Seismo-ionospheric GPS TEC anomalies before and after earthquakes

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Introduction
Global Ionospheric Map
Temporal Precursor

1998/05/01~2008/05/12  36 M≥6.0 earthquakes in China
2008/5/12 M7.9 Wenchuan Earthquake
Locations of the 35M≥6.0 earthquakes together with Wenchuan earthquake occurred in China during May 1, 1998-May 12, 2008.
A time series of GPS TEC right above the epicenter of the M7.9 Wenchuan earthquake on May 15, 2008.

Liu et al. (JGR 2009)
Spatial Precursor
The GIMs observed at 08:00 UT and global fixed 15:00 LT on day 6 before the 2008 Mw7.9 Sichuan Earthquake.

\[ R = 10^{0.43M} \]

Liu et al. (JGR 2009)
D-6, 5/6 2008
0600UT, 1300LT

D-5, 5/7 2008
0600UT, 1300LT

D-4, 5/8 2008
0600UT, 1300LT

D-3, 5/9 2008
1400UT, 2100LT

D-2, 5/10 2008
0400UT, 1100LT
The GIMs observed at 08:00 UT and global fixed 15:00 LT on day 3 before the 2008 Mw7.9 Sichuan Earthquake.
Observations and Simulations of seismo-ionospheric GPS TEC anomalies before the 12 January 2010 M7.0 Haiti Earthquake
The latitude-time-TEC plots extracted from the GIM during 4-15 January 2010.
Locations of the 30-day extreme enhancement (maximum) repeatedly appear at various time points on the local day of 11 January 2010 in Haiti.
Conclusion

• The observation shows that the TEC over the epicenter significantly enhances on 11 January 2010, 1 day before the Haiti earthquake.

• The spatial analysis further demonstrates that the enhancement anomaly specifically and persistently appears for the entire day in a small region in the northern epicenter area.
The 11 March 2011 M9.0 Tohoku earthquake
模擬結果可知海嘯到時與浪高中
Year: 2011, DOY: 070, Time: 05:40:00 UT
Time-differencing TEC (dTEC) for 29 GPS receiver-satellite pairs.
The correlation between the 29 epochs of the maximum dTEC and the corresponding distances from the epicenter reported by USGS to the sub-ionospheric points (SIPs), denoted by circles.
Contour of standard deviation (STD) of the travel times estimated by the 3-dimensional spherical simulation model.
Time-differencing TEC (dTEC) for 29 GPS receiver-satellite pairs for tsunami.

Tsai et al. (EPS submission 2011)
The correlation between the 29 epochs of the maximum dTEC and the corresponding distances from the epicenter reported by USGS to the sub-ionospheric points (SIPs), denoted by circles for tsunami.
Contour of standard deviation (STD) of the travel times estimated by the 3-dimensional spherical simulation model for tsunami.

Tsai et al. (EPS 2011)
Conclusion

- The GPS TEC variations of the pre-earthquake anomalies and the co-seismic ionosphere disturbances are about 1 and 10 TEC units (1 TECu=10^{16} \text{el/m}^2), respectively.
- The pre-earthquake anomalies are possibly induced by seismo generated electromagnetic signals (EM process), while the co-seismic ionosphere disturbances could be triggered by vertical surface motions of seismic and tsunami waves (mechanical process).
敬請批評指教 Thank you!!!