COST Action CA19109 "MedCyclones"

Summary of the research initiatives

October 2024

Activities have been organized in cooperative research initiatives, each involving several participants and led by one or two coordinators. These activities have reached to a different degree of maturity and for each of them, we provide in the following a brief description of the scope, main scientific results so far and perspectives. We also highlight connections and synergies among different activities, even across the WGs.

WORKING GROUP 1

1.1 DynForMed (lead: P. Patlakas and F. Pantillon)

Aim

The initiative is dedicated to the Dynamics and operational Forecasts of Mediterranean cyclones. The main goal is to develop a prototype website with operational forecast information on Mediterranean cyclones, that is a central platform with predicted cyclone track and intensity for researchers, forecasters and stakeholders. As a reference, the National Hurricane Center delivers trajectories, intensity and categories for tropical cyclones over the North Atlantic. Currently, there is a lack of such information for the Mediterranean. The goal is not to replace weather services, but to provide a prototype platform for information on Mediterranean cyclones for scientists, forecasters, stake holders and potentially also the general public.

Scientific production

Deterministic forecasts up to 7 days ahead from 8 operational systems (from both weather services and research institutions) were provided daily by members of the DynForMed initiative and a tracking algorithm was routinely applied for cyclones over the Mediterranean up to 7 days ahead. The resulting tracks and intensities were available on the web site hosted at ETHZ (only for Action participants and password protected https://data.iac.ethz.ch/cost/), until 27 March 2024. Also, warm conveyor belts and upper tropospheric systems which are responsible for cyclogenesis, were shown on the website, together with additional forecast products (winds and precipitation) aimed to provide some hints about the impact of Mediterranean cyclones. Then, while the archive remained available on the same web site, the web site was migrated to a new server, hosted by the National and Kapodistrian University of Athens (see below).

This research initiative is thus providing an intercomparison test bed that allows participating stakeholders to assess the performance of their prediction systems with the ones of their peers through a novel framework where the quality of simulations is assessed on the basis of physical processes. It has been regarded as a first step for building a common protocols for the assessment of

weather predictions. This is a step forward compared to model assessments based on comparison of atmospheric variables since it allows a more detailed interpretation of the results.

Perspectives

This activity has built a database that can be used as a forecasting benchmark for whoever wishes to contribute and can be really valuable for operational centres willing to assess their model performance.

Recently, the web site was migrated to the National and Kapodistrian University of Athens (NKUA) where it is operational and future developments are planned in order to keep it active beyond the end of the Action:

https://medcyclones.eu/dynformed/

It is now freely accessible.

Interactive graphics have been already implemented and allow to show and compare the forecast characteristics of the Mediterranean cyclones. These enhancements are designed to create a dynamic and engaging user experience, making it easier than ever to explore and understand cyclone forecasts.

One key upgrade that took place during the migration phase is the **Composite Tracks Approach**. This enhancement involves the exploitation and implementation of the "composite tracks" methodology, a concept developed during another scientific initiative developed in the first two years of the Action and named “3T: Tracks Task Team”. This approach (for more detail see https://doi.org/10.5194/wcd-4-639-2023) aims to refine the selection of cyclone tracks by adopting only those with a high level of agreement among different cyclone tracking algorithms. This ensures that users are presented with the most accurate and reliable cyclone track information. It should be mentioned that for the operational needs of this initiative, seven tracking algorithms are adopted.

The DynForMed team is also actively exploring the addition of new features to enrich the website's capabilities. These potential additions include phase space diagrams tailored for specific cyclone cases and impact-oriented graphics. These features will provide users with deeper insights into cyclone dynamics and their potential effects, further enhancing the utility of the platform.

1.2 Model intercomparison MIP (lead: F. Pantillon and S. Davolio)

Aim

The aim of this initiative is to perform a model intercomparison for case studies of Mediterranean cyclones, in order to better understand their dynamics and predictability, which are often linked.

The rationale behind the model intercomparison is to adopt a common model setup (details provided in Deliverable 1.1) and investigate on the one hand the systematic response of changes in the representation of physical processes (e.g. convection, cloud microphysics, air-sea interactions) among a range of models and configurations; on the other hand, understanding the processes responsible for weak model performances in cyclones intensity and tracks, so to provide guidelines and priorities for model development and implementation.

Scientific production

The recent tropical-like cyclone Ianos that hit Greece in mid-September 2020 was chosen as a first case study and to prepare the technical framework of the intercomparison. Several additional

cyclones were discussed as potential case studies and will be addressed in the future by following the same procedure. About 20 participants running 5 different models and several different configurations of WRF, took part to the initiative. Two different horizontal grid-spacings, 10 km (parameterized convection) and 2 km (explicit convection), initialized from both IFS and ERA5 data at various times were adopted.
The main results were recently published on a Weather and Climate Dynamics paper:
Pantillon, F., Davolio, S., Avolio, E., Calvo-Sancho, C., Carrió, D. S., Dafis, S., Flaounas, E., Gentile, E. S., Gonzalez-Aleman, J. J., Gray, S., Miglietta, M. M., Patlakas, P., Pytharoulis, I., Ricard, D., Ricchi, A., and Sanchez, C.: The crucial representation of deep convection for the cyclogenesis of medicane Ianos, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-1105, 2024.
The main results are summarized in the following. Reducing horizontal grid spacing from 10 km with parameterized convection, to convection-permitting 2 km, further improves the cyclone track and intensity. This highlights the critical role of deep convection during the early development stage. Higher resolution enhances convective activity, which improves the phasing of the cyclone with an upper-level jet and its subsequent intensification and evolution. This upscale impact of convection matches a conceptual model of upscale error growth in the midlatitudes, while it emphasizes the crucial interplay between convective and baroclinic processes during medicane cyclogenesis.
The initiatives fostered also another collaborative analysis about physical mechanisms involved in Ianos cyclone formation, that brought to a second companion paper published on Weather and Climate Dynamics:
Sanchez, C., Gray, S., Volonte, A., Pantillon, F., Berthou, S., and Davolio, S.: How a warmer Mediterranean preconditions the upper-level environment for the development of Medicane Ianos, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-2431, 2024.
The database populated with model simulation outputs concerning Ianos case study has been exploited by WG3 ImCyCoast research initiative, to assess the response of coastal sea level (storm surge) and sea state (waves) to Mediterranean cyclones.

Perspectives
The initiative is closed, but the proposed methodology represents a suitable example to follow for the collaborative study of other events.

1.3 Medicane definition (lead: M. M. Miglietta)

Aim
The purpose of this initiative is the definition of what exactly is a "Mediterranean tropical cyclone" (TLC), aka medicane. In the literature, the term “medicane” has been adopted in different ways, depending on the purpose of the study and the tool adopted for the analysis. A commonly agreed definition is critical and necessary to assess the ability of climatological datasets to reproduce this type of cyclones, their climatology, as well as to better understand the evolution of Mediterranean cyclone categories and their related processes in a changing climate.

Scientific production

Although there is still no consensus on the definition, medicanes are generally considered to be baroclinic cyclones that evolve into vortices with structural characteristics similar to tropical cyclones, i.e. axisymmetric, deep warm core with a windless center surrounded by strong winds. After a long discussion, a scientific paper is almost ready to be submitted, and the community reached an agreement.
The definition satisfied two requirements: (i) be accommodating to previous studies (ii) be solely based on earth observations. Therefore, the following definition of medicane is proposed: a *medicane is a mesoscale cyclone that develops over the Mediterranean sea. A medicane displays tropical-like cyclone characteristics: a warm core extending until the upper troposphere, an eye-like feature in its center, a nearly windless center surrounded by nearly-closed sea surface wind circulation with maximum wind speed within a few tens of km afar*.

Perspectives
The discussion within this initiative has stimulated a number of works (published or in progress) related to the characteristics of the Medicanes, analyzed both using remote sensing tools (D'Adderio et al., 2024) and reanalysis fields (Gutiérrez Fernández et al., 2024). ERA-5 reanalyses and passive microwave sensors have been used to identify structural and morphological characteristics of Medicanes at different stages of their lifetime. On the other hand, limited area model numerical simulations are currently in progress (in collaboration with other initiatives) to further investigate mechanisms of development, using different diagnostic algorithms (surface pressure tendency, PV budget analysis). The role of air-sea interaction is also investigated exploring the role of the sea surface temperature and the structure of the ocean mixed layer.
D'Adderio L. P., G. Panegrossi, S. Dafis, J.-F. Rysman, D. Casella, P. Sanò, Fuccello A., Miglietta M.M., Helios and Juliette: two falsely acclaimed medicanes? Atmos. Res., 299, 107179, 2024; https://doi.org/10.1016/j.atmosres.2023.107179
Gutiérrez Fernández J., M. M. Miglietta, J.J. González Alemán, M. A. Gaertner, A new refinement of Mediterranean tropical-like cyclones characteristics, Geophysical Research Letters, 51, e2023GL106429, 2024; https://doi.org/10.1029/2023GL106429

1.4 Building a first inventory of cyclone simulations in convection-permitting scales (lead: E. Flaounas)

Aim
This initiative aims to provide a rich dataset of high-resolution simulations to study cyclone dynamics and impacts. Simulations at convection permitting scales were performed with WRF model adopting an innovative modelling framework that follows the cyclone during its life cycle. The simulations will not be solely limited to Mediterranean cyclones but also to other systems over the Atlantic so that comparison studies are allowed.

Scientific production
The initiative was the topic of a successful ECMWF special project (www.ecmwf.int/en/research/special-projects/spgrflao-2023) "Understanding dynamics and impacts of cyclone systems through a comprehensive dataset of convection-permitting simulations".
A dataset including a large number of cyclonea is available and already used to perform other studies.

Perspectives
The dataset already fed other research initiatives, such as the one devoted to sting jets.
Here follows a non-exhaustive list of envisaged projects or applcations:
1. Use the ensemble of simulations to understand cyclone dynamics from the perspective of a "process-wise" PV budget.
2. Use the ensemble of simulations to understand cyclone impacts across resolutions.
3. Use PV budget in extreme cyclones for Eastern Europe; Mediterranean cyclones that re-enhanced over the Black Sea; windstorms and sting jet in intense Mediterranean cyclones and diabatic contributions in developments towards flood conditions over Eastern Europe
4. Determine how the size and location of the wind footprint and the intensity, timing and location of wind gusts depends on the large-scale background environment, the classical dynamical measures of cyclone strength (e.g. vorticity, MSLP) and the type of cyclone as determined by considering its spatial structure / location on a phase diagram (potentially identified by clustering)
5. Use the ensemble of simulations to improve the understanding of the dynamics of explosive Mediterranean cyclones and medicanes
6. Use of the ensemble to better understand the role of diabatic vs baroclinic forcing in the development of Medicanes
7. Use the ensemble to assess the relative importance of different diabatic processes for the cyclone evolution using offline diagnostics
8. Use the ensemble of simulations to investigate the formation of Diabatic Vortices and whether all medicanes experience explosive deepening.
9. Use of the high-resolution dataset of simulated Mediterranean cyclones as ground truth of present climate for comparison to corresponding pseudo-global warming simulations
10. Use the ensemble of simulations to understand cyclone dynamics and to better understand the role of diabatic vs baroclinic forcing in the development of Medicanes

1.5 Sting jets (lead: A. Volonté)

Aim
The aim is to investigate the potential presence of sting jets in Mediterranean cyclones. Sting jets are mesoscale air streams present in some intense extratropical cyclones. They are rare but responsible for some of the most extreme winds measured in the mid latitudes. Sting jets have been documented in numerous cyclones over the North Atlantic but in only one case over the Mediterranean yet.

Scientific production
A dataset of 200 intense Mediterranean cyclones was analyzed and two cyclones were identified as containing near-surface strong winds associated with airstreams meeting the constraints defining the behavior of sting jets in extratropical cyclones. The Lagrangian trajectories computed for each of those 200 cyclones and available in the dataset (exploiting also the dataset of the ECMWF Special Project described above) were interrogated using a set of thresholds to identify airstream consistent with the common evolution of sting jets in mid-latitude cyclones.
The results show the potential of this ongoing analysis, with the detection in convection-permitting numerical simulations of two Mediterranean cyclones of an airstream associated with near-surface

damaging winds and an evolution consistent with that of sting jets in extratropical cyclones. However, further analysis is needed to fully elucidate the properties of these "potential sting jet" airstreams and to characterize them in the context of the dynamics of the cyclones they are part of. Are these airstreams fully consistent with the current sting jet definition or are they a Mediterranean analogue?

Perspectives

The analysis will continue through the following activities:

- Comparison against the evolution of a sting jet identified in a North Atlantic cyclone in the corresponding dataset. This activity has two aims: 1) comparing and contrasting sting jet airstreams in Mediterranean cyclones vs the much better-known North Atlantic counterparts; 2) performing a sanity check of the model settings used in this activity by looking at the evolution of a well-studied cyclone.
- Ranking of the 200 Mediterranean cyclones according to the strongest low-level or surface winds, without constraints on airstream evolution. Doing this will allow us to evaluate the relative strength of the winds associated with the "potential sting jets" against the other most intense Mediterranean cyclones.

1.6 Data Assimilation (lead D. Carrio)

Aim

The aim of this initiative is to investigate data and data assimilation procedures that could be effective in improving the forecasts of cyclone track and intensity.

Scientific production

Different types of data are indicated as promising for assimilation in the framework of cyclone simulations, in particular high spatial and temporal resolution wind observations from different platforms : radial velocities from doppler radars, surface wind from scatterometers on-board of polar satellite, atmospheric motion vectors from geostationary satellite, and also new products from SAR.

Advanced Data Assimilation techniques need to be integrated with high-resolution coupled Ocean-Wave-Atmosphere models to enhance the accuracy of (tropical-like) cyclones forecasting. Some preliminary activities along this line have started, considering some specific case studies and testing the assimilation of high-resolution scatterometer surface wind observations (ASCAT) over the sea at the beginning of cyclone life cycle, to improve the initial conditions. Also, further simulations were conducted by assimilating ASCAT observations together with conventional in-situ observations (e.g., radiosondes, maritime buoys). The refined analysis from these assimilations was then used to further enhance the coupled model's performance.

Perspectives

Investigate the role of Data Assimilation and the different coupling levels on tropical-like cyclones, particularly focusing on elements with low predictability, such as cyclone trajectory and precipitation, is considered extremely relevant. In fact, as demonstrated in the MIP Initiative, the correct simulations of processes and of trajectory is strongly correlated. Moreover, if the simulated tropical-like cyclone follows a different path than the observed one, it interacts with different sea

water masses, significantly affecting air-sea interaction, heat and moisture fluxes, and consequently precipitation patterns.
Since the accurate simulation of the trajectory is crucial to investigate the role of air-sea interactions within the extremely complex marine environment, further steps have been already planned. It is planned to adapt the assimilation to both Coupled Atmospheric-Ocean and Atmospheric-Ocean-Wave simulations, and to progressively add data to be assimilated, ASCAT, conventional and atmospheric motion vectors.

WORKING GROUP 2

2.1 MedCyClass - Mediterranean Cyclone Classification (lead: S. Raveh-Rubin)

Aim
The purpose of this initiative is to classify Mediterranean cyclones to categories based on the governing processes that lead to their development. This activity represents the main research initiative carried out in the framework of WG2 and has been carried out by a team efforts of more than 20 researchers.

Scientific production
Upper-tropospheric forcing is known to govern cyclogenesis. While considered at the timing of maximum cyclone intensity, diabatic mechanisms often strongly enhance cyclone deepening and modulate its subsequent development and impact. In the first phase, to classify cyclones into categories based on these processes, diagnostic data, including identified feature-based products from members who joined the initiative were collected in a common database. A detailed description of the dataset is available in Deliverable 2.1.
The classification of the full dataset, for the years 1979-2020, was carried out based on the composite tracks data delivered by the MecCyclones Tracks Task team (3T) initiative (see below). These tracks have been classified into different clusters according to the upper tropospheric conditions (i.e. the precursor of cyclogenesis). The analysis performed is based on the use of ERA5 reanalysis, which may be considered as "observations" for the needs of analysing cyclone dynamics and as such are detailed enough to consider potential-vorticity-based diagnostics, and Lagrangian feature identification. More precisely, cyclone tracks at the time of cyclones mature stage were classified according to the morphological shape of the trough that initially triggered cyclogenesis. Based on the potential vorticity distribution in the cyclones environment, we have classified all ~3600 cyclones into 9 categories using a self-organizing maps algorithm. The categories represent the range of Rossby wave breaking patterns, as well as heat lows and strongly diabatically-influenced cyclones.
The classification algorithm of potential vorticity in an isentropic layer using the self-organizing maps, is available on the Action website.
Results have been presented at several conferences, and a scientific paper has been published on Weather and Climate Dynamics (Copernicus Ed):
Givon, Y.; Hess, O.; Flaounas, E.; Catto, J. L.; Sprenger, M.; Raveh-Rubin, S. Process-based classification of Mediterranean cyclones using potential vorticity, Weather and Climate Dynamics, 5, 133–162, https://doi.org/10.5194/wcd-5-133-2024, 2024.

The classification of Mediterranean cyclones has been already exploited in two studies dealing with compound extreme and weather hazard, recently published on Weather and Climate Dynamics:
Portal, A.; Raveh-Rubin, S.; Catto, J. L.; Givon, Y.; Martius, O. Linking compound weather extremes to Mediterranean cyclones, fronts, and airstreams. Weather and Climate Dynamics, 5, 1043–1060, https://doi.org/10.5194/wcd-5-1043-2024, 2024.
Rousseau-Rizzi, R.; Raveh-Rubin, S.; Catto, J.L.; Portal, A.; Givon, Y.; Martius, O. A storm-relative climatology of compound hazards in Mediterranean cyclones. Weather and Climate Dynamics, 5, 1079–1101, https://doi.org/10.5194/wcd-5-1079-2024, 2024.

Perspectives

An outstanding issue intricately linked to cyclone classification is the role of air-sea interaction in cyclone deepening. To this end, in a recent study initiated within a Virtual Mobility Grant, the composite cyclone track dataset (Flaounas et al. 2023) has been applied, classified into the Mediterranean basin-wide and year-round 9 categories (Givon et al. 2024). Ocean evaporation data from ERA5 have been classified, aiming to categorize air-sea interaction under Mediterranean cyclone conditions. Composite quantification of air-sea interaction by cyclone class has been obtained. The results of this work provide new insight on the association of ocean evaporation to cyclones from cyclone-centred (Lagrangian) perspective, as well as from a geographically-fixed view. Using cyclone attribution to the ocean variables and composite approaches, strong variability of surface fluxes by cyclone class has been found.

An additional outstanding challenge is to understand why, where and when cyclones develop catastrophic, convective storms. From the perspective of cyclone dynamics, a cyclone might be initially formed by upper tropospheric disturbances (i.e. exterior processes to the cyclone), but its development and intensification are tuned by convection (i.e. processes internal to the cyclone system). In turn, convection is also tuned by sea surface temperatures (SST), the proximity of cyclones to orography, the degree that large scale ascent is favorable for further development and other factors. Therefore, a further analysis of the 9 cyclone categories will be undertaken in light of the emergence of convection in the vicinity of the cyclones. Both upper tropospheric disturbances and convection will explain in large the processes that synergistically develop cyclones into catastrophic storms. First results in this direction indicate that mid-tropospheric diabatic heating occurs preferentially in certain clusters and almost absent from others, suggesting that upper-tropospheric forcing and convection are not independent factors.

Another critical perspective of this research initiative concerns the application of the classification tool to both operational forecasting models and to climate simulations already produced and available by other projects (e.g. IPCC simulations). In terms of numerical weather forecasting, our future goal is to automatically assign imminent cyclones to specific clusters, whereas in terms of climate simulations, our goal is to assess the similarity of cyclones climatology with the reanalysis of ERA5. This is a challenging step, since it will be necessary to infer the cyclone category with only partial availability of atmospheric data, compared to ERA5. For example, this requires to develop a conceptual approach for attributing cyclones to categories based on their geopotential height field at selected pressure levels only (see also Deliverable 2.2 for more details).

2.2 3T - MedCyclones Tracks Task Team (lead: E. Flaounas)

Aim

A key and critical issue in verifying forecasts of Mediterranean cyclones concerns the identification of cyclone tracks, since it is very sensitive to the tracking algorithm. As a consequence, there is no reference dataset of tracks for Mediterranean cyclones such as for tropical cyclones. Moreover, all cyclone tracking methods have limitations which are outcomes of the diagnostics used to identify cyclone centres in gridded datasets and track them in time. This initiative has a twofold objective: first to combine a wide number of cyclone tracking methods in order to provide a climatological "best tracks" dataset and second, to develop a methodology that performs daily tracking of cyclones, applied to forecast simulations.

Scientific production

A group of about 20 participants contributed with 10 different cyclone tracking methods. E. Flaounas developed a new tool that combines the cyclone track outputs from different tracking methods and rejects the ones that were only identified by single methods.

First, for a rather short target period of one month (September 2006), it was demonstrated that the new tool was able to reject a high number of "bogus" tracks. Most of these tracks were artifacts of the tracking methods and did not correspond to organized mesoscale vortices. As a result, the tool was shown to be promising for reasons of operational forecasting and for providing a climatological dataset of cyclone tracks.

In the second phase, the methodology was applied to a 42-year climatology derived from ERA5 in the period 1979-2020. Results confirmed the capacity of combined cyclone tracking methods in providing a climatological dataset that reduces dramatically "bogus tracks" and includes all major cyclone cases in the region.

Therefore, the 3T research initiative has developed a new diagnostic tool that combines different cyclone tracking methods provided by the participants in order to produce a common cyclone tracks dataset. This "best tracks" dataset is composed only by composite cyclone tracks that concentrate the agreement of ten different cyclone tracking methods. Therefore, the final product of 3T concerns the “best” outcome of combined cyclone tracking tools and provides also a confidence level of the tracks. This methodology allows to overcome the known lack of consensus among different cyclone detection and tracking methods that has jeopardized the production of a commonly accepted reference dataset of extratropical cyclone tracks.

The dataset has been released together with a paper published on Weather and Climate Dynamics:

Flaounas, E., Aragão, L., Bernini, L., Dafis, S., Doiteau, B., Flocas, H., Gray, S. L., Karwat, A., Kouroutzoglou, J., Lionello, P., Miglietta, M. M., Pantillon, F., Pasquero, C., Patlakas, P., Picornell, M. Á., Porcù, F., Priestley, M. D. K., Reale, M., Roberts, M. J., Saaroni, H., Sandler, D., Scoccimarro, E., Sprenger, M., and Ziv, B.: A composite approach to produce reference datasets for extratropical cyclone tracks: application to Mediterranean cyclones, Weather Clim. Dynam., 4, 639–661, https://doi.org/10.5194/wcd-4-639-2023 , 2023.

Perspectives

The initiative is closed and the dataset available, together with the paper. Given the advantage of the developed methodology in producing cyclone tracks with physically meaningful, distinctive life stages and including a minimum number of bogus tracks, the composite tracks is proposed as reference datasets for climatological research in the Mediterranean.

Applications of the dataset are ongoing and foreseen in many activities, since the method can be applied to operational forecasting, tailored to the needs of WG1 (e.g DynForMed initiative), but also to any gridded dataset for climatological purposes and impact studies.

2.3 MedCPM - MedCyclones in convection-permitting models (lead: S. Berthou)

Aim

The purpose of the initiative is to analyse Mediterranean cyclones in a set of hindcast simulations first and then in future simulations at km-scale resolution with explicit convection. Such simulations are increasingly available (e.g. CORDEX FPS - Convection over the Alps and H2020 EUCP simulations) for at least part of the Mediterranean.

Scientific production

Four simulations are already available for the Mediterranean by members of the Action participating in this initiative: (i) GUF COSMO (MedCordex 3km; 10y); (ii) Météo France AROME (Western Med; 30y); (iii) MOHC-HadREM3 2.2km (REU-3 domain; 20y); and (iv) Uni. C. Louvain: WRF (30y).

As a first step a common tracker (Aragão & Porcù (2021) algorithm) was adapted to km-scale resolution and run on the Met Office HadREM3-2.2km hindcast simulation. Analysis of the resulting cyclone tracks shows 84% matching of the tracks compared to ERA-5, for cyclones with central pressure lower than 1000 hPa.

Perspectives

A recent STSM grant supported Lisa Bernini visit to the Free University of Berlin. The research will exploit a convection-permitting dataset to (i) determine potential feedback explaining the increase in frequency and strength of convective precipitation over land; (i) identify differences in the origin of precipitation associated with Mediterranean extratropical cyclones and tropical-like cyclones. This would give some insight into the physical processes leading to the development of this latter category and increases our understanding on how explicitly simulating convection affects different types of Mediterranean cyclones.

2.4 Mediterranean cyclones in regional climate simulations (lead : T. Plotnik and A. Hochman)

Aim

This initiative aims to create a useful Mediterranean cyclone tracks composite dataset using Climate Models that will be made available to the Action community. Data of surface pressure and relative vorticity at 850 hPa, taken form a large ensemble of simulations from the CMIP6 projects and from ERA5 reanalysis, have been shared server in a uniform format. All participating algorithm developers have been able to run their tracking algorithms, following a common protocol. The data cover the period 1979-2015 and from 2050-2100 and include the entire northern hemisphere

Scientific production and perspective

The research activity is still ongoing and has plan for continuation after the end of the Action. Once we obtain all tracks, we will build on Flaounas et al. (2023) track composite protocol to create the tracks dataset. There are a few important considerations before the actual work starts. These directly link to the needs of the different groups in the COST-MedCyclones community. For example, which models fit best depending on the availability of data, temporal and spatial resolution, scenarios, adequacy of GCM for the Mediterranean climate, and more. For the historic scenario an ERA5 based tracks will be used to evaluate the CMIP6 based results. By interpolating the ERA5 to fit the same resolution of 1-degree and 6-hourly CMIP6 data we will show how CMIP6 sub-models represent the atmosphere. The tracks extracted for the interpolated ERA5 will be also compared with the former results. This comparison will present an insight on how change in spatial and temporal resolution may have affected on the algorithms ability to identify Mediterranean cyclones. Preliminary results already show difference in detection depending on the main variable used in the cyclone detection and tracking methods, sea level pressure, surface pressure or potential vorticity at 850 mb. The initiative will continue with the COST-ACTION “Future-Med”.

WORKING GROUP 3

3.1 ImCyCoast: Impact of cyclones on the sea state and coastal flooding (C. Ferrarin)

Aim

The ImCyCoast initiative exploited the simulation dataset available in WG1 (Model intercomparison initiative - MIP) to investigate the response of coastal sea level (storm surge) and sea state (waves) to Mediterranean cyclones. For an intense Mediterranean tropical-like cyclone (Ianos, September 2020), the atmospheric model ensemble was used as a forcing for coupled hydrodynamic-wave models to evaluate the uncertainty associated with the cyclones impacting the coast and to characterize the impact of Mediterranean cyclones accounting for the combined action of storm surge and waves.

Scientific production

The probabilistic approach, developed through the application of an ensemble of numerical experiments, provided insights into model uncertainty when resolving storms and into the limits of the probabilistic forecast of impacts. The ensemble mean and spread were used for defining sea level and wave hazard scenarios. To provide an overview of the expected potential hazard and its uncertainty associated with Ianos, the temporal maximum values of the sea level and the significant wave height computed using the ensemble mean and spread were used. The combined use of meteorological and ocean models enabled the analysis of extreme sea conditions.
This methodology and the results are described in detail in a paper published on Natural Hazards and Earth System Sciences:
Ferrarin C., F, Pantillon, S. Davolio, M. Bajo, M. M. Miglietta, E. Avolio, D. S. Carrio, I. Pytharoulis, C. Sanchez, P. Patlakas, J. J. Gonzalez-Aleman, E. Flaounas, 2023: Assessing the coastal hazard of medicane Ianos through ensemble modelling. Nat. Haz. Earth Syst. Sci., 23, 2273-2287.

Perspectives

The initiative is closed. However, beyond the specific results of this single case study and given the large model uncertainty associated with the reproduction of extreme meteo-marine events, the proposed ensemble approach represents a methodology that can be adopted for providing very useful information on flood risk management plans. The different simulations are combined to extract the ensemble mean and standard deviation (spread) used for outlining hazard scenarios. These simulated hazard conditions represent a fundamental component of the coastal risk assessment to be combined with the vulnerability and exposure of the specific coastal segment.
It is worth noting that every coastal location has site-specific flooding and damaging thresholds which depend on the coastal morphology and storm defenses. Therefore, the hazard scenarios of sea levels and waves could be extracted for particular coastal locations and used in combination with threshold levels.
Finally, the multi-model / multi-physics approach can be easily extended to operational forecasting for providing in advance information on the coastal areas potentially affected by hazardous sea conditions. The ensemble results can be used to develop dynamic flood maps of specific coastal areas, thus forecasting the potential flood impact of such extreme phenomena.

3.2 Review on the socio-economic impacts of Mediterranean cyclones (lead: S. Khodayar)

Aim
This initiative aims to review existing knowledge regarding the socio-economic impacts of Mediterranean cyclones, focusing on particularly vulnerable sectors in the region. As a result of this effort, knowledge gaps, as well as the vulnerability of the main societal sectors are identified. The overarching goal of gathering knowledge on the socio-economic impacts of Mediterranean cyclones is to inform decision-makers on the state of the art, thus contributing to the creation of resilient communities in the face of climate change contributing to future development beyond the current state of expertise in this topic.

Scientific production
A fruitful collaboration between experts from different disciplines has allowed for an exhaustive analysis of the state of the art in relation to existing knowledge regarding the socio-economic impacts of Mediterranean cyclones with focus on the main affected sectors in the Mediterranean region. This collaborative work led to the submission of a scientific paper to a renowned journal, Reviews of Geophysics and its preprint is currently available online:
https://doi.org/10.22541/essoar.172202069.91367609/v1
Khodayar,S.; Kushta,J.; Catto,J.L.; Dafis,S.; Davolio,S.; Ferrarin, C.; Flaounas, E.; Groenemeijer,P.; Hatzaki, M.; Hochman, A.; Kotroni,V.; Landa,J.; Láng-Ritter,I.; Lazoglou, G.; Liberato, M.L.R.; Miglietta, M.M.; Papagiannaki,K.; Patlakas, P.; Stojanov,R.; Zittis, G. Mediterranean cyclones in a changing climate: a review on their socio-economic impacts, ESS Open Archive, 2024.

Perspectives
In the context of the growing destructiveness inflicted by Mediterranean cyclones, the understanding of Mediterranean cyclones and particularly their impacts is of pivotal relevance.
This work contributes to future development beyond the current state of expertise by identification of knowledge gaps, as well as the vulnerability of the main societal sectors. The overarching goal of this effort is informing decision-makers on the state of the art, thus contributing to the efficient

design of responses toward climate change impacts and the creation of resilient communities in the face of climate change.

3.3 Preparation of an impact database in the Mediterranean (lead: S. Khodayar)

Aim

This initiative aims at creating an open-access freely available databases of weather hazards and associated impacts in the Mediterranean Basin. This effort aims to cover stakeholders needs, by filling one of the major knowledge gaps in the field. The main goal of this initiative will be achieved through the collection of existing relevant regional and local databases across Mediterranean countries into a reference database, which will serve as an info tool for stakeholders and targeted audiences. Access to data or related links will be made available to stakeholders and the public.

Scientific production

Despite the growing interest in understanding Mediterranean cyclones' impacts, there is a lack of systematic quantification of their contribution to Mediterranean socio-economic losses due to the complex and currently under-addressed hazard-risk processes related. Furthermore, operational databases of weather hazards and related impacts are useful because they provide essential information about past and current weather-related impacts on societies. Thus, the benefit and value of operational databases of weather hazards and related impacts are unquestionable allowing a deeper understanding of trends and threats. Given the increasing number of datasets worldwide, and in the Mediterranean, a harmonization of selection criteria and datasets would be desirable to facilitate data processing and to draw robust conclusions.

Perspectives

This initiative contributes to the fulfilment of one of the main research gaps for a better understanding of the impacts of weather hazards in general and Mediterranean cyclones in particular. This can be helpful in the research and analysis of the characteristics of different types of weather hazards, the trends and patterns in their occurrence, and the variability of impacts on diverse populations and regions. Additionally, this tool suite will help identify potential risk factors and vulnerabilities and develop strategies for reducing the likelihood and severity of associated impacts.

In the devastating aftermath of recent severe events, such as Ianos and Daniel Mediterranean cyclone storms, it becomes clear that reporting, recording and processing historical hazard and risk data is crucial in developing adaptation measures, in response to the impacts, and establishing long-term climate change mitigation strategies for sustaining a viable environment in the Mediterranean.

The development of this reference database is considered a living work that will prevail, continue and be completed after the end of the Medcyclones action. This work and the community created around this tool will continue in the FutureMed COST action (CA22162) that started in 2023. This will allow us to keep alive, updated, and even extend the proposed database for the benefit of the Mediterranean society.