COST Action CA19109 “MedCyclones” – Working Group 1

<u>Deliverable D1.1</u>

Report: description of case studies, modelling systems and protocol for sensitivity simulations

20 October 2021

1. Overview

This report presents the current state of a collective effort to better understand the dynamics and predictability of Mediterranean cyclones by performing a model intercomparison of case studies. For this aim, a model intercomparison project (MIP) is ongoing to investigate case studies using model setups that are not available to operational forecasts. This approach allows testing the sensitivity to advanced model setups such as convection-permitting resolution or various couplings and thus, complements the “DynForMed” initiative in WG1 that is solely based on operational forecasts with fixed configurations. More than 10 participants are running numerical simulations following a common protocol to look for a systematic response between models and setups. The focus is on the sensitivity to initial conditions and horizontal resolution.
Several promising case studies have been suggested by members of the COST Action and are listed in Table 1 for future collaborations. This report focuses on the recent cyclone Ianos from mid-September 2020 as a first case study and to prepare the technical framework of the intercomparison. It has been chosen for its interesting dynamics, strong societal impact, and poor predictability in operational forecasts.
Contributors who run different models and different configurations of the WRF model are currently involved (Table 2).

A detailed protocol and a technical list of required data are available on the Action website for any participant who would join at a later stage: https://medcyclones.utad.pt/wg1-initiatives/intercomparison/

We will proceed with Ianos first and then extend to other cases studies using the same protocol.

2. Detailed description of cyclone Ianos

Ianos appears as a promising case study, because it meets several criteria:

- it exhibited a tropical appearance that makes it a good candidate for the Medicane status
- it had a strong impact on Greece during its landfall on 18 September 2020 that make it of socio-economic importance

MedCyclones COST Action CA19109 | WWRP World Weather Research Programme | cost European Cooperation in Science & Technology | COST is supported by the Horizon 2020 Framework Programme of the European Union

- it involved intense convection but also dust and high sea surface temperature, which make it dynamically interesting
- it was a challenging case for operational forecasts, which make it relevant from the predictability point of view

Figure 1 illustrates the track and intensity of Ianos (as defined by the minimum MSLP) in the operational ECMWF ensemble forecast initialized prior to intensification. The 50 members are coloured in red if they intensify below 1000 hPa (arbitrary threshold) and in grey otherwise. For comparison, the ECMWF analysis intensified to 993 hPa (in black). While all members initialized on 16 September 2020 reach the threshold, the proportion decreases to about 2/3 on 15 September and drops to a few members on 14 September. The "DynForMed" initiative has confirmed that the intensification is largely missed in forecasts initialized on 13 and 14 September and is underestimated on 15 September, while there is a large spread between models and configurations.

We aim at better representing the intensification phase to better understand the involved processes.

3. Chronology of the case study

On 13 September 2020, a convective cluster is present to the south of Sicily associated with a weak cut-off low, while a separated weak surface low is present over Libya (Figures 2a and 3a). On 14 September, the convective cluster and the surface low approach each other (Figures 2b and 3b). Note the presence of dust revealing the cyclonic circulation on the MODIS image. On 15 September, the two structures have merged off the Libyan coast but the convection has weakened (Figures 2c and 3c). On 16 September, the cyclone moves northward and deepens quickly, while the convection redevelops in the north-western quadrant (Figures 2d and 3d). On 17 September, the cyclone attains its mature phase, exhibits a tropical-like appearance, and turns eastward (Figures 2e and 3e). On 18 September, the cyclone makes landfall in Greece and still involves convection (Figures 2f and 3f). Later on, the cyclone bifurcates southward and fills quickly (not shown). See also Figure 1 for the track and intensity in the ECMWF analysis (in black); note, however, that different analyses show different cyclone depth over the sea during the period of maximum intensity.

This short overview suggests that both the pre-existing convection and surface low play a role in the initial cyclogenesis, thus their representation may both be critical in model simulations.

4. Methodology

a. Run coarse-resolution simulations for the intensification period

Goal: compare different initial and lateral conditions to obtain a control run for the next steps

Model setup

- Initialization time: 14 Sep 00 and 12 UTC, 15 Sep 00 UTC (see Figures 2b and 3b)
- Run until 17 Sep 00 UTC (intensification); if possible, extend until 19 Sep 00 UTC (impact)
- Coupling data: IFS operational analysis (~10km, 6h) and ERA5 reanalysis (~30km, 1h)

- Domain: details will depend on model/projection but must include 28-43°N 10-25°E; e.g., 1800x1500km Lambert Conformal centred on 35.5°N, 17.5°E
- Resolution: 10 km horizontal grid spacing and at least 50 vertical levels
- Parameterizations: if possible, coordinate between users of the same model (esp. WRF)

Rationale: the relatively small integration domain and the use of (re)analyses should provide a constraint to the simulation for the large scale. The domain is however large enough to allow the mesoscale model to develop the cyclone. The idea is that each participant may use the model and configuration that he/she is used to and is comfortable with. However, try to have (more or less) the same integration domain and resolution (10 km) and also a vertical resolution suitable to properly describe the lower troposphere (although we do not pose a strict constraint on that). Model configuration should not change in the next step (only resolution will increase, if possible).

Model output
- Output will be provided on a common grid, regular lat/lon 0.1°x0.1° from 28-43°N 10-25°E so that it will be easy to plot all the simulations with the same python scripts
- Format: CF-compliant netCDF on the common grid, 3-hourly
- Variables: 2D surface fields, pressure levels and vertically-integrated values (Table 3)
- In view of possible collaboration with WG3 (impacts, e.g., coupling with storm surge models) we consider to produce a 15' output for surface variables of wind, precipitation and MSLP
- Analysis: the required output will be centralized on a server, while the full output should be stored locally by each participant

WRF users
- Emmanouil Flaounas provides a “plug and play” PV-tracer code on the central server
- The IFS operational analysis and ERA5 reanalysis data are provided on the central server
- Try to coordinate while avoiding to have exactly the same configuration (see Table 2). At this stage the initiative does not aim to assess the best scheme or best setup for WRF, but to assess the role of resolution, after having obtained a “good" control forecast.

Summary: 3 + 3 simulations are requested for this stage, starting from 3 different times and using 2 different sets of initial and lateral boundary conditions.

b. Run high-resolution simulations for the intensification period

Goal: test the sensitivity to the representation of convection; is it worth running km-scale models?

Model setup
- Initialization & coupling: select the best configuration (time & data) from the previous step
- Resolution: 2 km horizontal grid spacing on the same domain, no grid nesting (~750x750 pts). Try to jump directly from (re)analyses to high resolution.
- Parameterizations: no sub-grid scheme for deep convection; everything else as above!

5. Future opportunities

- Run coarse-resolution simulations on a larger domain

Goal: test the sensitivity to the representation of the large-scale forcing

- Run simulations with modified SST or surface fluxes

Goal: test the sensitivity to the representation of air-sea interactions; are coupled runs necessary?

- Run simulations with interactive aerosols

Goal: evaluate the impact of dust on the cyclone dynamics

- Run ensemble simulations

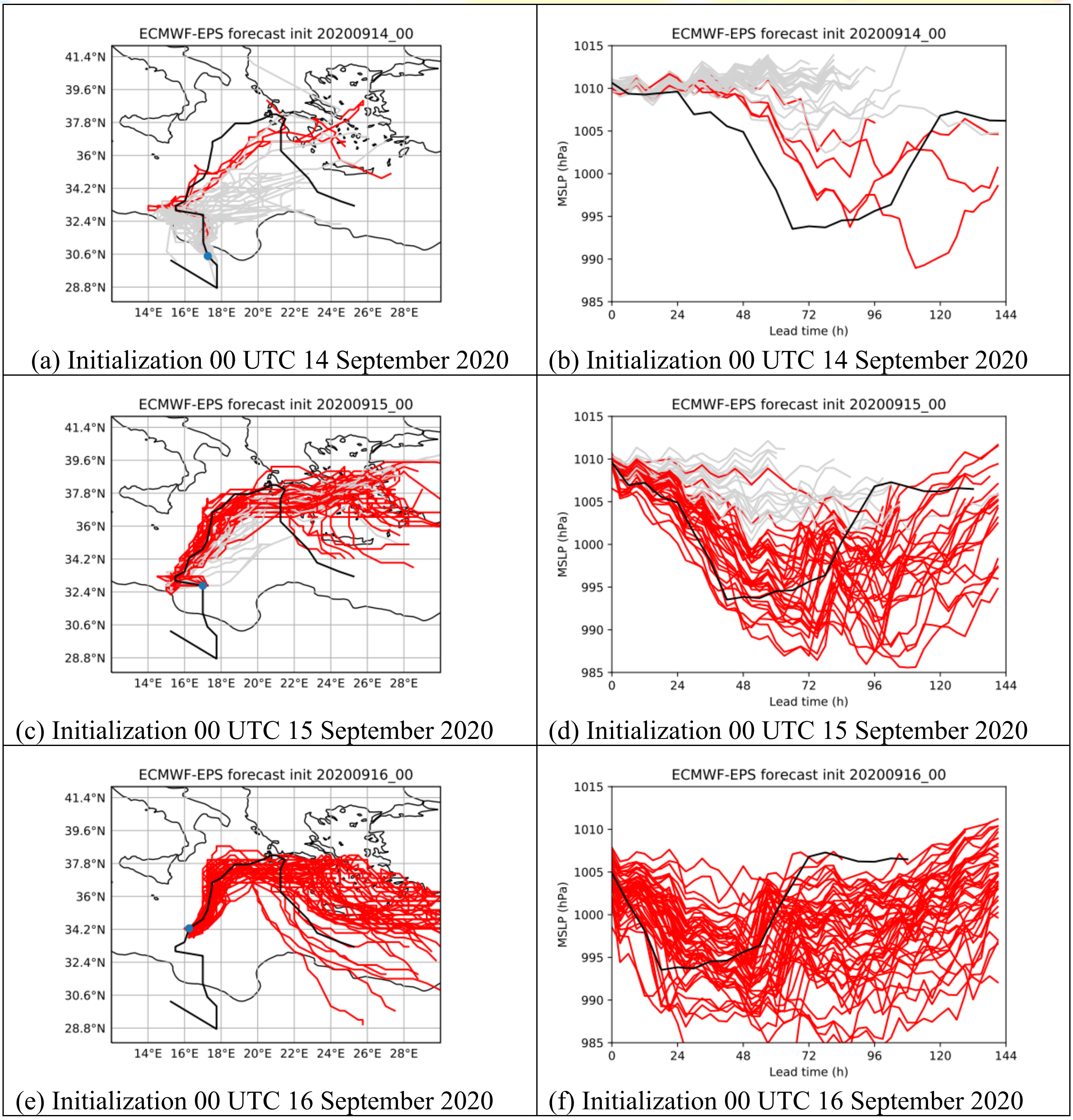
Goal: compare ad hoc data assimilation with downscaling a global ensemble forecast

6. References

Lekkas E., Nastos P., Cartalis C., Diakakis M. and coauthors, Impact of Medicane "Ianos" (September 2020), Newsletter of Environmental, Disaster, and Crises Management Strategies, ISSN 2653-9454.

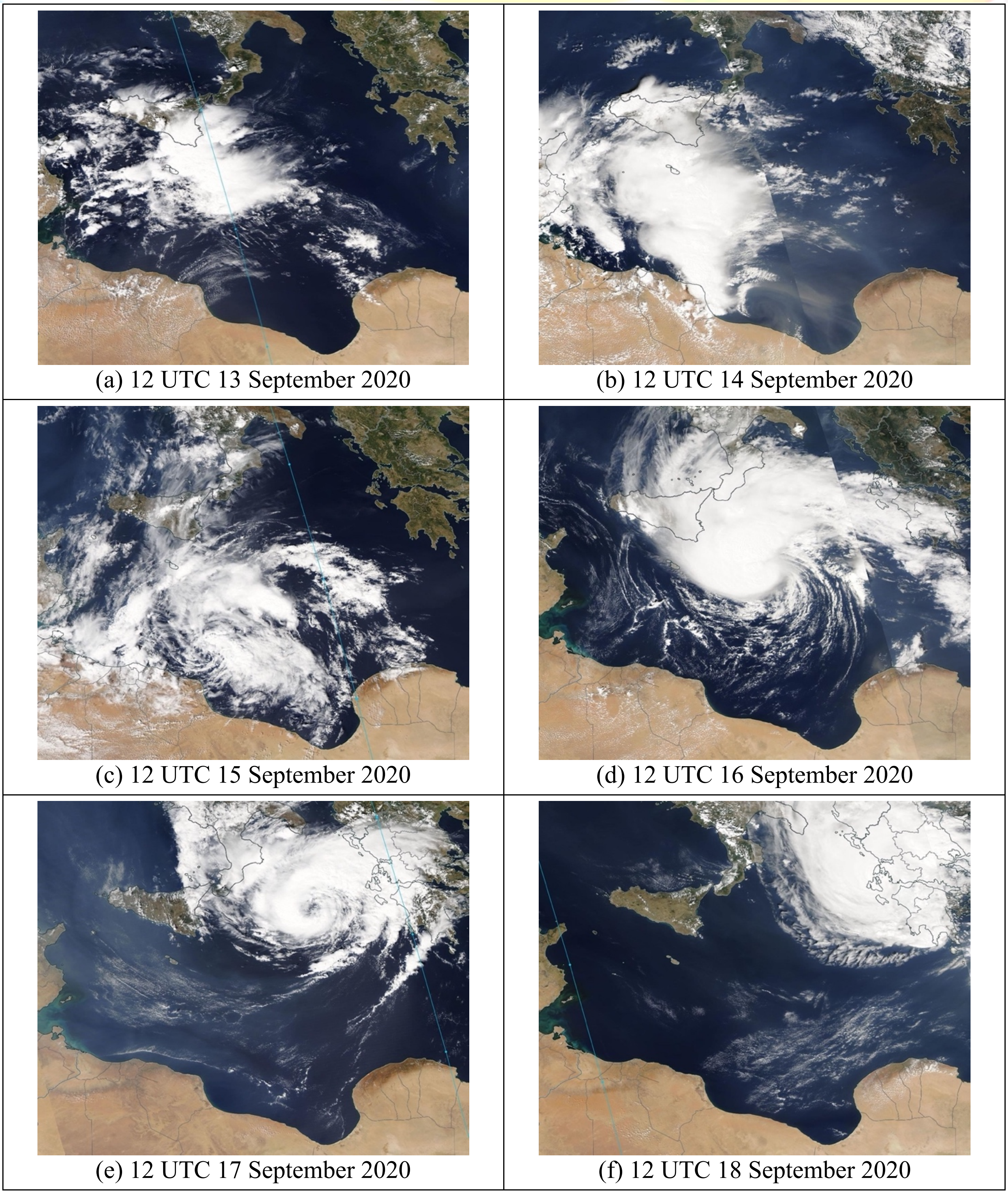
Smart, D. (2020), Medicane *'Ianos'* over the central Mediterranean 14–20 September 2020. Weather, 75: 352-353. https://doi.org/10.1002/wea.3871

Zekkos D., Alvertos A., Amatya P.M., Blunts P. and coauthors, 2020 Medicane Ianos, GEER-068, Technical report. https://doi.org/10.18118/G6MT1T



(a) Initialization 00 UTC 14 September 2020
(b) Initialization 00 UTC 14 September 2020
(c) Initialization 00 UTC 15 September 2020
(d) Initialization 00 UTC 15 September 2020
(e) Initialization 00 UTC 16 September 2020
(f) Initialization 00 UTC 16 September 2020

Figure 1: *Track and intensity of Ianos in ECMWF EPS (red: MSLP<1000 hPa) and analysis (black). Tracking by Philipp Zschenderlein (ETH)*



(a) 12 UTC 13 September 2020

(b) 12 UTC 14 September 2020

(c) 12 UTC 15 September 2020

(d) 12 UTC 16 September 2020

(e) 12 UTC 17 September 2020

(f) 12 UTC 18 September 2020

Figure 2: *Visible imagery from MODIS instrument aboard AQUA satellite; time is approximative. From https://worldview.earthdata.nasa.gov/*

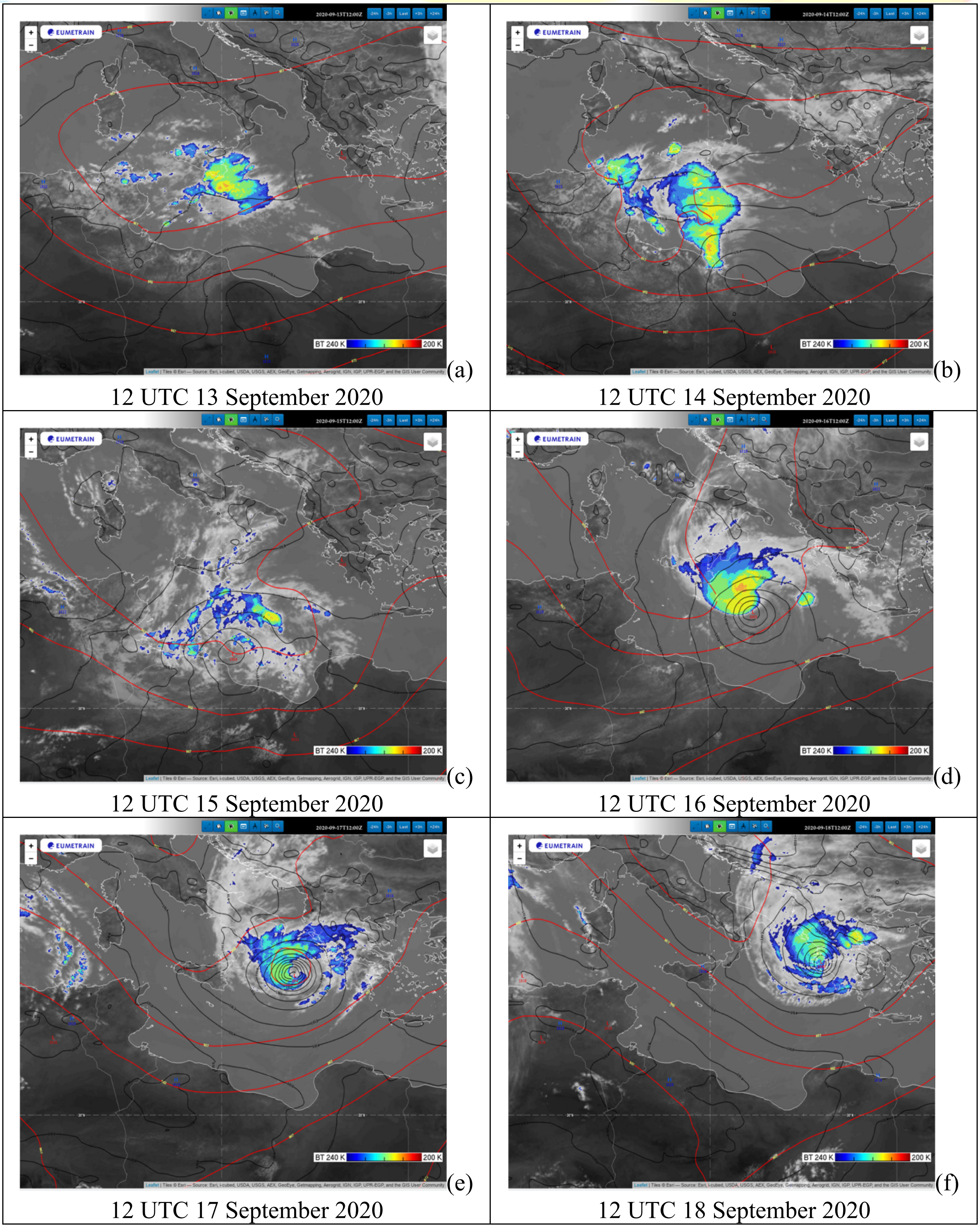


Figure 3: *MSG infrared imagery; analysis MSLP and 500-hPa geopotential (black and red curves). From http://www.eumetrain.org/ePort_MapViewer/*

Event	Brief description	Interesting aspects	What is needed	Contact
Qendresa 6-7 Nov 2014	Medicane developing south of Sicily	- Forecasting failure: the correct trajectory next to the eastern coast of Sicily was hardly (if ever) predicted - strong sensitivity to BC - good observation at the ground over Malta	Other NWP models to perform experiment with different IC and BC and different integration domains	Silvio Davolio
12 Nov 2019	Small scale cyclone in the Adriatic responsible for exceptional flood in Venice	-Operational models failed to reproduce the cyclone with the right intensity and track - Many observations are available near Venice - The cyclone showed a low-level warm core but a limited sensitivity to sea surface fluxes	Different simulations with different models, large-scale forcings, at different time scales, to explore the cyclone predictability	Mario Marcello Miglietta
5-8 Aug 2010	Med. cyclone with Vb (probably) trajectory affect Lithuania Aug 8 (night) it	Multiple strong squalls across territory (probably tornadoes), no radar data available. Meteo stations reported max sustained wind speed 20 - 26 m/s. The damage for the forestry - over 1 million m2 of timber in 70 thousand hectares; 3 victims, losses within private houses and farms	No warnings of extreme weather were produced as well as no complete cyclone (characteristics, trajectory etc) analysis was done. Maybe these consequences aren't related to the cyclone itself and only to its advected warm unstable air mass.	Gintas Stankunavicius

A comparative study of a few cases	Role of dry intrusions in the development of Medicanes	Dry intrusions are generally favorable to the intensification of extratropical cyclones and unfavorable to the deepening of tropical cyclones: what for Medicanes?	Trajectory analysis; diagnostic tools for dry intrusion analysis	Mario Marcello Miglietta
14-18 December 2020	Models show a possible medicane over Israel. I will have operational forecasts at 9, 3, and partly at 1 km grid sizes, WRF with IFS for IC/BC.	Not analyzed nor verified yet. May be used in a comparative study of few cases if medicane.	Other forecasts, tools for analysis.	Dorita Rostkier-Edelstein
22-24 Oct 2014 5-7 Jan 2017	Mediterranean cyclones with large scale altitude precursor	the earliest blizzard in Romania in 60 years extreme blizzard event in Romania	Mechanism analysis and predictability using high resolution data (including local obs network) and model simulations	Florinela Georgescu
35 Mediterranean cyclones	Produced heavy precipitation events in the eastern Mediterranean and have relatively good radar data available (see this paper for further details)	Radar data and high resolution WRF simulations (1 km for precipitation data; 5 km for other variables) are available	Further investigation of the meteorological ingredients triggering heavy precipitation	Moshe Armon

ROLF 06-10/11/2011 ILONA 19-23/01/2014 ZORBAS IANOS	Strong Tropical-Like Cyclones over western Mediterranean Sea that produced intense air-sea interaction, strong wind speed and heavy precipitation. Intense wind speed (around 120 km/h) and wave storm (close to 8-9 mt Hs.) Severe Tropical-Like Cyclones over Ionian Sea with landfall over Greece coast during maximum intensity phase	All simulations were performed using the approach : uncoupled (WRF model) Coupled : WRF (atm) and ROMS (ocean) models Fully coupled : WRF (atm) , ROMS (ocn) and SWAN (wave) models at 3 km of resolution (in atmosphere and ocean numerical grid)	analysis of modeling results in particular the interaction between atmosphere and ocean, and the effects of these interactions on precipitation and convection. Study of the phases of the cyclone and formulation a script that produces the cyclone phase diagram.	Antonio Ricchi

Table 1: *Potential case studies for future collaborations.*

Name	Contributor	Institution	Model
BOLAM-MOLOCH	Silvio Davolio	CNR - ISAC	BOLAM
MNH-LAERO	Florian Pantillon	Laboratoire d'Aérologie	MesoNH
WRF	Platon Patlakas	University of Athens	WRF
RAMS-ICLAMS	Platon Patlakas	University of Athens	RAMS-ICLAMS
UM-UKMO	Claudio Sanchez	UK Met Office	Unified Model
WRF-NSSL	Stavros Dafis	National Observatory of Athens	WRF
WRF-UIB	Diego Carrió	The University of Melbourne	WRF
WRF-HUJI	Dorita Rostkier-Edelstein	Hebrew University of Jerusalem	WRF
WRF-HCMR	Emmanouil Flaounas	HCMR	WRF
WRF-AUTH	Ioannis Pytharoulis	Aristotle University of Thessaloniki (AUTH)	WRF
WRF-WUR	Gert-Jan Steeneveld	Wageningen University	WRF
WRF-ISAC	Mario Marcello Miglietta	CNR – ISAC	WRF
WRF UNIVAQ	Antonio Ricchi	University of L'Aquila	WRF
WRF-ISAC2	Elenio Avolio	CNR – ISAC	WRF
HARMONIE-AROME	Carlos Calvo-Sancho & Juan Jesús González-Alemán	Uva & AEMET	HARMONIE-AROME

Table 2: *List of modelling systems and contributors.*

Category	Variable	Frequency	Levels	Unit
Grid	Latitude	Constant	2D original grid	°N
Grid	Longitude	Constant	2D original grid	°E
Grid	Orography	Constant	2D original grid	m
Dynamics	Wind component U	3 h	300/500/850 hPa	m/s
Dynamics	Wind component V	3 h	300/500/850 hPa	m/s
Dynamics	Wind component W	3 h	300/500/850 hPa	m/s
Dynamics	Temperature	3 h	300/500/850 hPa	K
Dynamics	Potential temperature	3 h	300/500/850 hPa	K
Dynamics	Geopotential height	3 h	300/500/850/1000 hPa	m
Dynamics	Water vapour mixing ratio	3 h	300/500/850 hPa	kg/kg
Dynamics	Potential vorticity	3 h	300/500/850 hPa	pvu
Dynamics	Relative vorticity	3 h	850 hPa	1/s
Dynamics	Total column water vapour	3 h	2D	mm
Dynamics	Total column cloud water	3 h	2D	mm
Dynamics	Total column cloud ice	3 h	2D	mm
Dynamics	Total column rain	3 h	2D	mm
Dynamics	Total column snow	3 h	2D	mm
Dynamics	Total column graupel	3 h	2D	mm
Dynamics	Inst. surface latent heat flux	3 h	2D	W/m2
Dynamics	Inst. surface sensible heat flux	3 h	2D	W/m2
Dynamics	Mean sea level pressure	3 h	2D	hPa
Impact	Accumulated precipitation	15 min	2D	mm
Impact	10-m zonal wind speed	15 min	2D	m/s
Impact	10-m meridional wind speed	15 min	2D	m/s
Impact	Surface pressure	15 min	2D	hPa
Impact	Max wind gust (if available)	15 min	2D	m/s

Table 3: *List of model output variables.*