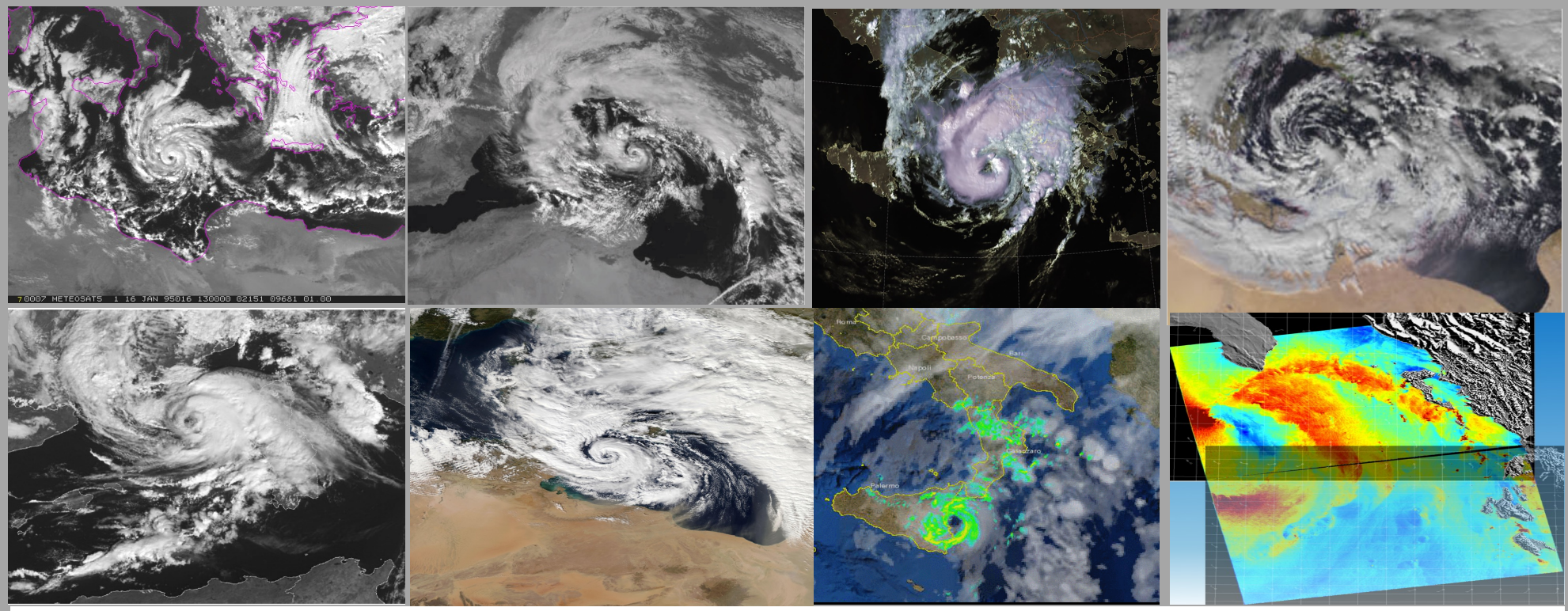
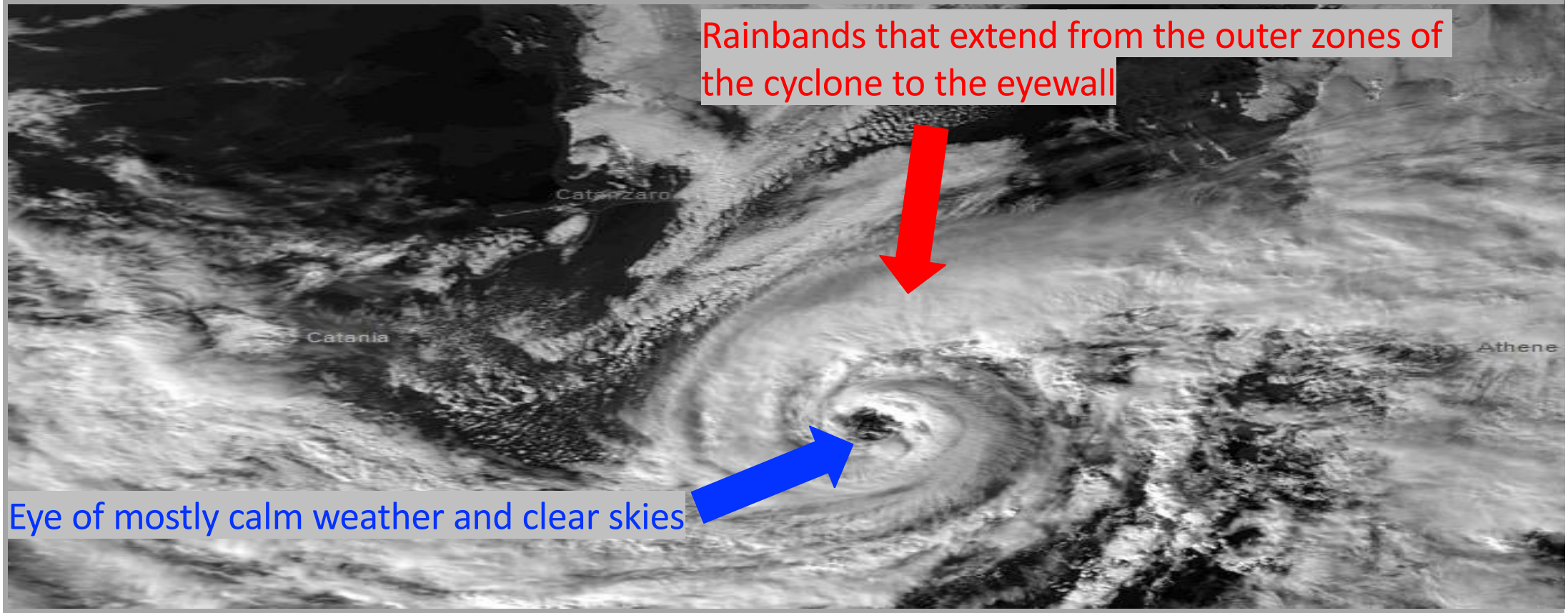
A phenomenological definition of "medicane"



Mario Marcello Miglietta, Emmanouil Flaounas, Juan Jesús González-Alemán, Giulia Panegrossi, Miguel Angel Gaertner, Florian Pantillon, Claudia Pasquero, David M. Schultz, Leo Pio D'Adderio, Stavros Dafis, Romain Husson, Antonio Ricchi, Diego Saúl Carrió Carrió, Silvio Davolio, Lluís Fita Borrell, Maria Angeles Picornell, Ioannis Pytharoulis, Shira Raveh-Rubin, Enrico Scoccimarro, Lisa Bernini, Leone Cavicchia, Dario Conte, Rossella Ferretti, Helena Flocas, Jesús Gutiérrez-Fernández, Maria Hatzaki, Victor Homar Santaner, Agusti Jansà, Platon Patlakas

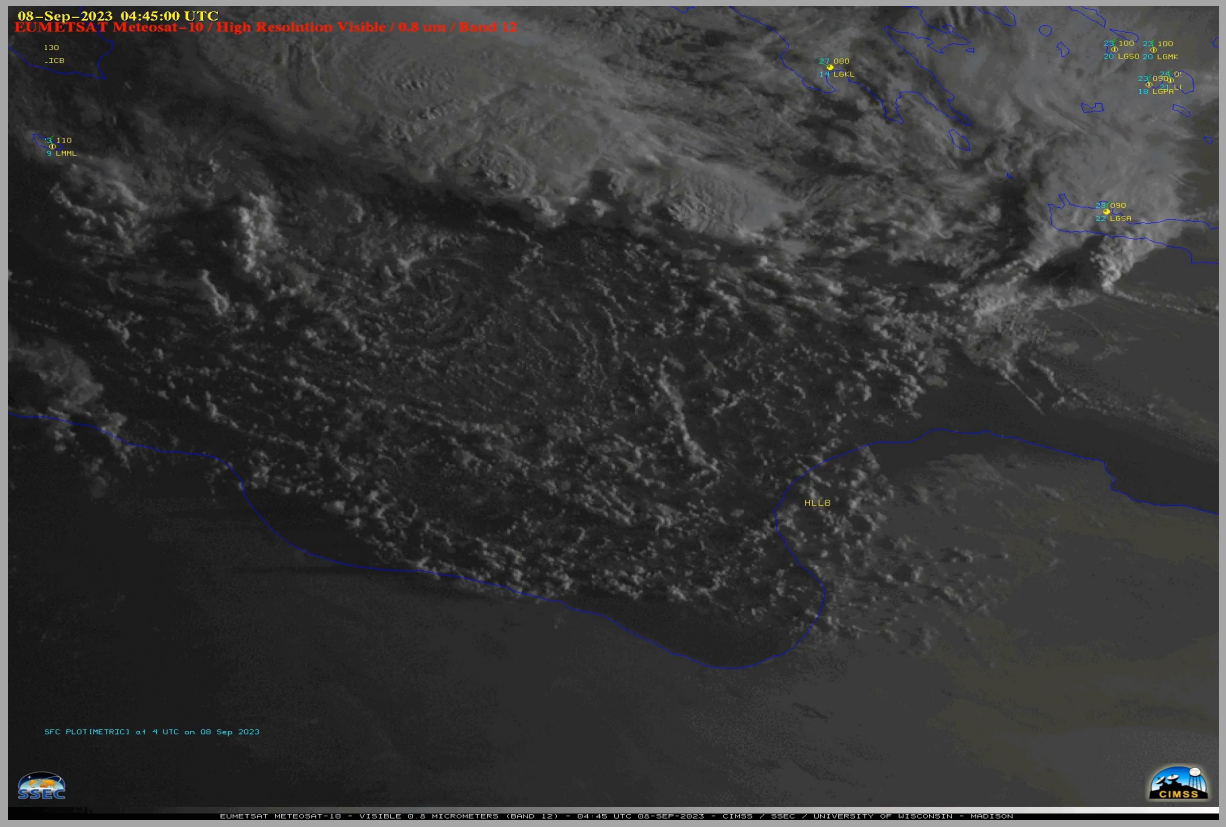
ECSS2025, 17 - 21 November 2025, Utrecht, Netherlands

Since satellite images became available, it has been possible to identify vortices in the Mediterranean basin whose characteristics are similar to those of Tropical Cyclones.



LEUCOSIA (26-27 JAN 1982)

Meteosat-10 SEVIRI HRV, 8 Sep 2023 04:00 UTC–10 Sep 2023 16:00 UTC (Source: CIMSS)

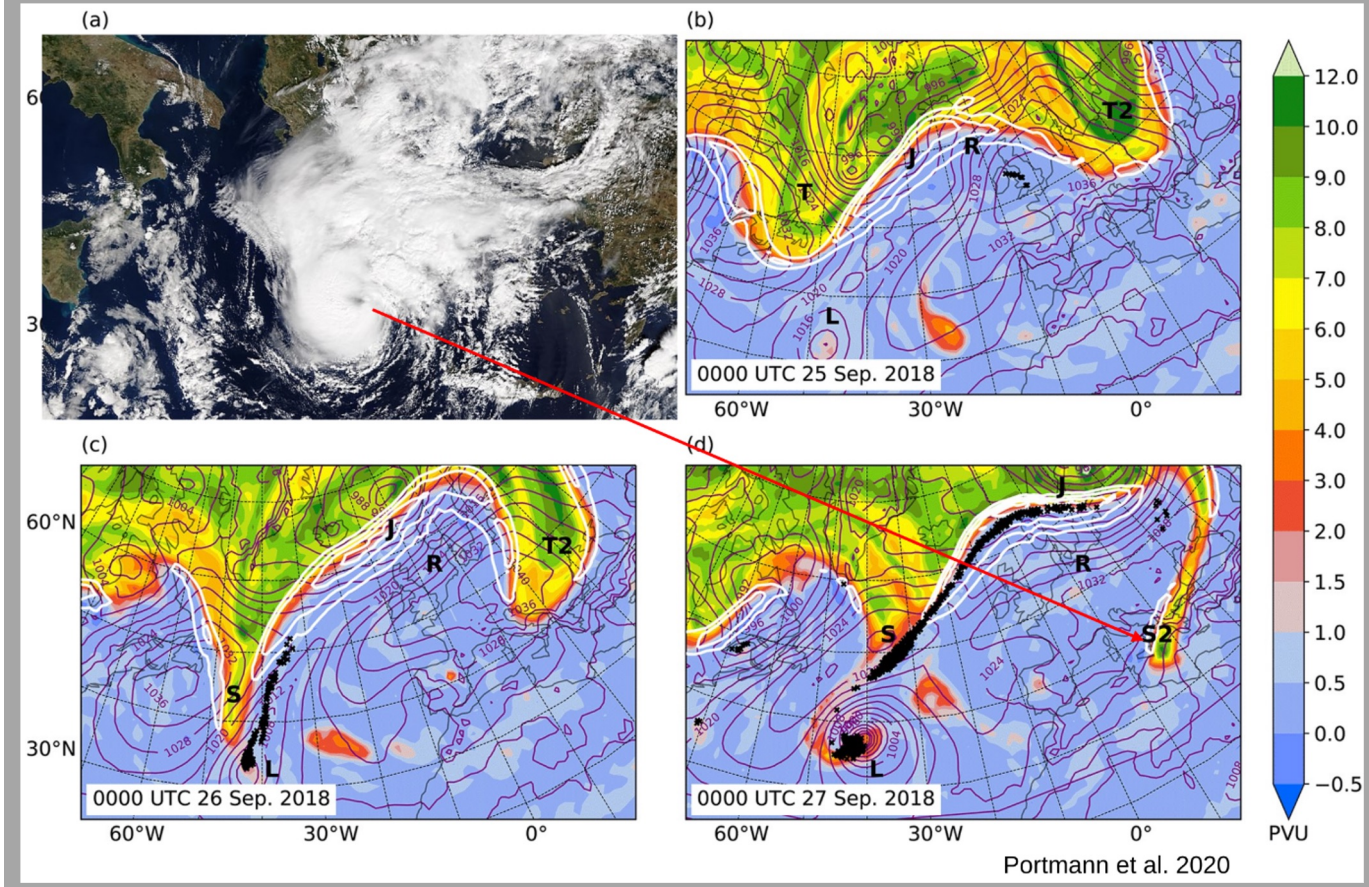


Fatalities	5,951 (confirmed)
Injuries	7,031
Missing	8,000+
Damage	>19.9 billion€
24-h rainfall	414.1 mm

In Greece, widespread hydrometeorological hazards across Thessaly plain (Portaria in Greece: 762 mm on 5 September and 1096 mm 5–8 September), leading to 17 fatalities, devastation of critical transport infrastructure, impact on agricultural production. Bulgaria and Turkey were also affected, with at least 10 deaths reported. As it evolved, Daniel transitioned into a tropical-like system that further intensified and struck Libya, causing catastrophic flooding, exacerbated by the collapse of aging dams in Derna (Karagiorgos et al., 2025).

DANIEL (4-13 SEP 2023)

How do Medicanes form?



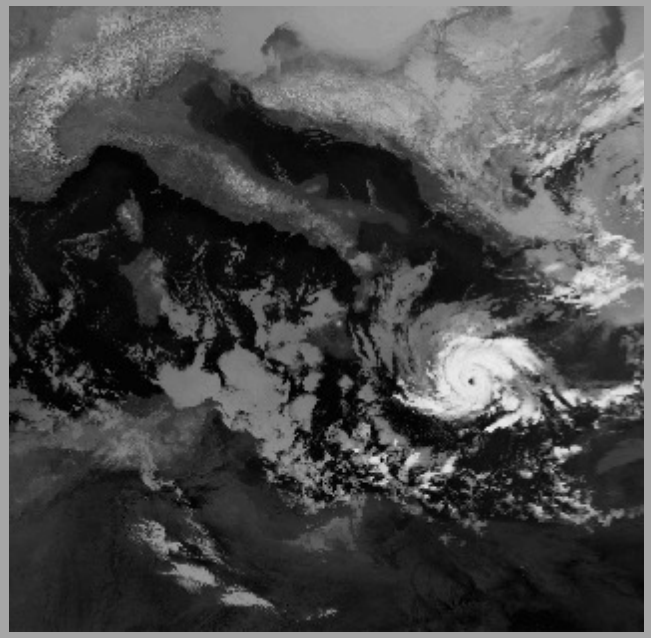
PV (shaded, in PVU) and wind speed (contours) at 325 K

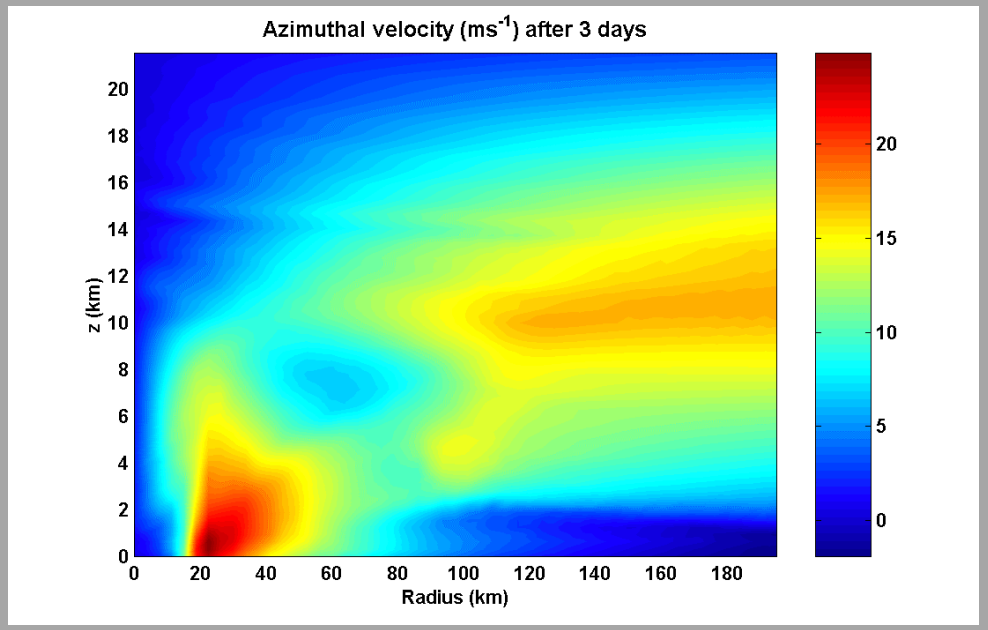
1. Rossby wave breaking leads to..
2. ... southern deviations of PV streamer over the Mediterranean where...
3. ... baroclinic instability leads to initial intensification

Common mechanism for all intense Mediterranean cyclones!

ZORBAS (27 SEP -2 OCT 2018)

Genesis and maintenance of “Mediterranean hurricanes” (Emanuel, 2005)





An **axisymmetric, cloud-resolving model** -in which any development may occur only due to the **feedback between surface enthalpy fluxes and wind** – was applied to show that a **cold, upper low** can produce high potential intensity (PI) in an Ionian cyclone.

CELENO (15-17 JAN 1995)

The Tropical Transition of the October 1996 Medicane in the Western Mediterranean Sea: A Warm Seclusion Event

EDOARDO MAZZA AND UWE ULBRICH

Institute of Meteorology, Freie Universität, Berlin, Germany

RUPERT KLEIN

Institute of Mathematics, Freie Universität, Berlin, Germany

(Manuscript received 15 December 2016, in final form 8 March 2017)

Quarterly Journal of the Royal Meteorological Society

RMetS

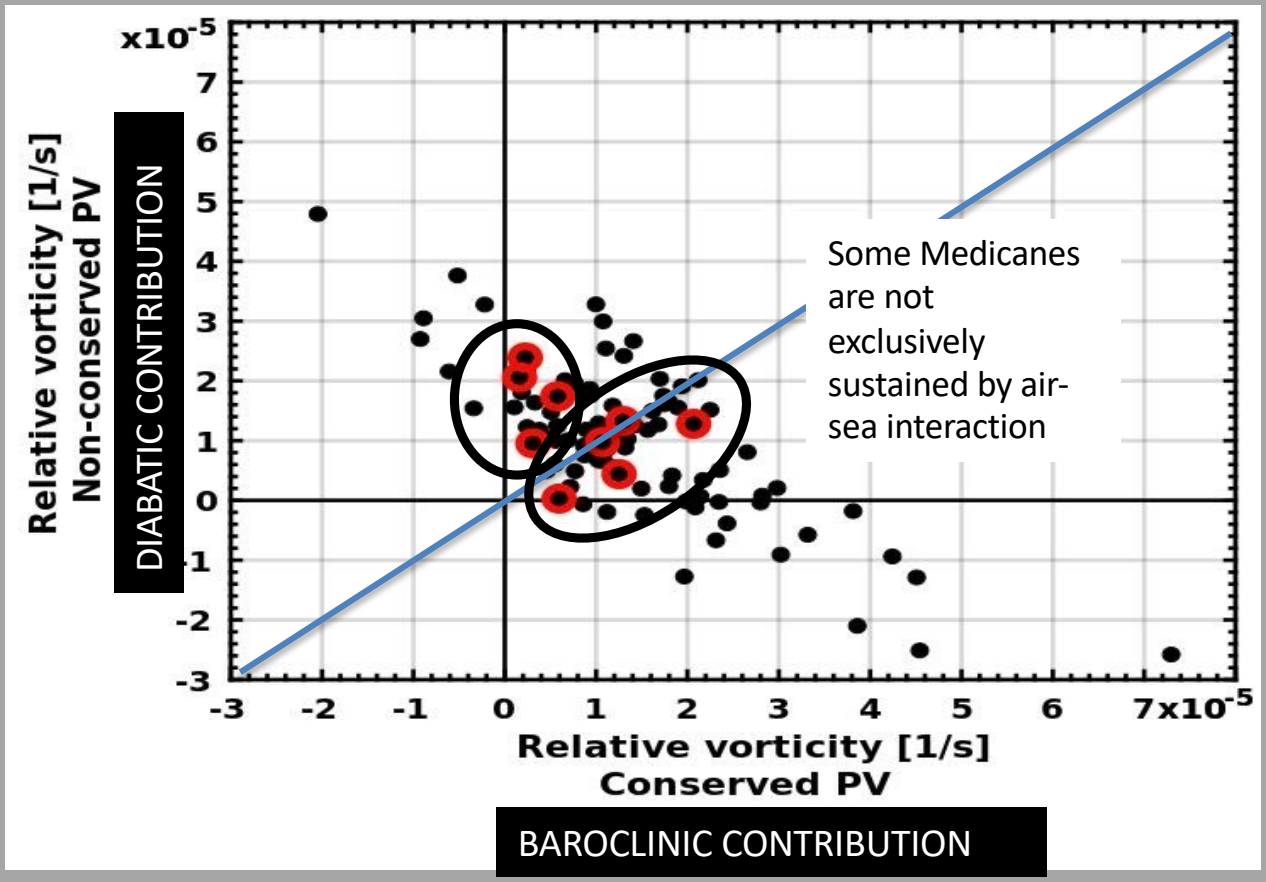
RESEARCH ARTICLE

Medicanes as subtropical cyclones: the December 2005 case from the perspective of surface pressure tendency diagnostics and atmospheric water budget

Lluís Fita, Emmanouil Flaounas

First published: 26 February 2018 | https://doi.org/10.1002/qj.3273 | Citations: 56

Contribution of baroclinic versus diabatic processes to 850 hPa relative vorticity



Mature stage

Contribution to 850 hPa relative vorticity, in the centre of 100 cyclones: conserved, adiabatically transported PV (x-axis) vs non-conserved, diabatically-produced PV (y-axis).

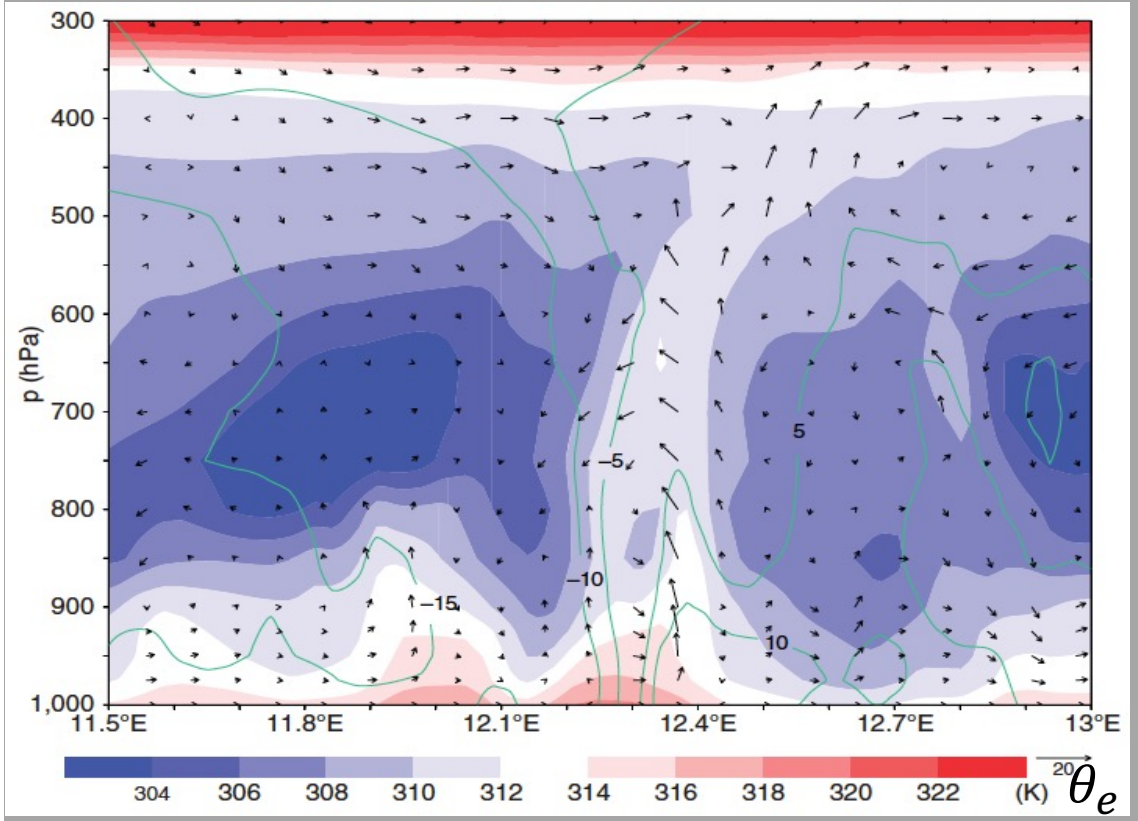
Medicanes (red) do not concentrate in a region of the parameter space ->

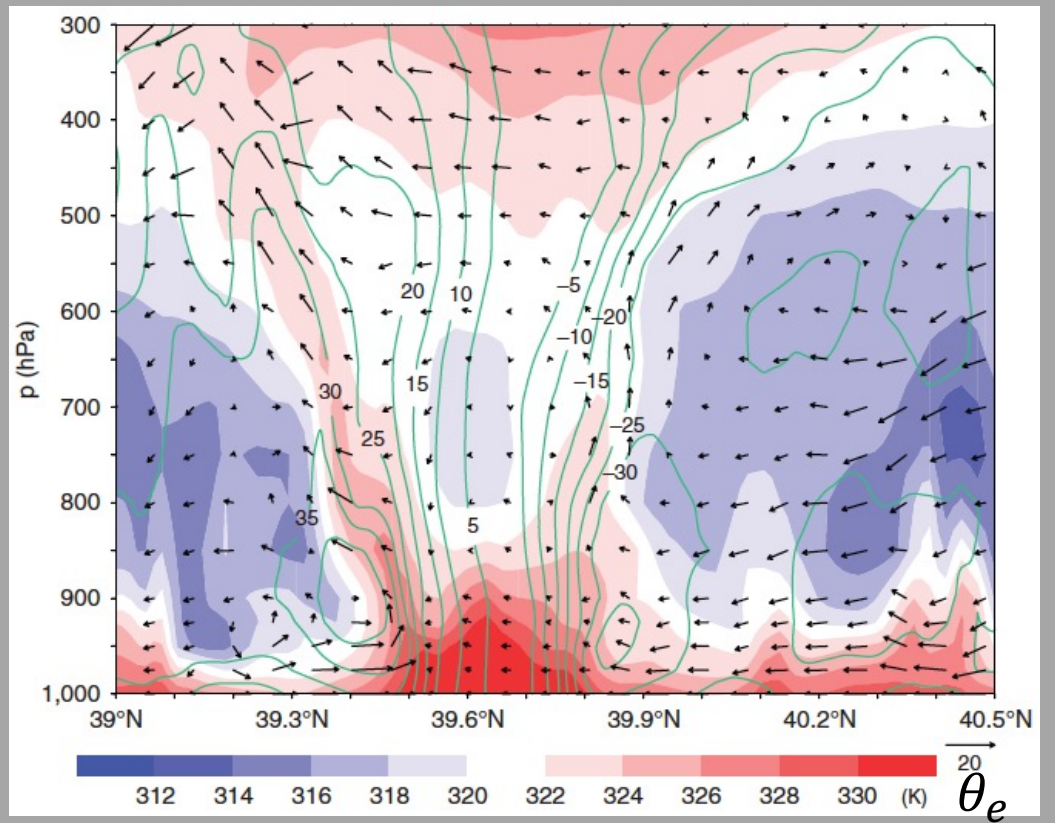
We cannot apply a pure air-sea interaction model.

Flaounas et al. (2021)

CROSS SECTION ALONG THE CYCLONE CENTER

Symmetric, deep warm core structures but only the second one shows the upward transport of warm/moist air typical of TC -> Different contribution of baroclinic versus diabatic processes





ZEO (DECEMBER 2005)

CORNELIA (OCTOBER 1996)

Vertical cross-section of θe (colours), storm-relative winds (vectors), absolute momentum (lines, contour interval=5m/s; zero not shown) near the cyclone centre

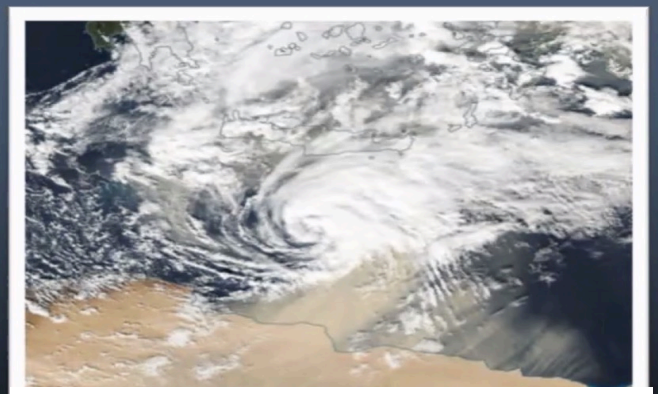
Miglietta and Rotunno (2019)

The term "medicane" has been used to cover a wide range of the continuum existing between ECs and TCs. Distinct **categories** can be identified, depending on the dominant process in the mature stage.

(**TYPE A: subtropical cyclone or warm seclusion; TYPE B: tropical transition**).

Type A

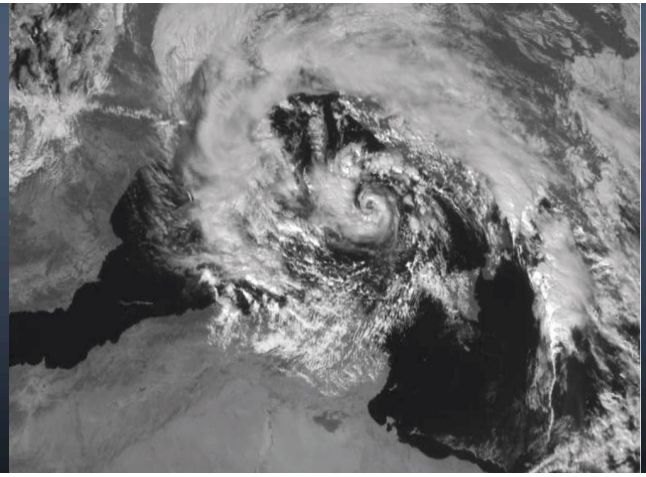
Warm core cyclones mostly driven by baroclinicity and weak diabatic processes



Hybrid characteristics

Type B

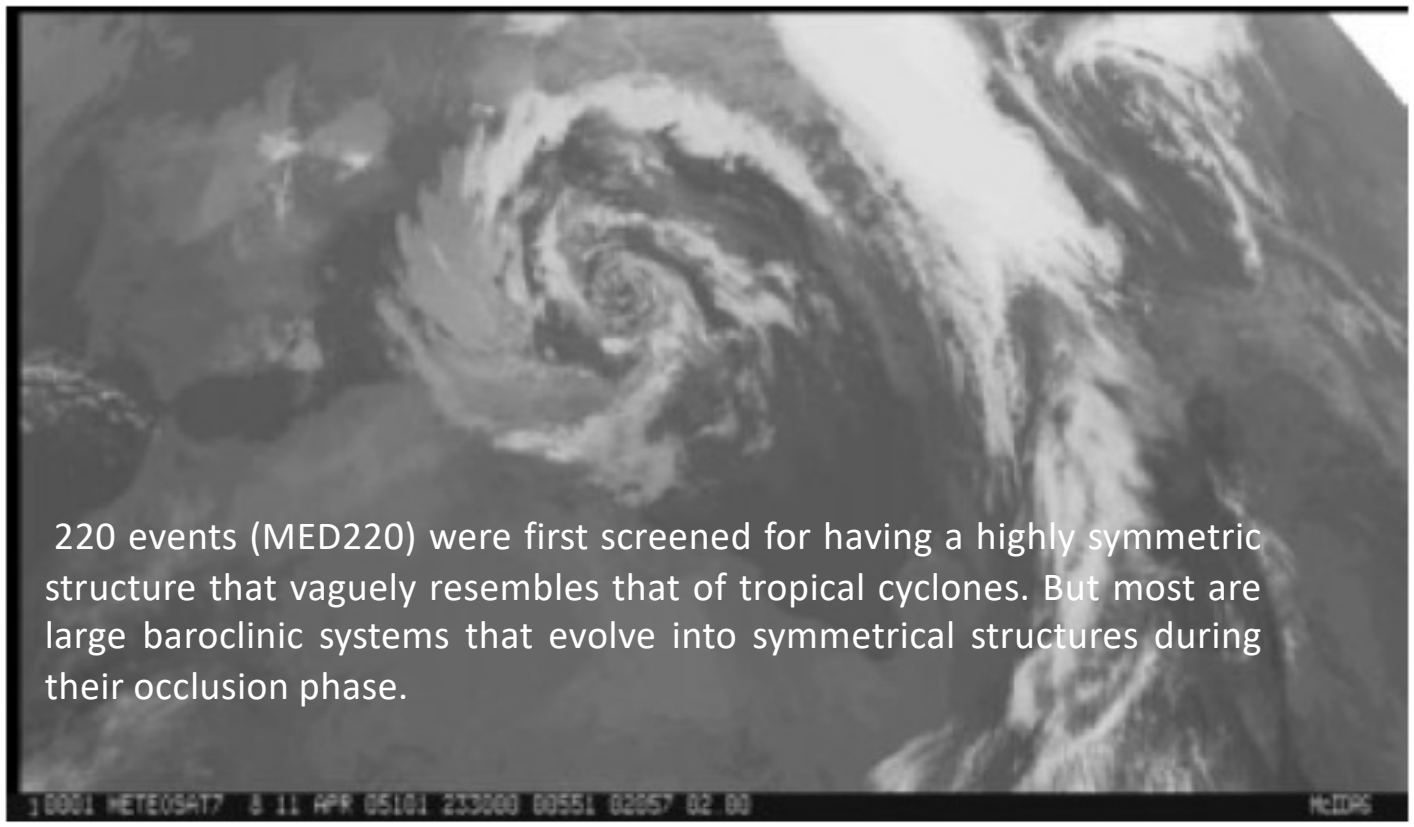
Deep warm core cyclones mostly driven by strong diabatic processes and weak baroclinic instability



Characteristics similar to TC for short periods

Miglietta and Rotunno (2019); Dafis et al. (2020)

Phenomenological criteria



220 events (MED220) were first screened for having a highly symmetric structure that vaguely resembles that of tropical cyclones. But most are large baroclinic systems that evolve into symmetrical structures during their occlusion phase.

Figure 2. Large and highly symmetric baroclinic cyclone on 11 April 2005 at 2330 UTC (IR image of Meteosat).

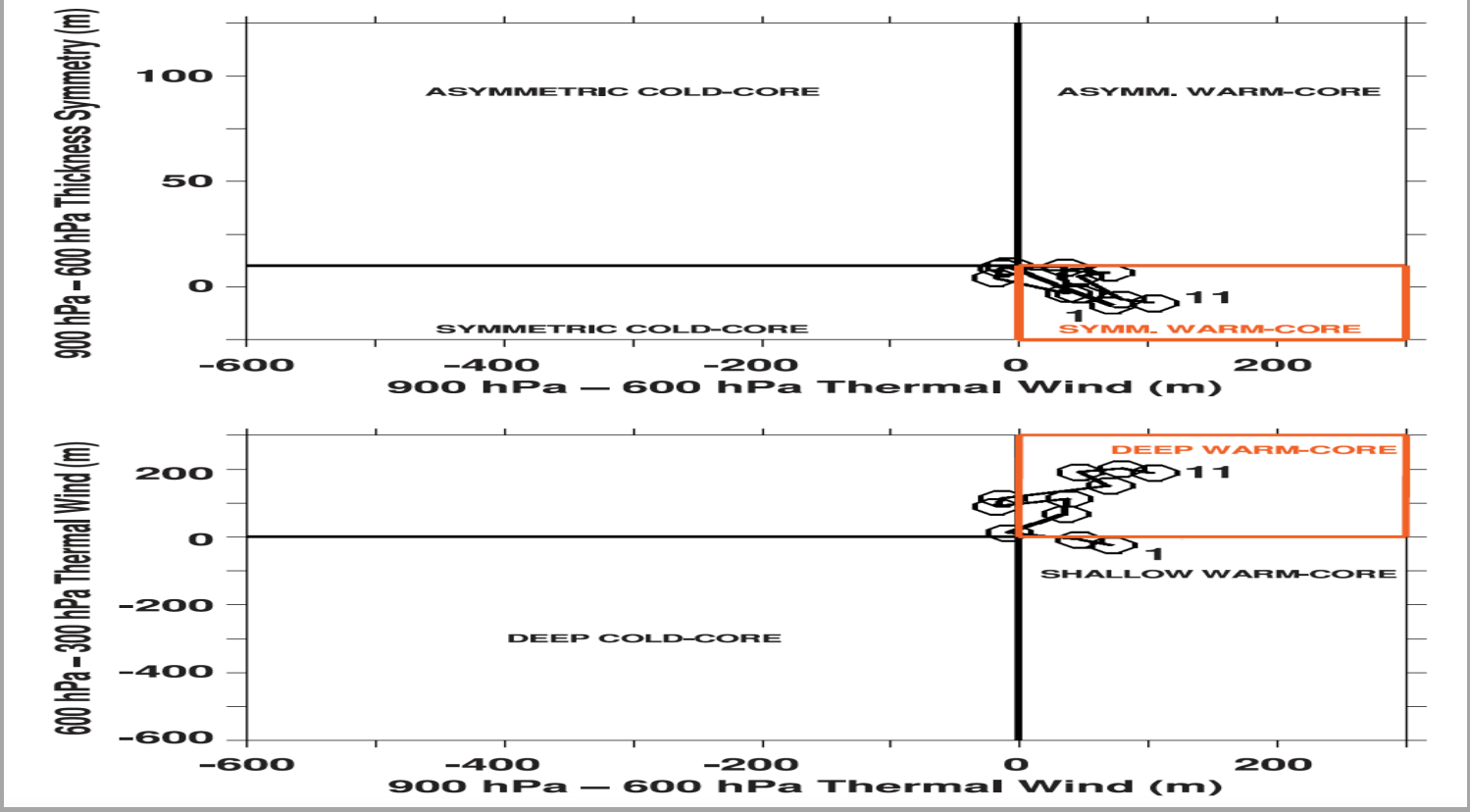
Tous and Romero (2013)

Structural criteria:

CYCLONE PHASE SPACE DIAGRAM

Symmetry

Upper-troposphere Temperature



Lower-troposphere Temperature

NOTE: the presence of a warm central core is not necessarily due to the release of latent heat due to vapor condensation.

Hart (2003)

ABSENCE OF OFFICIAL DEFINITION OF «MEDICANE»

Different Criteria to address medicanes as weather systems of tropical characteristics:

Phenomenological: empirical, rather arbitrary definition

Structural: based on structural characteristics (symmetric, warm core) and arbitrary thresholds applied to atmospheric variables of model outputs

Development mechanism: focusing only on "Type B" medicane

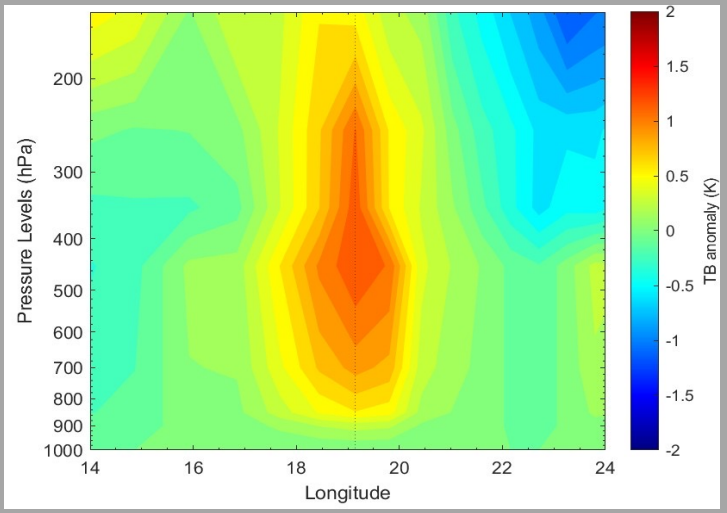
Leading to:

- Confusion within the scientific community (different criteria to physically define medicanes in model and observation datasets).
- Confusion among weather services for the purposes of issuing warnings of imminent high-impact weather.

Phenomenological/structural definition of medicane

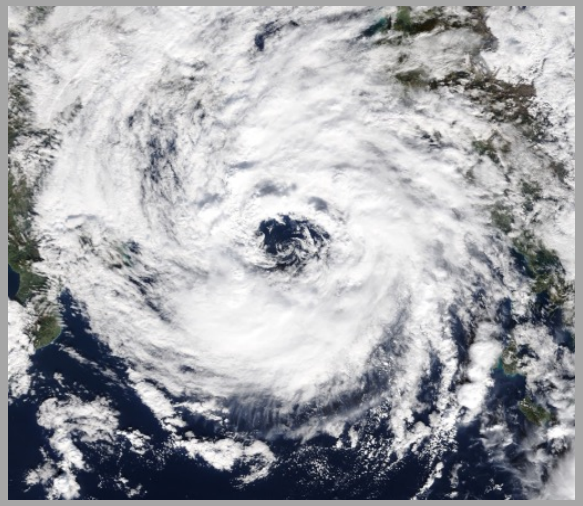
A medicane is a mesoscale cyclone that develops over the Mediterranean Sea and displays tropical-like cyclone characteristics:

A warm core extending into the upper troposphere



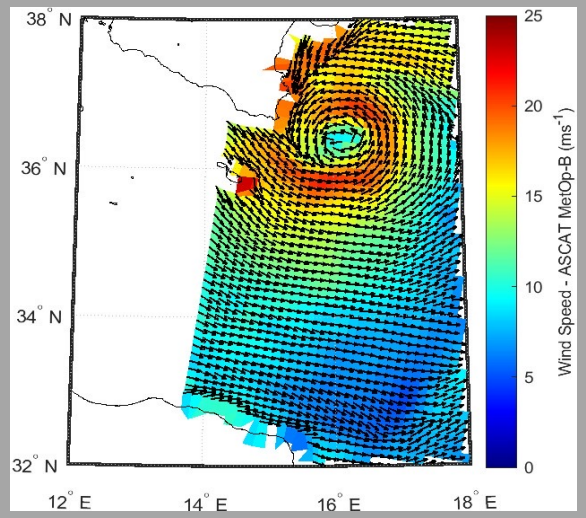
MW vertical cross-section of Brightness Temeperature anomaly for medicane Zorbas, 29 Oct. 2018.

An eye-like feature in its center with spiral cloud bands around



Medicane "Numa" MODIS Terra VIS image, 18 Nov. 2017

An almost windless center surrounded by nearly-symmetric sea-surface wind circulation with maximum wind speed within a few tens of km from the center



Medicane "Apollo" ASCAT wind field 29 Oct. 2021

Miglietta et al. (2025)

ADVANTAGES OF THE DEFINITION

- Based on Earth observations
- Simple enough to aid weather services in identification and communication
- Consistent with previous studies either using phenomenological or structural criteria
- Recognizes the existence of a deep warm-core induced by different mechanisms, following the indications from early studies that air-sea interaction is not expected to contribute exclusively to the development of a medicane

Miglietta M. M., Flaounas E., González-Alemán J. J., Panegrossi G., Gaertner M. A., Pantillon F., Pasquero C., Schultz D. M., D'Adderio L. P., Dafis S., Husson R., Ricchi A., Carrió D. S., Davolio S., Fita L., Picornell M. A., Pytharoulis I., Raveh-Rubin S., Scoccimarro E., Bernini L., Cavicchia L., Conte D., Ferretti R., Flocas H., Gutiérrez-Fernández J., Hatzaki M., Homar Santaner V., Jansà A., Patlakas P., Defining Medicanes: Bridging the Knowledge Gap Between Tropical and Extratropical Cyclones in the Mediterranean, BAMS, 106, E1955–E1971, https://doi.org/10.1175/BAMS-D-24-0289.1

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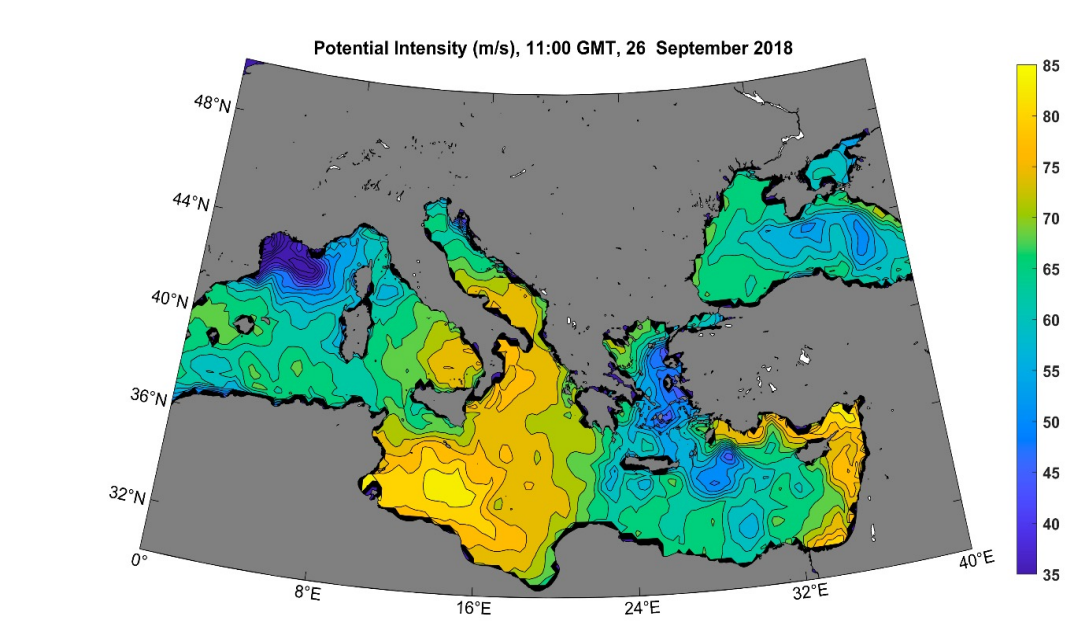
- COST action CA22162 - FUTUREMED “A transdisciplinary network to bridge climate science and impacts on society”
- “Earth Observations as a cornerstone to the understanding and prediction of tropical like cyclone risk in the Mediterranean (MEDICANES)”, ESA Contract No. 4000144111/23/I-KE, In response to: ESA CfP/5-50033/23/I-KE

ZORBAS



Potential intensity (PI) distribution in the Mediterranean and Black Seas, 11 GMT on 26 September 2018

In much of the Mediterranean, PI was typical of tropical warm pools with values approaching 80 m/s before the cyclogenesis.
The cold pool aloft did little to enhance PI -> tropical transition (Bosart and Bartlo 1991; Davis and Bosart 2003, 2004); however, it almost certainly humidified the middle troposphere, making genesis somewhat more likely.

Emanuel et al. (2025)

Medicane Celeno

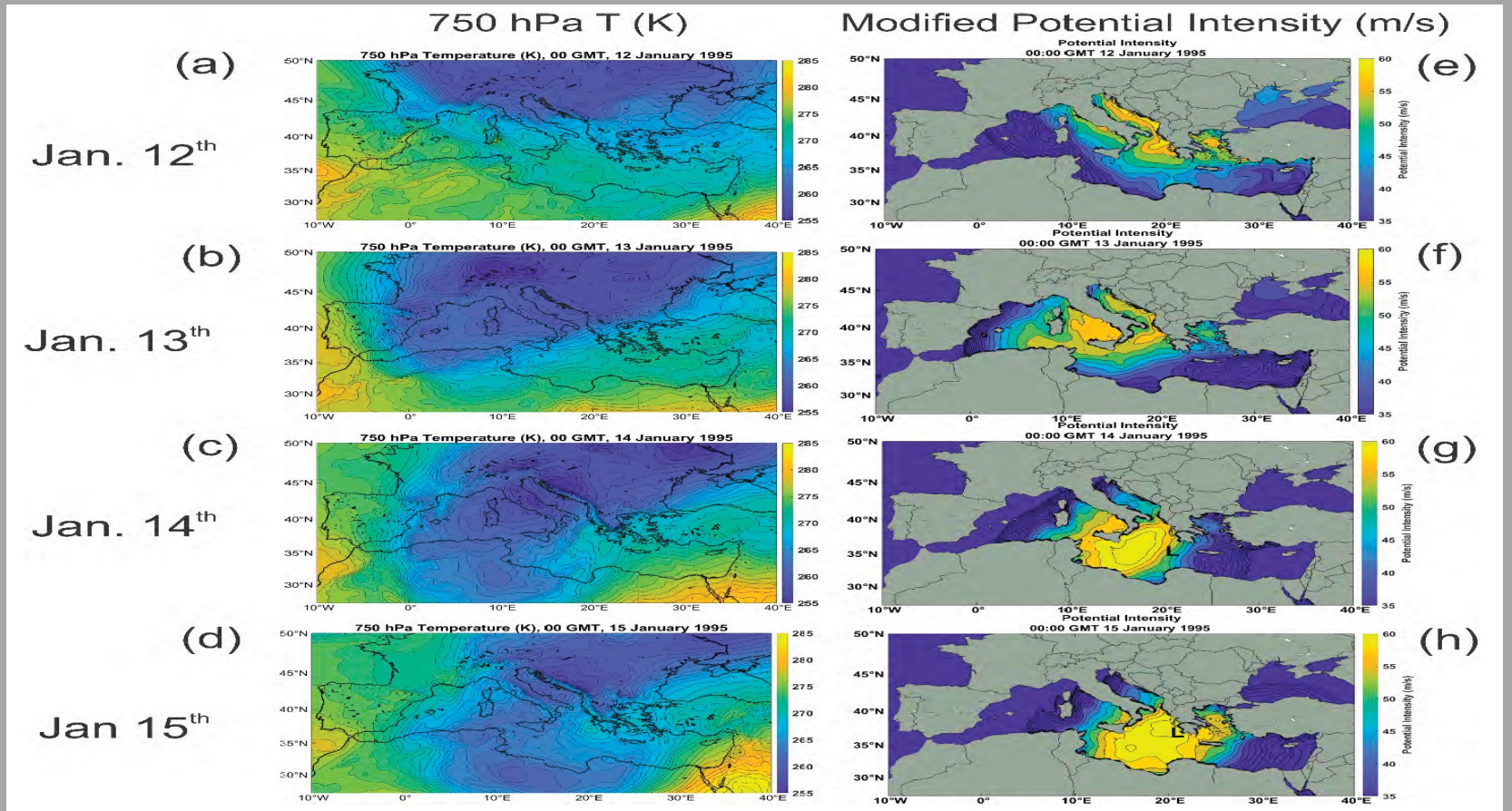
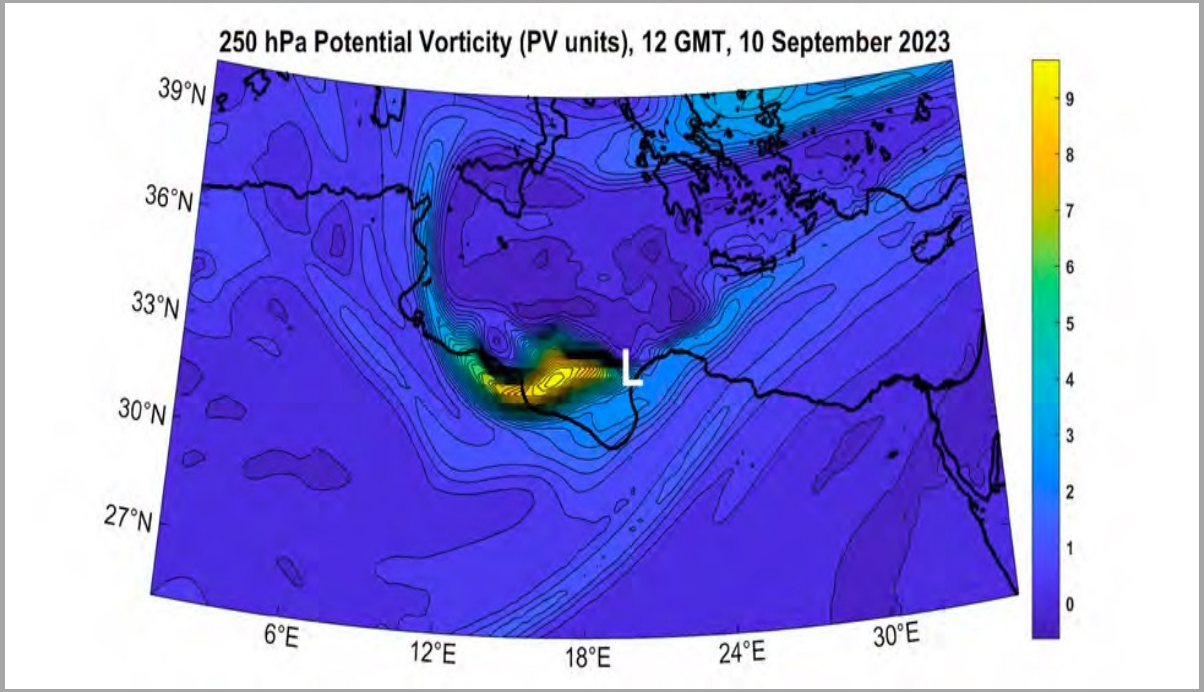


Figure 5: 750 hPa temperature (K; left) and modified potential intensity given by equation (1) (m/s, right) at 00 UTC on January 12th – 15th (top to bottom) 1995. The 750 hPa temperature spans from 255 K to 285 K at increments of 1 K, while the modified potential intensity ranges from 35 to 60 ms^{-1}at increments of 4 ms^{-1}. The black "L"s in panels g) and h) show the positions of the surface cyclone. From ERA5 reanalysis.

The cold pool aloft strongly enhanced PI -> **CYCLOPs**
(CYClones from Locally Originating Potential intensity) Emanuel et al. (2025)

Medicane Daniel



Potential vorticity (PV units, 10-6 K kg-1 m2 s-1) at 250 hPa at 12 GMT on 10 September, 2023. The white "L" marks the approximate surface center of Daniel at this time

Tropical transition as Zorbas, BUT as it approached the Libyan coast around Sep 10, it came under the influence of a mesoscale "satellite" PV mass rotating around the principal upper-level cutoff cyclone.

The superposition of the high-level PV anomaly with the surface-based warm core probably contributed to Daniel's intensification which, remarkably for a surface flux-driven cyclone, continued after landfall (Hewson et al., 2024).

Emanuel et al. (2025)