COST Action CA19109 "MedCyclones" – Working Group 3

Deliverable D3.2

Documentation addressed to stakeholders, on proposed new products on cyclone impacts, tailored to the needs of stakeholders (to be constantly updated).

First Release: November 2022
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The review paper (as planned in Deliverable 3.4) was finally submitted to 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.
The paper categorizes the impact-based applications and sectors that would benefit from an efficient co-definition and co-design of needs. Further, this work reviews 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 and 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 creating resilient communities in the face of climate change.

At present, the Action activity has delivered several products and results that are being used for assessing cyclone impacts. These will be described in more detail below.

Best Cyclone Track database

The Tracks Task Team (3T), a research initiative in MedCyclones led by Emmanouil Flaounas, 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 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.
In fact, in contrast to tropical cyclones which are clearly distinguishable from their environment and tend to present a single cloudless center, extratropical cyclones have a complex morphological nature, varying in size and shape, possibly with several centers within the vicinity of their single meso-to-large scale cyclonic circulation. This makes the tracking very difficult, and this is even more challenging for Mediterranean cyclones, due to their frequent proximity to complex geographical features such as abrupt land-sea transitions and the long mountainous chains that surround the Mediterranean Sea. These geographical features perturb the atmospheric fields which are used as input datasets to cyclone detection and tracking methods. Therefore, these methods tend to produce a significant number of bogus tracks that jeopardize the robustness of climatological results.
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 have been proposed as reference datasets for climatological research in the Mediterranean.
All composite cyclone tracks for different confidence levels are provided in the form of ASCII files. (the tracks dataset has been also submitted to ETH Research Collection for DOI attribution and approval). For each confidence level, we provide a separate file that includes a matrix of eight columns and a number of rows that varies among the datasets. Each row corresponds to a single track point, while the eight columns provide the following information:
- Column 1: A cumulatively increasing index that functions as an identifier of unique cyclone tracks.
- Column 2: Longitude of track points.
- Column 3: Latitude of track points.
- Column 4: Year of occurrence.
- Column 5: Month of occurrence.
- Column 6: Day of occurrence.
- Column 7: Hour of occurrence.
- Column 8: Lowest MSLP value (in hPa) within a 2.5 degrees radius from the geographical coordinates in columns 2 and 3 (approximate reference of intensity).

Considering the use of the dataset for scientific research and applications, it is worth pointing out that composite tracks of high confidence levels has the advantage of concentrating the agreement of many tracking algorithms and includes more intense systems. This reduces the potential of including bogus tracks (i.e. shallow, non-well organized systems). However, the shortcoming is the likelihood of omitting cyclone tracks that did actually occur but were not tracked by an enough high number of algorithms. Therefore, to adopt composite tracks as a reference dataset, one needs to consider a trade-off between "robustness" and "completeness" of the final dataset.
Such a dataset is now available and represents in the Mediterranean the starting point for cyclone impact studies.
The following paper was published on Weather and Climate Dynamics (Copernicus Ed):
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.

The DynForMed Initiative and the forecast website

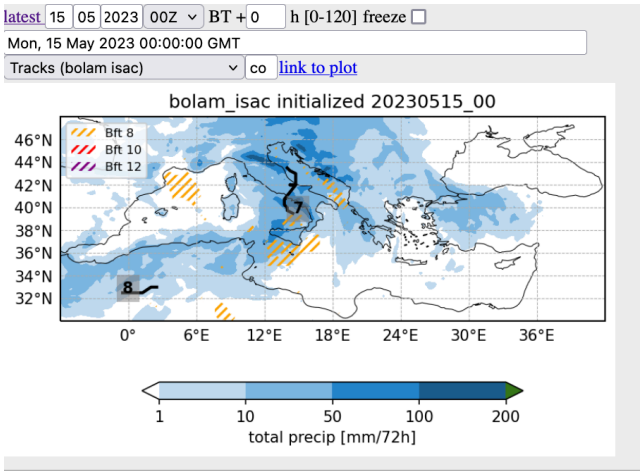
DynForMed is a significant community effort that aims to develop a prototype website providing operational forecast information on Mediterranean cyclones. The primary goal is to offer a central platform that predicts cyclone tracks, intensities and impacts tailored to the needs of researchers, forecasters, and stakeholders. Currently, the absence of centralized and reliable cyclone information in the Mediterranean region often leads to confusion and challenges in decision-making processes.

Over the years, the DynForMed website has undergone significant development efforts to enhance its usability and utility. In particular, the inclusion of impact-related data on the maps has been a notable improvement. Users can now easily identify regions possibly experiencing intense precipitation and strong winds, providing valuable insights for decision-makers and the public.

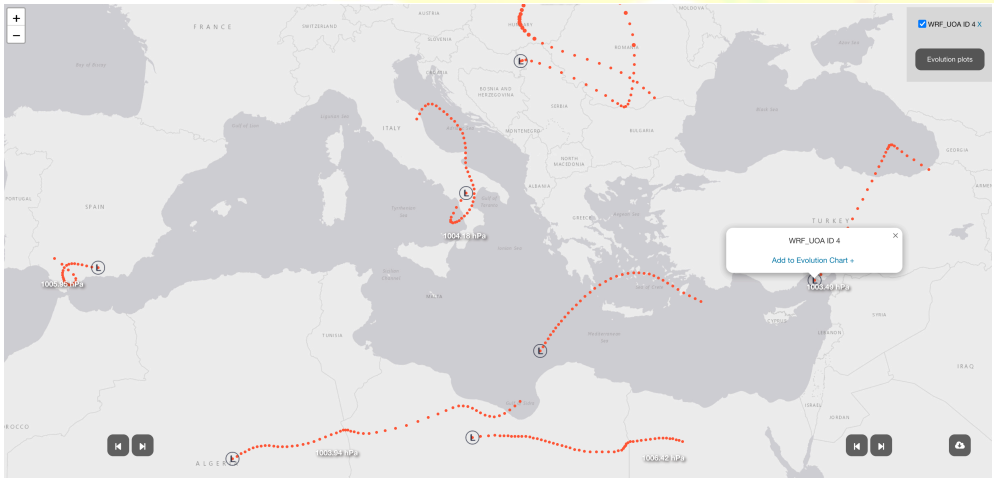
It is worth stressing that this web site is not considered to replace National Weather Service (NWS) duties. On the contrary, it aims at being an additional useful tool to be used to a variety of users, including NWS, based on the most advanced scientific achievements provided by the networking research activities carried on by the Cost Action.

The DynForMed prototype page has been accessible through an internal website hosted by ETHZ:
https://data.iac.ethz.ch/cost/

The web site still includes an archive of forecasts and analysis from different modelling systems, including impacts:



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/



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. The DynForMed team is also actively exploring the addition of new features to enrich the website's capabilities, especially to insert impact-related information.

Hazard scenarios of the potential impact of an extreme event (medicane) for flood risk management plan

The ImCyCoast (Impact of cyclones on the sea state and coastal flooding) initiative is led by Christian Ferrarin and it has exploited the simulation dataset available in WG1 (Model intercomparison initiative) to investigate the response of coastal sea level (storm surge) and sea state (waves) to Mediterranean cyclones.
In particular, 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. 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.
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.
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.

Building a first inventory of cyclone simulations in convection-permitting scales

This initiative aims at understanding dynamics and impacts of cyclone systems through the creation of a unique comprehensive dataset of very high spatial resolution (convection-permitting) cyclone simulations. Researchers working on cyclone dynamics, but also stakeholders interested in weather impacts, have a constantly increasing need to acquire climatological simulations and associated knowledge of cyclones at high resolutions. Such a climatological dataset would provide diagnostics about processes and impacts that cannot be explicitly resolved, or that are not available in reanalysis.
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 cyclones is available and already used to perform other studies.
A large ensemble of simulations has been produced for a wide number of cyclones in the Euro-Atlantic domain, giving priority to cyclones making landfall in Europe. Therefore, this project is expected to substantially promote our understanding of cyclone dynamics and in parallel, to provide deeper insights into the link between atmospheric dynamics and the impacts delivered by precipitation, wind and the sea state.

Reference database on Medcyclone-related impacts

In an effort to cover stakeholders needs, by filling one of the major knowledge gaps in the field, we have initiated the creation of a reference database of weather hazards and associated impacts in the Mediterranean Basin.
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. By doing so, we will contribute 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.

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.

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. WG3 highlighted these aspects also in a newsletter/report issued after Daniel, summarizing its phases and documenting its impacts in various stages. The report concluded that such high-impact events make evidence of the necessity to develop adaptation measures in response to the impacts and establish long-term climate change mitigation strategies as vital steps of utmost importance for sustaining a viable environment for the Mediterranean. The detailed document can be found at https://medcyclones.eu/wp-content/uploads/2023/09/MedCyclone_Daniel_v2.pdf

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, update, and even extend the proposed database for the benefit of the Mediterranean society.

Collaborative study of cyclone Daniel

Storm Daniel has been probably the deadliest single weather event in Africa, it has produced important damages in Greece and Libya and has attracted the interest of worldwide mass media. The storm affected the two countries during different stages of its lifetime: during cyclogenesis and at the mature stage of the storm

Our paper comes almost exactly a year after the occurrence of Daniel and after a long and insightful collaboration among many members of the Action. Combining different expertise and adopting a holistic approach, we finally devised this paper that covers many aspects of the event: from its dynamics to the impacts and the attribution to climate change. We show that implicated dynamics are different and that leads to different predictability of the whole event. We also demonstrate a unique approach that places the cyclone as a centerpiece of an analysis that articulates between atmospheric dynamics, weather forecasting, climate extremes, predictability of impacts (floods) and their attribution to climate change. We also consider the sea state and the predictability of significant sea wave extremes. Overall, this paper demonstrates an integrated approach that could be followed to any high-impact weather event.

The paper has been submitted recently to Weather and Climate Dynamics (Copernicus Ed), an open access journal with high impact factor that will ensure a wide dissemination of the results. At present, the paper is in open discussion:
Emmanouil Flaounas, Stavros Dafis, Silvio Davolio, Davide Faranda, Christian Ferrarin, Katharina Hartmuth, Assaf Hochman, Aristeidis Koutroulis, Samira Khodayar, Mario Marcello Miglietta, Florian Pantillon, Platon Patlakas, Michael Sprenger, and Iris Thurnherr: Dynamics, predictability, impacts, and climate change considerations of the catastrophic Mediterranean Storm Daniel (2023), submitted to Wea. Clim. Dyn., 2024.