NAVARINO
ENVIRONMENTAL
OBSERVATORY

ANNUAL REPORT

2012

Stockholm University
www.su.se

ACADEMY OF ATHENS
BRFAA
www.bioacademy.gr

TEMES
DEVELOPERS
OF COSTA NAVARINO
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1. 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 and climate changes, ii) geology, geomorphology and landscape changes climate, water and environmental changes. 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.

2. 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 centre carries on Bolin's heritage by conducting fundamental research on critical processes in the climate system.

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

3. Research

3.1 Atmospheric composition and climate changes

Research description

The Mediterranean area is populated by about 100 million people just on the northern part, with many cities including industrial and transport activity causing large emissions to the atmosphere. Climate change seems to already influence it with very high temperatures during summer and decreasing precipitation giving an increasing water deficiency. The climate projections suggest this trend to continue. The bad air quality has considerable effects on the public health causing more than 100 000 premature deaths per year. Including the further stress in hot spells combined with bad air quality it is a most serious public health problem in the populated areas around the Mediterranean Sea.

Increasing CO2 concentrations are the most important cause of raising temperature, but air pollutants as particles, soot and ozone have an important effect in modulating the temperature change. It also can affect the precipitation. However how and how much is not well known, e.g. the chain of processes behind cloud formation and precipitation has several missing links.

Observations of key components are important in increasing our knowledge about the atmosphere and its role in climate change. We develop our theoretical knowledge about different processes to be included into models and we can test the performance of the models. At NEO we have continuous measurements of atmospheric particles, their size distribution, and their chemistry including soot. Further, ozone and solar radiation in several wave length areas are measured. We also have campaigns with extended instrumentation, including e.g. LIDAR, focusing on specific emissions and atmospheric processes. The data is used in developing and supporting air quality and climate modeling of the Mediterranean area.

Researchers involved

- Christos Zerefos, Professor, Academy of Athens (AA)
- Evangelos Gerasopoulos, Research Director, National Obs. of Athens (NOA)
- Stylianos Kazadzis, Associate Researcher, NOA
- Vassilis Amiridis, Associate Researcher, NOA
- Vassilis Psiloglou, Senior Researcher, NOA
- Panagiotis Kokkalis, PhD student, National Technical University of Athens
- Andreas Kazantzidis, Assistant Professor, University of Patras
- Konstantinos Eleftheratos, Post doc, AA
- Konstantinos Douvis, Post doc, AA
- Ioannis Kapsomenakis, Post doc, AA
- Hans-Christen Hansson, Professor, Stockholm University
- Tabea Hennig. Research engineer, Stockholm University
- Radek Krejci, Researcher, Stockholm University
- Peter Tunved, Researcher,
- Nikos Kalivitis, former NEO Station Manager, Stockholm University
- Giorgos Maneas, current NEO Station Manager, Stockholm University

Major research activities 2012

The atmospheric research activities at NEO during the last year have focused on running the continuous atmospheric observation set up in April 2011. In June 2012 the measurements were intensified and extended in a campaign called ARGOS.

Continuous measurement and indicative results

All instrumentation at the NEO Library Tower atmospheric research station has been operating during the whole period with standard maintenance taking place. Malfunctions were either directly dealt with, or instruments were sent abroad for repair and calibration. Data was collected and the relevant data base maintained. Quality control and analysis of data was performed in parallel.

Radiometric instrumentation was operated and provided solar radiation data at different bands of the solar spectrum. Time-series were constructed and secondary products were calculated, as the UV Index and Aerosol Optical Depth (AOD) (Fig. 1).

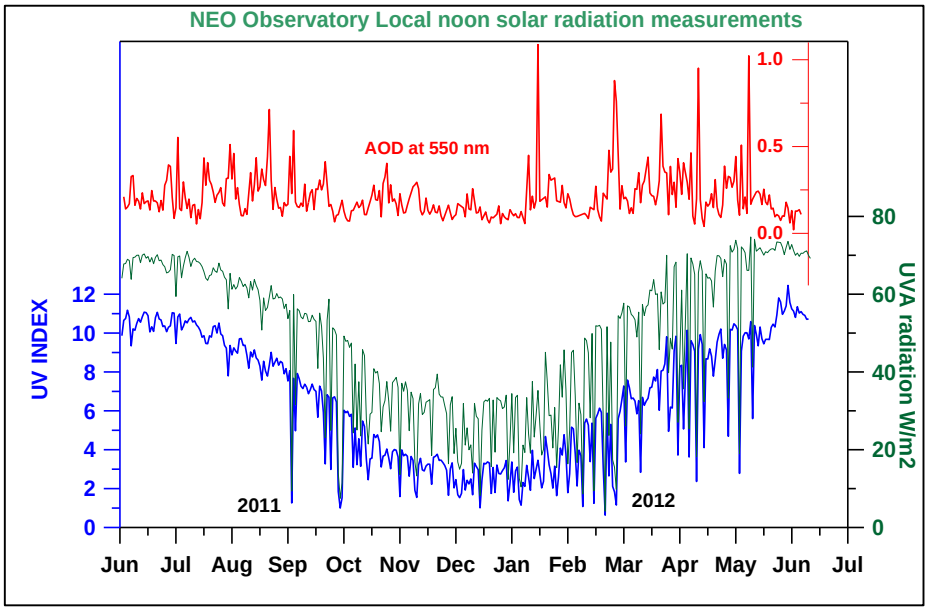

Figure 1. Solar radiation measurements (in the UV band) performed at NEO since June 2011. These measurements are used for the calculation of the UV Index (expressing the danger for skin damages due to UV radiation) and of the aerosol optical depth (columnar aerosol load).

Finding a new better sampling site

In the evaluation of the continuous measurements, the local contribution of particles and soot was found to be high during some periods of the day when the hotel was in operation. It is caused by emissions probably from traffic and restaurants in the resort. In total about 50 % of the data was lost due to these emissions. The NEO-atmospheric research group concluded that possible alternative locations should be investigated for part or whole of the instruments currently operated at NEO. The group visited different locations in the surrounding area that met basic requirements. The HNMS station at Methoni was found to be the most appropriate site and E. Gerasopoulos was assigned to make the first contacts with HNMS. A proposal on moving to Methoni, with a description on the site and move was sent to the director of NEO.

The ARGON field campaign

Description

The ARGON intensive campaign (Aerosol and TRace Gases Observational Campaign at NEO) took place 7–12 July, at NEO premises. The campaign was organized by the Academy of Athens and the Stockholm University, with the participation of the National Observatory of Athens (NEO associate partner), the National Technical University of Athens and the University of Crete. In conjunction to the routine aerosol, trace gases and radiometric measurements at NEO, additional instrumentation was transferred established and operated for the monitoring of NO_x (NO and NO_2), CO and PM_{10}, for the first time in the area. A PM_{10} sampler was used for the collection of 24h atmospheric samples on quartz filters for further in vitro chemical analyses for the determination of the major water soluble inorganic ions, concentrations of minerals and heavy metals, the carbonaceous content of aerosols as OC/EC and the water soluble organic carbon content. Finally, a LIDAR system on board of the new van type mobile lab of the Academy of Athens was deployed for the scanning of the vertical profile of aerosol in the atmosphere during the period of measurements (Fig. 2).

Figure 2. The LIDAR system on board of the new van type mobile lab of the AA/NEO.

Main results

During the ARGON campaign the station was influenced by air masses of different origins providing the opportunity of studying in detail the main characteristics and impacts from discrete sources. In particular, during the 36 days of the experiment there have been 20 days with NE winds dominating typical for continental sources (industrial-Megalopolis, urban-Athens etc), 4 days with air masses from the Po valley (industrial agglomeration) and the Adriatic Sea, 5 days with marine aerosol presence, 3 days with dust transport from Africa and finally 4 days with stagnant conditions.

The results have identified significant differences in pollutant levels depending on meteorological conditions and the origins of air masses. In Fig. 3 the concentrations of main primary gaseous emissions are shown (CO, NO_x) together with secondary production via photochemical processes of O_3.

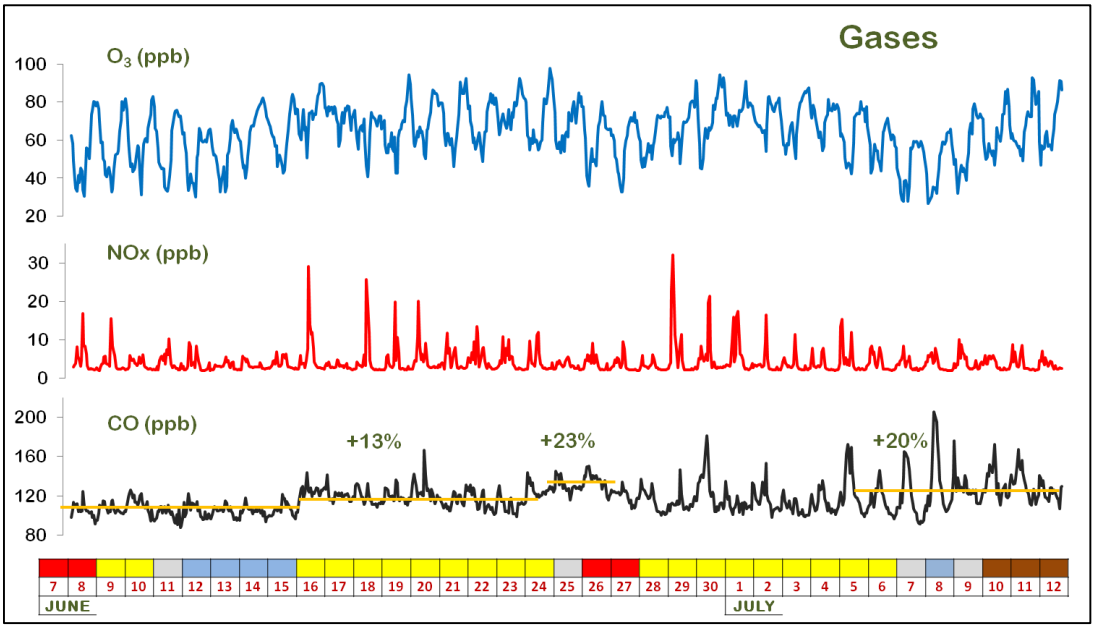

Figure 3. Contour plot s of the aerosol number size distribution in the size range 14-924 nm and 0.5-10 μm.

Apart from gases a full chemical and physical characterisation of aerosols was fulfilled. Samples on quartz filters were analysed and concentrations of main constituents were linked to different sources under the frame of a first source apportionment study. For example peaks in elemental and organic carbon (EC/OC) were successfully associated with small fires in the area, while the ratio EC/OC was used for the study of aging smoke processes. The size distribution of particles was also monitored with two instruments focusing on the fine and the coarse fractions of aerosols (Fig. 4). These measurements provided an idea of typical particle sizes and enabled the investigation of mechanisms that produce particles in the area as well as the size growth of particles. Monitoring of transported particles from natural sources (e.g. sea salt, dust) was also feasible.

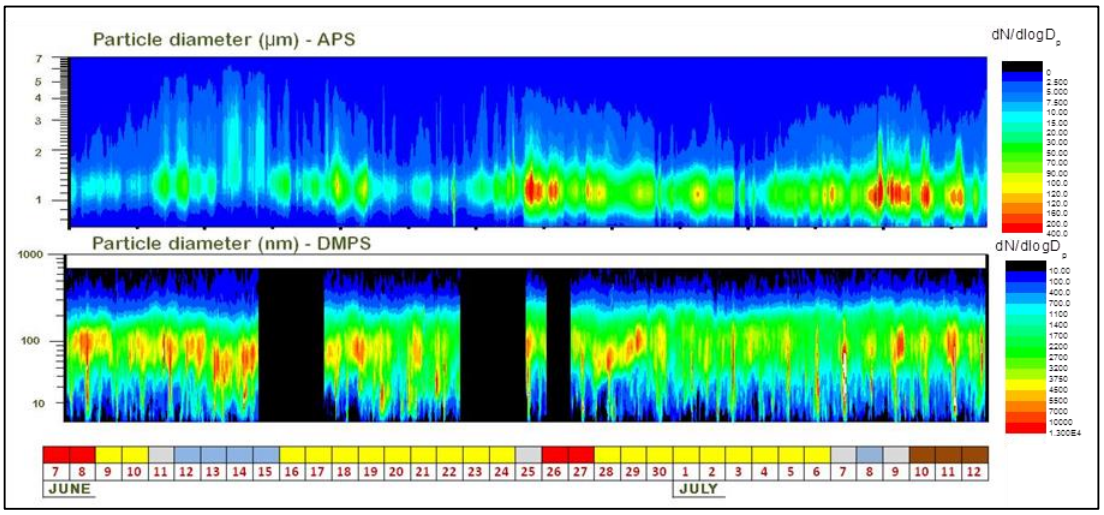

Figure 4. Contour plot s of the aerosol number size distribution in the size range 14-924 nm and 0.5-10 μm.

Finally, the vertical distribution of aerosols in the troposphere was captured during specific days of interest. An example of a dust event that took place on 10-11 July 2012 was observed, with dust layers up to 5km gradually descending and mixing within the boundary layer with other types of aerosol (Fig. 5).

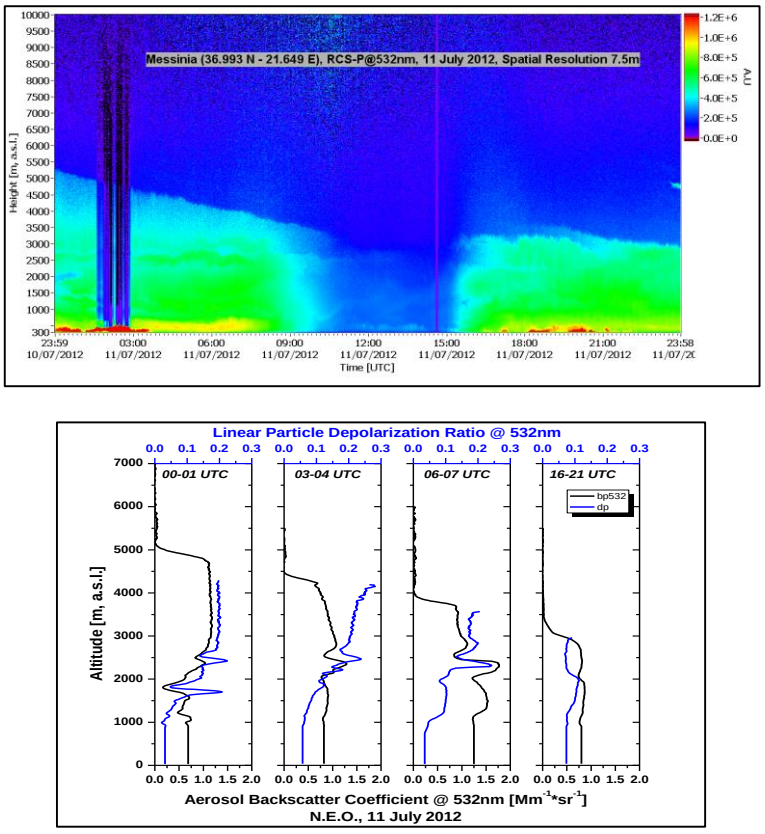

Figure 5. The 10-11 July 2012 dust event as captured by the LIDAR (left panel). Vertical profiles of aerosol backscatter and the depolarisation ration during specific time windows (right panel).

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

In 2012, the VAN type vehicle purchased by BRFAA to be dedicated to the works of NEO and relevant activities was subjected to special transform works, in order to host the LIDAR system. A rack for mounting other pollutant monitors (to be purchased upon funding attraction) was also placed in the VAN, which was also equipped with air-conditioning system and a platform for actinometric equipment on top.

Planned activities for 2013

The following activities are planned for 2013:

- Publication of the first 18 month of continuous aerosol measurements
- Publication on the impacts of various factors (aerosol, total ozone) on UV-A and UV-B
- Publications with results from the ARGON campaign
- Move of sampling site (most probable in June) at Hellenic National Meteorological Service (HNMS) station in Methoni.

3.2 Geology

Research description

How does mountain building influence the climate?

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.

Researchers involved:

- Alasdair Skelton, Professor, Stockholm University
- Barbara Kleine, PhD student, Stockholm University
- Ruben Fritzon, Licentiate student, Stockholm University
- Arjen Stroeven, Professor, Stockholm University
- Bradley Goodfellow, Post-doctoral fellow, Stockholm University
- Mark Caffey, Professor, Purdue University, USA
- Mike Bickle, Professor, Cambridge University, England.
- Marion Holness, Professor, Cambridge University, England.

Research activities in 2012

In 2012 we have studies on Syros and Naxos and planned for studies near Sparti.

Syros

On Syros, we have made a preliminary estimate of a minimum flux for carbon during mountain building of 0.4mol-CO_2.m^{-2}.yr^{-1}. This estimate is based on reactive transport modeling of the preservation of the carbonated blueschist facies (high pressure – low temperature) mineral assemblage glaucophane + phengite + calcite adjacent to a fault at greenschist facies (low pressure – low temperature) conditions (Fig. 6). Preservation of this assemblage from retrograde hydration at greenschist facies conditions adjacent to a fluid conduit (fault) requires that the fluid which is flowing along this fault contains CO_2 and that its flux is fast relative to the flux of the hydrating fluid within the surrounding rocks. The reactive transport model considers advective flow across the fault and parallel to the metamorphic foliation. Flow along the fault is assumed to be fast relative to flow within the surrounding rocks and transport of CO_2 outwards from the fault is assumed to occur by diffusion. The model assumes linear reaction kinetics. This best fit of this model to volume % calcite data (estimated by point counting of thin sections) is shown in figure 7. Using parameters obtained by Skelton (2011) for metamorphic porosity, diffusion coefficient for CO_2 in the fluid at greenschist facies conditions and tortuosity of the flow path and with XCO_2 = 0.03 (Schumacher et al., 2008), we obtained a carbon flux of 0.4mol-CO_2.m^{-2}.yr^{-1}. The carbon flux along the fault must be larger. This minimum carbon flux for greenschist facies retrogression on Syros exceeds the drawdown flux for CO_2 due to silicate weathering in mountains (Huh, 2010). This infers that mountain building is a source not a sink of atmospheric CO_2.

Figure. 6: This image shows preservation of blueschist facies minerals (shown by blue color in the middle of the image) adjacent to a fault (shown by yellow-white vein at the right side of the image) from retrograde hydration to a greenschist facies rock (shown by green color at the left side of the image). The width of the field of view is 1 meter.

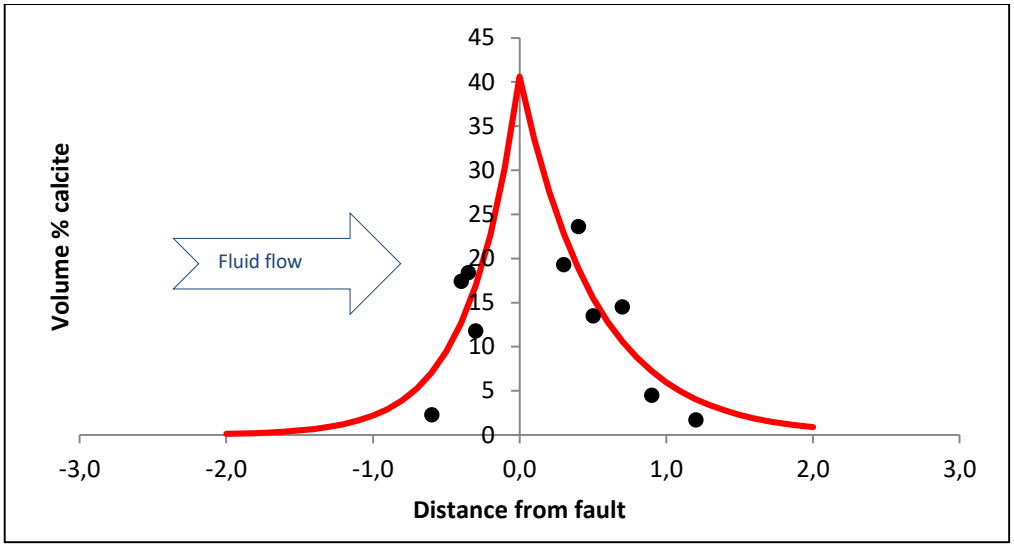

Figure. 7: This image shows the best-fit reactive transport model to volume % calcite data (which is inversely proportional to progress of the retrograde hydration reaction and therefore correlates positively with preservation of the carbonated blueschist facies assemblage).

This study is part of a PhD study conducted by Barbara Kleine. Barbara Kleine is co-financed by NEO, an EU mineralogy network (DeltaMIN) and the Department of Geological Sciences at Stockholm University. She is writing up this work for publication in the international peer-review journal Geofluids. Part of this work was presented at the Nordic Geological Winter Meeting in Reykjavik (January 2012) by Professor Alasdair Skelton.

Naxos

In August, samples were collected for stable isotope analysis from a marble layer on Naxos. We hope to use stable isotope data from this layer to calculate fluxes for water and carbon at amphibolites facies (high pressure – high temperature) metamorphic conditions. The transport model which will be used considers advective transport along grain boundary scale pathways and transverse diffusive transport outwards from these pathways. This approach was first used to study metamorphic systems by Bickle (1992). These samples have now been analyzed and data processing is ongoing. This study is being undertaken by a Masters student at Stockholm University. It will involve an ion microprobe study, for which beam time has now been secured. This study is being undertaken in collaboration with Prof. Mike Bickle and Prof. Marion Holness at Cambridge University in England.

Sparti

During 2012 we initiated plans and preparations for a study on the exhumed surface of the Sparti Fault (Fig. 8). This is the probably site of the 464 BC earthquakes which ruined the city of Sparti. Previous workers have used chlorine-36 dating to show that the fault scarp was exhumed by 3-4 earthquakes during the past ca. 10,000 years. This corresponds to an earthquake periodicity of 2,000 – 3,000 years. In our study, we will use a portable X-ray fluorescence (XRF) analyzer to detect exhumed soil weathering profiles on the fault surface. This field-based method with an analysis time of 60 seconds allow for analyses to be made at 5 cm intervals in a profile constructed along the fault surface. Preliminary findings suggest that Yttrium may serve as a useful

tracer for this purpose. This study will yield information about weathering rates because the age of the fault scarp is known and, by including further chlorine-36 dating from sub-surface samples, chlorine-36 penetration depths and uplift rates can be determined. The study is to be conducted by a licentiate student (Ruben Fritzon) as part of a new Research School for Teachers focusing on Natural Hazards, financed by the Swedish Research Council and the Swedish Government and for which Professor Alasdair Skelton is the principle investigator. Collaborators include Prof. Arjen Stroeven at Stockholm University and Prof. Mark Caffey at Purdue University.

Figure. 8: Sparti fault. The exhumed fault scarp dips at 56-70 degrees and at our study sites, 6-7 meters of this surface have been exhumed in ca. 10 thousand years. This equates to an uplift rate of approximately 1 mm/yr.

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Planned activities for 2013

During 2013 we plan to:

- finalise a manuscript on our study on Syros
- undertake an ion microprobe study of grain-scale diffusion as part of our study on Naxos
- perform a field campaign at our study site near Sparti.
- undertake geochemical analysis and chlorine-36 dating as part of our study near Sparti.

3.3 Geomorphology and landscape changes

Research description

Climatic and tectonic drivers for the Late Quaternary geomorphic evolution of Southwestern Peloponnese, Greece

Geomorphological evolution in Greece during the Late Quaternary is affected by large-amplitude climatic swings and uplift/subsidence related to large-scale tectonism resulting in forcing of the geomorphological evolution that is both area-specific and highly variable over time. A deeper understanding of the current geomorphology and its evolution therefore require a framework regarding the spatial patterns and more detailed nature of first-order drivers and the second-order controls on geomorphic evolution. We are currently developing such a framework for analysing the geomorphic evolution of Southwestern Peloponnese during the Late Quaternary. We focus primarily on the difference between present geomorphic regimes and those prevailing during Late Quaternary periods with full-glacial conditions. The project has links to many other NEO-projects, primarily to the hydrological projects and to the dendrochronology and speleothem projects on climate change.

Researchers involved:

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

Research activities in 2012

During the year we have focused on developing a coherent framework for further geomorphological studies. Fieldwork was carried out in the study area by Kleman and Borgström during October 2012 and will be continued in the spring of 2013.

The study area has undergone major climatic changes and significant tectonic events (Mather, 2009) during the last 120 kyr. Its relief and morphology can be classified into broad classes (see figure 9) but the landforms can often not be assigned to a single dominant process system. The prime evidence for vegetation change through glacial times comes from pollen analysis. Pollen data from Lesvos Island, 440km NE of the study area, indicate that vegetation during the time period 62 – 22 kyr oscillated between steppe, forest-steppe and forest (Margari et al., 2009), in concert with millennial-scale stadial/interstadial cycles reflected in the Greenland and deep-sea records.

We here attempt to identify and analyse the climatic and tectonic events that have driven the geomorphic evolution of Messinia during the last glacial cycles and suggest a simplified model for its geomorphic evolution.

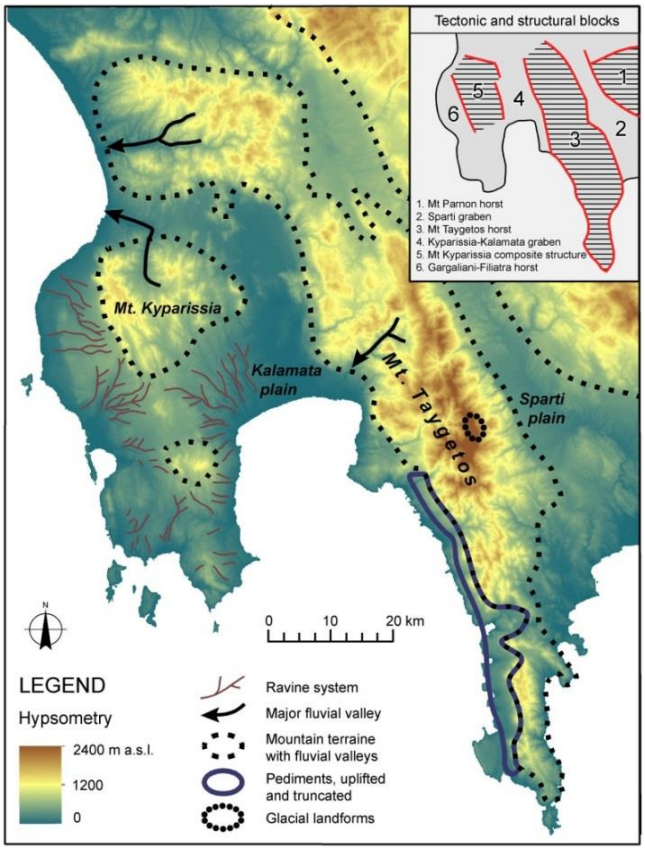

Figure 9: Relief map, location map, morphologic regions, tectonic blocks

Climate

For the purpose of our model, we regard climate as primarily a function of altitude and time, but essentially geographically uniform over the study area. It is conceivable that gradients in glacial times were different than today's gradients (Tzedakis, 2009), but the quality of available paleotemperature, and in particular paleoprecipitation data is not sufficient to discern such deviations. We employ regional or global data on climate and sea-level evolution, and assume that in the study area these parameters largely followed well documented larger-scale trends.

Temperature depression and precipitation

The Last Glacial Maximum (LGM) is the only glacial time period for which reasonably robust data and modelling results regarding temperature and precipitation changes exist. The sea surface temperature depression for the Mediterranean is estimated at 6°C in the Adriatic, 7°C in the Aegean, and 11°C in the western Mediterranean (Hayes et al., 2005). GCM modelling (Genesis 2) by Barron and Pollard (2002) indicates comparable temperature depressions, with southern Europe 7-10°C cooler than today, and reduced annual precipitation, especially during winter. Rock glacier distribution in the Pindos Mountains suggests an 8 - 9°C temperature depression relative to today. No available paleodata give reliable precipitation data for the last glacial maximum, and for the purpose of our analysis we therefore rely on the GCM data. We accept 8°C as a realistic measure for the decrease in annual mean temperature during glacial maxima. Based on a dry adiabatic lapse rate of 0.640°C / 100m this corresponds to a lowering of isotherms with 1250m.

Mastronuzzi et al (1994) reported the occurrence of 2-3 end moraines and small patches of roches moutonees close to the 2402 m summit of Prophet Elias. They estimated an ELA altitude of around 2000 m. The ages of these moraines are presently unconstrained. Our own air photo interpretation indicates a more widespread occurrence of moraine fragments within the elevation range already defined by Mastronuzzi et al. This will be further investigated in 2013.

Sea level

There is now a fair understanding regarding the global sea-level evolution during last glacial cycle (Lambeck & Chapell 2001). Evidence from the Mediterranean area is in good accord with the estimated global sea-level drop of 120 – 130m (Perissoratis and Conispoliatis 2003). From the paleo-sea level data, we note that during approximately 85% of the last glacial cycle sea-level, and therefore the base level for fluvial erosion, was in the – 25 to – 75 m range. The LGM maximum sea-level drop to - 120 to -130m was a rather short-lived condition.

A first order-model for the geomorphic evolution

The model we present here should be considered as an internally consistent and testable hypothesis for the first-order differences in geomorphological processes and activity that occurred between interglacial and full glacial conditions. We base the model on a description of current geomorphological activity (Fig. 10), proceed to an analysis of the difference in drivers and controls that were imposed by the radically different conditions at the LGM, and arrive at a model (hypothesis) that hindscasts the activity and spatial domains of the different geomorphological process systems at times of full-glacial conditions.

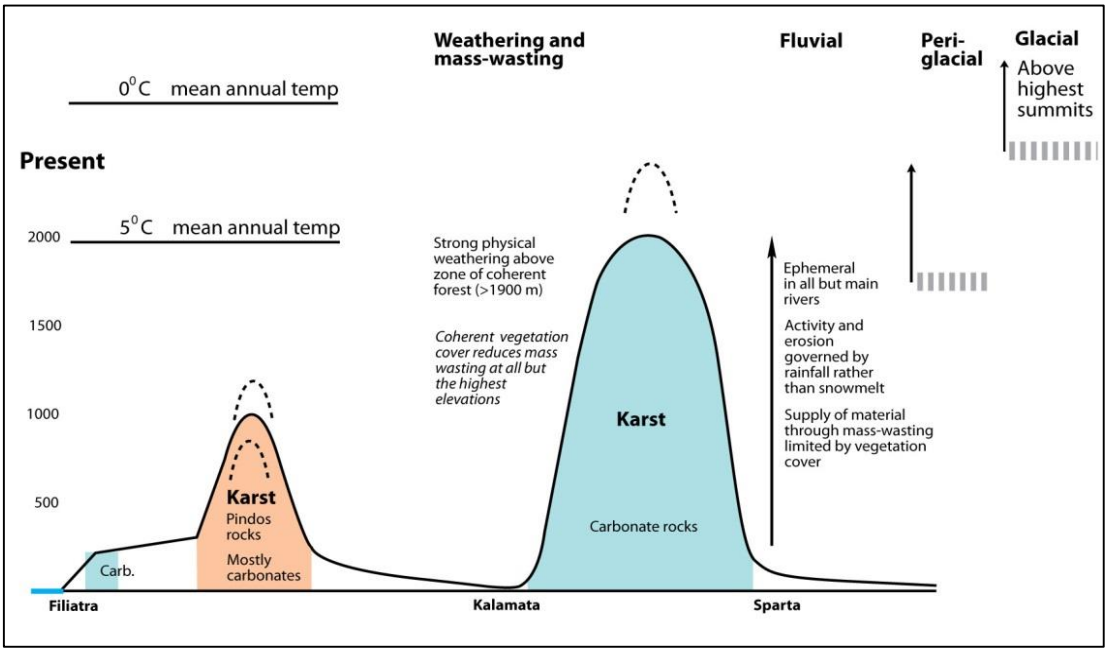

Figure 10: Model for present-day conditions and geomorphic development.

Model for conditions and geomorphic development during full-glacial conditions

The model is based on the notion that horizontal climate gradients are gentle, but vertical gradients are steep, i.e. geomorphic processes are a strong function of elevation. The model is primarily driven by changes in temperature, induced by climate change and tectonic uplift/subsidence. For all temperature calculations we use the average dry adiabatic lapse rate in the atmosphere (0.64^0C/ 100m). Hydrological change (precipitation, surface runoff, mass-balance of glaciers) is discussed qualitatively because of the scarcity of reliable paleo-data. We have chosen to employ recent GCM modelling as our primary source for precipitation hindcasts. Following the above reasoning, we employ a number of basic assumptions:

1/ Similar climate changes affected the entire study area, with only modest geographical gradients. 2/ Sea-level change closely followed global eustatic changes. 3/ Each identified tectonic block behaved as one unit, with uplift or subsidence being the dominant changes. Doming and tilting are not considered. 4/ Temperature changes are considered to affect geomorphological processes in the same way as tectonic uplift or subsidence, i.e. by lowering and rising terrain relative to a temperature field.

The model (Fig. 11) is based on the observed differences in temperature and the modelled differences in precipitation and predicts specific changes in dominant geomorphic processes. In relation to present-day conditions, the 1250 m lowering of isotherms, and the change to more arid conditions (Tzedakis et al. 2009) during full-glacial conditions are postulated to have caused the following main shifts in geomorphological activity:

Physical weathering increased in intensity and occurred down to much lower elevations than in interglacial times, due to a higher frequence of sub-zero temperatures and decreased forest cover. Such conditions today characterize the small areas above 2000m, in glacial time we expect intensified physical weathering down to less than 1000m elevation. At the highest elevations, physical weathering was replaced by glacial erosion.

Mass wasting intensified at all elevations in mountain terrain, due to reduced vegetation density and forest cover causing reduced root binding of soil material, seasonal frost occurring at lower elevations, and periglacial conditions with an active layer over permafrost occurring at higher elevations.

The changes in *fluvial erosion* are difficult to predict, because the water available for surface runoff would be influenced both by the opposing and poorly quantified factors of reduced precipitation and reduced evaporation. The amount of water available for runoff would also be strongly impacted by the increased extent of seasonal frost, and permafrost at the highest elevations. It is likely that fluvial erosion at higher elevations in the two primary mountain areas was most active during spring snowmelt, but that fluvial erosion in lower-elevation headwaters was dominated by the temporal structure of rainfall, as today. It appears fairly clear that *fluvial transport of material* must have increased strongly during full-glacial conditions because of increased availability of physical weathering products and intensified mass-wasting.

Karst processes may in general have been slightly augmented by lower groundwater temperatures. Any predictions regarding recharge of groundwater is surrounded by

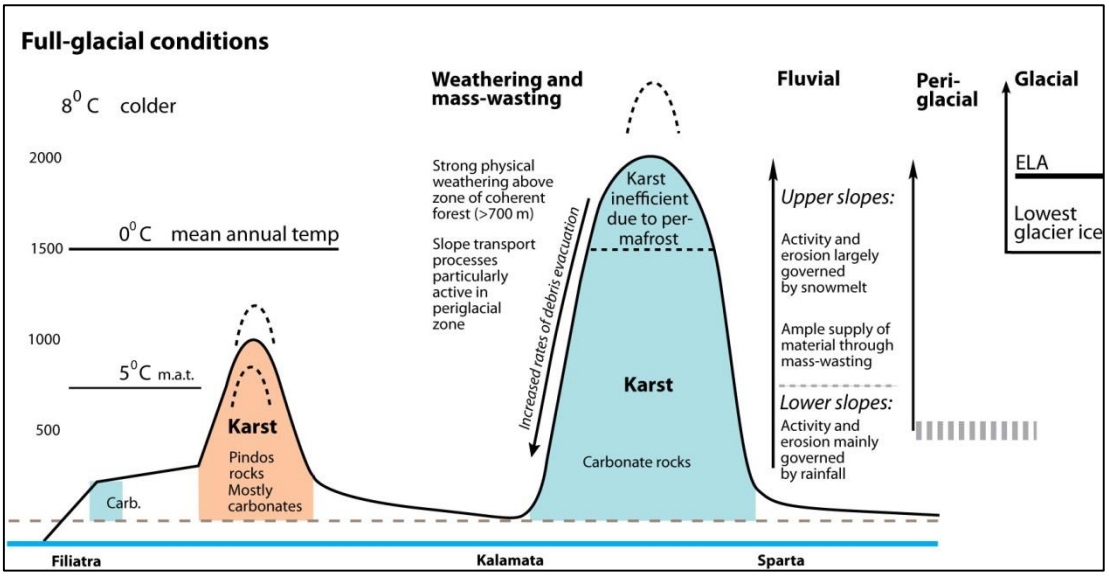

Figure 11: Model for conditions and geomorphic development during full-glacial conditions. The figure summarize the first-order changes in geomorphological processes that were induced by the climatic deterioration during full-glacial conditions. Lowering of the base level and localized tectonic movements added second-order effects to the dominating effects of climatic change.

similar uncertainties as for the water available for surface runoff. At the highest elevations, the occurrence of permafrost is likely to have severely reduced the recharge of groundwater.

The periglacial processes cannot here been regarded as an independent process system. Periglacial conditions primarily intensify physical weathering, intensify mass-wasting, and are also likely to intensify fluvial downcutting. It appears clear that periglacial processes must have operated at much lower elevations than at present, likely down to 7 – 800 m elevation.

Glacial processes are inferred to have affected the highest elevations in the Taygetos Mountains during at least one stage of the last glacial cycle. The presence of glaciers on the Taygetos before the last glacial cycle is not expected because of the rapid uplift of the Taygetos horst, which implies that elevations during e.g. MIS 6 was on the order of 200m lower than today. Glacial landforms are highly diagnostic; no other process system can create e.g. end moraines and roches moutonees.

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Planned activities for 2013

During 2013 we plan to:

- submit a manuscript to the international journal Geomorphology during the summer 2013.
- continue fieldwork in the area (a trip to Taygetos mountain is already planned for May 2013).
- initiate a separate study of what appears to be an uplifted and truncated semi-continuous pediment surface on the west-side of the Mani Peninsula (Figure 12). If the age of this surface and the inferred faulting at its western edge can be constrained, it may yield important information on whether uplift of the Taygetos Mountains was continuous or episodic, and also help in constraining the age of Kalamata Bay. The study will be conducted during 2013 by a bachelor's student, Peter Adler.

Figure 12: A gently sloping pediment remnant on the western side of the Mani Peninsula. Most of the surface is located at 200 – 300m elevation and slopes gently seaward. Its western edge appears to be fault-controlled.

3.4 Water research

Research description

The water research activities in 2012 had the following main foci and objectives:

- To publish a new, generalized analytical solution for seawater intrusion into sloping coastal aquifers developed by Koussis et al. during 2012.
- To apply the analytical solution of Koussis et al. (2012) to a study of the effects of climate-driven sea-level rise on seawater intrusion in coastal aquifers under different groundwater, hydroclimatic and sea conditions and change scenarios.
- To further apply the analytical solution of Koussis et al. (2012) to a study of seawater intrusion risk of specific aquifers around the eastern Mediterranean coast.

Researchers involved:

- Georgia Destouni, Professor, Stockholm University
- Steve Lyon, Lecturer, Stockholm University
- Carmen Prieto, Scientific Programmer/Research Engineer, Stockholm University
- Katerina Mazi, PhD student, Stockholm University
- Antonis Koussis, guest researcher at Stockholm University in 2012

Research activities in 2012

Main research developments and activities in 2012, with the foci and objectives described above, included:

Publication of new, generalized analytical solution for seawater intrusion into sloping coastal aquifers.

This work by Koussis et al. was published in *Journal of Hydrology* in 2012, addressing contamination of groundwater by intruding seawater, which is a major problem in many parts of the world and not least in coastal aquifers around the Mediterranean. The work was described in more detail in the annual report for 2011, during which it was developed for the 2012 publication. In summary, the published analytical solutions can be and are also used in our follow-up work (see below), for screening assessments of seawater intrusion vulnerability and management options across different groundwater, hydroclimatic and sea conditions and change scenarios.

Study of the effects of climate-driven sea-level rise on seawater intrusion in coastal aquifers.

This work by Mazi et al. was finalized in 2012 and published in *Environmental Research Letters* in January 2013. The study considers different projections of climate-driven sea-level rise and uses the generalized analytical model of Koussis et al. (2012) to investigate the responses of sea intrusion in unconfined sloping coastal aquifers to climate-driven sea-level rise. The results show high nonlinearity in these

responses, implying important thresholds, or tipping points, beyond which the responses of seawater intrusion to sea-level rise shift abruptly from a stable state of mild change responses to a new stable state of large responses to even small changes that can rapidly lead to full seawater intrusion in a coastal aquifer. The identified tipping points are of three types: (a) spatial, for the particular aquifers (sections) along a coastline with depths that imply critical risk of full sea intrusion in response to even small sea-level rise; (b) temporal, for the critical sea-level rise and its timing, beyond which the change responses and the risk of complete sea intrusion in an aquifer shift abruptly from low to very high; and (c) managerial, for the critical minimum values of groundwater discharge and hydraulic head that inland water management must maintain in an aquifer in order to avoid rapid loss of control and complete sea intrusion in response to even small sea-level rise. The existence of a tipping point depends on highly variable aquifer properties and groundwater conditions, in combination with more homogeneous sea conditions. The generalized analytical model used in this study facilitates parsimonious quantification and screening of sea-intrusion risks and tipping points under such spatiotemporally different condition combinations along extended coastlines.

Study of seawater intrusion risk in specific aquifers around the eastern Mediterranean coast.

During 2012, work was also initiated on further application of the analytical solution of Koussis et al. (2012) to a specifically study seawater intrusion vulnerability and risk in previously characterised specific coastal aquifers in Cyprus, Israel, and the central and eastern Nile delta, under changing climate, groundwater management, and sea level. This work was still ongoing at the end of 2012 and will be finalized in 2013. Figure 13 illustrates some preliminary results for the studied Akrotiri aquifer in Israel.

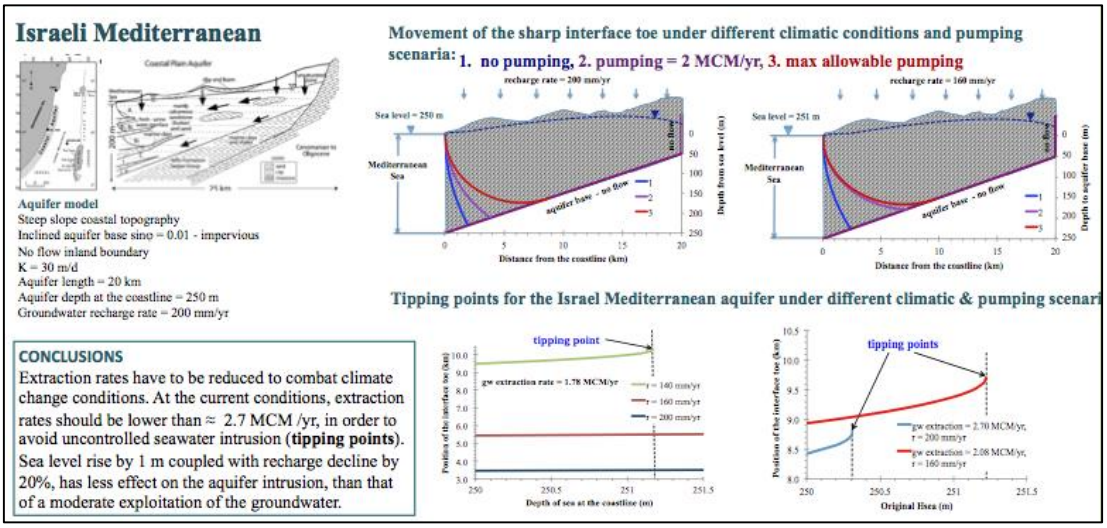

Figure 13: Preliminary results from study C for the Akrotiri aquifer in Israel.

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Distinctions

The European Geosciences Union (EGU) awarded its Henry Darcy Medal for 2013 to NEO researcher Georgia Destouni in recognition of ”her outstanding, path-breaking, and seminal contributions to hydrology and water resources research” (http://meetingorganizer.copernicus.org/EGU2013/session/13315).

Planned activities for 2013

During 2013 we plan to:

- finalize and publish the study of seawater intrusion risk in specific aquifers around the eastern Mediterranean coast
- start and develop a study of saltwater intrusion conditions and change scenarios for the Gialova Lagoon site.
- start and develop a study of long-term hydroclimatic change in Greece.
- initiate field measurements of soil moisture dynamics at NEO as part of an international network of similar measurements along a climatic gradient from the Arctic, through Sweden, to NEO.

3.5 Tree-ringing

Research description

The tree-ring research group at NEO had two main focii during 2012:

Dendroclimatology

This project investigates the impact from climate change on old-living trees in the high Greek mountains. Trees at high-elevation sites are growing close to their ecological limit which means that even small changes in temperature and/or precipitation will have a strong impact on growth conditions: Trees growing at relatively cold/moist sites are more sensitive to changes in temperature, while trees growing at relatively warm/dry sites are more sensitive to changes in water availability. The project takes advantage of this contrasting climatic sensitivity to study the effect on water-use efficiency in trees from changes in temperature, precipitation, and atmospheric CO2. The results are used to develop new and improved methods in dendroclimatology and in reconstructions of past climate variability in Greece.

Dendrochemistry

This project is exploring new physical and chemical tree-ring proxies that potentially can provide detailed information on extreme environmental events which can be linked to the human history.

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
- Christos Repapis, Professor, former Director of the Research Center for Climatology of the Academy of Athens

Major research activities 2012

Dendroclimatology

In 2011 six high altitude sites in Greece were selected for dendrochronological sampling (Fig. 14). The goal was to find old-living trees growing at their natural limits in terms of climate and environmental conditions. About 150 samples were collected at these six sites during the first field campaign and the samples were brought to Stockholm University's Tree-Ring Laboratory where they were analysed during 2012. The precise calendar date of each tree ring was determined by a technique of pairwise crossdating and the width of each ring was measured with a precision of 1/1000 mm.

Three site-chronologies were developed during 2012 (Tab. 1). The tree species is *Pinus Heldreichii* (PIHE) or "Bosnian pine" which, incidentally, does not grow on Peloponnesus. On Peloponnesus *Pinus nigra* (PINI) or "Black pine", replaces Bosnian

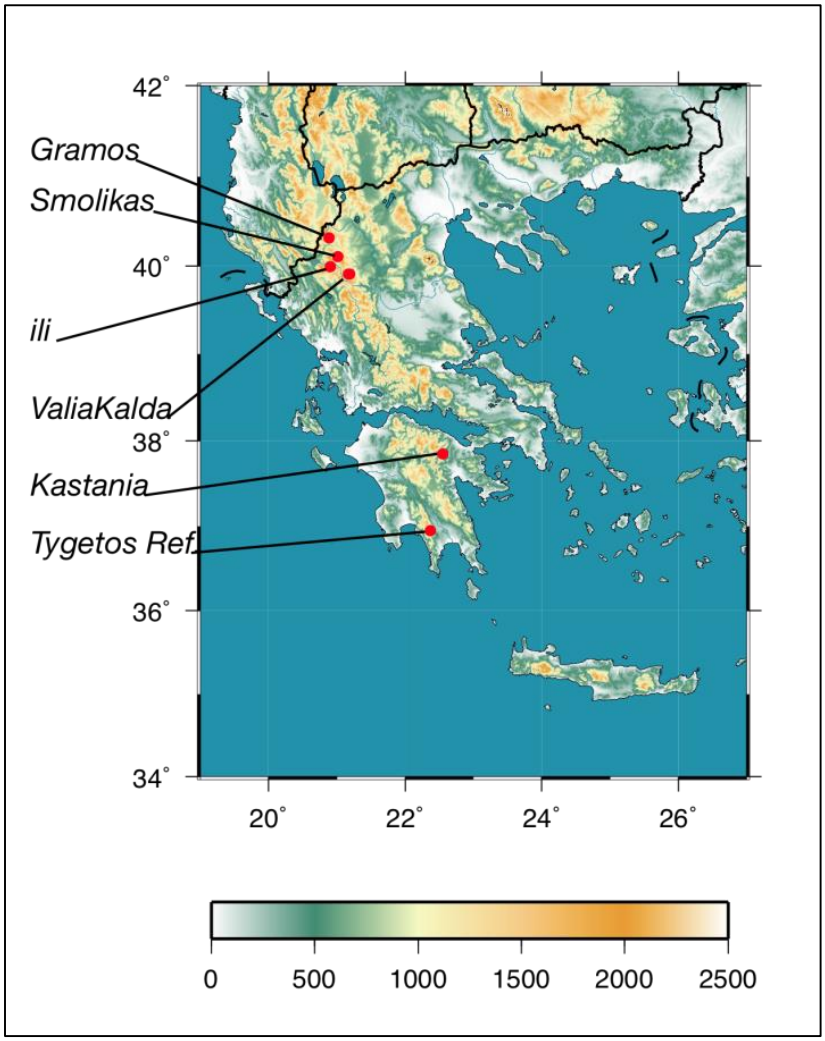

Figure 14:. Location of the sampling sites. The color scale shows altitude in metres above sea level.

pine as the targeted species. From these data a small network of climate sensitive chronologies from Northern Greece has been built. The composite chronology, consisting of all three sites has been analyzed for correlation with significant climate field variables. The variables of interest are maximum temperature (Tmax) and precipitation (ppt).

Table 1: Current site-chronologies and basic statistics.

Name	#cores	Master Series length	#years	Mean sensitivity
Valia Kalda	23	1291-2010	720	0.219
Smolikas	19	962-2010	1049	0.216
Ili	23	1255-2008	754	0.179

Using principle component analysis (PCA) and Varimax Rotation (VR), four significant groupings of the tree-ring data were defined. The first PC, explaining nearly 29% of the common variance amongst the trees, included all samples. This is to be expected as all the trees (despite their separate locations) are of the same species and not growing under demonstrably different climate regimes. The 2nd PC,

explaining only 10.5% of the common variance, perfectly identifies the three different sites. However, the Varimax Factor loadings suggest a slightly different story that seems to identify 2 functional groupings independent of the sites. In addition, this second factor (VF_2) explains 32% of the common variance. So the question is what do these two functional groupings represent in terms of a common signal in the trees? Could one be temperature, the other precipitation? Or could either be a more pronounced expression of the same variable?? To further investigate this condition we compute the Varimax scores for each of the two factors and then compare their performance against a number of climate variables using KNMI's Climate Explorer http://climexp.knmi.nl Figure 15 demonstrates the degree to which these three Greek chronologies record past climate variability. From this foundation we can examine various aspects of climate variability over the region.

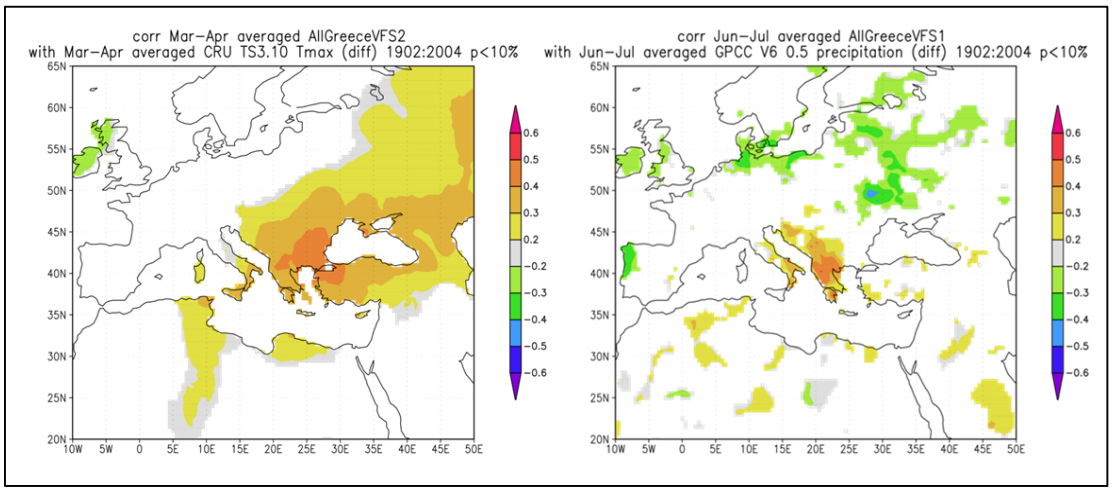

Figure 15: Field correlations between gridded climate data and the two Verimax Factor (VF) functional groupings. Left panel shows the correlation between VF_2 and March – April maximum temperature. Right panel shows correlation between VF_1 and June – July averaged precipitation.

Dendrochemistry

During 2012 the project produced the initial results of a multi-proxy analysis on a piece of oak from the region of Viotia, northwest of Athens. The analyzed samples belong to a gigantic oak tree, the "Pausanias tree" (Fig. 16), that was recognized as a historical natural monument for preservation in 1975. Unfortunately, the tree was severely damaged by thunderstorms and lightning in November 1987 and died sometime shortly after. The Academy of Athens was able to save part of a branch, one meter in diameter and about 10 meters in length.

Figure 16: The "Pausanias tree".

Ring widths were measured in two samples from the outer part of the cross section (Fig. 17). One sample was further analyzed with the Itrax MultiScanner at Stockholm University Tree- Ring Laboratory. The Itrax instrument can produce eight different ring width and x-ray density parameters for each ring.

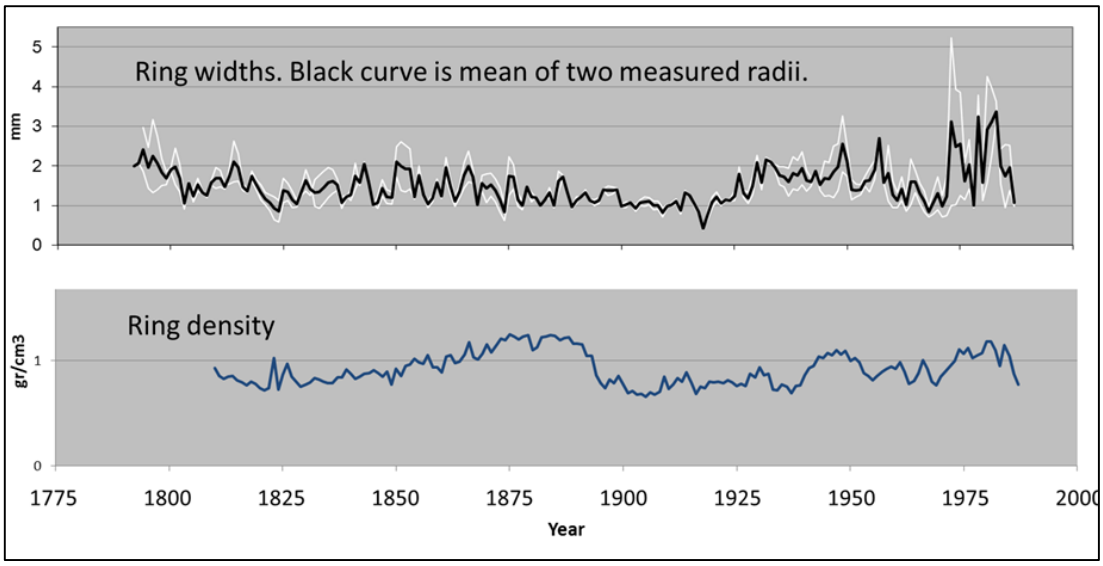

Figure 17: The upper panel shows the year-to-year change in ring width (mm) from the late 18th century up to 1987 when the tree died. Measurements were made on two different sections, then crossdated and combined into one average timeseries. The lower panel shows the corresponding year-to-year change in average ring density (g/cm^3).

The instrument can also determine a range of chemical elements in the wood using energy dispersive x-ray fluorescence (EDXRF). Some of the analysed elements are shown in Figure 18. The marked change in tree-ring density after about 1880 is contemporary with a marked change in the concentration of some elements. The cause of this event is not known.

Oak trees from this part of Greece are sensitive to changes in the hydrological climate. However, the tree-ring data from this one single tree show weak correlations with the climate records at a nearby meteorological station (Aliartos). More oak trees need to be sampled from this location in order to create strong regional records that can be used to study how changes in the environment will affect tree-ring width, density and chemistry. Once we are able to understand and quantify these relationships we will also be able to reconstruct details of environmental and climatic events in the recent history that may be linked to the human history of this region.

By carefully combining data from living trees with data from ancient wood - retrieved from natural sources, archaeology, or historical monuments – the tree-ring width, density and chemistry records may eventually be extended for hundreds and possibly thousands of years into the past.

Planned activities for 2013

During 2013 we plan to:

- perform a field campaign in May – July 2013 with extensive sampling of old-aged pine trees in the high Pindus mountain range. The field work will concentrate on those sites from 2011 that have the greatest potential of producing millennial length chronologies. New sites and species will be explored in central and southern Greece.
- Perform one week of fieldwork in the autumn for collecting new material for dendrochemical analyses.

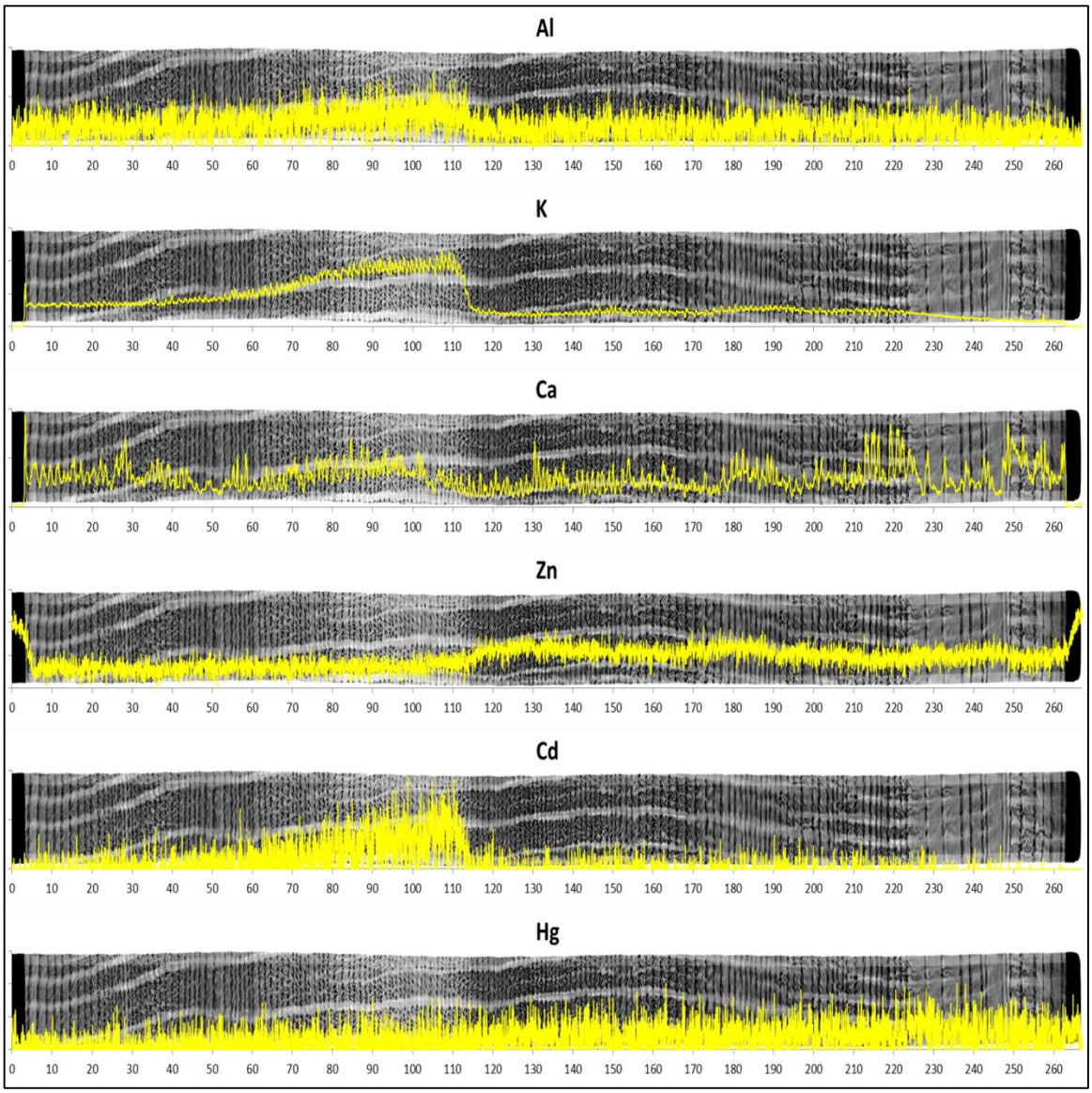

Figure 18: Energy dispersive x-ray fluorescence (EDXRF) line scans of one sample section (same as for the density analysis in Figure 17) showing the relative change in concentration of six different elements. The background image is the x-ray graph from the density analysis. The line scans are made in 0.05 mm increments and the x-axis scales are in mm.

3.6 Cave speleothems and wetland sediments

Research description

The Peloponnese peninsula offers an excellent opportunity to study the co-evolution of climatic, environmental and cultural changes in a historical perspective, going all the way back to Bronze Age civilizations. A focal point in this research theme is to extract precise and well-dated information on climate variability, flooding events and sea-level history, using speleothems in caves and sediments from wetlands, situated in Messinia, Lakonia and Arcadia (Fig. 19). The major objectives are to:

- improve the geographical coverage of terrestrial high-resolution paleoenvironmental records from eastern Mediterranean spanning from last Glacial to recent times;
- compare obtained terrestrial records with the marine isotope record and other marine climate records from eastern Mediterranean, thereby testing the connection between the marine and continental realm;
- contrast obtained records of past climate variability with results from climate models, thereby testing hypotheses for reasons behind past regional climatic changes;
- integrate the information on past climate variability and vegetation dynamics retrieved from this project with information from archaeological/anthropological focused studies carried out in parallel at the same localities. This will provide a holistic non-simplistic approach towards a deeper understanding of past societies resilience and adaptation strategies to a changing physical environment.

Provided ideal conditions, speleothems (i.e. cave formations, such as stalagmites, stalactites etc.) produce information about past climate variability with high chronological control. The most common climate proxies analyzed from speleothems are stable isotopes from oxygen and carbon. Studies of the variations in the isotopes can reveal information on past changes in temperature, precipitation and vegetation.

Sediments from lakes and wetlands contain information on past conditions that can be reconstructed through analysis of pollen, diatoms and phytoliths preserved in the sediments. Fossil pollen composition is conventionally used as a record for past regional vegetation, but can indirectly also infer changes in regional climate and local hydrological change. Phytoliths are siliceous remnants of plants, mainly grasses that are often very well preserved and used within studies of paleovegetation and archeobotany. Diatoms, or fossil silica algae, thrive in all environments containing water, and the species distribution in sediments inform about past environmental conditions related to rainfall and humidity.

The combination of using data from speleothems - mainly recorder of past changes in precipitiation and temperature - and lake sediments – mainly recorder of vegetation and humidity - will hopefully allow us to better distinguish the role of human versus climate factors behind observed vegetation changes.

<u>Researchers involved:</u>

- Karin Holmgren, Stockholm University

- Mira Bar-Matthews, Geological Survey of Israel
- Meighan Boyd, Stockholm University
- Martin Finné, Stockholm University
- Nikos Kalivitis, University of Crete
- Panagiotis Karkanas, Ephoreia of Palaeonthropology-Speleology of Southern Greece
- Giorgos Maneas, Stockholm University
- Elin Norström, Stockholm University
- Hanna Sundqvist, Stockholm University
- Nikos Zacharias, University of the Peloponnese

Figure 19: Map of Peloponnese showing the location of sites currently studied (Kapsia, Alepotrypa and Kapsia Caves) and sites planned to be studied (Schiza Cave, Sapienza sediments, Gialova and Evrota wetlands).

Major research activities 2012

Kapsia Cave and Glyfada Cave

Earlier initiated speleothem studies in Kapsia Cave and Glyfada Cave (Fig. 19), being part of PhD candidate Martin Finné's PhD project (supervised by Holmgren and Sundqvist) continued at a slower speed, due to the fact that Martin was on parental leave during most of the year 2012. Field work, focusing on monitoring of cave climate and recent stalagmite forming processes, was carried out in January and July. The first scientific results from the studies of speleothems in Kapsia Cave were presented orally and in a poster during the research workshop entitled *Climate and Environmental Change in the Mediterranean Region* that took place at the NEO Research Station, 26-27 October 2012, in connection to the official inauguration of

the station (Fig. 20). A near-ready manuscript will be submitted to the journal *Quaternary Research*, with Martin Finné as the lead author. A stalagmite from Glyfada Cave, previously dated to the Last Glacial period, was also sub-sampled for stable isotope analysis.

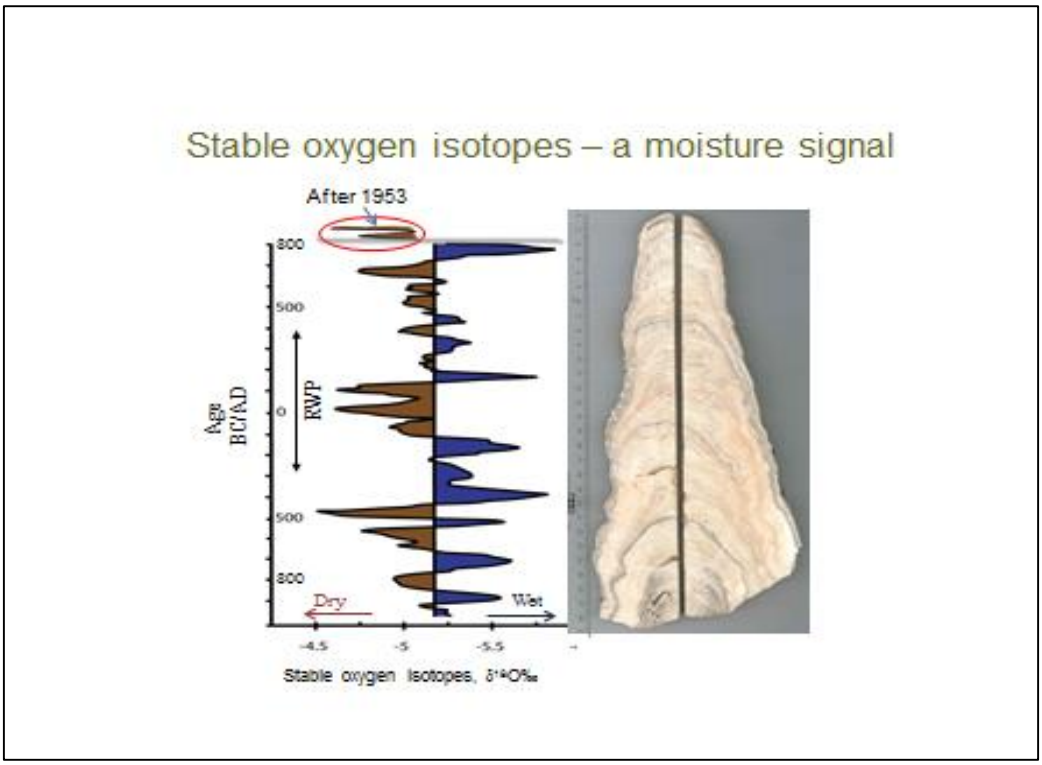

Figure 20: The Kapsia Cave stalagmite studied grew from 1000 BC until 800 AD. After a stop in growth it started grow again in the 1950s. Isotope analysis show that rainfall amount appears to have both multidecadal variability and a quasi-500-year-cycle with a slow trend towards drier conditions followed by a rapid change towards wetter situations.

Alepotrypa Cave of Diros.

Alepotrypa Cave is one of the most important Neolithic caves in Greece, and was inhabited by humans from ~7800 to 5000 years ago. Habitation ceased when an earthquake caused extensive damage to the cave. The entrance was sealed by rock debris leaving the humans inside to die, unburied. The cave is now part of a EU-funded cultural heritage restoration program. A joint Greek-American interdisciplinary research team, is currently excavating the cave for reconstruction of the past society, including studies on the settlement pattern, subsistence, diet and health status, long-distance to local-scale trading activities and land use system. In order to also get a better understanding of human responses to the regional climate Karin Holmgren was invited by one of the researchers in the on-going project, Dr P Karkanas, to evaluate the potential of the speleothems in the cave for paleoclimatic analysis. A field visit in March 2012 showed stalagmites representative of different time periods and significance:

- Actively growing stalagmites on a concrete stairway built in 1968. These deposits thus have the potential to provide a ~40-year-long record of calcite depostion, with a seasonal-to-annual signal (isotopes, trace elements, layer structure) that can

be compared to the in-strumental record, thereby improving our understanding between the speleothem-signal and regional climate parameters.
- Stalagmites growing on top of archaeological remains post-dating the time of human occupation.
- Stalagmites covered by soot from fireplaces and rituals during the time of occupation and predating the time of human occupation.
- Stalagmites of enormous size potentially providing information spanning > 100 000 years back in time

Dripping ocurred at several places in the cave during our visit and there were signs of present-day active spelothem formation, suggesting that the cave is suitable also for monitoring of recent speleothem-forming processes, which will give greater insight into past processes and conditions.

A new PhD candidate, Meighan Boyd, Stockholm University, was recruited and studies of Alepotrypa Cave will form the major part of her PhD studies, which will be supervised by Holmgren and Karkanas. Following permission that was kindly given by the Ephorate of Palaeoanthropology and Speleology of Southern Greece, the first field work was conducted in July and a second field visit took place in October. Speleothems, which are good candidates for paleoclimate analysis, were identified and a few samples of speleothem material from rubble piles were extracted from the cave under the supervision of the Ephoreia. Temperature loggers and stones collecting modern calcite precipitate were left in the cave. These will provide a baseline value for the climate signal seen in the cave today. Measurements of cave humidity, CO2 levels, and drip rates will be taken at logger and calcite collection sites, as well as in other cave chambers as part of the monitoring program.

Spartolakka, Sapienza Island

The Sapienza Island (9 km^2, highest peak 219 m.a.s.l) (Fig.19) belong to a group of four islands called The Inousses Islands which are included in the Greek Natura 2000 programme. No human activites or settlements exist today on Sapienza Island, which is famous for its wild goats and dense indigenous forest with 10-12 meter-tall evergreen broad-leaved trees, the so-called strawberry tree, *Arbutus unedo*. While – to our knowledge - no scientific studies have been carried out on any of the two islands, the forest on Sapienza is believed to be up to 10,000 years old. Central on the island there is a forest-free depression, with features resembling a paleo-lake that dried out (Figure 21). The depression is called Spartolakka in Greek, which means “Crop Pit”. From a field visit in March 2012 we found that the sediment section is more than 1 meter deep and a first investigation of the sediments show that they contain pollen, diatoms and phytoliths. The sheltered location makes the site suitable as a recorder of past regional vegetation and hydrology conditions.

New funds for extended paleoclimatic research

The Swedish Research Council approved the project application entitled "Late Quaternary Climate Variability and Vegetation Dynamics in southern Greece, with 5 000 000 Swedish crowns over a 4-year-period, 2013-2016. The application was submitted by Prof. Karin Holmgren, in collaboration with Dr. Panagiotis Karkanas from the Ephoreia of Palaeoanthropology-Speleology of Southern Greece and Dr.

Nikos Kalivitis from the University of Crete and Dr. Elin Norström, Stockholm University. The funds will enable us to study more sites on Peloponnese from a paleoclimatic and paleoenvironmental perspective. The research will increase the spatial coverage of annual-to-millennial-scale climate data, increase the accuracy of climate interpretations in the region, and provide data to improve existing climate modeling scenarios. Further, the information on past climate variability and vegetation dynamics retrieved from this project will be integrated with socio-cultural information from archaeological studies carried out in parallel at the same localities.

Figure 21: Group photograph during the visit to Spartolakka, Sapienza island, 22 March 2012.

Planned activities for 2013

During 2013 we plan to:

- publish results from Kapsia Cave
- perform stable isotope analysis and Uranium-series dating of speleothems of glacial times from Glyfada Cave
- sample speleothems from Alepotrypa Cave and initiate analyses of them
- uranium-series dating and isotope analyses of a speleothem from Schiza island (this might take form as a MSc-thesis)
- continue monitoring in all caves studied
- field inspections of the wetland at Evrotas floodplain (Fig.19) to determine if the site is suitable for sediment coring.
- a sediment coring campaign in Sapienza Island, Gialova Lagoon and Evrotas floodplain, provided that permits form the concerned authorities will be given.

4. Education

4.1 Courses

Bachelor's level course in Physical Geography and Quaternary Geology

The 2nd Student Field Course in Physical Geography and Quaternary Geology, given by the Department of Physical Geography and Quaternary Geology, Stockholm University, took place from 2 to 8 February 2012 (Figure 22). A total number of 55 students attended the course. Field course instructors were Ingmar Borgström, Sara Cousins, Alasdair Skelton, Martin Finné, Barbara Kleine and Matti Ermold. During the excursion we visited a number of different sites mainly in Messinia among them, the Gialova/Navarino Bay area, Artemisia, Sparta plain, Loussios River, Kapsia Cave, Mesochori, Methoni and Finikounda. The students looked at different subjects e.g. tectonics, geomorphology, land use changes, erosion and deposition, forest fires, biodiversity and hydrological processes. The different localities represent different types of environments e.g. coasts, mountains and plains, placing the subjects in different context for the students. In the Gialova area and in Loussios River students worked in smaller groups with projects with the aim of providing them with basic field work skills for example measuring distance, elevation and slope angles. In the Loussios River the projects involved the study of water discharge and water chemistry. In Gialova students worked with sand dune morphology, water chemistry, land use changes and bird diversity.

Figure 22: Stockholm University students during the 2nd Student Field Course at NEO at Lousios river canyon. Photo: Sara Cousins

Master's Level Course in Landscape Ecology - Theory and Design.

Within the Master's level course in Landscape Ecology, given by the Department of Physical Geography and Quaternary Geology, Stockholm University, we placed the field data collection for the projects to NEO. During 2-8 February 2012 six master-students took part in a field campaign to collect data for their projects. A focal point with the course was to analyse the way landscape changes affect ecosystems and species distributions. Emphasis was given to the conservation of species diversity in changing environments. The student were in charge of collecting data from several places around the Navarino bay, for example plant species richness along different road verges, difference in bird species distribution close to maccia vegetation and on the different "islands" on the golf course, as well as potential habitat restoration for the African Chameleon at Gialova Beach. Course instructor was Professor Sara Cousins and course assistant Matti Ermold.

Results from the course are available on our web www.navarinoneo.gr (short version, here) and on the NEO Mondo site (detailed version).

Plant biodiversity and evolution – a global perspective, 5-11 May 2012

A Master course, entitled "Plant biodiversity and evolution – a global perspective" took place 5-11 May at NEO. Associate Prof. Catarina Rydin, Department of Botany, Stockholm University, was the instructor of the course. The students were introduced to the natural and cultural flora of the Mediterranean and in particular Messinia (Fig. 23).

Figure 23: Stockholm University student during the ''Plant biodiversity and evolution – a global perspective'' masters course at NEO. Photo: Catarina Rydin

The 1st International Master's Level Course on Ecohydrology

This new international research course was jointly developed and given 17-23 June 2012 by teachers from Stockholm University, Steve Lyon and Cornell University, Todd Walter, to explore some of the central concepts of ecohydrology. The course brought together 8 students from both universities to investigate processes driving plant-water interactions in the Mediterranean environment surrounding Costa Navarino. Lyon et al. (2013) published important experiences and lessons learned from giving the course in the journal *Hydrology and Earth System Science*. Structuring an education strategy capable of addressing the various spheres of ecohydrology is difficult due to the interdisciplinary and cross-disciplinary nature and general breadth of this emergent field. Clearly, there is a need for such strategies to accommodate more progressive educational concepts while highlighting a skills-based edu-cation. The NEO course offers a case-study or "how-you-can-do-it" example, demonstrating a possible way to develop courses that include such concepts.

The main goal of the course was to explore some of the central theories in ecohydrology and their connection to plant–water interactions and the water cycle in a semiarid environment. Students designed and carried out several field experiments highlighting both the location's uniqueness and potential sensitivity to climatic changes (Fig. 24).

Figure 24: Participants in the NEO Ecohydrology course

The resulting paper from the course presents this roadmap for ecohydrology course development and explores the utility and effectiveness of adopting active teaching and learning strategies drawing from the suite of learn-by-doing, hands-on, and inquiry-based techniques. A potential gradient of "activeness" is tested across a sequence of three teaching and learning activities. Results indicate that there was a clear advantage for utilizing active learning with a preference among the students towards the more

"active" techniques. This demonstrates the added value of incorporating even the simplest active learning approaches in ecohydrology (or general) teaching.

2nd Training Course in Air Pollution, 8-9 November 2012

The 2nd training course in Air Pollution took place during 8- 9 November 2012 at NEO (Fi. 25). The course gave the chance to 16 undergraduate students from the Physics Department of the University of Patras, Greece, to:

- be informed about the air pollution characteristics at NEO greater area (climatology, local and regional air pollution sources, extreme air pollution events)
- be trained on chemical compound and aerosol measurements at the NEO Air Pollution Laboratory and the effects on radiative transfer in the atmosphere at the Solar Radiation Measurement Station.
- be able to process, analyze station data and present their results.

The training course was developed by Assistant Professor Andreas Kazantzidis, Laboratory of Atmospheric Physics, Physics Department, University of Patras, Greece. During the training course, the students were provided with key knowledge and skills taking into advantage the state of the art NEO instrumentation and facilities. They were competitive and motivated and created positive attitudes. They were guided through tasks and processes by their supervisor and the NEO experts, so that they learned how to perform a task and to what standard.

Figure 25: Students during their visit to the Atmospheric Laboratory at NEO (left) and working at the Computer room located at the new NEO building (right).

4.2 Navarino Natura Hall

Volunteers

For 2012 season, Natura Hall opened its doors in May 1, hosting interactive exhibitions about Messinia environment and culture and about environmental issues of more general interest. For the period June – September, six volunteers were recruited to assist visitors in the Natura Hall. Karin Ekstedt, Karin Widström and Miron Moraitopoulos Arljung, were students from Stockholm University. Estela Ruiz de Azua Sudupe and Lidia Roncero Crespo came from Spain with previous experience from Messinia environment, and Stathis Charitos was student from University of Patras. The NEO Station Manager acted as the volunteers local supervisor. During their stay they also visited Archelon's camp in Kyparrisia for two nights and took part in conservation activities concerning the protection of Caretta-Caretta/ sea turtle.

Astronomy

A telescope was purchased after consultation by experts from the National Observatory of Athens (NOA) concerning requirements etc, and was brought to NEO for developing educational/observational activities in the field of astronomy, linked to Natura Hall. The telescope will be operated by NEO Station Manager supervised by experts from NOA.

5. Dissemination and outreach

5.1 Official inauguration of the NEO Research Station

The official inauguration of the NEO Research Station was held on Saturday October 27 in Costa Navarino, in the Greek region of Messinia, by Professor Kåre Bremer, Vice-Chancellor of Stockholm University, Professor George Contopoulos, President of the Academy of Athens, Professor Gregoris Skalkeas, President of the Biomedical Research Foundation of the Academy of Athens and Mr. Achilles Constantakopoulos, President of TEMES S.A.. The ceremony's guests of honour were the President and 1st Vice-President of the Royal Swedish Academy of Sciences, Prof. Barbara Cannon and Prof. Stefan Claesson respectively, who delivered the keynote speeches. The ceremony was also honoured by the presence of the Greek Minister of Tourism, Mrs Olga Kefalogianni, the Greek Member of the European Parliament Mrs. Rodi Kratsa-Tsagkaropoulou, the Ambassador of Sweden to Greece Mr. Håkan Malmqvist, as well as by many other prominent guests (Fig. 26).

Figure 26: Prof. Claesson, Prof. Kontopoulos, Prof. Skalkeas and Mrs. Rodi Kratsa-Tsagkaropoulou at the Inauguration ceremony.

The well-attended inauguration event included scientific sessions as well as environmental and cultural activities. All this together highlighted a successful collaboration that is already an international point of reference for scientific and educational work that will contribute to the global efforts within the research field of climate change. Within the framework of the NEO inauguration, a panel discussion on the Mediterranean Climate and Environment was also held, that was moderated by Anders Wijkman (Senior Advisor, Stockholm Environment Institute, President of the Rome Club and former Assistant Secretary General, United Nations). Furthermore, Prof. Petros Themelis (Professor Emeritus in Archaeology at the University of Crete and head of excavations and restoration at Ancient Messini) gave a lecture on the Environment and its significance for ancient Greece.

5.2 Workshops

1st NEO-atmospheric research group workshop

The first NEO-atmospheric research group workshop was held at NEO 25-30 June with the participation of Evangelos Gerasopoulos, Academy of Athens, HC Hansson, Peter Tunved and Radovan Krejci ITM, SU. The first year of data was evaluated, a paper outlining the results was prepared and future research activities were planned.

Teachers' Collegium

The Teachers' Collegium of the Geology Department, Stockholm University took place at Costa Navarino 5-8 June. The Collegium was led by the Head of the Department, Prof. Alasdair Skelton

2nd NEO Research Workshop

The 2nd NEO Research Workshop, entitled Climate and Environmental Change in the Mediterranean Region was held on 26-27 October 2012 in the NEO Research Station, Costa Navarino, Messinia, Greece (Fig. 27). With more than 35 participants coming from several Institutes and Universities, it was an international and multi-disciplinary platform for sharing latest research results and developing new research initiatives. During the first day of the workshop the research themes included Atmospheric Science, Hydrology and Geomorphology. The second day included presentations on Past Climate and Environment. All NEO related research was presented orally as well as in poster session which is still exhibited at the NEO research station, and on our web: www.navarinoneo.gr.

Figure 27: Participants at the 2nd NEO Research Workshop outside the new building (left). Prof. Kåre Bremer, Vice-Chancellor of Stockholm University, at the poster session (right).

5.3 Publications

Annual Report

NEO Annual Report 2011 was published and up-loaded on the NEO web.

NEONEA

Four newsletters, called NEONEA, were published on the NEO web.

NEO leaflet

A NEO information leaflet was produced to be distributed to Costa Navarino guests and others interested in NEO. The leaflet is available upon request by NEO Management.

Scientific Peer-review Publications (NEO researchers highlighted in bold)

Anchukaitis KJ, Breitenmoser P, Briffa KR, Buchwa A, Büntgen U, Cook ER, D'Arrigo RD, Esper J, Evans MN, Frank D, **Grudd H,** Gunnarson BE, Hughes MK, Kirdyanov AV, Körner C, **Krusic PJ**, Luckman B, Melvin TM, Salzer MW, Shashkin AV, Timmreck C, Vaganov EA, and Wilson RJS, (2012): No evidence for misdating of tree-ring chronologies associated with volcanic cooling. *Nature Geoscience* 5, 836–837.

Eleftheratos, K., Isaksen, I. S. A., **Zerefos, C. S.** Tourpali, K. and Nastos, P. (2012): Comparison of Ozone Variations from Model Calculations (OsloCTM2) and Satellite Retrievals (SBUV), *11th International Conference on Meteorology, Climatology and Atmospheric Physics (COMECAP 2012)*, Athens, Greece, 29 May – 1 June 2012, C. G. Helmis and P. T. Nastos (eds.), Advances in Meteorology, Climatology and Atmospheric Physics, Springer Atmospheric Sciences, DOI 10.1007/978-3-642-29172-2_132, © Springer-Verlag Berlin Heidelberg, pp. 945–950.

Kalivitis, N., Stavroulas, I., Bougiatioti, A., Kouvarakis, G., Gagné, S., Manninen, H. E., Kulmala, M., and **Mihalopoulos, N**. (2012): Night-time enhanced atmospheric ion concentrations in the marine boundary layer. *Atmos. Chem. Phys.*, 12, 3627-3638.

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.

Ljungqvist FC, **Krusic PJ,** Brattström G, and **Sundqvist HS**, (2012): Northern Hemisphere temperature patterns in the last 12 centuries. *Climate of the Past*, 8, 227–249.

Zerefos, C. S., Tourpali, K., Eleftheratos, K., Kazadzis, S., Meleti, C., Feister, U., Koskela, T., and Heikkilä, A.(2012): Evidence of a possible turning point in solar UV-B over Canada, Europe and Japan, Atmos. Chem. Phys., 12, 2469-2477.

5.4 Presentations at conferences

Athanasopoulou E., **Gerasopoulos E.,** Vogel H., Kazadzis S., Liakakou E., Gratsea M., and Vogel B., Aerosol observations and predictions in the southeastern Europe

during the extreme summer 2007, EAC European Aerosol Conference, Granada, Spain, 2-7 September 2012.

Destouni G., Changes to Earth's freshwater – natural and anthropogenic drivers, Colloquium on *The greenhouse effect in our planetary system*, Academy of Athens, Athens, Greece, 29 October, 2012.

Kleine, B., Huet, B., **Skelton, A.,** Fluid-induced Blueschist preservation on Syros, Cyclades, Southern Greece. EGU, Vienna, April, 2012.

Kleine, B., Huet, B., **Skelton, A.** Fluid-induced Blueschist preservation on Syros, Cyclades, Southern Greece. DeltaMIN workshop, Spain, March, 2012.

Sciare J., Di Sarra A., Ellul R., **Gerasopoulos E., Hansson H.C.,** Kleanthous S., Mihalopoulos N., Pey J., Querol X., and Yassaa N., A Mediterranean Atmospheric Network for in-situ aerosol measurements: Motivation and Objectives, EAC European Aerosol Conference, Granada, Spain, 2-7 September 2012.

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

Zerefos, C *The greenhouse effect in our planetary system*, Academy of Athens, Athens, Greece, 29 October, 2012.

5.5 Meetings, Lectures and Visits

The NEO Lecture series 2012 was organized with the coordination of University of Peloponnese.The first lecture of NEO Lecture series 2012 was held by Prof. Sara Cousins, Stockholm University, on February 1 and titled "How landscape patterns influence species diversity". Alasdair Skelton's lecture was cancelled due to bad weather conditions.

Karin Holmgren gave a popular lecture at University of Patras in January 2012

Evangelos Gerasopoulos and Radic Krejci participated in ACTRIS-WP3 technical meeting in Leipzig during 15-19 October 2012, where NEO station status of infrastructure and measurements were presented.

Evangelos Gerasopoulos visited the Hellenic National Meteorological Service (HNMS) 13 November 2012, and presented NEO activities. He had discussions with the Commander of HNMS and the directors of different section on possible collaboration within common activities and sharing of infrastructure.

NEO was advertised at the American Geophysical Union fall meeting in December 2012. The AGU Fall Meeting is the largest worldwide conference in the geophysical sciences, attracting nearly 20,000 Earth and space scientists, educators, students, and policy makers.

In January 2012, NEO Director Karin Holmgren and NEO station manager Nikos Kalivitis visited the Hellenic Marine Environment Protection Association (HELMEPA) Junior and met with 25 third-grade pupils of the "Plato" Elementary School. The visit took place in the framework of an informative meeting with

HELMEPA and TEMES representatives with the aim to enhance cooperation and project the research findings to children and youth through the "HELMEPA Junior" environmental programs (Fig. 28).

Figure 28: NEO Director Karin Holmgren and NEO station manager Nikos Kalivitis at HELMEPA Junior

5.6 Media

Swedish Radio Science Magazine

Swedish journalists form the Swedish Radio Science Magazine called Klotet, have interviewed Karin Holmgren about the NEO initiative, visited Temes in Athens and the NEO office at Costa Navarino, 17-19 September. Giorgos Maneas demonstrated some of the on-going NEO activities and Johan Kleman and Ingmar Borgström informed about their research (Fig. 29).

Figure 29: Visit of a Swedish journalist at NEO office at Costa Navarino

Italian Journalists

NEO Station Manager met with Italian journalists on the 31 October and talked with them about NEO and the research conducted under this framework

National television

NEO Station Manager, gave a short interview about NEO at the National television (ET-3). The whole film, in Greek, is available http://www.youtube.com/watch?v=4Sye9oJmhZQ

Videos

A new video telling the story of NEO was produced by TEMES and Pan entertainment. The video, entitled 'The story so far' was presented during the Inauguration ceremony. Two more videos were produced by Gunnar Zetterberg, Roland Fredriksson & Malin Stenberg de Serves at Stockholm University, aiming to recruit students and new partners. The videos are available http://navarinoneo.geo.su.se/index.php/gr/videos .

Press releases

Among several press releases, a press release about NEO Inauguration was send to local (Greek and Swedish) and international media after the event. A press release about "Late Quaternary Climate Variability and Vegetation Dynamics in southern Greece" research project was send to local media in Greece. The releases are available http://navarinoneo.geo.su.se/index.php/gr/neo-in-press.

6. NEO management

6.1 Administration

The NEO Steering Committee had two meetings in Athens during 2012. Following an announcement and recruitment process, a new Station Manager was recruited for NEO. Giorgos Maneas, former leader of the Hellenic Ornithological Society project at Gialova lagoon was selected to replace Nikos Kalivitis who moved to a research position.

6.2 Infrastructures

The NEO building

NEO management has officially taken control of the management of the new building. The NEO Research Station (cover photo) is a field station where scientists and students can meet, exchange knowledge and ideas and perform research and education mainly in NEO-relevant fields. It is located at the southern part of Costa Navarino premises, close to Romanos village. Among others this building contains:

- a small laboratory
- eight 3-bedrooms and two 2-bedrooms
- a large kitchen
- a computer/reading/ social/lectures room (Conference facilities may be also provided by the adjacent Costa Navarino resort)
- offices

6.3 Associated members

Three new associated members have joined NEO family:

- The Environmental Chemical Processes Laboratory (EPCL) of the University of Crete, running under Professor Nikolaos Mihalopoulos

- The Laboratory of Atmospheric Physics of the University of Patras (LAPUP), running under Professor Athanasios Argiriou.

- The Climatology, Climate Dynamics and Climate Change, Department of Geography - Justus Liebig University Giessen.

NEO Annual Report 2012

Edited by NEO Management

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