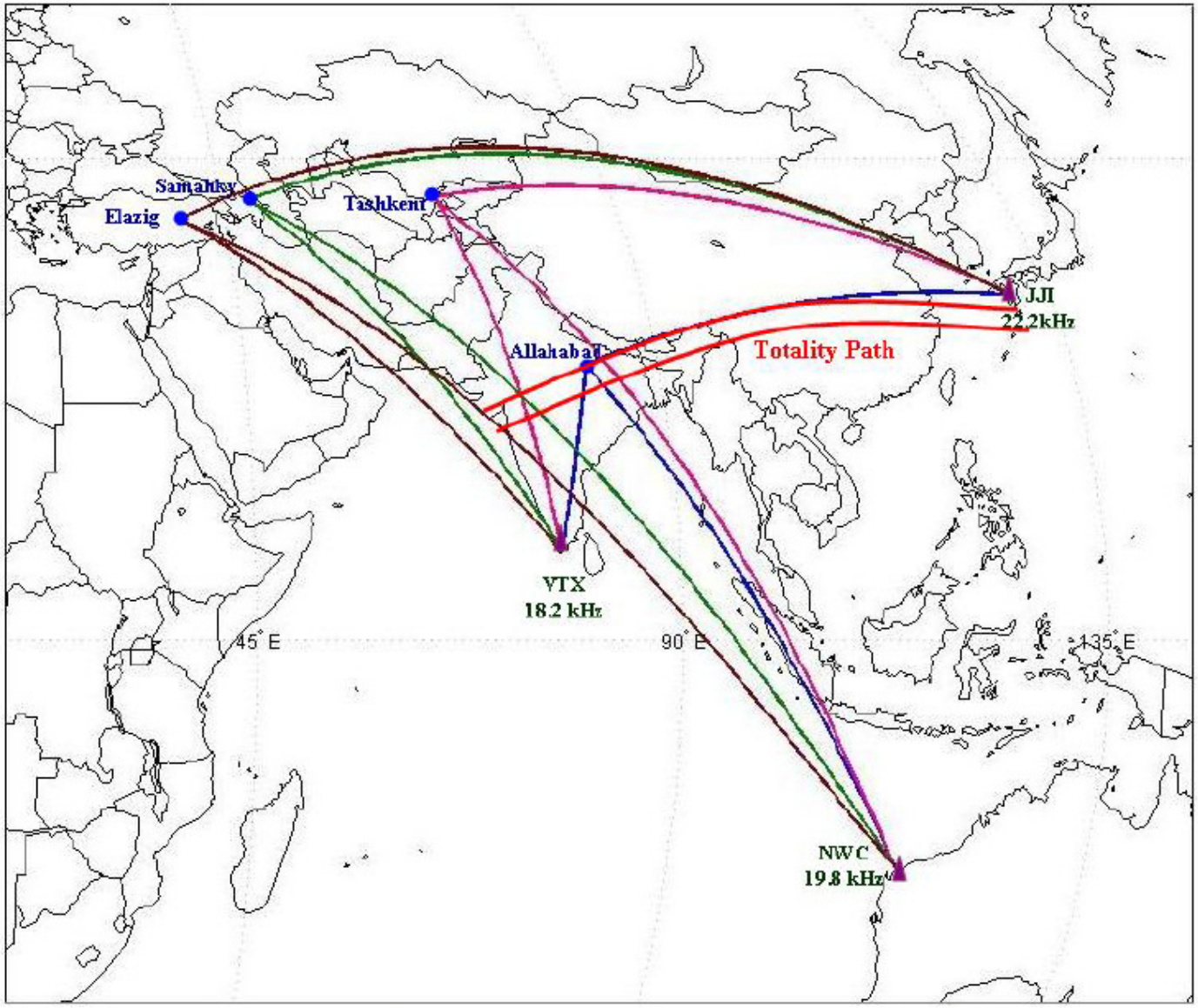


From *Inan et al.* 2007

SGR 0501 + 4516 is registered on 22 August 2008 in Tashkent station



Solar Eclipse



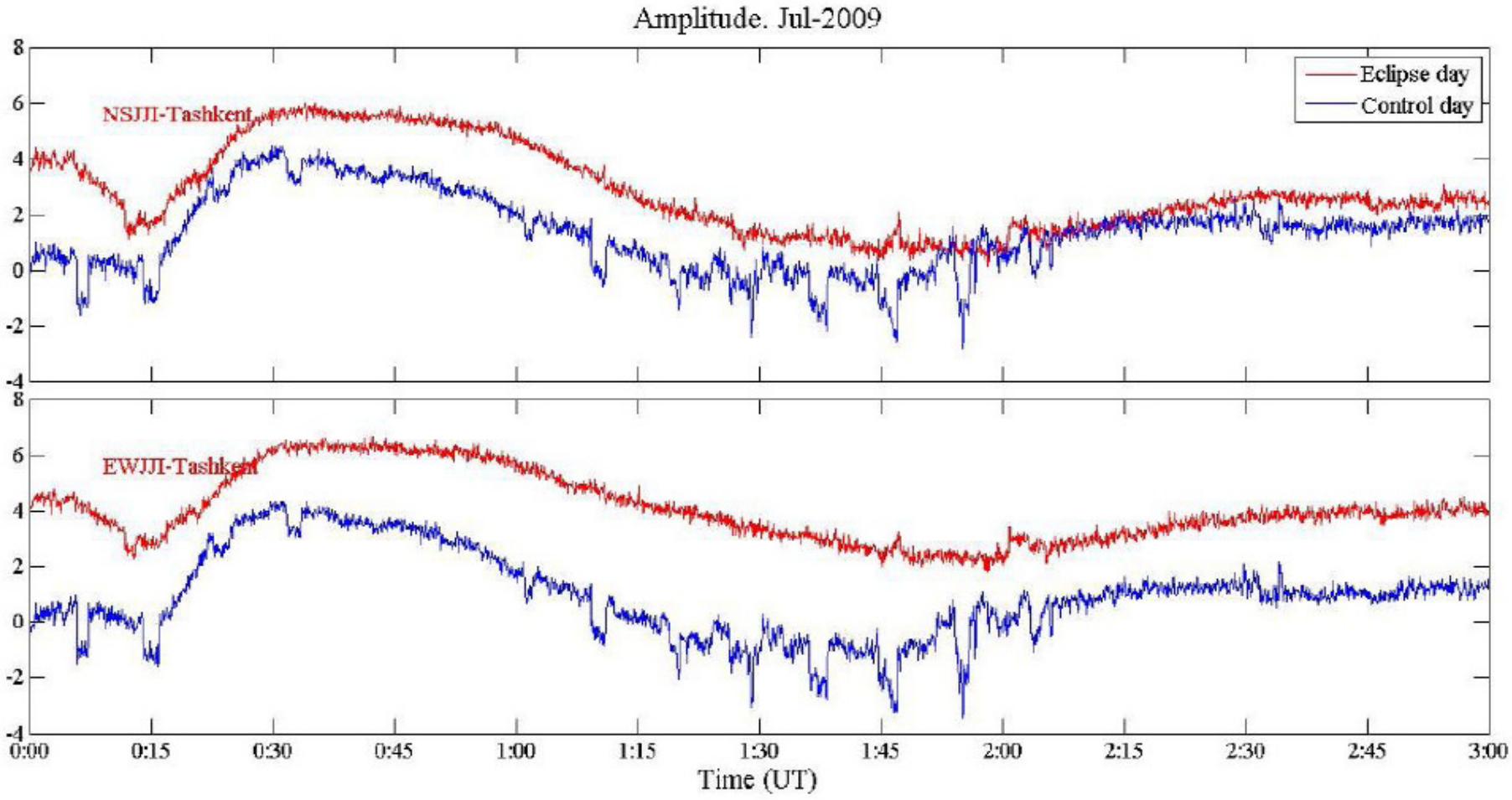
Solar Eclipse

TABLE 12
LOCAL CIRCUMSTANCES FOR ASIA
TOTAL SOLAR ECLIPSE OF 2009 JULY 22

Location Name	Latitude	Longitude	Elev.	First Contact				Second Contact				Third Contact				Fourth Contact				Maximum Eclipse					Eclip.	Eclip.	Umbral	Umbral
				U.T.	P	V	Alt	U.T.	P	V		U.T.	P	V		U.T.	P	V	Alt	U.T.	P	V	Alt	Azm	Mag.	Obs.	Depth	Durat.
			m	h m s	°	°	°	h m s	°	°		h m s	°	°		h m s	°	°	°	h m s	°	°	°	°				
AFGHANISTAN																												
Kabul	34°31'N	069°12'E	1815	–				–				–				01:51:05.1	125	184	16	01:00:37.7	190	245	6	69	0.599	0.512		
AZERBAIJAN																												
Baku	40°23'N	049°51'E	–	–				–				–				01:43:02.9	149	197	2	01:31 Rise	–	–	0	62	0.145	0.066		
BANGLADESH																												
Chittagong	22°20'N	091°50'E	–	23:59:15.3	289	358	8	–				–				02:04:38.8	93	170	36	00:58:13.5	11	84	21	76	0.873	0.855		
Dacca	23°43'N	090°25'E	–	23:59:19.1	286	353	7	–				–				02:03:51.1	96	171	34	00:57:58.5	11	82	20	76	0.930	0.927		
Dinajpur	25°38'N	088°38'E	–	23:59:54.0	281	346	6	00:56:42.0	151	219		00:59:15.7	231	300		02:02:55.1	100	173	33	00:57:58.5	11	80	19	76	1.067	1.000	0.236	02m34s
Khulna	22°48'N	089°33'E	–	23:58:58.8	287	355	6	–				–				02:02:21.9	95	170	33	00:57:06.1	11	83	19	75	0.909	0.899		
Rajshahi	24°22'N	088°36'E	–	23:59:22.1	284	350	6	–				–				02:02:14.9	98	172	33	00:57:20.0	11	81	18	75	0.968	0.971		
Rangpur	25°45'N	089°15'E	–	23:59:59.0	282	347	7	00:57:11.3	156	225		00:59:29.6	226	295		02:03:37.8	100	173	34	00:58:20.2	11	80	19	76	1.067	1.000	0.182	02m18s
Saidpur	25°47'N	088°54'E	–	23:59:58.9	281	346	6	00:56:45.0	145	213		00:59:37.4	237	306		02:03:16.3	101	173	33	00:58:10.8	11	80	19	76	1.067	1.000	0.307	02m52s
BHUTAN																												
Thimbu	27°28'N	089°39'E	–	00:00:55.2	279	343	8	00:58:01.6	56	124		01:00:53.7	326	33		02:04:49.5	104	174	35	00:59:27.3	191	258	20	77	1.068	1.000	0.297	02m52s
IRAN																												
Esfahan	32°40'N	051°38'E	1597	–				–				–				01:46:33.2	133	188	1	01:42 Rise	–	–	0	65	0.071	0.023		
Mashhad	36°18'N	059°36'E	–	–				–				–				01:47:20.1	134	188	8	01:03:55.9	190	241	0	64	0.452	0.345		
Tehran	35°40'N	051°26'E	1200	–				–				–				01:45:38.1	139	191	2	01:36 Rise	–	–	0	64	0.139	0.062		
KAZAKHSTAN																												
Alma-Ata	43°15'N	076°57'E	775	00:23:27.6	245	292	8	–				–				01:54:54.7	138	189	24	01:07:47.4	191	241	15	76	0.426	0.318		
Karaganda	49°50'N	073°10'E	–	00:40:19.6	230	271	10	–				–				01:49:00.7	154	197	21	01:14:00.8	192	234	15	77	0.221	0.123		
KOREA, NORTH																												
P'yongyang	39°01'N	125°45'E	29	00:34:41.4	272	327	46	–				–				03:01:39.6	129	153	69	01:46:14.8	201	248	59	118	0.742	0.689		
KOREA, SOUTH																												
Inch'on	37°28'N	126°38'E	–	00:34:22.9	275	332	46	–				–				03:05:21.6	127	149	71	01:47:54.1	201	250	60	117	0.790	0.750		
Pusan	35°06'N	129°03'E	2	00:36:12.1	280	339	49	–				–				03:13:06.0	125	138	75	01:52:50.8	202	253	64	118	0.856	0.835		
Seoul	37°33'N	126°58'E	10	00:34:55.6	275	331	47	–				–				03:05:50.4	128	148	71	01:48:27.8	201	250	61	118	0.785	0.745		
KYRGYZSTAN																												
Bishkek	42°54'N	074°36'E	–	00:23:54.1	244	291	6	–				–				01:53:21.5	138	189	22	01:07:18.1	191	240	14	75	0.417	0.307		
LAOS																												
Vientiane	17°58'N	102°36'E	170	00:05:13.2	303	20	17	–				–				02:17:12.5	83	168	48	01:06:57.7	13	94	31	77	0.647	0.571		
MONGOLIA																												
Ulaanbaatar	47°55'N	106°53'E	1307	00:32:47.0	251	297	31	–				–				02:23:15.3	141	181	48	01:26:24.0	196	240	39	104	0.458	0.352		
NEPAL																												
Kathmandu	27°43'N	085°19'E	1348	00:01:10.9	276	338	4	–				–				02:00:31.5	105	175	30	00:57:43.9	191	257	16	75	0.962	0.965		
PAKISTAN																												
Faisalabad	31°25'N	073°05'E	–	–				–				–				01:52:49.0	118	180	18	00:58:15.8	190	249	7	71	0.728	0.670		
Karachi	24°52'N	067°03'E	4	–				–				–				01:49:10.1	109	177	11	00:56 Rise	–	–	0	67	0.854	0.829		
Lahore	31°35'N	074°18'E	–	–				–				–				01:53:30.8	117	180	20	00:58:21.4	190	249	8	71	0.736	0.680		
SRI LANKA																												
Colombo	06°56'N	079°51'E	7	–				–				–				01:42:12.3	69	157	15	00:50:32.7	9	93	3	70	0.503	0.401		
TAJIKISTAN																												
Dusanbe	38°35'N	068°48'E	–	00:19:41.3	248	296	0	–				–				01:50:41.2	133	187	16	01:03:45.4	190	242	7	70	0.482	0.378		

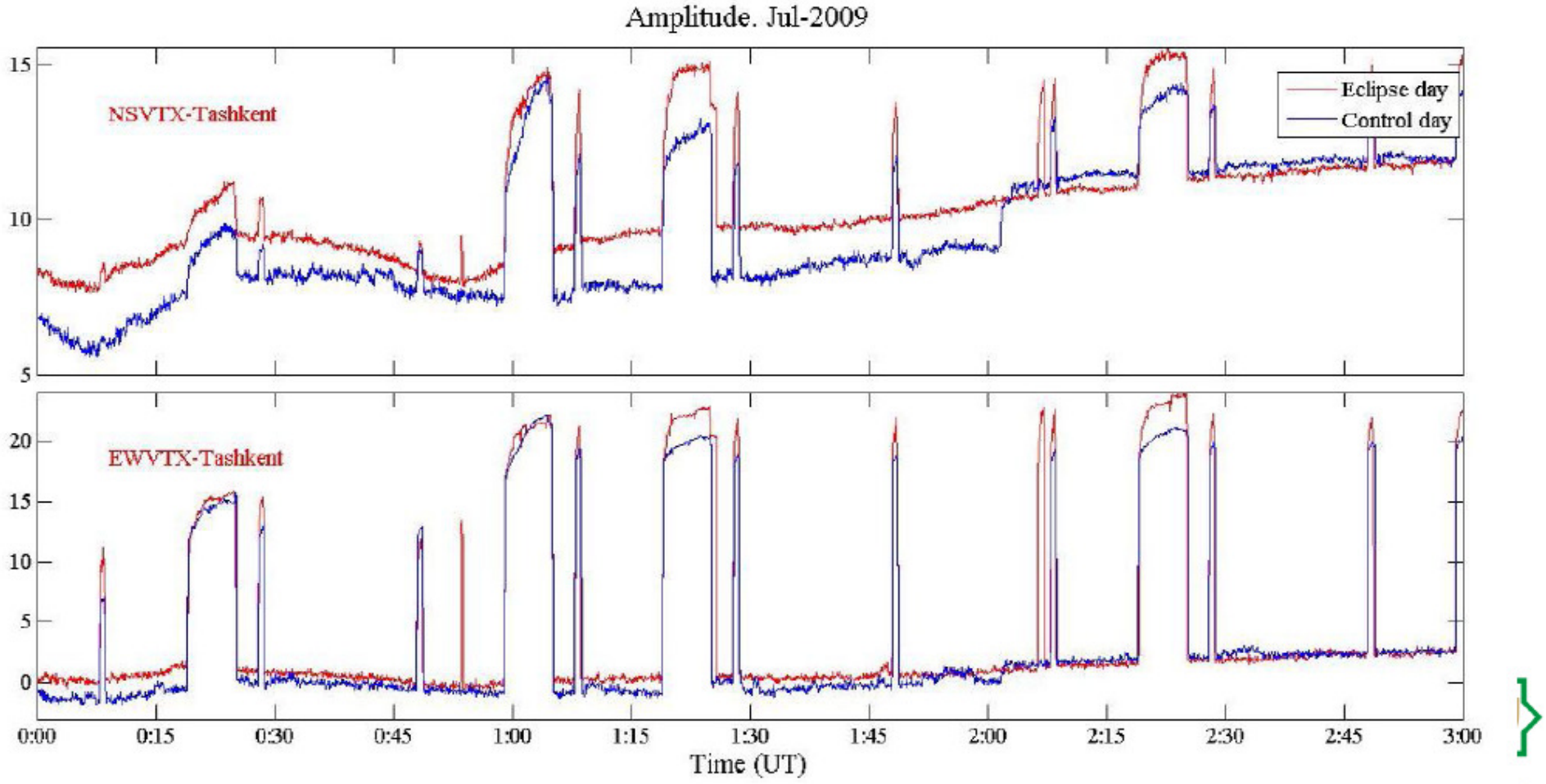
Solar Eclipse

Solar Eclipse is observed during sunrise from 00:23:59 UT to 01:50:27 on 22 July 2009.The results are signals of JJI transmitter



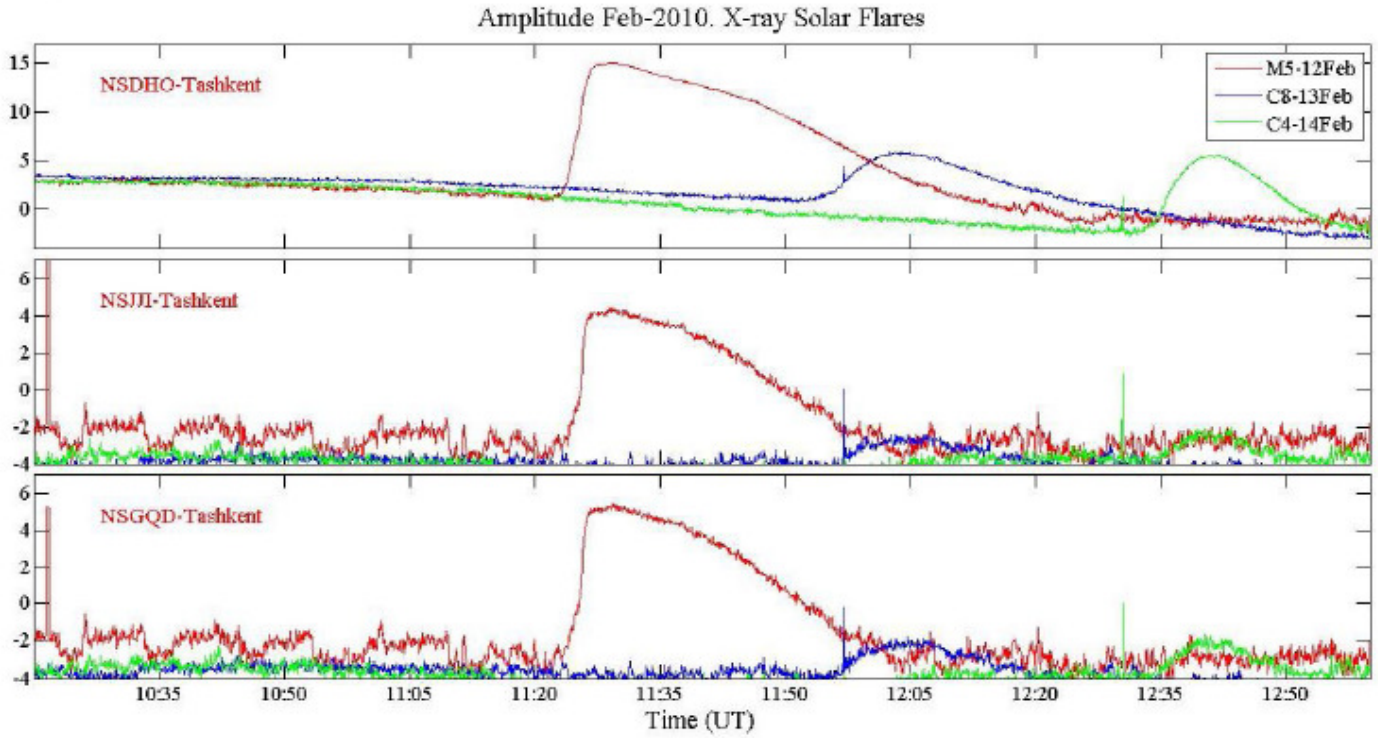
Solar Eclipse

Solar Eclipse is observed sunrise from 00:23:59 UT to 01:50:27 on 22 July 2009. The results are signals of VTX transmitter



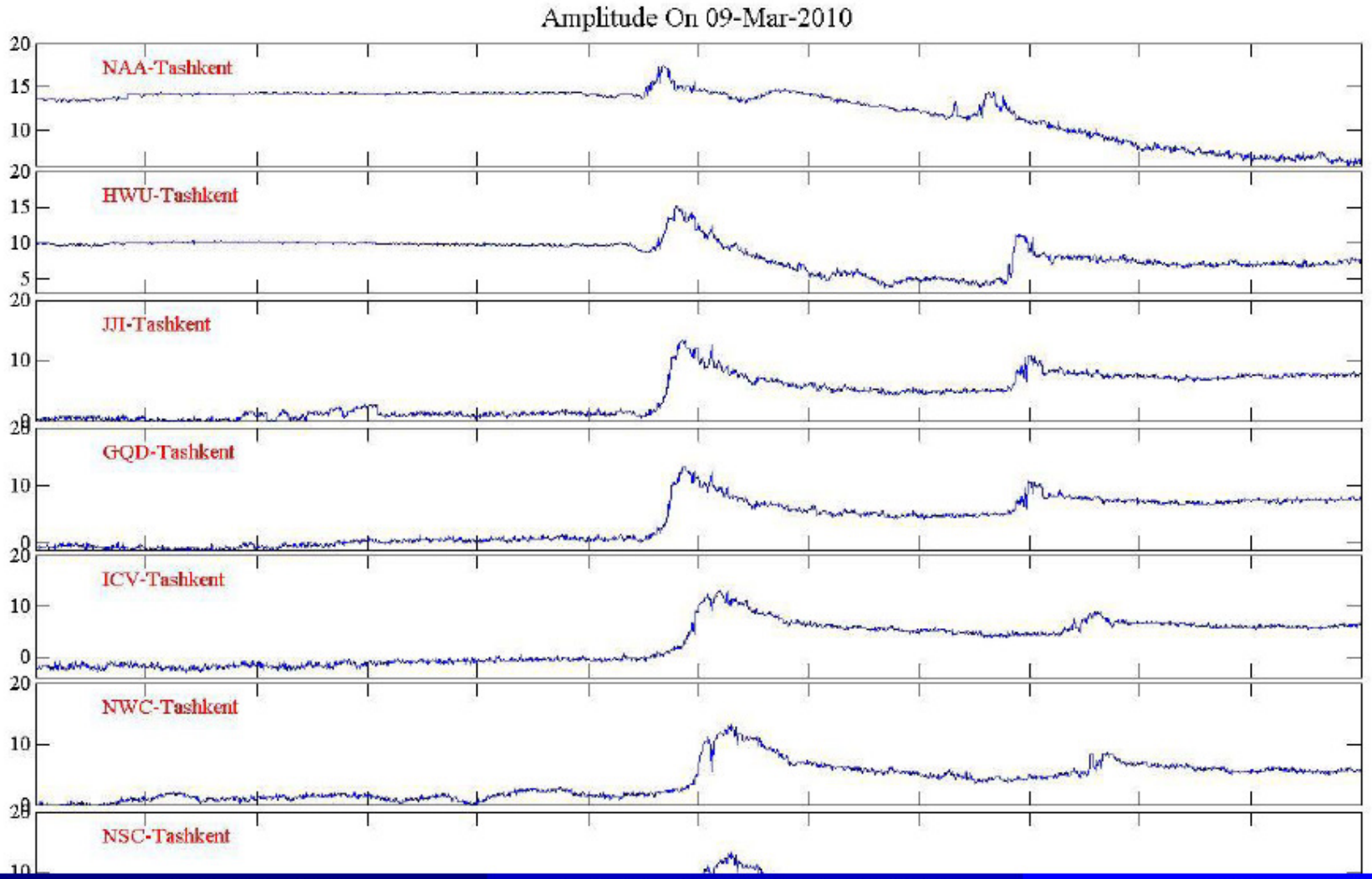
Solar Flare

X-ray Solar Flare are observed during February 2010.12 Feb M5, 13 Feb C8 and 14 Feb C4



Solar Flare

X-ray Solar Flare on 9 March 2010



Content

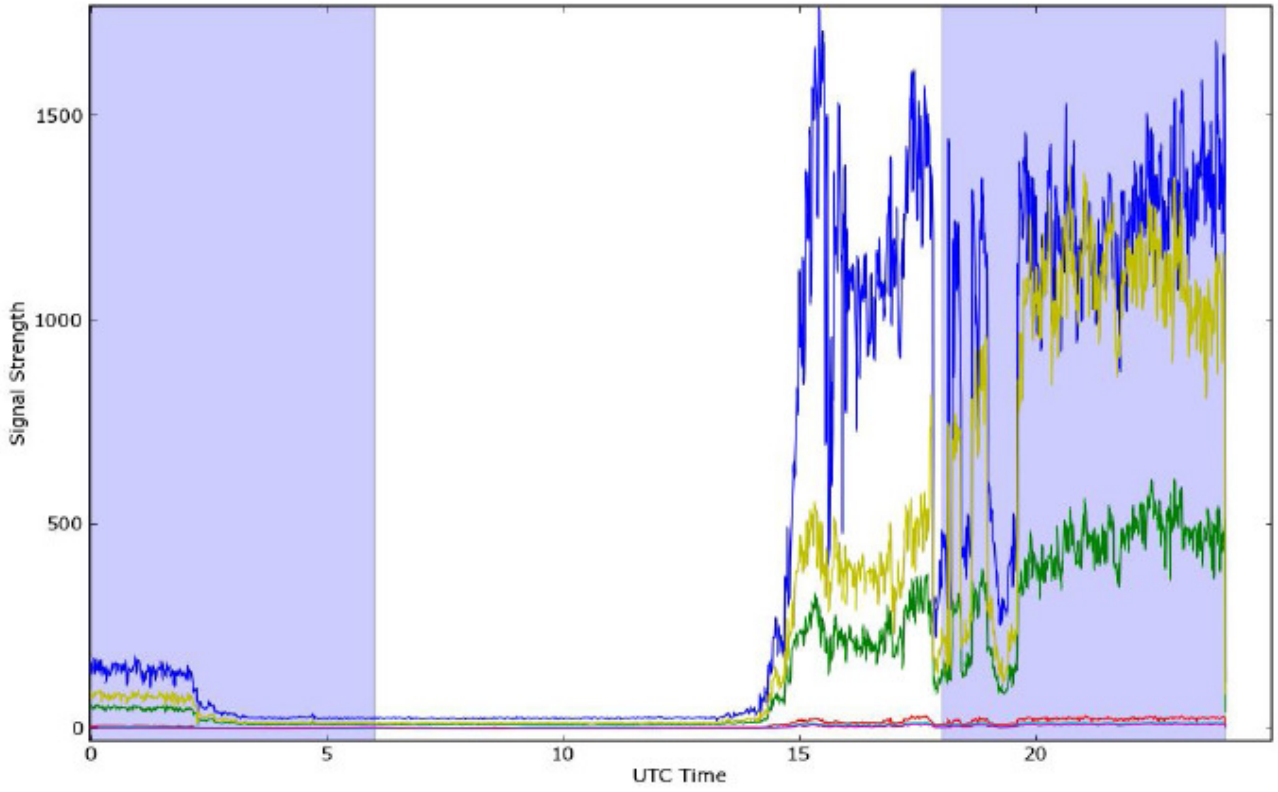
Super SID

SUPER SID ANTENNA

Super SID antenna(UZB1)

SUPER SID RESULTS

Results of the Super SID antenna



Content

Publications

Our very recent papers on Plasma MS of Magnetized Oscillating NSs:

- Abdikamalov E.B., Ahmedov B.J., and Miller J.C., The Magnetosphere of Oscillating Neutron Stars in General Relativity, **Mon. Not. R. Astron. Soc.**, 2009, Vol. 395, Issue 10, pp. 443-461.
- V. S. Morozova, B. J. Ahmedov and V. G. Kagramanova, General Relativistic Effect of Gravitomagnetic Charge on Pulsar Magnetosphere and Particle Acceleration in a Polar Cap, **Astrophys. J.**, 2008, V 684, 2 issue, 1359-1365.
- Ahmedov B.J. and Morozova V.S. "Plasma Magnetosphere Formation Around Oscillating Magnetized Neutron Stars", **Astrophys. Space Sci.**, 2009, V. 319, 115-117.
- Morozova V.S., Ahmedov B.J., and Olindo Zanotti, General Relativistic Magnetosphere of Slowly Rotating Oscillating Magnetized Neutron Star, 2010, **Mon. Not. R. Astron. Soc.** , in press, Preprint, Cornell University: Cornell. - 2010. - No. astro-ph/1004.1739. - P.1-13.
- A.A. Abdujabbarov, B.J. Ahmedov, Charged Particle Motion Around Rotating Black Hole in Braneworld Immersed in Magnetic Field, **Phys. Rev. D.**, 2010, V.81, Issue 4, 9pp, 044022.

Our very recent papers on Plasma MS of Magnetized Oscillating NSs:

- A.A. Abdujabbarov, B.J. Ahmedov Electromagnetic Fields and Charged Particle Motion Around Magnetized Wormholes, **Astrophys. Space Sci.**, 2009, V. 321, 225-232.
- A.A. Abdujabbarov, B.J. Ahmedov and V.G. Kagramanova, Particle Motion and Electromagnetic Fields of Rotating Compact Gravitating Objects with Gravitomagnetic Charge, **Gen. Rel. Grav.**, 2008, V.40, 2515-2532.
- Ahmedov B. J., and Fattoyev F. J., Magnetic Fields of Spherical Compact Stars in Braneworld, 2008, **Phys. Rev. D.**, V.78, No.4, 047501.
- Morozova V.S., Ahmedov B.J., Abdujabbarov A.A., and Mamadjanov A.I. Plasma Magnetosphere of Rotating Magnetized Neutron Star in the Braneworld, **Astrophys. Space Science**, 2010, DOI 10.1007/s10509-010-0388-9, P.1-10.
- U. A. Mofiz and B.J. Ahmedov, Plasma Modes Along the Open Field Lines of a Neutron Star, Preprint, Cornell University: Cornell. - 2007. - No. astro-ph/0705.4380. - P.1-19 [http://arxiv.org].
- B.V. Turimov, B.J. Ahmedov, A.A. Abdujabbarov, Electromagnetic Fields of Slowly Rotating Magnetized Gravastars, **Modern Physics Letters A**, 2009, V. 24, No. 10, 733-737.

Content

Conclusion

- Ionospheric data in F-layer obtained on ground based navigation stations in Tashkent and Kitab are used for analysis of earthquake precursors
- MatLab scripts for data analysis of observation and navigation files in RINEX format
- 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
- Studied anomalous TEC signals and significant correlation in time between these TEC anomalies and the occurrence of earthquake in Tashkent on 22 nd August, 2008
- The amplitude of TEC deflection reached up to 58% with compare to the nondisturbed initial monthly mean background value two days before the earthquake
- The obtained results have revealed a fine agreement with TEC anomalies observed in Tashkent and Kitab GPS station during strong earthquake in Tashkent and we demonstrate the capabilities of the GPS technique to detect ionospheric perturbations caused by the earthquakes during last years starting 2008

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Conclusion

- TEC decrease during the solar eclipse on August 1, 2008 is also obtained from data at GPS station in Tashkent and Kitab
- During the solar flare C4 occurrence on February 14, 2010 the amplitude of TEC reached up to 44 % with compare to the nondisturbed initial monthly mean background value after the flare
- Two Solar eclipses and a few earthquake events are registered by VLF receiver and being analyzed
- Few Solar flare events are observed by VLF signals during February in 2010 and the analysis showed that there is simultaneous correlation between the times of change of amplitude of the waves and the Solar flares
- SGR 0501 + 4516 is registered by VLF receiver in Tashkent station On August 22 in 2008 and defined the enhancement of amplitude of VLF signals

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Thank You [1]

[1] I hope you enjoyed it...and are not asleep right now