What Are the Environmental Characteristics Associated with the Tropical Transition of Mediterranean Cyclones?

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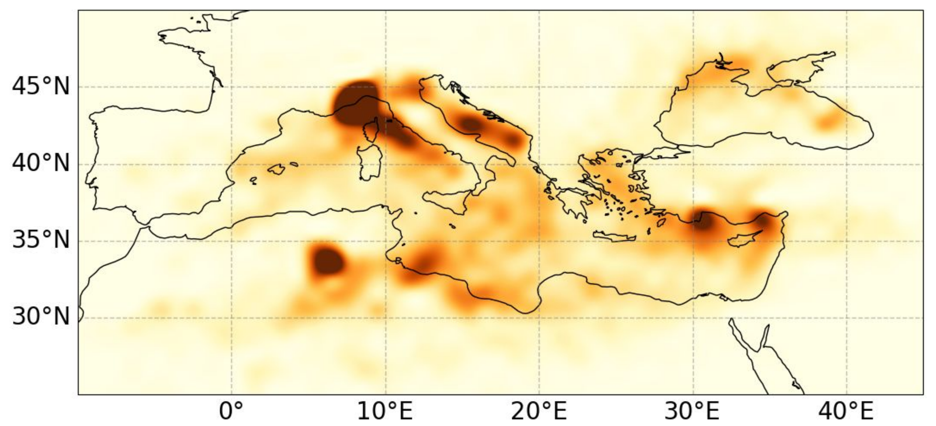
Introduction

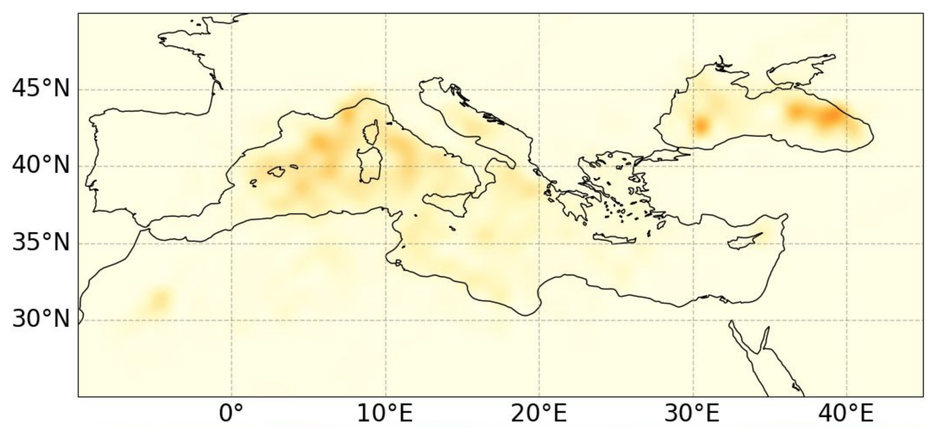
Various weather-induced natural hazards in the Mediterranean region like heavy rainfall, floods, or windstorms are associated with Mediterranean cyclones (Lionello *et al.*, 2006; Flaounas et al., 2022). These cyclones are extra-tropical cyclones (ETC) that have baroclinic origins, related to the deviation of the jet stream meanders over the Mediterranean Sea (Flocas, 2000; Fita *et al.*, 2007; Flaounas *et al.*, 2015).

In some rare cases, some cyclones develop in their mature stage similar characteristics to tropical cyclones (TC): an axisymmetric deep warm core, generally with a windless center surrounded by strong winds (Fita *et al.*, 2007; Tous *et al.*, 2013). Those Mediterranean Tropical-Like Cyclones (MTLC), are particularly severe and can cause important damage (Akhtar *et al.*, 2014, Nastos *et al.*, 2018).

To find out if there are specific environmental characteristics that promote the transition of classical extratropical cyclones into warm core cyclones, the evolution of those environmental conditions alongside the Mediterranean cyclones' lifetime has been analyzed. The difference found allowed the identification of precursors that could explain why some cyclones develop Tropical characteristics in the Mediterranean Sea.

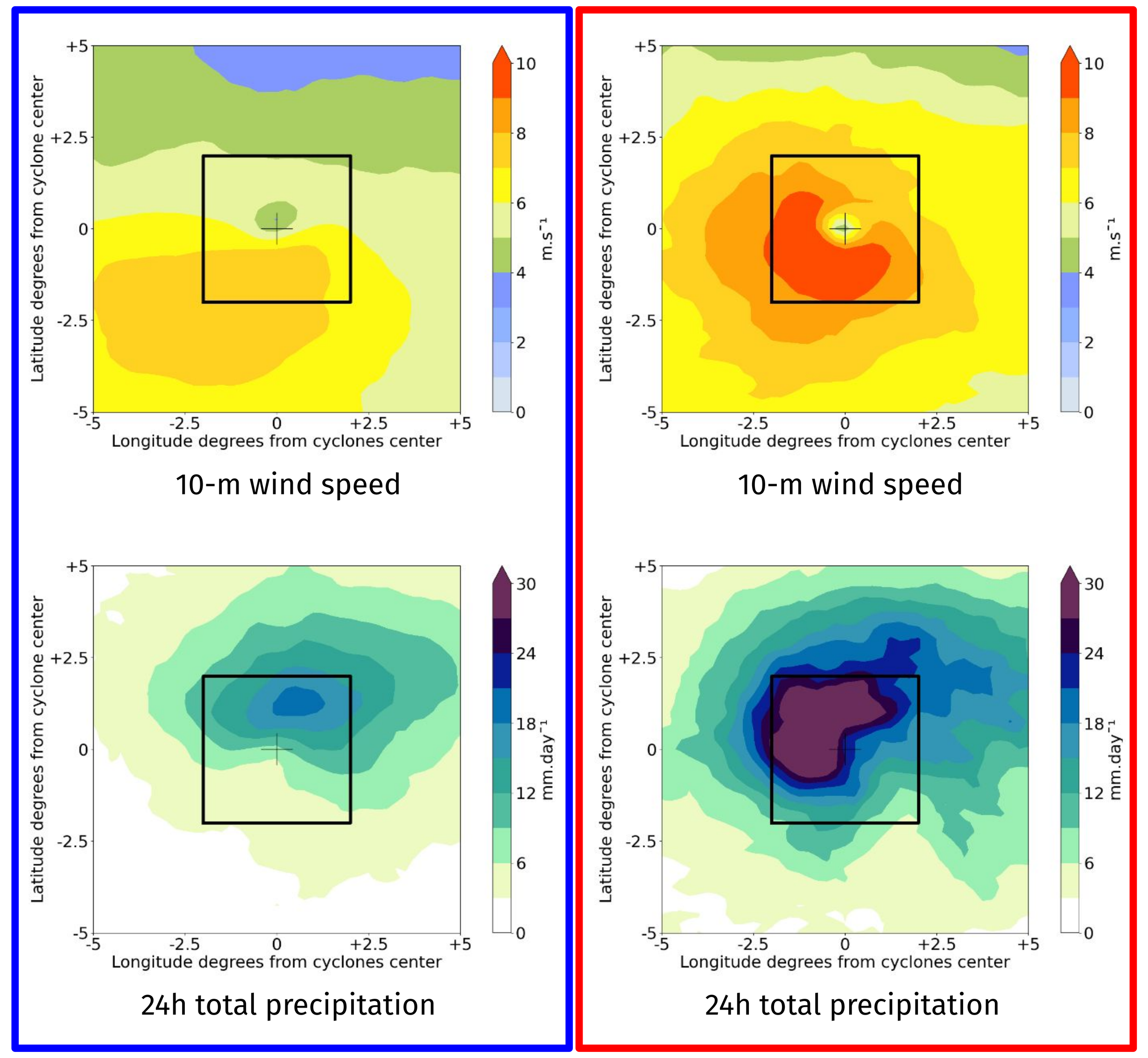


ETC ~ 23 cyclones per year



MTLC ~ 3.4 cyclones per year

Average number of tracks points per year in a 1° by 1° box



ETC

MTLC

2D composites of surface winds (top) and daily total precipitation (bottom) centered on the cyclones at time of maximum intensity for both extratropical cyclones and tropical-like ones.

Materials and Methods

Mediterranean cyclones can be studied through a dataset provided by Flaounas *et al.* (2023). It consists of composite cyclone tracks detected by ten different cyclone detection and tracking methods applied to hourly data of the ERA5 reanalysis in the 42 years of 1979-2020. In the following work, we retained the cyclones tracked by at least five of the ten tracking algorithms.

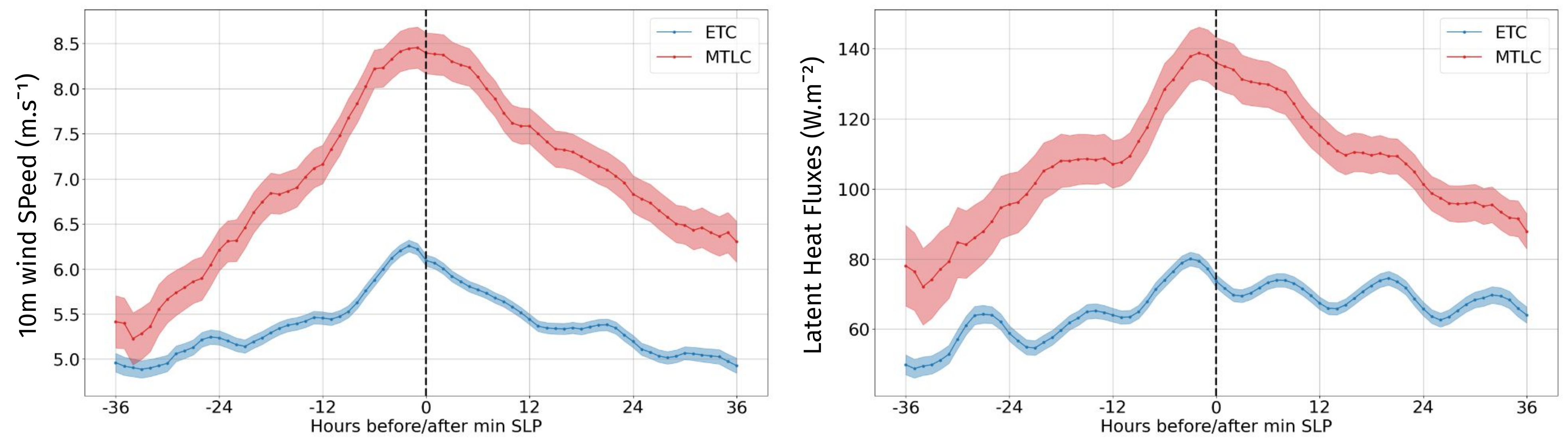
The cyclone phase space (CPS) diagram (Hart, 2003) has been applied to distinguish between typical frontal ETC with a cold inner core and axisymmetric MTLC with a deep inner warm core. In this study, MTLC are defined as cyclones that for at least 6 hours over the Sea, have negative lower and upper thermal winds.

The maximum intensity of the cyclone is defined as the lifetime minimum Sea Level Pressure, SLP, at the cyclone center, and the time of its first occurrence is defined as time 0. From 36 to 7 hours before the maximum intensity, less than 8% of the cyclones of MTLC already present a warm core. It means that the rest of them are still in their typical cold core conditions at those timesteps.

For this reason, the difference in the environmental conditions between ETC and MTLC from 36 to 7 hours before the peak intensity is investigated to identify possible precursors to the tropical-like transition. Anomalies have been computed as departures from the climatological seasonal cycle computed as a 7-day running mean of the daily mean values over the 42 years.

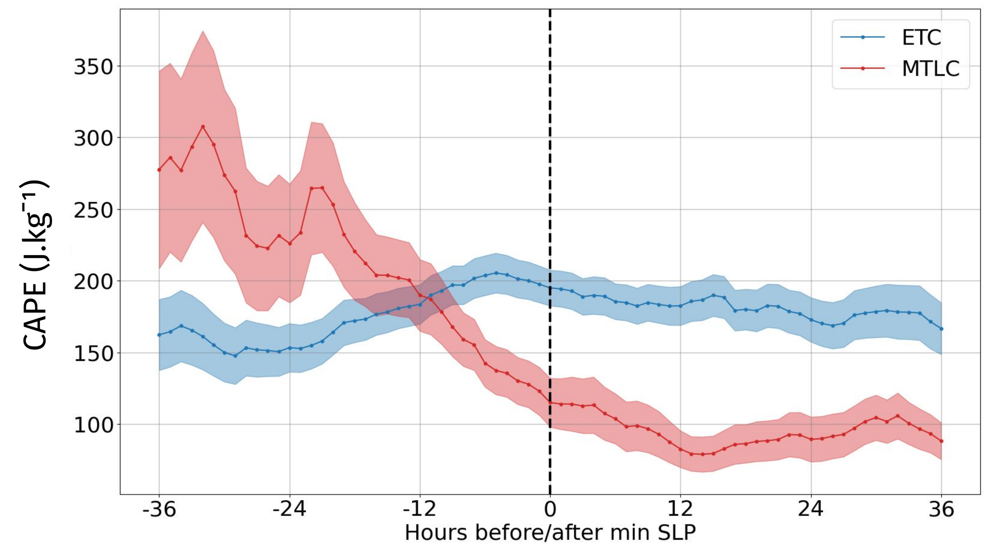
WISHE mechanism

The surface winds are typically stronger in MTLC than in ETC over the whole lifetime of the cyclones, not only at the time of their peak intensity. This is reflected in overall larger air-sea fluxes in MTLC, as driven by the wind-induced surface heat exchange effect (WISHE).



Composite time evolution with respect to minimum SLP (black dashed line) of the surface wind speed (left) and the surface latent heat fluxes in a 4°x4° box centered on the cyclone.

The WISHE mechanism is responsible for the intensification of the tropical-like cyclones once they already transitioned. However, at the very beginning of the cyclones' lifetime, what is responsible for the development of convection and the establishment of the warm core?



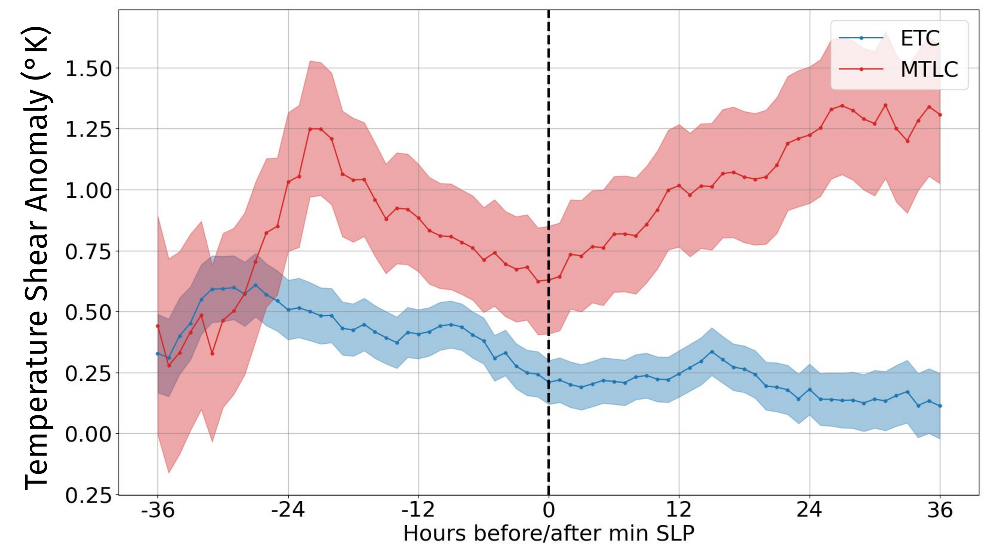
Composite time evolution with respect to minimum SLP (black dashed line) of Convective Available Potential Energy (CAPE) in a 4°x4° box centered on the cyclone.

Not the cold intrusions!

The temperature difference between the surface and the upper troposphere plays a crucial role in the development of tropical cyclones (Emanuel, 2003). This difference is influenced by sea surface temperatures in the tropics and upper-level cold intrusions in mid-latitudes.

In the Mediterranean Sea, cyclones exhibit anomalously large temperature gradient values, but there's no significant distinction observed between Mediterranean tropical-like cyclones (MTLC) and extratropical cyclones (ETC).

In essence, while upper tropospheric cold intrusions are common in all cyclonic disturbances, they do not serve as a distinguishing precursor between cyclones transitioning into tropical-like systems and those that do not.



Composite time evolution with respect to minimum SLP (black dashed line) of the temperature shear anomaly between sea surface and 300 hPa in a 4°x4° box centered on the cyclone.

Take home message

Mediterranean Tropical-like cyclones (MTLC), compared to the typical extra-tropical cyclones in this region, are characterized by a stronger depression, more faster wind speed, and more intense precipitation.

Their development is associated with an important release of latent heat in the air column favored by high moisture levels. Two possible mechanism can explain this moist environment: either pre-existing high level of humidity, either moisture advection by large-scale uplifting motion favored by a strong upper-level potential vorticity anomaly.

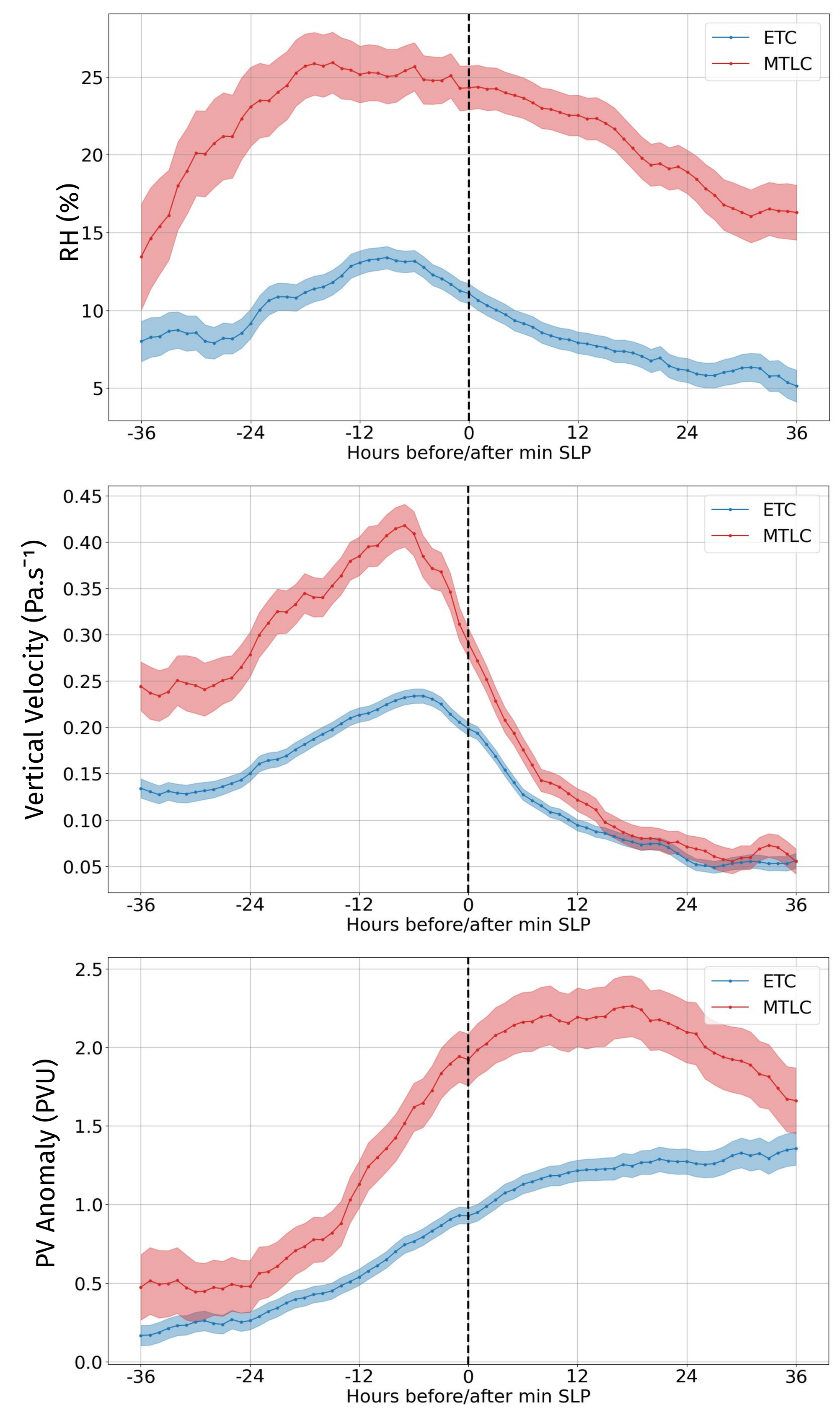
After their transition, at their maximum peak intensity, MTLCs are sustained by wind-induced surface heat exchange.

Anomalous moisture content

In the left exit region of a cyclonically curved jet streak, upper-level divergence induces uplifting motion throughout the troposphere and favors vertically developed convection (Chaboureau *et al.*, 2012). Indeed, vertical velocities at mid-levels are larger than normal for both ETC and MTLC, with much larger anomalies for the latter.

Stronger large-scale uplifting velocities advect moisture into the mid-levels, bringing the air column close to saturation conditions and favoring the release of latent heat which can thus become responsible for the development of the warm core and for the energization of the cyclone.

Alternatively or in a complementary way, pre-existing high levels of moisture associated with large-scale circulation could lead to the same enhanced release of latent heat compared to typical extra-tropical cyclones.



Composite time evolution with respect to minimum SLP (black dashed line) in a 4° x4° box centered on the cyclone of the: relative humidity (RH) at 500 hPa (top); vertical velocity at 500 hPa (center); potential vorticity (PV) anomaly at 300 hPa (bottom).

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