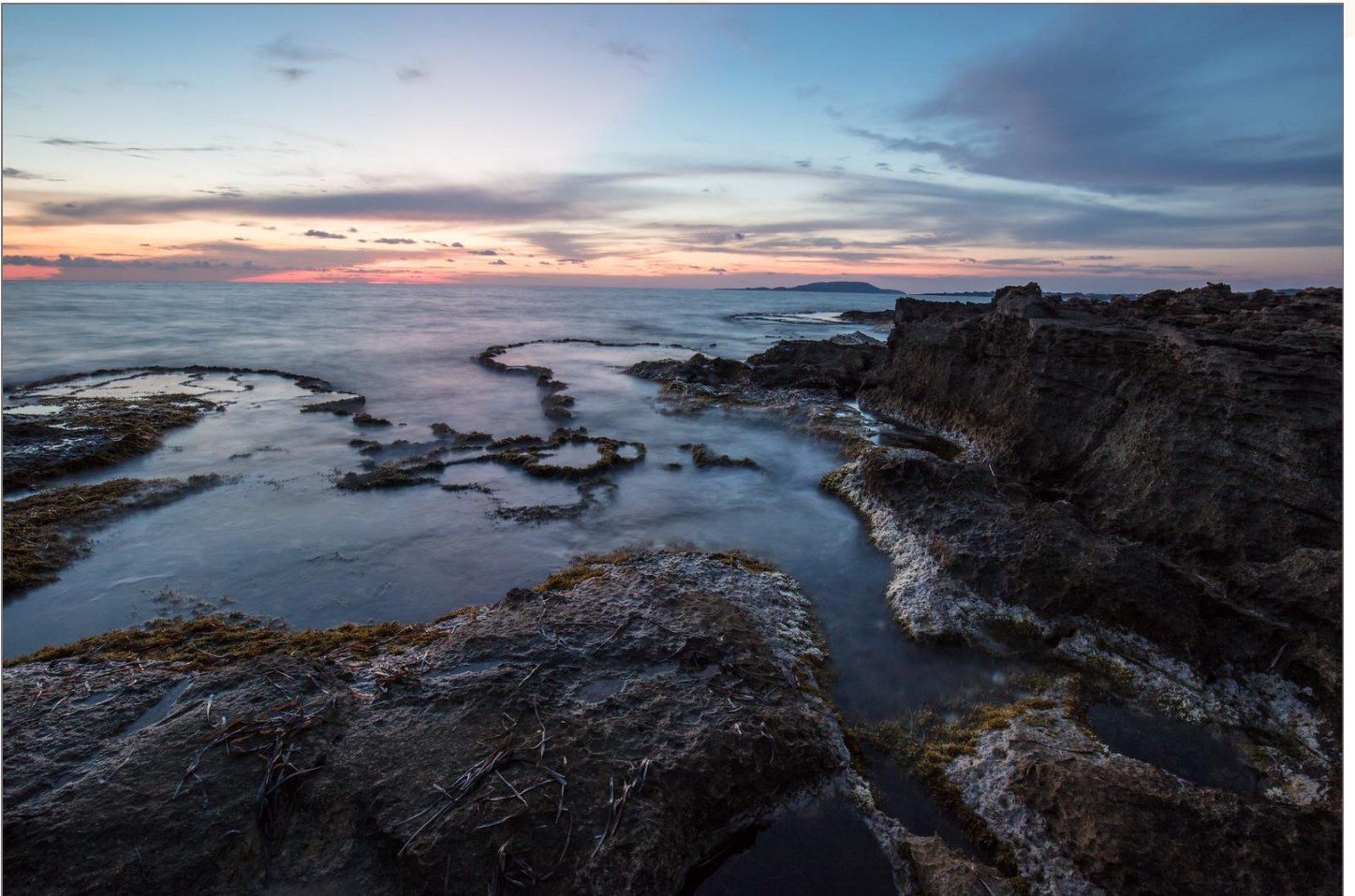


NAVARINO  
ENVIRONMENTAL  
OBSERVATORY

# ANNUAL REPORT

## 2019



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**Foreword**

NEO has continued to develop its operations within the framework of the new long-term strategy, decided by the three NEO core partners in 2018. Numerous activities and projects were implemented in 2019, linked to education, research and environmental monitoring. An example of NEOs attraction is the fact that over 250 students from seven different universities and institutions visited the station and conducted various forms of field studies last year. This demonstrates, not least, the Messenia region's high value in terms of offering an environment that illustrate different types of environmental and social issues.

The research agenda also continues to expand. In 2019, a number of stakeholder dialogues were organized within the EU Horizon 2020 project "Collaborative Land-Sea Integration Platform (Coastal)". These involved representatives from various economic sectors (fisheries, agricultural tourism) and local and regional decision-makers who, together with researchers, discussed challenges and opportunities related to the management of shared natural resources. Research work also continued to focus on the Natura2000 area, the Gialova lagoon. These two examples illustrate how scientific analysis and results forms the basis to inform decision makers and support the development of policy and management strategies.

Research on global water resources led by the Department of Natural Geography at Stockholm University can illustrates an example how NEO is increasingly connected to regional and global environmental and sustainability issues. One important example here is the integration of Greece and the eastern Mediterranean region to the map of continental and global science and database networks where large-scale hydro-climatic and freshwater variability and change are at the center of attention.

You can read more about these and other research projects in the annual report, but I wanted to highlight these three examples in order to demonstrate how the NEO collaboration increasingly attract research initiatives that ranges from the local to the global level and connects science and policy.

Environmental monitoring also continues at NEO and the associated Methoni atmospheric station, not least under the leadership of the National Observatory of Athens (NOA). In 2019, studies expanded on the long-term variability and trends in visibility across Greece, with a focus on identifying transport characteristics for the entire study period (1955-2012).

The NEO collaboration also continues to demonstrate strong convening power. An example of this was the conference "Challenges and Opportunities for a New Economy in the Context of Climate Change: Promoting Innovation for Sustainable Development", held at the Academy of Athens in May. The President of the Hellenic Republic Mr Prokopios Pavlopoulos and HRH Crown Princess Victoria of Sweden both attended the event. The seminar focused on opportunities arising from climate smart investments to promote Europe's 21st century low-carbon development, and efforts to meet the Paris Climate Agreement and Agenda 2030. The high-level participants included, among others, the Greek Deputy Minister for the Environment Socrates Fotmelos, the Ambassador of Sweden to Greece, Charlotte Sammelin, the heads of the three NEO core partner organizations, as well as state representatives, local government, prominent members of the Academy of Athens, civil society, banking and wider private sector.

A new cooperation agreement between the Atmospheric Environment Division of the Biomedical Research Foundation of the Academy of Athens, TEMES SA and Stockholm University was

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finalized in 2019. The agreement, which will take effect in March 2020, entails a commitment to another 5 years of collaboration and a strengthening of the core financial base for NEO. At the end of the year, NEO Director Johan Kuylenstierna also announced that he would step down from the position. The process of recruiting a new Director led to the appointment of Dr. Zahra Kalantari from the Department of Physical Geography at Stockholm University. The Steering Committee appointed Johan to become the new NEO Steering Committee Chair after the announcement by Professor Karin Holmgren that she would step down as Chair. The formal changes took place after the New Year, in early 2020.

As the new chair of the Steering Committee, I would like to take this opportunity to express my deep appreciation to Karin for all the work she has done for NEO, both as a previous NEO Director and in her role as the Chair of the Steering Committee. Karin has played an instrumental role in the development of NEO since the collaboration started in 2010.

As I write this foreword in May 2020, the world is suffering from the Covid-19 pandemic, which will affect all aspects of our countries and communities for many years to come. The more long-term effects on the environment, economy and society are still difficult to overlook, but one thing is clear; international, scientific collaboration will become even more important as a way to strengthening our capacity to deal with complex socio-environmental issues. The knowledge and skills generated through science and education must reach society even more effectively. This will clearly be a lesson from the handling of the current crisis and this is at the core of NEO's mission.



Johan Kuylenstierna  
Chairperson of the NEO Steering Committee

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### What is NEO?

[Navarino Environmental Observatory](#) (NEO), is an international cooperation between the academia and the private sector dedicated to research, education and science communication on the climate and environment of the Mediterranean region. Three partners constitute NEO: [Stockholm University](#); [Biomedical Research Foundation of the Academy of Athens](#); and [TEMES S.A](#) (Tourism Enterprises in Messina, SA). Located near Costa Navarino, Messinia, Greece, NEO is growing into a dynamic hub where scientists from all over the world conduct frontline research, develop new tools and methods, as well as meet to exchange knowledge and ideas.

### NEO Structure

The *NEO Steering Committee* (NEO SC) consists of a chairperson and two delegates from Stockholm University, two delegates from Academy of Athens and two delegates from TEMES SA (Figure 1).

*NEO management*, consists of the NEO director (Dr. Zahra Kalantari, Associate Professor in Land and Water Resources Engineering, and Research Area Leader of Bolin Centre for Climate Research, Department of Physical Geography, Stockholm University), the NEO Manager (Giorgos Maneas, PhD student at Department of Physical Geography, Stockholm University). In 2019, the NEO operations were strengthened with recruitment of a full time assistant, Mr. Christos Pantazis (National Observatory of Athens).



**Figure 1:** Structure of the NEO Steering Committee (2020).

### NEO Associated Members and networks

Since its start, NEO has gained several associated members, academic colleagues with which we collaborate. Our aim is to welcome more associated members from the private sector.

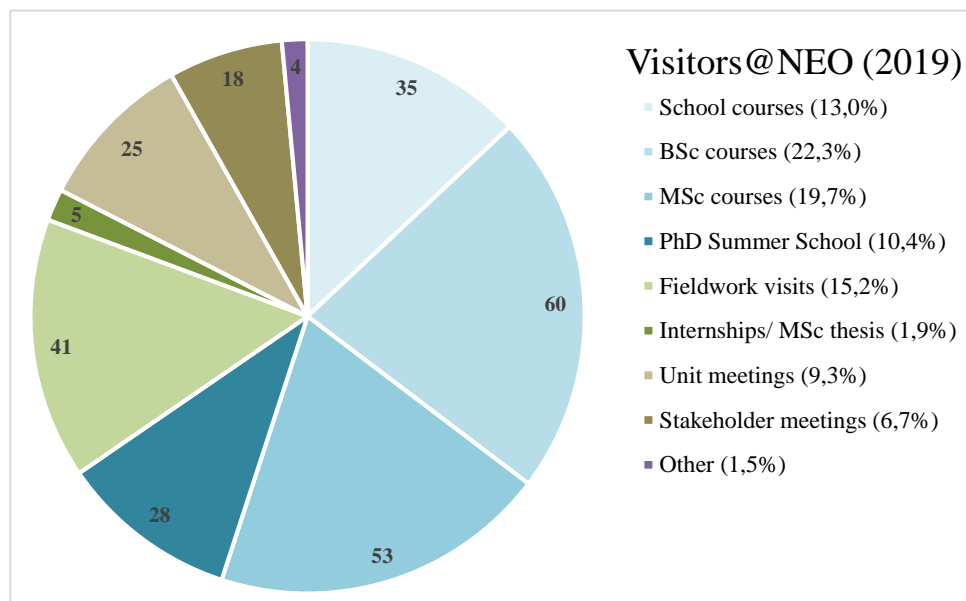
<b>Table 1:</b> NEO Associated members	
<b>Affiliation</b>	<b>Location</b>
<i>National Observatory of Athens</i>	Athens, Greece
<i>Environmental Chemical Processes Laboratory (ECPL), Dep. of Chemistry - University of Crete</i>	Iraklion, Greece
<i>Laboratory of Atmospheric Physics (LAPUP), Dep. of Physics - University of Patras</i>	Patras, Greece
<i>Laboratory of Climatology, Climate Dynamics and Climate Change, Dep. of Geography - Justus Liebig University Giessen</i>	Giessen, Germany
<i>Laboratory of Archaeometry, Dep. of History, Archaeology and Cultural Resources Management - University of Peloponnese</i>	Kalamata, Greece
<i>Soil and Water Lab, Dep. of Biological and Environmental Engineering, Cornell University</i>	Ithaca-NY, USA
<i>Laboratory of Tree-Ring Research, University of Arizona</i>	Tucson, USA
<i>Department of Geography, Johannes Gutenberg University</i>	Mainz, Germany
<i>Department of Archaeology and Ancient History, Uppsala University</i>	Uppsala, Sweden

Furthermore, NEO has become a member of [ACTRIS](#), the European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases, [GWEN](#), a Global Wetland Ecohydrology Network, and [LTER-Greece](#), the Greek Long-term Ecosystem Research Network which is a collaborative network of scientists and their stakeholders engaged in long-term, site-based ecological, social and economic research in Greece.

## 2019 NEO activities at a glance

Since 2010, NEO researchers have produced more than xx scientific publications. Recent NEO research initiatives, covering topics such as the effect of agriculture on biodiversity and water resources and the co-management of ecosystem services in Natura 2000 areas, illustrate our ambition to widen the scope of NEO inter-disciplinary research towards strategies for sustainable development of social-ecological systems and multifunctional landscapes in Messinia. To that end, NEO is gradually becoming a hub for sustainability research, contributing to local community. Since 2018, **NEO atmospheric station** at Methoni has become part of the PANACEA National Research Infrastructure (PANhellenic infrastructure for Atmospheric Composition and climatE change). Under the umbrella of the COASTAL EU project, which was initiated in 2018, local and scientific knowledge will be combined to identify problems and develop practical and robust business road maps and strategic policy guidelines, aimed at improving land-sea synergy. Furthermore, we have developed a new indicative strategy that outlines the future ambition for further development of the NEO collaboration.

*In 2019*, NEO hosted more than **250 students, teachers and researchers during 11 educational visits** from Greece, Sweden and Germany (one school, three bachelor courses, six master courses, one international summer school), **9 fieldwork visits**, and **2 workshops**. Christos Katrantsiotis defended his NEO related PhD thesis entitled “Holocene environmental



changes and climate variability in the Eastern Mediterranean: Multiproxy sediment records from the Peloponnese peninsula, SW Greece”. Gialova wetland has been the focus of several monitoring activities this year as well. Monitoring of birds, basic water parameters, climatic factors and touristic pressure, generate data which are fundamental for the future management of the area. Furthermore, in 2019 we developed a Groundwater Quality Monitoring Network around the Gialova lagoon. Two master students and three interns chose a subject in relation to the area this year.

A major event in spring 2019 was the conference on “*Challenges and Opportunities related to a new Climate Economy: Driving innovation for Sustainable Development*” that was organized at the Academy of Athens on 2 May as a collaboration between the NEO Partners and the Swedish Embassy in Greece. More than 200 participants from academia, business, civil society and the public sector attended and event was honoured with the presence of HE The President of the Hellenic Republic Mr Prokopios Pavlopoulos and HRH Crown Princess Victoria of Sweden. Under the umbrella of COASTAL project, in 2019, NEO in collaboration with HCMR (Hellenic Center of Marine Research) hosted the annual General Assembly of the project in May, and a stakeholder workshop in June. The workshop brought together representatives from key economic sectors of the region that, together with researchers, identified challenges and opportunities related to land-sea interaction, and integrated coastal zone management.

Two **members of NEO Board**, Christos Zerefos and Evangelos Gerasopoulos, have participated in the newly established **Special Committee for Tackling Climate Change of the Hellenic Ministry of Environment and Energy**. Professor Zerefos has been appointed as the State Representative for Climate Change.

## Education

### Activities @NEO station

Starting from the school level all the way to up to the PhD level, subjects studied during this year included geology, geomorphology, water resources, climate change, earth sciences, geography and interdisciplinary environmental management among others (Table 2). These courses were organized by several universities from Sweden, Greece and other European countries, and have attracted very many high esteemed scientists as lecturers or trainers. NEO in collaboration with the ACG (American College of Greece) continues “The Gialova experience” field course, for the students following Environmental studies at ACG.

For third consecutive year, the Hellenic Association of Aerosol Research (HAAR) picked NEO to host its summer school (Table 2). This summer school is becoming of increasing impact as it has become an official training activity of ACTRIS/ESFRI and has early managed to concentrate the lights of many high esteemed scientists and pioneer companies in the field, that participated in the one-week program that combined introduction to theory, hands on training on instrumentation and real measurements at NEO’s station in Methoni. The participants as well as the international audience of Post-Docs and PhD students that took the courses, are excellent ambassadors and significantly contribute to the visibility of NEO’s activities and facilities offered.

Course in	Level	Affiliation
<i>Natural disasters form a natural- and social science perspective</i>	Upper secondary school	Värmdö Gymnasium, Stockholm
<i>Physical Geography course</i>	Bachelor	Dep. of Physical Geography, Stockholm University
<i>The Gialova experience!</i>		American College of Greece, Athens
<i>Environmental History and Environmental Archives</i>		Institute for Ecosystem Research Kiel University
<i>Climate, Climate Change Impacts: Greece</i>	Master	Dep. of Geography, Justus-Liebig University of Giessen
<i>Cultural Heritage Materials and Technologies</i>		Dep. of History and Archaeology, University of Peloponnese
<i>Plant Biodiversity and evolution - a global perspective'</i>		Dep. of Biology Education, Stockholm University
<i>Applied Meteorology &amp; Environmental Physics</i>		Dep. of Physics University of Patras
<i>M.Sc. Hydrology, Hydrogeology and Water Resources</i>		Dep. of Physical Geography, Stockholm University
<i>Institute for Ecosystem Research</i>		Dep. of Physical Geography Kiel University
<i>Theory and practice of aerosol chemistry and engineering for climate, air quality, emissions and health effects, by means of In-Situ and Remote Sensing Observations</i>	PhD Summer School	Hellenic Association of Aerosol Research (HAAR)

### Students' thesis/ Internships

Two graduate students (Rana Chafez and Alex Galal) and one bachelor student (Philip Duzdabanian) have accomplished their internship at NEO during summer 2019. All three students have studied *Environmental Studies* at The American College of Greece (Deree) and their focus was on Ecosystem Services and human pressures on Voidokilia and Navarino bay. This internship and two additional bachelor theses, were co-supervised by researchers from NEO and the American College of Greece (Deree). Two master students from Stockholm University used NEO and Messinia as a base for their field studies. Edvin Holmerin, focused his thesis on the integrated olive farming and Sofia Maniatakou on the diverse values of water related ecosystem services. Furthermore, NEO in collaboration with the National Technical University of Athens, hosted Christos Pantazis, a master student at the program “Environment and Development”, Department of Rural and Survey Engineering, to do his thesis on NEO relevant research on Environmental monitoring of Gialova lagoon.

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**Table 3:** Completed Bsc and MSc thesis related to NEO in 2019.

Title	By	Level	Programme
<i>Evaluating the effects, seasonal fluctuations and persistence of microplastic littering in Voidokilia beach, Messinia</i>	Apostolos Fillipos Pappas	BSc	<b>International Honours Program</b> American College of Greece
<i>Winter Seasonal Variation in Mediterranean Wetlands and the Effect of Agricultural Activities on Water Quality: The case of Yalova, Greece</i>	Nephele Cauchi	BSc	<b>International Honours Program</b> American College of Greece
<i>Unraveling diverse values of ecosystem services: a socio-cultural valuation using the Q-methodology in Messenia, Greece</i>	Sofia Maniatakou	MSc	<b>Social Ecological Resilience for Sustainable Development</b> Stockholm Resilience Centre Stockholm University
<i>A Systems Perspective on Integrated Farming for Sustainable Coastal Development in Messinia, Greece</i>	Edvin Holmerin	MSc	<b>Environmental management and physical planning</b> Dep. of Physical Geography Stockholm University
<i>Groundwater dependent ecosystems of coastal aquifers. The case of Gialova (Messinia, Greece) hydro-system.</i>	Christos Pantazis	MSc	<b>Environment and Development</b> Dep. of Rural and Surveying Engineering, National Technical University of Athens



**Figure2:** Picture selection from educational activities @NEO station during 2019.

## Outreach

### *Events and café-NEO meetings*

In May 2019, NEO Seminar was held at the Academy of Athens entitled "***Challenges and Opportunities for a New Economy in the Context of Climate Change: Promoting Innovation for Sustainable Development***". The seminar focused on opportunities arising from climate smart investments promoting Europe's 21st century low-carbon development. The speeches highlighted integrated management of natural resources to achieve sustainable development and the role of innovation, entrepreneurship and investment in global climate change. The Greek Deputy Minister for the Environment Socrates Fotmelos, the Ambassador of Sweden to Greece, Charlotte Sammelin, as well as state representatives, local government, prominent members of the Academy of Athens, civil society, banking and wider private sector executives attended a series of thought-provoking sessions featuring distinguished speakers from Greece and Sweden. The event was honored with the presence of HE The President of the Hellenic Republic Mr Prokopios Pavlopoulos and HRH Crown Princess Victoria of Sweden.



**Figure 3:** The president of Stockholm University Astrid Söderbergh Widding giving her speech at NEO Seminar.

### *Workshops and day visits @NEO*

The members of the **Hydrological research unit** of the Department of Physical Geography, Stockholm University visited NEO in April, 2019. The main purpose was for the team to learn more about the NEO station as a resource for teaching and research, to become familiar with interesting aspects of the nearby environment, to make contacts with Greek scientists, and to stimulate the internal team building.

Two PhD students and their professor Mrs. Hrisi Karapanagioti from the **Chemistry department**, University of Patras visited NEO in order to participate in fieldwork activities related to the micro-plastic pollution on the beaches.



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### COASTAL - Collaborative Land-Sea Integration Platform, No 773782

#### Engaging local stakeholders

Under the umbrella of the COASTAL project, in 2019, NEO in collaboration with HCMR (Hellenic Center of Marine Research) hosted the annual General Assembly of the project in May, and a stakeholder workshop in June. The workshop brought together representatives from key economic sectors of the region and had a two-fold aim: (a) To inform the Multi Actor Lab (MAL) stakeholders about the outcomes from the six sectoral workshops, and (b) to ask them to work in groups and try to envision an ideal future for the area. The brand name “*Sustainable Messinia*”, was selected by our stakeholders as an ideal future for the region. In principal, this future would be based on the transition from conventional to integrated farming practises, but would expand across all sectors leading to improved environmental conditions, enhancing possibilities for thematic tourism (e.g. agritourism, ecotourism), among others. Based on this output, the next step of the project will include stock-flow modelling of critical parameters (e.g. water resources) aiming to present to the stakeholders how such a future can be achieved.



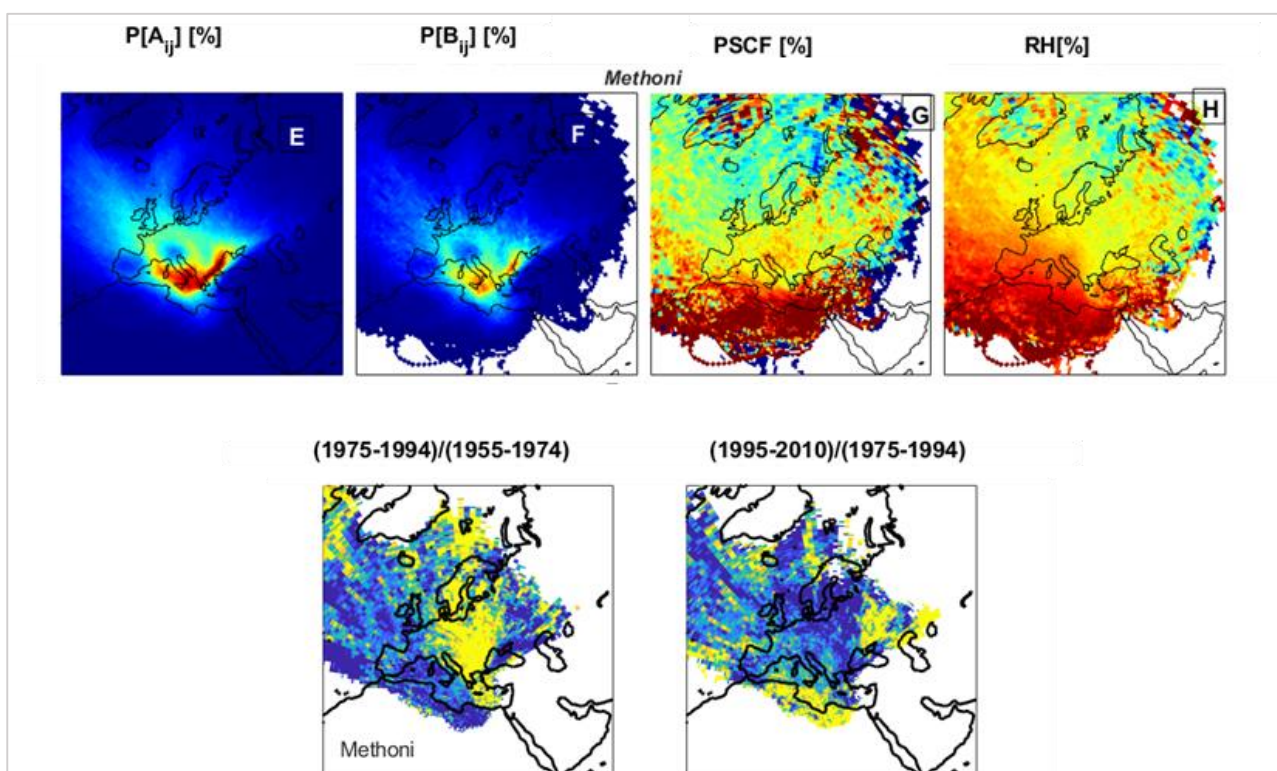
**Figure 4:** Group photo from the COASTAL General Assembly (top), and the Multi Actor Laboratory meeting (bottom) at NEO.

## Research

### Atmospheric research

NEO atmospheric research is undertaken by researchers from the Biomedical Research Foundation of the Academy of Athens (BRFAA), the Department of Environmental Science of Stockholm University (ACES) and the Institute for Environmental Research and Sustainable Development of the National Observatory of Athens (IERSD). The long-term monitoring of aerosol physical, chemical and optical properties, atmospheric trace gases, different solar radiation components as well as meteorological parameters, is the main focus of the atmospheric research activities conducted at NEO. The observations aim at shedding light on the factors that control the levels and variability of the species above as well as to discriminate the relevant contribution from long range transport versus local sources. NEO, as part of PANACEA, serves as one of the 3 sites selected in Greece to concentrate national and international efforts in the study of atmospheric composition and its relevance to climate change. PANACEA, standing for “PANhellenic infrastructure for Atmospheric Composition and climatE change (PANACEA)” (<http://panacea-ri.gr/>), was launched in September 2018. PANACEA, as part of the Hellenic Research Infrastructures (RI). The RI is actively linked with both ACTRIS/ESFRI and ICOS/ERIC, the relevant European Infrastructures that target aerosol, clouds, trace gases and the carbon observation, and aims at developing a coordinated system for monitoring of atmospheric composition, solar radiation variations, climate change and related natural hazards in Greece, merging all existing facilities and upgrading its infrastructure.

In 2019, the atmospheric group has expanded its studies on the long-term variability and trends in visibility over Greece. Its new analyses focused on the identification of transport characteristics for the whole study period (1955-2012) by calculating the most probable transport pathways, and the most frequent pathways of observing low and high visibility conditions. Moreover, the relative shift in transport patterns was revealed, comparing changes in trajectory transport probability function over the three main periods (1955-1974, 1975-1994 and 1995-2010). The results for Methoni station are presented in Figure 5, indicating two major transport pathways; one from NE and one from W-NW, being also the source regions of most frequently low visibility conditions.



**Figure 5:** (upper) Air mass transport probability function ( $P[A_{ij}]$ ), criteria probability function ( $P[B_{ij}]$ ), potential source contribution function (PSCF) and finally RH probability. Trajectory data corresponding to the time interval of visibility observations have been used. (lower) Trends in the transport probability function comparing the different periods.

Moreover, the transition between the two periods 1955-1974 and 1975-1994 involved more transport from central and eastern European source areas, well known to have increasing emissions during a large portion of the overall period, and a lessening of transport from the marine environment, and western Mediterranean in particular, in line with the observations of rapidly decreasing visibility during the two periods. During the transition between 1975-1994 to 1995-2010, the picture is quite the opposite, characterized by diminishing of European emissions of mainly sulfur dioxide, and a relative shift of source areas from continental Europe and the Balkans, to source regions in western Russia, western Mediterranean area and North Africa.

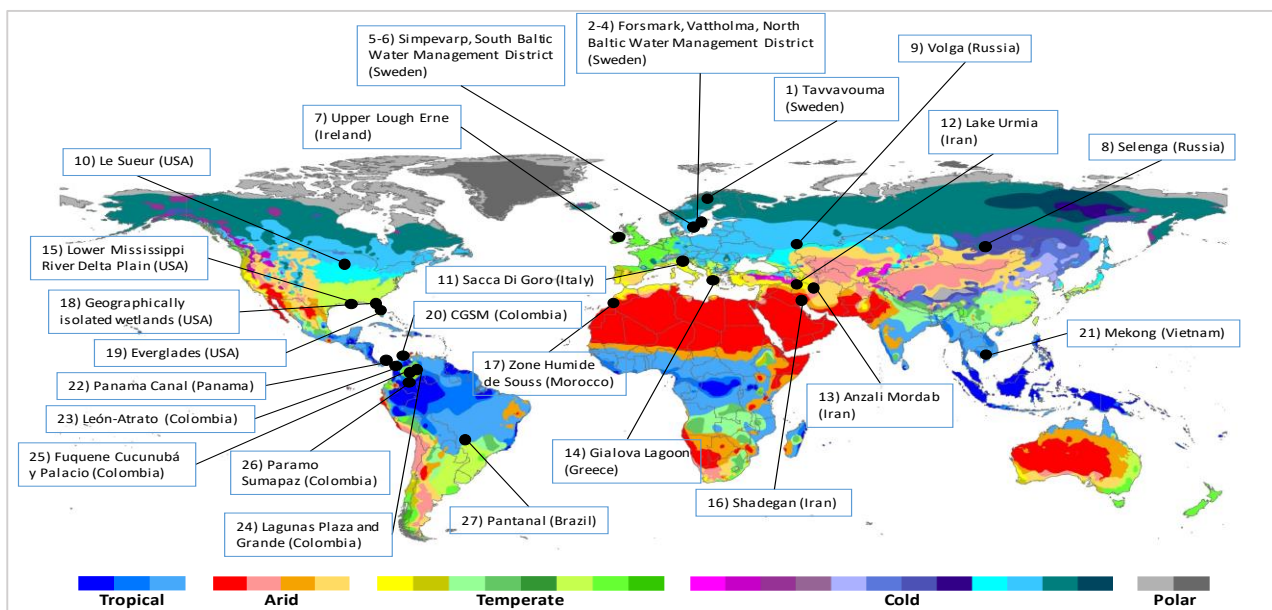
By analyzing historical visibility observations from different sites spread in the country, that represent areas of different climatic characteristics and different levels of remoteness from pollution sources, enables examination of the factors that have been controlling visibility levels throughout the decades, and decomposing to the extent possible climate change signals from regional urban growth/air pollution evolution. The delineation between the two major processes, climate change and man-made interferences, is not an easy task, but is probably what brings visibility in the forefront of scientists' attention lately.

Scientists from the Biomedical Research Foundation and the Academy of Athens have been involved in the implementation of the adaptation strategy for climate change for the Prefecture of Peloponnese, and are participating in the 8-year long EU competitive research project entitled “Boosting the implementation of adaptation policy across Greece LIFE-IP”.

### Water research

The water research undertaken by the team of Professor Georgia Destouni aims at advancing our understanding of key natural and human-driven environmental and societal processes and changes with impacts on water availability and quality in Greece and the Mediterranean region. Moreover, it aims at developing improved and novel methods and tools for process and change quantification that can support effective strategies for sustainable management of national and regional water resources. In previous NEO work, the team has, for example, investigated and identified tipping points for seawater intrusion into coastal groundwater under rising sea level and other hydro-climatic changes, and cost-efficient management measures for coastal aquifers via recharge with treated wastewater and desalination of brackish groundwater.

During 2019, the water research undertaken by researchers at and related to the Department of Physical Geography (NG) and NEO has largely focused on putting Greece and the eastern Mediterranean region on the map of continental and global science and database networks and advancements for large-scale hydro-climatic and freshwater variability and change.

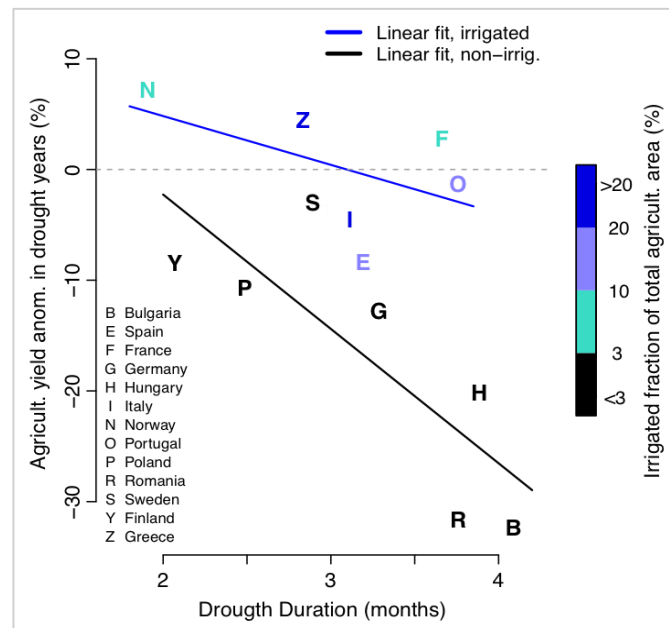


**Figure 6.** Geographical distribution of 27 wetlandscape sites included in the GWEN database, with the background map showing the Köppen-Geiger climate classification system. Source: Ghajarnia et al. (2019).

In its continued coordination of the Global Wetland Ecohydrology Network (GWEN, [www.gwennetwork.se](http://www.gwennetwork.se)), initiated at NEO in 2011, the NG team with GWEN colleagues has related wetland evolution issues, interactions, and priorities for the future to Agenda 2030 and its framework of Sustainable Development Goals (SDGs; Jaramillo et al., 2019). Furthermore, the NG and GWEN team has developed a key database for wetlandscapes and their climate and land-use driven changes around the world (Ghajarnia et al., 2019) (Figure 6).

For hydro-climatic changes over different time scales and climate zones across Europe, NG and NEO related researchers have further investigated and revealed warm-season covariations of temperature and precipitation, and shifts of these depending on considered time scale, since 850 CE (Charpentier Ljungqvist et al., 2019).

Moreover, for hydro-climatic extremes of droughts and their implications for vegetation in general and agricultural crop management in particular, NEO researcher Destouni and colleagues have investigated biospheric (vegetation, crop yield) responses to droughts across different parts the world (Orth et al., 2019). Results show that drought impacts generally intensify linearly with drought duration, but with different line relationships applying to world parts with different long-term hydro-climatic aridity characteristics, or infrastructural preparedness levels for agricultural irrigation. In particular, for Greece and its relatively high level of irrigation, results show relatively mild drought impacts on crop yields, on par with those of more humid parts of the world (Figure 7).



**Figure 7.** Drought duration control on drought-induced yearly agricultural yield anomalies across different countries. Source: Orth et al. (2019).

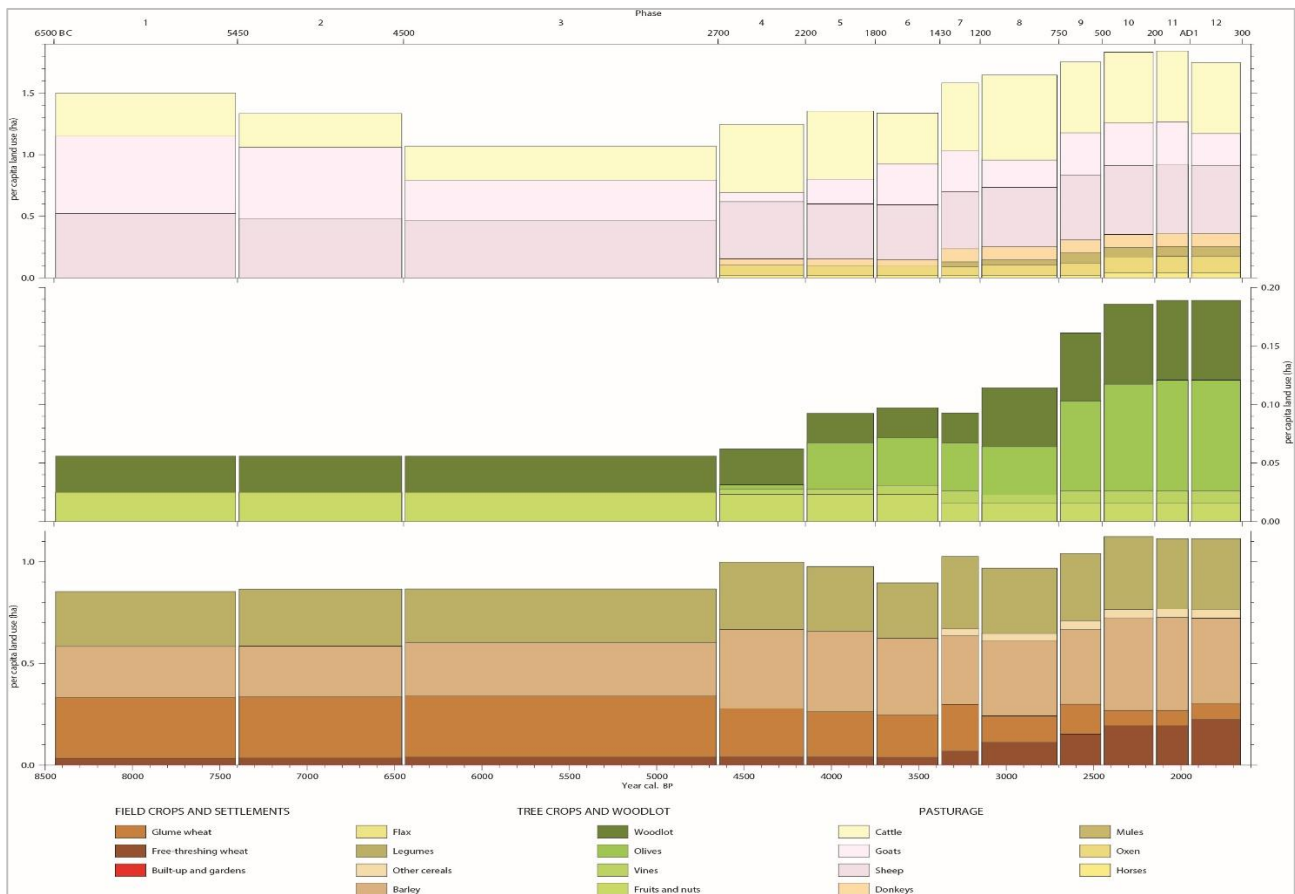
In addition to the large-scale efforts to include and investigate Greece and the eastern Mediterranean region as integral parts of continental-global hydro-climatic and freshwater variability and change, NEO water researchers have in 2019 also investigated local coastal wetland conditions and possible futures of Gialova Lagoon, using hydrological balance closure as main methodology (Manzoni et al., 2019). Moreover, several other NEO-relevant team studies have also been carried out and published in 2019. These include contributions to community-identification of key open unsolved problems in hydrology (Blöschl et al., 2019), and methodological developments that pave a way for analogous applications to Greece and the Mediterranean region on: how to assess flood risk for transportation infrastructure based on various catchment characteristics (Kalantari et al., 2019a); how to meet sustainable development challenges in growing cities by use of coupled social-ecological systems modeling of land use and associated water changes (Kalantari et al., 2019b); and how to use such coupled socio-ecological modeling to also support climate action planning for urban regions (Pan et al., 2019).

*Past societies and climate co-evolution*

*Domesticated Landscapes of the Peloponnese*

This project aims to understand human-environmental dynamics on the Peloponnese during 7 000 years from the Neolithic to the Roman period.

2019 marked the last full year for the Domesticated Landscapes of the Peloponnese (DoLP) which includes Martin Finné, a former NEO PhD student, and Erika Weiberg and Anton Bonnier, located at the Department of Archaeology and Ancient History, Uppsala University. During the year many results from the project was summarized into articles and book chapters. Key publications include: a review and synthetization of paleoclimate data from the Mediterranean region revealing long-term trends in climate variability during the Holocene (Finné et al., 2019), a comparative study that investigates the long-term trends of land use in Greece in relation to demographics and climate during the Holocene (Weiberg et al., 2019a), an examination of shifting spatial patterns of land use in the NE Peloponnese from the Neolithic to the Roman period based on a GIS based method developed within DoLP (Bonnier et al., 2019), and lastly a case study from Peloponnese that presents a characterization and quantification of the spatial requirements of land use from prehistory to antiquity (see suggested figure 8, Weiberg et al., 2019b).

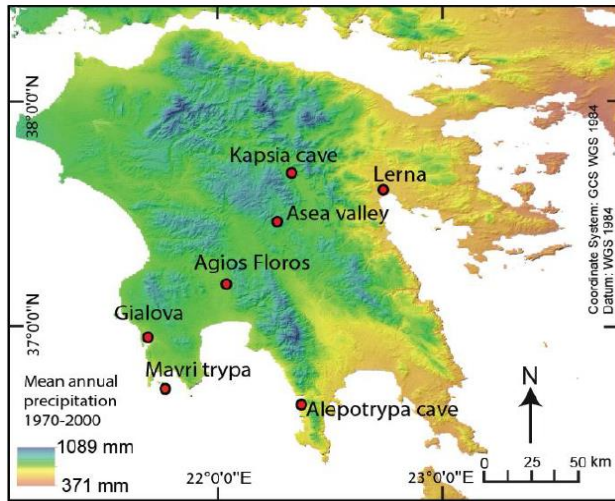


**Figure 8:** Modelled per capita spatial requirements from the Neolithic to the Roman period. Panels show the quantification of the three primary land use types: field crops (bottom panel), tree crops and woodlot (middle panel) and pasturage (top panel), utilized by Peloponnesian societies. Bars also show the individual land use parameters that make up each land use type and highlight an increasing diversity of crops and animals over time. Note differences in x-axis scale. Figure is from Weiberg et al., 2019b.

A suite of new questions raised during the four-year project led to a number of new funding applications. One application was granted and Martin and Erika will be able to continue their work on the Peloponnese in close collaboration with NEO within the VR funded project ‘Climate and ancient societies in Bronze Age Peloponnese (Greece)’.

*Holocene environmental changes and climate variability in the Eastern Mediterranean*

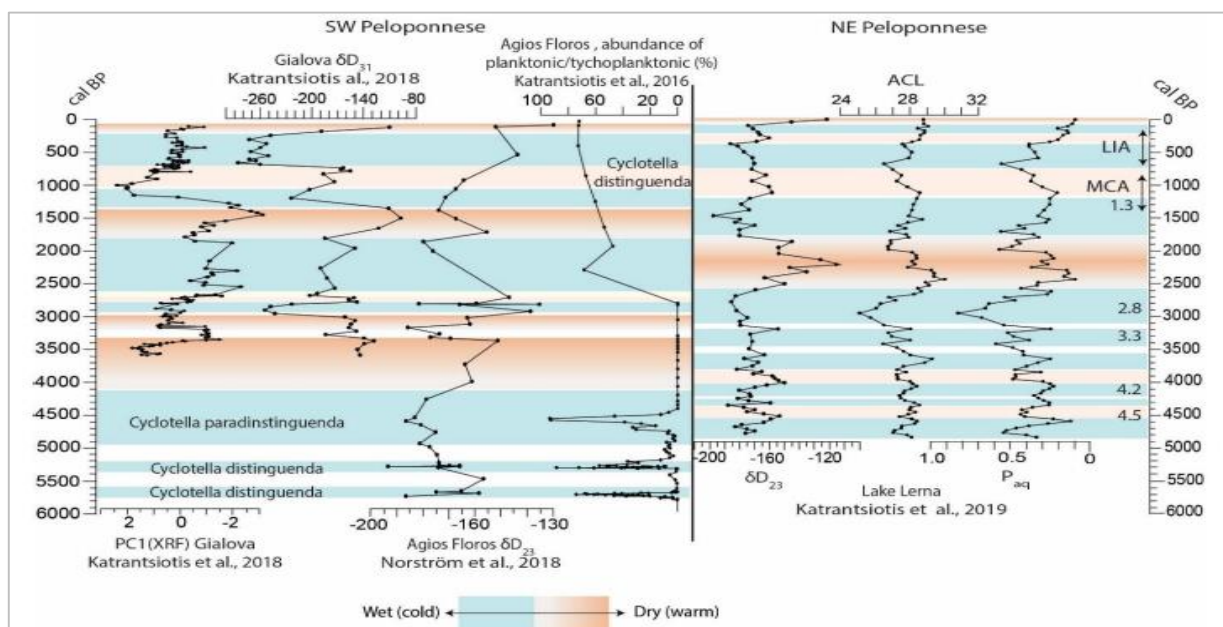
In 2019, Christos Katrantsiotis finalized and defended his PhD thesis entitled: “*Holocene environmental changes and climate variability in the Eastern Mediterranean: Multiproxy sediment records from the Peloponnese peninsula, SW Greece*” at the Department of Physical Geography, Stockholm University.



Christos Katrantsiotis aim was to contribute to a better understanding of climate evolution and the related drivers in the central-eastern Mediterranean over the last 6000 years, a period of centennial-millennial climate changes whose nature is not well-understood. For the purpose of the investigation, sediment cores were retrieved from the Agios Floros fen and the Gialova lagoon in SW Peloponnese and the Ancient Lake Lerna in NE Peloponnese (Figure 9). The cores were analyzed for biological (diatoms) and geochemical data (X-ray fluorescence spectrometry (XRF) elemental data, lipid biomarker compounds and isotopes).

**Figure 9:** Location of study sites i.e. Gialova Lagoon, Agios Floros (SW Peloponnese), and Lake Lerna (NE Peloponnese) in relation to previous records in the area.

Overall, the results highlight the complex interaction between climate and tectonics in the landscape development and further reveal changes in the W-E precipitation/temperature gradient over the peninsula connected to shifts in the large-scale atmospheric circulation patterns. The high-resolution record from the Agios Floros fen enables the identification of short-term events that can be attributed to local tectonic processes. Two earthquakes were identified in the record that changed the landscape around Agios Floros at 5700 and 5300 years ago. In addition, the multiproxy approach from all sites has contributed to the identification of synchronous changes between the records that can be attributed to a common climate mechanism. The synthesis of records indicates sometimes similar and sometime opposing climate signal between NE and SW Peloponnese (Figure 10; wetter in SW, drier in NE and vice versa). This can be attributed to the relative dominance of low latitude and high-latitude atmosphere patterns over the peninsula.



**Figure 10:** Synthesis of all records from the Peloponnese peninsula, showing periods of wetter and drier conditions. (dates in cal BP-Before Present)

*Tree-rings*

In a centennial–to–millennial scale context, proxy–based climate reconstructions are required to assess current climatic trends and changes in the amount, frequency and intensity of extremes, and to evaluate the full range of projected forcing impacts. Particularly in the Mediterranean region, an improved spatial distribution of high–resolution proxy archives is needed to expand our knowledge about pre–instrumental climate variability patterns and their relationship with natural forcing’s at regional to continental scales. At high–elevation sites in the Mediterranean region tree–growth is influenced by an interaction of temperature and precipitation constraining the use of tree–ring width (TRW) and maximum latewood density (MXD) as a temperature proxy.

In 2019, a group of dendroclimatologists from the Johannes Gutenberg University Mainz in cooperation with the Navarino Environmental Observatory conducted an excursion to Mount Smolikas in the Pindos Mountains in Northern Greece. Here, the 1075-year-old living tree “Adonis” (Konter et al., 2017, *Dendrochronologia*) is surrounded by massive living *Pinus heldreichii* trees as well as abundant relict material, which emphasizes the unique characteristics of the region within the Mediterranean. Already sampled wood material helped to establish a chronology reaching back to 575 CE, which serves as substructure for a reconstruction of temperature extremes over the 738-2014 CE period (Klippel et al. 2018, *International Journal of Climatology*) and Mediterranean summer temperature variations since 730 CE (Esper et al. 2020, *Climate Dynamics*). The aim of this years’ field trip was to boost the replication of the older (medieval) part of the chronology by taking 64 additional samples of the relict material from so far untouched slopes in the area.



**Figure 11:** Landscape of Smolikas Mountain in north Greece. (Photo: P. Schulz)

Co-management of Ecosystem Services in Gialova Lagoon wetland and surrounding areas

Research done in close cooperation with different stakeholders aim to develop multifunctional landscapes that can help to enhance and diversify the local economy, while still sustaining critical ecosystems and associated ecosystem services. Monitoring and analyses of socio-ecological parameters in the nearby coastal lagoon (Gialova lagoon) and adjacent streams, rivers and cultivated land, aiming to provide viable alternatives for long-term sustainable tourism and agriculture were initiated in 2016. The research considers resilience to future climate changes and minimization of the impact of tourism and agriculture on the Natura 2000 sites, exploiting the expertise and experience of local stakeholders. The work is based on the PhD work of Giorgos Maneas, his supervisor Dr. Håkan Berg, his co-supervisor Dr. Stefano Manzoni both Ass. Professors at the Department of Physical Geography, Stockholm University and a number of master students who during the last 3 years have contributed significantly to this direction. Since 2018, the area is also added as one of the six case studies of the COASTAL EU project, adding to our understanding and to the capacity to reach the local community.

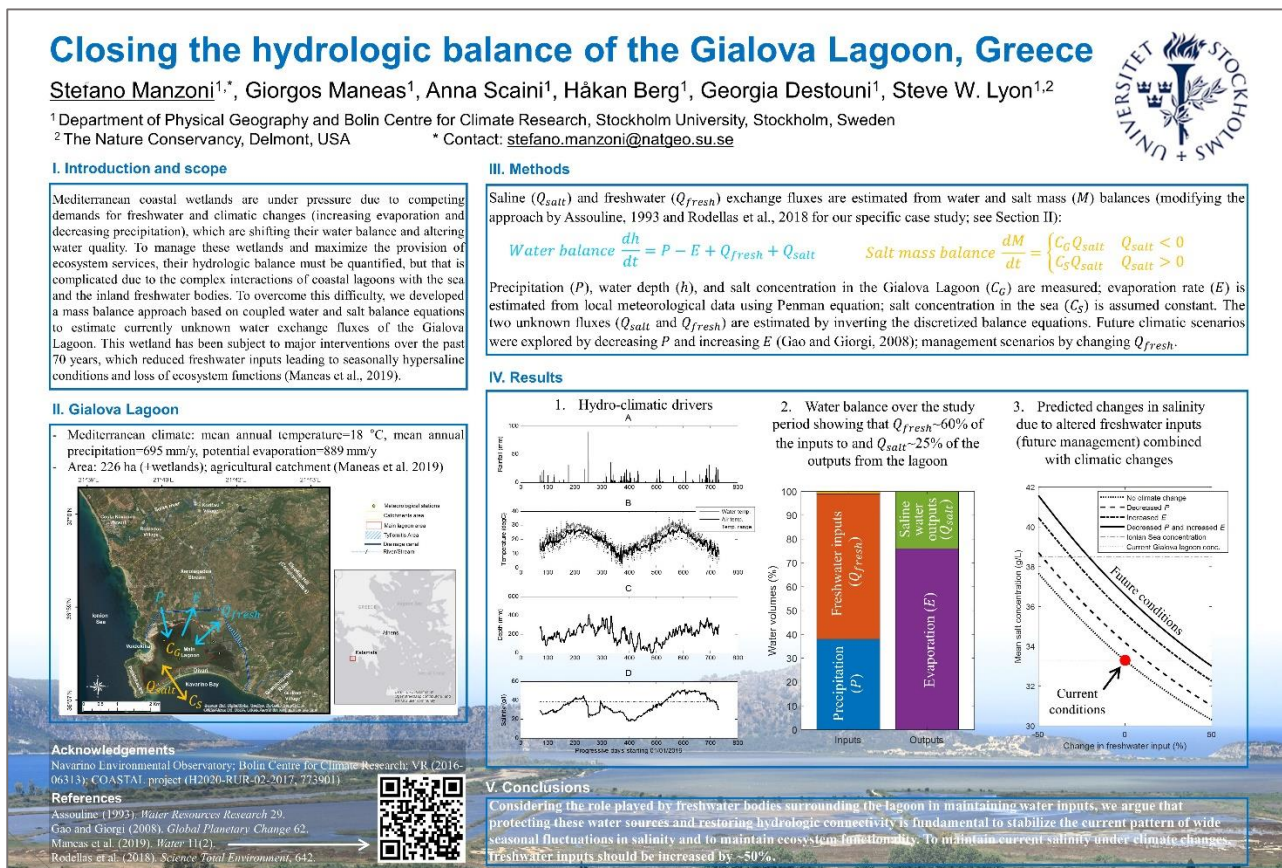


Figure 12: Poster presentation of the hydrologic balance of Gialova Lagoon at the EGU General Assembly 2019.

In 2019, we have submitted an article discussing the hydrological balance of the wetland (Figure 12), and one more article focusing on waterbirds status and distribution. These studies, were presented in detail by Giorgos during his half time seminar at the Department of Physical Geography, Stockholm University entitled “Co-adaptive management of wetland ecosystem services in the Gialova Lagoon. Part 1: Water, habitats and birds”.

Briefly, based on our results, the lagoon is hypersaline (over 38 g/L) for over 30% of the year. About 60% of water inputs to the lagoon are from surface and groundwater sources, and 40% from rainfall. Outputs of water are mostly due to evaporation (70%) and saline water loss (30%). Our results further show that, to adapt to expected climatic conditions by the end of 2100 and maintain the current annual average salinity in the lagoon, a more than 50% increase in freshwater inputs should be achieved, corresponding to at least 1750 mm y<sup>-1</sup>. At present, the wetland is mostly used by ducks, coots, herons, waders, flamingos and cormorants. Gulls, grebes, rails & crakes were found in relatively low numbers. Nevertheless, the number of wintering populations for the majority of wildfowl species (except *Anas platyrhynchos*), herons, and the coot, as well as the number of



migrating populations for waders were much less when compared to previous studies about the area. The restoration of fresh water inflows, could improve favourable conditions for waterbirds conservation and gradually lead to higher species richness and abundance. However, long-term differences and links to environmental parameters (e.g. salinity values, temperature, distance from freshwater inputs, distance from coast, etc.) need to be further investigated before concluding to specific water management strategies.

A sustainable management strategy for the GLw area should aim to improve and enlarge waterbirds' habitats taking account of existing human activities and social needs (Habitats Directive 92/43/EEC), at a broader scale. To that end, while monitoring of water quality and environmental conditions in and around Gialova lagoon continues, in 2019 we developed a Groundwater Monitoring Network around the Gialova Lagoon. The work of Sofia Maniatakou gave new insights on understanding the multiple ways stakeholder groups perceive the benefits derived from hydrologic services in the surrounding area of the "Gialova" coastal wetland in Messenia. At a catchment level, Edvin Holmerin, suggested in his thesis that a change from conventional to integrated farming practices would be able to contribute to sustainable development; environmentally, socially and economically, and therefore increase climate change resilience, production resilience, the attractiveness of the area, the cooperation within the agricultural sector and its cooperation with the tourism sector as well as an increase in farmer profitability.

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