ISSI proposal

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

Team leaders: F. Lefeuvre (LPCE, France) and O. Molchanov (UIPE, Russia).

Team members: M. Hayakawa (UEC, Japan), M. Balikhin, (Sheffield. Univ., UK), P.F. Biagi (Univ. of Bari, Italy), O. Pokhotelov (IPE, RAS, Russia) and E. Mareev (IAP, Russia).

Background of the research

This research is related to the general problem of lithosphere-atmosphere-ionosphere coupling and especially to seismic influence on the ionosphere plasma.

While appearance of seismic and nonseismic phenomena related to earthquakes on the ground is doubtless, a possibility of observations of seismo-associated effects in the atmosphere and ionosphere is claimed sometimes as questionable. There are quite many papers on satellite recordings of wave/plasma disturbances possibly associated with earthquakes. The first report by Migulin et al. (1982), based on a few examples of ELF/VLF bursts observed on board the Intercosmos-19 satellite above the epicentres of large earthquakes, made a sensation in Russia at that time. The similar findings from other satellites were followed (e.g. Parrot and Lefeuvre, 1985; Molchanov et al, 1993). In addition, seismo-associated events in the satellite ULF magnetic observations, plasma density and ion composition, and even in the fluxes of energetic particles were also reported. However, it is usual to refer to them as result of overoptimistic interpretation. Indeed, it is practically impossible to estimate a reliability of such case studies and to prove that events observed are not simply a coincidence in time of natural nonseismic wave /plasma phenomena and seismic ones (see e.g. reviews by Molchanov, 1993 and Hayakawa, 1997).

Furthermore the mechanisms underlying in the seismo-ionospheric or seismo-atmospheric effects are also unclear. It is recognized that direct penetration from the seismically-active region neither electromagnetic fields (Molchanov et al., 1995) nor quasi-steady electric fields (Pierce, 1976) cannot be very effective. Recently Molchanov and Hayakawa (1998) have reported rather reliable evidence of seismo-associated perturbations into the upper atmosphere from observation of VLF subionospheric signals. They suggest gravity waves (GW) turbulence as agent of such a perturbation. However the quantitative aspects of GW penetration from seismic source inside ionosphere and their interaction with ionosphere plasma is not well understood.

On the other hand, study of seismicity and underlying processes could be essentially improved by using the satellite methods as it happened with climate and weather study when proper satellite information became available. Recently, slow tectonic deformations after some great earthquakes have been analysed by Synthetic Aperture Radar (SAR) installed on the special satellites (e.g. Meyer et al., 1996) and by GPS technique (Calais and Minister, 1995). These remote-sensing efforts might be combined with other effective satellite recordings, first of all with on-board wave/plasma measurements and radar sounding of density perturbations in the space between satellite and ground. In future, these methods might be used for the creation of a global system of earthquake forecast and prevention. However, to do so it is desirable to be sure that atmospheric and ionospheric signature of the earthquakes exists indeed.

Some time ago Afonin et al. (1999) have shown that large data base ($\geq$ 3500 orbits) is needed for the reliable statistical analysis of correlation between satellite recordings of ion density and earthquake activity. They found clear ion density-seismic activity correlation only for the day conditions (10- 16 MLT), quiet magnetic condition ($Kp < 3$) and altitude range around 500- 800 km. The results are rather puzzling and definite questions appeared immediately: what are these special conditions (especially due to altitude limitations in a range of satellite heights from 500 to 2500 km) in which seismo-ionospheric influence is efficient? Is it possible to explain it by seismic triggering of some unstable situation in the ionosphere?

This defines the aims of the project proposed.

Expected Results

The present work is based on *in situ* simultaneous measurements of ion density, electron temperature and electric field fluctuations on board the IK-24 satellite as well as wave and plasma measurements on board the Aureol-3 satellite. IK-24 was launched on Sept.28, 1989 into elliptic polar orbit (perigee 511 km and apogee 2497 km) with inclination angle 82.6° and orbital period 124 min. The instrumentation allowed measuring both large-scale plasma irregularities and small-scale turbulence. As a result we can estimate the large-scale horizontal plasma irregularities along with the data on small-scale turbulence distribution at the altitudes 500-800 km. In particular, we were able to observe very pronounced turbulence generation at the outer slopes of the equatorial anomaly crests and compare them with the near equator turbulence. For IK-24 we are going to produce a sophisticated processing of the satellite data collected during two years of the regular observations starting from November 1989.

Furthermore we are going to use data of French satellite Aureol -3. It was a low altitude satellite launched in 1981 (perigee 400 km, apogee 2000 km, inclination ~ 89 degrees) and operated several years. It was devoted to the study of auroral zones but data have been recorded everywhere along the orbit. Its scientific payload comprised wave and particle experiments. The satellite was operated in two different modes: - a survey mode where reduced data were recorded all around the Earth (for example filterbank are registered by the wave experiment) and a burst mode above specific telemetry stations (waveforms are registered). The data of this satellite have been saved and are currently available in a data base centre in Toulouse (Data Centre of Plasma Physics).

We intend to perform a detailed theoretical analysis of our correlated observational results and try to prove that appearance of large-scale and small-scale irregularities associated with gravity waves from seismic source is possible as shows our preliminary analysis.

Expected contribution

The proposed project duration is two years. The results will be presented in the special reports (twice each year), in the joined papers and final review.

References

Afonin V.V., O.A. Molchanov, T. Kodama, M. Hayakawa, and O.A. Akentieva, Statistical study of ionospheric plasma response to seismic activity: search for reliable result from satellite observations, in *Atmospheric and Ionospheric Electromagnetic Phenomena Associated with Earthquakes*, Edit. by M. Hayakawa, Terra Sci. Publ. Comp., 597-618, 1999.

Calais E. and B. Minister, GPS detection of ionospheric perturbations following the January 17, 1994, Northridge Earthquake, *Geophys. Res. Lett*., **22**, No.9, 1045-48, 1995.
Hayakawa, M., Electromagnetic Precursors of Earthquakes: Review of Recent Activities, *Rev. Radio Sci*., 1993-1995, Oxford Univ. Press, p. 807-818, 1997.
Meyer B., R. Armijo, D. Massonnet, J.B. de Chabalier, C. Delacourt, J.C. Ruegg, J. Achache, P. Briole, and D. Papanastassiou, The 1995 Grevena (Northern Greece) earthquake: Fault model constrained with tectonic observations and SAR interferometry, *Geophys. Res. Lett*., **23**, 2677-80, 1996.
Migulin V.V., V.I. Larkina, O.A. Molchanov, M.B. Gokhberg, A.V. Nalivaiko, and V.A. Pilipenko, Detection of earthquake influence the ELF/VLF emissions at the upper ionosphere, *Preprint of IZMIRAN 25 (2390),* Moscow, 22 pp., 1982 (in Russian).
Molchanov O.A., Wave and Plasma phenomena inside the ionosphere and magnetosphere associated with earthquakes, in, Rev. Radio Sci., 1990-1992, edit. by W.R. Stone, 591-600, Oxford Univ. Press, New York, 1993.
Molchanov O.A., O.A. Mazhaeva, A.N. Goliavin, and M. Hayakawa, Observation by the INTERCOSMOS-24 satellite of ELF/VLF emissions associated with earthquakes, *Ann. Geophysicae*, **11**, 431-440, 1993.
Molchanov O.A., M. Hayakawa, and V.A. Rafalsky, Penetration characteristics of electromagnetic emissions from underground source into the atmosphere, ionosphere and magnetosphere, *J. Geophys. Res*., **100**, A2, 1691-1712, 1995.
Molchanov O.A. and M. Hayakawa, Subionospheric VLF signal perturbations possibly related to earthquakes, *J. Geophys. Res*., **103**, A8, 17489-17504, 1998.
Parrot, M., and F. Lefeuvre, Correlation between GEOS VLF emissions and earthquakes, *Ann. Geophys*., **3(6)**, 737-748, 1985.
Pierce, E.T., Atmospheric electricity and earthquake prediction, *Geophys. Res. Lett.*,**3**, 185- 188, 1976.

Reasons for choosing ISSI as implementation site

The Project suggested be based on the analysis and evaluation of existing unique data from two spacecrafts and eventual integration with theoretical models which corresponds directly to the ISSI goals. International team, involved in the Project, unifies European, Japanese and Russian specialists who have extensive experience in the subject. It is supposed to develop existing theoretical ideas as applied to concrete comprehensive experimental data for the solution of a fundamental physical problem of lithosphere-ionosphere coupling. The unique scientific environment offered by ISSI, joint efforts of leading international space science experts, as well as the world scientific information availability provide the potential for a successful realization of the project.

List of participants

1. Dr. *Francois Lefeuvre*- project leader, head of LPCE, France
2. Prof. *Oleg Molchanov* - project leader, head of the laboratory, UIPE, RAS, Russia.
3. Prof. *Masashi Hayakawa* - head of laboratory, UEC, Tokyo, Japan.
4. Dr. *Michel Balikhin* – Senior researcher, Sheffild University, UK
*5.*Prof. *Pierfranco Biagi*-Professor of the university of Bari, Italy
6. Prof. *Evgeny Mareev* - leading scientist, Institute of Applied Physics, RAS, Nizhny Novgorod, Russia.
7. Prof. *Oleg Pokhotelov*- head of department, IPE, RAS, Russia.

Schedule of the project

1st year: 2 meetings
2nd year: 2 meetings

Required facilities

Personal Computer, Workstation, Access to databases, Library

Financial requirements

1st year: 4 participants x 3 weeks
3 participants x 4 weeks
Total: 24 weeks

2nd year: 4 participants x 4 weeks
3 participants x 3 weeks
Total: 24 weeks

It would be desirable to cover also air-ticket cost Moscow-Zurich-Moscow to 2 participants from Russia:
1st year: 4 trips
2nd year: 4 trips

Appendix:

Addresses, telephone, fax, e-mail of all participants (appended)

1. Dr. F. Leveuvre , head of the laboratory, LPCE/CNRS, 3A Avenue de la Recherche Scientifique 45071 Orleans Cedex 2, France
Tel: (33) (0) 2 38 25 52 91, Fax: (33) (0) 2 38 63 12 34, e-mail: fleveuvere@cnrs-orleans.fr
2. Prof. Oleg A. Molchanov -, project leader, head of laboratory,UIPE, Moscow, Russia, Tel: (7095)-254-8905, Fax: (7095)- 255-6040,
e-mail: ol_molchanov@yahoo.com
3. Prof. M. Hayakawa -, project leader, University of Electro-Communications, 1-5-1 Chofugaoka, Chofu City,Tokyo 182-2525, Japan
Phone: +81-424 43-5159, Fax: (81) 424 43-5783, e-mail: hayakawa@whistler.ee.uec.ac.jp
4. Dr. M. Balikhin, senior scientist, ACSE dep. Univ. of Sheffield, Mappin Street, Sheffield, S1 3JD, UK;Phone: +44-(0)-1142-2225234
E-mail: balikhin@acse.shef.ac.uk
5. Prof. E. Mareev - leading scientist, Institute of Applied Physics RAS, 46 Ulyanov str., 603600 Nizhny Novgorod, Russia
Phone: 7-8312-384292, Fax: 7-8312-362061, E-mail: mareev@appl.sci-nnov.ru
6. Prof. P.F. Biagi- Department of Physiscs, University of Bari, Via Amendola, 173-70126 Bari, Italy.
7. 9. Prof. O. Pokhotelov, head of department,Institute of the Physics of the Earth RAS, 123 810 Moscow, Russia, Phone: 7-095-254-8805, FAX: 7-095-255-60-40
E-mail: pokh@uipe-ras.scgis.ru

Statement from each participant on participation and on financial backing (appended)

By signing this declaration, I certify that the information given in this proposal relating to me is to the best of my knowledge true and complete. I have been involved in the preparation of the

full proposal and I agree with its contents, inc
luding the condition
of 150 EUR/day grant from ISSI to cover my living and accommodation costs during my working visits to ISSI.
I am ready to set up and execute all tasks, duties and obligations assigned to me in this research proposal.

Signature: