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STRONG EARTHQUAKE PREDICTION POSSIBILITY WITH THE HELP OF TOPSIDE SOUNDING FROM SATELLITES

S. A. Pulinets

Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation, Russian Academy of Sciences, (IZMIRAN), Troitsk, Moscow Region, 142092, Russia

ABSTRACT

Large scale variations of electron density height distribution during specific local time intervals were discovered over regions where an earthquake was anticipated with the help of topside sounder installed onboard the orbiting satellite. Observed variations occur on time scale of the order 1 to 3 day before the earthquake. Mapping of the modified region have shown the ring structure forming within the ionosphere over the future epicenter position. Comparison with ground-based sounding shows that the satellite technique is preferable for detection and mapping of the epicenter position. Pure seismic monitoring and seismic risk methods could give estimations of the magnitude of the future earthquake, it is possible to determine the position of future epicenter, but no technique can give an answer to the question **"when?"** on a time scale of days. The satellite topside sounding could complement a global earth-space system of seismic warning and prediction. Experimental data for several earthquakes will be presented and a space seismic warning system will be proposed.

TOPSIDE SOUNDING PRINCIPLES

Topside sounding from onboard an orbiting satellite is a kind of remote sensing of near earth plasma (ionosphere). The sounder is an HF radar working within the frequency band of 0.1(or 0.3) MHz up to 16(or 20) MHz with the changing of sounding frequency from lower to higher edges of the band (frequency sweep). First topside sounders were designed basing on analogous circuits, but the latest models use a digital synthesizer with frequency step of 25 kHz and 50 kHz. In (Pulinets, 1989) one can find description of the sounder, whose data are used in present paper. The pulses emitted by the sounder on consecutive frequencies are reflected on different heights depending on electron density height distribution. The time delay dependence of emitted pulses on

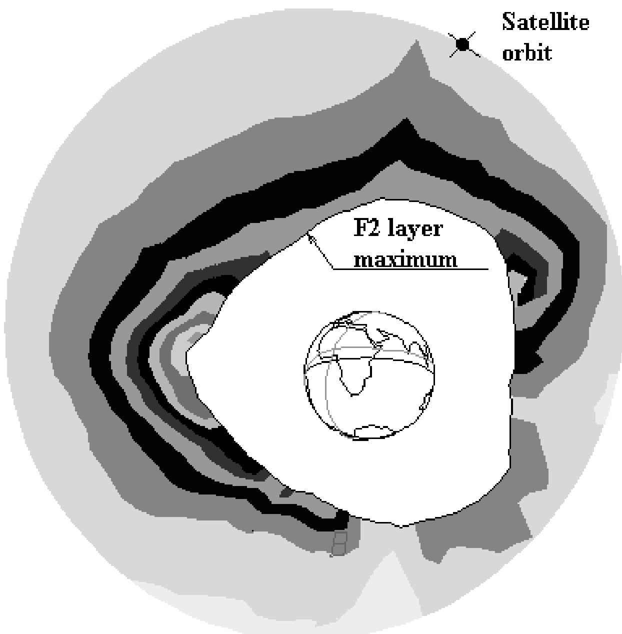

Fig. 1 Schematic presentation of topside ionosphere electron density cross-section produced by one orbit of topside sounder installed onboard the satellite

the frequency is called the height-frequency characteristic of ionosphere or ionogram, which with the help of a special algorithm, which takes into account the propagation characteristics of electromagnetic waves in magnetized plasma (Jackson, 1969), could be transformed into density height distribution from the height of satellite orbit up to maximum of F2 layer density distribution, which is usually situated at height of 250 to 350 km. One orbit cross-section of the ionosphere density distribution as it is seen from satellite is shown in Fig.1. The advanced methods were elaborated for automatic calculation of electron density profiles using the topside sounder data (Xuequin and Reinisch, 1982). For satellites with high inclination orbits, the longitude step between consecutive orbits is of the order of 25°. Taking into account the period of satellite orbit (~100 min at a height ~ 1000 km), during one day after 14.4 rotations we can obtain a global survey of the earth's ionosphere state for two local times (the high inclination orbit satellites have almost sun-synchronized orbit). The LT global maps of ionospheric parameters could be built every 24 hours. Having several satellites in orbit posed in different local time sectors, we are able to globally monitor the Earth's ionosphere (Pulinets, 1989), see Fig. 2.

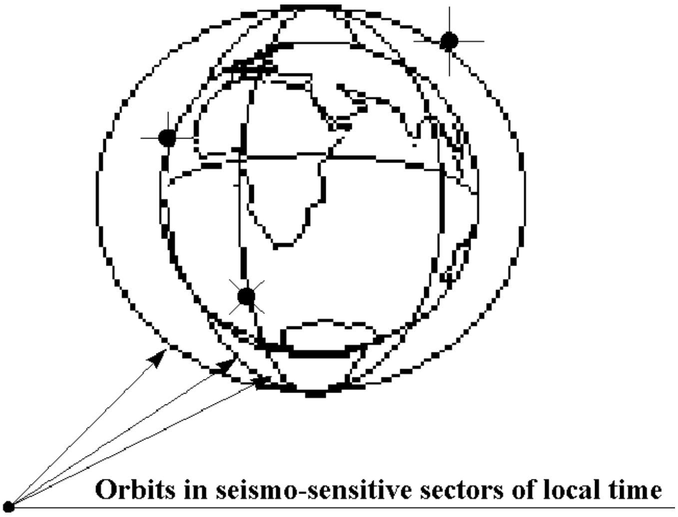

Fig. 2 Schematic presentation of the space system for seismic warning

IONOSPHERIC PRECURSORS OF THE STRONG EARTHQUAKES

With the help of a topside sounder installed onboard the Intercosmos-19 satellite, strong variations in the vertical structure of the ionosphere over the region of preparing earthquake were discovered (Pulinets et al., 1994). These include variations of electron density in F-layer maximum manifested in critical frequency variations. The density height distribution variations imply a change of the positive ion composition within the F-layer of the ionosphere. The ionosphere rises over the seismo-active region forming a dome of density depletion. These variations are most intensive for specific intervals of local time, i.e. before the sunrise (4 to 5 h LT) and in afternoon hours (14 to 18 h LT). These variations are demonstrated in Fig. 3 and 4. One can follow up in Fig. 3 the dynamics of development of a two dimensional distribution of the critical frequency deviation over the region where an earthquake took place on 16.07.80 in the

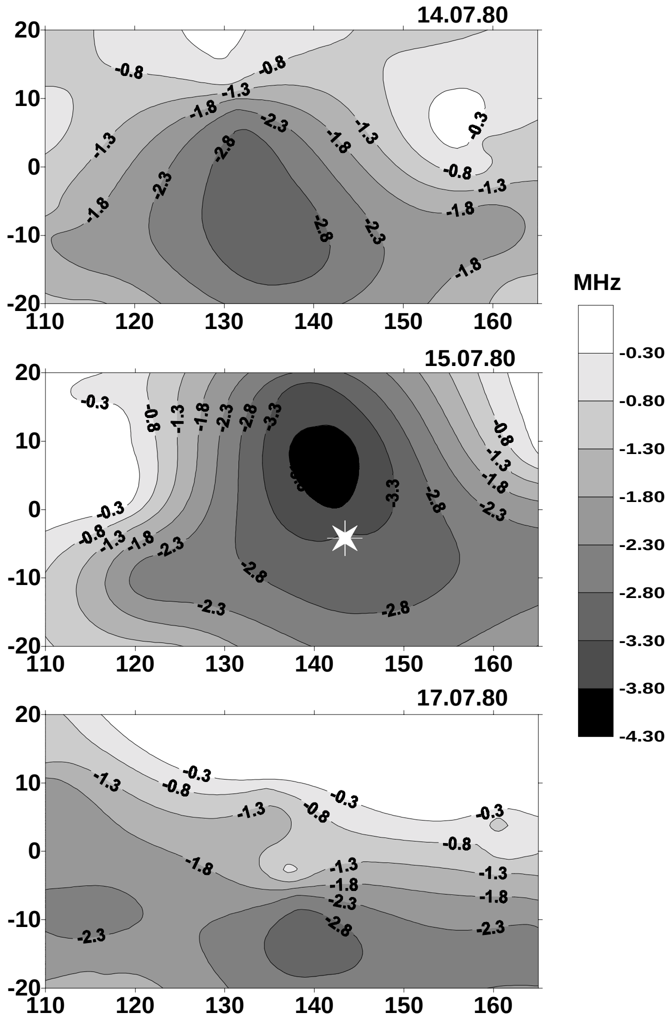

Fig. 3 Spatial distribution of Δf_0F2 over the region of anticipated earthquake (top and middle panels) and day after earthquake (bottom panel)

Australian and New Guinea Islands region. The distributions are built for the early morning hours two day before the earthquake (upper panel of the Fig. 3), one day before the earthquake (middle panel of the Fig. 3), and the day after earthquake (bottom panel of the Fig.3). Maximal dimensions of the disturbed region reach ~35° in latitude and ~60° in longitude. It should be noted that the maximal deviations are observed not exactly over the epicenter. The complex electrodynamical, meteorological and chemical processes involved in the ionospheric disturbance development probably are responsible for the observed displacement. Nevertheless, the satellite measurements clearly indicate the region of the future earthquake, and the exact position of the epicenter should be determined by ground-based pure seismological techniques after the satellite warning. The main advantage of the satellite technique is the time-scale stability of the observed ionospheric effects in anticipation of an earthquake.

In the Fig. 4 one can observe variations in F-layer height built as an integral picture for exclusively high seismic activity for 13 to 18 of June 1980, when more than 20 shocks of magnitude 5 or higher were registered in the New Guinea Islands region. The epicenter positions are marked by crosses. The seismic activity has an effect on the equatorial anomaly position. Its undisturbed position is shown in the figure by dashed line. **A** and **B** regions belong to undisturbed equatorial anomaly, while **C** and **D** regions reflect modification of ionosphere peak height by seismic activity. One can find a more detailed description of the technique for ionospheric precursors extraction in Pulinets et al. (1996).

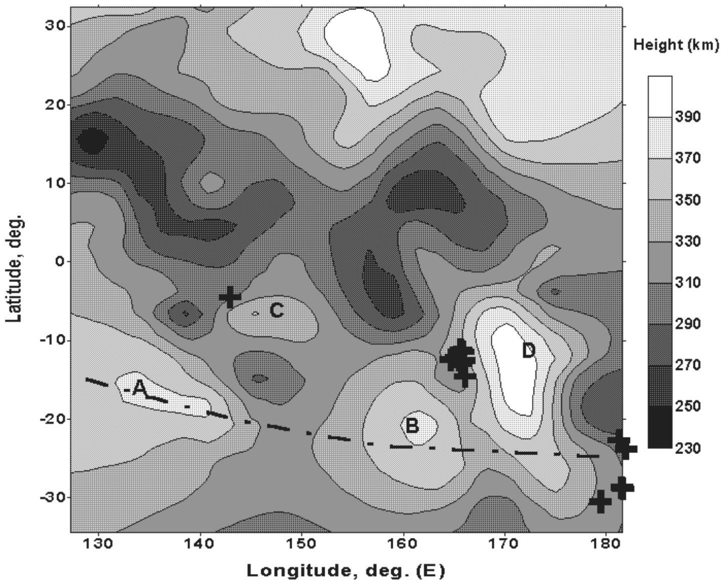

Fig. 4 Modification of the F2 layer peak height h_mF2 distribution during extremely high seismic activity in the vicinity of equatorial anomaly

Physical interpretation of the observed ionospheric variations is still under discussion. Nevertheless, it is possible to draw a rough interpretation which is supported by experimental evidence. One of the main sources of atmosphere-ionosphere modification over the regions of preparing earthquakes is the emanation from the earth of different chemical substances. We can mention among them radon, light gases (hydrogen and helium), and sub-micron aerosols with high metal content (Alekseev and Alekseeva, 1992; Alekseev at al., 1995). It leads to changes of electrodynamic properties of the atmosphere over the region of an anticipated earthquake and as a result to the observed phase variations of VLF signals passing over these regions. Aerosols in the atmosphere lead to the formation of large-scale electric fields up to several kV/m (Kikuchi, 1991). These vertical fields are mapped into the ionosphere where they transform into horizontal fields (Kim et al., 1994). This, in tern give rise to Joule heating, electron temperature growth within the ionosphere, gravity waves generation and formation of small-scale ionospheric irregularities. The large-scale irregularities observed by topside sounder could be caused by different reasons: large-scale horizontal electric fields, rise of electron temperature, increasing of light ions concentration, O^+ field-line convection or combination of the mentioned processes.

POSSIBLE GROUND-SPACE SYSTEM FOR SEISMIC WARNING

The experimental data from this research contributed to the study of seismo-ionospheric effects. Even for limited quantity of the data, the main characteristics of ionospheric disturbance dynamics were determined. Preliminary results warrant the construction of an operational satellite system. The technique created. Naturally, the satellite system should be supported by the ground-based measurements. The patrol satellites should be launched into the most effective sectors of local time (sensitive to seismo-ionospheric variations) on the circular solar synchronized orbit at 800 to 1000 km height (see Fig.2). The satellite should be equipped together with the topside sounder, by ELF-VLF receivers (effectiveness of this method was shown in many works, for example (Larkina et al., 1989)), *in situ* plasma parameters measurements, electric and magnetic field measurements, ion composition measurements and optical measurements. These ideas were implemented in the proposals for the special Sub-satellite for Active Measurements (SAM), which will be the part of the international satellite WARNING project devoted to the study of seismo-ionospheric coupling effects. Operative control and cooperation with ground-based seismo and ionospheric stations should be provided. As additional means for the global control of the ionosphere, the total electron content (TEC) measurements should be noted. The global network of the stations, using signals from the satellites of Global Positioning System (GPS), makes real the current global monitoring of the ionosphere (Lindquister et al., 1996). The information from this network together with topside sounding data will make the determination of the seismo-active regions more reliable. One can hope that the multi-parametric data procession of different kinds of ionospheric measurements will help solve the problem of earthquake prediction.

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