SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2023……………………………..……
Project Title:	ASIM-CPL - Air-Sea Interactions on the Mediterranean basin, using "atmosphere-ocean-waves" CouPLed numerical models
Computer Project Account:	spitricc
Principal Investigator(s):	Dr. Antonio Ricchi
Affiliation:	CETEMPS – Department of Physical and Chemical sciences, University of L'Aquila
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Prof. Rossella Ferretti Dott. Lorenzo Sangelantoni
Start date of the project:	Start report date 1 January 2023………………………………..……
Expected end date:	End report date June 2023

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	10.000.000	11.539.370	10.000.000	1.406.077
Data storage capacity	(Gbytes)	10000	100	10000	100

Summary of project objectives (10 lines max)

The complex energetic feedbacks that appear between air-sea interface, play a fundamental role in atmospheric dynamics both on a meteorological and climatological scale. In this work we take advantage of coupled atmosphere-ocean-wave numerical models to investigate physical interactions and processes at the air-sea interface in extreme atmospheric events. Air-see interactions will be characterized according to two temporal horizons, short-term (weather time scale) and mid-term (seasonal time scale). Hence, project's purpose is performing a two-fold investigation. (i) an assessment of the impacts of atmosphere-ocean-wave coupling and air-sea interactions in extreme atmospheric events (short-term) focusing on triggering and intensification mechanisms. (ii) the cumulative modulation introduced by coupling ocean and waves components on seasonal climate predictability. In this project it will be employed the coupled numerical model COAWST (Coupled Ocean Atmosphere Waves Modeling System; Warner et al., 2010) at a convection permitting scale (<= 4 km).

Summary of problems encountered (10 lines max)

During the period of work described in this report, only minor problems were encountered.
In particular, during the transition to the new "ATOS" HPC, we had to reconfigure the structure of the modeling system and set up scripts to execute runs in an optimized manner. For example, we disabled hyperthreading to improve calculation performance and minimize the SBUs used. We conducted short runs to optimize the scaling of models on a various numerical grids.

Summary of plans for the continuation of the project (10 lines max)

In the coming months, we will perform further mid-term simulations as planned, in order to complete our tests and obtain sufficient results for the reference paper. Additionally, 5-year simulations will be conducted in re-forecast mode using the uncoupled atmospheric model. The objective is to generate a "reference forecast run" that can be compared with the runs of the coupled models. Furthermore, the coupled and uncoupled simulations (utilizing the WRF model and COAWST framework, WRF coupled with ROMS and SWAN) will be completed to investigate the proposed case studies of extreme events. The study will primarily focus on analyzing the physical factors and air-sea processes that drive and develop flash-flood events generated by the Mesocyclone Convective System (MCS) and the Mesocyclone Convective Complex (MCC), such as the floods in Liguria, the Pescara hailstorm, and the Naples hailstorm in September 2015.

List of publications/reports from the project with complete references

Starting from the results obtained in the last 6 months, we have sent the following contributions to conferences:

EGU 2023
Ferretti, R., Liguori, G., Cavicchia, L., Miglietta, M. M., Bonaldo, D., Ricchi, A., and Carniel, S.: Exploring how a warmer Mediterranean Sea affects the origin and development of destructive Tropical-Like Cyclones, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-6526, https://doi.org/10.5194/egusphere-egu23-6526, 2023.

MetMed 2023 9th International Conference on Meteorology and Climatology of the Mediterranean

O4.6 - On the influence of ocean mixed layer depth and sea surface temperature development of the tropical-like cyclone “IANOS”
A. Ricchi, Ferretti, R., Liguori, G., Cavicchia, L., Miglietta, M. M., Bonaldo, D., and Carniel, S.:

ICAM 2023 36th **International Conference on Alpine Meteorology.** On the role topography and trigger mechanism on the development of a large-hail supercell storm event, on the Adriatic Sea. Antonio Ricchi (University Of L'Aquila, Italy), Rossella Ferretti, Mario Marcello Miglietta, Errico Picciotti, Alessandro Tiesi, Lorenzo Sangelantoni, Vincenzo Mazzarella, Richard Rotunno, Mario Montopoli, Simone Mazzà, Frank Silvio Marzano

We have submitted the following papers, currently in revision or advanced stage of production:

a) Analysis of the development mechanisms of a large-hail storm event on the Adriatic Sea: Part II
   Antonio Ricchi, Richard Rotunno, Mario Marcello Miglietta, Errico Picciotti, Mario Montopoli, F. S. Marzano, Luca Baldini, Gianfranco Vulpiani, Alessandro Tiesi and Rossella Ferretti
b) Impact of the SST and topography on the development of a large-hail storm event, on the Adriatic Sea: Part I
   Antonio Ricchi, Lorenzo Sangelantoni, Gianluca Redaelli, Vincenzo Mazzarella, Mario Montopoli, Mario Marcello Miglietta, Alessandro Tiesi, Simone Mazzà, Richard Rotunno and Rossella Ferretti
c) Ricchi, A., Ferretti, R., Liguori, G., Cavicchia, L., Miglietta, M. M., Bonaldo, D., and Carniel, S.: Exploring how a warmer Mediterranean Sea affects the origin and development of destructive Tropical-Like Cyclones
d) Analysis of An Intense Hail Event In The Po Valley Using WRF Model.
   Olivia Vashti Ayim; Antonio Ricchi; Pierpaolo Alberoni; Rossella Ferretti.

Summary of results

The results obtained in the last six months are characterized by a still immature state of analysis. In the other hands the works of the previous 12 months are highlighted in the previous annual report. Here are the preliminary results of the work carried out:

1. Senigaglia Flash flood, 16 Sept 2022:

   The Senigaglia flood was an extreme event that occurred in central Italy as a result of the interaction between unstable, humid air, which was pre-conditioned by its interaction with the sea, and the topography of Corsica and the Central Apennines. Downwind of the flow from Corsica, a series of linear, semi-stationary storm cells developed, causing an accumulation of over 400 mm in 12 hours. This led to a significant flood in the Senigaglia area, resulting in several fatalities. In this context, we configured the WRF model and the ICON model, with resolutions of 3-1km and 3km respectively, to assess the models' performance in simulating this event. The results are highly encouraging, as they accurately depict the timing, accumulation, and localization of the event, as shown in Fig. 1. We plan to employ the COAWST model for further investigations into the role of sea interaction in the formation processes of the storm structure, with the intention of proposing a scientific paper within the next 6 months.

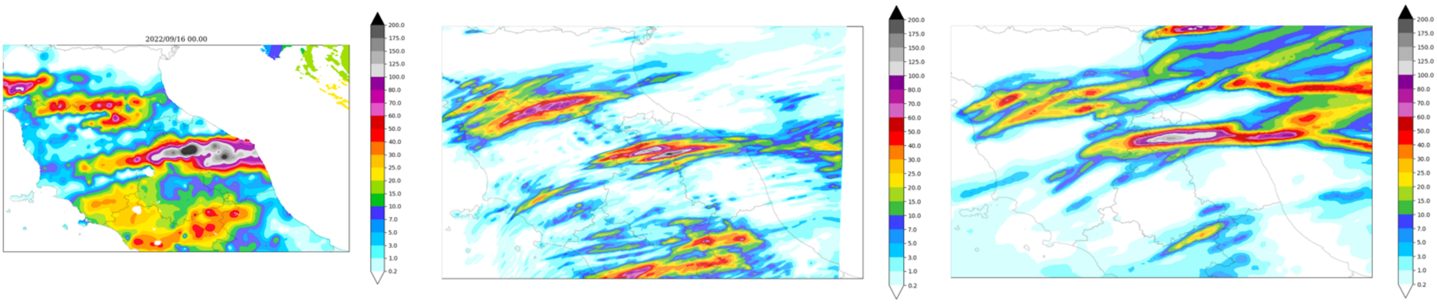


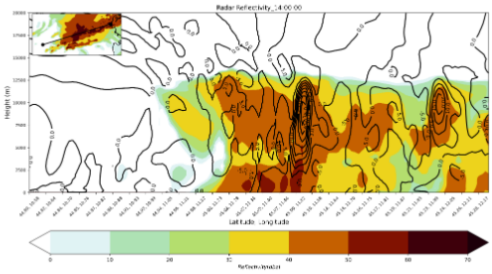
Fig. 1 shown total accumulated rainfall from weather station, WRF model at 1 km and ICON model at 3 km.

2. Tornado Campania Region (Caserta city, Italy) 12 March 2018:

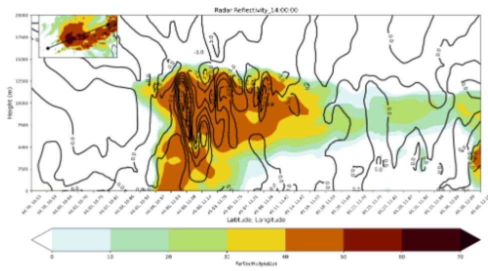
   In the afternoon of 12 March 2018, a thunderstorm cell with strong intensity characteristics, probably a supercell, developed downstream of the mountain range on the border between the Lazio region and the Campania region. This cell moved rapidly through the interior of the Campania region, heading south, and generated a tornado that affected the city of Caserta and its suburbs. The tornado reached F2 intensity. There are numerous challenges in reproducing this phenomenon, ranging from the size of the event, which requires a very high-resolution calculation grid (sub-km), to the dynamics and thermodynamics on a basin scale, with an influx of humidity from the sea likely triggering the intensification of the convective phenomenon. Due to these reasons and the complex feedback mechanisms influencing this phenomenon, we aim to investigate it with the assistance of the COAWST coupled model. The preliminary results obtained with the uncoupled model firstly reveal significant difficulties in replicating both the signal and the structure of the phenomenon. Additionally, the role of the topography in generating the initial structure is emphasized. Using the multiphysics ensemble approach we identified the most suitable physical configuration to simulate the event, with the use of a double-moment microphysics and the use of high resolution (uncoupled) SST and 3DVAR assimilation of weather station data.

3. Hailstorm Po Valley, 26 July 2021

On July 26, 2021, a storm formed over the Emilian Apennines between 10 and 12 UTC. The storm quickly spread to the Romagna coast (Adriatic) around 15 UTC. The storm produced intense rainfall (rain rate greater than 50mm/h), but more significantly, it brought a hailstorm with dimensions close to 6-8 cm and strong gusts of wind (up to 25 m/s). The simulations were performed using the WRF model at 9-3-1 km with ECMWF-IFS initialization at 9 km. To identify the role of Condensation Nuclei (CCN), we changed their origin from "continental" to "maritime," considering that the study area can be influenced by both continental currents and intense maritime flows. The preliminary results (under submission) indicate a significant impact of the types of "seeds" introduced into the "microphysics" of the convective process, leading to notable differences in the structure, intensity, and size of the hail (Fig. 2).



(a) Continental CCN



(b) Maritime CCN

Fig. 2 Cell Structure of the Hail Simulated at 14UTC, panel a Continental CCN, panel b maritime CCN.

4. SST and Topography impact on Hailstom over Pescara city, 10 July 2019

The study of the hailstorm event, which had a diameter greater than 12 cm and affected the city of Pescara, was conducted using a WRF model at a 1 km resolution. The study aimed to test the impact of topography and sea surface temperature (SST), while simultaneously examining the structure of the cell to determine if it was a supercell.The results of this study are presented in two papers that have been submitted and are currently under review.

e) Analysis of the development mechanisms of a large-hail storm event on the Adriatic Sea: Part II
Antonio Ricchi, Richard Rotunno, Mario Marcello Miglietta, Errico Picciotti, Mario Montopoli, F. S. Marzano, Luca Baldini, Gianfranco Vulpiani, Alessandro Tiesi and Rossella Ferretti

f) Impact of the SST and topography on the development of a large-hail storm event, on the Adriatic Sea: Part I
Antonio Ricchi, Lorenzo Sangelantoni, Gianluca Redaelli, Vincenzo Mazzarella, Mario Montopoli, Mario Marcello Miglietta, Alessandro Tiesi, Simone Mazzà, Richard Rotunno and Rossella Ferretti

5. Impact of Mixed Layer Depth, Sea Surface Temprature Anomaly and Sea Surface Temperature gradient on Tropical Like Cyclones IANOS.

   The Tropical-Like Cyclones developed in the Ionian Sea between September 15, 2020, and September 20, 2020, had a violent impact along the Greek coasts, resulting in severe socio-economic damage and some casualties. The TLC, named IANOS, moved across a sea basin (Ionian) with temperatures above the average by approximately 2-3°C. In this study, we investigated the impact of SST, SST anomaly, climatic projections of SST increase under different scenarios, SST gradients, and Mixed Layer Depth. The results demonstrate the crucial role of SST and MLD in determining the intensity of the cyclone. However, we observed an extremely marginal influence on the trajectory and timing of the cyclone, which were found to be very similar in the various experiments. This is likely because while intensity may be influenced by the cyclone's structure, phase, and thermodynamics of convection in pressure minima, the trajectory and direction may be more strongly influenced by synoptic-scale circulation. The results are presented in a paper currently under review

   Ricchi, A., Ferretti, R., Liguori, G., Cavicchia, L., Miglietta, M. M., Bonaldo, D., and Carniel, S.: Exploring how a warmer Mediterranean Sea affects the origin and development of destructive Tropical-Like Cyclones