STUDY OF THE IONOSPHERIC RESPONSE TO SURFACE WAVES GENERATED BY LARGE EARTHQUAKES

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Introduction

Global Positioning System is a powerful technique for monitoring the ionosphere. The quantity measured is the Total Electronic Content (TEC), that is the integrated quantity of the electronic density along the satellite - beacon ray path. Dense GPS networks like the Japanese network GEONET provide the proper sampling (~10 km) for imaging seismogenic ionospheric waves (whose wavelengths are hundreds of kilometers) finely. In instrumented regions, changes in the surrounding GPS-TEC map are observed for almost all the large earthquakes (magnitude greater than 6) within ten minutes after the rupture. This time corresponds to the propagation delay needed by the forced atmospheric waves to reach the ionospheric altitudes. In some favourable configurations, an integrated "seismo-ionospheric" radiative pattern is visualized. We are aiming here to investigate the potential of extracting informations on the source from the different type of waves observed. Their coupling with the atmosphere is very efficient and we observed at ionospheric level an overlap of the sound wave by the surface waves signal just after the Tokachi-Oki - 2003, September 25th Mw=8.1 earthquake. 3D synthetics of the atmospheric waves generated by surface waves are modelled by a normal modes summation method, where the solid earth is surrounded by an atmosphere with a radiative boundary condition. The geomagnetic field influence as much as the effect of ion drag are finally included in the three dimensional model developed according to the ionospheric coupling model.

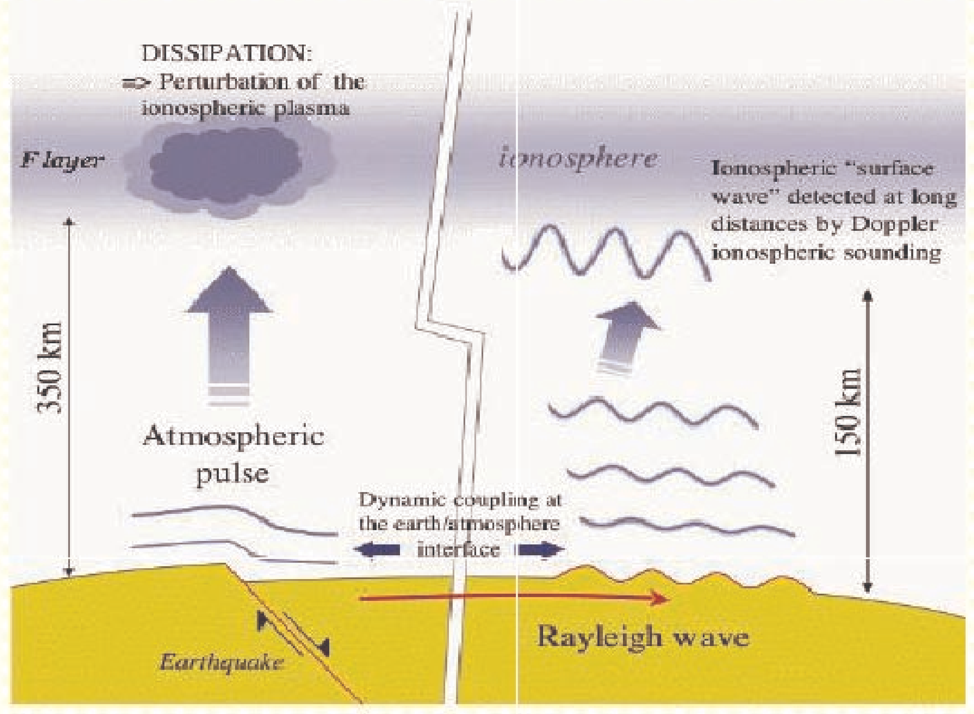


Fig. 1 : Coupling mechanisms between earth, its atmosphere and ionosphere involved after an earthquake (courtesy of J. Artru-Lambin)

I-1) Observation technique

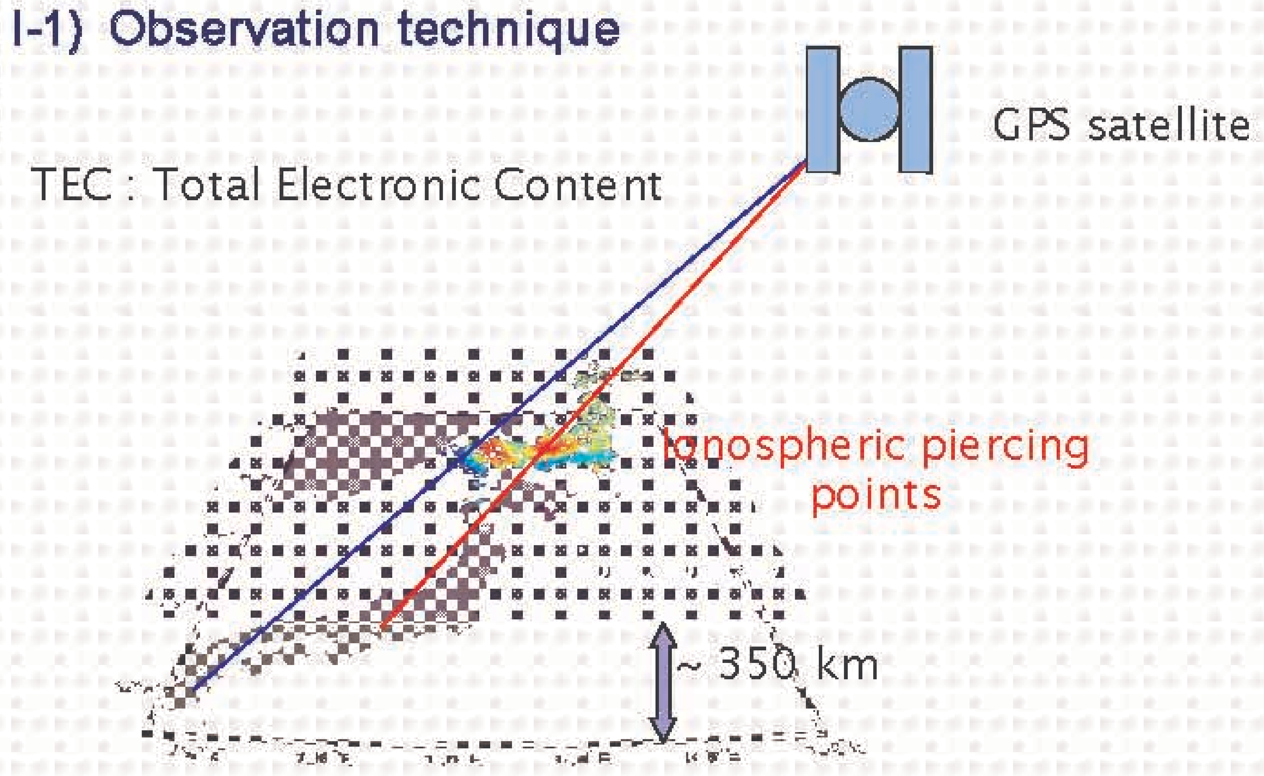


Fig. 2: Ionospheric mapping

I-2) Seismo-ionospheric waves imaging

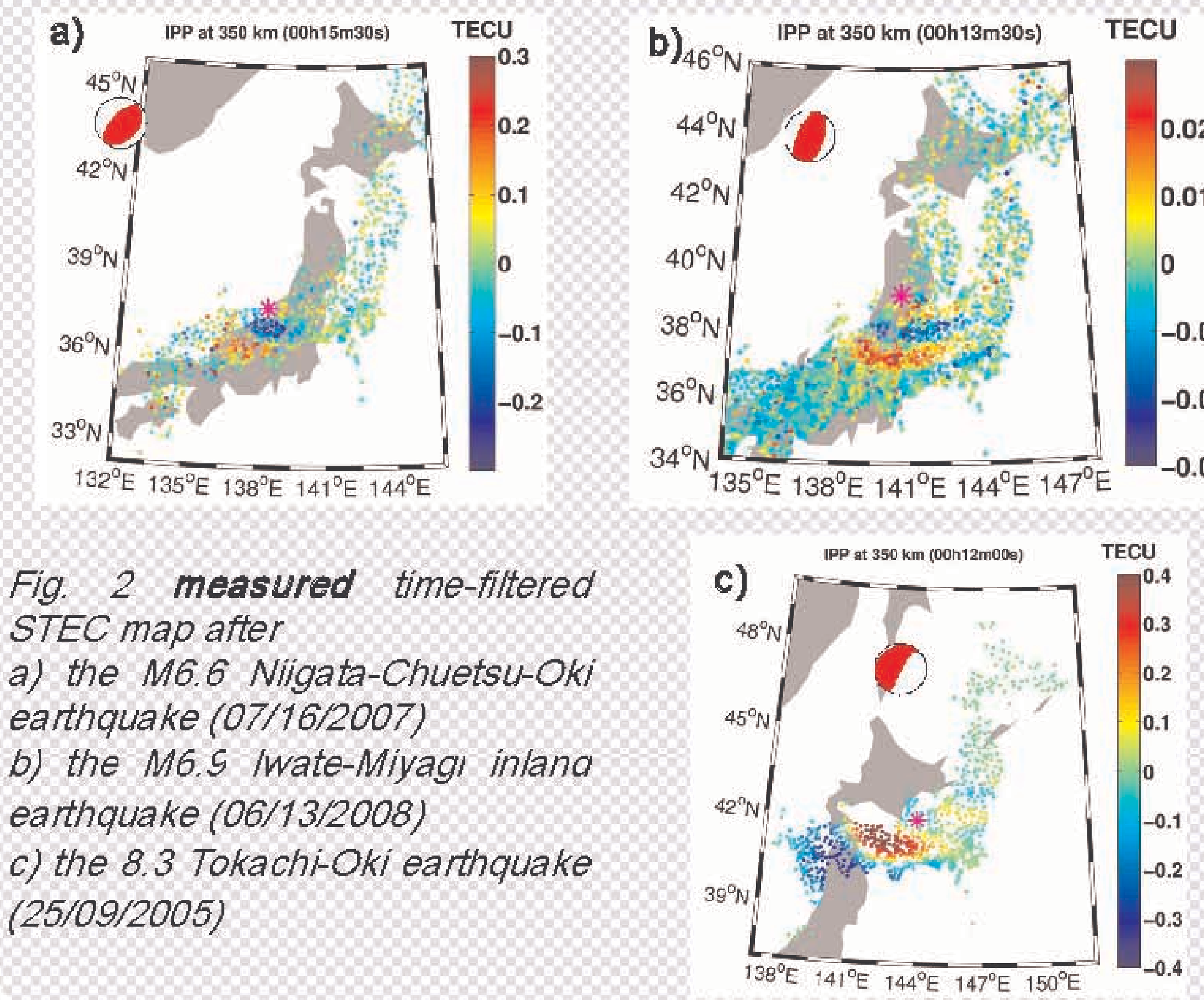


*Fig. 2 **measured** time-filtered STEC map after*
a) the M6.6 Niigata-Chuetsu-Oki earthquake (07/16/2007)
b) the M6.9 Iwate-Miyagi inland earthquake (06/13/2008)
c) the 8.3 Tokachi-Oki earthquake (25/09/2005)

II-1) Acoustic plume modelling

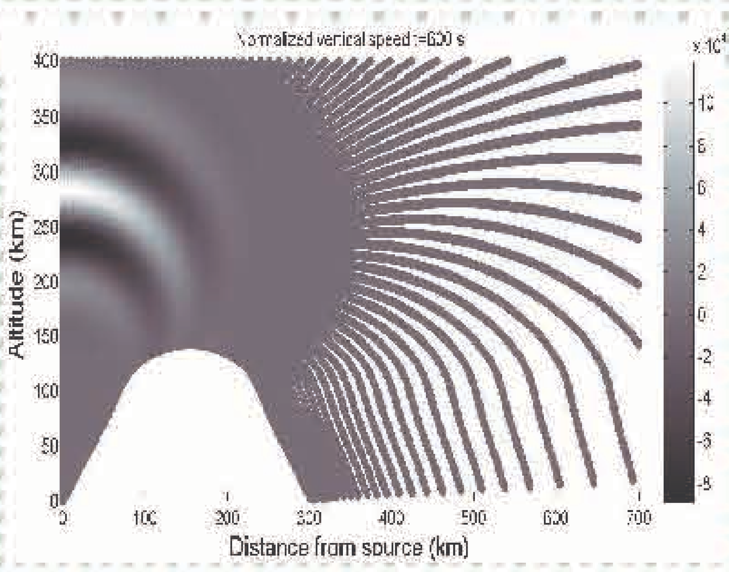


Fig. 4 : Acoustic plume launched in a stratified atmosphere : models the earthquake effect above the epicenter (after Heki & Ping, 2005)

Local B (42°N 144°E)

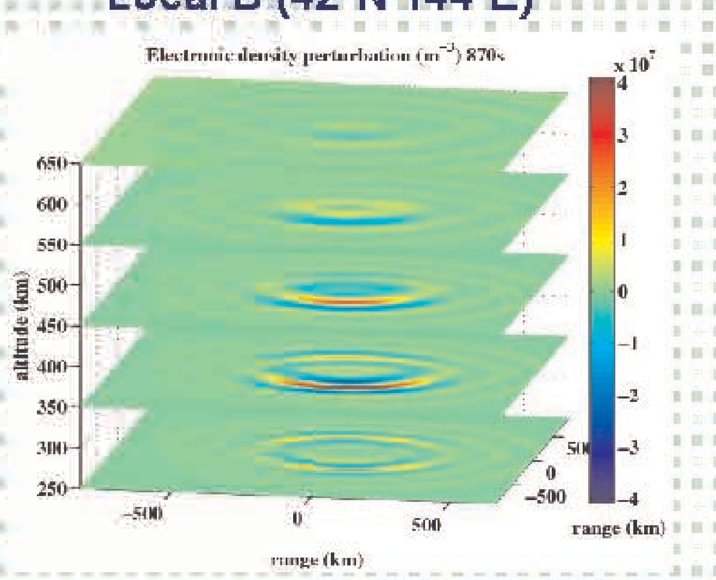


Fig. 5 : Simulated 3D electronic perturbation under the effects of an acoustic plume and the local geomagnetic field (I~60°, D~-10°).

I-3) Two kinds of waves

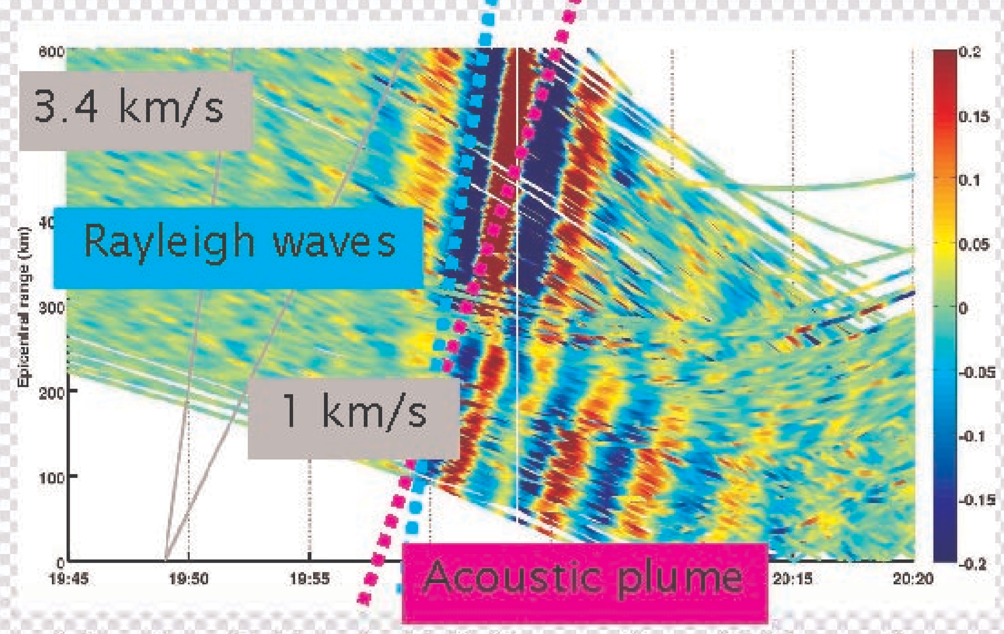


Fig. 3 : Epicentral distance time TEC series measured during the M=8.3 2003/9/25 Tokachi-Oki earthquake

II-2) Rayleigh waves modelling

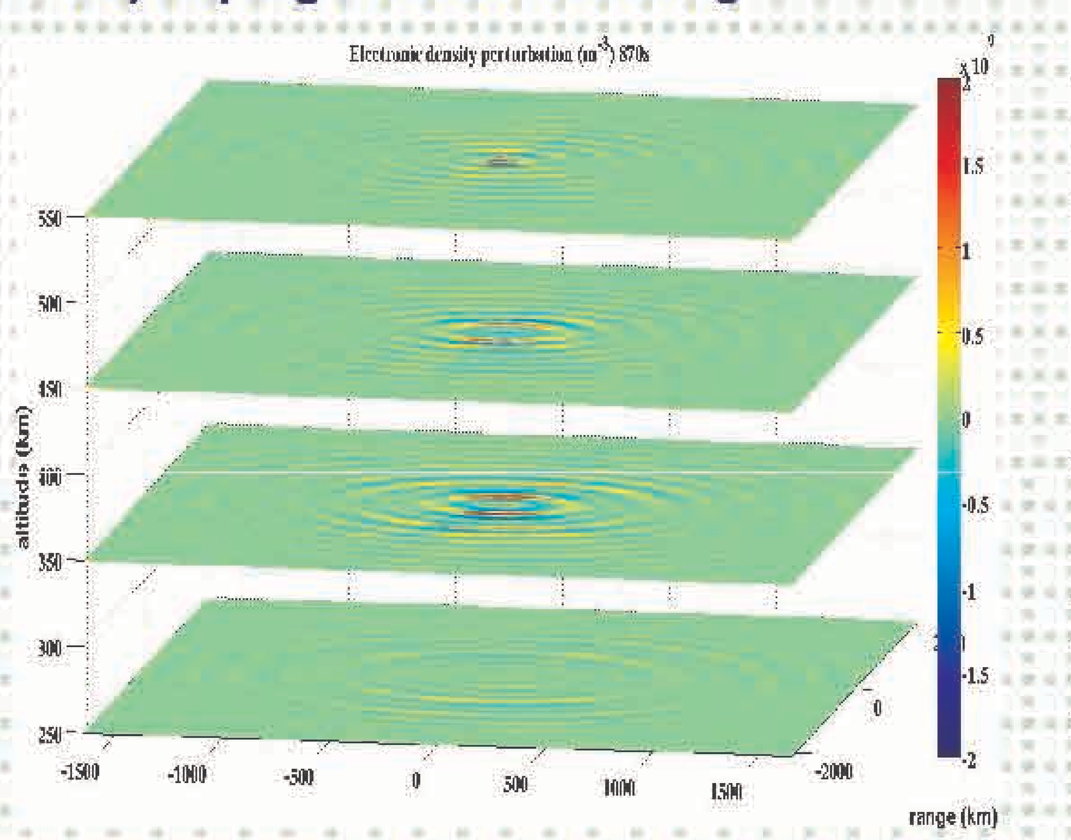


Fig.7 : Synthetics of the electronic density perturbation (horizontal slices) caused by Rayleigh waves 14m30s after the earthquake.
From normal modes summation technique (Lognonne et. al.,1998) applied with the CMT Harvard source parameters of the Tokachi-Oki earthquake. The North-South anisotropy is much fainter than in the acoustic plume case (see on fig.5).

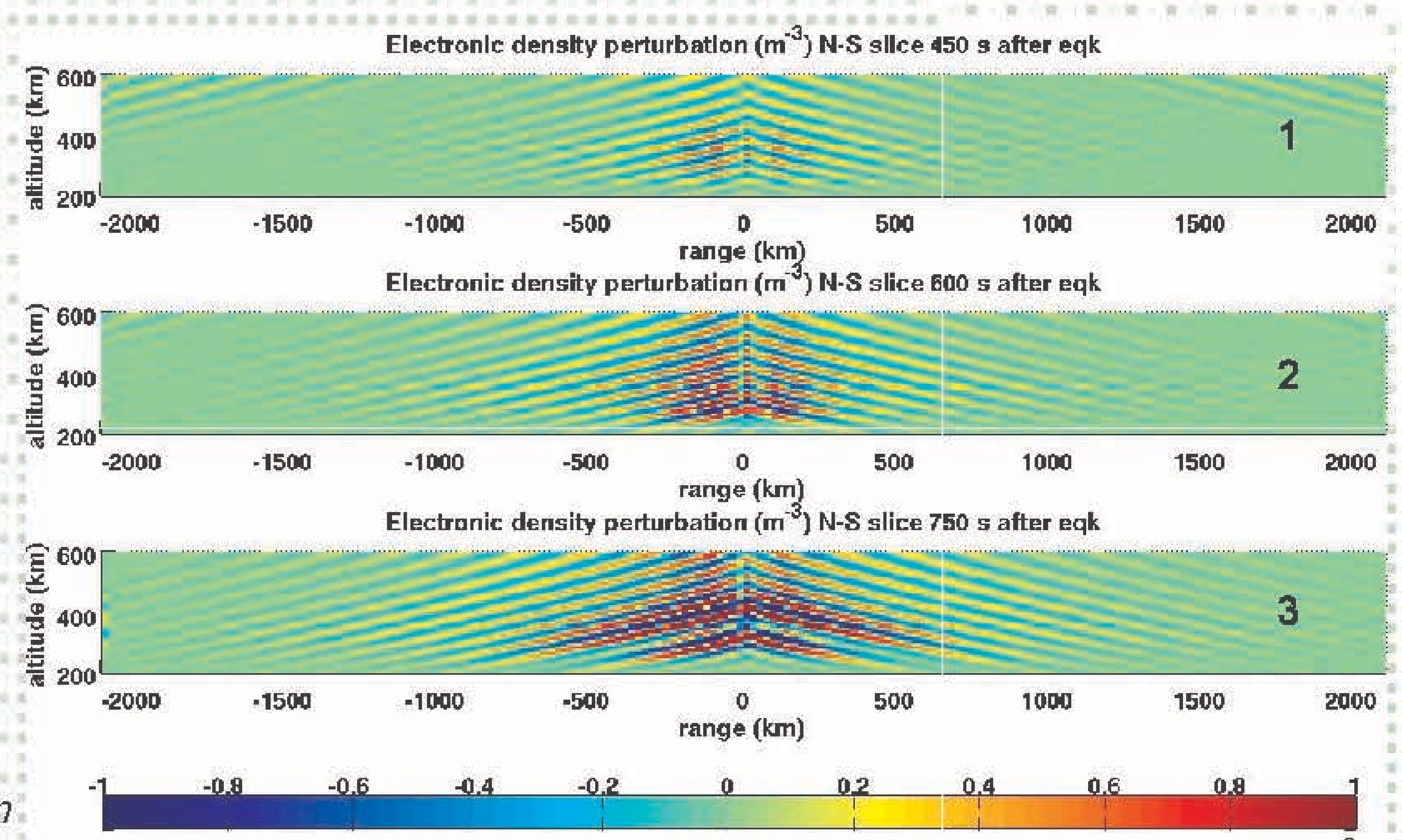
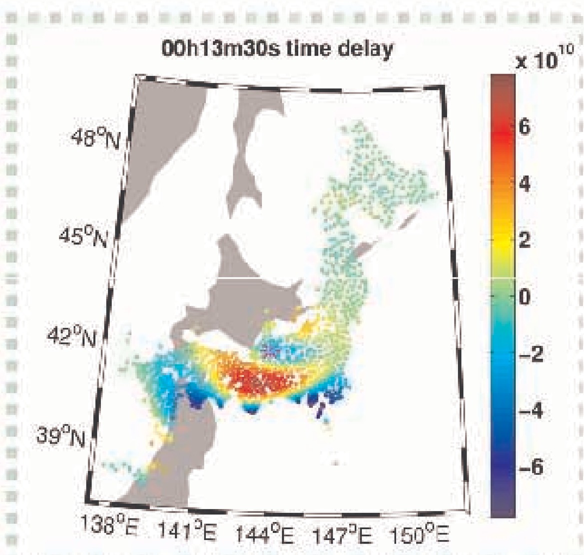


Fig.7 : Synthetics of the electronic density perturbation (vertical slices) caused by Rayleigh waves 7m30s, 10m and 12m30s after the Tokachi-Oki earthquake. The South is on the left side and North is on the right side. The waveform of the electronic density perturbation is very similar to the vertical velocity of the neutral atmospheric wave forced by the surface wave passage at ground level.

III) Data fitting

*Fig. 8 a) **synthetic** TEC map modelled by integration of the 3D perturbed electronic density (calculated by method II.1) along the GEONET stations-satellite ray paths*



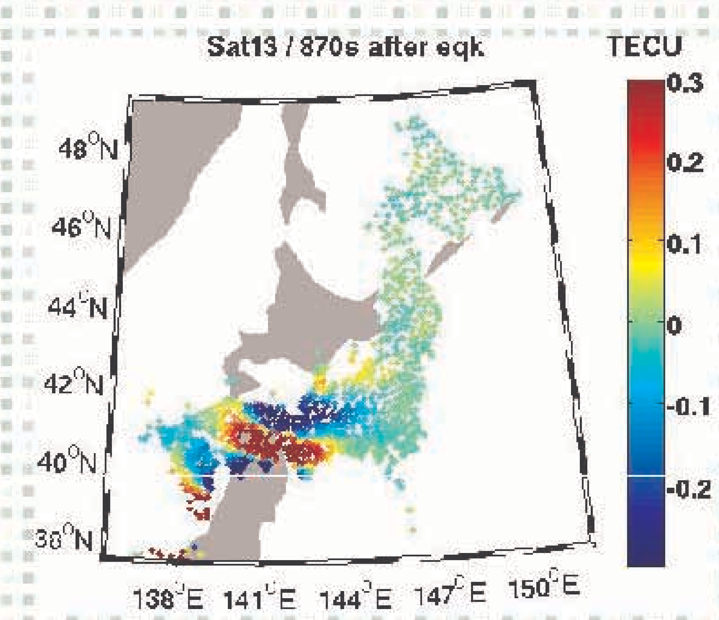


*Fig. 8 a) **synthetic** TEC map modelled by integration of the 3D perturbed electronic density (calculated by method II.2) along the GEONET stations-satellite ray paths*

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