February 2012

NAVARINO
ENVIRONMENTAL
OBSERVATORY

ANNUAL REPORT

2011

Stockholm University
www.su.se

ACADEMY OF ATHENS
BRFAA
www.bioacademy.gr

TEMES
DEVELOPERS
OF COSTA NAVARINO
www.costanavarino.com

Introduction

Navarino Environmental Observatory (NEO), a cooperation between Stockholm University, the Academy of Athens and TEMES S.A., is dedicated to research and education on the climate and environment of the Mediterranean region. Located at Costa Navarino, Messinia, Greece, NEO develops into a dynamic hub where scientists from all over the world can conduct frontline research, develop new tools and methods, as well as meet to exchange knowledge and ideas.

The Mediterranean area faces considerable environmental and climate challenges in the current and coming decades. In addition to the long-standing problems of marine, atmospheric and terrestrial pollution, the ongoing climate change is predicted to lead to significant changes in this part of the world. Particularly the Ionian and Aegean Seas have been described as the crossroads of transboundary transport of air pollutants and atmospheric aerosols, which play an important role on the radiation balance of the region and therefore influence climate change. The ongoing climate change is predicted to lead to higher summer temperatures and an increase in drought events and in the frequency of occurrence of forest wild fires. All these will significantly affect the society and the tourism industry in particular in the coming decades.

The research taking place at NEO is orientated towards these future challenges. Multi-disciplinary research is conducted and can be grouped under the following research profiles: i) atmospheric composition changes, ii) simulations of air quality and climate change at global and regional scales iii) climate and environmental changes in the context of tourism and urbanism iv) past climate and environmental evolution in Messinia from natural archives, v) coastal geomorphology, geology and landscape change. A wide range of activities is covering the above research topics. In particular atmospheric composition and meteorological parameters are continuously monitored in order to track the origin of particulate and gaseous pollutants and detect climate change signals. Global and regional scale modelling is applied for climate projections and future pollution level simulations. Hydrological research, monitoring and evaluation are undertaken in order to understand past, present and future processes and to develop suitable water resource management strategies for the region. Tectonic, climate, environment and landscape studies are carried out in a long-term perspective, in order to understand the physical science basis of our earth. Specific further goals are to understand the role of natural versus human induced climate/environmental

changes and to analyse the role of physical factors in the context of tourism and urbanism. All monitoring activities are linked to international networks.

In addition to the research taking place at NEO, emphasis is given to the education and training of graduate students and new researchers. For this reason special courses and trips are made in the field, training workshops are organized, and postgraduate and PhD students are already involved in NEO research activities.

Partners

TEMES SA

TEMES S.A. (Tourist Enterprise of Messinia) is a premier developer of luxury mixed-use resorts in the Mediterranean region. Costa Navarino in Messinia is its flagship development. At the heart of the company's business philosophy is its strong commitment to environmental and social responsibility with the aim of achieving sustainable tourism development in complete harmony with the natural environment and traditions of the destination.

More information: www.costanavarino.com

Academy of Athens

The Centre of Environmental Health and Biophysics of the Biomedical Research Foundation of the Academy of Athens has been involved in pioneering research on ozone, chemistry-radiation interactions and global change during the past decades. The Biomedical Research Foundation is a non-profit institution, established by the Academy of Athens, which traces its name to the 3rd century BC Plato's Academy; it therefore brings the heritage of the first Academy on Earth. The Centre has participated in all WMO/UNEP Ozone Assessments and in numerous competitive international research projects and campaigns.

More information: www.academyofathens.gr

Stockholm University with Bert Bolin Centre for Climate research

Stockholm University, located in Sweden's capital city, is a major northern European university and carries out successful research and education within the natural and social sciences, the humanities and law. With over 50,000 undergraduate and master's students,

1,800 doctoral students and 6,000 employees, Stockholm University is one of the largest universities in Sweden and one of the largest employers in the capital.

The Bert Bolin Centre for Climate research at Stockholm University is a pioneering institute within the field of climate and environmental research. The late Bert Bolin, professor at Stockholm University, was the leading force behind the establishment of the UN Intergovernmental Panel on Climate Change (IPCC), which was awarded the Nobel Peace Prize in 2007.

The Bert Bolin Centre for Climate research at Stockholm University carries on Bolin's heritage by conducting fundamental research on critical processes in the climate system. The Centre is developing an extensive research program on natural climate evolution and variability, as well as changes imposed by man's ever-increasing impact on the climate system through emission of greenhouse gases and aerosols, and changes in land-use, vegetation and hydrology.

More information: www.su.se , www.bbcc.su.se

Research Activities 2011

Atmospheric composition and climate changes

Research description

The main objective of the atmospheric and climate research programme of NEO is the study of air quality, radiometric and meteorological parameters in the area of western Peloponnese, and their use as indices of local and transboundary transport of pollutants. The above parameters will be deployed as tracers of changes in atmospheric composition and of climate changes in conjunction with climate modeling. The main motivation has been the particular characteristics of the area as cross roads of pollution, both in the particulate and the gas phase, which set it as an identical natural laboratory for the study of complex transport and chemical processes. The measurements are targeted towards full physical and chemical characterization of particulate matter in the atmosphere, as well as estimation of their optical properties, which is important for the identification and quantification of their climatic role. The objectives are to be fulfilled by:

1. Monitoring of air pollution and greenhouse gases, monitoring of aerosols, near the ground and in vertical profiles, with the use of a LIDAR system, and radiometric measurements of full spectral solar radiation (UV, VIS, IR).

2. Predictions and projections of global and regional scale, using focused climate and transport-chemistry models.

Major research activities 2011

The atmospheric research activities at NEO during the last year have focused on establishing the infrastructure, the Air Quality and Spectroradiometric Stations, building and assembling of the instrumentation, construction and setting up sampling inlets and the preparation and execution of climate model runs.

Researchers involved

(BRFAA Team)

- Christos Zerefos, Professor, Academy of Athens (AA)

- Evangelos Gerasopoulos, Research Director, National Observatory of Athens (NOA)
- Stylianos Kazadzis, Associate Researcher, NOA
- Vassilis Amiridis, Associate Researcher, NOA
- Mihalis Vrekoussis, Post doc, AA
- Constantin Eleftheratos, Post doc, AA
- Constantin Douvis, Post doc, AA
- Ioannis Kapsomenakis, Post doc, AA

SU Team

- Hans-Christen Hansson, Professor, Stockholm University
- Tabea Hennig. Research engineer, Stockholm University
- Radek Krejci – Researcher, Stockholm University
- Nikos Kalivitis - NEO Station Manager, Stockholm University

In particular, major activities include the following:

I. Installation of the inlets for the NEO station at the Library Tower of the Navarino Dunes Resort

The room hosting the Air Quality laboratory was ready in February 2011. In March 2011 members of the BRFAA group visited the NEO premises for the installation of the inlets for sampling of gaseous and particulate pollutants. The stainless steel pipes, the cut-off heads and relevant material, were purchased by the Stockholm University atmospheric group and were sent to the Academy of Athens contact person (Dr. E. Gerasopoulos) for collection, control, purchase of extra materials by the AA and organisation of the setup. The setup of the inlets on the roof of the Library Tower was implemented with the help of the NEO Station Manager, Dr. N. Kalivitis, and technicians assigned to the purposes of this work by TEMES S.A. (Fig. 1).

Figure 1. Installation works at the Library Tower and the final inlet setup on top of the roof.

II. Installation of the instrumentation for the NEO station at the Library Tower of the Navarino Dunes Resort

During the period March-April 2011 members of both atmospheric research groups, have gradually started the setup of instrumentation at NEO. The construction of the custom build instrumentation by SU, as the Differential Mobility Particle Sizer (DMPS) and the soot photometer (SP) was finished by March 2011and in April these instruments were installed by SU researchers. The DMPS measures the number of atmospheric particles in different size classes, ranging from 5 to 900 nm, while the SP measures the light absorption of these particles. The instruments installed during this phase upon the initiative of the AA and under its co-ordination, include: an ozone analyser (ozone ambient concentrations), an aethalometer (black carbon concentrations and absorption coefficients), a nephelometer (absorption coefficients) and an aerodynamic particle sizer (APS) spectrometer (particles size distributions) (Fig. 2). Complementary infrastructure e.g. UPS and data loggers has been also installed to support the monitoring purposes and safety of instrumentation

Figure 2. Instrumentation at the Library Tower of the Navarino Dunes Resort.

III. Installation of the instrumentation for the NEO spectroradiometric station at the Luxury Romanos Hotel Reception roof.

The platform for the Spectroradiometric station was ready in March 2011. In June members of the BRFAA group visited the NEO premises for the installation of radiometric infrastructure at the NEO spectroradiometric station at the Luxury Romanos Hotel Reception roof (Fig. 3). The instruments installed during this phase, upon the initiative of the AA and under its co-ordination, include: a Multi-Filter Rotational Shadowband radiometer (MFR-7, total and diffuse radiation, retrieved aerosol optical dept) and an Ultra-Violet radiometer (UV radiation measurements).

Figure 3. Installation works at the Luxury Romanos Hotel Reception roof.

IV. Maintenance and calibration of instruments to be positioned at NEO.

Regular maintenance and calibration was performed to all instruments prior to their transfer at NEO. Radiometric instrumentation was transferred to Thessaloniki for calibration procedures in the Laboratory of Atmospheric Physics (Physics Dept., Aristotle University of Thessaloniki), which possesses standards material (e.g. lamps) and has developed integrated calibration processes. At standard intervals part of the AA instruments are brought back to Athens for maintenance and calibration purposes.
Su instrumentation was calibrated prior to sending to Greece.

V. Collaboration with the Meteorological Institute (metno) and the Center for International Climate and Environmental Research (CICERO) of Norway, for regional Air Quality modelling

In the frame of the research activities of BRFAA in NEO, a collaboration with the Meteorological Institute (metno) and the Center for International Climate and Environmental Research (CICERO) of Norway has been established, for the implementation of regional Air Quality modelling for the area of study. To this direction specific runs have been performed with the Oslo CTM2 chemistry-transport model for the area of Greece, to study long term ozone, CO, NO_2, CH_4 and OH variations from 1997 to present. First model runs have been fulfilled and analysis acquired data is ongoing. The immediate goal is to compile these results with available measurements and evaluate the performance of the model over the area for further uses within the objectives of NEO. Figure 4 shows ozone and CO annual cycles at NEO-Pylos compared to other selected (remote background and urban) locations in Greece. It is noteworthy that CO concentrations at NEO are simulated to be the lowest (especially in summer) compared to the other locations.

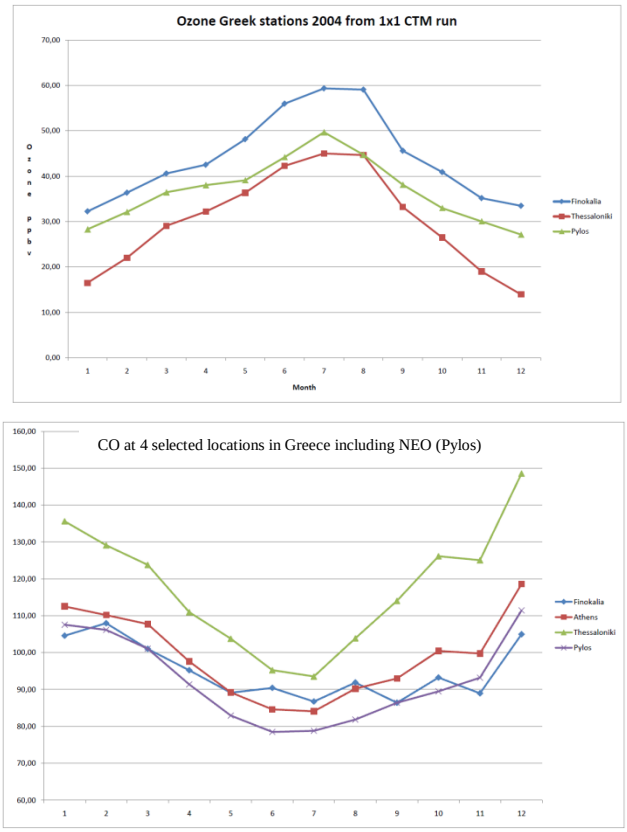


Figure 4. Oslo-CTM2 model runs for 2004. (Upper panel) ozone annual cycle at NEO-Pylos(green), Finokalia-Crete (blue) and Thessaloniki (red). (Lower panel) carbon monoxide annual cycle at NEO-Pylos(purple), Finokalia-Crete (blue), Thessaloniki (green) and Athens (red).

VI. Climate Modelling

Climate modelling runs have been performed from BRFAA staff to simulate present and future climate in Greece and the Mediterranean. From these runs, extensive data have been used to produce maps for use and exposition in Natura Hall (e.g. Fig. 5). In particular, temperature, precipitation, relative humidity, cloud cover and snow cover timeseries of a total of 12 Regional Climate Models (RCM) simulations carried out by the European program ENSEMBLES (http://ensemblesrt3.dmi.dk/) were used for this purpose. The 12 RCMs utilised are RCA3 (HadCM3Q), RM5.1 (ARPEGE), HIRHAM5 (ARPEGE), HIRHAM5 (ECHAM5), HIRHAM5 (BCM), CLM (Hadcm3Q0), RegCM3 (ECHAM5), RACMO2 (ECHAM5), REMO (ECHAM5), RCA (BCM), RCA (ECHAM5), RCA (HadCM3Q3); the name of the General Circulation Model (GCM), from which data were used as input in the simulation process for each RCM, appear in brackets, while the name of RCM used for the mentioned simulations appear in front of the bracket. The spatial resolution of the 12 RCMs is 0.22° longitude x 0.22° latitude. All time series cover the period 1961-2100 and plots were produced for the Mediterranean and Greece, respectively, showing the percentage change

relative to the reference period (1961-1990). The assessment of the climatic conditions within the 21st century was based on SRES A1B.

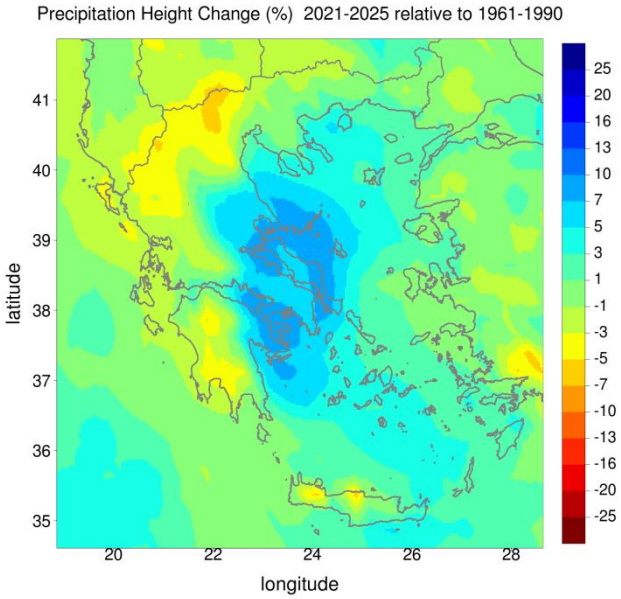


Figure 5. Example of a map produced for Natura Hall showing the percentage precipitation height change during 2021-2025 relative to the reference period 1961-1990.

VII. Proposal submission by Dr. E. Gerasopoulos to include NEO in ACTRIS Network (Aerosols, Clouds, and Trace gases Research InfraStructure Network).

ACTRIS is a European Project aiming at integrating European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds, and short-lived gas-phase species. ACTRIS bears the essential role to support building of new knowledge as well as policy issues on climate change, air quality, and long-range transport of pollutants. As a follow up of the participation of NEO in the EUSAAR (European Supersites for Atmospheric Aerosol Research) Network which has currently been merged with EARLINET (European Aerosol Research Lidar Network) to form ACTRIS, NEO has been now registered in ACTRIS as associated partner, with Dr. Gerasopoulos assigned as the contact person. Henceforth, it will be a first priority that NEO representatives follow major ACTRIS meeting and activities, to ensure that all measurement standards are met at NEO and to achieve the maximum possible communication of NEO activities.

VIII. Data collection and data base maintenance.

Researchers involved in NEO, in collaboration with the NEO Station Manager, have been collecting data from the instrumentation at NEO and have formed and maintained a relevant data base. Quality control and analysis of data is performed in parallel. A first preliminary evaluation of obtained data was done in August for DMPS and SP , revealing that measurements had a good coverage with only minor breaks due to instrumental problems (see figure 8). The SP had some mechanical problems forcing an exchange to another instrument. The size distribution measurements could not be performed with the full size range due to some electronic problems, but the size range measured is fully adequate for the first year evaluation of the site and to characterize the atmospheric aerosol and its variation at the site.

IX. VAN type special vehicle purchase for enhancement of NEO's mobility capacities.

In 2011, a VAN type special vehicle has been purchased by BRFAA to be dedicated to the works of NEO and relevant activities. The VAN will host infrastructure for major gaseous and particulate pollutants monitoring as well as a LIDAR system for aerosol profiling in the atmosphere.

X. First results

Indicatively, so far acquired time series of ozone and black carbon are presented in Figures 6 and 7, respectively.

Ozone maximum concentrations are found, as expected, during summer time (Fig. 6). The values lie in the range 40-50 μg m^{-3}, and decrease to about 30 μg m^{-3} towards winter. The summer levels appear somewhat lower to those observed at the other remote background station in Greece located at Finokalia, Crete (University of Crete). There, summer time values during 1997-2005 ranged between 60-70 μg m^{-3}, while in winter the range was 30-40 μg m^{-3} (Gerasopoulos et al., 2005). Additionally, the amplitude of ozone diurnal cycles is 1.5-2 times higher at NEO in summer than at Finokalia station (Gerasopoulos et al., 2006).

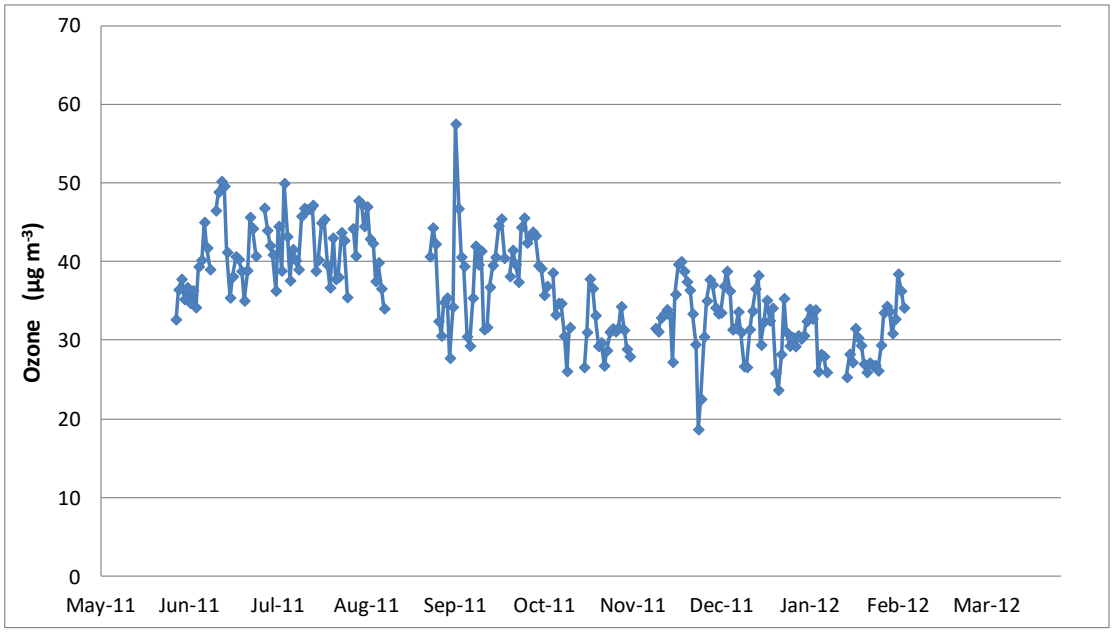


Figure 6. Ozone concentrations (daily means) at NEO Messenia.

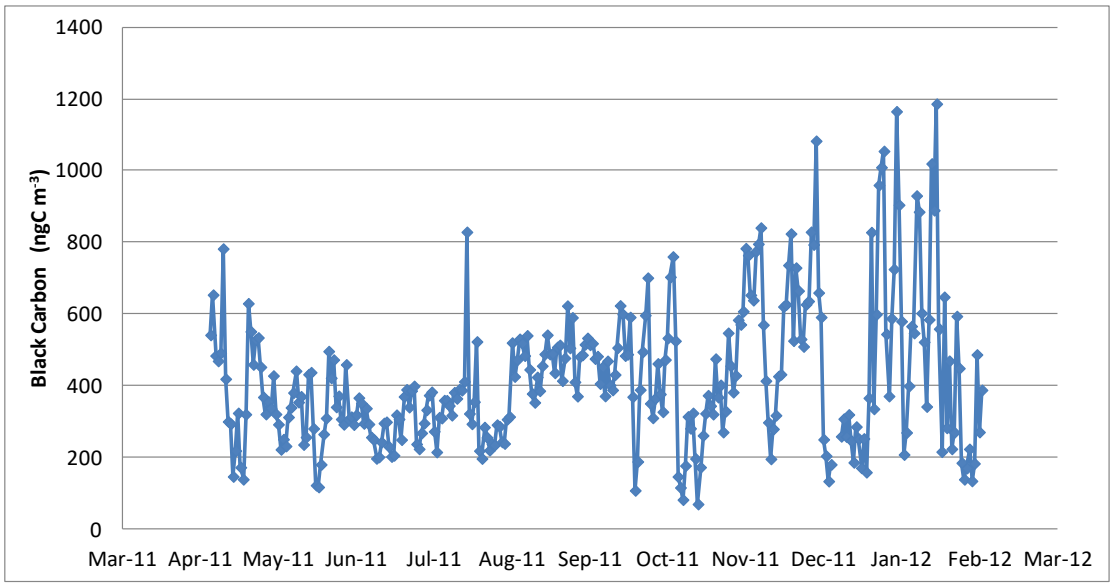


Figure 7. Black Carbon (BC) concentrations (daily means) at NEO Messenia.

Both findings provide a first indication of higher levels of anthropogenically produced NOx and/or VOCs produced or

transported at the vicinity of NEO, which favors intense photochemical activity in the area resulting to ozone destruction via titration. However, the different periods of data coverage in the two stations limits comparisons and immediate interpretation and these first indications have to be validated with longer data series from NEO and concurrent data from Finokalia or other sites in Greece.

Black Carbon (BC) concentrations lie in the range 200-400 ng m^{-3} in summer and enhances in winter to values up to 800-1200 ng m^{-3} (Fig. 7). This is probably due to heating processes and wood burning that is expected to have risen in Greece as a result of the economic crisis. Measurements at Finokalia (in 2006) show levels about 200 ng m^{-3} without strong seasonal variability (Marmer et al., 2009).

The measurements during the period April – August for number concentrations and size distributions of atmospheric aerosols show a strong diurnal pattern, with low concentrations of a few thousands per cc during night and high, about 10000 per cc, during daytime indicating a strong local influence on the daytime measurements (Figure 8). The particle size distribution during night is considerably different from the daytime size distribution. Figure 9 shows typical particle size distributions for a day in July, 2011.

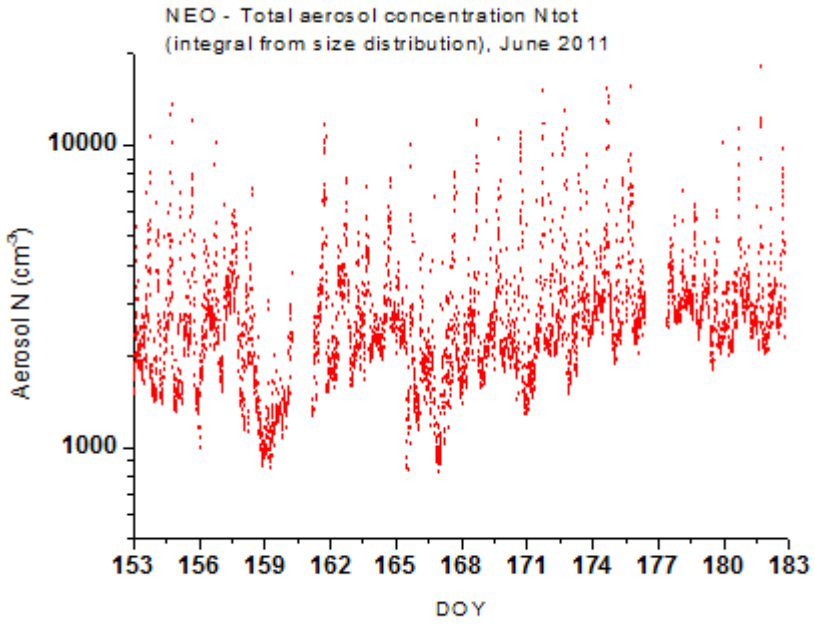


Figure 8. The total aerosol concentrations measured at the NEO site from April to August 2011.

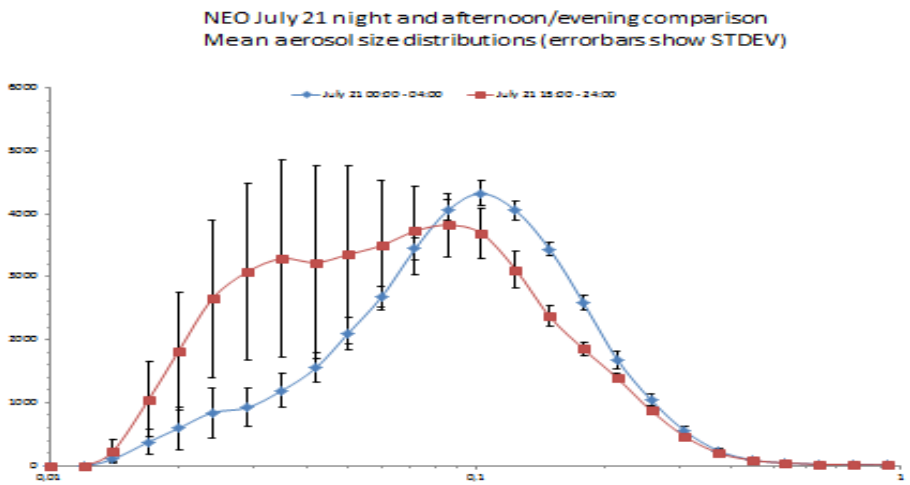


Figure 9. The particle size distribution for day and night July 21st, 2011.

Following the variation of the size distribution as shown in figure 10, it is found how the size distribution slide between a more bimodal size distribution with a small particle mode and a more unimodal size distribution with larger particles. The latter is typical of a primary combustion aerosol while the former a typical marine background aerosol. The question is whether the pollution is very local or a reflection of the general pollution in the Peloponnesus.

When the first year of measurements is concluded the measurements will be evaluated to determine the local influence and thus how well the measurements can be used for studies of the natural and pollutions situation for the region.

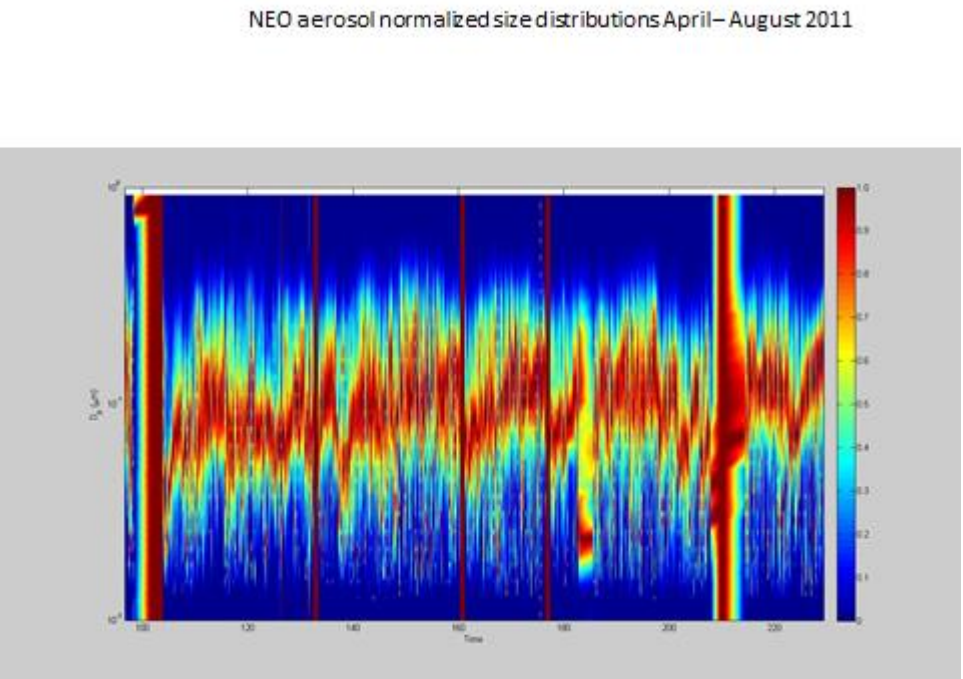


Figure 10. The particle size distributions at NEO shown for a week in July, 2011. The x-axis show the time, y-axis give the size and the colour give the number of particle at a specific size and time.

Regarding the spectroradiometric station, data of UV-A, erythemal dose, total and diffuse solar radiation are continuously monitored. Aerosol Optical Depth (AOD) values are calculated following the methodology described in Gerasopoulos et al., 2003; 2011. An example of AOD diurnal variability is shown in Fig. 11.

Fig. 12 presents the UV-A solar radiation measured at NEO (local noon) as well as the related UV-Index calculations. It should be stressed out that values of the UV-Index greater than 8 are labelled as "very high" suggesting special precaution for children and sensitive population groups.

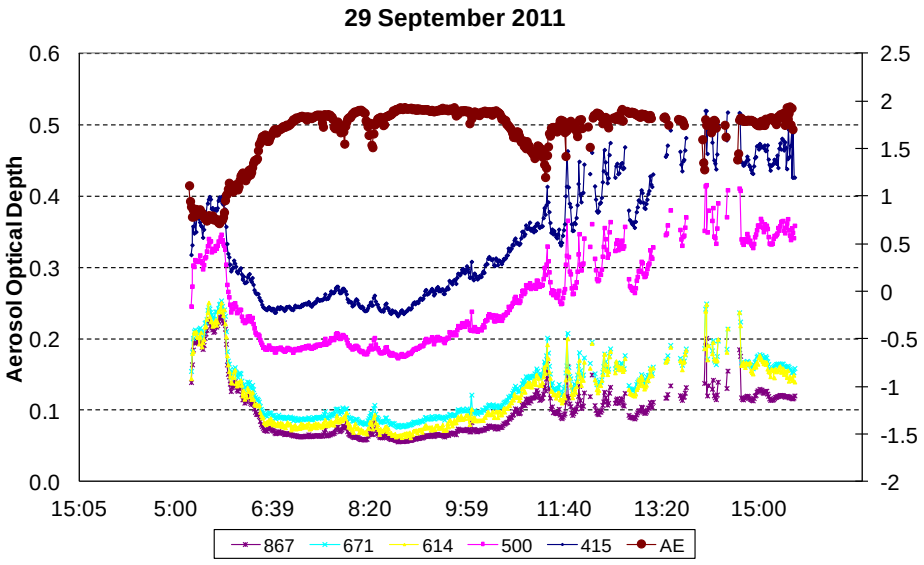


Figure 11. AOD diurnal course on 29 September 2011 at NEO Messenia. The brown line refers to the Angstrom exponent between 867 and 415 nm (right axis). Gaps correspond to clouds.

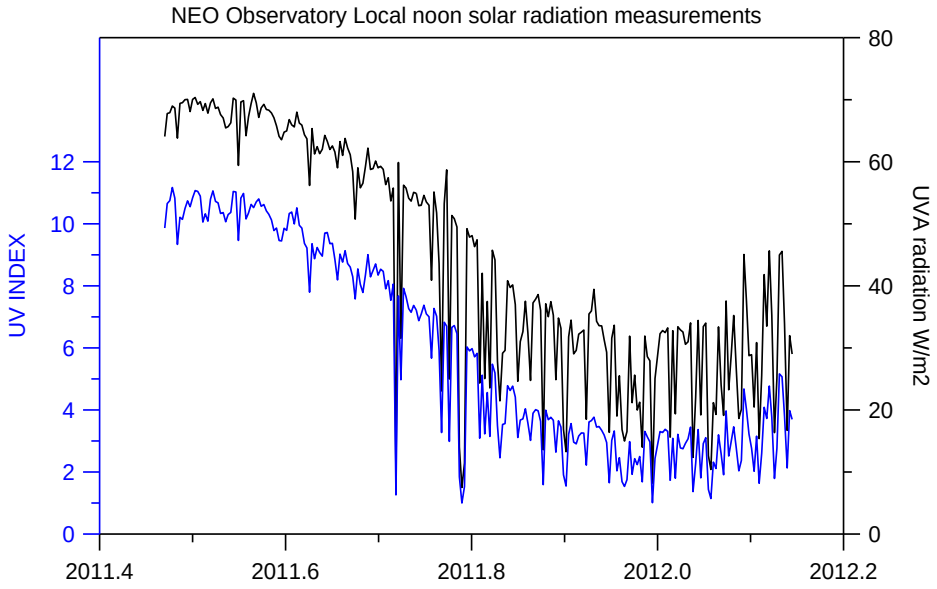


Figure 12. UV-A radiation and UV-Index at NEO, Messenia, since June 2011. Local noon values are here presented.

References

Gerasopoulos, E., Kouvarakis, G., Vrekoussis, M., Kanakidou, M., Mihalopoulos, N., 2005. Ozone variability in the marine boundary layer of the Eastern Mediterranean based on 7-year observations. Journal of Geophysical Research 110, D15309.

Gerasopoulos, E., Kouvarakis, G., Vrekoussis, M., Donoussis, C., Mihalopoulos, N., & Kanakidou, M. (2006). Photochemical ozone production in the Eastern Mediterranean. Atmospheric Environment, 40, 3057–3069. DOI 10.1016/j.atmosenv.2005.12.061.

Marmer E., F. Dentener, J. v. Aardenne, F. Cavalli, E. Vignati, K. Velchev, J. Hjorth, F. Boersma, G. Vinken, N. Mihalopoulos, and F. Raes, 2009,What can we learn about ship emission inventories from measurements of air pollutants over the Mediterranean Sea?, Atmos. Chem. Phys., 9, 6815–6831.

Gerasopoulos, E., Andreae, M. O., Zerefos, C. S., Andreae, T.W., Balis, D., Formenti, P., Merlet, P., Amiridis, V., and Papastefanou, C.: Climatological aspects of aerosol optical properties in Northern Greece, Atmos. Chem. Phys., 3, 2025–2041, doi:10.5194/acp-3-2025-2003, 2003.

Gerasopoulos E., V. Amiridis, S. Kazadzis, P. Kokkalis, K. Eleftheratos, M. O. Andreae, T. W. Andreae, H. El-Askary, and C. S. Zerefos, Three-year ground based measurements of aerosol optical depth over the Eastern Mediterranean: the urban environment of Athens, Atmos. Chem. Phys., 11, 2145–2159, 2011.

Scientific Publications

Balis, D., I.S.A. Isaksen, C. Zerefos, I. Zyrichidou, K. Eleftheratos, K. Tourpali, R. Bojkov, B. Rognerud, F. Stordal, O. A. Søvde, and Y. Orsolini, Observed and modelled record ozone decline over the Arctic during winter/spring 2011, Geophysical Research Letters, vol. 38, L23801, doi:10.1029/2011GL049259, 2011.

Outreach

The participation of NEO in ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) meetings and activities ensures outreach of NEO's activities to the scientific community and knowhow transfer to NEO for standardized measurements of high quality.

Dr. Konstantinos Eleftheratos, lecturer at the National Kapodistrian University of Athens and external collaborator of BRFAA, participating, on behalf of Prof. Zerefos, in the kick-off meeting of the DARECLIMED project (DATA REPOSITORIES AND COMPUTATIONAL INFRASTRUCTURE FOR ENVIRONMENTAL AND CLIMATE STUDIES IN THE EASTERN MEDITERRANEAN, http://eewrc.cyi.ac.cy/DARECLIMED), which was held in Nicosia, Cyprus on 12-13 April 2011, presented to partners the establishment and activities of NEO. The project topic and goals are in line with the objectives of NEO regarding the study of the Mediterranean climate, and it is anticipated that the communication of NEO infrastructure and action planning within this community will be of important NEO's benefit.

Planned activities for 2012

In 2012 BRFAA has already routed the purchase of a particle sampler for the collection of the PM_{10} aerosol fraction on quartz filters. Samples will be chemically analyzed for the estimation of major ions and cations, elemental and organic carbon as well as metals. This analysis will result to chemical characterisation of aerosols in the area and it is an essential step towards atmospheric composition evaluation and studies. The optimal location for the sampler needs to be clarified and decided in collaboration with NEO Management.

All necessary transformations to the VAN type special vehicle purchased by BRFAA in 2011, will be performed in early 2012. This will include the setup of the LIDAR system, the setup of special racks to host gaseous and particulate matter monitors, the setup of a small actinometric platform on top of the VAN as well as works for inlet pipes, electrical power and air conditioning. Instrumentation to operate onboard the VAN will be also purchased from BRFAA's funds other than that of NEO.

BRFAA research team will organise an extensive experimental campaign at NEO concentrating more instrumentation from NEO partners and other collaborating organisations. The timing of the campaign is set in summer time and remains to be finally decided upon availability of participants.

Data analysis of the extensive data series created as well as of model runs data produced will be done in parallel. Maintenance and calibration procedures regarding NEO instrumentation will be performed as planned, in collaboration with the NE Station manager. It is anticipated that a certain number of papers might be produced depending on findings of ongoing analysis.

SU group will update DMPS instrument so that size distributions will be collected in the total of the size range from 5 to 900 nm.

In 2012 a workshop will be organized with the participation of all researchers involved in NEO to evaluate the first year of measurements and to decide upon future actions.

Geology, geomorphology and landscape changes

Geology

Research description

On a global scale, southern Greece is situated in a region of plate convergence between Africa and Eurasia, whereas on a local scale, because Africa is rotating with respect to Eurasia, southern Greece is affected convergent and divergent tectonics, and because Turkey is moving westwards with respect to Eurasia, southern Greece is also affected by transform tectonics (Jackson 1994). Mountain building in southern Greece arises because of both convergent and divergent tectonics. Convergent tectonics is recorded by evidence of high pressure metamorphism in the Peloponnese, Cyclades and Crete. Divergent tectonics results in horst-and-graben type topography of the Peloponnese, which comprises N-S trending mountain belts, separated by N-S trending valleys.

Mountain building influences the climate by (1) exhuming rocks to the surface, where they are subjected to chemical weathering which removes carbon from the atmosphere, and (2) burying rocks to extreme depths, where they are subjected to metamorphism which releases carbon which can then migrate upwards entering the atmosphere via hot springs. The rate at which carbon is removed from the atmosphere by chemical weathering has been constrained mostly based on riverine fluxes of various proxies (Huh, 2010), whereas only preliminary estimates of the rate at which carbon is released to the atmosphere by metamorphism have been published (Skelton, 2011). Thus the net balance between these processes remains unknown to the extent that we cannot be certain whether mountain building should be viewed as a net source or sink of atmospheric carbon. Elucidating this balance, which is therefore necessary if we are to gain a full understanding of natural climate variability, requires calculation of chemical weathering and metamorphic carbon fluxes. Southern Greece is an ideal natural laboratory for their determination. On the Cyclades, rocks which were metamorphosed at the onset of mountain building are exposed at Earth's surface and in the Peloponnese, rocks exhumed on fault surfaces during earthquakes provide us with an opportunity to measure rates of chemical weathering.

<u>Researchers involved</u>

Alasdair Skelton, Professor, Stockholm University

Barbara Kleine, PhD student, Stockholm University

Major research activities 2011 and early 2012

In 2011, we have conducted a field campaign on Syros in the Cyclades and reconnaissance field work near Sparta. On Syros, we have conducted petrographic and geochemical (XRF) analysis of geological samples from Syros. Some of these samples preserve evidence of metamorphism at *blueschist facies* conditions. Blueschist facies metamorphism occurred at high pressure and low temperature during subduction. Evidence of blueschist facies metamorphism on Syros is variably overprinted (retrogressed) by later *greenschist facies* metamorphism. Greenschist facies metamorphism occurred at low pressure and moderate temperature during exhumation to Earth's surface (Figure 13).

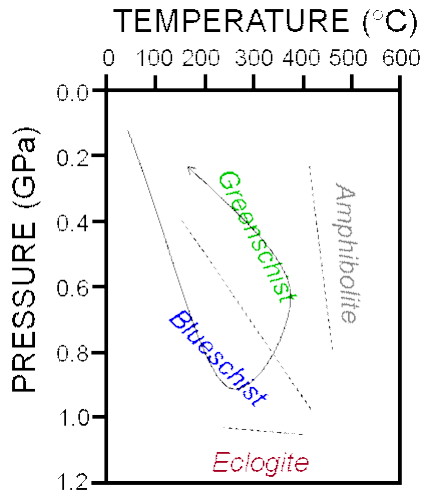


Figure 13. Typical pressure-temperature-time loop illustrating high pressure – low temperature *blueschist facies* metamorphism followed by low pressure – moderate temperature *greenschist facies* metamorphism.

Figure 14. Mafic rock from near Fabriko on Syros in the Cyclades showing (1) greenschist facies metamorphism (left, greenish-colored) with (2) blueschist facies metamorphic minerals preserved (middle, bluish-colored) adjacent to a fault (right, whitish-colored vein). The width of the image is approximately 1 meter.

Our work has revealed preservation of blueschist facies metamorphic minerals adjacent to faults (Figure 14). This is surprising because greenschist facies retrogression requires addition of H_2O and hydrous fluids are typically channeled along faults. It would thus seem more

logical to find retrogression to greenschist adjacent to these faults. One possible explanation for this enigma arises from the observation that the blueschist facies rocks which are preserved adjacent to faults on Syros contain carbonate minerals, primarily calcite (Figure 15). Preservation of *carbonate-bearing* blueschist facies rocks adjacent faults could occur if the fluid channeled along the faults was mostly CO_2. However, effective preservation of blueschist facies minerals could only occur if the flux rate of CO_2 within the fault was sufficiently fast compared with the rate of greenschist facies retrogression. The next stage in this project is to find a method for calculating the flux rate of CO_2 which is required to maintain this state of thermodynamic disequilibrium.

These initial results have been presented at the DeltaMIN workshop on the Canary Islands (October 2011) by NEO/DeltaMIN PhD student Barbara Kleine and the Nordic Geological Winter Meeting in Reykjavik (January 2012) by Professor Alasdair Skelton. These results have also been presented as part of an invited talk at Uppsala University (Sweden) by Professor Alasdair Skelton. The scientific publication which will arise from this work and will form one of the papers in Barbara Kleine's PhD thesis requires an additional set of samples, which will be collected on Syros in February 2012.

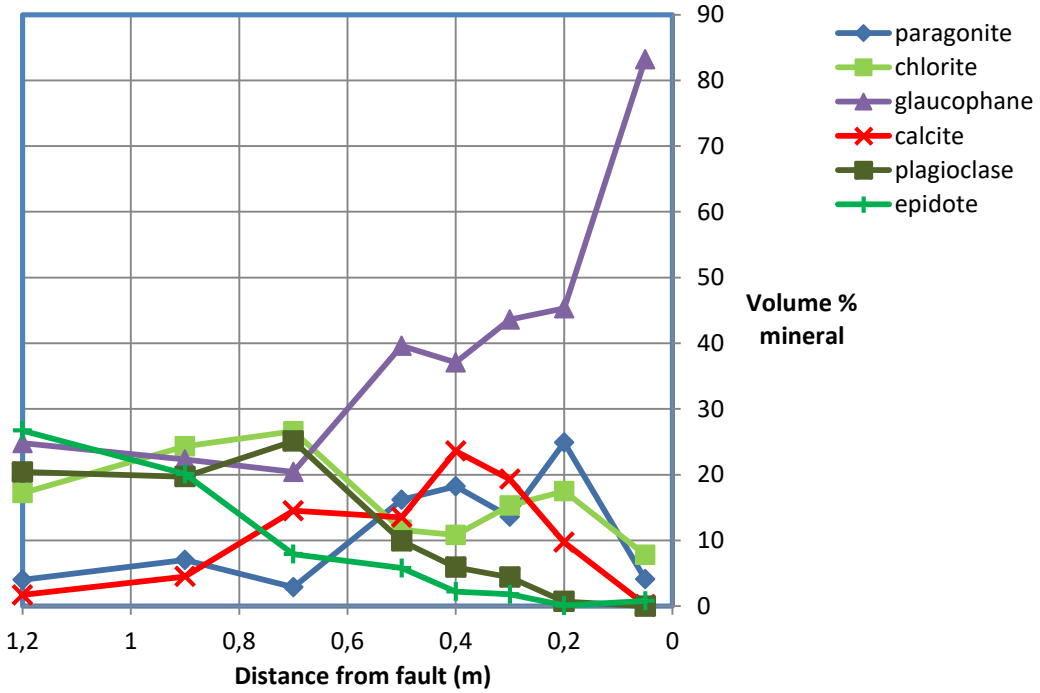


Figure 15. Volumetric mineral percentages determined by counting 1000 points in each thin section and plotted as a function of distance from the fault seen in figure 2. The carbonated blueschist facies mineral assemblage comprises glaucophane, paragonite and calcite. The greenschist facies mineral assemblage comprises epidote, chlorite and plagioclase. The overall trend shows higher percentages of carbonated blueschist facies minerals

closest to the fault. Note that whole rock chemical analyses by X-ray fluorescence (not shown) showed that the sample which was collected closest to the vein shows evidence of silica metasomatism. This explains its disproportionally high content of glaucophane. Reaction textures observed in thin section indicate that the blueschist facies minerals are progressively replaced by greenschist facies minerals with increasing distance from the fault. This indicates that blueschist facies minerals are being preserved adjacent to the fault.

Reconnaissance fieldwork near Sparta has been conducted to select sites along the exhumed surface of the Sparta Fault which are suitable for studying the rates of chemical weathering. These sites need to be accessible, safe for abseiling and as close as possible to sites where Benedetti et al. (2002) have determined the age of the fault surface by cosmogenic dating using chlorine isotopes.

The study will be conducted by a licentiate student (Ruben Fritzon) as part of a new Research School for Teachers focusing on Natural Hazards, which is financed by the Swedish Research Council and the Swedish Government and for which Professor Alasdair Skelton is the principle investigator. The field campaign is scheduled for spring 2013. We aim to use a portable X-ray fluorescence analyzer (provided by the Department of Geological Sciences at Stockholm University) to determine whole rock chemistry of the weathered fault surface. This field-based method with an analysis time of 45 seconds will allow for analyses to be made at 2-3 cm intervals in a profile constructed along the fault surface. We will then attempt to correlate concentration data for chemical indicators of weathering with cosmogenic age data for the fault surface. This correlation will form the basis for calculating weathering rates.

Scientific Publications

Kleine, B., 2011. Fluid-rock interactions in Scotland and the Cyclades. Abstract, DeltaMIN workshop, Canary Islands.

Skelton, A., 2012. Flux rates for water and carbon during greenschist facies metamorphism estimated from natural examples of carbon sequestration. Abstract, 30th Nordic Geological Winter Meeting, Reykjavik.

Outreach

I attempted to hold one a NEO lecture in Kalamata on February 8, 2012. Unfortunately, because of adverse weather conditions, this lecture was cancelled.

Planned activities for 2012

During 2012, we will conduct a second field campaign on Syros (February 2012). Petrographic thin sections of samples collected on Syros will be used to elucidate reaction textures and to quantify reaction progress in mafic and felsic rocks on both sides of the fault shown in figures 2. Whole rock chemistry of these samples will be determined using X-ray fluorescence to determine if reactions are isochemical or metasomatic (i.e. involving addition or removal of non-fluid components). These data, together with data acquired during 2011 will form the basis for one peer-review article focusing on blueschist preservation on Syros and its implications for carbon release fluxes during mountain building. This paper will be written and submitted during 2012. It will be led by PhD student Barbara Kleine.

Work conducted on Syros will be presented at the DeltaMIN workshop in Spain in March 2012 and at EGU in Vienna in April 2012.

In 2012, we will also prepare for our field campaign near Sparta during spring 2013. This preparation will encompass a review of recent literature on cosmogenic dating and geochemical studies of fault surfaces and studies of carbonate weathering. The portable X-ray fluorescence analyzer, which will be used to study the Sparta Fault, will be tested on comparable rock types in Sweden.

Geomorphology

Research description

I. Tectonic geomorphology (long term perspective)

Messinia has a complex geological structure, with block-faulting and shifts over short distances between uplifting horsts forming mountain ranges and downfaulting lowlands or grabens. The whole area is affected by the close proximity to the Hellenic Arc. Consequently the geomorphological evolution and denudation history of the landmass, the effects of sea-level change, and the effects of long-term climate change on landscape development, must be investigated in a context that includes a full appreciation of the tectonic history. We have during 2010 started preliminary geomorphological mapping of structural and medium to large-scale landforms in a high-resolution digital terrain model. A first step is a subdivision of the area in geomorphological units that link to the primary tectonic subdivisions. Once this is completed we will proceed with creating a database that summarizes the known uplift/subsidence rates, available dating constraints and basic geological data for each main morphotectonic unit. This database will form the foundation for the further analysis.

Key question we address are: During what time period(s) was the weathering mantle eroded from most of the mountain massifs? What is the age and formational environment of the large now fossil alluvial fans that are found at intermediate levels in the landscape? What are the rates of tectonic uplift? To what extent have landslides and other types of mass movement contributed to landscape development? What is the history of the flat-floored intermontane basins? What has caused the drastic difference in degree of river incision in different parts of Messinia?

II. Geomorphology and land use (short term perspective).

There is an ongoing debate among researches regarding the role of human impact on the development of the Mediterranean landscape. In Messinia very little focus has been on landforms and geomorphological processes in these studies. Our project aims to analyse the landscape changes that have occurred in Messinia in the last 100 000 years. At an early stage the research will be based on mapping of geomorphology and land use mainly using aerial photographs and satellite images. Later on we envision that dating techniques such as C14 and OSL will be used to solve chronological issues.

The project has links to many other NEO-projects, primarily to the hydrological projects and to the dendrochronology and speleothem projects on climate change. Some changes are planned for 2012 regarding scientific objectives.

Researchers involved

- Johan Kleman, Professor, Stockholm University
- Ingmar Borgström, Lecturer, Stockholm University
- Josefien Delrue, Stockholm University

Major research activities 2011

- A pilot study of geomorphology and land use in Messinia (separate document). This study has been conducted as a baseline for work on short-term (<3 kyr) geomorphological change (C in the plan for 2012). (See the appended summary of report: Delrue 2011)
- Mapping of the geomorphology of Peloponnese (Ottoson, Kleman & Borgström 2011). This map is the initial step for the work under (B) in the plan for 2012.
- Literature studies and in-depth planning for the research under (B) in the plan for 2012. It was realised that was described under "tectonic geomorphology" above should preferably be pursued as two research tracks, one trying to answer tectonic questions, while the other focuses on climatological and geomorphological questions. A brief account for the restructuring of what we did in 2011 is found in the plans for 2012.

Scientific Publications

1. Delrue. J. 2011: A prospective study of geomorphology and land use
2. Ottosson, F., Kleman, J. and Borgström, I. 2011: Map of Geomorphology of Peloponnese. Stockholm University, Dept. of Physical Geography and Quaternary Geology & Navarino Environmental Observatory. (Available also on https://mondo.su.se/access/content/group/5871e98f-2918-4aa4-8a44-25e8190efbde/Maps/Geomorphology%20of%20Peloponnese.pdf)

1. A prospective study of geomorphology and land use

Summary of a report by Josefien Delrue

A prospective study has been carried out aiming to present an overview of the geomorphology and land use change of the region around the Navarino Environmental Observatory. Hereby, we focus on the entire region of Messinia, but extend our specific interest to the immediate 20 km surroundings of the NEO-station. We distinguish between two types of data. 1) A first set of data is an overview of the existing GIS-layers, maps and images (both aerial photographs as well as satellite imagery) which we retrieved from different sources. 2) A second dataset contains data collected during a field survey of degraded areas in Messinia. From these datasets, we subsequently derived both general information and some preliminary results, such as topographic-geological transects cutting through the different geological blocks and change maps unveiling the most remarkable changes in land cover and land degradation over the last 60 years. The findings resulting from this first examination of the different datasets will serve as a basis to formulate research questions.

Study Area

Location

The research area is located around Pylos bay and Navarino Environmental Observatory Station (36°59'N, 21°38'E). It covers a surface of roughly 15km × 30km. Its northern part is situated in the Eparchy (´municipality´) Triphylias and the southern part in the Eparchy Pylos, which both belong to the Nomos (´perfecture´) Messinia.

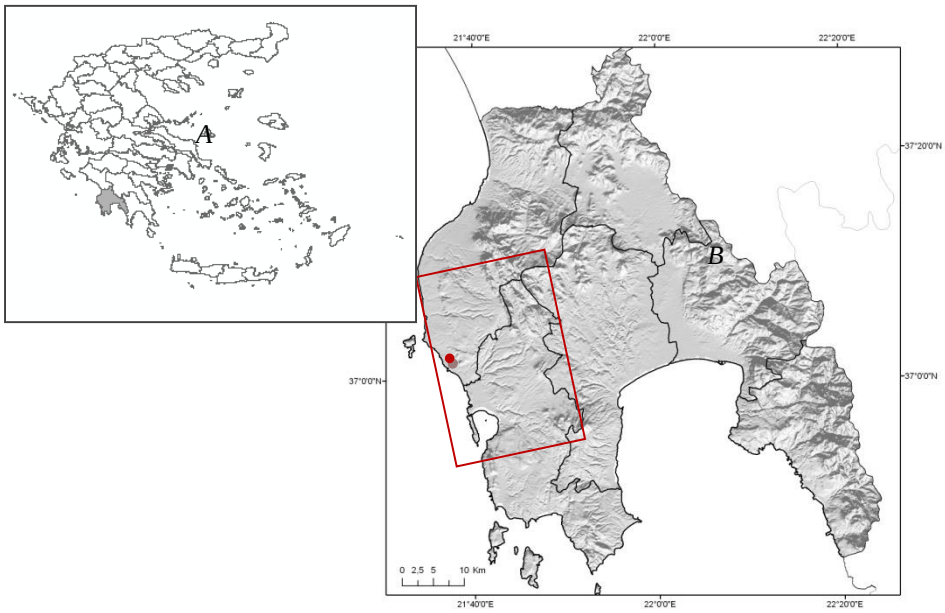


Figure 16. A) Location of prefecture Messinia (grey) on the map of Greece. B) Shaded relief of Messinia. The red box shows the location of the study area. The red dot marks the Navarino Environmental Observatory station.

Inland geomorphology

The eastern part of the study area is bordered by the Kyparissia Mountains, Mount Manglavas and Mount Likodhimos, following a north-south trajectory. The mountain range is tectonically active and characterized by numerous overthrusts and faults. The central part of the study area exists of a gently sloping horst-like plateau or ´kampos´. The plateau is intersected by several valleys through which seasonal (i.e. winter) rivers flow. The coastline exists partly of an interrupted coastal ridge: from North to South we see the islands of Proti, Sfaktiria and Mount Ayos Nikolaos. Along the coastline which is not protected by a coastal ridge, several smaller bays have formed. Behind Sfaktiria, the remarkable land features of Pylos bay and Gialova lagoon have formed (De Vliegher 1997).

Coastal morphology

The coastline has been smoothed by the formation of sand beaches and off-shore sand-bars. They result in lagoons which in some places become filled with sediments from coastal streams. This process is most obvious North of our study area between Pyrgos and Kyparissia. A remarkable coastline feature with large historical significance is Navarino bay (Fig. 17). Gialova lagoon was cut off from the Meditteranean Sea around 3000 B.C. by a sandbar. The inland precipitation and sea storm waves result in a large wetland area marked by the presence of brackish water. There has been human activity since Bronze Age, e.g. for fishing, fish cultivation or as a harbor for small boats. The lagoon has in certain times been more shallow than today, following the change in sea water level. In the 1970s, incoming water was stopped by a dike and canal and the lagoon was drained in order to claim the land for agricultural areas. As agriculture proved difficult and unproductive, the lagoon was abandoned, followed by a swift inundation of the lagoon. This area is now protected under the European Natura 2000 network, as this area is a crucial stop-over and resting area for large bird populations migrating between the Balkan and Africa. Next to it lays Voïdhokilia bay.

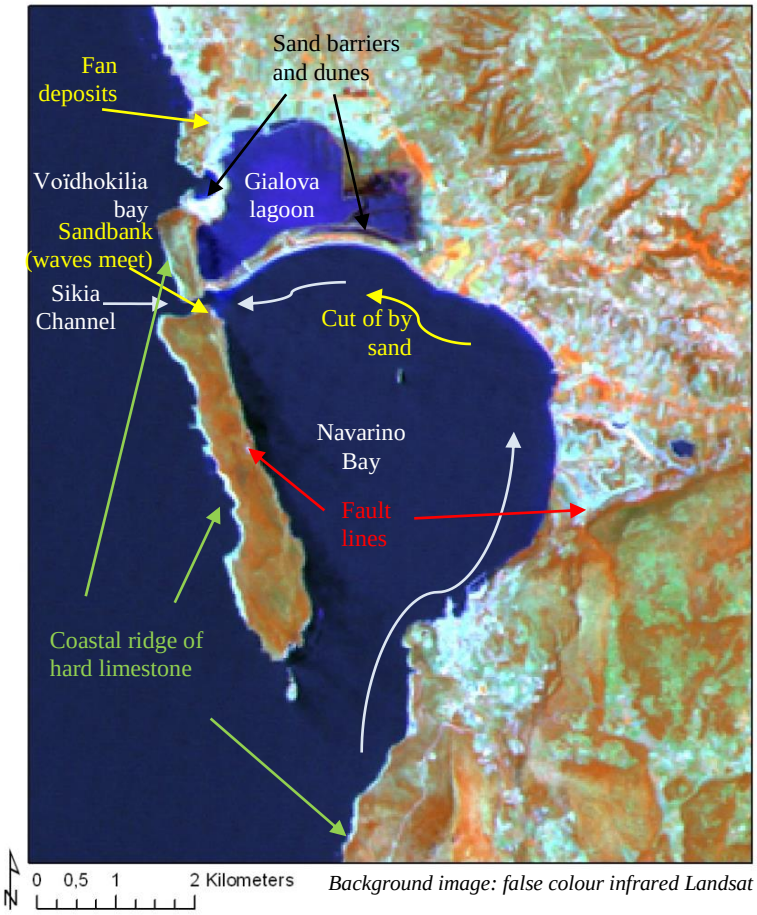


Figure 17. Dominant coastal processes around Navarino Bay and the Gialova lagoon which explain its current shape and formation.

Vegetation

The natural vegetation in the area varies with both lithology and topography. The flat or gentle sloping areas of the kampos are amongst the most fertile lands of the entire Messinian region. It is almost entirely used for intensive agriculture, with many of the arable land being irrigated. Olive groves currently dominate the agricultural production in the area, both in terms of cultivated area as in production. Grapes, for consumption, wine making or raisin production, are the second most important form of agriculture. Agroforestry-like fields of grapes and olives is equally common, mostly where grapes have been planted in between olive-trees in older olive groves (observed during fieldwork). Other forms of agriculture (wheat, livestock rearing, etc.) only form a marginal and negligible part of the cultivated land.

Steep hillsides are generally covered by Mediterranean maquis, an exceptionally species-rich and biodiverse ecosystem. It is predominantly composed of small trees and shrubs (Ericaceae), with dominant species being , among others, evergreen oaks (Quercus coccifera and Q. ilex), pistachios (Pistacia lentiscus, and P. terebinthus), wild olive (Olea europaea), carob (Ceratonia siliqua), strawberry tree (Arbutus unedo) and many others. Representative, dense and seemingly

untouched maquis vegetation can be still be found in the area, mostly in inaccessible areas such as ravines or very steep slopes. In most parts however, the remaining maquis has been severely degraded through grazing, wood cutting or repeated large-scale fires. This vegetation type is relevant for local inhabitants as it provides several interesting ecosystem services, such as honey production (pers. observation) and water retention. Near the rivers, dense vegetation composed of Arundo donax, Eucalyptus and Platanus orientalis is present. Most of these species can also be found in the swamp areas near the sea (e.g. Gialova lagoon). Above elevations of 700m, oak forest, including both deciduous and evergreen species can be found (Wright 1972 and De Vliegher 1997).

Preliminary results

Fieldwork

The aim of the fieldwork was to produce a geo-referenced ground truth database for land cover and land use in the study area, which will:

- provide insight in the current landscape with its land cover and land use distribution
- serve as validation data for two land cover transects
- serve as a reference for future photo-interpretation of similar landscapes throughout Messinia

To collect data for hillslope transects with different evolution in degradation/erosion, which will:

- give an overview on the occurrence and degree of slope erosion
- provide data for a pilot study and preliminary analyses and results
- serve as a guideline to devise future sampling schemes

Figure 18. Location of the field survey sites.

Reference database for Land cover types

The reference datasets were collected over two transects of 1 km × 15 km, one in the southern and one in the northern half of the research area. Transect 1 stretches from the coast near Pigadia and Vromoneri till Metamorfosi. Transect 2 starts at the coast near Paleoneri and reaches out till the hills north of Ampelokipoi.

Slope degradation

Two blocks of 2 km × 2 km with extensive slope erosion were selected as study sites, one in the southern and one in the northern half of the research area. Block 1 was located south of the villages of Pidasos and Mesochori, Block 2 was laid out west of the village Mouzaki.

Land cover change mapping using satellite imagery

LANDSAT satellite images, which are freely available, are an extremely useful data source to study general land cover changes. The oldest LANDSAT image for Messinia dates back to 1972 (50m resolution). Since 1984 however, one or more images are available each year and at an improved 30m resolution.

The Aristotle University of Thessaloniki and WWF Greece produced LANDSAT derived land cover maps for 1987 and 2007. These land cover maps give a first overall insight in the land use changes in the landscapes of Messinia over the past 20 years (see Fig. 19). The most obvious change is an increase in the surface area of arable land. New cultivated land has mostly been

created on parts which were covered by sparsely vegetated land, likely driven by European subsidy policies. More land cover change maps for the entire of Messinia based on the LANDSAT imagery acquired through WWF Greece can be found in Appendix.

Using more LANDSAT imagery, the classification could be refined or maps for other dates could be produced.

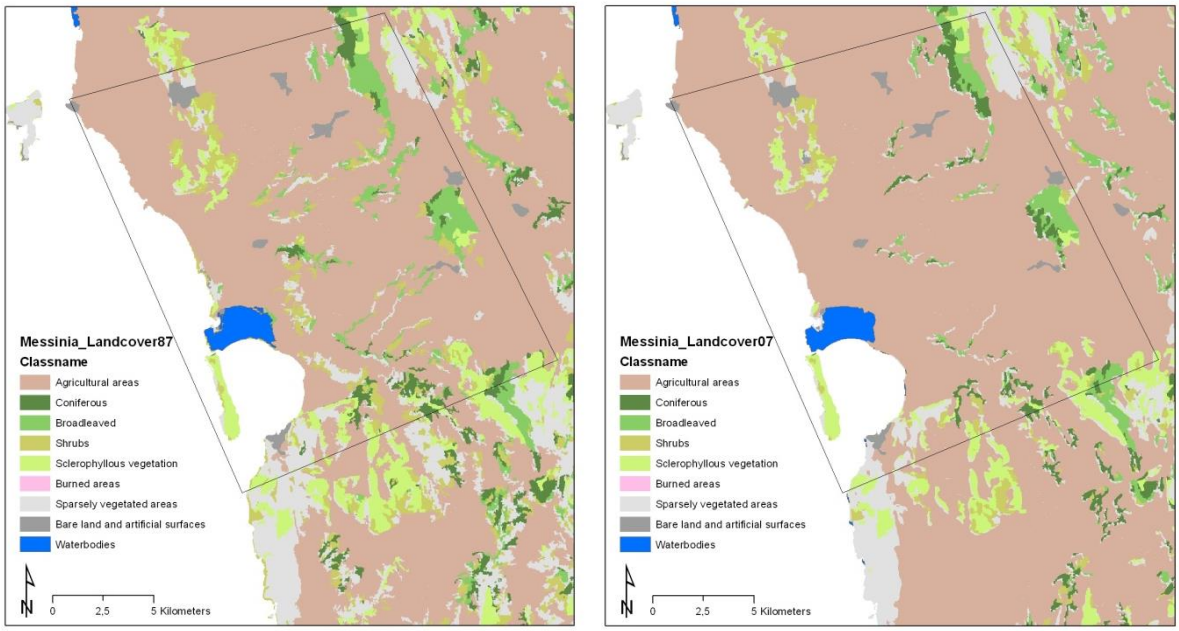


Figure 19. Land cover map for 1987 and 2007 based on LANDSAT satellite imagery. Maps produced by Aristotle University of Thessaloniki and WWF Greece, 2011.

Land cover change mapping using aerial photographs and very high resolution satellite imagery

To study land cover changes over a longer time frame, we ordered the earliest aerial photographs over the area, being 1945. Recent imagery at similar resolution was available for 2003 via Google Earth. (Aerial photographs for 2007 were ordered but not available at the moment this study was carried out).

For the two transects in the study area where we collected ground truth data (see figure 3), we accurately mapped the land cover for 1945 and 2003. The scale of the 1945 images was somewhat smaller and we therefore could not clearly distinguish vineyards from arable land. We thus merged these land use cover types and labeled all these parcels as ´raisins/arable´.

For both transects we can see that the land use is strongly linked to topography and/or geology (Fig. 20 and 21). In transect 1, the natural vegetation is restricted to slopes of hard calcite and

ravines of easily erodible flysh. The remainder of the land exists of sandstone and is rather flat. This area is very attractive for agriculture and has been converted from a mixture of olive groves and arable land (or vineyards) in 1945, to almost exclusively olive groves in 2003. A small percentage of natural vegetation (4%) has been claimed for new agricultural land.

Transect 2 is more undulating and consists primarily of calcite or flysh parent material. Therefore, less areas are favorable for intensive cultivation compared to transect 1. Cultivated land indeed only occurs on the flattest areas. The cultivation of olives has also considerably increased in this transect. Nonetheless, quite some parcels with arable crops still remain. In this transect, natural vegetated land has increased with 5% today compared to 1945.

Table 1 and 2 shows the percentage changes for each land cover type.

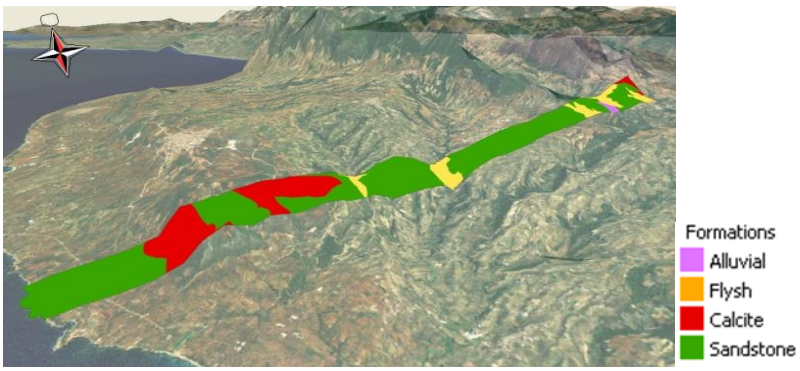
	2003								
1945	Olives	Raisins under olives	Raisins	Arable land	Orchard	Grassland	Natural vegetation	Build-up	Bare
Olives	**5,37**	0,01	0,01	0,15	0,01	0,01	0,81	0,00	0,00
Arable or Grassland with Olives	**13,30**	0,15	0,17	0,01	0,00	0,02	0,29	0,08	0,03
Arable or Raisins	**32,27**	0,58	**1,18**	0,81	0,27	0,57	**2,42**	0,34	0,00
Arable or Grassland	**2,17**	0,06	0,02	0,01	0,00	0,00	0,36	0,00	0,00
Grassland	**2,68**	0,00	0,22	0,07	0,00	0,02	0,73	0,04	0,04
Natural vegetation	**7,06**	0,07	0,27	0,45	0,01	0,07	**23,10**	0,00	0,74
Build-up	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**2,43**	0,00
Bare	0,02	0,00	0,00	0,00	0,00	0,00	0,03	0,00	0,48

Table 1. Changes in land cover type for transect 1 between 1945 and 2003 (percentage of total area of transect)

	2003						
1945	Olives	Raisins	Arable land	Grassland	Natural vegetation	Build-up	Bare
Olives	0,13	0,00	0,02	0,24	0,27	0,02	0,00
Arable or Grassland with Olives	0,06	0,00	0,00	0,18	**1,59**	0,00	0,00
Arable or Raisins	**12,11**	0,99	**6,33**	**7,72**	**7,38**	0,28	0,06
Grassland	0,05	0,00	0,00	0,03	0,12	0,00	0,00
Natural vegetation	**1,85**	0,00	0,09	**2,41**	**55,79**	0,08	0,20
Build-up	0,00	0,00	0,00	0,00	0,00	**1,43**	0,00
Bare	0,00	0,00	0,00	0,04	0,07	0,00	0,45

Table 2. Changes in land cover type for transect 2 between 1945 and 2003 (percentage of total area of transect)

A



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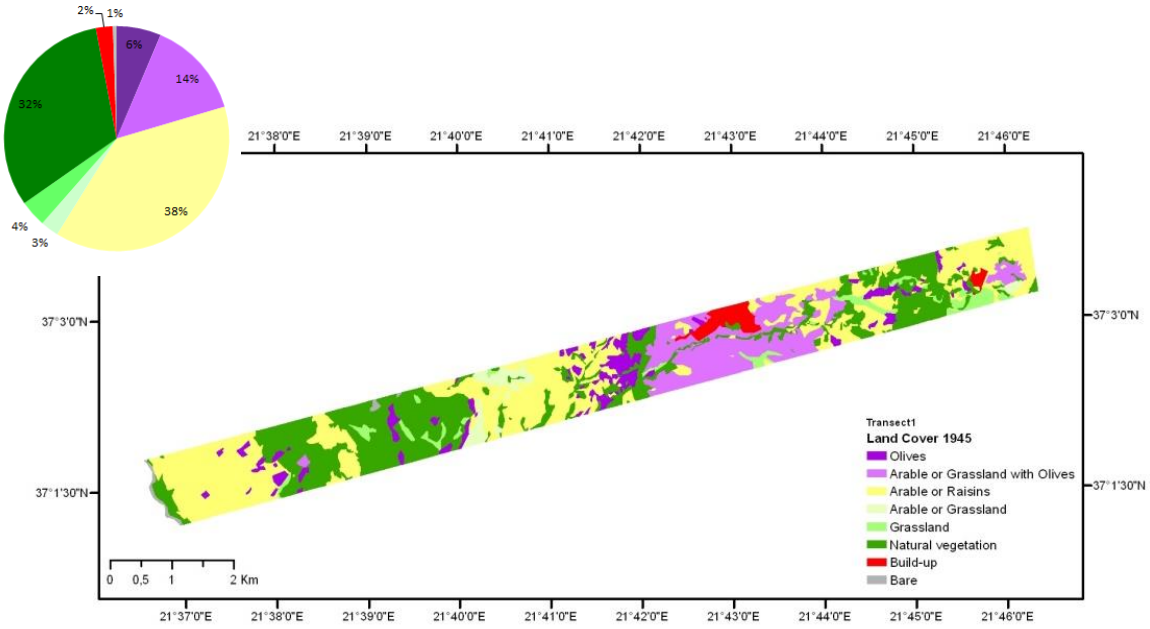

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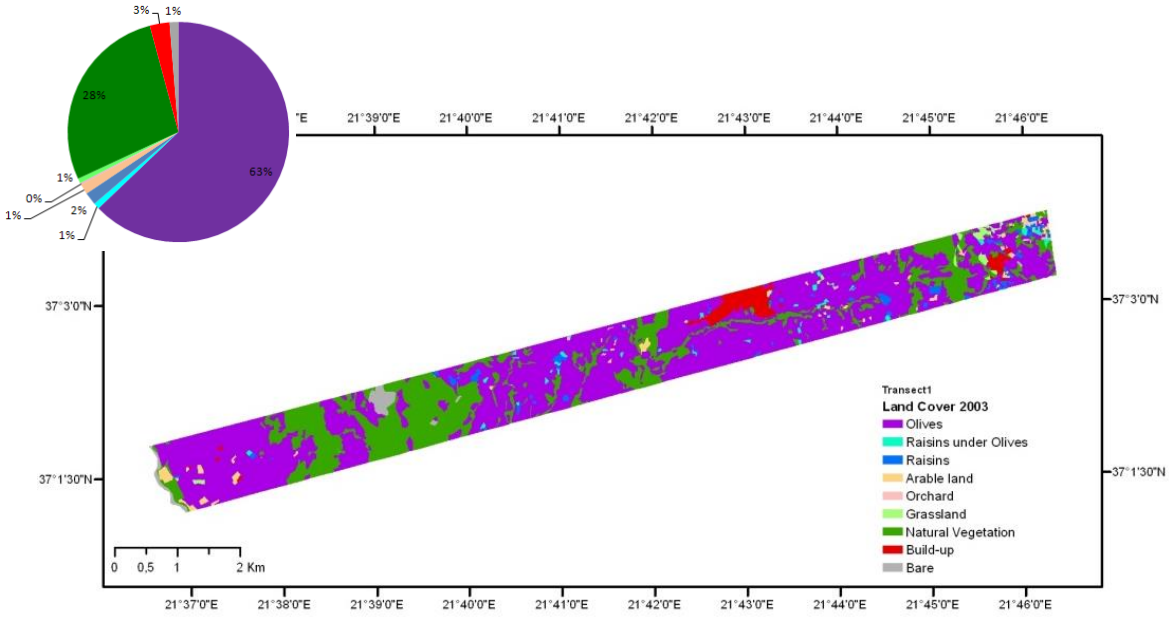
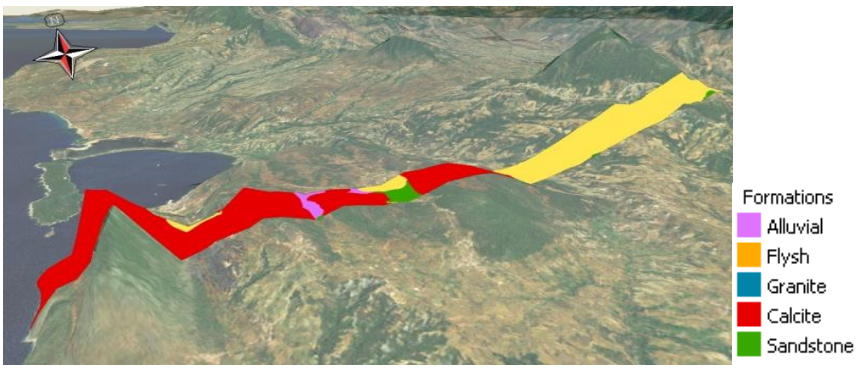


Figure 20. Maps explaining the changes in land cover between 1945 and 2003 for transect 1:A)Topography and geology based on geological map from geological mapping service and SRTM-DTM , B) land cover anno 1945 digitized on aerial photographs and C) land cover anno 2003 digitized on Google Earth**.**

A



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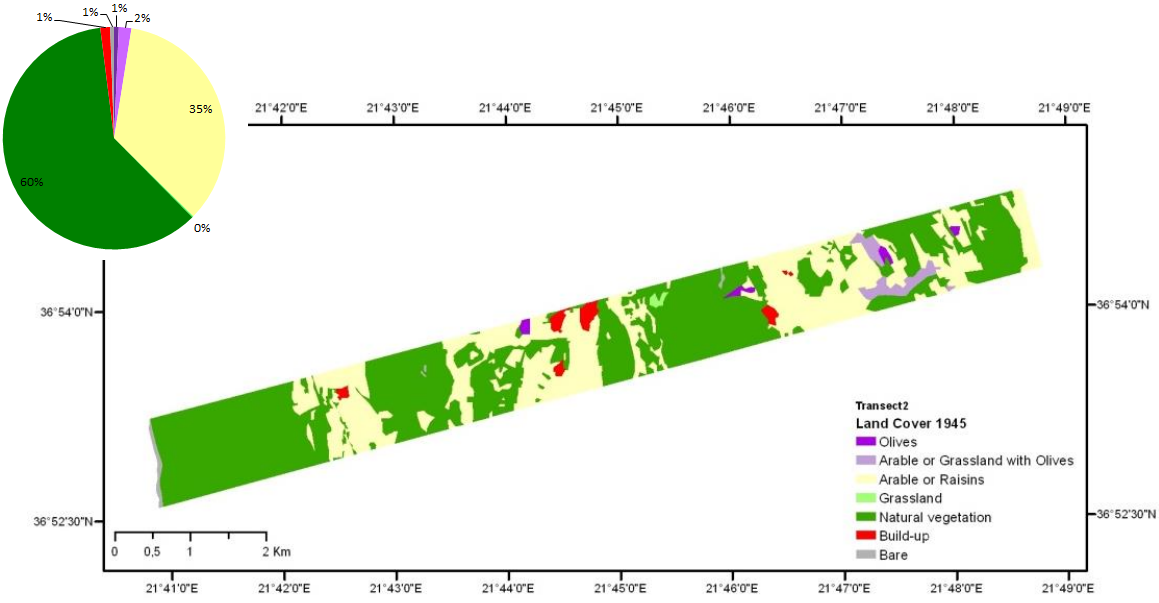

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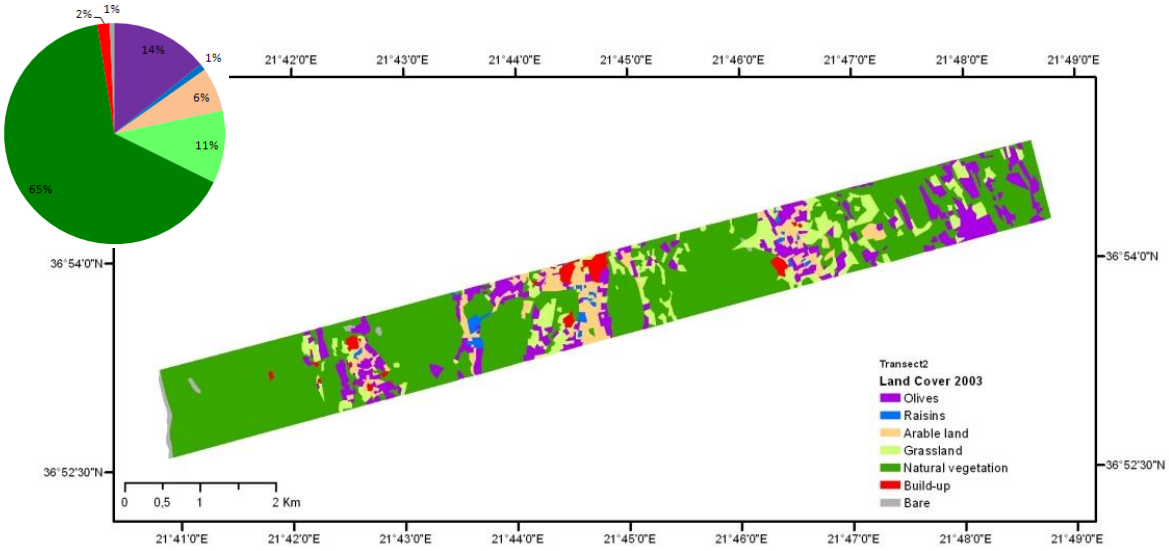


Figure. 21. Maps explaining the changes in land cover between 1945 and 2003 for transect 2: A) Topography and geology based on geological map from geological mapping service and SRTM-DTM, B) land cover anno 1945 digitized on aerial photographs and C) land cover anno 2003 digitized on Google Earth.

Hill slope erosion mapping using aerial photographs and very high resolution satellite imagery

The same images (1945 aerial photographs and 2003 images from Google Earth) were used to understand how vegetation cover has changed in the two blocks that are seriously affected by hill slope erosion (Fig. 18).

In both blocks we see an obvious decrease in areas still prone to slope degradation.

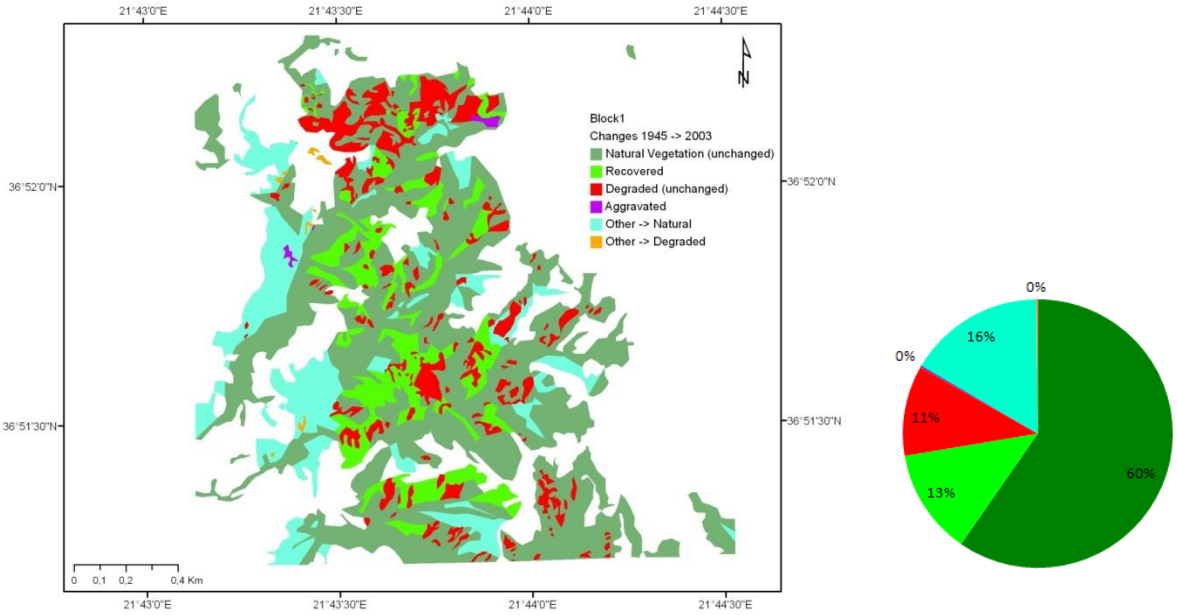


Figure 22. Map showing the changes in land cover and evolution in slope erosion between 1945 - 2003 for the ravines in Block 1. (Based on aerial photographs of 1945 and Google Earth images of 2003)

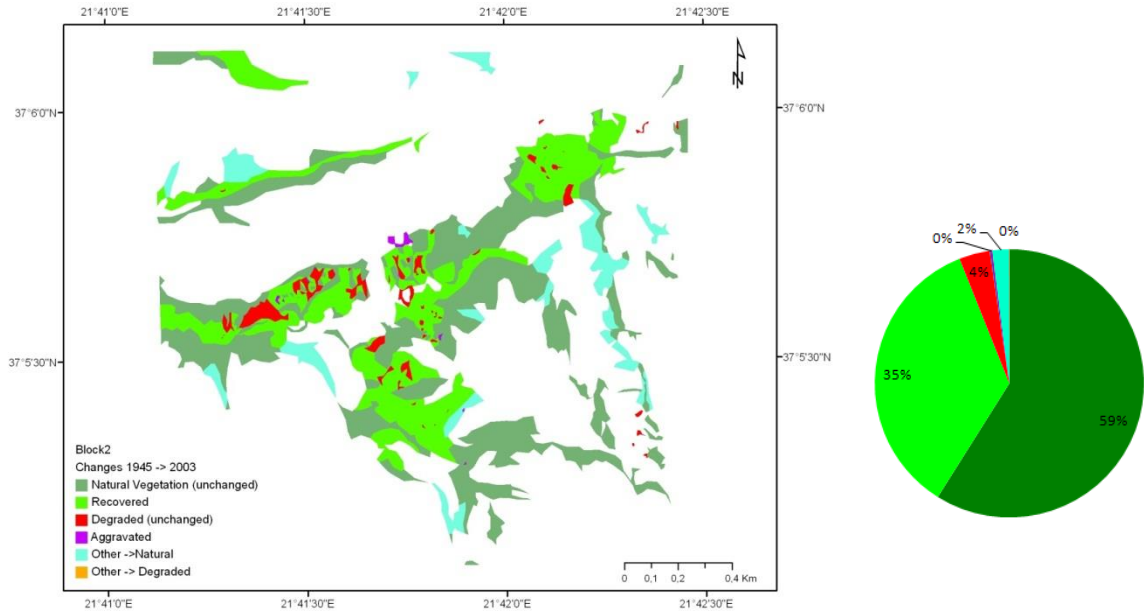
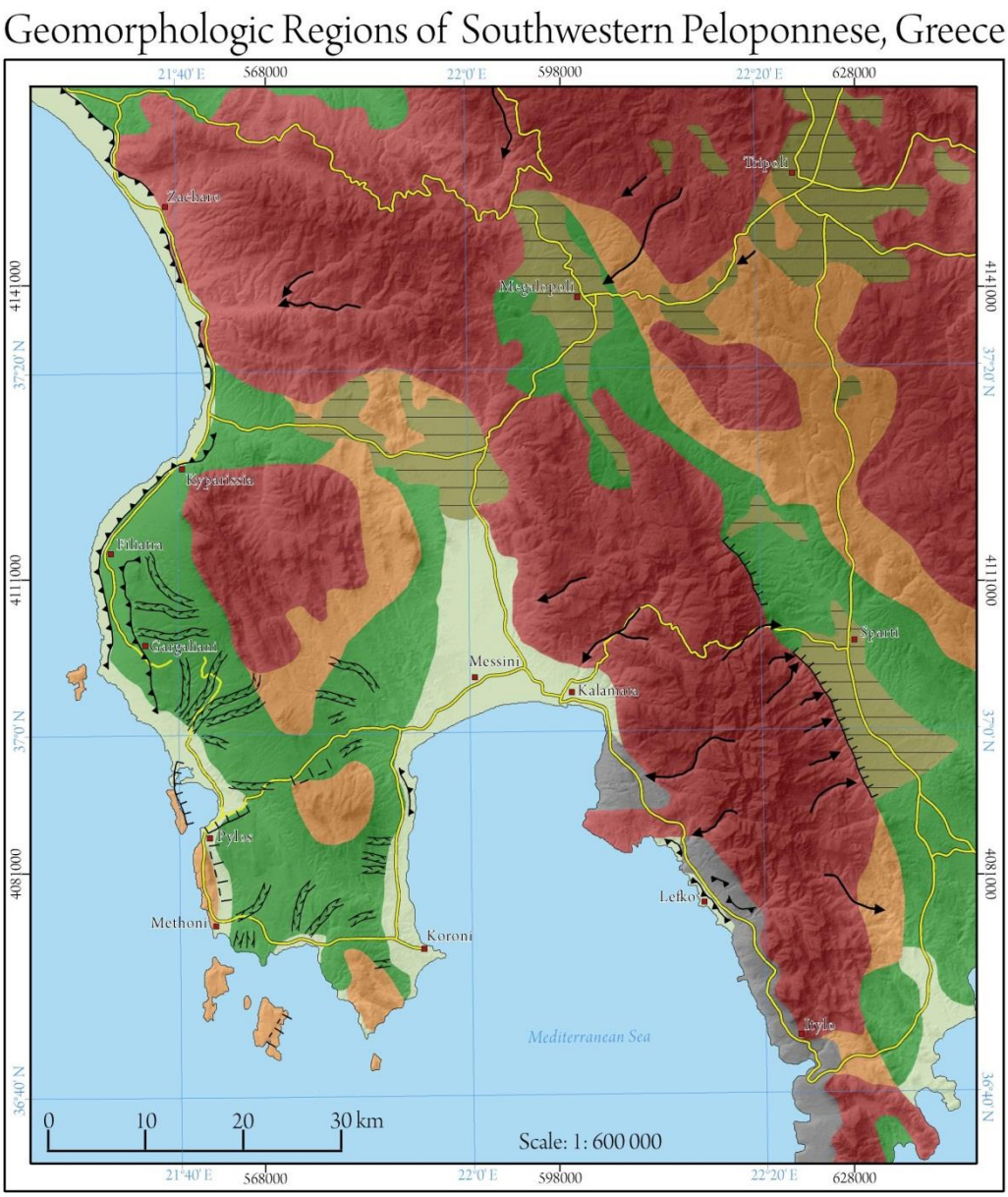


Figure 23. Map showing the changes in land cover and evolution in slope erosion between 1945 - 2003 for the ravines in Block 2. (Based on aerial photographs of 1945 and Google Earth images of 2003**)**

2. Map of Geomorphology of Peloponnese.



Mountain relief characterized by pronounced valleys and mostly bare bedrock or thin soil cover

Hilly relief

Mountain foreland

Pediment surface, truncated by marine erosion

Coastal lowland

Flat-floored intermontane basin

Sea

Canyon

Gullies and channels in marine sediment

Fault scarp

Fault scarp, inferred

Scarp formed by marine abrasion

Main road

Pylos Cities

This map was created by Fredrik Ottosson as a student projec at the Department of Physical Geography and Quaternary Geology, Stockholm University.
Interpretation of geomorphology: Johan Kleman and Ingmar Borgström.
Map datum: WGS84, Map projection: UTM Zone 34N.
UTM coordinates in black (m) and grid coordinates for latitude and longitude in blue.
Sources of information: ESRI, GSHSS, Google Maps, SRTM 30 m.
Year of production: 2011.

The hilly relief in the Navarino Bay area. The island Sfakteria with its almost vertical fault scarp to the right, and the Aghios Nikolaos mountain in the background. Pylos to the left.

Appendix 1: Transects showing topography and geology of Messinia.

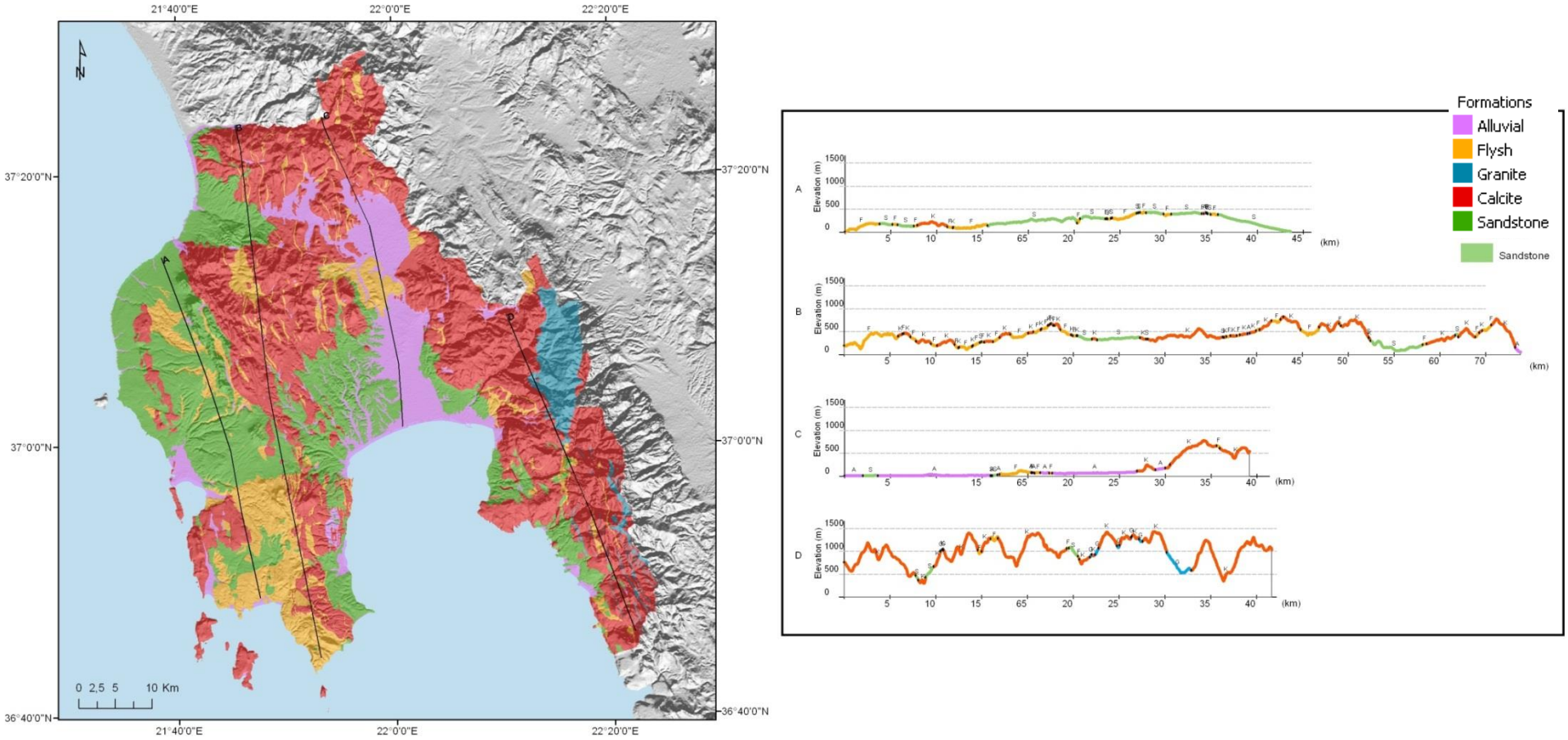


Figure 24. North-South transects for topography and geology of Messinia (based on geological map and SRTM-DTM)

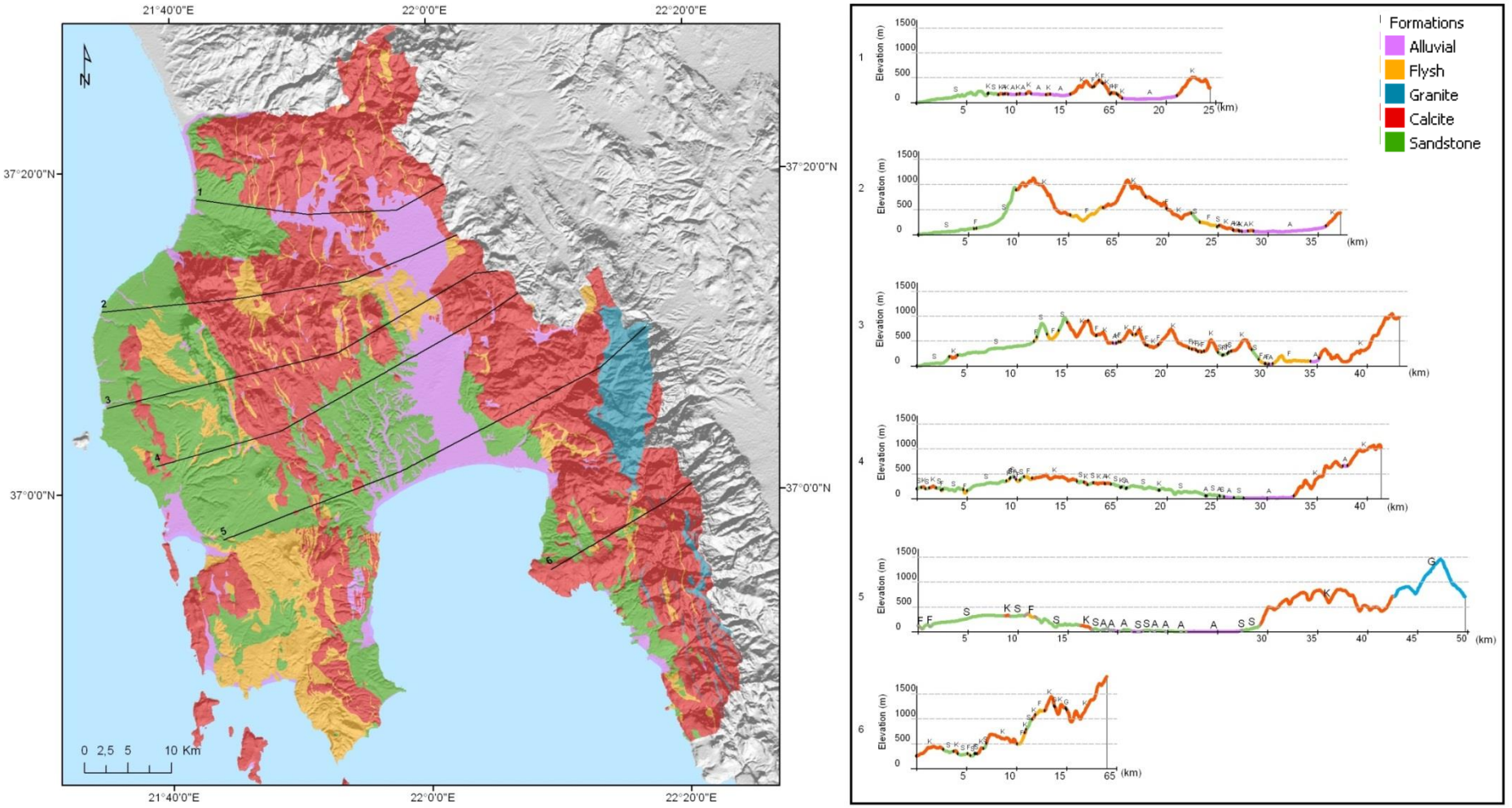
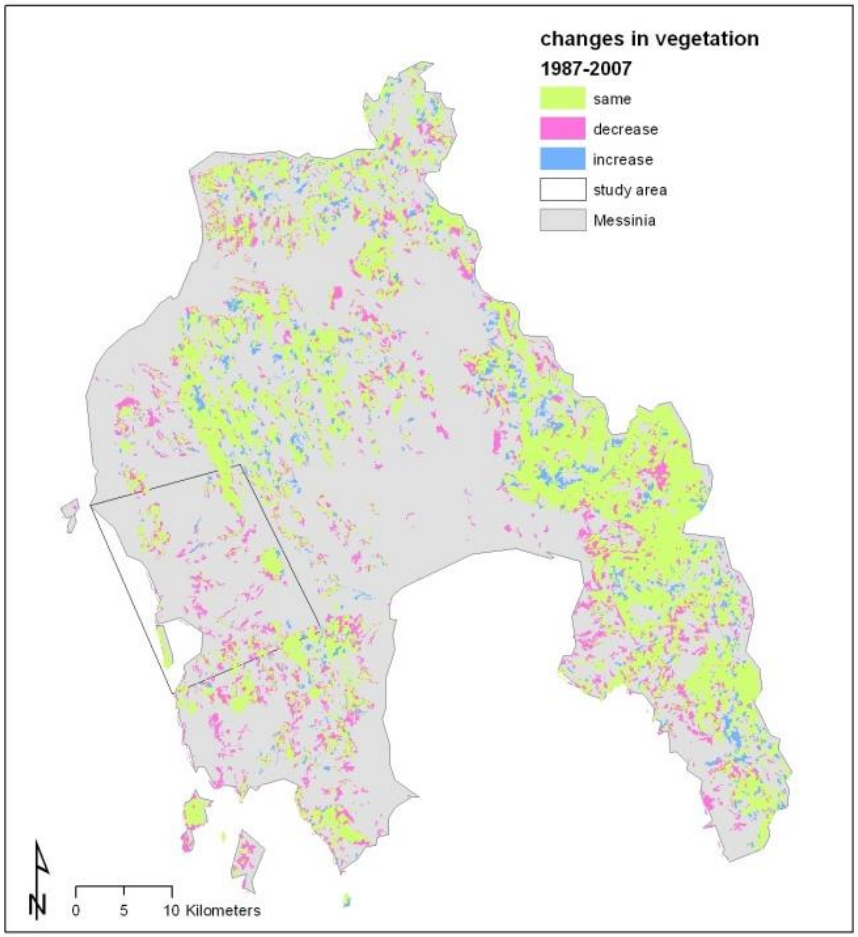


Figure 25. East-West transects for topography and geology of Messinia (based on geological map and SRTM-DTM)

Appendix 2: Transects showing topography and geology of Messinia.



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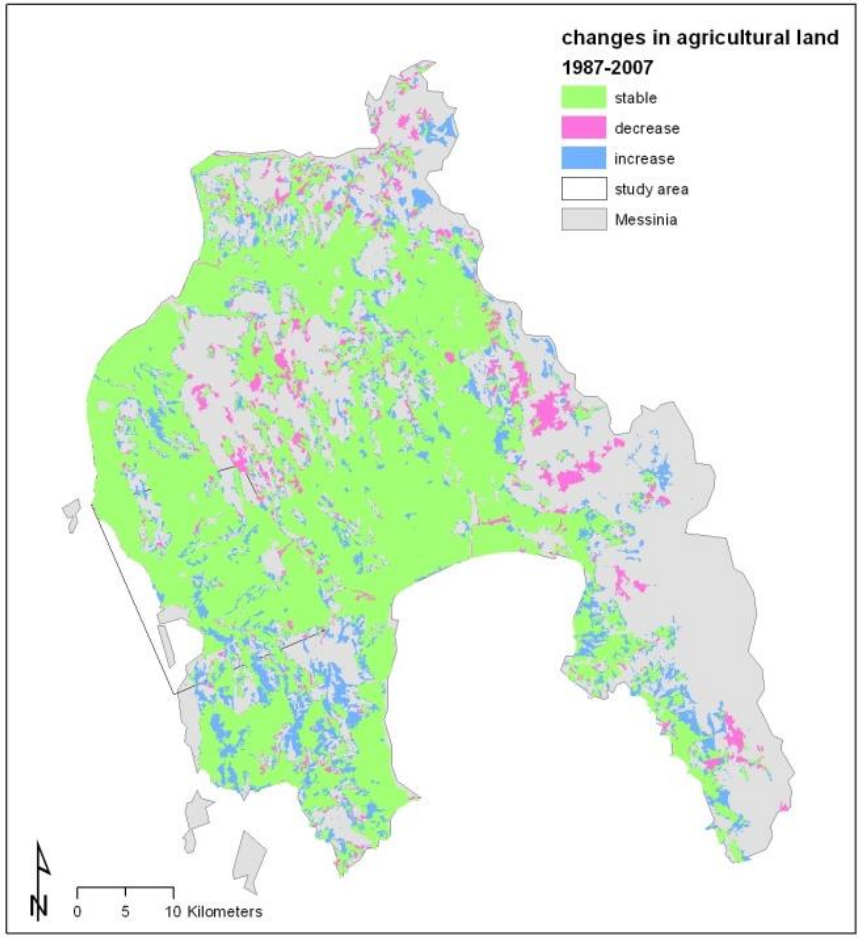


Figure 26. Changes between 1987 and 2007 in the area covered by A) natural vegetation and B) cultivated land.

Based on land cover maps derived from LANDSAT images by Aristotle University of Thessaloniki and WWF Greece, 2011.

Appendix 4: Coastal formation

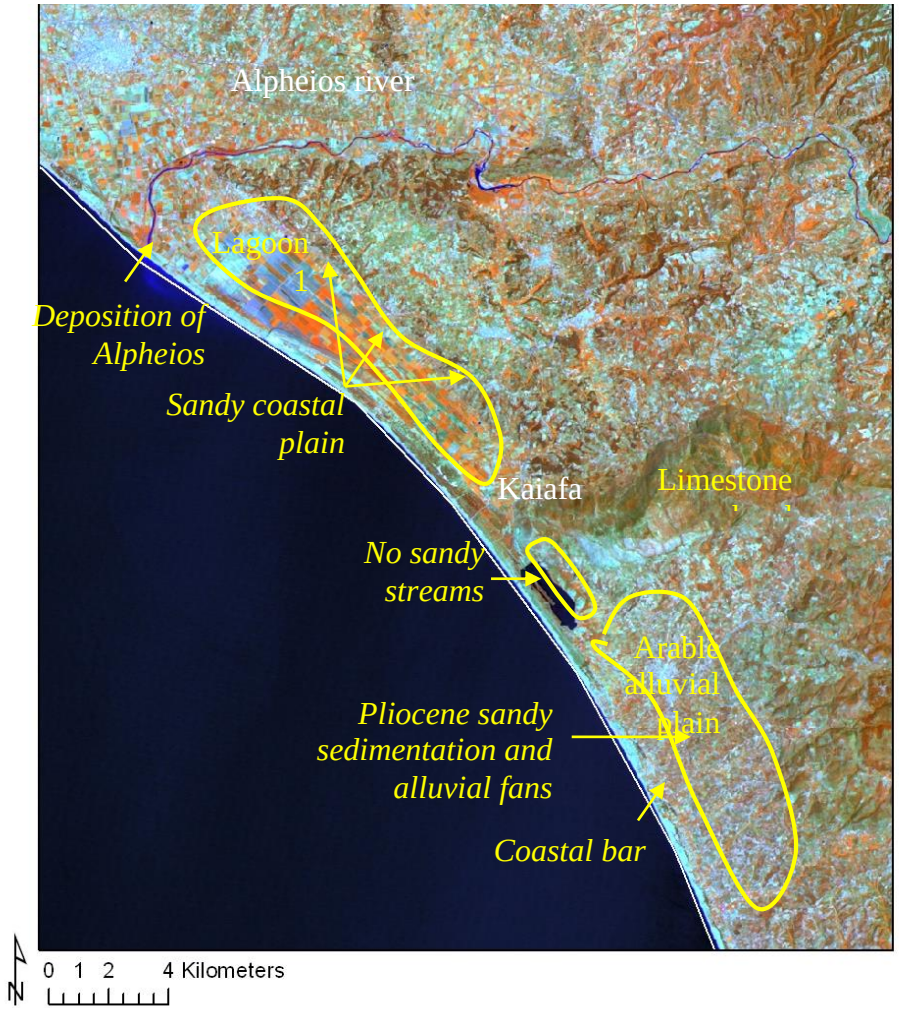


Figure . 27. Examples of different stages of lagoon formation between Pirgos and Kyparissia which lead to smoothening of coastline. (Based on Loy & Wright 1972)

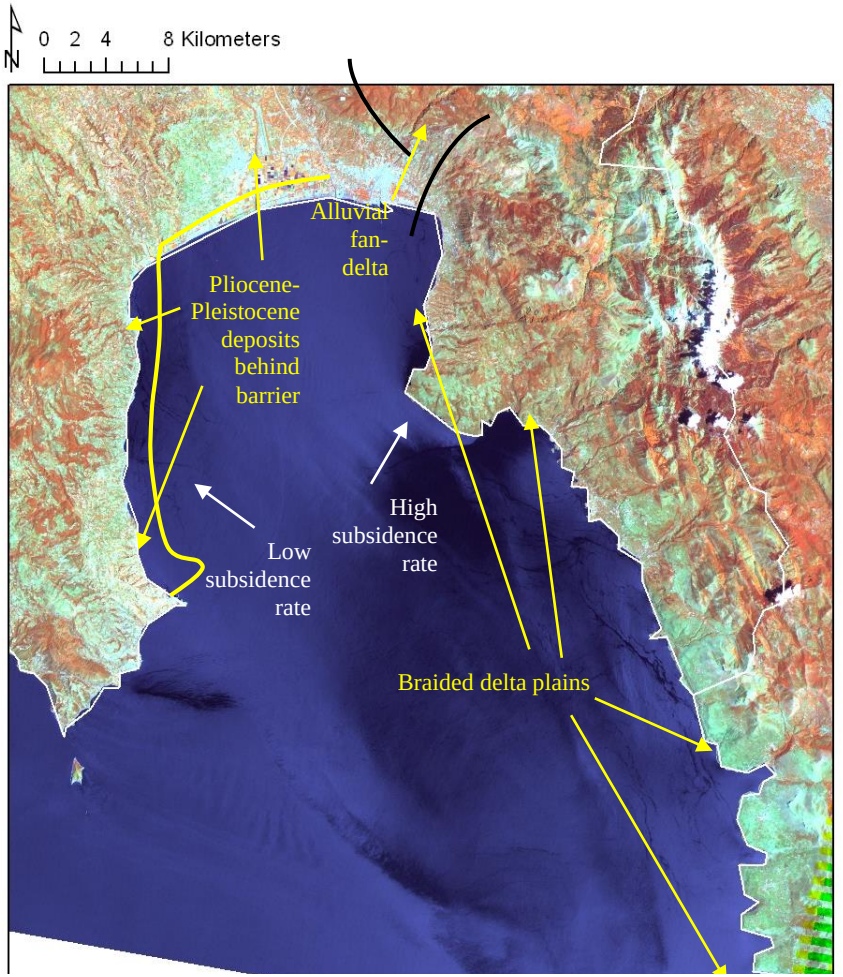


Figure . 28. Coastal processes in Kalamata bay (Based on Loy & Wright 1972 and Zeilidis & Kontopoulos 1999)

Outreach

No outreach activities were carried out in 2011

Planned activities for 2012

For 2012 we have restructured the research approach so that it constitutes three sub-projects:

A. *Tectonic geomorphology*

Here we primarily contribute with geomorphological mapping to underpin the work led by prof. Skelton, on dating of fault scarps and calculation of rates of tectonic movements. The *questions* we try to answer in this sub-project are primarily tectonic.

B. *Climatic-tectonic geomorphology over the last 120 kyr.*

This research track is developed to fully integrate the two main drivers for geomorphological change – climate and tectonics, and to more specifically focus on one time domain, the 120 kyr long last glacial cycle. From a geomorphological perspective, the rapid shifts in both temperature and precipitation in this period forced an altitudinal up-and-down migration of the dominant landform-producing processes. The 2400 m elevation range of the region gives very good opportunities to study the effects of this migration. Our approach involves three steps, (i) using published data on the present distribution of present-day geomorphological processes to establish a "baseline description" of spatial (including altitude) geomorphological process domains in the current climate, (ii) using available proxy data, and also climate modelling results, we "perturb" the baseline description from the first step, to arrive at hypothetical or predicted spatial domains of dominant process systems for each studied climate case. Initially we focus on two cases, full-glacial conditions, and one "intermediate glacial" climate". At this stage (iii), we correct for known tectonic movements, which may over this relatively long period have changed the altitude for each tectonic block. In the final step (iiii) we perform detailed field and airphoto studies to test whether there is evidence for the geomorphic evolution we predict to have occurred. The *questions* we try to answer here are primarily climatological and geomorphological.

C. *Geomorphology and land-use*

Focuses on the last few thousand years, the time period in which man has been a significant actor in shaping the landscape through changes in vegetation and land-use. Taking the amended pilot study by Josefien Delrue as a point of departure, we will focus on areas where change has been significant, and processes operate at such a speed that they can be studied by field investigations. Fieldwork as follow-up to the pilot study will be conducted in March 2012. We will also seek collaboration with archaeologists and geomorphologists at University of Patras for this sub-project.

Present and past climate, water and environmental changes

Water research

Research description

The water research in 2011 had the following main foci and objectives:

A. Derivation of generalized analytical solutions for quantification of seawater intrusion risk in coastal aquifers. The motivation for this derivation was to enable us to relatively simply account for different aquifer conditions, including realistic sloping aquifers, which could not previously be handled analytically, as well as climate and sea level change conditions, and different inland management scenarios for the fresh coastal groundwater. With these solutions derived, main follow-up objectives were to test them by site-specific application, and use them for general sensitivity analysis in order to understand the effects of different parameters, site conditions and change scenarios, and as a first separate follow-up application study, assess in particular the effects of climate-driven sea level rise on seawater intrusion under different aquifer, inland and sea level change scenarios.

B. Planning, carrying out and following up a NEO workshop on *Wetlands and Ecohydrology* held at Costa Navarino, October 20-26. The workshop had 23 participants in place from Stockholm University and the Royal Institute of Technology, Sweden, Purdue University, University of Iowa and University of Florida, USA, and the National Observatory of Athens (NOA), Hellenic Ornithological Society, TEMES and NEO management, Greece. Other invited participants, from Purdue University, USA, University of Western Ontario, Canada, and Institute of Marine Biology and Genetics, Hellenic Centre for Marine Research, Greece, could not make it to the workshop due to the strike situation at the time, but are part of follow-up activities, in which also additional participants have now started to join. Specifically, a main objective and actual follow-up outcome and activity from and after the workshop was the formation of an international research network: ***GWEN - G****lobal* ***W****etland* ***E****cohydrology* ***N****etwork: An Agora for Scientists and Study Sites*, which is described further below.

<u>Researchers involved</u>

- Gia Destouni, Professor, Stockholm University
- Steve Lyon, Lecturer, Stockholm University
- Carmen Prieto, Scientific Programmer/Research Engineer, Stockholm University
- Katerina Mazi, PhD student, Stockholm University

Major research activities 2011

The main research activities in 2011 with the foci and objectives A-B above included:

A. ***Derivation and application of generalized analytical solutions for seawater intrusion in coastal aquifers under changing conditions.*** Contamination of groundwater by intruding seawater is a major problem in the Mediterranean region as in many other parts of the world. Our work derived tnovel analytical solutions for addressing this problem by extending the Girinskii–Strack concept of discharge potential to represent regional, steady-state, sharp-interface seawater intrusion in sloping unconfined coastal aquifers. Any considered coastal aquifer is then described by hydraulic conductivity K, is recharged at the surface by natural precipitation and possibly also artificial recharge at the rate r, receives an inflow from regional groundwater flow at its inland boundary and may have groundwater pumped from it by a collector trough, or well gallery (idealised as line sink) located at some, arbitrary distance l_w from the coastline that penetrates the aquifer and draws groundwater at the rate q_w.

The theory rests on approximation of a linearised gravity-part of the hydraulic potential so that analytical solutions for the discharge potential could be derived, through which the hydraulic head, the flow depth and the sharp interface between intruding seawater and fresh groundwater, and particularly the location of the interface toe, l_T, into the aquifer can be determined. These solutions simplify to known, previous results for idealised, horizontal aquifer cases. The utility (and robustness to uncertainty regarding the aquifer base slope) of our generalized new solutions for sloping aquifers in realistic applications was tested and demonstrated by application to a regional example of the Akrotiri Coastal Aquifer, Cyprus.

By recasting the seawater intrusion problem in non-dimensional form, we further provided a relationship for the dependence of the relative interface toe location l_T/l_w on the appropriately normalised difference between the groundwater flow just up-gradient of the groundwater collector trough, q_o, and the pumping rate, q_w, given realistic values of aquifer base slope, r/K and H_{sea}/l_w, where H_{sea} is the sea-surface elevation above the aquifer base at the coastline. That relationship frames a common groundwater management problem in coastal aquifers subject to a certain exploitation scheme, with the resulting position of the seawater-fresh groundwater interface toe l_T as decision variable. In the exploratory demonstration study of the regional Akrotiri aquifer, non-dimensional sets of performance curves were calculated.

In general, the derived analytical solutions can be used for first-order assessments of seawater intrusion vulnerability and management possibilities across a wide range of current regional coastal aquifer conditions and/or projected water demand, groundwater management and climatic change scenarios. During 2011, we started a new application study of these solutions, assessing in particular the effects of climate-driven sea level rise on seawater intrusion under different aquifer, inland and sea level change scenarios. This study will be finalized and submitted for publication during spring 2012.

B. ***NEO workshop on*** **Wetlands and Ecohydrology,** ***Costa Navarino, October 20-26, and follow-up formation of the international research network:*** **GWEN - Global Wetland Ecohydrology Network: An Agora for Scientists and Study Sites.** The full agenda and list of participants (shown in Fig. 29 below) for the workshop are given in Appendices A and B, respectively. Here we focus on shortly describing the main workshop outcome, which is the formation of GWEN, based on the workshop participants, as well as additional participants that have by now also started to join, and their relevant investigation sites. The main objectives of GWEN are:

- To *catalyze and sustain collaborative international efforts* in research, education and outreach.
- To *investigate on different spatiotemporal scales and in different world regions:*

a. The dynamics of natural and managed wetland networks and individual wetlands (wetlandscapes) across a gradient of different climate, human disturbance, energy and organization conditions.

b. The reciprocal interactions between wetland networks and associated watersheds, and how humans influence these interactions.

c. How climate change and different human activities, in particular agrosystems, in the wetland watersheds influence the ecohydrology of wetland networks and individual wetlands.

d. The ecosystem services provided by networks of wetlands.

Figure 29. Participants in NEO workshop on *Wetlands and Ecohydrology* held at Costa Navarino, October 20-26, with view over the Gialova Lagoon. Photo taken by Ioannis Antonopoulos.

In view of the objectives, the following research questions have been prioritized for the first phase of GWEN:

1.

a. In what contexts and how are distributed wetlands in a landscape not functionally equivalent to a large wetland?

b. What general lessons can be learned from cross-regional comparisons of retrospective reconstruction of impacted wetland trajectories and monitoring of restoration efforts?

c. What strategies, management practices and system criteria contribute to successful and efficient wetland restoration efforts?

d. What are the socio-economic barriers (e.g., financial, risk aversion) contributing to social "resistance" along the decision paths toward adopting and implementing best practices for sustaining desirable wetland functionalities?

2. How are hydrology, biogeochemistry, biodiversity and ecological functioning at both watershed and wetland scales influenced by:

a. Landscape attributes (prevalence, connectivity, landscape position) of wetland networks, and internal feedback mechanisms within wetlands?

b. Management, and non-stationary climate and land-use?

3. What is the connection between wetland (individual and network) evolution and agricultural development-management – from the past, through present time, to future projections - in drainage basins?

4.

a. Can we identify some set of characteristic wetland network attributes that regulate and can be used in predictive modeling and evaluation of ecohydrological behavior and associated (bundles of) ecosystem services in drainage basins?

b. How do sediment-water-plant wetland systems, and individual wetlands, in drainage basins modulate the ecosystem services (and associated disservices, in parenthesis) of:

- Filtering/attenuating (and export loading) of waterborne tracers and pollutants in (from) the drainage basins?
- Sinks (and emissions to the atmosphere) of greenhouse gases – including water vapor - in (from) the drainage basins?

Active research by GWEN participants is conducted at several sites with diverse scientific foci within the main objectives and research questions outlined above. The GWEN coordination and integration, through data and model syntheses and evaluations, will enhance these efforts for the GWEN study sites, shown in Fig. 30 below. The current GWEN steering committee consists of:

- Nandita Basu, University of Iowa, USA

- Matt Cohen, University of Florida, USA
- Irena Creed, University of Western Ontario, Canada
- Georgia Destouni (chair), Stockholm University, Sweden
- Antonis Koussis, National Observatory of Athens (NOA), Greece
- Steve Lyon, Stockholm University, Sweden
- Suresh Rao, Purdue University, USA
- Ype van der Velde, Stockholm University, Sweden

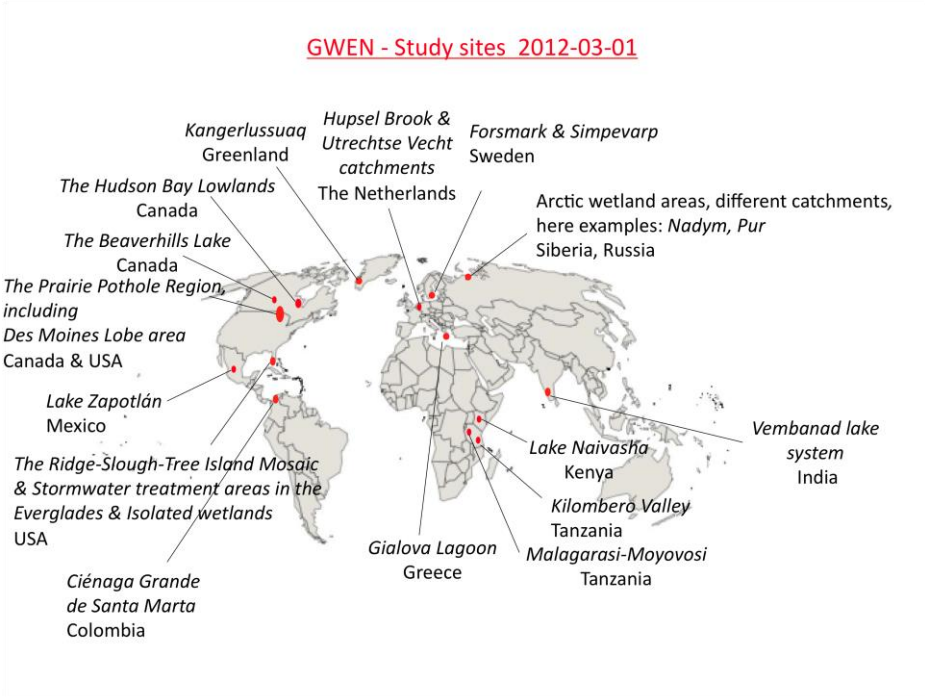


Figure 30. The current GWEN study sites.

Scientific Publications

A. Koussis A.D., Mazi K., Destouni G. (2012). Analytical single-potential, sharp-interface solutions for regional seawater intrusion in sloping unconfined coastal aquifers, with pumping and recharge. *Journal of Hydrology*, 416–417, 1-11, doi:10.1016/j.jhydrol.2011.11.012.

B. Georgia Destouni, Nandita Basu, Matthew J. Cohen, Helen Dahlke, Fernando Jaramillo, Jerker Jarsjö, James W. Jawitz, John Juston, Elin M. Karlsson, Antonis D. Koussis, Steve Lyon, Katerina Mazi, Johanna Mård-Karlsson, Carmen Prieto, Suresh C. Rao, Ype van der Velde, Nikki Vercauteren (2012). Hydro-Biogeochemical and

Environmental-Management Functions of Wetland Networks in Landscapes. Invited oral presentation at *9th International Wetlands Conference (INTECOL) – Wetlands in a Complex World*, Orlando, Florida, USA, June 3-8, 2012.

Abstract

A main application goal of ecohydrological science is to amplify opportunities of achieving water quality improvements, biodiversity enhancements and sustainable development, by improved understanding and use of ecosystem properties as a management tool. This paper draws on and synthesizes main result implications for the function and possible enhanced use of wetland networks in the landscape as such a tool, from a series of hydro-biogeochemical and environmental economics studies of nutrient/pollutant loading and abatement in different Swedish hydrological catchments. Results show large potential of wetland networks to reduce the cost of abating nutrient and metal loads within and from hydrological catchments, and emphasize some main research questions for further investigations of actual possibilities to realize this potential. The questions regard in particular the ability of wetland networks to extend the travel times and reduce the uncertainty of hydrological nutrient/pollutant transport through catchments.

The paper further presents and discusses some main joint conclusions of the participants in a recently held International Workshop on Ecohydrology and Integrated Water Resource Management (1) at the Navarino Environmental Observatory in Messinia, Greece (2), regarding essential goals for collaborative international efforts in wetland network research. The goals include to investigate on different spatiotemporal scales and in different world regions: a) the dynamics of natural and managed wetland networks across a gradient of different climate, human disturbance, energy and organization conditions; b) the reciprocal interactions between wetland networks and associated hydrological catchments; c) how climate change and different human activities in the wetland network catchments influence these interactions (in b) and generally the ecohydrology of individual wetlands and the whole wetland networks; and d) the ecosystem services provided by networks of wetlands.

(1) http://navarinoneo.geo.su.se/index.php/en/past-events/91-ecohydrology-and-integrated-water-resource-management-workshop

(2) http://navarinoneo.geo.su.se/index.php/en/

Contact Information: Georgia Destouni, Department of Physical Geography and Quaternary Geology, Stockholm University, SE-106 91 Stockholm, Sweden. Phone: +46 8 16 4785, Email: georgia.destouni@natgeo.su.se

Outreach

Destouni G., Water research challenges and opportunities for the 21st century, presentation within *NEO Lecture Series 2011*, at the University of the Peloponnese, Kalamata, Greece, October 19, 2011.

Planned activities for 2012

A. To finalize and publish the already in 2011 started application study of the derived new analytical solutions, on the effects of climate-driven sea level rise on seawater intrusion under different aquifer, inland and sea level change scenarios. Further to start a new study, where these solutions are applied to the understanding of saltwater intrusion and salinity conditions and development at the Gialova Lagoon site, linking this also to the general wetland research of GWEN.

B. To write and submit for publication a first GWEN synthesis paper. Furthermore to coordinate related research efforts and results at the different GWEN study sites, and possibly also add new sites and participants strategically, to increase the diversity and global coverage of different site conditions, system scales, and site investigators in terms of disciplinary knowledge, and modelling and monitoring approaches.

Appendix A

NEO workshop on *Wetlands and Ecohydrology*
Costa Navarino, Peloponnesos, Greece, October 20-26

AGENDA
THURSDAY, OCTOBER 20

Arrivals at Marathopolis

FRIDAY, OCTOBER 21

8:00 Meeting time to go together to the workshop venue

9:00 – 9:15 Welcome, workshop information, Georgia Destouni

9.15 Departure for Sgrapa monastery

9.30 Meeting at Sgrapa monastery. View of the lagoon from above, quick briefing on hydrology, flora and fauna by Hellenic Ornithological Society (HOS)

9.45 Departure for Gialova Lagoon

10.00-12.00 Visit of Gialova Lagoon covering the following topics:

· Birdwatching Trail till the Observation tower: Hydrology, birds and history of the lagoon

· Hide observatory: Birds and their habitats

· Nature Trail: Sensitive habitats/ chameleons

· Information Centre (old Pump House): HOS activities

12.00-12.30 Return to the workshop venue, quick coffee break

12.30-13.00 Presentation by HOS: "Gialova Lagoon. An Important Bird Area, part of the NATURA2000 network. Alterations occurred in hydrology and habitats during the 20th century". Dimitris Bousbouras, Giorgos Maneas

13.00-13.30 Presentation by TEMES: "TEMES environmental monitoring system. Use of meteorological stations network for assessing the spatial distribution of rainfall in West Messinia. Preliminary analysis concerning the Xerolagado catchment and Gialova Lagoon." G. Antonopoulos, V. Karakousis

14:00 – 15:30 Joint lunch

15:30 – 18:00 Discussion, working groups (coffee available from 16:30)

SATURDAY, OCTOBER 22

10:30 – 14:00 Working groups (coffee available from 11:30)

14:00 – 15:30 Joint lunch

SUNDAY, OCTOBER 23

Free day

Possible activities arranged by Navarino outdoors department. Please register latest on Monday 17th (see attached information):

- Bike Trekking (Level Easy) Gialova Lagoon / Voidokilia
- Bike Trekking (Level Easy) Gargaliani / Proti Island
- Hiking Tour (Level – Medium) Polylimnio Waterfalls
- Hiking Tour (Level – Medium) Paleokastro

MONDAY, OCTOBER 24

9:00 – 9:30 Presentation of NEO by Karin Holmgren, Professor in Physical Geography and
Director of NEO, and Nikos Kalivitis, PhD and NEO Station Manager
9:30 – 9:40 Georgia Destouni, WG introduction, tasks/questions

10:00 – 14:00 Speed presentations (5min + 5min questions/discussion) by participants

9:40 – 9:50 Georgia Destouni, Stockholm University - Linking climate, hydrological and ecological variability and change on landscape scales - role of wetlands?
9:50 – 10:00 Suresh Rao, Purdue University - Wetlandscapes AGOWRA
10:00 – 10:10 Jim Jawitz, University of Florida - Inequality and stationarity in catchment discharge and load
10:10 – 10:20 Nandita Basu, University of Iowa - Hydrologic Connectivity of Distributed Landscape Storage: Ideas for Collaboration
10:20 – 10:30 Matt Cohen, University of Florida - Emergent Inference from High Resolution Sensor Measurements in Wetlands and River Networks
10:30 – 10:40 Antonis Koussis, National Observatory of Athens (NOA) - Estimating flood discharges in ungauged Greek basins under conditions of hydro-climatic variability
10:40 – 10:50 John Juston, Royal Institute of Technology, Stockholm - Data based modeling and uncertainty analysis
10:50 – 11:00 Steve Lyon, Stockholm University - Linking landscape structure and hydrological response

11:00– 11:10 Jerker Jarsjö, Stockholm University - Plant uptake of elements in pore water

11:10 – 11:20 Katerina Mazi, Stockholm University and NOA - A sharp-interface analytical solution of sea-water intrusion in sloping coastal aquifers

11:20 – 11:30 Johanna Mård Karlsson, Stockholm University - Thermokarst lake and wetland complexes in north-western Siberia

11:30 – 11:45 Coffee break with NEO instrumentation presentation

11:50 – 12:00 Elin Karlsson, Purdue University - Wetlandscapes dynamics

12:00 – 12:10 Fernando Jaramillo, Stockholm University - Influence of land use change on basin hydrological flow partitioning

12:10 – 12:20 Carmen Prieto, Stockholm University - Land-sea and land-atmopshere hydro-climatic interactions

12:20 – 12:30 Ype van der Velde, Stockholm University - Catchment-scale mixing of water and nutrients

12:30 – 12:40 Nikki Vercauteren, Stockholm University - Open water surface evaporation

12.40 – 12.50 Helen Dahlke, Stockholm University - Identification of water sources using stable isotopes

14.05 – 14.15 Discussion

14:15 – 15:30 Lunch break

15:30 – 18:00 Working groups (coffee available from 16:30)

TUESDAY, OCTOBER 25

9:00 – 11:00 Working groups

11:00 – 11:30 Coffee break

11:30 – 13:30 Working groups

13:30 – 15:00 Lunch break

15:00 – 18:00 Working group reports. Discussion and conclusions. Action list. (coffee available from 16:30)

20:00 – 21:30 Joint dinner

WEDNESDAY, OCTOBER 26

Departures

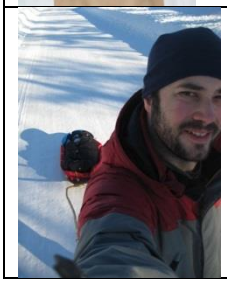
Appendix B

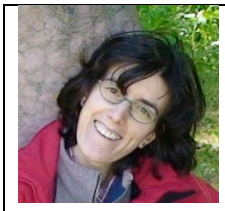
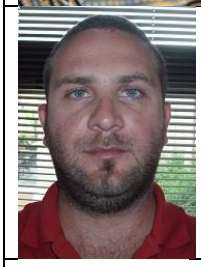
LIST OF PARTICIPANTS – AND THEIR PRESENTATION TOPICS

NEO workshop on *Wetlands and Ecohydrology*

Costa Navarino, Peloponnesos, Greece, October 20-26

	**Georgia Destouni** Stockholm University georgia.destouni@natgeo.su.se Linking climate, hydrological and ecological variability and change on landscape scales - role of wetlands?
	**Suresh Rao** Purdue University pscr@purdue.edu Wetlandscapes AGOWRA
	**Jim Jawitz** Univ of Florida jawitz@ufl.edu Inequality and stationarity in catchment discharge and load
	**Nandita Basu** University of Iowa nandita-basu@uiowa.edu Hydrologic Connectivity of Distributed Landscape Storage: Ideas for Collaboration
	**Matt Cohen** Univ of Florida mjc@ufl.edu Emergent Inference from High Resolution Sensor Measurements in Wetlands and River Networks
	**Antonis Koussis** National Observatory of Athens (NOA) akoussis@meteo.noa.gr Estimating flood discharges in ungauged Greek basins under conditions of hydro-climatic variability

	**John Juston** Royal Institute of Technology juston@kth.se Data based modeling and uncertainty analysis
	**Steve Lyon** Stockholm University steve.lyon@natgeo.su.se Linking landscape structure and hydrological response
	**Jerker Jarsjö** Stockholm University jerker.jarsjo@natgeo.su.se Plant uptake of elements in pore water
	**Katerina Mazi** Stockholm University and NOA kmazi@meteo.noa.gr A sharp-interface analytical solution of sea-water intrusion in sloping coastal aquifers
	**Johanna Mård Karlsson** Stockholm University johanna.maard@natgeo.su.se Thermokarst lake and wetland complexes in north-western Siberia
	**Elin Karlsson** Purdue University ekarlsson@purdue.edu Wetlandscapes dynamics
	**Fernando Jaramillo** Stockholm University fernando.jaramillo@natgeo.su.se Influence of land use change on basin hydrological flow partitioning

	**Carmen Prieto** Stockholm University carmen.prieto@natgeo.su.se Land-sea and land-atmopshere hydro-climatic interactions
	**Ype van der Velde** Stockholm University ype.vandervelde@natgeo.su.se Catchment-scale mixing of water and nutrients
	**Nikki Vercauteren** Stockholm University nikki.vercauteren@natgeo.su.se Open water surface evaporation
	**Helen Dahlke** Stockholm University helen.dahlke@natgeo.su.se Identification of water sources using stable isotopes
	**Karin Holmgren** Stockholm University and NEO Director karin.holmgren@natgeo.su.se NEO research presentation
	**Nikos Kalivitis** Stockholm University and NEO Station Manager nikos.kalivitis@natgeo.su.se NEO research presentation
	**Vasilis Karakousis** TEMES vkarakousis@temes.gr TEMES environmental monitoring system

	**Ioannis Antonopoulos** TEMES iantonopoulos@temes.gr TEMES environmental monitoring system
	Dimitris Bousbouras Hellenic Ornithological Society Gialova Lagoon presentation
	Giorgos Maneas Hellenic Ornithological Society Gialova Lagoon presentation
	**Dev Niyogi** - ***could not make it to the workshop due to strike situation*** Purdue University dniyogi@purdue.edu Land Surface Modeling
	**Irena Creed** - ***could not make it to the workshop due to strike situation*** Univ of Western Ontario icreed@uwo.ca Wetlands are determinants of hydrological, biogeochemical and ecological dynamics in landscapes
	Representative from Institute of Marine Biology and Genetics, Hellenic Centre for Marine Research **- *could not make it to the workshop due to strike situation***

Dendroclimatology

Research description

Annual layers of wood (tree rings) in old-living trees keep within their physical and chemical properties a history of past climate change. Depending on the age of living trees, and the timespan covered by dead wood remains, detailed information on past climates may be disclosed for hundreds and sometime thousands of years using analysis methods of dendroclimatology. Records of e.g. ring width, maximum density, and carbon and oxygen isotopes, can therefore be regarded as an approximation (proxies) of the past climate. Their high temporal resolution (annual) and relatively strong link to temperature and precipitation, together with their geographical distribution, have made tree-rings one of the most widely used proxies in reconstructions of climate change for the last millennium (c.f. Jensen et al. 2007, and Jones et al. 2009).

Tree rings like many other types of proxies are calibrated using modern day conditions and rely on the "principle of uniformitarism". That is, we have to assume that the present day observed links between environmental processes and tree growth have been uniformly in operation in the past. Tree-ring records are calibrated using instrumental meteorological data from the modern period; typically the last c. 100 years and the principle of uniformitarism can to some degree be tested by keeping a part of the record separate from the calibration and instead used for validation. However, the time period(s) used for calibration (and validation) are contemporaneous with a significant anthropogenic impact on the environment and the climate, which means that the veracity of this principle is difficult to test and any inconsistency may potentially bias reconstructions of the past climate. For example, the increasing concentrations of CO2 in the atmosphere have likely increased the water-use efficiency in draught sensitive trees.

Pine trees growing in the high Greek mountains are close to their ecological limit which means that even small changes in temperature and/or precipitation will have a relatively strong impact on growth conditions: High elevation trees at cold/moist sites will be more temperature sensitive while trees at warm/dry sites will be more draught sensitive. The NEO Dendroclimatology project will take advantage of the contrasting climatic sensitivity between different tree-line locations in Greece to study the impact

on water-use efficiency in trees from changes in temperature, precipitation, and atmospheric CO2. This knowledge will be used to develop new and improved methods in dendroclimatology and will be used in local and regional climate reconstructions for the past millennium.

Researchers involved

- Håkan Grudd, Senior researcher, Stockholm University
- Christos Zerefos, Professor, Academy of Athens
- Paul Krusic, PhD student, Stockholm University
- Evangelos Gerasopoulos, Senior researcher, National Observatory of Athens

Major research activities 2011

A PhD student (Paul Krusic) was employed in late 2010 in the NEO Dendroclimatology project. Initially, he has focused on advanced courses in statistics and climate change science at the Bert Bolin Centre of Stockholm University. He also participated in an international summer school in Kiato, Greece, on "Tree Rings, Climate, Natural Resources and Human Interaction" (http://www.dendro.gr/). As of December 2011 Paul Krusic has achieved 45 of the 60 course credits required for a doctoral degree.

In April, Paul Krusic and Håkan Grudd (PI) travelled to Athens and Messenia to meet with Professor Christos Zerefos and Dr. Evangelos Gerasopoulos of the Academy of Athens. During this meeting a new collaborative project was initiated regarding the potential to use oak tree rings from archaeological and historical monuments as dendroclimatic indicators. As a pilot study, samples from the famous "Pausanias tree" will be used. This tree grew up up at a point located 1 km from the famous statue of the Lion of Heronia, about 60 km to the northwest of Athens. The statue was erected to commemorate the victory of King Philip and his son, Alexander the Great at a battle which led to the unification of most of the Greek cities under one king, King Philip. According to historians, like Pausanias, Alexander the Great camped under an oak tree of immense dimensions before the battle and this tree got the name of Pausanias tree.

The samples belong to an almost 400 year gigantic oak tree growing at this location and which may be a descendant to the historical Pausanias tree. It was recognized as such by archeologists and they passed a bill at the Greek Parliament in 1975 considering the tree as a historical natural monument for preservation. Unfortunately, the tree was severely damaged by a series of thunderstorms and lightning in the mid 1980s. The Academy of Athens was able to save part of a branch, one meter in diameter and about 10 meters in length, from which there are cross sections preserved (Fig. 31).

Figure 31. Cross section of a branch from the "Pausanias tree".

One large sample section was brougth to the tree-ring laboratory in Stockholm for analyses of ring width, dendity and chemical composition. The tree-ring series will be compared to climate data from the same location to evaluate the potential for climate reconstruction..

A second purpose of the April visit to Greece was for Krusic & Grudd to familiarize with the nature and environment of Greece and to find good sites for the upcoming fieldwork. They also met with Dr. Ioannis Telelis at the Research Center for Greek and Latin Literature to discuss sources of climatic information in the historical Greek literature. During this first reconnaissance visit they also had the opportunity to meet with several representatives of forestry management in Messinia, which was very important for planning of the field activities.

A most important contact person and collaborator is Dr. Robert Brandes: From 2001 to 2006 he traveled all over Greece visiting treeline forests for his dissertation work on alpine forest ecology at the University of Erlangen, Nurnberg, Germany (Brandes 2007). Dr. Brandes has kindly helped with invaluable information on high-elevation sites and he even teamed up for the fieldwork to provide help and to introduce Paul Krusic for many local foresters, forest scientists and park officials.

Figure 32. Land Rover country. The *Pinus heldreichii* in the background are growing on the western slopes of Mt. Gramos.

The main fieldwork of 2011 was carried out in July: On June 25 Paul Krusic was driving from Stockholm to Greece in his private Land Rover specially equipped for fieldwork and travelling in the high mountains (Fig. 32). Upon arriving in Igoumenitsa by ferry from Venice he was met by Dr. Robert Brandes. From Igoumenitsa they drove to Ioannina then on to Samarina, a mountain village in the Smolikas range (SMO_1) near the border with Albania, the start of what would be a long north to south traverse of Greece ending at the bottom of Peleponnesos. The first site sampled was one Robert Brandes had visited eleven years earlier (Fig. 33). Here there are *Pinus heldreichii* (PIHE) growing in a barren landscape with little organic soil and serpentine bedrock, a perfect environment for extreme drought stress conditions. In 2000 when Dr. Brandes was working in Greece, he was most interested in the ecology of such sites, how trees regenerated and survived, the role of fire, anthropogenic impacts, etc. on shaping the forest we see today. Though Dr. Brandes did collect increment core samples from some of his sites, mostly for the purpose to

evaluate the vigor and community dynamics of the stands he studied, he did not directly assess his sites for climate reconstruction purposes.

Figure 33. Up: Coring *Pinus heldreichii* at high elevation in the Smolikas range of north western Greece. Down*: Pinus nigra* growing on the eastern slopes of Profitis Ilias in the Taygetos range, Peloponnesos.

From Samarina Krusic & Brandes worked their way to the Taygetos Mountains in southern Peleponnesos collecting samples from six locations along the way (Table 3). At three of the sites SMO_1, VK_02 and PE_01 there is definite potential for producing long, millennial-length, chronologies through the use of dead wood preserved by the dry and cool climates that dominate these treeline environments (Fig. 34).

Figure 34. Sampling dead and down *Pinus heldreichii* (PIHE) with a chain saw in Valia Kalda. Both living and fallen trees were collected.

Name	Site ID	Species	Lon.	Lat.	Elev.	Type	#radii
Smolikas	SMO_1	PIHE	21.01172	40.10713	2199	C	22
Mt.Gramos	GRA_1	PIHE	20.89000	40.31689	2042	C	18
Ilio Chori	ili_01	PINI	20.90071	39.98982	1050	C/D	42
Valia Kalda	VK_01	PINI	21.18871	39.90560	1455	C	18
Valia Kalda	VK_02	PIHE	21.1663	39.90842	1587	C/D	22
Profitis Ilias	PE_01	PINI	22.36556	36.95059	1513	C/D	26

Table 3. 2011 sites, species and collections. *Pinus heldreichii* (PIHE), *Pinus nigra* (PINI), cores (C), disks (D), Elevation (masl). A total of 148 samples.

In preparation for the analyses soon to come, Paul Krusic has started to look at the availability and integrality of various climate data sets from the region. To examine the regional significance of any climate proxy a useful first experiment is to determine how representative the climate signal in the proxy is relative to the region of interest. There are a number of ways to do this all involving correlating, in this case, tree-rings with some measure of climate. Gridded climate data sets are well suited for this purpose because of their large spatial extent, however when it comes to precipitation such interpolated, gridded fields also come with large uncertainties. Just how large and how spatially significant those uncertainties are is an important variable to understand.

Figure 35 represents a first look at the spatial coherency between two popular climate datasets the CRUTS3.1 gridded precipitation data and the GPCC gridded precipitation

data. The questions are: how well do these two products compare in their representation of the spatial patterns of precipitation over Europe and North Africa? How stable are their representations over time, and how realistic are their interpolations?

The top two panels of Figure 35 attempts to measure of how well the two datasets capture the variability of precipitation over Greece and the greater Mediterranean region. Here total monthly precipitation from June-August (1931-2002), as measured in Thessaloniki, is correlated to the same seasonal variable from each of the CRU and CPCC gridded datasets and it appears the GPCC model more accurately locates Thessaloniki. In addition there seems to be more spatial heterogeneity in the GPCC dataset that is consistent with what we know to be the case for precipitation patterns across large areas. The remaining final four panels in Figure 4 show a similar comparison between the two products only the Thessaloniki station data has been replaced by the Valia Kalda, *Pinus nigra* tree-ring chronology from Touchan et al. 2005. Additionally, the comparison has been performed on two time intervals, 1931-2002 and 1901-2002 (the latter being the common period). Immediately we see the degree to which the Valia Kalda chronology contains a recognizable precipitation signal and, as expected, how the strength of that signal decreases with increasing distance from the trees and length of comparison. Interestingly, the CRU data has a tendency to favor a strong connection between the Algerian desert and precipitation over Greece, whereas the GPCC dataset prefers to avoid this area completely. Secondly, the GPCC dataset appears to capture more local variability when using the entire length of the climate record, correlations actually increase locally over Greece and the Adriatic. Conversely, the local strength of correlations between the CRU product and tree-rings decays with increasing the number of years used in the analysis. All this leads to the conclusion that for characterizing the precipitation patterns the GPCC dataset is the preferred dataset. This dataset will be used to generate SPEI (Standardized Precipitation Evapotranspiration Index) which is an index of the difference between the cumulative precipitation and potential evapotranspiration computed on a monthly basis (Vicente-Serrano et al. 2010; http://sac.csic.es/spei/index.html). This index will be used with the hypothesis that SPEI is a more appropriate variable to use in quantifying drought stress than standard

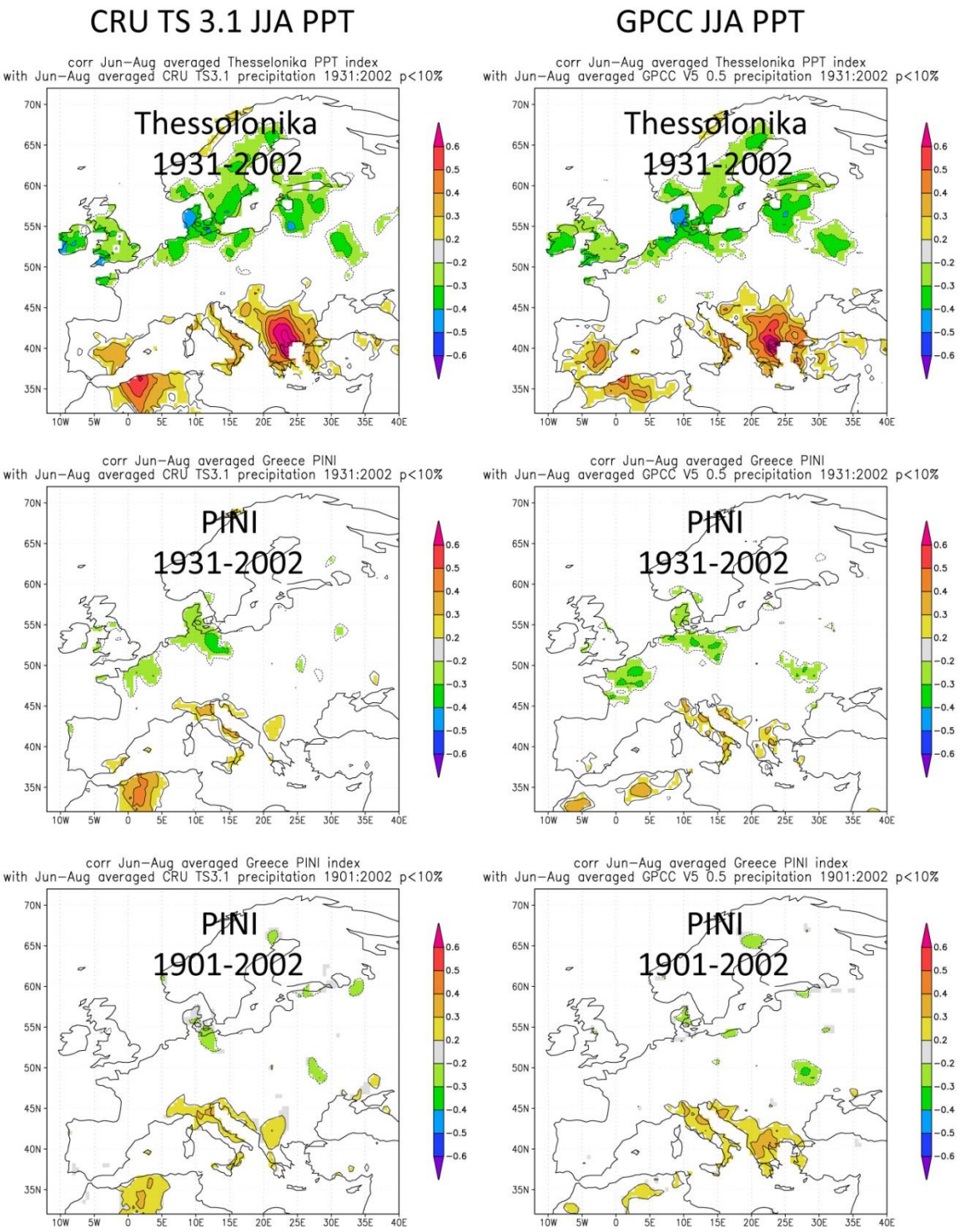


Figure 35. Comparisons of two gridded precipitation datasets to both an individual meteorological station record (Thessaloniki, GHCNv2_2011) and the Valia Kalda tree-ring chronology (Touchan et al 2005). Correlations fields produced by KNMI's Climate Explorer show how the two gridded datasets represent interpolated precipitation over Europe and North Africa.

measures of precipitation or the commonly used Palmer Draught Severity Index (PDSI).

References:

Brandes R. 2007: Waldgrenzen griechischer Hochgebirge. PhD dissertation, Friedrich-Alexander-Universität Erlangen-Nürnberg. (Erlanger Geographische Arbeiten / Sonderband ; 36) ISBN 978-3-920405-97-1

Jansen E. et al. 2007: Chapter 6 - Paleoclimate. In the IPCC fourth assessment report.

Jones PD. et al. 2009: High-resolution palaeoclimatology of the last millennium: a review of current status and future prospects. The Holocene, 19 (3), 3-49.

Touchan, R. et al. 2005: Reconstructions of spring/summer precipitation for the Eastern Mediterranean from tree-ring widths and its connection to large-scale atmospheric circulation. Climate Dynamics 25: 75-98

Vicente-Serrano SM et al. 2010: A Multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index – SPEI. Journal of Climate 23(7), 1696-1718, DOI: 10.1175/2009JCLI2909.1

Scientific Publications

There were no scientific publications in 2011

Outreach

No outreach activities were carried out in 2011

Planned activities for 2012

Over the winter/spring seasons 2012 Paul Krusic will concentrate mainly on processing the samples collected in July, 2011. In June and July 2012 he will return to Greece for a more extensive field season concentrating on those sites from 2011 that have the greatest potential of produce millennial length chronologies and exploring new sites and species in central and southern Greece. Once the samples from the 2011 collections are dated and measured, a first paper presenting a spatial reconstructing of SPEI will immediately follow.

Speleoclimatology

Research description

Paleoclimate data is scarce from the Peloponnese peninsula in southern Greece. The peninsula represents an archaeologically rich and relatively well explored area that could act as an interesting area to investigate climate impact on societal development on longer time scales. Available paleoclimate work from the Peloponnese has mainly been based on palynological studies. However, climate interpretation from palynological data is far from straightforward in this region due to its long history of humans altering the environment. In an attempt to provide climate data from an archive less affected by human activities a number of caves on the Peloponnese have been visited to find secondary cave deposits, speleothems. Although caves are abundant on the Peloponnese this climate archive has not been widely explored in the region.

Speleothems have been shown to produce excellent information about past climate variability with high chronological control. The most common climate proxies analyzed from speleothems are stable isotopes from oxygen (δ18O) and carbon (δ13C). Studies of the variations in the isotopes can reveal information on past changes in temperature, precipitation and vegetation.

Martin Finné, PhD student, supervised by Karin Holmgren, has sampled and dated stalagmites from Kapsia Cave on the Peloponnese. The dating results are used to construct and discuss an age model that is used together with δ18O and δ13C results to yield an interpretation of climate variability during a period from 2900 to 1174 years before 2009. A manuscript for submission to the journal Quaternary Research, is under preparation, with Martin Finné as the lead author. This report to NEO is a condensed version of the manuscript in preparation.

Kapsia Cave is situated close to the village Kapsia in Arcadia prefecture in central Peloponnese. The cave entrance is located approximately 700 meters above sea level where the Mantinea Plain meets the Pindos Mountains. The Mantinea Plain is a polje drained by 5 sinkholes. The cave is formed in a small limestone hill rising approximately 50 meters above the plain surface. Since 2010 tourists can visit parts of the cave through an artificial entrance opened in 2004.

Researchers involved

- Karin Holmgren, Professor, Stockholm University
- Martin Finné, PhD student, Stockholm University

Major research activities 2011

Methods

Actively growing stalagmites were collected in Kapsia Cave in September 2009 and one of them has been sampled for stable isotopes, U-Th and radiocarbon dating in 2010-2011. The stalagmite is visibly laminated with alternating more translucent thin dark layers and thicker white deposits throughout the full length. Petrographic thin sections (30 μm) were produced and analyzed under microscope.

For radiocarbon analysis, 6 samples were taken close to the top of the stalagmite to investigate if these parts of the stalagmite contain an elevated 14C activity that can be associated with the atomic bomb testing in the 1960s and thus provide independent evidence of recent deposition of the top of the stalagmite. 26 samples (0.5 g) were drilled for U-Th dating. Ages were obtained from MC-ICP-MS analyzes at the Geological Survey of Israel, Jerusalem. For stable isotope analysis, 196 samples were collected covering 280 mm along the growth axis using a hand held diamond coated drill-bit. Additionally, 28 samples were drilled along 5 different growth lamina for testing isotopic equilibrium conditions. Stable isotope samples were analyzed at the Stable Isotope Laboratory (SIL) at the Department of Geological Sciences, Stockholm University.

The cave is being monitored for the understanding of current processes behind speleothem formation. This is needed in order to draw conclusions about past processes. Field visits for monitoring purposes were performed in February, May and October 2011(Fig. 36).

Figure 36. Martin Finne and Nikos Kalivitis at Kapsia cave during a visit in October 2011

Drip water was collected and analyzed at SIL at the Department of Geological Sciences, Stockholm University. Three samples of modern calcite precipitated on monitoring equipment were analyzed for stable isotopes. Using drip water δ18O and cave air temperature the predicted δ18O value for precipitating calcite is calculated using established equations.

Results

The stalagmite shows alternating layers of columnar calcite and open columnar calcite throughout its length. Analysis of thin sections reveals presence of a hiatus and three horizons of renucleation. Considering the knowledge that the cave is prone to flooding we hypothesize that these horizons are results of flooding (Fig. 37).

Figure 37. Natural entrance of Kapsia cave flooded during winter 2002.

Radiocarbon activity in the calcite in the top show evidence of modern carbon and are elevated as a result of the bomb peak, and is thus deposited after the year 1955. From the radiocarbon analysis, at least two, different growth periods are evident.

The results from the 26 U-series MC-ICP-MS analyzes of material from the speleothem reveal that there is a need to correct all ages for a non-authigenic component of 230Th . The U-series dating results proved to be very complicated to interpret and Professor Mira Bar-Matthews from the dating laboratory in Israel, was invited to Stockholm, for consultations. By carefully selection of clean calcite samples for additional dating an age model has been possible to construct. This age model suggests that the sample grew from ~1000 BC to 850 AD, followed by a hiatus. The top 19 mm was deposited after the year 1953±1.

Based on previous research and the results from our monitoring of the cave, we suggest that in the context of Kapsia Cave precipitation amount effect is the main control on δ18O in drip water and ultimately in calcite δ18O, which means that increased (decreased) precipitation leads to more depleted (enriched) calcite δ18O values. Carbon isotopes in the Kapsia record are likely to be affected by biological activity as controlled by both climate and human activities, including: precipitation,

temperature, deforestation, grazing and fuel take out, with more depleted (enriched) values associated with high (low) biological activity caused by increased (reduced) precipitation or reduced (amplified) human activity.

A first tentative climate interpretation of the Kapsia stalagmite isotope record has been outlined. A drying trend is observed from 900 BC until 500 BC followed by wetter conditions at 400-100 BC, concurring with a period often referred to as the Roman warm period. The isotope record suggests that there was a rapid drying trend from around 100 BC with driest conditions prevailing from BC/AD – 100 AD. Towards the end of the isotopic record from Kapsia, from around 800 AD, wetter conditions seem significant. There is a clear cyclic pattern in the record, which is in focus for current analysis. Further, studies of the horizons believed to represent flooding event, using XRD-techniques, were intiated in 2011. So far we may conclude that the stalagmite records regional climate variability during a period from c. 500 BC years until Medieval times, although precision in age model is poor.

Scientific Publications

Martin Finné, Karin Holmgren, Hanna S. Sundqvist, Erika Weiberg, Michael Lindblom, Climate in the eastern Mediterranean, and adjacent regions, during the past 6000 years – A review, Journal of Archaeological Science, 38, pp. 3153-3173, doi:10.1016/j.jas.2011.05.007, 2011.

Outreach

Karin Holmgren gave a popular lecture in Kalamata in November 2011.

Planned activities for 2012

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Education

1st Student Field Course at NEO, January 25–31 2011

1st Student Field Course at NEO took place from 25 January to 31 January 2011 and was a great success!

On behalf of Stockholm University, Dr. Ingmar Borgström: "This has been a unique opportunity to study in depth the climate and landscape of the Mediterranean region. Being able to start the new course with this first excursion to Messinia means a lot to motivate and engage students in the subject. Messinia, with its long history of human activity, its active geological processes and its location in a climatically sensitive part of the Mediterranean area, offers a variety of interesting landscapes and environmental issues to work with. This course will lead to the students gaining a better understanding not only for the Mediterranean environment, but for the subject as a whole".

Figure 38. Stockholm University students during the 1st Student Field Course at NEO at Lousios river canyon.

On behalf of The Academy of Athens, Prof. Christos Zerefos: "This first educational visit combined with the imminent commencement of research activities at the

observatory, mark this admirable partnership. The participation of Greek, Swedish students, teachers and researchers in NEO's activities is aiming to become an opportunity for intervention and communication that will generate valuable results for educational and research purposes, as well as for the local community".

On behalf of TEMES S.A., Mr Nikos Katsikeros "The launch of the educational program has been a true rejoice. We hope that the outcomes will contribute valuable information to the global educational community and will act as motive for other organizations. We are also hoping that the first program will be succeeded by many to come, establishing NEO as a key contributor to research, education and knowledge on climate change, and Messinia as a point of interest for the academic sector, globally". Establishment of physical facilities for NEO

Atmospheric Pollution class of the Physics Department of University of Patra visit to NEO

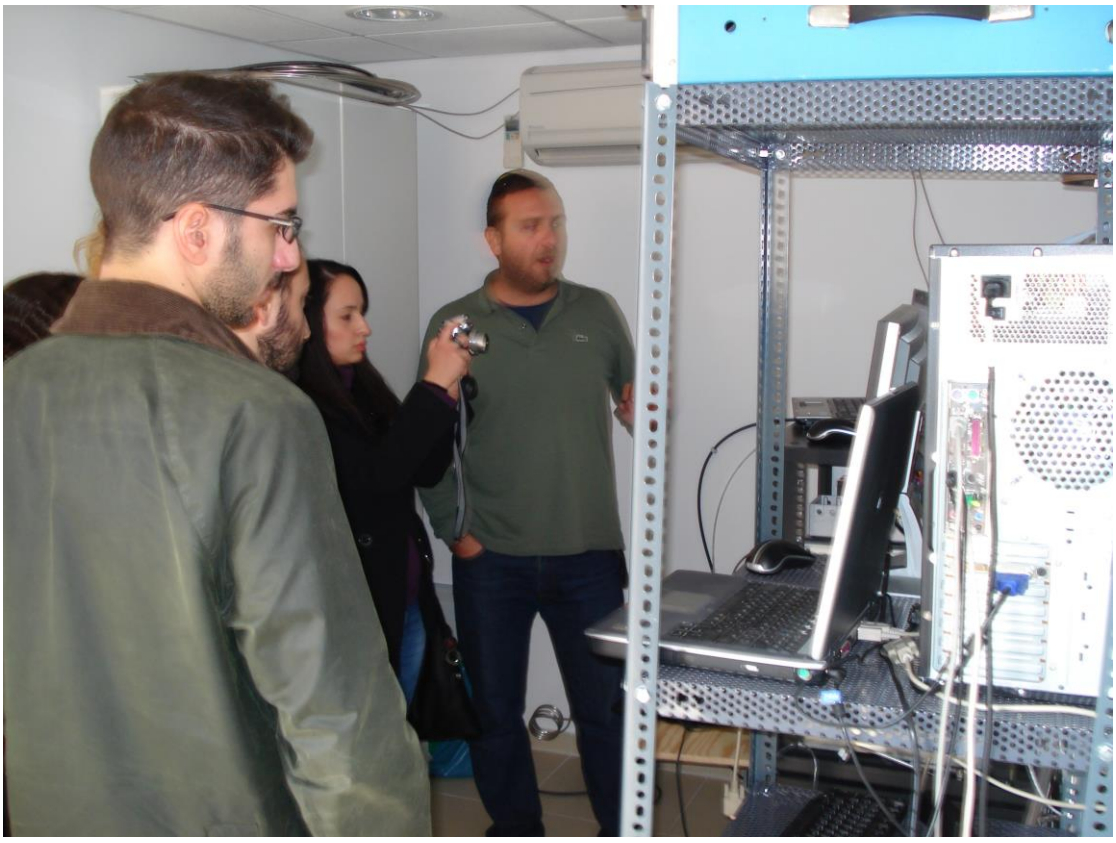

Figure 39. Students of Physics department, University of Patras are introduced to atmospheric monitoring techniques in NEO atmospheric research lab by NEO station manager.

On 28/11/2011 a group of 25 students, who follow the course of Atmospheric Pollution at the Physics Department of University of Patras, visited the Navarino Environmental Observatory (NEO). The NEO Station Manager informed the students about the recent and future activities at NEO, gave a lecture about aerosol measurements, instrumentation and their effect on climate were followed by practice at the air pollution laboratory of NEO.

Senior Lecturers meeting

During the period November 8–10 2011, Stockholm University, University of Patras and Univerisity of Peloponnese Senior Lecturers meeting for planning of educational activities at Messinia held by Karin Holmgren and Ingmar Borgström took place at NEO.

Figure 40. Lecturers at Sgrapa monastery.

Infrastructures

The NEO offices

In January 2011, TEMES handed to the NEO director the NEO offices. NEO offices are located within the premises of the Westin resort. The total area dedicated to the NEO offices is 135 m^2 (including internal separating walls), and includes the following facilities:

Facility	**Net area (sqm)**
Kitchen / common room	17.5
Director's office	15
Computer room	30
Reading & social/library	37
Lobby	14.5
Storage	7
Cleaning room	2
Total	123

This area will be used as NEO offices until the NEO building is completed.

The NEO building

In 2011 the construction of NEO building was initiated, ca. 1 km south of Navarino Dunes. It is expected to be ready in July 2012.

The NEO atmospheric research station

In March 2011 the room on the first floor of the library tower at Westin, Navarino Dunes was delivered from TEMES to host the atmospheric research lab. (Fig. 41).

Figure 41. The atmospheric research lab on the first floor of the library tower.

Events

- On 4 June, Karin Holmgren, on behalf of Navarino Natura Hall, received a donation during a Prize Giving Ceremony & Gala Dinner of the Aegean Airlines Pro-Am golf tournament held at Navarino Dunes. The donation will be used to expand the Natura Hall with a section about environmental-friendly building and the Messinian architecture, well-known for its harmonizing with the natural landscape.
- Natura Hall since 22 June has opened its doors, hosting interactive exhibitions about Messinia environment and culture and about environmental issues of more general interest. Four volunteers were recruited to assist visitors to the

Natura Hall. They are students from Stockholm University: Linn Borg, Therese Eriksson, Hanna Andrén and Josefin Klein Part of their volunteerships was carried out within the frame of a INK traineeship course and NEO Station Manager was their local supervisor.

- The NEO Lecture series 2011 was organized with the coordination of University of Peloponnese. On 19 October Gia Destouni talked about "Water research challenges and opportunities for the 21st century" while on 2 November, Karin Holmgren Director of NEO gave a talk with the title "Secrets from the underground-Caves as climate and environmental recorders". It was decided that NEO lectures should be to established so that NEO research activities are communicated to the local community and they serve as a communication and awareness tool.