ISSI proposal (for second year extension)

Earthquakes influence ionosphere as evident from satellite plasma density-electric field data

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Abstract

The project is aimed to the fundamental problem of Lithosphere-Atmosphere-Ionosphere Coupling due to Seismicity (LIACS). It combines results of observation both on board of satellites and on the ground together with theoretical interpretation of the results. Original approach to processing of the over- the-world electric field-plasma density variations recorded on a board of the satellites Cosmos-900, Intercosmos-24 and Aureol-3 allows us to find the statistical properties of the Ionospheric Turbulence (IT), its connection with ionospheric Equatorial Anomaly and its association with seismicity. In addition we consider also the geochemistry and ultra-low frequency magnetic field variations observed on the ground (at Kamchatka, Russia; and Italy), ground surface temperature changes retrieved on the base of NOAA satellites infra-red data (above Japan, Kamchatka and China) and seismo-induced perturbations from sounding by VLF and LF transmitter signals the atmosphere and lower ionosphere (at Japan, Kamchatka, Italy). As result a general scheme of the LAICS reveals. It includes generation of the internal gravity wave turbulence (GW) near the ground surface due to intensification of the temperature and atmospheric density variations related to seismicity; propagation of GW energy flux through the atmosphere into ionosphere; transformation of the seismo-induced GW atmospheric turbulence in the electrostatic IT at the lower ionosphere followed by transformation of the electrostatic IT in the electromagnetic Alfven and isotropic compression waves at the middle ionosphere and inverse influence the IT on penetration of the ULF magnetic pulsations from magnetosphere to the ground surface. In this framework the proper theoretical modelings have been started.

Report on first year scientific activity related to the project 45 "Earthquakes influence ionosphere as evident from satellite plasma density-electric field data" (Molchanov-Lefeuvre's team) **and proposal for second year continuation**

I. First year activity

. There were two meetings in the first year of the project performance: in September 9-20,2002 and April 22-May3, 2003. During these meetings the following reports have been presented and discussed in details:

1. Molchanov O. A (5 reports, on general concept, on results of Intercosmos-24 satellite observations on results of Ultra-Low Frequency observation in Kamchatka area and on modification of the Ionospheric Turbulence by seismicity).
2. Tronin A.A. (2 reports, on results of NOAA satellite observations of the ground temperature in association with earthquakes (EQ hereafter) appearance).
3. Akentieva O.S. (2 reports, on results of satellite Cosmos-900 and Aureol-3 observations).
4. Hobara Y. (2 reports, on results of satellite Aureol-3 observations).
5. Mareev E.A. (3 reports, on mosaic source of seismo-induced gravity waves and energy transport into the ionosphere, and on cascade processes in the ionosphere)
6. Pokhotelov O.A. (2 reports, on on seismo-associated temperature anomaly and on possibility of theoretical explanation of direct and inverse cascade processes in the ionospheric turbulence).
7. Balikhin M. (1 report, on fractal distribution of the seismo-associated temperature anomaly at the ground surface).
8. Biagi P.F. (3 reports, on geochemistry EQ precursors and on Low Frequency signal sounding of the atmospheric perturbations related to large EQs in Italy)
9. Lefeuvre F. (1 report, on nonlinear nature of the Ionospheric Turbulence)
10. Parrot M. (1 report, on the satellite project DEMETER)

The main results pointed out after discussions were:

a) Using long-time databases of IK-24, Cosmos-900, Aureol-3 satellite observations of electric field and plasma density variation it was pointed out that Ionospheric Turbulence (IT, hereafter) shows specific distribution on spatial scales with characteristic fractal number b = 1.4-2.1 from hundreds km to a few meters. It means that IT is a united process and it probably develops in a way similar to classic Kolmogorov's turbulence.
b) IT is connected with Ionospheric Equatorial Anomaly and during seismo-active periods both fractal number and IT intensity have a tendency to decrease.
c) Using the data of the atmosphere radio-sounding by VLF, LF and HF waves collected in different regions (Japan, Italy, and Kamchatka, Russia), it was pointed out that these radio-signals can change several days before large EQs. Such variations could be explained by an intensification of the atmospheric turbulence associated with the preparatory phase of EQs.
d) Using satellites data, the appearance of thermal anomalies on the Earth's surface around the date of some large EQs was discovered.
e) The analysis of the geochemical data collected in Kamchatka during the last 24 years revealed a clear correlation of water and gas eruption in a period about ± 10-20 days around the occurrence of some large EQ that can lead to the heating of the atmosphere near-surface layer.
f) The analysis of the ultra-low frequency (ULF) magnetic variations in the Kamchatka area revealed a statistically reliable depression of the ULF intensity several days before the

occurrence of large EQs. It can be explained by some IT modification in connection with EQ activity and by the corresponding decrease of the magnetic pulsation penetration through ionosphere.

As a result of the discussion at the meetings a general concept of the lithosphere-atmosphere-ionosphere coupling due to seismicity was outlined. It includes:

- Upward migration of the water-gas substrate to the ground surface during EQ preparation process.
- Generation of the internal gravity wave turbulence (GW) near the ground surface due to intensification of the temperature and atmospheric density variations related to seismicity.
- Propagation of GW energy flux through the atmosphere into ionosphere.
- Transformation of the seismo-induced GW atmospheric turbulence in the electrostatic IT at the lower ionosphere.
- Transformation of the electrostatic IT in the electromagnetic Alfven and isotropic compression waves at the middle ionosphere
- Inverse influence the IT on penetration of the ULF magnetic pulsations from magnetosphere to the ground surface.

In this framework the following theoretical consideration were developed:

A) Modeling of the upward migration of the gas-liquid " bubbles" due to stochastic interaction of water-saturated fractures.
B) Generation of GW energy flux induced by atmospheric near-surface temperature and density variations.
C) Propagation and focusing of the GW energy flux through atmosphere into the ionosphere
D) Generation of electrostatic IT in a presence of GW pumping and stationary neutral wind
E) Connection between turbulent variation of the electric field and electron density in the ionosphere

The first results of the data analysis and of the theoretical modeling are submitted to publication in 16 papers (see Annex I).

Annex I

Listing of papers, which are submitted for publication in a framework of ISSI project 45

1. Biagi PF., Molchanov O.A., T. Maggipinto, R. Piccolo, A. Ermini, A. Khatkevich and E. Gordeev, Detecting a seismic precursor, (*submitted, 2003)
2. Biagi PF., Molchanov O.A., T. Maggipinto, R. Piccolo, A. Ermini, A. Khatkevich and E. Gordeev, Correlation of seismicity and hydrogeochemical parameters from long-time observation at Kamchatka region, (*submitted, 2003)
3. Tronin A., PF Biagi., O.A. Molchanov, A. Khatkevich and E. Gordeeev, Temperature variations related to earthquakes from simultaneous observation at the ground stations and by satellites above Kamchatka area, (**submitted , 2003).
4. Tronin A., O.A. Molchanov and P.F. Biagi, Thermal anomalies and well observations in Kamchatka, (in press, Int. J. of Remote Sensing, 2003)
5. O.A. Molchanov, P.F. Biagi , A.Yu. Schekotov ,E.N. Fedorov, G.G. Belyaev, E.E. Gordeev , and M. Hayakawa , Preseismic ULF electromagnetic, hydrogeochemical and radio-physical effects and possible explanation by upward gas-liquid migration, (**submitted, 2003).
6. P.F. Biagi, R. Piccolo, A. Ermini, S. Martellucci, C. Bellecci, G. Perna, V. Capozzi, O.A. Molchanov, and M. Hayakawa, Variations in a LF radio-signal on the occasion of the recent seismic and volcanic activity occurred in Southern Italy, (**submitted, 2003).
7. Mareev E., D. Iudin, O. Molchanov, Penetration of gravity wave energy from mosaic seismic source into the ionosphere, (submitted, RadioScience, 2003)
8. Molchanov O.A. , O. A. Akentieva, V. V. Afonin, E. A. Mareev and M. Hayakawa, Small-scale electric field turbulence near ionospheric equatorial anomaly and possibility of seismic influence from data of Intercosmos-24 satellite, (**submitted, 2003).
9. Hobara Y., M. Parrot, F. Lefeuvre and O.A. Molchanov, Ionospheric turbulence associated with seismic activity from Aureol-3 satellite data, (**submitted, 2003).
10. Molchanov O.A., A.Yu. Schekotov, E. N. Fedorov, G.G. Belyaev, M. Solovieva, and M. Hayakawa, Preseismic ULF effect and possible interpretation, (submitted to Annals of Geophysics, 2003).
11. V.M. Sorokin, E.N. Fedorov, A.Yu. Schekotov, O.A. Molchanov and M. Hayakawa, Depression of the ULF Geomagnetic Pulsation Related to Occurrence of the Ionospheric Irregularities, (submitted to Annals of Geophysics, 2003).
12. Molchanov O.A. , A. Yu. Schekotov , E.N. Fedorov , and M. Hayakawa, Ionospheric Alfven Resonances events from observation at Kamchatka, (**submitted, 2003).
13. E.V. Liperovskaya, M. Parrot, O. A. Pokhotelov, M. A. Balikhin, Electromagnetic effects of lithosphere origin in the ionospheric F-layer, (submitted to Annals of Geophysics, 2003).
14. O. A. Pokhotelov , O. G. Onishchenko, R. Z. Sagdeev and R. A. Treumann, Nonlinear dynamics of the inertial Alfven waves in the Earth's ionosphere. Generation of convective cells, (submitted to JGR, 2002).
15. E. V. Liperovskaya, O. A. Pokhotelov, Y. Hobara, and M. Parrot, Variability of sporadic E layer semi transparency (foEs - fbEs) with magnitude and distance from earthquake epicenters to vertical sounding stations, (*submitted, 2003).
16. Molchanov O.A., E.N. Fedorov, E. A. Mareev, and M. Hayakawa, About origin of the low-midlatitude ionospheric turbulence, (**submitted, 2003).

Notes : a)* means submission in the **Natural Hazards and Earth System Sciences** after presentation in the EGS/AGU symposium in Nice b)**means submission in the **Physics and Chemistry of the Earth** after presentation in the EGS/AGU symposium in Nice

c) Underlining authors are participants of the ISSI project or invited consultants.

II Proposal for the second year activity

We believe that the main part of the observation data analysis and essential part of the necessary theoretical modeling is already produced. Previous results have been used to generate a global coupling model. Validity tests have been performed from observations produced on-board satellites and at ground. For that purpose, new analyses have been applied to data already studied in the past as well as to new data. Interpretation of the results have led us to select possible models at each interface, then to point out remaining questions.
The main remaining questions are the following ones :

a. Discussion on the seismological aspects of geochemistry anomalies;
b. Addition of data on atmosphere HF (FM) radio-sounding during seismo-active periods
c. Comparison of method of satellite thermal observation in Italy and Kamchatka
d. Modeling of the transformation of the electrostatic Ionospheric Turbulence in the fast electromagnetic Alfven modes inside ionosphere
e. Modeling of the non-linear three-wave interaction as a mechanism of development of the Ionospheric Turbulence.

Two or three other specialists would be very useful to help us to answer these questions. A provisional list of persons to contact has been established. The objective that will be proposed to the permanent team members and to the new specialists will be to publish a comprehensive review of the whole problem in a scientific journal with referees.

In order to achieve the above programme we would like to extend the project for the next year, in a frame of the usual ISSI financial regulations. We hope to discuss all the remaining problems during next two meeting in ISSI with participation of 5-7 specialists mainly from our team. In a case of the second year continuation of the project we are going to present the results in the comprehensive review, which could be published either in Space Science Review or in Review of Geophysics. Draft of the review content is presented in the Annex II.

Heads of the team,

Francois Lefeuvre

Oleg Molchanov

Annex II

Lithosphere-Atmosphere-Ionosphere Coupling due to Seismicity (LAICS)

(review, as a result of ISSI project 45 activity)

Introduction:

- There are several types of LAICS, e.g. due to the ionospheric currents (Sq magnetic field variation on the ground, magneto-telluric variation inside lithosphere), volcano eruption effects and so on. We are interested in the earthquake (EQ) influence the atmosphere and ionosphere.
- Three possibility of LAICS were discussed till now: origin of seismo-induced electric field; change of conductivity leading to change of thunderstorm activity ; and penetration of near-surface perturbation into the atmosphere and ionosphere by atmospheric acoustic-gravity waves (AGW). We will mainly discuss the latter possibility.

Chapter 1. Origin of near the ground perturbations related to strong EQs

1.1 Evidence of the water flux and gas-ion content variations related to seismicity:
- change in the difference values ,
  1 Biagi et al.
- correlation functions with Ks indices

1.2 Case study on the changes near-surface air temperature during large EQs in Kamchatka;
2. Biagi et al.

1.3. Satellite observations of the Earth's surface temperature related to large EQs,
3. ,4. Tronin et al.

1.4. Possible explanation of the observation results, mechanisms of seismo-induced atmospheric variations:
- Due to tectonic deformations
- Due to upward migration of the gas-liquid substrate,
  5. Molchanov et al.

Chapter 2. Atmospheric perturbations related to EQs

2.1. Radio-physics effects:
- VLF signal effect
- Over-horizon HF (FM) scattering in the atmosphere during EQs
- LF effect from observation during big EQs and volcano eruption in Italy,
  6. Biagi et al.

2.2.Generation of AGW near the ground surface and their propagation into the ionosphere,
7. Mareev et al.

Chapter 3. Modification of the ionospheric turbulence (IT) connected with seismicity

3.1. Evidence from the satellite observations:
- Results from registration on the Cosmos-900 and Intercosmos-24 satellites,
  8. Molchanov et al.
- Results form observation on the Aureol-3 satellite,

9.Hobara et al.

- Demonstration of non-linear nature of the IT (Lefeuvre et al.).

3.2. Influence of the IT modification before EQs on the ground ULF reception,

10. Molchanov et al., 11. Sorokin et al.

3.3. Influence of the seismic IT modification on the upper ionosphere from analysis of the Ionospheric Alfven Resonance structure recorded on the ground ,

12. Molchanov et al.

3.4. Generation of IT and mechanisms of its modification due to seismicity:

- Different instabilities,

  13.Liperovskaya et al., 14. Pokhotelov et al., 15. Liperovskaya et al.
- IT generation due to neutral wind influence,

  16. Molchanov et al.

Conclusions

- Universal nature of the atmospheric and ionospheric turbulence
- Application of the results to the future satellite projects (DEMETER) and probability of EQ forecast.