37th PhD program in Earth Science

Curriculum: Geoscience

Project Title:

The study of a past interglacial vegetation changes as a tool to understand the human role in hydrological changes

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Introduction and state of art

One of the great challenges that humanity is facing is climate warming and its impact on the environment, the economy and society. The future climate projections indicate that the Mediterranean region will be warmer and dryer (IPCC, 2013). However, there are still large gaps in the understanding how the water cycle and ecosystems will respond to global warming. With this regard, the fossil archives can provide valuable information on hoy climate system works under different boundary conditions and on how climate variability may impact on marine and terrestrial ecosystems.

A peculiar feature of the Quaternary climate is the marked cyclicity (led by the change of the Earth's orbital parameters) alternating glacial and interglacial periods. The comparable orbital configurations of MIS 19 and MIS 1 motivated much modelling of Earth's climate changes considering the MIS 19 as an analogy of the present (Vavrus et al., 2018; Fig. 1).

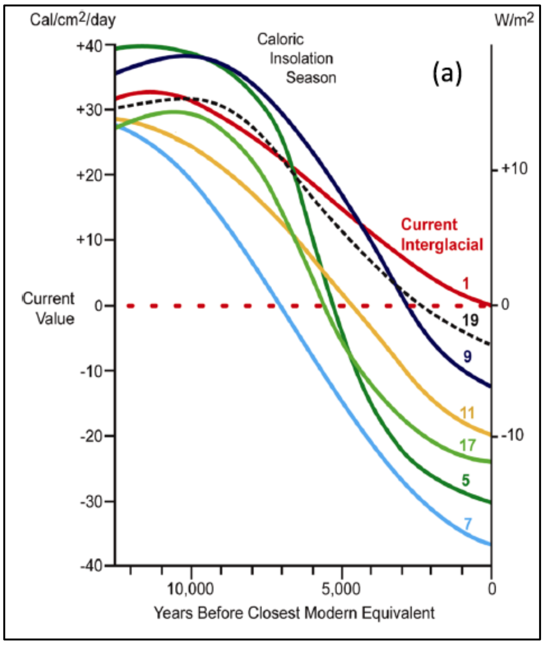

Fig. 1. Caloric Northern HeMIS phere half-year summer insolation for MIS 1, 5, 7, 9, 11, 17, and 19, relative to each stage's insolation minimum at year 0. This shows the similarity in the orbital configuration and insolation between MIS 19 and MIS 1 (present interglacial). From Vavrus et al. (2018).

The interglacial MIS 19c (788 – 777 ca. ka. ago) also had a very similar concentration of greenhouse gases compared to the present interglacial. For that reason, the MIS 19 climate and ecosystem variability provides a reference scenario of how the current interglacial could evolve in absence of human perturbations (Yin & Berger, 2011, Varvus et al., 2018).

Comparison of data from the continent/sea/ice is essential to unveil the mechanisms of interaction and feedback between the atmosphere, cryosphere and hydrosphere and thus elucidate the causes of the millennial-scale, Dangaard-Oeschger or NAO-like variability, or the long-term, glacial-interglacial cycles or the role of the variation in atmospheric CO_2. Likewise, these studies are very important for assessing the timing and the regional propagation of the climate change in the northern heMIS phere during certain climatic events. The study of temporally long paleoecological records is also necessary in order to have the resolution necessary to understand recurrent climatic or paleoenvironmental changes, produced with a certain periodicity (e.g., glacial-interglacial cycles).

The Sulmona Basin contains a unique sedimentary, through discontinuous, record of the Pleistocene that also includes a well-documented and radioisotopically constrained record of the MIS 19c interglacial (788-777 ka; Fig. 2), when the forest community and climate were supposed to be very similar to present (Vavrus et al., 2018).$\delta^{18}O$ isotopes analyses of the carbonate from different stratigraphical intervals of the Sulmona sedimentary successions, including MIS 19-18, MIS 12-11 and MIS 5, indicate a strong Mediterranean-North Atlantic climate teleconnection characterized by a close phase relationship between temperature change in North Atlantic and hydrological Variability in Mediterranean regions (Giaccio et al., 2015; Regattieri et al., 2015; Regattieri et al., 2016; Regattieri et al., 2019) However, hitherto, no data are available on the vegetal community responded the marked hydrological variability during the glacial termination T- IX, the MIS 19c interglacial and the ensuing MIS 19a-b glacial. A high-resolution pollen analysis of this interglacial with provide us with a better understanding of the impact of the hydrological changes in the area at that time. Then, through a comparison with the present MIS 1 interglacial, we can assess the role of the human impact on the local-regional vegetation systems since prehistoric times. Last, but not least, the pollen analysis of this period can contribute to the assemblage of a multi-proxy MIS 19c record anchored to a robust radioisotopic chronology that can be used as a "natural background" of the present interglacial for the climate models aimed at dissentingly the component of the natural variability from that of the anthropogenic atmospheric greenhouse eMIS sions.

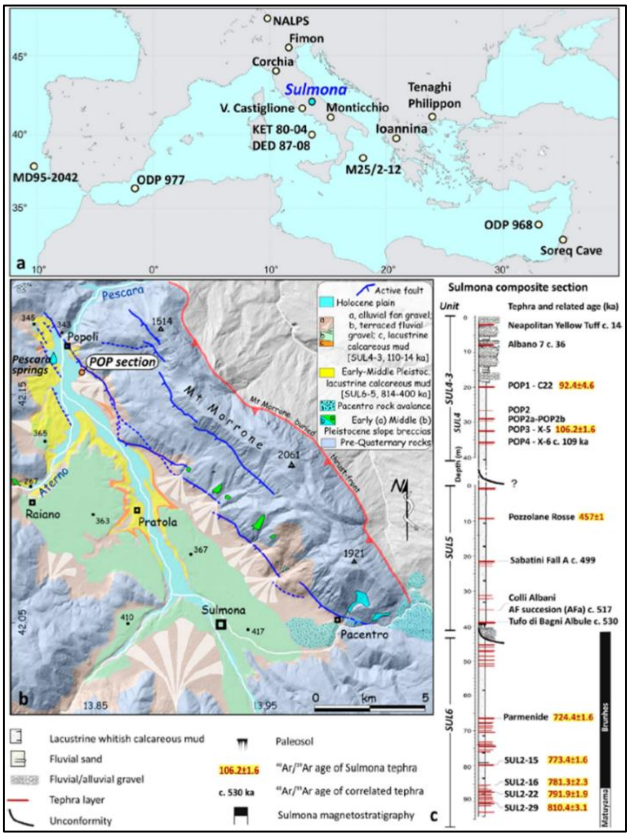

Fig. 2. Geographical location of the Sulmona Basin (A), geological sketch of the Sulmona basin (B) and composite section of the Sulmona Pleistocene sedimentary succession (C) (from Regattieri et al., 2015).

Research Objectives

The goal of this PhD project is the understanding of human influence on hydrological changes through the investigation of environmental and climatic change during MIS 19 (specifically MIS 19c). This period is the best orbital analogue of the present interglacial, and thus the best past reference for investigating the natural background of the present climate dynamics.

The Sulmona Basin, in central Italy, hosts a lacustrine succession with one of the few worldwide highly resolved paleoclimatic records of the MIS 19 and the only one in the World holding a fully independent and robust tephra and radioisotopic chronology. The main specific objectives of this PhD are:

1) Characterization of the vegetation dynamics in response to MIS 19 climate change through a high resolution pollen analysis of samples obtained from the MIS 19 Sulmona record.
2) Reconstruction of the millennial to sub-millennial scale hydrological variability using the pollen and a multi-proxy approach (e.g., O-C stable isotopes, geocheMIS try).

The obtained multi-proxy paleoclimatic data will be compared with the climatic changes during the human pre-industrial and present periods corresponding to the MIS 1.

Implications and applications

The main application of the data obtained throughout this PhD will be the completion of the multi-proxy database of the Sulmona Basin using pollen data. It will also allow knowledge development of the role of human beings after the industrial era in climate change. That is, it will permit a comparison between the current climate and what would have been its natural evolution.

The Sulmona multi-proxy record of the MIS 19c could be used as a natural background in climate models of the evolution of the present interglacial for reducing inherit uncertainty.

Work plan

A new core spanning the interval of interest has been recovered in Fall 2021, so a contribution to the processing (opening, XRF scanning and construction of composite depth) is programmed at Institute of Geological Sciences & Oeschger Centre for Climate Change Research, University of Bern, under the supervision of Hendrik Vogel.

In the first year of the PhD a systematic literature review for the characteristics of the Sulmona Basin will be undertaken (T-1, T-2). Furthermore, a high resolution pollen analysis will be initiated (T1→T-8). This analysis will be accomplished by the end of the second PhD year by performing a sampling with a resolution of 50-100 years (sample processing, identification and counting of relative abundances of pollen species obtained from the record using a microscope). Using this data, a Bayesian age model will be developed through appropriate software using the high-precision $^{40}Ar/^{39}Ar$ dating that are already available and new ones that will be acquired within the next year (T-2, T-4). During these two years attendance to seminars, courses, congresses and conferences will be undertaken in order to increase training and knowledge.

Additionally, field trips have been programmed for the first year in order to obtain further information about the regional geological setting of the Sulmona Basin and to study its present hydrological dynamics (T-2, T-3). This information will be compared to all the observed characteristics of the studied core. Moreover, during the first year a collaboration with GRAN GUIZZA S.P.A. will be undertaken. This collaboration will permit the understanding of the past hydrogeological dynamics and the comparison of these dynamics to the present ones (T-1→T-5).

In the second year of the PhD, a six month stay in the University College of London has been programmed so as to achieve an interpretation of several other Mediterranean and global pollen records as well as to compare these with the Sulmona Basin record obtained in the first year of the PhD (T-6, T-7).

During the last year of the PhD a comparison of the results obtained throughout the PhD with the present dynamics. Furthermore, human influence on the environment after the Industrial Period will be interpreted (T-9→T-12).

Milestones

Milestone 1: Characterization and pollen analysis of the Sulmona Basin core.

1.1. Completion of the systematic literature review (T-1, T-2)
1.2. Completion and development of the Bayesian age model (T-2→T-4)

1.3. Completion of the counting and calculation of the relative abundances of pollen species. Construction of the relevant pollen diagrams and establishment of the pollen zonation. (T-1→T-8)

Milestone 2: Geological setting. Lithological and physical characteristics of the studied sedimentary core.
2.1. Regional study of the geological setting of the Sulmona Basin (field trips) (T-2, T-3)
2.2. Characterization of the physical properties of the sediment from the core (grain size, colour, sorting, magnetic susceptibility…). (T-1→T-8)

Milestone 3: Reconstruction and interpretation of the obtained data.
3.1. Reconstruction of the evolution and climate change that occurred during MIS 19 using sedimentological studies. (T-7→T-12)
3.2. Reconstruction of the climate and vegetation changes, as well as the hydrological dynamics, based on the pollen analysis. (T-7→T-12)

Milestone 4: Evaluation of the regional environment changes.
4.1. Statistic integration and analysis of the pollen data. (T-9, T-10)

Milestone 5: Comparison between MIS 19c and MIS 1.
5.1.Comparison of the obtained results with the present dynamics (T-9→T-12)

Milestone 6: Training.
6.1. Acquisition of knowledge through courses, seminars and participation in other scientific training activities. (T-1→T-6)
6.2. Attendance at scientific congresses and conferences. (T-2→T-7)

Milestone 7: International mobility and collaborations
7.1. Six month stay at the University College of London (T-6, T-7)
7.2. Collaboration with GRAN GUIZZA S.P.A. (T-1→T-5)

Milestone 8: Dissemination
8.1. Publications in scientific journals (P1, P2 and P3).

Dissemination plan

Participation and subMIS sion of communications in national and international conferences (T-1→T-7) and publication of the results of the work in indexed journals. At least three manuscripts will be submitted at times T-5 (P1), T-8 (P2) and T-11 (P3).

Training activities

Participation in general, as well as specific, training courses offered by the PhD school in Earth Sciences (University of La Sapienza), as well as seminars on related topics available for PhD students enrolled in both the University of La Sapienza as well as the University of Granada.

Mobility abroad

During the second year of the PhD, a six month stay at University College of London has been programmed. Furthermore, during the full duration of the PhD, several stays at the University of Granada have been planned in order to to exchange knowledge and training between the two universities.

Time schedule in Graphical Form

A timeline for the next three years has been made to achieve the different main proposed objectives.

The time needed to achieve these objectives has been divided into four trimesters per year (three years). A number of more specific objectives have been identified to accomplish the main goal of this PhD project. The anticipated times periods (T-x) have been previously referenced.

Milestone		Year 1				Year 2				Year 3			
		T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	T-11	T-12
1	1.1												
	1.2												
	1.3												
2	2.1												
	2.2												
3	3.1												
	3.2												
4	4.1												
5	5.1												
6	6.1												
	6.2												
7	7.1												
	7.2												
8	8.1					P1			P2			P3	

Bibliography

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