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	2025
Project Title:	Numerical modeling of precipitation climatology and its sensitivity to climate change effects on the Apennines mountains
Computer Project Account:	spitsilv
Principal Investigator(s):	Lorenzo Silvestri
Affiliation:	University of Modena and Reggio Emilia, Modena, Italy
Name of ECMWF scientist(s) collaborating to the project (if applicable)	…… ……
Start date of the project:	01-01-2025
Expected end date:	31-12-2027

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)			5.000.000	45
Data storage capacity	(Gbytes)			10.000	0

Summary of project objectives (10 lines max)

The main objectives of the project are:
1) Understand and explain the main physical processes constituting the observed precipitation climatology over central Italy
2) Understand and explore possible causes of the recent climate trends observed in the precipitation climatology especially over the Apennines.
3) Generalise and build theoretical models for the effects of climate change on orographic convection and precipitation.

Summary of problems encountered (10 lines max)

From the point of view of model compilation, we did not encounter any problem. I am currently working on finding idealized initial conditions that better represents a certain type of convection triggered by precipitation.

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

The step we completed are the one regarding the production of idealized initial condition, which can represent typical rainfall events over the Central Italy. Actually, we will start with an extreme weather events where orography played a substantial role (The Flood event in Central Italy of 15 September 2022) and where the conditions are represented by a uniform moist zonal flow. In this purely zonal flow, most of the trigger of convection comes from the orographic forcing. We will use this initial condition as a first test to understand the role of Appenines in triggering quasi-stationary deep convective system over the Central Italy. The following steps (planned for September 2025) are:
- Running the model over the Central Italy domain with fixed boundary condition (equal to the initial idealized soundings) first at low horizontal resolution (4 km) and then at high horizontal resolution (250 m, Large-Eddy-Simulation)
- Performing sensitivity test to surface condition: only land without mountains, land with mountains, land and sea with mountains.
- Performing sensitivity to humidity and wind speed in the initial sounding.

List of publications/reports from the project with complete references

None

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

In the first phase of the project we conduct an analysis of the initial conditions representing a convective event where orography played a substantial role. We select the Flood in the Marche and

Umbria Region on 15 September 2022 (see the analysis by Tartaglione 2025). The convective event was almost stationary over the Apennines producing peaks of total rainfall above 300 mm within 12 hours. The synoptic situation is characterized by zonal flow, without cyclonic structures as shown in Figure 1. The zonal flow is almost orthogonal to the apennines mountains and is also characterized by high relative humidity, both at 500 hPa (Figure 1b) and 850 hPa (Figure 1d). This high humidity content has been associated to the presence of an atmospheric river (Tartaglione, 2025) coming from the Atalantic ocean. Figure 1c and 1d show also the presence of warm and dry air from the northern Africa. Therefore the convergence of these two different air-masses with different characteristics (cold and moist frome above and warm and dry from below) have played a significant role in the development of the convective system.

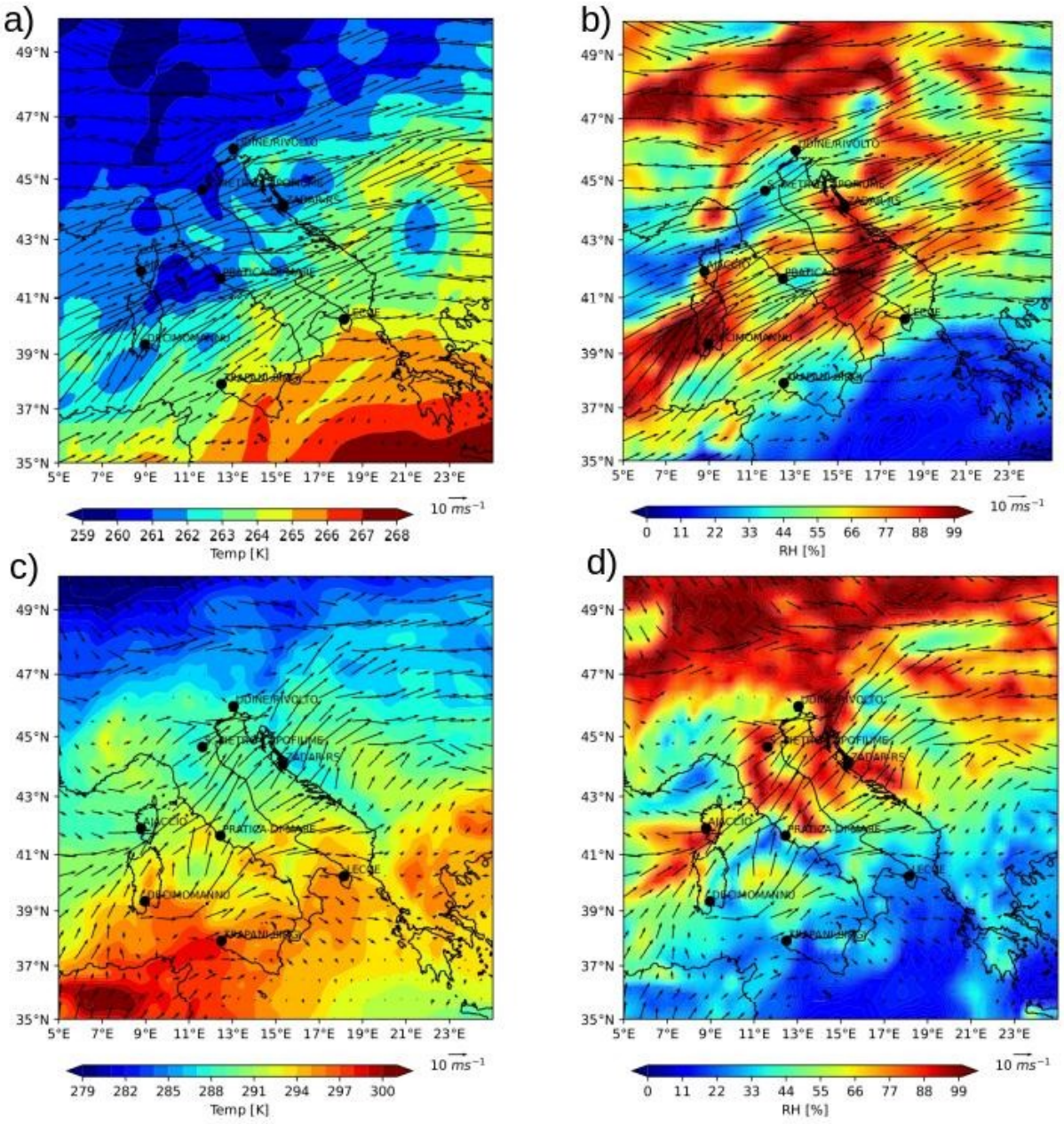

Figure 1: a) Temperature at 500 hPa, b) Relative humidity at 500 hPa, c) Temperature at 850 hPa, d) Relatrive humidity at 850 hPa as obtained from ERA5 on 15 September 2022 at 12:00 a.m.

Normally, such zonal flow configuration does not produce high rainfall over Central Italy, as observed by Silvestri et al. (2022). Therefore it represents a good candidate to isolate the impact of orography on the creation of quasi-stationary convective systems over Central Italy. This approach is similar to the idealized approach of Bresson et al. (2012) on the Northwestern Mediterranean.

In the first phase of the project we compare the observed sounding with those of ERA5 for the inflow conditions, as taken from the two stations of Ajaccio (Corsica) and Decimomannu (Sardinia).

Figure 2a, 2c and 2d show very similar soundings and a good agreement between ERA5 and observations, also in terms of CAPE. Very high CAPE values (>1000 J/kg) are found at those times. The main feature of such soundings are:
1) a humid and warm surface;
2) a warm and dry boundary layer up to 900 hPa (due to the warm and dry advection possibly related to desert air);
3) a cold and moist free troposphere related to the presence of the atmospheric river from the Atlantic Ocean.
Wind barbs show also the presence of south-westerly /westerly flows almost at all pressure levels, without any significant wind shear.
These sounding will be taken as reference to build an idealized sounding to initialize the simulations.

Figure 3 shows the same comparison for Pratica di Mare on the Tyrrhenian coast of Central Italy, just before the air impact the Apennines mountain chain. The temporal evolution of the sounding shows good agreement between ERA5 and observations how the high CAPE values build up only on 15 September at 12:00 a.m (Figure 3d). Low-level winds exhibit some rotation to southern directions when encountering land and some wind shear also starts to develop (Figure 3d).

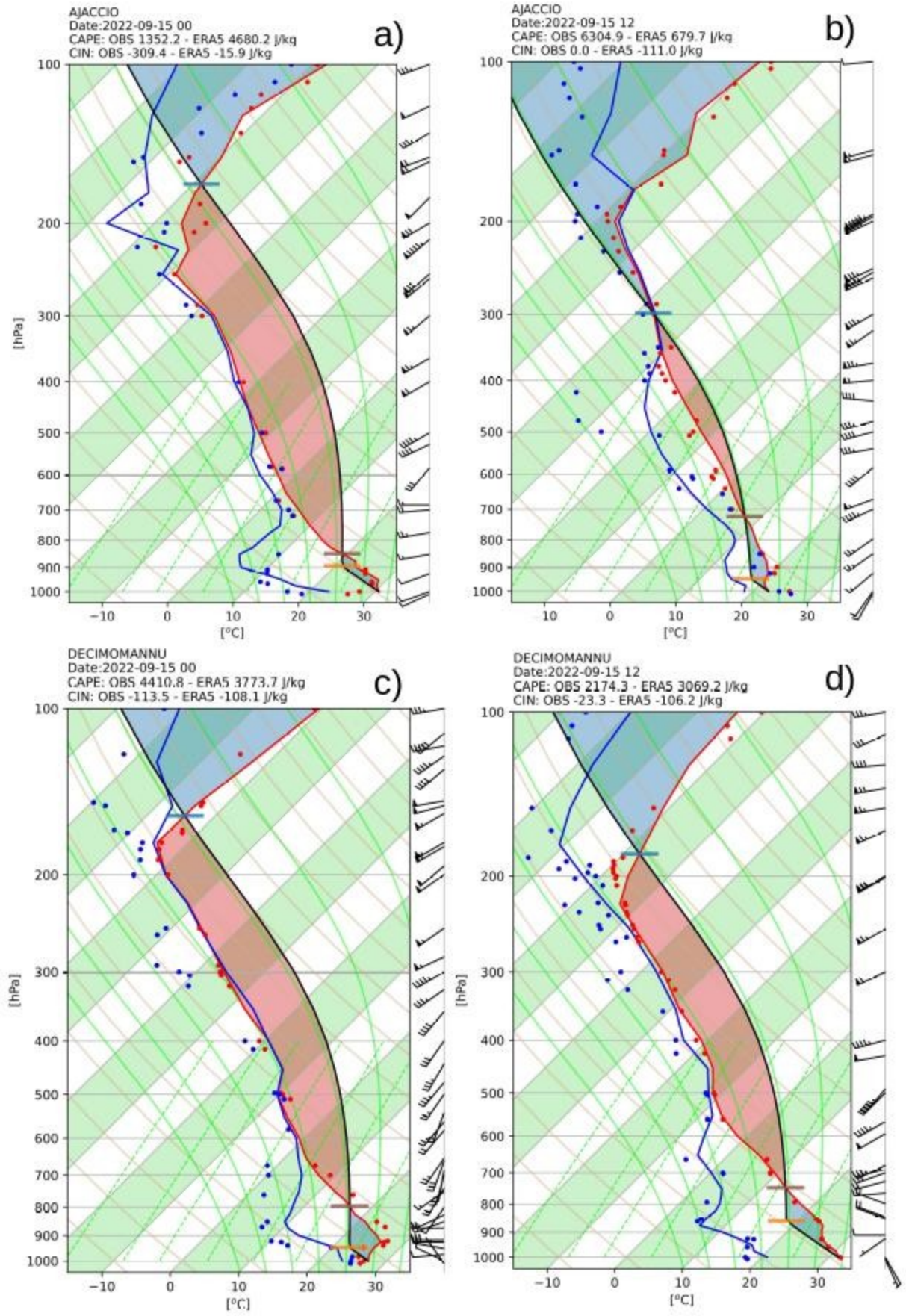

Figure 2: Comparison between observed (dots) and ERA5 soundings (solid lines) for a) Ajaccio station on 2022-09-15 00:00, b) Ajaccio station on 2022-09-15 12:00, c) Decimomannu station on 2022-09-15 00:00, d) Decimomannu station on 2022-09-15 12:00.

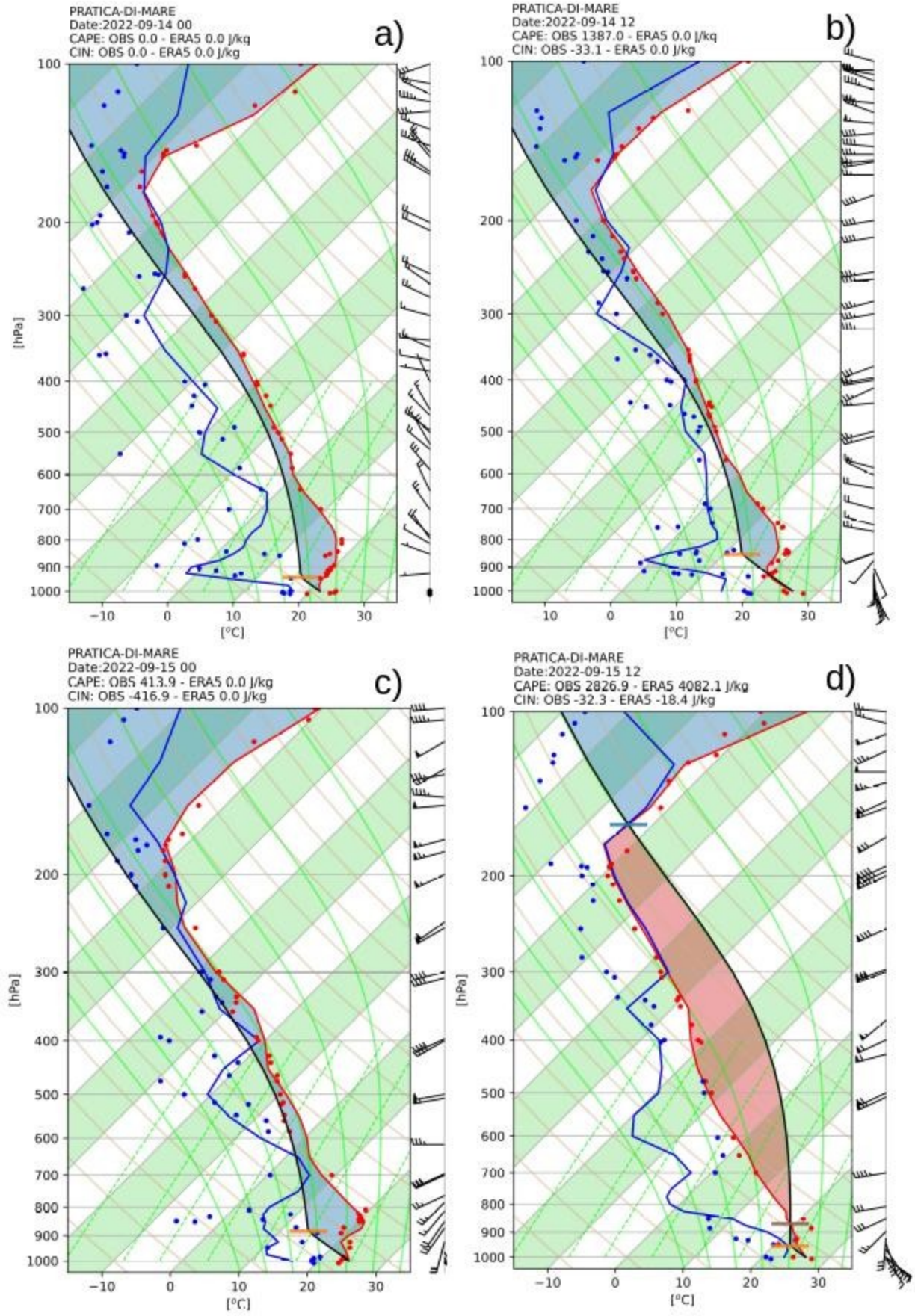
PRATICA-DI-MARE
Date:2022-09-14 00
CAPE: OBS 0.0 - ERA5 0.0 J/kg
CIN: OBS 0.0 - ERA5 0.0 J/kg
a)
PRATICA-DI-MARE
Date:2022-09-14 12
CAPE: OBS 1387.0 - ERA5 0.0 J/kg
CIN: OBS -33.1 - ERA5 0.0 J/kg
b)
PRATICA-DI-MARE
Date:2022-09-15 00
CAPE: OBS 413.9 - ERA5 0.0 J/kg
CIN: OBS -416.9 - ERA5 0.0 J/kg
c)
PRATICA-DI-MARE
Date:2022-09-15 12
CAPE: OBS 2826.9 - ERA5 4082.1 J/kg
CIN: OBS -32.3 - ERA5 -18.4 J/kg
d)
[hPa]
[°C]

Figure 3: Comparison between observed (dots) and ERA5 soundings (solid lines) for Pratica di Mare station on a) 2022-09-14 00:00, b) 2022-09-14 12:00, c) 2022-09-15 00:00 and d) 2022-09-15 12:00.

References:

Tartaglione, N. Unprecedented Flooding in the Marche Region (Italy): Analyzing the 15 September 2022 Event and Its Unique Meteorological Conditions. Meteorology 2025, 4, 3. https://doi.org/10.3390/meteorology4010003

L. Silvestri, M. Saraceni, and P. Bongioannini Cerlini. Links between precipitation, circulation weather types and orography in central italy. International Journal of Climatology 42.11: 5807-5825, 2022

Bresson E, Ducrocq V, Nuissier O, Ricard D, de Saint-Aubin C. 2012. Idealized numerical simulations of quasi-stationary convective systems over the Northwestern Mediterranean complex terrain. Q. J. R. Meteorol. Soc. 138: 1751–1763. DOI:10.1002/qj.1911