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Title: **European network for Mediterranean cyclones in weather and climate**

Acronym: **EUNETMEC**

Summary

Cyclones are the main weather modulators in the Mediterranean region and constitute a major environmental risk, often producing windstorms and heavy rainfall. Moreover, cyclones play a key role in the regional climate variability by controlling the oceanic circulation and regional water cycle, and by mobilizing and transporting large amounts of dust from North Africa.

Despite the recent achievements of the scientific community to provide deeper insight into the atmospheric processes and impacts associated with Mediterranean cyclones, there are still unaddressed scientific challenges that require a coordinated approach. In addition, the lack of direct interaction between academic researchers and weather/climate prediction scientists working in operational centres inhibits the efficient exploitation of fundamental research results to improve atmospheric models in a tangible way. Therefore, it is undeniable that there are potentially large societal benefits from improving cyclone predictions for weather to seasonal and climate timescales.

Efficient networking between stakeholders, operational weather forecasters and researchers is timely and essential to address both challenges of research coordination and operational implementation of scientific results into weather and climate services. This Action will coordinate the activities of researchers in meteorology and climatology and scientists from weather/climate services with the main aims to provide a deeper understanding of Mediterranean cyclones and to improve significantly the European capacity to predict their environmental and climate impacts. In this context, the network will identify, and involve in the network, relevant stakeholders with different backgrounds (e.g. civil protection, re-insurance companies) and co-develop cyclone prediction products tailored to their needs.

Key Expertise needed for evaluation

Earth and related Environmental sciences
Meteorology, atmospheric physics and dynamics
Earth and related Environmental sciences
Climatology and climate change
Environmental engineering
Risk assessment, prevention and mitigation

Keywords

Cyclones

High-impact weather

Climate variability and extremes

Weather prediction

Environmental risks

TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1. CHALLENGE

1.1.1. DESCRIPTION OF THE CHALLENGE (MAIN AIM)

The Mediterranean is a unique region, lying between the arid zone of North Africa and the North Atlantic storm track. It possesses a complex geography characterized by a relatively narrow and nearly closed sea surrounded by high mountains and abrupt land-sea transitions. For such a relatively small region, *cyclogenesis* (the formation of cyclones) is frequent, with cyclones producing the majority of high-impact weather in the basin. In fact, several of these Mediterranean cyclones have attained wind intensities comparable to those of named Atlantic hurricanes. The recent storm "Rolf" – a tropical-like cyclone that occurred in November 2011 to the south of France – caused fatalities and severe damage due to wind gusts of more than 40 m s^{-1}, sea waves that exceeded 6 m, and heavy rainfall that locally reached exceptionally high 6-day accumulated values of about 1000 mm. Beyond their primary impact on local weather extremes, Mediterranean cyclones influence the regional and global climate. These systems are responsible for mobilizing and transporting large amounts of dust from North Africa towards Europe, as well as for significantly contributing to the marine and atmospheric water budgets of the Mediterranean basin. As such, Mediterranean cyclones pose major environmental risks and act as climate modulators that affect more than 480 million people on three continents.

The complex regional geography and broad spectrum of atmospheric processes involved with Mediterranean cyclones render the accurate simulation of these storms by means of atmospheric models a very challenging task. This limited predictability has important implications for both weather forecasters and climatologists. Significant contributors to this problem are the complex atmospheric thermo-dynamical processes that occur across multiple spatial and temporal scales, and with significant nonlinear interactions among them, all of which need to be realistically reproduced by the models for accurate predictions. In the scientific literature there is a general consensus regarding the main processes essential to cyclone life cycle, although they act in different measures for different classes of events: (a) baroclinic instability, (b) air-sea interaction, (c) moist convection, (d) orographic interaction, (e) direct and indirect effects of aerosols, and (f) tropical/subtropical transition of baroclinic lows (i.e. the synergy of convection with baroclinic instability that may turn a Mediterranean cyclone into a tropical-like storm). Especially in climate studies, uncertainties in resolving these processes may lead to significant divergence of cyclone climatologies among models (e.g. Flaounas et al., 2016). This is a major issue for climate studies in a region that is highly responsive to climate change (Giorgi, 2006) and where risk related to cyclones is expected to significantly increase in the future (e.g. Romero and Emanuel, 2013).

In addition to generating high-impact weather and climate extremes, Mediterranean cyclones have been shown to modulate indirectly different aspects of the regional climate. However, these cyclone-related impacts on regional climate are currently only poorly understood by the scientific community. Therefore, research activities on Mediterranean cyclones need to prioritize the development of new understanding of processes including: (a) transport of dust from North Africa towards Europe; (b) troposphere-stratosphere interactions, especially through the convective overshooting, usually occurring in the vicinity of cyclones; (c) impacts of cyclones on the Mediterranean Sea circulation and deep water formation; and finally, (d) cyclones' impact on the regional water cycle and transport of

water into and out of the Mediterranean. Especially themes (a) and (b) concern processes of high importance for global climate, as they have been identified as major sources of uncertainties in future climate projections.

Realizing the great societal benefits of effectively forecasting high-impact weather and predicting regional climate variability and extremes largely relies on the accurate modelling of cyclone-related physical processes. This is a fundamental issue regardless of the specific time scale considered, from weather forecasts to seasonal and decadal predictions, to climate projections. However, the recent efforts of the scientific community to understand the atmospheric processes that govern Mediterranean cyclone dynamics lack coordination and the focus needed to improve cyclone predictions in a tangible way. In addition to scientific issues, all these research results have to be understandable by, and appealing to end users and stakeholders, including public and private entities interested in forecasts (e.g. civil protection, insurance companies). Therefore, **this Action tackles the overall challenges of (1) coordinating scientific efforts, (2) making research results directly applicable to cyclone prediction, and (3) enabling novel services tailored to stakeholder needs**.

To address these challenges, this Action will provide a nucleus around which knowledge from European experts concerning Mediterranean cyclones can coalesce. It does so by **bringing together researchers specialized in meteorology and climatology,** as well as **professionals involved in weather and climate predictions, within a structured network.** This network will benefit from the participation of international experts specialised in other cyclonic systems such as mid-latitude storms and tropical cyclones. Therefore, this Action will function as an ideal platform for weather and climate centres to exchange modelling skills, expertise and observations as well as to exchange with end users (stakeholders and the general public). It will also manage short-term scientific missions (STSM) and training schools to ensure long-lasting collaborations between the different participating communities. Improving the connections between researchers from the disciplines of climate, meteorology and atmospheric physics, forecasters from weather and climate services within a structured network is the foundation for effective coordination that will promote the development of ground-breaking research that improves cyclone prediction, and set an agenda for the future challenges in the field.

1.1.2. RELEVANCE AND TIMELINESS

In recent decades, the major scientific achievements in the field of Mediterranean cyclones have been attained through international coordinated programmes, mostly endorsed by the World Meteorological Organization (WMO). Such programmes brought together meteorological researchers and forecasters (e.g. ALPEX in the 80s; MAP and MCP in the 90s; and MEDEX in 00s). More recently, research interest has moved towards longer time scales (e.g. MedClivar, MedCORDEX) of direct relevance to climate scientists. At present, a coordinated international effort to exploit the synergistic potential of bringing together different research activities in the field of Mediterranean cyclones is missing. Instead, projects are organized at the national level and are thematically relatively narrow. In addition, the latest research progress has been largely achieved in an uncoordinated way, through the use of a large variety of modelling and/or observation-based approaches, mostly applied to case studies. It is thus of no surprise that the direct implementation of the diverse results into atmospheric models is a rather difficult task, and currently cannot meet the constant demand from weather and climate centres for credible cyclone predictions. It is the lack of scientific coordination that inhibits the advancement of applied science for the benefit of society, economy and civil protection. The current strategy does not do justice to the importance of Mediterranean cyclones in producing weather extremes and modulating the regional climate.

Beyond scientific research, cyclone prediction is not equally effective among the different European institutions (e.g. Bertotti et al., 2012). The origin of this inequality may be related to differences in infrastructures and/or human resources, but is also related to unbalanced expertise and use of state of the art numerical tools or modelling approaches. Therefore, networking between European institutions is a timely proposition and the ideal means for fostering the exchange of numerical tools and expertise in order to achieve improvements in performance with no additional infrastructure costs. Such a network can produce added value through both intra-Mediterranean collaboration, and collaboration with weather and climate centres across Europe. Indeed, the relatively small community of scientists dedicated to Mediterranean cyclones may benefit hugely from the expertise of different communities working on different cyclone categories outside the Mediterranean (e.g. tropical cyclones, extratropical storms, polar lows, diabatic Rossby waves). Moreover, Mediterranean cyclones are relevant also for countries outside the Mediterranean basin, since they significantly influence weather and climate in

central Europe (e.g. by triggering heavy precipitation and major flood events in Central Europe, as Elbe flood in 2013), African and Asian areas (e.g. due to dust or water vapour transport).

The current lack of international coordination in this important field, the need to channel new and already acquired knowledge to prediction models, together with the exploitation of new datasets (such as the new ERA5 reanalysis and CMIP6 climate simulations) make this Action exceptionally timely for harmonising and advancing weather and climate prediction capabilities in Europe and for significantly promoting the excellence of European research. Most important, this Action is designed to contribute significantly to four out of five priorities (except improving infrastructures) for weather and climate research as agreed by more than 50 countries, that will be announced to the 2019 World Meteorological Congress: deliver science for services, build seamless models, nurture a diverse workforce, and share ideas with stakeholders (Hov et al., 2017).

1.2. OBJECTIVES

1.2.1. RESEARCH COORDINATION OBJECTIVES

The overall challenges of this Action (outlined in Section 1.1.1) will be best tackled by performing a lateral exchange of models, tools, datasets and expertise among researchers and weather and climate prediction professionals. To this end, this Action will address the following research coordination (RC) objectives:

1) provide a deeper understanding of the main atmospheric processes responsible for cyclogenesis and cyclone intensification, as outlined in Section 1.1.1;
2) identify and set a scientific agenda for addressing new and poorly understood research questions related to socio-economic and environmental impacts of Mediterranean cyclones, especially those outlined in Section 1.1.1;
3) develop common protocols for assessing the quality of Mediterranean cyclone simulations by weather forecasting and climate models;
4) establish priorities for model development aimed at improving the representation of the formation, movement, and intensity change of Mediterranean cyclones;
5) foster the application of these common protocols to enhance timely and direct exchange between European weather and climate services, e.g. when imminent high-impact weather is forecast;
6) share observations between different countries commonly affected by Mediterranean cyclones;
7) increase public awareness of cyclone-related high-impact weather by maintaining a website, social media channels and newsletter;
8) actively involve and exchange with stakeholders to tailor weather and climate prediction services to their needs.

The number of joint and international peer reviewed publications and new research proposals with a special focus on observational campaigns will serve as a metric of the COST action advancement in RC objectives 1, 2 and 3. RC objectives 3, 4 and 5 will be achieved through dedicated reports/documents publicly available and distributed through the Action website. The fulfilment of RC objective 6 will be measured by the collection of sources of observational data to a dedicated common database. Finally, the number of website visits and subscriptions will be a metric of the achievements for RC objectives 7 and 8.

1.2.2. CAPACITY-BUILDING OBJECTIVES

The capacity building objectives of this Action focus on the application of scientific knowledge to prediction models and on the effective dissemination of the outcomes of this Action (RC objectives 1 to 4), as well as on the consolidation of long-lasting collaboration between research, weather and climate prediction centres (RC objectives 5 to 8). In particular this Action aims to do the following:

1) engage researchers with backgrounds in atmospheric physics, meteorology and climatology and professionals from weather/climate services for understanding cyclone processes in order to achieve RC objectives 1 and 2;
2) effectively promote the use of state-of-the-art modelling tools with coupling capabilities for weather and climate predictions, explicitly resolving air-sea interactions and dust direct and indirect effects;
3) train early career academic researchers and weather/climate prediction professionals on the new scientific advancements in the field of Mediterranean cyclones, as well as on the new evaluation

tools and prediction methods that are outcomes of this Action. This objective will be achieved through (i) open summer schools, (ii) STSMs and (iii) workshops;

4) promote exchange of scientific and modelling expertise (in particular through STSMs) between weather and climate prediction and research centres located in the Mediterranean and in other European countries. The involvement of North African partners will be pursued by looking for specific programs at universities or projects at weather/climate services that could benefit from being engaged within the network. STSMs and joint international scientific proposals will measure the fulfilment of this objective; exchanges between research and services will be further promoted through the website, which will function as a prototype for cyclone forecast dissemination (see WG1) with contributions from the involved partners.

1.3. PROGRESS BEYOND THE STATE-OF-THE-ART AND INNOVATION POTENTIAL

1.3.1. DESCRIPTION OF THE STATE-OF-THE-ART

Baroclinic instability is the fundamental mechanism of cyclone formation and intensification in the Mediterranean, typically enhanced by latent heat release in clouds associated with the developing cyclone. Indeed, intense cyclones are preceded by upper-tropospheric disturbances that intrude into the Mediterranean, such as troughs and cut-offs. After cyclogenesis takes place, cyclone dynamics is influenced by a set of atmospheric processes that is unique to the region, compared to hurricanes or other extratropical cyclones that develop over the larger ocean basins. Moisture availability is limited, constrained by the relatively narrow Mediterranean Sea, while dry and warm air from North Africa, rich in dust, is often transported to the centre of cyclones. High mountains surrounding the Mediterranean Sea play a role in the occurrence of lee cyclogenesis, and further influence cyclone dynamics via frictional forces and wind steering. These unique dynamics act in synergy with the "more typical" cyclone-related atmospheric processes of large-scale condensation, convection and air-sea interaction. The complexity of the interactions between all these atmospheric processes over different temporal and spatial scales leads to a broad range of categories of cyclones, each of them associated with different cyclogenesis mechanisms and different spatial and seasonal distribution within the Mediterranean basin (Lionello et al., 2012). For instance, Mediterranean cyclones may occasionally undergo a transition from initially baroclinic to tropical-like systems. The relative contributions of the different thermo-dynamical processes to the triggering of cyclogenesis, the intensification of Mediterranean cyclones and the promotion of tropical transition is still an open question, while the impacts of dust and mountains on the life cycle of Mediterranean cyclones has not yet been adequately investigated.

Several studies have established the direct relationship between Mediterranean cyclones, windstorms, heavy rainfall, floods and storm surges (e.g. Tripoli et al., 2005; Cavaleri et al., 2010; Nissen et al., 2010). However, several impacts of cyclones on the regional environment and on climate variability have not yet been systematically studied. For instance, it is only recently that the community started to investigate dust transport associated with Mediterranean cyclones and its relationship to severe particulate matter pollution episodes (e.g. Rizza et al., 2018). This lack of research is in contrast to the recently revealed leading role of Mediterranean cyclones for the mobilization and transport of dust from North Africa, the world's primary source of atmospheric dust (Knippertz and Todd, 2012). Furthermore, an improved understanding of convective overshooting and the associated moistening of the lowermost stratosphere, which often occurs in the vicinity of Mediterranean cyclones (Bedka, 2011), is a timely issue that needs to be addressed by the scientific community. These storms also appear to modulate the Mediterranean Sea water budget (Flaounas et al., 2016) and the formation of deep water (Romanski et al., 2012). Therefore, Mediterranean cyclones have a potentially strong impact on the marine and atmospheric water cycle; however, this effect is still far from being quantified or analysed in detail.

Atmospheric models are an essential tool for studying and predicting cyclones. Regardless of the time scales considered, major modelling issues include spatial resolution, atmospheric model coupling with an oceanic and/or chemistry model, and the choice of physical parameterisations. Moreover, numerical weather prediction also needs to address the issue of assimilating observations, while climate prediction needs to address issues of internal climate variability. Therefore, optimising model performance is not straightforward and it depends on the scales and specifics of the processes/fields to be reproduced (e.g. depending on model resolution a certain process may be parameterised rather than explicitly resolved). For instance, a complete representation of the direct and indirect effects of

dust is prohibitively computationally expensive and theoretically yet not well described for climate simulations, yet may be realizable in the simulation of a specific cyclone for weather predictions. The state-of-the-art of modelling Mediterranean cyclones suffers from a lack of coordinated research on the accurate reproduction of the atmospheric processes responsible for cyclone development.

Beyond scientific research and its effective operational implementation, the understanding and accurate prediction of cyclones is an issue that is of high interest to the general public and stakeholders (e.g. civil protection agencies and re-insurance companies), since cyclones affect a large variety of socio-economic activities. Nevertheless, providing the most relevant information to stakeholders and the general public is a complex and currently underestimated issue. For instance, products showing the probability of the occurrence of explosive cyclogenesis (rapidly developing storms) and the resulting cyclone trajectory and effects (winds, waves) are challenging to generate and need to be defined in detail so that their usefulness can be optimized for e.g. shipping transports (a simple weather chart is not of interest). As discussed above, cyclones are also responsible (directly or indirectly) for a large variety of environmental impacts on weather, seasonal and climate timescales. Therefore, this Action needs to interact with stakeholders in order to define in detail and to refine the cyclone-related products of weather and climate services. This is one of the major issues of the state of the art (World Weather Research Programme Implementation Plan of WMO for 2016-2023), which is only poorly addressed up to now. This Action aims at contributing to fill this gap between high quality services and stakeholder needs.

1.3.2. PROGRESS BEYOND THE STATE-OF-THE-ART

The atmospheric thermo-dynamical processes associated with Mediterranean cyclones have been well identified. On the other hand, their interactions and relative importance to cyclogenesis, storm motion and intensity changes remain open questions. This Action will address this issue through the coordination of research activities already being carried out by its participants. Research will focus on a large number of case studies identified by the forecasters as being the most challenging ones to be reproduced by models. In addition, research activities will also focus on climatological datasets in order to understand the models' uncertainties in reproducing the climatology of Mediterranean cyclones, their morphologies and their life cycles. Use of both case studies and climatologies will provide a considerable advancement to the state of the art in understanding and predicting the dynamics of Mediterranean cyclones.

New climate research objectives and perspectives are expected to emerge from this Action. The challenges related to the impact of cyclones on regional climate have only vaguely been identified so far (as outlined in Section 1.1.1) and thus further coordinated research is needed to understand how Mediterranean cyclones modulate the regional and global climate. The first steps in this direction will be brainstorming, reviewing literature, identifying the resources/observations needed for research, and eventually specifying the questions that need to be addressed. New joint proposals will certainly advance the state of the art and improve our understanding of the Mediterranean climate.

The Action will contribute to the set-up of a dedicated observational database, in the form of a catalogue, open to all participating countries. This effort will begin with the identification and collection of data already available, an important step that will ensure that all possible benefit is extracted from observations made during previous field campaigns. In this context, the Action will be open to North African countries whose participation could be mutually beneficial, especially concerning the potential of sharing aerosol observations. Therefore, their involvement will be actively pursued.

Beyond fulfilling RC objectives, this Action is expected to tailor scientific advancements to the needs of weather and climate prediction services. Indeed, adequate modelling guidelines for predicting cyclones at different time scales will improve the effectiveness of these services, while a considerable effort will be realized in order to adapt these services to the needs of stakeholders.

Finally, the Action will seek to identify and exploit new research perspectives in order to update research results with new techniques and new observations. Indeed, given constant technological progress, within the next years we expect an advancement in computational resources, an increase of model capabilities, new climate model simulations (e.g. CMIP6), new reanalyses (e.g. ERA5), and new satellite launches (e.g. the MTG Lightning Imager in 2021 will provide unprecedented information on lightning to be used for monitoring embedded convection in cyclones).

1.3.3. INNOVATION IN TACKLING THE CHALLENGE

This Action will apply an integrated approach to the investigation of the climatology, dynamics, forecasts and impacts of Mediterranean cyclones. This will be done through the coordination of the efforts of researchers and prediction experts from many countries with different scientific backgrounds and modelling experience. It is thus beyond doubt that such an unprecedented network will take significant steps towards the improvement of the reproduction of cyclones in atmospheric models across temporal scales from weather forecasting to seasonal and climate prediction. In fact, this represents one of the major innovative aspects of this Action: establishing a framework for improving the prediction of an important class of high-impact weather events. This framework can thereafter be applied to other atmospheric phenomena of high socio-economic interest more generally for Europe and overseas.

Given the main objectives of this Action, technological innovation is expected to arise through the network contribution to the development of numerical models, in particular concerning the parameterization of physical processes, atmosphere-ocean-aerosol coupled modelling, and seamless prediction approaches for regional applications. In this context, the network will also develop a common framework for model assessment and will propose new strategies for improving cyclone forecasts and process understanding.

Finally, concerning scientific innovations, this Action will define the relative contribution of different atmospheric processes to the formation, motion and intensification of Mediterranean cyclones. As a result, it will provide for the first time the criteria that qualify intense, convectively-dominated cyclones in the region as so-called medicanes (storms that have completed tropical transition). The Action will also start, organize and foster research activity on the poorly understood impacts of Mediterranean cyclones on the regional climate and the environment, not addressed by coordinated research projects so far.

1.4. ADDED VALUE OF NETWORKING

1.4.1. IN RELATION TO THE CHALLENGE

Beyond bringing together academic scientists and professionals from services with backgrounds in meteorology and climatology, this Action will benefit from the experience of scientists and forecasters from across the Mediterranean region. This will enable a valuable transfer of knowledge from communities that have worked often separately in the field of Mediterranean cyclones. In addition, considerable advancements in both scientific production and high-impact weather prediction are expected through the inclusion of researchers and forecasters from European countries outside the Mediterranean, specialised in other cyclonic systems such as mid-latitude storms and tropical cyclones. It is undeniable that international coordination of efforts between western and eastern Mediterranean countries, North European and non-European countries will produce significant added value aimed at improving our understanding of Mediterranean cyclones and their environmental and socio-economic impacts. As envisaged by this Action, interactions and collaborations between the members will be mutually beneficial.

This network will allow **weather forecasters and model developers at operational centres** to:

- profit from and acquire new tools for diagnostics, inter-comparison of forecasts, and numerical analyses;
- establish priorities for improving their forecasting systems, with focus on the simulation of cyclones;
- build new and enhance existing collaborations across weather services that would have not been possible without the network;
- profit from inputs from stakeholders in order to make their products more appealing to their needs;
- increase their visibility and interaction with the general public.

The network will allow **climatologists and climate model developers at operational centres** to:

- acquire new evaluation tools for addressing climate simulation uncertainties;
- find a stimulating environment to discuss and set the agenda for new research questions on cyclone-related climate impacts and extremes;

- interact with stakeholders and tailor climate products to their needs (e.g. mitigation strategies);
- increase their visibility to the general public on issues that are relatively poorly understood such as uncertainties in predicting future climate.

This network will allow **academic researchers** to:

- promote their research through synergetic approaches that include atmospheric physics, meteorology and climatology and through the development of new scientific objectives related to cyclone impacts on climate variability and extremes;
- gain access to a plethora of observations enabling a coordinated effort to understand the atmospheric processes involved in cyclones;
- gain a unique opportunity to write joint proposals that combine different scientific disciplines, cyclone categories (e.g. the relationship between mid-latitude storms and Mediterranean cyclones) and expertise from different European countries;
- be exposed to services of applied science and thus broaden their career development options, an element that is of special interest to the early career scientists;
- have a unique opportunity to communicate their results to the general public and to profit from bridging scientific research with public awareness of cyclone systems.

Finally, this network will allow **stakeholders** to:

- experience how academic research reaches and interacts with operational applications in weather and climate predictions;
- develop an in-depth understanding of the challenges and uncertainties associated with the prediction of Mediterranean cyclones;
- co-develop and exploit products tailored to their needs.

1.4.2. IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

This Action is expected to complement and collaborate with current international initiatives and projects that focus on the Mediterranean climate and extreme weather, in particular:

- the Hydrological cycle in the Mediterranean Experiment (HyMeX, Drobinski et al., 2014) provides the largest active consortium devoted to Mediterranean climate and high-impact weather. HyMeX focuses on the hydrological cycle in the region and hosts more than 160 participants at its annual meetings;
- EGU Plinius Conference on Mediterranean Risks, MetMed Conference and MedClivar network are Mediterranean forums to which the Action will contribute;
- the WMO World Weather Research Programme (WWRP) High Impact Weather (HIWeather) coordinates research activities and the dialogue with stakeholders related to severe weather impacts (e.g. winter weather and severe windstorms associated with cyclones);
- the Cyclone Workshop, an international workshop with over 100 participants designed to promote discussions and interactions between researchers and operational meteorologists in the field of synoptic and mesoscale meteorology, held every other year in North America and open to participants from any institution or organization in the world;
- the European windstorms workshop, a suitable opportunity to meet academics and stakeholders;

Although several of these projects/initiatives focus on climate/weather, currently there is no coordinated effort to study Mediterranean cyclones as a major player for producing severe weather in the region. This Action will collaborate with these research projects in order to promote complementary activities that provide a meteorological dimension to the climate extremes and new agendas for climate impact research. Moreover, this Action will benefit from related projects that issue model outputs for scientific research, in particular:

- the WMO World Climate Research Programme (WCRP) COordinated Regional climate Downscaling Experiment (CORDEX) hosts a wide variety of regional climate simulations performed at different resolutions, forced by reanalysis and by global circulation models operated in the context of CMIP5. In particular the Med-CORDEX initiative (Ruti et al., 2016) is especially focused on Mediterranean climate;
- the European Centre for Medium-Range Weather Forecasts (ECMWF) new ERA5 database offers global reanalyses with unprecedented high horizontal (of the order of 30 km) and temporal (hourly) resolutions;

- the International Grand Global Ensemble (TIGGE) corresponds to a database of ensemble forecasts of different lead times from many weather services;
- the Subseasonal-to-Seasonal (S2S) WMO project, bridging the prediction gap between weather and climate forecasts, provides an extensive database of (sub)seasonal forecasts and hindcasts from operational centres;
- the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) is a platform that has offered real-time dust forecasts since 2011 with a focus on the European domain and North Africa. Large datasets of dust forecasts are available to assist research in understanding dust-cyclone interactions.

This Action will take advantage of these datasets in order to produce ground-breaking research but will also help to establish development priorities that will improve the representation of Mediterranean cyclones in the modelling systems that will be used to produce future reanalysis and reforecast products. Therefore, this Action shows great complementarity and high potential for collaboration with international initiatives on dataset production.

2. IMPACT

2.1. EXPECTED IMPACT

2.1.1. SHORT-TERM AND LONG-TERM SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS

In terms of research, this Action will provide a real opportunity to build up a solid network for the coordination of existing research activities among scientists from atmospheric physicists, meteorology and climatology. In addition, research on Mediterranean cyclones will greatly benefit from the involvement of scientists and institutions from other European countries, permitting exploitation of knowledge from the larger research field of extra-tropical cyclones. Finally, the Action will identify new research horizons and perspectives that will pave the way for new coordinated research activities. These activities are also expected to continue in the long-term, beyond the end of the present Action, thus creating a legacy of new collaborations and new joint project proposals at the international level.

In terms of socioeconomic benefits, this Action will create for the first time a solid network between weather and climate services from Mediterranean countries with the aim of improving cyclone prediction. In this context, these services will greatly benefit from direct collaboration through the development of a common vocabulary, and shared comparison and assessment tools. The network foundation will be solidified through STSMs and training schools, and through opportunities for collaboration among scholars, practitioners and experts in the field. This is expected to harmonise high-impact weather prediction between European countries. This collaboration will be of great benefit especially for the research centres in less research-intensive countries.

In terms of outreach activities, this Action will increase public awareness of high-impact weather associated with Mediterranean cyclones, as well as of the future of cyclones in the context of climate change. In terms of conveying research findings and cyclone predictions to stakeholders, this Action addresses the constant demand for accurate and reliable weather and climate predictions. However, this Action goes one step further in aiming at including stakeholders in order to tailor cyclone prediction products to their needs; therefore, we expect this Action to be highly visible to a large variety of audiences. To support public awareness and to increase the Action's visibility, the dedicated website and social media feeds will be largely exploited through contributions (also for advertising the Action) by the international network (e.g. in case of imminent intense cyclone development) and eventually in order to prepare a prototype/experimental cyclone-devoted forecasting service similar to that used for tropical cyclones by the National Oceanic and Atmospheric Administration (NOAA) in the US (https://www.nhc.noaa.gov/cyclones/), with naming, predicted trajectories, intensity and categories of Mediterranean cyclones.

In the long term, the improved ability of numerical models to simulate Mediterranean cyclones and their impacts on the environment, for both weather and climate predictions will be an important legacy left by the Action. Methodologies and tools will remain available for continuous upgrading and exchanging between weather and climate services. Moreover, guidelines on the exploitation of new observations (e.g. for remote sensing of dust) and on monitoring network requirements will be distributed to the responsible agencies, while test of novel observation strategies will foster dedicated

field campaigns (possibly joining experiments supported by funded research projects). Finally, the Action will promote the training of a new generation of weather and climate professionals (academic and non-academic) who will carry on the legacy of this Action within an international environment devoted to Mediterranean weather and climate.

2.2. MEASURES TO MAXIMISE IMPACT

2.2.1. PLAN FOR INVOLVING THE MOST RELEVANT STAKEHOLDERS

This Action will serve as a platform for sharing, exchanging and applying scientific knowledge to weather and climate services, with the goal of improving cyclone prediction. Given the importance of Mediterranean cyclones to the regional weather, climate and its extremes, this Action will be open to the direct involvement of all potential stakeholders that make use of the forecasts. In this case, stakeholders are mainly professionals of agencies or private companies from the socio-economic sector charged with weather and climate predictions, such as insurance, risk assessment and energy production companies, agriculture and marine transport sectors, national civil protection, environmental agencies, and policy makers. To achieve this aim, several professionals from weather and climate services across Europe have been involved in this Action as secondary proposers. Their existing links with public and private stakeholders, especially at national level, represent an opportunity and a strong starting point for assuring stakeholder involvement.

Each WG is organized along three axes (see Section 3), one of them being dissemination. Therefore, for optimal communication at national level, each WG will identify and involve stakeholders in collaboration with the Management Committee (MC) members. Inclusion of stakeholders will be achieved generally through invitations, periodic newsletters and calls published on the Action website; however, this process will also proceed through personal invitation from MC members to highly qualified persons, and through presentations in project meetings and international conferences with the specific aim of disseminating Action outcomes. Finally, in order to attract relevant stakeholders, the outcomes of this Action will be presented through already-established networks, such as the different WMO groups (e.g. WWRP HIWeather Project, WCRP and Hydrology and Water Resource (HWRP) Programmes) that deal with high-impact weather, climate variability, and water resources, respectively, and through networks focusing on the assessment of climate change and its impacts in the Mediterranean basin (e.g. MedECC).

2.2.2. DISSEMINATION AND/OR EXPLOITATION PLAN

The MC will coordinate the dissemination activity. A Communication Office will be appointed (see Section 3.2). The dedicated website and social media channels will provide constantly updated information about the Action activities, meeting/workshop reports and presentations. Regular dissemination of results and activities will be performed during the Action, with emphasis during each formal meeting (MC or annual workshops) always adapted and tailored to four specific target groups:

- **The scientific community**: it is necessary to provide news on Action results in order to better orient the research activity of the Action participants, as well as to promote collaborations and further involvements in the network. Peer-reviewed papers (whose list will be promptly updated on the Action website) and international conference presentations (possibly made publicly available) will provide an up-to-date overview of the results of this Action. Participation in WMO working groups (e.g. WWRP, WCRP and HWRP) will further spread the results to the scientific community. Results will be summarized in annual workshops, and for the final workshop a special issue of a peer-reviewed journal will be prepared, collecting the main Action results. A scientist-in-residence program will be pursued, looking for external scientists (possibly on sabbatical) available to stay at one of the participating institutions. This would bring expertise and promote the visibility of the Action.
- **Weather and climate services**: the knowledge developed and the modelling progress made during the Action will be transferred through annual workshops, documentation and user-guides published on the website, advertised by a newsletter and, especially to early-career professionals, provided through planned training schools. Also, the Action will strongly recommend academic scientist STSMs to operational centres, in order ensure an efficient uptake of the research coming out of the Action.
- **Relevant stakeholders**: one specific activity of each WG will be devoted to the identification and invitation of stakeholders (see Section 2.2.1). Moreover, promotional and information material (web-based advertisements, presentations, leaflets, brochures, posters) will be produced to meet the

needs of a broad target audience. Presentations to local authorities or to specific groups of stakeholders will be also encouraged. Annual workshops will be also open to stakeholders and round tables will be organised for optimizing interactions between Action participants.

- **General public**: here the need is to disseminate results in a suitable manner and in a non-technical language through popular science articles, website and social media, interviews and presentations. A joint press release will be prepared during the kick-off meeting among the largest possible number of countries involved. Moreover, getting in touch with national meteorological or climate societies will build a bridge between academic research and the general public. In case of severe Mediterranean cyclones, the Communication Office will take care of a special effort to promote forecasting products, graphical output and also post-event visualization and information to attract the attention of the general public.

2.3. POTENTIAL FOR INNOVATION VERSUS RISK LEVEL

2.3.1. POTENTIAL FOR SCIENTIFIC, TECHNOLOGICAL AND/OR SOCIOECONOMIC INNOVATION BREAKTHROUGHS

In terms of scientific results, this Action will provide for the first time an integrated framework to tackle the challenge of understanding Mediterranean cyclones. This includes physical processes (e.g. dust and ocean interaction with the atmosphere) that have not been completely embedded so far. Furthermore, new and poorly understood linkages between cyclones and the regional climate will be addressed for the first time in a scientific agenda aiming at joint international project proposals.

In terms of high-impact weather prediction, it is the first time that a network of researchers and forecasting professionals will address the challenge of establishing a coordinated effort to improve cyclone predictions in the Mediterranean, where even tropical-like systems occur. To this end, a well-structured collaboration network between academic and non-academic institutions and weather and climate services is a necessity.

These innovative aspects are expected to contribute to modelling applications that aim at a seamless prediction of Mediterranean cyclones and related impacts. The new results and modelling approaches will be of great benefit not only to the Mediterranean cyclone community, but also to communities interested in other cyclones such as mid-latitude storms and tropical cyclones.

The mutual benefit to weather and climate prediction services and stakeholders is expected to be exceptionally high. The former will increase the visibility and application of their products, while the latter will acquire products tailored to their needs. The mutual benefit to researchers and weather/climate services is also expected to be high since the cornerstone of this Action is to accelerate and facilitate the application of core science to cyclone prediction. However, the seemingly obvious feasibility of exchange of modelling expertise and tools between research and operations may present difficulties, especially in countries where academic research and public environmental agencies (e.g. forecasting services) are not efficiently connected. To mitigate this risk, a specific task in each WG is devoted to disseminate Action outcomes and interact with stakeholders. This includes detailed modelling priorities with examples and easy-to-use numerical applications for model evaluations, dedicated workshop presentations of tools and hands-on tutorials during STSMs and training schools (other risks and corresponding mitigation measures are presented in Section 3.1.4).

3. IMPLEMENTATION

3.1. DESCRIPTION OF THE WORK PLAN

3.1.1. DESCRIPTION OF WORKING GROUPS

The core RC and capacity-building objectives as outlined in Sections 1.2.1 and 1.2.2 can be synthesised to form the three main axes, corresponding to the overall challenges of this Action (as indicated in Section 1.1.1): (1) international coordination of research, (2) implementation of the scientific knowledge into forecasting and climate prediction services and (3) effective dissemination of outcomes of this Action to stakeholders and the general public. However, depending on the time scale considered, there are different scientific questions of interest regarding Mediterranean cyclones, and different modelling issues involved in cyclone prediction. Also the needs of stakeholders may largely depend on the considered time scales, e.g. stakeholders interested in the timely and accurate forecast

of imminent high-impact weather or stakeholders interested in the future evolution of cyclones in a specific region. The same is also valid for the objective of increasing the general public awareness, where interest may range from the explanation of single catastrophic events to the future of environmental risks related to cyclones. Therefore, the Action main challenges and objectives are addressed through three WGs, each of them organised along these three aforementioned axes:

- **WG1: Understanding cyclone processes from weather to seasonal time scales**
- **WG2: Process-based classification of Mediterranean cyclones at climate time scales**
- **WG3: Mediterranean cyclone impacts in regional climate and the environment**

WG1 - Understanding cyclone processes from weather to seasonal time scales

Coordination of research: WG1 will mainly address RC objective 1 (described in Section 1.2.1). Coordinated research will be largely based on the analysis of a large number of cyclone case studies, from the early stages of cyclogenesis until dissipation. These case studies will be identified in collaboration, involving researchers and forecasters from both the eastern and western Mediterranean basin, giving priority to cases where forecasts failed to reproduce the cyclone properties (e.g. intensity or track) and/or the associated extreme weather phenomena (e.g. heavy rainfall, wind storms and dust transport). Research efforts will focus on identifying why the models failed in the reproduction of specific processes (outlined in Section 1.1.1). A particular effort will be made to gain a better understanding (i) of processes that are particularly relevant to Mediterranean cyclones but still poorly understood, and (ii) of the complex interaction among different mechanisms in a large variety of Mediterranean cyclones. This will be done (1) through coordinated model sensitivity tests, (2) through the use of state-of-the-art coupled models (ocean/chemistry/atmosphere), and (3) through the use of observation systems.

Operational implementation: WG1 will address RC objectives 3, 4 and 5 (Section 1.2.1), as well as capacity-building objectives 2 and 4 (Section 1.2.2). This will be done through the development and application of common protocols for assessing forecasting models, by proposing priorities for improving atmospheric modelling and operational forecasting procedures, and by fostering the application of protocols and assessment tools to past forecasts of Mediterranean cyclones. Studies will be performed using common datasets provided by the participants (observations and model outputs), while proposed priorities for forecasting improvements will be continuously updated (given the constant technological progress expected over the course of the Action; Section 1.3.2). Although implementing a real-time forecasting system is out of scope for this COST Action, WG1 will build a prototype of a cyclone-forecasting website to facilitate interaction between weather services and to set an example of the range of forecasting performances. This will be done for the case studies selected in WG1, as well as for exceptional cases that will occur during the Action.

Dissemination and public engagement: WG1 will address mainly RC objectives 7 and 8 (Section 1.2.1). The website, newsletters and social media will be the main tools for disseminating results, reports and generally the Action outcomes. The new scientific results and the proposed priorities for improving the forecasting of Mediterranean cyclones will be constantly communicated through newsletters to external stakeholders and weather services. Finally, further activities within WG1 include the development of strategies for increasing international visibility and attracting stakeholders who will provide input on possible impacts that the network's research activity should consider. Concerning the general public, outreach activities will be performed through 3D visualisations of forecasts on dedicated social media channels. In this context, the case studies selected in WG1 will be also presented in popular science, while press releases to national and international media will be disseminated in case of imminent high-impact Mediterranean cyclones, assisted by the prototype forecasting website. This dissemination will be done through collaboration between WG1 members, the MC and the Communication Office, and the involved forecasting centres.

Tasks T1.1: Define a set of case studies that are relevant from a forecasting and/or physical processes point of view; share validation tools and collect observations and model simulations.**T1.2**: Define and apply model assessment techniques to operational (including ensemble) forecasting for Mediterranean cyclones, including associated high-impact weather. **T1.3**: Define, propose and update priorities for improving cyclone prediction at weather forecasting scales. **T1.4**: Produce/publish scientific results on process understanding obtained through collaborative activities and submit joint proposals for scientific or services projects. **T1.5:** Identify, invite and interact with stakeholders about WG1 progress and perform outreach activities to increase public interest in and awareness of high-impact events related to Mediterranean cyclones.

Deliverables D1.1: Report including case study descriptions and modelling systems to be published on the website and on agreed protocols for (sensitivity) simulations. This report will serve as a detailed guide for partners who may join the Action at a later stage. **D1.2**: Documentation on protocols and techniques for assessing forecast performance; to be published on the website and tailored to the needs of weather services; this document will be constantly updated with new methodologies. **D1.3**: Report published on the website devoted to priorities for improving cyclone prediction (from weather to seasonal forecasting). This report will be constantly updated during the Action and it will be tailored to the needs of forecasters and model developers. **D1.4:** Mid-term report of T1.4 describing scientific production so far and setting research orientations. **D1.5:** Joint overview scientific article on the challenges in forecasting high-impact weather in the Mediterranean. **D1.6**: Yearly internal report on dissemination strategies (including website, social media, newsletters, scientific papers etc.; refer to Section 2.2.2), stakeholder involvement and products tailored to their needs.

Milestones M1.1: Deployment of the website section on forecasting and publication of the catalogue of the selected events to be analysed by WG1. **M1.2**: Repository with process-oriented validation tools (codes and user guides). **M1.3**: First version of documentation on model development priorities published on the website. **M1.4**: Training school organized on cyclone processes and relevant forecasting issues.

WG2 - Process-based classification of Mediterranean cyclones at climate time scales

Coordination of research: WG2 will mainly address the RC objective 2 (see Section 1.2.1). In contrast to WG1, activities will be performed in the framework of climate prediction (past, present and future). WG2 will take advantage of the new ERA5 reanalyses and will share and apply a variety of diagnostic tools (e.g. cyclone tracking tools, cyclone phase diagrams and decomposition of surface pressure tendency) in order to identify the physical criteria that distinguish Mediterranean cyclones (e.g. from North Atlantic cyclones) and that quantify the relative contribution of diabatic and adiabatic processes to cyclogenesis, intensification and decay. This is expected to define different categories of Mediterranean cyclones with regards their dynamical processes. Furthermore, WG2 is expected to establish a widely accepted definition of the criteria that qualify some Mediterranean cyclones as tropical-like systems. Results will be used in order to assess the ability of climatological datasets (e.g. MED-CORDEX simulations) to reproduce cyclone categories and their climatology, as well as to better understand the evolution of Mediterranean cyclone categories and their related processes in a changing climate. Finally, synergetic activities will be encouraged with WG1 in order to put the analysed cases as identified in Task 1.1 into a climatological context, e.g. define the representativeness of case studies with respect to the cyclone climatology.

Operational implementation: Similarly to WG1, WG2 will address RC objectives 3, 4 and 5 (Section 1.2.1), as well as capacity-building objectives 2 and 4 (Section 1.2.2). WG2 will establish protocols and assessment tools to be applied to cyclone climatologies for assessing climate models. Priorities will be proposed for improving regional climate modelling regarding cyclone processes (e.g. propose improvements to address systematic deficiencies). Comparisons of climate models with the ERA5 reanalysis will also provide the means for assessing uncertainties in future climate projections.

Dissemination and public engagement: The same means and methods as in WG1 will be used in WG2 in order to address RC objectives 7 and 8 (Section 1.2.1). WG2 dissemination and involvement strategies will be aimed at stakeholders interested in climate aspects and long-term mitigation strategies, while communication with the general public will mainly address climate change and the future evolution of cyclone-related high-impact weather.

Tasks T2.1: Define research protocol: catalogue of climatological datasets (past and future climate) including observations and model simulations. **T2.2:** Define protocol for assessing simulations: share diagnostic tools, making them easily applicable to all partners. **T2.3**: Define, propose and update priorities for improving cyclone prediction at climate scales. **T2.4**: Produce/publish scientific results on cyclone processes from a climatological perspective and on their future evolution, and submit joint proposals for scientific or service projects. **T2.5:** Identify, invite and interact with stakeholders about WG2 progress and perform outreach activities to increase public interest and awareness of Mediterranean cyclone-related high-impact events.

Deliverables D2.1: Internal report on the datasets available. **D2.2**: Documentation describing the available diagnostic tools, the protocols and techniques for assessing climate simulations (published on the website, and tailored to the needs of climate services). This document will be constantly updated with new methodologies. **D2.3**: Report published on the website devoted to priorities for

improving cyclone prediction on climate timescales. This report will be constantly updated during the Action and it will be tailored to the needs of model developers and climate prediction services. **D2.4:** Mid-term report of T2.4 describing scientific production so far and setting research orientations. **D2.5**: Climatological overview article on Mediterranean cyclone categories and on the future evolution of Mediterranean cyclones. **D2.6**: Yearly internal report on dissemination strategies (including website, social media, newsletters, scientific papers etc.; refer to Section 2.2.2), stakeholders involvement and products tailored to their needs.

Milestones M2.1: Deployment of the website section on climatological aspects of Mediterranean cyclones. **M2.2**: Repository of diagnostic tools for climatological analysis and user guides. **M2.3**: First version of documentation on model development priorities published on the website. **M2.4**: Training school organized on cyclone processes and relevant climate prediction issues.

WG3 - Mediterranean cyclone impacts in regional climate and the environment

Coordination of research: WG3 will mainly address RC objective 2. WG3 participants will set a scientific agenda in order to address the still uncharted impacts of cyclones on regional climate and the environment, several of them outlined in Section 1.1.1. This demands close collaboration between researchers and forecasters. Therefore, brainstorming is a core issue for WG3. First WG3 will identify and catalogue different cyclone impacts and will propose research approaches. The less clearly defined structure of WG3 (in comparison to WGs 1 and 2) reflects the fact it is highly innovative and therefore requires more flexibility. However, the impacts already mentioned in Section 1.1.1 will provide an outline and fast spin-up for WG3 activities, thereby minimizing risks. There may be a large variety of scientific and modelling issues to be dealt with by this WG, especially regarding poorly understood cyclone processes and their impacts on regional climate and the environment (Section 1.1.1). For instance, dust uptake and transport by cyclones may be of interest for weather forecasts when addressing air quality issues, but it is also of interest for climate when considering the regional radiative budget. In collaboration with WGs 1 and 2, WG3 participants will acquire simulations, climatologies and observations in order to address the identified cyclone impacts and advance the state-of-the-art in the field. Involvement of stakeholders but also of professionals from weather and climate prediction services is crucial for harmonising the research with socio-economic needs.

Operational implementation: WG3 participants will work closely with weather and climate prediction services involved in the Action in order to propose new products on cyclone impacts to regional climate and the environment. Stakeholders are expected to provide input in order to tailor these products to their needs and thus to maximize the visibility and appeal of the products.

Dissemination and public engagement: Website, newsletters and social media will be used in order to inform the general public and stakeholders about the new cyclone-related impacts. Special focus will be given to the general public through social media, while relevant case studies (connection with WG1) or climatological aspects of cyclones (connection with WG2) with new cyclone impacts will be further developed.

Tasks T3.1: Define the state-of-the-art in understanding cyclone impacts, in part by identifying missing observations and deficiencies in model applications at different time scales. **T3.2**: Define and propose forecasting and climate prediction products, relevant to the newly identified cyclone impacts. **T3.3**: Produce/publish scientific results on cyclone impacts and submit joint proposals for scientific or service projects. **T3.4:** Identify, invite and interact with stakeholders about WG3 progress and perform outreach activities to increase public interest and awareness of newly discovered impacts of Mediterranean cyclones on the environment and climate system.

Deliverables D3.1: Review article of Mediterranean cyclone impacts on the regional climate and the environment, including future perspectives. **D3.2**: Documentation on proposed new products on cyclone impacts, tailored to the needs of stakeholders (to be constantly updated). **D3.3**: Mid-term report of T3.4 describing scientific production so far and setting research orientations. **D3.4:** Overview article on Mediterranean cyclone environmental and climate impacts. **D3.5**: Yearly internal report on dissemination strategies (including website, social media, newsletters, scientific papers; refer to Section 2.2.2), stakeholder involvement and products tailored to their needs.

Milestones M3.1: Identification of new research orientations. **M3.2**: Training school organized on cyclone impacts.

3.1.2. GANTT DIAGRAM

Annual workshops will be devoted to the three WGs, where scientific presentations, training actions and round tables will be addressed to researchers, weather/climate services and stakeholders.

PROJECT: Duration: 4 years												
	Year 1			Year 2			Year 3			Year 4		
	I	II	III	I	II	III	I	II	III	I	II	III
WG1: Understanding cyclone processes from weather to seasonal time scales												
T1.1			D1.1									
T1.2			M1.2	D1.2								
T1.3					M1.4	D1.3 M1.3						
T1.4								D1.4				D1.5
T1.5		M1.1	D1.6			D1.6			D1.6			D1.6
WG2: Process-based classification of Mediterranean cyclones at climate scales												
T2.1			D2.1									
T2.2			M2.2	D2.2								
T2.3						D2.3 M2.3		M2.4				
T2.4								D2.4				D2.5
T2.5		M2.1	D2.6			D2.6			D2.6			D2.6
WG3: Mediterranean cyclones impacts in regional climate and environment												
T3.1			M3.1			D3.1						
T3.2						D3.2					M3.2	
T3.3							D3.3					D3.4
T3.4			D3.5			D3.5			D3.5			D3.5
WORKSHOPS	KO		WS1			WS2			WS3			WS4

3.1.3. PERT CHART (OPTIONAL)

3.1.4. RISK AND CONTINGENCY PLANS

Description of Risk	Risk-mitigation measures
Missing collaboration/coordination in WGs 1 and 2 and/or slow scientific production.	Shared protocol for simulations, sensitivity studies and verification will be established and distributed, possibly identifying also sub-groups and appointing a coordinator for each of them.
Non-effective involvement of North African countries.	Integrate in the Action or profit from already existing collaborations involving North African countries and European institutions. Identify strategy together with WMO to involve North African partners. Highlight added value provided by the network for meteorological/climate services.
Non-effective involvement of stakeholders.	MC members will be asked to suggest specific entities of high interest to this Action (e.g. institutions, companies, authorities) and the Communication Office will be in charge of contacting them directly.
Conflicts on data policies and data availability.	It will be explicitly explained that this Action does not aim at building its own database, but a catalogue linking already existing data from projects, which are usually open after a few years. Concerning new data, the direct participation of several meteorological and climate services in the Action is expected to facilitate the availability of new data at least within the network.
Limited interest from the general public.	Reinforce dissemination activities through the website and social media with animations and multimedia material.
Limited interest from stakeholders.	Further promote collaboration between partners. Enhance the participation of stakeholders, e.g. perform meetings with developers of assessment tools to favour their utilization.
Insufficient collaboration between WGs.	(1) Reinforce the interaction between the COST action participants (e.g. creation of a discussion forum on the web); (2) set more regular MC meetings to pinpoint problems and propose solutions; (3) guide and foster interactions between partners; (4) promote exchanges between institutions and between WGs in order to develop qualified personnel with broad interests and experience.

3.2. MANAGEMENT STRUCTURES AND PROCEDURES

The overall management and strategic guidance of the Action will be assured by the MC, composed of up to two national delegates from each country. In the kick-off meeting, the Action MC will elect the chair, vice-chair and WG leaders. MC activity will be performed through periodic videoconferences (3-monthly); the MC will be in charge of organizing Action meetings and workshops.

A Steering Committee (SC) composed by the MC chair and vice-chair, and WG leaders will monitor the workflow and take necessary actions in case of deviations or problems in accordance with the MC; it will ensure the project scientific management and will check the consistency of the deliverables. The SC will also organise, coordinate and monitor the STSMs and training schools. The SC will have monthly videoconferences to secure efficient day-to-day management and coordination of the Action.

The MC will appoint 8 members, two from each WG and two from the MC as the Communication Office, that will coordinate the dissemination of project results, ensure internal and external communication, including the Action website and social media feeds.

WG leaders and vice-leaders will be responsible for the good execution of work within each WG, while the exchange of information among WGs will be supervised by the SC. WG leaders will also (i) propose to the SC dates for joint WG meetings to favour exchanges of information and results, (ii) report progress to the MC, (iii) promote publication visibility within and outside of the network, and (iv) provide updates of the modelling priorities to the general public on the Action website and via social media.

3.3. NETWORK AS A WHOLE

The initial participants (secondary proposers) already represent a suitable critical mass needed to address issues concerning cyclone process-level understanding and the forecasting of Mediterranean cyclones at different time scales. However, the Action's intention is to actively foster the participation of a larger number of researchers and to enlarge the network with stakeholders from different backgrounds (e.g. civil protection, agriculture, energy and insurance companies). The SC will be in charge of enlarging the network and outreach to stakeholders.

The network has been built to balance the participation of research institutions and environmental agencies, including forecasting centres, covering the Mediterranean region and contiguous areas that are regularly affected by Mediterranean cyclones. Moreover, participants from countries outside the Mediterranean, and even outside Europe, will share in the network their expertise on other cyclonic systems such as mid-latitude storms and tropical cyclones, thus favouring mutual exchange of ideas, tools, diagnostics, and forecasting experience. Exchange of knowledge will be ensured through workshops, training schools and STSMs.

Mutual benefit with International Partner Countries (IPCs): this Action involves research institutions of USA, Canada, Australia and Argentina. The Mediterranean research community will benefit from their great expertise in the field of tropical, sub-tropical and extra-tropical cyclones and high-impact weather in different basins worldwide. Moreover, their participation will promote the dissemination of Action results towards a wider audience and enlarge the network into non-European communities.

Mutual benefit with International organization: (i) The participation of the WMO will facilitate interactions with many of the relevant programs described in Section 1.4.2 and the worldwide dissemination of the Action outcomes. The WMO will also support the effort of involving North African countries. On the other hand, Action topics are well in line with WMO science summit priorities (Section 1.1.2) and of great interest with respect to the objectives of the WMO HIWeather project. (ii) ECMWF will provide a valuable contribution on diagnostic studies and the performance of ECMWF model on medium-to-seasonal range will be a benchmark for the community. On the other hand, this Action represents an opportunity for ECMWF to compare their forecast performance with that of other systems, in simulating high-impact weather and climate extremes over the Mediterranean. (iii) ICTP participation will enable a fruitful sharing of modelling and diagnostic tools, knowledge and regional climate predictions specifically addressing the Mediterranean basin and climate extremes.

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COST Mission and Policies

EUNETMEC tackles the two challenges of coordinating scientific efforts to improve our understanding of Mediterranean cyclones and implementing new knowledge into atmospheric models so that we can significantly improve the European capability to predict these weather systems. Addressing these challenges will lead to great societal benefits since cyclones are the main modulators of weather in the Mediterranean: they strongly affect regional climate variability and pose major environmental risks due to their direct relationship with high-impact weather. The network is mainly composed of researchers and scientists from weather and climate services, while stakeholders are expected to gradually join the network to tackle a third challenge: developing new weather and climate related products, tailored to stakeholder needs.

EUNETMEC fulfils COST excellence and inclusiveness policy, in particular:

International cooperation

EUNETMEC creates a cross-border network of excellent academic researchers and professionals from weather/climate centres, not only from countries around the Mediterranean basin but also outside the Mediterranean, in Europe and internationally: a total of 28 countries, 11 of which are Inclusiveness Target Countries (ITC) and 4 of which are International Partner Countries (IPCs). Indeed, the growing interest from the international scientific community to understand Mediterranean cyclones assures fruitful collaborations, including exchange of scientific expertise and sharing of tools and methods. Therefore, the promotion of international cooperation is highly relevant to the objectives of EUNETMEC. This will result in an unprecedented increase in the visibility, reputation and integration of scientists interested in Mediterranean cyclones to the leading knowledge hubs of Europe and also to a larger international community. About half of secondary proposers are from ITCs. Inclusion of ITCs is one of the core priorities of EUNETMEC since a high number of these countries are located within the Mediterranean and thus are highly vulnerable to cyclones. Our purpose is to further enlarge the network with more participation of researchers, weather/climate services professionals and stakeholders from the ITCs already included in the Action as well as by involving more ITCs, especially from the Balkans where adverse impact of Mediterranean cyclone is frequent. At least half of the network meetings will be organized in ITCs. Furthermore, the engagement of Near Neighbour Countries (NNCs) is an issue that is highly relevant, especially concerning the mutual benefit of interactions between European and North African countries, which are equally vulnerable to Mediterranean cyclones. Actions have been planned for the inclusion of NNCs. Also Short Term Scientific Missions (STSM) and NNC's participation in training schools will be particularly encouraged. Finally, participants from three worldwide leading international organisations relating to weather and climate issues are already included in this Action. Their engagement will assist in identifying excellence across Europe and increasing Action worldwide visibility within environmental themes that are considered highly relevant. Further inclusion of more participants from these organisations, as well as from other specific organisations will be actively pursued during the Action.

Counterbalance unequal access to knowledge, funding and resources

The structure of the Action assures equal access to the knowledge and resources produced by the network. All participant researchers, especially those from ITCs, will have the unique opportunity to be fully involved in joint international initiatives and high quality research projects, to increase their visibility, build up new collaborations, communicate their results, and be exposed to services of applied science and thus broaden their career development options. Furthermore, the relatively small community of scientists dedicated to Mediterranean cyclones will benefit from the inclusion of researchers and forecasters from North European and other countries specialised in other cyclonic systems such as mid-latitude storms and tropical cyclones. Finally, weather and climate services will have the opportunity to exchange expertise, tools and methods and therefore this network will promote the growth of prediction capacities of less research-intensive countries. In this context, mutual exchanges between weather and climate prediction and academic research centres will provide equal access to knowledge and resources through planned training schools and STSMs, sharing of tools and protocols, provision of priorities on model development, and initiatives aimed at joint proposal submission. Finally, academic scientist STSMs to operational centres and a scientist-in-residence program will ensure an efficient uptake of the research coming out of the Action, promote its visibility and lead to exchange of excellent knowledge.

Impact on national socio-economic activities and scientific research

Two of the main challenges addressed by EUNETMEC are the inclusion of stakeholders in its network who are interested in weather and climate prediction (e.g. re-insurance, energy companies and civil protection agencies) and the increase of public awareness of cyclone environmental and socio-economic impacts. In fact, each working group (WG) is charged with dissemination duties through website and social media applications, as well as with the identification and invitation of stakeholders, including yearly reporting on these activities. Especially for stakeholders, each WG meeting will reserve a session for interaction among stakeholders, researchers and prediction professionals. Therefore, common funding proposals and cooperation strategies are expected to be produced by the activities of EUNETMEC to which all participants will have equal access. Finally, the development and application of common protocols for forecast assessment and the definition of priorities for improving cyclone predictions will favour structural changes to the operational activities of weather services and by extension to the national research priorities.

Gender, career stage and geographical balance

This Action comprises internationally recognized scientists at different career stages, but most importantly includes a significant number (25) of Early Career Investigators (ECI). In particular, the Action prioritizes participation of ECIs who will be involved in (i) action management, (ii) training programs and scientific exchanges (STSMs) and (iii) WG activities. Therefore, EUNETMEC will promote ECIs to become the next generation of leaders in research or weather/climate prediction. However, given the slight initial gender unbalance, female researchers will be particularly encouraged to participate, e.g. through personal invitation. Moreover, the Action plans a strategy to involve south Mediterranean countries (NNC) in order to balance the geographical distribution around the basin. In fact, participation of North African countries is relevant for collaboration between prediction services and research institutions, as well as for sharing observations.

Network of Proposers - Features

COST Inclusiveness target countries
45.83 %

Number of Proposers
60

Geographic Distribution of Proposers

Country	ITC/ non ITC/ other	Number of institutions from that country	Number of researchers from that country	Percentage of the proposing network
Argentina	other	2	2	3.33 %
Australia	other	2	2	3.33 %
Austria	non ITC	2	2	3.33 %
Canada	other	1	1	1.67 %
Croatia	ITC	3	3	5 %
Cyprus	ITC	2	2	3.33 %
Czech Republic	ITC	2	2	3.33 %
Finland	non ITC	1	1	1.67 %
France	non ITC	3	3	5 %
Germany	non ITC	3	3	5 %
Greece	non ITC	3	3	5 %
Hungary	ITC	1	1	1.67 %
Iceland	non ITC	1	1	1.67 %
Israel	non ITC	3	3	5 %
Italy	non ITC	4	4	6.67 %
Malta	ITC	2	2	3.33 %
Netherlands	non ITC	2	2	3.33 %
Norway	non ITC	2	2	3.33 %
Poland	ITC	1	1	1.67 %
Portugal	ITC	2	2	3.33 %
Romania	ITC	2	2	3.33 %
Serbia	ITC	3	3	5 %
Slovenia	ITC	1	1	1.67 %
Spain	non ITC	3	3	5 %
Switzerland	non ITC	4	4	6.67 %
Turkey	ITC	1	1	1.67 %
United Kingdom	non ITC	3	3	5 %
United States	other	1	1	1.67 %

Gender Distribution of Proposers

61.7% Males
38.3% Females

Average Number of years elapsed since PhD graduation of Proposers with a doctoral degree
13.7

Number of Early Career Investigators
25

Core Expertise of Proposers: Distribution by Sub-Field of Science
98.3% Earth and related Environmental sciences
1.7% Physical Sciences

Institutional distribution of Network of Proposers

61.7% Higher Education & Associated Organisations
33.3% Government/Intergovernmental Organisations except Higher Education
5.0% Standards Organisation

Government/Intergovernmental Organisations except Higher Education:20

- Number by Level
  Central and Federal Government:12
  Local government:5
  International:3
- Number by Type
  R&D Funding and/or R&D Performing bodies:3
  Government department or government-run general public services:11
  Other Public Non-Profit Institution:5
  Non-R&D executive agencies, including sector specific regulatory bodies:1

Higher Education & Associated Organisations:37

- Number by Field of Science of Department/Faculty of Affiliation
  Earth and related Environmental sciences:31
  Physical Sciences:4
  Other engineering and technologies:1
  Agriculture, Forestry, and Fisheries:1
- Number by Type
  Research Oriented:18
  Education Oriented:19
- Number by Ownership
  Fully or mostly public:35
  50-50 Public and Private:2

Standards Organisation:3

- Number by Membership type
  With no government membership:2
  Including at least partial government membership:1
- Number by Level
  National:2
  International:1

COST Country Institutions(24) : Austria , Croatia , Cyprus , Czech Republic , Finland , France , Germany , Greece , Hungary , Iceland , Israel , Italy , Malta , Netherlands , Norway , Poland , Portugal , Romania , Serbia , Slovenia , Spain , Switzerland , Turkey , United Kingdom

Near-Neighbour Country Institutions(0)
COST International Partners(4) : Argentina, Australia, Canada, United States
European Commission and EU Agencies(0)
European RTD Organisations(0)
International Organisations(3)

Network of Proposers - Details

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