

QUESTIONNAIRE

(* – mandatory fields)

	Details about organisation
* Organisation name	M. Nodia Institute of Geophysics
Organisation acronym	MNIG
* Organisation Activity Type (RES - Research, HE - University, SME - Small and Medium Enterprise, IND - Industry, OTH - Other)	RES
* Keywords of main research areas	Physics of Solid Earth, Atmosphere and Ocean, Solar-Terrestrial Physics, Physics of Space
* Head of organisation (first name, family name)	Nugzar Ghlonti
* Post code	0193
* Country	Georgia
* City	Tbilisi
* Street, House	Alexidze str., 1
* Telephone (+ country & city codes)	995 32 33 30 71
* Fax (+ country & city codes)	995 32 33 59 34
* E-mail	Ghlonti60@yahoo.com

*** Description of organisation and its research achievements for the last five years
(~ 5000 signs)**

M. Nodia Institute of Geophysics, Ministry of Science and Education of Georgia
Founded in 1933 on the basis of Tbilisi Magneto-Meteorological Observatory, operating since 1844.

The general problems:

1. Mapping and monitoring of geophysical fields (gravity, seismic, electromagnetic, etc) on the territory of Georgia for revealing their spatial-temporal regularities.
2. Earth's structure, dynamics and evolution models.
3. Seismology, seismic hazard/risk assessment and earthquake prediction.
4. Dynamics of atmosphere and sea and modeling of ecological systems.
5. Physics of atmosphere, clouds, aerosols and weather modification.
6. Solar-Terrestrial Physics (cosmophysics, physics of magnetosphere and ionosphere).
7. Engineering, prospecting and environmental geophysics, geohazards and associated risks, archaeogeophysics, hydrogeophysics, monitoring of stability of large engineering constructions.
8. Fractals and Nonlinear Dynamics in Geophysics.

Director: Dr. Ghlonti Nugzar

Chairman of Scientific Council: Chelidze Tamaz, Professor, Doctor of Sciences Physics and Mathematics, Doctor of Sciences in Chemistry, corresponding member of Georgian Academy of Sciences

Staff: Members of Georgian Academy of Sciences: 3
Number of Doctors of Sciences: 20; number of PhD-s: 65

Structure (Departments):

Seismology and Experimental Geophysics
Dynamics of Geophysical Fields and Computational Geophysics
Physics of Earth and Geomagnetism
Applied Geophysics
Solar-Terrestrial Physics
Physics of Atmosphere
Mathematical Modelling of Geophysical Processes in Sea and Atmosphere
Space Research Center

Periodicals: Journal of the Georgian Geophysical Society (in English, two issues per year); Transactions of Institute of Geophysics (in Russian, one issue per year);

Experimental Bases: Geophysical monitoring network, consisting of Tbilisi Seismological Observatory, 14 seismic, 1 magnetic, 2 strainmeter stations (now partially under Seismic Monitoring Centre)

Dushety Geophysical Observatory;
Earth's Tides International Laboratory;
Thermobarochamber with volume 350 cubic m. , cloud chamber and wind tunnel;

Cosmophysical complex for registration of cosmic rays variations

Ingouri Dam International Test Area

Surface ozone monitoring laboratory (Tbilisi) and station (Ruispiri)

Atmospheric electricity monitoring station (Dusheti)

Data bases: i. The seismic catalogue of Caucasus , including parameters of 50 000 events from 550 B.C. till our time; ii. The data base of gravitational field of Caucasus in various reductions; iii. The aeromagnetic data base of territory of Georgia; iv. The data base of geomagnetic observations of Dushety Geophysical Observatory from 1844 till our time; v. Atmospheric data bases (atmospheric and thunderstorm electricity, clouds radar parameters, precipitations, fogs, atmospheric aerosols, surface ozone concentration.

The main achievements during last 5 years:

- ***Fractals and nonlinear dynamics in geophysics***
- Recent methods of analysis of so called disordered systems show that many objects and processes that earlier were considered as completely random reveal clear evidence of having some ordered structure in both time and space. These new methods (fractals, percolation, nonlinear dynamics and complexity theories) allow visualization and quantitative assessment of the level of complexity (orderliness) of these structures, using both theoretical models and experimental data.
- The physical properties of geophysical medium are not always self-consistent and manifest fractal behavior on selected spatial and temporal scales. Mechanical percolation theory can be used for modeling geometry of fracture

process. Namely, we consider fractal and connectivity aspects of delayed failure, including energy emission during fracturing. Special attention is paid to relating the intensity of geophysical anomalies to the strain in the framework of the pressure-induced anomalous strain-sensitivity (percolation) model, which explains naturally the observed heterogeneity of response of a geophysical media to the strain variation.

- Modern linear and nonlinear tools of time series analysis allow revealing ordered patterns in these complicated recorded geophysical sequences. Extent of complexity of these time series can range from close to determinism or low dimensional chaos to high dimensional (measurable) nonlinear dynamical structure. Application of new universal tools reveals such details in experimental time series, which were beyond the reach of classic data analysis methods and helps to understand and predict geophysical phenomena on different scales.

Our research was aimed to reveal synchronization, including high order synchronization (HOS) in the frictional system, namely in the stick-slip process of spring-slider set up, subjected to weak electromagnetic (EM) or mechanical forcing. The spring-slider system is considered as a proxy of geological faults under tectonic stress; we also guess that the AE during stick-slip is a proxy of seismic activity at the active fault. So it is clear why the spring-slider system is the object of intensive research in seismology and tectonics. Our experiments show that weak enough EM or mechanical forcing invokes synchronization of stick-slip and associated acoustic emission. The analysis of field data round large lake revealed significant increase of order in local seismicity when water filling-discharge regime became periodic. In order to measure the strength of synchronization quantitatively modern methods of analysis were used, such as phase difference and phase diffusion determination technique, Shannon entropy based synchronization measure ($\gamma H-Sh$), recurrence plots (RP) and recurrence quantification analysis (RQA), namely, the percent of determinism - *Det%*.

The nonlinear analysis of geomagnetic time series allows obtaining new characteristics of geomagnetic field.

Seismology, seismic hazard/risk assessment and earthquake prediction.

All information about historical earthquakes in Georgia was systematized, stocked and revised. It contains: a catalogue with the main parameters of 47 historical earthquakes that took place during 30 centuries; detailed information (“passport”) of historical earthquakes; GIS-maps of the earthquakes. On this base an updated catalog of earthquakes in Georgia with magnitude of $M \geq 4.0$ was compiled using improved velocity model for instrumental periods. On the bases of historical earthquake catalog by means of the time-dependent model of seismicity and the methods worked out by B. Papazachos and et al. (1987) the relative probability of the strong earthquakes ($M > 6$) in the nearest 20 years have been calculated for each segments and sub-segments of the tectonic area. New World Stress Map (WSM) data are calculated from the single focal mechanisms for the South Caucasus. About 240 focal mechanisms of earthquakes with magnitude $M \geq 4$ were estimated used first motions and about 20 focal mechanisms of earthquakes of low magnitude were calculated used semi-automatic and frequency sensitive moment tensor inversion developed by A. Barth and et al. (2007) the majority of which had been classified C according to the WSM quality ranking table. The local tomography method of Zhao (2004) was applied to determine P and S wave

velocity perturbations of the crust beneath Georgia. The new catalogue of seismoactive structures was compiled. Seismoactive structures are based on the correlation between regional neo-tectonic units and earthquakes taking into account the new tomography model. For the first time in Georgia the complete catalog of landslides related to earthquakes has been compiled, which enables to identify zones related to so-called 'secondary landslides'. In Georgia this is a new component in the methodology of seismic hazard assessment.

For comparative analysis of seismic risk in the capitals of the South Caucasian States - Baku, Yerevan and Tbilisi - the methodology of determination of Earthquake Disaster Risk Index (EDRI) has been used. Chronological data of manifestations of the largest regional and average intensity local earthquakes in Tbilisi is discussed. Regularity of 7 intensity shake recurrence observed in Tbilisi is established, which is in accordance with theoretically calculated corresponding results. Conditional probabilities of occurrence of earthquakes with intensity 7 and 8 in Tbilisi are defined for the next 20 years.

Integration of instrumental, macroseismic and geological data on the Tbilisi earthquake of April 25, 2002 is done.

The seismic history and seismotectonic conditions of earthquake initiation are investigated in Central Georgia (Gori and surrounding area). The levels of seismic risk of 7, 8 and 9 intensity scenario earthquakes are estimated in Gori. Also damage of city caused by destroying Qartli earthquake of 1920 is estimated.

Complex geological-tectonic, geomorphological, seismotectonic and geophysical investigations on the Kartsakhi-Akhalkalaki section of the Kars-Akhalkalaki-Tbilisi railway section are done. Seismic hazard and seismic shaking for assessments Kazreti and Batumi region were done. Multiple risk assessment for the South Caucasus was done for the five natural hazards: earthquake, landslide, debris flows, floods and snow avalanches using method proposed by the Columbia University project "Natural Disaster Hotspots: A Global Risk Analysis" and the Atlas of Natural Hazards of South Caucasus is published.

Mapping and monitoring of geophysical fields (gravity, seismic, electromagnetic, etc) on the territory of Georgia for revealing their spatial-temporal regularities.

The gravity, magnetic and seismic data on the territory of Georgia and Caucasus are collected and the corresponding maps in GIS are compiled. Geothermal and thermoelastic models of Caucasus are elaborated. Practical environmental, hydrogeological, archaeological and engineering tasks problems are resolved using geophysical prospecting methods.

- ***Dynamics of Atmosphere and Sea and Modeling of Ecologic al Systems***
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- On the basis of investigations (analytical, numerical) of linear and nonlinear stages of the dynamics of neutral and electromagnetic disturbances in the space environment (atmosphere, ionosphere, magnetosphere), it is revealed that in such perturbations self organize in the form of an ensemble of various stable enough nonlinear strongly localized solitary vortices.
- The macroscopic consequence the presence of the nonlinear solitary vortex structures in magnetized space environment is investigated. Strongly localized

- The new model of the strong vortex turbulence in magnetized space environment is proposed. Turbulence is represented as gas of ensemble of the strongly localized (therefore weakly interacting) identical vortices creating the main state. The vortices with various amplitudes randomly distribute in space (due to collisions) and the statistical approach is applied for their description. It is supposed that the stationary turbulent state is formed due to a balance of competitive effects: spontaneous birth of the vortices due to nonlinear twisting of the perturbations' fronts, pumping of noise into the short scale structures (direct spectral cascade) and collisional or collisionless damping of the perturbations in short-waves area. Noise pumping toward smaller scales in an inertial range occurs due to merging of structures via collisions.

Physics of atmosphere, clouds, aerosols and weather modification.

Climate change effects were analyzed for Georgia and it has been found that the effect is different in West and East Georgia.

Models of convective clouds, thunderstorms and hail processes taking into account man-made impact are created.

Regularities of Ozone concentration variations at the day surface are revealed; the environmental impact is assessed.

- ***Solar-Terrestrial Physics (space physics, physics of magnetosphere and ionosphere)***
- New models of magnetosphere and ionosphere are developed. The parameters of the magnetic barrier before magnetosphere are evaluated and the effect of asymmetry plasma flow is investigated. As a result of integrated study of 27-days variations of heliogeophysical data the interconnection of solar-magnetospheric-ionospheric-geomagnetic phenomena is revealed.
- On the basis of investigations (analytical, numerical) of linear and nonlinear stages of the dynamics of neutral and electromagnetic disturbances in the space environment (atmosphere, ionosphere, magnetosphere), it is revealed that in such perturbations self organize in the form of an ensemble of various stable enough nonlinear strongly localized solitary vortices.
- The macroscopic consequence the presence of the nonlinear solitary vortex structures in magnetized space environment is investigated. Strongly localized vortex structures contain the trapped particles and, kneading in the medium, excite sufficient density, electric and magnetic fields fluctuations and thus intensify the energy, heat and mass transport processes, i.e., such vortices ensemble can form the strong vortex turbulence.
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	Contact Information
* Contact person (first name, family name)	Tamaz Chelidze
* Department / Laboratory	Seismology and Experimental Geophysics
* Position	Head of Department
* Qualification and research experience	Seismology, physics of heterogeneous media, nonlinear dynamics in geophysics
* Post address (house, street, city, code, country)	1, Alexidze str., Tbilisi, 0193, Georgia
* Telephone (+ country & city codes)	995 32 33 28 67
* Fax (+ country & city codes)	995 32 33 28 67
* E-mail	chelidze@ig.acnet.ge

International co-operation / Participation in EU RTD programmes or other bilateral / multilateral actions
INTAS, TACIS, TEMPUS, COST, EUREKA, other RTD programmes (please specify programme/s, project title/s and year/s)
<ul style="list-style-type: none"> • 1) Seismic Hazard Assessment for Big Cities in Georgia Using the Modern Concept of Seismic Microzonation with Consideration of Soil Non-linearity 1998-2000 INTAS • 2) Protection of Thermal Ground Water Resources in Seismic Areas 1998-2001 INCO-COPERNICUS • 3) Test Area for Seismic Hazard Assessment in the Caucasus 1995-1997 INTAS • 4) Toxic Pollution Detection in Ground Water: From Real Time Early Warning to Overall Assessment 2000-2001 INCO-COPERNICUS • 5) Induced Seismicity and Earthquake Hazard Mitigation by Electromagnetic Impact of MHD Generator 2000-2001-INTAS • 6) Seismic Risk in Large Cities of Caucasus: Tools for Risk Management 2001-2003-NATO NATO SfP • 7) Caucasian Seismic Information Network 2002- 2003 ISTC • 8) Strategy development for long term pollution control in regions of extreme environmental risk (ENVRISK) 2002-2004-INTAS • 9) Prediction of major events in multiscale fracture based on the theory of critical phenomena. 2002-2004-INTAS • 10) Geodynamical Risks of High Dams 1996-2006 Council of Europe • 11) Creation of acoustic warning system (EWS) of catastrophic debris flows in Mountainous areas. 2006-2007 Council of Europe • 12) GIS – mapping of integrated major hazards in the Southern Caucasus as an early warning tool. 2006-2007 Council of Europe • 13) Triggering and synchronization of seismic / acoustic events by weak external forcing as a sign of approaching the critical point. 2006-2007 INTAS

- 14) Applying Isotope Techniques for the Assessment of Water Resources In Georgia. 2006-2007 IAEA
- 15) Stress related geohazards in South Caucasus. 2007-2009 INTAS
- 16) Open network of scientific Centers for risk of natural hazards in the Southern Caucasus and Central Asia. 2006-2008 ISTC
- 17) Assessment of radon-hazard potential, residential exposure, lung cancer and COPD in West Georgia. 2007-2009 STCU
- 18) The study of the structure of the lithosphere of Caucasus by means of surface wave tomography and three-dimensional modeling 2006-2008 ISTC
- 19) Nongaussian Transport, Strong Turbulence and Nonlinear Phenomena in the Magnetosphere and Ionosphere, 2007-2009, INTAS.
- 20) Study of the ULF electromagnetic phenomena related to earthquakes (SUPRE), (INTAS-99-1102) 2000-2002
- 21) Black Sea ecosystem processes and forecasting/operational database management system 1999-2002 NATO
- 22) ARENA- A regional capacity building and networking programme to upgrade monitoring and forecasting activity in the Black Sea basin 2003 – 2006 EEU
- 23) THREE DIMENSIONAL ELECTRO-MAGNETIC AND THERMAL TOMOGRAPHY OF THE ACTIVE CRUSTAL ZONES 2004-2007 INTAS
- 24) Hydro and thermodynamic processes in the “Black Sea – land-atmosphere” system and regional climate. Development of fundamentals of monitoring and forecasting system. 2005-2006 BSEC
- 25) Black Sea SCENE-Black Sea Scientific Network 2005-2008 EEU
- 26) ECOOP - Coastal-shelf sea Operational observing and forecasting system 2007-2010 EEU
- 27) ADAMS – Advanced Data Assimilation Methods for Seas 2008-2010 French National Scientific Fund
- 28) ADOMENO - Assimilation de Donnees pour la Mer Noire 2008-2010 French National Scientific Fund
- 29) UP-GRADE BS-SCENE – Up-grade Black Sea Scientific Network 2009-2011 EU
- 30) Seismic Hazard and Risk Assessment for Southern Caucasus-Eastern Turkey Energy Corridors, 2009-2011, NATO SfP

	* Please, use “X” to indicate the scientific area/s of your potential project
CHEMISTRY	
SOCIAL AND HUMAN SCIENCES	
ECONOMIC SCIENCES	
ENGINEERING SCIENCE	X
ENVIRONMENT	X
AGRICULTURE AND FOOD	
HEALTH	
MATHEMATICS	
INFORMATION SCIENCE	
PHYSICS	X
NANOTECHNOLOGIES	

ENERGY	
TRANSPORT	
SPACE	

*** Summary of potential research project envisaged hosting of European researcher for the period of between 1 and 2 years**

Project 1. Dynamics of seismic and geomagnetic fields related to earthquake generation in Caucasus

Despite its extreme importance and decades of scientific efforts worldwide, earthquake prediction still remains to be achieved in future. Recent discussions in the literature on this topic demonstrated that even there is no agreement as to whether, in principle, large earthquakes are by their very nature predictable or not. Intensive debates between opponents [Kagan, 1992, 1994, 1997; Kanamori, 2001; Geller, 1999; etc.] and supporters [Aceves and Park, 1997; Main, 1997; Wyss, 1997; Chelidze, 1997; Knopoff, 1999; etc.] of possibility of earthquake prediction still proceed.

Meanwhile, though the underlying physics is still poorly understood, last decades it becomes more and more clear that in spite of its extreme complexity the process of earthquake generation could not be considered as completely random [Goltz, 1998; Rundle, 2000; Matcharashvili, 2000; Telesca, 2000]. This in turn means that the earthquake prediction, as well as earthquake triggering and control, the challenging problem of nowadays science, could not be regarded as an “alchemy of the present time” [Geller, 1999]. In other words, the quest for earthquake predictive markers, or triggering and controlling factors, should be recognized as obviously difficult, though scientifically well posed task related to the evaluation of the extent of determinism in the complex seismic process.

Generally, the scientific researches aimed at finding long and/or short-term earthquake precursory markers have long history. In an attempt to systematically evaluate results of such researches by the IASPEI (International Association of Seismology and Physics of the Earth’s Interior) a special commission on earthquake prediction was organized and through a peer-review process a preliminary “List of Significant Precursors” has been created [Wyss, 1991; Wyss and Booth, 1997; Wyss, 1997]. The five most known events from this preliminary list include foreshocks, seismic quiescence before large aftershocks, radon decreases in ground water, and ground water level increases [Wyss, 1997]. At the same time, as it follows from above discussion and practical experience, search for events having the self-sufficient precursory value or expanding predictive significance of ones from the IASPEY list, remains as a main scientific challenge for geophysics.

Recent achievements in seismology and geocomplexity assure that the most promising direction of the scientific researches aimed at detection of reliable precursors, passes through the quantitative investigation of dynamical characteristics of earthquake related processes. Here we mean investigation of dynamical structure of seismic processes as well as other processes related to seismicity using modern data analysis tools originally developed for complex hierarchical systems and turbulent flows.

In general, using nonlinear data analysis approach to seismic processes is not

new. For last decade and half many applications on evaluation of nonlinear characteristics of time series compiled from seismic catalogues have been reported such as waiting time series, magnitude sequences, interearthquake distances time series, etc. [Goltz, 1998; Telesca, 2000; Matcharashvili, 2000]. These investigations resulted in better understanding of dynamical peculiarities of seismic process already discussed above. At the same time seismic catalogues for strong events are rather short; that often causes serious restrictions for correct nonlinear analysis. These restrictions are not the case for digital records of seismic waves (including microseisms) which are quite long. Generally, seismic records as an important data sets always been the subject of intense scientific investigation [Tanimoto et al., 1998; Kobayashi and Nishida, 1998]. The problem of these investigations was that most researchers used linear data analysis approaches, which are not intended for analysis of non-stationary process comprising bursts of different amplitudes and duration. Thus use of the complex time series analysis methods appears to be more promising for seismic records, which may contain meaningful information on physical processes in seismic source. Indeed, very interesting changes in dynamics of seismic process have been observed recently before large events using modern methods of seismic record analysis. Sobolev and colleagues [Sobolev et al. 2003, 2004, 2007] through time-frequency and multifractal analysis of seismic records of the vertical component with discretization frequency of 20 Hz reported appearance of periodic components in microseisms before strong earthquakes in Kamchatka peninsula and Japan. Furthermore, essential changes of dynamical properties of seismicity several hours before strong earthquakes in Spain and California have been claimed by Tabar et al. [2007] using method of self-similarity analysis and estimation of the Markov time scale of a seismic time series – the time over which the data can be represented by a Markov process. These results emphasize importance of investigation of dynamical structure of earthquake generation process using long seismic time series.

At the same time we should bear in mind that the process of earthquake generation is complex both in spatial and temporal domains and that present methods of data analysis still have specific restrictions for such so called high dimensional processes. Therefore, it looks reasonable to compare results of nonlinear analysis of seismic recordings with behavior of other processes, which are related to the seismicity (such as hydraulic, geoelectric, geomagnetic time series, acoustic emissions etc.).

It should be added here that investigation of dynamics of these non seismic factors which may be related to the same tectonic processes, which generate seismicity is important from the other point of view; namely, the influence of these small compared to tectonic forces factors may lead to triggering and control of seismicity as it is usual in complex process.

In the last years a main focus of the research has been devoted to the analysis of mentioned processes, associated with earthquake preparation, e.g. ULF/ELF variations of geomagnetic field, geoelectric potentials (telluric currents), VLF signals from navigation radio transmitters, acoustic emissions, gas release etc. [Zakrzhevskaya, 2002; Rikitake, 1976; Sidorin, 1992; Sobolev, 1993; Duma, 2003; Gladyshev, 2001; Uyeda, 2000; etc]. Investigation of geomagnetic field variations is recognized as one of the most pronounced directions in this sense. At the same time it is worth mentioning that in the past the data processing, relevant to this general problem, was limited as a rule to the analyses of their separate aspects, i.e. analyzing either precursory or triggering role of magnetic field impact. Moreover, no complex investigations involving the modern methods of quantitative analysis of unknown dynamical processes as well as methods of analysis of multiscale properties and nonlinear

interdependence between considered data sets has been used (neither on regional nor on global scales). Just recently several interesting articles describing scaling characteristics of ULF geomagnetic field variations and their relation to earthquake preparation appear in press [Telesca, 2007; Hatori, 2004; 2006]

Thus, in order to answer the question about precursory value of dynamical changes in seismic process and geomagnetic field variation as well as on possible triggering role of magnetic field variation in general and for Caucasus in particular, we propose to perform:

- nonlinear analysis of seismicity of Caucasus using time series compiled from earthquake catalogues,
- retrospective analysis of regional long-term magnetic field variation data,
- investigation of extent of causal relationship between dynamics of geomagnetic field variation and regional seismic activity for the last several decades
- nonlinear analysis of (digital) seismic records,
- dynamical characteristic testing of simultaneously recorded seismic and geomagnetic (digital) data on short and long temporal scales
- analysis of laboratory data from spring-slider system as a proxy of geological faults under tectonic stress and influence of variable external magnetic/electrical field on stick-slip process

We will use state of the art modern methods of time series analysis that are sensitive to small dynamical changes [Spratt, 2003; Abarbanel, 1996; Pikovsky, Rosenblum and Kurths, 2001].

Project 2. Natural Hazards and Environmental Disasters in the Carpathian-Crimea-South Caucasus Region: Quantitative Assessment and Risk Reduction

The main goal of the proposed research is to estimate multiple risk of most widespread types of natural hazards in the region, namely, earthquakes, landslides, avalanches, floods, mudflows, hails, hurricanes, drought, mud volcanoes (in Azerbaijan), freezes (in Georgia), and glazes (in Ukraine).

The specific objectives of the proposed project are as follows:

1. To develop electronic databases of the natural disasters (listed above) in Armenia, Azerbaijan, Georgia, and Ukraine, collecting and analysing all available data and information on the events. These databases will consist of the various parameters of hazardous phenomena that caused natural disasters.
2. To elaborate mathematical models and algorithms for multiple hazard risk assessment taking into account the specific regional conditions (e.g. specific hazard, exposure and vulnerability). This will include: (i) comprehensive analysis of previous models of risk assessment and (ii) development of a transition-model from the analysis of individual risk to multiple risk model.
3. To study quantitatively energy and spatial-temporal regularities of the extreme natural hazards in the region, namely,
 - to review the magnitude scale of the large disasters and to obtain the new scales of the phenomena for which the corresponding formalization wasn't conducted to specify the occurrence of natural disasters and to develop appropriate maps of hazards using GIS technology.

4. To estimate the vulnerability of people and constructions, namely,
- to estimate integrated vulnerability of individual administrative units of Armenia, Azerbaijan, Georgia, and Ukraine.
 - To estimate the impact of vulnerability and hazards on natural disasters for each administrative unit.
5. To assess multiple natural disaster risks for each administrative units and the expected maximum probabilistic losses due to natural disasters.

	Please, confirm your agreement on data publication and dissemination
I agree with the publication of the data on the web-site http://www.inco-ecca.net , and dissemination among Mobility National Contact Points of the EU MS and AC (YES / NO)	YES
Date	03 December 2008