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Climate Change and Natural Hazard Research - Series 2

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EUROPEAN COMMISSION

European research on Natural Hazards

Catalogue of selected FP5 and FP6 projects

Volume 1

Avalanches, Earthquakes, Floods, Forest Fires,
Landslides, Multirisks, Tsunamis, Volcanoes

Environment Directorate

Edited by Environment and Climate System Unit

Climate Change and Natural Hazard Research - Series 2

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AVALANCHES

CADZIE - Catastrophic Avalanches: Defense Structures and Zoning in Europe

EVG1-CT-1999-00009

<http://cadzie.grenoble.cemagref.fr/>

Instrument:	FP5 – Research Project	Ending date:	01/04/2003
EC contribution:	689,599.00 €	Duration:	36 months
Organisation:	CEMAGREF		
Co-ordinator:	Dr Mohamed Naaim (Mohamed.naaim@cemagref.fr)		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The extreme avalanche winter of 1999 has made the European avalanche experts to rethink existing methods in order to calculate avalanche runout distance and prepare hazard maps. New methodologies, based on modern computer methods presently under development in all European countries, must be introduced in order to be able to manage the extreme avalanche periods better. This project had two main objectives:

- 1) Development of new methods and tools allowing an objective and accurate hazard zoning of snow avalanches;
- 2) Quantification of the effects of defence structure on dense and powder avalanches flows.

Scientific achievements

In accordance with the initial plan, the collaboration between the partners allowed significant progresses in the snow avalanche sciences. First of all, with regard to the hazard zoning, a state of the art in terms of technical and legislative practices was drawn up. With regard to the structures of protection the methods of design and the technical rules employed were surveyed. The limits and the lacks in terms of knowledge and methods in the determination of the hazard zoning and design of protection structures were highlighted. The scientific work of the involved laboratories consisted in developing the needed knowledge to fulfil the gaps and increase the scientific and technical knowledge.

First, a data base containing well documented events was developed and fed by the partners. The creation of this common data base was the first step toward fruitful collaboration. The data contained were used to validate the numerical models and to determine their uncertainties. A method combining, morphological considerations, historical data and the existing models were developed. The statistical distributions of initial conditions and avalanche release probabilities are fixed using the measured data (more or less close to the avalanche path) or obtained from morphological considerations. The parameters of friction of the propagation models are fixed using the historical data on a local scale (when possible) or on a regional scale. These statistical distributions and propagation models are used to predetermine run-out distances or pressure fields corresponding to the rare frequencies.

With regard to the protection structures, physical and numerical experimentations on various scales were undertaken to quantify the local and global effects of protection structures on the avalanche flows. The avalanches were characterized by their height, their speed and consequently their Froude number. The defence structures were characterized by their heights. An analysis of the dynamical equations allowed to identify the similarity criteria. The numerical and physical experiments allowed to explore a large range of cases. The deposits behind the dams were studied and a scaling law was written and validated. The losses of momentum generated by the shocks with the structure, the flying phase and the shock with the substratum were quantified for dense and powder avalanches. The local incorporation of the ambient fluid, the reduction of the momentum of the avalanche were also studied and their scaling laws set up. These results were published as scientific publications and synthesized as technical reports and guidelines devoted to end-users such as avalanche experts.

Socio-economic relevance and policy implications

In the avalanche field, engineering methods were strongly based on historical data and expert knowledge and analyses. In the framework of this project we developed new scientific and technical methods and knowledge. The issued technical tools were synthesized in the form of guidelines for a broad diffusion for end-users. These tools, will contribute to a better knowledge shearing between the European engineers in the fields of the avalanche zoning and the defence structures. There are no direct industrial developments. But, these methods will contribute to improve and make safe the technical studies. It will be considered as first step toward regulations and norms required to attain quality requirements.

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SATSIE - Avalanche Studies and Model Validation in Europe

EVG1-CT-2002-00059

www.leeds.ac.uk/satsie/

Instrument:	FP5 – Research Project	Ending date:	31/05/2006
EC contribution:	1,231,680.00 €	Duration:	44 months
Organisation:	Norwegian Geotechnical Institute		
Co-ordinator:	Dr Lied Karstein (kl@ngi.no)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

Acquire a deeper understanding of the physical processes in snow avalanches through experiments at reduced and full scale and subsequently improve the tools for hazard mapping of snow avalanches and the design of protective measures by:

- Developing novel instruments and data analysis techniques for probing the structure of avalanche flows;
- Carrying out experiments designed to measure the rheological behaviour of granular flows and snow at the laboratory scale, and of snow at full scale;
- Studying the mechanisms of snow entrainment and deposition;
- Investigating the behaviour of laboratory flows impacting on obstacles and comparing the results to measurements at full scale;
- Developing new dynamical flow models for hazard mapping that take into account new insight into the structure and rheological behaviour of avalanches;
- Issuing a Handbook of Dam Design that summarises state-of-the-art knowledge and best practices;
- Developing reduced-cost radar systems for use in monitoring and alarm systems;
- Making the results from the project accessible to avalanche professionals through publications and a European Summer University course.

Scientific achievements

- Fluidised head with density below 100 kg m^{-3} and length 10–100 m observed in most dry-snow avalanches in Ryggfonn. Density increases and velocity decreases with distance from head. Similar flow transitions seen in granular chute experiments but not in snow chute measurements. Velocity profile (linear vs. curved) appears to depend sensitively on the flow conditions. Novel results on powder-snow avalanche formation and behaviour from laboratory experiments.
- Direct observation of erosion processes in granular chute flows, indirect observations from Ryggfonn (abrasion in dry-snow avalanches, ploughing in wet-snow avalanches).
- Very high impact pressures observed in slow flowing humid avalanche in Ryggfonn highlight role of snow cohesion and may necessitate reevaluation of hazard from wet-snow avalanches.
- Insight from experiments was directly used in specifying the rheology and the entrainment rate in novel numerical flow models.
- Seismic signals usable for velocity measurements; can be interpreted with regard to avalanche size and flow regime in favourable situations.
- Novel or improved sensors (opto-electronic, radar, multi-directional air-pressure sensors for powder-snow avalanches) and corresponding data analysis techniques were developed and may be applicable to other phenomena as well.

Comprehensive experiments and theoretical investigation of shock formation in avalanche–dam interactions led to improved criteria for dam dimensioning. However, some further work is needed to determine the limits of applicability of the new theory.

Socio-economic relevance and policy implications

- New numerical models contribute to more accurate hazard maps and thus to higher degree of safety and improved land use in mountain communities.
- Handbook on dam design will help to spread best practices and to obtain higher degree of safety at lower costs.
- Newly developed radar systems have moderate potential for commercialisation.
- The high degree of collaboration in SATSIE paves the ground for continued collaboration, better use of research resources, and for future harmonisation of hazard mapping regulations.
- Some of the project results may be applied to other gravity mass flow hazards (debris flows, rock avalanches), the new data analysis techniques even beyond that field.

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FLOODS

CARPE DIEM - Critical Assessment of Available Radar Precipitation Estimation Techniques and Development of Innovative Approaches for Environmental Management

EVG1-CT-2001-00045
<http://carpediem.ub.es>

Instrument:	FP5 – Research Project	Ending date:	31/12/2004
EC contribution:	1,659,745.00 €	Duration:	36 months
Organisation:	Environmental Agency of Emilia Romagna		
Co-ordinator:	Dr Pier Paolo Alberoni (palberoni@arpa.emr.it)		
EC officer:	Tobias Bertold Fuchs		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The key objectives of CARPE DIEM were to improve actual flood-forecasting capability through a better understanding of the processes and mechanisms that drive hydrogeological hazards.

The sensitivity of hydrological models to the errors, associated with the different input data sources, clearly reveals the need of state-of-the-art rainfall input values. To meet this goal we have worked on improving the performance of numerical prediction at short forecast times (i.e. from +6 to + 24 hours) and improving the real-time estimation of rainfall fields during severe weather events that are related to flooding and flash-flooding problems. We achieved this goal by coupling together multiparameter/polarimetric radar data and numerical weather prediction techniques (NWP).

We exploited NWP results in order to improve the interpretation of radar observations. This exercise not only enables a general improvement in extracting information from radar but also allows the reduction of inherent radar errors, thus allowing to quality control radar measurements.

Scientific achievements and results

The project has reached all planned objectives. Advanced methodologies to increase the operational exploitation of radar information have been created. This will have a direct feedback in the quality and availability of rainfall estimation and prediction fields. Advancement in understanding of basic processes and mechanisms that drive hydrogeological hazards is a natural consequence of the work done. The forecasting quality assessment will be based upon end-user requirements that will be called to specifically suggest their needs and to verify the effectiveness of the results.

Work was divided into three co-operative blocks. In the first block a coordination work package is envisaged, where technical and financial coordination work was done. The second block of activities is mainly devoted to research, with a definition of three areas.

Pre-processing and assimilation of radar measurements and their products in NWP are covered under Area 1.

- Dual-Doppler wind extraction software programmes have been developed and used in an assimilation exercise. In addition the methodology developed has been installed in the Po Valley area and it is used in the operational analysis routine.
- Innovative de-aliasing algorithm developed has been tested over a number of cases covering the different climatic area analyses.
- A VSRF system based on LAPS analysis system and a LAM have been implemented. The domain of analysis has been enlarged. Convective episodes have been analysed using satellite information and polarimetric radar data.
- Software modules to pre-process and assimilate Doppler radar data have been tested. First results of the assimilation experiment are available.

Area 2 addresses the improvement of radar-derived parameters using NWP information.

- The work on beam blockage has resulted in a journal publication. The beam blockage evaluation code has been installed and tested in different areas. The work and methodology on anaprop simulation has been successfully completed.
- A schema based on the shape of VPR measured close to the radars (2 - 40 km) and time-space interpolated freezing level height at radar sites has been now operationally implemented to classify VPR. A "climatology" description and analysis in a cold climate is done.
- The use of NWP data to diagnose OP has been tested, but it has proved to be not enough reliable to be used operationally.
- Quantitative polarimetric methods have been examined in terms of the relative advantage over conventional, reflectivity only precipitation estimates. The net outcome was that the polarimetric observables are too noisy in S-band, but might be better in C-band.
- The Entropy-Alpha decomposition, based on Pauli-matrices, has been tested to classify radar echoes.

The main objectives of the Area 3 are the development of procedures for combining radar and rain-gauge estimates of rainfall with numerical weather predictions (NWP) and the assessment of the quality of the predicted rainfall field in terms of discharge forecasts in urban and rural catchments.

- The work has identified rather complex spatio-temporal error characteristics in precipitation estimates from various sources, and thereby highlighted the importance of careful quality control when designing algorithms for combining estimates.
- The runoff modelling experiments clearly demonstrated the sensitivity of a hydrological model to precipitation errors. Especially the impact of the timing of the errors was revealed.
- The application of combined MW-IR satellite rainfall techniques have shown that problems arise when trying to keep the MW-IR histogram matching for a long time. Precipitating systems obviously modify very fast and matching is lost quite rapidly, especially in convective situations.
- The TOPKAPI model has been applied to the Dargle catchment in Ireland. The model can be applied, using existing topographical, soil and land-use data, without calibration and gives physically realistic outputs.
- Model performance can be improved by manually adjusting some of the parameters.
- The sensitivity analysis confirms the appropriateness of the simple manual calibration for matching flow peaks.

The end-users activities and project results dissemination form the third block.

The main deliverables cover the following themes:

- Dual Doppler software code (DARWIN);
- New dealiasing algorithm;
- Assimilation of radar Doppler data in NWP models.;
- Anomalous propagation modelling;
- Optimisation of VPR technique in a radar network;
- Assessment of precipitation estimates errors;
- Sensitivity studies on hydrological modelling.

Socio-economic relevance and policy implications

The main objective of the CARPE DIEM project is to improve flood forecasts in small urban and rural catchments by means of improved rainfall estimation and prediction. This is an extremely important problem of which the socio-economical relevance is very high and its policy implications relate to the possibility of improving the decision process, during emergency situations, particularly in densely populated urban areas.

Natural End-users of CARPE DIEM outcomes are civil protection and ground defence agencies, as well as hydrological and weather services. Furthermore as the CARPE DIEM End-Users panel demonstrates improvements in rainfall detection, estimation and prediction will benefit a much wider audience, such as sewage management agencies, hydro-electric power industries and highway management agencies, e.g. for snow clearance etc.

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EFFS - European Flood Forecasting System

EVG1-CT-1999-00011

<http://effs.wldelft.nl>

Instrument:	FP5 – Research Project	Ending date:	01/10/2003
EC contribution:	1,821,045.00 €	Duration:	43 months
Organisation:	WL Delft Hydraulics		
Co-ordinator:	Dr Paolo Reggiani (paolo.reggiani@wldelft.nl)		
EC officer:	Tobias Fuchs		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The objective of the EFFS project is the implementation and testing of a prototype continental-scale European flood forecasting system working at lead-times between 4 to 10 days. The system provides 6 to 12 hourly information on river discharges for large European drainage basins. It utilises state-of-the-art meteorological forecasts from weather services of the various member states to provide early flood warning to local river basin authorities and civil protection agencies that already operate 0-3 day forecasting systems. The system constitutes a major effort of integrating meteorological products with hydrological and hydraulic modelling capabilities and thus integrating the hydrological with the meteorological community. The forecasting results are broadcasted to end-users, that are responsible for warning and evacuation of the population in case of imminent flood disaster.

Scientific achievements and results

The scientific achievements and results of the EFFS projects are in several areas. Principally the project has significantly contributed in bringing the meteorological community together with hydrologists and hydraulic engineers.

These two communities work traditionally in separate areas. The EFFS project has efficiently integrated these two areas of expertise. The project started originally with a consortium of 11 partners, that has been enlarged in the second phase of the project to 19 partner institutes by including 7 institutes of the new member countries.

Several scientific achievements were made in the area of downscaling meteorological models from larger low-resolution models to smaller high-resolution limited area models. The impact of topography on the cumulative predicted rainfall was investigated.

From the hydraulic and hydrological modelling point of view the EFFS project contributed significantly in developing methodologies of integrating meteorological forecasts with hydrological models and the latter ones with hydraulic models for flood propagation along rivers and in inundation areas.

Achievements were made in modeling of inundated areas during a flood. Also the concept of model uncertainty in the context of flood forecasting has been addressed in the EFFS project.

The principal deliverable of the project is an open-architecture software platform for data and model integration for flood forecasting. The strength of this product is given by the fact that different models originating from independent third-party software producers can be integrated within the flood forecasting platform. The philosophical shift in flood forecasting is thus from a model-centered and thus static approach in traditional systems to an open data-centered approach of model integration

The project also involved end-users that are responsible of producing operational forecasts and issuing flood warnings.

Socio-economic relevance and policy implications

Flood occurrence and flood frequency is increasing throughout Europe. Recent flood in 2002 in Germany and 2005 in the UK and large parts of central Europe have caused large damage to infrastructure and property and have claimed lives of people. Flood forecasting is a cost-effective and fast-to-implement non-structural measure for flood protection.

By planning evacuation in time and taking provisions based on forecasts property can be protected by putting protective measures such as controlled flooding into action. These interventions serve to save lives. The products developed during the EFFS have led to a flood forecasting system Delft FEWS (Flood Early Warning System) that is currently being implemented on a broad scale in large European river basins such as the river Po and the river Rhine.

The UK National flow forecasting system (NFFS) has been implemented on the basis of technology that has been developed during the EFFS project. Following the disaster caused by the hurricane Catharina the Southern United States there is interest from the side of the National Weather service to utilize EFFS-developed technology of Delft FEWS to manage data for the US national flood forecasting activities.

The European Flood Alert System (EFAS) operated pre-operationally for Entire Europe at the Joint Research Centre of the European Commission is based on technology and scientific developments pioneered during the EFFS project.

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ELDAS – European Land Data Assimilation System to Predict Floods and Droughts
EVG1-CT-2001-00050
<http://www.knmi.nl/samenw/eldas>

Instrument:	FP5 – Research Project	Ending date:	30/11/2004
EC contribution:	1,480,000.00 €	Duration:	36 months
Organisation:	Royal Netherlands Meteorological Institute		
Co-ordinator:	Dr Bart van den Hurk (hurkvd@knmi.nl)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

In brief, the project has the following goals:

- *Combine current (European) expertise* in soil moisture data assimilation, and design and implement a *common flexible and practical data assimilation infrastructure* at a number of European NWP-centres
- *Validate* the assimilated soil moisture fields using independent observation material;
- *Assess the added value* of soil moisture data assimilation for prediction of the seasonal hydrological cycle over land (associated with drought prediction) and for the risk of floodings;
- Build a *demonstration data base* covering at least one seasonal cycle and the European continent;
- Anticipate on the use of data expected from new satellite platforms, in particular METEOSAT Second Generation (MSG) and the ESA Soil Moisture/Ocean Salinity Mission (SMOS);
- Provide a European contribution to the Global Land Data Assimilation System ([GLDAS](#)), a US initiative for generating near-realtime information on land surface characteristics on a global scale.

Scientific achievements and results

First, a precious data base of precipitation and radiative forcings has been prepared. The precipitation data are interpolated to a regular $0.2 \times 0.2^\circ$ lat/lon grid covering the whole of Europe, at 3hrly intervals between 1 October 1999 and 31 December 2000. It is a hybrid data base containing observations from more than 20,000 gauges giving wind corrected daily precipitation amount, interpolated to subdaily fields using rain radar reflectivities in a large part of the domain and ERA40 model forecasts in the remaining area. The data base is unique in its quality, extent and spatial resolution, and is valuable for numerous model evaluation or application studies in the future. The resources spent in compiling this data base clearly point at the difficulty of collecting the data from a wide range of European institutions owning the data. Given the clear significance of the availability of a near-realtime high density high quality precipitation data base for soil moisture estimation and related applications, a European-wide initiative to facilitate this data flow would be very welcome.

At a similar spatial and temporal resolution a data base of surface longwave and shortwave radiation has been compiled, using a blend of METEOSAT Top-Of-Atmosphere observations and radiative transfer modeling in a system for Numerical Weather Prediction (NWP). Both data bases are available from the Meteorological Archival and Retrieval System (MARS) at ECMWF.

In addition to these forcing data bases, a data base of surface heating rates has been compiled, using METEOSAT surface temperature observations. The heating rate (defined as the surface temperature rise after sunrise per unit cosine zenith angle) has been atmospherically corrected and cloud cleared. Additional quantities are stored in conjunction to estimate observation error statistics. Apart from the 1999/2000 target period, data have been stored for the growing season in the dry year 2003.

For 36 locations spread across Europe validation data were collected and stored in a validation data base. These in situ data include soil moisture measurements, surface flux data, vegetation data and atmospheric observations.

Parallel to the compilation of these data bases, soil moisture assimilation systems have been further developed and implemented at four different European NWP centres (ECMWF, DWD, INM and CNRM). The complexity of these data assimilation systems required substantial manpower resources. Since the ELDAS systems will become part of the operational practice at these NWP centres, this investment of manpower is justified. The basic knowledge of the ELDAS infrastructure is exported to a number of other projects, including the FP6 project GEOLAND and a similar data assimilation infrastructure project in Canada, labeled CalDAS.

The data bases and data assimilation systems have been used to compile a number of soil moisture estimates for a range of spatial (up to the European area) and temporal (up to the 15month ELDAS period) scales. The resulting products have been analyzed, validated and used in a range of applications for demonstration purposes. These studies gave rise to the following insights.

First, analysis using in situ data at up to 36 field stations spread across Europe demonstrated that the additional increments added to the soil moisture dynamics produced by the NWP land surface schemes alone has the tendency to accumulate to systematic additions of water to the local water budget, with larger proportional contributions (up to 20% of the annual precipitation) of the increments in the more southern parts of the European domain. However, the validation with precipitation minus evaporation data collected at the sites revealed that these increments do result in a better resemblance to observations, indicating that indeed the soil moisture assimilation fixes systematic deficiencies in the free running land surface schemes.

While the increments do generally improve the cumulative hydrological fluxes, the resulting soil moisture fields themselves still compare relatively poorly with observed in situ soil moisture data. Without detailed improvement of the hydraulic parameterization in the land schemes a proper match of both hydrological fluxes and soil moisture content is impossible. As long as soil moisture content verifies poorly with truth, scaling transformations need to be applied to compare or use soil moisture content generated in one land surface model to another soil moisture product. Probably the most optimal transformation is the use of so-called cumulative distribution functions, in which the soil moisture anomaly relative to the longterm climatological mean is compared to the anomaly in the other data source. This preferably requires generation of long time series in order to construct climatological records.

The issue of transferability appeared important in a number of demonstration applications investigated here. In an application using a hydrological flood forecasting model, the main conclusion was that blind use of ELDAS soil moisture content in the application at hand deteriorated the results of the default configuration, which was internally calibrated to local observations. For specific occasions and after careful transformation the use of ELDAS data could improve the results, but not systematically nor significantly. The soil hydrological module in NWP systems need to be tailored more carefully to the hydrological application at hand. Also, the comparison to both synthetic and real microwave satellite data required a careful translation of ELDAS products into the quantity actually measured: data assimilation experiments using the Southern Great Plains data set confirmed that it is possible to improve the modeled hydrological fluxes with data assimilation but at the cost of deterioration of the actual soil moisture content. This issue needs additional careful evaluation in the context of future data assimilation of (synthetic) SMOS data.

Preliminary analyses of the use of surface heating rate data as a source of information for the surface wetness state revealed that major modeling issues need to be resolved prior to the useful application of this data type. In particular, heating rates modeled by NWP land surface schemes appear to be very sensitive to the parameterized aerodynamic coupling to the atmosphere. Also in reality, surface heating rates are not solely determined by the soil wetness state but also by the aerodynamic cooling by wind. Realistic inclusion of this dependence has been attempted by spatially calibrating relevant aerodynamic model parameters, but the validation of these quantities remains a difficult task.

Socio-economic relevance and policy implications

The resources spent in compiling this data base clearly point at the difficulty of collecting the data from a wide range of European institutions owning the data. Given the clear significance of the availability of a near-realtime high density high quality precipitation data base for soil moisture estimation and related applications, a European-wide initiative to facilitate this data flow would be very welcome.

The combination of European expertise in soil moisture assimilation has resulted in a clear improvement of the practice in this area. It is a positive development that the basic knowledge of the ELDAS infrastructure is exported to a number of other projects, including the FP6 project GEOLAND and a similar data assimilation infrastructure project in Canada, labeled CalDAS.

Soil moisture assimilation products derived from an NWP system are yet too immature to be successfully applied in flood forecasting applications. However, the application in NWP systems yields to more realistic soil moisture fields, which may in the future improve the predictability of drought conditions. This has yet to be demonstrated in a subsequent study.

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ENVISNOW - Development of Generic Earth Observation Based Snow Parameter Retrieval Algorithms

EVG1-CT-2001-00052

<http://projects.itek.norut.no/EnviSnow/>

Instrument:	FP5 – Research Project	Ending date:	30/06/2005
EC contribution:	2,589,768.00 €	Duration:	42 months
Organisation:	Norut Informasjonsteknologi		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

To develop and validate new and improved multisensor algorithms for retrieving snow and soil parameters from EO data improved for use in global climate study and hydrology, in particular run off and flood prediction

Scientific achievements and results

EnviSnow has contributed to the improvement of hydrological modeling and runoff forecast by improving the methods and services needed to retrieve snow and soil parameters from earth observation satellites. The main focus has been to improve the retrieval of snow parameters, in particular from synthetic aperture radars (SAR) but also from optical sensors and passive microwave sensors. Integrations of data from multiple sources to improve temporal and spatial coverage have also been in focus. The project has succeeded in establishing several pre-operational services in Scandinavia and the Alps on multisensor snow cover monitoring, which delivers data to hydrological modeling. The project has also made several contributions to the research on advanced snow parameter retrieval (i.e. on snow water equivalent, snow wetness, snow surface temperature) and to retrieval of soil moisture. The results of the project have been properly validated through field campaigns and aerial campaigns involving radar and optical imaging.

The improved snow parameters have been assimilated in hydrological models. The model output with and without improved snow parameters have been tested against real runoff measurements at gauging stations with favorable results. Some of the methods developed in the project were implemented and demonstrated in pre-operationally and in near real time. The results from the EO based services and the hydrological runoff forecasts were distributed to end-users and the wide audience via the EnviSnow prototype system, which is accessible via Internet.

Socio-economic relevance and policy implications

Accurate snow parameter algorithms are in particular needed for hydrological management, hydropower planning, climate monitoring/modeling and meteorological forecast modeling. All countries with seasonal snow cover have to take this into consideration for hydrological management. Snow-cover monitoring is in particular important for flood prediction. Countries with significant hydropower production and regions with seasonal snow cover usually do snow inventory at the end of the accumulation season in order to plan power production. Many companies are also interested in monitoring the melt rate. Climatological applications are mostly related to global and regional climate modeling, while snow plays a similar role in meteorological forecasting models.

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EURAINSAT – European Satellite Rainfall Analysis and Monitoring at the Geostationary Scale

EVG1-CT-2000-00030

<http://www.isac.cnr.it/~eurainsat/>

Instrument:	FP5 – Research Project	Ending date:	31/12/2003
EC contribution:	1,806,304.00 €	Duration:	36 months
Organisation:	Consiglio Nazionale delle Ricerche		
Co-ordinator:	Dr Vincenzo Levizzani (v.levizzani@isac.cnr.it)		
EC officer:	Dr Tobias Fuchs		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The launch of new sensors, such as the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) on board METEOSAT Second Generation (MSG), makes available new spectral channels for quantitative cloud and rainfall monitoring from geostationary orbit, which correctly addresses the space-time scales of rainfall phenomena.

The main aim of the project was to improve rapid-update, quantitative satellite rainfall estimation methods using infrared and passive microwave imagery, and cloud top microphysical characterisation. This was achieved through the use of the new spectral features together with the more frequent time scanning of SEVIRI on one hand, and the rainfall estimations from microwave imagery and radar data on the other. The assimilation of rainfall fields into local area models for mesoscale weather forecasting was also pursued. The assimilation of real rainfall fields is demonstrated to improve the model initialisation, specially for short range forecasting within the 48 hour range.

The new cloud and rainfall products are conceived to enhance the use of satellite data in weather and hydrological forecasting and were disseminated to weather services, civil protection agencies and satellite agencies.

Scientific achievements and results

A new retrieval algorithm to infer cloud top height, relative humidity above the cloud top and effective radius of optically thick cloud from satellite sensor data at 3.7, 11 and 12 μm was produced. As a consequence of EURAINSAT studies on visible (VIS), near-infrared (NIR) and infrared (IR) wavebands recommendations were given to NOAA and EUMETSAT for present and future sensors. At the same time studies were conducted on the fore/aft observation strategy for passive microwave (PMW) observations, 3-D cloud effects, drop size distribution (DSD) analysis and the use of lightning detection for the determination of precipitation type and aerosol-cloud interactions. Recommendations for the Global Precipitation Mission (GPM) and future European geostationary missions were given.

New observations using the EURAINSAT retrieval algorithm show that precipitation from polluted clouds over oceans is much less affected than over land, because large sea salt nuclei override the precipitation suppression effect of the large number of small pollution nuclei. Raindrops initiated by the sea salt grow by collecting small cloud droplets that form on the pollution particles, thereby cleansing the air. Therefore, sea salt helps cleanse the atmosphere of the air pollution via cloud processes. This implies that over oceans, the climatic aerosol indirect effects are significantly smaller than current estimates.

Several algorithms were developed and tested during the project:

- A Neural Networks (NN) code fusing IR images with SSM/I rainfall estimates generated with a frequency difference algorithm.
- Maximum Entropy-based Histogram matching technique for operational rainfall estimates, a new method to generate rainfall estimates for the tropical region. The main advantage of the method is its

simplicity and the code was already disseminated to several tropical countries through the International Precipitation Working Group (IPWG, <http://www.isac.cnr.it/~ipwg/>).

- Histogram matching techniques. A technique to generate half hourly, 12 km near global rainfall estimates derived from a combination of IR and PMW satellite estimates.
- The Calibration of Infrared-derived Rain Areas by Microwave Measurements (CIRAMM) algorithm has been applied to several heavy rainfall cases over the Mediterranean basin. The design of a general approach to the statistical integration of PMW and IR satellite radiometric measurements to retrieve rainfall rate at the geostationary scale was addressed and a new EURAINSAT algorithm developed called Microwave Infrared Combined Rainfall Algorithm (MICRA).

The development and testing of a nudging scheme, based on modification of humidity profiles, has been performed and applied to the limited area model BOLAM. An assimilation algorithm was developed for the Regional Atmospheric Modeling System (RAMS). The technique for convective rainfall assimilation into RAMS, by means of the inversion of the cumulus convection parameterization scheme.

An operational site was set up in Florence by upgrading the rapid update satellite precipitation estimation operational chain and the RAMS model assimilation of rapid update satellite rainfall estimates.

The rainfall PMW attenuation models of the project was refined and a K-band attenuation prediction method using PMW satellite data was proposed. This approach represents a feasible alternative to the estimation of beacon path attenuation of satellite telecommunication channels from surface rainrate. The choice between these two approaches may be based not only on their relative accuracy, but also on the algorithm efficiency being the near real-time property an essential feature.

Socio-economic relevance and policy implications

The impact of more accurate and timely satellite rainfall measurements is to be found in weather analysis and forecasting, hydrogeological management, risk assessment, and climate change at global and regional scales.

End-users of the project results include international organizations that have responsibilities for weather analysis and forecasting, the World Meteorological Organization (WMO) (e.g. impacts in remote or insufficiently monitored areas), the Food and Agriculture Organization (FAO) of the UN (food production monitoring especially in developing countries), satellite exploitation organizations (EUMETSAT, NOAA), weather forecasting offices at the national and regional scale, civil protection agencies. Updates at 15 min intervals have a possible direct impact on the monitoring of severe events in hazardous areas and is of fundamental importance to this activity.

Finally, the project represented the European seed to help implementing the IPWG under the sponsorship of the Coordination Group for Meteorological Satellites (CGMS) and WMO. Activities continued after the project ending date and continue, especially devoted to rainfall data calibration and validation.

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FLOODMAN - Near Real-Time Flood Forecasting, Warning and Management System Based on Satellite Radar Images, Hydrological and Hydraulic Models and in-Situ Data

EVG1-CT-2002-00085

<http://projects.itek.norut.no/FloodMan/>

Instrument:	FP5 – Research Project	Ending date:	31/01/2006
EC contribution:	1,865,455.00 €	Duration:	36 months
Organisation:	Norut Information technology		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The main objective of the FloodMan project is to develop, demonstrate, and validate an information system for cost effective flood forecasting and management using EO data, in particular spaceborne synthetic aperture radar (SAR) data, hydrological and hydraulic models, and in-situ data. The prototype system will provide near real-time information on hydrological parameters relevant for forecasting and monitoring of flood events

Scientific achievements and results

We have implemented and demonstrated methods for mapping of surface water in non-forested areas from SAR images with little or no user intervention. The prototype production line is installed at KSAT, a satellite data provider. Our tests indicate that the automatic processing time will be in the order of three hours after satellite data acquisition. This is within the delivery time specified by most flood-forecasters we have interviewed. Still, the quality of EO-based flood maps must be evaluated, in order to remove false flood detections. The methods have been tested and refined for test areas in Finland, Germany, Italy and Norway. Validation has been done in Finland and Italy by comparing the water line extracted from Satellite images with the water line detected from air-photos and GPS reference points. Generally the accuracy is within on to two pixels. The main challenge of is to process satellite images with non-optimal incidence angels, spatial resolution and polarizations with sufficient accuracy.

We have developed a method for estimating soil moisture content (SMC) from SAR imagery. The SMC values have been grouped in 5 classes. Ground measurements and Envisat images have been collected different sites in Northern Italy. The methods have also been tested with encouraging results on satellite imagery from Finland. Studies are ongoing in order to relate the EO based soil moisture to the “true soil moisture” and to use EO-data of soil moisture for data assimilation. The challenge here is that the soil moisture from EO-data is valid for the top few cm, whereas the soil moisture in the hydrological model goes deeper. Therefore the soil moisture simulations in the hydrological model must be divided into moisture of the top layer and deeper layers.

A data assimilation model system (Neith) has been further developed. The model system contains a hydrological rainfall runoff model (HBV) for the Sieg catchments, a flood routing model (WTM) for the Sieg River and a hydraulic model (Sobek) for the Rhine River. Data-assimilation is carried out on the HBV and the Sobek model. With the Sobek results the system generates floodmaps that can be compared with the satellite images.

The hydrological model is used for making real time forecasts in Finland (SYKE-WSFS) is based on the HBV-model, with major local modifications. Two model concepts are developed for inundation modeling of embanked floodplains in lowland areas. The framework of the model package for improved flood forecasting

using data-assimilation is implemented. Surface water storage was implemented in the hydrological model for Kemijoki to be compared with EO-data. If the EO data can provide information of the extent of surface water, it has the potential to improve the accuracy of the discharge forecasts at least 1-2 days ahead.

Socio-economic relevance and policy implications

Essential for the Flood Warning and Management System are the hydrological and the hydraulic models by which the water levels are computed and predicted. This project will not stop or diminish the floods but may reduce the damages by flooding. Flood damages are reduced significantly if the flood warning comes in time and is accurate. Accurate and timely information for the citizens is essential for their perception of security and will prevent panic. Collecting, controlling and standardized providing of hydrological data is fundamental, especially for research, examination, analysis and modeling.

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GLACIORISK – Survey and Prevention of Extreme Glaciological Hazards in European Mountainous Regions

EVG1-CT-2000-00512

<http://glaciorisk.grenoble.cemagref.fr>

Instrument:	FP5 – Research Project	Ending date:	31/12/2003
EC contribution:	647,624.00 €	Duration:	36 months
Organisation:	Cemagref		
Co-ordinator:	Didier Richard (didier.richard@cemagref.fr)		
EC officer:	Tobias Fuchs		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The main objective of this project was to develop scientific studies for detection, survey and prevention of future glacial disasters in order to save human lives and to reduce damages.

A first specific objective was therefore to make a comprehensive inventory of the past catastrophic events related to the glacial environment in the Alps and in the Nordic countries. The six countries concerned in priority are France, Switzerland, Italy and Austria in the Alps, Norway and Iceland in Northern Europe.

The studied natural hazards are:

- Glacier lake outburst floods (GLOF),
- Jökulhlaups (sudden draining of internal water pockets),
- Stability of steep glaciers,
- Snow or ice avalanches triggered by serac falls,
- Length change of glaciers (creation of temporary dams for instance).

Among the potentially dangerous sites recorded in an exhaustive and updated inventory realised at the beginning of the project, some field sites representative of each glacial hazard have been selected and equipped to conduct various field surveys. For each type of risk, different possible technologies and methods have been specified, then studied and tested. On the basis of these field investigations and of existing models for landslides or dam breaking, numerical models have been developed in order to simulate the processes and to better understand the triggering mechanisms.

Scientific achievements and results

The Glaciorisk Data Base system storing all the data about glaciers, risks, events and damages, GRIDATABASE, has been completed and opened to everyone in Internet, favouring the knowledge of the problems dealing with risky glaciers and possible solutions to solve it. The structure of web pages allows to list glaciers, events and damages / victims in different ways. In addition atlas have been published in France, Iceland, Switzerland, Austria and Norway.

Another purpose was to improve the scientific knowledge of the three main glacial hazards (glacier floods, ice avalanches and glacier length variations) with the aim of prediction and mitigation. A first task was to carry out a bibliographical review to gather all the scientific information on this topic and to establish contacts with the scientists already involved in this field, anywhere in the world. In parallel, every glacial hazard has been studied on various selected representative field sites, using and testing various geophysical and glaciological techniques. Diverse numerical simulations have been applied on different dangerous sites. Various models applicable to the various glaciological hazards have been recollected or fully developed. The scientific contributions cover various situations ranging from the use of existing models for either simulating the subglacial water flow explaining some Jökulhlaups or the water discharge following a sudden

release of water, to the complete developpement of specific damage mechanics models applied to the breaking off of large ice masses for instance.

The main production mainly concerns theoretical developments under the form of scientific publications which are intended to serve as a basis for more applied forthcoming applications.

A new procedure for hazard-risk management was developed and put into operation to cover the entire area of Canton of Valais. For this purpose, workshops with experts stationed at the concerned place were organized, and their evaluations taken into account. On the basis of the risk overview of 10 glaciers posing the greatest risks, a preliminary planning for preventive measures was carried out. For these ten glaciers, various security measures were considered and their cost-effectiveness determined. This procedure has been described in a document, and is now available for adaptations to other national or local contexts if necessary.

To make glacial risks sensible to a larger audience and to make public and local organisations more responsible, an educational film has been produced and diffused. This 14-minute film presents real events like serac falls, water pocket sudden draining and examples of prevention, protection and mitigation. A french as well as an english version have been realised.

Socio-economic relevance and policy implications

The main soio-economic objective is the improvement of safety. Glacial risks threaten economic targets such as buildings, villages, roads, highways, railways and footpaths. A better understanding of those risks, a systematic survey and appropriate mitigation of risk should reduce the damaging consequences of future disasters. European scientists are consulted as experts for problems in South America or Asia and the increase of skill will help with a better dissemination of European knowledge.

Potential end-users of GLACIORISK are services in charge of tourist infrastructures, communication networks, villages, towns, etc. The deliverables of the project can be used directly by these end-users and even by the different governments for the purpose of glacial risk prevention and mitigation. French and swiss main end-users were partners to the project. Elected people responsible for the inhabitants of their mountain village or town can use the glacial risk data base GRIDATABASE, the atlas and the guidelines for risk prevention and mitigation in order to take the right decisions for safety. The results of the scientific studies of GLACIORISK can also be very helpful for them to act towards the best safety of inhabitants and tourists.

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IMPACT – Investigation of Extreme Flood Processes and Uncertainty

EVG1-CT-2001-00037

<http://www.impact-project.net>

Instrument:	FP5 – Research Project	Ending date:	30/11/2004
EC contribution:	1,493,992.00 €	Duration:	36 months
Organisation:	HR Wallingford Ltd		
Co-ordinator:	Dr Mark Morris		
EC officer:	Tobias Fuchs		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

Research for this project has been structured in order to have the greatest impact on reducing uncertainty in predicting extreme flood conditions. Specific objectives are to advance scientific knowledge and understanding, and develop predictive modelling tools in four key areas. Firstly, the movement of sediment (and potentially with pollutants) generated by a failure. Secondly, the mechanisms for the breaching of embankments (dams or flood control dykes) and factors determining breach location. Thirdly, the simulation of catastrophic inundation of valleys and urban areas and fourthly the use of geophysical techniques for the rapid integrity assessment of flood defence embankments. Research is being undertaken through a combination of fieldwork (controlled testing and analysis of 6m high embankment failures), laboratory physical modelling and combined desk study and numerical simulation. A key objective of the IMPACT project is to advance the understanding of uncertainty associated with the above processes. This knowledge will be combined through a single system (case study etc.) to demonstrate the real magnitude of uncertainty associated with the end data and implications for its application within industry (i.e. for asset management, emergency planning etc.).

The Impact project addresses the assessment and reduction of risks from extreme flooding caused by natural events or the failure of dams and floods defence structures.

Scientific Achievements and results

The IMPACT Project has allowed significant advances to be made in the understanding and modelling of a range of extreme flood processes including breach formation, flood propagation, sediment movement, modelling uncertainty and embankment integrity assessment. This has placed European researchers, and subsequently European flood modellers, at the forefront of current capabilities in this field.

Research within the project process areas has identified and advanced current best practice. In particular:

- Breach formation modelling: A range of breach models have been assessed and developed using large scale field and laboratory data. These models offer improved capabilities and reliability in comparison to earlier models and offer the current state of the art for breach modelling. The widely used US NWS model, developed in the 1980's, has now been shown to be obsolete in its approach.
- Flood Propagation modelling: Analysis of different modelling techniques for simulating urban flooding and dam break propagation has highlighted differences between models and modelling approach. Limitations in modelling are found to be constrained by the accuracy of data provided for the models, modelling assumptions (roughness values) and computing power, rather than by the mathematical modelling approaches. Grid resolution should improve further as computing power increases, so allowing wider use of more complex 2D modelling techniques, although research is urgently needed to clarify modelling roughness values for extreme flow conditions.
- Sediment movement: Research has confirmed that sediment movement during extreme floods has a significant effect upon the depth of flood water and on the wave propagation rate. However, the level of understanding of these dynamic processes, and the performance of new models, mean that no tools are

readily available for use within the flood risk management community. Further research into this area is required in order to advance knowledge and modelling ability and to allow these important processes to be included within flood risk management assessments.

In terms of quantifying uncertainties, a practical approach to assessing the potential magnitude of uncertainty within the flood modelling process was developed and applied to a case study. In practice, this was applied to breach and flood propagation models only; the uncertainty associated with predicting sediment movement was found to be too large to warrant such an assessment. The size of uncertainty in predicted flood water levels for the project case study was found to be quite large – in the order of ~30% of water depth. This has significant implications for end users (e.g. emergency planners, asset managers, development planners etc.) in how they use flood modelling results; end users should accommodate such degrees of uncertainty within their applications.

Concerning integrity assessment, a review of geophysical investigation techniques has been undertaken and new technology tested to identify a new approach that would allow the 'rapid', non intrusive integrity assessment of flood defence embankments. Results of a new system are promising and, with further development, may allow integrity assessment of 5-10km of embankment per day compared with the relatively slow and expensive existing approach of isolated sampling.

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MITCH - Mitigation of Climate Induced Natural Hazards

EVG1-CT-2000-20001

<http://www.hrwallingford.co.uk/Mitch/default.htm>

Instrument:	FP5 – Scientific Support Action (SSA)	Ending date:	31/07/2003
EC contribution:	198,400.00 €	Duration:	30 months
Organisation:	HR Wallingford Ltd		
Co-ordinator:	Prof. James Dent (j.dent@hrwallingford.co.uk)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The broad interdisciplinary scope of MITCH cuts across different themes of the Environment and Climate programme, and the work of Directorates covering Environment and Spatial Planning. MITCH has endeavoured to provide a forum for discussion and communication for research projects dealing with flood forecasting, flood emergency, unstable land, and other problems related to climatic extremes. The participants in MITCH covered a wide range of researchers and practitioners involved in specialist disciplines, which relate to the main natural hazards of flood, drought and land instability. Their expertise also covers tools and methods for improved monitoring and modelling, which are recognised as best practice. The aims were achieved through providing a wide forum for interchange and dissemination, to include a series of 3 workshops, a website and an internet discussion group.

The MITCH Concerted Action formed a bridge between academic researchers, applied researchers, public authorities and industry in the area of hydrological and geological hazards. It has provided the opportunity to:

- Build Awareness of the outputs of EC and other relevant research,
- Develop an Appreciation of its relevance,
- Make the research outputs Accessible,
- Gather experiences to demonstrate the Application of the research.

Climate induced hazards, such as floods, storms, droughts and landslips, have a significant impact on the social and economic well-being of Europe, and on occasions can be life threatening. Much theoretical and applied research is ongoing into many aspects of the science related to climate induced hazards, but there is a wide perception that the take-up and dissemination of this research has been insufficient. Within this dissemination problem lie a number of links where improvement of communications is necessary.

- Between scientific specialists, particularly between meteorologists, hydrologists and geologists;
- A two-way exchange between the scientific community and the users, in order that research advances are better understood, and that researchers are informed of user needs;
- The use of this information to improve awareness and warning to the general public;
- The need for continued dialogue between researchers in different aspects of risk mitigation.

This Concerted Action for the Mitigation of Climate Induced Natural Hazards (MITCH) sought to address these problems, utilising the commonality that exist in risk based studies for a range of scientific specialisations and situations.

Close communication between the partners and their projects was aimed at by MITCH to ensure best use of resources. This also provided an objective of improving the understanding of science between the various specialists, as individual advances are made. The main means of providing a wide forum for interchange and dissemination was through a series of workshops, and a website for dissemination of results.

Scientific achievements and results

During the course of the project, four workshops were held:

- Workshop 1: Floods droughts and landslides -management in a changing climate.
- Workshop 2: Advances in flood forecasting, warning and emergency management
- Workshop 3: Floods droughts and landslides -who plans, who pays?
- Workshop 4: Lessons from the European floods of summer 2002.

MITCH attempted innovation in two main areas:

- The encouragement of dialogue and development of understanding between meteorologists and the range of scientists and engineers concerned with the resulting surface phenomena;
- The dissemination of such research to users with responsibility for design, planning management and operation that focus on public safety from natural hazards, which inherently have significant financial and economic implications.

The second of these issues should provide the link to end users, which includes the public. The involvement of the insurance industry recognised the growing role of insurance both in social and governmental aspects of disaster preparedness and response. The workshops aimed to attract outside participation, and involved the Commission by inviting participation from senior representatives.

The workshops encouraged practical demonstrations, including presentation of demo-versions of commercial software, or of existing automated warning or monitoring systems as examples. The emphasis was on practical and operational systems, rather than fundamental research. Some key topics focussed upon were:

- new and improved technologies for monitoring;
- new and improved modelling techniques;
- the linkage between models, particularly meteorological, hydrological and hydrogeological models;
- spatial recognition and mapping indicators for natural hazards;
- improvements in the dissemination of forecasts and warning;
- practices for emergency awareness, preparedness and operations at both the institutional level and with the individual citizen.

The issues for research uptake into practice were a consistent theme through all the workshops. The Concerted Action identified some specific topics within its focus of interest, which require further research effort or development, including:

- Quantitative precipitation forecasting (QPF).
- The definition and management of uncertainty.
- Understanding the applications of ensemble forecasting.

There is a need for extended “buy-in” by a wide range of “end-users”, but in particular from planners, administrators and emergency managers. The evolution of MITCH should include establishing suitable fora for these target groups, and it is hoped that FP 6 projects can address this point effectively. Results from MITCH have been used in interactions of the EFFS and ACTIF programmes. The findings of MITCH were the subject of a presentation in a special session on the EC programme of research at the EGS/EGU/AGU Symposium at Nice in April 2003.

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PHEFRA – Palaeoflood and Historical Evidence in Flood Risk Assessment

EVG1-CT-2002-60001

<http://www.ccma.csic.es/dpts/suelos/hidro/phefra/index.html>

Instrument:	FP5 – Scientific Support Action (SSA)	Ending date:	31/12//2003
EC contribution:	70,000.00 €	Duration:	15 months
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The essential aims of this workshop were:

- To demonstrate the existing techniques for the reconstruction of past flood discharges;
- To discuss the standardisation of this methodology;
- To comprehensively disseminate such methodologies for technical personnel in administration and the private sector;
- To demonstrate the effective ready to use tools (such as software, GIS applications etc.) developed in past and on-going projects;
- To provide guides for data collection and their correct statistical use.

Scientific achievements and results

The workshop was attended by 140 researchers and professionals, representing some 20 countries. It was divided into distinct thematic sessions that together form a methodological framework for using past flood data in flood risk assessment. The 6 sessions were: palaeoflood data collection (session 1); historical flood evidence (session 2); the hydraulic modelling of past floods (session 3); flood frequency analysis incorporating non-systematic data (session 4); flood-climate relationships and the meteorological context of flood events (session 5); and flood management, education and risk estimation (session 6). In addition to these sessions, two field excursions, to Gerona and Monistrol de Montserrat, were organised in order to illustrate the methodology developed during the EC SPHERE project (EVG1-CT-1999-00010) for obtaining palaeo-and historical flood data, estimating past discharges and applying this data in risk analysis.

Palaeofloods and historical flood evidence allow a record of extreme events to be compiled over centuries to millennia. The instrumental record is a basic source of information in risk analysis that can be improved by incorporating past flood data. Some of the floods witnessed in Central Europe and in the south of France have been designated the largest since instrumental records began. However, some of these discharges were lower than those estimated using palaeoflood and/or historical flood evidence. Palaeoflood and historical flood evidence also allow s investigation into the effects of climatic variability on flood events. Climatic variability clearly effects flood magnitude and frequency. Non-stationarity of the flood record is not surprising, given that it may also be evident within instrumental series of 50 years length. Tools should be developed that allow quantification of the non-stationarity of a flood series and new procedures in flood frequency analysis of mixed populations. Within the legislative framework, there is, therefore, a need to address the European standardisation of flood risk policies.

The accuracy of discharge estimates derived from palaeoflood and historical flood evidence has improved recently with increased computational capacities and new technologies for obtaining topographic data (GPS, LIDAR, etc.) which has allowed improved hydraulic modelling using one and two-dimensional models. In terms of risk planning (in construction of bridges and dams, for example), that uses return periods of between 100 and 500 years, the traditional method of using only hydrological data or hydrometeorological calculations should be modified. This information has been shown to be insufficient in the absence of long term gauge records.

Socio-economic relevance and policy implications

The universal nature of flooding makes it the most widely distributed natural threat to human life and economic losses in Europe, as was recently shown in the floods in 2002 that devastated many parts of Central Europe causing 230 fatalities and economic losses in the region of € 55 billion. The PHEFRA Workshop was directly aimed at the dissemination, particularly to end-users, of results and methodological guidelines from current European RTD projects on the use of palaeoflood and historical flood data in flood risk assessment. End-users, such as Civil Protection, flood warning offices, environmental agencies, land-use planners and insurance companies for example, attended the workshop which ensured that results and information are disseminated beyond the scientific research community. An abstracts volume, field guide and book (*Palaeoflood, historical data & climatic variability: applications in flood risk assessment (2003)*). Edited by V.R.Thorndycraft, G. Benito, M. Barriendos, M.C. Llasat. ISBN-84-921958-2-7) were published to enable dissemination of the most significant findings to a wider interested audience.

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SPHERE – Systematic, Palaeoflood and Historical Data for the Improvement of Flood Risk Estimation

EVG1-CT-1999-00010

<http://www.ccma.csic.es/dpts/suelos/hidro/sphere/home.html>

Instrument:	FP5 – Research project	Ending date:	31/05/2003
EC contribution:	949,100.00 €	Duration:	39 months
Organisation:	Consejo Superior de Investigaciones Cientificas		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The catastrophic floods occurring in Europe in the last decade of the 20th Century warned of the critical need for hydrologic data on floods over long-time scales. Paleohydrological techniques provide information on hydrologic variability and extreme floods over long-time intervals (100 to 10,000 yr.) and may be used in combination with historical flood data (last 1,000 yr.) and the gauge record (last 30-50 yr.). In this project, new scientific frameworks and technical tools integrating multidisciplinary approaches (geologic, historical, hydraulic, statistical and GIS) on extreme flood risk assessment were generated. These were tested in case study areas in Spain and France. New methods of reconstructing paleofloods and the historical flood record of these basins lead to the elaboration of a complete catalogue of the major past floods. Systematic and non-systematic data were combined in the flood frequency analysis using improved methods for the adjustment of distribution functions.

- To generate new scientific frameworks and technical tools for integrating data on extreme floods using multidisciplinary risk assessment methods. This new approach complements hydrologic modelling efforts by applying historical information and palaeoflood hydrology methods together with statistical and hydrological procedures to specifically increase data on the largest storms/floods over timespans that range from decades to millennia.
- To provide a new methodology to estimate the frequency of the highest risk floods and transfer the resulting tools to end-users and decision makers of different technical and administrative levels. To provide a methodological guide for climatic/flood data collection and temporal analysis.
- To improve the understanding of the climatic forcing conditions related to the formation of extreme floods in the short and long term (decades to millennia).
- To suggest strategies for improving public awareness and flood risk education with regard to extreme flood events.

Scientific achievements and results

The palaeoflood stratigraphy, and associated chronology, has been determined for 5 Mediterranean river basins within Spain (Segre, Llobregat and Ter rivers) and France (Ardèche and Gardon rivers). Methodological advances in palaeoflood research have focused on the sedimentology of slackwater flood deposits and the application of OSL (Optically Stimulating Luminescence) and ¹³⁷Cs dating methods to slackwater palaeoflood deposits. The palaeoflood records identify two periods of increased flood frequency: the late Bronze Age (ca. 2700-2800 BP) and the Little Ice Age (16-18th centuries AD). Hydraulic modelling results indicate that the magnitude of the flooding during these periods was higher than that of the largest floods recorded in the instrumental records. For example, in the Llobregat Basin, a minimum discharge

estimate of $4680 \text{ m}^3\text{s}^{-1}$ was modelled for a flood event radiocarbon dated to calibrated AD 1516-1642, compared to $2500 \text{ m}^3\text{s}^{-1}$ for the 1971 flood, the largest in the instrumental record.

Methodological guidelines for the collation of historical flood data derived from documentary sources have been developed. The methodology was implemented to accurately obtain a detailed flood chronology from the study basins; to identify historical flood marks illustrating the elevation floodwaters reached during past flood events; and to obtain as much detailed information as possible relating to the topography of the river channel and the boundary conditions at the time of the flood to enable accurate hydraulic modelling. Flood chronologies were obtained from: Gerona, Camprodon, Ripoll (Ter basin); El Prat (Llobregat); Seu d'Urgell, Balaguer and Lleida (Segre); Vallon (Ardèche); and Grenoble (Isère). A total of over 500 flood references were collated, with Spanish chronologies starting in the 14th Century, French chronologies from AD 1600. An increase in flood frequency was noted between AD 1570-1630, AD 1750-1800 and AD 1840-70 (Spanish basins), and AD 1620-70, AD 1730-80 and AD 1840-60 (French basins). Threshold discharges were computed for the historical floods with at least 3 level marks.

One of SPHERE's innovative approaches was the combined methodological approach of using palaeoflood and historical flood data to reconstruct long-term flood chronologies. This has led to notable improvements, for example in providing more accurate palaeoflood chronologies. In the case of the Llobregat palaeoflood dated to AD 1516-1642, the historical evidence suggests that this event was the AD 1617 flood, the largest historical flood. The palaeoflood data is located in a more stable reach than the historical evidence allowing a more accurate discharge estimate for this particular event ($4680 \text{ m}^3\text{s}^{-1}$).

Flood-climate relationships were analysed at different spatial-temporal scales. Circulation patterns producing flood events were identified from sea-level pressure data. Downscaling methods were applied to quantitatively link the large scale to local scale conditions. The palaeoflood and historical flood data were tested using GCM palaeoclimate simulations. Old instrumental data enabled synoptic reconstruction of Spanish floods during the AD 1840-70 period of increased flood frequency.

Flood frequency analysis was carried out using the combined systematic and non-systematic (palaeoflood and historical information) data sets using the FRESH software developed during the project. In general the incorporation of the long-term data tends to increase the flood quantiles meaning that only using the short-term instrumental record underestimates the different return period discharges.

Databases have been constructed to store all the collected palaeoflood and historical flood information. These have been linked to the SPHERE-GIS that enables spatial and temporal queries to be made regarding the data, as well as statistical analysis. A major tool for results dissemination is the SPHERE webpage, located at: <http://www.ccma.csic.es/dpts/suelos/hidro/sphere/home.html>.

The SPHERE project has successfully compiled long-term palaeoflood and historical flood data within French and Spanish Mediterranean basins and developed data bases, GIS and statistical analysis software for efficient data management. The SPHERE consortium recommends the use of long-term flood data for more accurate flood risk estimation in Europe and has produced a detailed set of methodological guidelines outlining the best-practice in obtaining and using such data.

Socio-economic relevance and policy implications

The universal nature of flooding makes it the most widely distributed natural threat to human life and economic losses in Europe, as was recently shown in the floods in 2002 that devastated many parts of Central Europe causing 230 fatalities and economic losses in the region of € 55 billion. The SPHERE project has developed new methods of flood frequency analysis where information from past floods (palaeoflood and historical information) has been included in the data-set resulting in a longer record of flood events. This 'real' flood information provides more accurate flood magnitude/frequency data than can be derived from the short instrumental record. This long-term data can be utilised in flood frequency analysis and ultimately provides a more informed scientific framework on which flood risk policies and strategies can be based.

The EU Water Framework Directive will benefit from the use of the SPHERE methodology by promoting the use of past flood records within the "best practice document" as a means to improve flood prevention, risk assessment and flood hazard zoning on floodplains.

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THARMIT - Torrent Hazard Control in the European Alps: Practical Tools and Methodologies for Hazard Assessment and Risk Mitigation

EVG1-CT-1999-00012

http://www.geol.unipd.it/03_ricerca/progetti/tharmit/tharmit.htm

Instrument:	FP5 – Research project	Ending date:	01/07/2003
EC contribution:	930,800.00 €	Duration:	36 months
Organisation:	University of Padova		
Co-ordinator:	Prof. Rinaldo Genevois (rinaldo.genevois@unipd.it)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

In the Alpine region the topography, the geological structure and the climate are of such a character that the risk of natural catastrophes, and especially landslides and gravity flows, is evident when certain conditions are fulfilled. Hydrogeological, hydrological and geotechnical/ geomechanical factors influence the probability of occurrence of such events, as do the interference of the human activity with the physical environment.

The main aim of the project is to increase the control of torrent hazard by a deeper understanding of practical tools and methodologies for risk assessment and mitigation, focusing on prevention and reduction of risks.

Objectives

- 1) The set up of a data-base on torrential hazards in the Alpine area for numerical models calibration and countermeasures evaluation, as well as a practical tool for statistical analyses;
- 2) The maintenance and operation of the existing observation system as an essential tool for both prediction of torrent hazards and understanding of their behaviour;
- 3) The improvement of both the knowledge of natural processes and the existing numerical models for a more effective establishment of hazard and risk assessment methodologies;
- 4) The set up of countermeasures construction rules;
- 5) The development and installation of a warning system
- 6) The supplying of friendly geo-referenced interfaces and guidelines for the use of specific tools as well training courses for end-users.

Lastly, existing tools for hazard assessment and risk mitigation suffer from a lack of transparency and are still of a heavy use. On the contrary, these tools should be available to practitioners providing friendly geo-referenced interfaces and guidelines for the use, including the characterisation of the type of phenomenon, domains of validity, methods of computation of input data and estimation of relevant parameter values.

Scientific achievements and results

Monitoring activities developed at the stations operated by the partners provided new field data at the occurrence of events and stressed the importance and the effectiveness of real-time monitoring systems in reduction of the risk from debris flow occurrence. The results obtained in the both installed systems show that different sensors could be used to get different data and information about debris flow theology and relationships with precipitations intensities that are fundamental for sound and reliable modelling and for effective hazard mapping and correct design of active defensive measures. The achieved results in field investigations allow to carry out systematic analysis of debris flow prone catchment with the aim to establish hazard maps and to reveal possible scenarios of debris flow events: contributions of numerical simulations of propagation and deposition processes can be then used for land use mapping, particularly considering man-caused alterations of the environment responsible for torrential activity modifications. The manual on the application of reconstructive methods for hazard evaluation and the guidelines for the use of the GIS-based model PROMOTOR-df to predict the probability of hazardous torrential debris flows have been completely

developed keeping user-friendly accessibility and operation in mind. Ease of access and free availability of software and guidelines will be greatly enhanced by their publication on the Internet. A new method of classification of torrent control measures has been developed by grading the construction types. By evaluation of the effectiveness of open barriers the reasons for insufficient function fulfilment have been verified. The influence from several barrier types in connection with water connectivity and "good ecological quality" has been detected. By model experiments approaches were found to derive impact forces on debris flow breaker from flow velocity and flow depth. A warning system has been implemented at Wartschenbach, but the implementation of warning systems in contingency plans has to be carefully checked with the responsible authorities and organisations. Actual outcomes of the project are represented by:

- 1) The analyses of the domains of validity and necessary specific requirements for GIS-modelling and hazard assessment taking advantages from the results of field data, models application and hazard and risk assessment and mitigation in selected areas of the Alps.
- 2) The systematic application of numerical simulation models leading to recommendations on correct approach to modelling and application of prediction formulae for sediment transport in torrents.
- 3) The know-how transfer to practitioner by disseminating the results through seminars and training workshops, besides reports and scientific publications.
- 4) The preparation of reports for end-users with the summary of results and the cost-benefit analysis.

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FLOODSITE – Integrated Flood Risk Analysis and Management Methodologies

GOCE-CT-2004-505420

<http://www.floodsite.net>

Instrument:	FP6 – Integrated Research Project (IP)	Ending date:	28/02/2009
EC contribution:	9,680.000 €	Duration:	60 months
Organisation:	HR Wallingford Ltd		
Co-ordinator:	Prof. Paul G Samuels (floodsite@hrwallingford.co.uk)		
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PROJECT SUMMARY

Floods from rivers, estuaries and the sea threaten many millions of people in Europe. Flooding is the most widely distributed of all natural hazards across Europe, causing distress and damage wherever it happens. Previous research has improved understanding of individual factors but many complex interactions need to be addressed for flood mitigation in practice. Thus the first round of the Sixth Framework Programme of the European Commission (2002-2006) includes an “Integrated Project” on flood risk management, called FLOODsite. To achieve the goal of integrated flood risk management, FLOODsite brings together managers, researchers and practitioners from a range of government, commercial and research organisations, all devoted to various, but complementary, aspects of flood risk management. The FLOODsite project covers the physical, environmental, ecological and socio-economic aspects of floods from rivers, estuaries and the sea. The project is arranged into seven themes covering:

- Risk analysis – hazard sources, pathways and vulnerability of receptors.
- Risk management – pre-flood measures and flood emergency management.
- Technological integration – decision support and uncertainty.
- Pilot applications – for river, estuary and coastal sites.
- Training and knowledge uptake – guidance for professionals, public information and educational material.
- Networking, review and assessment.
- Co-ordination and management.
- Within these themes there are 35 project tasks including the pilot applications in Belgium, the Czech Republic, France, Germany, Hungary, Italy, the Netherlands, Spain, and the UK.

The main aim of FLOODsite is to provide an integrated framework for flood risk management from operational to strategic planning time horizons. The ambition for the project is to deliver:

- An integrated, European, methodology for flood risk analysis and management.
- A consistent approach to the whole system, comprising the natural hazard, the socio-economic vulnerability and the natural ecological and human cultural values.
- Consistency across cause of flooding from rivers, estuaries and the sea.
- A framework for integrated flood risk management
 - Sustainable “pre-flood” measures (infrastructure provision, planning and vulnerability reduction)
 - Flood event management (early warning, evacuation and emergency response)
 - Post-event activities (review and regeneration)
- Integration with and advancement from other EC and national research.

The potential impact of the FLOODsite Project covers a wide range of issues including from the challenges of sustainability to the contribution to policy development and implementation at national, regional and European level.

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WATCH – Water and Global Change

CT – 036946

Instrument:	FP6 – Research Project	Starting date:	Autumn 2006
EC contribution:	9.980.096,00 €	Duration:	48 months
Organisation:	Natural Environment Research Council		
Co-ordinator:	Prof. Richard Harding (rjh@ceh.ac.uk)		
EC officer:	Marta Moren Abat (marta.moren-abat@ec.europa.eu)		

PROJECT SUMMARY

The aim of the project (in connection with the Climate Change areas) is to bring together the hydrological, water resources and climate communities to analyse, quantify and predict the components of the current and future global water cycles and related water resources states, to evaluate their uncertainties and clarify the overall vulnerability of global water resources related to the main societal and economic sectors.

In relation to the Natural Hazards area, the project is going to:

- 1) Analyse and describe the current global water cycle, especially causal chains leading to observable changes in extremes (droughts and floods),
- 2) Evaluate how the global water cycle and its extremes respond to future drivers of global change (including greenhouse gas release and land cover change).

PROJECT CO-ORDINATOR

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The WATCH consortium includes 25 partners from 14 different countries.

FOREST FIRES

FIMEX - Forest Fire Fighting Method with Explosive Hoses filled with an Extinguishing Agent
EVG1-CT-2000-30002
<http://www.wagner.de>

Instrument:	FP5 – Research project	Ending date:	31/03/2003
EC contribution:	370,368.00 €	Duration:	24 months
Organisation:	WAGNER Alarm – und Sicherungssysteme GmbH		
Co-ordinator:	Ms Florence Daniault (Florence.daniault@wagner.de)		
EC officer:	Karen Fabbri		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The problem of forest fires is a world-wide one. It is especially serious in areas with Mediterranean climate, where weather and forest conditions are very often conducive to major conflagrations. The high social and environmental costs make the need for effective forest fire prevention, suppression and rehabilitation activities very urgent.

Existing fire fighting products are insufficiently flexible and effective. By fighting fire with helicopters or planes, a substantial part of the huge amount of water required never reaches the fire due to evaporation and the influence of winds. This method is also very expensive. The "fire-extinguishing bombs" have proved disadvantageous because they do not apply a directed extinguishing effect due to the detonation, and rather fan the flames when they are ignited in the centre of the fire. The stationary fire extinguishers like fixed water mist spraying installations have only a localized effect. They also have high initial and high maintenance costs.

In the United States, blasting cords are used to extinguish forest fires but without extinguishing agent. The only effect of blast allows the extinction of fire. This method is very hazardous for the crew and requires specific and specialized personnel. The new explosive hose method is a more adaptive and effective device for extinguishing fires as the devices described above. It is also a very economical alternative because it requires only a limited amount of water.

Scientific achievements

The FIMEX project provided a new method for the suppression of forest fire that will improve the efficiency of the fire fighting services. This new forest fire fighting system has been developed to fill the gaps in current extinguishing methods. It is based on the deployment of an explosive hose system, which allows controlling of high intensity fire fronts, with flame temperatures greater than 1000° C. Water filled hoses with inserted blasting cords are exploded in the fire front to generate firebreaks. The water accelerated through the explosion is spread almost simultaneously in form of small water droplets onto the fire. Thus the extinguishing of large flame fronts can be achieved.

The explosive hose system can be integrated in an European manoeuvre tactic to facilitate the work of firemen of the different countries in Europe and worldwide. The explosive hose method will be a very economical alternative compared to the use of helicopters and planes in fighting forest fires or fixed water mist spraying installations, which have high initial and high maintenance costs. The principal market targeted for the explosive hose product is fire fighting services in the Mediterranean countries of the European Union. Users will benefit from a fire control system completed with fire suppression decision support and system application plan capabilities.

Other potential markets include fire control services in the non EU Mediterranean countries and in some overseas countries, even if the product will have to be adapted to non European vegetation and regulations.

Socio-economic relevance and policy implications

The extensive experimentation campaigns and the demonstration with controlled burnings have proved that the developed explosive hose system fulfils the fire brigade requirements in terms of preparation time on site and fire extinguishing efficiency. It has been proved that the FIMEX system is especially suitable for fighting high intensity fires, under extreme weather conditions and in isolated areas. The extinguishing efficiency can even be improved when the hose is filled with water and a retardant solution.

The code of good practice and the fire simulation software are good support tools for operational teams for the planning of the use of this new fire extinguishing method as complementary mean to the existing fire fighting equipment.

The results of the FIMEX project are products which are ready for the introduction on European and overseas markets, the latest barrier being the missing approvals for the use of explosives to fight fires.

The whole results obtained during the different experimentations are available on the French Sécurité Civile website <http://www.ceren.org/>.

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WARM – Wildland-Urban Area Fire Risk Management

EVG1-CT-2001-00044

<http://www.eumarm.org>

Instrument:	FP5 – Research project	Ending date:	31/05/2004
EC contribution:	1,416,591.00 €	Duration:	30 months
Organisation:	TYPSA		
Co-ordinator:	Dr David Caballero (davidcaballero@tecnoma.es)		
EC officer:	Karen Fabbri		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

Forest fires in the Wildland-Urban Interface and Rural Areas (W-UI/RA) in Europe is an emerging and growing problem, with social and economical consequences. In Europe, especially in Mediterranean countries, forest fires affect people, properties and natural environment.

WARM project is concerned with the development of a methodology and a Decision Support System (DSS) for the characterisation and assessment of forest fire risk in the Wildland-Urban Interface and Rural Areas (W-UI/RA) in Europe.

To accomplish this objective, a number of tasks have been scheduled grouped in project phases that have been sequentially inter-related, thus experimentation is preceded by users needs identification, study areas selection, data gathering campaign and data base elaboration. Development of the tool is based on the outcome of experimentation activities and, finally, application to study cases, in FR, IT, GR, CZ, SK, SP and validation is subject to the development of WARM tool.

W-UI problems have, at least, three different scales which must be approached in different ways, but consistently between them: landscape, settlement and house levels.

Scientific achievements and results

A seen forest fires in the Wildland-Urban Interface in Europe is a problem that has to be studied at several scales, each one entailing a scientific approach to the analysis and search for solutions.

Users needs have been identified at different scales, and some important conclusions have been obtained at different levels, homeowners, protection bodies, territorial managers, developers, insurance companies, etc.

Main components of W-UI affected by wildland fires have been identified and described. A methodology of inventorying them has been described and applied. As a result, a first version of the European catalogue of W-UI cases has been obtained.

Information technologies have helped to the data gathering and analysis across the 6 participating countries. Remote Sensing and Internet-based solutions have played an important role. New techniques and information technologies can help in the identification and measurement of main components of W-UI at settlement (local) and house (particular) levels.

Methods for forest fire risk assessment have been obtained at such levels, together with the adaptation and development of the associated information technologies. The obtained results have been transferred to the end users in the participating countries in the form of guides and assessment for regulation and good practices for the prevention planning and emergencies management in the urban interface.

Experiments have been complemented with the study of historical records of fires affecting the wildland-urban interface and their consequences. Besides, real fires have served, as an important source of information about the causes and consequences of destruction in the settlements. At local level, this information has been tested in a 3D radiation-convection model and proved to be a useful tool to understand and demonstrate fire behaviour in the vicinity of houses.

At landscape level, it has been obtained and demonstrated the relationships between land-use patterns and fire risk level, particularly in the land structures with urban interface. At settlement level, certain conclusions on the fire behaviour and destruction level (as well as survival of houses) have been obtained through the statistical analysis of an ad-hoc database. Particular attention has been paid to the type, distribution and load of vegetation and how this contributes to the propagation and affects the effectiveness of fire fighting. These conclusions have been complemented with the study of particular phenomena in the experimental tunnel, such as the production of heat flux and its relationship with convection and radiation and its final effect on houses components and human beings.

Erosion and landslides in the vicinity of settlements have been studied and modelled for two study cases. An improved version of the models has been obtained in which specific factors have been considered. As mentioned in the previous reporting period, the importance of runoff in the vicinity and inside the settlements has been addressed and modelled, as a complementary source of risk.

All the data about the different levels of detail has been incorporated to the WARM on-line database and map server, together with the algorithms for the calculation of fire risk potential. The other models have been incorporated to the WARM toolbox and are complementary to the analysis done in the Tool. These include stand-alone applications, GIS macro-language scripts and technical papers.

The demonstration and validation activities have taken place in the participating countries with a noticeable interest of the implied actors. A closing workshop was held in Madrid (Spain) as main activity of experiences and information sharing, as discussion platform and as a good wind to show research results to end users. Their needs and expectations have been transferred to the potential market analysis and services provision opportunities study, in order to outline the potential transfer of WARM results in the form of services prototypes.

WARM project has noticeably raised the interest and sensibilisation of the W-UI problem in Europe, in light of the obtained feedback after the three workshops and the mass-media activities in the participating countries. However, this initiative should be continued in the future with deeper and more extensive research and demonstration activities, and new activities should take place to increase and improve market opportunities in the field of W-UI defence against forest fires.

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**FIRE PARADOX – An Innovative Approach of Integrated Wildland Fire Management
Regulating the Wildlife problem by the Wise Use of Fire: Solving the Fire Paradox
CT – 018505**

Instrument:	FP6 – Integrated project	Starting date:	01/03/2006
EC contribution:	11.999.860,00 €	Duration:	48 months
Organisation:	Instituto Superior de Agronomia		
Co-ordinator:	Prof. Francisco Rego (frego@isa.utl.pt)		
EC officer:	Ewald Pertlik (ewald.pertlik@ec.europa.eu)		

PROJECT SUMMARY

Wildfires are a major problem for many European societies threatening human lives and property with disastrous impacts particularly at the wildland-urban interface. On the other hand humans always used fire as a tool to regulate nature and traditional use of fire is known in many regions in Europe. The understanding of this paradox is thus essential for finding solutions for integrated wildland fire management. This concept requires considering the various aspects of fire, from its use as a planned management practice (prescribed fire) to the initiation and propagation of unplanned fires (wildfires) and to the use of fire in fighting wildfires (suppression fire). Prescribed or suppression fires will therefore set the limits for wildfires by controlling their spatial extent, intensity and impacts. This is the main approach adopted aiming at the creation of the scientific and technological bases for new practices and policies under integrated wildland fire management and in the development of strategies for its implementation in Europe. Three major domains of related activities were considered: research, development and dissemination. In research, the project will focus on understanding the mechanisms and modelling the processes associated with fire, from physics to biology and social sciences. Experimental and sampling methods will be used. The scientific and technical knowledge gathered will allow the development of a technological platform that will integrate the fire model, the temporal and spatial variability of fuels and weather, and the potential ecological and social-economical impacts. Documentation and demonstration platforms will also be extensively used for dissemination, focusing in the development of strategies for public awareness, academic and professional training using new communication technologies and networks, and for the implementation of new practices, policies and regulations under the concept of integrated wildland fire management.

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The Fire Paradox consortium includes 32 partners from 12 different countries but concentrates on Mediterranean European countries most affected by fires: Spain, France, Greece, Italy, Poland, Portugal, Slovenia and also two Maghreb countries – Tunisia and Morocco.

LANDSLIDES

ALARM - Assessment of Landslide Risk and Mitigation in Mountain Areas

EVG1-CT-2001-00038

www.citimac.unican.es/Alarmproject/alarm.htm

Instrument:	FP5 – Research Project	Ending date:	30/11/2004
EC contribution:	911,187.00 €	Duration:	36 months
Organisation:	Consiglio Nazionale delle Ricerche		
Co-ordinator:	Dr Sandro Silvano (s.silvano@irpi.pd.cnr.it)		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

This project aims to contribute to improve prevention and mitigation of morpho-hydrogeological hazards and risks in Europe. A review of legislation and rules in European countries, of GIS analytical procedures for hazard studies, GIS techniques and multi-media tools, has led to the proposal and application of methodologies common to all participants, for assessing hazard, vulnerability and risk in the study areas. Essential features of this project are, on the one hand, the integration of socio-economic and natural process factors with the aim of providing comprehensive information on natural hazards as well as their consequences for society, and, on the other hand, the appeal of GIS and information technology for the creation of database infrastructures, spatial data analysis, mapping of hazard and risk, guidelines for mitigation actions and communication with decision-makers and the general public.

Scientific achievements and results

The major innovative contributions of the research are the preparation of a common vulnerability and risk assessment methodology, to be applied at a European level. New and significant advances have been obtained on the theoretical framework of landslide research and on the understanding of natural and human factors conditioning environmental dynamics and evolution. The second innovative imprint of this project lies in the essential role given to the GIS and new multimedia/information technology tools. The use of multimedia to generate interfaces for non-specialists for risk perception, and of new tools such as the Open GIS Concepts (OGC), geo-enabled inter-operative databases capable of representing and managing risk information.

Vulnerability was evaluated via an initial analysis of the social and economic features of the territory. It was therefore possible to identify the exposed elements that were more vulnerable. The assessment of the physical damage allowed quantifying the economic damage as direct cost to recover the involved elements, and indirect cost, caused by the interruption of economic activities. Nevertheless, vulnerability assessment posed the problem of understanding the interaction between disarray processes and exposed elements. The teams have decided to tackle the problem of defining the exposed elements using two different approaches:

- 1) Semi-quantitative method (Italy, France);
- 2) Qualitative method (all teams).

The methodologies can be summarized in the following points: description of landslides; description of each exposed elements and/or homogeneous exposed zones and integration under GIS + research of an automatic extraction to define homogeneous urban zones; pure data collection (economic data, social data) and traffic data; evaluation of vulnerability of the exposed elements or homogeneous zones; evaluation of hazard; use of Varnes' definition of risk; evaluation of direct costs and indirect costs; strict co-operation with local administrations in order to assess risk prevention and mitigation measures; awareness of the general public; dissemination of results.

The main deliverables were:

- Database for each country with inventory of legislation; review of GIS tools;
- Production of GIS material and training; assessment of existing spatial databases; design of system for stakeholder involvement; definition of multimedia architecture.
- Maps and database of landslides;
- Landslide vulnerability map; relational database connected to a GIS;
- Risk maps at medium and large scale; economic data and their attribute tables relational to a GIS; general procedures methods for risk assessment;
- Maps of land-use regulation proposal; guide-book presenting cost/effective mitigation actions;
- Web-pages presenting the case studies; educational products; organisation of Symposia at an International level; scientific papers.

Socio-economic relevance and policy implications

In Europe, significant examples of catastrophic landslides, which claimed lives and involved high socio-economic consequences, have occurred periodically in many countries, and they are destined to support high costs for the damage in the next few years, or for sustaining prevention and mitigation measures because of new disasters.

The prevention policies are not so advanced in the European countries subject to natural risks and risk assessment. Even in countries where prevention has been in progress for several decades, prevention tools and document conception has changed, at the light of encountered difficulties, particularly in regular plans and in obtaining the agreement of the public concerned.

Owing to all these reasons, a methodology like the one proposed in this project, base on a correct and preventive management of a specific territory, will be able to contribute to a reduction of losses both in terms of human lives and economic damage.

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DAMOCLES – Debrisfall Assessment in Mountain Catchments for Local End-Users

EVG1-CT-1999-00007

<http://damocles.irpi.cnr.it/welcome.htm>

Instrument:	FP5 – Research Project	Ending date:	28/02/2003
EC contribution:	857,500.00 €	Duration:	36 months
Organisation:	University of Newcastle upon Tyne		
Co-ordinator:	Dr James Bathurst (j.c.bathurst@ncl.ac.uk)		
EC officer:	Maria Yeroyanni		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

- To develop and apply advanced quantitative models for debris flow and rockfall hazard assessment, impact prediction and mitigation studies, relevant at the local, river basin and regional scales;
- To conduct field surveys and assemble databases in support of model development and to improve mapping and data analysis techniques;
- To transfer the technologies to end-users and make the outcomes accessible through the public domain.

Scientific achievements and results

DAMOCLES has developed a suite of quantitative and spatially distributed models for debris flow and rockfall hazard assessment, impact prediction and mitigation studies. They provide an integrated approach which is applicable at scales ranging from the local to the regional and which indicates susceptibility as well as potential impacts. They improve upon previously existing techniques through their ability to quantify hazard on a spatially distributed basis, to explore the mitigating effects of torrent control works and land management for present and future conditions and, in the case of the rockfall model, to determine hazard in a three-dimensional setting. The models have been validated for focus areas in the Pyrenees and the Alps and the methodologies have been made available to the end-user community. The model development has been supported by a field programme which has provided new quantifications of debris flow characteristics, databases for running the models and improved techniques for assessment mapping and data analysis. Strong end-user involvement, including participation in training courses and model applications, and continued upgrading of the website have maximised the transfer of the project technologies into the public domain.

WP1 Development of functional relationships for debris flow behaviour derived from field data and existing databases Predictive relationships for key debris flow characteristics, such as runout distance, were derived and used to refine the WP3 and WP4 models. Discriminant analysis defined the main factors that contribute to the triggering of debris flows in the flysch sector of the Central Spanish Pyrenees, providing the basis for a logistic model of the spatially-varying probability of occurrence of debris flows. Maps were constructed of the spatial distribution of extreme rainfall events in the Central Spanish Pyrenees, to support predictions of debris flow occurrence and the design of public works for mitigating debris flow impact.

WP2 Development of a GIS hazard assessment methodology using field data, available databases and model developments Using statistical multivariate regression models, regional scale debris flow susceptibility maps were generated for Lecco Province (Lombardy pre-Alps, Italy) and the flysch sector and the Benasque Valley field areas in the Central Spanish Pyrenees. Within Lecco Province a debris flow probability map constructed for the Valsassina focus basin, showed a prediction reliability of 78.4%. A new three-dimensional rockfall model was developed for scales ranging from the hillslope to the regional. A rockfall hazard assessment procedure containing the model was also developed and used to construct hazard maps for Lecco Province and the Benasque valley. Model applications in California and central Italy gave the rockfall hazard along local transport networks.

WP3 Development of a small basin debris flow impact model using field data and a physically based modelling approach A debris flow impact model, DEFLIMO, applicable at the scale of a small catchment (typically up to 10 km²) containing a mountain torrent channel linked to a fan was developed. With a user-supplied debris flow hydrograph as input, the model routes the debris flow along the channel using a one-dimensional scheme. This has the innovative ability to account for the effect of structures such as check dams and bridges, constrictions in channel cross section and overbank flow. A two-dimensional scheme then represents debris flow propagation and sedimentation on the fan area on a time-varying basis. Applications to catchments in the North-eastern Italian Alps and the Central Spanish Pyrenees showed a good ability to identify critical sections for overflow and to evaluate the debris flow hazard area within the fan.

WP4 Application of a physically based, basin scale, landslide erosion and sediment yield model to land use and climate scenario analysis for selected sites The existing SHETRAN model was applied to determine debris flow spatial and temporal occurrence and impact on sediment yield for focus basins in the Italian pre-Alps and Spanish Pyrenees. Validation of the model for present-day conditions demonstrated an ability to bracket the observed spatial occurrence of debris flows with simulated distributions and to determine catchment sediment yield within the range of regional observations. Future land use and climate scenarios were developed for the focus catchments. Comparison of the scenario and present-day simulation results showed the sorts of changes in landslide incidence and sediment yield response which may be observed in the future and thus provide a context within which guidelines for land management can be developed to minimize debris flow impacts.

WP5 Dissemination of the project deliverables via training courses, workshops, implementation by end-users and placement of demonstration material on a web site Training courses on the WP2 landslide and rockfall hazard assessment techniques and the WP3 debris flow impact model and workshops for publicizing the project technologies were held for the project end-users. The WP4 scenario simulation results for the Italian and Spanish focus basins were transferred to the end-users on CD. The DAMOCLES project website <http://damocles.irpi.cnr.it> was set up at the start of the project and maintained and upgraded throughout the project. A GIS-based web technology was installed for the internet distribution of landslide inventory and hazard maps generated by the project, at a range of scales.

Socio-economic relevants and policy implications

Every year debris flows and rockfalls cause loss of life and injury, direct damages running to tens of millions of euros and further large indirect costs arising from impacts such as road closures and insurance cover. The DAMOCLES project therefore achieves its relevance through the development of modelling and mapping technologies designed to allow more accurate (and quantitative) hazard assessments from the local to the regional scale. In turn these are intended to allow more efficient land use planning and improved design of torrent control works, to the benefit of life and livelihood. The project end-users have been closely involved and are already making use of the technologies to achieve the above aims. EU policies which could benefit from the project results include the Water Framework Directive and the Cohesion and Agriculture Policies.

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IMIRILAND - Impact of Large Landslides in the Mountain Environment: Identification and Mitigation of Risk
EVG1-CT-2000-00035

Instrument:	FP5 – Research Project	Ending date:	31/12//2003
EC contribution:	638,760.00 €	Duration:	34 months
Organisation:	Regione Piemonte		
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EC officer:	Maria Yeroyanni		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The project is dedicated to the assessment and management of the risk related to large landslides. The main objectives are to:

- 1) Achieve a comprehensive review of hazard analysis methodologies considering short and long term prediction, specifically suitable for large landslides;
- 2) Compare the reliability of hazard assessment in different situations according to various criteria;
- 3) Develop practical risk analysis methodologies considering direct as well as indirect damage potential;
- 4) Apply the developed methods to real situations in different countries in order to show how they can be incorporated in land planning procedures;
- 5) Test the applicability of such approaches by a close interaction with administration or political managers, so as to get to proper mitigation strategies applicable in the different legal European and national frameworks.

Scientific achievements and results

Through the analysis of the state of the art and the consideration of the peculiar aspects related to large landslides, a quantitative procedure for hazard and risk assessment has been developed, organized in the following steps:

- 1) Data-collection;
- 2) Danger identification and characterization on the basis of collected data and field observations;
- 3) Multidisciplinary approach to hazard analysis, considering geological, geo-morphological and geo-mechanical modeling (triggering and run-out);
- 4) Consequences analysis (including vulnerability analysis and estimation of the value of the elements at risk);
- 5) Risk calculation (multiplying consequences by occurrence probability).

The procedure has been applied to eight selected large landslides, where complex risk situations exist Rosone (I), Cassas (I), Ceppo Morelli (I) Oselitzenbach (A), Sedrun (CH), Conters-Gotschnahang (CH), Séchilienne (F), Encampadana (Andorra). An evaluation of the levels of direct and indirect risk for various scenarios has been done for each sites, allowing to test the validity of the proposed methodology. Furthermore, various hazard evaluation techniques (triggering, run-out methods) have been used on the same sites. This allowed to find out the advantages and disadvantages of each technique. The role to be assigned to the geological and geomechanical approaches has also been stated.

Risk management problems have been taken into account both at local and national level, in the countries involved in the project. In particular a report on the most adequate strategies have been produced for some of the selected sites, and management guidelines for the relationship among decision-makers, scientists and the people exposed to risk have been proposed.

Risk assessment and management in the case of large landslides is a difficult task, due to the uncertainties of the scientific evaluations and to the importance of the socio-economic implications. It is essential that several aspects are taken into account in hazard assessment of different scenarios, through a multidisciplinary approach. Scientific and decisional components should also be in tight relationship using a common view of the situation. The experience in each of the countries in this matter is low because very few case histories are available; it is therefore essential to share these experiences at the European level. The comparison of the eight selected sites allows suggesting a common basis to the risk management.

Socio-economic relevance and policy implications:

The extreme physical conditions make mountains a fragile environment, where natural phenomena, often increased by man-made land uses or misbehavior, interfere with human activities and then cause natural hazards and risks. The project proposes a methodology for the quantitative risk assessment of large landslides in order to contribute to the management of the endangered zones by a better evaluation of the level of risk. This can contribute to improve the quality of life and safety in mountainous areas. Following the examples of application to some selected sites, the proposed guidelines and suggestions on the methodology can be easily used for the quantitative risk assessment of other European cases and can represent a support for technicians or public officers in assuming decisions concerning civil protection and land use planning.

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LEWIS - Landslide Early Warning Integrated System
EVG1-CT-2001-00055
<http://www.silogic.fr/lewis>

Instrument:	FP5 – Research Project	Ending date:	31/09/2005
EC contribution:	1,498,181.00 €	Duration:	42 months
Organisation:	Bari University, Physics Department		
Co-ordinator:	Prof. Luciano Guerriero (Luciano.Guerriero@ba.infn.it)		
EC officer:	Denis Peter (denis.peter@ec.europa.eu)		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The main objective of the LEWIS project has been the development of a prototype landslide warning service based on the integration of comparatively low-cost, wide-area satellite data with ground data in order to detect significant surface changes which are taking place on landslide susceptible areas. The system has been designed to monitor and watch over wide areas rather than a single landslide. It thus helps to pinpoint locations that have an increasing tendency towards slope instability, where more detailed and costly ground investigations might be required.

To this end LEWIS consortium has i) integrated multidisciplinary research expertise in remote sensing and in geological, physical and computing science, ii) created a very efficient link among scientific - academic institutions, companies and potential future providers for EO data processing and specialized services, and iii) improved collaboration with the administrations participating in the consortium as providers of territorial knowledge.

Scientific approach and results

Rather than concentrate on an analysis of high resolution EO images on a specific date, a variety of EO and ground data from selected test areas can be processed periodically to detect surface feature changes which can be correlated with the development of instability mechanisms. LEWIS approach has been based on the well known principle that either an increase of shear stresses and/or the decrease of effective material shear strengths over a period of time are the primary cause of increasing susceptibilities to slope instability, thus contributing to first-time failures or reactivated movements on pre-existing slip surfaces.

An assessment of spatial and temporal scale requirement of the Earth observation data associated with different instability detection scenarios, at different scales of resolution, has been preliminarily established in relation to recent, current and future EO sensors. Taking into account the cost effectiveness of an operational system, continuous monitoring of wide areas utilizing the newest very high resolution space sensors did not appear to be practicable for cost-benefit reasons. As a result, Landsat and ERS-1/2 EO data have been adopted for the definition of the LEWIS early warning system because they can be adopted and maintained by interested administrations at a reasonable cost.

Following this decision, LEWIS project has not attempted to infer absolute values of relevant local geophysical parameters from EO data, but only **significant changes in time** in the wider sense of “deviations from a known temporal evolution model”. Other periodic information, relevant for this project, have been obtained from existing ground networks for rain and earthquakes.

The detected changes have been integrated into a GIS, together with other more static parameters, and used to infer potential slope stability changes and to produce Early Warning.

A new model approach was designed with an output that provided the potential geotechnical impact from the cumulative surface change detected by EO. The geotechnical inference model firstly uses GIS topographic

and geological ground data to identify potential levels of susceptibility to deformation in slopes which are close to a factor of safety of 1.0, i.e. they are susceptible to mass movement. Secondly it integrates EO surface change data to show levels of warning with respect to that deformation. It uses a simple geotechnical framework within which data inputs and outputs can be selected and managed.

A slope map derived from a Digital Elevation Model (DEM), a previous landslide map, a description of the lithological classification distinguishing between soil and rocks, and a brittleness index, reflecting the stress-strain behaviour of the engineering soils have been obtained from existing topographic and geological ground data. These datasets have been combined to establish seven levels with different susceptibilities to potential slope deformation, i.e. areas of level 7 having ground conditions most likely to deform by sliding while level 1 the least.

In the study areas different slope thresholds, were determined for each lithology present, and only those slopes exceeding the threshold were considered as "susceptible". Therefore, the LEWIS early-warning maps have been obtained through the detection of temporal ground surface changes, associated with static landslide susceptibility mapping.

Interpretation of the change maps, processed in automated mode by incorporating expert knowledge into an inference engine, have produced a warning map indicating where the detected changes are leading towards a slope instability condition.

At the end of the project, the consortium has identified five chief products which may be of interest for deployment in a variety of practical situations:

- The Watch map: all the information, static and dynamic, collected from EO and from ground networks and included in the GIS after all processing but before the application of the inference engine. This is intended to be given to academic and research institutions for scientific purposes, perhaps even transcending that of landslide applications.
- The susceptibility map, which consists of a "zonation" of the area into seven levels of susceptibility based on the static information (slope, lithology, geology, past landslide activity,...) extracted from EO and field data.
- The warning map or updateable susceptibility map, which is the final product highlighting seven levels of warning. The warning map is based on the small displacement information coming from the Permanent Scatterers detection using SAR Interferometry and on the outcomes of the inference engine, incorporating detected land use changes and automating expert competences in recognizing areas of increasing landslide hazard.
- The GIS module, which includes the innovative models for producing both the susceptibility and warning maps. It could thus also constitute the basis for an integrated marketable product for landslide warning .
- The user Consultation enhancer, which is based on a visualization and analysis tool of the Permanent Scatterers. This is a support tool dedicated to all kinds of customers interested in landslide studies. This could also be deployed as a standalone product.

Socio-economic relevance and policy implications

The results of LEWIS are well in line with GMES policy. In fact, GMES is based on the principle that crisis situations can be better anticipated and managed.

LEWIS applications rely heavily on satellites for earth observation and frequent data collection on environment.

It is evident that the methodology developed within the LEWIS project is in harmony with this EU scenario. A cost effective regional service that is user friendly and designed to localise areas of increasing instability seems to be of interest to administrative bodies and decision makers. This service has the potential to periodically locate areas where local investigation and/or where more costly high resolution aerial or space observation might be warranted. Within this framework, the potential European landslide warning market targeted by LEWIS can be categorized through four major market segments: Land use planning, Civil protection, Insurance, Consultancy services

The warning maps and the GIS tool for visualization and analysis of the permanent scatterers are perhaps the most promising products, since they highlight situations of increased landslide hazard. As such, these products are of interest for deployment in land use planning, environmental impact assessments, civil protection, insurance and engineering consultancy services.

At the present development stage, LEWIS is a workable prototype of a system which links EO land use change, ground deformation and several ground based datasets into a GIS (Geographical Information System). By interrogating the GIS through a geotechnical model, it provides warning of areas subject to possible future slope instability. One of the main advantages of such a system is the possibility to evaluate a wide area (one single image covers typically an area of 100 km x 100 km) at a low cost.

It has been estimated that, to maintain an operational system which is able to produce LEWIS landslide susceptibility and warning maps covering an area of approximately 50X50 Km², 2 to 4 Landsat images and 10 to 15 SAR images per year are necessary. In addition to the image costs, 4 to 8 man months per year of specialised interferometry analysis are required for the PS monitoring and 1 to 2 man months per year for land use change processing. Finally, geology/geotechnical engineering expertise and field work are needed to define appropriate lithological boundaries, the physical properties of the geological materials and slope thresholds. Some pre-existing topographic, geologic and other ground data are usually available for most study areas (certainly in Europe) and are often in digital format. These would generally be made available by and to administrations commissioning a LEWIS type project at little or no cost.

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MUSCL – Monitoring Urban Subsidence, Cavities and Landslides by Remote Sensing
EVG1-CT-1999-00008

Instrument:	FP5 – Research Project	Ending date:	31/08/2002
EC contribution:	452,598.00 €	Duration:	30 months
Organisation:	University of Innsbruck		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The project was aimed at contributing to the fight against natural hazards related to mass movements on unstable mountain slopes and excavations in urban areas. New techniques, based on Earth observation from space, were to be developed or refined which improve the detection and monitoring of hazard zones and advance the understanding of mass wasting processes. In addition, the complementarity of ground-based InSAR for landslide monitoring was studied. An important goal was also to validate and demonstrate the new techniques in different environments.

Scientific achievements and results

In extension of previous work of the project partners, remote sensing methods and applications were developed or improved to measure and monitor displacements at the Earth's surface with very high accuracy over extended areas and time periods. The main data source are satellite based imaging radar systems (SAR). The interferometric technique was applied to map motion fields of various type and extent from regional scales down to displacements of individual targets. Millimetric accuracy is achieved for the displacement measurements which are carried out over repeat intervals ranging from a few weeks to several years.

The methods were applied and validated in several test sites in Alpine and Mediterranean regions, including synergistic studies with optical image data and ground-based geophysical and geodetic measurements. In addition, ground-based interferometric SAR (InSAR) methods were further developed in the project which can be used to monitor the displacement of individual slopes in detail with high temporal and spatial accuracy.

The main results are:

- Improved methods and software to map and monitor fields of surface motion on mountain slopes and subsidence in extended built-up areas using the area-extended InSAR technique based on few SAR images;
- Improved methods to monitor surface motion and subsidence in a wide range of environments, including motion of individual objects, using the Permanent Scatterer Technique based on time series of SAR data;
- Improvements of a ground-based InSAR system to map the displacement of individual slopes, providing complementary capabilities for surveying fast slides and complex small scale slope geometries, and for continuous monitoring;
- Validation in InSAR methods and products in comparison with field data;
- Information on application potential and limits of the InSAR tools and products, based on tests in Alpine and Mediterranean regions and in urban areas, and development of strategy for operational use in comparison with conventional techniques.

The developed methods and application examples are described in technical reports, available to the public, and in several articles in the open literature. The methods and tools for measuring surface displacement at millimetric accuracy, developed by the project partners, can be applied to monitor movements at unstable mountain slopes and to monitor subsidence related to construction activities, tunnelling, oil and ground water pumping, mining etc.

Socio-economic relevance and policy implications

The information and observation tools, based on remote sensing methods and products developed in the project have great potential for improving the safety related to natural hazards from landslides and subsidence. The improvement of hazard prevention and mitigation is an issue of great social and economic importance in regions which are exposed to hazards from landslides and other terrain instabilities. The developed satellite-borne InSAR tools for observation and monitoring of surface displacements with very high accuracy and spatial detail provide an economic means for detecting hazardous mass wastes over a wide range of spatial scales, from regional and country-wide surveys down to tracking of individual objects, as well as for long-term monitoring of these phenomena. Complementary to satellite observations, ground-based InSAR is of particular interest for continuous monitoring of individual slopes and for mapping the motion of fast slides, thus being an excellent tool for online warning systems.

In addition to the socio-economic relevance of the project work in improving the safety of the citizen, the technological advancements and the involvement of young researchers represent a basis to increase employment opportunities and improve skill levels in promising technological fields, namely Earth observation and geotechnical engineering. New techniques were developed and tested for generating remote sensing products and for utilization of these products for landslide characterization and hazard assessment.

The project results are of relevance for two important objectives of EU policy: (i) the fight against major natural hazards as part of civil protection activities; (ii) the European Strategy for Space. The project achievements contribute to the reduction of risks from natural hazards and to improving the information to the public, topics which are addressed in the EC Action Programme for Civil Protection. The project results are of relevance for the EC/ESA Global Monitoring for Environment and Security (GMES) initiative, which is aimed at establishing the basis for sustainable services in Earth observation from space, where landslide risk management is addressed explicitly as one of the GMES priority areas.

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OASYS – Integrated Optimization of Landslide Alert Systems

EVG1-CT-2002-00061

www.vce.at/oasys/

Instrument:	FP5 – Research Project	Ending date:	28/02/2006
EC contribution:	1,104,495.00 €	Duration:	38 months
Organisation:	VCE Holding GmbH		
Co-ordinator:	Dr Helmut Wenzel (wenzel@vce.at)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The objectives of the project were the development of observation methods allowing:

- to detect potential landslides,
- an efficient and continuous observation of critical areas,
- the derivation of real time information about actual risks.

The general concepts of the approach were:

- **Multidisciplinarity:** There is a strong emphasis on the integration of different disciplines like geology, geodesy, geo-informatics, software engineering etc. Each working group consist of members of several disciplines to assure a maximum of horizontal integration;
- **Productivity:** In order to gain acceptance by the practitioners it is necessary to develop highly productive methods that enable the user to acquire the necessary information he needs for a decision with a minimum of effort. This requires the use of remote sensing and information technology which have been both successfully applied in the project;
- **Vertical integration, multi scale approach and modularity:** One target of the project is to provide the practitioner with support in all levels of his decision making process. Therefore several decision levels have been developed and different scales of observation, which use appropriate methods.

Scientific achievements and results

Generally the project can be divided into three principal impacts:

- The first comprises the optimisation of early warning systems on a regional scale, where landslide prone areas are detected and classified;
- The second on local scale active zones are detected and observation methods and devices are optimised for the specific case;
- The third area comprises all issues related with the transfer of information about possible hazards to the affected population. The aim of this information transfer is an increased awareness of the impending hazards and effective alerting in the case of a catastrophic event.

The following works have been carried out within the project period:

- **Development of online alert system:** Comprises of a technology that bridges the gap from scientific monitoring and assessment of hazard towards the information to the public. It considers scenarios such as non-availability of power, wide spread distribution of people to be reached or the situation of panic;
- **Development of decision support system:** The transfer of data into information and finally decisions has been elaborated. A set of rules determines which consequences incoming data have on the assessment of the situation. The output is a rating and finally an alert;
- **Gaining of new knowledge:** Using the many test sites of the project new knowledge has been generated, which led to a number of new rules used for the decision support system. New tools based on GIS technology have been applied for the first time;

- Collection of data: A wide collection of data from all monitoring sites of the project has been done and opened to the interested community by the internet.

Socio-economic relevance and policy implications

Worldwide landslides are one of the major types of natural hazards killing or injuring a large number of individuals and creating very high costs every year. Between 1990 and 1999, for example, in Italy at least 263 people were killed due to landslide events. In the United States of America landslides are annually causing estimated 25 to 50 deaths and damages exceeding US\$ 2 billion. Figures for Asia, particular China, Africa and South America may easily exceed those for Europe and the US.

Besides direct costs landslides are also reason for even higher indirect costs like interruption of important infrastructure facilities or losses for the tourist industry etc. In future it is very likely that the damages caused by landslides will even increase as the hilly areas, where the majority of the landslides occur, are used by a growing number of tourists and intersected by increasingly powerful trans-national networks. In addition many global climate change scenarios predict an increase in the probability for heavy rain, which is a primary trigger for landslides. This implies that there is urgent need for highly productive and reliable tools for landslide hazard management at an operational level.

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GALAHAD – Advanced Remote Monitoring Techniques for Glaciers, Avalanches and Landslides Hazard Mitigation

CT - 018409

www.galahad-euproject.org

Instrument: FP6 – Research Project **Starting date:** 01/06/2005
EC contribution: 1,675,440.00 € **Duration:** 36 months
Organisation: CESI
Co-ordinator: Dr Giorgio Franchioni (franchioni@cesi.it)
EC officer: Bjorn Vangelsten (bjorn-vidar.vangelsten@ec.europa.eu)

PROJECT SUMMARY

This project addresses to landslides, avalanches and glaciers-related hazard mitigation, through the development of advanced monitoring techniques and the improvement of forecasting methods and tools. Landslides hazard is increasingly causing substantial damages in mountainous and hilly regions. Its occurrence is frequently related to human activities, which affect the land use (e.g. deforestation, urban development, etc.) and is increasing due to the continental climate changes with intense and prolonged rainfalls and the risk of tropicalisation. Analogously, climate changes are the main causes of the improved occurrence of avalanches as well as the dangerously increased movements of glaciers. The above effects largely impact on critical infrastructure safety and on social and economic activities. Their mitigation is therefore a paramount for protection of citizens and their properties.

The enhancement of forecasting methods and tools plays a crucial role in this frame. This can be achieved, besides other aspects, through the development and the integration of monitoring solutions, able to provide measurements over large areas, at useful accuracies, that are affordable, reliable and operational.

Remote monitoring techniques based on ground-based SAR technologies have been already developed, at a first stage, for investigations of landslides. However, their reliability for the early warning still face with intrinsic limitations related to operative and interpretation issues. Laser scanning techniques, on the other hand, have found so far very limited applications in detecting landslide movements. Furthermore, preliminary work suggests that these techniques can play a role of great relevance in assessing and forecasting landslides, avalanche and glacier hazards.

The GALAHAD project aims at developing new and fundamental functionalities of the above remote monitoring techniques, some of which derived from satellite applications, enabling the improvement of reliability, precision and operative usefulness of the measurements and, as a consequence, of the forecasting capacity of the interpretation tools. Attention to cost-benefit considerations and to European standardisation policies will be an important goal of the project as well. To achieve these results a research team formed by institutions and companies of European relevance, with complementary knowledge and interests, has been formed, including research institutes, service providers, civil protection related bureaus, industries and end-users.

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IRASMOS – Integral Risk Management of Extremely Rapid Mass Movements

CT – 018412

www.slf.ch/irasmos

Instrument:	FP6 – Research Project	Starting date:	01/09/2005
EC contribution:	2,424,000.00 €	Duration:	24 months
Organisation:	Swiss Federal Research Institutes WSL/SLF		
Co-ordinator:	Dr Jakob Rhyner (jrhyner@slf.ch)		
EC officer:	Denis Peter		

PROJECT SUMMARY

Rock avalanches, debris flows, and snow avalanches are landslide and landslide-related processes, subsumed under the term extremely rapid mass movements. These processes pose varying degrees of risk to land use, infrastructure, and personal security in many mountainous regions. Despite increasing efforts to quantify the risk in terms of potential damage or loss of life, most previous studies have achieved partial rather than total risk solutions. IRASMOS addresses these shortcomings by reviewing, evaluating, and augmenting methodological tools for hazard and risk assessment extremely rapid mass movements. Results will be synthesized in strategies proposed within the framework of an Integral Risk Management (IRM) in selected European mountain catchments, targeted to equally address measures pertaining to landslide and snow-avalanche disaster prevention, response, and rehabilitation. The proposed project adopts the character of a comprehensive take-up and feasibility study, recognizing fundamental problems of (a) constraints in data quality, availability and analysis, (b) constraints in technical, logistical, and financial support, (c) integrating the synchronous or interdependent occurrence of rapid mass movements and their potential off-site and long-term effects in a multi-risk context. Key results include a set of IRM Best Practice Handbook for quantifying and managing total risk from rapid mass movements given possible constraints set by known environmental and administrative boundary conditions. Integrated critical thresholds needed for risk-oriented planning will be quantified and tested. A comprehensive catalogue of triggers and threshold conditions for extremely rapid mass movements, countermeasures, and sensitivity of hazard, vulnerability, and risk indicators will serve as further measures for total risk assessment, allowing customized decision-support for prevention, intervention and rehabilitation efforts in European mountain ranges.

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MULTIRISKS

AUTO-HAZARD PRO – Automated Fire and Flood Hazard Protection System

EVG1-CT-2001-00057

<http://www.autohazard.org>

Instrument:	FP5 – Research Project	Ending date:	31/12/2004
EC contribution:	1,199,997.00 €	Duration:	36 months
Organisation:	University of the Aegean		
Co-ordinator:	Prof. Kostas Kalabokidis (kalabokidis@aegean.gr)		
EC officer:	Karen Fabbri		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The AUTO-HAZARD PRO project has been designed to improve the level of technological development on wildfires, and the resulting flood hazard, in Europe and therefore to help authorities on taking the appropriate actions to protect the environment and human lives. The main objective of this project was to integrate real-time and on-line wildfire hazard and post-fire (i.e., floods) management schemes into a GIS-type platform. The project targeted on the development of: (i) an environmental and technological Data Base Management System, with electronic information (i.e., fire occurrence, topography, soils, weather, vegetation, land use, administrative and technical resources) and digital mapping capabilities for natural hazards/ fire protection and effects mitigation, and environmental impact assessment; (ii) a Decision Support System (DSS) dealing with proactive planning and emergency management of real-time fire episodes, including fuels management, socio-economic criteria, a priori risk forecasting, automatic fire detection and optimal resource dispatching. All in all, the project aimed to contribute to the development and validation of a methodology that supports and strengthens forest management and protection.

Within this scheme, integrated satellite and ground technologies have been applied using advanced tools and models (such as remote sensing, GPS, digital mapping and GIS) for the inventory, mapping and monitoring of topography, land cover and use, and atmospheric processes. Development of the prototype system was accomplished on 3 study areas in Lesvos Island of Greece for wildfires, in Samos Island of Greece for floods (as post-fire hazard effects) and in the Madrid Province of Spain for wildfires.

Scientific achievements and results

Multi-spectral QuickBird satellite images (2.5-m resolution) for the whole island of Lesvos, Greece, and for the forest area within the Province of Madrid, Spain, and IKONOS 1-m panchromatic and 4-m multi-spectral data for Samos Island, Greece, were used to extract useful geographical information to study and monitor the wildfires and floods (e.g., fuel models, road networks, land-use boundaries, watersheds and stream networks, etc.). The appropriate database was developed and integrated into the DSS; the database was also used as input to various simulation models and for mapping purposes.

High resolution weather forecasts were provided by the SKIRON/Eta weather modeling system at approximately 10-km horizontal grid increments for AUTO-HAZARD PRO's study areas. The forecasts were validated with Remote Automatic Weather Stations (RAWS) observations, and further improvement of the forecasts was carried out by developing and using a Kalman filtering technique to SKIRON/Eta outputs (<http://forecast.uoa.gr/forecastnew.html>). The high visibility of the weather webpage (more than 5000 visitors per day) ensured the publicity of the project results to a large number of potential users.

An innovative large scale Wildfire Danger Rating System (WDRS) was developed, with the ability of short-term forecasting of wildfire risk in order to help in better and realistic prevention and pre-suppression planning. The forecasting scheme is based on multiple layers of information that are coming from the quantitative and systematic analysis of fire occurrence and growth factors; parameters taken into consideration include vegetation, topography, weather conditions and human geography of the pertinent

areas. The main output of WDRS is the Fire Danger Index, which is based on Fire Weather Index, Fire Hazard Index, Fire Risk Index and Fire Behavior Index. These indices are not just a relative probability for fire occurrence but a quantitative rate for fire danger appraisal in a systematic manner. The function mapping of the indices accomplished with Artificial Neural Networks (NN), and the training of NN was based on historical fire data. The whole wildfire risk forecasting scheme was tested and validated with promising results during the fire season of 2004 by the project's end-users in Spain and Greece. In addition, the fire propagation simulation estimates the severity of an incipient fire by predicting fire size (area, perimeter), fire spread speed and direction, energy release, flame length and intensity; predicts possible threats and damages; it also assists to plan tactical operation, and select and dispatch resources.

A new ground based forest fire detection system was developed and demonstrated on Lesvos Island, Greece, and near Madrid, Spain. The detection system consisted of a multi-spectral camera that detects the smoke via its near-infrared channel and provides on-line and real-time an NDVI (Normalized Difference Vegetation Index) image. The NDVI was used as it gives the best contrast between vegetation and the smoke. Position accuracy of the camera was sufficient to create a good overlap between consecutive images and during trial tests performed in Lesvos in 2003 and Madrid in 2004, smoke detection was very accurate in distances up to 12 km. Within AUTO-HAZARD PRO, field sensors of fire detection system are linked to selected operational centers, where the manager evaluates the alarm signal and the image to stimulate proper responses.

The AUTO-HAZARD PRO has investigated the flood phenomena as post-fire effects on the island of Samos, after the devastating fires and floods of the year 2000. The estimation of flood risk in real-time and the long term estimation of soil erosion risk independent of real-time were the two basic aspects of the Flood Module of the AUTO-HAZARD PRO DSS. The assessment of the flood risk on burned areas is based on the forecast of the extreme events in combination with multiple information levels for the catchment under consideration, in order to support decision making pertinent to the protection against such extreme weather events. The Flood Module is based on two separate procedures, namely the pre-processing and the on-site analysis procedure.

The AUTO-HAZARD PRO final application DSS, which integrates real-time and on-line wildfire hazard and post-fire management schemes into a GIS-type platform, was developed and validated by the consortium and official end-users. The DSS is the main outcome that combines and automates the methodologies and the scientific results of the work done along the project, by using a user-friendly graphical interface. It is divided into six main modules that allow the user visualizing different kinds of information and performing different tasks that will support her/him during the whole fire management process. These modules are the: Fire weather module, Fire detection module, Fire danger rating module, Fire propagation simulation module, Resource dispatching module, and Flood danger module. The AUTO-HAZARD DSS once installed in an Operational Management Center can provide for prompt decision making with important information in regard to proactive planning and levels of readiness with the help of risk forecast, fire detection and fire simulation. More specifically, the DSS includes the following functionalities to: download weather data and create today's and predicted meteorological maps; calculate Fire Danger Index and create corresponding maps; receive automatic alarm messages and images from a detection camera; simulate fire propagation; provide advice on dispatching and dispersion of resources to forest fires; and send information regarding a fire in a selected group of users via mobile SMS or e-mail.

New technologies of Geo-informatics (Geographic Information Systems, Decision Support Systems, Digital Technology, Remote Sensing, etc.) and Electronics (Remote Automatic Weather Stations, detection sensors, etc.) contribute to more effective organization for environmental protection with prompt detection and risk assessment, systematic observation of bio-physical and socioeconomic parameters and decision support management.

The WWW presence of the project (<http://autohazard.org>) has contributed to its dissemination procedures and as a means of internal project communications. In addition, the Arc Internet Map Server (IMS) cartographic modelling capabilities, the on-line and real-time weather information and the Fire Danger Indices were also uploaded on the project's web site in order to inform the end-users for operational, training and scientific purposes.

Socio-economic relevance and policy implications

Based on the fact that wildfires have both regional and local detrimental effects on the environment (i.e., flora, fauna, soils, water resources, air quality and aesthetics) and human life and property (e.g., civilians, firemen, agriculture, livestock and forage production, houses and other buildings) in rural and urban areas, it

can be considered that improvement of the technological knowledge on this subject assets important economic and social impacts. More specifically, the improvement of the scientific knowledge about technological and physico-chemical fire processes involved in the Mediterranean Basin, should minimize environmental degradation and optimize the ecosystem management strategies, contribute to the design of emergency response procedures, and help to assess wildfire's role on vegetation damage, wildlife changes and air pollution in various scales.

AUTO-HAZARD PRO, through the inter-disciplinary cooperation between experimental and operational groups across Europe, assisted regional authorities on designing strategies on improvement of forest fire control and helped on minimizing the effort and cost required for solving fire problems in Europe, especially in some of the regions identified as "hot spots." Focusing on floods, an overall understanding of their nature and development may facilitate their quantitative prediction, and therefore may lead towards appropriate management responses as well as in early warning so as to mitigate their catastrophic effects (loss of human lives, resources and property damage).

The project has had end-user participation, contribution and support of state agencies responsible for natural hazards confrontation in these countries (e.g General Secretariat for Civil Protection, Ministry of the Interior, Athens, Greece, and Council for Environment of the Madrid Region, Madrid, Spain). End-users, who had previously little potential of becoming seriously involved and knowledgeable in information technology and systems, are now more aware of and interested in the new technology. Individuals working in today's and tomorrow's organizations will be expected to have some understanding of and the ability to use the rapidly developing information technologies and systems, especially if the application of the technology allows an aid to support decision making.

The Euro-Mediterranean region has to confront the challenge of surviving in a semiarid environment exacerbated by periodic wildfires and floods, which propagates a continuous air of crisis. In this context, the incorporated AUTO-HAZARD PRO analysis and forecasting modules may offer considerable services particularly after devastating fire and flood events.

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GEODEV - Centre on Geophysical Methods and Observations for Sustainable Development

EVK2-CT-2002-80005

<http://geodev.igf.edu.pl>

Instrument: FP5 – Specific Support Action (SSA) **Ending date:** 30/11/2005
EC contribution: 315,410.00 € **Duration:** 36 months
Organisation: Inst. of Geophysics of the Polish Academy of Sciences
Co-ordinator: Prof. Zdzislaw Kaczmarek (kaczmar@igf.edu.pl)
EC officer: Denis Peter

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

GEODEV Centre of Excellence has been established in 2002 by the Government of Poland, and supported by EU under the FP5 “Accompanying Measures” sub-programme. The Centre’s goal was to promote integration of the Institute of Geophysics of the Polish Academy of Sciences (IGF-PAS) into European Research Area. Fields of scientific competence of IGF-PAS include *inter alia*: assessment of risk threats caused by geophysical hazards, impact of climate on environment and national economy, rational use of water resources in agreement with the EU Water Framework Directive, studies on atmospheric ozone, seismic and geomagnetic soundings for identifying alternative energy sources.

Scientific achievements and results

Nine workshops (conferences) with 387 participants from 19 countries were organized in years 2003-2005 by the GEODEV team. The topics under discussion were: impact of climate on sustainable use of water, ozone and UV radiation over Central Europe, geodynamics of Central Europe, water quality hazards and dispersion of pollutants, electrical properties of Carpathian rocks, and impact of mining on geophysical processes (see the GEODEV website). 37 scientists from 18 countries visited IGF-PAS to present their research results at GEODEV seminars (see website). 14 PhD students from the IGF-PAS participated in training courses abroad. Senior IGF-PAS scientists paid 35 visits to various European geophysical research institutions, based on the GEODEV funds (see website).

Socio-economic relevance and policy implications:

Poland has been conditioned by unfavorable socio-economic circumstances during and after World War II, and therefore the environmental issues have for many years lagged behind economic issues. GEODEV results promote links with European research institutions in order to develop measures to reduce negative environmental impacts at the regional level.

PROJECT CO-ORDINATOR

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MAGMA - Prague Centre of Mathematical Geophysics, Meteorology and their Applications

EVG3-CT-2002-80006

<http://karel.troja.mff.cuni.cz/magma/>

Instrument:	FP5 – Scientific Support Action (SSA)	Ending date:	31/12/2005
EC contribution:	399,740.00 €	Duration:	36 months
Organisation:	Charles University in Prague		
Co-ordinator:	Dr Jiri Zahradnik (jiri.zahradnik@mff.cuni.cz)		
EC officer:	Tobias Fuchs		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The MAGMA Center aims at increasing international recognition of Geophysics and Meteorology at the Charles University in Prague. The Center should contribute to coordination of research and education in dynamic phenomena of the solid Earth and atmosphere by adopting unifying mathematical viewpoint. The Center should apply a multi-disciplinary approach and application to European environmental problems, such as climate change, pollution transport, earthquake hazard, as well as the energy problems, such as the oil exploration.

Scientific Achievements and results

The main instrument of the MAGMA Center is inviting PhD students, post-doctoral researchers and senior researchers to Prague, organizing scientific meetings, and participating in EC projects (including submission of the new ones). Research behind the above mentioned mobility is focused on the following tasks: Thermal convection, Viscoelastic response of the Earth, Temporal changes of the gravitational field, Seismic waves, Earthquakes, Climate system, Air quality. Dissemination of results is effectuated through scientific journals, conference contributions, seminars and web.

Main results of the MAGMA Center in 2005 comprise the following activities:

- Four international workshops organized by WP4, WP7 and WP8, and an intensive lecture course with international attendance organized by WP9.
- Participation in current EC projects SPICE, 3HAZ, IMAGES, ENSEMBLES, QUANTIFY, and participation in submission of new EC projects: REAP (rejected), GEOHAB, C2C, CECILIA (coordinated at the Charles University, now already accepted).
- The 87 visitors spent more than 38 person-months at the Charles University during 2005. Lectures were given by the guests, training was provided by us to some of them, and joint research has been carried out.
- Constantly upgraded web page (including abstracts of lectures) enabled rapid dissemination of all information related to MAGMA activities and achievements. Valuable seismic data, gathered by the MAGMA seismic stations in Greece, have been freely available from the web page, too.

Socio-economic relevance and policy implications

The knowledge transfer has been achieved by participation in the EC ToK project IMAGES, 2005-2009. The regular (annual) meeting was organized for representatives of major oil companies. Moreover, there were other contacts with research institutes, state organizations and municipality concerning environmental tasks such as coal mining, underground gas storage, nuclear waste disposal etc. More than 50 internal seminars in 2005 proved to be an efficient way of research and societal interaction between the MAGMA Center and

the other research institutes in the Czech Republic. In 2005, 2 (geophysics) + 6 (meteorology) MSc, and 2 (geophysics) PhD students successfully defended their theses. Participants of the MAGMA Center wrote three popularization articles and were active in several public lectures, TV interviews and spots, mainly those related to the disastrous Sumatra earthquake of December 26, 2004, to the global climatic change, and to the air quality issues.

PROJECT CO-ORDINATOR

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RETINA – Realistic Evaluation of Temporal Interaction of Natural Hazards

EVG1-CT-2001-00046

<http://www.acri-st.fr/retina>

Instrument:	FP5 – Research Project	Ending date:	31/07/2005
EC contribution:	1,370,100.00 €	Duration:	42 months
Organisation:	ACRI-ST		
Co-ordinator:	Philippe Bardey (prb@acri.fr)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The objective of RETINA is to use new space geodetic observational techniques for precisely monitoring surface deformation to determine the source of that deformation, and then calculate the Coulomb failure stress generated by that source to quantify the likelihood of triggering further events. To achieve this goal, RETINA has sought to:

- Recognize periods of elevated hazard by monitoring the temporal evolution of geodetic and seismic signals;
- Locate areas of elevated hazard by mapping crustal deformation and identifying areas of rapid strain accumulation;
- Identify from these maps areas where one event may trigger another;
- Derive exploitable models for the physical mechanisms underlying correlated events;
- Provide a component of hazard and risk assessment that is currently lacking, by re-evaluating the probability of hazardous events in time and space including the effects of triggering;
- Share expertise and resources in risk management at the European.

Scientific achievements and results

During the 42-month span of the project, we have:

- defined the User Requirements, building bridges between the “user” and “scientific” communities (WP 2000),
- developed new methodologies, including models of geophysical processes (WP 3000),
- compiled data from existing sources and monitoring networks into GIS (WP 4000),
- developed and applied coupling models to 3 natural laboratories (WP 5000),
- incorporated coupling models into hazard assessment (WP 6000),
- implemented this approach in risk-related decision-making in all 3 natural laboratories (WP 7000).

In the Iceland Natural Laboratory, a sequence of earthquakes in June 2000 led to the following insights regarding the mechanical coupling of earthquakes, landslides and volcanoes:

- Documented the co-seismic observations,
- The June 17 earthquake triggered the June 21 earthquake by transfer of static stress,
- Post-seismic processes continued deform the lithosphere for years afterwards,
- The June 17 earthquake triggered other events, including rockfall and at least two partially aseismic deformation events over 50 km away, apparently by dynamic triggering,
- Evaluated magma intrusions and their triggering effects,
- Recorded aseismic slip on an earthquake fault and interpreted its significance,
- Forecasted in long-term and short-term the 2004 Grimsvotn volcanic eruption.

In the Alps Natural Laboratory, no major landslide or earthquake events occurred between 2002 and 2005. We achieved the following:

- Developed an open, continuous GPS system for monitoring landslides (WP 3300) and used it to monitor La Clapière landslide (WP 4210) and La Valette landslide.
- Demonstrated that groundwater infiltrating rock tens of meters below the landslide surface, rather than rainwater falling on top of it, drives landslide movement at La Clapière.
- Analyzed several types of multi-temporal remote-sensing images and digital elevation models to define the complete deformation field of the La Clapière landslide.
- Developed a GIS database for geological risk analysis.

In the Azores Natural Laboratory, a period of increased seismic activity began in the summer of June 2005. Prior to the excitement it generated, we achieved the following:

- Mapped over 3000 landslides on San Miguel Island, including them in a GIS database.
- Reassessed seismic hazard through a thorough analysis of historical seismicity on San Miguel Island.
- Used geodetic measurements GPS campaigns between 1996 and 2000 to characterize the crustal deformation field on San Miguel Island.
- Deployed a continuous GPS station at QBN1 on San Miguel Island and analyzed data from it.
- Showed that measuring crustal deformation using ERS INSAR is feasible only under optimal conditions: large (co-seismic) signal, short time intervals (months), and resistant ground cover (rock or concrete).
- Developed a GIS database for geological risk analysis.

By considering the geophysical processes common to the three natural laboratories, we achieved the following:

- Developed algorithms for joint analysis of INSAR and GPS data.
- Developed models for the stresses generated at boundaries between tectonic plates.
- Developed algorithms for calculating seismic motion in complex media with topography.
- Discovered coupling between landslide-driven erosion and earthquakes.

Socio-economic relevance and policy implications

- The RETINA project has brought together geologists, geophysicists and other earth “scientists” and civil-defence decision-makers (“users”) to work together toward the common goal of managing risks due to coupled natural hazards on the following occasions:
- RETINA partners including Civil Protection users and Geophysical Scientists completed a simulation exercise based on an earthquake-triggered landslide scenario in the Azores Natural Laboratory.
- The special session we organized at the European Geophysical Society (EGS) meeting was attended by several civil protection users.
- We have attended the EU-MEDIN workshop, where we interacted with colleagues facing the issue of harmonizing risk management across Europe according to the INSPIRE principles.
- We have extended our work in RETINA, which has concentrated on evaluating hazards in FP5, to FORESIGHT, which is focussing on risk management in FP6.

As part of the final review meeting of the RETINA project in the Azores in May 2005, the RETINA partners held a discussion entitled “Towards risk management at the European level” that achieved consensus on the following conclusions and recommendations:

- During the alert and response phases of the disaster cycle, members of the scientific community should go to the field during a situation and communicate with the Civil Protection services according to a protocol prepared in advance.
- Effort in the other phases of the disaster cycle, notably documentation, risk analysis, mitigation and preparedness, are equally important for disaster reduction. It is important to include experts in these domains (e.g., civil engineers for para-seismic building codes, economists for evaluating their cost-to-benefit ratios, and psycho-social scientists for addressing issues of risk perception).
- During these other phases of the disaster cycle, when the scientists have the time for hypothesis testing and peer review, their far-sighted views can contribute substantially to risk management, especially when combined with those of other actors.
- The RETINA partners recommend that civil protection and scientific communities elsewhere in Europe gain experience from the lessons learned in RETINA.
- The RETINA partners recommend that Europe work to extend, maintain and strengthen the bridges between the civil protection and scientific communities.
- The RETINA partners recommend extending this bridge-building model to include other actors involved in risk management.

- The RETINA partners recommend that further work follow the RETINA project to apply its methodologies, for example, by staging another simulation exercise like those in RETINA with realistic scenarios based on coupled geophysical phenomena and involving Civil Protection participants and observers from the entire European Union.

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3HAZ CORINTH – Earthquakes, Tsunamis and Landslides in the Corinth Rift, Greece

GOCE-CT-2004-004043

Instrument:	FP6 – Research Project	Starting date:	01/11/2004
EC contribution:	1,500,000.00 €	Duration:	24 months
Organisation:	Institut de Physique du Globe de Paris		
Co-ordinator:	Dr Pascal Bernard (bernard@ipgp.jussieu.fr)		
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PROJECT SUMMARY

The project will contribute to better measure, model, and predict the processes leading to earthquakes, landslides, submarine slides, and tsunamis, and their effect in terms of hazard. The target area is the rift of Corinth, well known for its exceptional activity with respect to these hazards. This work will focus on the western end of the rift, close to the cities of Patras and Aigion, where the risk is highest.

We will study the short term seismic hazard with methods involving seismology, geodesy, geophysics, and geochemistry. In addition to strong motion analysis and prediction, transient processes (seismic swarms, “silent” earthquakes, fluid transients) will be studied, for a better modelling of fault mechanics and earthquake preparation processes. In addition to the existing monitoring arrays and data base, specific new instrumentation will be built. Near-real time alarms systems for significant earthquakes will be developed and tested. For the long term seismic hazard, the seismic potential of active faults will be assessed on land and offshore.

For submarine slope failures, places of past and future potential slumps will be mapped, and complemented by marine sediment coring and dating on selected places. Scenarios of slope failure and of coseismic displacement of the sea floor will be the inputs for tsunami modelling. The latter will be implemented using the existing high resolution bathymetry for modelling of the wave run up. Early warning alarms will be developed and tested.

For landslides, the main objective is to monitor and model the perturbation of the sliding of a well documented active landslide, in response to ground shaking from local earthquakes. Continuous GPS, seismic and tilt monitoring, and repeated advanced geodesy, will quantify sliding rates and constrain first order models. The feasibility of alarm systems will be studied.

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ARMONIA – Applied Multi Risk Mapping of Natural Hazards for Impact Assessment
GOCE-CT-2004-511208
<http://www.t-6.it>

Instrument:	FP6 – Research Project	Starting date:	01/10/2004
EC contribution:	1,000,000.00 €	Duration:	30 months
Organisation:	T6		
Co-ordinator:	Ms Katja Firus (k.firus@t-6.it)		
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PROJECT SUMMARY

The overall aim of ARMONIA is to provide the EU with a new harmonised methodology for producing integrated risk maps to achieve more effective spatial planning procedures in areas prone to natural disasters in Europe. Objectives to be achieved by ARMONIA are as follow:

- Integration/optimisation of methodologies for risk assessment for different types of potentially disastrous events;
- Harmonisation of different risk mapping processes for standardizing data collection/analysis, monitoring, outputs and terminology for end users (multi-hazard risk assessment);
- Design of and proposal for a harmonised decision-making tool structure for applying hazard and risk mitigation in spatial planning;
- Contribution to the implementation of natural hazard awareness into the improvement of Environmental Assessment policy.

ARMONIA comprises the following steps:

- Analysis of state-of-the-art for spatial planning and natural risk mapping,
- Development of methodology for a harmonized integrated maps,
- Development of a harmonized knowledge base of terminology,
- Integration of harmonized risk maps with spatial planning decision processes,
- Implementation, integration and analysis of a case study simulation.

ARMONIA will seek to achieve outcomes that can mitigate the adverse effects of natural phenomena, through the joint effort of the scientific community, technology experts and end users. The target is therefore not a solely scientific output, but a measurable impact on policies and practices for disaster mitigation initiated within the period of the project.

The strategic impact of ARMONIA can be generally summarised as:

- Implementing multi-hazard and risk methodologies with a special regard to climate change effects that may result increased occurrence of extreme events and impacts on the anthropogenic system;
- Harmonising techniques and processes of analysis of multiple hazards and risk assessment;
- Promoting more effective cooperation among different disciplines involved in spatial planning, as well as between scientific expertises and decision makers;
- Incorporating multi-hazard and risk assessment into a new European directive/guideline for the harmonisation of hazard/risk mapping to be applied in spatial planning.

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EU-MEDIN COMPANIONS – Supporting Publications on Natural Hazards Research

GOCE-2004-009972

<http://www.eu-medin.org>

Instrument:	FP6 – Specific Support Action (SSA)	Starting date:	01/07/2005
EC contribution:	300,000.00 €	Duration:	24 months
Organisation:	Algosystems		
Co-ordinator:	George Eftichidis (geftihid@algosystems.gr)		
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PROJECT SUMMARY

The European Commission has previously (FP5) supported setting the EU-MEDIN (Euro-Mediterranean Disaster Information Network) to foster co-ordination among the research & user communities for improved communication, and exchange of data and knowledge via a portal <http://www.eu-medin.org>. The EU-Medin web portal is a large forum as well as a potential source of data and information regarding the achievements of research in Natural Disasters.

The aims of this project is basically to provide a set of publications that will be created within the scope of the EU-Medin initiative and will be used to disseminate information and research results in the field of Natural Hazards to the stakeholders in general.

These publications should include:

- A book on the state of the art of natural hazards in Europe. A wide board of Editors and external experts will collaborate for the preparation of this publication;
- English glossaries of terms commonly used to describe concepts used in references of various types of Natural Hazards (Forest fire, Earthquakes, Landslides, Floods, Desertification, Volcanic Risk, etc);
- A publication including a collection of information regarding the initiatives, services and policies of the EC in the field of Natural disasters.

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FORESIGHT – Frequent Observation-Driven Realistic Evaluation and Simulation of Interacting Geophysical Hazard Triggers

GOCE-2003-511139

www.acri-st.fr/foresight/

Instrument:	FP6 – Research Project (STREP)	Starting date:	01/09/2004
EC contribution:	1,080,000.00 €	Duration:	24 months
Organisation:	ACRI-ST S.A.S		
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PROJECT SUMMARY

The overarching scientific objectives of FORESIGHT are:

- To understand the mechanically coupled, interrelated processes leading to the hazardous activity associated with earthquakes, volcanoes, landslides and tsunamis;
- To assess, mitigate and manage the risks posed by these hazards, existing and fresh data from multi-sensor surveillance networks and satellites will be combined within a time-dependent Geographic Information System (GIS).
- To harmonise data and methodologies for understanding geophysical processes across Europe FORESIGHT will focus on four natural laboratories: Iceland, Azores, Alps and Turkey.
- To emphasise the mechanical coupling and temporal interactions between geophysical processes.
- To apply advanced methods of GIS analysis to enhance physical models for calculating, predicting, and interpreting the consequences of such geophysical activity.
- To support the implementation of new European-scale risk management systems by civil defence participants in the project.

To achieve these goals, the FORESIGHT consortium seeks to:

- Recognise times of increased geophysical activity by assimilating fresh data from existing sensors.
- Locate areas of increased geophysical activity by mapping crustal deformation, seismicity, and other indicators.
- Develop exploitable models for the physical mechanisms underlying correlated events.
- Calculate stress fields to identify areas where one event may trigger another.
- Identify times and areas of increased hazard, accounting for triggered events in conditional probabilities.
- Introduce these time-dependent assessments of hazard into risk management systems.
- Share expertise and resources in risk management at the European level.

As a result, FORESIGHT will help reduce the effects of natural disasters upon the citizens and infrastructure of Europe.

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LESSLOSS – Risk Mitigation for Earthquakes and Landslides

GOCE-CT-2003-505448

www.lessloss.org

Instrument:	FP6 – Integrated Research project (IP)	Starting date:	01/09/2004
EC contribution:	6,430,000.00 €	Duration:	36 months
Organisation:	Università degli Studi di Pavia		
Co-ordinator:	Prof. Michele Calvi (gm.calvi@unipv.it)		
EC officer:	Denis Peter (denis.peter@ec.europa.eu) Bjorn Vangelsten (bjorn-vidar.vangelsten@ec.europa.eu)		

PROJECT SUMMARY

Objectives

Earthquake and landslide risk is a public safety issue that requires appropriate mitigation measures and means to protect citizens, property, infrastructure and the built cultural heritage. Mitigating this risk requires integrated and coordinated action that embraces a wide range of organisations and disciplines. For this reason, the LESSLOSS IP is formulated by a large number of European Centres of excellence in earthquake and geotechnical engineering integrating in the traditional fields of engineers and earth scientists some expertise of social scientists, economists, urban planners and information technologists.

The LESSLOSS project addresses natural disasters, risk and impact assessment, natural hazard monitoring, mapping and management strategies, improved disaster preparedness and mitigation, development of advanced methods for risk assessment, methods of appraising environmental quality and relevant pre-normative research.

In order for the multi-disciplinary S&T ingredients of the project to be tackled in an efficient and productive manner, the research programme has been split into three distinct areas: physical environment, urban areas and infrastructures. For each one of these areas four main types of transversal fields have been identified as fundamental and capable of producing permanent effects on risk mitigation:

- 1) Instrumentation and monitoring,
- 2) Methods and technologies to reduce vulnerability,
- 3) Innovative approaches for design/assessment,
- 4) Disaster scenarios and loss modelling.

Within this general framework, specific objectives will be pursued, such as the development of innovative methods and approaches to design and assessment of structures and earth slopes for both short and long term implementation, the development of advanced monitoring techniques and devices, and the development, manufacturing and testing of innovative isolating and dissipating seismic devices.

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MEDIGRID – Mediterranean Grid of Multi-Risk Data and Models

GOCE-CT-2004-004044

www.eu-medigrid.org

Instrument:	FP6 – Research Project	Starting date:	01/10/2004
EC contribution:	950,000.00 €	Duration:	24 months
Organisation:	ALGOSYSTEMS S.A.		
Co-ordinator:	Dr George Eftichidis (geftichid@algorithms.gr)		
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PROJECT SUMMARY

The MEDIGRID project aims to create a distributed framework for multi-risk assessment of natural disasters. In order to achieve the above strategic objective several parallel tasks must be accomplished and a number of particular objectives to be addressed. The project will integrate in the above framework models of forest fire behaviour and effects, flash floods and landslides, developed in frame of previous EC projects. These models will be upgraded to web applications in order to be able to run remotely as web services over the internet. A distributed repository with EO data, combined with field measurements from countries that have suffered important forest fires during the last summer will be created by the project partners. Such data will be defined according to the requirements of the models that will be integrated and tested within MEDIGRID. The data structure and organization will be designed in order to comply with the concept of respective EC initiatives (INSPIRE, EU-MEDIN, ESPON) for data standardisation. The individual models in the context of a models validation framework will use these data. The entire system of models and data will be shaped further as a multi-risk assessment and decision support information platform.

The proposed project shall contribute to the definition of the needs of multi-risk management related to forest fire triggered disasters such as post-fire run-off and flash floods, soil erosion and debris flow. Furthermore it will contribute towards the formalization and organization of datasets that can be used for the validation of risk assessment models as well as for integrated risk management.

The main objectives of the MEDIGRID proposal will be:

- The definition of a multi-risk assessment platform based on distributed data and models;
- The contribution to the standardization of the structure of data sets that can be useful for model testing and multi-risk assessment;
- The establishment of a framework to validate risk models developed in the context of previous R&D projects;
- The management of distributed disaster data networks;
- The development of web based risk assessment models, using distributed disaster data.

The proposed project will provide a significant impact to the post-fire management of the Mediterranean landscape of the EU since it will make available data, provide knowledge and practice that hasn't been made available to the land developers, politicians and researchers in the past.

The contribution of the project towards the investigation of the mechanisms that govern the initiation and the severity of related hazards will be a significant adding to the existing scientific knowledge in this field. This approach can support management and political decisions for solving societal problems such as land use and development, and reinforce civil protection planning.

The project aims to create a distributed repository with data of areas in South EU that suffered devastating fires during the last summer. A number of models dealing with the risk assessment of post fire hazards will be used for (model) validation purposes by assessing the situation in comparison to observations that will be made in the context of the area monitoring plan. A generic multi-risk management framework will be designed and evaluated within the context of the project.

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**NARAS – Natural Risks Assessment Harmonisation of Procedures, Quantification
and Information**
GOCE-CT-2003-511264

Instrument:	FP6 – Specific Support Action (SSA)	Starting date:	01/09/2004
EC contribution:	240,000.00 €	Duration:	26 months
Organisation:	Università di Napoli Federico II		
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PROJECT SUMMARY

Mediterranean countries are subject to frequent and different natural catastrophes which pay a high toll in terms of economic loss and human life. Since some tens of years EU countries are trying to mitigate the effects of these events mainly by means of prevention. Scientific progress in natural risk assessment and mitigation has increased the capacity of public administration to cope with high risk deriving from volcanic and hydro-geological events, to use satellites for short term prediction of meteorological events and floods, to work out, refine and enforce seismic EUROCODE 8. Several research project have been supported by EU Framework Programs. In all these cases risk assessment and managing have been approached individually for each risk typology and, often, differently even for a same typology in different countries. The consequence has been that the deliverables produced for different types of hazard are often not comparable and different deliverables for the same hazard types are produced in different countries. The need of harmonisation of terms and procedures has been stressed out in different EU MEDIN and UN Workshops. The aim of this project is to contribute to harmonise the risk assessment procedures and indicate ways to quantitative evaluation of hazard and risk levels through a two years long programmed series of Workshops, seminars, meetings, formation and educational activities which involve scientists, administrators and insurance experts who have been actively working in risk assessment problems in the latest years. Regions of South Italy, Greece and France will be used as test cases. The project is divided into 4 WP, dealing with: (1) Dissemination, comparisons of results and harmonisation, (2) Risk evaluation for land, urban planning and emergency management, (3) Formation and education (4) Publication of results.

This project aims at contributing to this need by:

- 1) Disseminating and discussing the results obtained by EU funded projects, in order to make specialists of each area aware about the results attained by other areas' specialists;
- 2) Promoting harmonisation of scenarios and procedures of risk evaluation among different countries and among different types of natural risks and by a critical analysis of existing normative codes, such as EC8;
- 3) Stimulating the development of quantitative probabilistic methodologies of evaluation of risks and different emergency scenarios using improved stochastic methods;
- 4) Promoting information and education actions in the schools aimed at increasing consciousness of natural risks among young people.

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SCENARIO – Support on Common European Strategy for Sustainable Natural and Induced Technological Hazards Mitigation
CT – 036979

Instrument: FP6 – Specific Support Action (SSA) **Starting date:** 01/09/2006
EC contribution: 652,000.00 **Duration:** 18 months
Organisation: Politecnico di Milano
Co-ordinator: Dr Scira Menoni
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PROJECT SUMMARY

Modern society is increasingly characterized by strong interactions between physical, infrastructure and human domains of the environment. Disasters are a critical collision between climatic and geophysical dynamics and are dramatic examples of people living in conflict with their environment. Disaster reduction and resilience are key priorities identified by the EC and the Hyogo Framework for Action. A sustainability framework for natural and technological hazards is of critical importance.

Therefore the main goals of SCENARIO are:

- To develop an European roadmap on sustainable mitigation of natural and induced technological hazards and risks which will support future European research priorities for the 7th framework programme, contribute to European policies on natural hazards, sustain the scientific community by providing a strategic picture and support potential end-users/stakeholders. An European roadmap may inspire an European Strategy for reduction and mitigation of effects by natural and induced technological Disasters and the building of greater resilience;
- To integrate fragmented research approaches, concepts and results by incorporating existing experiences on natural disaster projects and initiatives at European level, including important national and international initiatives;
- To assess and reorganise the Logic Value Chain of natural disasters, also considering induced technological disasters, through updating knowledge and state of the art on natural disaster prevention and mitigation in the context of modified societal and environmental features.

In order to reach the objectives, SCENARIO will set up a networking process among existing projects and activities dealing with natural disasters with several workshops and meetings for knowledge sharing and dissemination.

SCENARIO fits with Europe's goals regarding sustainable development in supporting environmental policies by defining an European roadmap on sustainable mitigation of natural and induced technological hazards and risks.

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SEISMIC

CORSEIS - An Integrated Study of Seismic Hazard Assessment in the Area of Aigion, Gulf of Corinth, Greece

EVG1-CT-1999-00002

http://www.corinth-rift-lab.org/index_en.html

Instrument:	FP5 – Research Project	Ending date:	31/07/2002
EC contribution:	662,000.00 €	Duration:	28 months
Organisation:	IPGP		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

- To improve our knowledge of the tectonic and seismic activity of the western part of the rift of Corinth, integrating tectonics, seismology, geodesy, geophysics, and geochemistry, and to install a number of continuously monitoring arrays.
- CORSEIS was devoted to the installation and development of surface and near-surface monitoring arrays (seismometers, accelerometers, geodesy, deformation, geochemistry) and to the detailed tectonic and geochemical studies of the active faults.
- To constrain the long and medium term activity of the major active normal faults outcropping to the south of the gulf, and to identify and to date paleoearthquakes on these faults.
- To record weak and strong motion accelerograms for source, attenuation laws, and site effects studies.

Scientific achievements and results

Tectonic studies have quantified the recent activity of the Helike and Aigion major faults, and identified unreported historical large earthquakes. The new surface seismic array CRL provides a continuous monitoring of the local seismicity, revealing fine fault structures at depth. The new borehole accelerometer array in soft soil, CORSSA, should provide evidence for non linear response even at low ground acceleration level. New continuous GPS, strain, et tiltmeter measurements, combined with inSAR analysis, provide the space-time deformation framework to understand seismic and aseismic fault slip, and in particular transient processes. The latter may also be revealed by the continuous geochemical monitoring station, selected after a detailed survey of shallow groundwater. The database from these newly installed arrays form the main basic input for the development of the Corinth Rift Laboratory project.

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EMICES - European-Mediterranean Infrastructure Co-ordination for Earthquake Seismology

EVK2-CT-2001-80002

<http://orfeus.knmi.nl/emices/>

Instrument:	FP5 – Scientific Support Action (SSA)	Ending date:	30/04/2004
EC contribution:	69,855.00 €	Duration:	24 months
Organisation:	Royal Netherlands Meteorological Institute		
Co-ordinator:	Dr Torlid van Eck (vaneck@knmi.nl)		
EC officer:	Denis Peter		

PROJECT SUMMARY

The consortium has organised three European workshops to co-ordinate on-going European efforts in earthquake data management and exchange. The immediate goal was to engage more observatories and researchers from Europe and the Mediterranean area in existing initiatives, notably EC-project MEREDIAN (EVRI-CT2000-40007) and EPSI (EVRI-CT2000-40006). Another goal was to co-ordinate a large number of both regional and global on-going initiatives with regard to earthquake data.

Our objectives for the three workshops were:

- Co-ordinate and improve real-time waveform data exchange within Europe.
- Co-ordinate different initiatives for Internet software development to facilitate earthquake data exchange and earthquake information distribution in Europe.
- Plan and co-ordinate rapid exchange of earthquake data within Europe and the Mediterranean Area.

The workshops were essential in co-ordinating existing rapid international developments in management and exchange of earthquake data and to initialise new activities.

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EUROSEISRISK - Seismic Hazard Assessment, Site Effects and Soil Structure Interaction Studies in an Instrumented Basin

EVG1-CT-2001-00040

<http://euroseis.civil.auth.gr/>

Instrument:	FP5 – Research Project	Ending date:	30/06/2005
EC contribution:	1,465,971.00 €	Duration:	42 months
Organisation:	Aristotle University Thessaloniki		
Co-ordinator:	Prof. Kyriazis Pitolakis (kpitolak@civil.auth.gr)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The research objectives of the present project are the following: (a) experimental and theoretical research for improving existing methods, tools and procedures to estimate local ground motion variations due to site specific effects within the context of engineering applications, (b) development and improvement of methods, models and tools for hazard, vulnerability and risk assessment (c) enhancement of the earthquake resistance of R/C buildings and bridges, (d) contribution to the ongoing elaboration of the new generation of Eurocode 8 (e) establishment of th a permanent 3D strong motion array covering the whole Euroseistest sedimentary valley and (f) creation of a database of high quality and well constrained data easily accessed from European and International researchers through Internet that may be used to validate and/or improve existing methods and tools, to develop new and in general innovative approaches in all aspects of earthquake engineering.

Scientific achievements and results

The purpose of this summary is to expose the major scientific achievements in many topics in earthquake engineering, engineering seismology and seismology taking advantage of a multidisciplinary field and laboratory experiment using the largest research infrastructure in Europe and one of the best in the world. The major scientific achievements can be summarized as follows:

i) Definition of 3D soil structure. The detailed three dimensional definition of a large scale geological structure such as in the Euroseistest - Volvi instrumented basin, improved our understanding of the site effects physics and consequently of the correct modelling of strong ground motion whose prediction during future earthquakes is sought. Moreover, the well-known stratigraphy and mechanical, physical and dynamic soil properties along the N-S direction of the basin, provided the opportunity to well constrain the whole 3D subsoil structure with complementary geophysical, geotechnical and geodetical surveys. Therefore, the initial objectives of the project related to the definition of the geometry, thus stratigraphy and the soil properties of the basin were accomplished at the most feasibly detailed level. In particular, a) the dynamic properties of the main soil formations were accurately defined, b) the geometry of the soil stratigraphy and the interface between soil layers and bedrock were studied and c) the location of the faults, which cross the whole basin were investigated and defined.

ii) Research on soil and site characterisation. Bearing in mind the complexity of soil structures but also the simplifications that modern code provisions make for describing soil profiles, it was deemed necessary to focus on the following two issues in order to gain a better insight into the problem: a) The use of microtremors for soil and site characterization which is of major practical importance especially for microzonation studies of densely populated areas, where the use of other techniques is either impossible or very expensive, b) the development of an innovative method to measure and monitor in-situ transient and permanent ground deformations. Moreover, the applicability of this new technology in order to have direct

deformation measurements either on soil formations or structures is evaluated. c) The present research and discussion is contributing to the open discussion regarding soil categorization in Eurocode 8.

iii) *Seismicity and earthquake source studies.* Identifying the seismicity of the particular area, which affects a population of more than two million people and a major economic, cultural, industrial and commercial centre (Thessaloniki region), is of major importance. Along these lines, the high level of microseismicity and seismicity within the Mygdonian basin, where the test site is located, as well as the fact that this seismic activity is being permanently monitored by a telemetric network of 16 seismographs which is operated by one of the major partners of the project, all these provided a significant opportunity: a) to study wave propagation issues and source parameters related to past and future earthquake events b) to evaluate alternative epicentre localisation techniques and c) to assess seismic hazard of the particular seismotectonically active area and to validate current methods of hazard assessment.

iv) *Strong ground motion prediction – site effects.* Taking advantage of the unique features of Euroseisest and using the recordings obtained from both weak and strong earthquakes, it is aimed to: a) study the physics of site effects so that all observations at a given site could be modeled correctly were studied thoroughly and thus obtained confidence in the predictions made with predictive models, b) contribute to the “open” problems in earthquake engineering and engineering seismology such as complex site effects due to 2D and 3D soil structures, differential motion due to edges effects and lateral variation were investigated taking into account all phases of the earthquake evolution such as source mechanism, ray path and site effects in complex soil structures, c) to focus on azimuthal dependencies and directivity effects, d) investigate the soil non linearity through moderate and strong earthquakes recordings in the downhole arrays of the test site, e) study in case of a possible future earthquake, liquefaction phenomena that are expected since they have been observed during past events, f) study the spatial variability of ground motion and to identify the major parameters that control the extent of this variability were studied, g) investigate the reliability of various empirical techniques that are used for site amplification estimation in case of small, moderate and strong events, h) evaluate the empirical techniques to estimate of signal modifications in the time domain (duration increase in particular), i) the accuracy of the existing constitutive models for the dynamic soil behaviour and the relevant program codes were validated, j) explore and discuss the numerical and analytical background of the existing modelling techniques as well as to develop new simulation methods and software and finally k) contribute in the more explicit inclusion of site effects on the design earthquakes and spectra of Eurocode 8.

v) *Soil - structure interaction in the presence of yielding and actual soil conditions.* Although the effect of soil-structure interaction on the dynamic response of typical residential or commercial structures and infrastructure (i.e. bridges) has long ago attracted scientific attention, it is widely recognised that there is an urgent need for further experimental support. This need is far more crucial in cases where the structure responds inelastically and/or the soil conditions favour the appearance of SSI phenomena: Therefore, the Euroseisrisk project aimed to study the following aspects: a) to investigate the beneficial or detrimental role SSI plays in presence of yielding of the superstructure lying on a very soft soil, b) to examine the nature and the effect of the waves transmitted by the oscillation of the superstructure to the foundation level and the surrounding soil, c) to scrutinize the effect of foundation flexibility (i.e. footing / single cast) on the extent of dynamic SSI phenomena, d) to propose and test rehabilitation methods and e) to identify possible code implications of soil-structure interaction phenomena.

EUROSEISRISK project allows the better understanding of the physics of earthquakes and earthquake ground motion and to refine methodologies in the whole chain of seismic hazard assessment as well as of the mitigation of seismic risk. The resulting increase of expertise in Europe allows better advising and collaboration with end-user, for practical application at European or regional and national scales taking appropriate safety measures through the improvement of regulatory codes for buildings and lifelines. This expertise helps engineers, and public administration authorities to enhance safety to buildings, lifelines like bridges and other structures, and to design retrofitting techniques in a more efficient way.

EUROSEISRISK project is actually a very powerful multidisciplinary European experimental site to perform integrated studies in earthquake engineering, engineering seismology, seismology, and soil dynamics. It generates a set of high quality data relevant to the above scientific topics, which will be easily accessible through Internet. Scientists, researchers, engineers working in any of the above fields have access to valuable data to check their models and methodologies, to validate and to improve models and processes, and to develop new ones.

The project itself brought together scientists, researchers, structural and geotechnical engineers, seismologists, geophysicists and geologists from different parts of Europe, Japan and worldwide through the establishment of the international network of experts and users, from other parts of the world as well, to work

together focusing on the assessment of seismic hazard, the mitigation of seismic risk and hence the improvement of the quality of life. At the same time, it allowed the improvement of their scientific and technological knowledge and expertise. As most of the contributors and partners are University institutes, this knowledge is transferred to the academic community and other end users.

Finally, for the specific area of Thessaloniki as well as for the wider area of central Macedonia (northern Greece), the project lead to an improved knowledge of the seismic hazard. To a great extend the methodologies developed are certainly going to be useful for other regions as well.

Socio-economic relevance and policy implications

EUROSEISRISK has a strategic impact along two major lines: First, code implications is a crucial part of the overall research scheme since it is generally known that the vast majority of state-of –the art knowledge is widespread within the scientific community but is not reflected in the current seismic codes and in particular Eurocode 8. As a result, the more refined and explicit description of soil categories, the potential inclusion of complex site effects on the design earthquakes and spectra, the importance of the soil presence on the dynamic response of bridge pier structures, the assessment of SSI effects in the presence of yielding and the proposal of optimal retrofitting techniques, are some of the code oriented issues that are promoted, enable the enhancement of European competitiveness in terms of seismic provisions and guidelines. Secondly, the existing test site itself, which is a unique densely instrumented site in Europe and one of the best in the world which involves instrumentation of a 3D basin and structures, being further improved and extended in this research scheme, significantly helps towards the elimination of a serious European deficiency which is observed with respect to U.S. and Japan and is related to strong ground motion instrumentation and the use of well constrained data.

Finally, apart from promoting EC scientific priorities, EUROSEIS-RISK support EU social and economical policies thus it is contributing to the general growth of the community. It is worth mentioning that the project not only improved locally employment (more that 100 new scientists have been involved in the project) but also strengthened scientific mobility (the project involved partners from Greece, U.K., Germany, Italy, Spain, France, Slovakia and Japan), thus creating the necessary background human capital which will promote future joint research projects. Furthermore, the detailed seismic hazard analysis of the area including a major city of Greece (i.e. Thessaloniki) contributes to the global mitigation of seismic risk in the area and hence it shall have a considerable impact on the economical development of the region.

This research and development/installation was made possible by the large effort carried out during the EUROSEISRISK project. The high quality database accumulated is a very important achievement. Moreover, the continuing operation of this test site, together with deployment of additional instruments, will make this test site very important in Earthquake Engineering during many years to come. It should be considered as a real Large Scale Facility.

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INDEPTH - Development of Innovative Devices for Seismic Protection of Petrochemical Facilities

EVG1-CT-2002-00065

<http://indepth.boku.ac.at/sitemap.php>

Instrument:	FP5 – Research Project	Ending date:	31/08/2005
EC contribution:	1,242,200.00 €	Duration:	36 months
Organisation:	Enel. Hydro – Business Unit ISMES		
Co-ordinator:	Dr Fabrizio Gatti (gatti.fabriziog@enel.it)		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIVEMENTS

Objectives

The objectives of the Project were to develop improved risk prevention techniques through new seismic isolation and energy absorbing devices to reduce seismic damage and avoid catastrophic collapse of critical structures at petrochemical facilities located in seismically active areas throughout Europe. In addition, the development of special guidelines encompassing the seismic design of both new and existing critical structures at petrochemical facilities represented an important by-product of this work. These objectives were pursued through the development of a seismic protection system for a number of liquid-filled structures (fully/partly, varying over time, i.e. variable mass structures), with new isolators and dissipators. In addition, in order to preserve system integrity and functionality, the displacements resulting from the use of such isolation systems at the interconnected piping was compensated through the use of flexible piping couplings and joints.

Scientific achievements

The project enabled the demonstration of the capability, for the petrochemical structures studied, of withstanding seismic actions for a wider range of ground accelerations with respect to the conventional configuration. It helped the development of both simplified and sophisticated numerical procedures for the design/verification of isolated tanks. It facilitated the development of innovative devices (at low cost) or devices able to substitute elements already present in the structures (e.g. bracings). It made the demonstration of the advantages even for excitation levels and mass different from the design ones.

The project also enabled a cost/benefits analysis specifically tuned on the petrochemical facilities; the design guidelines specifically tuned on the petrochemical facilities and the flexible piping joints for aseismic application, BRBs for retrofitting and low-cost isolators (FRRB).

Socio-economic relevance and policy implications

For petrochemical/industrial facilities, the motivation for the proposed project was simply to increase the seismic performance reliability of such facilities, both existing and future, in the face of high earthquake risk, in order to protect the environment from petrochemical facility product release, to improve the plant safety at existing and new facilities, to increase the public safety and to reduce the economic losses (both direct and indirect) due to loss of production.

Concern for society, quality of life of surrounding communities and impact on the environment, forces policy makers to assess the risk of hazardous material releases from refineries and petrochemical facilities during earthquakes. In fact, a major seismic event in an industrialised area could damage (and has damaged in the past) process equipment, storage facilities and transfer (or lifeline) systems. The start of fires and the release of airborne toxic gases and/or volatile liquids may obstruct post-earthquake rescue operations and have

major social and economic consequences. An example in case is the initiation of multiple fires at the Tupras oil refinery and loss of production after the Izmit earthquake in Turkey.

The main achievements of the Project, along with the supplementary information given by the main deliverables, make possible to have a wider availability of sites in which a petrochemical facility could be built and, by consequence, a major possibility to find sites at lower costs. It could be envisaged that the seismic isolation concept, already mature in other fields, like civil construction, be introduced in the field of petrochemical facilities, characterised by structures with variable mass, hard environmental conditions and very particular structural typologies as the application of this technology allows to reach both technical and economical advantages.

Details can be found on the homepage of INDEPTH (<http://indepth.boku.ac.at>) that will be maintained for two other years after the ending date of the Project.

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OPTSDET - Novel Optical Devices and Techniques for Seismic Activity Detection and Measurement

EVG1-CT-2002-00062

<http://cordis.europa.eu/etip/dc/index.cfm?fuseaction=pjc.viewCompleteProjectInfo>

Instrument:	FP5 – Research Project	Ending date:	28/02/2006
EC contribution:	494,799.00 €	Duration:	39 months
Organisation:	University “Politehnica” of Bucharest		
Co-ordinator:	Emil Smeu (emil_smeu@physics.pub.ro)		
EC officer:	Denis Peter (denis.peter@ec.europa.eu)		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The project aimed to research, design, manufacture and test new types of seismic sensors and measurement techniques based on optical principles. These sensors and techniques belong to a new generation design having several targeted goals: to improve the resolution, dynamic range and accuracy in seismic measurements; to eliminate nearly totally the noise due to electrical signal transmission links between sensors and data loggers/computers (improving the signal/noise ratio); to eliminate the complex mechanics present in classical sensors. All prototype sensors were calibrated in dedicated laboratories, tested in the field and finally used in seismic activity survey and measurements.

Scientific achievements

Design, tests and data analysis for:

- Two types of fibre optics accelerometers (one with high resolution HiRes and another with low resolution Lores; the combination has high resolution and dynamic range); both types were mounted in a tri-axial configuration;
- A fibre Bragg gratings (FBG) sensor to monitor structural changes inside buildings.

Main deliverables:

- Report containing the procedures for calibration and field testing of new optical seismic sensors.
- Prototype of an optical sensor for structural dynamic and also quasi-static behaviour of buildings, to be used inside (based on FBGs).
- Tri-axial versions of a low resolution and a high resolution optical accelerometer, based on Michelson interferometers (prototypes).
- A 3 channel computer digital interface for the optical seismometers, together with appropriate software for acquisition/processing/display of the data delivered by the sensors (prototype).
- Report on the laboratory tests of the optical seismometers (including calibration on a shaker table).
- Report on the most suitable configuration of the optical seismometers along with dedicated instrumentation and software.
- Report on the investigation of a low cost time division or wave length division multiplexing configurations for the optical seismometers, suitable for field deployment.
- Report on testing the reliability and the signal to noise ratio of networks of the optical seismometers prototypes in the field.

Socio-economic relevance and policy implications

Earthquakes affect extended territories with devastating effects that do not stop at regional or national boundaries. Over a million villages, towns, and cities are placed in earthquake-prone areas in the world, therefore, it is important to improve the overall process for undertaking risk assessment and management at national, regional, state, provincial, and local scales. It is therefore understandable that scientists from different countries summoned their scientific potential in order to limit the earthquake effects. The problem of the urban earthquake risk management is of extreme interest for public, government officials, and business leaders. Due to the rapid urban growth the earthquakes affect today larger sectors of the population and of the infrastructure. The most seismic active zones are Mediterranean and Balkan regions (Greece, Turkey, Italy, Spain, Macedonia, Romania, Bulgaria, Albania). In the Carpatho-Balkan Region for instance, the buildings are more vulnerable and the local resources to manage rare events such as earthquakes are still poor. Harmonization of Eastern and Western Europe in terms of safety compliance requires joint efforts of European laboratories to complete the investigation cycle: seismic motion measurement - realistic seismic input modeling - seismic risk assessment - seismic risk reduction by prevention of damages. Such joint efforts were made under this contract.

The expertise acquired so far is priceless. Software further developments and theoretical methods to study the tri-axial sensor behavior (especially for signals at noise limit) will be performed by permanent personnel. We also have in mind further hardware developments, but we should find funds for this.

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PREPARED - Application of Practical Experience Gained from Two Recent Large Earthquakes in the South Iceland Seismic Zone in the Context of Earthquake Prediction Research to Develop Technology for Improving Preparedness and Mitigating Risk

EVG1-CT-2002-00073

<http://hraun.vedur.is/ja/prepared/>

Instrument:	FP5 – Research Project	Ending date:	31/07/2005
EC contribution:	1,117,618.00 €	Duration:	30 months
Organisation:	Icelandic Meteorological Office		
Co-ordinator:	Dr Bardi Thorkelsson (bardi@vedur.is)		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The project aims at preparedness towards earthquake hazards and to mitigate seismic risk. It aims towards technology to assess what earthquake effects may occur and where. It aims to use observed earthquake forerunners and crustal changes to develop methods for earthquake warnings on a long-term and short-term basis. By fast evaluation of the impacts of earthquake hazard, before or after its onset, it helps to prepare necessary and effective rescue actions. It develops close relationship with an early warning and information system, the National Civil Defence of Iceland, and the test area for PREPARED, for testing and application of its methods.

The objective is to develop methodology which can be applied to mitigate risks anywhere. Understanding what ground motions can be expected at various places in populated areas is socially and economically significant. To understand where the faults rupture the surface and when, is of huge significance in any earthquake prone country.

Scientific achievements

On the basis of observations and earth-realistic modelling, new understanding is emerging on the significance of fluid-rock interactions and migration of fluids from depth in the lithosphere for the earthquake nucleation process. Increased pore fluid pressures which result from upflow of such fluids into the seismogenic zone play a significant role in the long-term build-up process for large earthquakes, as the short-term nucleation process is of the order of days and hours. Methods have been developed within the project to visualise such processes and follow their progress towards the earthquake as well as for short term alerts.

New understanding is emerging on long-range stress migration (of the order of 100 km) from earthquakes or volcanic eruptions that may trigger new earthquakes or eruptions.

New understanding of the faulting mechanism of earthquakes in the area, as well as mapping of old earthquake faults on the surface and at depth, together with new studies of historical seismology and paleoseismology, creates a basis for long-term warnings about potential earthquake hazards. Rapid evaluation of observations of the earthquake nucleation process as well as the earthquake sequence when it occurs helps to prepare necessary and effective procedures for risk mitigation.

The achieved scientific knowledge and multidisciplinary real-time observations are collected in an Early Warning and Information System (EWIS) in Iceland, where they are easily accessible for fast evaluations by scientists in pre-hazard and hazard situations. With EWIS we are able to assess scientific knowledge and findings from other researchers and institutions and create cooperative ties with them during earthquake

crisis, as well as crises related to other geohazards. Furthermore, EWIS helps to maintain close working relationships with the National Civil Defence of Iceland and with the public.

Tools created in PREPARED for alerting, evaluating and visualising earthquake- and pre-earthquake processes have been produced and are gradually being applied by scientists in their hazard watching and installed for testing and practical use in the EWIS system.

Socio-economic relevance and policy implications

To understand when and where bedrock faults are liable to rupture the surface is of huge significance in any earthquake-prone country. Equally significant is to forecast the intensity or the ground motion to be expected at each place. In the PREPARED project we have shown by modelling and by experience that useful warnings ahead earthquakes are possible and useful for saving people and infrastructure.

In the project's test area, research products will be tested and applied using the Icelandic early warning and civil defence infrastructure. Results will be distributed to project participants, which come from 8 European countries, and to other countries using EC dissemination mechanisms.

The coordinator of PREPARED and several of the project's collaborators are members of the EC funded FORESIGHT project that is concerned with earthquakes, volcanism, landslides and tsunamis. New projects are being planned within the EC which make use of the results of the PREPARED project. The EWIS system has a central position in FORESIGHT and the results of PREPARED will be applied there. Wider application of EWIS is being planned.

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**PRESAP - Towards Practical, Real-Time Estimation of Spatial Aftershock
Probabilities: A Feasibility Study in Earthquake Hazard
EVG1-CT-1999-00001**

Instrument:	FP5 – Research Project	Ending date:	30/09/2003
EC contribution:	495,100.00 €	Duration:	40 months
Organisation:	University of Ulster		
Co-ordinator:	Dr John McCloskey (j.mccloskey@ulst.ac.uk)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

It now seems clear that the occurrence of aftershocks following large, damaging earthquakes is controlled by stress perturbations in the crust around them that in turn are caused by the mainshock rupture. Recently much progress has been made in calculating the magnitude and spatial distribution of these stress perturbations and it is now possible to reconstruct the stress perturbation field which results from an earthquake and thereby explain, using the so-called Coulomb stress technique, the location of the majority of its aftershocks. To date, however, this science has only been applied retrospectively. The aims of PRESAP were to assess the extent to which it is scientifically feasible and practically possible to identify, in real time, the areas surrounding an earthquake which are most likely to suffer aftershocks. PRESAP was a feasibility study in real-time aftershock hazard assessment.

Scientific achievements and results

The Coulomb stress technique involves several steps. The co-seismic slip due to an earthquake rupture must be determined, the stress perturbation tensor resulting from that slip must be calculated, and that stress tensor must be resolved into shear and normal components on the plane of interest. Additionally, if the methodology is to advance beyond identifying areas likely or unlikely to experience aftershocks to those likely to experience strong shaking, techniques must be developed to link strong motion modelling with calculations of Coulomb stress. To address these issues, a systematic program of research was conducted in which:

- The data requirements for performing the technique in real time were identified,
- A new methodology and computer program for computing stress was created,
- New techniques for quantifying the success of Coulomb maps were developed,
- The scientific issues relating to the real-time computation of Coulomb stress were resolved,
- New methods for computing strong motion from finite faults were developed,
- The strong motion and Coulomb stress techniques were linked.

The results and methodologies developed during the project were tested in a pseudo real time scenario in which data (disguised in location and time) was fed to participants in the time sequence in which it would have been available in reality. Only 4 hours and 25 minutes after the mainshock, a Coulomb stress map was "released"; this release highlighted the danger of a particular fault which ruptured in a large magnitude event approximately 6.5 hours later. A subsequent release, 14 minutes before the large aftershock, increased the emphasis on this potential region of high hazard.

The conclusions of PRESAP are:

- 1) It is scientifically feasible to make real time estimations of the likely spatial distribution of aftershocks but more work is required before the technique could be socially useful. In particular:
 - a. Better statistical tests are required in order to assess the confidence of any Coulomb estimation;

- b. Better methodologies need to be developed to estimate the likely aftershocks sources if ground motion estimations are to be made;
 - c. More work is required to provide output in societally useful terms, and
 - d. Outreach training must be provided if end-users are to understand the results.
- 2) The technique is technologically feasible in Europe but not, at present, everywhere in Europe. In order to apply the technique:
- a. Pre-existing data – namely fault maps, catalogues of fault plane solutions, catalogues of Greens functions, historical earthquake information, and regional attenuation information – should be collected in advance and stored in a readily accessible database;
 - b. Real-time analysis tools are required to get accurate, real-time, aftershock data including focal mechanisms;
 - c. Local seismological networks may need to be upgraded, and
 - d. Data collectors, processors and researchers need to work together to quickly develop the data required by the analysis.

Socio-economic relevance and policy implications

If the Coulomb stress technique is to advance from scientifically feasible to societally useful, then

1. Seismic networks must be upgraded where necessary in order to provide broadband data and to permit accurate real-time aftershock locations and focal mechanisms. These data must be made freely available, through the internet, in real time.
2. Regions intending to apply these techniques must begin a program of data collection to provide fault maps, catalogues of fault plane solutions, historical data, and information about 1D crustal structure; these data must be available to all scientists in real time.
3. Additional research must be carried out, specifically better statistics must be developed to assess the quality of stress maps with small numbers of aftershocks, the step from Coulomb stress to strong motion must be investigated further, and the likelihood of producing probabilistic results must be examined.
4. A network of trained scientists who understand all aspects of the technique must be created.
5. The best practice for presenting user-friendly results to end users must be developed. End users, in turn, must be trained to understand the strengths and limitations of the technique.
6. Many more pseudo real time scenarios must be carried out to test the scientific, technical and societal results of the above.

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QUAKER - Fault-Rupture and Strong Shaking Effects on the Safety of Composite Foundations and Pipeline Systems: Quantification and Reduction of Seismic Risk through the Application of Advanced Geotechnical Engineering Techniques

EVG1-CT-2002-00064

<http://www.dundee.ac.uk/civileng/quaker/>

Instrument:	FP5 – Research Project	Ending date:	31/05/2006
EC contribution:	€ 848,277	Duration:	43 months
Organisation:	University of Dundee		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The project has two main aims both with the overall goal of reducing seismic risk:

1. Proposal of rational recommendations for seismic design manuals, based on investigating the following two topics:
 - Topic A: Effect of earthquake fault movements on foundations, pipelines and communication links that are very close to faults.
 - Topic B: Seismic behaviour of composite foundation systems during strong shaking.
2. Dissemination of the findings to engineers, scientists, and planners, so that they will be used in the assessment of seismic risk, design of new infrastructure and retrofitting of existing infrastructure.

The first aim was achieved by multi-stranded research work on each of the two topics ranging from investigating field case histories, physical model testing and numerical analysis. The project working groups: (i) collected field data from both the literature and by observing structures in a number of seismically active zones after strong earthquakes and fault ruptures; (ii) conducted numerical and analytical modelling studies, and (iii) performed novel centrifuge model tests. This work has provided information on which to validate and base design methods and recommendations for the design manuals of structures in seismically active zones.

Dissemination was achieved using a range of methods to maximise contact with different end-users. The techniques used included an end-user workshop, international publication, poster and seminar presentations, direct contact with industry and web page dissemination.

Scientific achievements and results

Field studies were conducted for structures in seismically active regions. The scientific achievements were:

- To propose parameters and questions for further study for both research topics. These questions were used when selecting the boundary value problems investigated in the physical, numerical, and analytical studies
- To examine recommendations for current design methods for foundations and infrastructure.
- The raised parameters included: the influence of the rigidity of the foundations, superstructures and pipelines on limiting the failure/excessive deformation of the structure during fault rupture, limiting the fault displacements, and diverting the fault break.
- The raised questions were about the design rules in most of the codes of practices that prohibit using inclined piles in seismically active regions, as well as the influence of the ratio between building height and width on its response to seismic loading.

The numerical and experimental studies produced the following:

- Novel centrifuge model tests were conducted to investigate fault rupture propagation in sand and the interaction of such faulting with infrastructure (foundations and pipelines). New information has been gained about the varying rupture propagation in different soil depths and in different soils. Fault interaction with shallow foundation was found to be subtle and data on foundation and soil movements was produced for 12 different fault-footing interaction scenarios. The interaction of pipelines with propagating normal and reverse faults was studied for both 'elastic' thick walled pipelines and non-linear thin-walled pipes. Novel data was produced for each of these types of problems for validation of the numerical work and for development of new design methods.
- Centrifuge model tests were conducted to investigate rigid buildings subject to overturning during earthquakes (Adapazari, 1999) and pile groups subject to dynamic and cyclic loading. A new large data set comprising of both quasi-static and dynamic loadings have led to increased understanding of these foundation types during strong shaking.
- Numerical modelling of the fault rupture problem has allowed further study of fault propagation mechanisms and fault-infrastructure interaction. Results have been compared favourably to the centrifuge data. Further parametric study has confirmed mechanistic reasons for the behaviour which have led to design recommendations.
- Numerical modelling of raked pile group response to horizontal loadings has been performed using Winkler approaches and 3D finite element analysis. The results have been compared to the centrifuge data for both the quasi-static and dynamic loadings.
- Numerical modelling of shallow foundations during earthquake shaking has been compared to the centrifuge data. Again, this has allowed increased understanding of the complex phenomena which will lead to design recommendations.

Synthesis of the above findings allowed design rules to be considered:

- Design recommendations were presented for foundations in areas where surface fault rupture is likely. These included recommending the use of strong, rigid foundations where possible.
- New analytical approaches have been developed to evaluate the behaviour of buried pipelines that are subjected to fault rupture and fault-foundation interaction. These use the methods of limit equilibrium and the subgrade reaction method to predict the failure and serviceability states and have been validated against the centrifuge modelling.
- Design recommendations have been produced for composite foundations during strong earthquake shaking.

Socio-economic relevance and policy implications

The QUAKER project has allowed verification of current design methods and led to the development of new recommendations. These findings will:

- Improve the ability of current design manuals to produce safe and economic designs for infrastructure and geotechnical structures in seismically active regions.
- Reduce the human and economic losses that take place after strong earthquake strikes to urban areas in seismically active regions, by reducing the casualties and the destruction of structures that accompany the earthquakes.

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**RELIEF - Large Earthquake Faulting and Implications for the Seismic Hazard
Assessment in Europe: The Izmit-Duzce Earthquake Sequence of August-November
1999**

EVG1-CT-2002-00069

<http://www.ingv.it/paleo/RELIEF/>

Instrument:	FP5 – Research Project	Ending date:	30/11/2005
EC contribution:	810,051.00 €	Duration:	36 months
Organisation:	CNRS – Institut Physique du Globe de Strasbourg		
Co-ordinator:	Prof. Mustapha Meghraoui (Mustapha@eost.u-strasbg.fr)		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

- 1) Long-term faulting behaviour, determined through systematic geological, geomorphological and paleoseismological analyses (with trenching) along each earthquake rupture-segment to document the earthquake characteristics (fault dimensions, slip/event, slip rate, stress drop, elapsed time and return period of seismic events, seismic moment and moment magnitude) during the Holocene and late Pleistocene;
- 2) Understanding of physical dimension and dynamic properties of earthquake faulting (coupling between faults, the interseismic strain and fault loading characteristics), determined through use of Radar interferometry and Digital Elevation Modelling, and comparisons with the source time function (seismometer and strong motion waveform analyses);
- 3) Detailed understanding of the relationship between site effects (including response spectra) and the earthquake rupture process;
- 4) Development of a new time-dependent seismic-hazard approach based on the integration of multidisciplinary datasets, and thereby contribute to improved seismic-risk assessments for the Istanbul area.

Scientific achievements and results

After 3 years of field investigations, preparation of updated seismicity catalogues and database in active tectonics, seismotectonics and seismic hazard, and 30 deliverables, the RELIEF Project provides with a comprehensive and systematic earthquake studies along western section of the North Anatolian Fault.

The numerous studies in the aftermath of the 17 August (Izmit, Mw 7.3) and 12 November 1999 (Duzce, Mw 7.1) large earthquake served well as a basis for the development of integrated methods of seismic hazard assessment. New approaches in fault investigations, analysis of data in active tectonics, seismicity and seismotectonics, physics of the seismic source and engineering seismology were developed during the project. The third year programme allowed the preparation of results that includes:

- 1) The contribution of remote sensing using optical and SAR images in the fault modelling and characterization of earthquake fault parameters;
- 2) Synthetic models of ground motions for the area in 1D and in 3D and the results are compared to the empirical data;
- 3) Local attenuation model and distribution of ground motion values using the poissonian PSHA results compared with the time dependent models (probabilistic seismic hazard solution);
- 4) Models of seismic behaviour and simplified three-segment fault-zone model for fully spontaneous dynamic rupture simulations of large through-going events on the Central Marmara Fault and for the seismic hazard assessment in the Istanbul metropolitan area.

- 5) The application of a hybrid ground motion simulation technique including a multi-asperity, complex source model, and ground motion calculations based on multi-cycle earthquake simulations, with results presented in various maps showing the ground motion distribution in Istanbul and the surrounding areas;
- 6) Ground motion simulation for the Rapid Response station sites using hybrid techniques combined with the existing vulnerability functions for the building categories, and production of damage maps are produced showing the distribution of collapsed buildings based on a scenario earthquake (M=7.5) in the Marmara Sea;
- 7) Preparation of publications, posters and reports for dissemination tasks;
- 8) Implementation of the web site of the project;
- 9) Preparation of all dataset and results with maps, photos, catalogues, diagrams, reports and publications for the Geographic Information System of the project.

Socio-economic relevance and policy implications

The results of the RELIEF project have important implications for the EU policy in seismic risk mitigation. Several models of seismic behaviour and dynamic rupture simulations of large through-going events in the Marmara Sea and for the seismic hazard assessment in the Istanbul metropolitan area. Another important implication of the RELIEF project is to benchmark the modern European building code against a real earthquake, as a crucial test toward the calibration of the EuroCode-8. This research programme and related results imply new opportunities to the participating institutions in their educational and public-awareness missions.

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RISK-UE – An Advanced Approach to Earthquake Risk Scenarios with Applications to Different European Towns

EVK4-CT-2000-00014

<http://www.risk-ue.net>

Instrument:	FP5 – Research Project	Ending date:	30/09/2004
EC contribution:	1,625,378.00 €	Duration:	44 months
Organisation:	BRGM		
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PROJECT SUMMARY

Decision makers in earthquake-prone cities need concrete figures of the possible impact of seismic event. RISK-UE will develop a general and modular methodology for creating earthquake-risk scenarios that concentrates on the distinctive features of European towns, including both current and historical buildings. It will be based on seismic-hazard assessment, a systematic inventory and typology of the elements at risk and an analysis of their relative value and vulnerability, in order to identify the weak points of urban systems. The resulting scenarios will give concrete figures of direct and indirect damage of possible earthquakes. With the participation of urban council representatives, the methodology will then be applied to seven selected cities from the EU and Eastern Europe for its adaptation and validation. A European cities network for seismic-risk reduction will be created during a final symposium.

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S.A.F.E – Slow Active Faults in Europe Assessing Fundamental Input for Seismic Risk in Regions of Low Seismicity

EVG1-CT-2000-00023

<http://www.aramis-research.ch/e/14485.html>

Instrument:	FP5 – Research Project	Ending date:	30/04/2004
EC contribution:	970,231.00 €	Duration:	39 months
Organisation:	Université Pierre & Marie Curie		
Co-ordinator:	Dr Michel Sébrier (michel.sebrier@lgs.jussieu.fr)		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

SAFE main objectives were to develop innovative research methodologies supplying data for seismic hazard assessment in key regions of Western Europe. This will be achieved through a better understanding of mechanics and recurrence properties that are typical of slow slipping active faults. Based on the combined strategy of FAUST and PALEOSIS European projects, four main objectives were identified:

- 1) Extend geologic investigations of fault activity beyond Holocene to establish criteria for identifying active faults;
- 2) Develop an expert system combining diverse lines of geologic evidence to diagnose the existence and seismogenic potential of slow active faults; Delineate and characterize high seismic risk areas of Western Europe, either from historical evidence or geological evidence;
- 3) Demonstrate and discuss the impact of the project's results on risk assessment through a case study in the pilot area of Basel-Mulhouse characterized by several urban concentrations.

Scientific achievements and results

The actual outcome of the SAFE project covers four different domains of interest:

- 1) The *characterisation of potentially seismogenic faults* has been performed in seven different regions (Alhama-Lorca Fault, eastern Iberia Peninsula, Moroccan High Atlas, Po Plain, Provence, Lower Rhine Embayment, Upper Rhine Graben) spanning over seven countries of Western Europe (Belgium, France, Germany, Italy, Netherlands, Spain, and Switzerland). SAFE consortium has produced in each region a database of active fault parameters. These results show that potential seismogenic faults in Europe are characterized by slip rates on the order of 10-1 to 10-2 mm yr⁻¹ and maximum magnitudes ranging between 6 and 6.7. Since SAFE results have confirmed the incompleteness of seismicity catalogues, these new data are crucial for a proper assessment of seismic hazard in Western Europe, especially for hazardous (nuclear or chemical) plants. SAFE results showed that slow normal faults may provide the same kind of seismic parameters than faster active faults, observations of recurrent earthquakes indicate very long recurrence interval (\approx on the order of 10⁴ years) between destructive events. In contrast, reverse faults in Western Europe are less accurately characterized from the seismic hazard perspective. Nonetheless, seismic strain release, even very low, localises repeatedly on the same normal or reverse faults, delineating sources of seismic hazard.
- 2) *Methodologies for the identification and analyses of potentially seismogenic faults* in slow deforming regions have been developed during the SAFE project. They correspond to several scientific approaches (landform analysis, geophysics, Cosmic Ray Exposure ages...) and include new developments and softwares that may be used in the future by either other scientists or engineers that are involved in seismic hazard assessment. In particular, an expert system, SAFE-T, has been developed for diagnosing active faults in slowly deforming areas, this software can be used in the future through internet by seismic hazard engineers to help them handling contradictory data on a specific area. New

developments consisted in elaborating methodologies for: analyzing historical seismic data, modelling landscape evolution under various conditions of tectonic forcing, defining a depth-profiling technique to apply Cosmic Ray Exposure ages to active tectonic studies in Europe, using geophysical techniques on potentially seismogenic faults. Several of these developments represent scientific breakthroughs that have been already published and will be implemented in future researches by the scientific community.

- 3) *Earthquake strong motions* have been considered by SAFE partnership. Broken speleothems (sodastraw stalactites) were analyzed as possible indicators of past strong seismic motions opening future prospects on seismic hazard in Europe. Concerning strong motions, project results were implemented through a 3D numerical modelling of shaking scenario for the Basel urban area, which identified a potential damage zone in Basel.
- 4) Finally, *risk analysis* was already implemented through a global damage assessment in the Mulhouse urban area. This seismic risk evaluation was developed on the basis of a realistic earthquake scenario, which considered the possible occurrence of a moderate magnitude (M=5,3) earthquake, that was selected to identify the weaker points in the vulnerability of the urban system. This scenario demonstrated that a potentially frequent, but moderate, seismic event might cause significant damage in the Mulhouse urban area.

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SAFEFLOOR – Low Risk and Totally Recyclable Structural Buildings

EVK4-CT-2000-00020

Instrument:	FP5 – Research Project	Ending date:	30/09/2004
EC contribution:	1,553,740.00 €	Duration:	44 months
Organisation:	Bouygues – Travaux Publics		
Co-ordinator:	Dr Mouloud Behloul (m.behloul@bouygues-construction.com)		
EC officer:	Adèle Lydon		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

- A high percentage of victims and people injured during and after earthquake disaster is due to the heavy structural elements necessary to be removed during the rescue operations. To cut down response time by 15% will reduce the injured during earthquake. If we do not provide a lighter and easy disassembling design the victims due to the traditional dead load of the building will be maintained.
- A great number of accidents which occur in the Construction Sector (the most important industrial activity in urban areas) derive from the need to transport heavy loads in site areas. To cut down loads in site area by 70% during structural works will reduce the current figures of victims in construction accidents.
- Lack of rationality within the construction process. The final product of this project will permit a major rationality in the construction of building and a reduction of the construction period. Consequently the high environmental impact in urban areas due to the construction activity will be also reduced.
 - 10% of noise disturbs produced in the site.
 - 20% dust contamination.
 - 20% of traffic disturbs.
 - 25% of labour accident risk
 - 15% of works period.
- Through the use of composite materials and high strength concrete, integrating the finish pavements we aim to develop a totally new and technologically advanced light structural element. During the project we will pursue the following objectives:
- To develop a construction procedure that allows the structure to be quickly assembled and disassembled by stages.
- To reduce the building square meter cost, in terms of foundations, structure and indoor pavements. To integrate the finished pavement into the structural floor member.
- To optimise the materials to lower the structural floor dead load down to 80 Kg/m² (a reduction of the 70% regarding the actual products)
- To optimise the combination of high strength concrete and composite materials (carbon fibre and Aramida), using prestressing techniques)
- To develop a calibrated software programme to help designers calculate the building structure

In the consortium the construction partner is interesting to solve these problems in order to improve the productivity, the quality, the safety and security in sites, as well as the environmental impact of the construction activity.

The composite materials industry is interesting to solve some problems linked to the application of these materials in the construction sector and regarding the design, the calculation and the construction process.

The universities and research institutes involved in this project want to look deeply into the durability, recycling and seismic behaviour of composite structures.

The rescue organisations are interested in developing new structural system more suitable to facilitate the rescue operation.

If the consortium can resolve these problems we will provide to the society a low risk structural element, we will improve the productivity of the construction industry, and the European composite material technology will surpass the levels already existed in EEUU or Japan.

As a result of the weight of the construction materials being reduced, the plant and equipment used during said construction shall be lighter and quieter. Because the items to be moved shall be lighter, construction rates shall be higher and construction periods shall be cut down. The impact upon the urban environment "The City of Tomorrow" can be summarised as follows:

- A 10% reduction in the level of noise caused by the construction of buildings in the towns.
- A 20% reduction in truck traffic (for material transportation purposes), with respect to current traffic.
- As a result of the overall weight of the building being reduced and consequently the loads transmitted to the ground being lighter, it shall be possible to build on grounds currently considered unsuitable and located in the outskirts of towns. A more rational utilisation of the ground available in the big cities.

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**SEISLINES - Age-Variant Seismic Structural Reliability of Existing Underground
Water Pipelines**
EVG1-CT-1999-00005

Instrument:	FP5 – Research Project	Ending date:	31/08/2002
EC contribution:	651,700.00 €	Duration:	30 months
Organisation:	Computer Technology Institute		
Co-ordinator:	Dr Dimitris Kalles (kalles@tci.gr)		
EC officer:	Maria Yeroyanni		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

Many underground water pipelines were built without adequate earthquake protection; they are old and may have been subjected to aggressive environmental stressors that have resulted in corrosion, settlement, soil erosion and caused their seismic structural resistance to decrease. Damages to those pipelines during earthquakes are unavoidable and losses can be substantial. Preventive mitigation by upgrading existing pipelines for seismic resistance is cost effective for failure critical ones. This work aimed to assess the structural reliability of deteriorating underground water pipelines (especially the asbestos cement ones) and develop a decision-support system (DSS) for upgrading and keep them in service following a major earthquake.

The objectives of the proposed research were: to develop a methodology for the quantitative assessment of deteriorating underground water pipelines and implement this methodology in the case of asbestos cement, concrete, ductile iron, steel, PVC and PE pipelines; to validate the predictive ability of the above methodology in laboratory simulated conditions and to produce a decision- support- system (DSS).

To test the validity of the above assessment of seismic resistance, intact corroded asbestos cement pipes were subjected to seismic loads in laboratory experiments. The above was translated into a software programme in the form of a DSS for the seismic upgrading of critical waterpipelines, in order to remain in service following an earthquake.

Scientific achievements and results

During the first twelve months of the project a methodology for the quantitative assessment of the seismic structural reliability of straight and curved pipe segments and joints of asbestos cement, cast iron, concrete, steel, ductile iron, PVC and PE pipelines has been devised.

Based on this methodology at the end of the first year, a prototype of the DSS Module on the Seismic Reliability of Deteriorating Water Pipeline was developed.

Additionally the lifecycle costs of the main rehabilitation and replacement options for the above pipelines were assessed and a prototype of the DSS Module on Lifecycle Costs of Rehabilitation and Replacement Options was developed.

Finally, a prototype of the Expert System with the Knowledge Base and the Database was developed in the form of a DSS for the seismic upgrading of critical water pipes in order to remain in service following an earthquake.

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SESAME – Site Effects Assessment Using Ambient Excitations

EVG1-CT-2000-00026

<http://sesame-fp5.obs.ujf-grenoble.fr/index.htm>

Instrument:	FP5 – Research Project	Ending date:	31/10/2004
EC contribution:	889,648.00 €	Duration:	42 months
Organisation:	Université Joseph Fourier/Grenoble		
Co-ordinator:	Dr Pierre-Yves Bard		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The work of the SESAME project will consist of 4 main, complementary tasks. On the upstream side, the project will try and fill the gap concerning the understanding of the real nature of noise, especially in urban areas. On the technical side, series of investigations will be carried out to clearly identify the key points in each of these techniques and their reliability, and to clearly assess the conditions under which they have to be performed: experimental conditions for the measurements, and processing techniques as well. Finally, on the downstream side, after - hopefully - having shown that these techniques do provide useful information when applied with care, we want to offer a framework for reliable measurements by proposing user guidelines that could form the basis for a quality label.

Scientific results and achievements

New data sets have been obtained and/or gathered: experimental recordings of ambient vibrations on various sites (single point as well as array measurements), simulation synthetics for many different geological configurations, including both canonical models and real sites, a site effect data base gathering ambient vibration and earthquake recordings for about 200 sites. This huge data set (up to 100 Gbytes) has been carefully documented and archived, so that it may be used for further analysis or revisited with any new emerging technique; it may also constitute the basis of any larger data base (in particular the SIS data base is certainly worth being enlarged so as to become a reference data set for statistical studies).

New methods have been developed and tested. Beyond the selection of various algorithms for the classical H/V technique, original developments for a much richer use of H/V curve (inverting the H/V ellipticity) have been proposed and tested. Concerning array processing techniques, the main contribution has not been the development of new methods, but the careful cross-comparison of each of them (at least the main ones), the underlining of their respective advantages and drawbacks, and their implementation in a common software. Major forward steps have been achieved for the inversion of velocity profiles, pinpointing the severe limitations of previous techniques (those which are presently widely used in commercial softwares), and outlining the confidence intervals for the results – as well as the importance of other reconnaissance techniques to bring additional constraints on some critical parameters. The general conditions for a relevant numerical simulation of noise are now better framed and, while some further developments are still welcome (excitation box for long period waves with an oceanic origin), they offer a very useful tool for testing the data processing techniques on well constrained "data".

New softwares have been written for implementing some of these methods in "user-friendly", properly documented computer programs (3, while only two were promised in the proposal: JSESAME for the H/V technique, SES-ARRAY for array processing techniques, NOISE for noise simulation in 3D structures). Accompanying *user manuals* and *interpretation guidelines* have been carefully prepared in order to avoid their misuse, especially for the JSESAME one, which is totally free for a wide dissemination.

Extensive field tests have allowed to end up with *practical recommendations for field measurements* concerning both the H/V and array techniques, which, hopefully, should provide future users with the lessons of the good and bad experience of all the SESAME participants.

A large amount of *scientific results* could be achieved, as already witnessed by the number of contributions in International Conferences; the number of papers published in international journals is still relatively

modest, but will drastically increase in 2005 and 2006, given the delays for a) the maturation of latest results and b) the reviewing process. A special issue of the Bulletin of Earthquake Engineering, the official journal of the European Association of Earthquake Engineering, planned for late 2005 early 2006, should widely disseminate the main results within the engineering community.

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**SPACE - Semi-Active and Passive Control of the Dynamic Behaviour of Structures
Subjected to Earthquakes, Wind and Vibrations**
EVG1-1999-00016

Instrument:	FP5 – Research Project	Ending date:	31/03/2003
EC contribution:	1.658.653,50 €	Duration:	36 months
Organisation:	Maurer Soehne GmbH & Co. KG		
Co-ordinator:	Dr Renzo Medeot (medeot@iol.it)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

They are all concerned with the mitigation of the effects of vibrations induced in different types of structures by wind and earthquakes. In greater detail, the SPACE Project provides for the developments of the following systems:

- Three innovative semi-active damper based on magneto-rheological fluids, especially suited to both high-demand applications and retrofit projects
- Two improved passive floor-isolation systems suitable for horizontal seismic inputs alone (2-D isolator) or in combination with vertical inputs from ground-borne vibrations (3-D isolators).
- An advanced magneto-rheological fluid, suitable for semi-active dampers used in seismic engineering.

With respect to the existing state of the art, the Innovative Aspects are:

- the use of magneto-rheological (MR) fluids in semi-active controlled dampers to achieve both high reliability and very short reaction times
- elastomeric or mechanical devices able to combine horizontal seismic Floor Isolation (FI) with vertical isolation against ground borne vibrations

Scientific achievements and results

The attainment of the main project objectives has also generated a series of collateral technical and scientific outcomes, which are illustrated here below with their self descriptive titles:

- Two control algorithms (LQR and Energy-based),
- One data acquisition system and one dedicated semi-active control system for the demo-intervention,
- One stable magneto-rheological fluid with good sedimentation stability and re-dispersing properties, as well as high mechanical characteristics,
- Three types of semi-active dampers based on MR fluid (linear for seismic applications, rotational for footbridges, special for wind induced vibrations in cables),
- Fabric-reinforced seismic isolator and adaptation of air-bag for use as seismic isolator,
- Three-directional floor isolator,
- Three numerical models implemented in the most diffused finite element codes for structural analysis, namely ABAQUS, ANSYS and MATHLAB,
- Seven sophisticated numerical models of structures incorporating semi-active devices (4 bridges, 2 edifices and one chimney),
- One numerical model of structures incorporating 3-D devices,
- Advanced testing methods for passive and semi-active devices on shaking table, as well an in-situ testing,
- User manual containing design procedures for optimised innovative device,
- Exhaustive report on the evaluation of technical and economical benefits of the new devices use in both new and retrofit projects user manual containing design procedures for optimised innovative device. Furthermore, an additional important outcome (non anticipated in the Project's Workprogramme) shall be listed,

- Use of semi-active systems based on MR-fluid in Tuned Mass Damping for vibration control of bridge decks.

The newly conceived devices MR-damper and 3-D isolator have been manufactured and successfully tested. Both these devices have already found practical application, namely:

- The MR-damper in a 112 m long bridge (*Fuß- und Radweg Brücke über den RMD-Kanal*) in Forchheim (Germany)
- The MR damper in a 142 m long architectural bridge (*Abandoibarra Bridge*) in Bilbao-Spain
- The 3-D isolators on the anti-seismic protection of an ancient Roman vessel discovered near Ercolano (Italy).

Socio-economic relevance and policy implications

The protection of transport infrastructure, industrial plants and strategic buildings from earthquake damage is vitally important, particularly to southern areas of the European Union. The risk of major economic dislocation, and environmental hazards following damage to chemical plants needs to be minimised.

At least some degree of earthquake protection is likely to be stipulated more widely. Moreover, some European countries, which are not subjected to seismic risk, export in areas where such risk exists.

Thus, dissemination of modern techniques of seismic protection is increasingly important to constructors and equipment makers of such European countries.

In earthquake-prone areas in other parts of the developed world, for instance California (USA), Japan and New Zealand, it is recognised that traditional methods do not provide adequate protection of structures and contents. The countries are actively engaged in the development of novel techniques and devices, and there is a risk that, without a corresponding development effort in Europe, companies based overseas will penetrate the European market. Japanese construction companies in particular devote substantial resources to developmental work which European industry is unable to match without a collaborative programme.

Additionally the successful development of competitive anti-seismic devices is opening the possibility of increased exports for manufacturers both of the devices themselves and of seismically protected sensitive equipment.

The European social and economical cohesion has benefited from this project due to the technological co-operation of nine partners from five different countries, and will allow for an upgrading in the technical level of materials and devices used for the damping /isolation of vibrations of different origin, resulting in comfort, safety and consumer satisfaction.

The project has thus provided new chances for an industrially profitable production of more efficient, more reliable and more environmentally adapted materials and devices, thus aiding the promotion of an effective European Policy, to the benefit of consumers and industry.

Furthermore, although the technology required for the development of these types of systems is very high, the technology required for their production is within the reach of any European country.

Thus, a technology transfer in these areas to less developed European countries will result in the medium term in creation of jobs in the less favoured countries, thus actively promoting European cohesion.

The availability of the innovative anti-seismic devices and reliable evaluations of their technical and economical benefits will open large markets to the European manufacturers and the construction industry in the sectors of both civil and industrial structures. This fact will also create new jobs in the medium term.

The operability and availability of buildings and structures during and after strong earthquakes, made possible using the innovative systems, will be profitable to all industrial sectors.

Protection of mankind and environment will save costs because economy and ecology will be closely related in the future.

The innovative devices will enable construction in highly seismic areas including those with a high population allowing industrial growth (e.g. large plants dealing with hazardous material and growing damage potential).

As regards the Mediterranean area, it has been estimated that about 50% of all structures of different types are located in seismic areas, but that only 40% of bridges, 10% of buildings and 15% of industrial plants could be seismically isolated by means of traditional systems (e.g. rubber bearings).

The medium-term potential of markets for the European manufacturers of the new innovative devices and European construction industry are largely additive, and can be estimated to be at least comparable, to those concerning the isolation of structures by means of rubber bearings (note that for the most valuable structures - namely buildings and industrial plants - the potential for application of the new devices is even larger than that related to the rubber bearings).

The economical benefits have been duly examined (a Work-Package was dedicated to this subject) and the conclusions are more than encouraging. In some specific cases (e.g. retrofit projects) the net economical benefit can be in the order of 50% with respect to the conventional solutions.

The project has contributed to increased co-operation amongst various types of companies such as end-users, manufacturer of equipment or construction companies, and fabricator of anti-seismic devices - which need to be directly involved for the improvement in seismic resistance of structures or equipment.

The collaboration from northern European countries to minimise the threat of earthquakes in southern Europe has benefited greater social cohesion.

Furthermore, the exchange of know-how on vibration control technologies between northern and southern European countries, has enhanced the environmental consciousness in the countries receiving these technologies.

The European dimension of the partnership has been a determining factor for the successful completion of the project, because of its remarkable interdisciplinary nature. In fact, its development needed the competencies on magneto-rheological fluids of KTH (Sweden) and their application to anti-vibration devices, which are mainly held by Maurer Söhne (Germany), as well as the know-how on natural rubber material and its possible application to three dimensional isolation, which is held by TARRC (UK).

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SPIDER - Strands Prestressing for Internal Damping of Earthquake Response EVG1-CT-1999-00013

Instrument:	FP5 – Research Project	Ending date:	30/08/2002
EC contribution:	295,700.00 €	Duration:	30 months
Organisation:	Bouygues – Travaux Publics		
Co-ordinator:	Dr Mouloud Behloul (m.behloul@bouygues-construction.com)		
EC officer:	Maria Yeroyanni		

PROJECT SUMMARY

Earthquake protection of buildings is of key importance. Retrofitting of a large amount of structures, not respecting the new regulations, is becoming an important market. The traditional methods require important additional strengthening inducing works at high costs. Dissemination of energy dissipation devices, is also limited. The objective is to overcome the limits of energy dissipation devices through coupling of a series of dampers and cables. Some promising preliminary studies have already been carried out.

The technical key problem concerns the connections between the cable and the structure to be protected. Moreover, the following items must be addressed: architectural constraints, end-user needs, public authorities approval aspects. The project includes the development of prototypes and tests on full-scale mock-ups, full-scale mock-ups.). Laboratory tests and preliminary studies carried out by the damper manufacturer have shown the feasibility of the damper/cable system (DCS). The ambition is to limit the number of dampers needed to protect the structure against earthquakes. Identification of the requested DCS characteristics and the structural typologies for which the system is applicable. Design of the DCS components, and supply of DCS prototypes. Study of architectural issues related to the installation of DCS. Experimental analysis of the DCS prototypes and of full-scale structures equipped with them. Evaluation of the technical and economical benefits of the use of such devices. Design guidelines for the implementation of the semi-active and passive control technologies.

The industrial results of this project – prototype innovative devices – for earthquake protection of structures at low costs, will contribute to the increase of European retrofitting market world-wide. In collaboration with construction companies, effective and economic solutions for the retrofitting of schools and hospitals will be proposed.

PROJECT CO-ORDINATOR

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VAST-IMAGE - Development of Variable Stiffness Seismic Isolators and Vibration Mitigation Dampers Based on Magnetically Controlled Elastomers
EVG1-CT-2002-00063

Instrument:	FP5 – Research Project	Ending date:	28/02/2006
EC contribution:	1,307,119.00 €	Duration:	42 months
Organisation:	Université Pierre & Marie Curie		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The general objectives of this Project comprise primarily the mitigation of the undesired effects induced in different types of structures by earthquakes, windstorm and, secondarily, the mitigation ground-borne vibrations, namely:

- To overcome the poor performance of passive seismic isolators to earthquakes smaller than the design level;
- To increase performance of anti-seismic visco-elastic dampers by making them semi-active devices;
- To reduce strongly the transmission of ground-borne vibration into either civil and industrial structures.

These general objectives would be met by the development of an improved “smart” elastomer whose variable stiffness is controlled by means of a magnetic field, semi-active seismic isolators and semi-active dampers. Both types of device will utilise the developed Magnetically Controlled Elastomer (MCE) and thus be characterised by the capability of varying their stiffness. In particular, the seismic devices will improve the isolation efficiency at below design level earthquakes by reducing the small displacement stiffening seen in conventional high damping elastomeric isolators. Thus structures benefiting from use of the devices are those, such as hospitals and emergency centres, for which protection of sensitive contents is important.

Scientific achievements

In the first two years the Project has suffered significant delay due to the failure to perfect the “smart” elastomer. Fortunately thanks to responsibility, sense of co-operation and prompt response of the Partners in the third contractual period important scientific and technological objectives have been achieved and the work was successfully completed: a smart MCE material was successfully developed and MCE isolators were manufactured and the semi-active vibration dampers based on MCE material were further improved.

Scientific achievements that took place during the course of the last contractual period undoubtedly permitted to secure objectives with a greater degree of completeness. The experimental tests and the numerical studies showed that the new devices are effective and improve the seismic isolation efficiency if compared with other conventional devices.

Socio-economic relevance and policy implications

This Project addresses the solution of socio-economic problems connected with seismic risk and thus intends to safeguard life and limb, health, property and public welfare and thus respond to several social needs, such as assuring safety by improving the reliability of structures and safeguarding employment in seismic areas, maintaining in operation energy production plants during the emergency phase following an earthquake, minimising the risk of major economic dislocation etc. The studies with numerical models show that the semi-active variable stiffness isolators are particularly suitable to seismic retrofit projects since they permit upgrading a structure without requiring any preventive structural strengthening.

The successful development of competitive devices substantially increases the productivity of manufacturers as well as boost their exports of both devices and sensible equipment. The adoption of innovative devices significantly reduces the effects of seismic actions on buildings and other structures. It will lead to simpler design concepts for them as well as savings in building materials. Also, the adoption of these new systems and techniques will yield lower construction costs, considerably conserve energy and contribute to greater safety in buildings and structures, that can retain full functionality / operability during and after earthquakes.

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SAFER – Seismic Early Warning for Europe CT – 036935

Instrument:	FP6 – Research Project	Starting date:	15/06/2006
EC contribution:	3,600,000.00	Duration:	30 months
Organisation:	Geoforschungszentrum Potsdam		
Co-ordinator:	Prof. Jochen Zschau (zschau@gfz-potsdam.de)		
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PROJECT SUMMARY

Earthquakes are a serious threat for many countries of Europe, particularly for those around the Mediterranean Sea. Early warning systems, based on real time, automated analysis of ground motion measurements, can play an important role in reducing the negative impact of catastrophic events on densely populated areas and, particularly, in mitigating the damage to strategic structures and lifelines. Europe is covered by numerous high quality seismic networks, managed by national and by European agencies, including also some local networks specifically designed for seismic early warning around large cities like Bucharest, Istanbul and Naples, respectively.

This project is aimed at fully exploiting the possibilities offered by a real time analysis of the signals coming from seismic networks for a wide range of actions, performed in a time interval of a few seconds to some tens of minutes. These actions range from the shut down of critical systems of lifelines, industries, highways, railways, etc. and the activation of control systems for the protection of crucial structures, to decision support for rapid response of the emergency management (ground shaking, maps, continuously expected damage scenarios, aftershocks hazard etc.).

The general objective of the proposed work is to develop tools that can be used by the disaster management for effective earthquake early warning in Europe and, particularly, in Europe's densely populated cities. The tools are expected to be user-friendly, have the maximum possible portability, and be in accordance with the present state of research. In particular, they will be:

- a) Development of improved algorithms for fast determination of earthquake source parameters (real time event detection and – location, real-time fault mapping as well as new approaches for fast magnitude/moment determinations based on strong motion data, modern seismic array technology or the concept of energy magnitude).
- b) Further elaboration of new concepts, including the virtual seismologist, for providing in an evolutionary process real-time alert maps and predicted shake maps within seconds and minutes as well as measured shake maps within a few minutes.
- c) Development of fast algorithms for damage scenario simulations and improvement of the existing methods for real-time simulation and prediction of earthquake triggered secondary landslides and related losses.
- d) Deployment of real-time structural control mechanisms for immediate protection of endangered structures and devices.
- e) Improvement of the reliability of assessments of the aftershock hazard in real-time.
- f) Applications to selected test cities (Istanbul, Bucharest, Athens, Napoli, Cairo).

To reach these objectives we have developed a strategic approach addressing all major components of the earthquake early warning chain. It starts with real-time hazard assessment (WP2, WP4) immediately from the first detection of a strong earthquake, includes the components of vulnerability assessment (WP3), real-time risk assessment (WP3) and real-time risk reduction (WP3) within a few seconds before the first damage may occur, and also deals with the new aspect of real-time aftershock hazard assessment (WP5). Strengthening the interface of these scientific-technological components with the decision-making and response component (WP6) is especially emphasized.

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**SEHELLARC – Seismic and Tsunami Risk Assessment and Mitigation Scenarios in
the Western Hellenic ARC**
CT – 037004

Instrument:	FP6 – Research Project	Starting date:	01/06/2006
EC contribution:	1.295.911,00 €	Duration:	36 months
Organisation:	Hellenic Centre for Marine Research		
Co-ordinator:	Dr Joanna Papoulia		
EC officer:	Denis Peter (denis.peter@ec.europa.eu) Bjorn Vangelsten (bjorn-vidar.vangelsten@ec.europa.eu)		

PROJECT SUMMARY

The western part of the Hellenic Arc between Pirgos and Pylos, western Peloponnese, has been repeatedly affected by large magnitude earthquakes that caused severe destruction and human loss. Some of the largest regional tsunamis in the Mediterranean Sea have been reported in association with large earthquakes affecting remote coastal areas, whereas many other earthquakes have caused local but strong tsunami waves. We will consider on and offshore seismic observations and integrate offshore real time data transmission to the permanent seismograph network of Greece. Such technology is still missing in Greece or elsewhere in the Mediterranean countries. By observing seismicity in real-time, early warning scenarios will be considered and their possible application will be proposed to local authorities. As a final step we will propose a pilot study for the city of Pylos and create a GIS data base for seismic and tsunami risk and mitigation scenarios.

The main objectives of the research are:

- To establish a realtime onshore/offshore network for seismic and tsunami observations.
- To develop an innovative methodology and tools by the simultaneous observation and evaluation of onshore and offshore data for seismic and tsunami safety;
- protection of coastal areas;
- To improve the technology and capabilities of the involved public and private organizations in the field of seismic and tsunami risk assessment, increasing their competitiveness to international levels;
- To investigate possible early warning scenarios that may find application in sensitive areas of western Peloponnese.

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TSUNAMI

NEAREST – Integrated Observations from Near Shore Sources of Tsunamis: toward an Early Warning System

CT – 037110

<http://nearest.bo.ismar.cnr.it/>

Instrument: FP6 – Research Project
EC contribution: 2,850,000.00
Organisation: Consiglio Nazionale delle Ricerche
Co-ordinator: Dr Nevio Zitellini (nevio.zitellini@bo.ismar.cnr.it)
EC officer: Denis Peter (denis.peter@ec.europa.eu)

Starting date: 01/10/2006
Duration: 36 months

PROJECT SUMMARY

NEAREST is addressed to the identification and characterisation of large potential tsunami sources located near shore in the Gulf of Cadiz; the improvement of near real-time detection of signals by a multiparameter seafloor observatory for the characterisation of potential tsunamigenic sources to be used in the development of an Early Warning System (EWS) Prototype; the improvement of integrated numerical models enabling more accurate scenarios of tsunami impact and the production of accurate inundation maps in selected areas of the Algarve (SW Portugal), highly hit by the 1755 tsunamis. In this area, highly populated and prone to devastating earthquakes and tsunamis, excellent geological/geophysical knowledge has already been acquired in the last decade.

The methodological approach will be based on the cross-checking of multiparameter time series acquired on land by seismic and tide gauge stations, on the seafloor and in the water column by broad band Ocean Bottom Seismometers and a multiparameter deep-sea platform this latter equipped with real-time communication to an onshore warning centre. Land and sea data will be integrated to be used in a prototype of EWS.

NEAREST will search for sedimentological evidence of tsunamis records to improve the knowledge on the recurrence time for extreme events and will try to measure the key parameters for the comprehension of the tsunami generation mechanisms.

The proposed method can be extended to other near-shore potential tsunamigenic sources, as for instance the Central Mediterranean (Western Ionian Sea), Aegean Arc and Marmara Sea.

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TRANSFER – Tsunami Risk and Strategies for the European Region

CT – 037058

Instrument:	FP6 – Research Project	Starting date:	01/09/2006
EC contribution:	3,300,000.00	Duration:	30 months
Organisation:	Università di Bologna		
Co-ordinator:	Prof. Stefano Tinti		
EC officer:	Denis Peter (denis.peter@ec.europa.eu)		

PROJECT SUMMARY

The project main goal is to contribute to our understanding of tsunami processes in the Euro-Mediterranean region, to the tsunami hazard, vulnerability and risk assessment and to identifying the best strategies for reduction of tsunami risk. Focus will be posed on the gaps and needs for the implementation of an efficient tsunami early warning system (TEWS) in the Euro-Mediterranean area, which is a high-priority task in consideration that no tsunami early warning system is today in place in the Euro-Mediterranean countries. Therefore, the three pillars on which the project has posed its foundation are:

- 1) Scientific progress for Europe,
- 2) Techniques to evaluate risk and strategies for its reduction,
- 3) Transferring experience and methods into political, societal and cultural practices.

The main items addressed by the project may be summarised as follows: the present Europe tsunami catalogue will be improved and updated, and integrated into a world-wide catalogue (WP1). A systematic attempt will be made to identify and to characterise the tsunamigenic seismic (WP2° and non-seismic (WP3) sources throughout the Euro-Mediterranean region. An analysis of the present-day earth observing and monitoring (seismic, geodetic and marine) systems and data processing methods will be carried out in order to identify possible adjustments required for the development of a TEWS, with focus on new algorithms suited for real-time detection of tsunami sources and tsunamis (WP 4). The numerical models currently used for tsunami simulations will be improved mainly to better handle the generation process and the tsunami impact at the coast (WP5). The project Consortium has selected seven test areas in different countries. Here innovative probabilistic and statistical approaches for tsunami hazard assessment (WP6), up-to-date and new methods to compute inundation maps (WP7) will be applied. Here tsunami scenario approaches will be envisaged; vulnerability and risk will be assessed; prevention and mitigation measures will be defined also by the advice of end users that are organised in an End User Group (WP8). Dissemination of data, techniques and products will be a priority of the project (WP9).

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VOLCANO

DORSIVA – Development of Optical Remote Sensing Instruments for Volcanological Applications

EVG1-CT-2002-00060

<http://www.chalmers.se/ors/dorsiva/>

Instrument:	FP5 – Research Project	Ending date:	30/09/2005
EC contribution:	786,640.00 €	Duration:	36 months
Organisation:	Chalmers University of Technology		
Co-ordinator:	Dr Bo Galle (bo.galle@rss.chalmers.se)		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The objectives of this project were to develop robust and reliable optical remote sensing instruments and measurement strategies for surveillance of volcanic gas emissions, and to test and demonstrate their use in field experiments. A major goal of the project was to provide a monitoring capability for remote and automated measurement of volcanic gas ratios and fluxes with high temporal resolution, (1-5 minutes). This will represent a major advance in the toolkit of volcano observatories.

The main source of error in both mobile and scanning mini-DOAS measurements, as well as COSPEC measurements, is determination of wind-speed at plume height. Thus the project also aimed at developing procedures to obtain wind speed at plume height from meteorological measurements and modeling, as well as from direct spectroscopic measurements.

Scientific achievements and results

With the *mobile mini-DOAS instrument*, a small, cheap compact and accurate tool was introduced that have dramatically changed volcanic gas monitoring. The mobility and flexibility of this instrument as compared to the previously used COSPEC systems have opened up a new world of possibilities to conduct measurements on locations that was previously inaccessible or unaffordable.

The main source of error in flux measurements of volcanic gases are usually the transport speed of the plume and in some applications the plume height. In the project two instrument concepts have been developed that directly measures these parameters using DOAS spectroscopy; the *Dual-Beam mini-DOAS instrument* and the *Static Multispectrometer DOAS system*. An alternative approach to derive the wind speed at plume height is by using a *Meso-scale meteorological model* that takes into account the impact of local topography on the wind fields downwind the volcano.

Although halogens like HCl and HF have previously been measured in volcanic plumes using FTIR spectroscopy, the possibility to measure BrO with DOAS was a major scientific achievement. Both because DOAS thus provide a much simpler platform for multi-species gas monitoring in volcanology, and because of the importance to be able to quantify the volcanic contributions of these gases for global atmospheric chemistry. These measurements were first demonstrated using the sensitive *MAX-DOAS instrument*.

Another major development was to couple the mini-DOAS instrument to a scanning device, the *Scanning mini-DOAS instrument*, providing time resolved measurement of the gas emission. This opened up the possibility to correlate gas emission data with other geophysical data, e.g. seismic signals, and thereby significantly improve the understanding of the ongoing geophysical and geochemical processes.

Although a primary interest in volcanology is the emission rate and composition of the emitted gases, the concentration fields in the atmosphere downwind a volcano may be of great relevance for studies of local impact of gases, validation of dispersion models and studies of relative composition in the plume. Two

different approaches for 2-dimensional mapping of vertical concentration fields have been developed. One concept uses a *Tomographic interpretation* of data from 2 or more *Scanning mini-DOAS instruments*, while the other concept uses a 2-dimensional detector array to achieve the concentration field, the *Imaging DOAS*.

An important problem when using scattered Sunlight to study volcanic gas emissions is multiple scattering of the Solar light. Depending on the conditions this effect may result in serious over- or underestimation of the emissions/concentrations. Two different approaches have been used to deal with this problem: *Radiative transfer modeling*, (*TRACY*), and use of Solar Infrared Spectroscopy, the *Solar Occultation Flux instrument*. The latter instrument has the advantage, in addition to negligible scattering problems, to be able to simultaneously quantify fluxes of SO₂, HCl and HF. However, at a significantly higher cost and complexity as compared to the UV systems.

New estimates of the non-explosive volcanic fluxes and gas composition have been obtained from numerous volcanoes worldwide, during the testing and exploitation of the various prototypes developed.

Socio-economic relevance and policy implications

The development of the different mini-DOAS instrument concepts has already had a major impact on the volcano monitoring community worldwide. With the support of DORSIVA partners, several instruments are now in operation at observatories in Montserrat, Nicaragua, Italy, Mexico, Papua New Guinea, Tenerife, El Salvador and D.R. Congo. These instruments have already significantly improved the monitoring capacity of these observatories, and thus improved their risk assessment capability to the benefit of the people living in the areas close to these volcanoes

In addition, several partners have tested the UV spectrometers for SO₂ and NO₂ emissions from power stations and industry in England, Germany, Mexico, Spain and China. The potential to use also the Solar Occultation technique for quantification of industrial emissions have been demonstrated. It is foreseen that these techniques may be a very important tool in future emission inventories and environmental control.

The new system for meso-scale modelling is comparatively cheap and runs in a stand-alone mode on a PC, a clear advantage for potential users in the future.

The modification of the COSPEC V can be applied to upgrade existing COSPEC instruments presently in use for volcanic gas monitoring worldwide. This will improve the continued use of these instruments for routine monitoring of volcanoes for risk prevention, forecasting, decision-support and disaster preparedness.

A significant part of the work, related to DORSIVA but partly funded by other sources, has been to conduct field campaigns and give support and training to other research groups and volcano observatories. More than 20 volcanoes have been visited and studied using the developed techniques.

An active collaboration, typically involving joint field work, inter-comparisons and training have been accomplished with universities and institutes worldwide. In addition cooperative research has also been undertaken in other disciplines than volcanology, e.g. industrial monitoring and urban air pollution, involving 6 partners from USA, Europe and China.

Several of the achievements from the project, including the Scanning mini-DOAS, measurements of BrO/SO₂ ratios, tomographic mapping, Dual-beam plume speed measurements and meteorological modeling, are condensed into the NOVAC instrument. In the recently started Fp6 project NOVAC, these instruments will be installed on 15 volcanoes worldwide with the purpose to improve local risk assessment, study global volcanic gas emissions and monitor the atmospheric composition.

The project has, with a few exceptions, achieved its goals. We have made a significant improvement in instrumentation and measurement strategies for volcanic gas monitoring. It is without doubt that Europe presently leads the international field in ground-based remote geochemical monitoring of volcanoes.

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ERUPT - Processes and Timescales of Magma Evolution in Volcanic Systems

EVG1-CT-2002-00058

<http://dur.ac.uk/erupt.geolsci/>

Instrument:	FP5 – Research Project	Ending date:	31/12/2005
EC contribution:	1,302,124.00 €	Duration:	36 months
Organisation:	University of Durham		
Co-ordinator:	Prof. Jon Davidson (j.p.davidson@durham.ac.uk)		
EC officer:	Denis Peter		

PROJECT SUMMARY

Objectives

Important questions concerning eruptions – how big? What type (how violent or explosive)? How frequent? Can be addressed by examining the record contained within rocks erupted from a volcano, or frozen beneath it. The underlying principle of the work embodied in ERUPT is to determine the conditions and timescales of magma storage in volcanic systems. The approach uses novel technological advances that allow us to undertake geochemical analyses at the scale of the components that constitute a volcanic rock. A key set of clues comes from the study of cores and rims on crystals which have grown from the magmas and can consequently be read like tree rings.

These data are integrated with experimental data, textural data and field constraints and enable us to estimate the rate at which magma differentiates the conditions (pressure, temperature, volatile content) of magma storage and the architecture, in terms of relative volumes, of the magma storage system.

Within Europe there are several active volcanic systems which pose a significant hazard to human life, property and economic success. The volcanoes of Vesuvius and Campi Flegrei near Naples in particular represent a significant threat to the welfare of over half a million people. Beyond immediate risk, environmental degradation over both long and short term follows the deposition of volcanic materials over the land surface and the injection of gases into the atmosphere. Our current ability to forecast the timing, sizes and effects of volcanic eruptions is very poor. ERUPT aims to improve this significantly.

Our objective in **ERUPT** is to work at a European level to provide new methodologies to relate the characteristics of volcanic rocks to the conditions leading to their eruption.

Scientific achievements and results

We have discovered that chemical profiles across crystals can be converted into timescales which appear to be related to geophysical phenomena presaging eruption (Morgan et al. in press). The team working on Vesuvius dated a magmatic event which appears to correspond to the occurrence of an earthquake 17 years before the volcano famously erupted in AD79. The importance of this is that for the first time volcanologists can set a timescale on the impact of geophysical activity on magma systems and interpret the link to volcanic eruptions or hazards. These factors all affect the potential “risk” associated with a given eruption.

Socio-economic relevance and policy implications:

In line with one of the main goals of ERUPT, we have disseminated our results and findings explicitly to communities/ authorities that potentially might be affected by volcanic hazards via a major workshop held in Naples/Stromboli during September 2005. The workshop was organised to interface directly with public and civil authorities so that they can be made aware of our findings and use them accordingly in practical hazard mitigation planning. The coordination of this workshop was one of the major achievements in the final year of the project, and the attached package is submitted as supporting evidence for this important activity. A press

release following the meeting resulted in a number of newspaper articles and radio interviews describing the work of ERUPT.

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E-RUPTIONS – A Satellite Telecommunication and Internet-Based Seismic Monitoring System for Volcanic Eruption Forecasting and Risk Management

EVR1-CT-2001-40021

<http://www.e-ruption.info/>

Instrument:	FP5 – Infrastructure	Ending date:	31/03/2005
EC contribution:	1,993,995.00 €	Duration:	36 months
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PROJECT SUMMARY

The EU, through the issue of *Council Decisions 98/22/EC* and *1999/847/EC*, has set forth its aims in the field of civil protection. These aims relate to the detection and study of the causes of natural or technological disasters; to the protection of the environment, people and property in the event such disasters; and to improve the preparedness and response of those involved in civil protection in Member States, by the developing and adapting of new technologies to meet requirements of civil protection and support co-operation between Member States. The improvement in volcanic disaster forecasting, planning, management and response to reduce risks to the environment and local population in volcanic regions addresses these aims.

Although there is empirical evidence to suggest that there is a relationship between the type of earthquake and volcanic activity, there is insufficient understanding and reliable data to be able to determine the precise nature of the relationship. Seismic and other information pertinent to the understanding of volcanic eruptions is not generally collected, nor commonly made available outside the local monitoring area. There is a need, therefore, to establish a quantitative relationship between the dynamic behaviour of magmatic and hydro-geothermal systems and the nature and occurrence of the related seismicity, not only to improve the accuracy of predicting volcanic eruptions, but also to be able to provide information on their potential in a timely and reliable manner.

Because most active volcanoes are situated in remote or difficult to access parts of the world, facilities are rarely available to assess the likelihood of a volcanic eruption and provide advanced warning to the local population. The establishment of a seismo-volcanic monitoring system linking volcanic sites to fully equipped and staffed volcanic observatories in real-time would be able to provide the necessary early warning of an ending eruption.

The principle objective of *e-Ruption* is to design and develop a prototype Internet and telecommunication-based seismic monitoring and early warning system for improved prediction of volcanic eruptions. *e-Ruption* will investigate the type and nature of volcanic seismicity that are precursors to an impending eruption and will assess their significance in terms of eruption potential through theoretical and applied seismo-volcanological research and the use of advanced information and communication technology. *E-ruption* is foreseen as a potential major contributor to the decision-making process of environmental and civil protection agencies. *E-Ruption* will allow rapid collecting, processing, analysing and distributing of relevant data and information in an up-to-date and timely manner on the threat and risk associated with volcanic events to the environment and society and to help them better assess the different protection schemes and options for reducing risks.

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EXPLORIS – Explosive Eruption Risk and Decision Support for EU Populations Threatened by Volcanoes

EVR1-CT-2002-40026

http://exploris.pi.ingv.it/non_conf/description/index.html

Instrument:	FP5 – Infrastructure	Ending date:	31/05/2005
EC contribution:	1,976,358.00 €	Duration:	42 months
Organisation:	Consiglio Nazionale delle Ricerche		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

In recent decades the population worldwide has become concentrated in large conurbations and volcanic islands at high risk from volcanic disasters. The most serious hazards are related to eruptive phenomena that characterize explosive volcanoes, such as the dispersal of ash and lapilli over wide regions all around the volcanic center and the occurrence of pyroclastic flows travelling at high speed and temperature along the volcano flanks. Within the European Union there are several examples of these volcanoes whose eruptions could have major socio-economic implications across the EU, as well as for individual countries.

The EU EXPLORIS project (“*Explosive Eruption Risk and Decision Support for EU Populations Threatened by Volcanoes*”), funded under the Fifth Framework, Energy, Environment and Sustainable Development Programme, is one of the first systematic attempts to quantify the explosive risk at four European volcanoes. These are Vesuvius (Italy), La Soufrière, Guadeloupe (France), Sete Cidades, Azores (Portugal), and Teide, Canary Islands (Spain). Risk is the probability of a specified loss and can be mathematically expressed as $\text{risk} = \text{hazard} \times \text{vulnerability} \times \text{value}$. Hazard is the probability of an eruption within a given period of time, vulnerability is the proportion of the value likely to be lost in the event, and value is the number of lives, properties or productive capacity at risk. But despite its potential, this approach has rarely been applied in the assessment of volcanic risk in populated European regions. As a result, national disaster planning for volcanic eruptions has not included quantitative estimates of the anticipated impact and risk, or the likely effect of new mitigation measures that can be adopted.

Objectives

The main objective of the EXPLORIS project is the quantitative analysis of explosive eruption risk through the development of volcanic risk tools - such as 3D supercomputer simulation codes, vulnerability functions, and probabilistic risk assessment protocols. In more detail, the specific objectives of the project are: 1) define quantitative volcanological scenarios for the most dangerous European volcanoes, 2) develop parallel 3D supercomputer models for the simulation of fallout dispersal and pyroclastic flows, 3) develop vulnerability relationships for buildings, infrastructures and inhabitants, 4) quantify the potential impact of the eruptive phenomena, 5) develop and apply probabilistic risk assessment protocols, 6) suggest potential mitigation measures, and 7) transfer the project findings to civil authorities in order to provide policy-relevant information. Most importantly, the approach adopted aims at combining knowledge deriving from different fields in order to provide a strategic multidisciplinary set of expertises. Competence in geology, physics, applied mathematics, computer science, engineering, architecture, medicine, and risk analysis are all part of the project.

Scientific achievements and results

EXPLORIS has now reached its end and results were presented during an international workshop organized in Naples on May 10-13, 2006. The workshop was attended by civil protection authorities of four European countries and by several International experts in volcanic hazard and risk. Major progress was achieved in

the reconstruction of the eruptive records and definition of scenarios at the four project volcanoes based on new field and historical investigations. In terms of volcano dynamics, a better understanding of the eruptive phenomena was reached due to the development and application of new transient 3D codes for the simulation of ash fallout and pyroclastic flow propagation. As regards vulnerability, a complete set of vulnerability relationships and databases related to the variety of volcanic actions, including combination of effects, were, for the first time, defined and combined with hazard and exposure information. A remarkable outcome of the project was also the definition of probabilistic Event Trees for all project volcanoes, as well as the formulation of probabilistic hazard-vulnerability-casualty risk protocols. Finally, the advanced visualization tools developed, able to combine simulation outputs with territorial and geographic data, appeared particularly effective in educating public officials and the general public about hazards and their impact on society.

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MULTIMO – Multi-Disciplinary Monitoring, Modelling and Forecasting of Volcanic Hazard

EVG1-CT-2000-00021

<http://earth.leeds.ac.uk/Multimo/>

Instrument:	FP5 – Research Project	Ending date:	31/01/2004
EC contribution:	1,200,000 €	Duration:	36 months
Organisation:	University of Leeds		
Co-ordinator:	Prof Jürgen W Neuberg (J.Neuberg@see.leeds.ac.uk)		
EC officer:	Denis Peter		

PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

- Design improved multi-parameter volcano monitoring techniques,
- Obtain a better understanding of volcanic processes by integrating these multi-parameter data sets within modelling procedures,
- Employ the resulting new insights in risk forecasting and hazard mitigation.

More in particular:

- Development of a modern multi-sensor monitoring system and multi-parameter interpretation strategies.
- Quantitative evaluation of magma properties and their connection to magma storage and flow processes.
- Develop an understanding how to link internal and external magmatic processes quantitatively to observable signals.
- Evaluation of patterns of volcanic activity, identification of key parameters or sets of parameters which can be used for forecasting by using deterministic and stochastic statistical tools.
- Dissemination strategies of expert opinion and development of public relations.

Scientific achievements and results

In MULTIMO we measured key properties of magma that control eruption dynamics, developed advanced models of magma flow from magma reservoirs to the surface and linked these models to the major observables of earthquakes, ground deformation, gas fluxes and extrusion rates, as well as different eruptive styles. Multi-parametric data were acquired in the field, and archived and accessed using a flexible web application server. Geostatistical methods were then applied to analyse time series of integrated data, and compared to predictions of dynamical models to improve the reliability of forecasts. A good overview of the scientific results can be found in a special issue of the Elsevier Journal of Volcanology and Geothermal Research: Volume 153, Issues 1-2, Pages 1-166 (1 May 2006): "MULTIMO: Multi-Parameter Monitoring, Modelling and Forecasting of Volcanic Hazard - Results from a European Project", edited by J. Neuberg, R. Carniel and O. Navon. The papers published in the special issue span many of the achievements of MULTIMO, including the remote access to multiparametric data, the automatic classification of seismic events, the automatic evaluation of a volcano unrest, the characterization of variable regimes during a volcanic eruption, the issue of forecasting and its relationship to modelling, the modelling of several of the stages of a volcanic eruption, such as the attenuation in gas-charged magma, the trigger of low-frequency earthquakes, the fragmentation of explosive volcanic eruptions, the temperature dependence of seismic wave velocities, the conduit flow dynamics. The Special issue is obviously also an excellent starting point to explore the vast literature output generated by the MULTIMO project during the previous years.

Socio-economic relevance and policy implications

The many significant scientific advances made by MULTIMO are not considered in scientific isolation, however. The new insights provided by the different approaches offer the opportunity for improving volcanic eruption forecasting and therefore enhancing the contribution of science to society and social objectives. Thus, an important part of the project is the development of a framework for integrating a multidisciplinary approach to monitoring, modelling and analysis of volcanic activity to improve forecasting and decision support for civil protection. Many threads of evidence need to be incorporated: direct empirical observations of a variety of variables on a variety of timescales, interpretations of different modelling techniques for various aspects of the problem, a range of data analysis techniques, as well as immediate contributions of expert judgment in urgent situations. Given the inevitable presence of scientific uncertainty in all forms of data and evidence, the totality of the various indicators can be treated only probabilistically for forecasting purposes. The Bayesian Belief Network (BBN) is a formalism which can accommodate multiple threads of evidence and weight them according to their relative likelihoods of occurrence, and MULTIMO is innovating its application to volcanic forecasting with multi-parametric representations of activity. The challenge for MULTIMO has been to configure a practical BBN scheme that can combine scientific evidence derived from many sources, on many timescales and with different sampling and repetition rates, in order to provide an optimised decision support procedure that focuses on the timescales which are typically of most concern for administrative decision-making and effective civil protection. In addition to conventional analysis of the temporal behaviour of hard observational data in a statistical sense, MULTIMO has developed the concept of representing the eruptive potential of a volcano as a progressive process 'state' in a hidden model in continuous time, for which indirect observational markers may be available only irregularly or intermittently. Within a model of this kind, observed data are governed by probability distributions conditional on the true but unobservable state. The BBN approach offers a straightforward but systematic and structured way to accommodate all sources of multiple uncertainty, providing a robust pathway for parsing complex, and sometimes contradictory, scientific information into vernacular risk decision formats, such as simplified Alert Level schemes. A lot of effort was put in order to disseminate the whole range of work undertaken in MULTIMO, from novel magma science through to innovative science-informed decision-making procedures, directly to observatory teams and to the wider volcanological community through IAVCEI-related initiatives, dedicated workshops and conferences, apart from the special issue cited above.

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VOLCALERT - Innovative Techniques for Forecasting Volcanic Eruptions

EVG1-CT-2001-00047

<http://benfieldhrc.com/VolcAlert/Website/Root/home.htm>

Instrument:	FP5 – Research Project	Ending date:	31/01/2004
EC contribution:	647,884.00 €	Duration:	26 months
Organisation:	University College London		
Co-ordinator:	Dr Christopher Kilburn (c.kilburn@ucl.ac.uk)		
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PROJECT SUMMARY – SCIENTIFIC ACHIEVEMENTS

Objectives

The aims of Project VOLCALERT were to investigate the evolution of short-term precursors before a volcanic eruption in order (1) to develop objective, quantitative methods for issuing eruption forecasts and (2) to identify the most efficient means for communicating the forecasts to non-specialist decision makers, such that emergency procedures can be implemented effectively

Scientific achievements and results

Project Volcalert has focused on precursors before first-time eruptions after repose intervals from ~years to centuries. These are the eruptions responsible for the greatest threat to populations; indeed, when repose intervals exceed a human generation or more, populations tend to forget the potential threat from a volcano and so are ill-prepared to respond to a new volcanic crisis. First-time events are also likely to be subject to similar pre-eruption conditions and so may show repeatable precursory behaviour that can be interpreted in terms of a single physical model.

Accelerating seismicity before eruptions: the role of crustal failure at constant stress

Precursors to long-dormant volcanoes can be accounted for by the growth and interaction, under constant applied stress, of a population of fractures between a static magma body and the surface. Initially the rate of fracturing increases exponentially with time, but about 10 days before eruption it changes to a hyperbolic increase with time, the transition occurring when the growing fractures reach a state of close packing in the crust.

In comparison to eruptions after long repose intervals, those at frequently-active volcanoes show a greater variation in precursory increases. Individual sequences may show pronounced increases in seismicity from hours to days before eruption. When the sequences are superimposed, however, they show a more regular accelerating trend that begins about 10 days before eruption. Apparently, the crust attempts to relieve applied stresses in a regular manner, but is normally prevented by random stress fluctuations among clusters of fractures. The similarity between the 'stacked' timescale and the timescale for hyperbolic accelerations at long-dormant volcanoes suggests that both require crustal fractures to have achieved a close-packing condition. Possibly, therefore, the more regular patterns at long-dormant volcanoes represent an end member to a spectrum of conditions, a greater part of which is encountered at frequently-active volcanoes. Seismic accelerations without eruptions also show similar patterns to pre-eruptive accelerations. The non-eruptive episodes may reflect the formation of a fault that does not intersect a magma body, or magma intrusion, rather than extrusion. In either case, such ambiguity increases the potential for false alarms at frequently-active volcanoes.

Accelerating seismicity: the role of magma ascent

A new boundary-element code has been developed to simulate the deformation of crust containing aligned and randomly-oriented fractures of equal or variable length. The model has been tested against field data from Isu, Japan, and Long Valley, California. The results provide quantitative constraints for distinguishing

seismic increases due to dyke ascent from those due to the widening of a stable intrusion, and also constrain conditions for the stability of sills.

The effect of crustal heterogeneity on dyke movement has also been simulated in the laboratory with a series of analogue experiments using air injected into layered gelatine. Scaling the laboratory results to field conditions suggests that changes in velocity by up to an order of magnitude might be feasible beneath volcanoes, especially as dykes approach weaker surface horizons. The results provide constraints on the combination of magma input rate and strength of overlying crust that determine whether a dyke will remain stable, extend as a sill without eruption or, after a period of sill development, will again become unstable and reach the surface.

Accelerating seismicity: controls at volcanoes in repose

Boundary-element and finite-element models have been developed to evaluate the stress fields of surface topography, crustal heterogeneity, and coupled mechanical and thermal fluid-dynamical processes for describing changes in fluid pressure. Applied to calderas, the models demonstrate that: (1) ground deformation is concentrated within the caldera by the presence of ring faults; (2) time-dependent uplift is controlled by the influx of magma to shallow level, coupled with an increase in aquifer pressure due to the expansion of water pushed beyond its critical state; and (3) Coulomb stresses are able to induce normal faulting in elastic rock adjacent to reverse ring faults that deform aseismically. The analyses also suggest that background seismicity at volcanoes in repose may be punctuated by intense seismic swarms triggered by explosive impulses, possibly due to vesicle exsolution during magma crystallisation, or to heating of deep aquifers. Such swarms can generate concern about an imminent eruption, so that understanding their genesis is important for reducing the frequency of false alarms.

Perception of volcanic risk

Fifty representatives were interviewed from Vesuvius and Naples, including monitoring scientists, regional directors of the Civil Protection and mayors from 12 of the 18 communes around the volcano. A recurring issue to emerge among non-scientists is that, although they are aware of some of the problems of volcanic emergencies, they believe that they have *fully* understood all the problems. Indeed, several of the authorities interviewed have sufficient knowledge of specialised vocabulary to give the impression of a good understanding of volcanic behaviour. As a result, scientific communiqués are released *assuming* that the authorities appreciate their significance. Much of the authorities' knowledge, however, appears in fact to be restricted to repetition of the current emergency plan. In a real emergency, it is almost certain that some decisions will have to be made on the initiative of local authorities in the field: there will not always be sufficient time for warnings and orders to be issued from a control centre. Given that few of the authorities have experienced volcanic eruptions, it is clear that, until levels of awareness are raised sufficiently, the scientific community should release technical information together with guidelines on the implications of that information for emergency procedures.

Additional questionnaires (available in English, French, Italian and Spanish) were distributed among workers on Mt Etna, Piton de la Fournaise and Tenerife. Although the data base for each volcano was smaller than that for Vesuvius, the results are broadly similar to those reported above. Project results are available at the new address: <http://benfieldhrc.com/VolcAlert/Website/Root/home.htm>

Socio-economic relevance and policy implications

Europe and its dependent territories include some of the most volcanically active regions on Earth. They host about six percent of the 600 volcanoes known to have erupted in historical time and, of those in Europe, two or three are normally in eruption each year. Some 4-5 million people live within sight of an active European volcano, while at least one-tenth of the EU population is economically vulnerable to an eruption. Improved methods for reducing volcanic risk are thus important for enhancing the quality of life both of European citizens and of vulnerable populations worldwide.

Project VOLCALERT has demonstrated that a key control on short-term precursors of volcanic eruptions is the behaviour of interacting crustal fractures, whether they are growing under stress from a static magma, an ascending dyke, a heated aquifer or even a non-magmatic source, such as regional tectonism or large-scale gravitational sliding. New models of fracture interaction provide the basis for recognising distinct regimes of crustal failure, each of which is associated with its own level of variability about a preferred trend. As a result, it is possible to devise a number of simplified scenarios to help non-scientific decision makers understand the uncertainties in forecasting eruptions, and how these uncertainties may change according to the nature of the volcano involved. It is essential that these scenarios are disseminated as soon as possible. One very reliable forecast is that Europe will face a major volcanic emergency within a decade or so. To mitigate the

impact of that emergency, plans for raising general awareness among decision makers should be implemented today.

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NOVAC – Network for Observation of Volcanic and Atmospheric Change

GOCE-2004-018354

<http://www.novac-project.eu>

Instrument:	FP6 – Research Project	Starting date:	01/10/2005
EC contribution:	2,644,355.00 €	Duration:	48 months
Organisation:	Chalmers University of Technology		
Co-ordinator:	Dr Bo Galle (bo.galle@rss.chalmers.se)		
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PROJECT SUMMARY

The idea of the NOVAC project is to establish a global network of stations for the quantitative measurement of volcanic gas emissions by UV absorption spectroscopy making use of a novel type of instrument, the Scanning Dual-beam miniature – Differential Optical Absorption Spectrometer (Mini-DOAS) developed within the EU-project DORSIVA. Primarily the instruments will be used to provide new parameters in the toolbox of the observatories for risk assessment, gas emission estimates and geophysical research on the local scale. In addition to this, data are exploited for other scientific purposes than local volcanic gas emissions, e.g. global estimates of volcanic gas emissions, large scale volcanic correlations, studies of climate change, studies of stratospheric ozone depletion. In particular large scale validation of satellite instruments for observing volcanic gas emissions will be possible for the first time, allowing to bring observation of volcanic gas emissions from space a significant step forward.

The Scanning Dual-beam Mini-DOAS instrument represents a major breakthrough in volcanic gas monitoring, it is capable of real-time automatic, unattended measurement of the total emission fluxes of SO₂ and BrO from a volcano with better than 5 minutes time resolution during daylight. The high time-resolution of the data enables correlations with other geophysical data, e.g. seismic data, thus significantly extending the information available for real-time risk assessment and research at the volcano. By comparing high time resolution gas emission data with emissions from neighbouring volcanoes on different geographical scales, or with other geophysical events (earthquakes, tidal waves) mechanisms of volcanic forcing may be revealed.

The spectra recorded by the instrument will also be used to derive data that complement global observation systems related to climate change and stratospheric ozone depletion research. These data are particularly valuable due to the fact that many volcanoes are located in remote areas sparsely covered by existing networks.

The consortium encompasses observatories of 15 volcanoes from five continents, including some of the most active and strongest degassing volcanoes in the world. New partners are welcome to join on their own funding.

The *societal need* to conduct this project emanates from the fact that an estimated 500 million people live under the direct threat of volcanoes. Volcanoes also constitute a major source of certain gas input to the troposphere and stratosphere (HCl, SO₂, BrO, HF), which cause impact on both the local and global level. The state-of-the-art instrumentation planned to be used in this project will improve the possibility to predict eruptions but will also improve our understanding of the global gas emissions coming from volcanoes.

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VOLUME – Volcanoes: Understanding Subsurface Mass Movement

GOCE-CT-2004-018471

<http://volume-project.net>

Instrument: FP6 – Research project
EC contribution: 3,102,625.00 €
Organisation: University College Dublin
Co-ordinator: Dr Christopher Bean (chris.bean@ucd.ie)
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Starting date: 01/10/2005
Duration: 36 months

PROJECT SUMMARY

Volcanic eruptions are preceded by mass migration through a subsurface fracture network. A primary goal in monitoring active volcanoes is to capture, from the surface, measurements of sub surface mass movement. Such movements of multiphase fluids are generally detected at the surface in terms of changes in geophysical (ground deformation, seismicity) and geochemical observables.

Such variations are therefore viewed with considerable interest in terms of early recognition of precursors to an eruption. However, changes in the seismicity, ground deformation and/or geochemical tracers are not always related to the dynamics of magma bodies alone and therefore do not necessarily indicate an eruption onset. Modern volcanology, even with abundant monitoring data, still does not identify diagnostic, unambiguous precursors to an eruption.

The dynamics of volcanoes result in fact from the complex interplay between tectonic forces on regional scales, gravity forces on local scales and forces related to the activity of hydrothermal and magmatic systems. Understanding the relationships between these processes is therefore one of the major goals to be attained toward a quantitative assessment of precursors to volcanic eruptions.

The rationale behind this VOLUME project is to increase our understanding of how subsurface mass movement manifests itself at the surface, in turn revealing the significance of such movements as precursors to impending eruptions.

In this project, we employ and integrate seismic, gravimetric, geochemical, terrestrial and space based deformation data. We undertake joint inversions of these datasets through iterative numerical forward modelling of coupled processes (eg: multi-phase fluid pulses with elastic wave radiation in solids; gas and temperature with ground deformation and seismicity...).

We will utilise existing data from permanent installations for a suite of test sites comprising different volcano types at differing times in their activity.

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