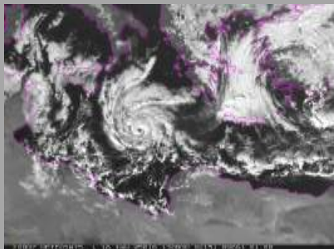
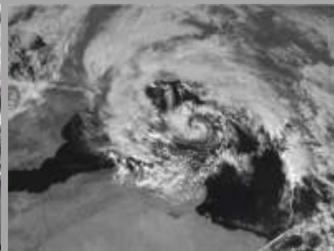
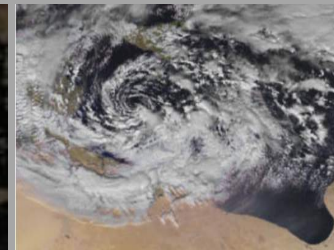
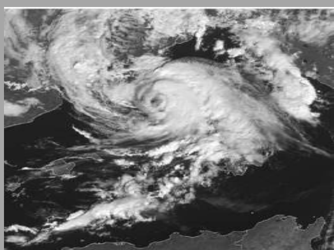
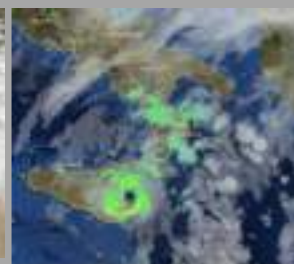
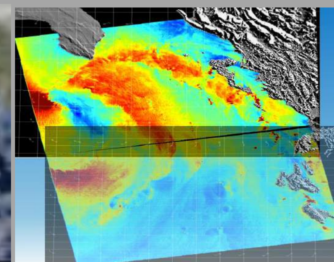
TOWARD THE DEFINITION OF «MEDICANE»

Mario Marcello Miglietta
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3rd MedCyclones Workshop & Training School
15-19 July 2024 | ESA-ESRIN | Frascati (Rome), Italy

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OUTLINE

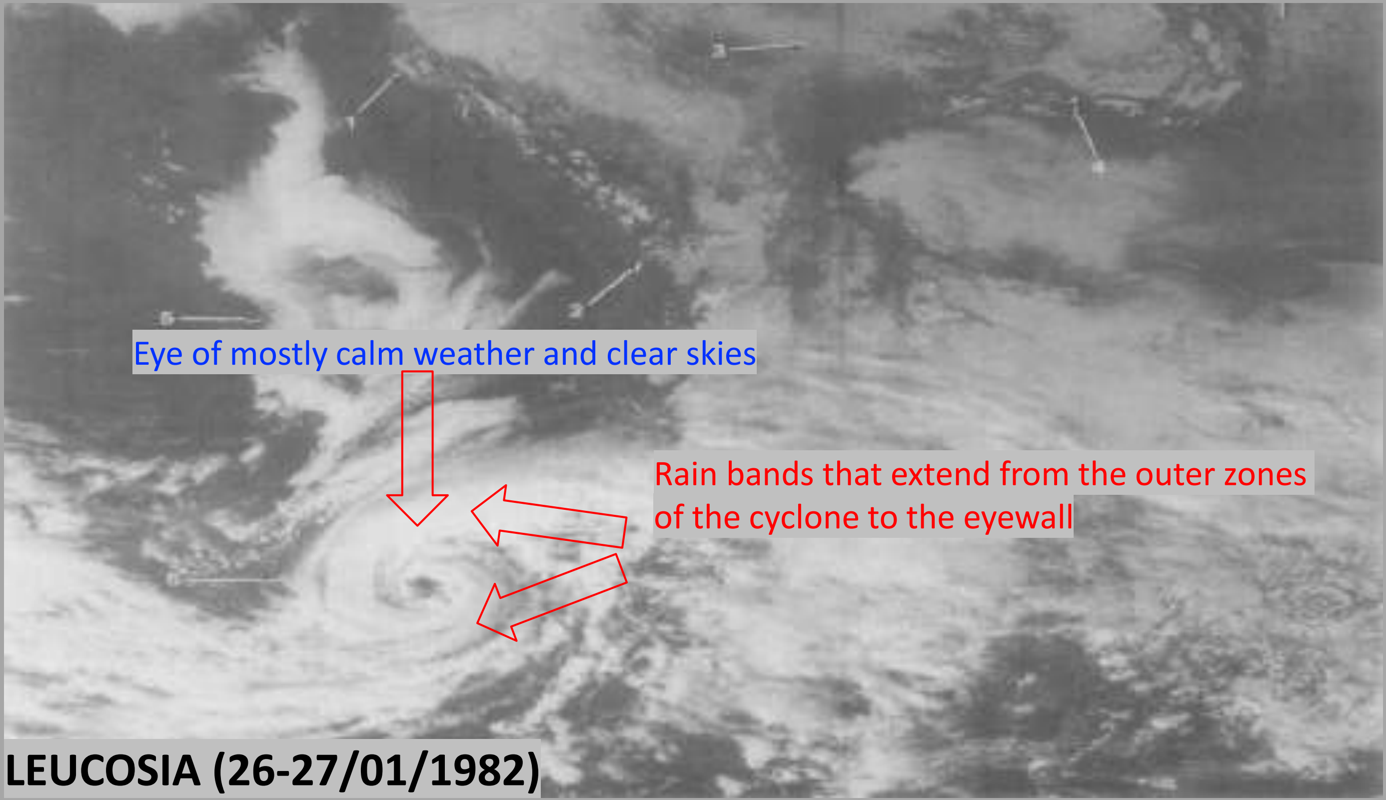
1. CASE STUDIES

2. MEDICANES vs TROPICAL CYCLONES

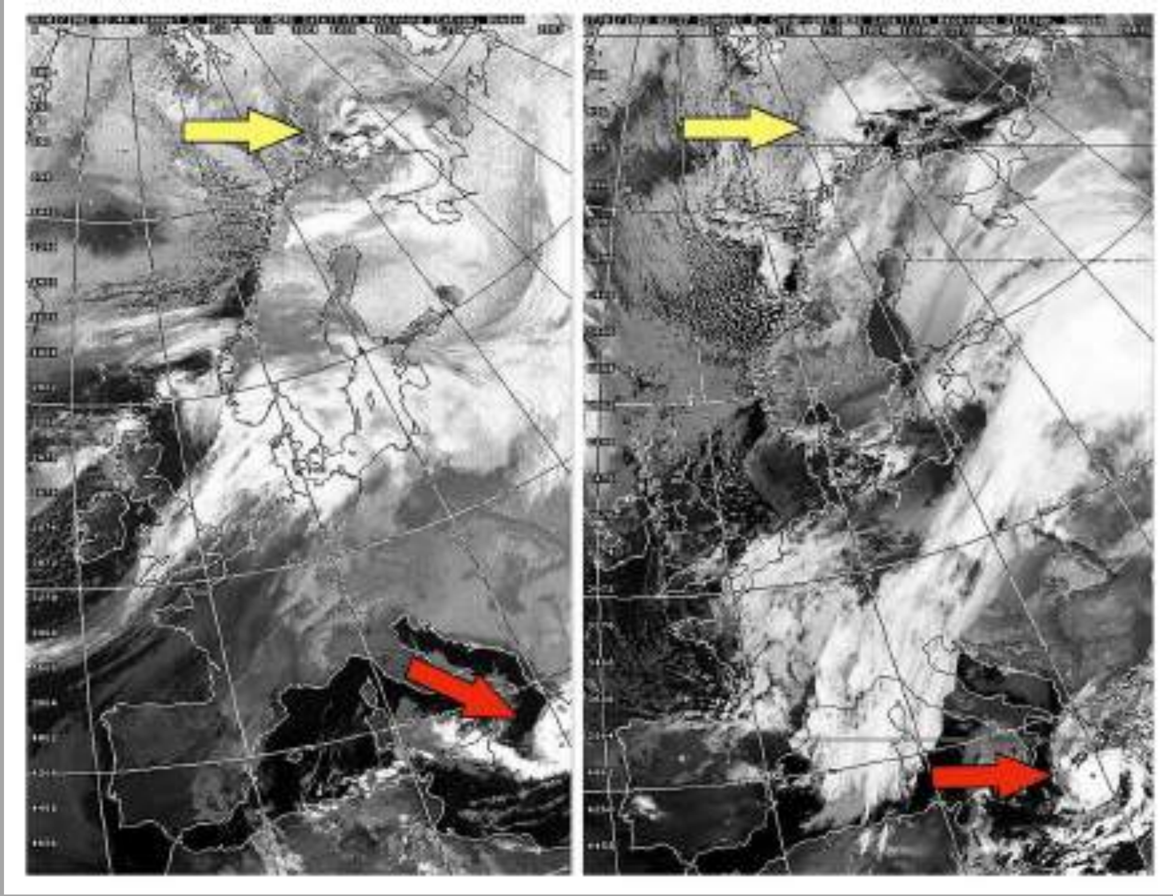
3. CLIMATOLOGY AND CLIMATE CHANGE

4. TOWARD A DEFINITION OF «MEDICANE»

Since satellite images became available in the 1960s it has been possible to identify vortices in the Mediterranean basin whose characteristics are similar to those of TC.



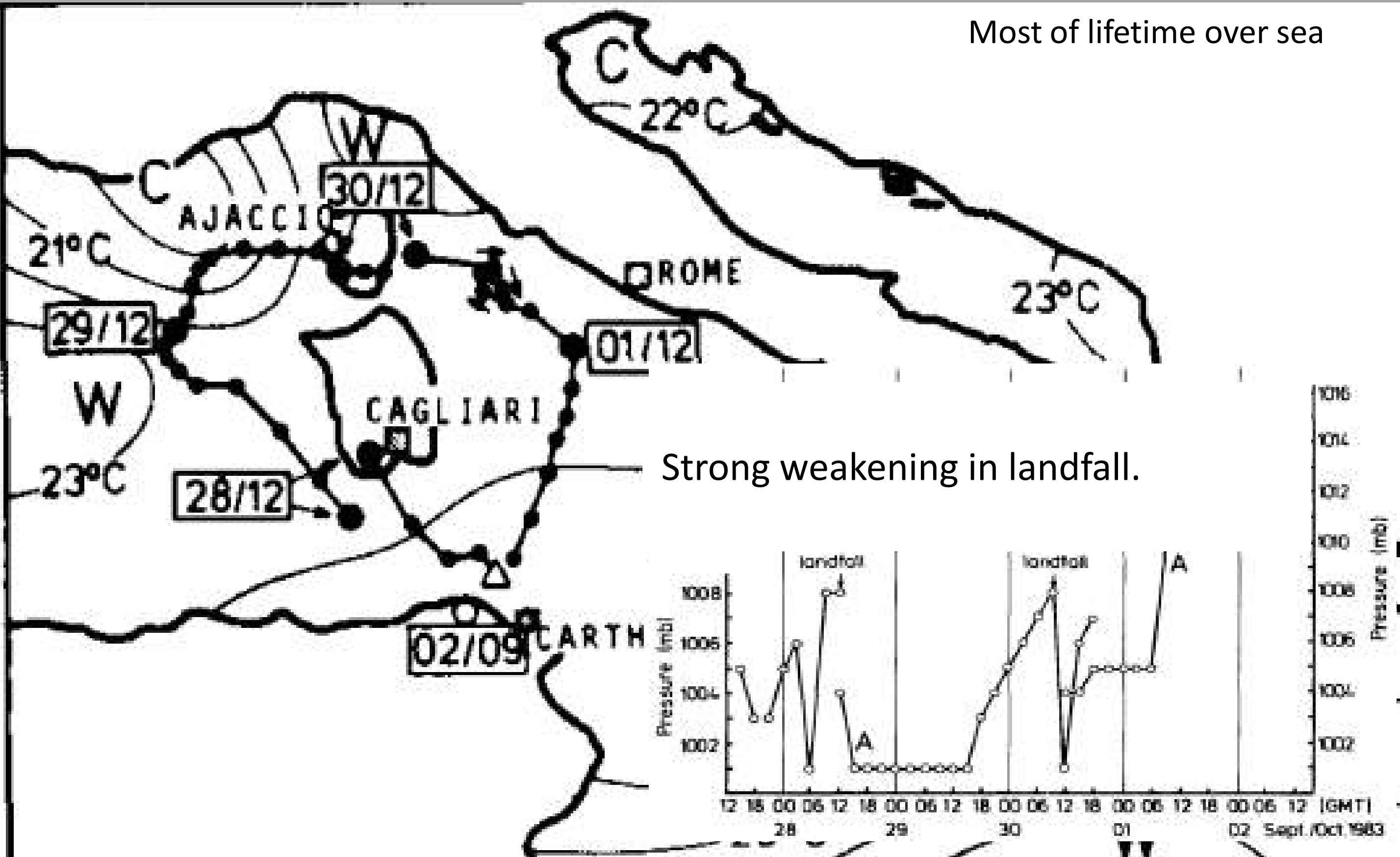
NOAA-7 visible band image of January 1982 storm. Arrow number 5 indicates southeastern Italy, arrow number 2 corresponds to the coast of Albania (Ernst and Matson, 1983).



Satellite images of a polar low PL (yellow arrow) and an MTLC (red arrow) on 26 (left) and 27 (right) January 1982 (Dafis, 2020). This NOAA-17 satellite swath with a coincidence of MTLC and PL is the only one known in the satellite era and provides a unique opportunity to compare the size and structure of these two types of cyclones

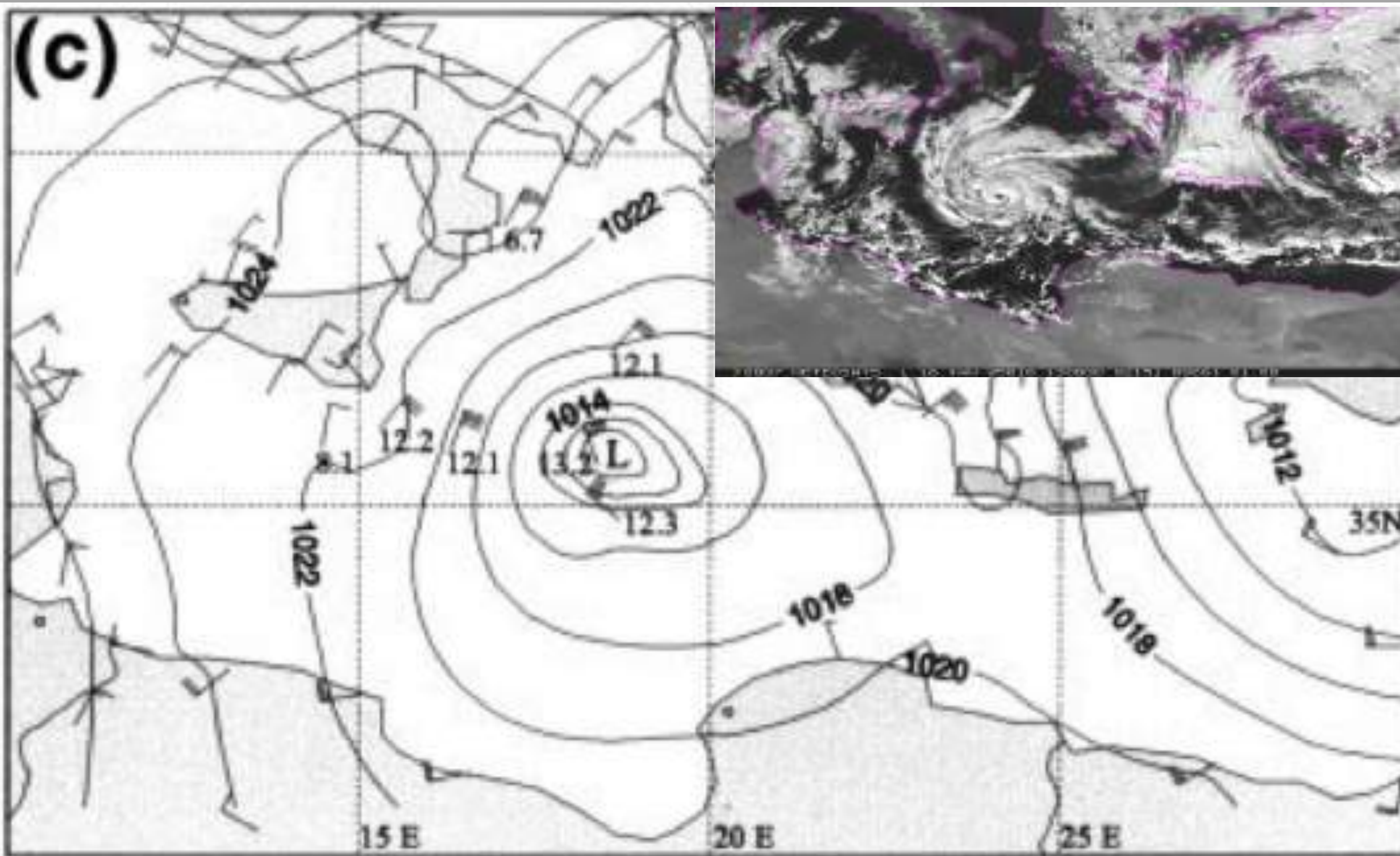
NAMES

- “Hurricane-like cyclones” (Billing et al., 1983)
- “Mediterranean tropical storms” (Ernst and Matson, 1983)
- “Warm core cyclones” (Mayengon, 1984)
- “Mediterranean hurricanes” (Medicanes; Emanuel, 2005)
- “Mediterranean Tropical-Like Cyclones”

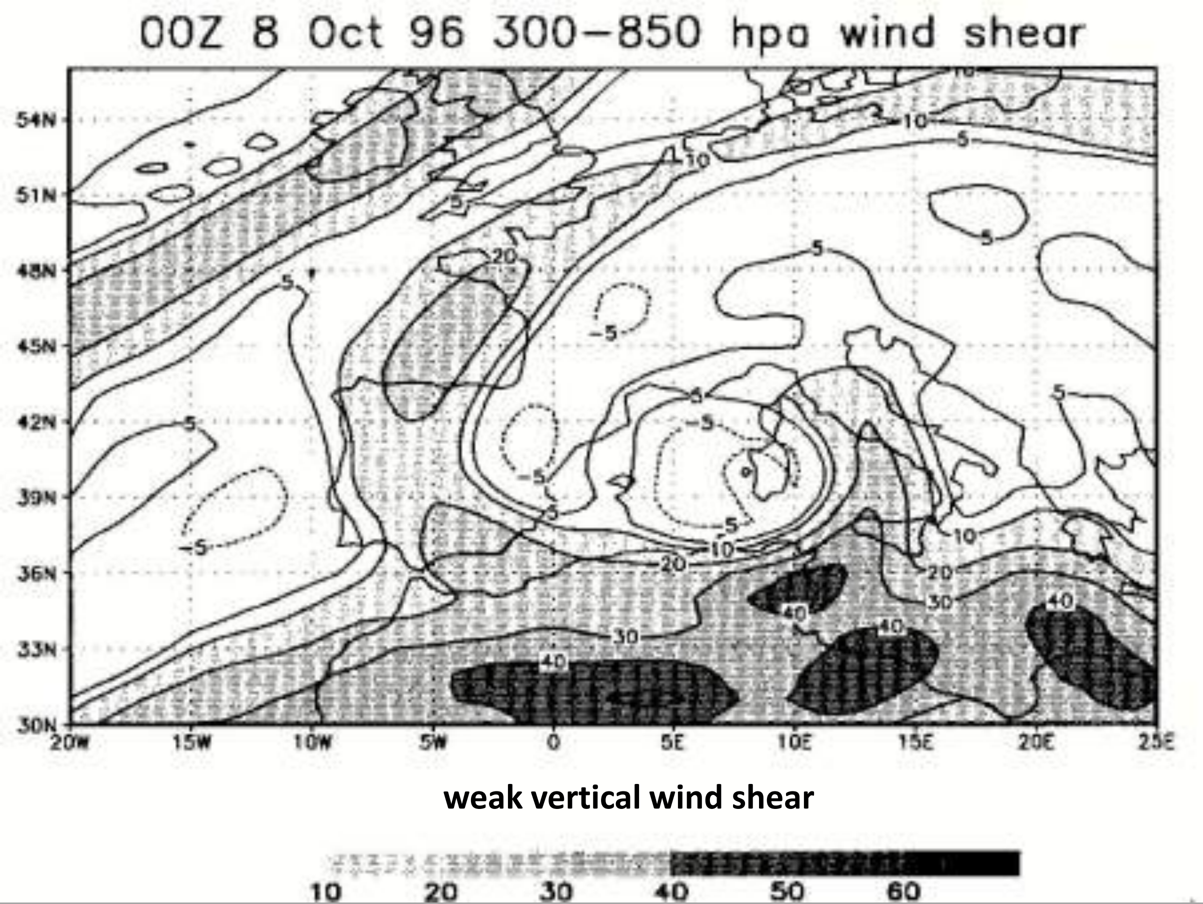


Track of low pressure center (solid line) and SST reconstructed from satellite data and ship measurements (contours). Cyclone of 28 Sep 1983 (Rasmussen and Zick, 1987).

Strong rotation around a central warm core



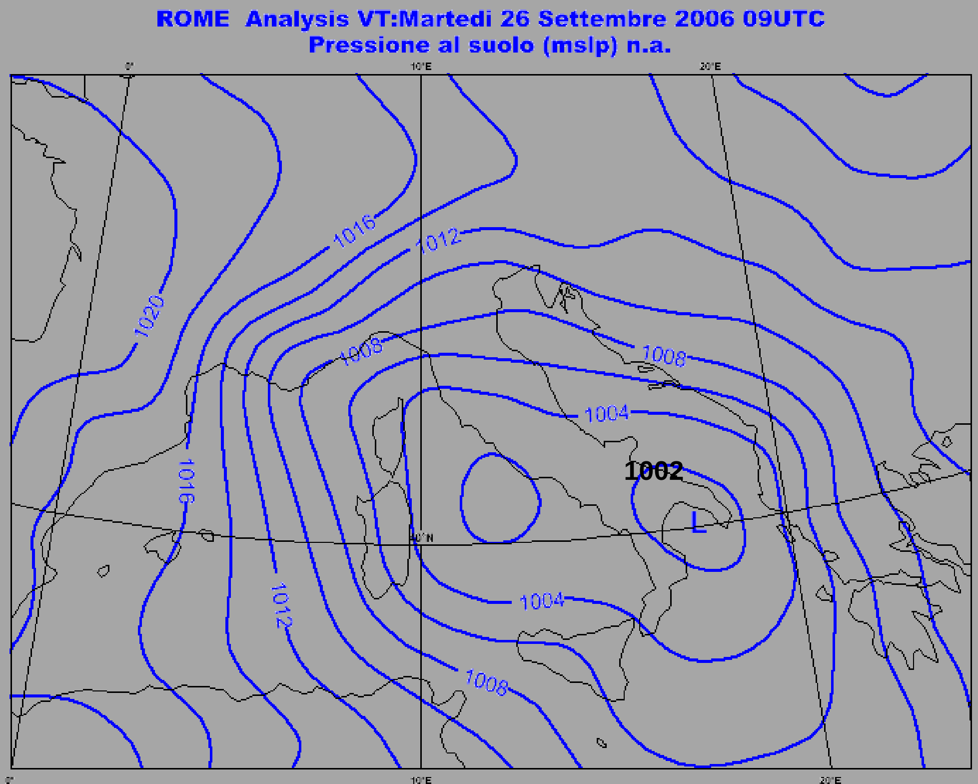
Sea level pressure (solid lines), wind (pennants) and surface air temperature values measured by ships. Cyclone of 16 Jan 1995 (Lagouvardos et al, 1999).



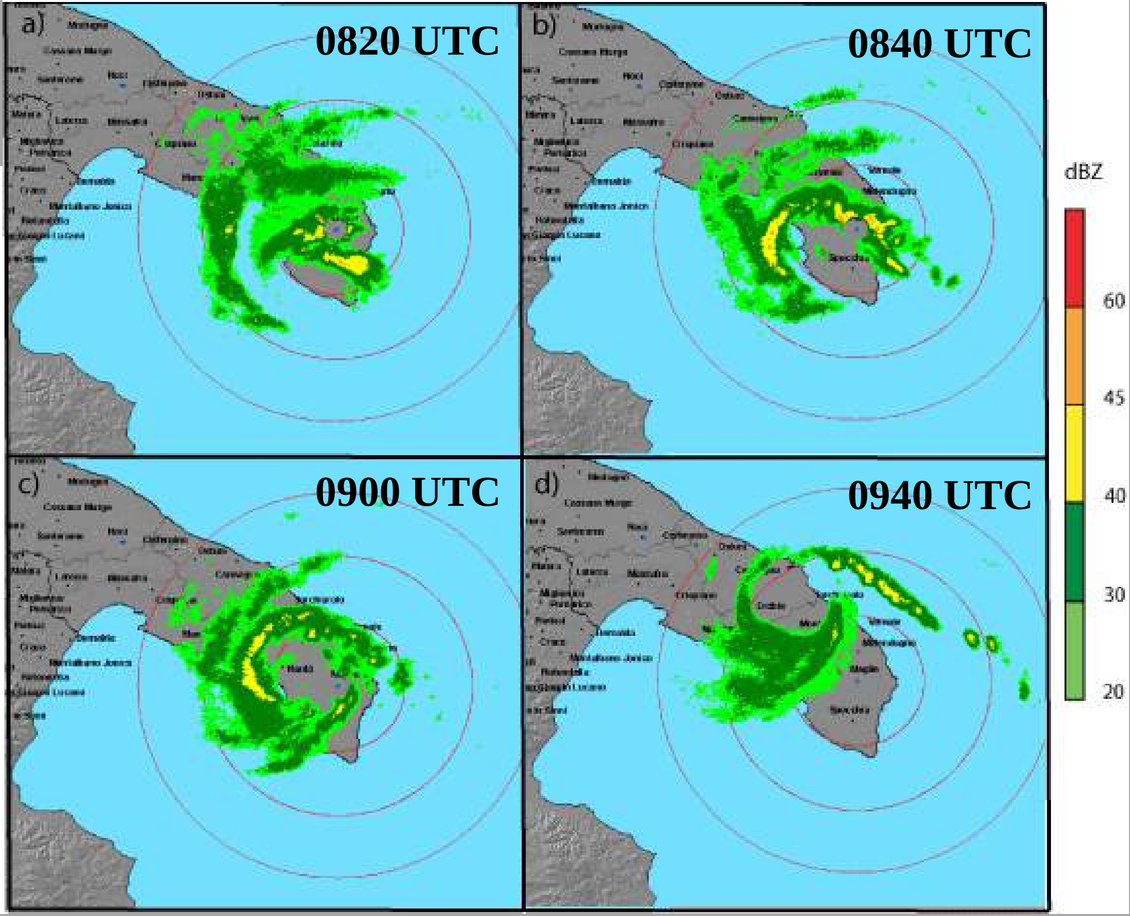
weak vertical wind shear

October 1996 medicane: shear at 0000 UTC 8 Oct 1996, represented as the difference in wind speed (m/s) between the 300- and the 850-hPa levels (Reale and Atlas, 2001).

SYNOPTIC ANALYSIS 26 September 2006 – 0900 UTC



RADAR REFLECTIVITY (dBZ)

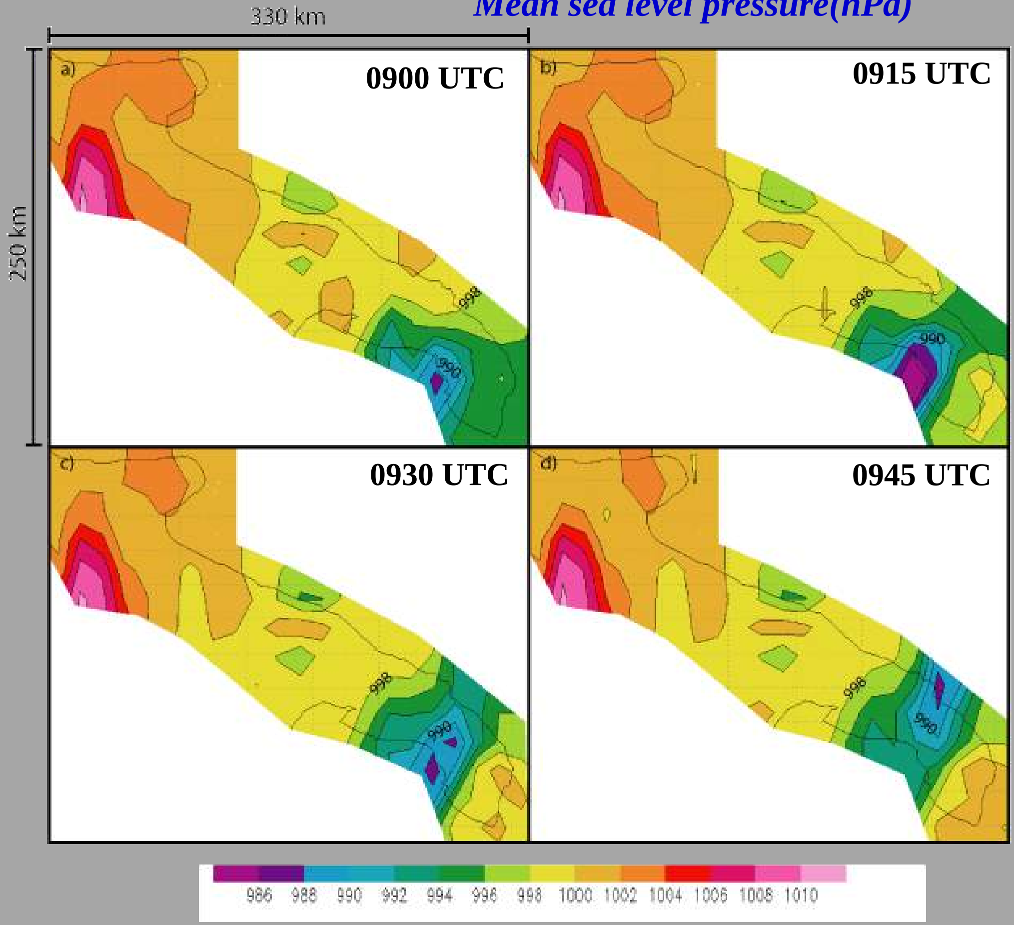


MARIA (26/09/2006)

Moscatello et al. (2008a)

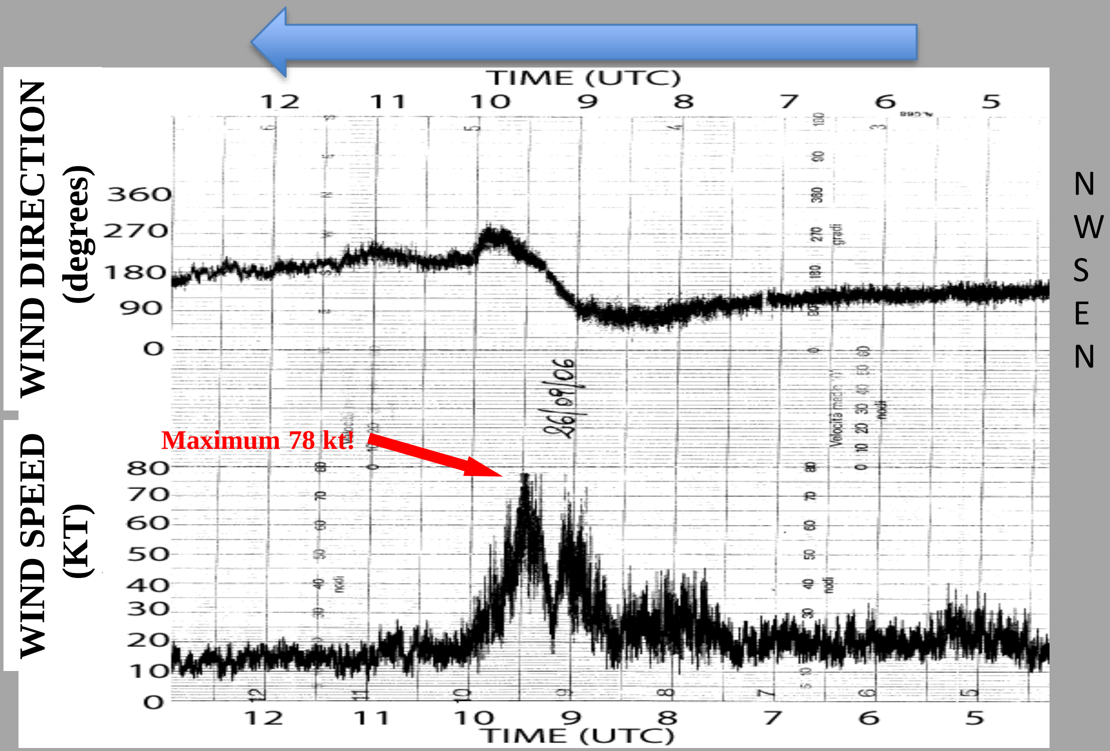
Southern Track

Mean sea level pressure(hPa)



- *33 surface stations*
- *Cressman horizontal interpolation*

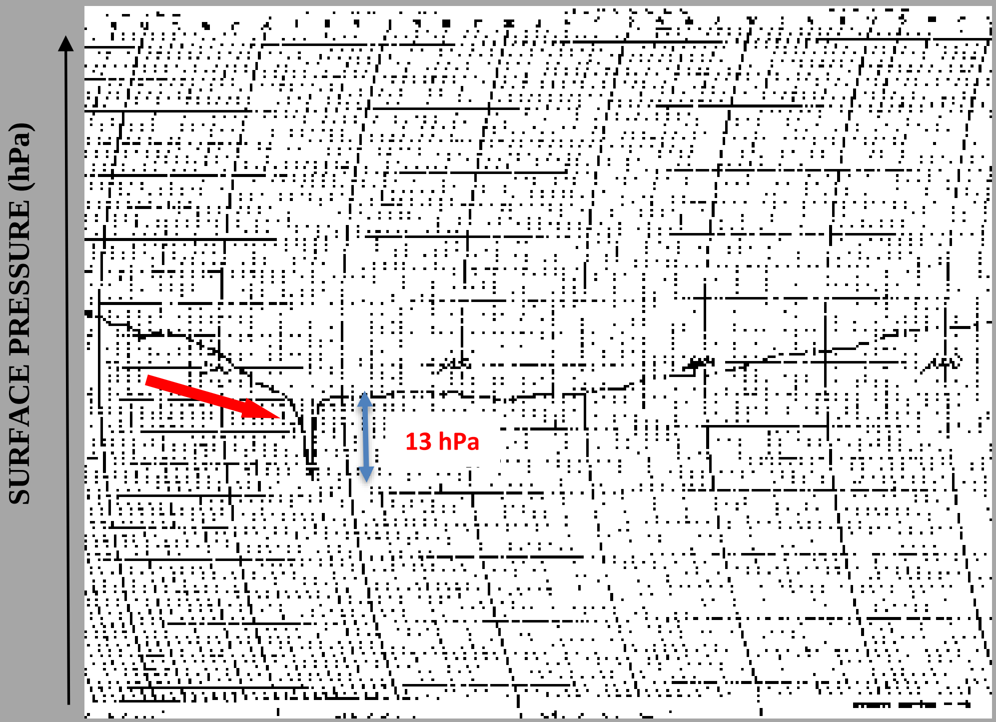
GALATINA AIRPORT



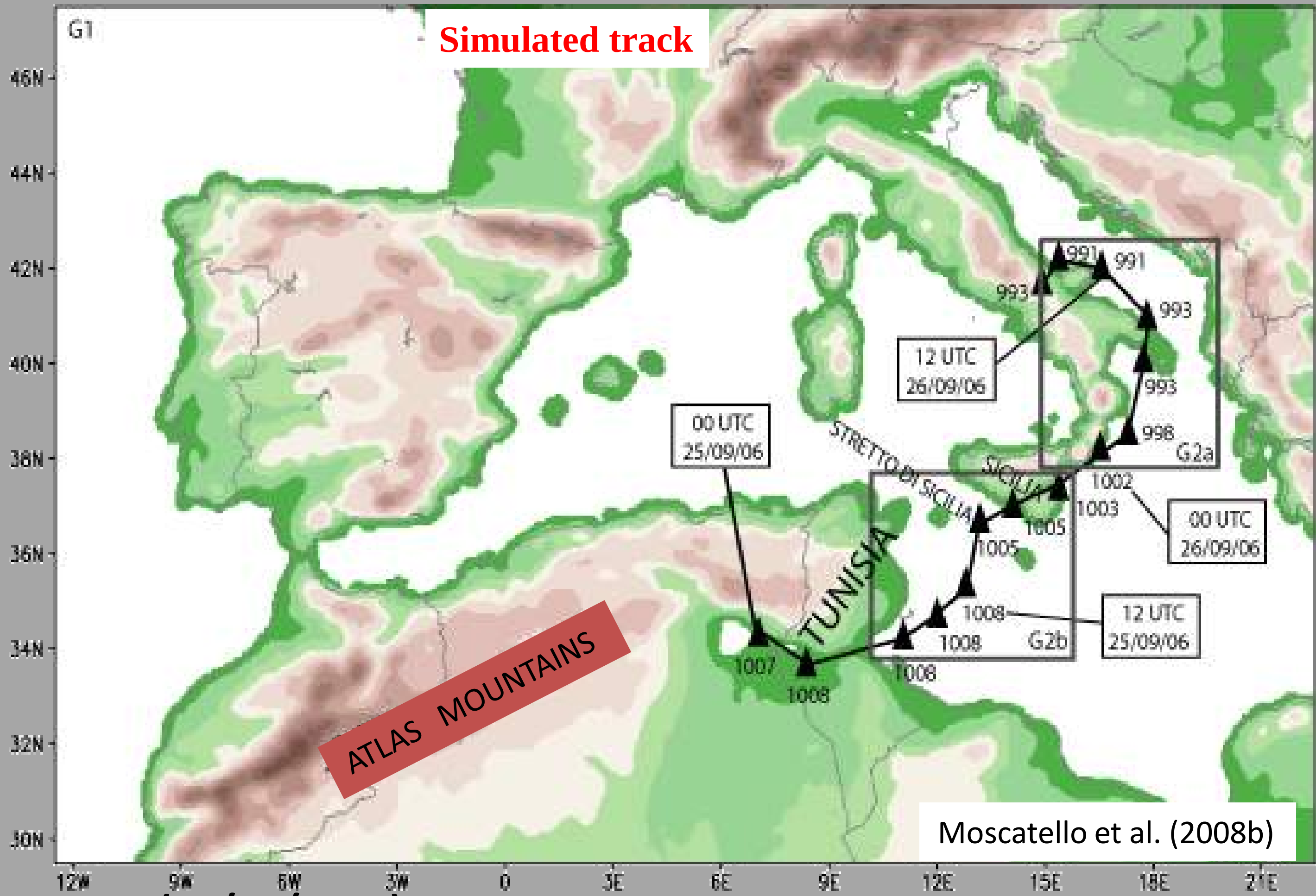
MARIA (26/09/2006)

Moscatello et al. (2008a)

GALATINA AIRPORT

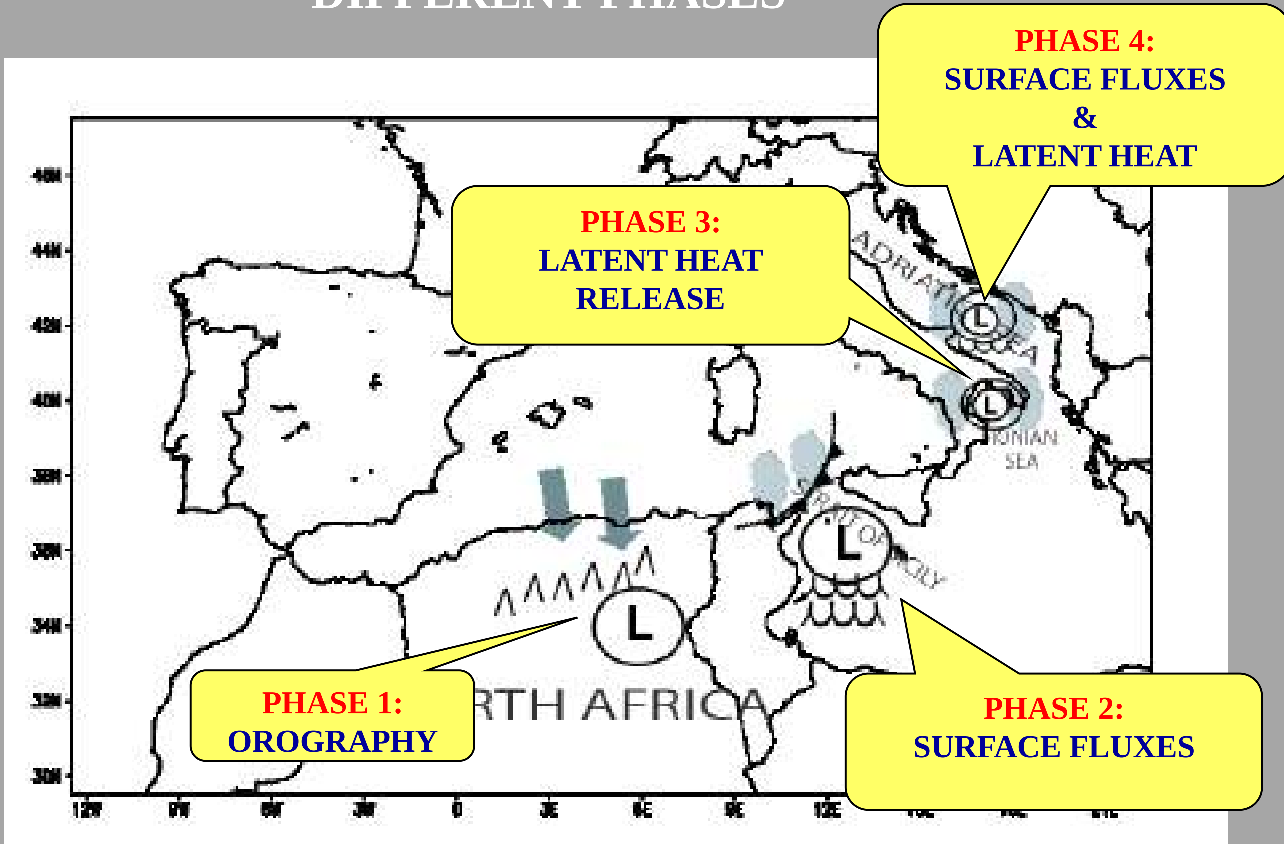


MARIA (26/09/2006)



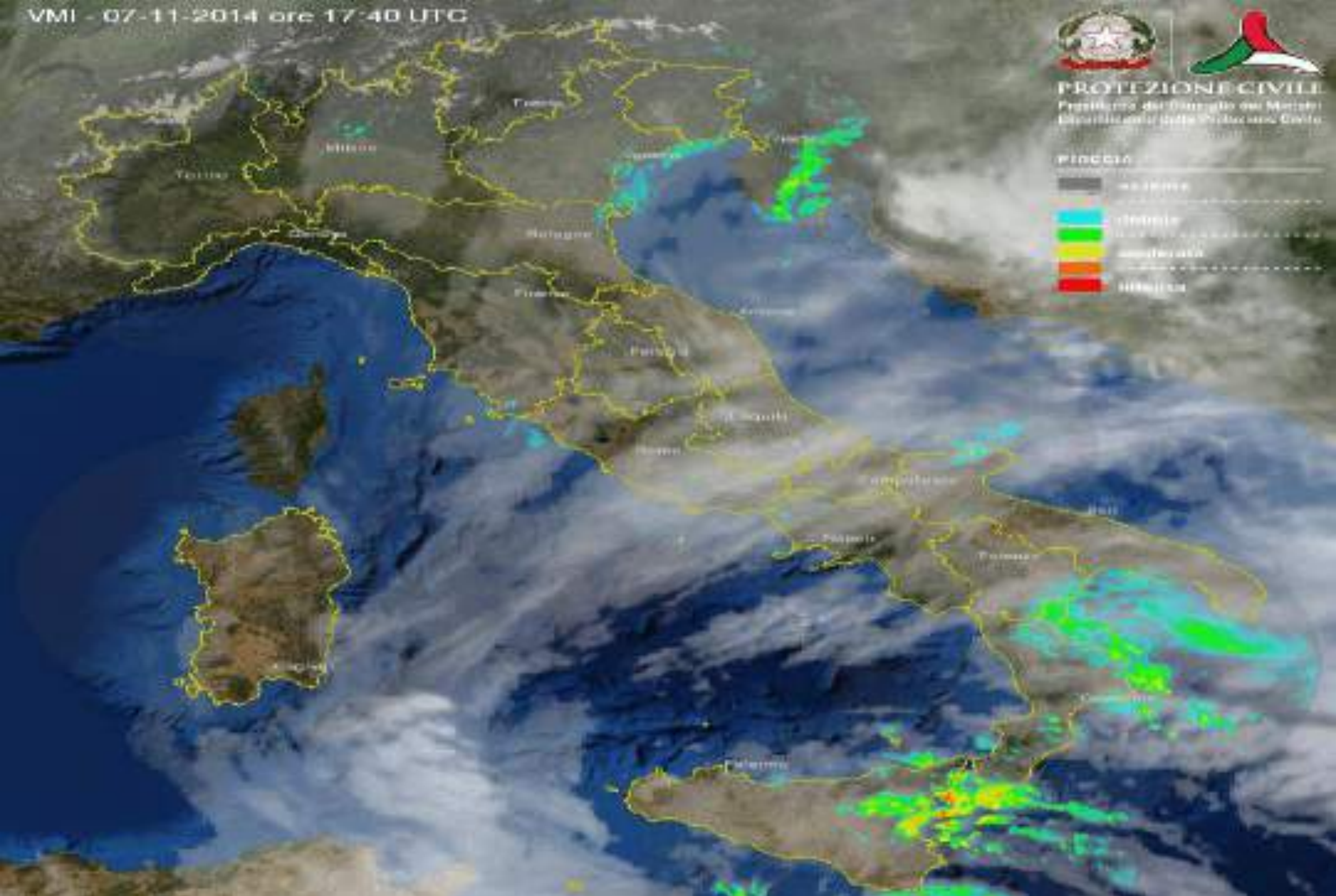
MARIA (26/09/2006)

DIFFERENT PHASES

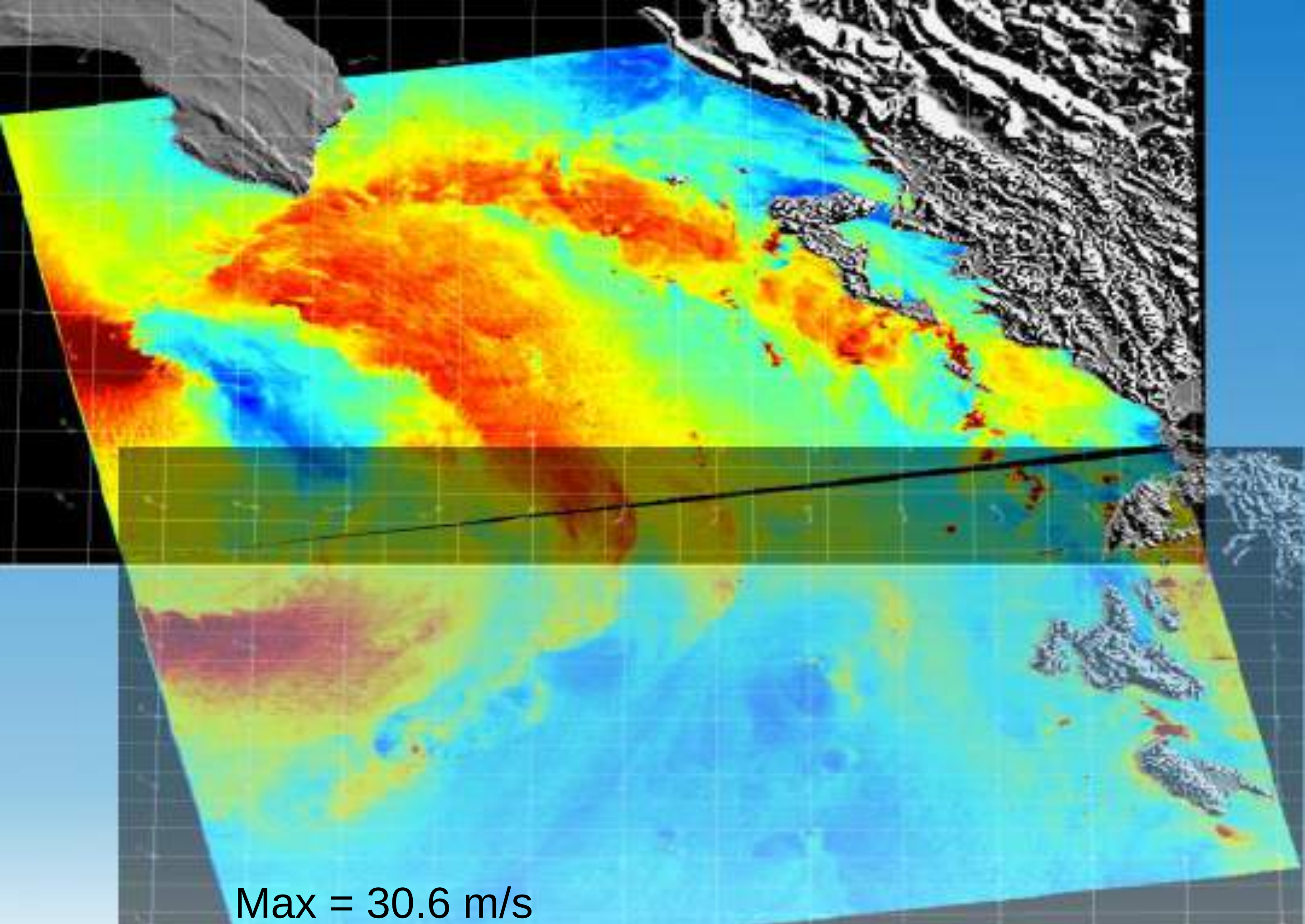


MARIA (26/09/2006)

Moscatello et al. (2008b)

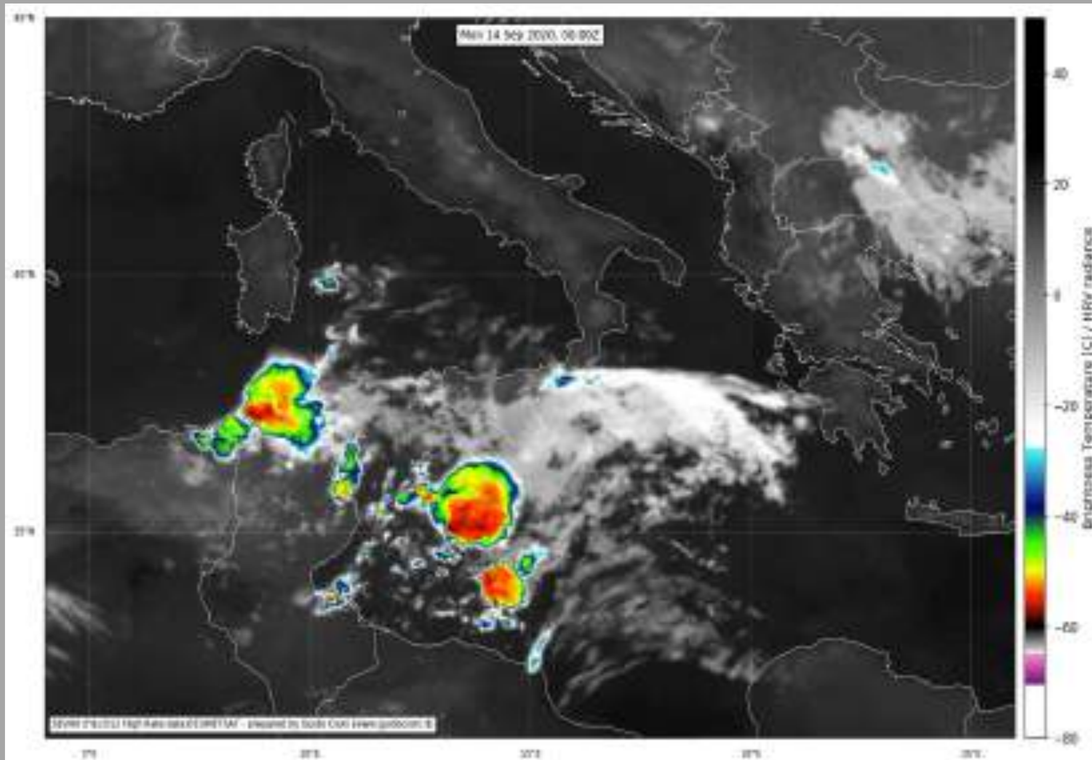


QENDRESA (07/11/2014)



NUMA wind speed (17/11/2017)

IANOS – HRV and Cloud Temperature top



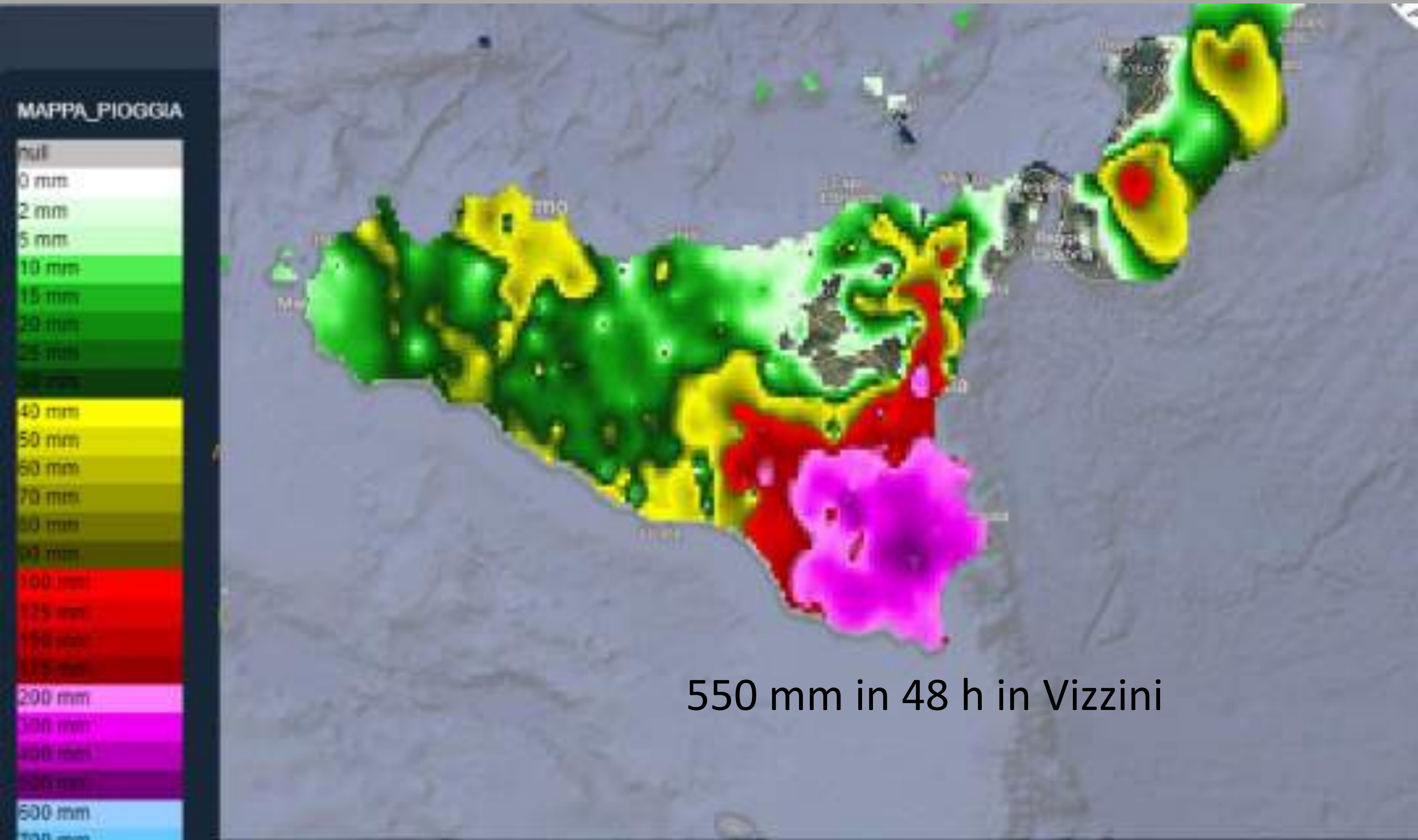
Medicane Ianos struck Greece causing four victims and massive damage in the western and central part. Wind gusts of up to 54.2 m/s and 645 mm/24 h (769 mm/48 h vs. yearly average of 812.3 mm in Argostoli station) of rain have been recorded on the island of Kefalonia (Lagouvardos et al., 2022:; Diakakis et al., 2023).

IANOS 17-18/09/2020

CUMULATED RAINFALL

APOLLO 24-28/10/2021

48-H CUMULATED RAINFALL



HELIOS 9-11/02/2023

Courtesy: DPC

OUTLINE

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Photo from space

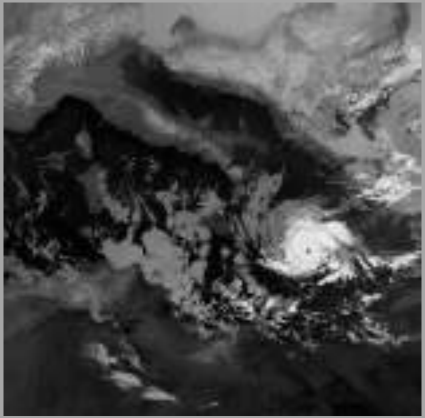
Mediterranean Tropical-like cyclones («Medicanes» = Mediterranean hurricanes)

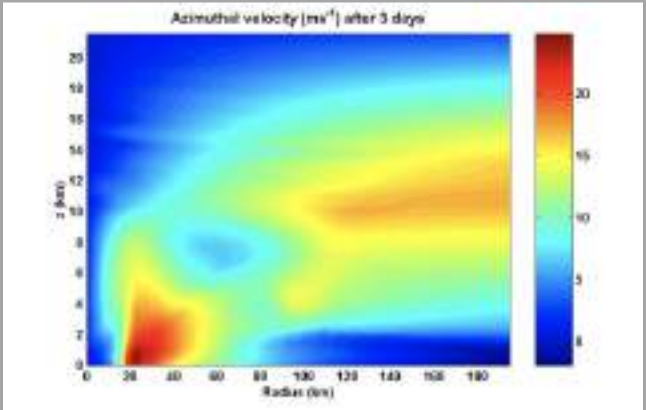
Cyclones with characteristics similar to TC for part of their lifetime are possible in the Mediterranean (e.g., presence of a central “eye”, warm core, symmetric structure)

They are less intense and smaller than TC (they can rarely reach level 1 of the Saffir-Simpson scale)

They are rare (0-3 per year)

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

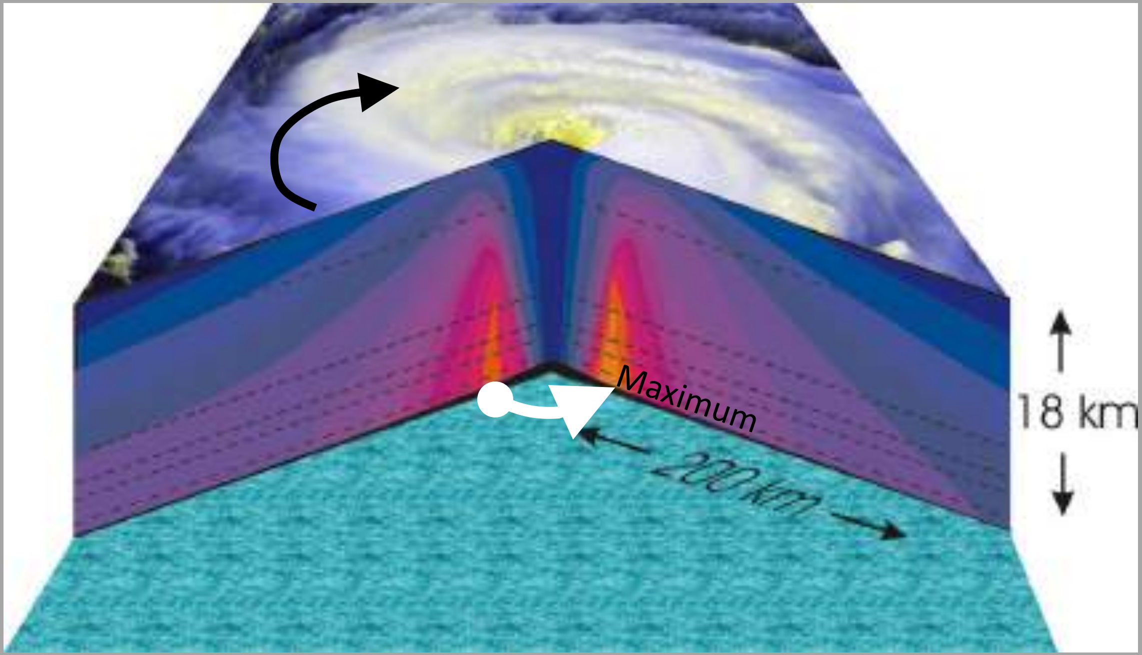




An **axisymmetric, cloud-resolving model -**in which any development may occur only due to the **feedback between surface enthalpy fluxes and wind** – was applied to show that a **cold, upper low** can produce high potential intensity in an Ionian cyclone (Jan 1995)

CELENO (15-17/01/1995)

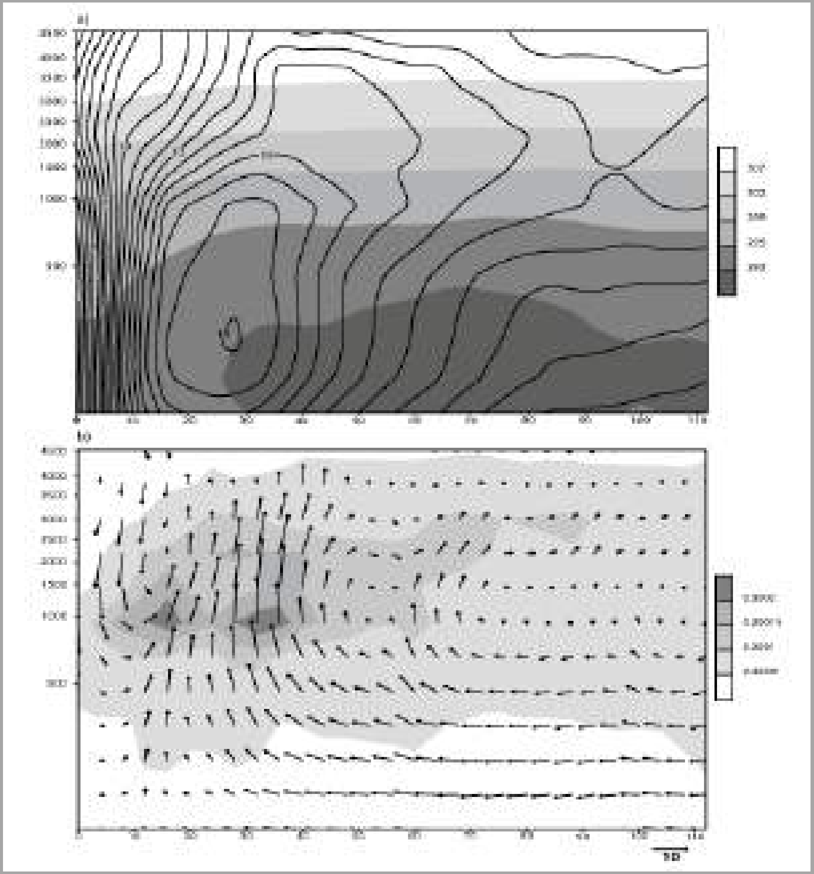
1. WIND STRUCTURE



- Eye: weak wind (20 KT o less)
- Peak at 20-30 km from center, discontinuous with strong gusts
- Wind weakens with distance

Coordinate system origin in the pressure minimum

11UTC
26 Sep 2006



Azimuthal wind component (m/s, contours)
Theta (K, grey scale)

Radial wind + w (arrows)
qc (g/kg, grey scale)

Moscatello et al. (2008b)

But this pattern is not observed in all medicanes!

2. MECHANISM OF DEVELOPMENT

Low SST and initial baroclinic environment

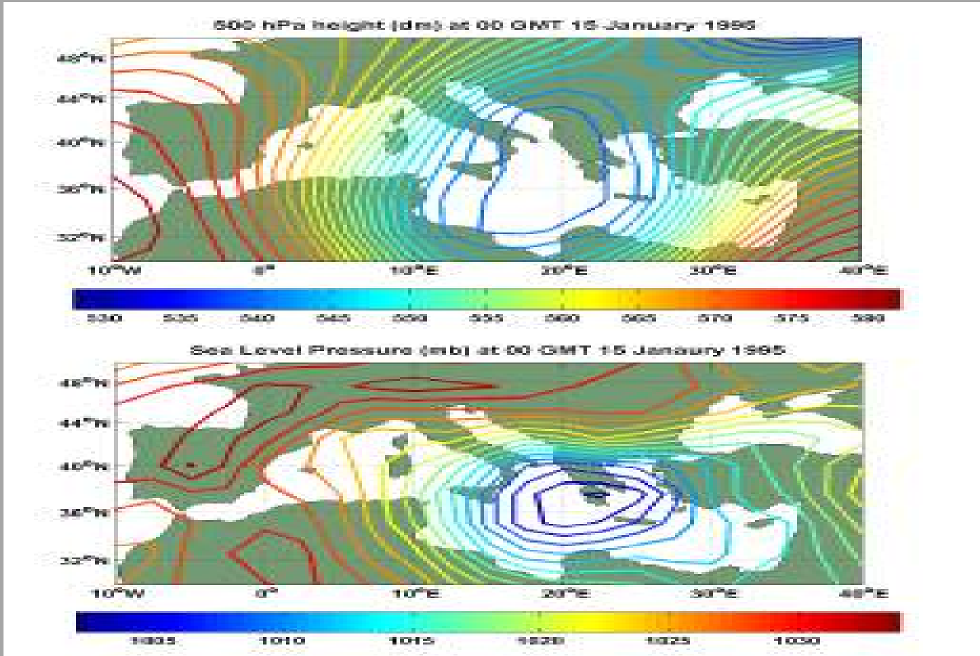


Fig. 2. 500 hPa geopotential height (dm, top) and sea level pressure (hPa, bottom), at 00:00 GMT on 15 January 1995. Analyses from NCAR/NCEP 2.5 degree re-analysis data.

Emanuel (2005)

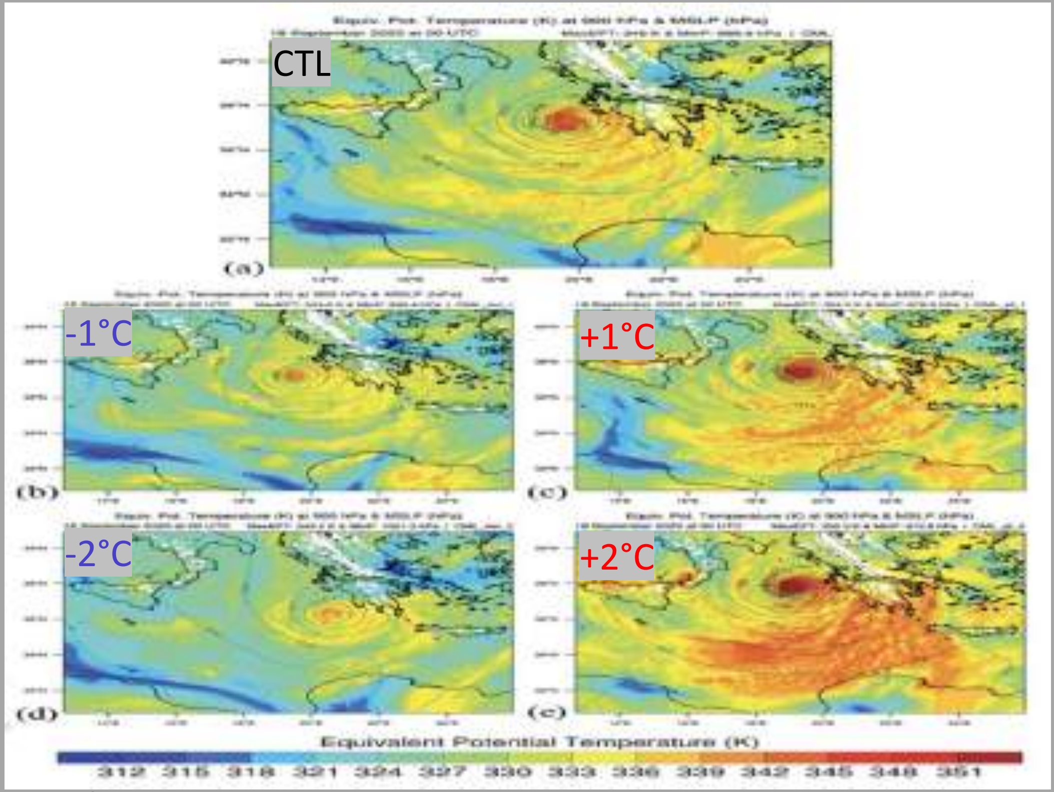
500 hPa Geopotential height

Mean Sea Level Pressure

Mediterranean hurricanes usually, and perhaps always, generate directly underneath an unusually deep, cut-off low at upper levels, in regions of large air-sea **thermodynamic disequilibrium** due to unusually **deep, cold air associated with a trough.**

Emanuel (2005) applied his axisymmetric model for hurricanes to this case successfully.

ROLE OF SST ANOMALY

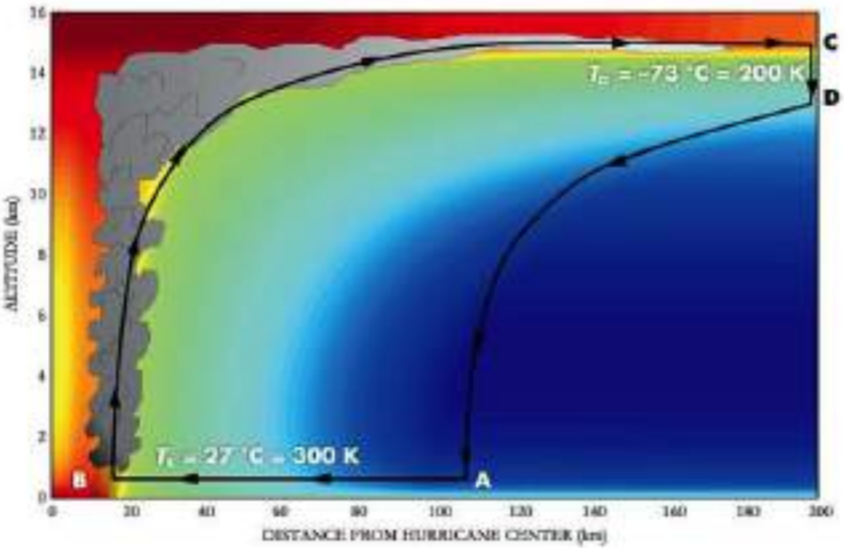


No SST significant anomalies prior to cyclone development, but higher SST anomalies intensify the cyclone warm core and the pressure minimum (e.g., Varlas et al., 2023). No SST threshold (differently from TC).

IANOS (15-20/09/2020)

HURRICANE AS A CARNOT CYCLE

The mature hurricane idealized by Emanuel (1986) as a **Carnot engine** converting heat energy extracted from the ocean to mechanical energy, that, in a steady state, balances frictional dissipation that occurs mostly at the air-sea interface.

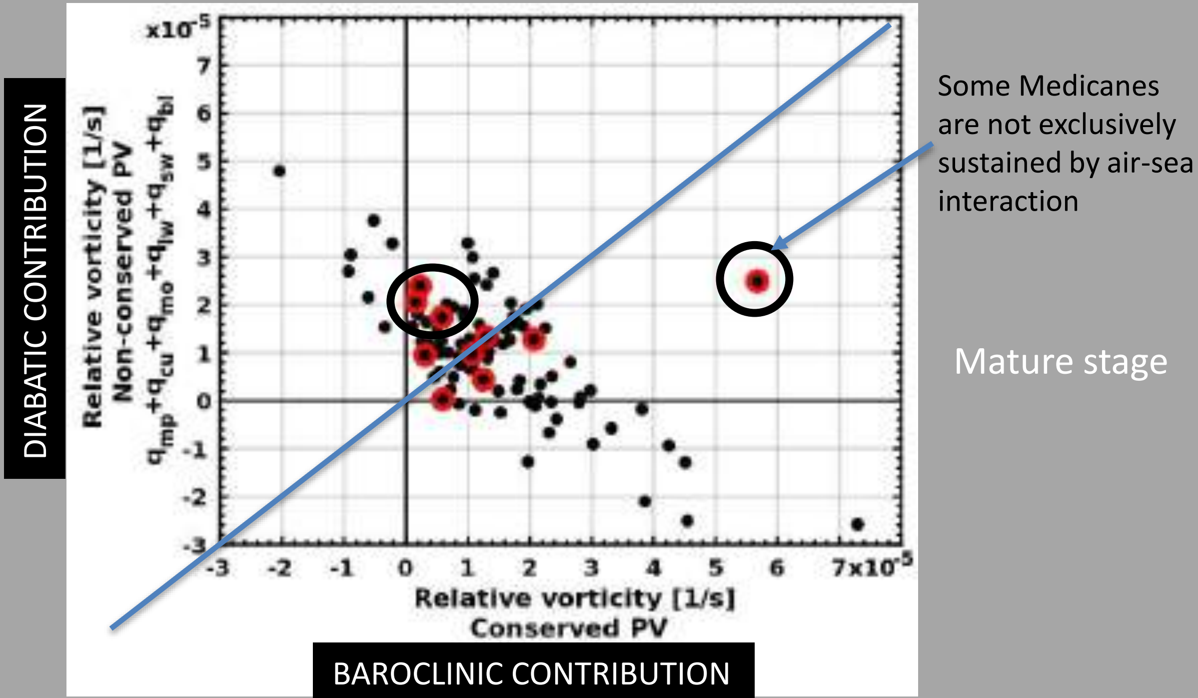


The Hurricane Carnot cycle: the colors depict entropy distribution (blue-green indicates lower entropy; red-yellow indicates higher entropy).

EFFICIENCY = $(T_s - T_0)/T_s$ (for typical atmospheric conditions in the tropics, is 1/3).

In MEDICANES T_0 can play an important role differently from most TC

Contribution of baroclinic versus diabatic processes to 850 hPa relative vorticity



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

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

Flaounas et al. (2020)

3. UPPER-LEVEL DYNAMICS

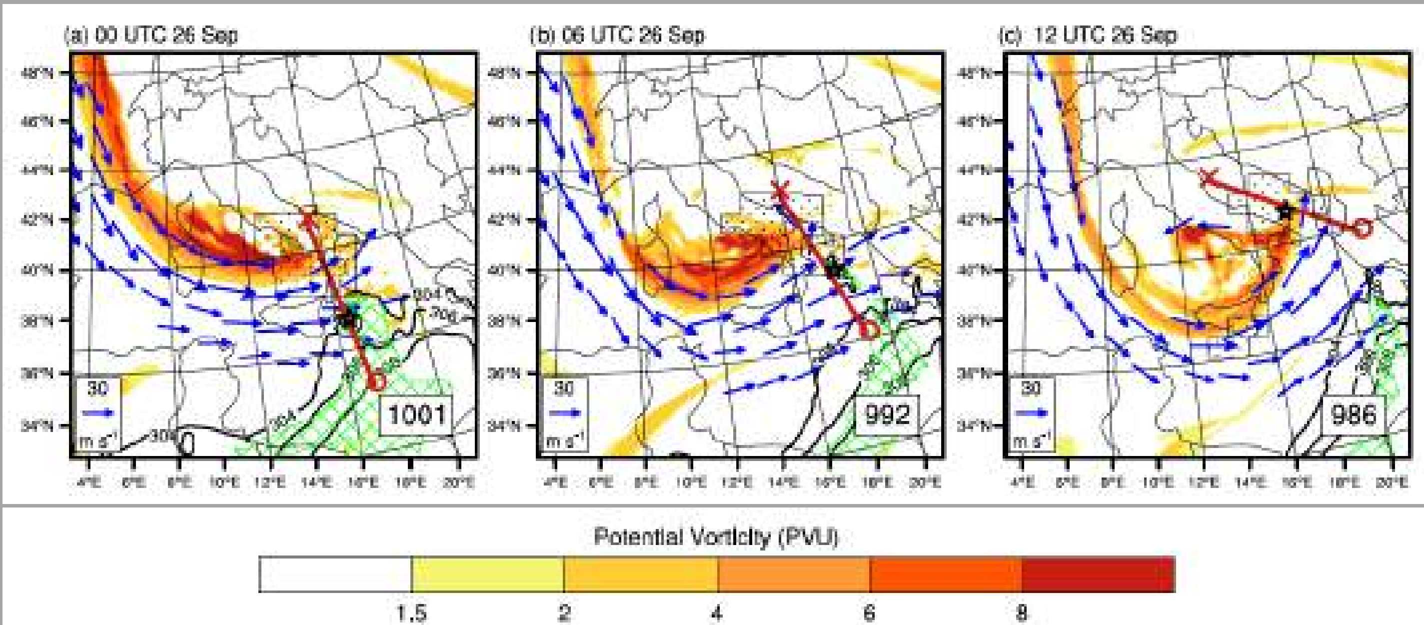
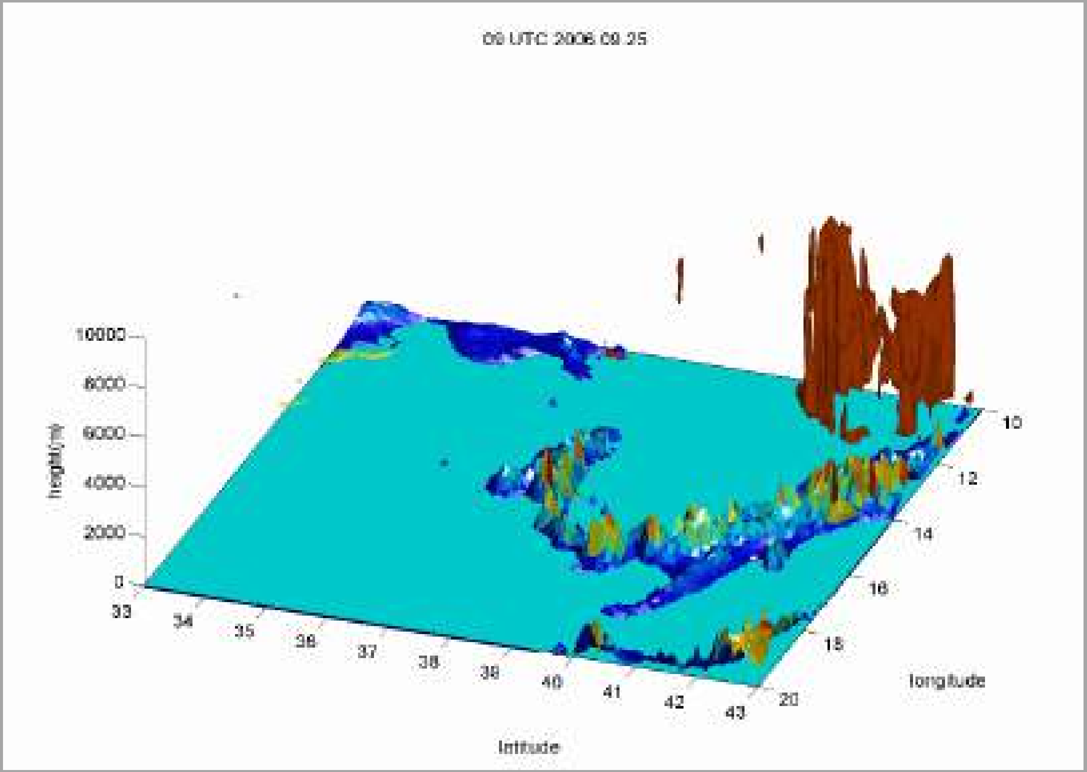


Figure 12. Results for BCMA at 0000, 0600, and 1200 UTC on 26 September 2006. Top: potential vorticity at 300 hPa (shaded, PVU), wind speed at 300 hPa over 30 m s^{-1} (vector), ω_{dp1} at 400 hPa less than −0.4 Pa s^{-1} (dotted) and CAPE larger than 1500 J kg^{-1} (hatched). The star and the figure in the white box give the position and MSLP minimum, respectively, of the mesocyclone. Bottom: vertical cross-section of potential vorticity (shaded,

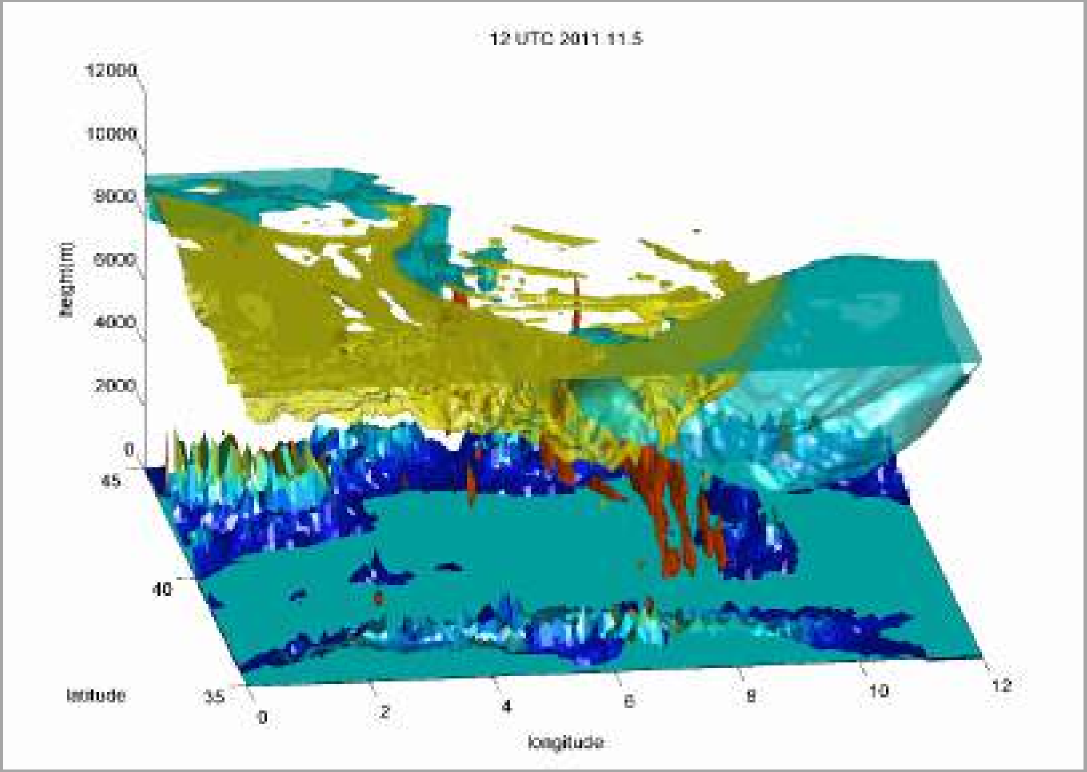
Chaboureau et al. (2012)

Brown: diabatic PV
Yellow: adiabatic (conserved) PV
Green: Intense wind



Miglietta et al. (2017)

Brown: diabatic PV
Yellow: adiabatic (conserved) PV
Green: Jet Stream

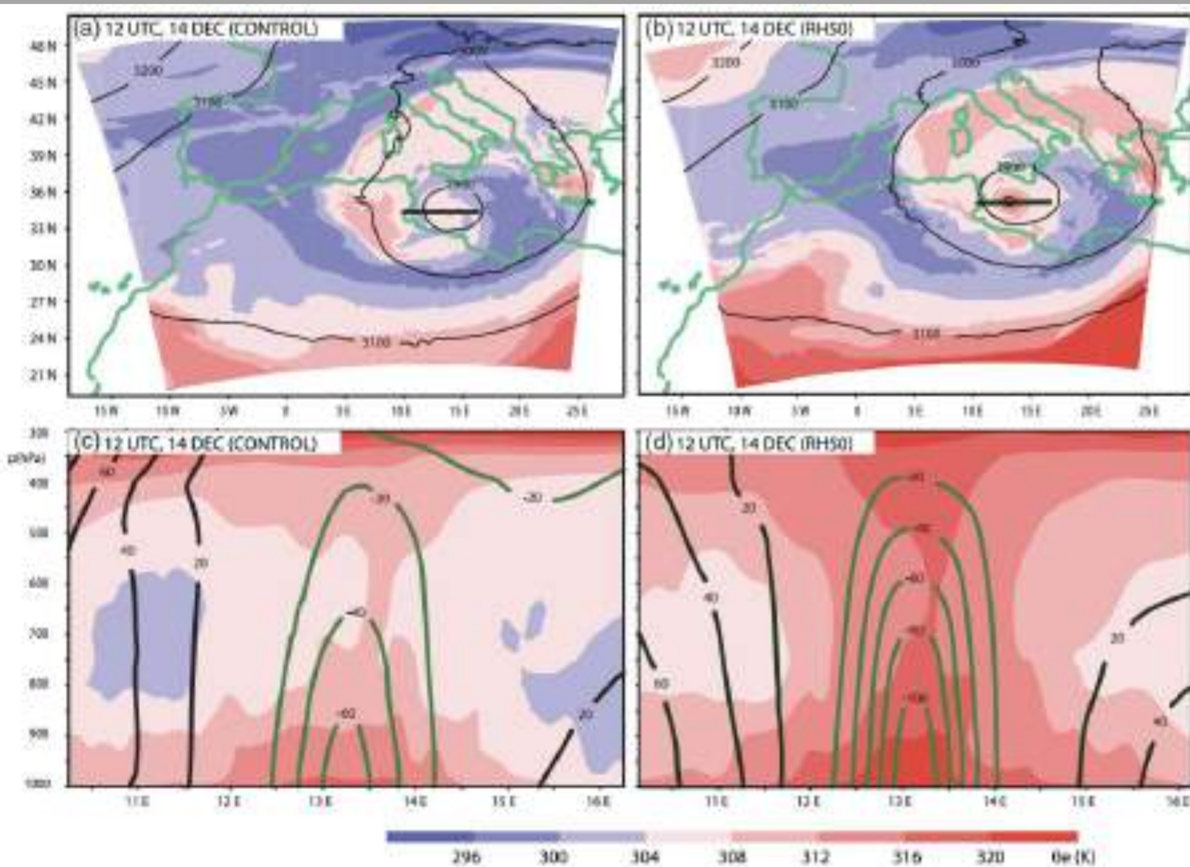


Miglietta et al. (2017)

EFFECT OF DRY INTRUSION IN THE DEVELOPMENT OF THE CYCLONES

CONTROL RUN

RH50 RUN

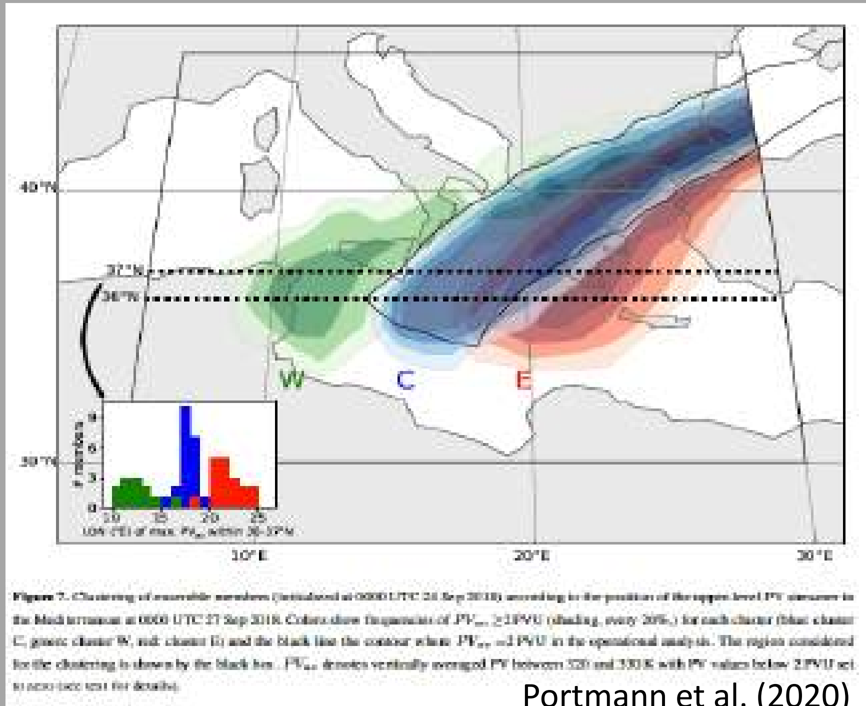


700 hPa Geopotential height and θe

θe and anomaly of geopotential height

Miglietta et al. (2021)

UPPER LEVEL DYNAMICS AND PREDICTABILITY ISSUES



PV streamers control the coupling with the low-levels and determine its location and intensity. Portmann et al. (2020) found that short-wave perturbations on the North Atlantic waveguide a few days before the development of an intense medicane dramatically affected its subsequent evolution.

ZORBAS (27-30/09/2018)

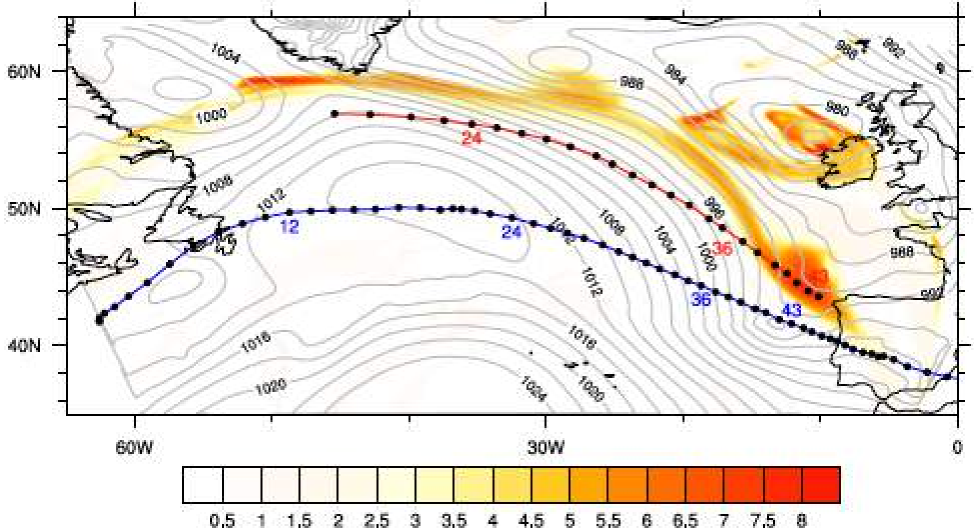


Figure 16. MSLP minimum (blue line) and 350 hPa-PV maximum (red line) trajectories from BOLAM simulation (black dots every hour). Grey contours show the MSLP field from the BOLAM forecast valid at 18 January 2014 18 UTC, while the shading shows the PV at 350 hPa (only positive values) at the same time. The numbers superimposed on both trajectories (12, 24, 36, 43) indicate the lead time in hours.

Cioni et al. (2016)

4. LIGHTNING AND DEEP CONVECTION

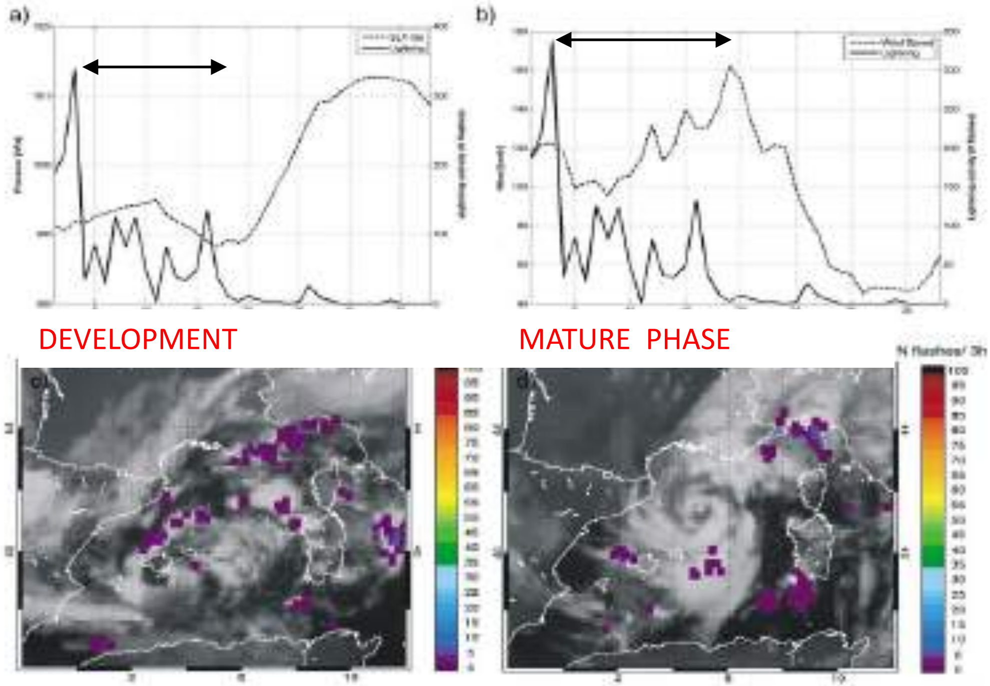
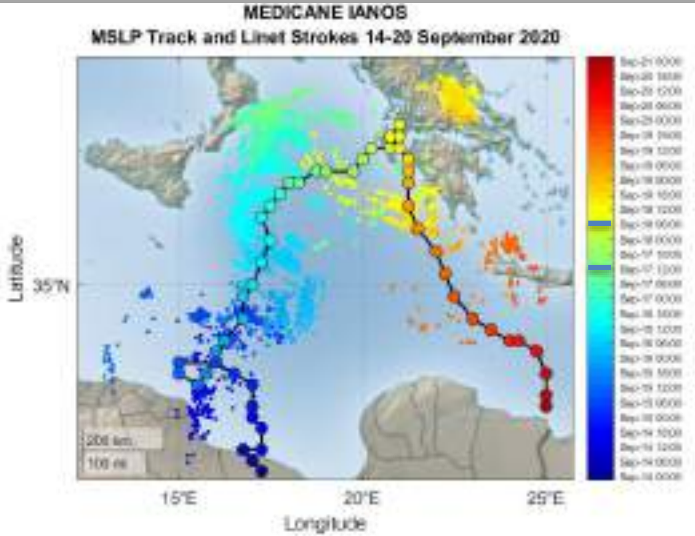


Figure 3. (top) Lightning strokes cumulated in 3 h, from 0300 UTC, 06/11/2011 to 1500 UTC, 10/11/2011 (solid line), counted in a moving window of 5° (latitude) × 6° (longitude) centered at mslp minimum location, versus mslp minimum (left) and maximum surface wind (right). (bottom) MSG images and number of lightning strokes at 1800 UTC, 6 November (left) and 0000 UTC, 8 November (right); one time step corresponds to 3 h.

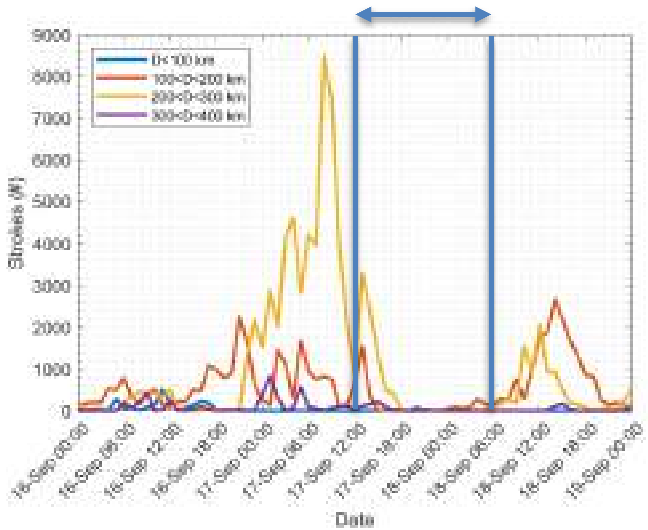
Miglietta et al. (2013)

4. LIGHTNING AND DEEP CONVECTION

LIGHTNING ACTIVITY IN IANOS

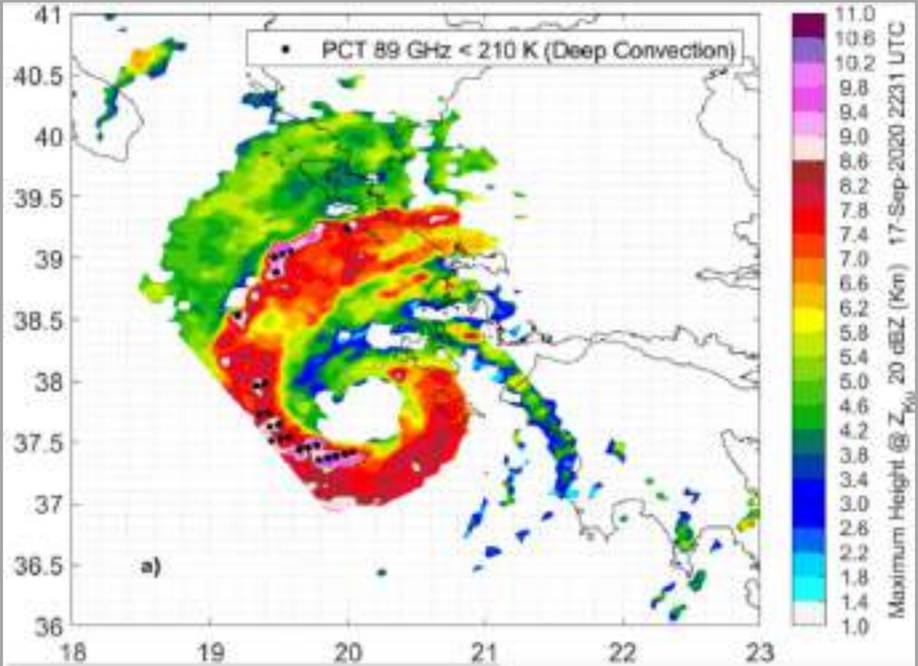


Mature stage



D'Adderio et al. (2022)

DEEP CONVECTION IN IANOS



D’Adderio et al. (2022)

Satellite analysis - 26 September 2006 case

DEVELOPMENT

MATURE PHASE

MWCC

183-WSL

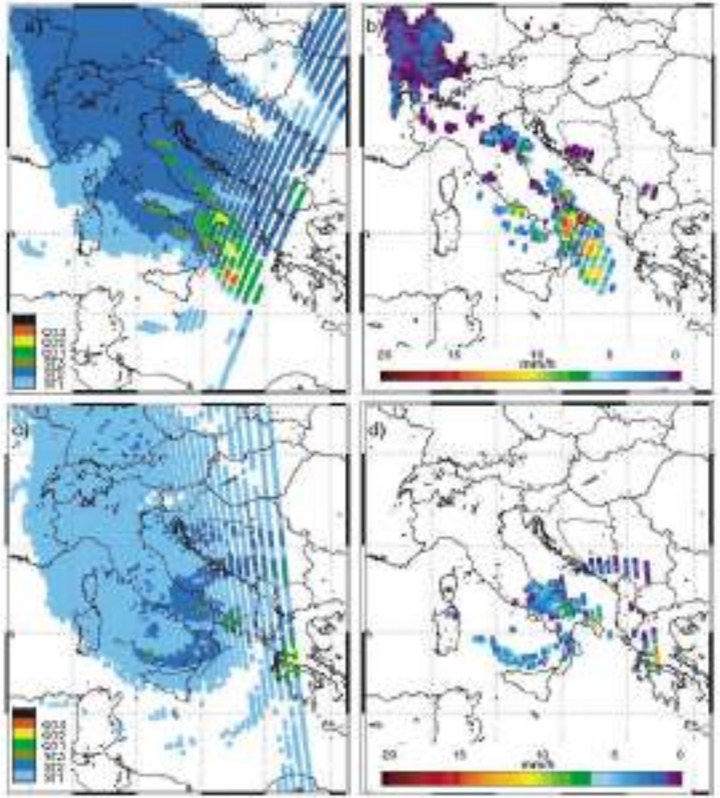


Figure 2. Cloud type identification [for midlatitudes, stratiform type: ST1 (cloud top at: 1–3 km), ST2 (3–5 km), and ST3 (5–6 km); convection type: CO1 (6–7 km), CO2 (7–9 km), and CO3 (>9 km); left] and rain rate (right) from the 183-WSL algorithm at 0139 UTC (top), 1431 UTC (bottom), 26 September 2006.

Miglietta et al. (2013)

Satellite analysis- 6-8 November 2011 case

MWCC

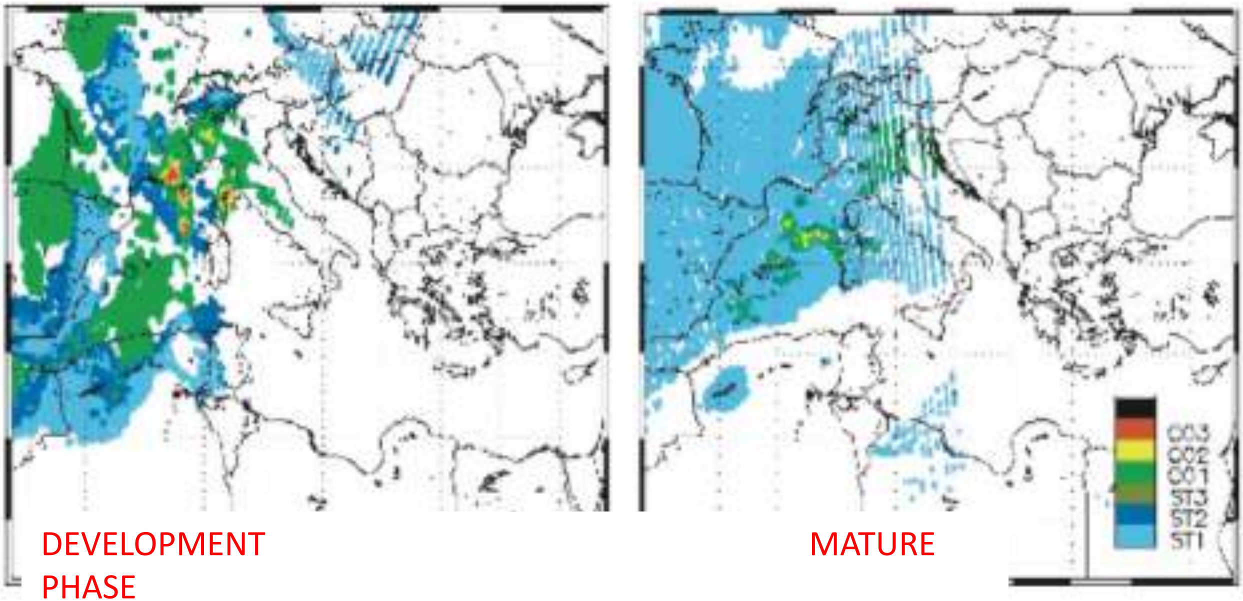


Fig. 2: Cloud type identification [for mid-latitudes, stratiform type: ST1 (cloud top at: 1÷3 km), ST2 (3÷5 km), and ST3 (5÷6 km); convection type: CO1 (6÷7 km), CO2 (7÷9 km), and CO3 (>9 km); left] from the 183-WSL algorithm at 0247 UTC, 05 November 2011 (left), and 1250 UTC, 07 November 2011 (right).

Miglietta et al. (2013)

Features common with Tropical cyclones

- **Weak** environmental **vertical wind shear**
- **Strong rotation** around the center
- **Central deep warm core**
- **Symmetry** around the center
- “**Eye**” of mostly calm weather and clear skies
- **Eyewall** of deep convective, towering clouds, with rainbands extending outside (in some cases)
- Most of lifetime over sea, **strong weakening inland**
- **Reduction in lightning activity** in the mature stage

TROPICAL CYCLONES

- Lifetime: some days to 1-2 weeks; BUT a substantial proportion of TCs have a duration equal or less than 2 days (about 25%, see Fig. 2 in Klotzbach et al. (2022),https://doi.org/10.1029/2021GL095774)

- Diameter: 500 km or more

- Pressure minimum 950 hPa on average (but sometimes close to 900 hPa) => strong pressure gradients => Rotation speed of 100 kt (200 km/h) near the eye; BUT a substantial part have a tropical storm intensity, between 65 km/h and 120 km/h

MEDICANES

- Lifetime: a few hours-few days

- Diameter: 300 km or less

- Pressure minimum at most around 980 hPa (wind speed rarely exceed the threshold for category 1; however, IANOS reached category 2)

TROPICAL CYCLONES	**MEDICANES**
- Formation over SST > 26.5°C (importance of heat and humidity fluxes + condensation latent heat release); BUT between 4 and 7% of TCs are generated over waters below 26.5ºC. These cases correspond mainly to TCs of baroclinic origin (Mc Taggart Cowan et al., 2015)	- No threshold on SST (disequilibrium mainly due to upper-level cold air; importance of heat and humidity fluxes + condensation latent heat)
- No baroclinicity (occasionally in the early stage); about 17% of TCs are generated from baroclinic precursors (Table 1, McTaggart Cowan et al., 2015, DOI:10.1175/BAMS-D-13-00254.2). TCs of baroclinic origin, that develop over SSTs below 26.5ºC, occur more frequently over the North Atlantic, at latitudes similar to the Mediterranean Sea.	- Baroclinic generation; sometimes important in the mature stage too
- Limited, if any, role of upper level dynamics in the mature stage	- Central role of upper level dynamics (jet, PV streamers)

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ABSENCE OF OFFICIAL DEFINITION OF «MEDICANE» :

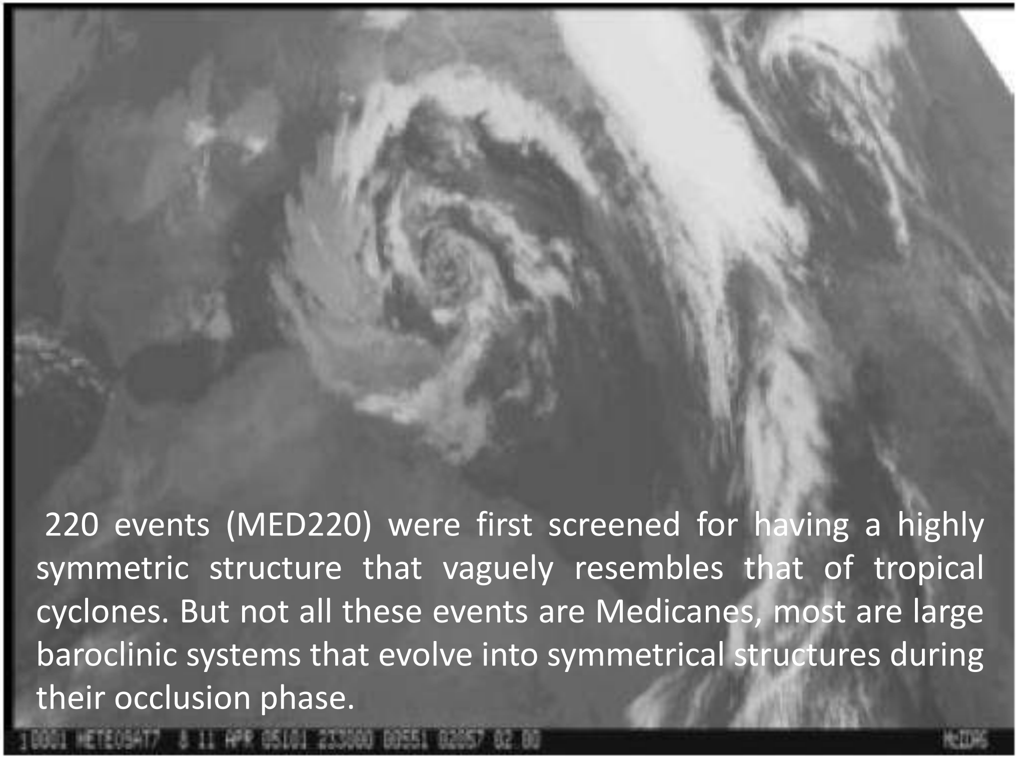
- Confusion within the scientific community (different criteria to physically define medicanes in model and observation datasets).
- Confusion among weather services for the purposes of issuing warnings of imminent high-impact weather.
- Social-media sources, private and governmental weather services, or even individuals felt entitled to classify new cyclones as medicanes.

Criteria to address medicanes as weather systems of tropical characteristics: *phenomenological* and *physical*.

Phenomenological criteria: empirical, rather arbitrary definition.

Physical criteria: based on physical properties and thresholds applied to atmospheric variables of model outputs.

Phenomenological criteria



220 events (MED220) were first screened for having a highly symmetric structure that vaguely resembles that of tropical cyclones. But not all these events are Medicanes, 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)

GEOGRAPHICAL DISTRIBUTION

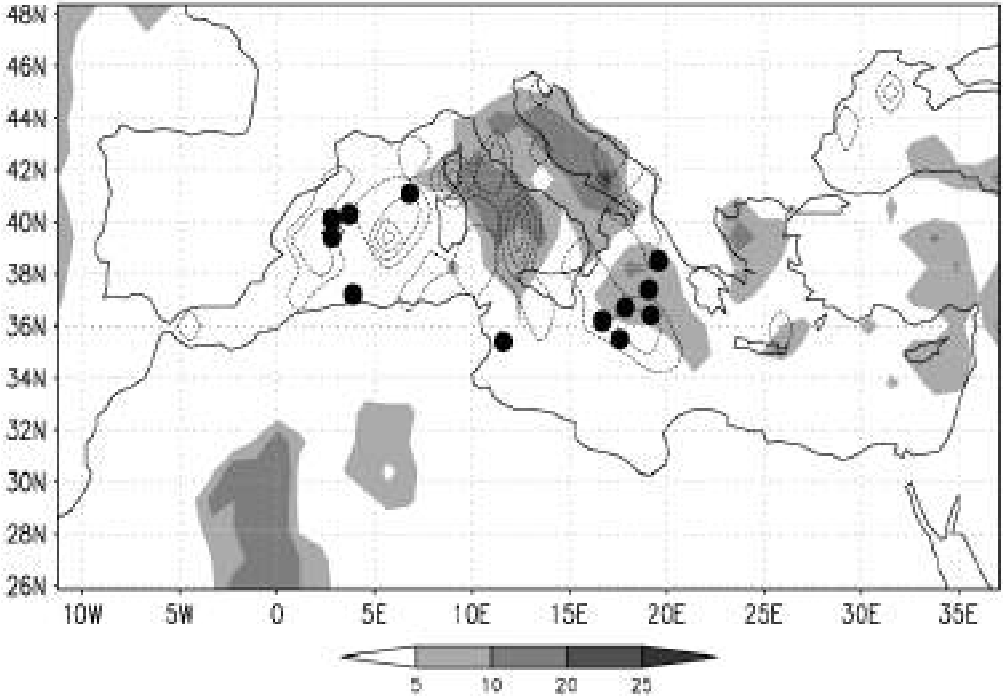


Figure 3. Spatial density distribution of intense cyclones from the MEDEX project (shaded) as number of events in a square of 1.125° lat–lon; density distribution of MED220 cyclones (dashed lines, contour interval is one event/$(1.125°)^2$ starting at value 1); and the 12 detected medicanes (black points).

Tous and Romero (2013)

Phenomenological criteria:

- UIB website
- Nastos et al. (2018)
- Few examples of detection of medicanes by NOAA using the Dvorak technique (automated detection techniques may work in the Mediterranean)
- «Storm naming» initiative

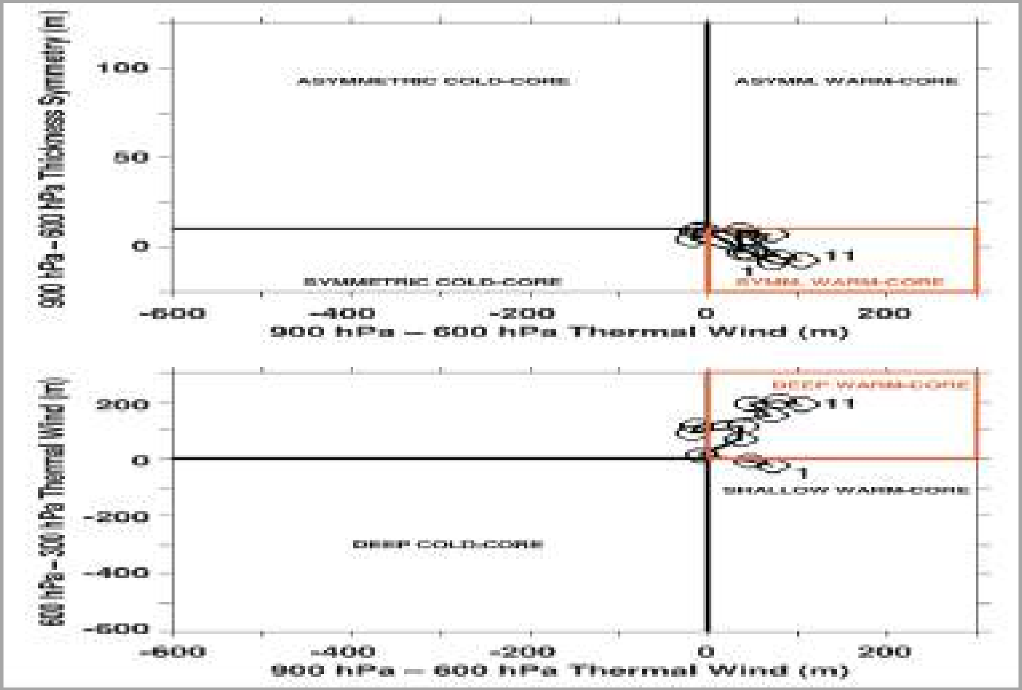
Physical criteria

How can we discriminate Medicanes from a dynamic perspective?

HART (2003) DIAGRAM

Symmetry

Upper-troposphere Temperature



Lower-troposphere Temperature

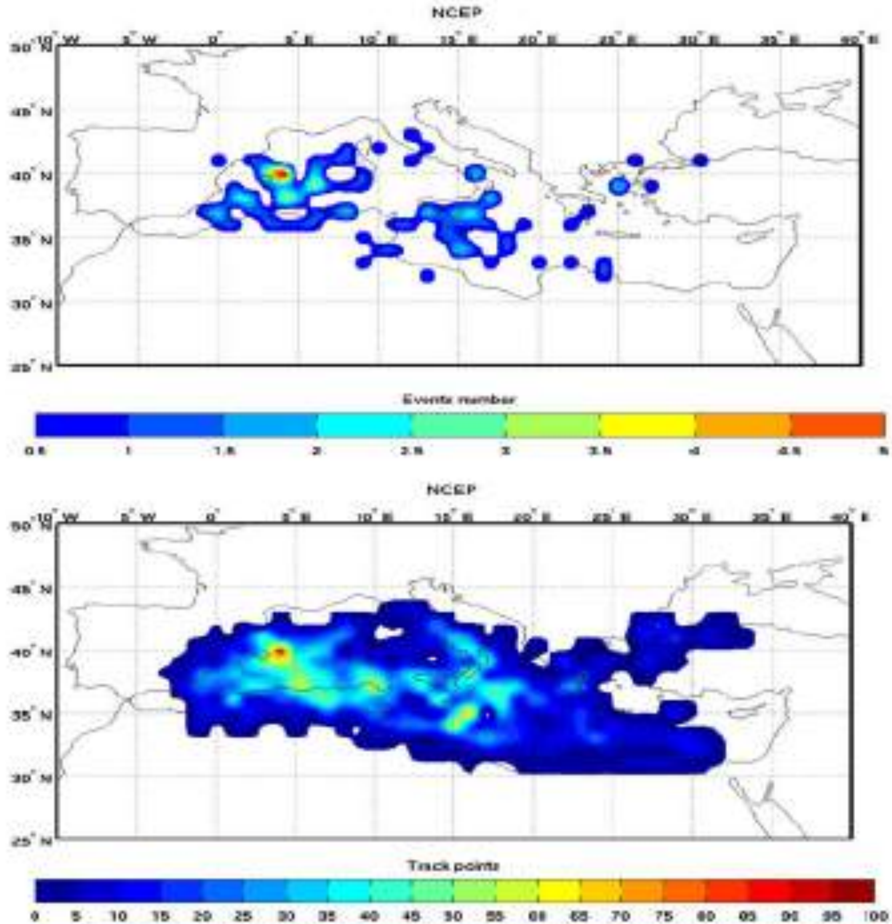
NOTE: the presence of a warm central core must be due to the release of latent heat due to vapor condensation.

Gaertner et al. (2007)

Fig. 2 Locations of all the medicanes detected. *Top* genesis density (first location in the track) per 1° × 1° box. *Bottom* track density per 1° × 1° box

Genesis density

Track density



NCEP/NCAR reanalysis
Downscaling by CCLM
10 km resolution
Period: 1948-2011

Cavicchia et al. (2013)

MONTHLY DISTRIBUTION

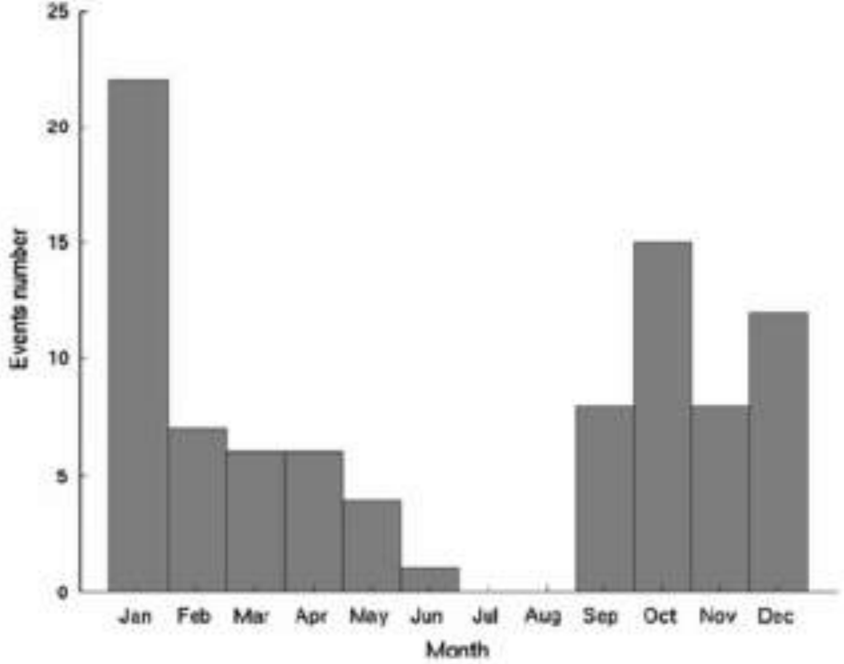


Fig. 3 Number of medicanes per month (total number in the period 1948–2011)

Cavicchia et al. (2013)

INTERANNUAL VARIABILITY

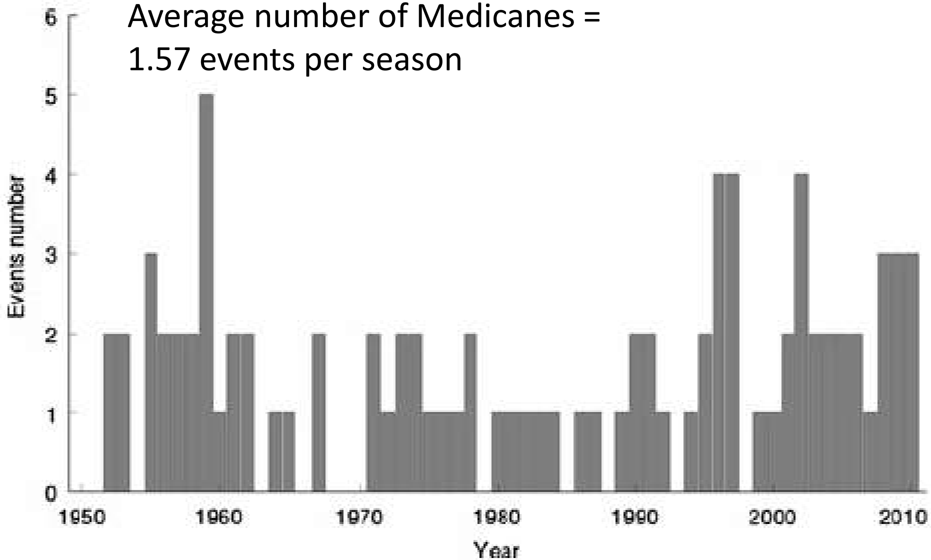
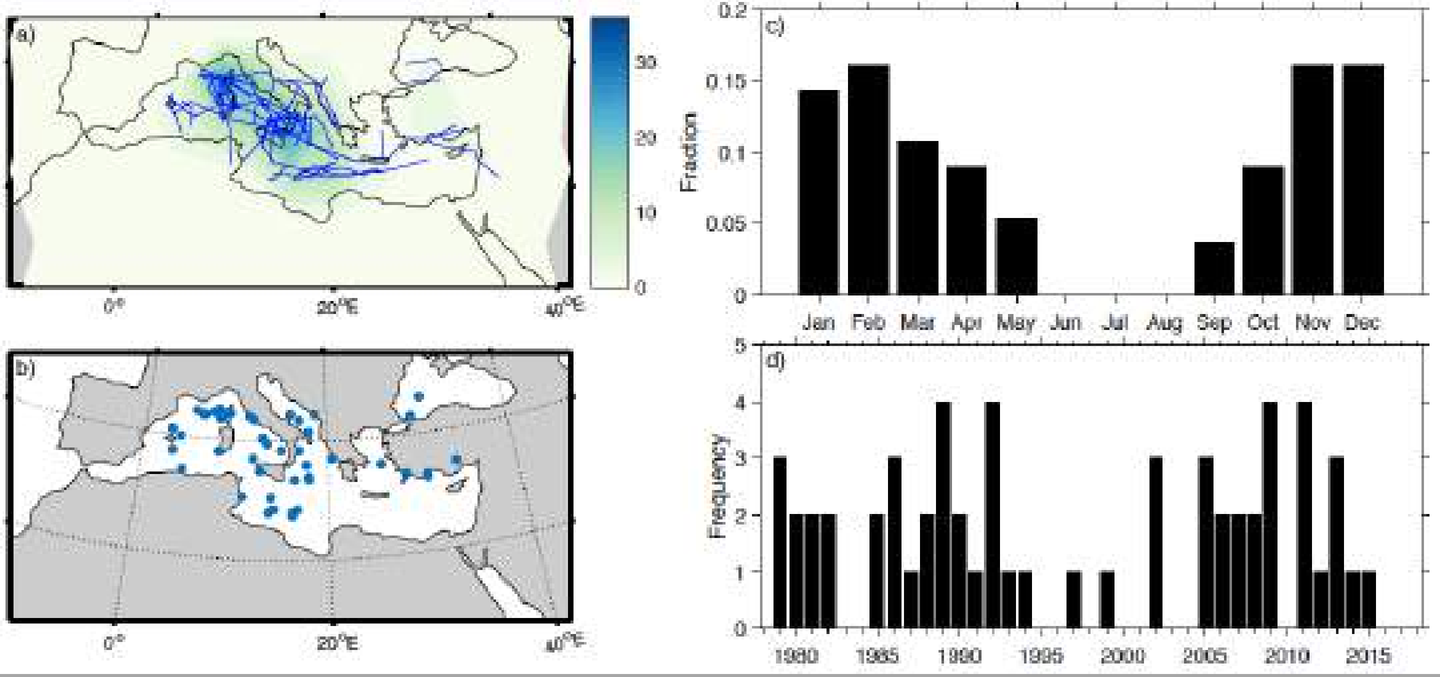


Fig. 4 Number of medicanes per year. Instead of calendar year, "medicane seasons" are reported on the *x* axis. A medicane season is defined to extend from August every year to July next year

Cavicchia et al. (2013)

ERA-5 climatology

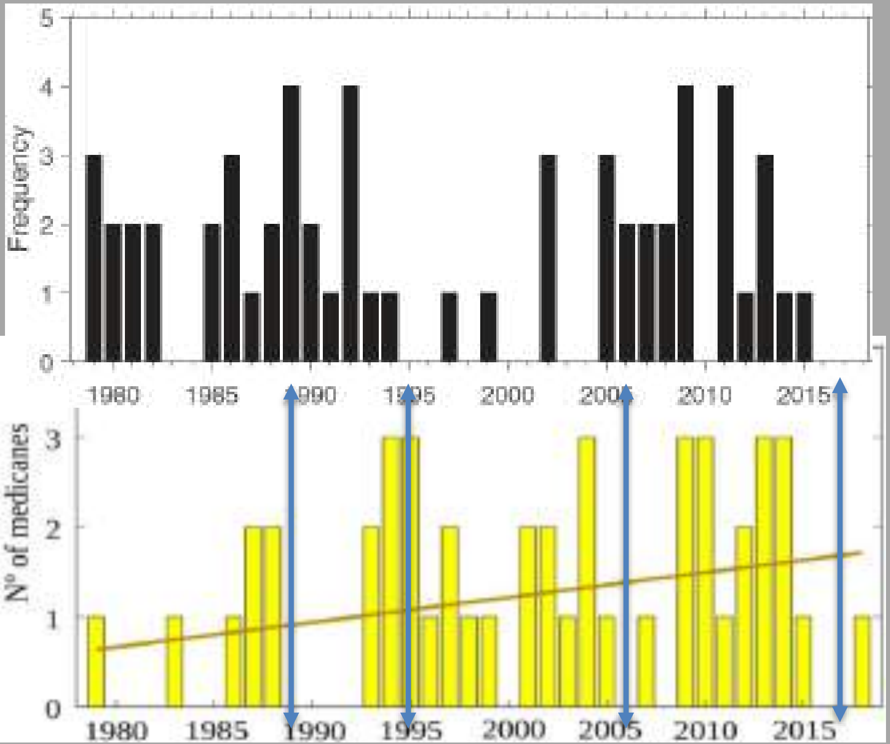
Average number of Medicanes =
1.51 events per season



ERA-5 reanalysis

Zhang et al. (2020)

ERA-5 climatology



(a) Zhang et al. (2020)

The case of September 2006 is included in (a) but not in (b); in 1989 (a) found 4 cases, while (b) did not find any; in 1995 (a) found 0 cases and (b) 3; neither study includes the known case of November 2017

(b) De la Vara et al. (2020)

Need for a common tracking strategy?
See Flounas et al. (2023)

Additional criteria on intensities to match occurrences in Tous and Romero (2013).
Different modeling approaches, criteria and configuration thresholds -> inconsistent list of medicanes (weakness of the diagnostic method)

ANOMALIES OF METEOROLOGICAL PARAMETERS

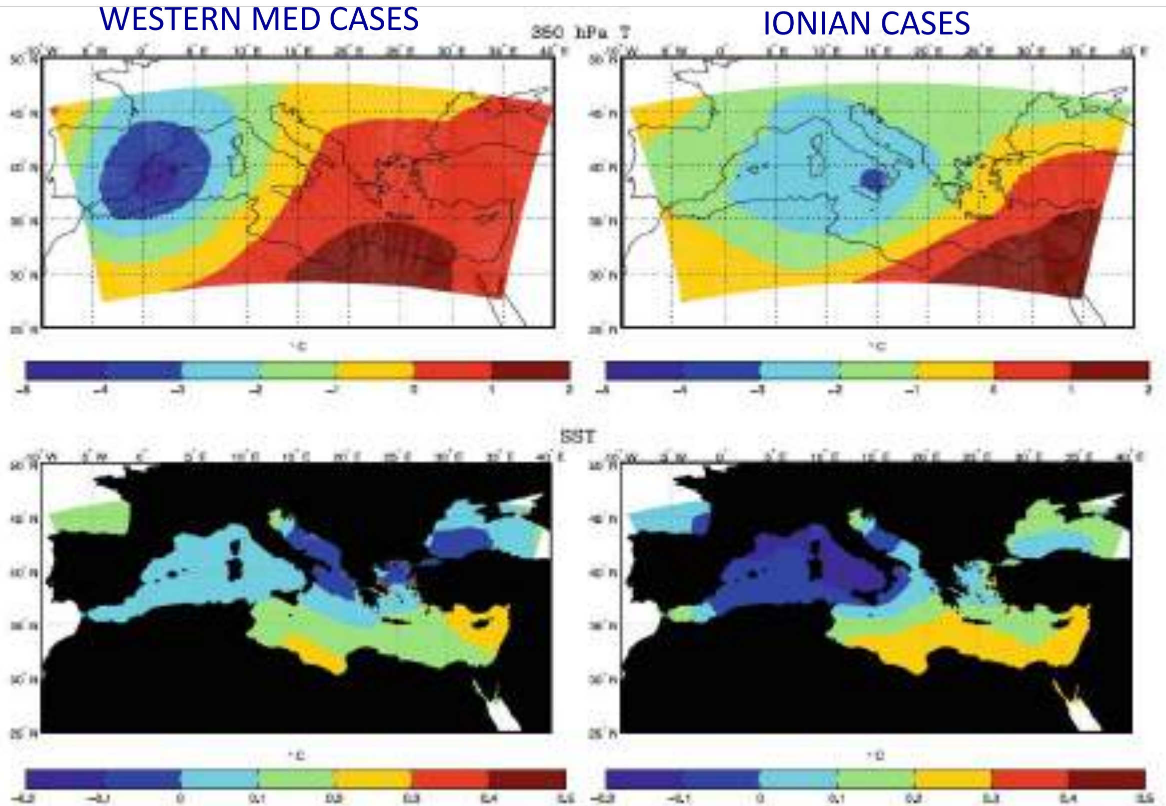


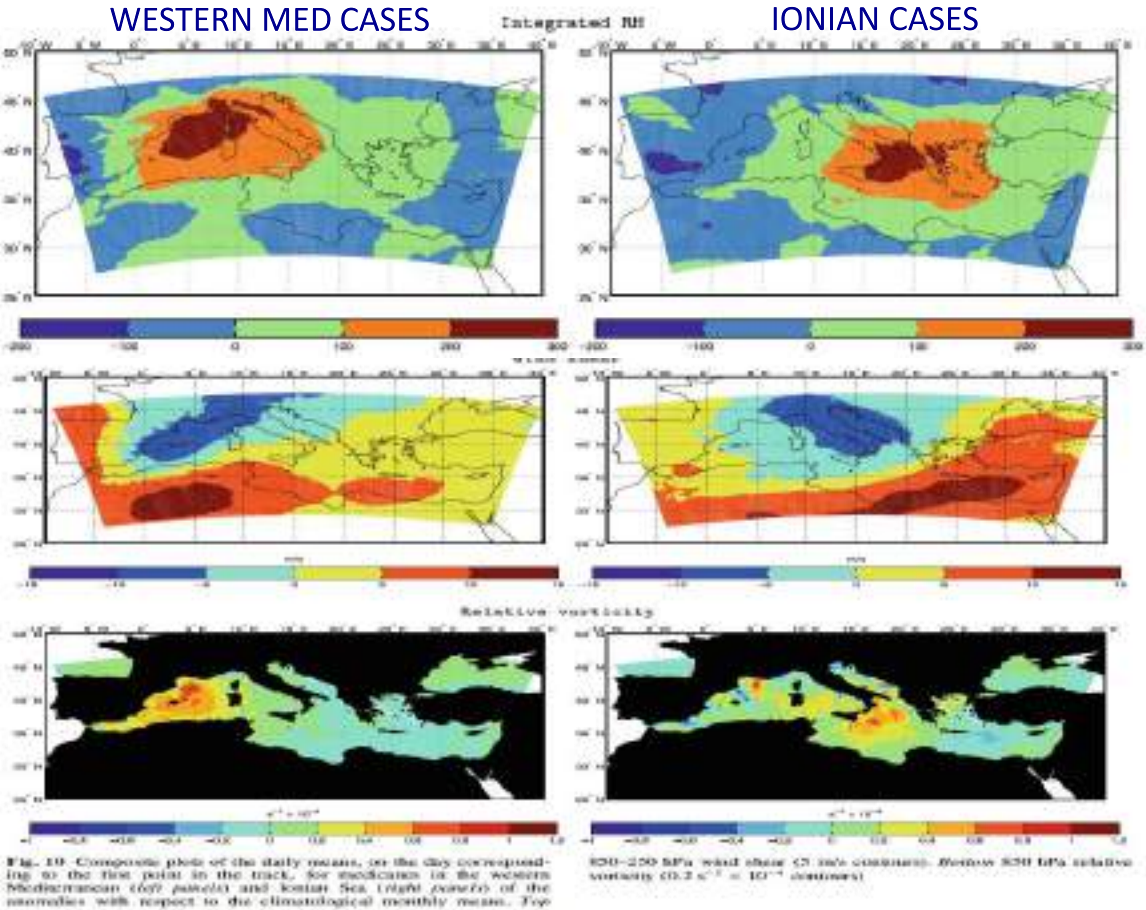
Fig. 9 Composite plots of the daily means, on the day corresponding to the first point in the track, for medicanes in the western Mediterranean (*left panels*) and Ionian Sea (*right panels*) of the anomalies with respect to the climatological monthly means. 350 hPa temperature (*top*, 1 °C *contours*), sea surface temperature (*bottom*, 0.1 °C *contours*)

350 hPa Temperature

SST

Cavicchia et al. (2013)

ANOMALIES OF METEOROLOGICAL PARAMETERS



Integrated RH

850-250 hPa Wind shear

850 hPa Relative Vorticity

Cavicchia et al. (2013)

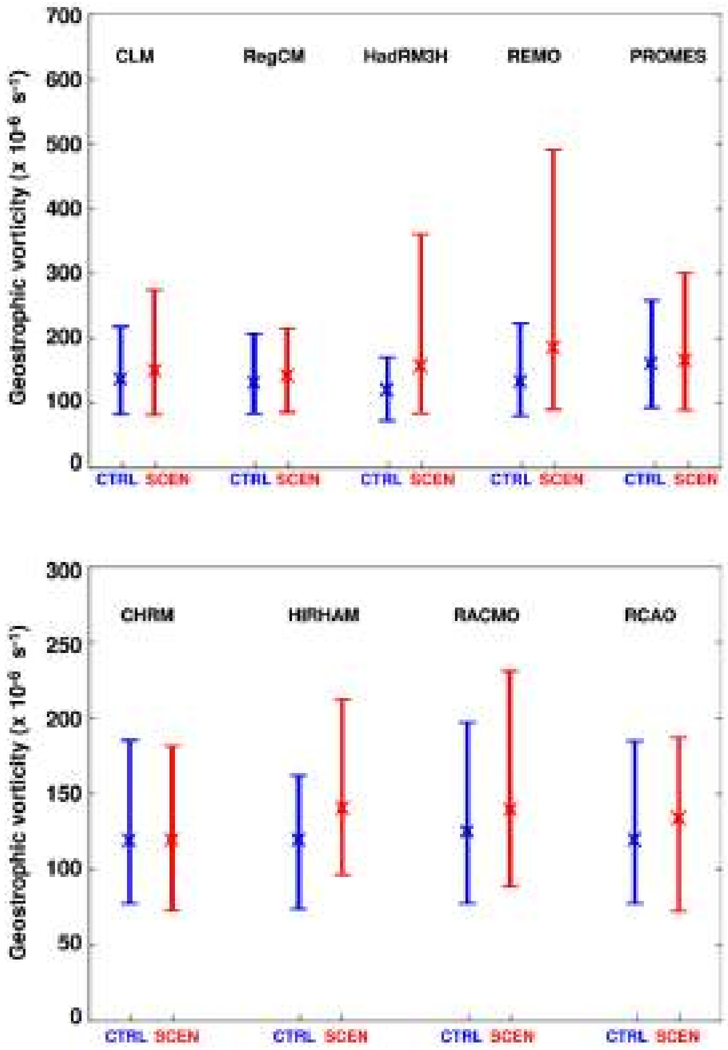
MEDICANES AND CLIMATE CHANGE (Gaertner et al., 2007, 2009)

HadAM3H

Downscaling by **9 RCM**

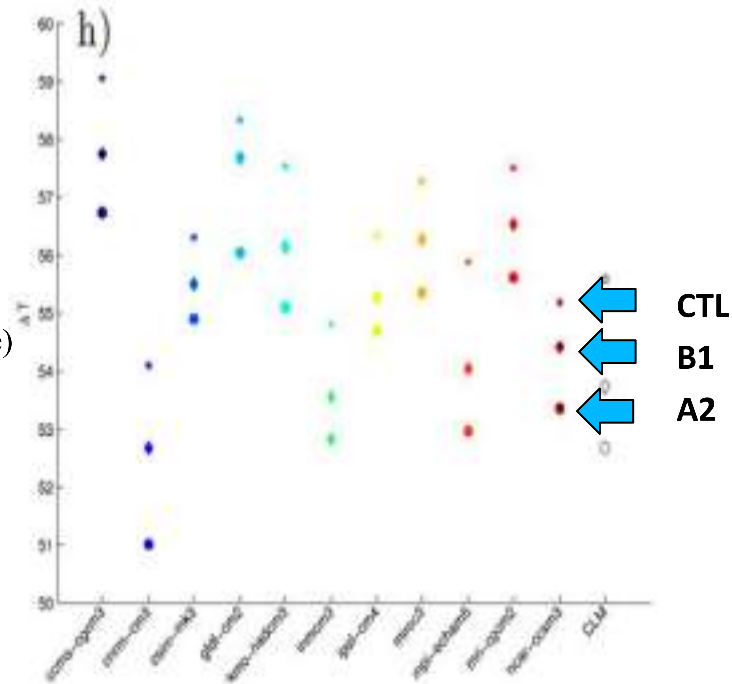
high emission scenario SRES-**A2**

Horizontal resolution: **50-55** km



MEDICANES AND CLIMATE CHANGE (Cavicchia et al., 2014)

ECHAM5/MPI-OM (atmospheric-ocean GCM)
Downscaling by **COSMO-CLM**
emission scenario: SRES-**A2** (high), **B1** (moderate)
Horizontal resolution: **10** km

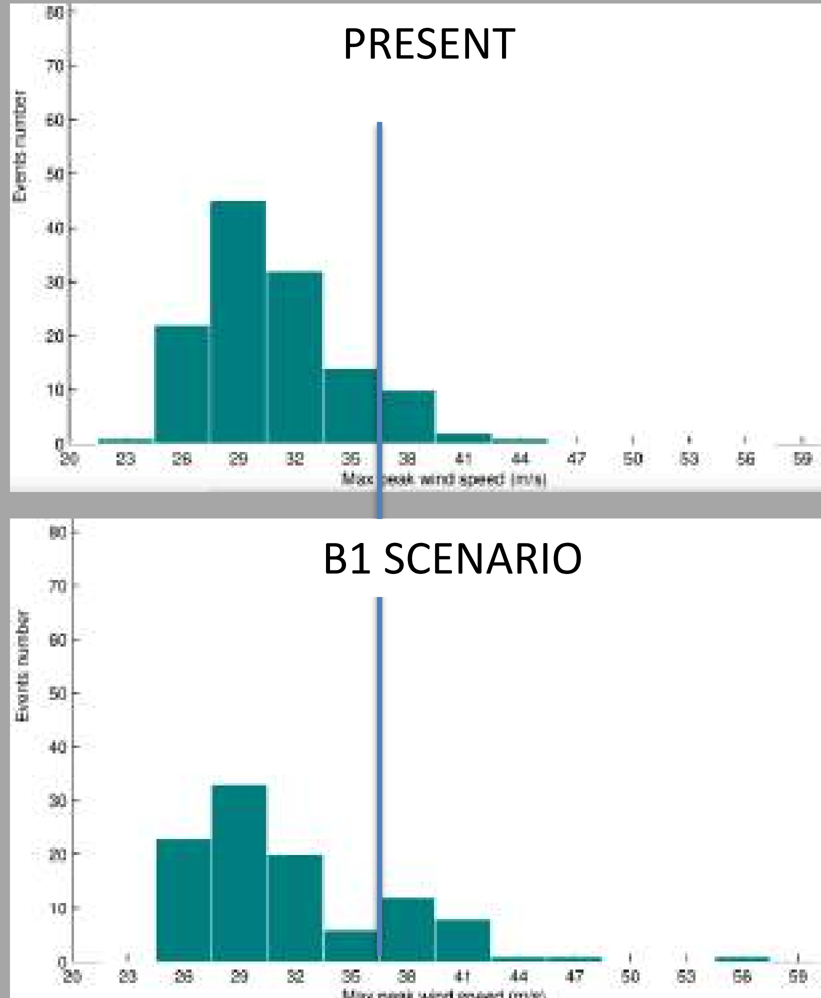


- The major change between present and future climate is found in the reduction of vertical atmospheric temperature gradient -> Less cyclones

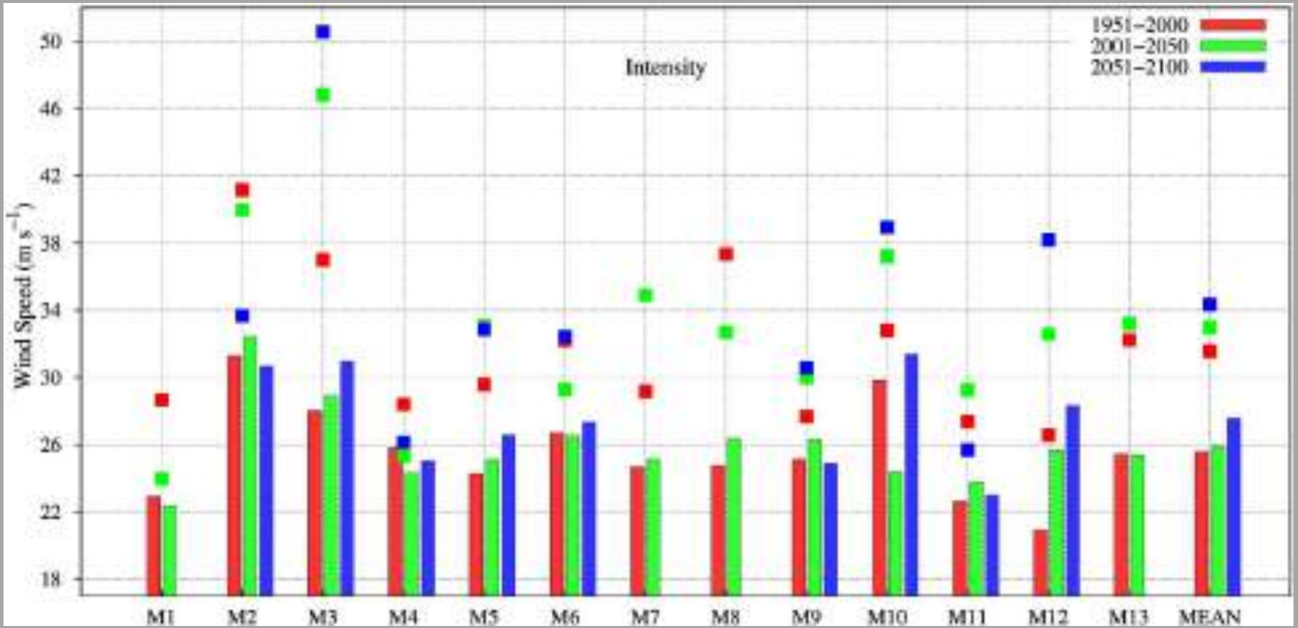
MEDICANES AND CLIMATE CHANGE (Cavicchia et al., 2014)

Less cyclones but increase in the number of the most intense -> SST increase

ECHAM5 (GCM)
Downscaling by **RegCM**
emission scenario: **A1B**
Horizontal resolution: **25** km
(Walsh et al., 2014)



Wind Speed p95 and maximum



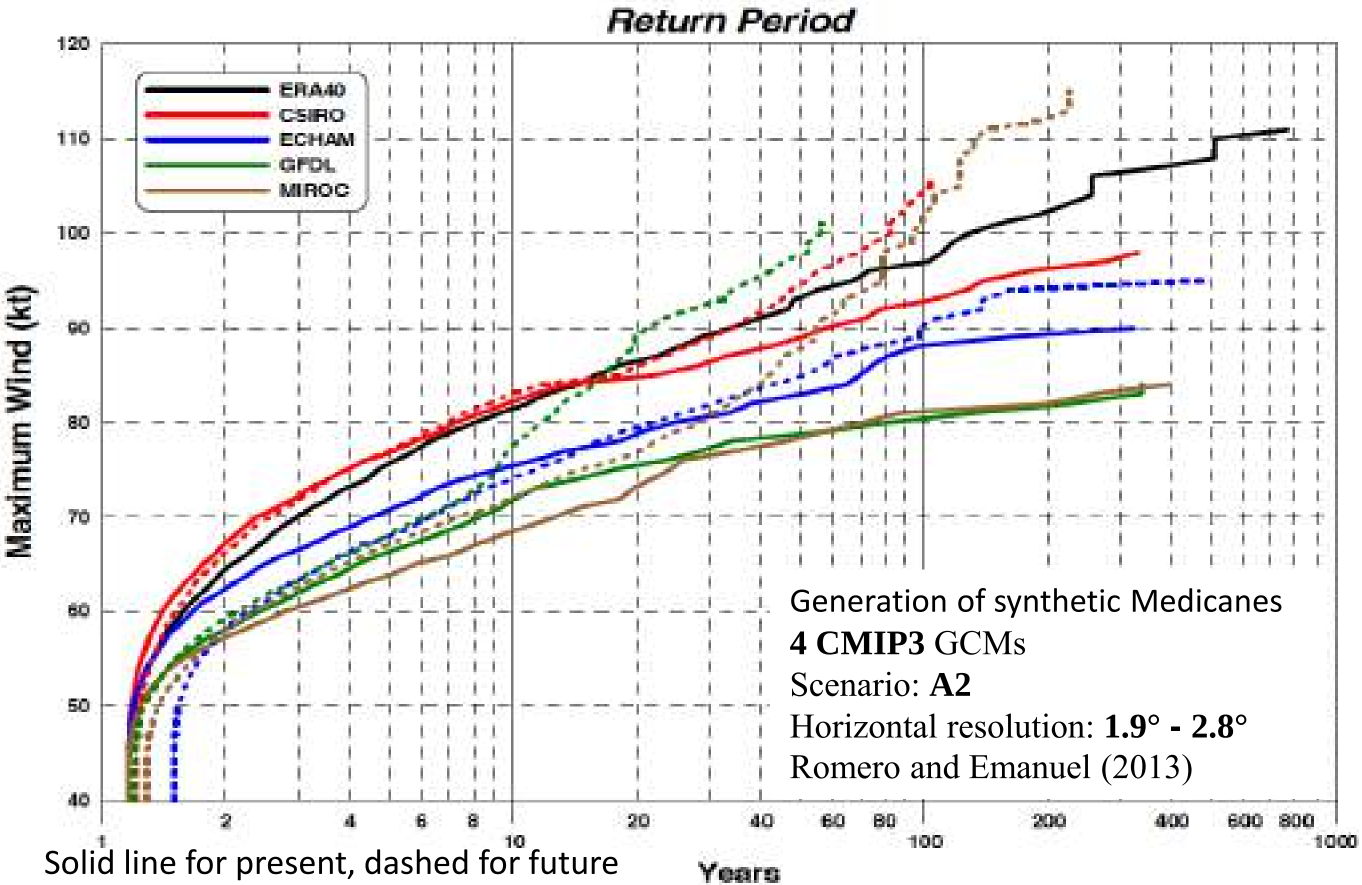
6 GCM

Downscaling by **13 RCMs**

Emission scenario: **A1B**

Horizontal resolution: **25** km

(Romera et al., 2016)

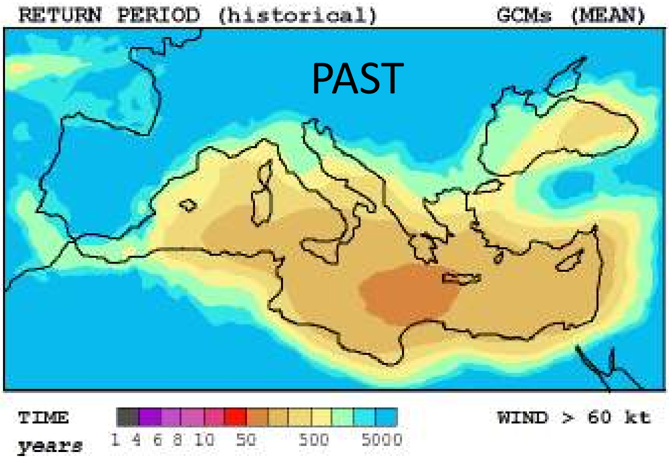


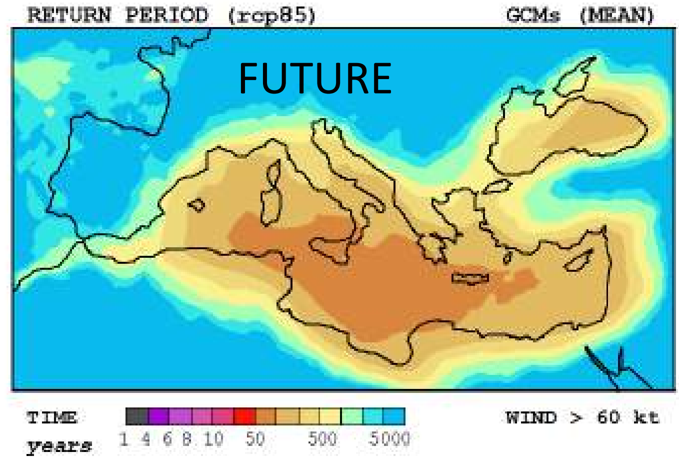
Generation of synthetic Medicanes
4 CMIP3 GCMs
Scenario: **A2**
Horizontal resolution: **1.9° - 2.8°**
Romero and Emanuel (2013)

Solid line for present, dashed for future

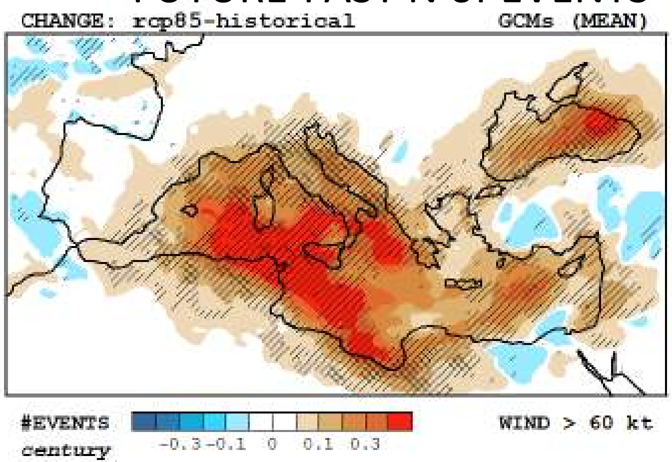
4 models: Fewer medicanes but a higher number of violent storms in the future

RETURN PERIOD (ENSEMBLE OF 30 MODELS): INCREASE OF INTENSE MEDICANES





FUTURE-PAST N of EVENTS

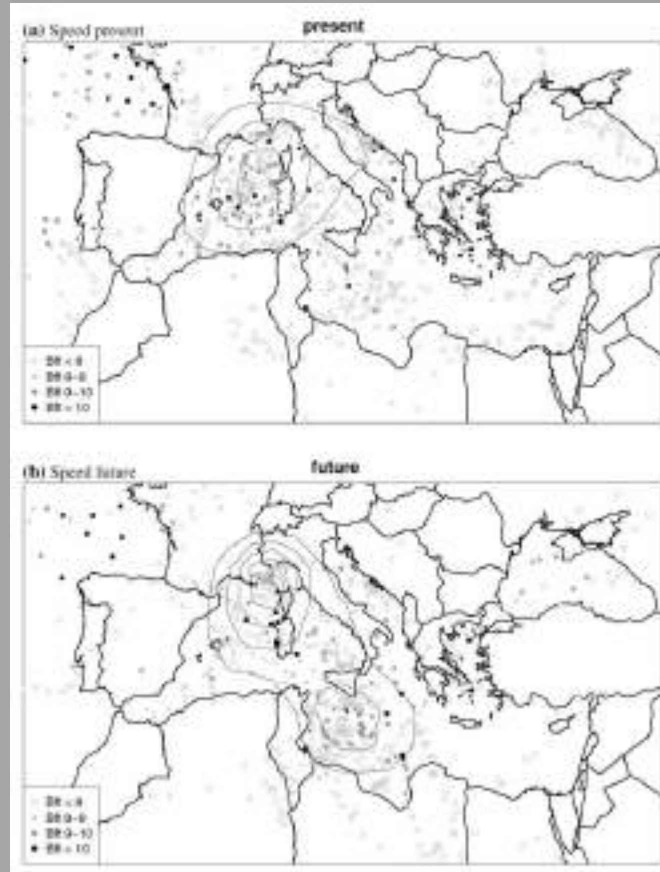


Synthetic Medicanes
30 CMIP5 GCMs
Scenario: **RCP8.5**
Horizontal resolution:
0.7° - 2.8°
Romero and Emanuel (2017)

Threshold = 60 KT

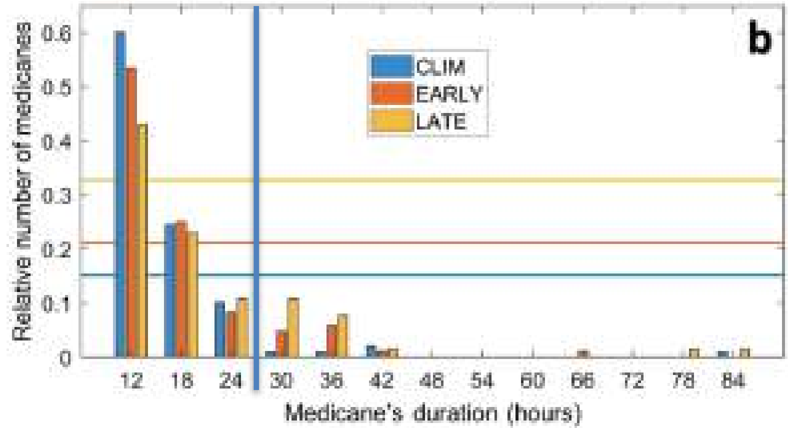
MEDICANES AND CLIMATE CHANGE (Tous et al., 2015)

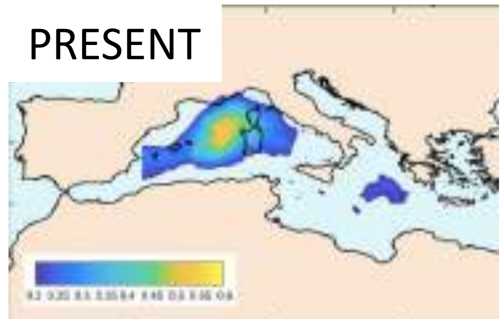
HadGEM3 GCM
Extreme Scenario: **RCP8.5**
Horizontal resolution: **25 km**

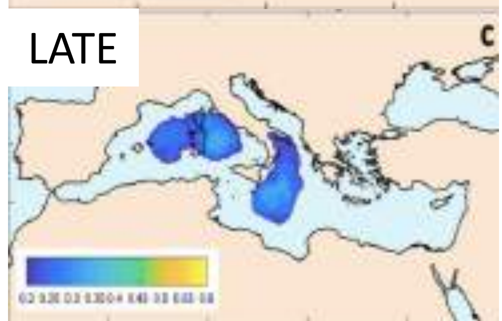


Increase in number of very strong cyclones (Contours every 10 intense (Beaufort scale ≥ 8) Medicanes)

MEDICANES AND CLIMATE CHANGE (Gonzalez-Aleman et al., 2019)







HiFLOR atmospheric-ocean coupled GCM
Intermediate Scenario: **RCP4.5**
Horizontal resolution: **25 km**

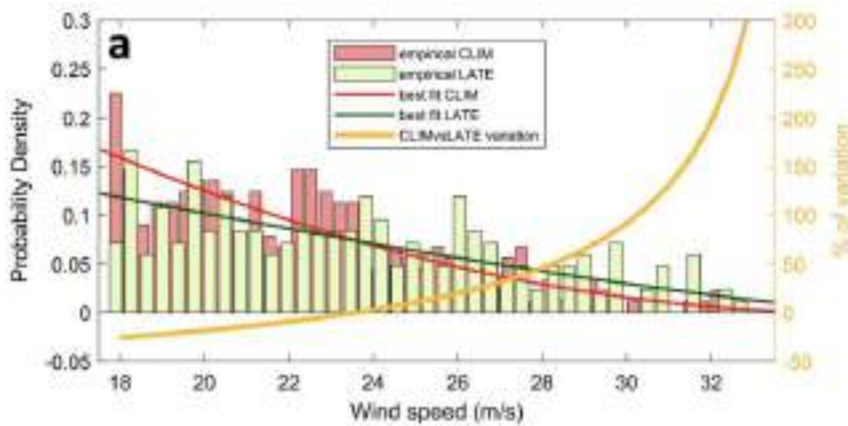
MEDICANES AND CLIMATE CHANGE (Gonzalez-Aleman et al., 2019)

HiFLOR atmospheric-ocean coupled GCM

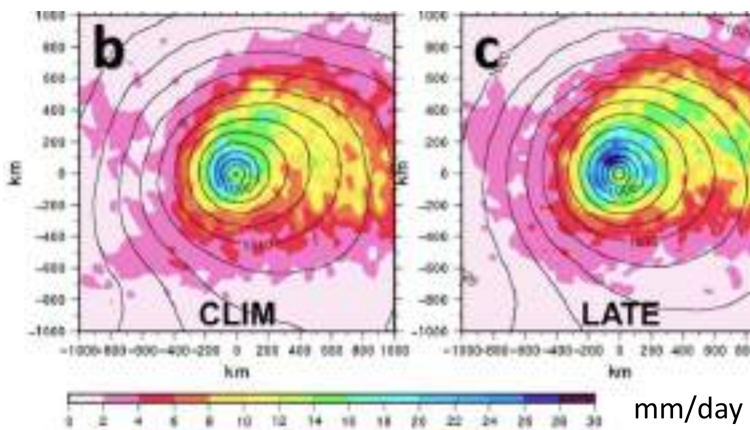
Intermediate Scenario: **RCP4.5**

Horizontal resolution: **25 km**

WIND



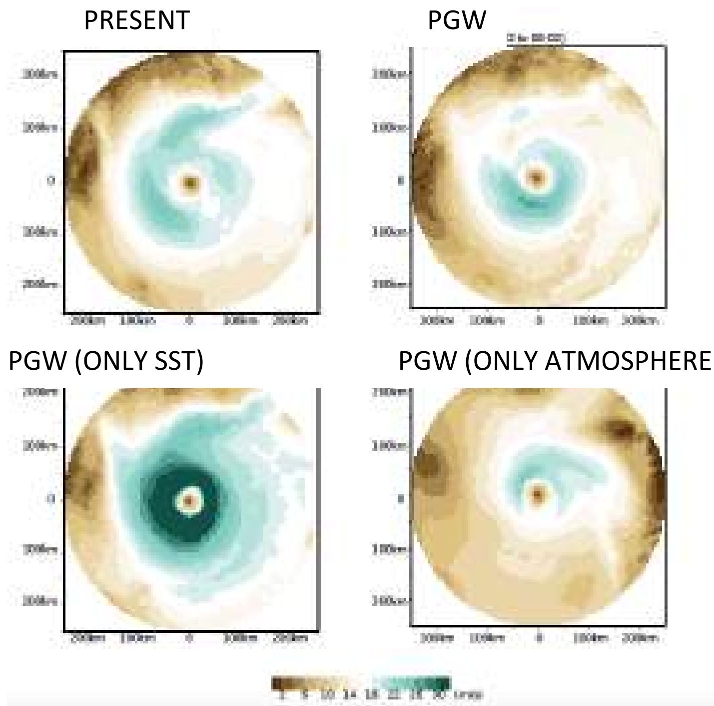
PRECIPITATION



ROLF – PSEUDO GLOBAL WARMING (PGW) Simulation

Koseki et al. (2020)

- Surface wind speed during SLP minimum for (a) PRS, (b) PGWALL, (c) PGWSST, and (d) PGWATMS around the cyclone centre, respectively



OUTLINE

1. CASE STUDIES

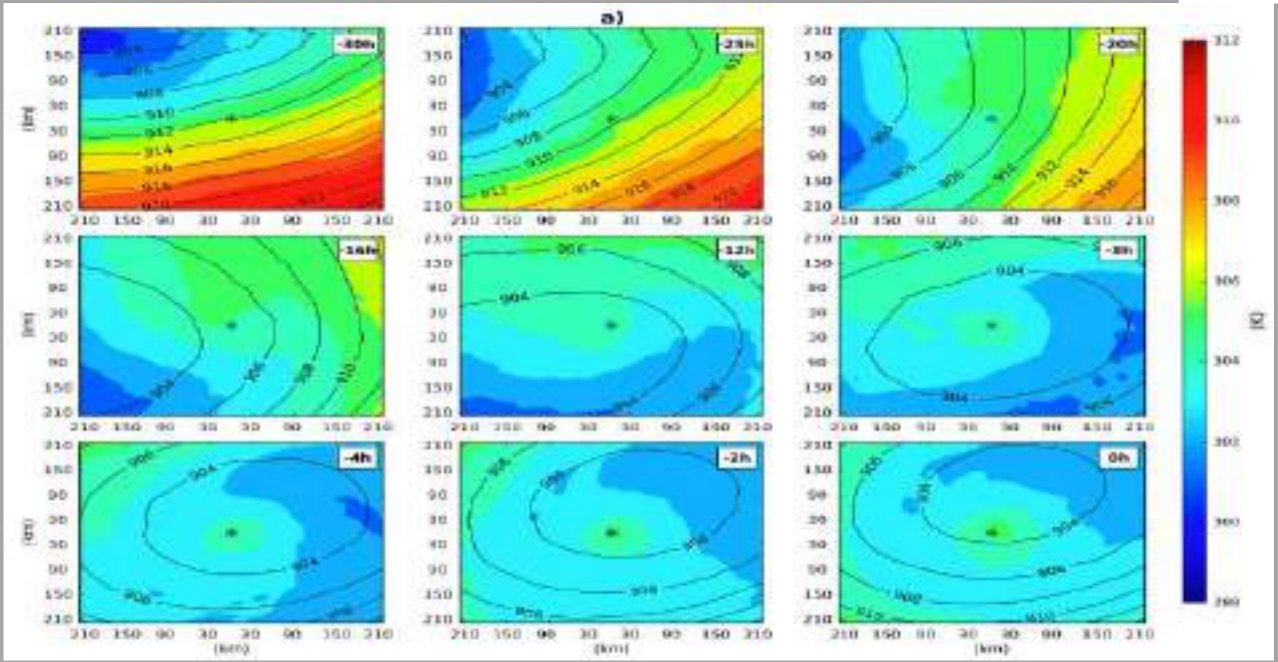
2. MEDICANES vs TROPICAL CYCLONES

3. CLIMATOLOGY AND CLIMATE CHANGE

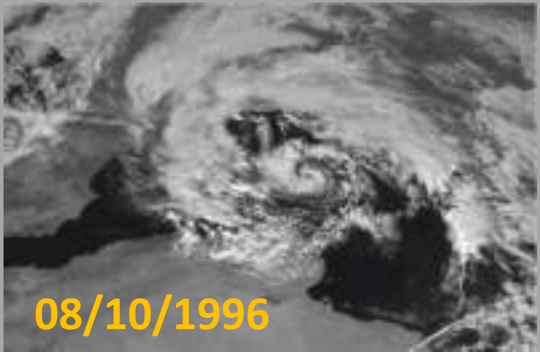
4. TOWARD A DEFINITION OF «MEDICANE»

WARM SECLUSION

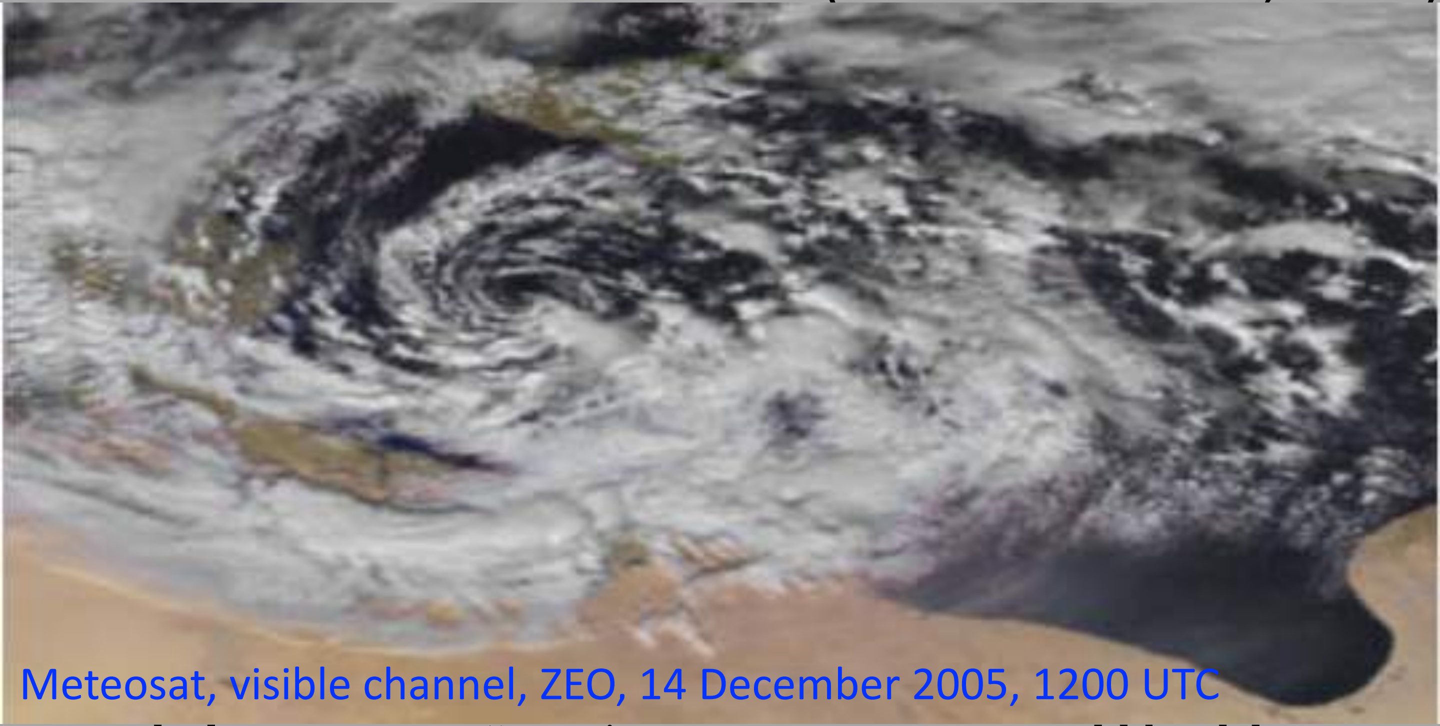
500 hPa θ



Mazza et al., 2017: "The tropical transition takes place as the cyclones undergo a **warm seclusion** … the simulations do not provide sufficient evidence that a cooperative process similar to **WISHE** is in place"



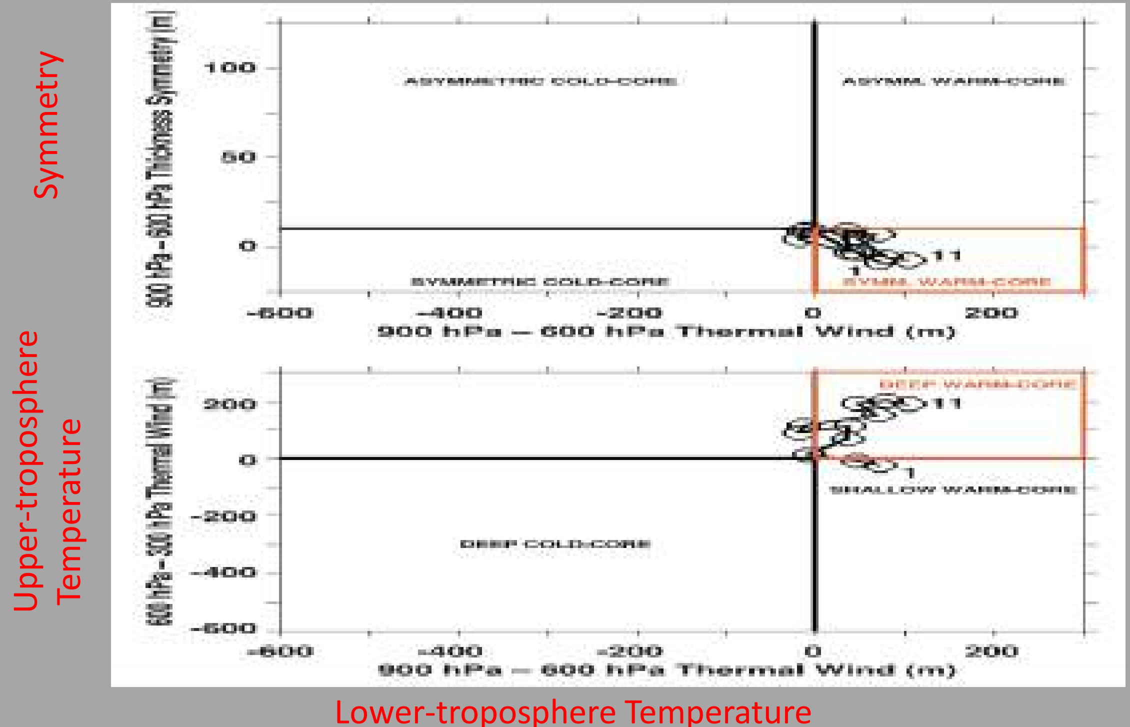
13-15 December 2005 case (Fita and Flounas, 2018)



Fita and Flounas, 2018: “Despite its importance, it would be delicate to suggest that diabatic heating due to convection is able to sustain the medicane vortex similarly to the **WISHE** mechanism … it is **warm air seclusion** that makes the system to attain a warm core with respect to its environment” (DEC2005 case).

How can we discriminate Medicanes from a dynamic perspective?

HART (2003) DIAGRAM

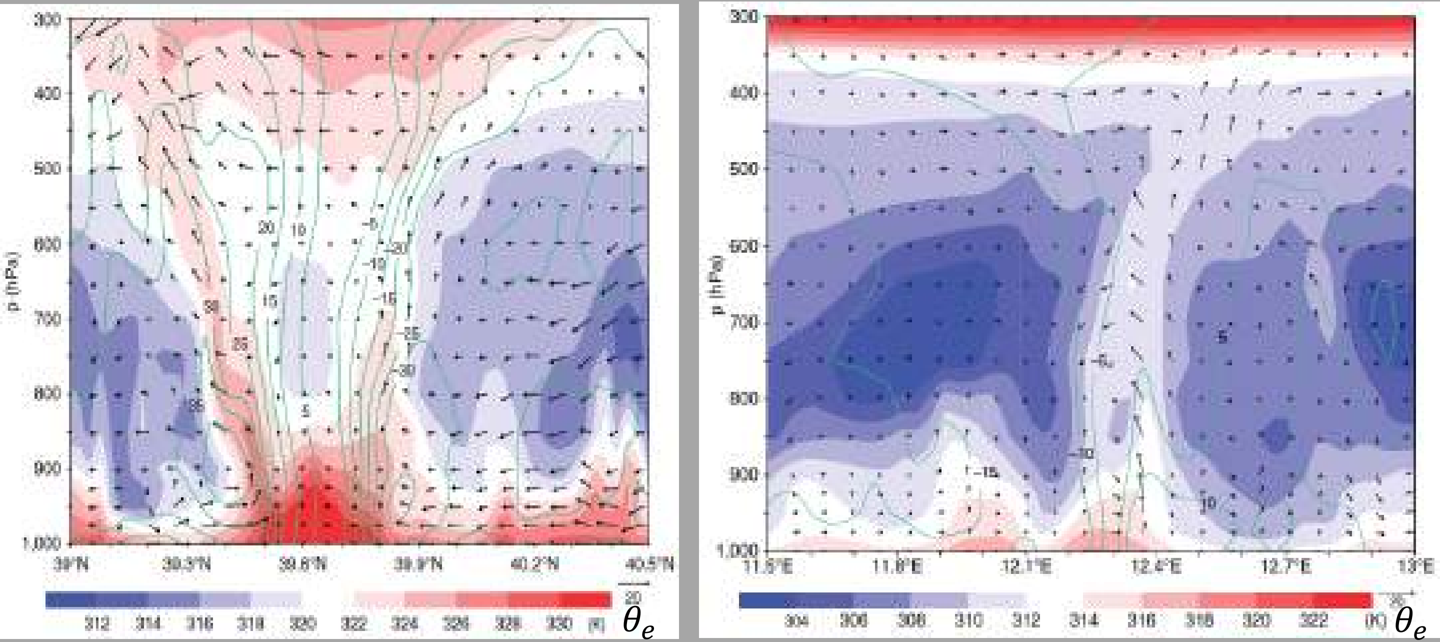


BUT the presence of a warm central core may be due to a warm seclusion (Mazza et al., 2017; Fita and Flaounas, 2018).

Gaertner et al. (2007)

CROSS SECTION ALONG THE CYCLONE CENTER

In both cases symmetric, deep warm core structures but only the first one shows the upward transport of warm/moist air typical of TC
Different contribution of baroclinic versus diabatic processes



CORNELIA (OCTOBER 1996)

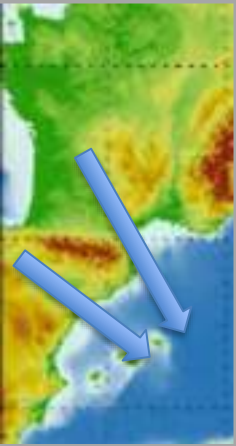
ZEO (DECEMBER 2005)

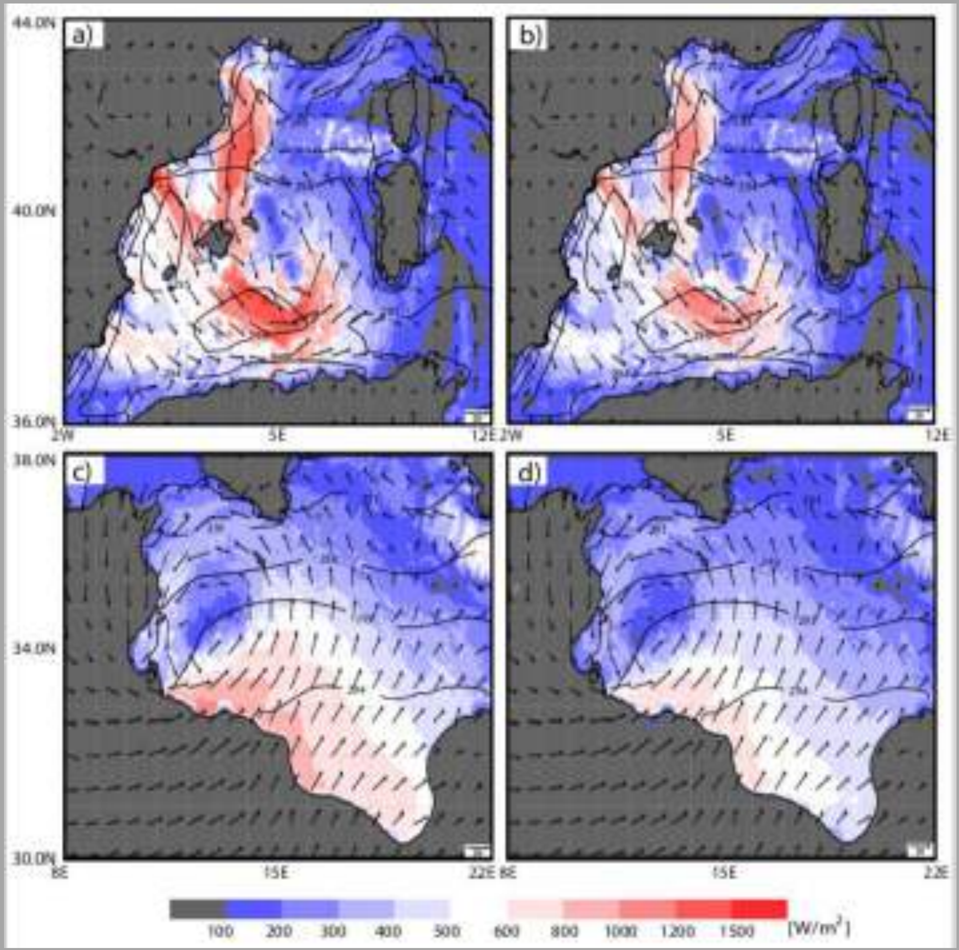
Vertical cross-section of θe (colours), storm-relative winds (vectors), absolute momentum (lines, contour interval=5m/s; zero not shown) near the cyclone centre

Miglietta and Rotunno (2019)

DIFFERENCE IN AIR-SEA INTERACTION

TOTAL SEA SURFACE FLUXES **LATENT HEAT FLUXES**





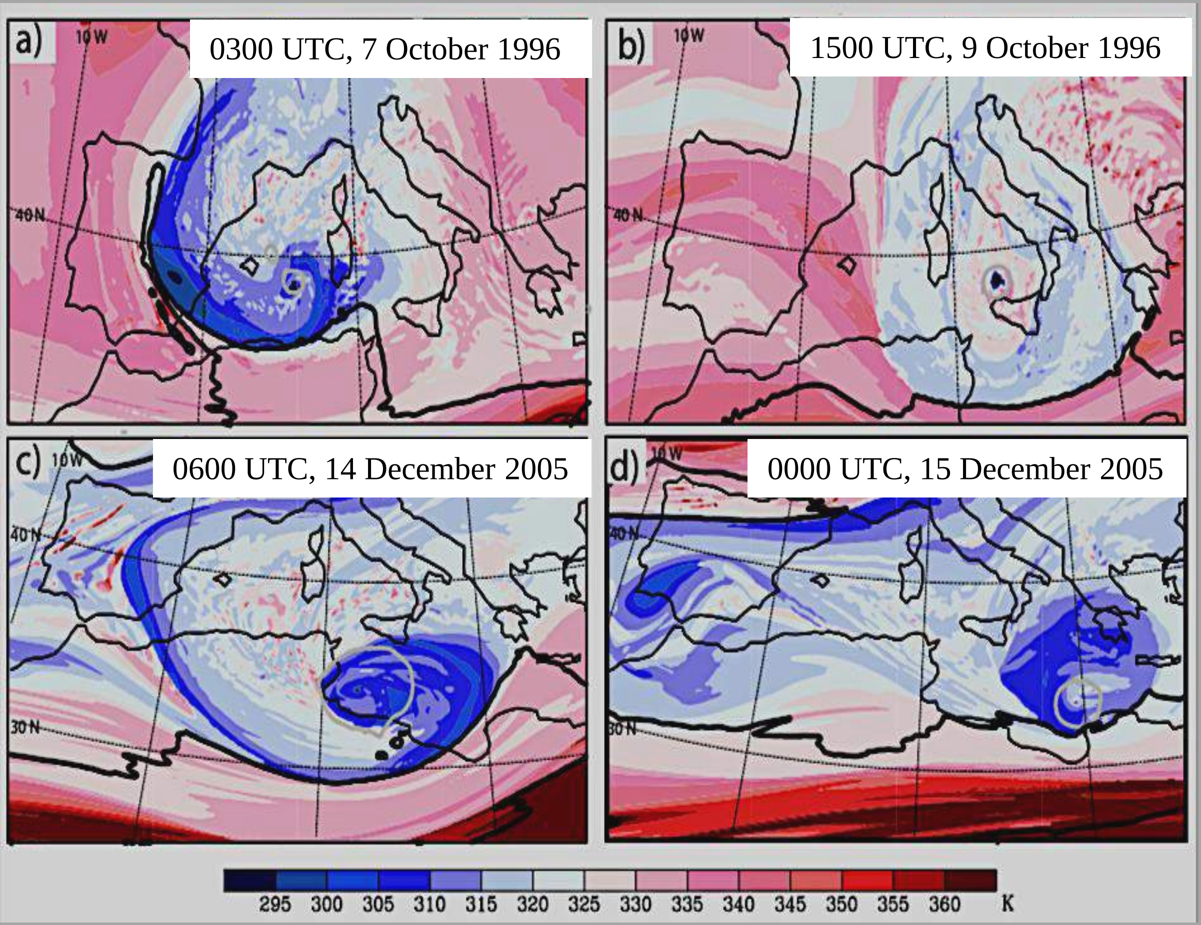
1996 case

0300 UTC
October 7

2005 case

0600 UTC
December 14

THETA ON 2 PVU surface



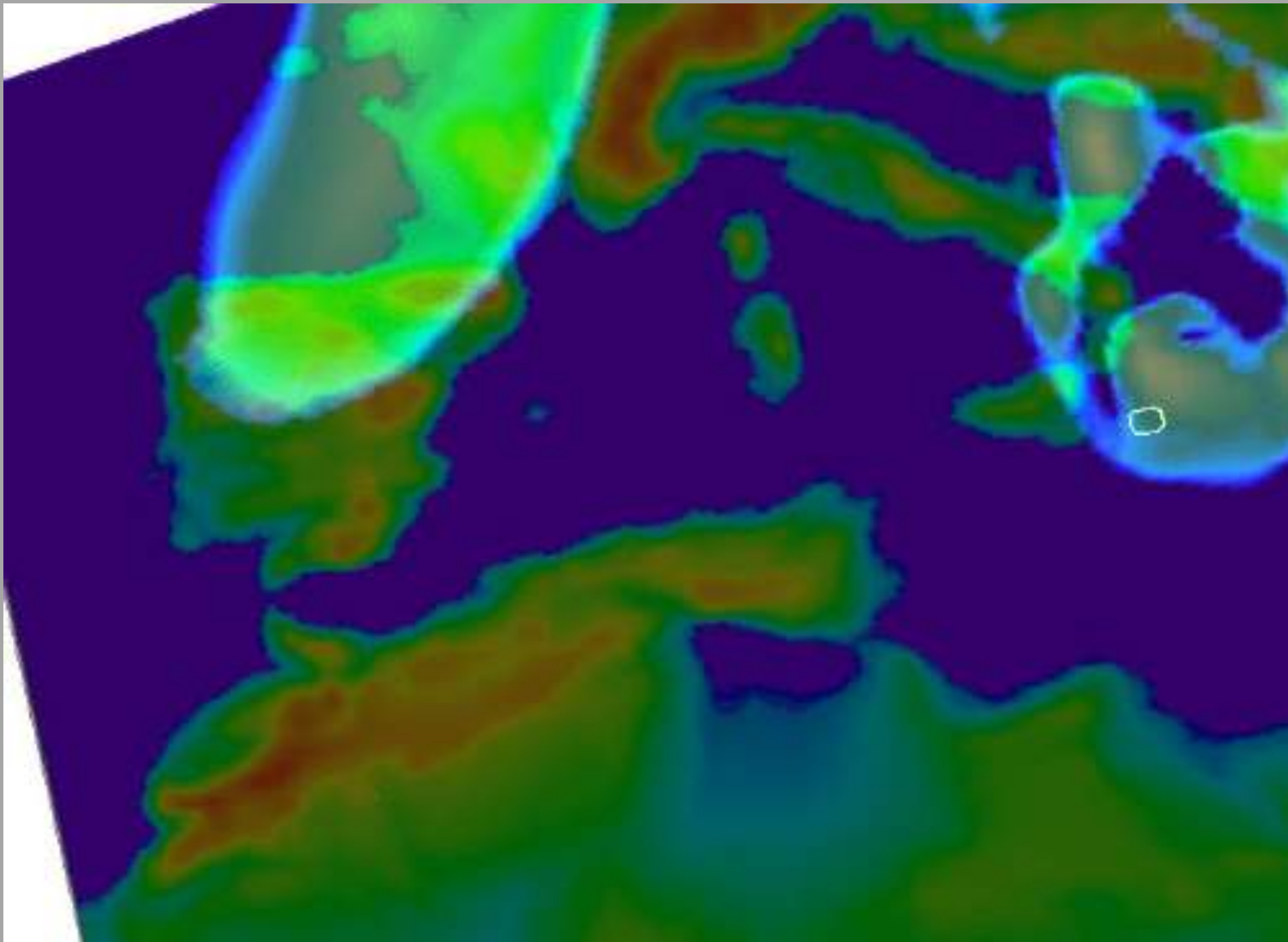
1996 case

2005 case

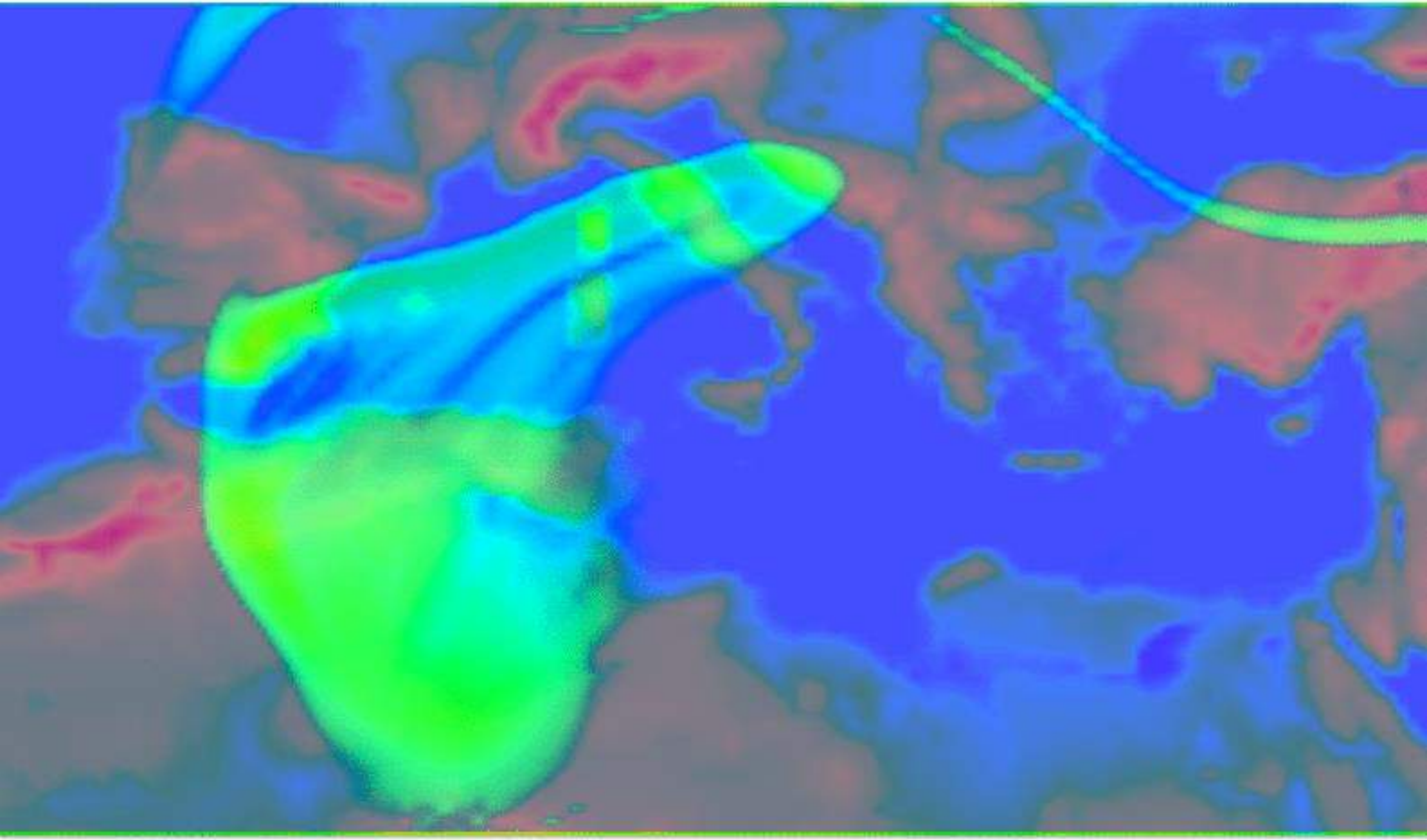
EARLY STAGES **FINAL STAGES**

grey bold line = isobar of 1000 hPa

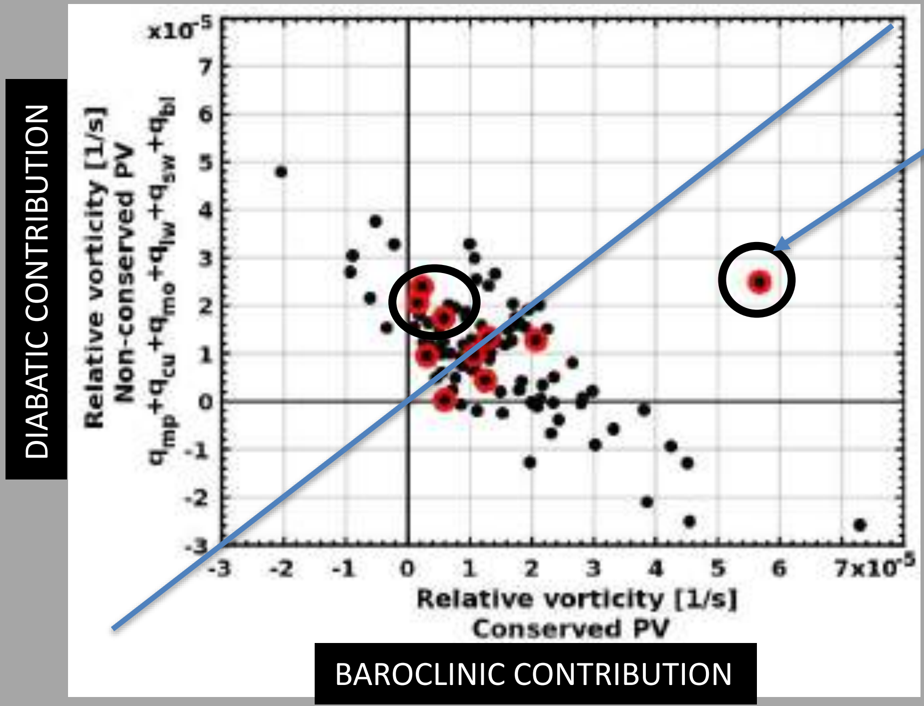
OCTOBER 1996 CASE: PV @ 9000 m; mslp



DECEMBER 2005 CASE: PV @ 9000 m; mslp



Contribution of baroclinic versus diabatic processes to 850 hPa relative vorticity



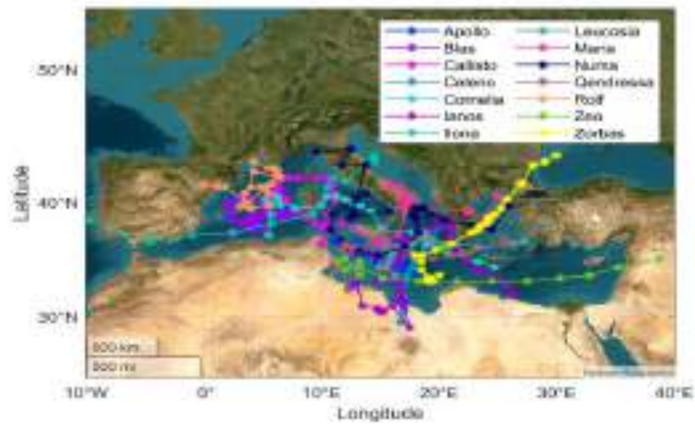
Contribution of different PV sources to 850 hPa relative vorticity, in the centre of 100 cyclones: conserved, adiabatically transported PV (x-axis) and non-conserved, diabatically-produced PV (y-axis).

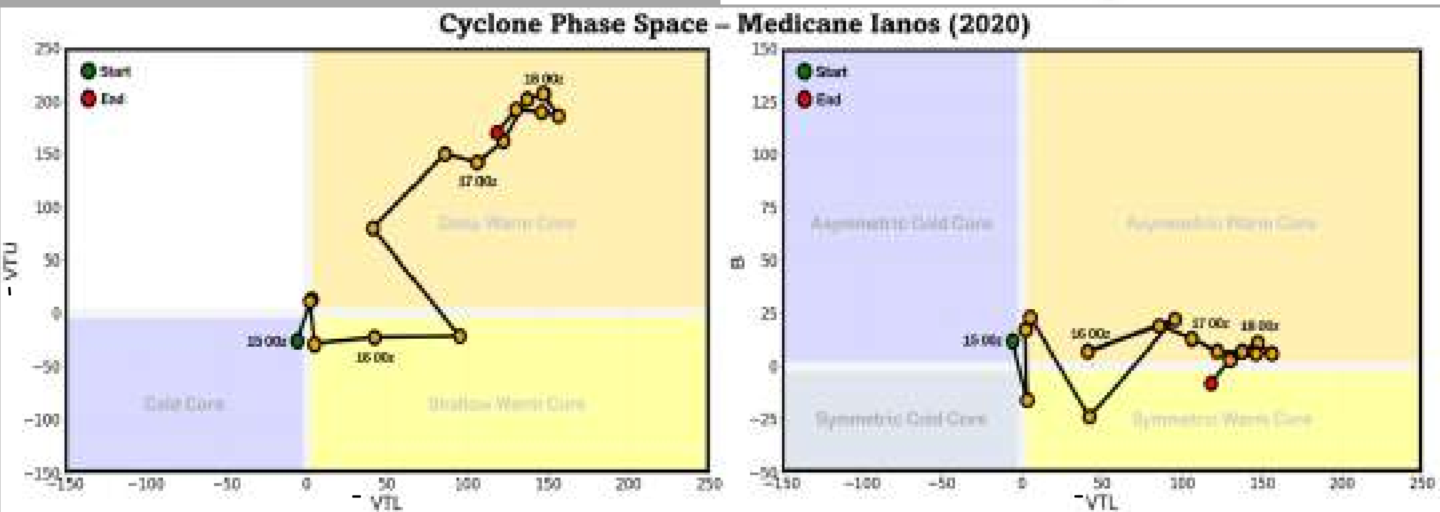
Medicanes (red) do not concentrate in a region of the parameter space.

Flaounas et al. (2020)

DATA

ERA5 (Hersbach et al., 2020):
We considered **14 medicanes** and applied the CPS diagram.





MOTIVATION

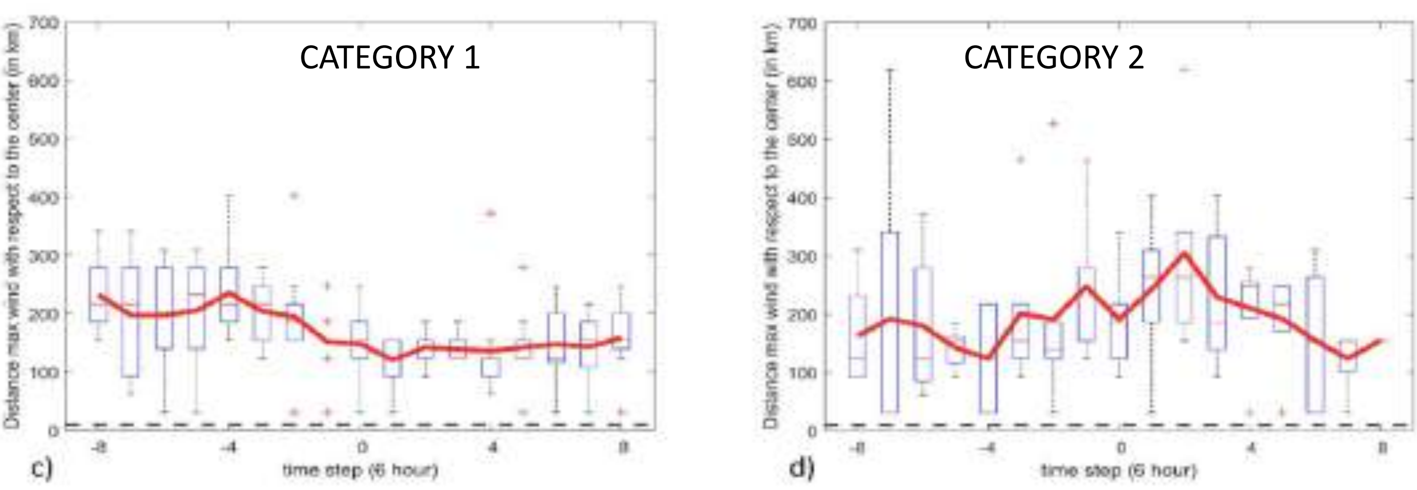
- The **CPS diagram** is not able to discriminate deep warm core due to latent heat release generated by convection from warm seclusions.
- Can we find some **parameters** to distinguish real TLC from warm seclusions?

Ianos medicane (2020)

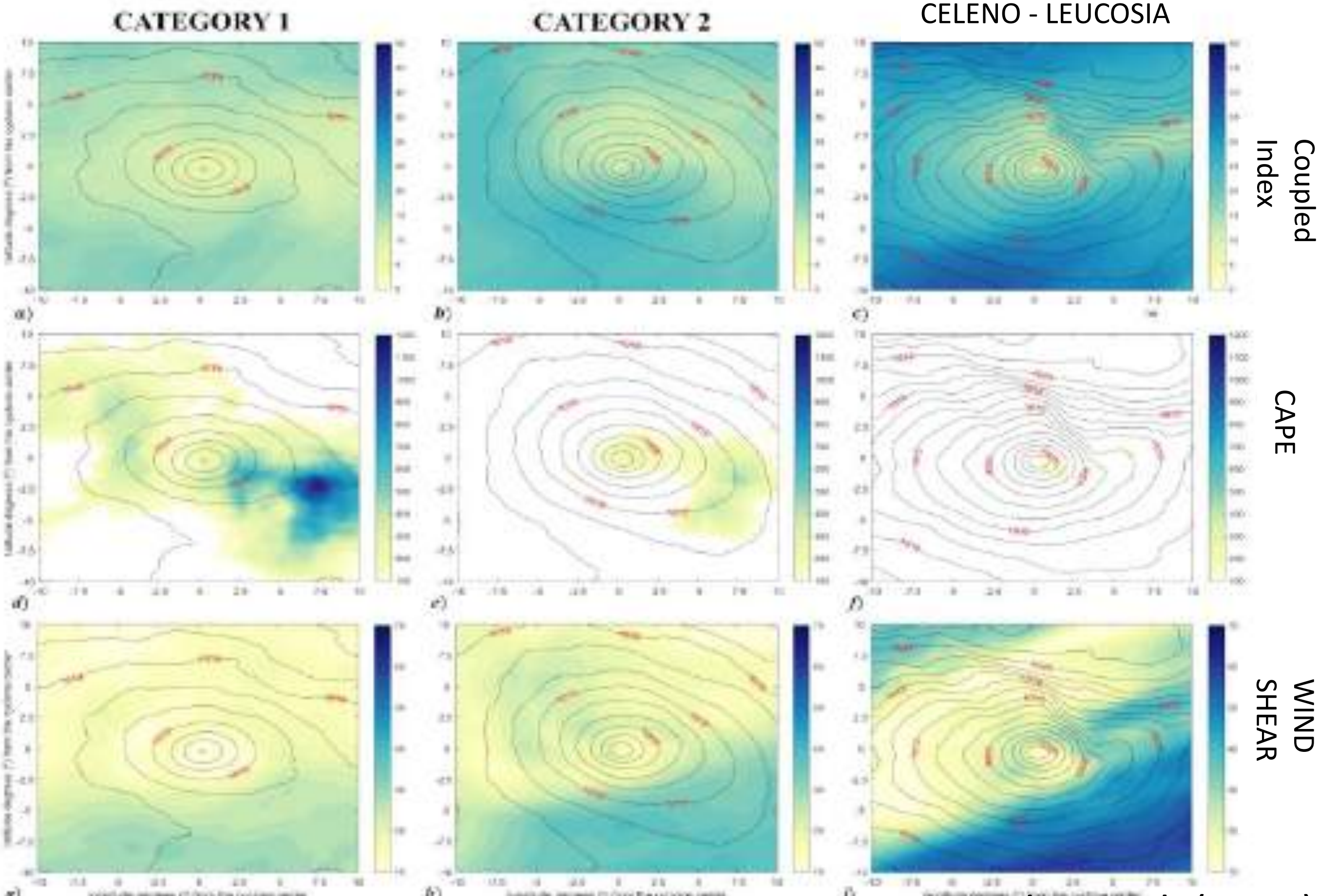
warm seclusion (2018)

DISTANCE OF REGION WITH MAX WIND VS TIME

In **<u>tropical cyclones</u>** the ***distance of the region with max wind from the center will decrease around the time of tropical transition*** (Holland and Merrill, 1984).

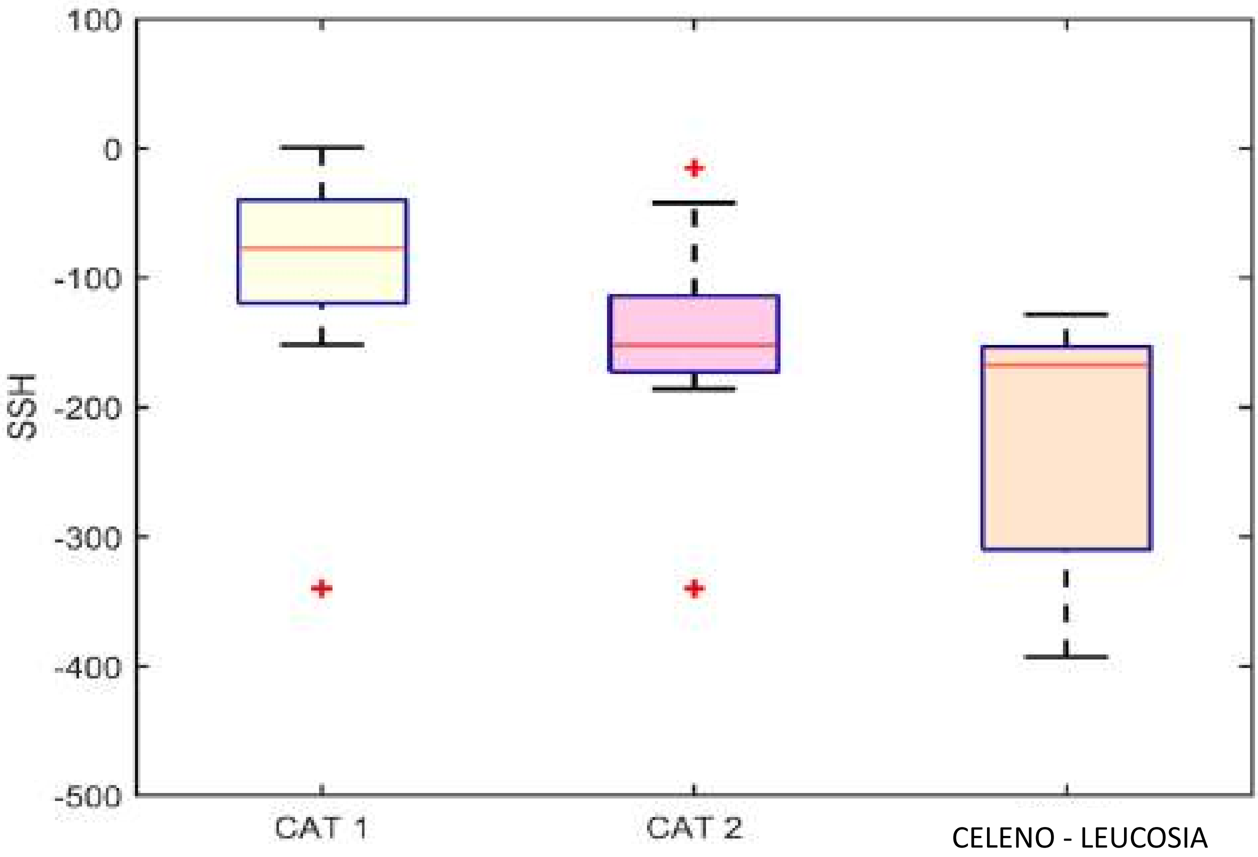


COMPOSITE AT MATURE STAGE



Gutierrez-Fernandez et al. (2024)

SENSIBLE HEAT FLUXES



- DEEP WARM CORE CYCLONES CAN BE IDENTIFIED IN ERA5 REANALYSIS

- DIFFERENT CYCLONE CHARACTERISTICS CAN BE IDENTIFIED BY THE DECREASE OF THE DISTANCE OF THE REGION OF MAX WIND FROM THE CENTER IN THE MATURE STAGE -> ENVIRONMENTAL CHARACTERISTICS ARE DIFFERENT BETWEEN THE TWO CATEGORIES

- CELENO AND LEUCOSIA (JANUARY CYCLONES) SHOW CHARACTERISTICS CLOSER TO «POLAR LOWS»

Gutierrez-Fernandez et al. (2024)

REQUIREMENTS FOR A NEW DEFINITION

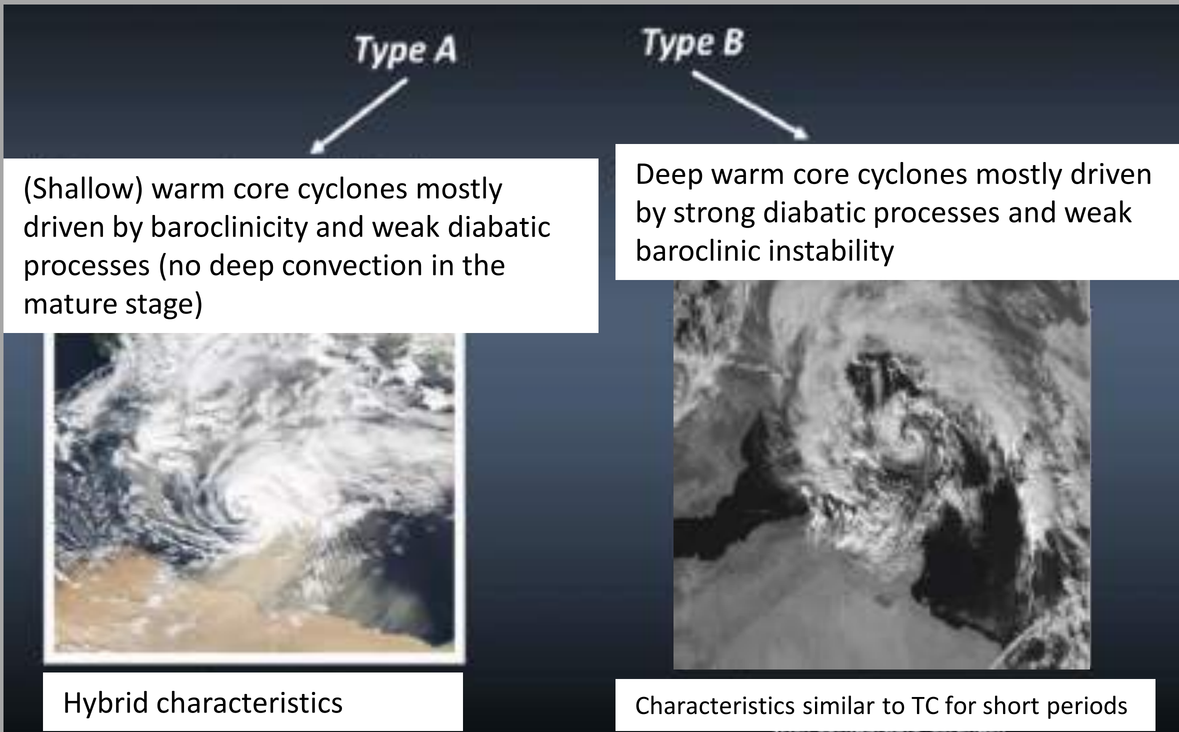
- Be accommodating to previous studies
- Be solely based on earth observations

TENTATIVE DEFINITION:

- *“A medicane is a mesoscale cyclone that develops over the Mediterranean sea. A medicane displays tropical-like cyclone characteristics: a deep warm core, an eye-like feature in its center, a nearly windless center surrounded by symmetric maximum 10-m wind speed within a few tens of km afar”*.
- Hence, medicane and Mediterranean tropical-like cyclone should be considered as equivalent.
- This particular definition recognizes the existence of a deep warm-core induced by different mechanisms, following the indications from early studies (e.g. Emanuel, 2005; Fita et al., 2007) that WISHE is not expected to contribute exclusively to the development of a medicane.

The term “medicane” has been used to cover a wide range of the continuum existing between ECs and TCs.

A classification in **categories** was proposed, depending on the dominant process in the mature stage.



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

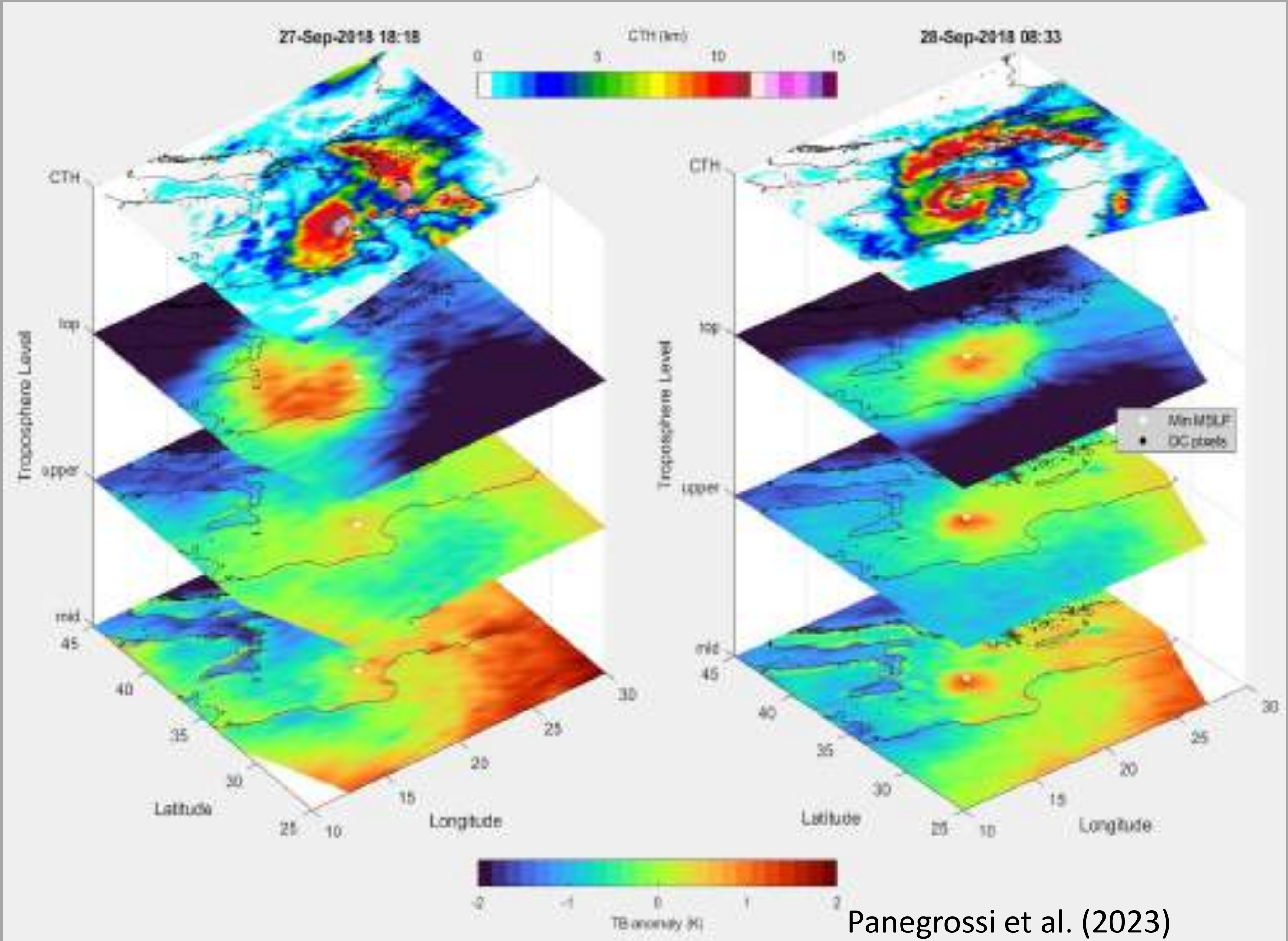
Toward a definition of Medicanes

For Mediterranean cyclones one may sustain what Emanuel and Rotunno (1989) noted for polar lows: "there is evidently more than one mechanism operating …, although one mechanism may dominate the other in a particular circumstance. One of these mechanisms is certainly **baroclinic instability** while the other(s) involve … **air-sea interaction**."

LIST OF CASES

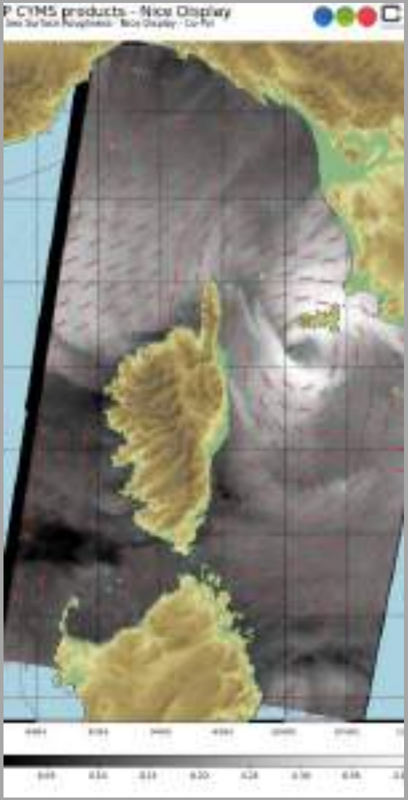
ID	Name	Cyclogenesis	Cyclolysis	Cyclogenesis area	Development area	Cyclolysis area
1	Leucosia	1982/01/23 01 UTC	1982/01/28 14 UTC	Strait of Sicily	Ionian Sea	Aegean Sea
2	Callisto	1983/09/26 20 UTC	1983/10/02 13 UTC	Strait of Sicily	C Med	Tunisia
3	Celeno	1995/01/13 02 UTC	1995/01/18 10 UTC	Ionian Sea	Ionian Sea	Libya
4	Cornelia	1996/10/06 09 UTC	1996/10/11 06 UTC	Balearic Island	Tyrrhenian Sea	E Med
5	Zeo	2005/12/13 02 UTC	2005/12/16 10 UTC	Strait of Sicily	Strait of Sicily	E Med
6	Maria	2006/09/25 00 UTC	2006/09/27 21 UTC	Tunisia	Ionian Sea	Albania
7	Rolf	2011/11/05 10 UTC	2011/11/09 13 UTC	Balearic Island	Gulf of Lion	France
8	Ilona	2014/01/18 22 UTC	2014/01/22 08 UTC	Atlantic Ocean	W Med - Adriatic Sea	Adriatic Sea
9	Qendresa	2014/11/06 09 UTC	2014/11/10 12 UTC	Libya	Strait of Sicily	Aegean Sea
10	Trixie	2016/10/28 00 UTC	2016/10/01 00 UTC	Ionian Sea	southern Mediterranean	Crete
11	Numa	2017/11/14 23 UTC	2017/11/19 15 UTC	Italy	Ionian Sea	Aegean Sea
12	Zorbas	2018/09/27 03 UTC	2018/09/30 15 UTC	Gulf of Sirte	Ionian Sea	Aegean Sea
13	Ianos	2020/09/13 13 UTC	2020/09/21 04 UTC	Libya	Ionian Sea	Egypt
14	Apollo	2021/10/24 17 UTC	2021/10/31 21 UTC	Libya	Ionian Sea	E Med
15	Blas	2021/11/07 16 UTC	2021/11/14 18 UTC	Sardinia	Balearic Islands	Sardinia
16	Helios	2023/02/08 08 UTC	2023/02/11 04 UTC	Libya	Strait of Sicily	Libya
17	Juliette	2023/02/26 19 UTC	2023/03/03 08 UTC	Balearic Islands	Balearic Islands	Sardinia
18	Daniel	2023/09/04 20 UTC	2023/09/12 11 UTC	Ionian Sea	Ionian Sea - Libya	Egypt

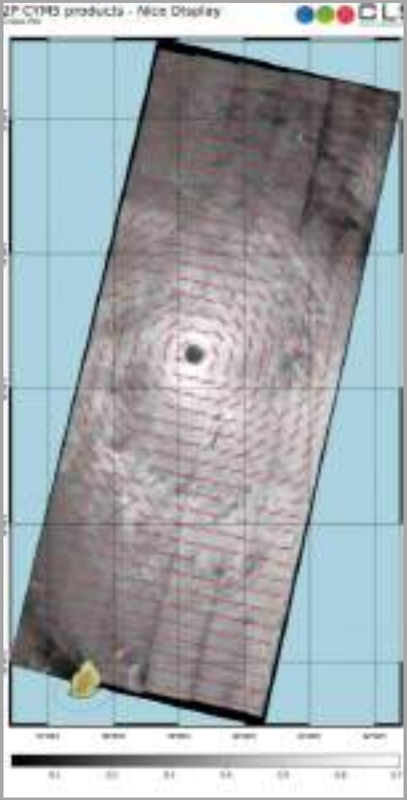
ZORBAS THERMAL STRUCTURE (PMW)

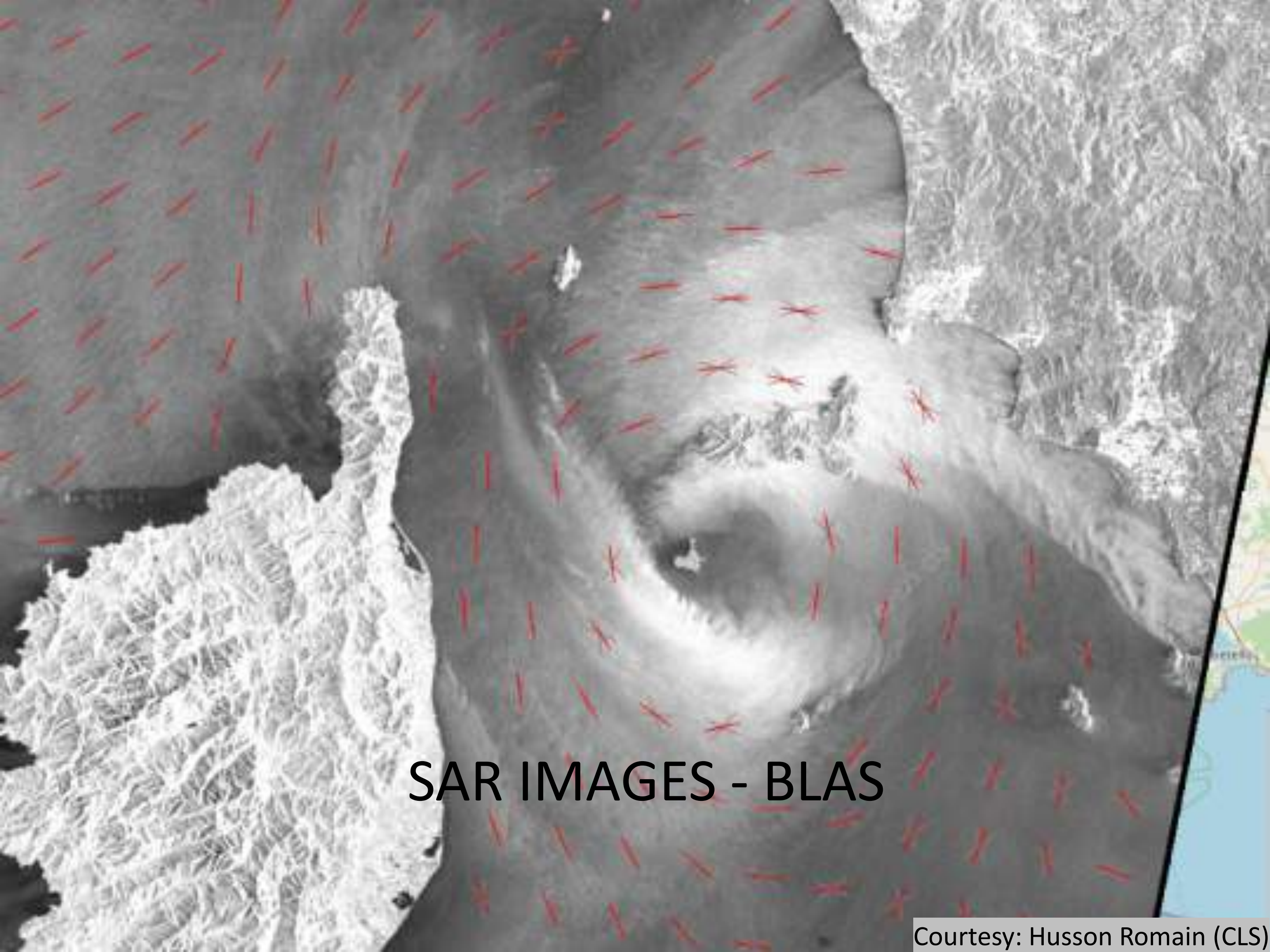


Panegrossi et al. (2023)

SAR images: Medicane BLAS vs TC Emnati



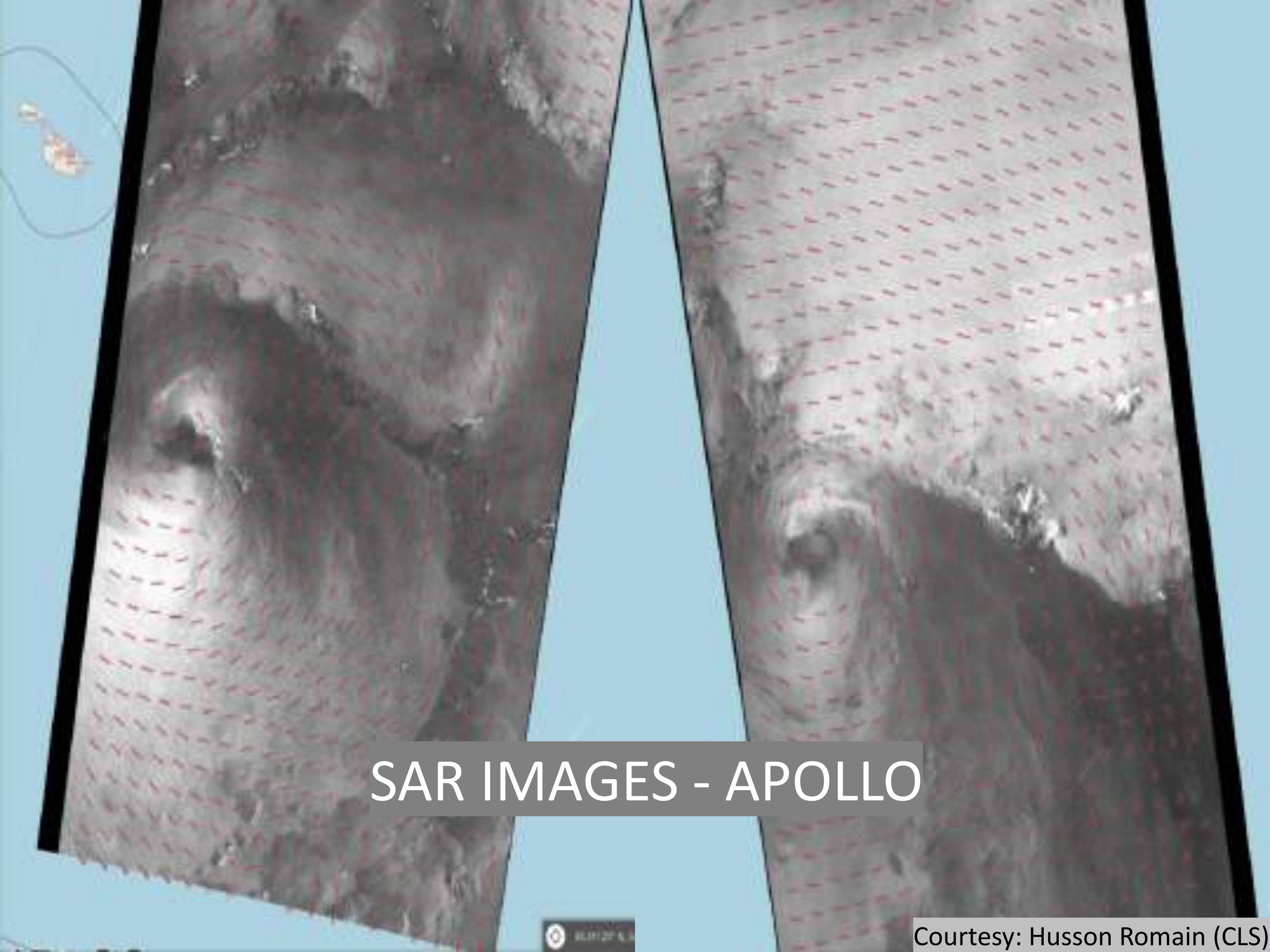




SAR IMAGES - BLAS

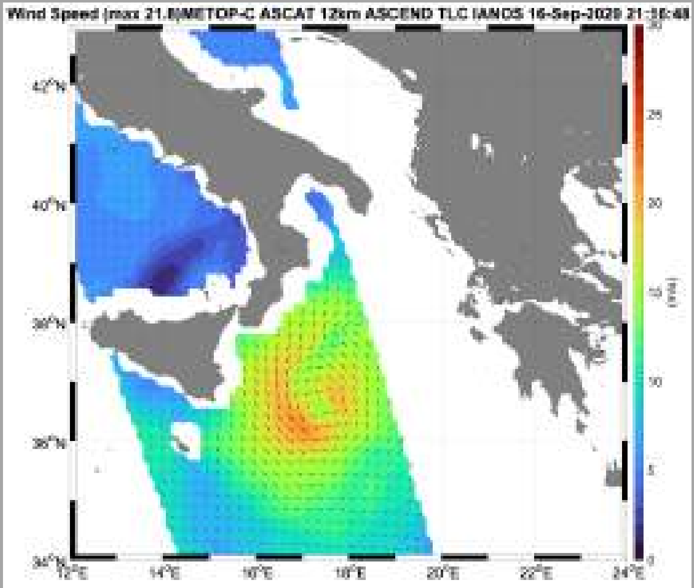
Courtesy: Husson Romain (CLS)

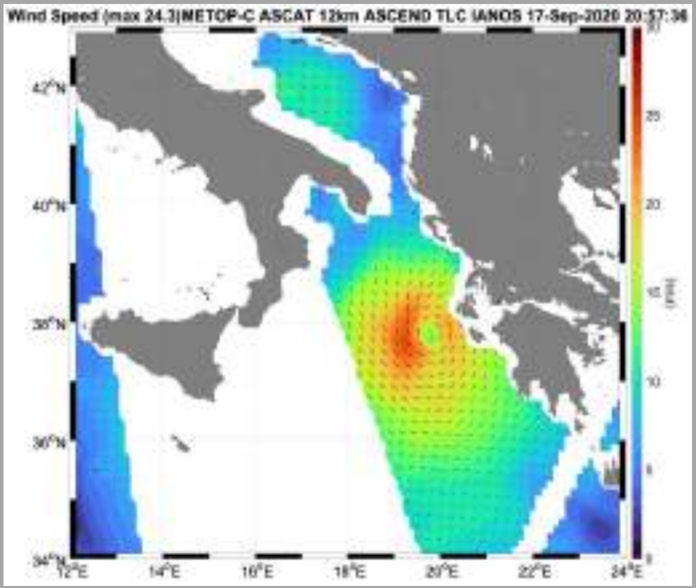
SAR IMAGES - APOLLO



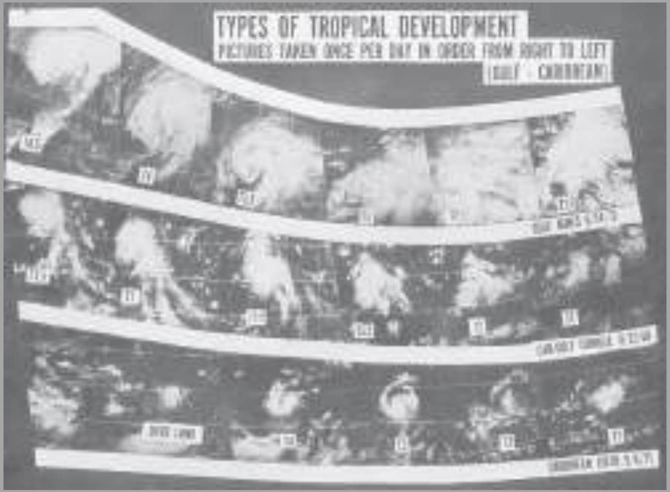
Courtesy: Husson Romain (CLS)

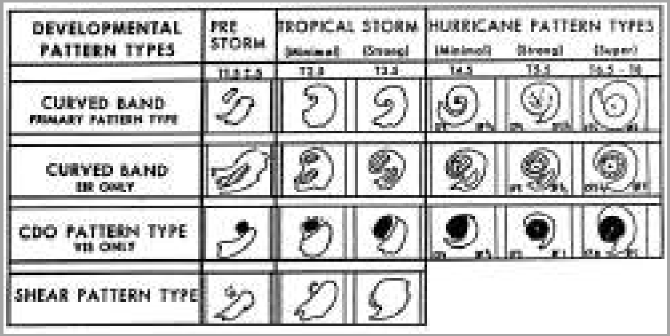
METOP-C ASCAT images: Medicane Ianos





Dvorak technique





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Acknowledgements

- COST action CA19109 - MEDCYCLONES "European network for Mediterranean cyclones in weather and climate"
- "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
- TROPICANA (TROPIcal Cyclones in ANthropocene: physics, simulations & Attribution)

Phase-space diagnostic

The detection of the environmental characteristics and the classification of cyclone is based on the *Hart* (2003) algorithm.

The methodology is based on coupled tests: a geometric test which evaluates the symmetry of the system and a thermodynamic test which computes the difference between the geopotential in the middle and high atmosphere

1) Thermal symmetry: $B = \pm(\overline{Z_{600hPa} - Z_{900hPa}}\,|_{\mathrm{R}} - \overline{Z_{600hPa} - Z_{900hPa}}\,|_{\mathrm{L}})$
(+ for N Hem.; – for S Hem.)

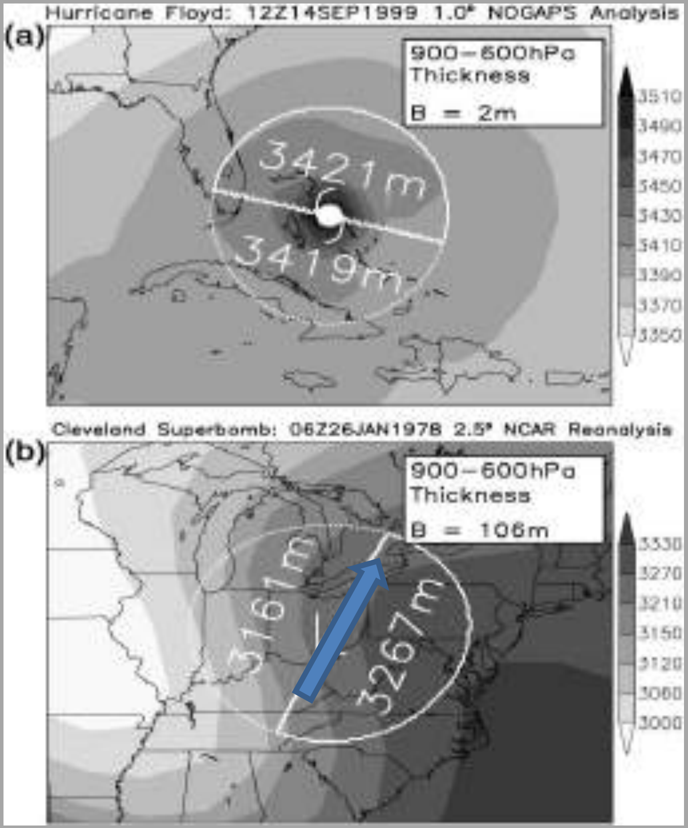
2) Thermal wind: $-|V_T^L| = \frac{\partial(\Delta Z)}{\partial \ln p}\Big|_{900\ hPa}^{600\ hPa}$. $-|V_T^U| = \frac{\partial(\Delta Z)}{\partial \ln p}\Big|_{600\ hPa}^{300\ hPa}$

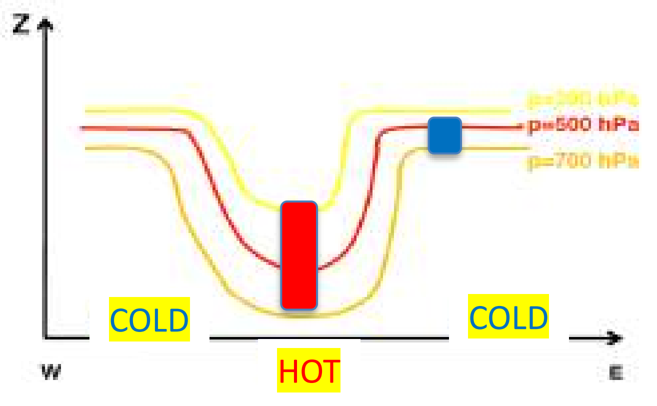
Selection criteria:

$$B < 10\ m$$
$$-|V_T^L| > 0$$
$$-|V_T^L| > 0$$

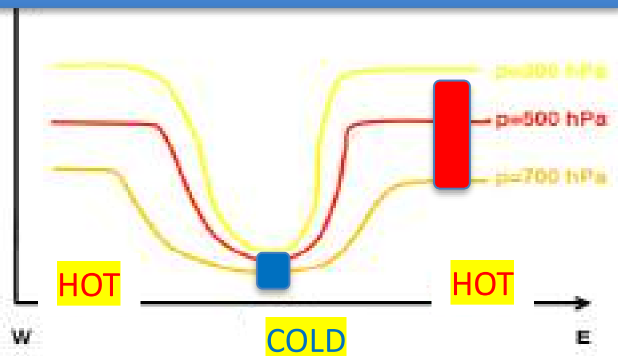
Hart, R. E., 2003: *A cyclone phase space derived from thermal wind and thermal asymmetry.* Monthly Weather Review , 131, 585-616

1) Thermal symmetry: $B = \pm(\overline{Z_{600hPa} - Z_{900hPa}}\,|_R - \overline{Z_{600hPa} - Z_{900hPa}}\,|_L)$
(+ for N Hem.; – for S Hem.)



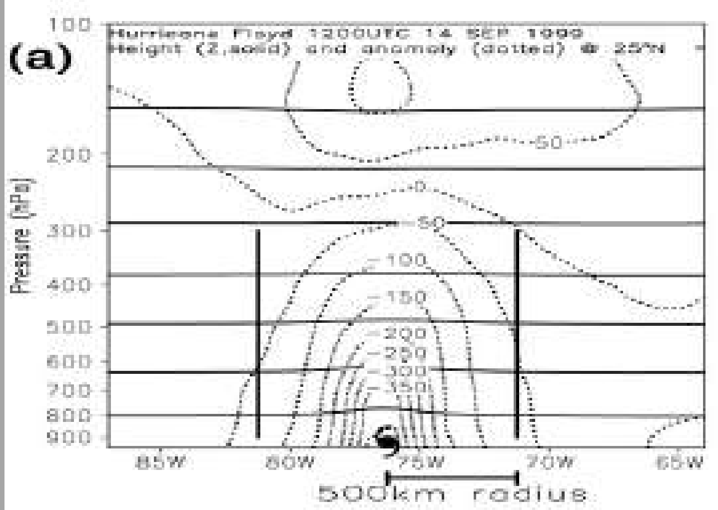


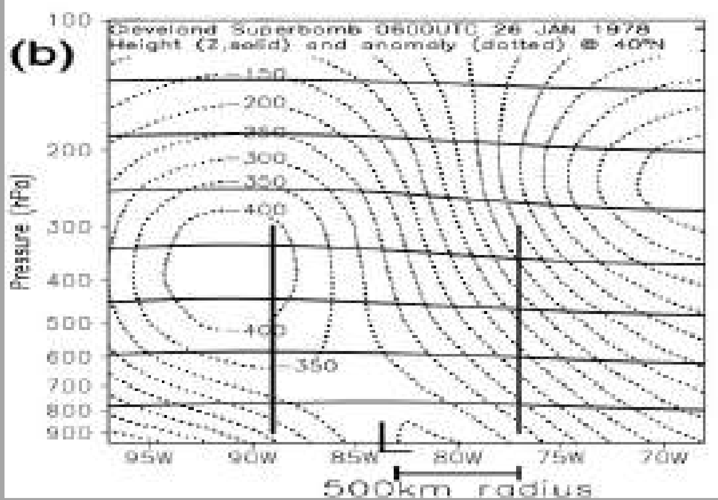
WARM CORE

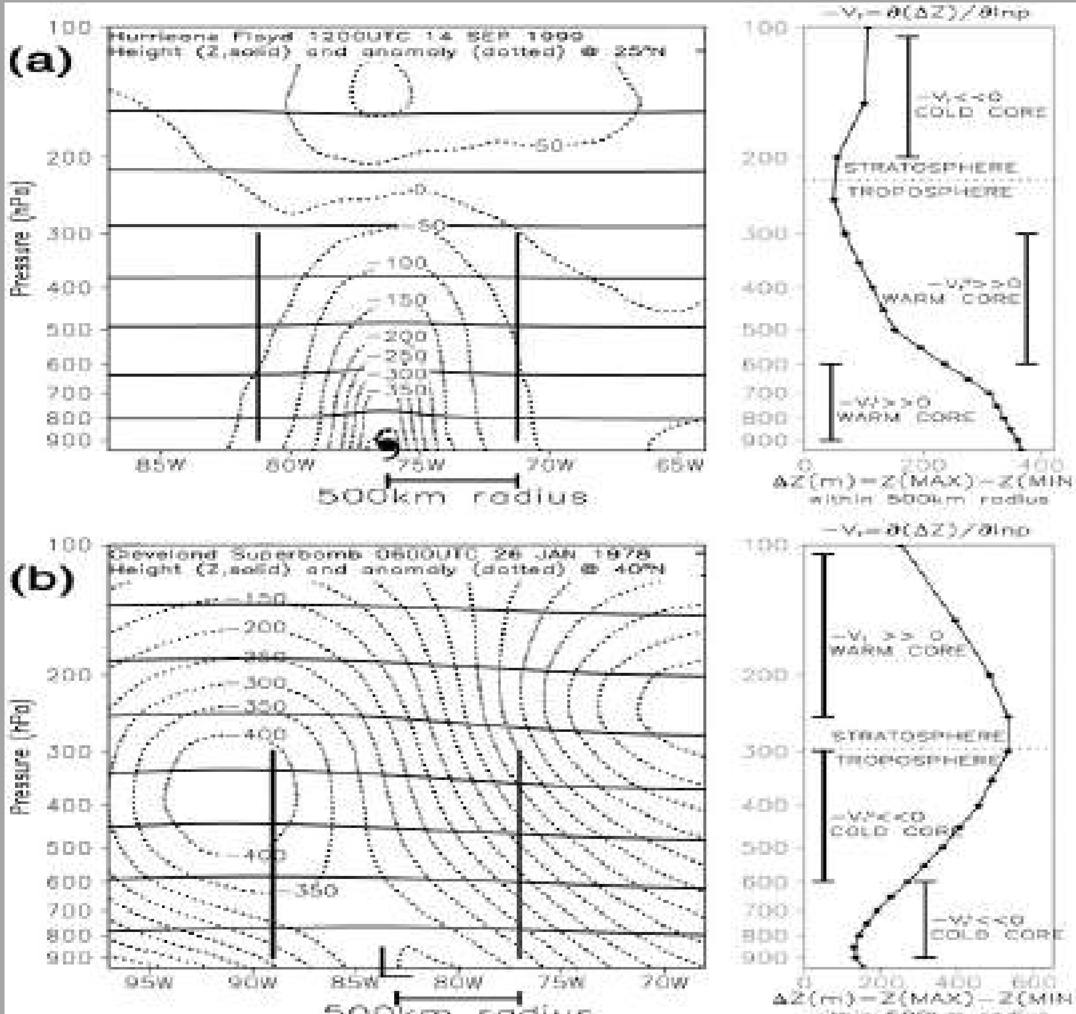


$$Z_2 - Z_1 = \frac{R_d T_V}{g_0} \ln\left(\frac{p_1}{p_2}\right)$$

COLD CORE

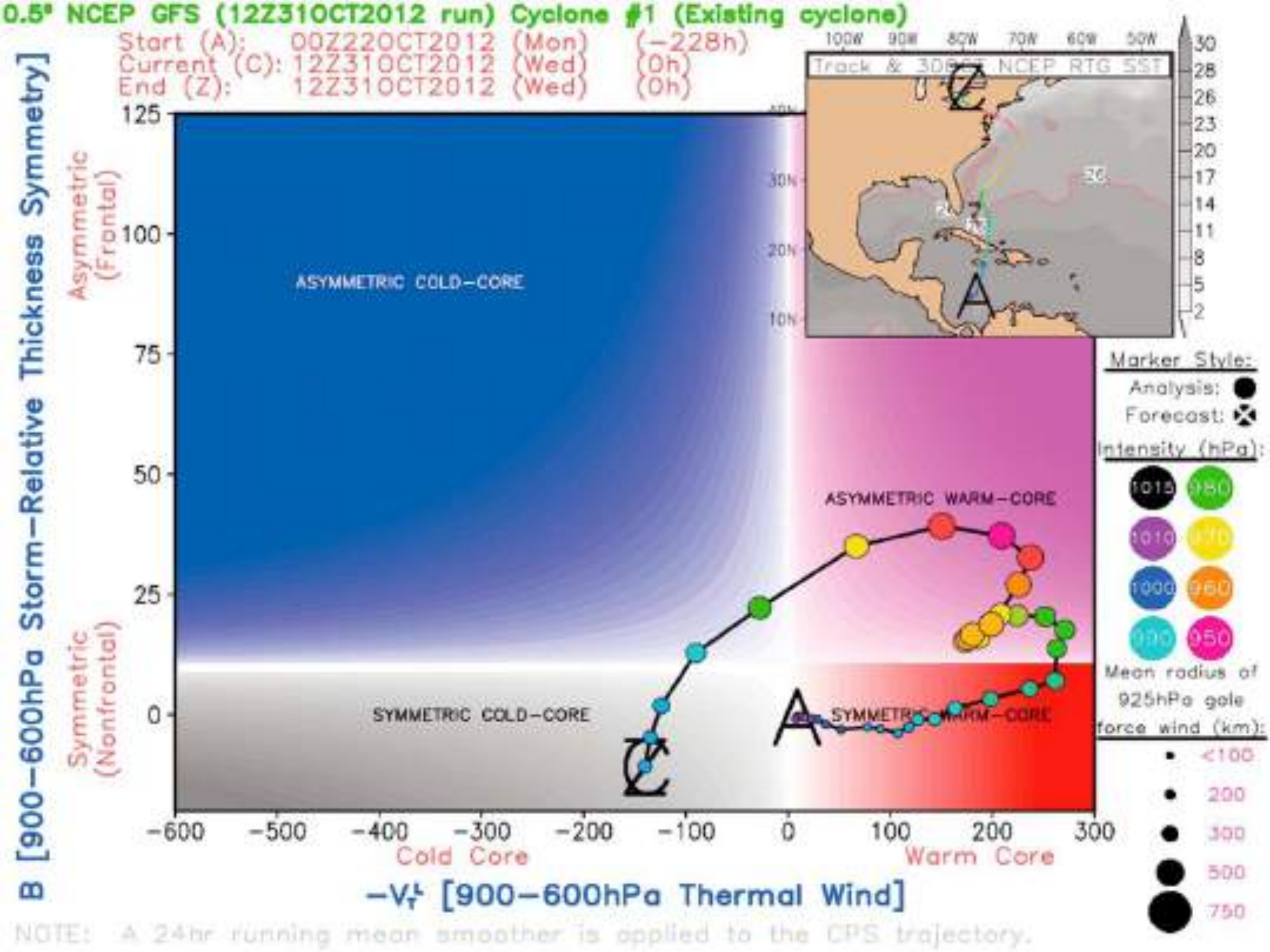






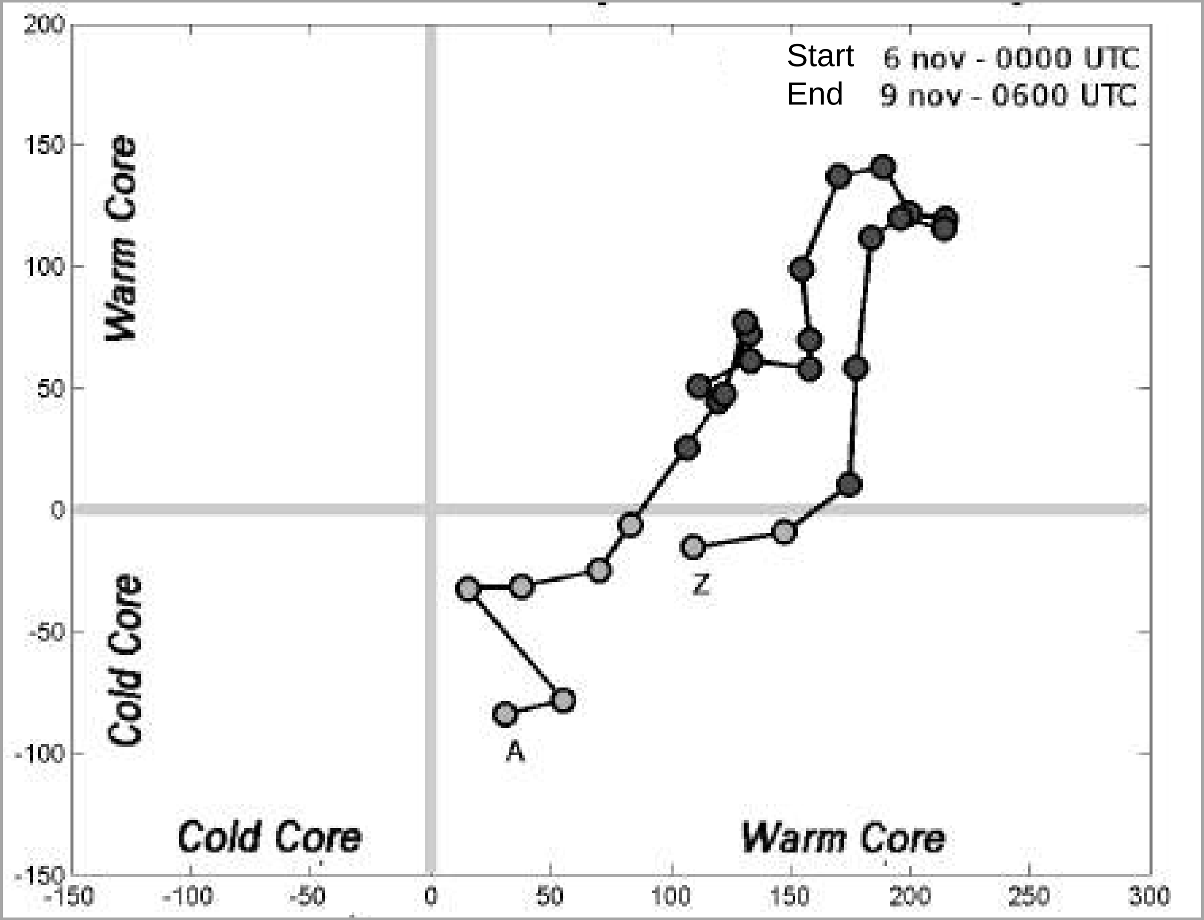
$$-V_T = \frac{\partial(\Delta Z)}{\partial(\ln p)} \propto -\frac{\partial(\Delta Z)}{\partial z}$$

Longitudinal cross section of height and anomaly from zonal mean


0.5° NCEP GFS (12Z31OCT2012 run) Cyclone #1 (Existing cyclone)
Start (A): 00Z22OCT2012 (Mon) (-228h)
Current (C): 12Z31OCT2012 (Wed) (0h)
End (Z): 12Z31OCT2012 (Wed) (0h)
B [900-600hPa Storm-Relative Thickness Symmetry]
Asymmetric (Frontal)
Symmetric (Nonfrontal)
ASYMMETRIC COLD-CORE
ASYMMETRIC WARM-CORE
SYMMETRIC COLD-CORE
SYMMETRIC WARM-CORE
Cold Core
Warm Core
-V$_T^L$ [900-600hPa Thermal Wind]
Track & 30DAY NCEP RTG SST
100W 90W 80W 70W 60W 50W
40N 30N 20N 10N
Marker Style:
Analysis:
Forecast:
Intensity (hPa):
1015 980 1010 970 1000 960 990 950
Mean radius of 925hPa gale force wind (km):
<100
200
300
500
750
NOTE: A 24hr running mean smoother is applied to the CPS trajectory.

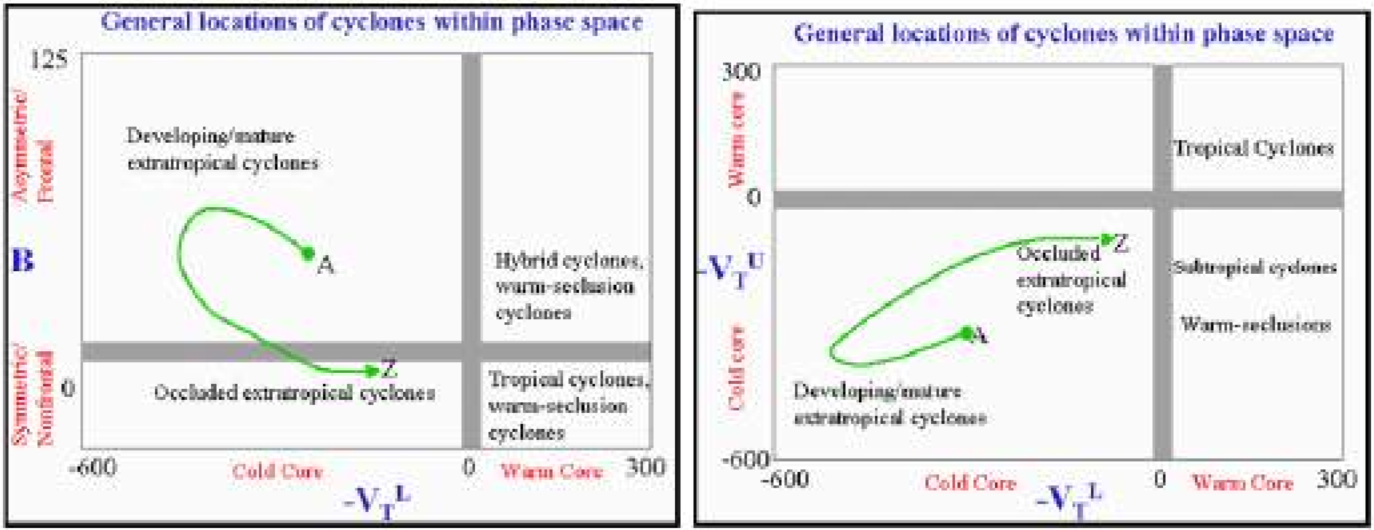
CASE STUDY: 6-8 November 2011 – APPLICATION TO MEDCYCLONES

$-V_T^U$



$-V_T^L$

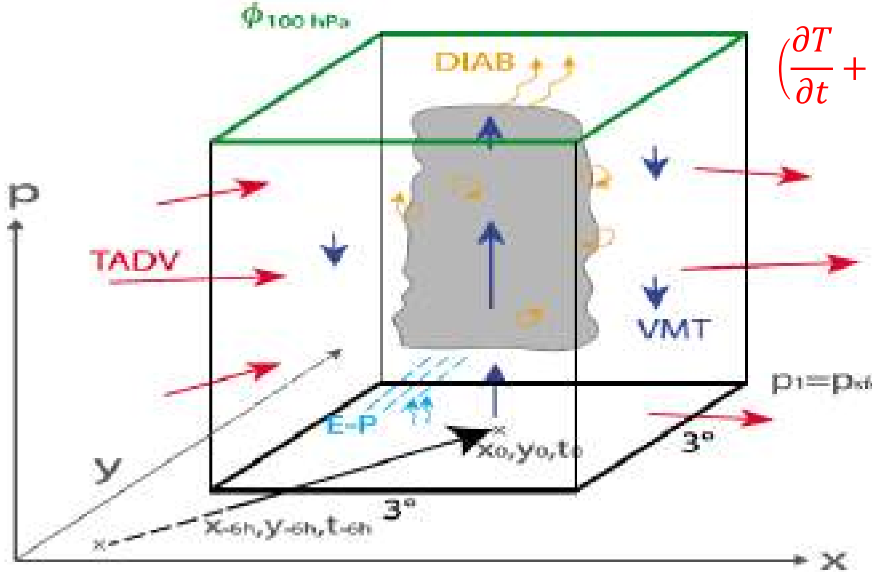
This phase space provides an objective classification of cyclone phase, "unifying the basic structural description of tropical, extratropical, and hybrid cyclones into a continuum" (Hart, 2003). Within this space it is also possible to illustrate the transitions between cyclone phases, as extratropical transition, subtropical and tropical transition, and the development of warm seclusions within extratropical cyclones.



(a) $-V_t^L$ versus B (b) $-V_t^L$ versus $-V_t^U$

http://moe.met.fsu.edu/cyclonephase/

$$\left(\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) - S_p\omega = \frac{Q}{c_p}$$

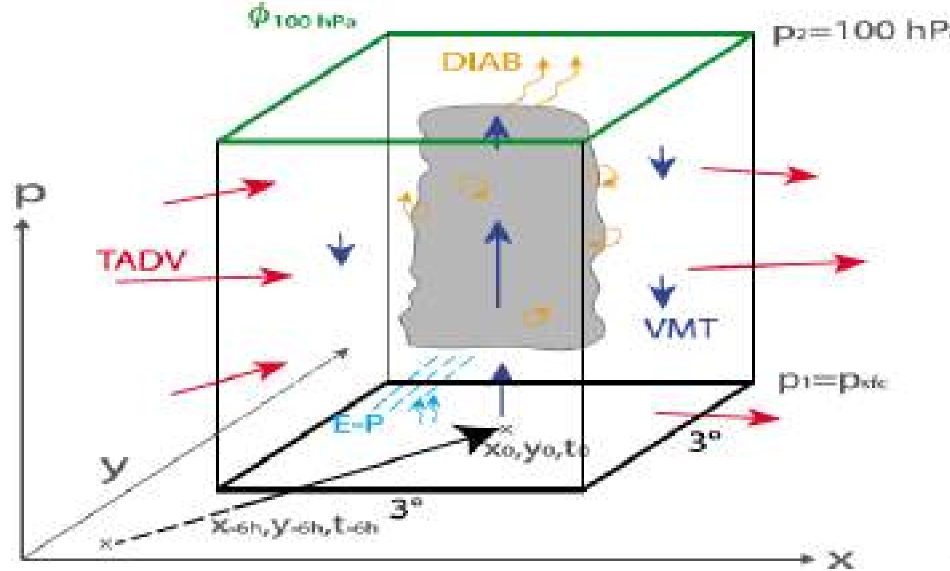


$$S_p = \frac{RT}{pc_p} - \frac{\partial T}{\partial p}$$

$$\underbrace{\frac{\partial p_{sfc}}{\partial t}}_{Dp} = \underbrace{\rho_{sfc}\frac{\partial \phi_{p_2}}{\partial t}}_{D\phi} + \underbrace{\rho_{sfc}R_d\int_{sfc}^{p_2}\frac{\partial T_v}{\partial t}d\ln p}_{ITT} + \underbrace{g(E-P)}_{EP} + RES_{PTE}$$

(Dp), the change in geopotential at the upper boundary (Dϕ), the vertically integrated virtual temperature tendency (ITT), the mass loss (increase) by surface precipitation P (evaporation E; EP), and a residuum due to discretization (RES_{PTE}).

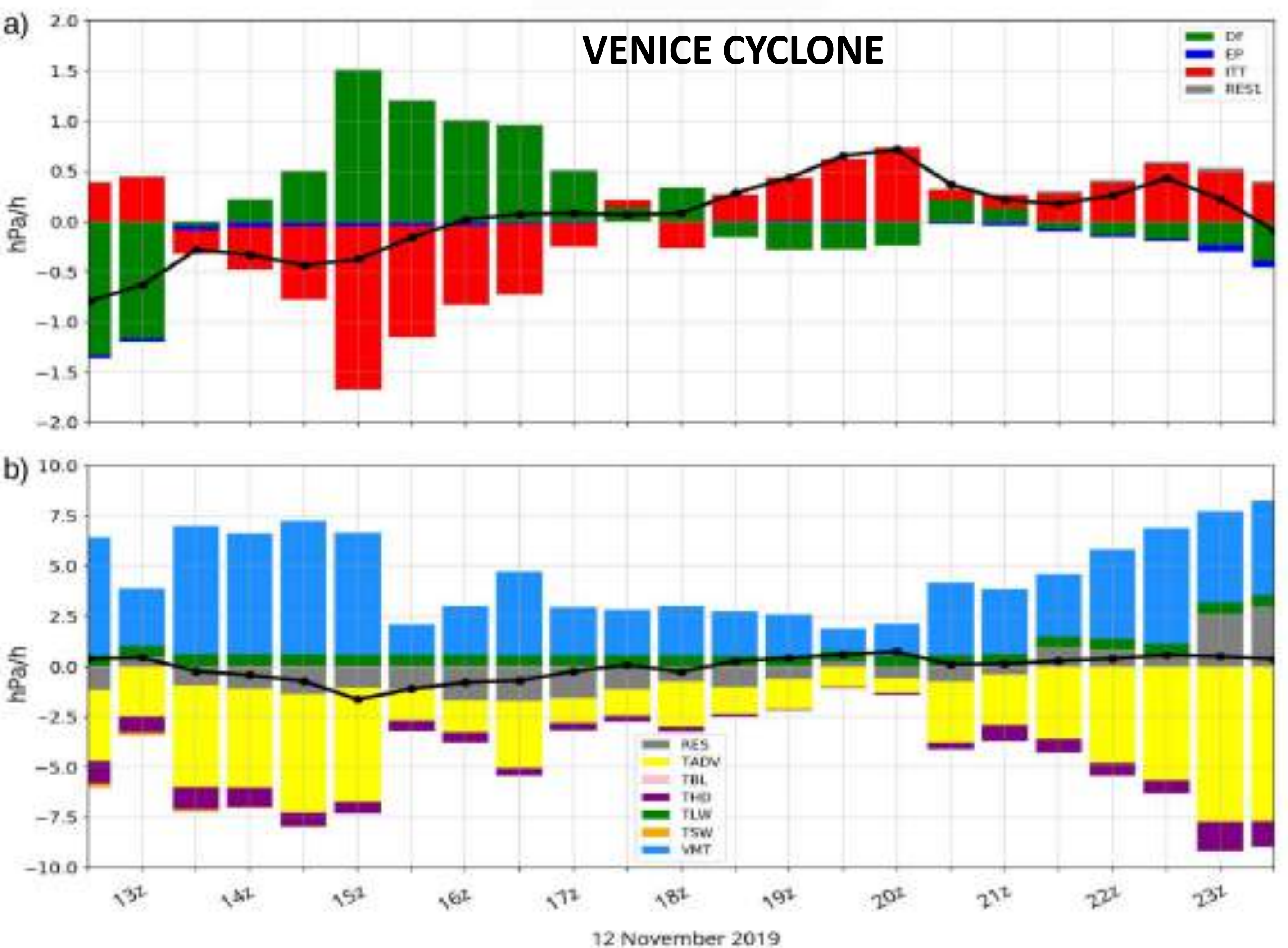
Fink et al. (2012)



$$
\begin{aligned}
ITT = &+ \rho_{sfc} R_d \int_{sfc}^{p_2} - \vec{v} \cdot \vec{\nabla}_p T_v \, d\ln p \qquad (TADV) \\
&+ \rho_{sfc} R_d \int_{sfc}^{p_2} \left(\frac{R_d T_v}{c_p p} - \frac{\partial T_v}{\partial p} \right) \omega \, d\ln p \qquad (VMT) \\
&+ \rho_{sfc} R_d \int_{sfc}^{p_2} \frac{T_v Q}{c_p T} \, d\ln p \qquad (DIAB) \\
&+ RES_{ITT},
\end{aligned}
$$

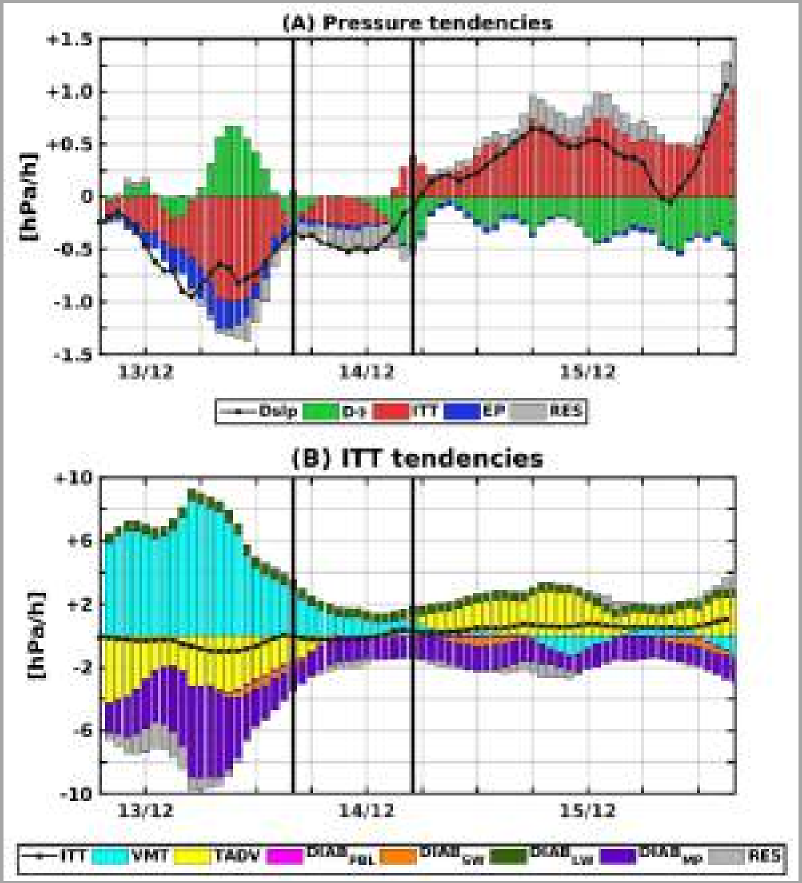
of horizontal temperature advection (TADV) and vertical motions (VMT) on the column-integrated temperature tendency. DIAB contains the influence of diabatic processes such as radiative warming/cooling, latent heat release due to phase changes of water, diffusion, and dissipation. In cloudy

Fink et al. (2012)



a)
VENICE CYCLONE
DF
EP
ITT
RES1
hPa/h
b)
RES
TADV
TBL
THD
TLW
TSW
VMT
hPa/h
13z
14z
15z
16z
17z
18z
19z
20z
21z
22z
23z
12 November 2019

ZEO


(A) Pressure tendencies
+1.5
+1.0
+0.5
0
-0.5
-1.0
-1.5
[hPa/h]
13/12
14/12
15/12
Dslp
D-I
ITT
EP
RES
(B) ITT tendencies
+10
+6
+2
-2
-6
-10
[hPa/h]
13/12
14/12
15/12
ITT
VMT
TADV
DIAB PBL
DIAB SW
DIAB LW
DIAB MP
RES