Event-based attribution of Mediterranean extreme cyclones in a changing climate

Tommaso Alberti[1], Davide Faranda[2]

[1]Istituto Nazionale Di Geofisica E Vulcanologia, Rome, Italy, [2]Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL), Paris, France

Climate change is modifying both the dynamics and the intensity of extreme weather events, amplifying impacts from heavy precipitation, floods, droughts, and heatwaves. Attributing such extremes requires understanding how large-scale climatic forcing interacts with regional nonlinear processes, particularly in areas where small-scale dynamics play a dominant role.

The Mediterranean basin is a climate-change hotspot characterized by strong land–sea contrasts, complex orography, and convective activity. High-impact events, such as the recent Mediterranean cyclone Harry (2026), emerge from multiscale interactions and exhibit intermittency, threshold behavior, and strong sensitivity to initial conditions. These features challenge traditional attribution approaches based on coarse-resolution models.

Here, we present an event-based, data-driven framework for the attribution of Mediterranean extreme cyclones, combining reanalysis data with extreme value theory and machine learning pattern recognition. Extreme events are represented as rare trajectories in a high-dimensional phase space, enabling the identification of analog events and regime shifts. Using events such as cyclone Harry as test cases, the framework quantifies changes in frequency, intensity, and spatial organization under climate change, providing a physically consistent basis for improved attribution and predictability of Mediterranean extreme cyclones.