

“Oxygen isotopes as tracers of Mediterranean climate variability: linking past, present and future”: SCIENTIFIC REPORT

An ESF MedClivar workshop, University of Pisa, Italy, 11-13 June 2008

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Summary

Key indicators of natural climatic variability over timescales beyond those based on direct monitoring or historical observations come from the ratio of oxygen isotopes preserved in materials such as cave carbonates, and lake and marine sediments. Oxygen isotopes also provide one of the best tracers of the Mediterranean hydrological cycle from source areas in the oceans, through precipitation, to ground- and surface freshwaters. This three-day ESF MedClivar workshop meeting in Pisa considered how oxygen isotopes can be used to provide records of Mediterranean climate variability. It focussed on five main themes in oral and poster presentations, and discussion sessions, namely 1) water isotopes as tracers for monitoring and modelling patterns of precipitation, 2) lakes and surface waters, and their sedimentary records, 3) groundwaters and cave systems as preserved in speleothems, 4) marine systems, including both deep-sea sediments and surface corals, 5) intercomparison and calibration of different archives. Participants discussed a number of key achievements, such as isotope data bases enabling regional-scale data:model comparisons, and future priorities, including improved calibration of proxy-climate data via monitoring of contemporary systems and mass balance modelling, and a focus on synthesising high-resolution climate reconstructions during the last 2000 years. The workshop meeting involved 56 participants from 14 countries, and papers from the meeting will be published in a special issue of *Global and Planetary Change*.

Scientific content and discussion

Given predictions of future climate, changes in rainfall and water resources seem certain to have important socio-economic and political impacts in the Mediterranean region (Giorgi 2006). Understanding the variability of hydro-climate over different time scales is therefore an essential prerequisite for establishing predicted future climate change and its possible impact on human society in the Mediterranean. Because they vary directly with the physical processes of the hydrological cycle and are normally not compromised by human impact (e.g. pollution), oxygen isotope ratios provide an important hydro-climatic tracer at all time scales - instrumental, historical and geological.

This workshop meeting, held in the historic city of Pisa, provided a timely opportunity to bring together members of the scientific community engaged in different aspects of stable isotope research around the Mediterranean basin. ESF was the principal meeting sponsor, under its MedClivar programme, with additional local sponsorship and support (see list below). The meeting was held over three days in the University of Pisa's Botanical Gardens, one of the oldest in Europe, and included 21 oral and 20 poster presentations, with 56 participants from 14 countries, including most of those that are supporting the ESF MedClivar initiative. Pisa has played a very significant role in the development of stable isotope research, and we were delighted that this workshop included contributions by Professors Antonio Longinelli and Roberto Gonfiantini, who have played such a key part in these developments. The meeting was followed by an optional one-day scientific field visit to the nearby Alpi Apuane region, including the Monte Corchia cave system.

The meeting commenced with an introductory session in which Ricardo García Herrera (Madrid) outlined the wider context of the MedClivar programme and Neil Roberts (Plymouth) set out the scientific background to the Pisa meeting. The rest of the meeting was structured around five main themes, each involving presentations and discussions.

Session #1 examined how water isotopes have been used as tracers in monitoring and modelling contemporary patterns of precipitation over the Mediterranean, particularly in relation to source area characterisation and air mass trajectories. Luis Araguas (Vienna) outlined the IAEA water isotope monitoring programme, which has included a Coordinated Research Project on Isotopic Composition of Precipitation in the Mediterranean Basin (IAEA 2005), while Spyros Lykoudis (Athens) described methods and results of spatial interpolation of precipitation isotope data for the eastern Mediterranean region. Oxygen isotopes are one of few outputs from GCMs that can be measured directly by natural climate archives, and Georg

Hofmann (Paris) discussed nested meso-scale GCM simulation experiments via REMO and their application to isotopes from tree ring cellulose.

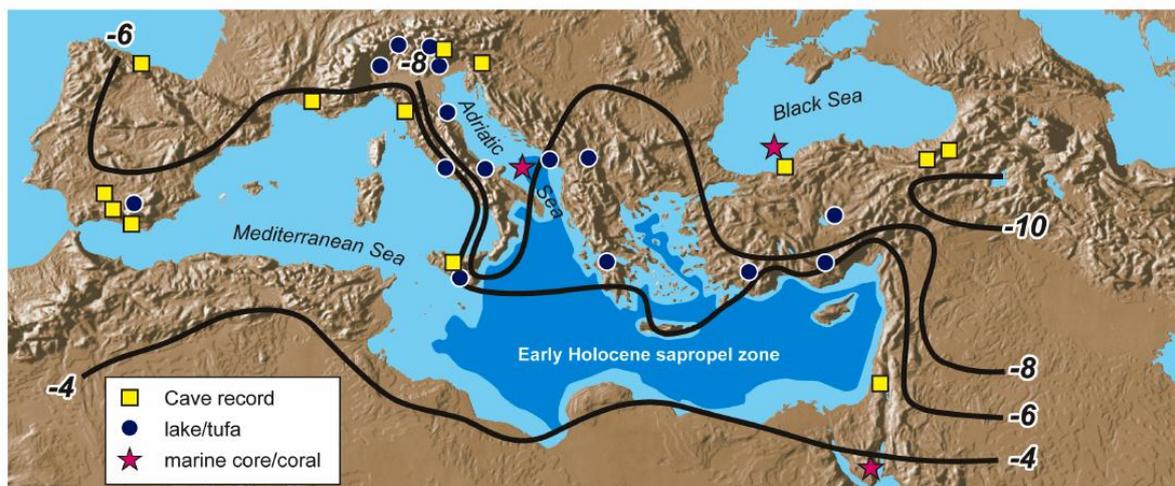


Figure 1:

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Surface waters provided the focus of session #2, involving both contemporary and palaeohydrology, the latter via isotopes preserved in authigenic carbonates and silicates. Melanie

Leng (British Geological Survey, Nottingham) examined the isotopic record preserved in lake sediments with special reference to the problem of detrital carbonate contamination, and Ulrich von Grafenstein (Paris) provided examples from Sebino in northern Italy via the DecLakes project and from Ohrid – Europe’s most ancient lake. Matthew Jones (Nottingham) presented a mass balance model of isotope response to climatic forcing for different lake types, while Julian Andrews (Norwich) showed how laminated tufa deposits from Greece can potentially be used to extract a signal of past climate seasonality.

Session #3 was devoted to karst hydrology and cave carbonates such as stalagmites and flowstones. Andy Baker (Birmingham) focused on the calibration of carbonate isotope records against instrumental climate data - a key theme of the workshop meeting - and Frank McDermott (Dublin) compared $\delta^{18}\text{O}$ against other proxy-climate parameters from speleothems to highlight how no single proxy provides a “magic bullet” solution to climate reconstruction. Dominik Fleitmann (Bern) used speleothem isotopes to show palaeo-climatic gradients from south (Oman) to north (NW Turkey), with caves in the latter appearing to display a strong Black Sea signal. In the final paper in this theme, Hagit Affek (Yale, New Haven), outlined the new technique of clumped-isotope paleothermometry and its application to the well-known Soreq Cave record from Israel over the last glacial-interglacial hemicycle.

In session #4, the focus shifted to marine isotopes. The Mediterranean and adjacent seas are largely enclosed water bodies with isotopic and water balance histories that differ significantly from that of the world ocean – indeed, the Black Sea was a freshwater lake during glacial stages of the Pleistocene. They also provide the source of much of the evaporated water that subsequently rains out over the surrounding circum-Mediterranean land area. Eelco Rohling (Southampton) provided an analysis of palaeoceanographic conditions during the formation of the enigmatic sapropel layers when the eastern Mediterranean Sea became anoxic, as the Black Sea is today. This occurred most recently during the early Holocene when, as Michel Fontugne (Paris) showed, runoff from the Nile and North African wadi systems contributed to the creation of a freshwater lid. The last paper of this session and day two was by Thomas Felis (Bremen), who presented high-resolution isotopic analyses of northern Red Sea corals – the most northerly anywhere on the planet – during different time windows of the late Holocene, with teleconnections to “centres of action” under different climate modes such as the NAO/Arctic Oscillation.

The fifth substantive theme, which started the third day of the meeting, involved intercomparison of different isotope archives. Michel Fontugne had already discussed issues of correlation and dating between lake and marine sediments, and Giovanni Zanchetta (Pisa)

extended this range of archives to include lakes, caves and land snails in a review of Holocene isotope changes in Italy. The integrated multi-archive OLOAMBIENT project, also in Italy provided the basis of two linked papers, Maria Letizia Filippi (Trento) describing the results of seasonal monitoring of Lake Lavarone, and Andrea Borsato (Trento) outlining isotopic and other analyses of speleothems from three cave systems in the same Trentino region. The final presentation was by Antonio Delgado-Huertas (Granada), who compared lake carbonate isotopes with those on bone phosphate from archaeological sites in Iberia.

The meeting also included a dedicated poster session. Among the 20 excellent poster papers were presentations by five ESF-sponsored early career scientists, namely

- Pedro Freitas (Lisbon) on experimental calibration of the oxygen-isotope palaeotemperature proxy in marine bivalve shells,
- Olga Kwiecien (Potsdam) on a multi-proxy approach to the last deglaciation as recorded in a western Black Sea sediment core,
- Arne Leider (Bremen) on multidisciplinary study of continental/ocean climate dynamics using high-resolution records from the eastern Mediterranean
- Clara Mangili (Potsdam) on stable isotope oscillations during peak interglacial conditions at 400 ka in the Piànico palaeolake sequence, northern Italy
- Andrea Zerboni (Milano) on isotopic investigation of Holocene freshwater carbonates from Libya

The final session of the meeting was a semi-structured panel discussion of key cross-cutting issues between different time periods and different archives, many of which form the basis for future recommended research.

Results of the meeting and impact on future research directions

The Pisa workshop provided an ideal forum for improving the currently under-developed dialogue between palaeo-, contemporary and modelling groups who use stable isotopes to understand Mediterranean climate change. This dialogue is essential if we are to improve our knowledge of the hydro-meteorological factors that determine isotopic signals, including temperature, source-water composition, air mass changes and evaporation, over different temporal and spatial scales.

The workshop participants identified a number of key outcomes and future objectives, including

- Synthetic stable isotope data bases in a form that can be compared to regional-scale model output predictions. Such metadata now exist for isotopes in precipitation (via IAEA GNIP http://www-naweb.iaea.org/naweb/ih/GNIP/IHS_GNIP.html), marine waters and deep-sea sediment cores (e.g. <http://www.giss.nasa.gov/data/o18data/>), and lakes (via the ISOMED project; <http://www.geog.plymouth.ac.uk/research/groups/is18omed.htm>). Palaeo-isotope data sets are currently based on multi-millennial timescales; i.e. Glacial-Interglacial or whole Holocene. In future it would be desirable to establish similar data bases for well-dated records from speleothems, corals and lakes for the last 2000 years at decadal or better resolution, in order to compare them against data from historical sources and observational records (e.g. Luterbacher et al 2006).
- Monitoring of modern hydro-climatic conditions in the same systems (e.g. individual caves or lakes) that preserve longer term isotope-climate records in carbonate deposits. The OLOAMBIENT project provides an excellent model for this type of integrated study incorporating a range of timescales. Monitoring also provides key insights into the role of seasonality that is preserved in climate archives. It would especially be desirable to improve isotope data coverage in North Africa, both palaeo and modern.
- Harmonising methods for numerically calibrating palaeo-isotope data in order to derive quantitative values for past temperature, precipitation, relative humidity. These include not only site-specific monitoring, but also statistical correlation of time series against local multi-decadal instrumental records, and mass balance modelling. A particular challenge in that regard is the spatial inhomogeneity of precipitation (and associated isotopes) compared to temperature or relative humidity. Palaeo- $\delta^{18}\text{O}$ data should also be evaluated in their own right in terms of the water cycle, and not just as dummies for other climatological parameters.
- Data-model comparisons, both for individual systems and a Mediterranean-wide scale. The latter should include comparison between meso-scale numerical model outputs for different boundary conditions (e.g. insolation forcing) and palaeo-data for the Mediterranean region. This often requires site-specific palaeo-data to be transformed into regional-scale patterns.
- The reconstruction of Mediterranean Isotope Gradients at important time periods e.g. present-day, late Holocene, Early Holocene, Glacial.

Specific outcomes: the abstracts of papers (oral and poster) presented at this workshop meeting are available at the web-site

http://www.geog.plymouth.ac.uk/research/groups/MedCLIVAR_isotope_workshop.html

We are pleased to report that agreement has been reached with the editors and publisher of the international journal *Global and Planetary Change* (Elsevier) for publication of papers resulting from this ESF meeting. The deadline for receipt of manuscripts is November 30th 2008, to be followed by external peer review, with publication planned for the 2nd half of 2009. At this time, 19 papers have been promised for submission.

This workshop will also feed directly into the overall ESF MedClivar programme (2006-2011) <http://www.medclivar.eu/>, not only via the past evolution of Mediterranean climate over different timescales, but also in understanding underlying controls over Mediterranean climate and how they are likely to respond to future forcing.

Workshop sponsors:

- ESF MedClivar programme
- University of Pisa, Dipartimento di Scienze della Terra and Dipartimento di Biologia
- CNR Istituto di Geoscienze e Georisorse, Pisa
- Regione Toscana
- University of Plymouth
- University of Nottingham

References

- Giorgi, F. 2006 Climate change hot spots. *Geophysical Research Letters* 33, L08707, doi:10.1029/2006GL025734, 2006
- IAEA-TECDOC-1453 2005 *Isotopic composition of precipitation in the Mediterranean Basin in relation to air circulation patterns and climate*. Final report of a coordinated research project 2000–2004, IAEA, Vienna.
- Luterbacher, J., and 48 coauthors, 2006 Mediterranean climate variability over the last centuries: A review, in: *The Mediterranean Climate: an overview of the main characteristics and issues*, Eds. Lionello, P., Malanotte-Rizzoli, P., and Boscolo, R., Elsevier, Amsterdam, the Netherlands, 27-148.

Meeting programme

	Speaker	Title
June 11th	<i>Session 0: The Mediterranean climate: past and present</i>	
17.00	Mauro Rosi Roberto Gonfiantini	Welcome
17.10	Neil Roberts	Introduction: Oxygen isotopes as tracers of Mediterranean climate variability
17.35	Ricardo García Herrera	The Medclivar Program
June 12th	<i>Session 1: Isotopes and modern climate</i>	
9.00	Luis Araguas	Stable isotope variability of precipitation in the Mediterranean area
9.25	Spyros Lykoudis	Spatially interpolated time series of stable isotopes in Eastern Mediterranean precipitation
9.50	Antonio Longinelli	Isotopic composition of atmospheric precipitation: unpleasant tricks and possible misunderstandings
10.15	Georg Hoffmann	Water Isotope Modelling using global and regional climate models
	<i>Session 2: Lakes and tufas</i>	
11.15	Melanie Leng	Controls on the oxygen isotope composition of lacustrine sediments with examples from the Mediterranean
11.40	Ulrich von Grafenstein	Stable isotope records from deep lakes Sebino (Italy) and Ohrid (Albania/Macedonia)
12.05	Matthew Jones	Lake isotope models
12.30	Julian Andrews	Depositional continuity of seasonally laminated tufas: implications for $\delta^{18}\text{O}$ based palaeotemperatures
14.00	Poster session	
	<i>Session 3: Cave isotopes</i>	
15.00	Andy Baker	Calibrating speleothem ^{18}O against instrumental climate data
15.25	Frank McDermott	A multi-proxy approach to unravelling oxygen isotope variations in Holocene speleothems
15.50	Dominik Fleitmann	Cave carbonate isotopes from Turkey to Oman
16.15	Hagit Affek	Glacial/interglacial temperature variations in Soreq cave speleothems as recorded by 'clumped isotope' thermometry
	<i>Session 4: Marine isotopes</i>	
17.15	Eelco Rohling	Marine oxygen isotopes and Mediterranean palaeoclimate
17.40	Michel Fontugne	Stable isotopes and palaeoclimate from Mediterranean deep sea and lake cores. Chronology and correlations
18.05	Thomas Felis	Southeastern Mediterranean climate variability documented in coral oxygen isotope records from the northernmost Red Sea
June 13th	<i>Session 5: Intercomparison of different isotope archives</i>	
9.00	Gianni Zanchetta	Oxygen stable Isotope composition of continental carbonates in Central and Southern Italy during the Holocene
9.25	Maria Filippi	Oxygen isotope composition in meteoric and lake water, and lake sediment traps: monitoring as a key for paleoclimate reconstruction
9.50	Andrea Borsato	Temperature and rainfall variability during the Holocene: reconstruction from speleothem $\delta^{18}\text{O}$ in northeast Italy
10.15	Antonio Delgado - Huertas	Stable isotopes in lake sediments and archaeological remains as records of SW European climate
	<i>Session 6: Panel discussion</i>	
11.15	Integrating isotope archives over different timescales	

List of participants

name	institution	ESF support	Oral / Poster
Hagit Affek	Yale, US	X	O
Julian Andrews	U.E.A., Norwich, UK	X	O
Luis Araguas	IAEA, Vienna, Austria	X	O
Ilaria Baneschi	CNR Istituto di Geoscienze e Georisorse, Pisa, Italy		
Andy Baker	Birmingham, UK	X	O
Andrea Borsato	Trento, Italy	X	O
Benoit Caron	University of Pisa, Italy		P
Colonese Andre	Museo e Istituto Fiorentino di Preistoria, Italy		P
Luigi Dallai	CNR Istituto di Geoscienze e Georisorse, Pisa, Italy		
Antonio Delgado - Huertas	CSIC, Granada, Spain	X	O
Elissavet Dotsika	Lab of Archaeometry, National Center for Scientific Research, Attiki, Greece		
Russell Drysdale	University of Newcastle, Australia		P
Tony Fallick	SUERC, Glasgow, UK		
Thomas Felis	Marum, Bremen, Germany	X	O
Maria Filippi	Trentino/Torino, Italy	X	O
Dominik Fleitmann	Bern, Switzerland	X	O
Michel Fontugne	LSCE, Gif, France	X	O
Pedro Freitas	INETI, Portugal	X	P
Ricardo García Herrera	Madrid, Spain	X	O
Biagio Giaccio	Istituto di Geologia Ambientale e Geoingegneria - CNR, Roma, Italy		P
Roberto Gonfiantini	CNR Istituto di Geoscienze e Georisorse, Pisa, Italy	X	O
Ulrich von Grafenstein	LSCE, Gif, France	X	O
Georg Hoffmann	LSCE, Gif, France	X	O
Matthew Jones	Nottingham University, UK	X	O
Olga Kwiecien	GFZ Potsdam, Germany	X	P
Liina Laumets	University of Tartu		P
Gabriello Leone	Pisa University, Italy		
Arne Leider	Organic Geochemistry, University of Bremen, Germany	X	P
Melanie Leng	NIGL, Keyworth and Nottingham University, UK	X	O
Antonio Longinelli	University of Parma, Italy	X	O
Marc Luetscher	University of Innsbruck, Austria		
Spyros Lykoudis	National Observatory of Athens, Greece	X	O
David Matthey	RHUL Geology, UK		

Michel Magny	Besançon, France		P
Clara Mangili	GFZ Potsdam, Germany	X	P
Frank McDermott	University College Dublin, Ireland	X	P
Paolo Messina	Istituto di Geologia Ambientale e Geoingegneria - CNR, Roma, Italy		
Lea Numberger	University of Tübingen, Germany		P
Konstantin Pustovoytov	University of Hohenheim, Germany		P
Simone Riehl	University of Tübingen, Germany		P
Eelco Rohling	Southampton, UK	X	O
Peter Rowe	University of East Anglia, UK		P
Neil Roberts	University of Plymouth, UK	X	O/P
Laura Sadori	Dipartimento di Biologia Vegetale, Roma, Italy		
Giuseppe Siani	Lab 'Interactions et Dynamique des Environnements de Surface', Paris, France		P
Christoph Spötl	Institut für Geologie und Paläontologie, Universität Innsbruck, Austria		P
Andrea Sposato	Istituto di Geologia Ambientale e Geoingegneria - CNR, Roma, Italy		
Barbara Stenni	Università di Trieste, Italy		
Roberto Sulpizio	University of Bari, Italy		P
Michael E Weber	Univ. Köln, Germany		
Gianni Zanchetta	University of Pisa, Italy	X	O/P
Andrea Zerboni	Earth Sciences, University of Milan, Italy	X	P
Lelya Zhornyak	University of Pisa, Italy		P