3RD MEDCYCLONES WORKSHOP & TRAINING SCHOOL

ABSTRACT BOOK

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ORAL PRESENTATIONS

Decomposing the role of dry intrusions for ocean evaporation during mistral

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The Mistral wind is a northerly gap-wind regime blowing through the Rhone Valley in Southern France. It is held responsible for the sea-surface cooling necessary to produce deep convection in the Gulf of Lion through turbulent ocean heat loss. The Mistral is tightly connected to lee-cyclogenesis in the Gulf of Genoa, where topography forces substantial downward motion. Potentially embedding the Mistral, dry intrusions (DIs) are large-scale Lagrangian air streams flowing along the descending branch of the Genoa cyclone. Known to induce cold and dry surface anomalies, DIs are thus potential contributors to enhanced surface evaporation during Mistral. In this study, a climatological database (ERA-INTERIM, 1981-2016) of Mistral-DI co-occurrence is constructed, allowing the quantification of the impact of DIs on the Mistral evaporative hot spot for the first time. We find that on average, Mistral-DI events are more intense by ~50%, compared to Mistral without DIs. However, cluster-composite analysis reveals mean amplifications exceeding 300% between dynamically similar Mistral events, with response to DIs. Daily latent heat flux anomalies in the Gulf of Lion are decomposed into contributions from the various parameters to analyze the Mistral evaporation response to DIs. Mistral-DI events are shown to produce extreme evaporation rates, mainly through increased Mistral wind speeds. The results highlight the downward momentum flux delivered by DIs to the Mistral as the primary driver of the evaporation amplification mechanism. We further explore the variability between different Mistral-DI events and conclude that extreme Mistral-DI evaporation events are linked to steeper trajectories entering the Gulf of Lion at a relatively early stage of their lifetimes. These DIs charge the Mistral with maximum vertical momentum fluxes, which act to intensify surface winds and hence evaporation rates.

The Impacts of Wintertime North Atlantic Storm Track Regimes on Cyclonic Activity Downstream: An Extreme Test Case over the Eastern Mediterranean

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A unique chain connects the flow over the North Atlantic and the development of cyclones within the Mediterranean basin. One typical mechanism includes upper-level flow perturbations upstream that cause Rossby wave breaking (RWB) events along the jet stream, which in turn develop into potential vorticity streamers. These streamers reach the Mediterranean, and through increased baroclinicity they enhance cyclonic activity in the region.
Using ERA5 reanalysis data and rain gauge measurements, we provide a systematic analysis connecting wintertime North Atlantic storm track regimes and Eastern Mediterranean cyclones and rainfall. To do so, we use different detection algorithms for each element in the chain (RWBs, streamers and cyclones). A cluster analysis of upper tropospheric eddy kinetic energy reveals a typical configuration of the storm track where North Atlantic storms are able to propagate far enough northeast, towards Scandinavia. This results in upper-level PV streamers forming more eastward and positive monthly precipitation anomalies in the Eastern Mediterranean (on average nearly 50% more over the Levant). Meanwhile, other latitudinal positions of the storm track were found to hinder cyclonic activity in the region and reduce rainfall in the eastern part of the basin.
The 1991-1992 December-February test case in the Mediterranean exemplifies this mechanism in its extreme. This was the rainiest wet season in Israel in recent decades, with many stations reaching their annual rainfall amount over the course of only several weeks. We show that the rain-enhancing North Atlantic storm track regime was prominent throughout most of this season, resulting in almost double the amount of streamers reaching the region compared to the climatology. During one extreme rain spell specifically (December 18th through January 3rd), at least 4 RWB-streamer chains were found in succession, followed by severe weather impacts in the Levant.

Atmospheric blockings and downstream cyclones in the Euro-Mediterranean sector

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Societies across the Mediterranean and wider European region can be significantly affected by weather extremes such as heatwaves, cold spells, windstorms and intense rainfall events. Temperature extremes are connected to atmospheric blocking, while heavy precipitation and windstorms have been associated with Mediterranean Cyclones (MCs). However, the connection between atmospheric blocking and MCs is still understudied, despite evidence suggesting their mutual importance for cyclone development and for exacerbating and synchronizing surface extremes. The aim of the present study is the systematic investigation of the frequency of MC development downstream of atmospheric blocks over the Euro-Atlantic region, and to examine how different cyclone track characteristics along with cyclone-attributed-precipitation might be modulated under such conditions. To this end we employ the combined 'best tracks' MCs dataset with objectively identified (using potential vorticity anomalies) blocking features in ERA5 for the 1970-2020 period. From a cyclone-relative perspective, we find that in the presence of atmospheric blocks, MCs that develop downstream tend to be more intense and to be associated with increased precipitation compared to other MCs. Moreover, under blocking conditions, the distribution of precipitation varies geographically, with moisture transport being an important contributor to this difference. Results show that the north-west Mediterranean region receives increased amounts of moisture and MC-attributed-precipitation when the cyclones develop downstream of atmospheric blocks, while the south-eastern Mediterranean is drier. Furthermore, MCs developing under this scenario form particular subsets of MCs, with preferred seasonality and geographical distribution, compared to all MCs. Lastly, certain MCs tend to be more static, while their mobility exhibits variability under blocking conditions. These results have important implications for MC predictability and their various impacts in the region on both weather and climate time scales.

Sting jets in Mediterranean cyclones? Working towards their identification using high-resolution simulations

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Sting jets are airstreams descending from the tip of the cloud head and accelerating into the frontal-fracture region of intense extratropical cyclones that develop a warm seclusion. They are associated with strong and damaging surface wind gusts. The potential presence of sting jets in intense Mediterranean cyclones and more generally the identification of low-level airstreams associated with damaging surface gusts in such cyclones are currently open questions. In this work we use a dataset of 200 Mediterranean cyclones simulated with the convection-permitting WRF model to assess the presence of sting jets. Cyclones developing warm seclusion and containing descending airstreams reaching high wind speeds at low levels are identified. The evolution of these airstreams is illustrated and the associated surface gusts are compared against those generated in cyclones that do not contain those airstreams. This initial work thus moves us towards answering the questions on the presence of sting jets in Mediterranean cyclones and their relative importance in generating damaging gusts in such events.

Sensitivity study to physical parametrisations and resolution of the Mediterranean derecho of 18 August 2022

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During the night of 17 to 18 August 2022, thunderstorms formed off the Balearic Islands. These thunderstorms formed a convective line which, as it spread over the Mediterranean Sea, became a derecho, generating violent winds over Corsica and parts of northern Italy, Austria, Slovenia and the south of the Czech Republic.

Simulations with the Meso-NH model, starting from the AROME analysis at 00 UTC, managed to reproduce a convective system propagating very rapidly over the sea. The line is more elongated than in the AROME forecasts. The echo takes a curved shape offshore just before reaching Corsica, as in the radar observations, but the line is delayed by 1h15 for Meso-NH and 1h30 for AROME.

There is a strong pressure minimum associated with the development of the northerly eddy, with the convective line rolling up. Strong gusts are associated with strong pressure gradients along the bow echo, its mesovortices and the northern eddy.

Various sensitivity experiments have been carried out with the Meso-NH model. We note :
- an impact of turbulence (mixing length) on wind and gust intensity,
- an impact of diffusion (physical and numerical) on the propagation speed of the system,
- an impact of the microphysics (2 moment versus 1 moment) on the intensity of the reflectivities and the extension of the convective system,
- an impact of the resolution (1 km versus 250 m) on the extension of the line and on the intensity of the gusts.

Climate change fingerprint on the 2023 Emilia Romagna floods

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The region of Emilia Romagna in northeastern Italy, with its capital in Bologna, experienced a sequence of flooding events on May 2nd, 10th, and 16th, 2023. These three events were linked to the passage of three extratropical cyclones, identified as Mediterranean cyclones, over the same region within a short period. We investigate the influence of climate change on each of these cyclones using an Extreme Event Attribution framework.

We use the analogues approach to identify similar cyclones in two periods characterized by weak and strong climate change. Cyclones are defined using a multivariate method based on sea level pressure, surface wind speed, and precipitation rate. We first normalize the fields via quantile normalization. We then calculate the spatially averaged Euclidean distance between the cyclones and other time steps within the phase space defined by the normalized sea level pressure, wind speed, and precipitation rate. Analogues are identified as those with the minimum Euclidean distance.

We assess detected changes using daily ERA5 reanalysis data, comparing the meteorological hazards of the analogues of the past period (1950–1985) with the present (1987–2022). To evaluate future changes, we conduct a multi-model study with high-resolution regional models within the EURO-CORDEX program, comparing historical (1970–2000) with future projections (2070–2100). We found an increase in precipitation associated with two of the cyclones during the present period compared to the past. Future projections also indicate an increase in precipitation compared to the present climate. Hence, our findings suggest a possible role of climate change in increasing the severity of such cyclones.

Hindcast Simulation of Medicanes with the Regional Earth System Model

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Medicanes are among the strongest systems with important impacts on the coastal areas and small islands in the Mediterranean region. Despite their importance, we still lack a comprehensive understanding of the mechanisms that cause them, especially the interactions between the atmosphere and the sea. To understand these mechanisms, we used reanalysis products (ERA-Interim and ERA5) and utilized four high resolution coupled/uncoupled simulations conducted with the Regional Earth System Model (RegESM) to investigate 16 medicane events. The RegESM model was run in both coupled mode (atmosphere-ocean-wave) and uncoupled mode (standalone atmosphere/wave) for 1979-2012 period over the Med-CORDEX (Mediterranean -Coordinated Regional Climate Downscaling Experiment) domain. We analyse the ability of the coupled and uncoupled modes to reproduce the characteristics of the observed medicanes and to investigate the role of air-sea interaction in the simulation of key processes that govern medicane occurrences over the study area. In general, the spatial extent and the timing of the observed medicanes was better simulated by the atmosphere-ocean-wave coupled model, due to improved roughness length simulation over water and its interaction with the atmospheric boundary layer provided by the active wave model.

The Impact of Tropical Sea Surface Temperatures on Sub-seasonal Precipitation Variability and Predictability in the Eastern Mediterranean; Insights from El Niño and Indian Ocean Dipole Interactions

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Understanding sub-seasonal precipitation patterns is pivotal in climate science as it extends our comprehension and forecasting beyond the typical time frame covered by standard weather forecasts. In our presentation, we delve into the influence of tropical sea surface temperatures on sub-seasonal precipitation variability and predictability in the Eastern Mediterranean. Specifically, we will highlight the joint impact of two significant climate phenomena: the El Niño Southern Oscillation and the Indian Ocean Dipole (IOD), particularly during October, a crucial month for water resource management in the region.
It's noteworthy that the combined occurrence of El Niño and a positive IOD leads to approximately 50% more precipitation compared to La Niña and a negative IOD. We'll explore the underlying reasons for these substantial disparities, including shifts in water vapor fluxes and alterations in the frequency of key rain-bearing weather systems. Interestingly, our research reveals that El Niño, when coupled with a positive IOD, paradoxically boosts the occurrence of Eastern Mediterranean cyclones, commonly referred to as 'Cyprus Lows.' We'll elucidate the mechanism behind this seemingly contradictory phenomenon.
Despite the insights gained, the synergistic interplay of El Niño and positive IOD presents challenges for sub-seasonal precipitation prediction, both practically and intrinsically. Our findings underscore the intricate relationship between tropical sea surface temperatures and precipitation patterns in the Middle East, illuminating the complexities inherent in sub-seasonal to seasonal weather and climate prediction within this vulnerable region.

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WIVERN: An ESA Earth Explorer Candidate that Fill the Gap of Wind Observations Inside Cyclones

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The WIVERN (WInd VElocity Radar Nephoscope) mission, currently in Phase-A of the ESA Earth Explorer program, aims to significantly advance our knowledge of winds and cloud microphysics by globally observing vertical profiles of horizontal winds in cloudy regions of the Earth for the first time. One of the main focuses of the WIVERN science team is to explore the potential of WIVERN measurements in filling the wind observation gap within tropical cyclones (TCs) and Mediterranean cyclones (medicanes). For this initial research, realistic WIVERN notional observations of TCs are simulated by integrating CloudSat radar reflectivity observations from 2007 to 2009 with ECMWF co-located winds. The results show that despite the short radar wavelength (3 mm), which may lead to strong attenuation in the presence of large amounts of liquid hydrometeors.

Identification and characterization of Medicanes using Passive Microwave radiometry

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The Mediterranean Sea is a well-known hot-spot for cyclogenesis with hundreds of cyclones of variable structure, lifetime and intensity forming every year. Mediterranean cyclones often have a high impact, providing significant amounts of precipitation, strong winds and storm surges, thus affecting both the regional environment and the population. This motivates great research effort that has been made over the last few decades to study these weather systems, in particular to identify Mediterranean warm core (WC) cyclones which show some similarities to tropical cyclones for their appearance in satellite imagery and for some thermodynamical and microphysical features. Such cyclones are called Tropical-Like Cyclones (TCLs) or MEDIterranean hurriCANES (Medicanes). This study aims to analyse, through an observational, satellite-based approach, 26 potential Medicanes occurred over the past two decades, from 2000 to 2023. The analysis, based on spaceborne passive microwave (PMW) data along with both well-established diagnostic tools and newly-developed techniques, is used to identify and inspect Medicanes' unique characteristics. The methodology, originally developed for tropical cyclones, exploits the 50-60 GHz temperature sounding channels to characterize WC depth, intensity, and symmetry. On the other hand, high frequency channels are exploited to retrieve cloud properties such as cloud top height and ice water path and detect deep moist convection (DC). Furthermore, the Medicanes often exhibits the presence of a quasi-cloud-free calm eye. Within this work, a new detection method to identify the so-called "closed eye" has been developed in order to investigate the possibility to carry out a fully-PMW-based analysis of tropical-like cyclones. The results shed light on the role of the DC in the WC origin and development highlighting the relative contribution of diabatic vs. baroclinic processes. The significant number of inspected case studies, conveys reliability and robustness to a new PMW-based classification of TLCs which complements previous model-based classifications. Three different classification groups are identified distinguishing the case studies presenting a tropical-like evolution from the very early stages to the latest (i.e., diabatically-driven WC, DC within the WC region and closed-eye), the ones where the WC cannot be fully attributed to diabatic origin, and the group that although is characterized by WC and closed-eye, does not report DC within the WC region. The results of this study contribute to the "Medicane's definition" activity in the context of the MedCyclones COST Action 19109 (https://medcyclones.eu/) and to the development of satellite-based diagnostic and monitoring tools within the ESA MEDICANES project.

Satellite-based analysis and Characterization of Medicanes' surface wind field

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Recent studies exploiting satellite observations characterized both the thermodynamic and the microphysical structure of Mediterranean cyclones supposed to go through a tropical transition (Medicanes) with particular reference to the warm core and the deep convection features. These studies also shed light on the role of deep convection in the development of the warm core. Another key feature characterizing Medicanes is the surface wind field, which, in analogy with what happens in tropical cyclones, could give additional information on their evolution.
This work aims to characterize the surface wind field associated within the different phases of a Medicane highlighting the differences between the development and the tropical-like phase. A key feature characterizing a Medicane wind field is the radius of maximum wind (RMW), which investigation could provide information about the intensification vs the steady-state stage. Furthermore, the presence of deep convective cores within the RMW provides additional information on the detection of Medicane's intensification phase. In the present work, recalling the definition provided for the tropical cyclones, the RMW is defined being equal to the distance between the location where the maximum wind speed occurs and the Medicane's center of rotation.
To retrieve the surface wind field over the sea, data provided by the Advanced SCATterometer (ASCAT) real-aperture radar onboard MetOp satellites and by the Wind Radar (WindRAD) onboard of Feng Yun FY-3E satellite series are used. Specifically, for both sensors the surface winds field (i.e., speed and direction) estimation is related to the roughness of the sea surface through the back-scattered electromagnetic signal.
A reliable estimation of the RMW is subject to the correct identification of Medicane's center of rotation. For this purpose, we proposed an empirical methodology based on both wind direction and speed fields analysis. We exploited all the available ASCAT and WindRAD overpasses for the Medicanes occurred in the Mediterranean basin since year 2000.
Results show that in the mature stage the RMW decreases with respect to the development phase. Morevover, in the tropical-like phase, deep convection is detected at distances shorter than RMW in such cases. Finally, the reliability of the results depends on the correct identification of the center of rotation, which is more reliable during the mature phase when the surface wind field shows a closed cyclonic structure with a quasi-calm area in its center.

Contribution of Copernicus High Resolution Missions to the monitoring of Medicane

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In the last decades, several Mediterranean cyclones have attained similar cloud structures and comparable intensities to tropical cyclones. This direct parallelism is debated and can be considered reductive with regards to the dynamics of these two types of storms. In particular, a common definition and common practices to exploit Earth observations specifically for operational activities (diagnostics, short-term forecasting) or scientific applications (theoretical validation) are still to be developed. Here, we propose to exemplify how the Copernicus constellation of high-resolution Sentinel sensors, capable of probing the ocean surface at high resolution (hundreds of meters or less), could help answer these open questions.
The capability of the Sentinel-1 Synthetic Aperture Radar to provide information on the wind field structure, including the size of the vortex, the shape of the eye, the nature of convection in the marine atmospheric boundary layer, and the wave field, will be illustrated. The presence of Medicane cloud-free areas, even in the most intense phase of the storm's life cycle, can also be exploited thanks to the ultra-high-resolution observations of Sentinel-2. It can help to identify breakers and characterize the wavelength and direction of the waves generated by the Medicane within the strong wind areas.The complementary nature of these two missions for characterizing the medicane will be discussed. Additionally, similar to a Tropical Cyclone, the analysis of sea-surface temperature and chlorophyll measurements before and after the storm's passage can also be used to inform about the upwelled impacts occurring these strong air-sea interacting events. All these different aspect will be presented and discussed with different Medicane cases.

The surface wind structure of Mediterranean cyclones in Earth observation data

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With spiralling cloud patterns and a distinct clear eye region, similarities between the Mediterranean cyclones and their tropical counterparts are suggested by satellite imagery. In the case of tropical cyclones, important physical processes (e.g air-sea exchanges, turbulent diffusion) occur in the lowest levels of the circulation. High-resolution ocean surface wind speed estimates from spaceborne synthetic aperture radar (SAR) demonstrated that such processes may be assessed from the surface wind structure, including the storm intensity, its inner- and outer-size, and the near-core wind decay. For tropical cyclones, these structural characteristics are classically used by both the research and operational communities to better examine and monitor the different events. With the aim of constructing a physical definition of Mediterranean cyclones and better assessing their dynamics, the question arises whether their low-level wind structure could be described with the same metrics. This issue is examined with satellite observations of the ocean surface in Mediterranean storms, in particular using high-resolution (SAR) ocean surface wind speed estimates.

Estimation of Medicane Intensity and Structure from Multispectral Satellite Imagery

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Global Tropical Cyclone (TC) warning agencies routinely use multispectral satellite imagery from both geostationary and polar orbiting satellites to determine the TC storm center location and intensity. Though aircraft reconnaissance is routine in the Atlantic ocean basin the primary method for estimation of the position and intensity of tropical and subtropical cyclones globally is through the use of satellite imagery. A variety of objective and subjective satellite-based techniques now exist to determine the center location and storm intensity of tropical and subtropical cyclones. This imagery is also used routinely by TC warning agencies to determine where a particular low pressure system exists within the phase space or thermal structure of the storm spectrum. For example whether the system is warm core, cold core or transitioning between these two thermal structure types. Starting in 2023 a collaborative effort between CNR-ISAC and CIMSS via the European Cooperation in Science and Technology (COST) Working Group 1 (https://medcyclones.eu/) began in order to assess the usefulness of techniques applied in the tropical ocean basins to medicane analysis. The eventual goal of this work is to transition these tools to the application of near real-time monitoring of medicanes to improve the forecast and hazard warning process. The collaboration will continue
within the ESA Medicanes project. This presentation will discuss the early results of this collaborative effort for application of these techniques to estimating the thermal characteristics and intensity of medicanes.

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A Satellite Analysis: Comparing Two Medicanes

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Morphological features of the Mediterranean Sea basin have recently been precursors to a significant increase in the formation of extreme events, in relation to climate change effects. It happens very frequently that rotating air masses and the formation of mesoscale vortices can evolve into events with characteristics similar to large-scale tropical cyclones. Generally, they are less intense, with smaller size and duration; thus, they are called Medicanes, a short name for Mediterranean hurricanes, or tropical-like cyclones (TLCs). In this paper, we propose a new perspective for the study and analysis of cyclonic events, starting with data and images acquired from satellites and focusing on the diagnostics of the evolution of atmospheric parameters for these events. More precisely, satellite remote sensing techniques are employed to elaborate on different high spatial-resolution satellite images of the events at a given sensing time. Two case studies are examined, taking into account their development into Medicane stages: Ianos, which intensified in the Ionian Sea and reached the coast of Greece between 14 and 21 September 2020, and Apollo, which impacted Mediterranean latitudes with a long tracking from 24 October to 2 November 2021. For these events, 20 images were acquired from two different satellite sensors, onboard two low-Earth orbit (LEO) platforms, by deeply exploiting their thermal infrared (TIR) spectral channels. A useful extraction of significant physical information was carried out from every image, highlighting several atmospheric quantities, including temperature and altitude layers from the top of the cloud, vertical temperature gradient, atmospheric pressure field, and deep convection cloud. The diagnostics of the two events were investigated through the spatial scale capabilities of the instruments and the spatiotemporal evolution of the cyclones, including the comparison between satellite data and recording data from the BOLAM forecasting model. In addition, 384 images were extracted from the geostationary (GEO) satellite platform for the investigation of the events’ one-day structure intensification, by implementing time as the third dimension.

How does ocean-wave-atmosphere interaction affect Medicane intensity? A coupled model study based on Ianos (2020)

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This study aims to investigate coupled processes in the modelling of Mediterranean cyclones. By conducting numerical experiments with varying coupling complexity between ocean, wave, and atmosphere model components, we simulated the evolution of Medicane Ianos (2020), one of the most intense cyclone events recorded in the Mediterranean. Results indicate that the coupling feedback is the key factor controlling the deepening of the cyclone, while the model's initial conditions are essential to reliably represent the cyclone track. The ocean-atmosphere coupled system successfully reproduces the strong upper-ocean cooling in the wake of the cyclone (reaching up to 3.7 °C), which has a negative feedback on its intensity. The wave-related processes further enhance the upper-ocean cooling by about 1.2 °C, while causing varying feedback to the cyclone intensity driven by increased sea surface roughness. Our results highlight the importance of ocean-wave-atmosphere interaction processes in predicting the intensity of extreme weather events such as Medicanes.

Influence of wave driven air-sea interactions on a strong Mediterranean cyclone

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Waves play a crucial role in the Earth system. They modulate air-sea exchanges, mix the upper ocean, and inject sea spray into the atmosphere when breaking. Air-sea fluxes of enthalpy and momentum greatly influence the dynamics of the marine atmospheric boundary layer (MABL). Waves increase the surface roughness but sea spray loading may act as a buffer layer reducing drag and stabilizing the MABL. Larger droplets increase air-sea enthalpy and decrease momentum transfers thus promoting the intensification of tropical cyclones. Waves also contribute to the upper ocean cooling under tropical cyclones which can set off a negative feedback loop on the system's intensity.

Strong Mediterranean cyclones displaying some characteristics of tropical cyclones produce a cold wake as evidenced by remotely sensed sea surface temperature maps. This was the case of Ianos which hit Greece during the third week of September 2020. Here we show results of a series of coupled simulations of Ianos. The coupled framework consists of the atmospheric model Meso-NH, the 3rd generation wave model WAVEWATCH III®, and the oceanic model CROCO. We contrast the impact of ocean-atmosphere coupling without waves to full coupling with and without sea spray physics. The results are discussed for the oceanic and atmospheric response and assessed against in situ and satellite-borne observations. They are further compared with with COAWST (coupled ocean atmosphere wave sediment transport) coupled simulations using WRF (atmosphere), SWAN/WW3 (waves) and ROMS (ocean) for the sensitivity to the model framework.

Geometrical properties and cloud types observed during Mediterranean cyclones using decadal dataset

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The increasing trend of the intensity of the Mediterranean cyclones, which is linked to the fact that the Mediterranean Sea is warming faster than the larger oceans, raises the necessity of an insight to their patterns not only from a dynamical approach but also from a microphysical perspective.
Tropical-like cyclones on the Mediterranean Sea (Medicanes) are occasionally observed on satellite images, often with a clear eye surrounded by an axisymmetric cloud structure. Clouds are one of the largest sources of uncertainty in regional and climate models. In this study, we show how satellite-based active remote sensing can be used to illustrate the clouds characteristics.
The aim of this work is to characterize the clouds and investigate their microphysical properties at the different stages of their evolution from the active low-pressure disturbance to the development stage of the Medicanes and their tropical-like cyclone phase, in order to comprehend clouds' contribution to the cyclone dynamics and correlate the atmospheric processes with cloud microphysics.
We use measurements of the CloudSat's 94-GHz nadir-looking Cloud Profile Radar (CPR) at a 1.4 and 1.7 km cross and along-track resolution respectively from 2006 to 2020 for the Mediterranean region. Specifically, we detect the Medicane events based on the high radar reflectivity (indicating deep convection) by utilizing the 2B-GEOPROF product. Then, cloud types, cloud top and base heights are derived for five different intense Medicane cases, using the 2B-CLDCLASS-LIDAR product. The clouds formation and evolution throughout the Medicanes' trajectory is shown in three-dimensional plots, from which we notice the primary cloud and precipitation generating flow in all events. We identify the existence of a frontal structure and a stronger convective activity at the development phase.
We, also, correlate the 10-year mean total cloud fraction above the Mediterranean basin with regions in which cyclogenesis occur more frequently. Statistics regarding the cloud tops are produced, concluding to intrusions of cold air in the upper troposphere. Finally, we study the warm core structures during the genesis stages of the Medicanes, which had been unclear since now, based on the vertical cloud distribution.
Our next steps include analyzing data from the EarthCARE's CPR during future Medicanes, their comparison with in-situ measurements and investigating the impact of the aerosols to Medicanes' formation, while the results of this study can be used from models to evaluate their cloud predictions and investigate the performance of different cloud microphysics schemes.

Monitoring Cyclones using EO: Current Initiatives and Future ESA Missions

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Effective monitoring of cyclones is crucial for mitigating the devastating impacts on human lives and infrastructure. This presentation delves into the European Space Agency's (ESA) current initiatives and future missions dedicated to enhancing our understanding and prediction of cyclones through Earth Observation (EO) technologies. We will first explore the array of ESA-developed missions that significantly contribute to cyclone monitoring. Notably, EarthCARE, Aeolus, Sentinel-1, and Sentinel-3 provide vital data for tracking and analyzing cyclonic activities. Additionally, we will highlight the forthcoming Earth Explorer 11 mission, which promises to bring innovative capabilities to this field.

The second part of the presentation will showcase various ESA-funded projects that leverage EO data obtained from these missions to develop practical applications for cyclone monitoring. These projects illustrate the direct use of EO data to better understand cyclones environment, genesis and intensification but also to improve forecasting accuracy in terms of impacts, and ultimately enhance early warning systems.

Lagrangian and Eulerian view points on the link between Mediterranean cyclones and compound extremes

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The rising scientific interest in the topic of compound extremes has encouraged us to analyse Mediterranean weather compounds and their relations with Mediterranean cyclones (MCs). Specifically, we focus on bi-variate combinations of rain, wind and wave extremes, with three main research questions in mind : (i.) What is the average spatial distribution of compound extremes around MC centres, and does it depend on the MC type? (ii.) How does the presence of MCs modulate the regional compound frequency? (iii.) What role do air-streams and fronts surrounding MCs play in compound extremes? While question (i.) is addressed from a Lagrangian (cyclone-centred) point of view, questions (ii.) and (iii.) are investigated from an Eulerian (geographical) view point. The latter provide new insight on the importance of the interaction between cyclonic atmospheric flow and topographic structures around the Mediterranean basin in producing compound extremes. By putting together the two perspectives, we are able to build a comprehensive climatology of the link between Mediterranean cyclones and compound extremes.

The marine and coastal hazards of Mediterranean cyclones

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The correct reproduction of sea-level and wave dynamics during extreme marine events is crucial for evaluating and managing the storm impact. In this work, we use an unstructured and coupled hydrodynamic-wave modelling system applied to the Mediterranean Sea for evaluating the impact of cyclones - in terms of sea level and waves - in both the open sea and the near-shore regions. The adopted modelling system comprises the SHYFEM hydrodynamic model, two-way coupled with the WW3 wave model, thus accounting for the wave-current interaction in deep and shallow waters. The hydrodynamic and wave numerical computations are performed on the same spatial domain representing the Mediterranean Sea using an unstructured grid with a resolution varying from 10 km in the open sea to less than 1 km at the coasts. A 1994-2020 hindcast simulation is performed using the Copernicus European Regional ReAnalysis (CERRA) as meteorological forcing. The hindcast is extensively validated against tide gauges, wave buoys, and satellite-borne instruments showing a good performance for specific storm events and mean conditions in different areas of the Mediterranean Sea. The sea level and wave results have been analysed for more than 1100 cyclones allowing the evaluation of storm impact indicators of each single event. The processed results are then used to classify the Mediterranean cyclones by their marine impact. To better characterise the impact of the most extreme cyclones, we performed additional numerical experiments forcing the ocean models with high-resolution (2.8 km resolution domain following the cyclone centre) WRF surface forcing.

Deep Learning for Cyclone-induced Storm Surge Forecasting

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Cyclones and coastal floods are among the most disastrous natural hazards. Both are intimately related to storm surges, as their causes and effects, respectively. However, the short-term forecasting of storm surges has proven challenging, especially when targeting previously unseen locations or sites without tidal gauges.Furthermore, recent work improved short and medium-term weather forecasting but the handling of raw unassimilated data remains non-trivial.

This work tackles both matters. Specifically, we train a deep neural network for storm surge forecasting on global data, fusing in-situ data sources with atmosphere reanalysis products and ocean state simulations. The deep neural network shares parameters across pixels of gauged and ungauged sites, and thus learns densifying forecasts at locations without tidal gage data available. Our model is trained and evaluated on events of cyclones and extreme surge. We demonstrate the feasibility of the proposed approach and close with remarks on its applicability to forecast storm surges following cyclones over the Mediterranean sea.

Estimating Medicane Extreme Rainfall Risk in the Context of Climate Change

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Romero & Emanuel 2017 (DOI: 10.1175/JCLI-D-16-0255.1) employed a statistical-deterministic approach to generate thousands of synthetic tracks of medicanes, examining the current and future risk of these storms and their associated violent winds. These synthetic storms were produced to align with climate simulations from 30 CMIP5 models (later reduced to the top 20 models through comparison with two reanalyses), focusing on historical and RCP8.5 scenarios (1986-2005 and 2081-2100 periods, respectively). The study analyzed present-to-future multimodel mean changes in storm genesis, trajectories and wind risk, emphasizing robust geographical patterns identified through consensus among individual models. Building upon this methodology, we revisit the calculated tracks and enhance the risk analysis by incorporating a rainfall algorithm. This algorithm, drawing from Zhu et al. 2013 (DOI: 10.1002/2013GL058284) and Feldmann et al. 2019 (DOI: 10.1175/JAMC-D-19-0011.1), estimates key contributions to storm-scale vertical velocity and considers the significant influence of the Mediterranean region's complex coastal orography. While the future frequency of medicanes remains uncertain (with our projections indicating no significant change or a slight decrease in total storm frequency on average), the intensification of storms identified in terms of wind (with more moderate and violent medicanes at the expense of weaker storms) is mirrored in the context of rainfall risk. Future scenarios indicate a notable increase in the occurrence of potentially flood-producing accumulations (e.g., storm total rainfalls exceeding 100, 200, or 400 mm), with probabilities more than doubling in many coastal areas and exhibiting high model consensus.

Attribution of the destructive Mediterranean derecho in 2022 to anthropogenic warming

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An extremely intense and organized convective storm, classified as a “derecho”, developed over the western Mediterranean Sea on August 18, 2022. The system affected Corsica, northern Italy, and Austria, with wind gusts up to 62 m/s and giant hailstones (diameter of around 11 cm), being responsible for 12 fatalities and 106 injured people.
The derecho developed over an extreme and persisting marine heatwave over the western Mediterranean. Therefore, the hypothesis of a relationship between the atmospheric event and the marine heatwave rapidly arose, suggesting a possible link with anthropogenic climate change.
By performing model simulations with both the Model for Prediction Across Scales (MPAS) and the nonhydrostatic operational AROME model and using the pseudo-global warming approach, we find a relationship between the marine heatwave, the actual anthropogenic climate change conditions, and the development of this extremely rare and severe convective event. These results suggest the increase of probability of development of similar events with respect to the past associated to climate change, and illustrate how climate change effects can cascade through a chain of extreme weather and climate events.

Analysis and modelling of the September 2023 flood-inducing precipitation in Greece due to cyclone Daniel

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The Mediterranean basin is one of the most cyclogenetic regions in the world and is influenced by various high-impact weather phenomena. This study investigates the extreme precipitation event that affected Greece due to cyclone Daniel in early September 2023 and claimed 17 lives. Extreme rainfall amounts were recorded at various Greek stations from 4 to 7 September, locally exceeding 1000 mm in four days. Severe flooding, livestock deaths, damages and economic losses occurred mainly in the region of Thessaly, central Greece. Large moisture amounts were transported from the Aegean Sea to the eastern mainland of the country and the vertically integrated water vapor flux exceeded 700 kg m-1 s-1. During this period, the sea surface temperatures (SSTs) were warmer than the climatology of September 1981-2020, with anomalies larger than 2-2.5^{o}C in large parts of the Aegean Sea. The study aims to investigate (a) the synoptic conditions that influenced the evolution of Daniel and this extreme precipitation event's development and (b) their sensitivity to the SSTs. The non-hydrostatic Weather Research and Forecasting numerical model has been employed at high resolution. Sensitivity experiments have been performed with different (spatially uniform) SST anomalies and climatological SSTs, in order to understand their role in the development of Daniel and the intensity of the precipitation event.

Medicanes impact on the physical and biogeochemical properties of the upper Mediterranean Sea

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This study examines the impacts of extreme cyclones in the Mediterranean Sea (MS; medicanes) on ocean biogeochemical parameters. A comprehensive analysis was conducted on 14 significant extreme cyclones between 2007 and 2021, focusing on their profound impact on the different regions of the MS. Our findings revealed the existence of some consistent patterns: during a cyclone event, surface concentrations of Chl-a (Chlorophyll-a), phytoplankton, nutrients, and oxygen tend to rise above the MLD, and temperature tends to decrease. Significant increments of these variables have been observed in the presence of WCEs and CCEs. In correspondence with WCEs, the increase in Chl-a, phytoplankton, and oxygen concentrations is driven by cyclone-related mixing and upwelling. The presence of WCEs intensified the cyclone, leading to enhanced mixing and elevated surface Chl-a levels. Moreover, cyclone local mixing injects nutrients into the ocean's upper layer and drives significant phytoplankton blooms. In fact, the injection of nutrients into the euphotic zone and the availability of sufficient light conditions for photosynthesis favors the increase of Chl-a concentration. Moreover, strong cyclonic winds frequently lead to a drop in sea surface temperature (SST), a key factor in primary productivity. Analysis of mean sea level pressure (MSLP) and wind speed (WS) along the track of the cyclone revealed the sudden drop (increment) in MSLP and sudden rise (drop) in WS at WCE (CCE) locations. It is observed that a few cyclones, such as Zissi, Anton, and Xandra, show exceptional behavior. Among them, Zissi exhibited an exceptionally high translational speed (TS). The rapid movement of Zissi resulted in limited interaction with the underlying ocean, which is responsible for its unique characteristics during the cyclonic event.

Addressing the impacts of Mediterranean cyclones by integrating a relational geodatabase in ARCHIMEDE Web-GIS platform

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The coastal areas of the Mediterranean Sea experiencing effects due to various cyclogenesis phenomena. This research focuses on studying the effects of cyclones in the Mediterranean Sea, with particular focus on the Mediterranean Hurricanes, which cause significant damage to coastal areas. Advanced remote sensing and Geographic Information System (GIS) techniques have been considered to analyze climatic data and observe geomorphological evidence, such as flooding, coastal erosion, landslides, and debris flow. By integrating climate features and geomorphological evidence, this study establishes a connection between the occurrence of Mediterranean Hurricanes and their impacts. The investigation was focused on the south-eastern coasts of Sicily, where Mediterranean Hurricanes have caused extensive damages like flooding, erosion, and storm surges. To assess coastal flooding and erosion, pre and post-storm morpho-topographical surveys were performed using aerial photogrammetry and Terrestrial Laser Scanner surveys. Some particular effects were detected on the landscape during the impact of Mediterranean Hurricanes, such as the dislodgement of big coastal boulders and acute erosion on the sandy coasts. The data collected were stored in a geodatabase named ARCHIMEDE, enabling the visualization of climate features and geomorphological evidence. Moreover, an open-source Web-GIS platform integrated with the geodatabase was developed to facilitate the sharing of geographic information among stakeholders and researchers, fostering collaboration and informed decision-making. This study enhances our understanding of Mediterranean cyclones and aids in the preparation of effective coastal management strategies to mitigate the impacts of Mediterranean Hurricanes.

POSTER PRESENTATIONS

Atmospheric circulation changes and turbulence modifications over Europe: implications for commercial flight operations in a changing climate

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The unprecedented changes in Earth's climate are reshaping atmospheric dynamics on a global scale, with profound implications for various sectors, including aviation. One of the critical aspects lies in the alterations to atmospheric circulation patterns and the concurrent effects on different phenomena (e.g., storms, precipitations, heatwaves, droughts).
In this study, we investigate the extent to which changes in atmospheric dynamics amplify the impacts of human-induced climate change, focusing specifically on aircraft turbulence. Our analysis centers on the identification of weather patterns derived from the classification of daily mean sea level pressure (SLP) field. This atmospheric variable is a pivotal controlling force governing a substantial portion of weather phenomena within the mid-latitudes, justifying its historical prominence in meteorological broadcasts, reanalysis products, and model of different complexity. By focusing on the morphology of large-scale SLP patterns that are less or more frequently encountered during the last 7 decades we can devise the less-/most-encountered spatial pattern of key variables related to aircraft turbulence episodes (e.g., eddy dissipation rate, vorticity, and divergence of air masses). We observe a growing frequency of large-scale atmospheric patterns conducive to moderate or greater (MOG) turbulence levels over the UK and Northern Europe, mostly associated with clear sky. With this condition, forecasting zones where turbulence can occur is challenging for any model, and can only be approached by pilots' reports flying within these regions. Our approach in examining individual atmospheric circulation patterns modifications and trends and their impacts on turbulence-related variables provide a holistic understanding of how alterations in atmospheric dynamics contribute to the intensification of aircraft turbulence.

A climatological perspective on cyclones and precipitation in the Eastern Mediterranean using potential vorticity-based classification

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Eastern Mediterranean Cyclones (EMCs) are a major contributor to extreme weather in this region, including precipitation, strong winds, cold extremes or dust storms, significantly impacting the population and natural environment. Thus, understanding the relationship between EMC variability and associated impacts is key to understanding their predictability and forecasting these hazards.
Previous approaches for cyclone classification over the Eastern Mediterranean region involved the cyclones' location, intensity, or structure. Such approaches do not consider the involved processes and, therefore, result in limited physical interpretations of cyclone variability and associated impacts and predictability.
Various processes come together to govern the genesis and development of EMC, and these processes have distinct signatures on the potential vorticity (PV) distribution. Here, we classify EMCs based on their associated upper-tropospheric PV structures into 6 clusters and analyse the impacts of resulting clusters.
We find that each cluster has its own signature of precipitation pattern. For each of the seasons, there are dominant clusters that bring extreme precipitation. In particular, two clusters of anti-cyclonic Rossby wave breaking PV patterns dominate the eastern Mediterranean's annual precipitation. Evidently, a strong ridge upstream of the PV trough has a greater impact on precipitation and temperature extremes than the PV pattern with a weak ridge upstream. Moreover, cyclones with low PV values, which correspond to heat-lows in the transition seasons, have an increasing trend in their occurrence frequency.
This classification approach enhances our understanding of the link between cyclone variability and their surface impacts in the region through processes reflected in upper-level PV distributions. These findings could benefit strategies for managing the societal and environmental impacts of EMCs at weather and climate timescales.

Sensitivity analysis of WRF microphysics and PBL schemes for precipitation extremes based on scenario simulations over the Black Sea

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The Black Sea Basin is one of the climate change hotspots due to complex topographical features and strong air-sea interactions in the Mediterranean region. Specifically, the warming of the Black Sea has intensified extreme precipitation events in recent decades. Therefore, the Black Sea Basin needs a specific attention for regional climate studies. Recently, regional climate models (RCMs) have been run at the convection-permitting scale to investigate precipitation extremes in the Black Sea Basin. The sensitivity of these models has been tested by performing historical simulations to find the most suitable parametrizations in representing precipitation amount and distribution. However, model configurations may exhibit different spatiotemporal characteristics in simulating extreme precipitation due to the shift of the seasons in a possible warmer future. Notably, previous studies highlighted the model sensitivity to increasing sea surface temperature over the Black Sea. Therefore, future simulations focusing on different model configurations may provide valuable information to understand the response of RCMs in a changing climate. In this study, we tested the WRF model's sensitivity to six microphysics (Kessler, Lin, WSM5, Thompson, Morrison, WDM5) and two planetary boundary layer (PBL) (MYJ and YSU) parameterization schemes by performing 3-day long convection-permitting simulations under the SSP5-8.5 climate change scenario. To this end, we downscaled the CMIP6-based MPI-ESM1.2-HR outputs to 3 km horizontal resolution for the selected cold (22–24 February 2050) and warm (3–5 October 2090) extreme precipitation cases over the Black Sea Basin. In the cold case, the precipitation amount is impacted primarily by the microphysics scheme. The standard deviation of microphysics schemes in simulating 3-day total precipitation is ~75 mm. In particular, the single-moment Kessler scheme simulated lower precipitation amount of about 100 mm compared to double-moment schemes over mountainous regions. The PBL schemes do not have a significant effect on precipitation amounts in the cold case. On the other hand, the choice of the PBL scheme changes wind speed and direction, as well as the upward moisture flux intensity, affecting the location of maximum precipitation amount in the warm case. Particularly, the 3-day total precipitation difference between the simulations reaches 100 mm due to stronger upward moisture flux by about 0.5 g/m^2s in simulations with the MYJ scheme over coastal areas. The outcomes of this study enhance our understanding of model sensitivity to parametrization options and provide a basis for future climate simulations over the Black Sea Basin.

A Local Wave Activity Interpretation of the Large Scale Drivers Behind the Projected Drying of the Mediterranean

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The projected drying of the Mediterranean basin is a robust signal of future climate change. Dynamically, this is manifested as a large anticyclonic anomaly covering the region, alongside a decrease in cyclonic activity. Various processes have been previously proposed as drivers of this trend, both thermodynamical (decreased land-sea temperature gradient) and dynamical (intermediate-scale stationary wave response, poleward shift of the jet stream). Several elements of the North Atlantic large-scale circulation are known to affect Mediterranean cyclonic activity (extratropical storms, jet stream position, weather regimes), individually and through mutual interactions. However, their contribution to the overall drying remains an open question.
In this work, we use the framework of Finite Amplitude Local Wave Activity (FALWA; Huang & Nakamura, 2016) to deconstruct the role of the North Atlantic circulation in the projected changes downstream. FALWA is a diagnostic that keeps track of the wave activity ”stored” within circulation undulations, relative to a zonalized flow. It obeys an exact conservation relation; thus, its local rate of change is either due to a flux convergence, or to non conservative source-sink terms. This allows for a closed mechanistic budget analysis of the response, differentiating between horizontal advection by the mean flow, barotropic and baroclinic processes, and diabatic forcing.
We analyze this budget in a 10 member CMIP6 ensemble and investigate the multi-model mean circulation response and ensemble spread over the North Atlantic and the Mediterranean basin. Preliminary results show a prominent baroclinic contribution over the eastern North Atlantic combined with enhanced advection of upper tropospheric potential vorticity towards Europe. Both elements imply that the shifting of the North Atlantic storm track plays a role in the projected drying trend of the Mediterranean.

Evaporative features of differently-driven Mediterranean cyclones

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Mediterranean cyclones (MCs) generate intense ocean evaporation rates due to the intense winds they deliver across the sea surface. The latent heat added to the cyclone acts to deepen it once it is released. To better understand the evaporative capabilities of MCs, their variability, and change under global warming, it is useful to analyze the evaporative response of differently driven MCs.
In this work, we use a climatological dataset of ocean turbulent heat fluxes based on ECMWF ERA-5 reanalysis and CMCC Global Ocean Physical Reanalysis System (C-GLORS). Using composite cyclone tracks and a potential-vorticity cyclone classification framework, we evaluate the evaporative features of differently driven MCs and their geographical distribution, from 1980-2020. Our results suggest the alternating dominance of different storm types in different regions and seasons, with the strongest ocean evaporation attributed to the winter MCs which decrease in frequency in the last decades. On the other hand, summer heat lows are growing more frequent and are shown to trigger intense evaporation rates before their peak, possibly affecting the entire Mediterranean basin. We further compare the performance of the two models, to evaluate the impact of the different resolutions on cyclone-related SLHF features.

Climatology of moisture sources associated with extratropical cyclones reaching the western Mediterranean: a Lagrangian approach

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Despite the singularity of its geographic conditions, the Mediterranean basin is considered one of the main cyclogenesis regions in the world. The extratropical cyclones (ECs) that affect it often become intense, causing high-impact climatic conditions and severe socio-economic and environmental damage throughout the region. For this reason, it is essential to carry out in-depth analysis and research related to these systems to minimize the impacts and disasters they may cause. Previous studies have analyzed important aspects related to climatology using different databases, pointing out the dynamic structure and intensity. Additionally, studies of the impacts and moisture sources associated with ECs stand out. However, most studies consider low spatial resolution databases, so the general objective of this research is to carry out a climatology of moisture sources associated with ECs arriving in the Western Mediterranean (WestMED). For this purpose, a dynamic downscaling methodology will be considered, at a spatial resolution of 0.18o, using the regional models WRF-ARW, FLEXPART-WRF, and the processing software TROVA. ERA5 reanalysis is used as initial and boundary conditions and as study period 1985-2022. It was obtained that the regions with the highest density of probability of occurrence were the east of the Iberian Peninsula, southern Europe, and the WestMED. In addition, 273 EC cases that arrived at WestMED during this study period were determined. It was found that the moisture source regions with the greatest contribution to these ECs were the Western and Central Mediterranean with values greater than 1.8 mm/day, and then the Eastern Atlantic.

Moisture sources associated with extratropical cyclones that reach the Western Mediterranean: study case.

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Regional weather and climate in midlatitudes are largely influenced by extratropical cyclones (ECs). The Mediterranean basin hosts several of these hydrometeorological phenomena, distinguished by its unique and complex orography, within a constrained geographical area. It is characterized by an almost closed basin with strong land-sea interactions. Despite the cyclone genesis record in this region, a large number of ECs originating from other basins, such as the North Atlantic, arrive in this area. This makes it a focal point for increased research efforts on these phenomena to mitigate potential damage. Previous studies have focused on analyzing dynamics, prediction, climatology, and impacts, while also providing an additional dimension by examining the water budget associated with cyclone precipitation. The main objective of this study is to describe the moisture sources associated with an EC case study that affected the Western Mediterranean, originating in the North Atlantic. This will be achieved through high spatial resolution weather simulations, aiming to capture small-scale features. For this purpose, a dynamic downscaling methodology will be used using the WRF-ARW Eulerian mesoscale model fitted by the ERA5 reanalysis data at 0.25 oC. Subsequently, these WRF-ARW outputs will be used to force the Lagrangian particle dispersion model FLEXPART-WRF and calculate the moisture source pattern. This EC arrived in the Mediterranean on January 29, 2006; during the last stages of its life ,which began on January 23, 2006. It was found that this EC uptaked the most moisture near its center, in regions located over the central and eastern Atlantic from 30-45 oN. In addition, these moisture sources contribute about 15-35% of the total gains along cyclone life. Furthermore, a minor contribution is observed to the south of the Iberian Peninsula.
materials that strongly depends on the oxygen concentration in the environment to which the materials will be exposed (maximum current 30% for ISS/Shuttle) while the pressure effect is much smaller and can be ignored at cabin crew pressures < 1 Atm.
In addition, assessments of flammable materials behavior and acceptability criteria, to date, are based on ground testing facility and equipment capability at 1 g, used at different configurations and operative conditions.
Past and new investigations on how the 1g results, and the influence of O2 % vs pressure, could actually be applicable to flammability scenarios, are not fully consistent and deserve a step forward.

For this reason the Multi-Purpose Habitation Program (MPH) is in a challenging scenario in many respects, no less the environmental condition in terms of flammability risks. At the moment, design requirements for MPH moves to environments with higher concentrations of oxygen and this could be in conflict with the current understanding of fire behaviour in these atmospheres.

While awaiting progress and validation of tests in different g-conditions by agencies and the relevant update of applicable standard and methods, possible impacts and limitations, or, safety-wise, conservative assumptions to use will be analyzed in this presentation to emphasize the lack of documented assessments and flammability data.

Projection of Mediterranean cyclone frequency using HadGEM3 simulations

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On the basis of our validation study, HadGEM3-GC3.1 performed the best for the Mediterranean cyclones amongst historical simulations of six different GCMs of the CMIP6 program compared to ERA5 reanalysis data. Therefore, this GCM is selected to analyse the projections of Mediterranean cyclone frequency for the SSP1-2.6 (rapid mitigation and effective adaptation) and SSP5-8.5 (business as usual) scenarios, thus the future anthropogenic effect can be assessed. We compare the future projections for the end of the 21st century (2071–2100) to the historical simulations of the 1985–2014 period. Cyclone tracks and centres are analysed on an annual, seasonal, and monthly basis for the Mediterranean region with a special focus on four action centres, i.e. the Ligurian Sea (Gulf of Genova), the Central Adriatic Sea, Aegean Sea, and the Northeastern Mediterranean (North of Cyprus).

Aeolus satellite wind data for regional-scale assimilation: Case study on a Mediterranean cyclone

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The on-going developments in new-generation remote sensing satellite systems, have offered new insights into weather analysis and applications. These advancements also enable Numerical Weather Prediction systems to incorporate high-resolution and precise height-assigned wind shear information. The Aeolus Level 2B wind profile data has been found beneficial for assimilation in several global systems, enriching spatially and temporally the observed state of the atmosphere related to wind profile. To improve the understanding of assimilation Aeolus Level 2B winds using a limited-area model, this work focuses on the development and evolution of a Mediterranean cyclone. Between 27–30 September 2018, Aeolus alignment corresponded well with the broader area and time periods during which a cyclone, known as medicane Zorbas, originated and developed. This provided an opportunity to examine the direct influence of Aeolus satellite retrievals in model initialization processes. To assess the impact of data assimilation of Aeolus wind profiles, the WRF 3DVAR modeling system was used, conducting experiments at times coincided with the retrieval of Aeolus data. Results showcase the effects on model results stemming from Aeolus data ingestion, with the main differences appearing after the first 24 hours of simulation. Deviations in the runs with and without the Aeolus wind data assimilation, are evident, with smaller or larger differences observed in most cyclonic characteristics.

Generation of a mesoscale cyclone over deep mountain Lake Hovsg

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Cyclones are an integral part of the atmosphere system. Depending on their genesis and location they are usually classed as tropical cyclones - which take their energy from evaporation over the warm ocean mainly - or as extratropical cyclones - which take their energy from the large-scale baroclinic instability mainly. The latter includes most cyclones in the Mediterranean sea. However, some cyclones such as medicanes and polar lows develop from both baroclinic instability and surface exchanges over the relatively warm sea. There were also cases when cyclones were observed over lakes, such as Great Lakes, or Lake Victoria, but in most cases these cyclones developed elsewhere and their size was several hundreds of kilometers - much larger than the lakes themselves.

We discuss a mesoscale cyclone that has been formed in December 2023 over the deep mountainous Lake Hovsgol in Mongolia. The lake is 120 km long and up to 36 km wide, with depths over 220 m. Its latitude is 51°N, it is located at an altitude of 1645 m asl and is surrounded from all sides by mountains with heights over 3000 m. Lake Hovsgol is located in continental climate conditions and is ice-covered every year between December and June. In winter large water volume lead to significant heat inertia, late ice cover formation and strong temperature contrast between air over the lake and over land.

We analyse the generation, evolution and dissipation of this cyclone using various satellite imagery in the visible, thermal and microwave ranges, as well as meteorological data. Rapid decrease of air temperature from –8 to –30°C led to wind oriented from the coast to the lake, creation of several convergence lines and ultimately formation of a cyclone with outer radius of about 35 km. This cyclone has been generated over the lake itself (and not advected from some other regions) and its size was limited by the lake size. The cyclone was short lived (about 24 hours) but had a well-developed cloud-free eye with diameter of 3.5 km, comma head and outflow cirrus shield. Heavy snowfall was observed at that time by local populations. Two days after cyclone dissipation most of the lake was ice covered.

We present data on cyclone position and displacement, estimate speed and direction of wind-driven ice drift during the cyclone presence and based on this assess potential speed of surface wind. We also estimate height and temperature of cloud cover. We discuss the potential structure of the cyclone, its influence on surface water currents and ice formation.

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Deep convection around Mediterranean cyclones

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In the Mediterranean region the presence of warm sea surface temperatures and of complex topography favour per se the development and triggering of deep convection. This work, based on reanalysis and observational datasets, shows how the synoptic circulation, airflows and fronts around Mediterranean cyclones (MCs) further organise the spatial distribution of convective environments. By building on a classification of MCs based on their upper-level structure, we show the typical frequency, intensity, spatial distribution and time evolution of convective environments around the center of each cyclone class. Typically, small and deep cyclones occurring in autumn show highest potential for the development of convective environments. Across all cyclone classes deep convection is detected more frequently in regions of strong warm conveyor belt ascent than in cold frontal regions. These findings are relevant for the understanding of meso-scale processes occurring around MCs and are potentially useful for operational weather forecasting and communication of MC surface impacts.

Preliminary results of WG2 MedCyclones track in Regional Climate Models initiative

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The initiative in WG2 of the Medcyclones COST-action aims to produce a data set of 'useful' cyclone tracks in Regional Climate Models. Cyclone centers are typically defined as local maxima of relative vorticity, or as local minima of geopotential height or mean sea-level pressure (MSLP). However, locations of cyclone centers may differ significantly among CDTMs, even if the same input fields are used. In respect to Emmanouil Flaounas study in 2022, where he presented a new methodological approach that combines overlapping tracks from different CDTMs and produces composite tracks that concentrate the agreement of more than one CDTM.

Stratospheric Influence on Tropical Cyclone Intensification

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Tropical cyclones (TC) are rapid rotating storms originating over tropical oceans, which drive them by heat transfer. Recognized as one of the most significant natural threats, their landfall is responsible of extensive damage to properties and loss of lives. Despite the ongoing debate about their frequency in future years, there's broad consensus that climate change and the associated rise in average sea surface temperatures will increase TC intensities and rainfall rates. Consequently, it is imperative to gain a comprehensive understanding of the origin, intensification and dynamics for enhancing forecasts and minimizing their impacts.
Being primarily driven by the large-scale steering flow, the forecast of TC tracks has improved in recent years. However, the mechanisms responsible for TC genesis and intensification still pose significant scientific challenges. Investigations during the last decade have highlighted the potential role of the stratosphere in TC intensification, suggesting that the interaction between TCs and the stratosphere could significantly influence their development. It has been hypothesized that the intrusion of warmer (and dryer) stratospheric air at the top of the eyewall, due to radial pressure gradients, may lead to the formation of a “high-level warm core” (HWC) near the tropopause or a “double warm core” structure if two different regions characterized by positive temperature anomalies can be identified. According to literature, the formation of either of these structures contributes to TC intensification by lowering the hydrostatic pressure at the surface level and, thus, increasing the overall cyclone strength. However, this theory overlooks that warming of the upper atmosphere also leads to increased stabilization of the air column which inhibits convection and thus reduces the intensity.
In this study, we analyse the outcomes of simulations conducted using the non-hydrostatic model SAM (System for Atmospheric Modelling). Specifically, we investigate both highly idealized scenarios with doubly periodic domains and fixed sea surface temperatures, as well as more realistic ones by analysing the output of a high-resolution, global simulation run according to the DYAMOND protocol.
We focus mostly on vertical profiles of temperature to detect the formation of an HWC or DWC structure, vertical wind speed to observe the regions of convective activity and troposphere-stratosphere interaction, and moist static energy (MSE). The latter is used as a metric to estimate the imbalance due to the intrusion of stratospheric air between lower and upper levels and, thus, its overall contribution to intensification as MSE is conserved in convection. Finally, we compute the role of stratospheric air intrusion in the lower levels to the hydrostatic pressure deficit in the cyclone core.

Spectral Decomposition of the Mistral Wind

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The Mistral is a northwesterly flow that blows over the Gulf of Lion in the Mediterranean Sea. This wind is driven by a cyclonic low in the Genoa region, whereby cool, dry continental air is brought through the Rhone Valley and funneled between the Alps and Massif Central in France. This results in large air-sea heat fluxes, causing the cooling of the Gulf of Lion and can help lead to oceanic deep convection in the late winter and early spring. Here, we investigate the spectral representation of the Mistral to determine which frequencies the Mistral signal is found in. Prior investigations have shown that the Mistral has both a high frequency component (on the order of a few days to weeks) and low frequency component (on the order of months and years). The high frequency component comes from the pulse like behavior of the Mistral, that lasts around 6 days with each pulse separated by roughly 10 days. Meanwhile, the low frequency component comes from more Mistral events occurring in the winter than summer, imprinting a seasonality in the resulting heat fluxes (which is reflective of the more common occurrence of cyclones in the northwest Mediterranean during the winter, as they are the driver of the Mistral winds). What is not known is the full understanding of the spectral representation of the Mistral, and if it acts on different frequency bands as well. The goal of this presentation is the elucidate this full spectral representation and explore the resulting contributions to the air-sea fluxes in the Gulf of Lion.

Exploring how a warmer Mediterranean Sea affects the origin and development of destructive Tropical-Like Cyclones IANOS and DANIEL

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In a complex contest of climate change, we observe the evolution of extreme events that greatly challenge many areas of human life. Although the Mediterranean Sea is a relatively mild basin, it is however characterized by, occasionally intense cyclones with tropical-like characteristics known as Tropical-Like Cyclones (TLC). Many studies have highlighted that sea surface temperature (SST) distribution play a crucial role in modulating the intense air-sea exchange, hence controlling both development and evolution of TLCs. However, given the complex interplay among ocean mixed layer, heat content and temperature, the role of the mixed layer depth (MLD) and SST Anomaly is of paramount importance. In this study we investigated the role of both SST anomaly, horizontal gradients and MLD profile on the origin and evolution of a recent record-breaking TLC (named IANOS and DANIEL). IANOS and DANIEL are originated over the southern Ionian Sea. The first made landfall over Greece mainland coast and DANIEL made landfall over Libyan coasts. These TLCs developed over a basin where a positive SST anomaly up to 4 °C was detected, which coincided with the sea area where it reached the maximum intensification and strength. We conducted a series of experiments using an atmospheric model (WRF - Weather Research and Forecasting system) driven by underlying SST (standalone configuration), either with daily update or coupled to a simple mixed-layer ocean model (SLAB ocean), with SST calculated at every time step using the SLAB ocean for a given value of the MLD. Sensitivity tests were performed increasing or decreasing MLD depth by 10 m, 30 m, 50 m, 75 m, 100 m, removing the horizontal gradients, removing the SST anomaly. Then, possible past and future climatological scenarios of MLD thickness were identified and tested. Preliminary results show that the MLD influences not only the intensity of the cyclone but also the structure of the precipitation field both in terms of magnitude and location. The fundamental role of the SST anomaly was also found to be essential to provide intense characteristics to IANOS and DANIEL. Results deserve further investigation in the context of climate change scenarios that can provide useful insights into impact on coastal civil and economics in the whole Mediterranean region.

Environmental and Socio-Economic Impacts of Vulnerability of Mediterranean Cyclones on the Egyptian Mediterranean Coast

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The Egyptian Mediterranean coast, a pivotal region for the nation's economy, culture, and environment, has increasingly faced the wrath of Mediterranean cyclones, phenomena intensified by climate change. This study delves into the socio-economic impacts of these cyclones, (aim)shedding light on the vulnerabilities of coastal communities. The research methodology involves a comprehensive analysis of ERA5 meteorological data, complemented by field observations and the application of the Wind Enhance Scheme for cyclone modeling (WES) model. The analysis focuses on Mediterranean cyclones spanning the winter months between December and March, over the years 2018 to 2023. It specifically examines the cyclone trajectory across the eastern Mediterranean, from Beirut to Crete's southern coast, with a notable emphasis on their pronounced impact on Egypt. This geographical span underscores the cyclones' broad influence while highlighting Egypt's significant susceptibility to these weather phenomena. The application of the WES model aims to assess the number of well-defined small-scale cyclones. The model results were validated and calibrated using field observations through calculations of correlation coefficient, root mean square error, and scatter index as error statistics, which assess the accuracy of the model. The results reveal that approximately 11 small-scale Mediterranean cyclones per year, lasting from 1 to 3 days with an average speed of 13 m/s, were formed. Thirty-five percent of these cyclones affected various locations on the Egyptian Mediterranean coasts either by direct contact with the cyclone or by being situated in its vicinity. Furthermore, it is evident that the most vulnerable areas are the coastal cities, where the Egyptian Mediterranean coast suffers from a high rate of erosion as a consequence of climate change. This erosion is exacerbated by cyclone events, which in turn accelerate the erosion rate and induce damage to the marine environment.
Furthermore, climate change induces extreme weather events, making Egypt one of the most vulnerable countries. While severe events like small-scale cyclones may seem insignificant compared to those in other countries, they can have a significant impact on Egypt. Most cyclones occur near the Nile Delta, the main agricultural area, posing a threat to food security. Additionally, Egypt's Nile Delta is recognized as one of the top three global hotspots for extreme vulnerability. The increased frequency of cyclones leads to changes in weather conditions and agricultural damage. A danger emerges due to both flooding and erosion, leading to the subsequent depletion of agricultural land, infrastructure, and urban spaces.
The resilience of the Egyptian Mediterranean coast is examined through the lens of governmental and community initiatives. This study underscores the complex interplay between natural phenomena and environmental and socio-economic structures, revealing the Egyptian Mediterranean coast's vulnerabilities to Mediterranean cyclones. While the economic and social impacts are profound, the emergence of robust resilience strategies offers hope for mitigating future risks. Our findings call for integrated approaches combining scientific research, policymaking, and community engagement to enhance the region's adaptive capacities. As Mediterranean cyclones continue to pose significant challenges,

fostering resilience will be crucial for safeguarding the socio-economic fabric of the Egyptian Mediterranean coast.

Vulnerability Assessment of Transit Transfer Stations Exposed to Multiple Hazards - Wind and Hydraulic Actions

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Transport infrastructure and Transit transfer stations (TTS), such as ports and airports, are pylons of global economy and underpin social equity, serving as essential nodes within transport networks and aiding connections between different transport modes. Hazards, e.g. flooding, scour and sea level rise, affect assets of TTS leading to physical damage to the infrastructures and loss of functionality. Development of techniques for the assessment of risks and vulnerability of TTS under hazard events, performance due to increased stressors due to climate change and achieving a bounce back after hazard events aids in efficient infrastructure management. A transition from risk/loss and restoration models into quantifiable resilience despite the challenges in quantifying vulnerability and resilience worsened by the complex nature of climate change quantification. Nevertheless, today there is a complete lack of established resilience frameworks based on which the operators and owners of TTS can make informed decisions. To address this capability gap, this research aims to develop a detailed framework for enabling the assessment and quantification of TTS resilience under multiple hazards considering structural/physical interactions and correlated functional/operational interdependencies. The interaction and interdependency in this case is between assets within the same TTS and not an entire network i.e. treating the TTS as a critical node within the network. The proposed framework is based on a representative TTS which was selected on the basic of well-thought criteria, to set a TTS-benchmark for future resilience assessments. This benchmark is modelled with a three-dimensional finite element combined bridge – building model showing physical interactions of the asset's components and underlying soils. A step for developing fragility curves for combined systems within a TTS exposed to multiple hazards and also considering increasing environmental stressors due to climate change. A framework and tools for quantitative risk and resilience assessment of a TTS (in this case a port) exposed to multiple hazards will be developed as a useful tool for infrastructure owners and managers. This research envisages enabling accurate resilience assessment for TTS to be readily applied by TTS operators and owners and ultimately facilitate investment prioritisation and optimisation in future to combat the impact of climate change in the built environment.

Reducing impacts of coastal Floods Associated with Cyclogenesis in the Mediterranean Sea

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Coastal areas are especially vulnerable to the effects of Medicanes, as the convergence of powerful winds and wave activity often results in significant coastal inundation. This occurrence not only threaten coastal environments and ecosystems but also puts at risk human settlements, vital infrastructure, and economic endeavors located along the coast. The ensuing devastation can have extensive ramifications, disrupting the livelihoods of nearby communities and requiring considerable resources for recovery. This work aims at reducing the impacts of the coastal flooding associated with the formation of the cyclone in the Mediterrrean Sea. Firstly, by improving early warning systems involves investing in cutting-edge meteorological technologies and predictive models. These advancements enhance the precision and promptness of weather forecasts, delivering vital advance notices to areas at risk. Swift distribution of information across multiple communication platforms ensures that communities receive ample time to prepare and, if needed, evacuate. Secondly, enhancing infrastructure resilience involves strengthening buildings, particularly roofs, to withstand the powerful winds typical of Medicanes. Coastal protections like seawalls, breakwaters, and sand dunes can be improved or built to safeguard against storm surges and coastal flooding. Moreover, enhancing drainage systems is key to effectively preventing and managing flash floods. Third, through enforcing rigorous building codes and zoning regulations can deter development in vulnerable regions, especially flood-prone and coastal areas. Encouraging the incorporation of green areas and permeable surfaces in urban planning mitigates surface runoff and minimizes flood hazards. Further, mitigating climate change - Tackling the larger challenge of climate change, which exacerbates the severity and occurrence of extreme weather phenomena such as Medicanes, is imperative. Embracing sustainable methods, shifting towards renewable energy alternatives, and curbing greenhouse gas emissions are vital approaches in lessening the enduring effects of climate change. Moreover, research investment - directing resources towards advancing research on Medicanes, including their patterns, behaviors, and consequences, offers invaluable insights for improving readiness and response tactics. Collaboration among governments, scientific communities, and international organizations fosters the exchange of knowledge and the creation of innovative solutions.

The role of convection-permitting RegCM5 simulations in representing synoptic-scale cyclones over Southeastern South America

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Southeastern South America (SESA) stands out as a hotspot on the planet where weather and climate extremes occur with notable frequency, exerting negative impacts on various socio-economic activities. One cause of these extremes are the synoptic-scale cyclones. In this sense, the objective of this study is to evaluate the performance of a convection-permitting scale simulation (CP) with Regional Climate Model version 5 (RegCM5) in simulating the cyclone features (frequency, intensity, lifetime, preferential regions, precipitation, etc.) in the SESA region from January 2018 to December 2021. The CP simulation was driven by ERA5 reanalysis with 3.0 km of horizontal grid spacing in a domain covering from ~ 11°S to 35°S. Cyclones are identified with a tracking algorithm based on relative vorticity at 925 hPa. The cyclone features in the CP simulation are compared with that from ERA5. The mesoscale structure of the simulated precipitation associated with cyclones is compared with satellite estimates. Overall, CP simulation captured the main observed features associated with cyclones.

The climatological influence of extratropical cyclones on temperature and wind extremes

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Extratropical cyclones are the main system controlling midlatitude weather. In the wake of cyclones are dry air intrusions that descend equatorward, in a slantwise manner, from the upper troposphere towards the near-surface cold front. There, in the cold sector of the cyclone, anomalously cold temperatures and strong winds are expected due to cold advection and vertical momentum transport in dry intrusions. However, the association of extratropical cyclones with temperature and wind extremes has not been globally quantified. The goal of this research is to understand the contribution of extratropical cyclones, through dry intrusions, to wind and cold extremes, and their compounding. Using objective identifications of extremes based on ERA5 reanalysis from 1979-2019 and Lagrangian-based analysis of dry intrusion airmass trajectories, a global quantification of co-occurrences is performed. The results are found to depend on the latitudes of the extremes, with the strongest association of extreme events to dry intrusion (over 60% of the extremes) in the subtropics, where dry intrusions rarely reach (~5%). The role of extratropical cyclones is thus non-local, in the sense that they affect surface extremes away from the cyclone's centre. We further focus regionally on northwest tropical Africa to better distinguish between compound cold-wind events that occur with and without the presence of dry intrusions. The connection of Mediterranean cyclones to extremes in the subtropics and tropics of northern Africa puts the results in the context of extratropical-tropical interaction, with potential implications for the predictability of tropical extremes.

Validations study of Mediterranean cyclones in GCM simulations

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This study focuses on mid-latitude cyclones in the Mediterranean region, with a particular focus on the western Mediterranean. Using ERA5 reanalysis data and six different historical simulations from the CMIP6 project, we aimed to identify changes in the number of cyclones and their characteristics in the period between 1950 and 2014, which is the historical period of CMIP6 experiments. Low-pressure systems are located by analysing mean sea level pressure values. Potential cyclone centres are connected over subsequent timesteps to generate cyclone trajectories. For the sake of comparability, all the simulation data are regridded to a spatial resolution of 1°. Moreover, a common temporal resolution of 6-hour is used. Substantial differences are recognised in both the frequencies and the locations of cyclones across the model simulations.

Reconstructing Eastern Mediterranean Cyclone and Precipitation Characteristics during the Last Interglacial: Insights from PMIP4 Simulations

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Climate models are vital for understanding climate change and offering insights into future trends, including changes in cyclone characteristics, particularly in the sensitive Eastern Mediterranean. Proxy-based climate records of the peak of the last interglacial, considered an analogue to future warming, indicate increased precipitation overall hyperarid conditions in the southern Levant, which are superimposed by episodic precipitation that is particularly identified in more southerly locations, though the driving mechanisms are still not well explained.

Simulations from the 4th Phase of the Paleoclimate Model Inter-comparison Project (PMIP4) are used to evaluate and reconstruct the precipitation characteristics of the southern Levant, between the Red Sea and east Mediterranean, during the last Interglacial. We analyzed changes in the frequency, seasonality, and persistence of Eastern Mediterranean cyclones, often termed Cyprus Lows, and the Red Sea Trough. In addition, we analyzed the dynamic-thermodynamic contributions to changes in precipitation-evaporation balance. While no statistically significant differences in the frequency or persistence of the rain-bearing synoptic systems were found compared to the pre-industrial period, each Cyprus Low and Red Sea Trough day tended to yield significantly more precipitation in the region at the peak of last interglacial compared to pre-industrial. We attribute these changes to significant changes in thermodynamic processes during the last interglacial. Our research contributes to a better understanding of past hydroclimate changes in the Eastern Mediterranean region and provides a longer perspective on future anthropogenic climate change. These findings underscore the importance of considering long-term climate variability in coupled model simulations to interpret paleo-proxy records.

Improving prediction of heavy rainfall in the Mediterranean region using Neural Networks

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The Mediterranean region is prone to Heavy Precipitation Events (HPE) causing significant human fatalities and material damages. Therefore, their prediction is crucial but challenging due to the complex processes involved. In this context, artificial intelligence methods have recently been shown to be competitive with state-of-the-art Numerical Weather Prediction (NWP). Our work focuses on improving the prediction of the occurrence of HPE in the Mediterranean region based on Neural Network (NN) models.
We use the MeteoNet open source database from Meteo-France on southeastern France from 2016–2018 including station observations (OBS) and forecasts from the NWP models Arome and Arpege. We train a NN model to predict the occurrence of daily rainfall above a threshold of 10 mm / 24 h at the location of the stations. Our verification metric is the Peirce Skill Score (PSS) with Arome forecasts as a benchmark.
Our results are 1) the NN model using both OBS and NWP data as inputs has the highest PSS, 2) the NN model using only Arome data as input has higher PSS than the benchmark, 3) the NN model trained only with OBS data has lower PSS than the benchmark, showing the crucial contribution of NWP forecast data at a lead time of 24 h, and 4) due to the rarity of rainfall events meeting the threshold, training the NN model with a weighted loss function significantly increases the PSS.
When extending the results to shorter time scales, we find that the contribution of OBS data to the NN model is dominant at 1–3 h lead times, while including NWP forecast data allows to mitigate the degradation of prediction skill with longer lead time. Finally, a comparison with northwestern France confirms the results, although with slightly lower PSS than for southeastern France due to the different rainfall climatology.

Lightning observations and data assimilation over Italy: impact on lightning forecast

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In this study we show, for the first time over Italy and over part of the central Mediterranean Basin, the impact of lightning data assimilation (LDA) on the strokes and precipitation forecast for a two seasons period. We use the Weather Research and Forecasting (WRF) model coupled with the Dynamic Lightning Scheme (DLS) at convection allowing horizontal resolution (3 km).
The study is divided in two parts: in the first part we show some characteristics of stroke data over the central Mediterranean Basin then we show the potential of lightning data assimilation on the strokes forecast. For the first point we consider a database of 13-years of the LINET (Lightning NETwork) over Italy and the Central Mediterranean area, recently analyzed in Petracca et al. (2024). For the second point, we carried out a two-seasons experiment (summer 2020 and fall 2021) providing the forecast of lightning and precipitation for the next 6 h (nowcasting), considering two sub-periods (0-3 h and 3-6 h) for verification.
It is shown that LDA has a notable potential at improving the strokes forecast. The improvement can have different patterns as relocating convection, initiating new convection, most of times missed by the control forecast, without LDA, or suppressing spurious convection. This improvement is, however, confined to the first three-hours of forecast. Interestingly, the improvement pattern is different in summer and fall, depending on the convection development in different seasons.
The analysis of the Fraction Skill Score shows the usefulness of the forecast for practical purposes, considering the current areas used by the Civil Protection Department to issue meteorological alerts for intense convective events over Italy. Finally, it is shown that the forecast at the short-range (0− 3h) using LDA can improve the strokes' forecast issued on the previous day, and the methodology of this work can be applied to issue warnings and alerts as the storm is approaching.

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On the dynamics of a case of Mediterranean Explosive Cyclogenesis Using the Pressure Tendency Equation

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The objective of this study is the evaluation of the physical processes responsible for the genesis and evolution of an explosive cyclone in the central Mediterranean with the aid of the surface pressure tendency equation with the aid of ERA5 datasets. For this reason, the equation is solved numerically, providing the opportunity to quantitatively specify the relative significance of the diabatic processes in Mediterranean explosive cyclogenesis. It was found that the interaction between the upper level baroclinic and low-level diabatic processes triggered the development of the explosive cyclone, but low-level baroclinicity and diabatic processes prevailed during the cyclone evolution.

The High-Impact Flash Flooding Event of Antalya-Turkey on 13 February 2024: Sensitivity studies with focus on WRF physics options and sea surface temperatures

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On 13 February 2024, in Kepez and Muratpaşa provinces of Antalya, which is located on the south-western Mediterranean part of Turkey, had torrential rain of 348 mm and 259 mm in 24-hour and 113 mm and 74 mm in an hour, respectively. The event caused devastating flash floods in the area, which left behind human casualties, ruined houses, about 948 hectares of flooded farmland, severely damaged horticulture, etc. Damage was so extensive that the government initiated a 20 million Turkish lira (TL) recovery aid program. The complex topography surrounding Antalya paves the way for the convergence of low-level atmospheric flows and then the uplift of warm moist air masses that come from the Mediterranean Sea to over the coastal areas, and thereby leading to intense convection. Sea surface temperatures (SST) of the Mediterranean in February 2024 were 2-4 degC above the climate mean of 1991-2020. Analysis of the European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System (IFS) model products, and examination of conventional and remote-sensing observations, indicated that the large amounts of precipitation were strongly modulated by mesoscale effects induced on the synoptic-scale flow. Numerical model sensitivity experiments forced by initial and boundary conditions from the ECMWF IFS model are conducted to generate 3-km and 1-km simulations with the Weather Research and Forecasting (WRF) Advanced Research dynamical core (WRF-ARW). The impact of various microphysics schemes, planetary boundary layer schemes, surface layer schemes and land surface schemes on the high-impact precipitation event are studied. Other numerical sensitivity experiments are also tailored to shed light on the mesoscale aspects of the precipitating structures and their dependence on complex topography, sea surface temperatures, surface fluxes and latent heating.

The effect of upper level processes on simple models for tropical cyclones in high resolution simulations

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Existing theoretical models for tropical cyclones have been critical in explaining some of the underlying processes which drive their intensification. The potential intensity (PI), first introduced by Emanuel 1986, provides an upper bound for the intensity that a tropical cyclone can reach based on the environmental conditions prior to cyclogenesis. However, this and other models are based on idealized settings that may not always match real-world conditions. Using simulations from the high resolution cloud resolving model SAM in rotating radiative-convective equilibrium settings, we assess the validity of these idealizations in the simulations. We find that some idealizations, such as a neutral atmosphere to moist convection, are only partially valid. In order to understand the reasons behind these deviations from theoretical assumptions of the model, we look at different possible mechanisms, such as upper level processes, which have been identified in a recent study.

Influence of ocean-atmosphere interaction on cyclone properties in the eastern Mediterranean: implications for sub-seasonal forecasting

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The Eastern Mediterranean (EM) region is considered a global warming hotspot projected to experience increased temperatures, water shortages and droughts during summer, as well as high-intensity precipitation and flooding events during winter. These impacts, in a region already struggling with water shortages, highlight the importance of improving the skill of sub-seasonal forecasting, as part of ongoing adaptation efforts. Here we aim to assess the influence of ocean-atmosphere interaction on sub-seasonal forecasting of precipitation in the Levant. Specifically, we find robust statistical relations between ocean parameters such as heat content and surface energy fluxes over parts of the Mediterranean and precipitation in the Levant, on timescales of weeks or longer. Given the critical role of Mediterranean cyclones on winter precipitation in the Levant, we analyze the influence of ocean parameters on changes in the genesis, intensity and trajectory of these cyclones. We find that both dynamic and thermodynamic processes explain the link between ocean properties, cyclones, and Levant precipitation. Specifically, sea-surface conditions modulate the intensity and trajectory of cyclones, as well as the thermodynamic properties of the air advected via cyclone activity. In ongoing targeted simulations using a regional weather forecasting model (WRF) we isolate the thermodynamic and dynamic processes and seek simple representations of these processes which can be implemented in operational forecast models.

On the possible relationship between Mediterranean tropical-like cyclones and SST

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The influence of Sea Surface Temperature (SST) on the genesis and evolution of Mediterranean Tropical-Like Cyclones (TLCs) is analyzed considering the most important TLC events reported in the scientific literature of the past four decades.
The relationship between the SST and TLCs has been explored by a limited number of studies, most of which referring to single events and/or sensitivity tests in which the SST is artificially modified to explore the potential effects in terms of intensity of the cyclones.
From these studies it follows that the role of SST on the development of Mediterranean cyclones mainly depends on the specific cases; however, all of them agree in showing that a stronger (weaker) SST anomaly favors the intensification (weakening) of these cyclones.
At the same time, one of the few climatological studies on TLCs considering SST (Cavicchia et al., 2014) assessed the absence of significant SST anomalies in the environment in which the cyclones developed.
Aim of this work is to re-assess the results of Cavicchia et al. (2014) adopting a higher resolution SST dataset (the Mediterranean Sea - High Resolution L4 Reprocessed Sea Surface Temperature product, distributed through the Copernicus Marine Service) and extending the analysis to more recent cyclones.
Our results confirm the absence of significant anomaly in the early stages of the TLC lifetimes, except for winter cases in which a positive anomaly emerges. Again, we also found that high SST values are favorable for the intensification of the most intense cyclones.