



Satellite-based characterization of Mediterranean tropical-like cyclones (Medicanes)



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2 LMD & LadHyX, CNRS, 'Ecole Polytechnique, Institut Polytechnique de Paris, Palaiseau, France

3 Institute of Environmental Research and Sustainable Development, National Observatory of Athens, Athens, Greece

4 Data4Risk, Paris, France

5 CESBIO, Université de Toulouse, CNES/CNRS/INRAE/IRD/UT3

6 Cooperative Institute of Meteorological Satellite Studies (CIMSS) - University of Wisconsin-Madison



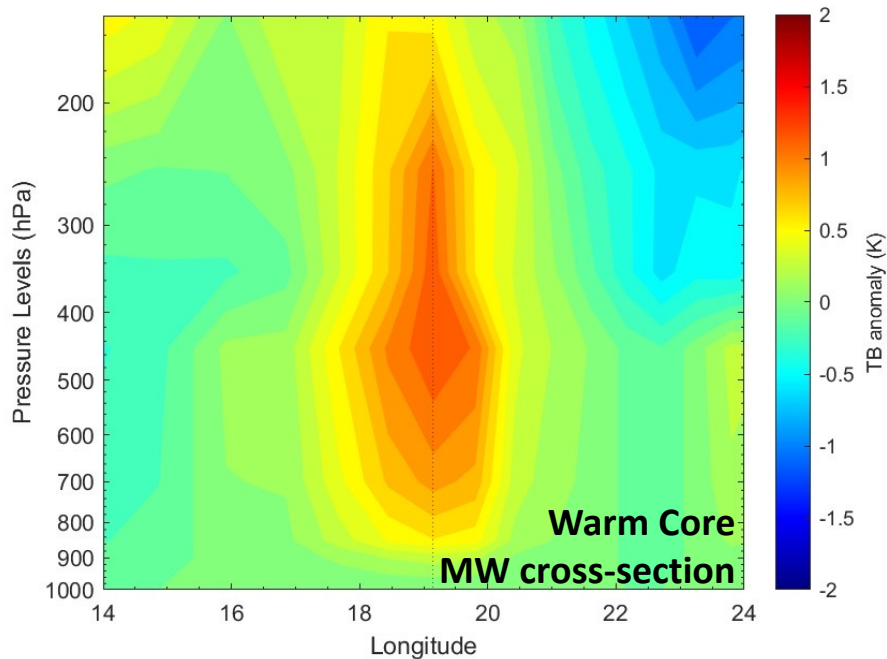
**18th Plinius Conference on Mediterranean Risks – Chania, Crete
30 September – 3 October 2024**



What is a Medicane?

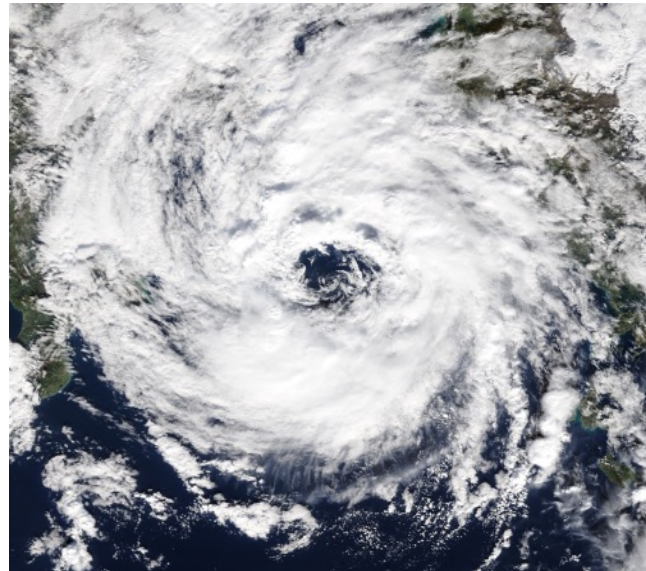
A **Medicane** or **Tropical-Like Cyclone (TLC)** is a mesoscale system which develops in the Mediterranean Sea and displays characteristics similar to Tropical Cyclones (TC):

Presence of **Warm Core (WC)**



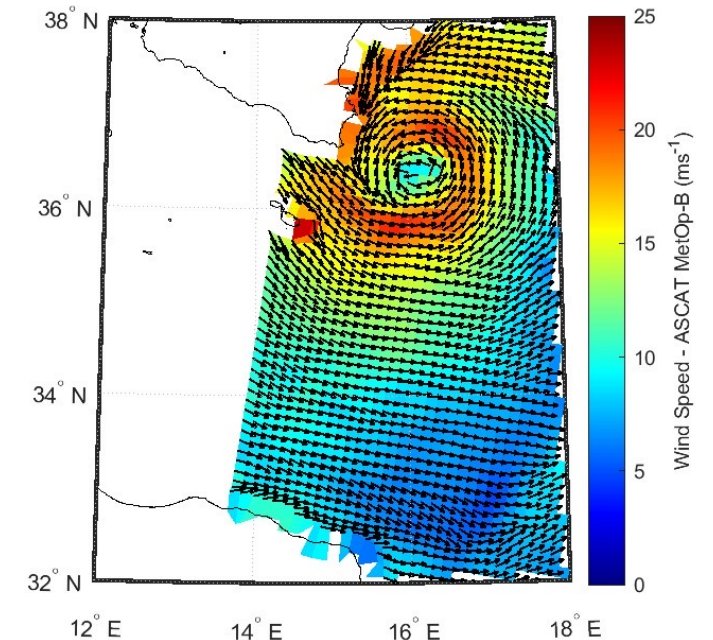
MW vertical cross-section of TB anomaly for medicane Zorbas, 29 Oct. 2018.

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



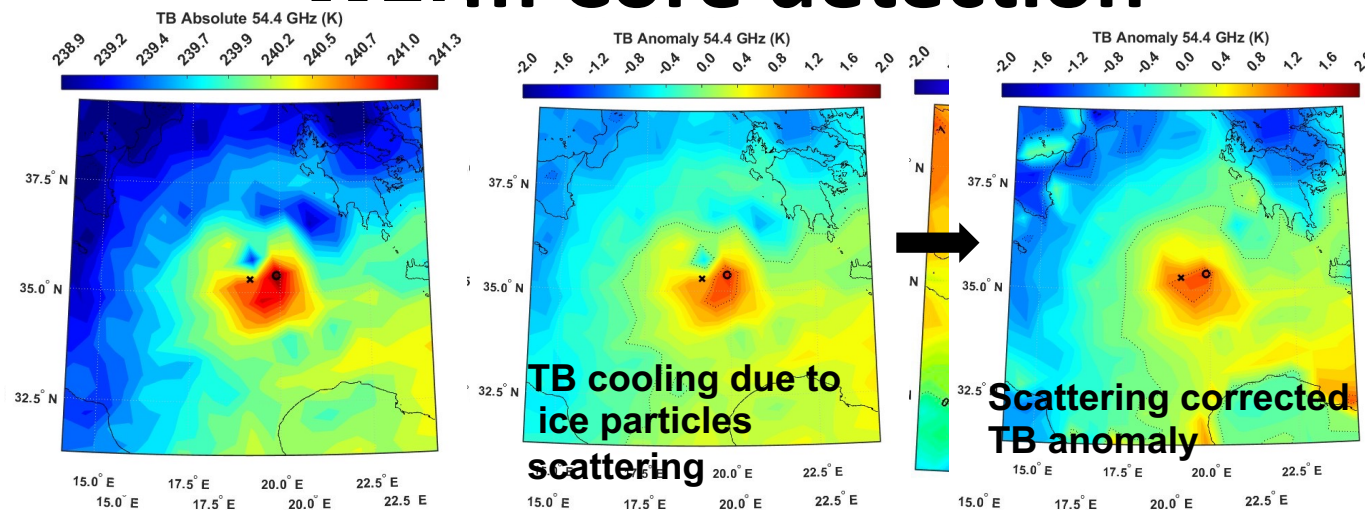
Medicanne “Numa” MODIS Terra VIS image, 18 Nov. 2017

Nearly-closed surface wind field with maximum speed within a few tens of km from the center



Medicanne “Apollo” ASCAT wind field 29 Oct. 2021

Warm Core detection



T sounding channels 54-55 GHz

(TB anomaly at 600-200 hPa)

Well established methodology for Tropical Cyclones

Panegrossi et al., Rem. Sensing, 2023

D'Adderio et al., Atmos. Res., 2024

In TC TB warm anomaly is related to storm intensity (min MSLP and max wind) (Herndon and Velden, 2021)

DC and closed eye detection

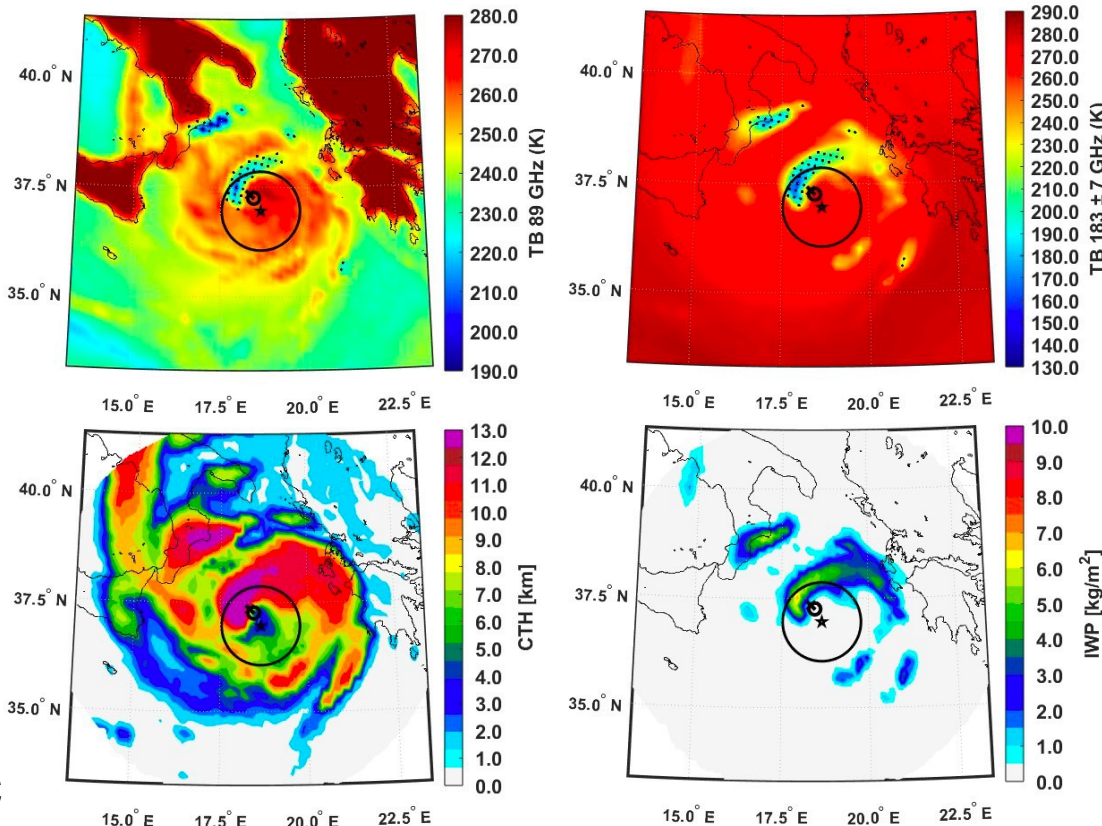
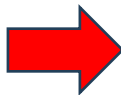
High Frequency channels 89-190 GHz:

Deep convection detection

Cloud Top Height Estimation

Ice water Path estimation

(DeepStorm *Rysman et al., JGR, 2021*)



Medicane – Tropical Transition

Tropical transition <-> WC sustained by diabatic processes

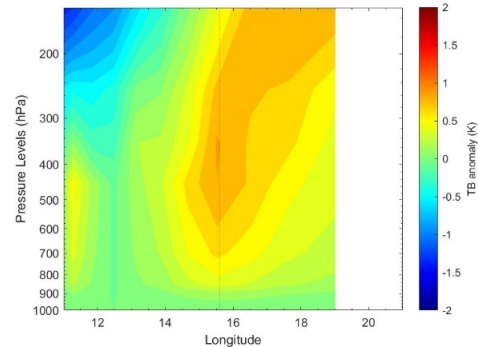
Goal: demonstrate that satellite data provide useful tools to identify tropical transition

- ✓ Closed surface wind circulation, center of rotation, RMW (see Poster P11, Session PL2, Wed.)
- ✓ Detection of axy-symmetric vertically aligned WC
- ✓ Deep convection close to the cyclone centre
- ✓ Closed-eye

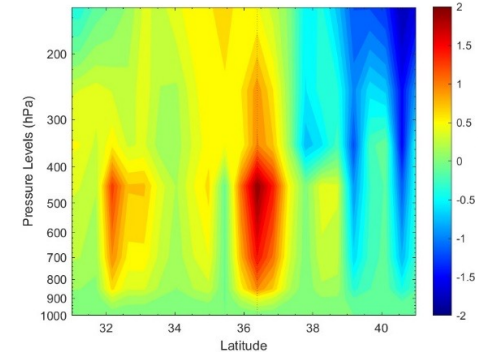
WC detection and characterization

- ✓ Development phase
 - ✓ Top-down WC
 - ✓ WC originating from baroclinic processes (stratospheric warm air intrusion)
- ✓ Tropical Transition
 - ✓ Bottom-up WC
 - ✓ WC originating from diabatic processes (air-sea interaction and latent heat release)

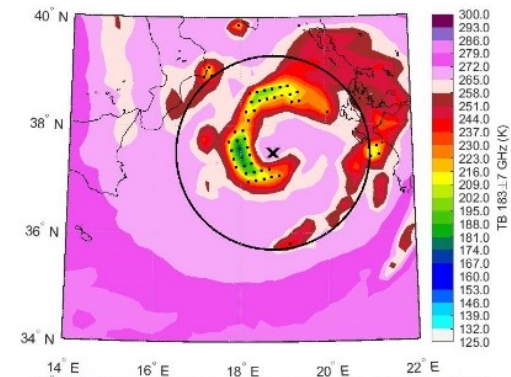
Apollo
26 Oct 2021 – 09:22 UTC



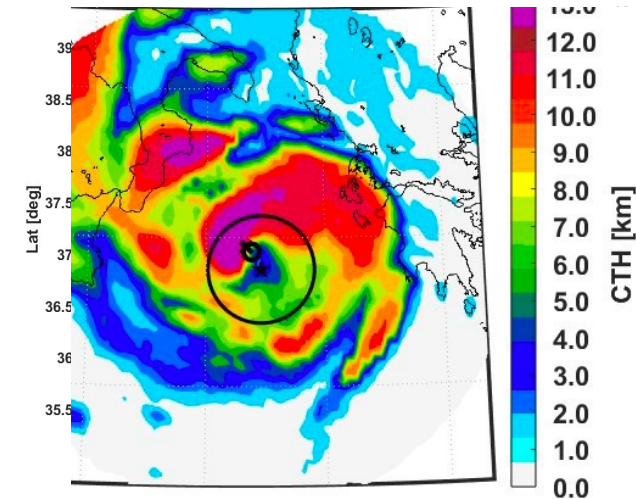
Apollo
29 Oct 2021 – 08:20 UTC



Cloud and deep convection features

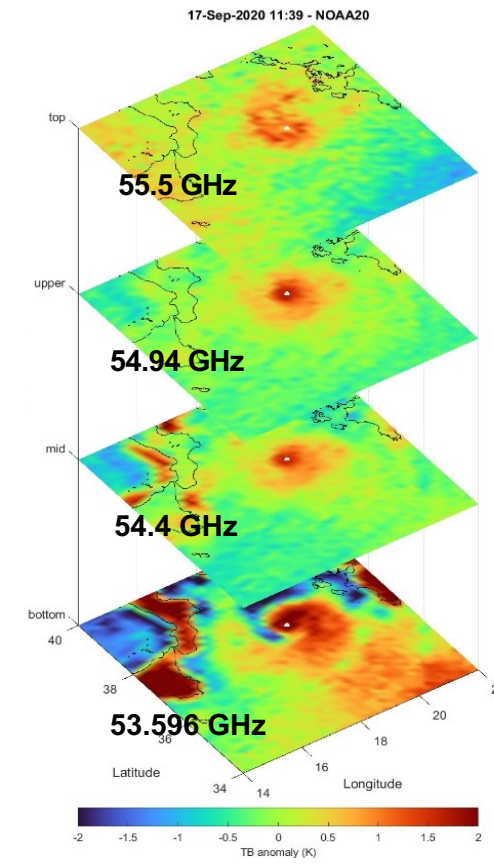


Deep
Convection
distribution and
intensity



Automated
closed eye
detection
within WC
area
(IWP~0 kg/m²
CTH < 5 km)

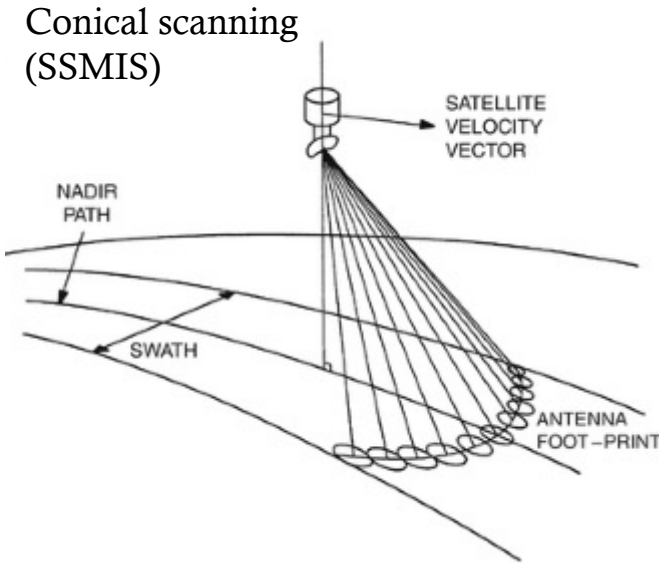
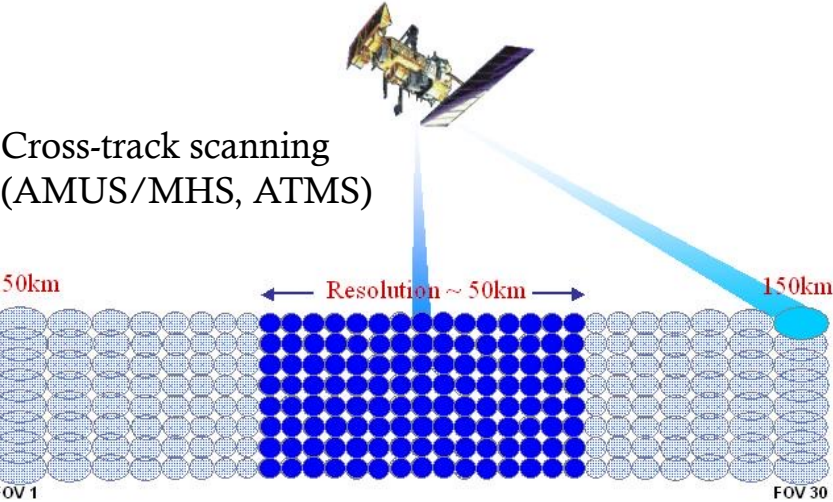
Di Francesca et al., Atmos. Res. in review



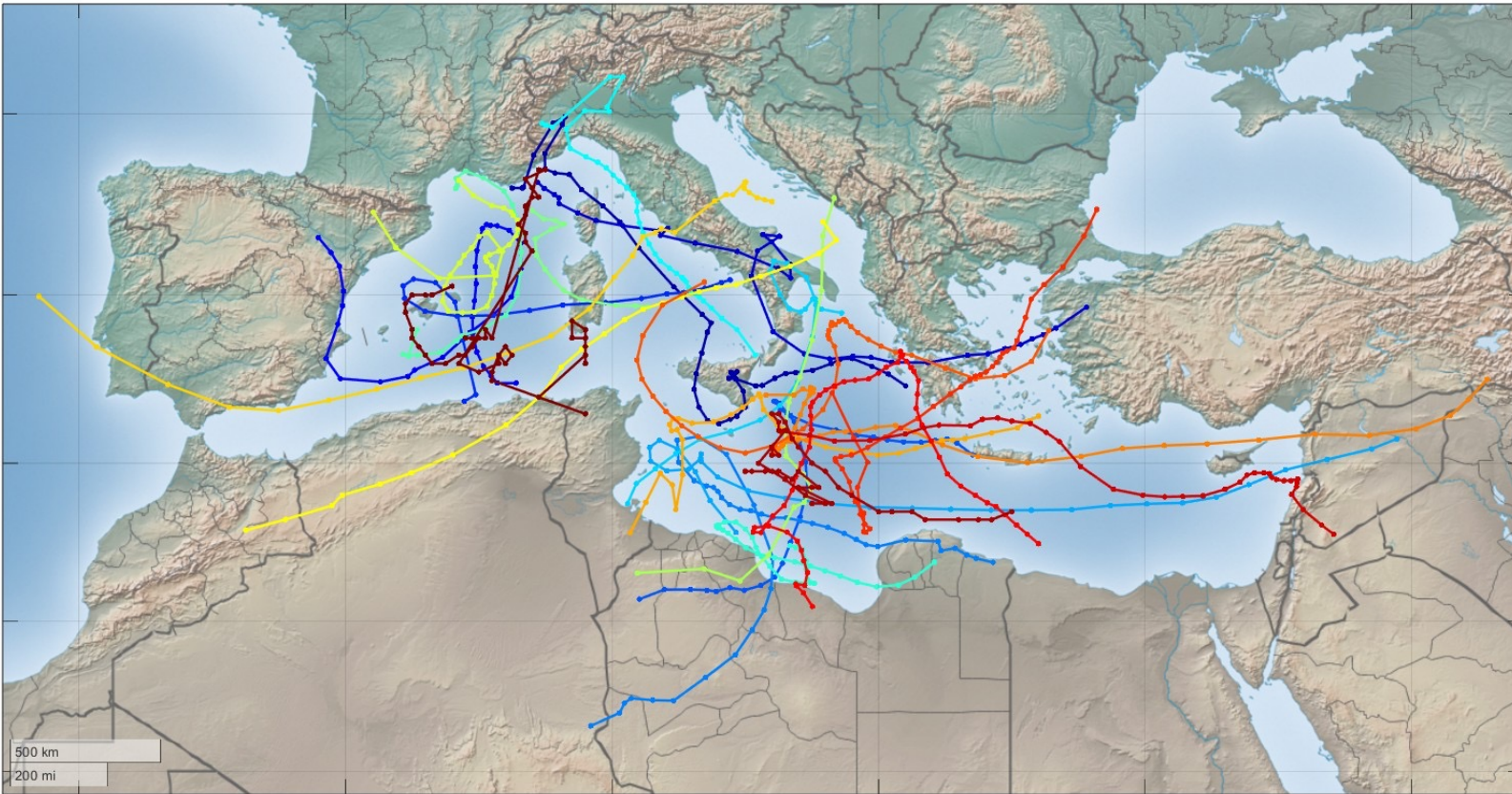
Passive Microwave Radiometry – Instruments & Frequencies

	AMSU-A/B - MHS	SSMIS	ATMS
Satellites	NOAA15/16/17/18/19, MetOp-A, MetOp-B, MetOp-C	F16, F17, F18	S-NPP, NOAA20
Scanning Type	Linear cross-track	Conical	Cross-track
54 GHz channels resolution	48 km (nadir); 150 km x 80 km (swath's edge)	25.8 km x 17.5 km	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)	14.4 km x 13.1 km	15.8 km (nadir); 68.4 km x 30 km (swath's edge)

Frequency (GHz)	Application
53.596	Atmospheric T at 600 hPa (~4 km)
54.4	Atmospheric T at 450 hPa (~6 km)
54.94	Atmospheric T at 300 hPa (~9 km)
55.5	Atmospheric T at 250 hPa (~12 km)
89	TB warming due to cloud water emission + TB cooling due to scattering by graupel-hail
183.31 ±7	TB warming due to WV emission + TB cooling due to scattering by cloud ice ~ 6 km
183.31 ±3	TB warming due to WV emission TB cooling due to scattering by cloud ice ~ 9 km
183.31 ±1	TB warming due to WV emission emission TB cooling due to scattering by cloud ice ~ 12 km



Observational Dataset



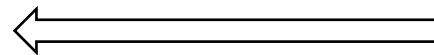
Tracks of the 23 case-studies cyclones.

Dataset provided by MedCyclones COST Action - WG1

**Total of parsed satellite
overpasses = 447**

AMSU/MHS, ATMS, SSMIS MW radiometers

Di Francesca et al., under review



**+ 3 medicanes in 2023
Helios, Juliette, Daniel**

Name (Year)	AMSU/SSMIS/ATMS	TOT
Unnamed (2000)	8/0/0	8
Unnamed (2000)	7/0/0	7
Fernando (2003)	16/0/0	16
Adelina (2003)	13/0/0	13
Unnamed (2004)	8/0/0	8
Unnamed (2004)	13/0/0	13
Zeo (2005)	14/6/0	20
Maria (2006)	15/6/0	21
Antinoo (2007)	18/5/0	23
Ortensiano (2007)	21/5/0	26
Unnamed (2007)	11/4/0	15
Unnamed (2007)	8/2/0	12
Unnamed (2008)	9/2/0	11
Rolf (2011)	25/14/0	39
Unnamed (2012)	17/9/0	26
Ilona(2014)	22/4/6	32
Qendresa (2014)	15/3/3	21
Trixie (2016)	11/0/6	17
Numa (2017)	12/0/6	18
Zorbas (2018)	12/0/9	21
Ianos (2020)	8/0/15	23
Unnamed (2020)	14/0/13	27
Apollo (2021)	16/0/14	30

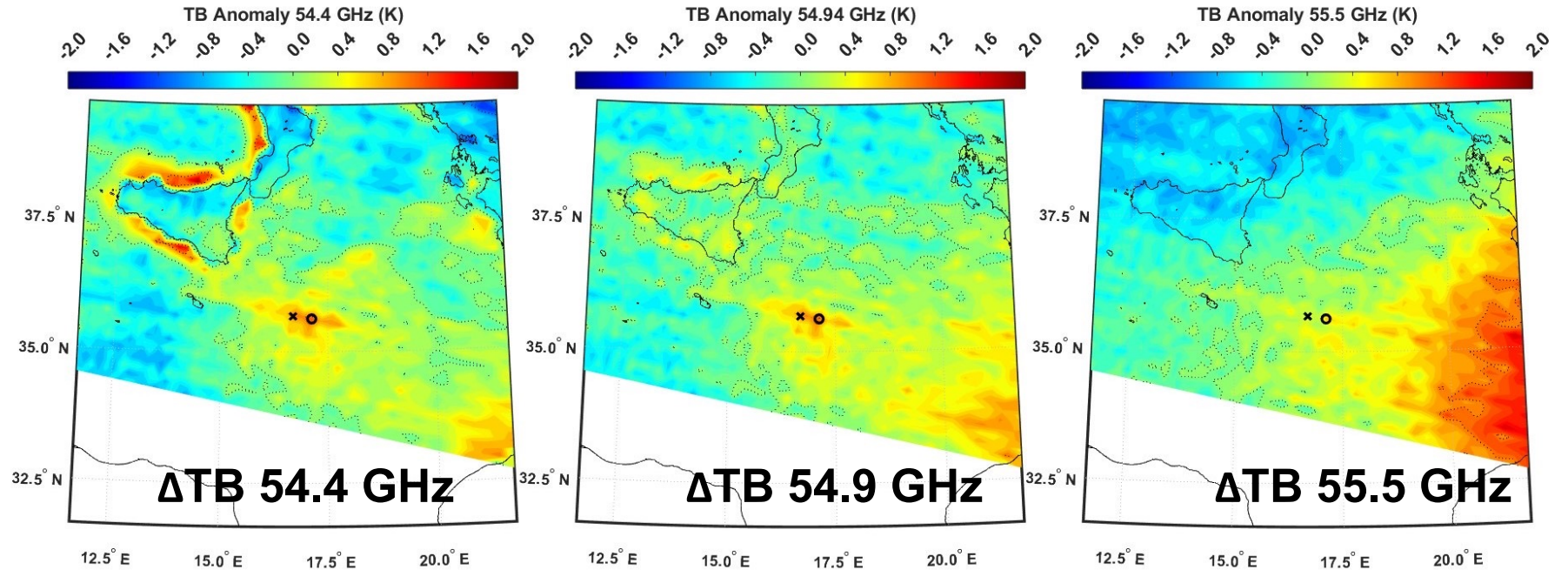
Results: Warm Core Analysis

Trixie (October 2016)

ATMS – SNPP
30/10/16 00:55 UTC

Development stage:

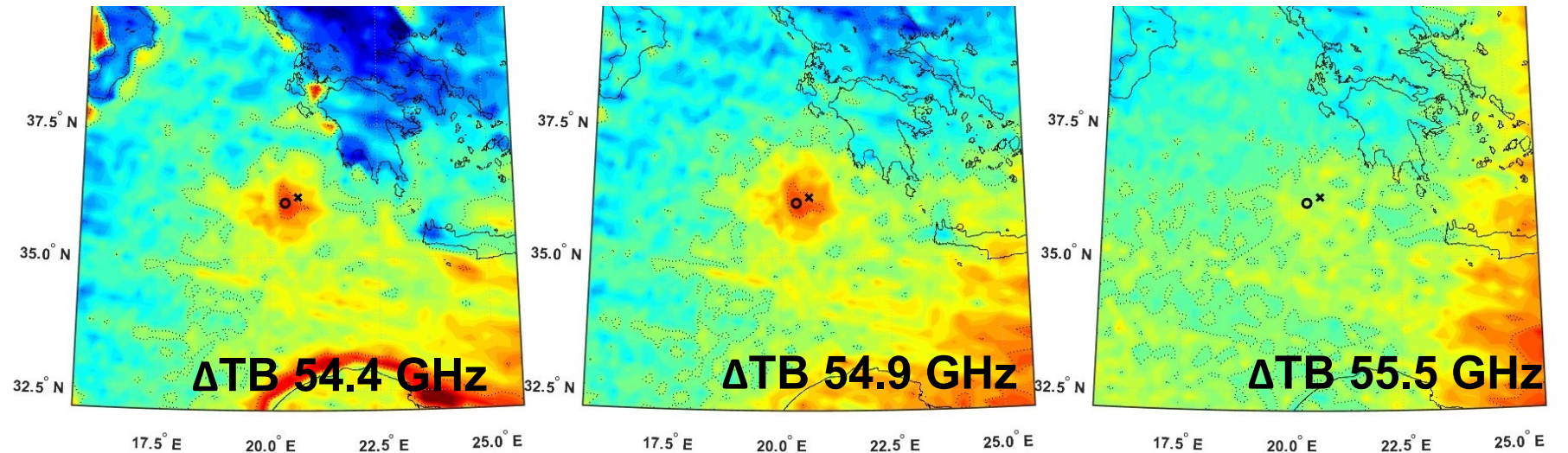
- **shallow**
- **irregular**
- **weak**



ATMS – SNPP
31/10/16 00:38 UTC

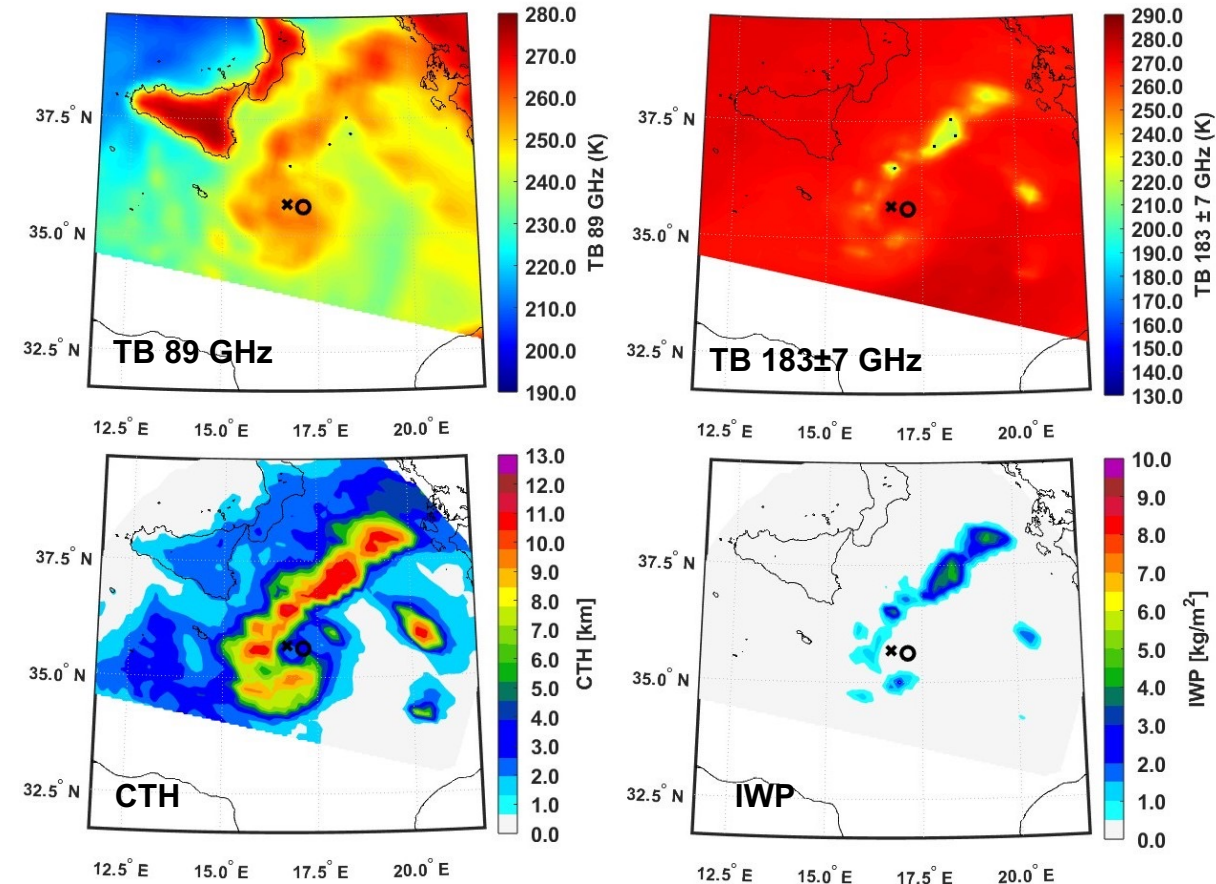
Mature stage:

- **shallow**
- **symmetric**
- **intense**



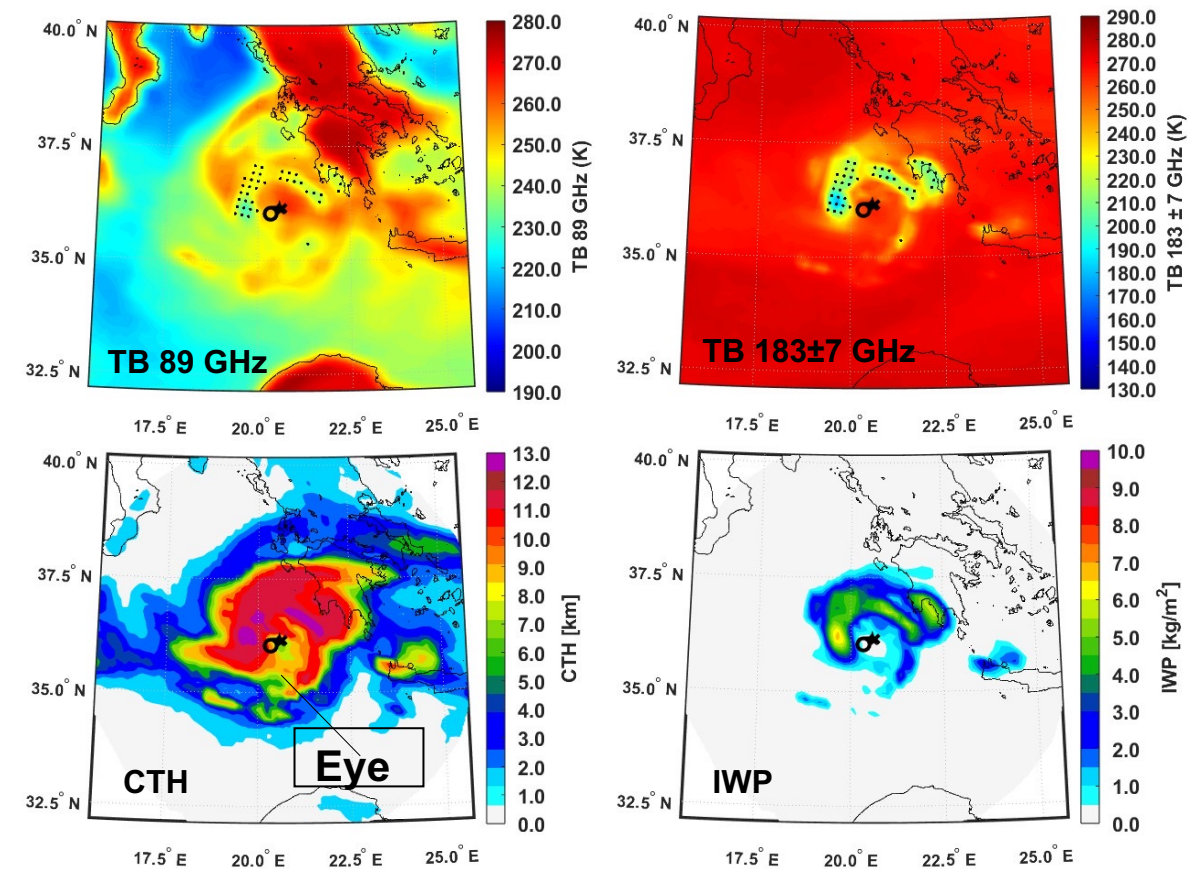
Results: Trixie Analysis (October 2016)

Development Stage



- **DC almost absent**, far from the centre
- **Low CTH** near the centre (< 7 km)
- **Very low IWP** near the centre (<1.5)

Mature Stage



- **Closed eye**
- **Organized and intense DC** within 100 km
- **CTH ranging from 11 to 13 km** near the centre
- **Extensive and high IWP** near the centre (> 5 km)

Results: Warm Core Analysis

Fernando (May 2003)

ATMS – SNPP
30/10/16 00:55 UTC

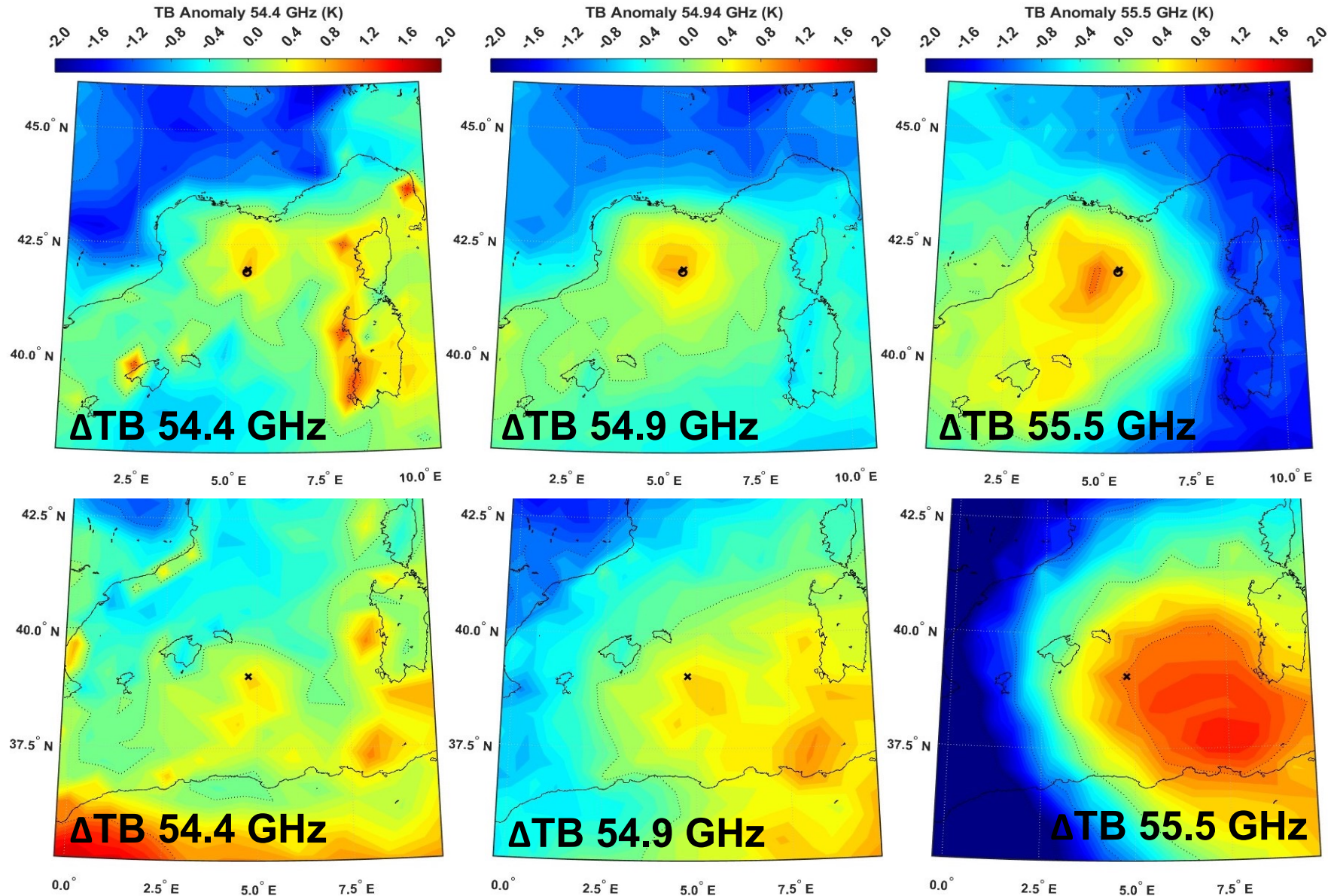
Development stage:

- **shallow**
- **irregular**
- **weak**

ATMS – SNPP
31/10/16 00:38 UTC

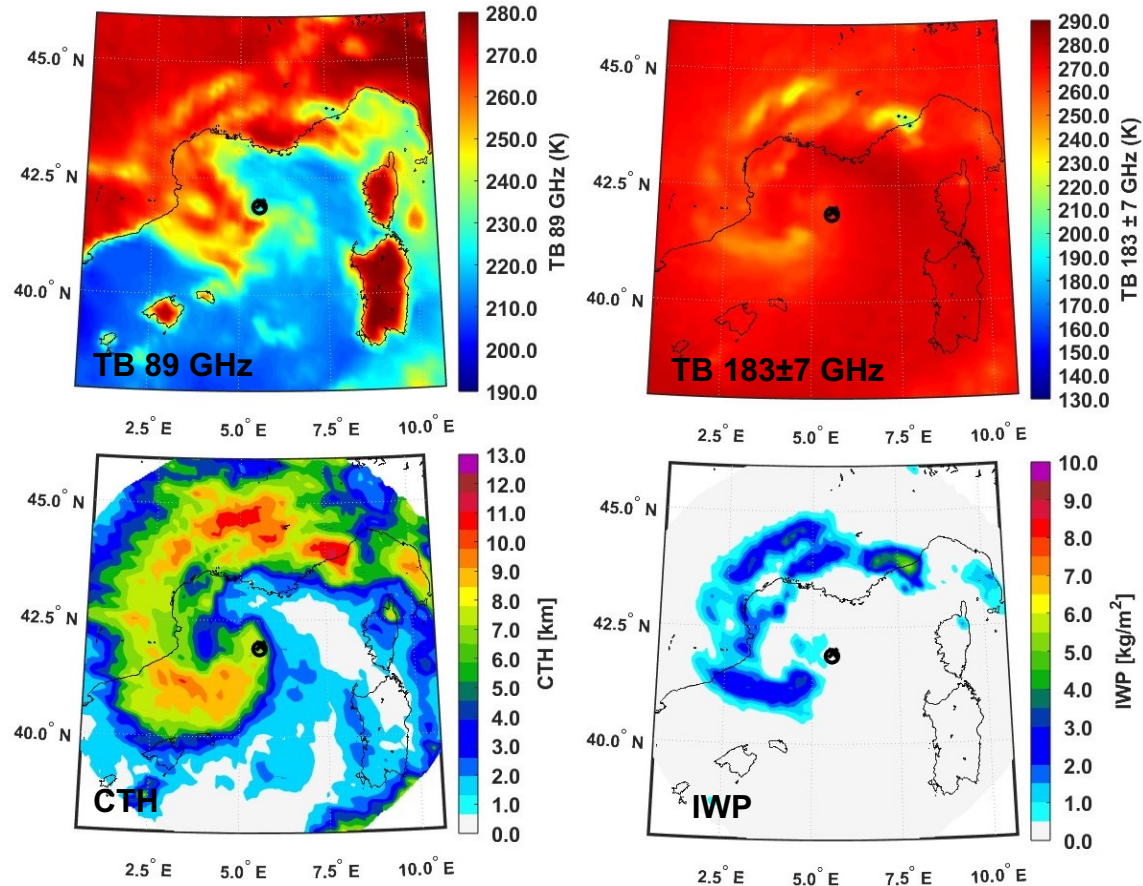
Mature phase:

- **Irregular**
- **indication of top-down development**



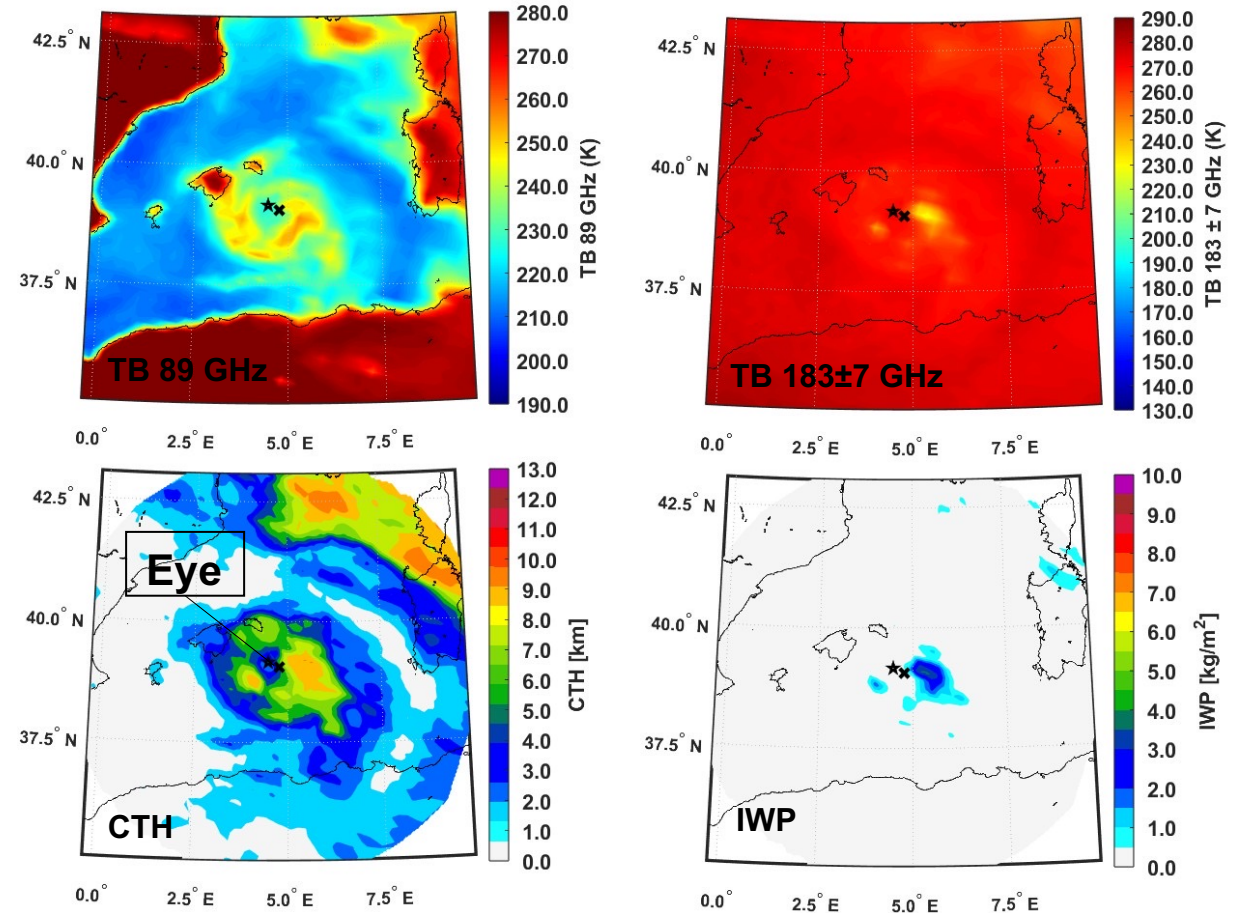
Results: Fernando Analysis (May 2003)

Development Stage



- DC almost **absent**, far from the centre
- **Low CTH** near the centre (< 7 km)
- **Very low IWP** near the centre (<1.5)

Mature Stage



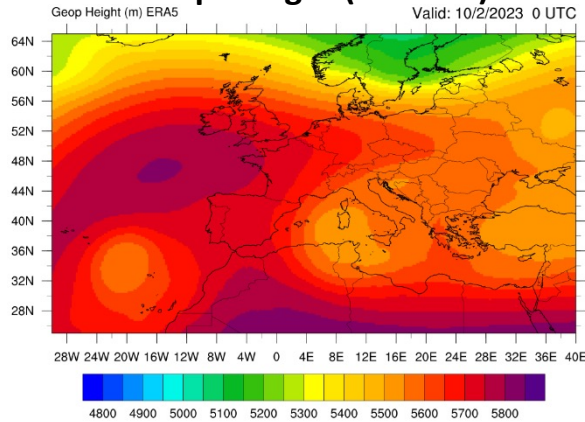
- **Closed eye**
- **DC absent within 100 km** from the centre
- **Low CTH** near the centre (< 7 km)
- **Low IWP** near the centre (< 2.5)

Did the 3 most recent medicanes undergo a tropical transition?

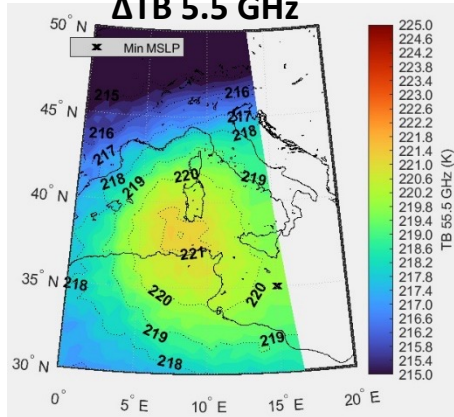
Helios

- 8 - 10 Feb 2023
- South Mediterranean

Geop. Height (500 hPa)



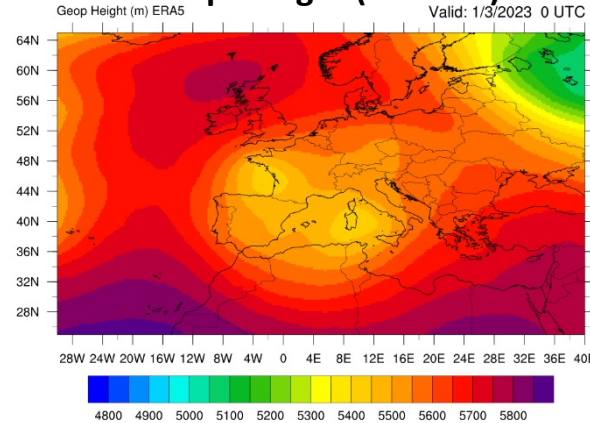
ΔTB 5.5 GHz



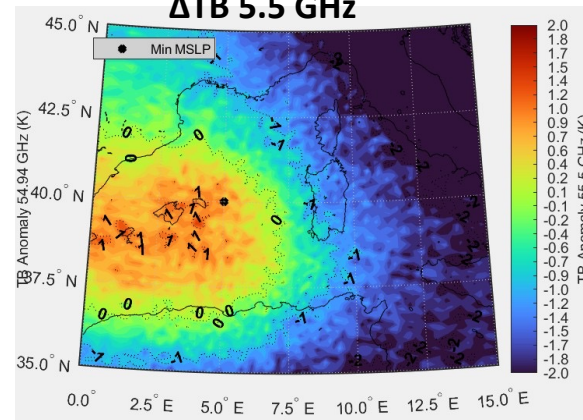
Juliette

- 27 Feb – 3 March 2023
- West Mediterranean

Geop. Height (500 hPa)



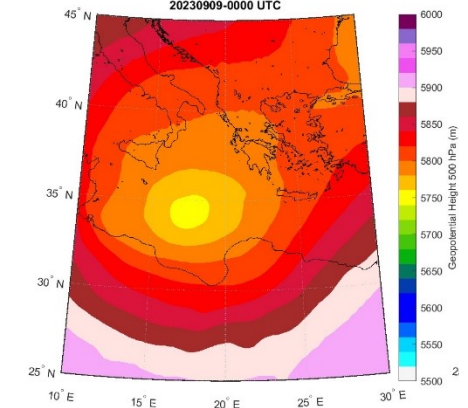
ΔTB 5.5 GHz



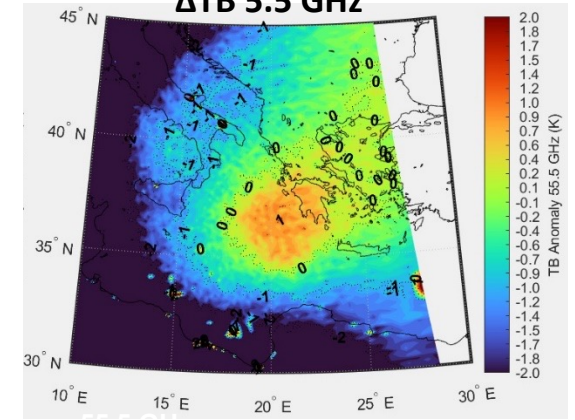
Daniel

- 5- 10 Sep 2023
- Ionian Sea

Geop. Height (500 hPa)



ΔTB 5.5 GHz



Development phase: stratospheric warm air intrusion evidenced by TB anomaly at 55.5 GHz (200 hPa)

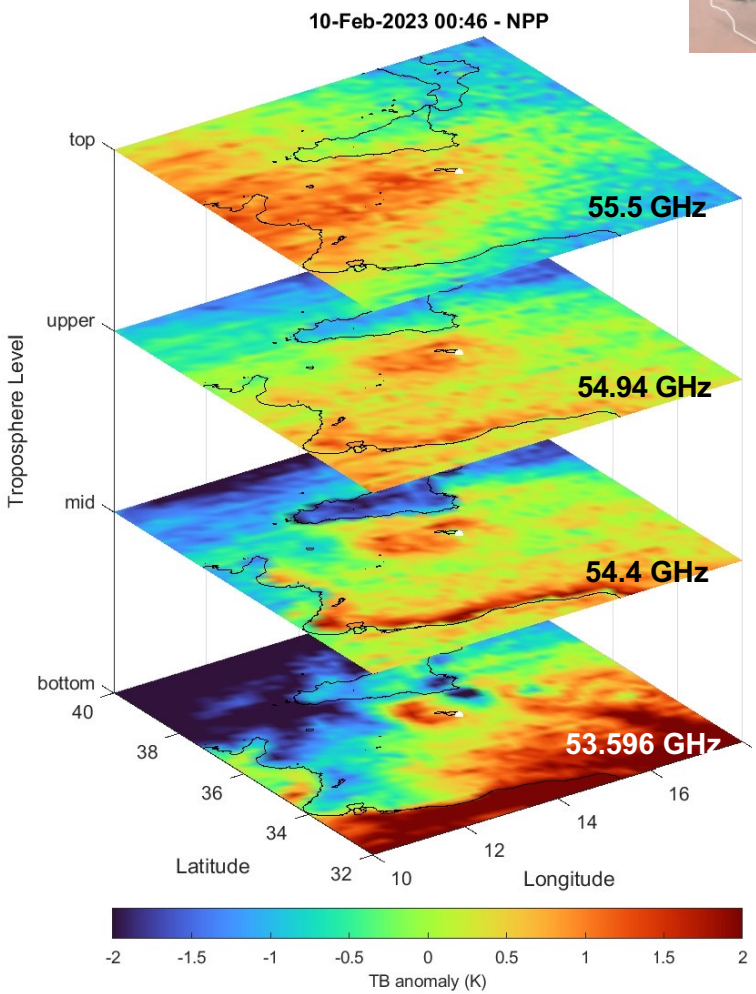
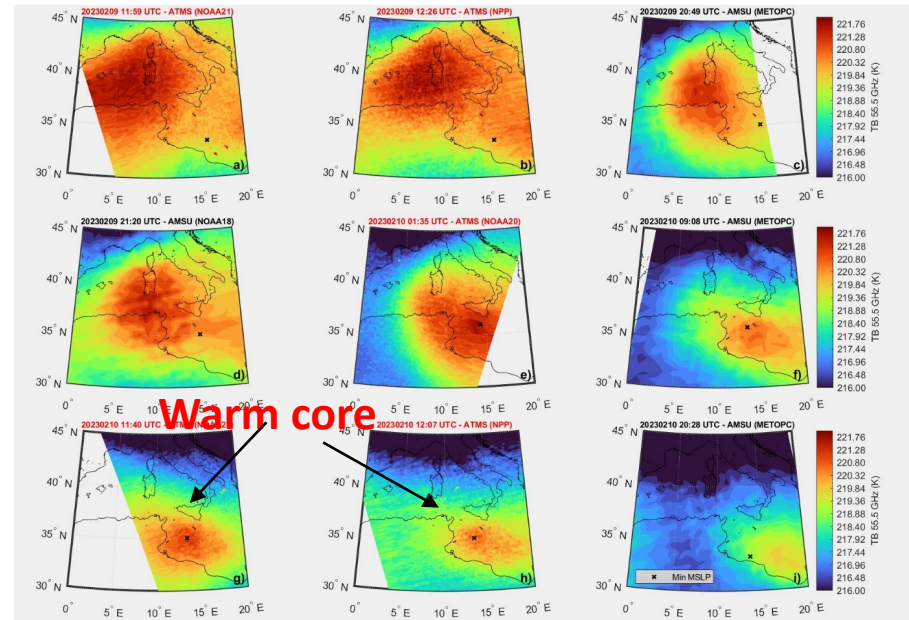
Helios

8-10 Feb 2023

- ✓ Spiralling cloud structure
- ✓ Closed-eye not detected

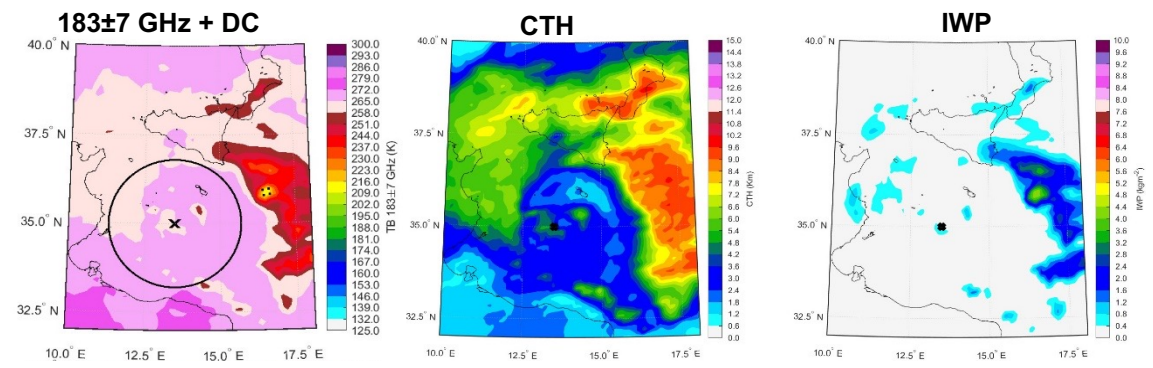


Evolution of the TB map at 55.5 GHz (9-10 Feb 2023)



- ✓ **Top-down development WC**
- ✓ The WC shape is quite well defined at 54.4 and 54.94 GHz
- ✓ Positive TB anomaly at 55.5 GHz indicates stratospheric intrusion
- ✓ 53.596 GHz affected by surface precipitation (warming) and ice scattering (cooling)

ATMS - DC features

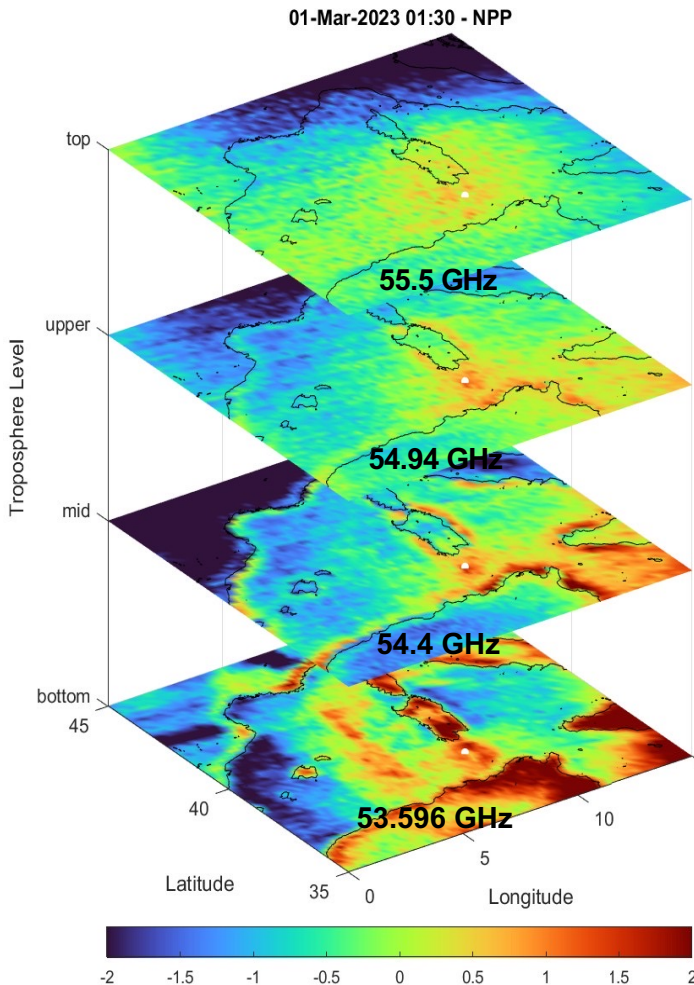


- ✓ **No scattering signal** close to the cyclone centre (no ice hydrometeors, warm rain processes)
- ✓ Deep convection only in the outer rainbands far from cyclone centre

Juliette

27 Feb – 3 March 2023

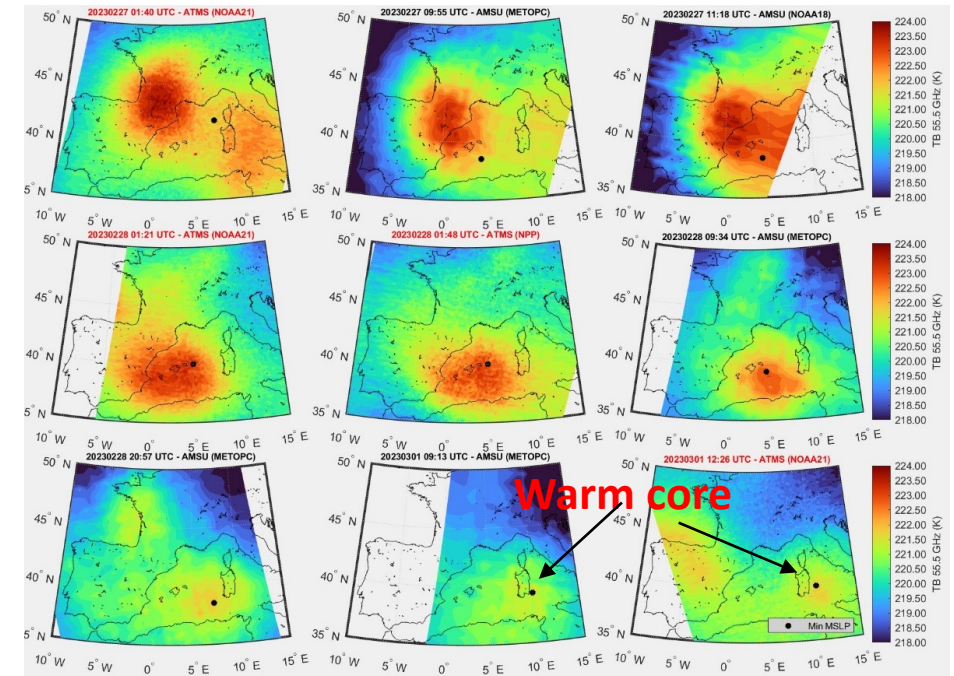
- ✓ Spiralling cloud structure
- ✓ Well defined closed eye



SEVIRI VIS 20230301 12:00 UTC

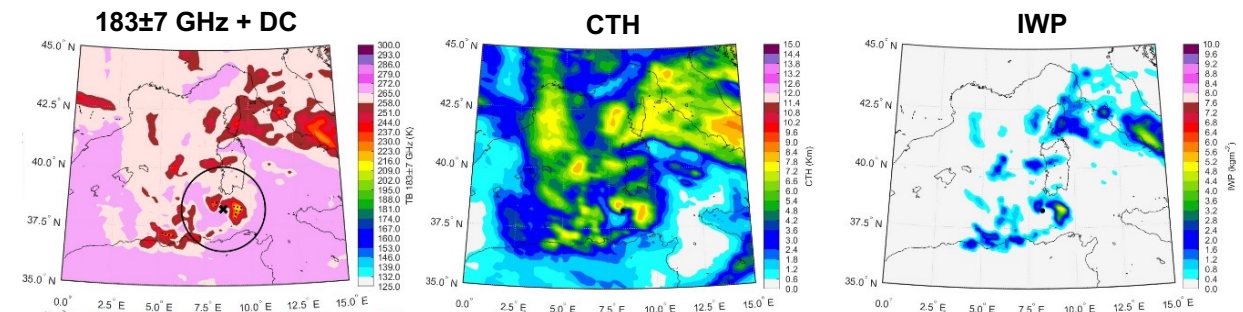


Evolution of the TB map at 55.5 GHz (27 Feb-1 Mar 2023)



- ✓ **Bottom-up** WC initial development
- ✓ Shallower and smaller well defined and marked at 54.4 and 54.94 GHz
- ✓ Contamination of land emissivity on TB anomaly signal

ATMS – DC features



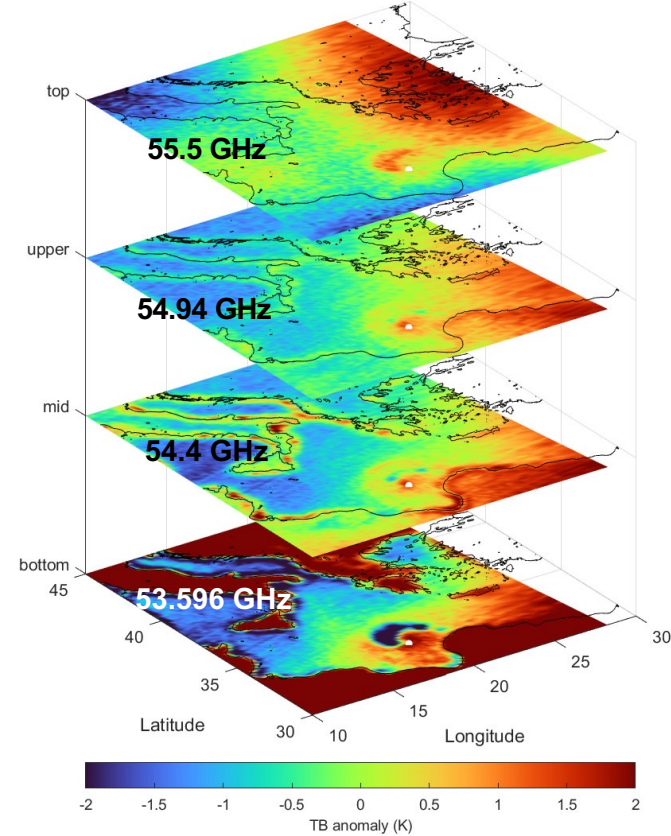
- ✓ **Weak scattering signal** close to the cyclone centre
- ✓ Nearly closed-eye
- ✓ Deep convection near the center (gets more organized at later stage)

Daniel

5-10 Sep 2023

- ✓ Spiralling cloud structure
- ✓ Not completely closed cloud-free eye

09-Sep-2023 12:00 - NOAA20

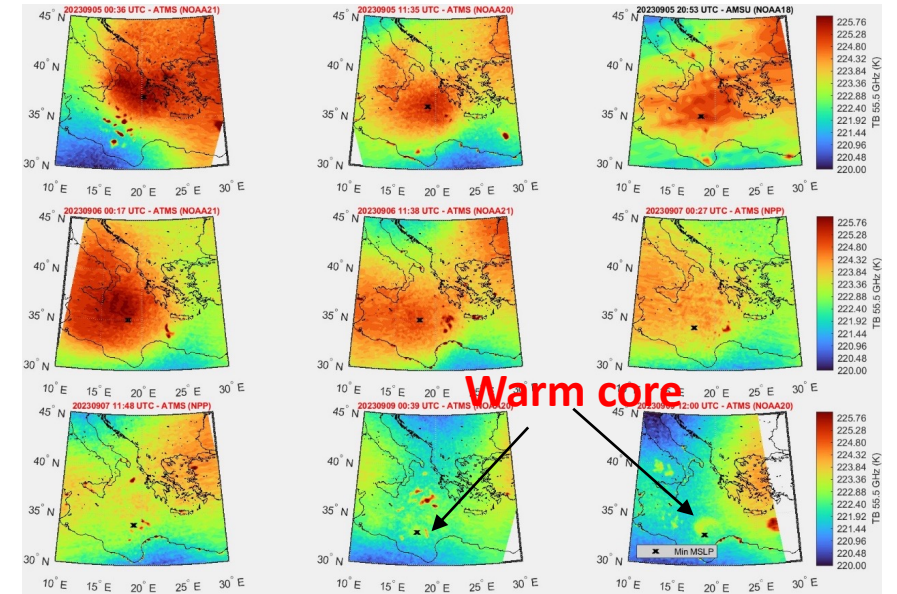


Strong indication of Tropical Transition just before making landfall in Libya

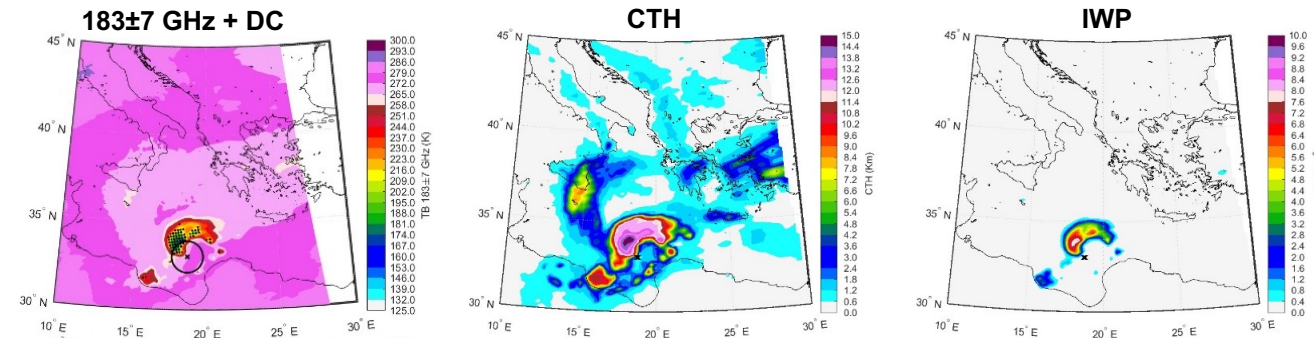


- ✓ **Deep WC bottom-up development**
- ✓ The WC is well defined and marked in all channels
- ✓ The TB signal at 53.596 GHz highlights both the presence of DC (negative TB anomaly)

Evolution of the TB map at 55.5 GHz (5-9 Sep. 2023)



ATMS – DC features



- ✓ **Strong scattering signal** close to the cyclone centre
- ✓ Nearly-closed eye
- ✓ Deep convection near the center

Conclusions

- Satellite passive microwave (PMW) radiometers provide 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, deep convection strength and organization can be inferred from PMW measurements: categorization of Type A (tropical transition) and Type B medicanes
- First EO-based contribution to definition and categorization of Medicanes

CATEGORY «A» (Tropical Transition) WC driven by diabatic processes	CATEGORY «B» Warm core driven by baroclinic processes
<ul style="list-style-type: none"> • Persistent, shallow/deep, symmetric, hor. Extended, intense, bottom-up developed WC • Extensive DC in mature stage in proximity to the center (→WC has a diabatic origin) • «Closed» eye in mature stage • Season of most likely occurrence: Sept. - Nov. • Location of occurrence: central Med., Ionian Sea 	<ul style="list-style-type: none"> • Persistent, shallow/deep, top-down developed WC • Absent or very scarce DC in mature stage; persistent stratospheric intrusion • (→WC has a baroclinic origin) • «Closed» eye in mature stage
<ul style="list-style-type: none"> • Rolf (2006/11) Numa** (2017/11) • Zorbas (2018/09) Ianos (2020/09) • Apollo** (2021/10) Trixie (2016/10) • Juliette (2023/03) Daniel (2023/09) 	<ul style="list-style-type: none"> • Fernando (2003/05) Unnamed (2007/11) • Unnamed (2008/12) Unnamed (2012/04) • Ilona (2014/01) Qendresa (2014/11) • Helios (2023/02)

Work in progress

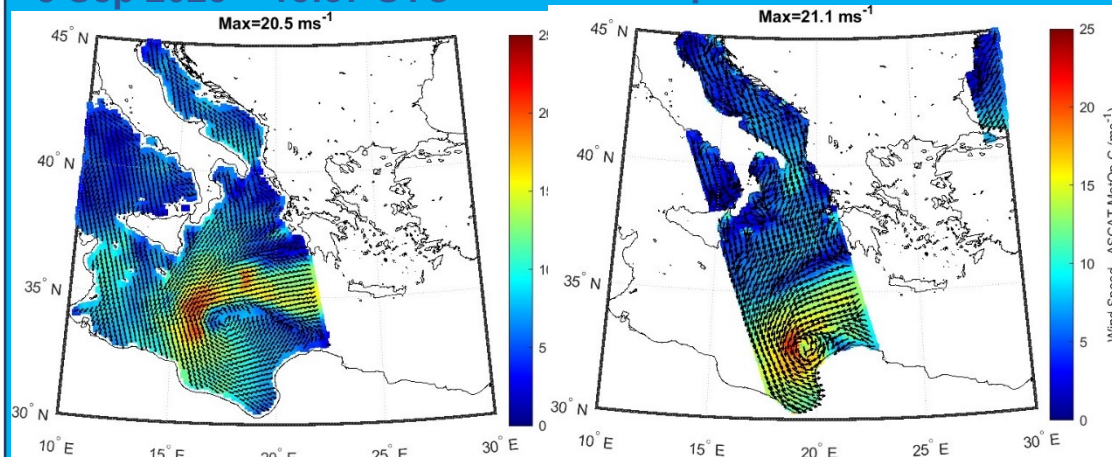
Development of **AI-based tools** for closed-eye and WC detection, and for **NRT tracking** of medicanes using PMW radiometry, ASCAT winds, and MSG VIS/R imagery

Poster P11, Session PL2, Wed.

FY-3E and ASCAT near surface winds

8 Sep 2023 – 15:37 UTC

9 Sep 2023 – 19:21 UTC



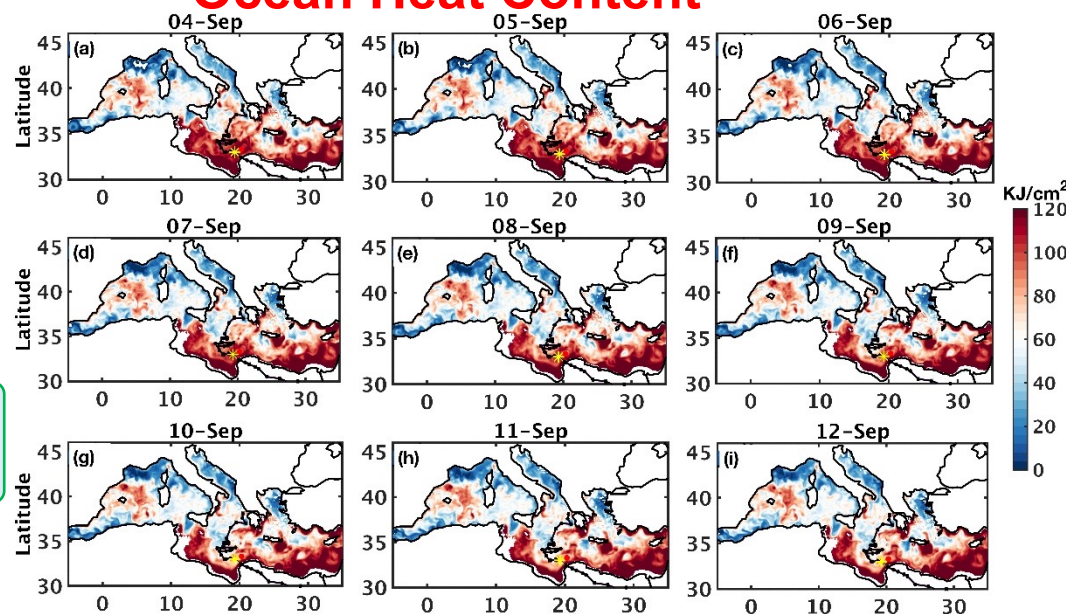
Intensification diagnostics based on PMW radiometry and near surface wind features



MEDCANES

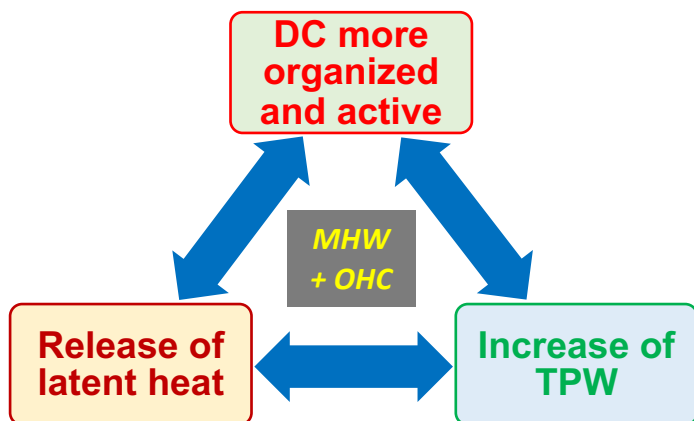
<https://medicanes.isac.cnr.it/>

Ocean Heat Content



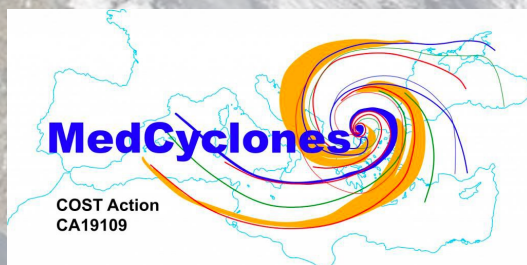
Contribution of **air-sea interaction processes** (marine heat wave and ocean heat content) **on tropical transition only** at its final stage

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



Thank you for your attention

g.panegrossi@isac.cnr.it



<https://medcyclones.eu/>

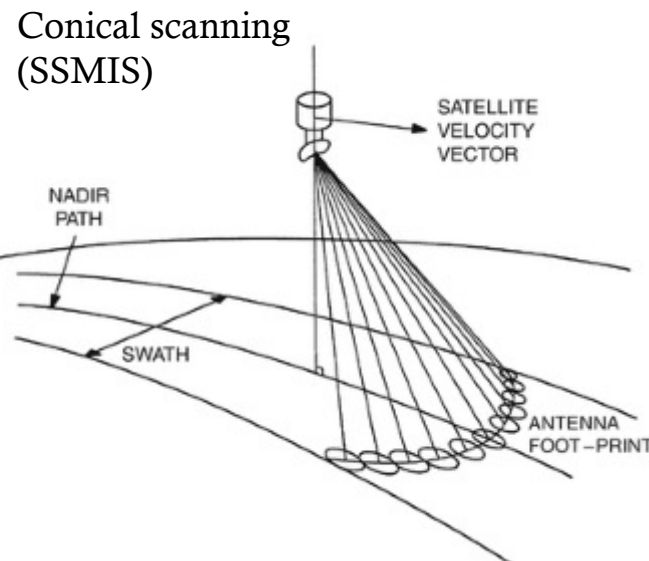
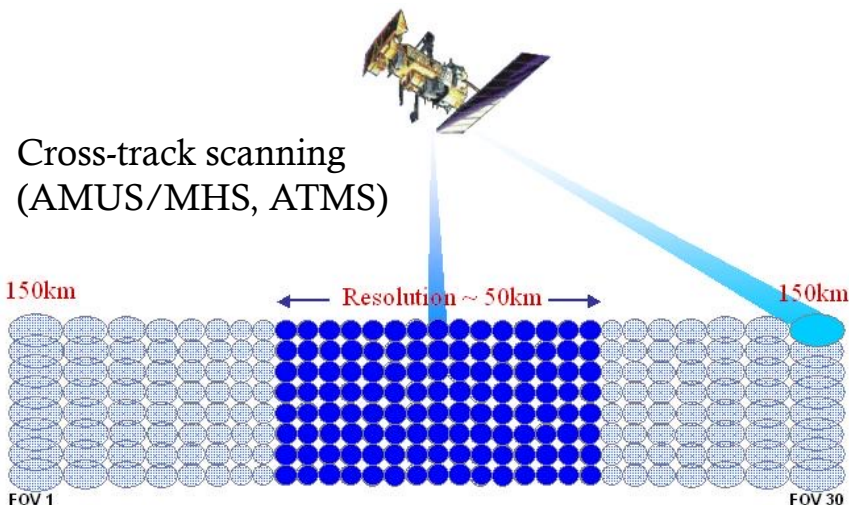


<https://medicanes.isac.cnr.it/>

Extra slides

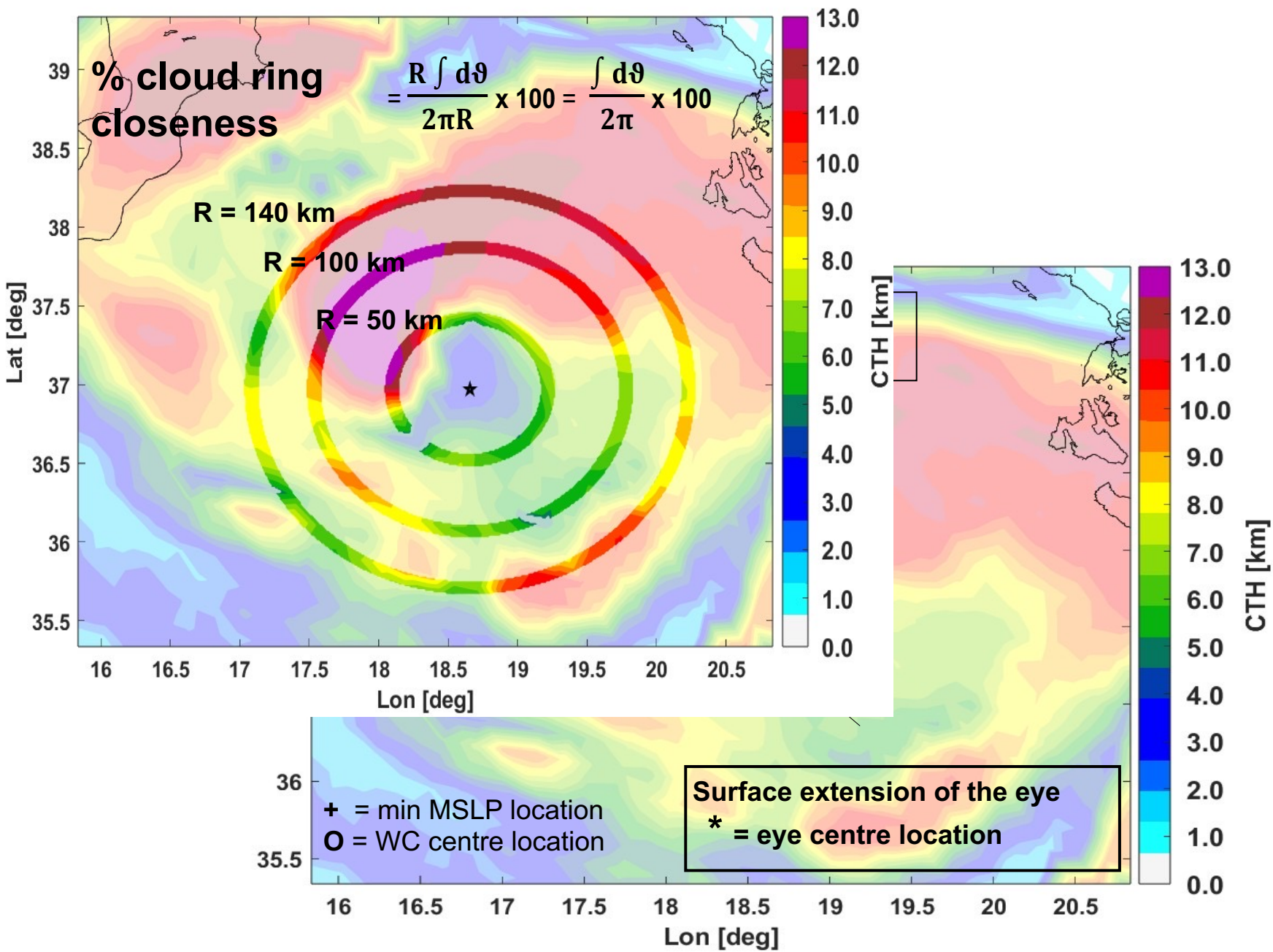
Passive Microwave Radiometry – Instruments & Frequencies

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183.31 \pm 1	TB warming due to WV emission emission TB cooling due to scattering by cloud ice ~ 12 km

Medicane Diagnostics based on PMW radiometry: automated closed-eye detection



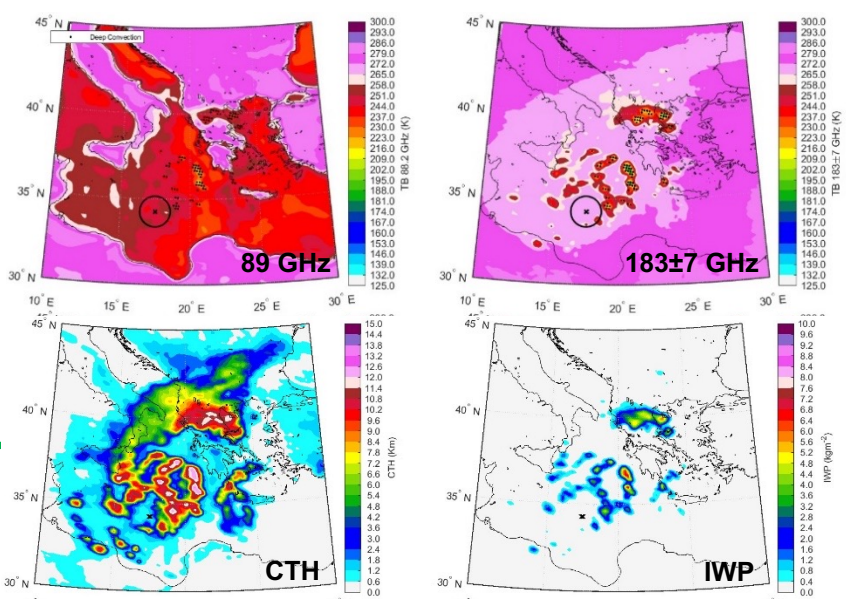
The closed eye is searched within an area nearby the WC centre where **ice is absent** and **cloud tops are low** → **CHT < 5 km** (due to PMW low spatial resolution)

Medicane Ianos
17 September 2020
08:39 UTC
ATMS - SNPP

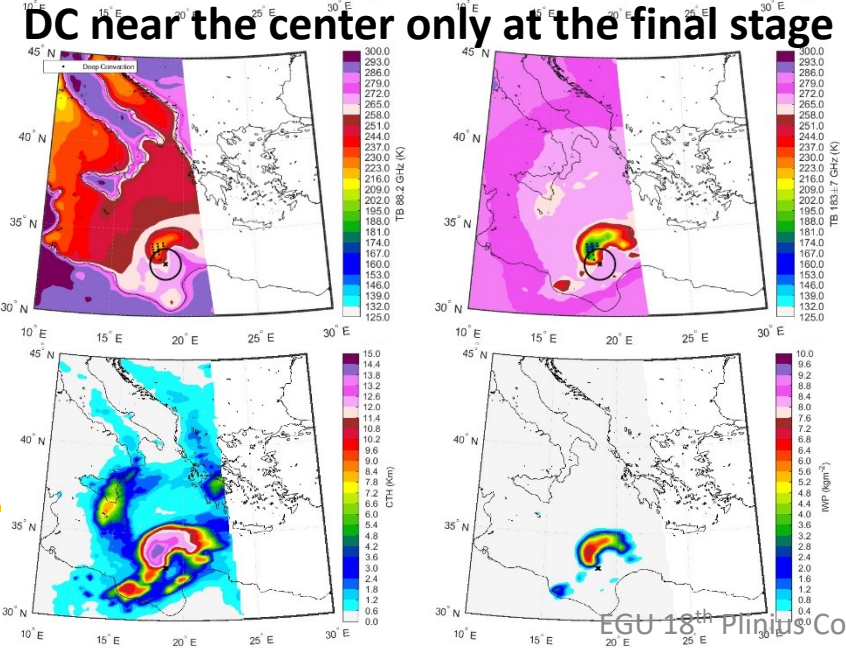
Daniel

- Why the tropical transition occurred only just before landfall?

7-Sep-2023 00:27 UTC



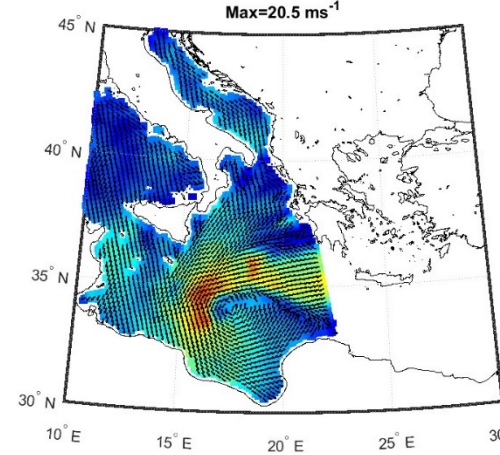
9-Sep-2023 12:22 UTC



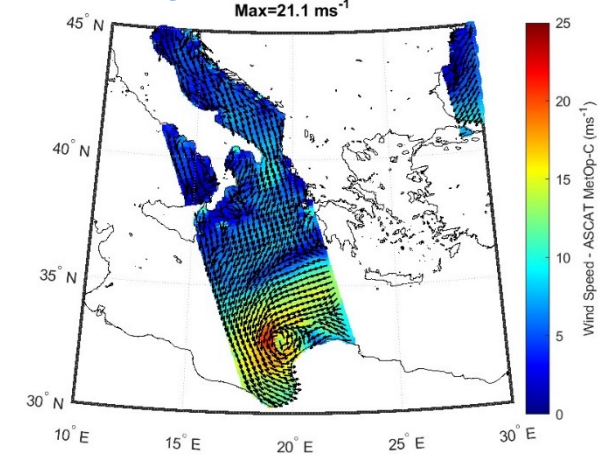
DC near the center only at the final stage

FY-3E and ASCAT near surface winds

8 Sep 2023 – 15:37 UTC

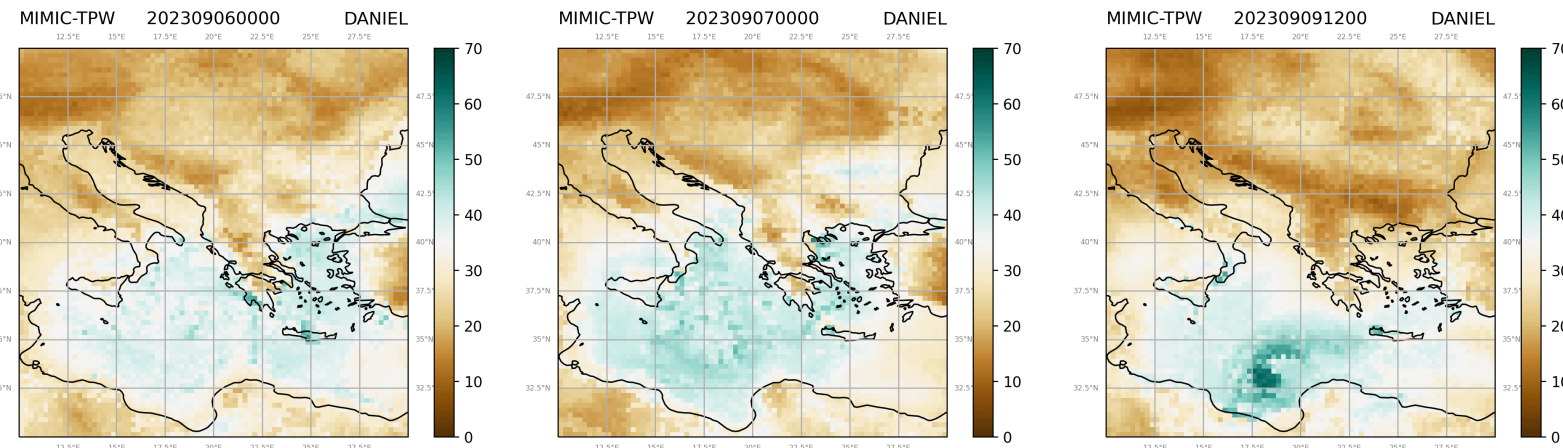


9 Sep 2023 – 19:21 UTC



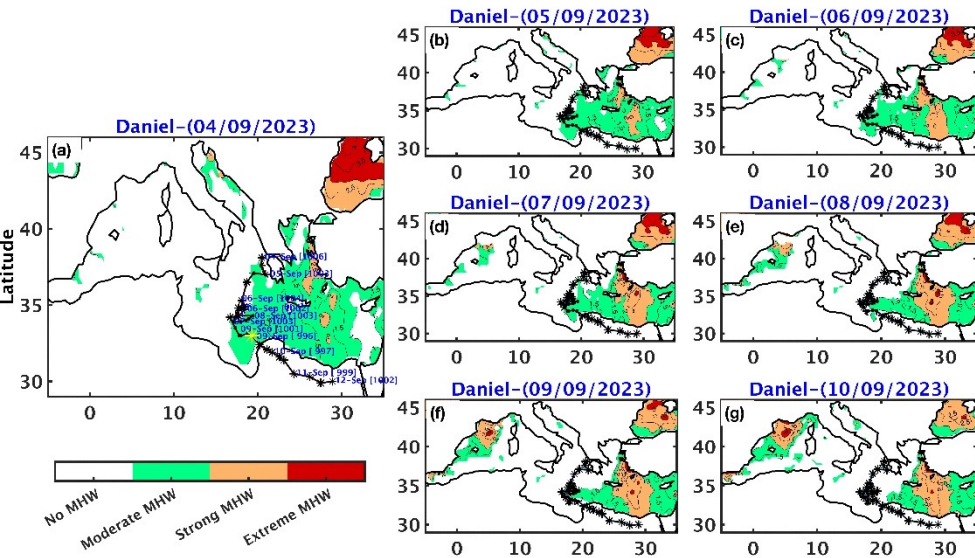
Analysis of Total Precipitable Water (TPW)

Increase of TPW in the region close to the cyclone centre

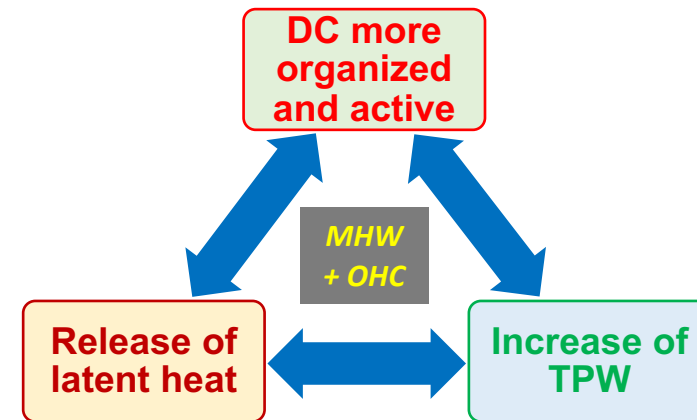


Daniel – Air-Sea Interaction (preliminary analysis)

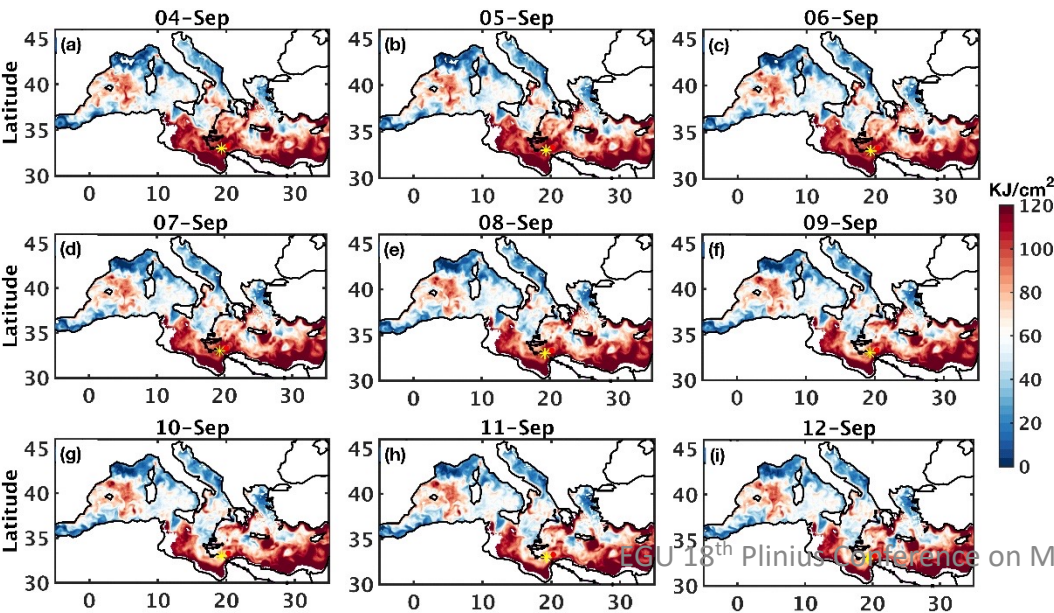
Marine Heatwave



- ✓ 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



Ocean Heat Content



- ✓ 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)*