Ionosphere Sounding for Pre-seismic anomalies identification (INSPIRE): Results and Perspectives

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The INSPIRE project is dedicated to the study of physical processes and their effects in ionosphere which could be determined as earthquake precursors together with detailed description of the methodology of ionospheric pre-seismic anomalies definition. It was initiated by ESA and carried out by international consortium. Anomalous variations registered in the ionosphere before earthquakes were reported as early as in 1960's after the Alaska "Good Friday" earthquake [1]. The purposeful studies of ionospheric precursors with the use of ground based ionosondes started in 1970's [2]. Development of the seismo-ionospheric anomalies identification techniques was carried out in parallel with the development of the physical mechanism explaining these anomalies generation [3]. The full set of key parameters of the ionospheric plasma was selected basing on the retrospective analysis of the ground-based and satellite measurements of pre-seismic anomalies. Using this classification the multi-instrumental database of worldwide relevant ionospheric measurements (Ionosonde and GPS networks, LEO satellites with in situ probes including DEMETER and COSMIC RO) was developed for the test cases.

The physical mechanisms of the ionospheric pre-seismic anomalies generation from ground to the ionosphere altitudes were formulated within framework of the Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model [4]. The processes of precursor's development were analyzed starting from the crustal movements, radon emission and air ionization, thermal and atmospheric anomalies, electric field and electromagnetic emissions generation, variations of the ionospheric plasma parameters, in particular vertical TEC and vertical profiles of the electron concentration. Assessment of the LAIC model performance with definition of performance criteria for earthquake forecasting probability has been done in statistical and numerical simulation domains of the Global Electric Circuit. The numerical simulations of the earthquake preparation process as an open complex system from start of the final stage of earthquake preparation up to the final point – main shock confirms that in the temporal domain the ionospheric precursors are one of the most late in the sequence of precursors. The general algorithm for the identification of the ionospheric precursors was formalized taking into account the external Space Weather factors able to generate the false alarms. Importance of the special stable pattern called the "precursor mask" was highlighted which is based on self-similarity of pre-seismic ionospheric variations. The role of expert decision in pre-seismic anomalies interpretation for generation of seismic warning is important as well. The algorithm performance of the LAIC seismo-ionospheric effect detection module has been demonstrated using the L'Aquila 2009 earthquake as a case study.

The results of INSPIRE project have demonstrated that the ionospheric anomalies registered before the strong earthquakes could be used as reliable precursors. The detailed classification of the pre-seismic anomalies was presented in different regions of the ionosphere and signatures of the pre-seismic anomalies as detected by ground and satellite based instruments were described what clarified methodology of the precursor's identification from ionospheric multi-instrumental measurements. Together with scientific and technical tasks the set of political, logistic and administrative problems should be resolved for the real earthquake forecast effectuation.

References

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