Modelling of periodic TEC variations associated by the Earthquake

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1. Introduction

The Sumatra-Andaman earthquake of 26 December 2004 was a large seismic moment magnitude (Mw) 9.3. The epicenter is located at 3.30N, 99.95E of the northern Sumatra with its onset time at 00:58:53 UT. This earthquake did not only generate the tsunami wave in the ocean, but it was also the one that leaded the disturbances in the ionosphere. Recently, by using ground-based GPS receiver, the disturbances in the ionosphere can be observed, and extracted the perturbations of Total Electron Content (TEC).

2. TEC Observations

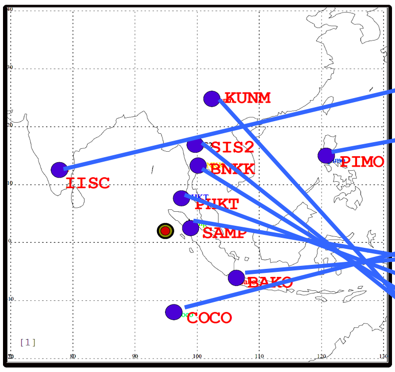


Figure 1 shows the area of the study and the epicenter of the Sumatra Earthquake (3.30N,99.95E), the permanent GPS stations with the 30 seconds sampling rate were selected to use on 26 December 2004 after the Mw 9.3 earthquake occurrence (00:58 UT).

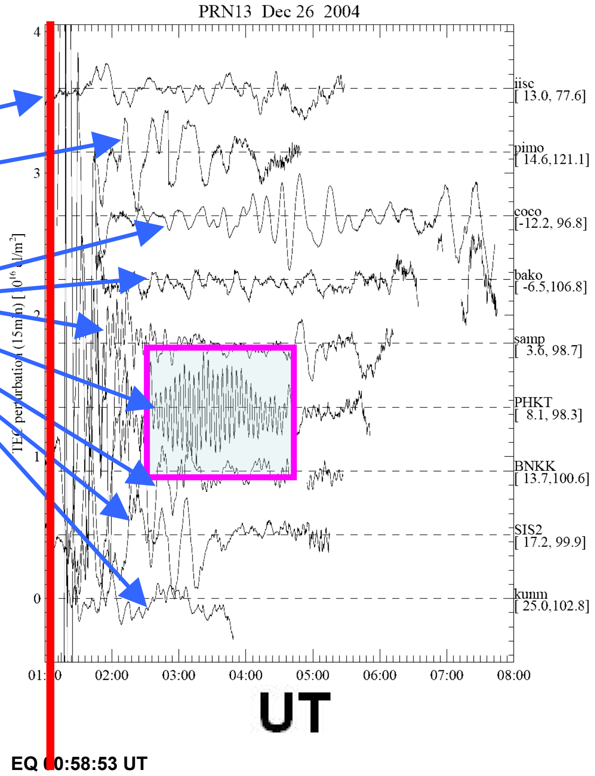


Figure 2 The TEC perturbation of nine GPS receivers of PRN 13. The periodic TEC variations were observed at PHKT station.

The TEC can be extracted from the GPS data and converted to the TEC perturbation in the unit of TECU [1016/m2]. Each Pseudorandom Noise (PRN) of GPS satellite can be provided each TEC data. Figure 2 shows the TEC perturbation at PHKT station with high-pass-filtering with 15 minutes cut-off of PRN13 at each station. Clear Periodic TEC variation was observed at Phuket (PHKT) station PRN13 ~1 hr after the Earthquake

The four minutes periodicity of TEC perturbation.

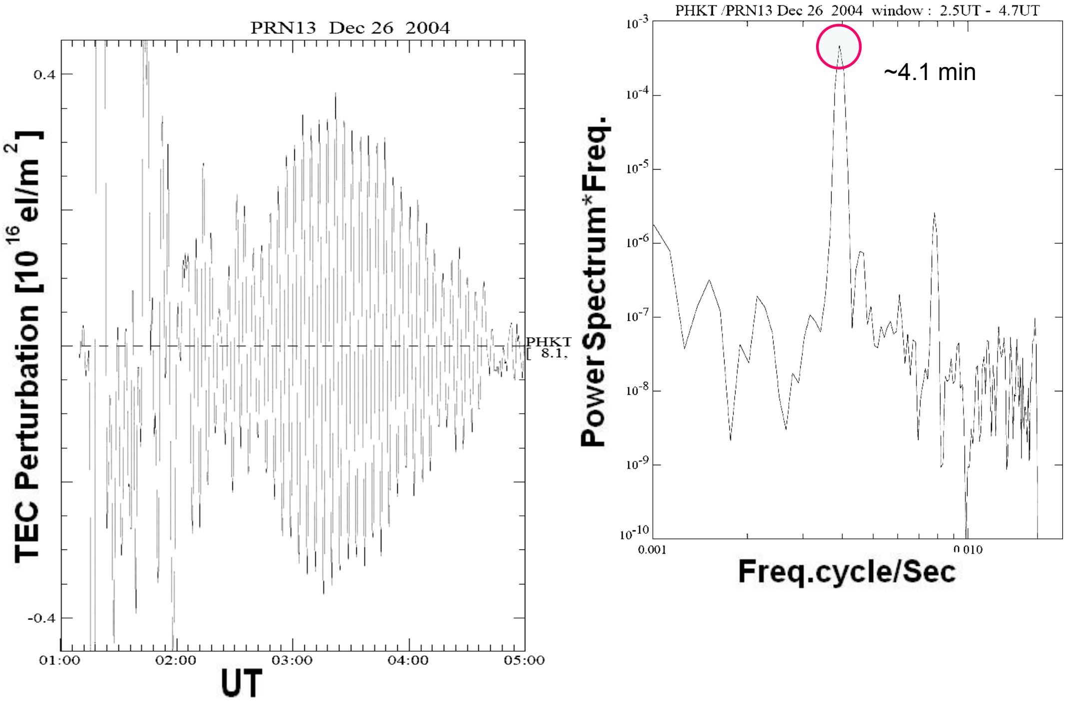


Figure 3 The Power Spectrum of PRN 13 at PHKT station. During the period of 2.5 UT – 4.7 UT, the four minutes period variation is dominant.

The clear periodic TEC variations in Figure 2 were the quasi-periodic TEC perturbations of four minutes. To infer that they were the four minutes periods, we plot the power spectrum of TEC variations by using FFT method. Figure 3 show the power spectrum of PRN 13 of PHKT station during 2.5UT and 4.7UT.

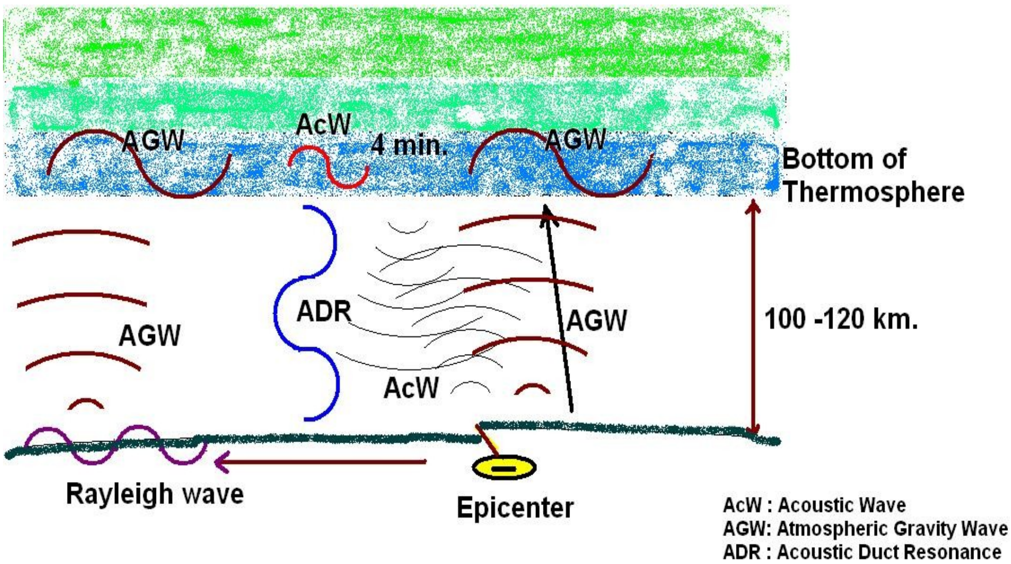


Figure 4 The sketch of wave propagations after the 26 December 2004 Sumatra Earthquake.

It was showed that the AcW propagated when the Earthquake occur, the vertical uplift of earth crustal (ground surface) generated the AcW in term of the atmospheric air-pressure propagated from the epicenter. The AcW propagated through the atmosphere and hit the Bottom of the thermosphere. Some of them reflected and back propagated to the ground. In this case, the Acoustic Duct Resonance (ADR) was generated [Iyemori et al., 2005]. The long duration times of periodic TEC perturbations of four minutes period may be causes by ADR between the ground surface and the bottom side of the thermosphere. The ADR could be oscillating for long time with its resonances property and also become to the "source" of the four minutes periodic TEC variations in the ionosphere.

3 Zenith Angle dependence

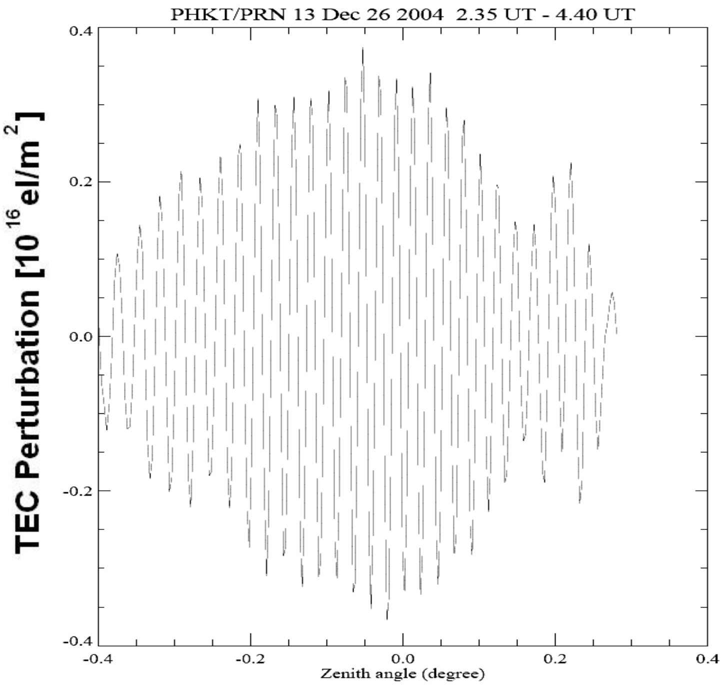


Figure 5 Zenith angle dependence

Figure 5 illustrates the observational data of the amplitude change with the effect of the zenith angle change. The amplitude increases when the satellite moves above the GPS station. The amplitude is maximum when the satellite is above the station (zenith angle = 0.0). The amplitude decreases when the satellite moves out to the GPS station.

4. Modelling of periodic TEC variations

In order to understand this phenomenon, a numerical model was used to simulate the periodic TEC perturbations. Where as TEC = sin(kx +π/2), k =2π/w, x=(300+t)*tan(θ) which are t : Thickness of electron density and w: wavelength. Figure 6 show the simple sinusoidal waveform of acoustic wave in the ionosphere was applied to this model. The ionospheric structure was assumed to be at 300 km altitude with some kilometers of its thickness.

The model shows good agreement to the observational data that the amplitudes of periodic TEC perturbations were dependent on the elevation angle of the GPS radio wave

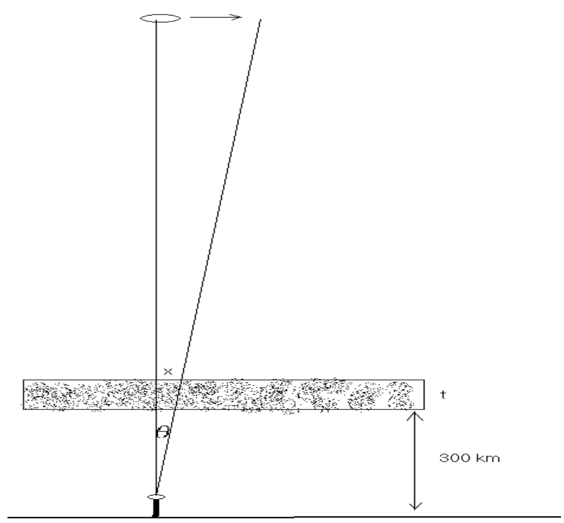
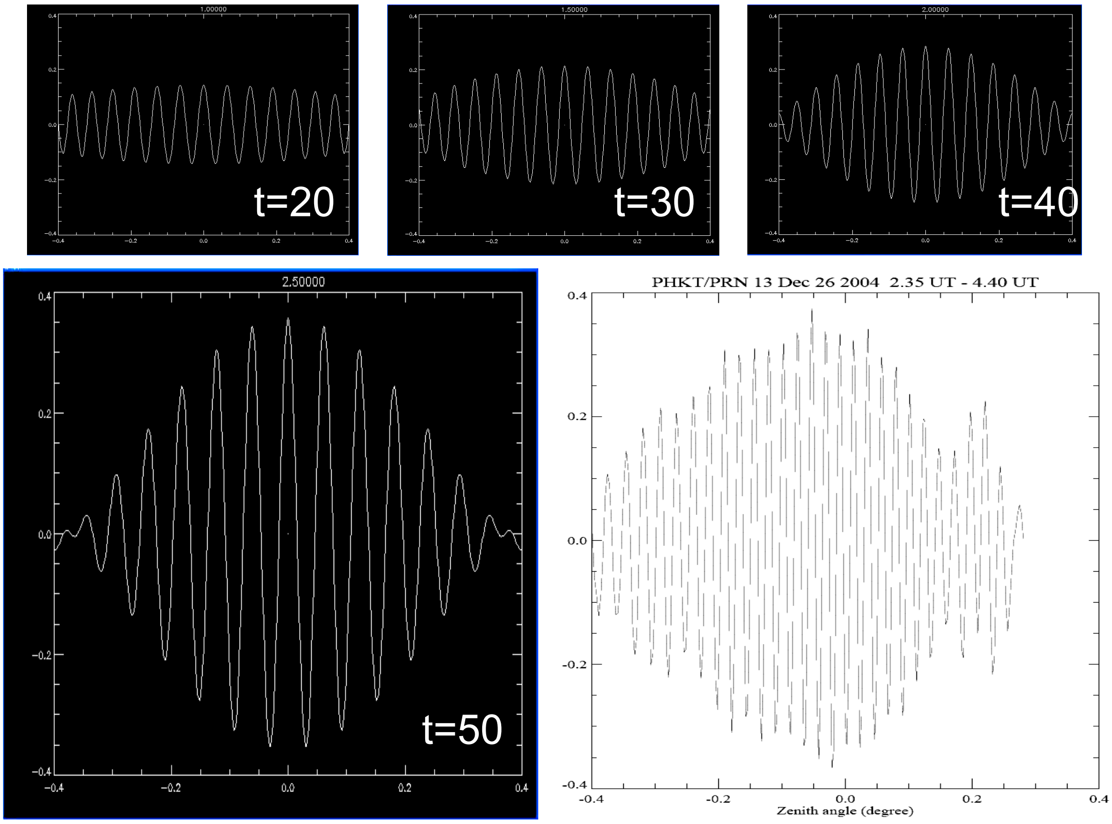


Figure 6 the model ionospheric structure path. The maximum amplitudes of the periodic TEC perturbations were observed when the elevation angle of the radio wave path between a GPS satellite and a receiver at its maximum.



Observations data

Figure 7 The Comparison between The Observational data and Model Estimation

5. Conclusions

After the 26 December 2004 Sumatra Earthquake, the periodic TEC perturbations were observed. The observational data shows that the periodic TEC perturbations had clear four minutes period and oscillated for about two hours. We believed that acoustic waves generated by the earthquake played an important role to generate this kind of the periodic TEC perturbations in the ionosphere. In order to understand this phenomenon, a numerical model was used to simulate the periodic TEC perturbations. The simple sinusoidal waveform of acoustic wave in the ionosphere was applied to this model. The ionospheric structure was assumed to be at 300 km altitude with some kilometres of its thickness. The model shows good agreement to the observational data that the amplitudes of periodic TEC perturbations were dependent on the elevation angle of the GPS radio wave path. The maximum amplitudes of the periodic TEC perturbations were observed when the elevation angle of the radio wave path between a GPS satellite and a receiver at its maximum. The model also reproduced the temporal and special structures of the observational periodic TEC perturbations.