

MedCyclones

Working Together toward Understanding Mediterranean Cyclones

Maria Hatzaki, Emmanouil Flaounas, Silvio Davolio, Florian Pantillon, Platon Patlakas, Shira Raveh-Rubin, Assaf Hochman, Jonilda Kushta, Samira Khodayar, Stavros Dafis, and Margarida L. R. Liberato

1st MedCyclones Workshop and Training School

What: Scientists and stakeholders came to discuss together the most recent research results in understanding processes and impacts of Mediterranean cyclones and train the new generation of scientists.

When: 27 June–2 July 2022

Where: National and Kapodistrian University of Athens, Athens, Greece

KEYWORDS: Mediterranean Sea; Extratropical cyclones; Climate; Forecasting; Societal impacts

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Corresponding author: Maria Hatzaki, marhat@geol.uoa.gr

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AFFILIATIONS: **Hatzaki**—Department of Geology and Geoenvironment, National and Kapodistrian University of Athens, Athens, Greece; **Flaounas**—Institute of Oceanography, Hellenic Centre for Marine Research, Athens, Greece; **Davolio**—Institute of Atmospheric Sciences and Climate (CNR-ISAC), National Research Council of Italy, Bologna, Italy; **Pantillon**—LAERO, Université de Toulouse, CNRS, UPS, Toulouse, France; **Patlakas**—Department of Physics, National and Kapodistrian University of Athens, Athens, Greece; **Raveh-Rubin**—Department of Earth and Planetary Sciences, Weizmann Institute of Science, Rehovot, Israel; **Hochman**—Fredy and Nadine Hermann Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel; **Kushta**—Climate and Atmosphere Research Centre (CARE-C), The Cyprus Institute, Nicosia, Cyprus; **Khodayar**—Mediterranean Centre for Environmental Studies (CEAM), Valencia, Spain; **Dafis**—Institute for Environmental Research and Sustainable Development, National Observatory of Athens, Athens, Greece; **Liberato**—Instituto Dom Luiz (IDL), Faculdade de Ciências, Universidade de Lisboa, Campo Grande, Lisbon, Portugal

A great number of intense cyclones occur every year in the Mediterranean basin, which is identified as one of the climate change hotspots. Mediterranean cyclones, although typically weaker and smaller than midlatitude cyclones over open oceans, represent a very distinct element of the global climate system. They often cause a broad range of severe socioeconomic and environmental impacts in this densely populated region. This calls for the coordination of community efforts to advance the field of Mediterranean cyclones as a whole, including interdisciplinary approaches, and involving the scientific community, the stakeholders, and the general public.

The MedCyclones COST Action

The European Network for Mediterranean Cyclones in Weather and Climate (MedCyclones) European Cooperation in Science and Technology (COST) Action (CA19109; 2020–24) comprises an international network of about 170 scientists from research institutions, universities, and weather/climate centers in 30 countries. Its objective is to establish efficient networking between stakeholders, operational weather forecasters, and researchers, a timely and essential action toward addressing the challenges of both research coordination and operational implementation of scientific results into weather and climate services.

The MedCyclones COST Action coordinates the activities of scientists and professionals in meteorology and climate, with the primary aim to deepen our understanding of Mediterranean cyclones and significantly improve the forecasting of their environmental and climate impacts within the European continent and the neighboring Mediterranean countries. In this context, the network identifies also relevant stakeholders with different backgrounds (e.g., civil protection and insurance companies), involved to co-develop cyclone prediction products tailored to their needs.

Meeting overview and goals

About a hundred experts from 16 countries and International Organizations gathered in Athens for the 1st MedCyclones Workshop and Training School from 27 June to 2 July 2022 to present and discuss the scientific progress on the topic of Mediterranean cyclones. The event, which took place on the premises of the National and Kapodistrian University of Athens (NKUA)

and with its full support, provided a unique opportunity for direct in-person interaction between the Action participants, specifically the following:

- Within the 1st MedCyclones Workshop, the most recent scientific advances in understanding processes and impacts of Mediterranean cyclones were presented, as well as progress in monitoring and forecasting, from weather to climate time scales. The 3-day Workshop allowed to establish and foster efficient networking and collaborations between stakeholders, weather/climate services professionals, and academic researchers.
- The 1st MedCyclones Training School provided the next generation of scientists an improved understanding of weather time-scale aspects of Mediterranean cyclones and their impacts, addressed primarily to Ph.D. students, early career investigators, and scientists from regional and national meteorological agencies.

Discussion

The scientific program of the Workshop was actualized through two thematic round tables, devoted respectively to forecasting Mediterranean cyclones, and to tropical-like systems known as Medicanes. Both discussion sessions involved representatives of European weather services and were open by inspirational talks. Moreover, several parallel sessions were dedicated to discussing scientific results and perspectives of the collaborative research initiatives within each Working Group (WG) of the Action.

Working Group 1: Process-based understanding of Mediterranean cyclones at weather time scales. WG1 research efforts focus on gaining a better understanding of processes (and their interactions) that are particularly relevant to Mediterranean cyclones—though still poorly understood—and identifying why models fail in their reproduction. This is achieved through, on the one side, the investigation of operational model forecasts and, on the other side, the coordination of model sensitivity experiments. The first day of the workshop (27 June 2022) was dedicated to presentations of this particular WG, chaired by Dr. Emanuele Silvio Gentile (University of Reading, United Kingdom) and Dr. Florian Pantillon (LAERO, France).

Several presentations were devoted to investigating the physical processes responsible for the development of Medicane Ianos over the Ionian Sea, and affecting Greece, in September 2020 (Lagouvardos et al. 2022). This large interest stems from a model intercomparison exercise that started from this case study (Fig. 1). Moreover, a strong focus within this COST action has been put so far on Medicanes

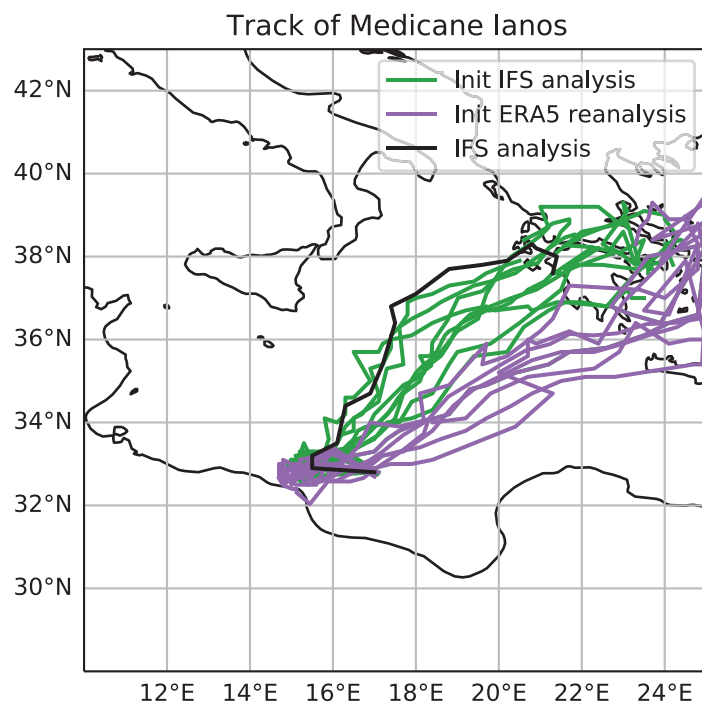


Fig. 1. Track of Medicane Ianos in multimodel simulations initialized from the IFS analysis and ERA5 reanalysis.

and their definition, something widely discussed within the framework of the meeting. Ianos-related presentations mainly focused on

- a satellite-based characterization of the tropical-like phase,
- an investigation into the triggering mechanisms,
- its representation in a convection-permitting model, and
- the sensitivity of dynamics to the sea surface temperature (SST).

Another important scientific aspect that emerged in the session concerned the study of intense winds and air–sea interactions associated with Mediterranean cyclones. It included the possible presence of sting jets, which are mesoscale airstreams responsible for some of the most extreme winds in North Atlantic cyclones, but barely documented over the Mediterranean (Brâncuş et al. 2019). Wind-related presentations discussed

- the mesoscale airstreams at the origin of strong near-surface winds,
- the downward transport of strong winds by boundary layer convective rolls,
- the microphysics of the air–sea interface under hurricane conditions, and
- the effect of sea spray generation due to surfactants on cyclone intensity.

Further discussion during parallel sessions highlighted the progress within each research initiative and plans for the next steps. In particular, the necessity for the following emerged:

- *Renew efforts for a prototype website collecting operational forecast information on Mediterranean cyclones* developed by Dr. Philipp Zschenderlein [Federal Institute of Technology (ETH Zurich), Switzerland]. A centralized source of information on cyclones (e.g., similar to the NOAA/National Hurricane Center) is currently lacking for the Mediterranean and would improve communication and help all impacted countries to better prepare for severe events. Given the strategic importance of this website, it was decided to implement developments from ongoing research initiatives such as the innovative combination of cyclone tracking algorithms to filter out bogus tracks as proposed by Dr. Emmanouil Flaounas [Hellenic Center for Marine Research (HCMR), Greece].
- *Extend case studies of windstorms toward a systematic investigation of the origin of strong winds in Mediterranean cyclones.* Besides the disputed presence and importance of sting jets in the region, mesoscale airflows are generally understudied compared to the North Atlantic area (Clark and Gray 2018). A systematic approach will be supported by a proposed community effort to build a high-resolution model database of Mediterranean cyclones.
- *Continue the numerical analysis of Medicane Ianos.* Model sensitivity experiments will, on the one hand, disentangle the complex Medicane dynamics involving both convection and baroclinic forcing (Miglietta and Rotunno 2019). They will, on the other hand, shed light on the poor predictability of Medicane Ianos and prepare for the next generation of operational forecasts, including the use of novel data assimilation approaches.
- *Better connect with WG3 to move beyond meteorological hazard modeling, toward impact-based forecasts, following WMO guidelines.* A successful example was shown by Dr. Christian Ferrarin [Institute of Marine Research, National Research Council (CNR-ISMAR), Italy], who assessed how forecast uncertainty propagates from the atmosphere to the ocean and to the subsequent coastal impact by applying a wave–current model to the multimodel meteorological data of Medicane Ianos.

Working Group 2: Process-based understanding of Mediterranean cyclones at climate time scales. The research activities of WG2 pertain to climate prediction (past, present, and future). By sharing and applying a variety of diagnostic tools for climate data (e.g., cyclone tracking tools, cyclone phase diagrams, and decomposition of surface pressure tendency), the main aim is to quantify and thereby understand cyclone processes on those scales. This point of view on the one hand generalizes our understanding of cyclones and their impacts from the single-storm perspective to climate scales, and on the other hand considers the more slowly varying climate drivers on cyclones. Major initiatives in these directions aim to identify different categories of Mediterranean cyclones with regard to their relevant thermodynamical processes and to establish a widely accepted definition of the criteria that qualify some Mediterranean cyclones as Medicanes. Results are used to assess the ability of climatological datasets to reproduce cyclone categories and their climatology, as well as to better understand the evolution of Mediterranean cyclone categories and their related processes in a changing climate. In synergy with WG1, the aim is to improve cyclone's representation in weather and climate models. At the same time, the climatological results can inform quantitative-based estimates of cyclones' impact on these time scales, in synergy with WG3.

Accordingly, presentations and discussions during the second day of the workshop (28 June 2022) concerned the latest findings in a session chaired by Dr. Marco Reale [National Institute of Oceanography and Applied Geophysics (OGS) and International Centre for Theoretical Physics (ICTP), Italy], highlighting three major themes:

- *Cyclone diagnostics in climate datasets.* Presentations highlighted the usage of different diagnostics for the intensity of midlatitude cyclones, which potentially affect the conclusions concerning their climatological frequencies and associated hazards, such as wind gusts. However, there is no consensus on the best metric to use for Mediterranean cyclones, which is expected to vary depending on the interest. Still, one should always bear in mind the sensitivity of any climatological result to these underlying metrics.
- *Climate drivers of cyclone processes.* Cyclone occurrence was shown to be connected to larger-scale climate variability. Diagnosed with EOF analysis over the North Atlantic, these modes are often related to cyclone track density across the Mediterranean basin, with remote influence also in the eastern Mediterranean basin, having implications for precipitation in those regions.
- *Emerging cyclone variability, trends, and their relation to impact projections.* Future cyclone activity in the Mediterranean was summarized based on an ensemble of models from the second phase of the Med-CORDEX program (www.medcordex.eu), exhibiting cyclone occurrence decrease across the basin, with agreement mostly in the central region (Reale et al. 2022). However, cyclone-induced precipitation and winds are projected to increase. The mere association of different hazards with the driving systems, be it cyclones, fronts, or thunderstorms, adds valuable information on the causes of projected trends of hazards, their compound extremes (Catto and Dowdy 2021), and their scaling with increasing temperatures.

Discussions on future research avenues in the following parallel session highlighted the need to systematically classify Mediterranean cyclones into types according to their driving mechanisms. This systematic view complements ongoing discussions on the definition of Medicanes, described above. Efforts in this direction are already underway within a research initiative led by the WG2 leader Dr. Shira Raveh-Rubin (Weizmann Institute of Science, Israel), in which upper-tropospheric potential vorticity spatial distributions during cyclone

deepening are classified to eventually make a distinction between baroclinic, diabatic, orographic, and thermal cyclones across the Mediterranean basin and throughout the year, in a unified framework. In this context, the role of air–sea interaction was additionally discussed. Particularly, the Mediterranean SST, heat, and freshwater exchanges have an active role in cyclone deepening of some cyclones, and these have a trend projected to further increase in their magnitude under a warming climate. This key aspect is of particular interest for climate trends in cyclone occurrence and associated impacts.

Working Group 3: Mediterranean cyclone impacts on regional climate and the environment. In WG3, through close collaboration between researchers, forecasters, and stakeholders, the main, still uncharted, impacts of cyclones on regional climate and the environment are investigated, including dust mobilization or hydrogeological hazards associated with cyclones. Collaboration with WG1 and WG2 allows to exploit simulations, climatologies, and observations to address the identified cyclone impacts and advance the state-of-the-art in the field, with the crucial involvement of stakeholders and professionals from weather and climate prediction centers toward harmonizing the research with socio-economic needs.

The presentations of WG3 were performed on the third day of the workshop, Wednesday, 29 June 2022, in a session chaired by Dr. Georgia Lazoglou [Cyprus Institute (CyI), Cyprus] and Dr. Platon Patlakas (NKUA, Greece). The session opened with an overview of Cyclone Characteristics in Past, Present, and Future Scenarios and their impacts on public health in the eastern Mediterranean, a region that often receives less attention in the literature than the western Mediterranean. Other presentations addressed related applications, such as

- the role of the Mediterranean Sea in the precipitation behavior of Mediterranean cyclones,
- large-scale forcing of the mistral wind and impacts on evaporation and deep convection,
- quantifying the compound flooding risk associated with extratropical cyclones,
- sea level rise impact on compound coastal river flood risk,
- impact of Medicanes on cyclonic vortex and other conditions like persistent warm and dry winter extremes over the eastern Mediterranean,
- wind and wave extremes associated with tropical-like cyclones in the Mediterranean basin,
- seasonal prediction for ocean energy, and
- lightning forecast and uncertainties during cyclonic activity.

The session was concluded through a general discussion on perspectives in the field. As summarized by the WG3 leaders Dr. J. Kushta (CyI, Cyprus) and Dr. S. Khodayar [Mediterranean Center for Environmental Studies (CEAM), Spain], the Mediterranean basin enjoys very attractive geographical, climatic, and cultural features while being at the same time an extremely sensitive area to climate change, frequently affected by high-impact weather inducing detrimental socioeconomic and ecological consequences. Such events include Mediterranean cyclones that are responsible for a wide range of weather-induced natural hazards in the region. However, the relationship between cyclone intensity and the severity of impacts is not linear, depending on various factors and characteristics. It was highlighted that this is still a field in which many open questions remain and call for extensive research.

Since cyclones affect a large variety of socioeconomic activities, this topic raises significant interest to the general public and stakeholders (e.g., civil protection agencies and reinsurance companies). Thus, in addition to scientific research gaps to be covered, other complex and currently underaddressed challenges emerged such as, in particular, how to effectively provide the most relevant information to stakeholders and the general public.

Moreover, the purpose of gathering knowledge on the socioeconomic impact of climate change is twofold: (i) to advise decision-makers how to mitigate and adapt to climate change impacts and (ii) to contribute to the creation of resilient communities, providing key information for proper training and education of the society.

Key messages from the WG3 discussions indicated the following;

- *An improved knowledge about the intrinsic relationship between Mediterranean cyclones and high-impact weather is needed.* In this context, the state-of-the-art suffers from the lack of systematic quantification of cyclones' contribution to Mediterranean high-impact weather (Flaounas et al. 2022).
- *The need to step from hazard forecasts (such as heavy rainfall, wind gusts, etc.) to impact-based forecasts is essential* (Taylor et al. 2018; Zhang et al. 2019).
- *New research lines on the socioeconomic impacts of Mediterranean cyclones are rising*, such as the impact of Mediterranean cyclones on fires, snow, and lightning.
- *Mapping stakeholders and establishing a close relationship* is key for an efficient co-definition and co-design of needs and tools.

Training school

The MedCyclones Training School, spanning all six days of the meeting, provided to the trainees an up-to-date theoretical overview on the dynamics, processes, forecasting, and predictability issues of Mediterranean cyclones, accompanied by extensive practical hands-on exercises and interactive discussions. The attendance to the workshop plenary sessions and discussions were considered to complement the training.

The most recent advances in the field were elaborated through dedicated lectures on synoptic aspects of Mediterranean cyclones (Dr. Jennifer Catto, University of Exeter, United Kingdom), mesoscale aspects of Mediterranean cyclones (Prof. Suzanne Gray, University of Reading, United Kingdom), and tropical cyclones (Dr. Richard Rotunno, NCAR, United States). Moreover, several seminars covered specific aspects of Mediterranean cyclones: forecasting (Dr. Estíbaliz Gascón, ECMWF and Dr. Jean-Christophe Vincendon, Météo France); medicanes [Dr. Mario-Marcello Miglietta and Dr. Giulia Panegrossi, both from the Institute of Atmospheric Sciences and Climate (CNR-ISAC), Italy]; explosive cyclones (Prof. Helena A. Flocas, NKUA, Greece); natural hazards, compound impacts and atmospheric rivers [Prof. Margarida Liberato, University of Trás-os-Montes and Alto Douro (UTAD), Portugal, and Dr. Silvio Davolio, CNR-ISAC, Italy]; and natural and socioeconomic impacts (Dr. Samira Khodayar, CEAM, Spain and Dr. Jonilda Kushta, Cyi, Cyprus). Finally, a lecture on Science Communication was given by Prof. David M. Schultz (University of Manchester, United Kingdom), who provided many suggestions for preparing an engaging scientific presentation.

For the hands-on sessions, groups formed by 3–4 trainees were guided by a tutor to perform a specific analysis, such as the investigation of a certain case study using NWP output, the application of diagnostic methodologies, or the understanding of impacts associated with Mediterranean cyclones. The final day was entirely devoted to trainees' presentation, reporting, and discussing the analysis undertaken in the hands-on activities.

Outlook and next steps

Scientific activities have been fostered by in-person meetings and discussions during the workshop and are currently producing important tangible results, such as the submission/publications of scientific articles, resulting from these collaborations. Virtual meetings allow to keep these initiatives alive, in anticipation of the next important MedCyclones Workshop and Training School that will take place in Toulouse from 26 to 30 June 2023, at the

Météo-France international conference center, including also the second MedCyclones training school. This second edition will be a combined event with the European Storm Workshop series (<https://stormworkshops.unibe.ch/>). The joint workshop aims at better connecting the Atlantic and Mediterranean cyclone communities in order to exchange ideas, practices, and methodologies applied to different types of extratropical cyclones and their impacts.

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