COST Action CA19109 “MedCyclones” – Working Group 2

Deliverable D2.5

Climatological overview article addressed to scientific community, on Mediterranean cyclone categories and on the future climatology of Mediterranean cyclones.

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As planned, the main initiative within the WG2 has reached to a relevant conclusion and the results have been published on Weather and Climate Dynamics, an Open Access journal edited by Copernicus with high impact factor that will ensure a wide dissemination.

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Process-based classification of Mediterranean cyclones using potential vorticity

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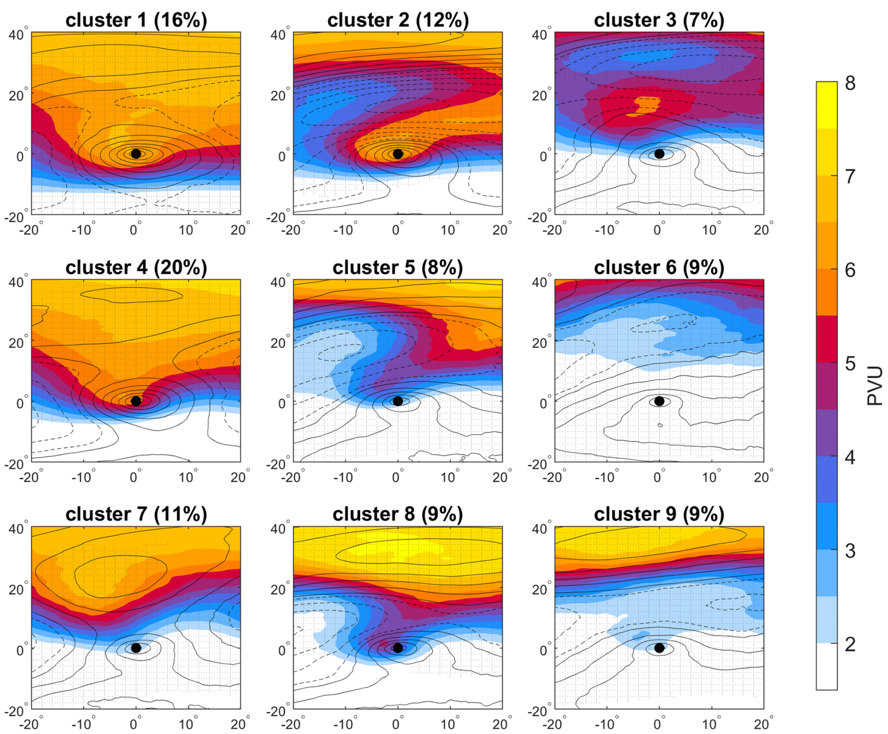
The MedCyClass - Mediterranean Cyclone Classification initiative, led by Shira Raveh-Rubin, aimed at classifying Mediterranean cyclones to categories, based on the governing processes that lead to their development.
The combined cyclone-tracking algorithm (produced by the 3T initiative of the Action) is used to detect more than 3000 Mediterranean cyclone tracks in ECMWF ERA5 from 1979–2020. Cyclone-centered, upper-level isentropic PV structures in the peak time of each cyclone track are classified using a self-organizing map (SOM). The SOM analysis reveals nine classes of Mediterranean

cyclones, with distinct Rossby-wave-breaking patterns, discernible in corresponding PV structures. Although classified by upper-level PV structures, each class shows different contributions of lower-tropospheric PV and flow structures down to the surface. Unique cyclone life cycle characteristics, associated hazards (precipitation, winds, and temperature anomalies), and long-term trends, as well as synoptic, thermal, dynamical, seasonal, and geographical features of each cyclone class, indicate dominant processes in their evolution.

While so far most of the Mediterranean cyclone classification relied on geographical–seasonal features, this classification is based on the dominating driving mechanisms.
Since upper-level PV is an adiabatically conserved quantity that provides a dynamic diagnostic of the atmosphere indicative of different dynamical and thermodynamical processes, its anomalies have been used to classify Mediterranean cyclones. In fact, upper-level PV anomalies are a crucial condition for Mediterranean cyclogenesis and play a major role in MC evolution.



Using a SOM approach, upper-level PV serves to classify cyclones and systematically evaluate the large-scale patterns driving different cyclone types, with distinct seasonal and geographical distributions, a characteristic cyclone life cycle, dynamic and thermodynamic responses, and associated hazards.
The results of this study improve our current understanding of Mediterranean cyclones and are very relevant since Mediterranean cyclones are a major cause of severe weather, affecting the lives of millions throughout Europe, northern Africa, and the Middle East. They provide a robust basis for further research at both weather and climate time scale, but even more important is the potential application to investigate distribution and intensity of cyclones impacts (precipitation, temperature, surface winds).

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Along this promising line, the classification has been already exploited in two studies dealing with compound extreme and weather hazard, recently published on Weather and Climate Dynamics:
Portal, A.; Raveh-Rubin, S.; Catto, J. L.; Givon, Y.; Martius, O. Linking compound weather extremes to Mediterranean cyclones, fronts, and airstreams. Weather and Climate Dynamics, 5, 1043–1060, https://doi.org/10.5194/wcd-5-1043-2024, 2024.
Rousseau-Rizzi, R.; Raveh-Rubin, S.; Catto, J.L.; Portal, A.; Givon, Y.; Martius, O. A storm-relative climatology of compound hazards in Mediterranean cyclones. Weather and Climate Dynamics, 5, 1079–1101, https://doi.org/10.5194/wcd-5-1079-2024, 2024.

Another outstanding issue intricately linked to cyclone classification is the role of air-sea interaction in cyclone deepening. To this end, in a recent study, developed within a Virtual Mobility Grant, the composite cyclone track dataset (Flaounas et al. 2023) has been applied, classified into the Mediterranean basin-wide and year-round 9 categories (Givon et al. 2024). Ocean evaporation data from ERA5 have been classified, aiming to categorize air-sea interaction under Mediterranean cyclone conditions. Composite quantification of air-sea interaction by cyclone class has been obtained. The results of this work provide new insight on the association of ocean evaporation to cyclones from cyclone-centred (Lagrangian) perspective, as well as from a geographically-fixed view. Using cyclone attribution to the ocean variables and composite approaches, strong variability of surface fluxes by cyclone class has been found.