

## **ABSTRACT BOOK**

# WATER IN GEOSCIENCES

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Conference of Young Researcher organized by PhD students of the Department of Earth Sciences of the University of Pisa



Department of Earth Science, University of Pisa Via Santa Maria, 53 – 56126 Pisa





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## Index

## S1. Critical zone, water resources and environmental pressures

Barbeta M. A. [Keynote] – Stable isotopes as tracers of plant water sources at
multiple spatiotemporal scales
Chemeri L., Taussi M., Cabassi J., Capecchiacci F., Tassi F., 3, Renzulli A., Vaselli O. –
Hydrogeochemistry of the groundwater system in the Mt. Catria-Mt. Nerone
carbonate ridge (northern Marche, central Italy)
lannone A., Guarino A., Pacifico L.R., Ambrosino M., Germano G., De Tullio G.,
Cicchella D., Albanese S. – The Rn-222 risk assessment for Campania region tap
waters
Izarif Y., Laftouhi N.E., Lezzerini M., Pagnotta S., Baid S., Ezzahzi S., Benkirane M.,
Ghanem M., De La Hera Porto A. – First elements of the combined use of GIS and
RS to characterize an arid mountainous basin towards a better water resource
management: case of Zat basin (High Atlas of Marrakech, Morocco)
Landi L., Filippini M. – Numerical modelling as a tool for water management
adaptation to climate change: a case study of a complex hydrogeological system
In the Northern Apennines
Lucchelli A., Fiandaca G., Pedretti D., Gisolo M. – Hydrogeological exploration
perspective for groundwater springs potential assessment: the "MountainHydro"
Maccelli C Natali C Nisi B Casalini M Vaselli O Venturi S Avanzinelli P – Diffuse
anthronic contamination in the Valdinievole sub-basin river system (Tuscany
Italy)
Pagnotta S. – Hole Water: use of water resources in mining operations
Paschetto A., Leso C., Manfroni F., Bonetto S. – Territorial analysis for the potential
of hydroelectric energy production and its impact in the Dora Riparia, Sangone
and Stura di Lanzo catchments (Turin)
Penna D. [Keynote] – Tracing water fluxes in the Critical Zone: stable isotopes of
hydrogen and oxygen as interdisciplinary diagnostic tools1
Pugliese E., Dematteis A. – Development and calibration of tools and models for
quantification of the hydrogeological interference risk by tunnelling through
different geological settings
Signora A., Spagna S., Sullivan N.A., Burkey B., Lonardi M., Dauti F., Lucchelli A., Gisolo
M., Fiandaca G. – Time-Domain Induced Polarization to depict geological
heterogeneity controlling the groundwater features
Toller S., Giambastiani M.S.B., Funari V., Greggio N., Zannoni D., Antonellini M., Ivo V.,
Dinelli E. – Water chemistry and sediment quality in a Large Dam reservoir:
implications for water management in Ridracoli14
Vital H. [Keynote] – Impact of Brazil's Largest Recent Oil Spill on the Coastal
Waters

Vreča P. [Keynote] – Isotopes of water molecule as water cycle fingerprints	16
Žagar K., Kanduč T., Bračič Železnik B., Jamnik B., Vreča P. – Use of environmental	
isotopes to investigate the partitioning of water in the water supply system of	
Ljubljana, Slovenia	17
Zhou J., Lu H., Yang K., Jiang R., Yang Y., Wang W., Zhang X. – Projection of China's	
future runoff based on the CMIP6 mid-high warming scenarios	18

## S2. Open lab

Maccelli C., Natali C., Nisi B., Casalini M., Vaselli O., Venturi S., Avanzinelli R	
Suspended Solid Load: sampling and analytical procedures of a river system	
geological matrix	20
Natali S., Nigro M. Giannecchini R., Baneschi I., Doveri M., Zanchetta G. – Field testing	
of tube-dip-in water precipitation collectors used in isotope hydrology	21
Nigro M. – Custom instrumentation for hydrology and water monitoring	22
Pasquetti F., Natali S. – Tips for researchers in geosciences: useful software and	
databases	23

## **S3.** Learning from the past: traces and shapes related to water

Carvalho L. G. F. J. – Mapping landslides and slope failure from seismic data on	
the Brazilian Equatorial Margin	25
Coletti G. [Keynote] - Memories of landscapes and people: floods, climate and	
society at the mouth of the Magra River	26
Granata V., Collareta A An addition to the Middle Triassic Monti Pisani	
Ichnoassemblage: Characichnos, a tetrapod swimming trace	27
Bufalini M., Lampa F. – The significance of recent and short pluviometic time series	
for the assessment of flood hazard in the context of climate change: examples	
from some sample basins of the Adriatic Central Italy	28
Merella M., Collareta A., Casati S., Di Cencio A., Pieri A., Bianucci G. – It's time to eat:	
evidence for great white shark (Carcharodon carcharias) feeding on a	
Mediterranean Pliocene right whale	29
Nobile F., Collareta A., Merella M., Peri E., Aringhieri G., Bianucci G. – Stenopterygius	
(Reptilia, Ichthyosauria) in Italian museums: morphometric and palaeoecological	
considerations	30
Pieri A., Merella M., Collareta A A sea of pufferfishes: how vertebrate	
palaeontology can shed light on the future of an iconic Mediterranean bioinvasion	31
Sassenroth C., Baroni C., Salvatore M.C., Hauber E. – Potential of geomorphological	
features favouring the development and conservation of cryopegs on mars and	
earth	32

### **Session 1**

## Critical zone, water resources and environmental pressures

Chairpersons

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# Stable isotopes as tracers of plant water sources at multiple spatiotemporal scales

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#### Abstract

Water pools flowing and stored in the Critical Zone present a contrasting natural abundance of the stable isotopes of oxygen and hydrogen that respond to various isotopic fractionation and mixing processes. The temporal scales relevant for the variability of these processes can range from sub-daily (e.g., leaf water evaporation) to decadal (e.g. aquifer recharge). Nowadays, our mechanistic understanding of the processes that modify the isotopic composition of water along the soil-plant-atmosphere hydraulic continuum allows us to obtain valuable qualitative and quantitative information on ecosystem water fluxes. Stable isotopic applications have been used to show how plant water sources change in response to seasonal environmental variations and extreme climatic events. They have also highlighted the pervasive plant use of groundwater at the global scale and its relative importance in seasonally dry ecosystems. In addition, the isotopic composition of water is partly transferred to tree rings and therefore, decadal-scale patterns in tree water sources can also be inferred by the analysis of oxygen isotopes in the cellulose. In this talk, I will summarize my experience with stable isotopic applications to address different but closely linked research questions in forest ecohydrology.





## Hydrogeochemistry of the groundwater system in the Mt. Catria-Mt. Nerone carbonate ridge (northern Marche, central Italy)

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#### Abstract

The Mt. Catria-Mt. Nerone (northern Marche, central Italy) carbonate ridge contains a defined and isolated hydrogeological system composed by three main sedimentary aquifers hosted in the *Scaglia*, *Maiolica* and *Massiccio* Formations. These calcareous and marly-calcareous aquifers belong to the Umbria-Marche series and are divided by marly and marly-clayey aquicludes. The groundwaters from the Mt. Nerone-Mt. Catria calcareous formations represent the main water supply for 360k inhabitants of the Province of Pesaro-Urbino. Despite the social and economic importance of these water reservoirs, the scientific knowledge is rather scarce (e.g., Bison et al., 1995; Capaccioni et al., 2001). Therefore, in this study the number of sampling points (31) as well as that of analysed geochemical parameters (i.e., major and trace solutes, water stable isotopes and dissolved gases) was implemented with respect to previous investigations, in order to better characterize the geochemical processes, (ii) understand the hydrogeological pathways and fluid circulation patterns and (iii) assess the quality of these waters.

The waters can be classified into four different groups: (a) Ca-HCO<sub>3</sub> waters with TDS < 500 mg/L; (b) Ca-HCO<sub>3</sub>(SO<sub>4</sub>) waters with slightly high TDS; (c) Ca-SO<sub>4</sub> waters associated with mineral springs (TDS > 1100 mg/L); (d) Na-HCO<sub>3</sub> waters with pH > 9 and negative Eh values.

The isotopic values of hydrogen and oxygen clearly indicate a meteoric origin for these waters. The composition of Ca-HCO<sub>3</sub> waters is almost exclusively related to the dissolution of carbonate-bearing formations, whereas those showing an SO<sub>4</sub>-enrichment (up to 200 mg/L) suggested a deeper circulation and the interaction with the gypsum-anhydrite formation (i.e., Burano Formation). The Ca-SO<sub>4</sub> waters are related to a deep circulation within the Messinian formations. Finally, the Na-HCO<sub>3</sub> waters are due to long-lasting interactions between meteoric waters and Na-rich silicate rocks (e.g., Marnoso-Arenacea Formation) in saturation/oversaturation conditions for carbonate-bearing minerals.

The dissolved gases of Na-HCO<sub>3</sub> waters are enriched in CO<sub>2</sub> and CH<sub>4</sub>, whose source is likely pertaining to layers characterized by a higher content of organic matter where anaerobic degradation occurs.

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## The Rn-222 risk assessment for Campania region tap waters.

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#### Abstract

Groundwaters of Campania in Italy represent one of the most precious natural resources for both the region itself and surrounding areas. Their quality is strongly conditioned by the composition of host rocks which vary from volcanic to sedimentary lithologies. Since these waters are mostly used to supply the regional aqueduct system, they are subject to several and constant checks of their quality with the aim of preserving public health. It is well known that natural waters as well as air and soil can contain naturally occurring radionuclides (NORs) such as K-40, U-238 and Th-232, their decay products, and other radionuclides of cosmogenic origins. Radon-222 is a daughter product of U-238 and it is a natural radioactive gas present in drinking water. Its ionizing radiation provides, through inhalation and ingestion, the largest human internal exposure to natural radiations and can represent a serious threat for human health.

In Italy, the Legislative Decree No 28/2016 establishes a guideline value of 100 Bq/l for tap waters to be used as a reference to prohibit their use for drinking purposes. Scientific literature showed that the application of a risk assessment-based approach can lead to more reliable results in terms of public health safety compared to the mere use of general guidelines. WHO (2004) and the EU Council (EU, 2001) do not consider the "guideline approach" as a suitable method and suggest assessing health risk for Rn-222 by determining the Indicative Dose (ID). This latter is the dose of radiation assumed by an individual through ingestion and/or inhalation, as a result of an environmental exposure.

This work represents the first large scale monitoring campaign of Rn-222 on tap waters of Campania region. Specifically, 181 measurements were completed on different aqueduct sections such as public fountains (98), water tanks (52), wells (21) and springs (10).

With the aim of evaluating the effectiveness of the risk assessment-based approach in improving the degree of protection of human health, a stochastic risk assessment was performed for homogeneous areas supplied by specific hydrogeological units of the region.

The probability for local population to be exposed to an unacceptable risk for Rn-222 due to water drinking or showering resulted to be considerably high for those areas totally or partially supplied by waters proceeding from the regional volcanic domains (E.g.: Mt. Somma-Vesuvius, Mt. Roccamonfina, etc.).

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## First elements of the combined use of GIS and RS to characterize an arid mountainous basin towards a better water resource management: case of Zat basin (High Atlas of Marrakech, Morocco)

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#### Abstract

Water resource management and preservation is currently a major challenge for many regions in the world, particularly in regions that are characterized by arid and semi-arid climates where water resources are becoming scarce by the minute as a result of combined effects of climate change and rising water demand for agricultural development and population growth. Which is the case of many north African regions especially Morocco, over the past few years, Moroccan groundwater and surface water resources have significantly degraded as a result of various liquid and solid pollution sources, as well as an increase in drought brought on by climate change.

Watersheds surface water is mainly influenced by the environment, notably its form., substrate type, precipitations, slope and the proximity to humid air masses. These factors help explain the river's system hydrological characteristics, which is crucial for managing water resources. GIS and remote sensing are functional methods for evaluating a watershed's morphometric properties. These approaches were used to characterize the Zat watershed's physical characteristics. Zat basin is one of the main watersheds descending from the High Atlas of Marrakech and contributing significantly to the water supply of many cities in the region and more efficiently refilling the Haouz plain Plioquaternary aquifer.

The results obtained demonstrate that the Zat basin is distinguished by an elongated morphology that favors the collection of runoff water in the main rivers of the basin. the watershed has highly variable elevations and slopes, and has predominantly north and northwest facing slopes (30.42%) and due to losses from infiltration and evaporation, surface flows are decreased. The Zat watershed hydrological behavior observed affects how people use surface water which is demonstrated on the Seguias system that is used for agricultural and domestic reasons. The study conducted on the Zat watershed is a contribution to a better understanding of water resources management and a helpful tool to support making decisions as well as locally as in other similar watersheds.





## Numerical modelling as a tool for water management adaptation to climate change: a case study of a complex hydrogeological system in the Northern Apennines

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#### Abstract

Groundwater is the global main source of water supply, but it is also very vulnerable to climatic pressures, suffering for drought events that are becoming very common in the last years. Since it is known that impacts of climate change will grow in intensity and frequency, the adaptation of water management is essential to mitigate the issue of water scarcity and its socio-economic consequences. To this end, improving our knowledge on hydrogeological systems and their response to climatic stress is crucial. Numerical models represent an important tool to verify and upgrade preliminary knowledge, and they are also useful in a forecasting approach, allowing to simulate the future behavior of complicated systems by varying their main climatic stressors such as the aquifer recharge. Indeed, a numerical model can implement recharge estimations and forecasts that can be carried out at different levels complexity.

The study aims to show the potential of integrating a simplified climatic analysis into a numerical model of a complex and critical hydrogeological system in the Northern Apennines.

The study shows the worth of the numerical model for improving remarkably our preliminary knowledge of the natural system by integrating all the available geological and hydrogeological data. The results show significant effects of climate pressure on groundwater resources, with a considerable decrease in springs discharge which is consistent with recently observed trends. Eventually, a possible solution to improve the local water supply through implementation of pumping wells is suggested as a management strategy to mitigate the climate impacts.





## Hydrogeological exploration perspective for groundwater springs potential assessment: the "MountainHydro" project

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#### Abstract

Groundwater is a vital resource, as it represents one of the most important freshwater reservoirs. It provides about 49% of the water withdrawn for domestic use by the global population (United Nations, 2022). Climate change threatens the long-term sustainable consumption of groundwater. Several studies have shown that climate change can have direct and indirect impacts on aquifer recharge by altering precipitation and evapotranspiration patterns, or groundwater quality.

Ensuring adequate protection of groundwater resources and assessing their long-term sustainable use is thus required. This can be achieved through a comprehensive understanding of the groundwater system entailing different tools and approaches.

This presentation introduces MountainHydro, a multidisciplinary project financed by A2A Ciclo Idrico that adopts a multifaceted approach for the evaluation of hydrogeological exploration of the complex aquifers in the Val Sabbia (Brescia) valley in the Italian Southern Alps. The approach consists of a 3D geological and hydrogeological modelling fed by geological mapping, field observations, ground-based hydrological and hydrogeological data, and densely spaced ground and airborne geophysical data.

The Val Sabbia is characterized by a complete Permian-Cenozoic succession (Cassinis et al., 2008). Karst-fissured rocks represent the main groundwater reservoirs. Groundwater flow is controlled by lateral and vertical variation in hydrostratigraphic units. The occurrence of a groundwater flow is proved by the presence of some groundwater springs, some of them with estimated discharge rates up to  $0.3 \text{ m}^3/\text{s}$ .

Geophysical surveys provide key information on the structural setting at different depths over the exploration area. In the MountainHydro project, 20 km of electrical resistivity tomography (ERT), 150 km of ground-based time-domain electromagnetic survey (TEM), and 4000 line-km of airborne electromagnetic survey (AEM) are being deployed to provide the 3D resistivity model of the investigated area. These methods shall provide unprecedented spatial coverage for the characterization of the aquifers and will help in identifying variations in rocks' hydraulic properties. Specifically, in karst terrains, geoelectrical and electromagnetic methods support the spatial mapping conduits, main fractures, and other preferential seepage zones.

Geological and geophysical mapping will be integrated into a 3D finite elements flow model for different purposes. First, the model provides insight into the architecture of the karst system, particularly on the key areas of recharge and the more likely flow pathways. Secondly, the model willprovide quantitative information on currently available groundwater resources and generate scenariosto predict the impact of climate change on future resources.

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# Diffuse anthropic contamination in the Valdinievole sub-basin river system (Tuscany, Italy)

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#### Abstract

Trace element geochemistry of surface waters is receiving increasing attention due to their sensitivity to anthropogenic pressure and climate change. The development of highly performant analytical techniques, e.g. Inductively Coupled Plasma (ICP-MS) and Thermal Ionisation (TIMS) Mass Spectrometry, allow to measure trace and ultra-trace elements and radiogenic isotopic composition, respectively, to better characterize natural and anthropic sources and related geochemical processes. The environmental matrices which constitute a fluvial system are intimately related each other and their simultaneous investigation is a powerful tool to understand the complex ecosystem existing in the rivers at which geogenic and human influences are to be added. The Valdinievole sub-basin (Tuscany, Central Italy) hosts a large number of important productive sectors such as paper mills, flora nursery farms, thermal spas, and tanning industries and consequently, it represents a good opportunity to evaluate at which extent water, sediment and suspend solid load (SSL) respond to such anthropic burden. Besides, the Valdinievole sub-basin comprehends the Padule di Fucecchio, one of the most relevant Tuscan swampy zones in the migratory birds' routes. The environmental matrices were collected during the high and low river discharge periods in 2021 and 2022, as follows: 95 water, 65 SSL and 40 sediment samples. The water geochemistry highlighted a wide compositional variability, which ranged from Ca<sup>2+</sup>(Mg<sup>2+</sup>)-HCO<sub>3</sub><sup>-</sup> to Na<sup>+</sup>-Cl<sup>-</sup>(SO<sub>4</sub><sup>2-</sup>) and Total Dissolved Solids up to 6390 mg/L. It is to mention the relatively high contents of the reduced N-species which were up to 4.4 (NO<sub>2</sub>) and 23 (NH<sub>4</sub><sup>+</sup>) mg/L, suggesting the presence of a fresh (likely diffuse) pollution. A few water and SSL samples showed cesium content up to  $170 \,\mu$ g/L and  $42.9 \,$ mg/L, respectively. In the middle to lower reaches of the Valdinievole sub-basin, the SSLs were characterized by high heavy metals concentrations, e.g. Pb, Cu, Zn and Cr up to 174, 766, 1899 and 4800 mg/kg, respectively, whose source is likely derived by the human activities affecting the study area. This is further supported by i) the Pb isotopic ratios, which allowed to identify a clear tendency from a geogenic to an anthropogenic signature and ii) the heavy metals Enrichment Factors, whose values are indicative of the relatively strong impact exerted and the key role played by the local anthropic activity. The geochemical characterization of the sediment samples is presently in progress, although the preliminary data indicate, as expected, a remarkable high content of heavy metals, similar to that recorded in the SSLs.





## Hole Water: use of water resources in mining operations

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#### Abstract

Water resources play a critical role in mining operations, from extraction and processing to tailings management and site rehabilitation. The use of water in mining can lead to the depletion of local water resources, as well as the generation of acidic and metal-rich waters that can have a significant impact on the surrounding ecosystem. To mitigate these impacts, mining companies must carefully manage their water resources through strategies such as recycling and reuse, treatment of affected waters, and the use of dry tailings management techniques. Additionally, the use of modern technologies such as satellite imagery and geospatial analysis can aid in the sustainable management of water resources in mining operations.





## Territorial analysis for the potential of hydroelectric energy production and its impact in the Dora Riparia, Sangone and Stura di Lanzo catchments (Turin)

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#### Abstract

It is now generally assumed that a radical reversal in economy is needed in order to cope with the effects of climate change and to improve the resilience of local populations. In relation to these effects. European policies for climate change and economic recovery due to Covid-19 (Guidance to Member States, Recovery and Resilience Plans, 8th Environmental Action Program) are supposed to work in synergy to promote green and efficient production of energy, shifting the cost/benefit ratio in favor of renewable natural resources. As part of these policies, Italy is increasing the number of mini-hydroelectric plants, which are considered advantageous both in economic and environmental terms, avoiding contrasts with the surrounding environment.

The first goal of this study is to evaluate the potential production of hydroelectric energy in the western area of the Province of Turin (Piemonte Region, Nort-western Italy), in particular in the Dora Riparia, Sangone and Stura di Lanzo catchments. It is performed with RENERFOR methodology, that will be employed to calculate the Flow Duration Curve (Ganora *et al.*, 2009). The second aim of the study will be to produce data congruent with European and national guidelines regarding the Environmental Impact Assessment. This will be performed considering geological, hydrogeological, morphological, ecological and climatic territorial components. Three parameters will be assessed to quantify environmental impact on superficial water bodies: sediment transport rate, fauna components and water quality. Sediment transport rate will be estimated by reconstructing, through remote sensing, hystorical series describing the evolution of channel features and the changing anthropic landscape.

Impacts on fauna will be analyzed not only with the tools provided by actual regulations, but also through models of the habitat of target species (Vezza *et al.*, 2014).

Water quality will be evaluated following the Water Framework Directive 2000/60/EC and the *Decreto Legislativo* n°152/2006.

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## Tracing water fluxes in the Critical Zone: stable isotopes of hydrogen and oxygen as interdisciplinary diagnostic tools

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#### Abstract

The critical zone, the thin dynamic skin of the Earth extending from vegetation to groundwater, is the domain where water cycle dynamics connect the subsurface to vegetation, atmosphere and climate, controlling water quantity and quality. Understanding water supply, storage and transfer within the critical zone is therefore vital for addressing key environmental and social problems linked to ecosystem services in natural and human-impacted environments: maintaining soil productivity in intensively managed systems, ensuring forest vitality, and improving landscape resilience to natural hazards. Given the complexity of interrelated processes in the critical zone and the factors that affect them, interdisciplinary tools that integrate the specific knowledge of complementary disciplines, such as hydrology, hydrogeology, soil physics, forest and landscape ecology, agroecology, biogeochemistry and plant physiology are extremely beneficial. Stable isotopes of hydrogen and oxygen are part of the water molecule and can be considered as water fingerprints, allowing for effective tracing of water as it moves in the hydrological cycle.

In this talk, I will present potentials and limitations of stable isotopes as tracers to investigate water exchanges and flow paths in different ecosystems of terrestrial environments, including runoff generation processes, spatial and temporal origin of surface and subsurface water, vegetation water uptake from different sources, groundwater recharge rates, catchment residence and travel time. I will report examples, recent developments, and ways forward in the application of stable isotopes in interdisciplinary investigations on the origin and fate of water. Finally, I will introduce a recent European initiative aiming at connecting researchers and stakeholders using isotopes as diagnosis and supporting tools in studies on water supply and management of water resources.





## Development and calibration of tools and models for quantification of the hydrogeological interference risk by tunnelling through different geological settings

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#### Abstract

In works related to tunnelling through permeable rocks, the importance of a hydrogeological study is particularly linked to geomechanical issues during advancement and to the prevention and protection of water resources and associated ecosystems all around the broader area of potential interference. Otherwise unforeseen undesirable effects without forecasted mitigation measures are consequent (High Speed Railway connection between Florence and Bologna, Gargini et al., 2008).

Predicting and quantifying the hydrogeological interference of big underground works, in particular base tunnels through mountain chains, is a challenging task subject to considerable uncertainty in relation to the difficulty of reconstructing the conceptual geological and hydrogeological model of the area of potential influence along with the identification of the pattern of groundwater flow systems, either in natural and affected conditions. Many are the methods, both non-physically based (parametric) and physically based (analytical or numerical mathematical models), which aim to predict both the magnitude and distribution of water inflows and the transfer of the interference to the surface receptors (springs, surface water bodies, wells, groundwater dependent ecosystems).

Analytical models tend to oversimplify the setting, assigning homogeneous boundary conditions and often overestimate impacts and water drainage (Molinero et al., 2002) Numerical models, on the other hand, are challenging and require large amounts of data and lengthy human efforts.

The aim of this work, representing a PhD research co-funded by Italferr Spa, is to establish a protocol that can be used in the feasibility planning phase, where large amounts of data are not yet available, and that could provide robust results in four main geological settings (karst, volcanic, hard rock, sedimentary).

Among the parametric methods, the DHI (Drawdown Hazard Index, Dematteis et al., 2001) waschosen for the first evaluation, through the comparison with recently completed tunnels excavation projects with a plenty of collected data.

Results are presented based on environment and tunnel hydrogeological monitoring data collected during excavation. The presented memory is about the initial outputs of the research, with the verification of DHI toward case studies where actual impacts againts springs occurres and were monitored in a detailed way.

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## Time-Domain Induced Polarization to depict geological heterogeneity controlling the groundwater features

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#### Abstract

In recent years, Direct Current (DC) and Time-Domain Induced Polarization (TDIP) surveys have been employed in environmental applications widely, showing successful for subsoil electrical properties distribution retrieving. Ground electrical properties depend on physical-chemical features of the geological bodies, therefore being informative on litho-stratigraphic and hydrogeological site characteristics. Within this study, these subsoil features represent the main targets of a dense DCIP survey implemented within a complex fluvioglacial depositional environment hosting a former gravel pit filled with waste in the late 80s. The final aim is to depict the geological heterogeneity in the pit surroundings (0.8 km<sup>2</sup> ca.), to infer its hydrogeological features lastly.

The proper recovery of this area's hydrogeological features demands more dense and extensive data coverage, than the boreholes drilled already, due to site heterogeneity. For this purpose, 9.8 km of 2D TCIP data have been acquired in the gravel pit surrounding, with profile lengths ranging from 400 to 1000 meters and electrode spacing of 5 or 10 meters. All data have been collected with the ABEM Terrameter LS2, recording full-waveform DC and IP data with a 100% duty cycle protocol and on-time of 12.3 seconds. The IP decays have been processed following Olsson et al. (2016), allowing increases in the usable range of IP decays to almost four decades in time.

The gathered data have been inverted via traditional resistivity inversion process first, to image the subsoil electrical conductivity distribution up to 250 meters from the surface. Induced Polarization data have been inverted following the approach proposed by Fiandaca et al., (2021), to implement hydraulic conductivity (K) as a model space parameter, allowing for straightforward K estimation where subsoil petrophysical relations for K hold (Weller et al., 2015).

Good coherence is evidenced among the profiles, and the K estimates agree with the borehole information at the site allowing for very accurate geological and hydrogeological interpretations both. Furthermore, the resistivity models show better coherence between different acquisition length profiles when inverted along with IP data. These results will inform the groundwater flow modelling under development.

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## Water chemistry and sediment quality in a Large Dam reservoir: implications for water management in Ridracoli

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#### Abstract

The problem of managing and conserving the quantity and quality of water resources has become increasingly important in recent decades due to climate change and human activity. The increase in drought periods and the concentration of rainfall, along with the growing demand of freshwater for drinking, agricultural and industrial uses, requires a thoughtful management for the exploitation and contextual safeguard of human health and the environment. The case study is the Ridracoli water reservoir in Northeast of Italy, managed by Romagna Acque Società delle Fonti S.p.A. It is one of the most important national reservoirs that provides drinking water for about one million people in Romagna region. Reservoirs are anthropic barriers built to store water for different purposes: electricity production, drinkable water storage, irrigation. A common side effect in a water reservoir is the trapping and accumulation of sediment at the bottom over time. The accumulation of sediments affects the maximum water volume and can influence the chemical water quality.

Water monitoring shows that the Ridracoli reservoir is affected by an alternation of stratification and mixing along the water column due to seasonal change in temperature, density and reservoir water level (Toller et al., 2020). The reservoir is characterized by a dynamic system in which the water quality changes seasonally due to absorption and release processes, equilibrium between soluble and insoluble components, nitrification and denitrification processes, and organic matter degradation. Water stratification and the establishment of anoxic conditions at the bottom during summer influence the concentration and mobility of some metals (i.e. Fe and Mn) within the water body and at the water-sediment interface, with consequences for the water quality that reaches the treatment and purification plant. The sediment composition indicates that the most easily mobilised elemental species were predominant in the area near the dam, in correspondence with sediments affected by seasonal anoxic layer formation (Toller et al., 2022). The total composition of sediments is similar over the whole reservoir, but the sequential extraction results highlight a certain inhomogeneity in function of environmental conditions, with upstream sediments more stable and sediments from the deepest area, near the dam and at the centre of the reservoir, more sensitive to environmental changes.

The study of seasonal changes of water quality and the characterisation of the sediment and element mobility help to assess the source and transport of elements, which are fundamental to plan water treatment operations and optimise resource management.

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## Impact of Brazil's Largest Recent Oil Spill on the Coastal Waters

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#### Abstract

In 2019, an oil spill in Brazil impacted coastal ecosystems in eleven Brazilian states. It is considered as the worst environmental disaster ever recorded in any tropical coastal region, due to its geographic extension, and diversity of environments affected. Here we present a brief review about the diverse ecosystems affected with regard to their different geological settings, origin, extension, chronic impacts, and the action to manage it, and what is the current situation after more than 3 years. A great scientific knowledge has been generated from the beginning of the disaster to the present day, which contributed to a better understanding of the different environmental and socio-environmental aspects related to the oil spill on the Brazilian coast. Lessons learned from this incident, based on scientific knowledge, should be used to evaluate policies and procedures to improve the governance in future similar situations.





## Isotopes of water molecule as water cycle fingerprints

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#### Abstract

An improved understanding of the water cycle under different environmental and socio-economic conditions to ensure availability and sustainable management of water and sanitation for all is the 6<sup>th</sup> United Nations sustainable development goal. The challenging tasks to achieve specific targets, i.e. safe drinking water, sanitation and hygiene, water quality, water-related ecosystems, integrated water resources management and water efficiency, are complex, and an interdisciplinary approach and knowledge for appropriate decisions today and for the future is necessary, particularly in climatically, morphologically, geologically and socio-economically diverse environments.

Stable (<sup>1</sup>H, <sup>2</sup>H, <sup>16</sup>O, <sup>17</sup>O, <sup>18</sup>O) and radioactive (<sup>3</sup>H) water isotopes are known as powerful tools to track the path of water molecules throughout the hydrological cycle, and to quantify the exchange of water, solutes, and particulates between hydrological compartments during different hydrological processes from local to global scale (e.g. Aggarwal et al., 2005, Vreča and Kern, 2022). During evaporation and condensation, the concentrations of oxygen and hydrogen isotopes in a water molecule undergo changes that result according to the history and route of the molecules through the water cycle in characteristic isotopic fingerprints in particular water cycle components.

In this presentation, we will discuss:

- examples of implications of isotopes for water resource management in Slovenia, and present the main gaps identified on national and local scale in previous investigations (e.g. Vreča and Malenšek, 2016, Nagode et al., 2020),
- the Slovenian Network of Isotopes in Precipitation (SLONIP) a research platform available at <u>https://slonip.ijs.si/</u> (Vreča et al., 2022), and
- recommendations and challenges of the future use of isotopes in water management.

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DIPARTIMENTO DI SCIENZE DELLA TERRA UNIVERSITÀ DI PISA www.dst.unipi.it

## Use of environmental isotopes to investigate the partitioning of water in the water supply system of Ljubljana, Slovenia

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Although water stable isotopes have been used in various hydrological investigations, they have mainly been applied to the natural water cycle, while their application to examine urban environments has been underutilized (Ehleringer et al., 2016). Despite this, studies of urban hydrology have demonstrated that the stable isotope approach, especially when combined with other geochemical parameters, can be effectively utilized in urban catchments to investigate tap water sources and groundwater systems. To date, no systematic investigation of the isotope composition of drinking water from "source to tap" has been performed in Ljubljana, the capital of Slovenia. In this research, we aim to fill the existing knowledge gap by examining the water circulation in the city of Ljubljana to enhance the evaluation of the freshwater resources for domestic use with the help of environmental isotopes ( $\delta^{18}$ O,  $\delta^{2}$ H,  $\delta^{13}$ C<sub>DIC</sub>) and in-situ parameters (temperature and electrical conductivity) in the aquifers regions supplying the city of Ljubljana (Nagode et al., 2022).

Preliminary sampling was conducted between September and November 2018, collecting 108 samples from source to end users at the Ljubljansko polje and Ljubljansko barje aquifers. The Water Supply System (WSS) components investigated included wells, joint exits from water pumping stations, reservoirs, water treatment sites, drinking fountains, taps, and the wastewater system.

Temperature analysis revealed that the system is more sensitive to external temperature than the temperature in the wells, while other parameters showed greater variability, indicating more uniform water in the WSS. The Precipitation signal ( $\delta^{18}$ O,  $\delta^{2}$ H) can demonstrate seasonality; however, no such signal was detected in the WSS over the short duration of the study. The results indicate that each well has a distinct isotopic signature (O, H, C) determined by the ratio of surface water to precipitation and that in all of the examined wellfields, the  $\delta^{13}$ C<sub>DIC</sub> is impacted by the decomposition of organic matter and the dissolution of carbonates.

In summary, monitoring the water supply system is essential for assessing potential changes, and multiparameter sampling should be conducted to evaluate the sensitivity of the Ljubljana aquifers to climate change, so as to identify any potential risks and take appropriate measures to mitigate them.

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## Projection of China's future runoff based on the CMIP6 mid-high warming scenarios

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#### Abstract

The latest Coupled Model Intercomparison Project Phase 6 (CMIP6) proposes new shared pathways (SSPs) that incorporate socioeconomic development with more comprehensive and scientific experimental designs; however, few studies have been performed on the projection of future multibasin hydrological changes in China based on CMIP6 models. In this paper, we use the Equidistant Cumulative Distribution Function method (EDCDFm) to perform downscaling and bias correction in daily precipitation, daily maximum temperature, and daily minimum temperature for six CMIP6 models based on the historical gridded data from the highresolution China Meteorological Forcing Dataset (CMFD). We use the bias-corrected precipitation, temperature, and daily mean wind speed to drive the variable infiltration capacity (VIC) hydrological model, and study the changes in multiyear average annual precipitation, annual evapotranspiration and total annual runoff depth relative to the historical baseline period (1985-2014) for the Chinese mainland, basins and grid scales in the 21st century future under the SSP2-4.5 and SSP5-8.5 scenarios. The study shows that the VIC model accurately simulates runoff in major Chinese basins; the model data accuracy improves substantially after downscaling bias correction; and the future multimodel-mean multiyear average annual precipitation, annual evapotranspiration, and total annual runoff depth for the Chinese mainland and each basin increase relative to the historical period in near future (2020–2049) and far future (2070–2099) under the SSP2-4.5 and SSP5-8.5 scenarios. The new CMIP6-based results of this paper can provide a strong reference for extreme event prevention, water resource utilization and management in China in the 21st century.

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## Session 2

## **Open lab**

Chairpersons

Luppichini Marco (Università di Pisa) Lazzarotti Marco (Università di Pisa)





## Suspended Solid Load: sampling and analytical procedures of a river system geological matrix

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#### Abstract

River systems are composed of several geological matrices (solids and liquids) that differently reflect the geochemical contribution of natural and anthropogenic sources. Suspended Solid Load (SSL) plays a central role in the comprehension of all those processes that take part in fluvial systems, since the SSL's high specific surface and its composition (most likely clay minerals and organic matter) favour the enrichment of heavy metals and other organic pollutants. In the last decennia, the widespread diffusion of advanced analytical facilities, such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Thermal Ionisation Mass Spectrometry (TIMS), allowed a consistent production of analytical data in parallel with an increasing awareness of the trace elements geochemistry in the river system. The Valdinievole sub-basin (Tuscany, Central Italy) represents a perfect case study to evaluate the different anthropogenic contributions on the SSL composition, due to the varieties of industrial activities in the area, such as paper mills, flora nursery farms, thermal spas, and tanning industries. This area is of particular interest also for the presence of the most important continental swampy zone of Italy (Padule di Fucecchio), an ideal environment for the evaluation of the transfer of pollutants in riverine basins. For my Ph.D. project, I designed the most suitable procedures for sampling, preparation, and analysis of the SSL collected along the hydrographic network of the Valdinievole sub-basin, for a total amount of 77 samples. All the analytical procedures and analyses of trace elements and Sr, Pb and Nd isotopic compositions were carried out at the University of Study of Florence. The data were evaluated using the software OriginPro, Version 2021b (OriginLab Corporation) and ArcGIS Pro (ESRI). The results show variable heavy metals enrichments in the SSL samples, with concentrations of Pb, Cu, Zn and Cr up to 174 mg/kg, 766 mg/kg, 1899 mg/kg and 4800 mg/kg, respectively. The observed relationships between Enrichment Factors (EFs) and the Pb isotopic ratios suggested the presence of different pollution trends linking the geogenic to many anthropogenic sources and allowed identifying two distinct areas of the Valdinievole sub-basin with different clusters of heavy metals enrichments.





# Field testing of tube-dip-in water precipitation collectors used in isotope hydrology

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#### Abstract

The oxygen and hydrogen stable isotope composition in precipitation serves as a benchmark in most isotope atmospheric, (eco-)hydrological, and paleoclimatological applications. Several rain collectors have been designed for collecting monthly, daily or event-based precipitations aiming to prevent evaporation and associated isotope fractionation. Oil collectors have been the most widely used for many years and only recently they are being progressively replaced by free-oil Tube-dip-in water collectors, especially after their formal publication by Gröning et al. (2012) and the production of a commercial version (Palmex Ltd). Although the reliability of this precipitation collector has been proven, many doubts remain when dealing with small precipitation amounts (Michelsen et al., 2018). Field testing of precipitation collectors is therefore encouraged, which should be carried out under the same environmental conditions of areas where researchers want to undertake their studies.

In this work, we tested the field performance of different precipitation collectors in preventing evaporation and isotope fractionation. Two main objectives were behind this study: i) to evaluate the reliability of tube-dip-in water collectors for very low precipitation amounts; ii) to test a homemade Tube-dip-in water collector for different water amounts. The experiment consisted of simulating the collection of small monthly precipitation samples in spring and summer when atmospheric conditions are more likely to promote evaporation. The experiment was carried out on the rooftop of the Earth Science Department of the University of Pisa from March 2022 to July 2022. Four different collector designs were tested simultaneously over four different periods (each lasting approximately one month): a Control collector with no anti-evaporative system; an Oil collector; a Palmex Tube-dip-in water collector; a homemade Tube-dip-in water collector. They were filled to 1.4% of their total volume (10 L) with water of known isotope composition. Since the diameter of 13.5 cm of most common funnels, this percentage corresponds to ~10 mm. Other two homemade Tube-dip-in water collectors were filled to 5% and 10%, corresponding to ~35 mm and ~70 mm. All the collectors were placed outside at the start of each period. Evaporative mass losses were determined gravimetrically and samples for isotope analyses were collected at the end of each period. On average, the Oil collector showed the smallest mass losses, and the isotope shifts were much lower than analytical errors. The Palmex collector failed, with even larger mass losses and isotope shifts  $(\Delta \delta^{18}O = 0.42\%)$  and  $\Delta \delta^{2}H = 1.6\%)$  than the Control collector. The home-made Tube-dip-in water collectors performed well and better than Palmex. Mass losses and isotope shifts tended to increase with increasing temperature and decreasing relative humidity.

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## Custom instrumentation for hydrology and water monitoring

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#### Abstract

The detailed monitoring of any water body, both superficial water and groundwater, obviously requires dedicated field automated instrumentations. Moreover, the number of monitoring devices is often crucial for a good characterization of the observed water system. Often commercial devices require significant investments of money, which rapidly grow with the number of acquired parameters and device functionalities (such as solar recharger, GSM connectivity, etc). This limits the number of devices that can be used in such monitoring studies. Additionally, commercial options usually lack modularity, which may be necessary for adapting to different environments and monitoring objectives.

Open-source electronics platforms offer both low-cost components and modularity of the devices. Particularly, the Arduino platform, an open-source and low-cost prototyping platform allows for building and developing versatile and effective water monitoring loggers. Moreover, due to its long presence on the market, the Arduino platform has a consistent community of users both from the hobbyist and the scientific world which represents a wide source of information and inspiration.

In the present work, a few basic information about the microcontrollers and the Arduino board will be presented. Then we'll report an example of an Arduino Nano board-based datalogger for monitoring water temperature and water level, with a particular focus on the hardware part of the logger and different sensor options.





## Tips for researchers in geosciences: useful software and databases

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#### Abstract

Over the past decades, science has experienced a great growth in the volume of data available for research and in the number of software and tools for data management and processing. However, due to the large amount of possibilities, it is sometimes not easy to know and find suitable tools to meet a research need.

The aim of this contribution is to provide a list of useful software and available databases for geoscientists, to share knowledge and, hopefully, help students and researchers struggling with issues related to data searching, processing, and reporting.

The list of regional and international databases, as well as the list of useful software to extract and process data, arises from personal experience, especially in the field of water and sediments geochemistry, and therefore we do not pretend to be exhaustive.

## Session 3

## Learning from the past: traces and shapes related to water

Chairpersons

Peri Emanuele (Università di Pisa) Nigro Matteo (Università di Pisa)





## Mapping landslides and slope failure from seismic dataset on the Brazilian Equatorial Margin

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The Brazilian Equatorial Margin developed due the break-up between Africa and South America during the Cretaceous, the opening left the Equatorial Atlantic marked large offset of transform faults. The investigated part on the margin is the offshore portion of the Potiguar Sedimentary Basin, NE-Brazil. Understand the seabed morphology of the region is imperative since the area is the new target for wind power offshore and exploration of oil in deep waters. Construction in areas of instability could represent hazards and cause accidents. The area beyond the shelf is not covered by high resolution bathymetrical dataset. To provide the first high resolution mapping of the continental shelf and slope we used two 3D high resolution seismic blocks. The dataset was conceded by the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP). With the seabed mapped the aim was: a) Provide the first high resolution mapping of the slope of the Potiguar Basin and b) Map the most representative geomorphological features, especially those that could indicate instability. In addition, the subbotom seismic interpretation was used to verify if: a) Any of those features were being controlled by Neotectonism related to a possible reactivation of an Ocean Fracture Zone or if b) They were related only with gravitational/erosional processes. To conduct the seismic interpretation Petrel E&P Software was used. The seabed mapping revelled that the continental slope is marked by submarine channels, slope failure, sediments deposits, gullies and at least 4 landslide scarps. The largest landslide scarp Ls1 has a semi-elliptical shape-oriented NW-SE and reaches a slope dip of ~14.4°. The subbotom seismic interpretation revealed at least three types of landslides processes occurred at the slope: slide, collapse and slumps. The tectonic interpretation did not evidence any tectonic faults affecting the sedimentary packages younger than the Miocene. This indicates that the present seabed morphology is probably not or little affected by neotectonic processes and a possible reactivation was not proved on the area covered by the dataset. The complex morphology revelled by the seabed mapping seems to be controlled only by gravitational, erosional, and sedimentary processes. Our dataset indicates that areas close to the channel's walls, marked by scarps and close to landslide scars, are areas prone to collapse, due to theelevated steepness in which offshore constructions should be avoided.





## Memories of landscapes and people: floods, climate and society at the mouth of the Magra River

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#### Abstract

Humans and other K-selected species profit from climatically stable conditions and the resulting steady availability of resources. It should come as no surprise that early humans spent a significant amount of time observing and learning about the seasonal cycles in order to forecast the weather and ensure a steady supply of food and water. Initially, this kind of task was only completed by memory. This is highlighted by ancient mythical stories that indicate a deep knowledge of the climate and its multi-year cycles. Modern scientific and technical developments have significantly increased our weather forecast ability. Despite the fact that we still don't fully understand a number of regional and global processes, the wealth of data collected in the last two hundreds of years allows us to forecast climatic evolution on the very-short time-scale. However, global climate is a complex system with, spatially coherent, large-scale patterns of anomalies on inter-annual and longer time scales. Although, these patterns can be successfully followed by a number of indices (such as the North Atlantic Oscillation) and that they have a significant impact on temperatures and precipitations, little is known about their long-term dynamics. Actually, several of these climatic patterns seem to display a pseudo-periodical behavior on the a decadal to secular time-scale. Since -in the best-case scenario- our recorded data only spans the last two centuries, we have no means to scientifically assess whether or not these pattern truly have a periodical nature and what causes it. This lack of knowledge greatly restricts our ability to predict how these patterns might change in the near future and in response to the current climate change.

Unlike our modern meteorological series, the geological record extends for million of years and is rich of proxies that can be related to environmental parameters. Unfortunately, it is exceedingly challenging to link and integrate the data from the geological record with those of contemporary oceanography and climatology, even in depositional settings characterized by an exceptionally high sedimentation rate (e.g., river deltas, lakes). Historical information can fill this gap, by bridging the extremely-long time scale of the geological record, with the decadal and secular time-scale that seems to be relevant to understand climatic patterns.

To test these assumptions, the "Memorie del Magra" project focused on collecting a coherent dataset on the last two thousands year of evolution of this northern Italian river. The very narrow basin of this river is characterized by both massive, disastrous floods and times of low discharge. The sedimentation rate at its mouth is very high, meaning that even short-lived events can be recorded by the river sediments. Additionally, since Magra's valley has been populated for the past two thousand years, there are numerous historical records that can shed light on the climate and the dynamics of rivers.

Four cores were obtained at varying distances from the river mouth following an initial geophysical investigation to identify areas of the seafloor that had not been disturbed. Sedimentological analysis of the cores was used to recognize flood related layers, while petrographic and heavy minerals analysis were used to recognize different flood-layers and the provenance of the floods. Wood fragments, and shells where collected from the core for radiocarbon dating. Foraminifera were also examined for geochemical analyses aimed at reconstructing the paleotemperatures as well as for paleoenvironmental reconstruction of the study area.

Historical analyses focused on various archives in order to find a complete chronology of the floods in the area. These results where then compared to those of similar analyses performed on Arno, Po, Tiber and Rhône rivers. In order to assess how the shoreline has changed throughout time, historical document examinations have also concentrated on maps and charts of the region. Finally, the local communities were involved in order to gather first-hand accounts of the floods in the area. This effort resulted in a large dataset that may be used to better understand the dynamics of the local climate and of the precipitations. It also demonstrated the advantages and disadvantages of this method, thereby laying the groundwork for future studies.





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## An addition to the Middle Triassic Monti Pisani Ichnoassemblage: *Characichnos*, a tetrapod swimming trace

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#### Abstract

The paleoichnological (trace fossil) record testifies to the ancient behaviours of the tracemaking organisms, which include walking, eating, resting and nesting among others. Trace fossil evidence for swimming is particularly rare, since the conditions for preservation of swimming-induced traces are extremely peculiar. Here, we describe new and previously collected traces from the Ladinian (Middle Triassic) Quarziti Viola Zonate Member of the Quarziti del Monte Serra Formation, (Monti Pisani massif, northern Appennines) as belonging to the ichnogenus *Characichnos*. The latter was originally described for groups of two to four, slightly sinuous, parallel hypichnial ridges (or epichnial grooves) that reflect the tracemaker's underwater scratching of shallow floor while buoyant (White & Romano, 2001). The overall size and morphology of *Characichnos* isp. from the Monti Pisani trace fossil assemblage are comparable to those of the lepodosauromorph and archosauromorph ichnotaxa *Rhynchosauroides, Rotodactylus*, and *Synaptichnium*, all of which have been previously reported from the Quarziti del Monte Serra Formation, whose remarkable tetrapod ichnoassemblage has been recently revised (Marchetti et al.,2021). Our discovery of representatives of Characichnos in the Quarziti Viola Zonate strata is consistent with previous reconstruction of the palaeoenvironmental setting of this deposit as a coastal pond system, covered by very shallow water and periodically dried up (Rau & Tongiorgi, 1974).

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## The significance of recent and short pluviometic time series for the assessment of flood hazard in the context of climate change: examples from some sample basins of the Adriatic Central Italy

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#### Abstract

Numerical hydrological models are increasingly a fundamental tool for the analysis of floods in a river basin. If used for predictive purposes, the choice of the "design storm" to be applied, once set other variables (as basin geometry, land use, etc.), becomes fundamental.

All the statistical methods currently adopted to calculate the design storm, suggest the use of long rainfall series (at least 40–50 years). On the other hand, the increasingly high frequency of intense events (rainfalls and floods) in the last twenty-five years, also as a result of the ongoing climate change, testify to the need for a critical analysis of the statistical significance of these methods.

The present work, by applying the Gumbel distribution (Generalized Extreme Value Type-I distribution) on two rainfall series (1951–2022 and 1998–2022) coming from the same rain gauges and the "Chicago Method" for the calculation of the design storm, highlights how the choice of the series may influence the formation of flood events.

More in particular, the comparison of different hydrological models, generated using HEC-HMS software on three sample basins of the Adriatic side of central Italy, shows that the use of shorter and recent rainfall series results in a generally higher runoff, mostly in case of events with a return time equal or higher than 100 years.





# It's time to eat: evidence for great white shark (*Carcharodon carcharias*) feeding on a Mediterranean Pliocene right whale

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#### Abstract

Modern marine waters are inhabited by more than 500 shark species. Among them, the great white shark (*Carcharodon carcharias*) occupies the topmost position of most marine food pyramid, representing the apex predator of the present-day global ocean. Even if *Carcharodon carcharias* is well-known as a formidable active predator of marine mammals (including pinnipeds and diminutive odontocetes), it also constitutes an example of scavenger (Compagno, 1984). In fact, several anecdotal and scientific records exists for white sharks feeding on floating whale carrions, which are rich of blubber, and as such, highly energetic food.

Given the latest Miocene origin of *C. carcharias*, the Plio-Pleistocene marine deposits preserve occasional evidence for the feeding activity of white sharks in the form of bite marks on bones and teeth embedded into (or closely associated with) marine mammal bones.

Here, we report on a new example of white shark-cetacean trophic interaction evidence from Pliocene shelf sediments of the Argille Azzurre Formation exposed at Monterotondo Marittimo (Tuscany, Italy).

The fossil specimen described herein consists of a well-preserved cetacean scapula whose lateral surface is densely incised by serrated shark bite marks up to several centimeters long. Based on osteoanatomical considerations, the scapula can be referred to a likely diminutive extinct member of Balaenidae (right and bowhead whales, which are no longer part of the poorly diverse Mediterranean fauna), about 8 m long. In addition, during the recovery operations, a shark tooth fragment was found embedded into the scapular.

Considering the fragmentary nature of the studied specimen, whether the observed bite marks represent scavenging or active predation could not be assessed. What is remarkable here is the kind of trophic interaction that it witnesses to, which includes a member of a baleen whale morphotype that is no longer present in the modern Mediterranean Sea, not even in the rest of the global ocean.

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## *Stenopterygius* (Reptilia, Ichthyosauria) in Italian museums: morphometric and palaeoecological considerations

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#### Abstract

*Stenopterygius* is a genus of parvipelvian ichthyosaurs whose fossil remains are mostly found in Lower Jurassic strata of the Württemberg area, Germany. Large amounts of complete, exquisitely preserved specimens of *Stenopterygius* have been recovered from the famous locality of Holzmaden (Württemberg) and sold to museum collections throughout Europe since the early 19<sup>th</sup> century. Many *Stenopterygius* skeletons found their way to Italian natural history collections, most of which have never been properly studied.

*Stenopterygius* fossils are widespread across museum collections, thus comprising an ideal statistical sample for investigating the inter- and intraspecific morphological variability of this genus. The study pf this sample could in turn shed light on the diversity and disparity of large-sized marine predators in coastal and shelfal environments of the Early Jurassic.

Here, we report on nineteen ichthyosaur skeletons from five Italian museums (Museo Geologico Giovanni Capellini, Museo Geologico Paleontologico dell'Università di Padova, Museo di Paleontologia di Napoli, Museo di Storia Naturale di Milano, Museo di Storia Naturale dell'Università di Pisa) identified as *Stenopterygius* by using modern taxonomic schemes. Updated species-level identifications of these fossils were also attempted by relying on the linear morphometric analyses proposed by Maxwell (2012) as well as on the phylogenetic matrix elaborated by Maxwell & Cortés (2020).

Out of nineteen studied specimens, eight were assigned to *Stenopterygius quadriscissus*, three to *S. triscissus*, with all other examples being referred to *Stenopterygius* cf. *quadriscissus*, *Stenopterygius* cf. *triscissus* or *Stenopterygius* sp. The inclusion of the aforementioned 19 specimens in morphometric analyses would likely result in improving the precision and resolution of these methodologies by increasing the statistical sample size. The studied specimens were documented by means of high-resolution photographs and the acquisition of 3D models via structured-light scanning and photogrammetry. Two skeletons kept at the Museo di Storia Naturale dell'Università di Pisa (MSNUP) were CT-scanned, revealing interesting anatomical elements, such as the hyoid bones and ischiopubis, which would have been otherwise hidden beneath the embedding limestone. Moreover, the CT-scans resulted in the reconstruction of the tridimensional rostral morphology of one of the MSNUP specimens, allowing for some morphofunctional inferences on the feeding behavior of *Stenopterygius*. According to the metrics reported by McCurry & Pyenson (2019), the rostra of some extinct and extant long-snouted odontocetes (toothed whales) and istiophoriforms (billfishes) may represent good functional analogues of those of parvipelvian ichthyosaurs.

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## A sea of pufferfishes: how vertebrate palaeontology can shed light on the future of an iconic Mediterranean bioinvasion

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#### Abstract

The main goal of the Paris Climate Accords is to keep the rise in mean global temperature well below a maximum of 2°C above pre-industrial levels, recognizing that this would substantially temper the effects of global warming. As regards the Mediterranean Basin, mean temperatures have increased 1.4°C since the late XIX century (i.e., distinctly more than the global average of +1.1°C), and they are projected to increase by an additional 1.5°C by 2050 in case of no decarbonization. During the Pliocene, temperatures were 2-3°C higher than today, which means that the Mediterranean Pliocene palaeoenvironments may provide a much realistic example of what the Mediterranean Sea might become in a not-so-far future (would we fail the main goal of the Paris Agreement). Thus, we may turn to vertebrate palaeontology to envision how the Mediterranean fauna would look like in perspective. Pufferfishes (Tetraodontiformes: Tetraodontidae) are instructive in this respect. Until the XIX century, a single pufferfish species, Lagocephalus lagocephalus, was known to inhabit the Mediterranean for sure, being rarely reported from the waters off Sicily. Nowadays, as many as six more pufferfish species are spreading across the Mediterranean, representing some of the more striking examples of "lessepsian immigrants" that have entered the eastern portion of the basin through the Suez Canal. These include the poisonous pufferfish Lagocephalus sceleratus, which currently represents 4% of the weight of total artisan catches in the Eastern Mediterranean. Pliocene fossils of Tetraodontidae, mostly consisting of premaxillae and dentaries, are fairly common in the Mediterranean area as north as in Tuscany and Emilia-Romagna (Adriatic palaeo-area), taking their place besides thermophilic relics of the Tethys ocean and other warm-water, currently extra-Mediterranean taxa (e.g., the tiger shark, Galeocerdo cuvier) that may be on the cusp of re-entering the basin. The whole Mediterranean could thus become a sea of pufferfishes.





# Potential of geomorphological features favoring the development and conservation of cryopegs on Earth and Mars

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#### Abstract

Cryopegs are enclosed entities of supercooled brine that exist within permafrost. Due to an accumulation of soluble salts and increase of pressure during the process of top-down freezing, cryopegs can remain liquid at temperatures as low as -11 °C. The chemical and microbiological conditions of these brines are similar to those present during their formation, as they had limited to no exchange to external hydrological influence. Therefore, cryopegs represent the only habitat on Earth where isolated units of liquid water can remain stable in sub-zero temperatures for extended geological time periods. The specific physical and chemical properties of cryopeg-brines depend on the history of landscape evolution and an interplay of specific sedimentological, climatological, and hydrological variables. Cryopegs provide a unique habitat for polyextremophile organisms and are critical for understanding the habitability of brines on extraterrestrial planetary bodies, like Mars (Gilichinsky et al., 2005). On Mars, cryopegs may have formed during the planet's cooling and could potentially serve as a habitat for extraterrestrial life, providing shelter from extreme planetary surface conditions. Investigating the existence of cryopegs in relation to remotely identifiable geomorphological features, such as deltaic or beach deposits, which are associated with past water activity, has important implications for advancing the understanding of planetary habitability and the search for biosignatures. However, direct evidence for cryopeg locations on Mars are missing due to a lack of ground truthing data. Therefore, studying the correlation between cryopegs and geomorphology

in terrestrial Martian analogue sites is a critical step in assessing the cryopeg-bearing potential of geomorphological landscape elements on Mars.

The coastal plain of Kvadehuksletta on the western coast of Spitsbergen, Norway, offers a suitable analogue site for investigating cryopegs, as sequences of beach ridges have formed due to marine regression after the Last Glacial Maximum. The dynamic interplay of various geomorphological processes, including coastal and fluvial dynamics, and permafrost-related cryogenic processes, in Kvadehuksletta create a complex landform assemblage that offers a high potential for the development of cryopegs in this area.

Based on high resolution remote sensing datasets acquired during the DLR MACS flight campaigns in 2020, a landscape analysis was carried out and a detailed geomorphological map of Kvadehuksletta in Norway, on a scale of 1:8000, was created. Remotely identified were areas where cryopegs could potentially be found based on the history of their formation within the complex landscape. High-resolution geomorphological maps highlighting cryopeg bearing sites on earth and mars, can support the identification of possible landing sites for future space missions to directly locate cryopeg-bearing layers on Mars.

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