The latest satellite-based advancements on the characterization of potential Mediterranean tropical-like cyclones

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Motivation

- Can be a cyclone defined as medicane?

- If yes, did it go under tropical transition?

- All the analysis are satellite-based

Outline

- New definition of medicane

- Brief description of instruments and frequencies used

- Three case studies: cyclone Helios, Juliette and Daniel
  - ➢ short introduction
 - ➢ we are going to answer to these questions

- Conclusions

What is a *Medicane*?

A ***Medicane*** or ***Tropical-Like Cyclone*** (***TLC***) is a mesoscale system which develops in the Mediterranean Sea and displays characteristics similar to Tropical Cyclones (TC):
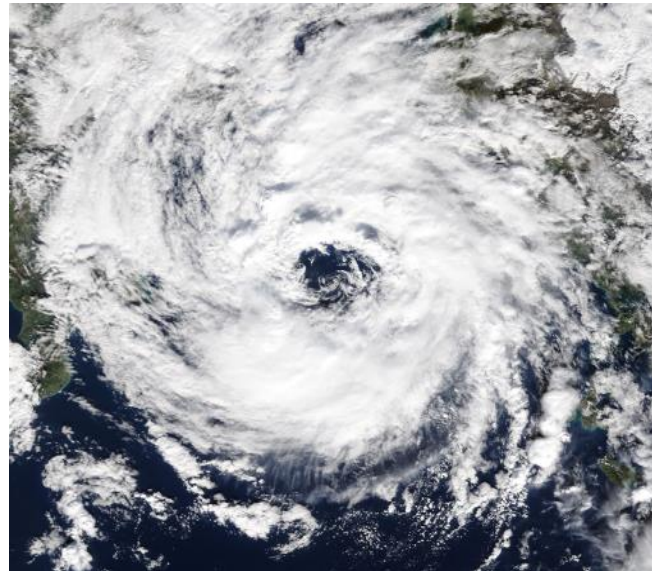
Presence of **Warm Core (WC)**

Spiraling cloud structure and rainbands around an **almost-cloudless** ''**eye**''

Symmetric surface wind field with maximum speed within a few tens of km from the center
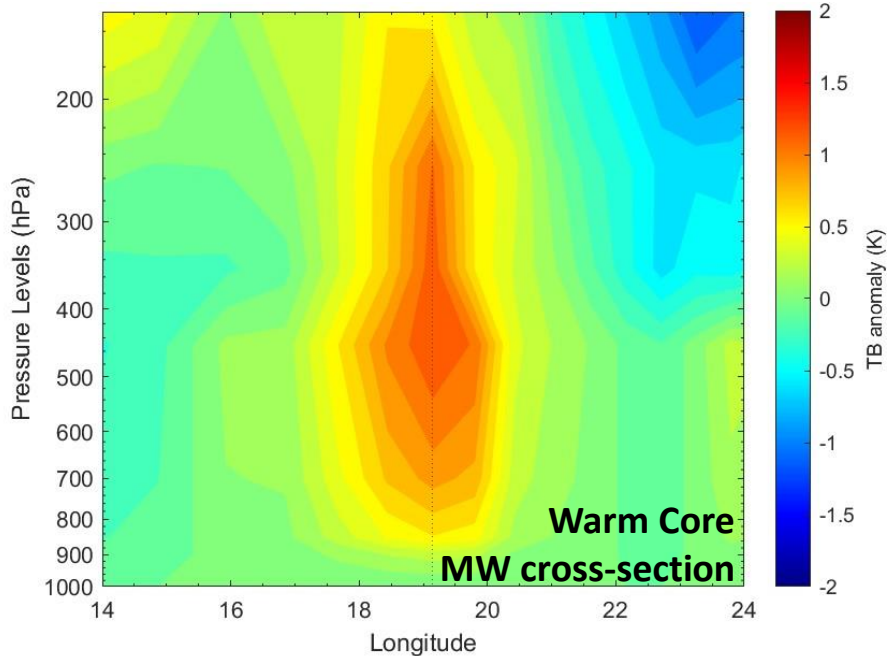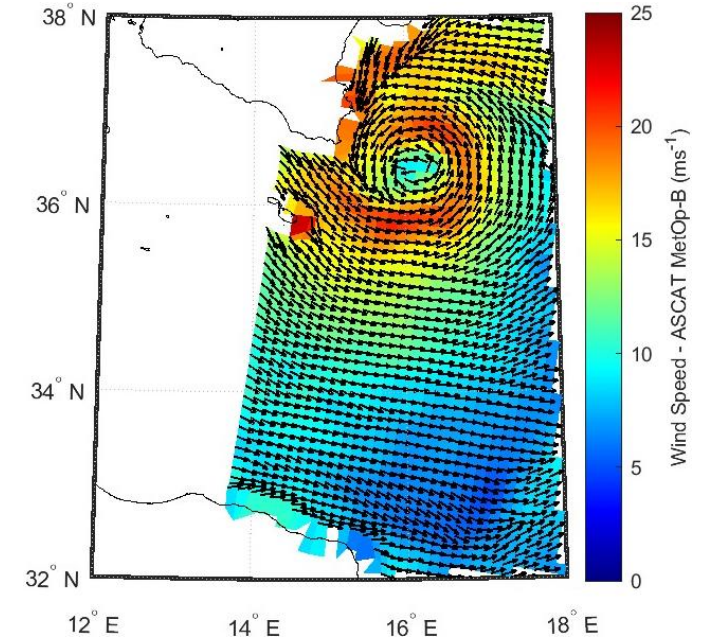

MW vertical cross-section of TB anomaly for medicane Zorbas, 29 Oct. 2018.

Medicane "Numa" MODIS Terra 18 Nov. 2017

Medicane "Apollo" wind field 29 Oct. 2021

Medicane – Tropical Transition

- Different features can be used to identify a tropical transition for a medicane:
  - ✓ WC sustained by diabatic forcing
  - ✓ Deep convection close to the cyclone centre triggering the WC
  - ✓ Latent heat exchange with sea surface
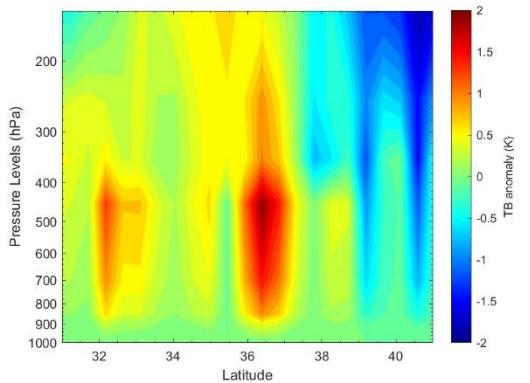- Satellite data and tools are useful to identify the tropical transition
- Passive microwave data are able to characterize both thermodinamical and microphysical processes

Di Francesca et al., 2024
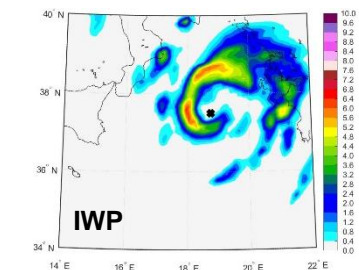*Atm. Res., Under Review*

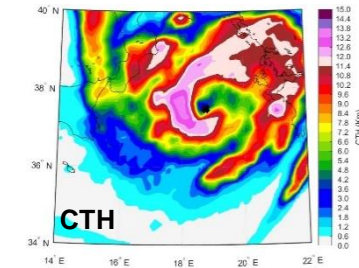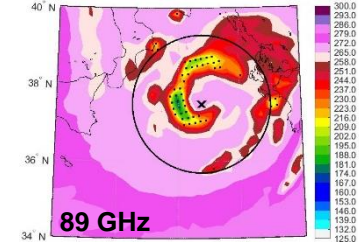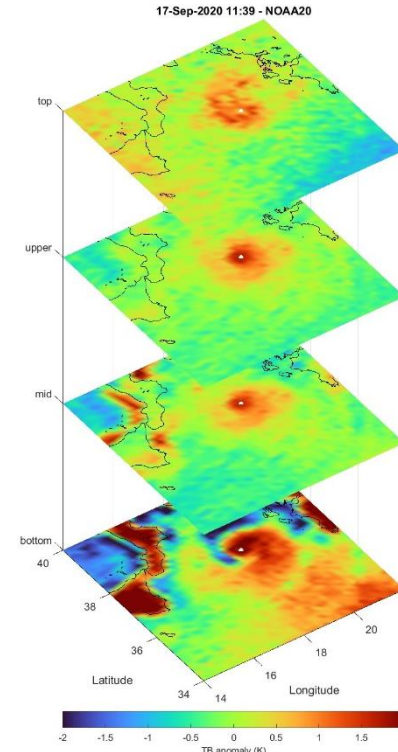**Apollo
26 Oct 2021 – 09:22 UTC**
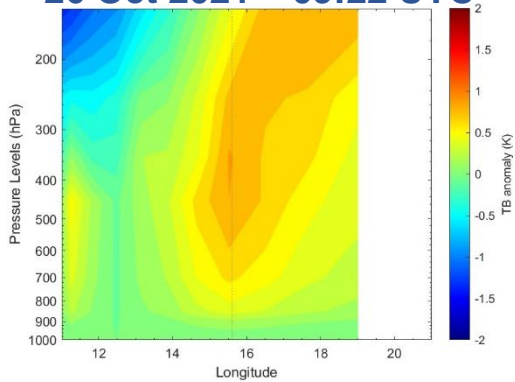
- ✓ Top-bottom WC
- ✓ WC development originating from stratospheric warm air intrusion

**Apollo
29 Oct 2021 – 08:20 UTC**

- ✓ Bottom-top WC
- ✓ WC development originating from diabatic heating, air-sea interaction and latent heat release

Deep convection close to the cyclone centre is an indication of the development of a bottom-top WC

89 GHz

CTH

IWP

Passive Microwave Radiometry – Instruments & Frequencies

	AMSU-A/B - MHS	ATMS	Feng-Yu
Satellites	NOAA15/16/17/18/19, MetOp-A-B-C	S-NPP, NOAA20, NOAA21	FY-3D, FY-3E, FY-3F
Scanning Type	Linear cross-track	Linear cross-track	Linear cross-track
54 GHz channels resolution	48 km (nadir); 150 km x 80 km (swath's edge)	31.6 km (nadir); 137 km x 60 km (swath's edge)	31.6 km (nadir); 137 km x 60 km (swath's edge)
183 GHz channels resolution	16 km (nadir); 50 km x 26.7 km (swath's edge)	15.8 km (nadir); 68.4 km x 30 km (swath's edge)	16 km (nadir); 68.4 km x 30 km (swath's edge)

Frequency (GHz)	Application
53.596	Atmospheric TB at 600 hPa (~4 km)
54.4	Atmospheric TB at 450 hPa (~6 km)
54.94	Atmospheric TB at 300 hPa (~9 km)
55.5	Atmospheric TB at 200 hPa (~12 km)
89	TB warming due to cloud water emission + TB cooling due to high-density ice scattering
183.31 ±7	TB warming due to WV emission ~ 6 km + TB cooling due to medium-density ice scattering
183.31 ±3	TB warming due to WV emission ~ 9 km + TB cooling due to medium-density ice scattering
183.31 ±1	TB warming due to WV emission ~ 12 km + TB cooling due to low-density ice scattering
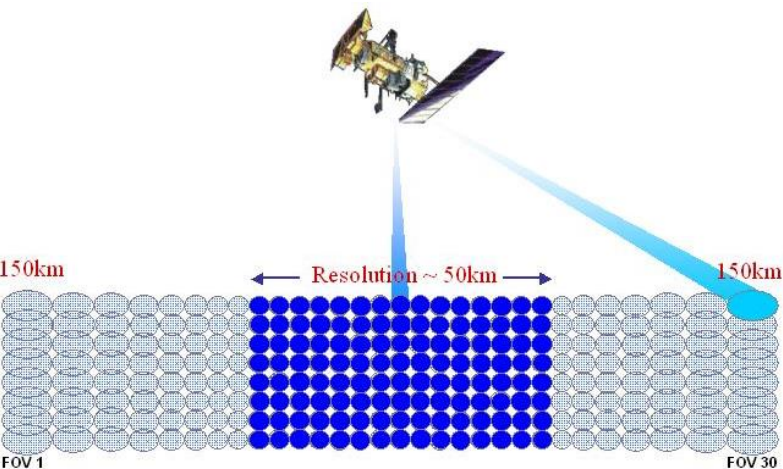
ASCAT scatterometer (C-band radar) to derive wind field at the sea surface (data only over sea)

WinRad scatterometer (C/Ku-band radar) to derive wind field at the sea surface (data only over sea)
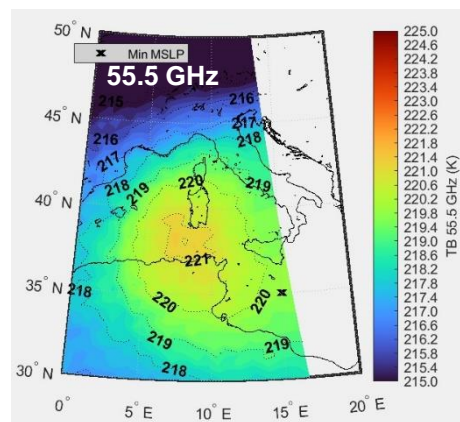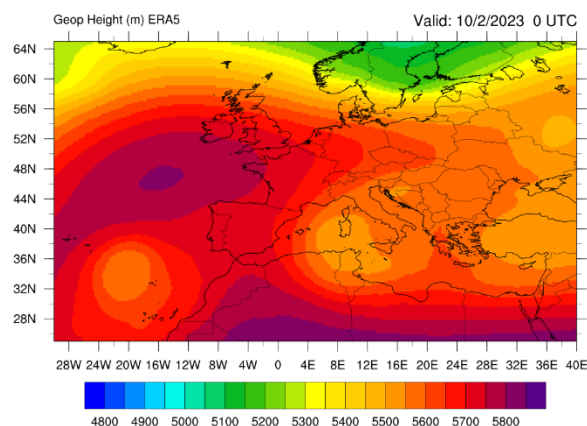
Investigation of usefulness of this channel to reconstruct the WC's 3D shape of a medicane

150km

Resolution ~ 50km

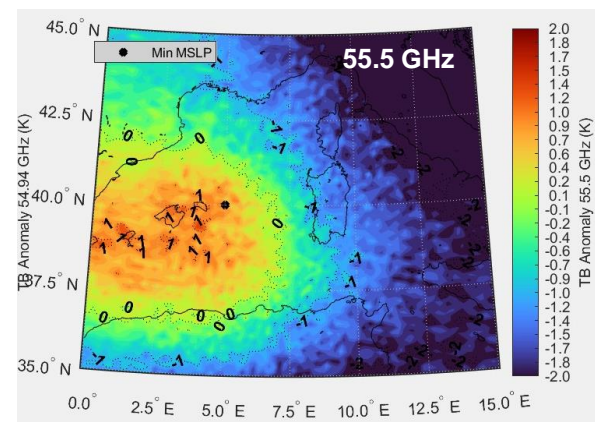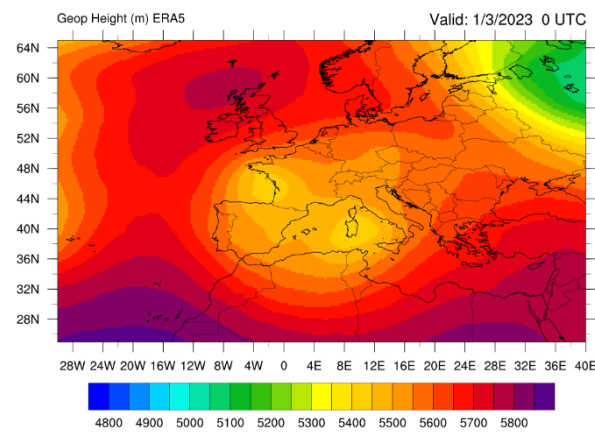150km

FOV 1

FOV 30

2024

Case Studies

Helios

- 8 - 10 Feb 2023
- Originated from stratospheric warm air intrusion
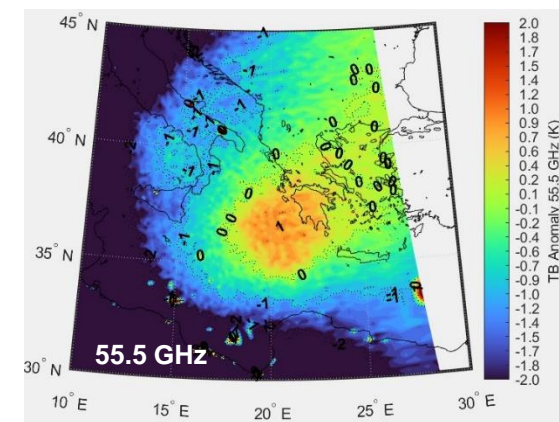- South Mediterranean

Juliette

- 27 Feb – 3 March 2023
- Originated from stratospheric warm air intrusion
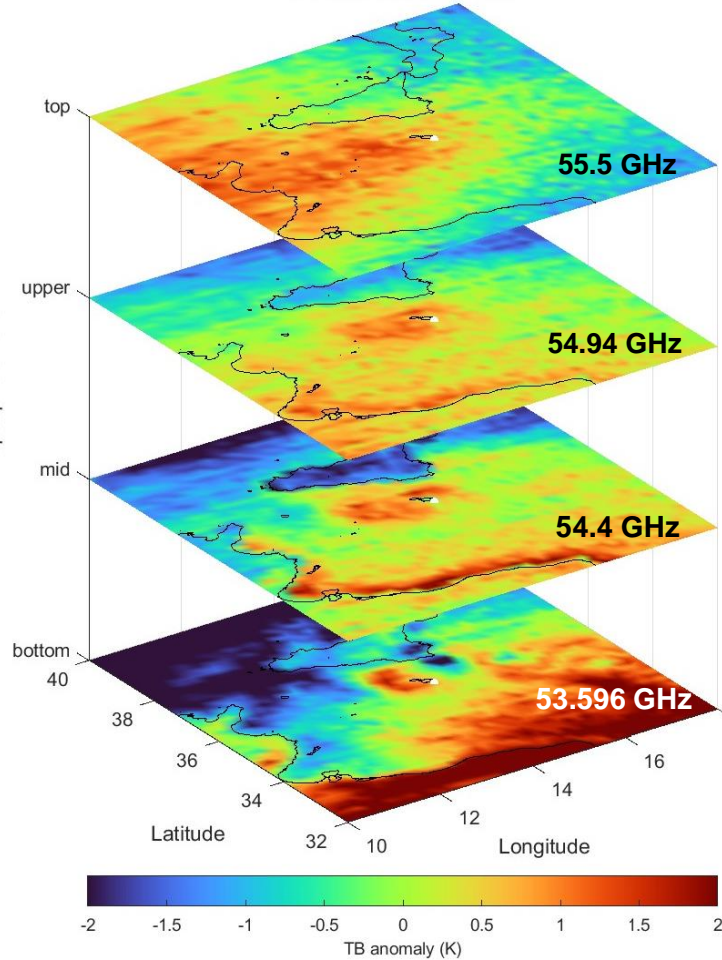- West Mediterranean

Daniel

- 5- 10 Sep 2023
- Originated from stratospheric warm air intrusion
- Ionian Sea
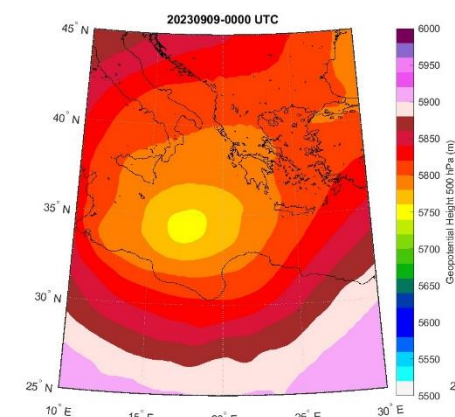
Helios

- Can Helios be considered a medicane?

10-Feb-2023 00:46 - NPP

✓ The Warm Core (WC) is present
✓ The WC shape is quite well defined at 54.4 and 54.94 GHz
✓ The positive TB anomaly at 55.5 GHz is broader and larger
✓ Clear contamination of land and coastal lines on TB anomaly signal
✓ 53.596 GHz affected by droplets emission (warming) and ice scattering (cooling)
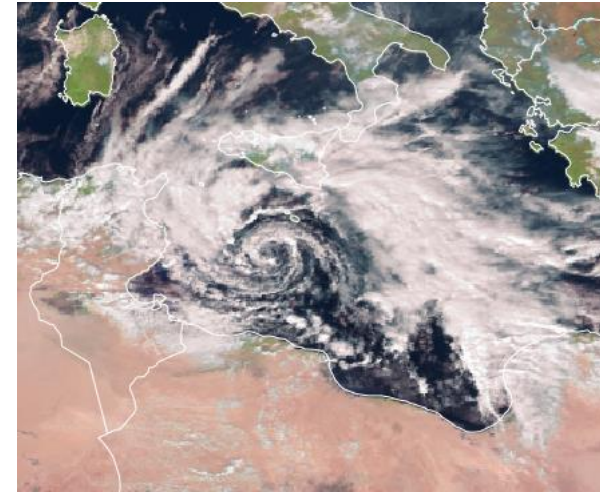
✓ SEVIRI VIS channel 12:00 UTC 10 Feb 2023
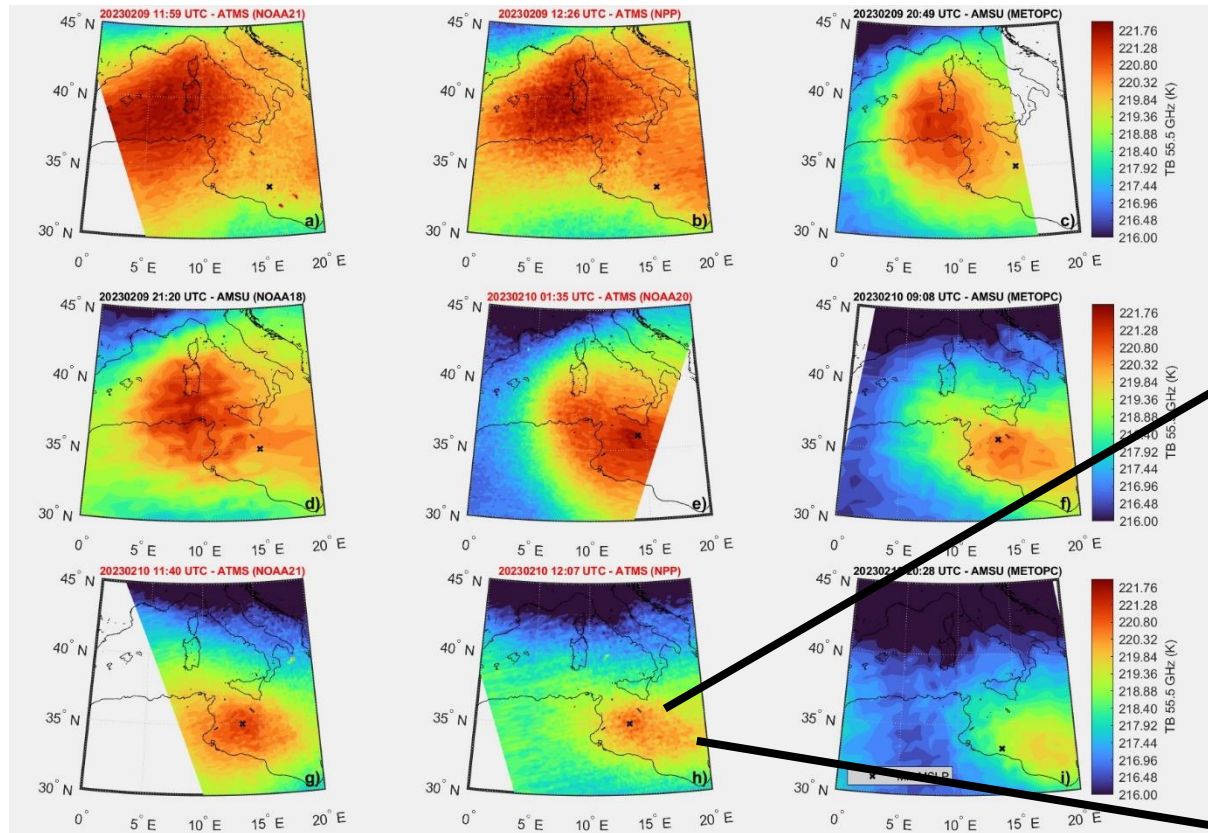✓ Spiralling cloud structure
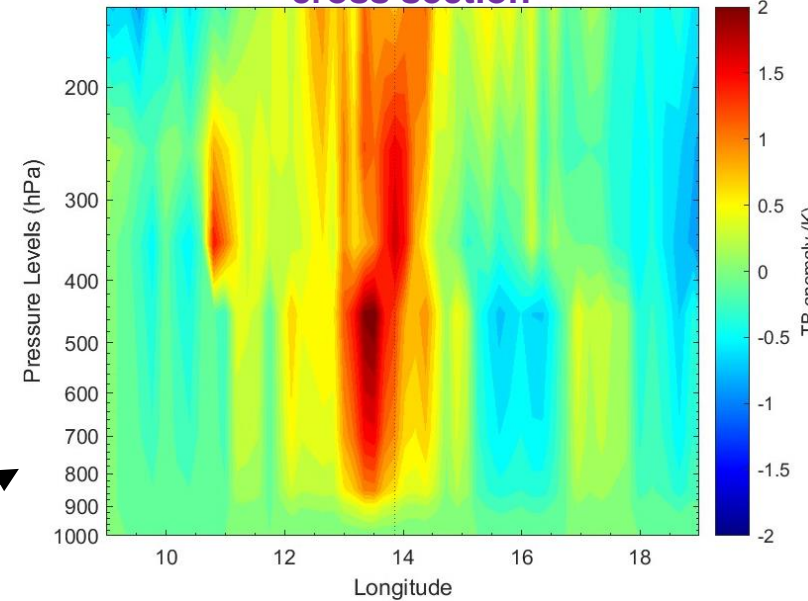✓ Quite large cloudless eye

9 Feb 2023 – 09:29 UTC
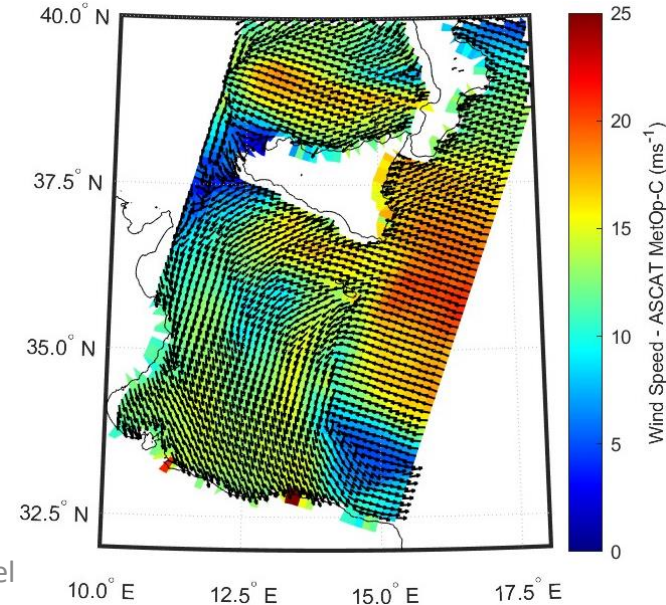
✓ No wind data available during the Helios mature phase
✓ Only two satellite scatterometers (ASCAT onboard MetOp-B/C) working at Helios time

Helios

- Did Helios undergo tropical transition?
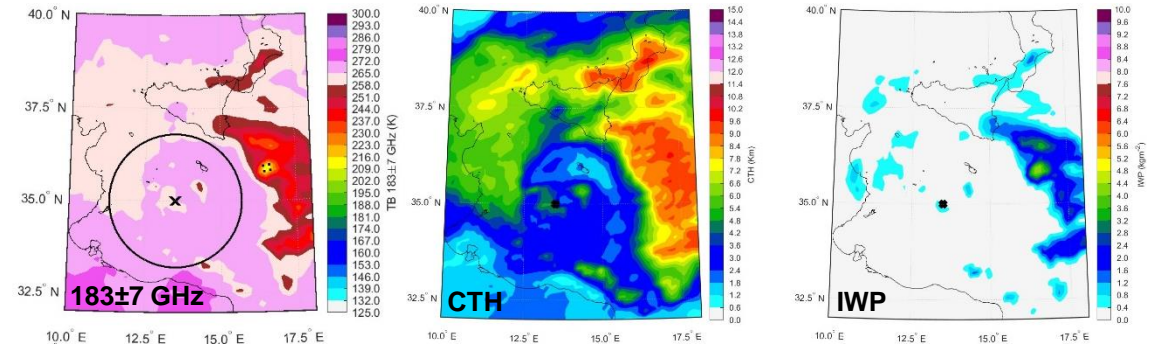- Evolution of the TB map at *55.5 GHz*

TB anomaly vertical cross section

- ✓ TB positive signal above 200 hPa (stratosphere)
- ✓ TB anomaly>2K between 400 and 500 hPa
- ✓ WC larger in the upper troposphere/stratosphere than in the middle/lower troposphere
- ✓ Top-bottom WC development

✓ *Considering both thermodynamical and microphysical properties, Helios did not undergo tropical transition*
✓ *Helios can be labelled as warm seclusion*

ATMS high frequency channels
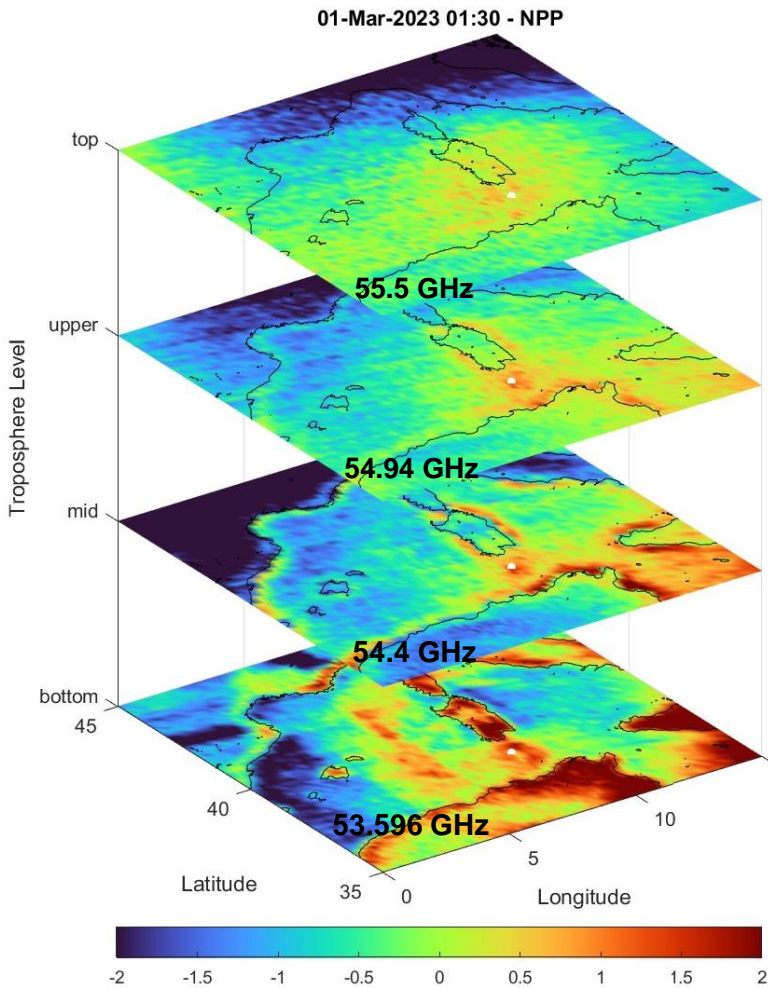

183±7 GHz   CTH   IWP

- ✓ No scattering signal close to the cyclone centre
- ✓ Absence of light and heavy ice particles
- ✓ Deep convection (DC) activity very far from cyclone centre

Juliette

- Can Juliette be considered a medicane?

01-Mar-2023 01:30 - NPP

✓ The Warm Core (WC) is present
✓ The WC shape is quite well defined and marked at 54.4 and 54.94 GHz (small size)
✓ The positive TB anomaly at 55.5 GHz is weaker and not well defined
✓ Clear contamination of land and coastal lines on TB anomaly signal

✓ SEVIRI VIS channel 12:00 UTC 1 Mar 2023
✓ Spiralling cloud structure
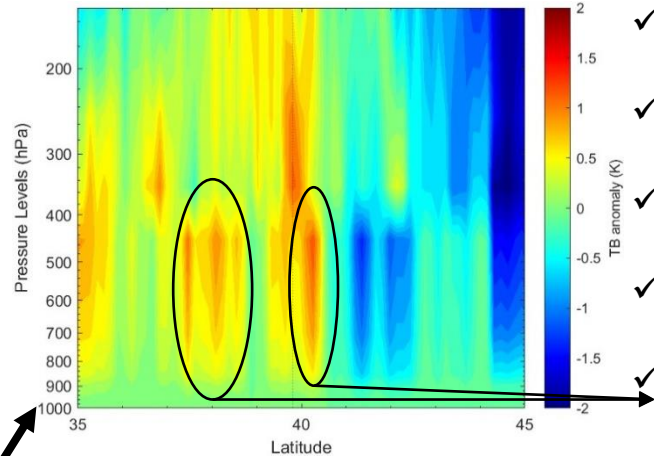✓ Well defined cloudless eye

28 Feb 2023 – 20:56 UTC
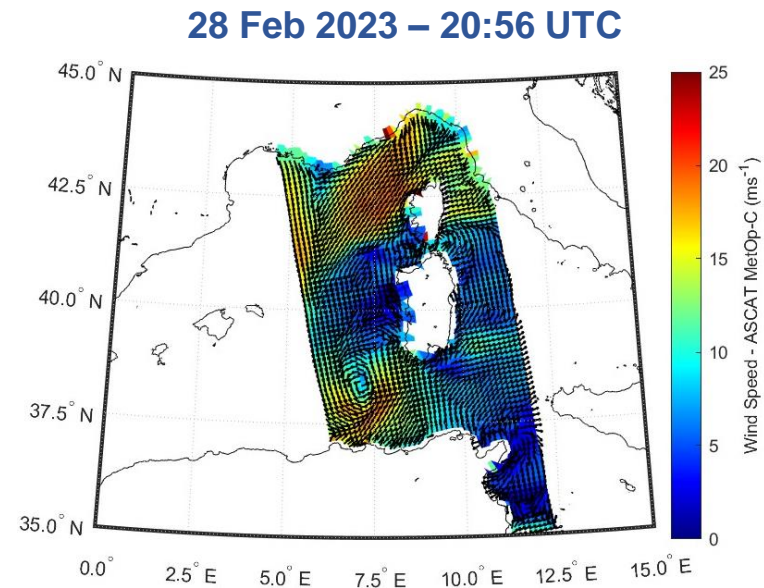
✓ Cyclonic wind structure already visible at the end of 28 Feb
✓ Some frontal lines still present at this stage

Juliette

- Did Juliette undergo tropical transition?
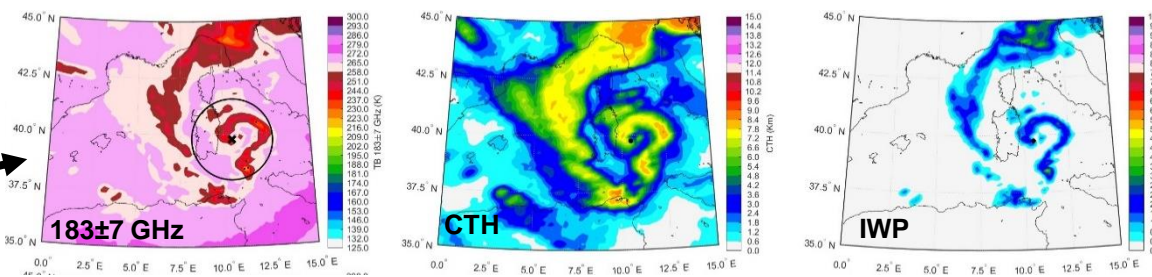- Evolution of the TB map at **55.5 GHz**
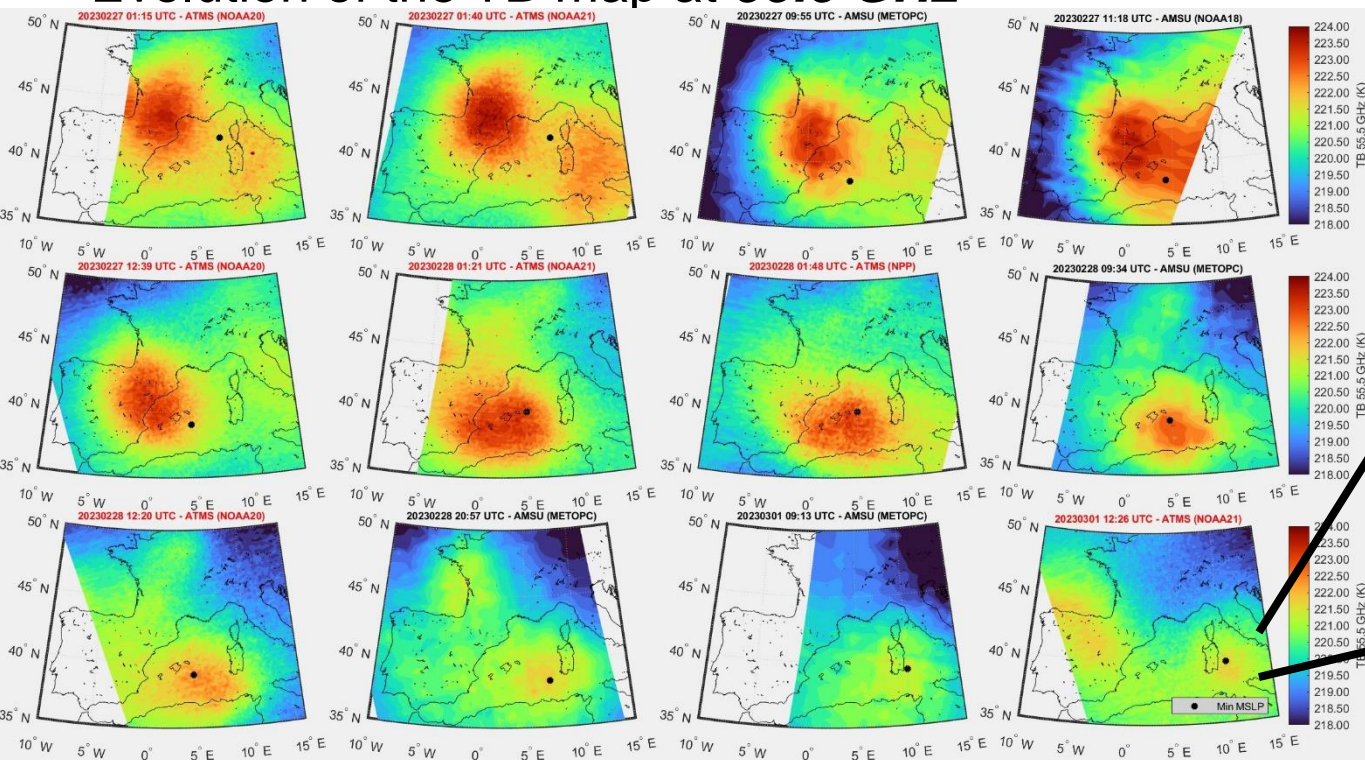
TB anomaly vertical cross section

- ✓ Max TB positive signal between 200 and 400 hPa
- ✓ Max TB anomaly around 1.5 K
- ✓ Different WC structure with respect to Helios
- ✓ Bottom-top WC development
- ✓ Signal in the lower troposphere are due to land

ATMS high frequency channels

183±7 GHz   CTH   IWP

- ✓ Stratospheric warm air intrusion started on 27 Feb 2023
- ✓ The effect of stratospheric warm air intrusion ended from the night on 1 Mar 2023

- ✓ Weak scattering signal close to the cyclone centre @ 183±7 GHz channel
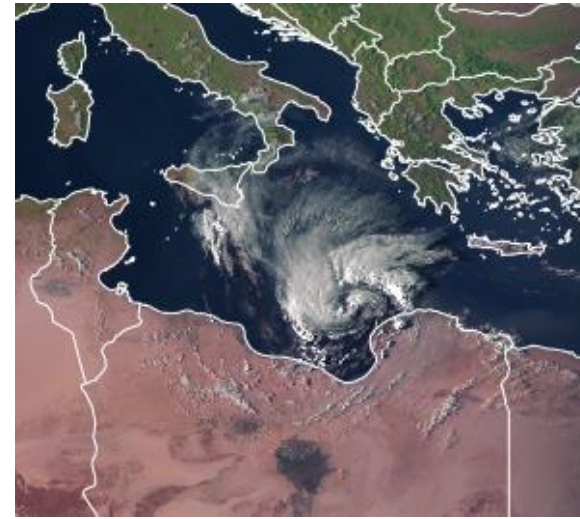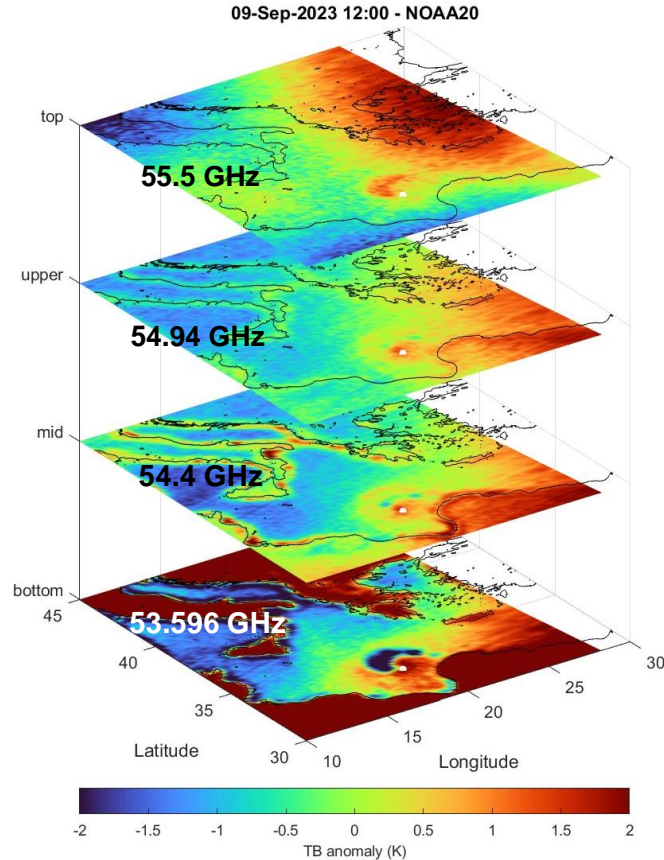- ✓ Cyclonic cloud structure evidenced by high frequency channels

Differently from Helios, the presence of DC close to the cyclone centre and the bottom-top WC development, highlighted as Juliette underwent tropical transition

CTH   IWP
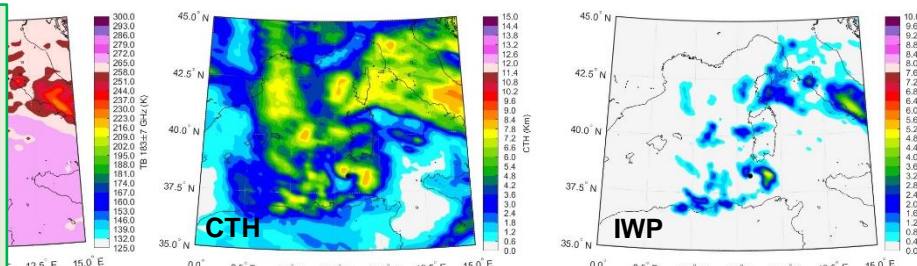
- ✓ In the previous overpasses the DC activity was more evident
- ✓ The development of WC is driven by DC
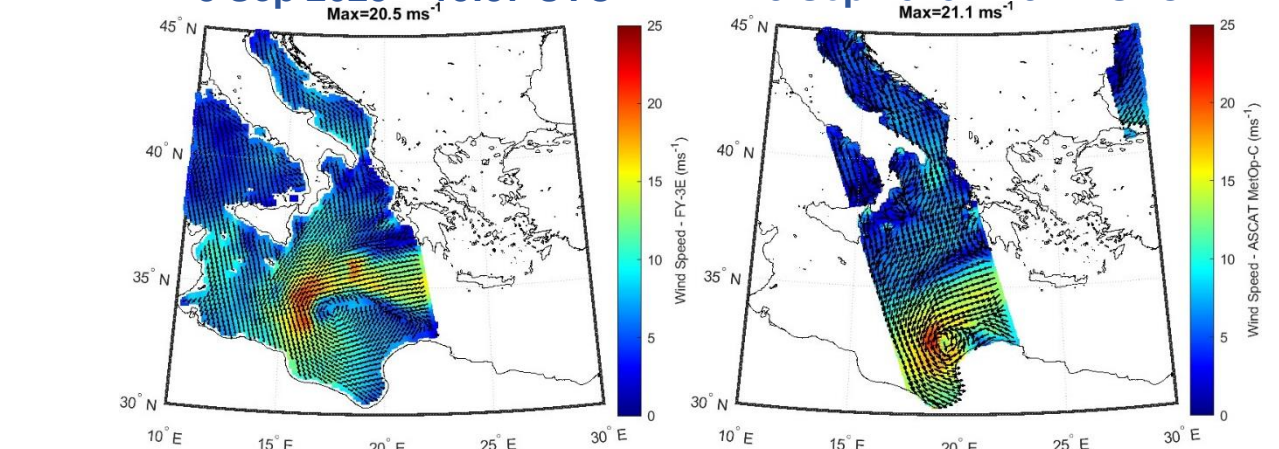
Daniel

- Can Daniel be considered a medicane?

09-Sep-2023 12:00 - NOAA20

55.5 GHz
54.94 GHz
54.4 GHz
53.596 GHz

TB anomaly (K)

✓ The Warm Core (WC) is present
✓ The WC shape is quite well defined and marked from 54.4 to 55.5 GHz channels
✓ The TB signal at 53.596 GHz highlights both the presence of DC (negative TB anomaly) and the emission of raindrops (positive TB anomaly)
✓ The proximity to the coastal lines slightly affects the TB anomaly signal

✓ SEVIRI VIS channel 9 Sep 2023 15:45 UTC
✓ Spiralling cloud structure
✓ Not completely closed cloudless eye
✓ Unavailability of VIS images later on this day

8 Sep 2023 – 15:37 UTC   9 Sep 2023 – 19:21 UTC
Max=20.5 ms⁻¹   Max=21.1 ms⁻¹
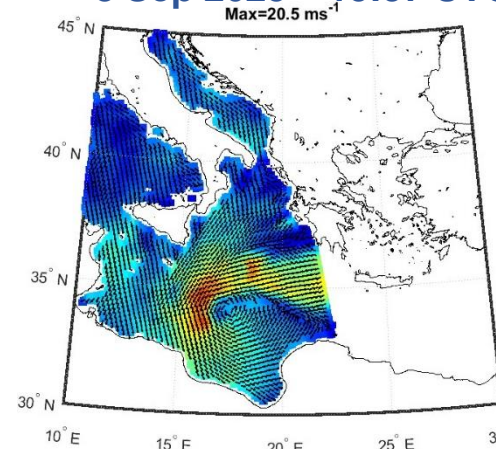
✓ Availability of Feng-Yun WinRad data increase the monitoring capability medicanes
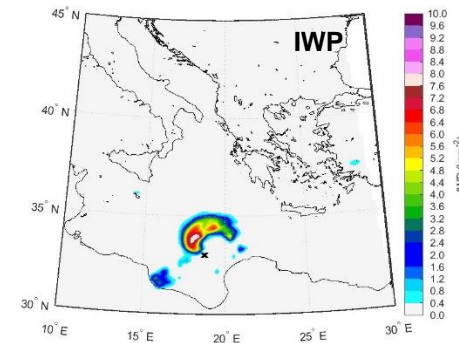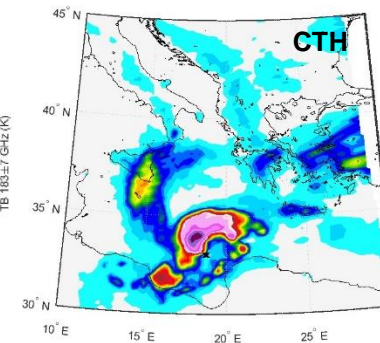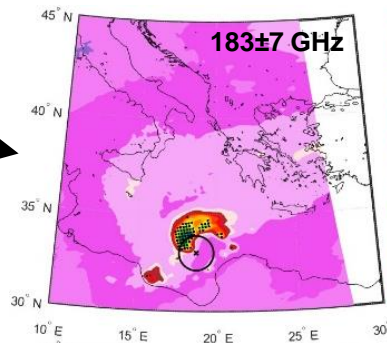✓ Evolution from a more frontal to a cyclonic wind structure

Daniel

- Did Daniel undergo tropical transition?
- Evolution of the TB map at **55.5 GHz**
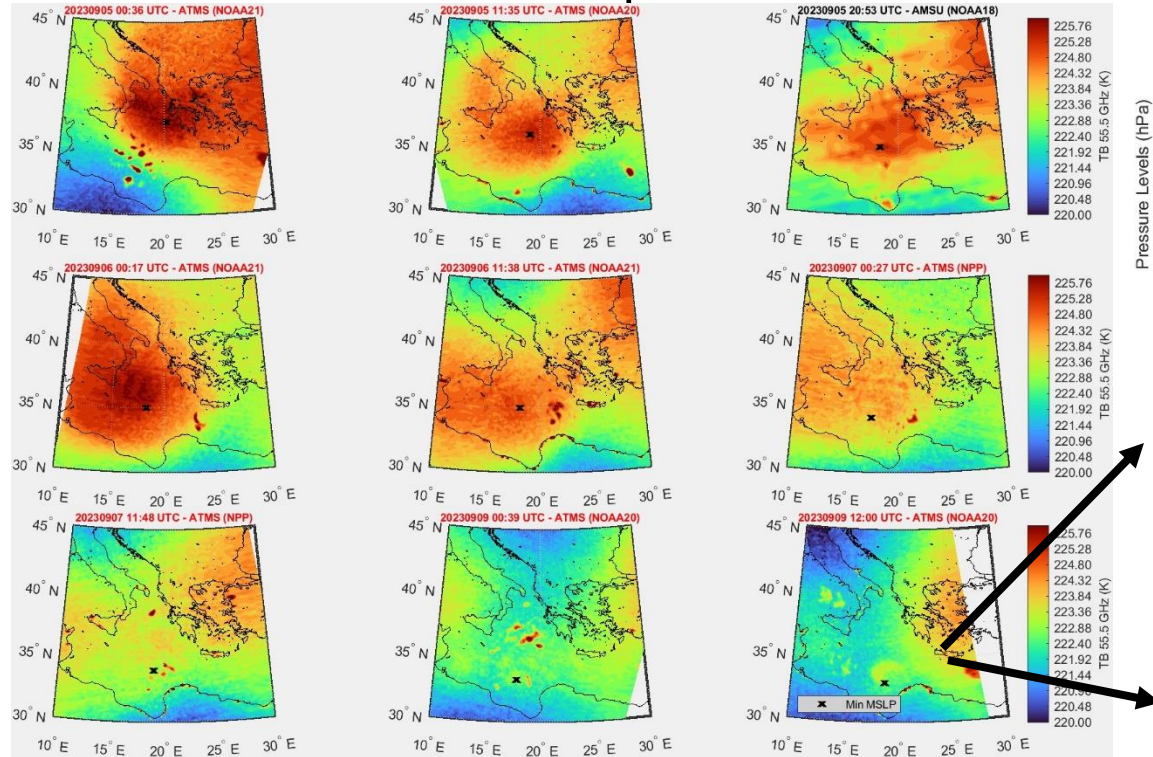

TB anomaly vertical cross section
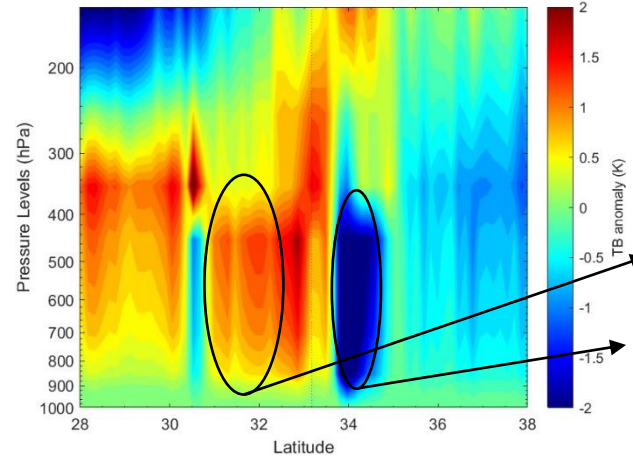
- ✓ Max TB positive signal between 400 and 500 hPa
- ✓ Max TB anomaly slightly higher than 2 K
- ✓ WC extension up to 200 hPa
- ✓ Bottom-top WC development
- ✓ Signal in the lower troposphere is due to land
- ✓ TB cooling due to the ice scattering within convective core

✓ Stratospheric warm air intrusion affected the region from 5 Sep through 7 Sep 2023

✓ Warming of the upper troposphere/lower stratosphere visible again on 9 Sep 2023

ATMS high frequency channels

183±7 GHz   CTH   IWP

Daniel showed the presence of DC close to the cyclone centre and the bottom-top WC development
Daniel underwent tropical transition

✓ Marked scattering signal at all high frequency channels close to the cyclone centre

✓ TB cooling at 89 GHz highlights the presence of heavy ice particles

Daniel

- Why Daniel showed medicane's features and underwent tropical transition only just before the landfall?
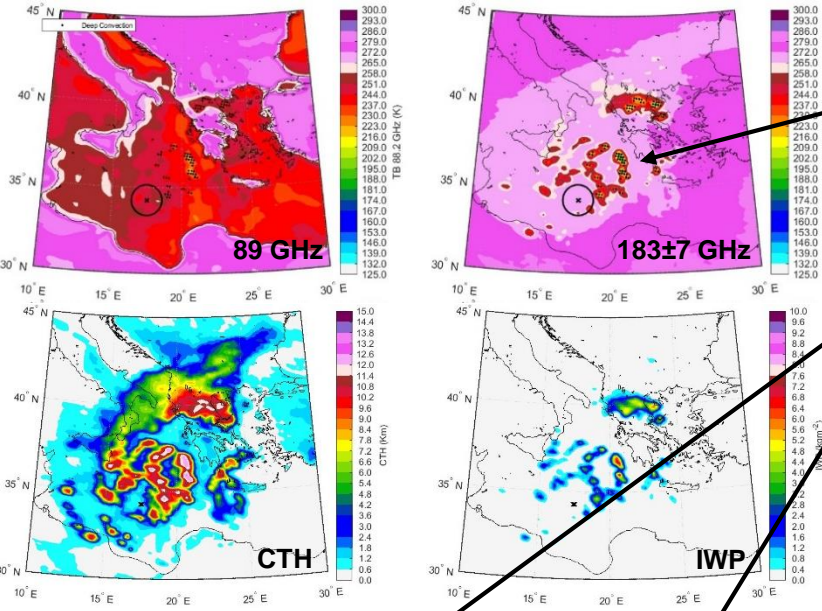

✓ Daniel stayed more the 4 days over the Ionian Sea
✓ In the initial phases, the DC was scattered, weak and far from the cyclone centre
✓ In the mature stage, the DC became organized, more intense (TB cooling at 89 GHz) and close to the cyclone centre
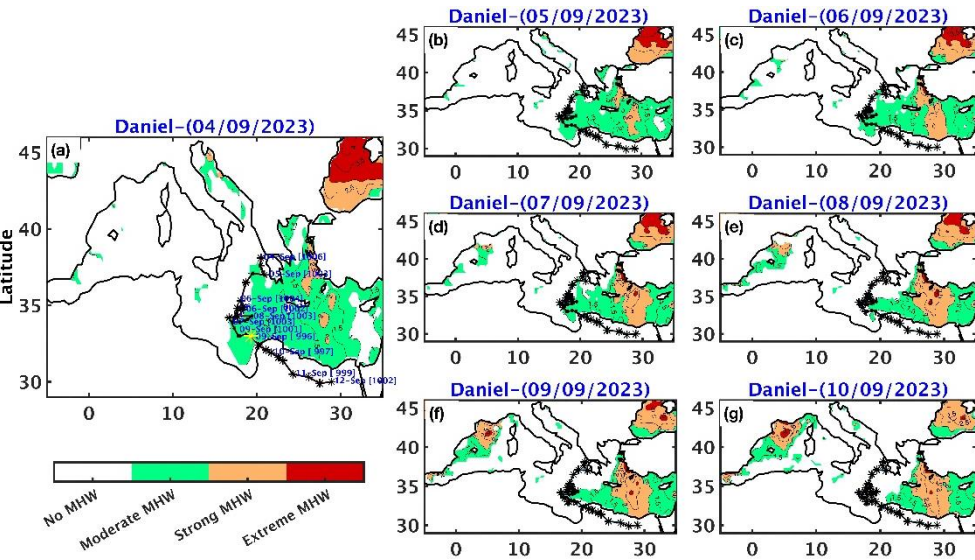✓ Are we able to explain this evolution?

Analysis of Total Precipitable Water (TPW)

- Increase of TPW in the region close to the cyclone centre
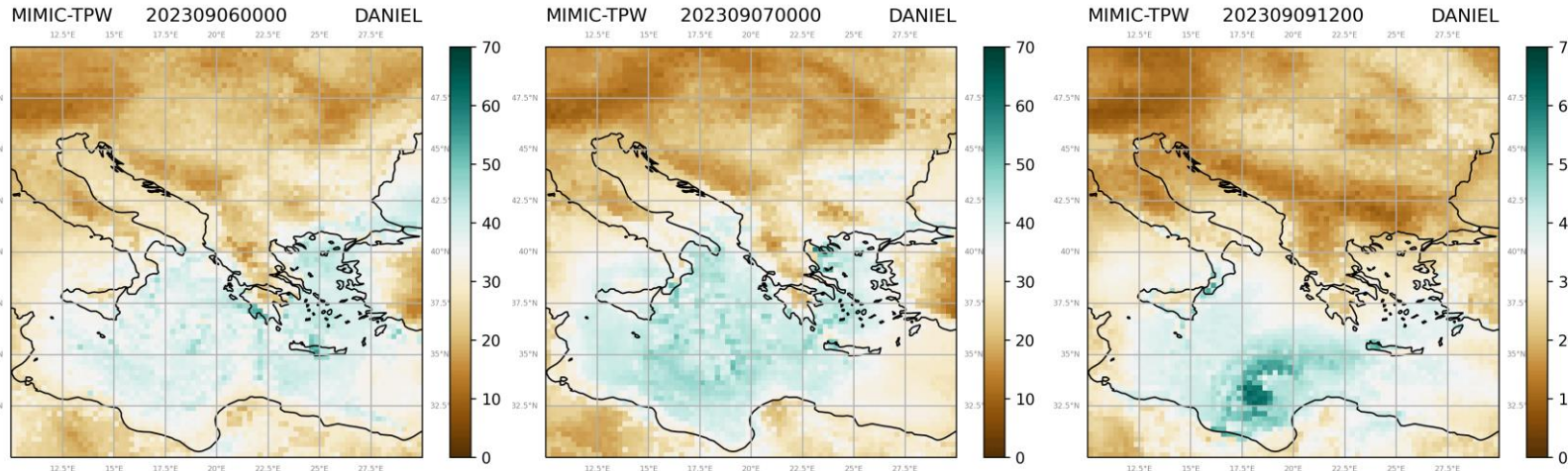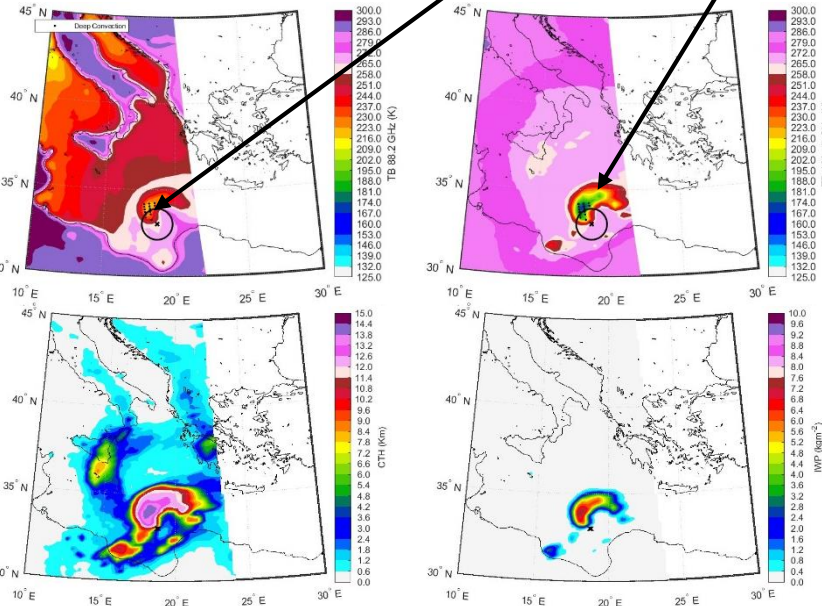
Daniel – Air-Sea Interaction

Marine Heatwave

Ocean Heat Content

- ✓ Daniel overpassed a moderate marine heatwave (MH) providing additional strength to the cyclone
- ✓ Considerable amount of ocean heat content (OHC) was available in the offshore the Libyan coasts

DC more organized and active

Overpass on the MH

Release of latent heat

Increase of TPW
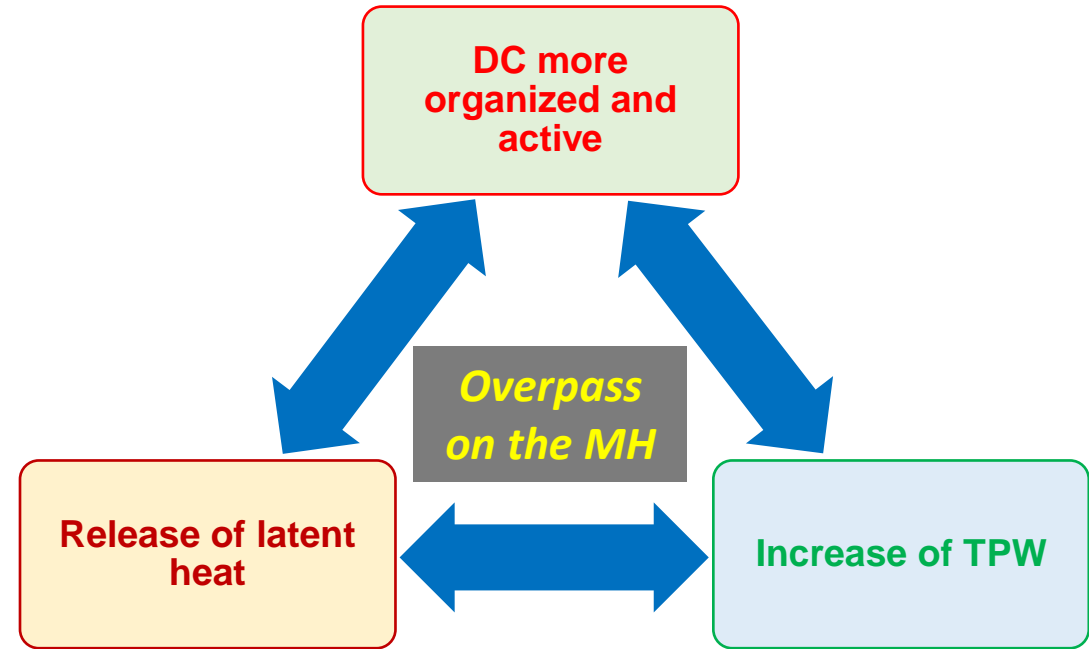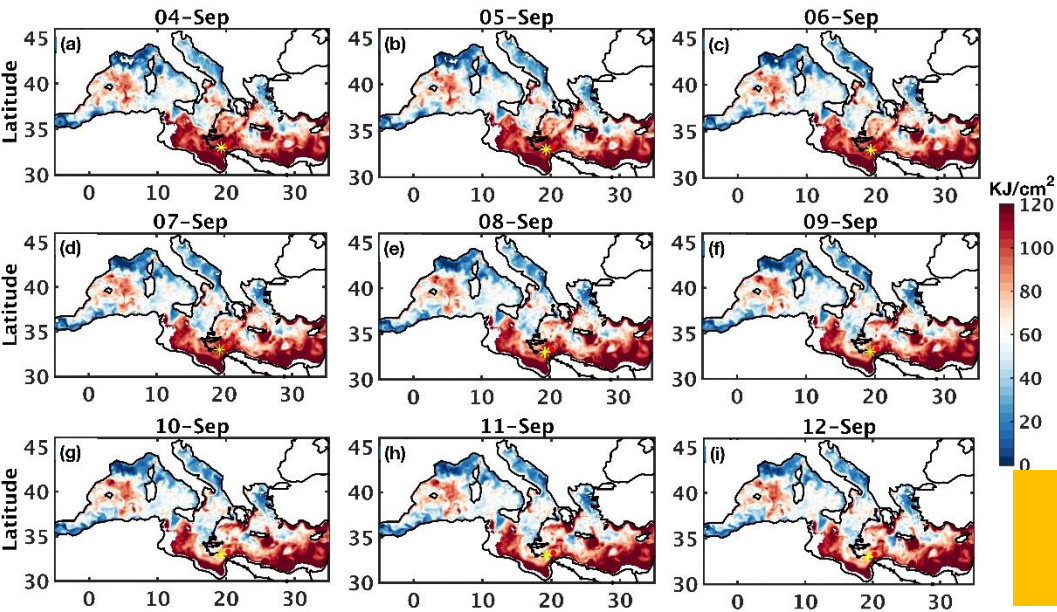
- ✓ Positive air-sea interaction feedbacks which provided addition power to Daniel favouring the tropical transition

Courtesy of Babita Jangir Jangir et al., 2024 (In preparation)

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Conclusions

- Satellite passive microwave (PMW) radiometers provides useful measurements for identification and characterization of phenomenological features and physical processes in medicanes

- Presence and origin of the warm core, presence of the closed eye, wind field structure can be inferred from PMW measurements

- Deep convection features allow to identify a tropical transition for Juliette and Daniel, but not for Helios

- In addition, the analysis of air-sea interaction shed lights on the reason why Daniel showed medicane's features and went under tropical transition only in the last part of its lifetime

- Compound analysis of atmospheric and marine parameters provides useful results in characterizing the physical processes responsible for medicane formation

Thank you for your attention!

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