

IEEE International Geoscience and Remote Sensing Symposium

"Remote sensing for a Dynamic Earth"

22-27 July 2012, Munich, Germany

**VALIDATION OF ATMOSPHERE/IONOSPHERE SIGNALS ASSOCIATED WITH
MAJOR EARTHQUAKES BY MULTI-INSTRUMENT SPACE-BORNE AND
GROUND OBSERVATIONS**

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The latest catastrophic earthquake in Japan (March 2011) has renewed interest in the important question of the existence of pre-earthquake anomalous signals related to strong earthquakes. Recent studies (DEMETER 2006, 2011 and VESTO 2009 workshops) have shown that there were precursory atmospheric/ionospheric signals observed in space associated with major earthquakes. The critical question, still widely debated in the scientific community, is whether such ionospheric/atmospheric signals systematically precede large earthquakes. To address this problem we have started to investigate anomalous ionospheric / atmospheric signals occurring prior to large earthquakes.

We are studying the Earth's atmospheric electromagnetic environment by developing a multi-sensor model for monitoring the signals related to active tectonic faulting and earthquake processes. The integrated satellite and terrestrial framework (ISTF) is our method for validation

and is based on a joint analysis of several physical and environmental parameters (thermal infrared radiation, electron concentration in the ionosphere, lineament analysis, radon/ion activities, air temperature and seismicity) that were found to be associated with earthquakes.

A physical link between these parameters and earthquake processes has been provided by the recent version of Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model [Pulinets and Ouzounov, 2011]. Our experimental measurements have supported the new theoretical estimates of LAIC hypothesis for an increase in the surface latent heat flux, integrated variability of outgoing long wave radiation (OLR) and anomalous variations of the total electron content (TEC) registered over the epicenters. Some of the major earthquakes are accompanied by an intensification of gas migration to the surface, thermodynamic and hydrodynamic processes of transformation of latent heat into thermal energy and with vertical transport of charged aerosols in the lower atmosphere. These processes lead to the generation of external electric currents in specific regions of the atmosphere and the modifications, by dc electric fields, in the ionosphere-atmosphere electric circuit.

We retrospectively analyzed temporal and spatial variations of four different physical parameters (gas/radon counting rate, lineaments change, long-wave radiation transitions and ionospheric electron density/plasma variations) characterizing the state of the lithosphere /atmosphere coupling several days before the onset of the earthquakes [Arellano et al, 2006; Kon et al, 2011; Liu et al, 2009; Němec et al, 2009; Píša et al, 2011, Yang et al, 2007; Ouzounov et al, 2007 and 2012]. Validation processes consist in two phases: A. Case studies for seven recent major earthquakes: Japan (M9.0, 2011), China (M7.9, 2008), Italy (M6.3, 2009), Samoa (M7, 2009), Haiti (M7.0, 2010) and, Chile (M8.8, 2010) and B. A continuous retrospective analysis was performed over two different regions with high seismicity- Taiwan and Japan for 2003-2009.

Satellite, ground surface, and troposphere data were obtained from Terra/ASTER, Aqua/AIRS, POES and ionospheric variations from DEMETER and COSMIC-1 data. Radon and GPS/TEC were obtained from monitoring sites in Taiwan, Japan and Italy and from global ionosphere maps (GIM) respectively. Our analysis of ground and satellite data during the occurrence of 7 global earthquakes has shown the presence of anomalies in the atmosphere. Our results for

Tohoku M9.0 earthquake show that on March 7th, 2011 (4 days before the main shock and 1 day before the M7.2 foreshock of March 8, 2011) a rapid increase of emitted infrared radiation was observed by the satellite data and an anomaly was developed near the epicenter [Ouzounov et al, 2011]. The GPS/TEC data indicate an increase and variation in electron density reaching a maximum value on March 8. From March 3 to 11 a large increase in electron concentration was recorded at all four Japanese ground-based ionosondes, which returned to normal after the main earthquake. Similar approach for analyzing atmospheric and ionospheric parameters has been applied for China (M7.9, 2008), Italy (M6.3, 2009), Samoa (M7, 2009), Haiti (M7.0, 2010) and Chile (M8.8, 2010) earthquakes. Results have revealed the presence of related variations of these parameters implying their connection with the earthquake process.

The second phase (B) of this validation included 102 major earthquakes ($M > 5.9$) in Taiwan and Japan. We have found anomalous behavior before all of these events with no false negatives. False alarm ratio for false positives is less than 10% and has been calculated for the same month of the earthquake occurrence for the entire period of analysis (2003-2009). The commonalities for detecting atmospheric/ionospheric anomalies are: i.) Regularly appearance over regions of maximum stress (i.e., along plate boundaries); ii.) Anomaly existence over land and sea; and iii) association with $M > 5.9$ earthquakes not deeper than 100km. Due to their long duration over the same region these anomalies are not consistent with a meteorological origin. Our initial results from the ISTF validation of multi-instrument space-borne and ground observations show a systematic appearance of atmospheric anomalies near the epicentral area, one to seven (average) days prior to the largest earthquakes, and suggest that it could be explained by a coupling process between the observed physical parameters and the pre-earthquake preparation processes.

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