2nd MedCyclones & 9th European Storm Workshop

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Posters presentations

Climate change and variability in the past and future — poster session 1

Extreme weather events in the Monthly Climate Bulletin of Albania for the period 2017-2023.

Petrit Zorba, Elsuida Hoxha, Gazmir Cela.

This presentation will show all outputs that we got during our monthly analyses for the climate change of Albania during the last 7 years.

Weather extreme events in Albania related to climate change.

Petrit Zorba, **Elsuida Hoxha**, Gazmir Cela

It will present the situation of precipitation during the last years in the context of climate change in Albania and treat as well as the problem related to the high intensity of rain and droughts.
Different indexes of atmospheric precipitation will show the new tendency of rain in Albanian territory.

Effect of anthropogenic climate change on explosive cyclogenesis cases in Europe

Mireia Ginesta, Emmanouil Flaounas, Pascal Yiou, Davide Faranda

Mid-latitude storms are essential features of atmospheric variability in the cold season. The subsequent damages are caused by high wind speeds and heavy precipitation. Among such events, explosive cyclones can lead to extreme impacts when they make landfall. Climate change is affecting the underlying characteristics of such types of extremes. Being able to understand the way it modifies their dynamics is of great importance. In this work, we assess the influence of anthropogenic climate change on observed explosive cyclones in an Extreme Event Attribution framework using a large ensemble dataset. We evaluate three storms that hit different parts of Europe: Xynthia in February 2010, Alex in October 2020, and Eunice in January 2022.
We use three ensembles of 35 members of the Community Earth System Model (CESM). We compare two periods of 6-hourly data: present-day climate [1991-2001] and future climate [RCP8.5 scenario, 2091–2101]. We find analogues of the trajectories of the three storms before their highest intensity in both periods. We do that by tracking all cyclones in the dataset and selecting the cyclone tracks that have the minimum Euclidean distance in km from the trajectories of Xynthia, Alex, and Eunice. We explore the characteristics of the analogues of the trajectories in both periods such as frequency of explosive cyclogenesis and intensity to evaluate whether the dynamics of the storms have been affected by climate change. We further compare the analogues in terms of precipitation and low-level wind in the regions of impact.

Wind-Flood Correlation in Europe

Ching Ho Justin Ng, Jessica Turner

Events bringing a combination of extreme wind and precipitation can inflate losses relative to events where either peril occurs separately from each other. However, wind and flood are often thought of and simulated as separate perils, in traditional catastrophe modelling. In this study we investigate into the correlation between wind and flood over Europe, at the event timescale, and the impact of this correlation on compound wind-flood losses. In addition, the impact of climate change on this correlation is analysed. Historical and future climate runs from downscaled CMIP5 simulations over Europe are examined, together with ERA5 reanalysis data.
We find that there is significant correlation in parts of UK and continental Europe, particularly on the windward side of mountains. This correlation translates into a slight increase (up to a few percent) in compound wind-flood losses, compared to where they are modelled as separate perils. At the event timescale, climate change is expected to bring a small increase to the wind-flood correlation in Europe, and this is not statistically significant in many locations.

The phenomena of extreme weather in the territory of Albania during the last years

Petrit Zorba, **Gazmir Çela**, Elsuida Hoxha

This material develops an analysis of extreme weather conditions in Albania in recent years by examining the data from meteorological stations in Albania. This analysis is based on the processing of a wide range of numerical data and satellite images processed in accordance with all the technical and scientific standards of the field of meteorology.
The risks of extreme temperatures and temperature variations are one of the most discussed issues in today's scientific circles. Albania, as a Mediterranean country, is affected by such events. Social and economic consequences are increasingly affecting people and states. Reaching some conclusions about trends and frequencies of extreme events related to temperatures, precipitation, and forest fires is helpful for the public, state institutions, and a more significant contribution to creating a more complete picture of the situation in the Mediterranean.
The analysis of trends through various graphs from data series, processing of maps, and the presentation of some conclusions and recommendations in the field is the aim of this work.

Resilience Assessment of Transit-Transfer-Stations exposed to multiple hazards.

Emmanuel Ebo

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.

Climatological conditions of the Black Sea-effect snowfall events in Istanbul, Turkey

Hakki Baltaci, Maria Cristina Lemos da Silva, Helber Barros Gomes

A climatological analysis and overlying synoptic conditions of Black Sea-effect snowfall events were investigated for Istanbul, Turkey, during the 1971–2006 winter (DJF) periods. Using the synoptic climatological approach, the Lamb Weather Type (LWT) method was applied to NCEP/NCAR daily mean sea level pressure data. Basically, northwesterly (NW), northerly (N), and northeasterly (NE) circulation types (CTs), which blow from the Black Sea (BS), were thought to be important for sea-effect snowfall events to occur. Wind speeds and flows at 850-hPa, directional shear, and temperature difference between sea surface and 850-hPa level (SST-T850) thresholds were applied to these three CTs in order to find suitable snowfall cases originating from the Black-Sea. The results showed that 4, 14, and 111 snowfall episodes occurred during NW, N, and NE circulation types over Istanbul with the 2.8, 4.1, and 3.5 cm daily mean snow cover depths (DMSCD), respectively. In particular, it was found that interaction between a surface high located over continental Europe and a low pressure located over the central Black Sea, and a relatively warm sea surface temperature (SST), and cold temperature anomaly at the low level of the atmosphere (SST-T850 > 17C) are a favourable environment for the development of intense Black Sea-effect snowstorms (DMSCD > 10 cm) sourced by NE cases. A statistically significant positive relation between snow cover depths and SST-Tmax (daily maximum temperature) under NE cases ($r = 0.28$, $p < .05$) indicated that we observe intense daily snow accumulation when land-sea temperature contrast increases (>7C) in the region.

Effects of climate variability and climate change on cyclones in the Mediterranean

Onno Doensen, M. Messmer, W.M. Kim, C.C. Raible

The Mediterranean is characterized by a high extratropical cyclone activity. These cyclones are an important source for water availability in the region, but at the same time they have the potential to cause extreme weather in the form of precipitation and wind extremes. The Mediterranean is heavily affected by the ongoing anthropogenic climate change, which is expected to have a profound effect on cyclones in this area. In this study, we investigate the effects of internal climate variability and anthropogenic climate change on the characteristics of Mediterranean cyclones. The analysis is based on two simulations from the Community Earth System Model 1.2 (CESM): a seamless simulation spanning 3500 years from 1500 BCE to 2012 CE and a simulation of future RCP8.5 scenario from 2013 to 2100 CE. The simulations have a 1.9°x2.5° horizontal resolution, and cyclones are identified using an established detection and tracking algorithm. Comparison with the ERA5 reanalysis for the period 1981–2010 shows that CESM is able to realistically represent cyclone frequency on a global scale, though it slightly underestimates cyclone activity in the Mediterranean. Our results indicate that cyclone activity in the Mediterranean varies on interdecadal to centennial time scales before 1850 CE. These variations are mainly linked to fluctuations in strength of several modes of circulation, such as the North Atlantic Oscillation. The variations caused by internal variability are, however, of smaller magnitude than the effects of future climate change on the Mediterranean cyclones. In the RCP8.5 scenario, Mediterranean cyclones will become less frequent based on our simulation, and cyclone related precipitation will decrease in addition to that, which is contrary to what is being observed in other important storm track regions, such as the North Atlantic. Overall, the study suggests that cyclone activity in the Mediterranean is projected to leave the bandwidth of variability of the last 3500 years near the end of the century.

Changes in the concurrence of atmospheric rivers and explosive cyclones in the North Atlantic

Ferran Lopez-Marti, Mireia Ginesta-Fernandez, Davide Faranda, Anna Rutgersson, Pascal Yiou, Lichuan Wu, Gabriele Messori

The explosive development of extratropical cyclones and the presence of atmospheric rivers play a crucial role in driving extreme weather events in the mid-latitudes by increasing the baroclinic instability of the cyclone. Although these phenomena are individually well-established and their relationship has been studied, there is still a gap in our understanding of how a warmer climate may affect their concurrence. Here, we focus on evaluating the current climatology and assessing trends in the future climate of the concurrence between atmospheric rivers and explosive

cyclones along the North Atlantic.
We use the ERA5 reanalysis data with a resolution of 0.25º from 1959 to 2022 over the North Atlantic during the extended winter (October to March) not only to evaluate the concurrences between atmospheric rivers and explosive cyclones in the current climate, but also to assess trends within this long period to evaluate the influence of the anthropogenic climate change in the 63 years of data. Moreover, we analyse the IPSL large ensemble historical simulation extended for the SSP2-4.5 scenario with 32 members and other CMIP6 historical simulations to study the concurrences within three periods: past (1949-1959), present (1999-2009), and future (2049-2059). We further detect and track independently atmospheric rivers and extratropical cyclones. We classify each cyclone as explosive if it exhibits a minimum drop of 24 hPa of its minimum sea level pressure within a 24-hour period and classify each cyclone as concurrent to an atmospheric river if we detect any within 1500 km around the minimum sea level pressure of the cyclone.
Our findings reveal that atmospheric rivers are more often detected within the vicinity of explosive cyclones than non-explosive cyclones. This relationship supports the hypothesis that the concurrence of an atmospheric river and a cyclone increases the possibility of developing explosive cyclogenesis. Moreover, in both datasets, we have found significant trends in the concurrences for the different periods analysed. As such, our work provides a novel statistical relation between explosive cyclones and atmospheric rivers in climate projections and a new climatology of the concurrences for an extended higher-resolution reanalysis.

"Study of Omega blocking and its correlation with the occurrence of temperature extremes over Europe and the Mediterranean region"

Iliana Koutsoupi, Constantinos Cartalis, Kostas Philippopoulos, Ilias Agathangelidis

The study focuses on investigating Omega blocking. Firstly, omega-blocking events are identified using geopotential height at 500 hPa for the summer months from 1981 to 2020 in Europe, by evaluating the corresponding anomalies. Of the identified 115 blocking systems, 77 are recognized as Omega, and in most cases, their duration does not exceed 20 days.
The correlation between the phase of the North Atlantic Oscillation (NAO) index and the occurrence of Omega blocks is investigated. The zonal wind at 250 hPa changes' role in creating favorable conditions for the system formation is identified.
The association of temperature extremes in the Mediterranean with the occurrence of Omega blocking is based on the calculation of the Excess Heat Factor (EHF).
A strong relationship of Omega blocks and the intensification phase of an upstream cyclone 2 days prior to blocking onset is revealed and the dynamics of the two systems formation and connection are analyzed.
Characteristic case studies of heatwaves in the Mediterranean and in Greece are investigated. It is concluded that 83% of the Omega blocks in Europe are directly related to extreme temperatures in the Mediterranean, while Greece is affected by 12% of the events.
In conclusion, an increasing trend in the duration and intensity of Omega blocks is observed over the last decade, with the major part being moderate intensity systems affecting western Europe during the summer period, resulting in climatological changes to the European and Mediterranean region.

North Atlantic storms drive remote ocean swells into the Eastern Caribbean

Timothy W. Hawkins, Isabelle Gouirand, Theodore Allen**, Ali Belmadani**

Large wintertime ocean swells in the Caribbean, remotely driven by mid-latitude North Atlantic storms and known as north swells, generate high surf and expose communities, ecosystems, and infrastructure to hazardous conditions. Empirical orthogonal functions and cluster analyses using ERA5 reanalysis swell data are performed to characterize north swells in the eastern Caribbean and to establish a ranked list of historical events. ERA5 atmospheric and swell data are used to create basin-scale sea-level pressure, surface wind and swell composites for north swell events of different magnitudes. Additionally, storm events are identified in the mid-latitude North Atlantic Ocean.
North swells are predominantly generated by storms that intensify off the North American east coast. However, there is a subset of moderately sized swells associated with a westward-located high-pressure system in the North

Atlantic. While lower sea-level pressure and stronger surface winds are important for generating larger swells, the location of the low-pressure center and storm track as well the zonal speed of the storm are critical in the development of large eastern Caribbean north swells. The largest such events are associated with storms located comparatively further southeast, with a more zonal trajectory, and slower zonal speed. Large storms located further northwest, with a more southwest to northeast trajectory, and faster zonal speeds are associated with weaker north swells or in many cases, no significant north swell in the eastern Caribbean. Implications for future projections and low-frequency control of north swell events are discussed.

New convection-permitting simulations of extreme European cyclones in present and future climates

Ben Harvey, Oscar Martinez-Alvarado, Len Shaffrey

Convection-permitting regional climate models (CPMs) are high-resolution regional models driven by global climate model (GCM) simulations, at resolutions allowing for an explicit representation of convection. Recent work has shown that CPMs add value over the coarser resolution GCMs: as well as having improved distributions of hourly rainfall rates, particularly for extreme events, they have improved representations of mesoscale wind features embedded within extratropical cyclones including cold conveyor belts and sting jets.

In addition, CPM-based future projections exhibit different features from those derived using their driving GCMs. For example, they exhibit an enhanced intensification of future rainfall extremes compared to their driving GCMs, as well as an enhanced intensification of future wind extremes associated with extratropical cyclones. However, whilst robust, these results are based on relatively short (~10 year) time slice experiments with limited model outputs due to cost of running the CPMs. There is a strong societal need to better sample these future extreme wind and precipitation events, as simulated by CPMs, to inform policy decisions and to better understand the dynamical changes involved.

This poster will describe a new set of targeted CPM simulations being run by the CANARI project (Climate change in the Arctic – North Atlantic region and impacts on the UK) with the aim of simulating the most impactful extratropical cyclones over the UK and Europe in present day and future climates. The experimental design will be described and opportunities for utilising the data by the community will be outlined.

Multiproxy reconstruction of the Mediterranean Oscillation Index since 1000 CE

Arnau Sanz i Gil

Climate indices are useful tools for assessing hydroclimatic variability over long timescales. Moreover, paleoclimatic reconstructions of these indices provide vital insights into past atmospheric circulation. In particular, the Mediterranean Oscillation, a dipole between the west and east basin of the Mediterranean, is a valuable index that explains the temperature and precipitation distribution in the region during the cold season. Recent studies have used paleoclimatic data, known as proxies, to reconstruct several indices successfully. However, little is known about the Mediterranean Oscillation index. Here, we will develop a multiproxy Mediterranean Oscillation reconstruction over the last millennia. The reconstruction will be calibrated with the instrumental record and reanalysis data to validate its performance. This project aims to understand the atmospheric circulation patterns behind the multiproxy data records, investigate the spatiotemporal fluctuations of the Mediterranean's natural cycles, assess abrupt changes, and quantify their uncertainty. Finally, the project will provide the community with helpful knowledge about the past climate in the region, which can be further studied and used across various disciplines ranging from climate forecasting to hydroclimatology.

Extratropical cyclones over the North Atlantic and western Europe during the Last Glacial Maximum and implications for proxy interpretation

Kim H. Stadelmaier, Joaquim G. Pinto and Patrick Ludwig

Extratropical cyclones are a dominant feature of the midlatitudes, as their passage is associated with strong winds, precipitation and temperature changes. The statistics and characteristics of extratropical cyclones over the North Atlantic region exhibit some fundamental differences between pre-industrial (PI) and Last Glacial Maximum (LGM) climate conditions. Here, the statistics are analysed based on results of a tracking algorithm applied to global PI and

LGM climate simulations. During the LGM, both the number and the intensity of detected cyclones were higher compared to PI. In particular, increased cyclone track activity is detected close to the Laurentide ice sheet and over central Europe. To determine changes in cyclone characteristics, the top 30 extreme storm events for PI and LGM have been simulated with a regional climate model and high resolution (12.5 km grid spacing) over the eastern North Atlantic and western Europe. Results show that LGM extreme cyclones were characterised by weaker precipitation, enhanced frontal temperature gradients and stronger wind speeds than PI analogues. These results are in line with the view of a colder and drier Europe, characterised by little vegetation and affected by frequent dust storms, leading to reallocation and build-up of thick loess deposits in Europe.

Extreme precipitation events associated to western Mediterranean cyclones

Pongracz R., Bartholy J., Dolgos E.

Mid-latitude cyclones form an essential part of large-scale atmospheric circulation pattern, and their evolution, intensity, trajectory, and associated weather events, e.g., extreme precipitation, consequent floods, are all important from a local and regional point of view. The western Mediterranean region is especially interesting where relatively shallow mid-latitude cyclones occur compared to the North-Atlantic region. That is why the detection of Mediterranean cyclones requires different criteria from the North-Atlantic cyclones. For this purpose we use the 6-hourly mean sea level pressure field from ECMWF reanalysis database ERA-20C covering the long time period from 1900 to 2010 with a spatial resolution of 1°. This length allows validating global climate model simulations, and then, the best performing simulations can be used to evaluate future trends under different scenarios until the end of the 21st century. Our research aims to detect changes in Mediterranean cyclone characteristics (frequency, intensity, duration, precipitation zone) for the 20th and 21st centuries, especially those cyclones, which reach the Carpathian Basin.

Is there any climatic evidence for the drop of the olive-tree cultivation in the hilly are of Bologna?

Rodica Tomozeiu, **Fabrizio Nerozzi**, Arpae Emilia-Romagna

The olive tree is a typical tree crop of the regions of the Mediterranean basin, but there are numerous indications that its cultivation was widespread in the past on the hilly area of Bologna (located in the Southern Po Plain, Northern Italy). Confirmations in this sense can be found in the presence still today of secular trees on the territory and in the toponymy of the municipalities or fractions of them, whose names contain an explicit reference to the cultivation of the olive tree, such as, for example, the Oliveto fraction of the municipality of Monteveglio. Moreover, direct testimonies on the cultivation of the olive tree in the Bologna area from the Middle Ages onwards are also considerable: Giovanni Garzoni in his "Commentari de rebus bononoiensis" (1503), Leon Battista Alberti in his "Descrition of all Italy ..." (1551), Andreas Schott in his "Itinerary or new description of the main journeys of Italy", published in Venice in 1622.

News of plots dedicated to the cultivation of olive trees date back to 1668, in a pen sketch depicting the church of S. Maria di Monteveglio and the new road called Calvario. Before falling into the long phase of oblivion that distinguishes the Emilian tradition of olive production, further evidence concerning the cultivation of the olive tree in the Bologna area is only available a century later, starting from the second half of the 18th century.

The period in which historical information on olive tree cultivation becomes rarer and more fragmentary corresponds to one of the coldest periods of the Little Ice Age (1300-1900), the so-called "Maunder Minimum", which goes from 1645 to 1715, approximately. This period is known to be characterized by low solar activity and intense volcanic activity, with the emission of gases and aerosols into the troposphere. The overall effect of these factors was a marked climatic variability, particularly characterized by a strong decrease in temperature.

The aim of this work is to reconstruct the historical series of minimum winter temperatures and some indicators of temperature extremes in order to study what was the influence of climatic variability on the abandonment of olive tree cultivation in the Southern Po Plain during the period 1675-1715. Specifically, a statistical reconstruction technique, based on the analysis of canonical correlations, has been here applied using the mean sea level pressure and 500 hPa geopotential height (WDCA Paleo data) as predictors and the mean, the tenth percentile of seasonal averages of minimum temperature and the number of frost days as predictands.

The results obtained confirm for the period taken in exam that the Southern Po Plain was characterized by strong negative temperature anomalies compared to the climate 1961-1990 and, therefore, they connect us to the idea that it was precisely the recurrence of cold winters that led to irreversible damage to the olive trees located in the hilly area of Bologna, thus forcing the abandonment of its cultivation. The climatic variability of this period acted as a real catalyst for the decades-long process of deconstruction of peasant communities. The laceration of the social fabric, with the consequent reduction in the number of settlers, was so devastating that, a century later, when the climatic conditions returned to being more temperate, none of the initiatives promoted, either by the Agricultural Society or by part of the world academician from Bologna, for the reintegration of olive cultivation in the hilly area of Bologna was successful.

Large-scale precursors of Mediterranean Tropical-Like Cyclones

Lisa Bernini, Leone Cavicchia, Fabien Desbiolles, Claudia Pasquero, Enrico Scoccimarro

Cyclones from a reference data-set of Mediterranean tracks (Flaounas, 2023) have been classified based on thermal winds. This classification allowed us to explore the major differences between extra-tropical cyclones with a cold inner core and tropical like cyclones with a deep inner warm core. In order to better understand the transition of cold core extra-tropical cyclones into warm core tropical like cyclones, we computed the time evolution along the cyclones lifetime of the climatic anomalies of different environmental properties. The environmental characteristics studied are wind, moisture content, precipitation, temperature and air-sea heat exchanges. The originality of this work compare to previous studies is the climatological approach and the number of warm core cyclones considered: 384 tropical like cyclones between 1979 and 2020.

Impact of the Ocean-Atmosphere coupling on extratropical cyclones around the Mediterranean basin

Marco Chericoni, Giorgia Fosser, Alessandro Anav

The Mediterranean basin is well recognized as one of the main climate change hotspots; besides, this region is one the most active cyclogenetic area of the Northern Hemisphere with a large number of intense cyclones occurring every year mainly during winter and fall. The climatology of Mediterranean cyclones has been deeply investigated in the past years, leading to a high agreement on the tracks density, seasonal cycle and favourite locations of cyclogenesis. Nevertheless, open questions still remain on the future evolution of Mediterranean cyclogenesis and associated impacts. Mediterranean cyclones typically present weaker intensities, smaller sizes and shorter lifetimes than tropical cyclones or other mid-latitude cyclones that develop over open oceans. However, they are often responsible for extreme precipitation and wind events leading to severe socio-economic and environmental impacts especially over densely populated regions and coastal areas. Thus, studying the feedbacks of air-sea interactions on Mediterranean cyclones will bring to a better understanding of both the contribution of cyclones to the variability in and extremes of the regional climate and the impacts on the marine ecosystems as well as the associated risks in maritime transportation and coastal structures.
This study aims to investigate the added values of the ocean-atmosphere coupling in regional climate models in reproducing Mediterranean cyclones. To this end, two simulations are performed using the ENEA-REG regional earth system model at 12 km over the Med-CORDEX domain. The first experiment uses the mesoscale WRF model with prescribed Sea Surface Temperature (SST), while in the second WRF is coupled to the MITgcm ocean model. Different tracking methods, based on sea level pressure, are used to account for the uncertainties linked with mathematical and physical definitions of cyclone itself. The simulations are validated against ERA5 reanalysis dataset in terms of their ability to reproduce the statistics (intensity, lifetime and speed) and the seasonal distribution of the cyclones but also to represent sub-daily fields, such as precipitation, evaporation and wind speed, in the area of influence of the cyclone. Here we show how the use of coupled simulations has to offer a better and deeper understanding of high frequency dynamical processes which take place during the development of intense Mediterranean cyclones.

Role of small-scale SST structure and warming on the Mediterranean Cyclone: Case Study for 'IANOS'

Alok Kumar Mishra, Babita Jangir, Ehud Strobach

The Mediterranean Sea's distinctive and complicated bathymetry, as well as the surrounding high mountain systems, create a favorable environment for cyclogenesis. Although Mediterranean cyclones have relatively weaker intensities, smaller sizes, shorter lifetimes, and are rarer than open ocean mid-latitude cyclones, they strongly influence the Mediterranean climate, including extremes. This study examines the influence of mesoscale Sea Surface Temperature (SST) structures and large-scale SST on the Medicane 'IANOS'. The controlling mechanisms are being investigated through a set of sensitivity experiments with a non-hydrostatic, fully compressible state-of-the-art numerical model, namely Weather Research and Forecasting (WRF).
Simulations with coarse-resolution SST fields from OISST (CTRLO) and a high-resolution mesoscale eddy-permitting

SST field from HYCOM reanalysis (CTRLH) indicate a better performance of CTRLH in terms of precipitation and wind intensity. We further investigate the role of mesoscale SST boundary conditions by smoothing the SST gradients and increasing the magnitude of SST by 2 0C. Compared to the control simulations, a simulation in which a 60km smoothing filter was applied on the SST field results in a Medicane centered slightly to the west (or delayed by 3-6 hours), which is further shifted to the west (or delayed) when increasing the smoothing filter to 150km. SST warming in both simulations, with and without smoothing, exhibit intensification and a north-eastward shift of the Medicane. However, warmer SST and smoothing (in the absence of mesoscale SST structure) exhibit relatively less intensification.

Investigating the role of sea eddies on the intensity of cyclones in the Mediterranean Sea

Babita Jangir, Alok Kumar Mishra, and Ehud Strobach

The Mediterranean Sea (MS) basin is a region with a diverse and unique geography. The complex geographical features of MS and remote effects from the Atlantic sector facilitate favorable conditions for cyclone genesis and maintenance. Despite the important role of ocean eddies in cyclones' track and intensity changes, they are insufficiently explored, especially over the MS. This study investigated the effects of eddies (size, intensity, and area) on the intensity of the atmospheric cyclones in the MS. Eight cyclones have been analyzed using observation-based datasets. Out of those, four cyclones, namely Zorbas, Boron, Numa, and Messala, had a persistent Warm Core Eddy (WCE) in their path, and four cyclones, namely Anton, Med-2009, Julia, and Zissi, had a persistent Cold Core Eddy (CCEs) in their path.

The analysis indicates that cyclones undergo a sudden change in intensity due to the presence of underlying eddies. It is also found that the size and extent of the eddies strongly modulate the latent and sensible heat flux exchange, leading to cyclone intensification/diminishing. Larger (smaller) size and extent eddies are responsible for increased (decreased) heat exchange and higher (lower) precipitation amounts. A Shallower (Deeper) Mixed Layer Depth (MLD) is present in the case of WCEs (CCEs). Thus, in the presence of WCEs, reduced mixing in the stratified ocean restricts the entrainment of the subsurface cooler water to the surface and leads to surface warming, which intensifies the cyclones.

Localized Finite Amplitude Wave Activity as a Diagnostic for Mediterranean Cyclones: Variability, Life Cycles and Mechanisms

Dor Sandler, Tel Aviv University, Tel Aviv, Israel; and Baruch Ziv, Hadas Saaroni, and Nili Harnik

Finite Amplitude Local Wave Activity (FALWA; Huang & Nakamura, 2016) is a diagnostic that keeps track of the wave activity ”stored” within circulation undulations, relative to a zonalized flow. It is therefore particularly suited for analyzing the Mediterranean region, which is influenced by the North Atlantic storm track and highly distorted PV streamers. FALWA obeys an exact conservation relation, thus its local rate of change is either due to a flux convergence, or to non conservative source terms. This work presents a FALWA-based mechanistic framework for analyzing Mediterranean cyclones. Using ERA5 data, we investigate the intra-seasonal and interannual variability of FALWA and its components, and link them to cyclone characteristics in the region (distribution, intensity, vertical profile). A particular focus is given to the relative contributions of diabatic heating and baroclinic growth, as they are reflected in a cyclone-centered FALWA budget. Concretely, significant budget differences were found between cyclone cases developing under streamers, and those that are mainly driven by diabatic processes.

Helios, a warm seclusion in the Mediterranean Sea

D'Adderio L.P., Fuccello A., Miglietta M.M., Panegrossi G., Dafis S., Rysman J.F., Husson R.

Generally, the term Medicane has been used for both cyclones with tropical characteristics and for weaker subtropical cyclones or warm seclusions. Recently, a certain consensus has been reached in considering the latter category as separate, based on the different characteristics of these cyclones. As an example, the cyclone Helios recently affected the southern part of the Mediterranean basin.

The cyclone developed between 8 and 9 February 2023 in the Strait of Sicily, within a wide cyclonic circulation affecting the central Mediterranean for several days. The environment was strongly baroclinic, due to the north-

easterly cold air on the northern side and milder sub-tropical air from the south-west. A strong pressure gradient formed that favored intense easterly winds on the southeastern coast of Sicily. The orographic uplift favored intense accumulations inland, that locally reached 550 mm in 48 hours. Due to the cold temperatures, snowfall was observed at hilly altitudes over eastern Sicily.
From satellite images, in particular from passive microwave (PMW) radiometry, warm air seclusion is apparent in the center of the cyclone, which favored a weak and not so well-defined warm core structure evidenced by the warm brightness temperature anomaly in the 54 GHz oxygen absorption band channels. An isolated warm core is clearly visible in the upper levels while at lower levels the warm TB anomaly region is larger and the warm core is less defined if compared to the one occurring during the most intense Medicanes. The different PMW radiometer overpasses reveal a limited duration of the warm core and a poor vertical alignment, evidencing a weakly barotropic structure. In addition, the limited instability and the strong wind shear associated with the approaching polar jet, which pushed the cyclone toward the interior of Africa, prevented the cyclone from developing deep convection close to its center. This is evidenced by the PMW imagery revealing the presence of shallow/warm rain in the extensive warm core region in the Southern Mediterranean, associated to the diabatic heating revealed by the warm TB anomaly, while deep convection is confined in the outer band spiraling around the cyclone center in correspondence with the intense precipitation which affected Sicily. In addition, SAR acquisition form Sentinel-1 can also be used to describe the atmospheric processes ongoing at high resolution: the sea surface roughness on one hand confirms the presence of deep convection in the outer band while, on the other hand, a sharp wind speed and direction discontinuity within the cyclone center indicates the presence of the atmospheric front. Besides, wind derived from the dual-polarization channels indicates wind speeds reaching 37 m/s. The satellite images are also very useful in evidencing how the warm air seclusion characterizes only the second stage of the cyclone, while during the first, extratropical phase more convective activity is observed. This study is a useful example of how satellite imagery can provide useful insights on the dynamic and thermodynamic process in Mediterranean cyclones contributing to the ongoing discussion in the scientific community on the definition of Medicanes.

Impacts of Sea Spray in a coupled (ocean-)wave-atmosphere model : realistic Mediterranean and idealized tropical cyclone case studies

Sophia Brumer, Marie-Noëlle Bouin, Jean-Luc Redelsperger

Air-sea fluxes of enthalpy and momentum greatly influence the dynamics of the marine atmospheric boundary layer (MABL). Already at moderate but certainly at high winds, wave breaking is a key driver of air-sea fluxes and the sea spray generated by whitecaps is thought to be a crucial component when modelling air-sea interactions. Sea spray is thought to enhance tropical cyclone intensity and could play an important role in extra-tropical cyclones dynamics. Here we will showcase latest efforts incorporating sea spray mediated momentum and heat fluxes into SURFEX, the surface component of the non-hydrostatic mesoscale atmospheric model of the French research community Meso-NH. Developments include two updated bulk flux algorithms based on COARE and WASP which can be implemented in simulations with varying degrees of atmosphere-wave coupling/forcing as well as in stand-alone atmospheric runs. Several sea spray generation functions (SSGF) can be activated based on published measurement derived parameterizations. Sea spray production remains to be adequately quantified. Existing SSGFs span several orders of magnitude resulting in uncertainties in simulated fields which will be discussed.
Impacts of sea spray will be illustrated with realistic case studies in the Gulf of Lion (NW Mediterranean Sea) under stormy winds including Mistral and Tramontante using the coupled model framework developed within the scope of the CASSIOWPE project aiming at characterizing the physical environment in the prospective of future floating wind farm deployment. The framework consists Meso-NH, the 3rd generation wave model WAVEWATCH III®, and the oceanic model CROCO. In order to assess impacts in higher wind conditions results of a series of idealized tropical cyclone wave-atmosphere simulations will also be shown.

Characteristics of some of the most important medicanes in the last 40 years with ERA5 reanalysis data

Gutierrez-Fernandez, Jesús ; Miglietta, Mario Marcello ; Gonzalez-Alemán, Juan Jesús ; Gaertner, Miguel Angel

Several Medicanes, which have been previously analyzed in the literature, have been studied using ERA-5 reanalyses to identify the environment in which they develop and possibly distinguish tropical-like cyclones from warm seclusions. Initially, the cyclone phase space was analyzed to identify changes in the environmental characteristics. Subsequently, the temporal evolution of several parameters was considered, including the distance between the maximum azimuthal wind and cyclone center, sea surface fluxes, CAPE, coupling index, potential intensity, baroclinicity.

Although the results are not consistent for all cyclones, some general characteristics can be identified: cyclones develop in areas of moderate-to-high baroclinicity associated with intense jet streams, while in the mature stage the environment becomes less baroclinic. A general reduction in the horizontal extent of the cyclone can be observed as the cyclones begin to show a shallow warm core. In this phase a progressive reduction of the CAPE can be observed in proximity of the cyclone center. Finally, the wind speed appears strongly underestimated compared to the observations, raising some concerns about the applicability of ERA-5 for the detection of wind features.

Decomposing the role of dry intrusions for evaporation in the Gulf of Lion during Mistral

Yonatan Givon, Douglas Keller Jr., Romain Pennel, Philippe Drobinski, Shira Raveh-Rubin

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. Dry Intrusions (DIs) are Lagrangian air trajectories flowing along the descending branch of extra-tropical cyclones. Known to induce cold and dry surface anomalies, DIs are 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 at the Gulf of Lion 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 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 acts to intensify surface winds and hence evaporation rates.

A user friendly and flexible set-up for baroclinic life cycle simulations in OpenIFS

Clément Bouvier, Daan van den Broek, Madeleine Ekblom, **Victoria Sinclair**

Idealised simulations of extra-tropical cyclones (ETCs), often referred to as baroclinic life cycles, have previously been extensively used to understand ETC dynamics. More recently, baroclinic life cycle simulations have proved useful to investigate how ETCs may respond to climate change. However, these simulations are notoriously difficult to set up in a manner which is numerically balanced (when run without a triggering perturbation), realistic, and easy to manipulate. Here we present an initial state for baroclinic life cycles which is specified analytically as a function of longitude, latitude, and a normalised pressure (eta) coordinate. First, the zonal wind speed is specified, then the geopotential is obtained by integrating gradient wind balance, and lastly hydrostatic balance is used to determine the virtual temperature. Moisture is included via a specified function of relative humidity as eta. As all integrals and derivatives are performed analytical

ly, unlike many other methods to initialise baroclinic waves, there is no need for numerical integration which can introduce imbalances. This initial state has been implemented successfully into OpenIFS, a global state-of-the-art numerical weather prediction model. A key strength of this set-up is that via the namelist a user can control many aspects of the basic state: the height, width and strength of the jet, the average temperature, the environmental lapse rate, the surface relative humidity and the surface roughness thus meaning that huge of ensembles of baroclinic waves can be easily generated. Examples of the basic state, and the resultant weather systems, will be shown along with preliminary results considering how the intensity and structure of the ETCs depends on the specified initial state.

Sensitivity to physical parameterizations for kilometer-scale simulations of medicane Ianos

Didier Ricard, Florian Pantillon

Numerical experiments have been performed with the Meso-NH model (Lac et al, 2018) at a horizontal resolution of 2 km following the framework of the MedCyclones model intercomparison project. The impact of different physical parameterizations is assessed on the development and intensity of medicane Ianos.
Thus, the two-moment microphysical scheme LIMA (Vié et al, 2016) is evaluated in comparison with the one-moment microphysical scheme ICE3 (Pinty and Jabouille, 1998). Indeed, sensitivity experiments on NAWDEX Atlantic cyclone cases have shown that latent heat release is greater over larger areas with ICE3 (Mazoyer et al, 2021). With the LIMA scheme, there is less spread precipitation, a smaller cloudy area and a less intense cyclone. Moreover, the impact of the subgrid condensation scheme is also evaluated.
Turbulent mixing is also evaluated, first by testing a 3D versus a 1D turbulence scheme and two different mixing lengths (Deardorff versus Bougeault and Lacarrère, 1989). Further evaluation is done by testing a modification of the turbulence scheme based on Leonard terms (Moeng et al, 2010) instead of the classical K-gradient approach for turbulent vertical heat and moisture fluxes (Verrelle et al, 2017, Strauss et al, 2019). The current scheme (Cuxart et al, 2000) has indeed shown a deficit of subgrid turbulence in convective systems. More turbulence mixing induces a less intense cyclone and less precipitation. The impact of the shallow convection scheme is also assessed. No shallow convection scheme results in less precipitation and a less intense cyclone.
A spectral analysis is also applied on the differences of these simulations in order to study the upscale error growth related to physical parameterizations.
The results on the importance of physical parameterizations for the organization of convection will be discussed during the conference.

Impact of mixed-phase cloud parameterization on warm conveyor belts and upper-tropospheric dynamics

Marie Mazoyer, Didier Ricard, Gwendal Rivière, Julien Delanöe, Sébastien Riette, Clotilde Augros, Mary Borderies, Benoit Vié

This study investigates mixed-phase cloud (MPC) processes along the warm conveyor belts (WCBs) of two extratropical cyclones observed during the North Atlantic Waveguide and Downstream Impact EXperiment (NAWDEX). The aim is to investigate the effect of two radically distinct parameterizations for MPCs on theWCB and the ridge building downstream; the first one (REF) drastically limits the formation of liquid clouds while the second one (T40) forces the liquid clouds to exist. REF exhibits a stronger heating below 6 km height and a more important cooling above 6 km height than T40. The stronger heating at lower levels is due to more important water vapor depositional processes while the larger cooling at upper levels is due to differences in radiative cooling. The consequence is a more efficient potential vorticity destruction in the WCB outflow region and a more rapid ridge building in REF than T40. A comparison with airborne remote sensing measurements is performed. REF does not form any MPCs whereas T40 does, in particular in regions detected by the radar-lidar platform like below the dry intrusion. Comparison of both icewater content and reflectivity shows there may have too much pristine ice and not enough snow in REF and not enough cold hydrometeors in general in T40. The lower ice to snow ratio in T40 likely explains its better distribution of hydrometeors with respect to height compared to REF. These results underline the influence of MPC processes on the upper-tropospheric circulation and the need for more MPC observations in mid-latitudes.

The medicane IANOS: a test case in the development of a regional atmosphere-ocean coupled model.

Francesco Maicu, Silvio Gualdi, Nadia Pinardi, Enrico Scoccimarro, Leone Cavicchia and Giovanni Coppini

A regional atmosphere-ocean coupled model was implemented at 1/24-degree resolution for both components in the Euro Mediterranean area, and the medicane Ianos was selected as a test case. The oceanic and atmospheric dynamics were simulated with different uncoupled model configurations to assess their skills and the heat fluxes at the interface. These experiments were also useful to determine the coupling strategy more appropriate to reduce the heat fluxes imbalance between the components.
The skills in reproducing the observed SST are slightly degraded at the Mediterranean basin scale, while are comparable with those of the uncoupled oceanic model in the development area of the medicane. In terms of heat fluxes, the coupling does not change the Mediterranean basin averaged values, but locally in the Ionian Sea it does, for the latent heat flux and the shortwave radiation. The coupling is not relevant for the intensification of the cyclone, whereas it enhances the representation of its path and the time of the landfall on the Ionian Islands. The subsequent southward trajectory along the Greek coastline remains unresolved. The importance of the ocean-atmosphere feedbacks in the development of this extreme event are investigated changing the coupling frequency in further experiments.

The intrinsic relationship between cyclones, anticyclones, and Rossby Wave Breakings in the North-Atlantic, and some implications for Mediterranean storm evolution and Atlantic weather regimes

Talia Tamarin Brodsky and **Nili Harnik**

Rossby wave breaking events describe the last stage in the life-cycle of baroclinic atmospheric disturbances. These breaking events can strongly influence the large-scale circulation, and are also related to weather extremes such as heat waves, blockings, and extreme precipitation events, as well as to weather regimes. Nonetheless, a complete understanding of the synoptic-scale dynamics involved with wave breaking events is still absent. Here we highlight the fundamental relation between low-level weather systems and upper-level wave breaking events in the North Atlantic region, by combining a storm tracking technique together with a wave breaking detection algorithm.
We show that Anticyclonic Wave Breaking (AWB) events are associated with a strong upper-level ridge and a low-level anticyclone to its east, which are both located in the anticyclonic side of the jet, while Cyclonic Wave Breaking (CWB) events are associated with a strong upper-level trough and a low-level cyclone to its east, which are both located in the cyclonic side of the jet. We also find that during AWB, the associated anticyclone is often flanked by a strong cyclone to its north-northwest while during CWB, the associated cyclone is flanked by an anticyclone to its northeast. Time evolution composites around the anticyclones during AWB, and the cyclones during CWB show the cyclone - anticyclone pairs rotate in a similar sense as the upper level wave breaking, such that the initially zonally oriented low-high SLP anomaly dipoles become meridionally oriented by the end of the life cycle, with a low-above-high for AWB and high-above-low for CWB. Unlike for CWB, during AWB, a second, weaker cyclone is often found to the south-southeast of the central anticyclone. These secondary cyclones, which are typically located over the Mediterranean, rotate anticyclonically around the central anticyclone, resulting in a significantly slower zonal propagation and weaker poleward propagation than average Atlantic cyclones. The wave breaking-(anti)cyclone-tracking framework also provides a simple kinematic interpretation for the poleward and equatorward shifted jets associated, respectively, with AWB and CWB events, as well as mechanistic interpretation of some of the Atlantic weather regimes.

Effects of the Mistral on the Overturning Circulation of the Northwestern Mediterranean Sea

Douglas Keller, Yonatan Givon, Romain Pennel, Shira Raveh-Rubin, Philippe Drobinski

The Mistral is a northwesterly wind that flows through the Rhône Valley, the low point between the Massif Central and the Alps, and out over of the Gulf of Lion. It occurs periodically, more often during the winter, and is formed by a lee cyclone in the gulf of Genoa. It brings cool, dry air out over the sea surface in the Gulf of Lion, leading to large surface fluxes that destabilize the water vertical column. These winds in combination with the seasonal atmospheric change, can lead to large vertical mixing in the sea in the gulf. This large vertical mixing, known as deep convection when it reaches at or near the sea floor, assists in the Mediterranean Sea's overall thermohaline circulation. The circulation is formed by fresh Atlantic water flowing into the sea at the Strait of Gibraltar, then flowing counterclockwise around the sea while being subjected to surface heat and evaporative fluxes, causing it become more dense and sink. The dense waters that are f
ormed continue the counterclockwise rotation and eventually flow back out the strait below the incoming Atlantic water. In this work, the direct connection between the Mistral and the circulation of the ocean water in the Gulf of Lion is investigated, effectively investigating the direct link between cyclones and the sea circulation in the northwestern Mediterranean. This was accomplished with a year long ocean simulation with the NEMO ocean model covering the winter of 2012-2013; a simulation that covers an exceptionally well observed case of deep convection in the Gulf of Lion with a large number of Mistral events. Spatial differences in both the zonal and meridional overturning between days with Mistral events and days without are presented.

On the influence of Ocean Mixed Layer and Sea Surface Temperature in development of the three Mediterranean Tropical-Like cyclones, using 1D ocean model and fully-coupled models.

Antonio Ricchi, Giovanni Liguori, Leone Cavicchia, Mario Marcello Miglietta, Davide Bonaldo, Sandro Carniel, and Rossella Ferretti

Over the Mediterranean basin we can occasionally observe intense cyclones showing tropical characteristics and known as Mediterranean Tropical-Like Cyclones (TLC). Previous studies focusing on past TLCs events have found that SST anomalies play a crucial role in air-sea interaction hence controlling development of TLCs. However, given the connection between ocean mixed layer, ocean heat content and sea surface temperature, it is important to explore also the role of the mixed layer depth (MLD). In this study we investigated the role of both SST, MLD and ocean surface dynamics on development mechanisms of a recent TLC over Jonian Basin, also known as ZORBAS (2018), IANOS (2020), APOLLO (2021).

They developed due to strong positive anomalies of SST. We conducted a series of experiments using an atmospheric model WRF, driven by underlying SST (standalone configuration) with daily update or coupled to a simple mixed-layer ocean model (SLAB ocean), and using a fully-coupled atmosphere-ocean-wave model (AOW) (COAWST suite). WRF was implemented with 3 km grid spacing, forced with GFS-GDAL analysis (0.25°x0.25° horizontal resolution), while SST, MLD and ocean structure. initialization, for standalone or coupled runs, respectively, are provided by the MFS-CMEMs Copernicus dataset at 4 km of horizontal resolution. For the studied TLC, the mean MLD is modified by increasing and decreasing the depth from 5 to 100 m, removing the SST anomaly, removing SST horizontal gradient; Furthermore, the coupled AOW model was used to investigate the impact of surface circulation on mixing phenomena in the ocean and in the atmosphere, and compare their performance, and any relevance, with respect to the simplified ocean. 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. Then we identified possible past and future climatological scenarios of MLD thickness. Starting from these data, we simulated the impact of the MLD, and consequently of the Ocean Heat Content, on the TLC. In the other hands the use of the fully coupled model solves the ocean dynamics in a much more coherent way, even if the use is much more complex and the simulation times are tripled. Very similar results were found for all three investigated TLCs, despite their different intensity, structure and genesis.