Identification and Characterization of *Medicanes* using Passive Microwave Radiometry

Valentina Di Francesca [3], Leo Pio D'Adderio[1], Paolo Sanò[1], Daniele Casella[1], Jean-François Rysman[2], Giulia Panegrossi[1]

1 Institute of Atmospheric Sciences and Climate (ISAC), CNR, Rome, Italy

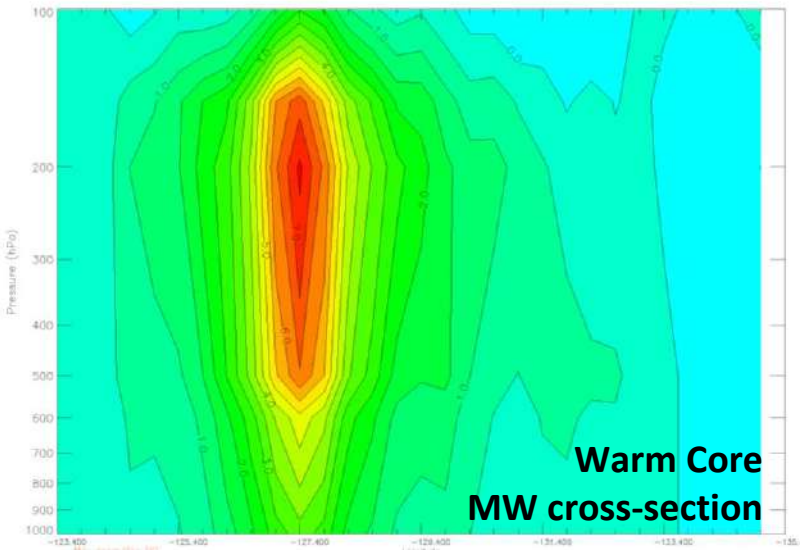
2 LMD & LadHyX, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, Palaiseau, France

3 Centre d'Etudes Spatiales de la Biosphère (CESBIO), CNES/CNRS/INRAE/IRD/UT3, Toulouse, France

What is a *Medicane*?

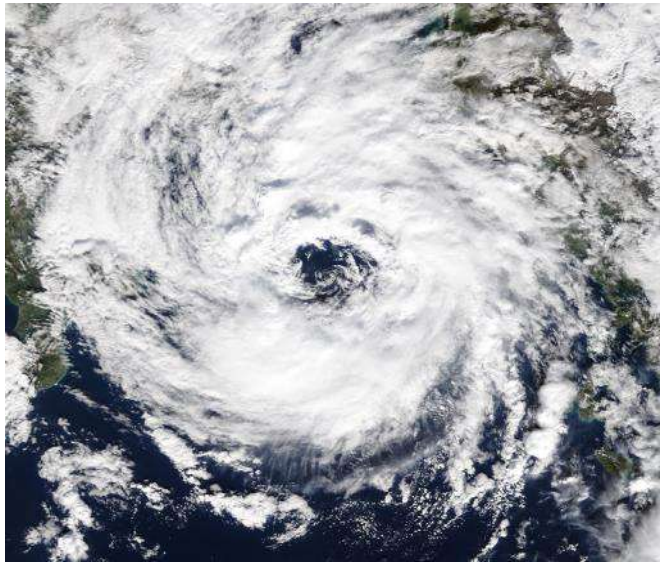
A ***Medicane*** or ***Mediterranean Tropical-Like Cyclone*** (***MTLC***) is a mesoscale system which develops in the Mediterranean Sea and displays characteristics similar to Tropical Cyclones (TC):

An **axis-symmetric Warm Core (WC)**



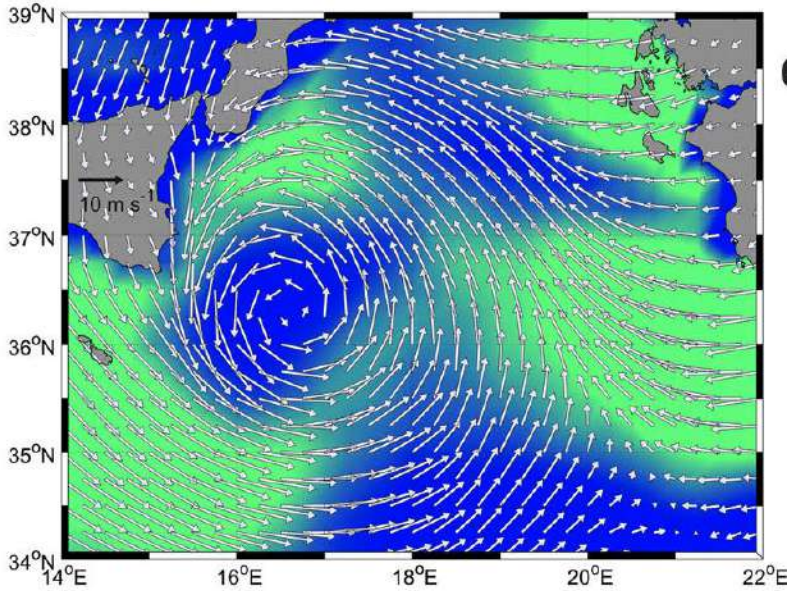
MW vertical cross-section of atmospheric T anomaly in mid-upper troposphere (500-150 hPa) for a tropical cyclone.

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



Medicane “Numa” MODIS Terra 18 Nov. 2017

Symmetric maximum 10m wind field within a few tens of km afar.



Medicane “Apollo” wind field 29 Oct. 2021

Study Goals

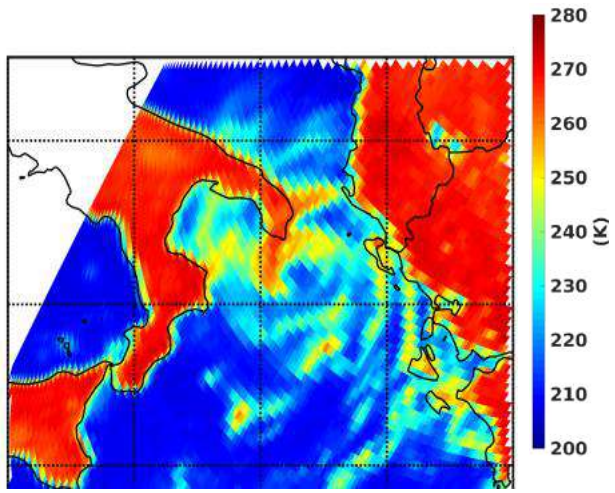
Extensive analysis **based solely on satellite observations** for:

1. Identification of the **warm core** and its **formation mechanisms** (e.g., diabatic vs. baroclinic processes)

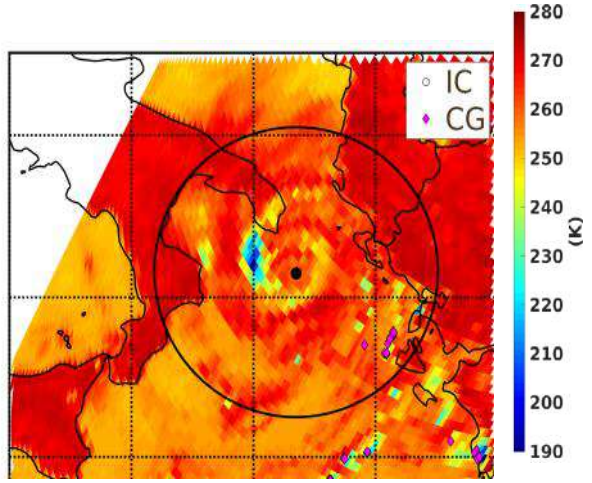
2. Detection of the **transition between development- and mature- stage** exploiting a newly-designed algorithm for **cloud-free eye detection**

3. Categorization of Medicanes: tropical transition or baroclinic warm-cored cyclones?

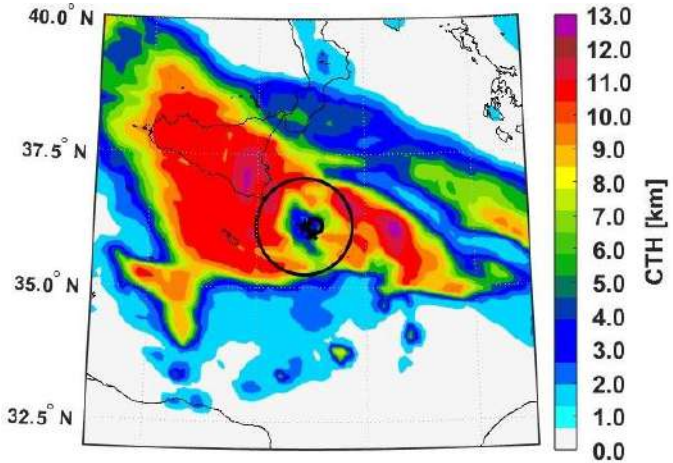
Dataset and Methodology: **Satellite Passive Microwave (PMW) TB imagery and products**



Medicane "Numa" PMW TB imagery at 37 GHz



Medicane "Numa" PMW TB imagery at 89 GHz

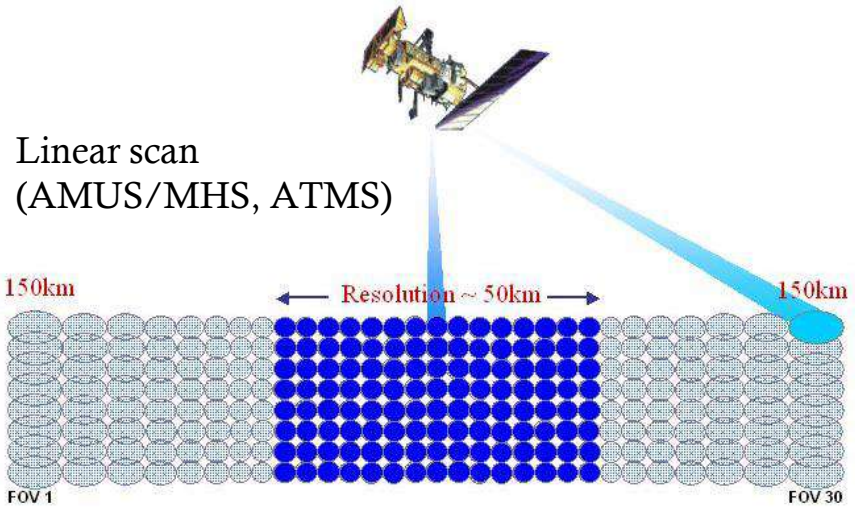


Medicane "Apollo" PMW-derived CTH product at high frequencies

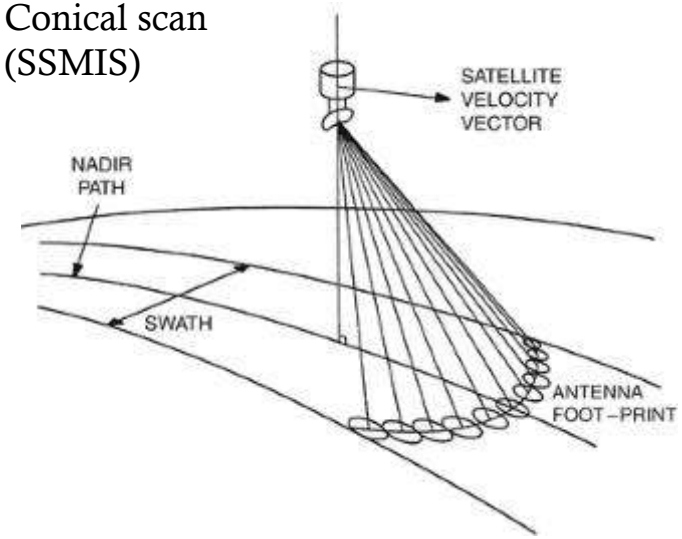
Passive Microwave Radiometry – Instruments & Frequencies

	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	Linear 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)

Linear scan
(AMUS/MHS, ATMS)



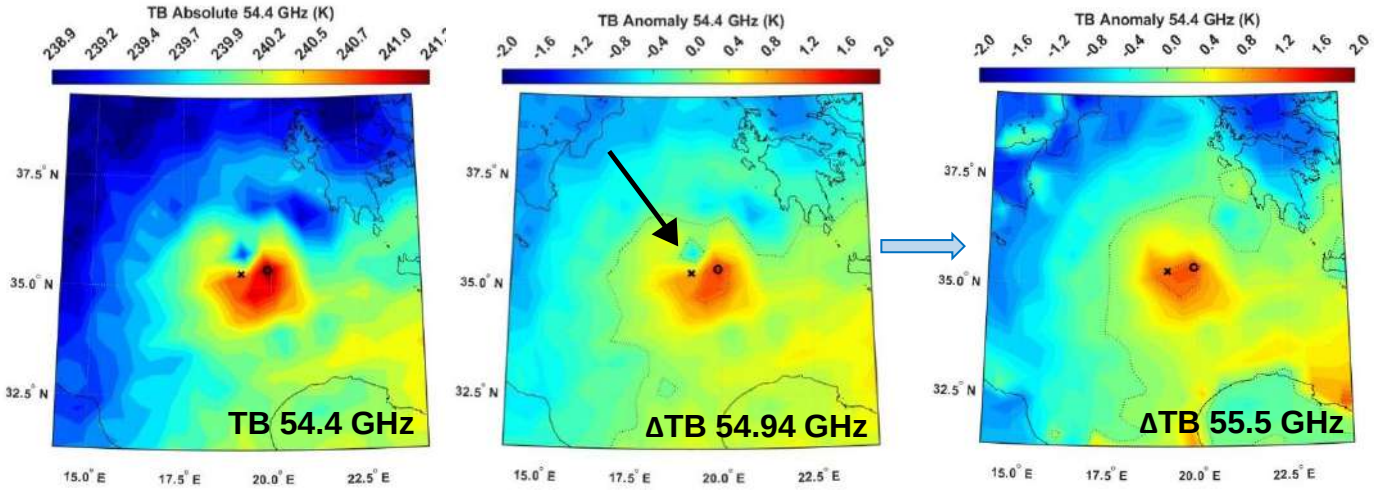
Conical scan
(SSMIS)



Frequency (GHz)	Application
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	Cloud emission TB + high-density ice scattering
183.31 ±7	TB cooling due to medium-density ice scattering at ~ 6 km
183.31 ±3	TB cooling due to medium-density ice scattering at ~ 9 km
183.31 ±1	TB cooling due to low-density ice scattering at ~ 12 km

PMW-based Diagnostics

Ianos: MetOp-B AMSU/MHS 17 Sept. 2020 at 08:39 UTC



TB cooling due to ice particles scattering

Scattering-corrected TB anomaly

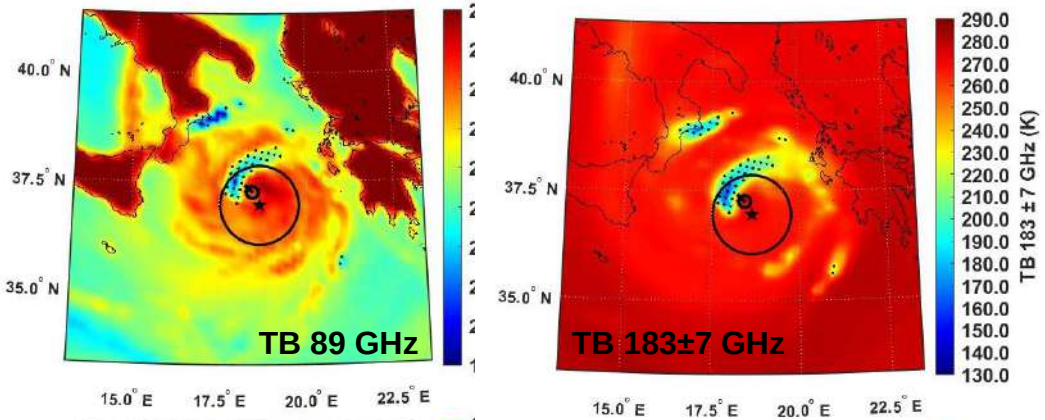
Warm Core detection

Use of 3 T sounding channels at 54-55 GHz (TB anomaly at 500-200 hPa)

Well established methodology for Tropical Cyclones

Panegrossi et al., Rem. Sensing, 2023

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



Cloud properties

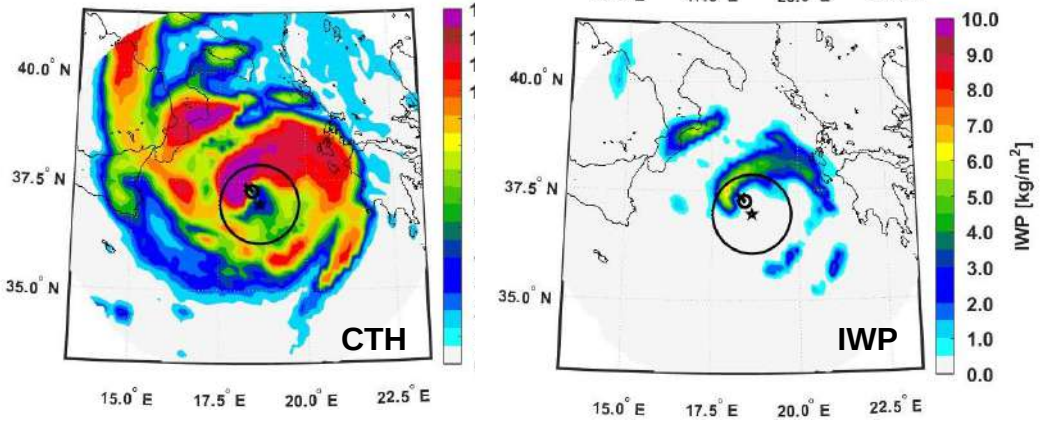
High Frequency channels 89-190 GHz:

Deep convection detection (**Hong et al., 2005**)

Cloud Top Height (CTH) estimation

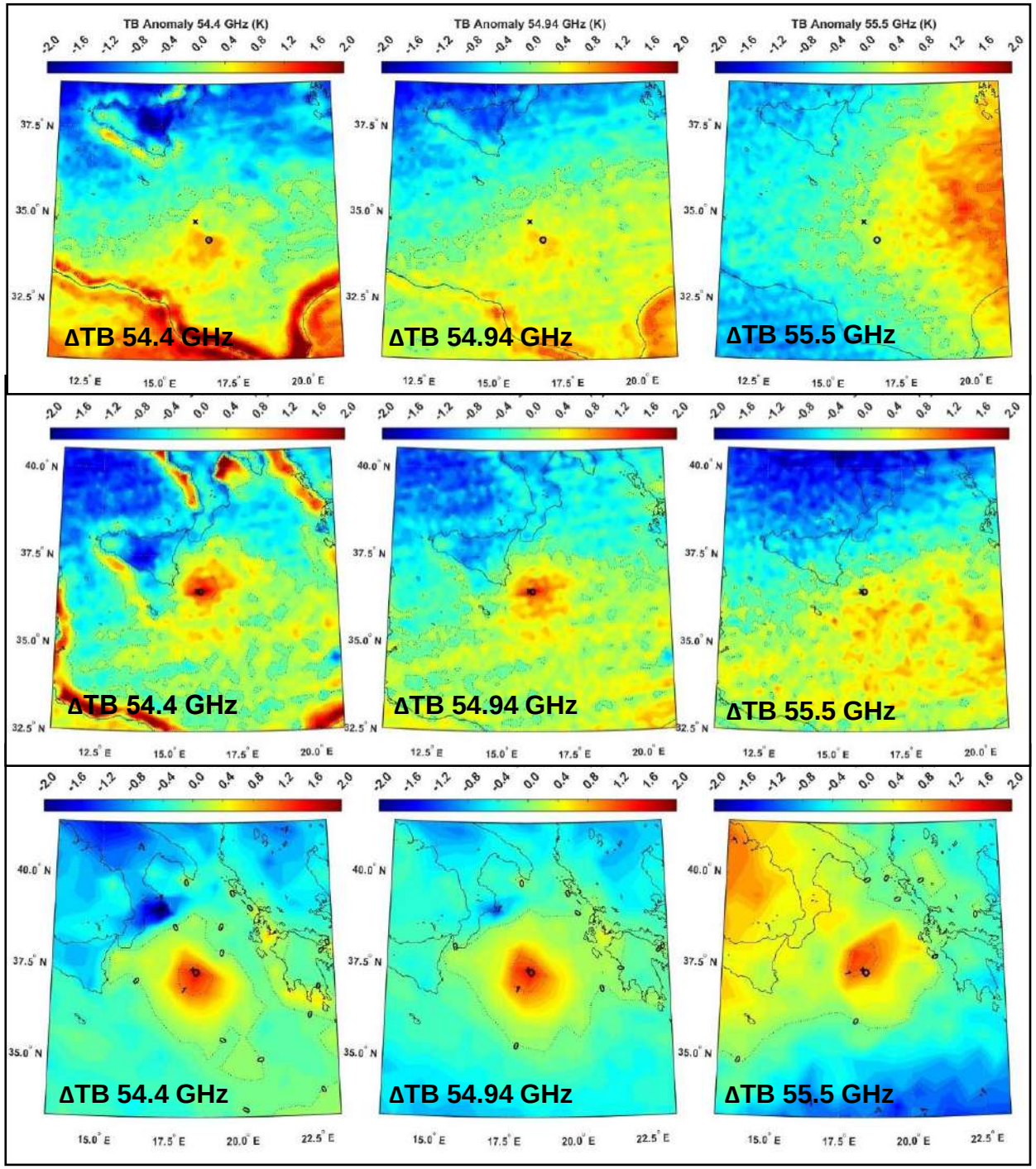
Ice water Path (IWP) estimation

(ML algorithm, DEEPSTORM ***Rysman et al., JGR, 2021***)



PMW Methods – Warm Core Detection and Analysis

WC classfication based on its «**depth**»



Very Shallow

ΔTB>0 signal only in ch. 54.4 GHz

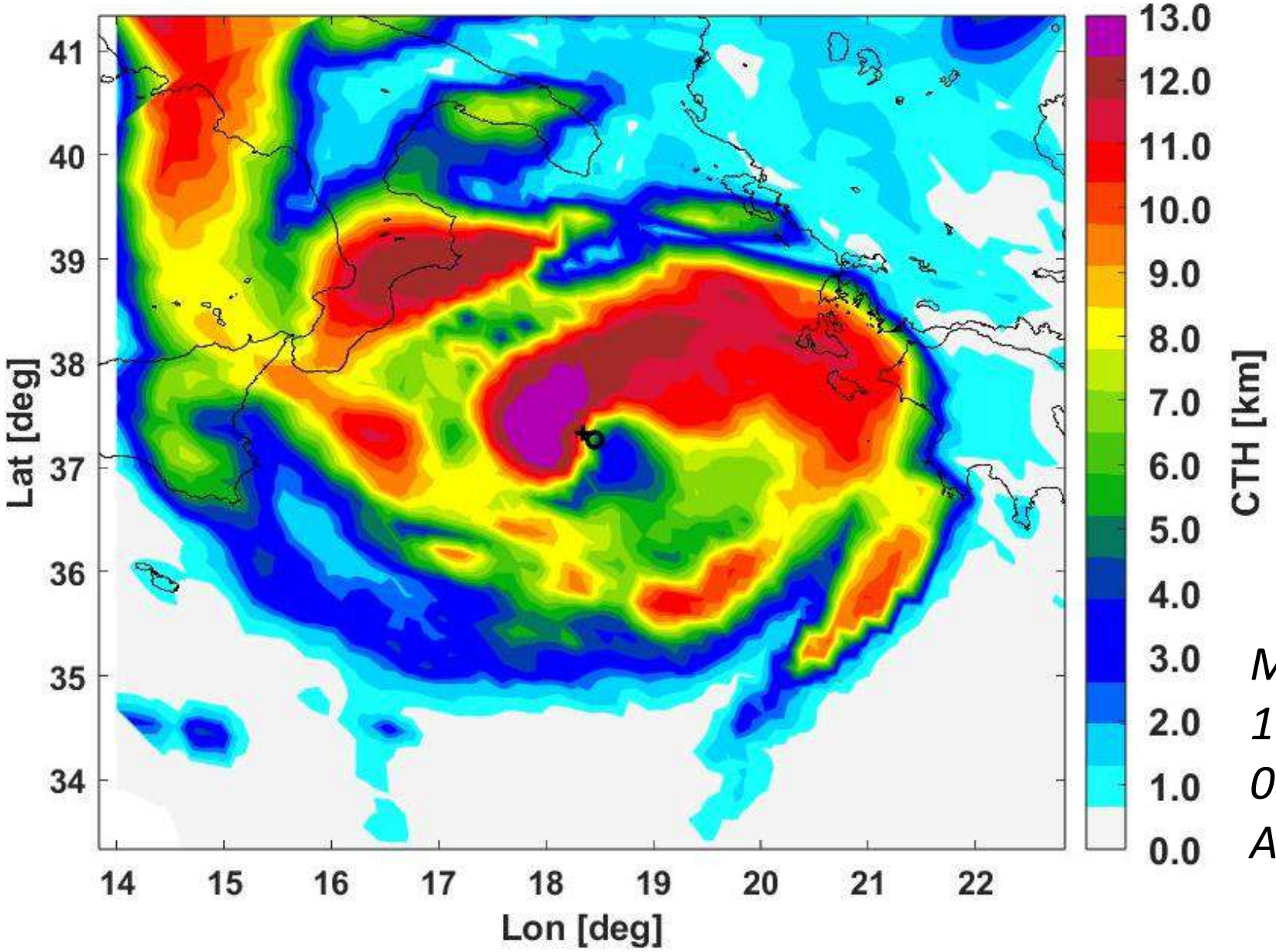
Shallow

ΔTB>0 signal in ch. 54.4 e 54.94 GHz

Deep

ΔTB>0 signal in all channels

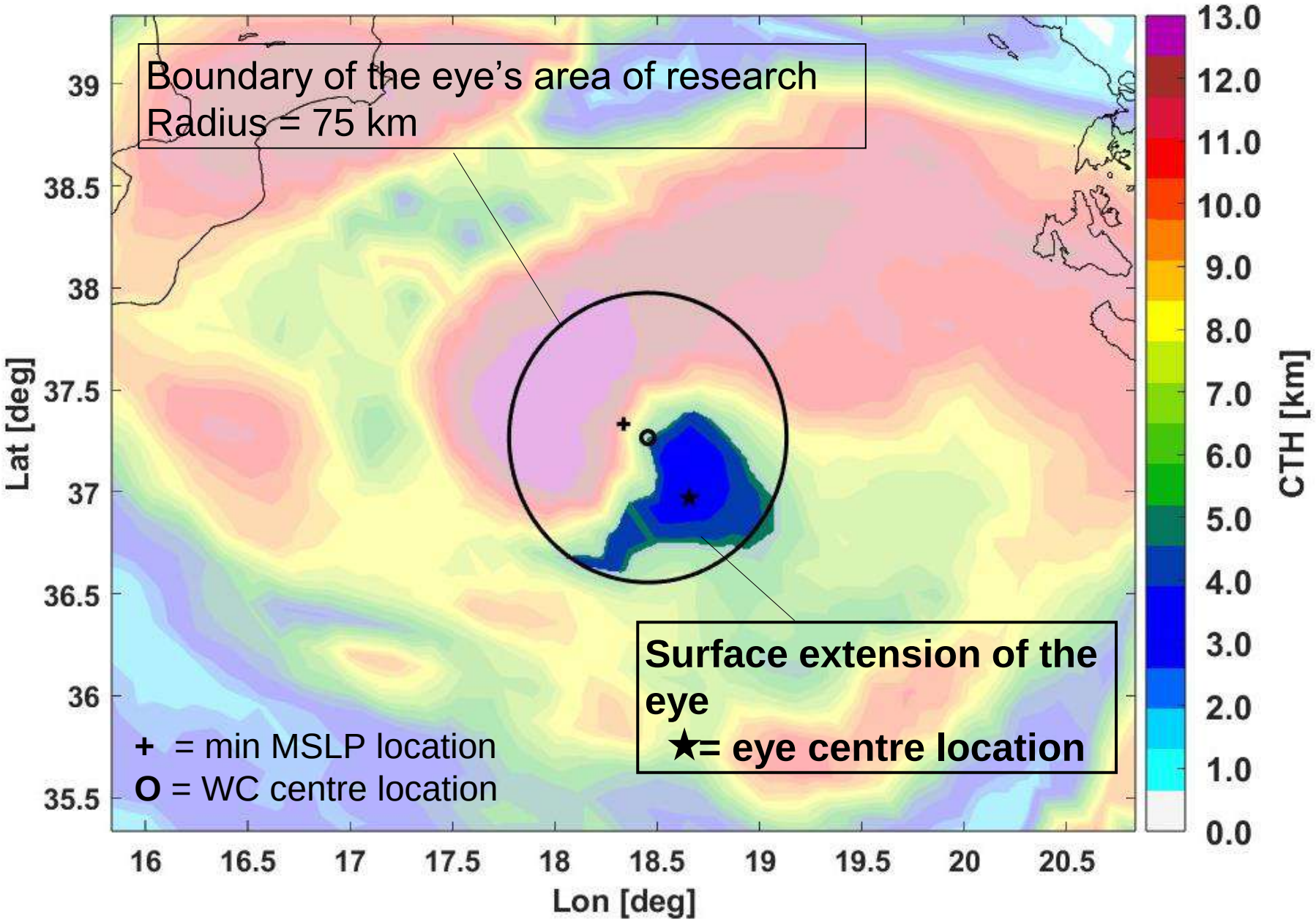
PMW Methods – Eye Detection



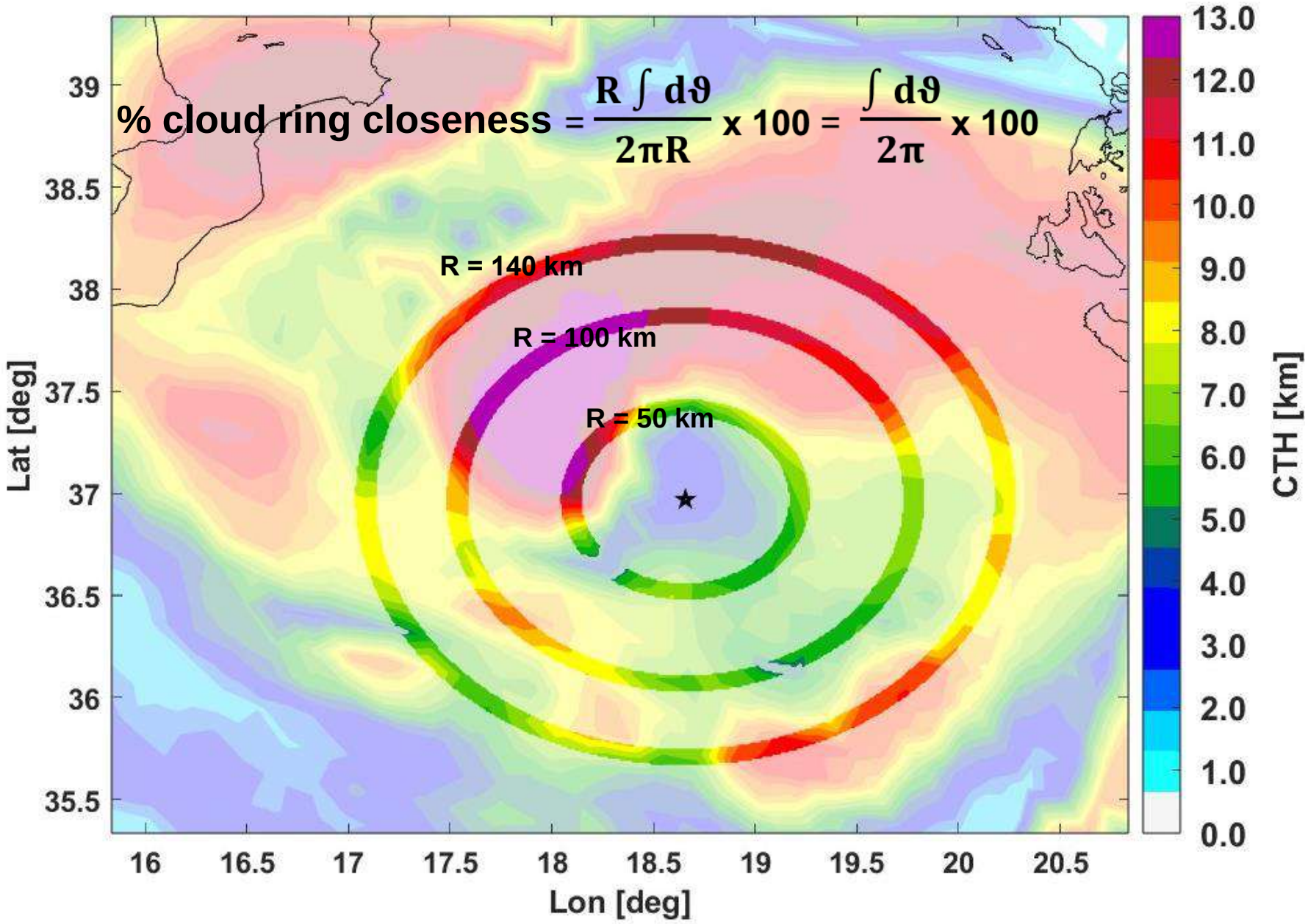
Operational definition of «**eye**» for PMW imagery (low spatial resolution) := area nearby the WC centre where **ice is absent** and **cloud tops are low** → **CHT < 5 km**

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

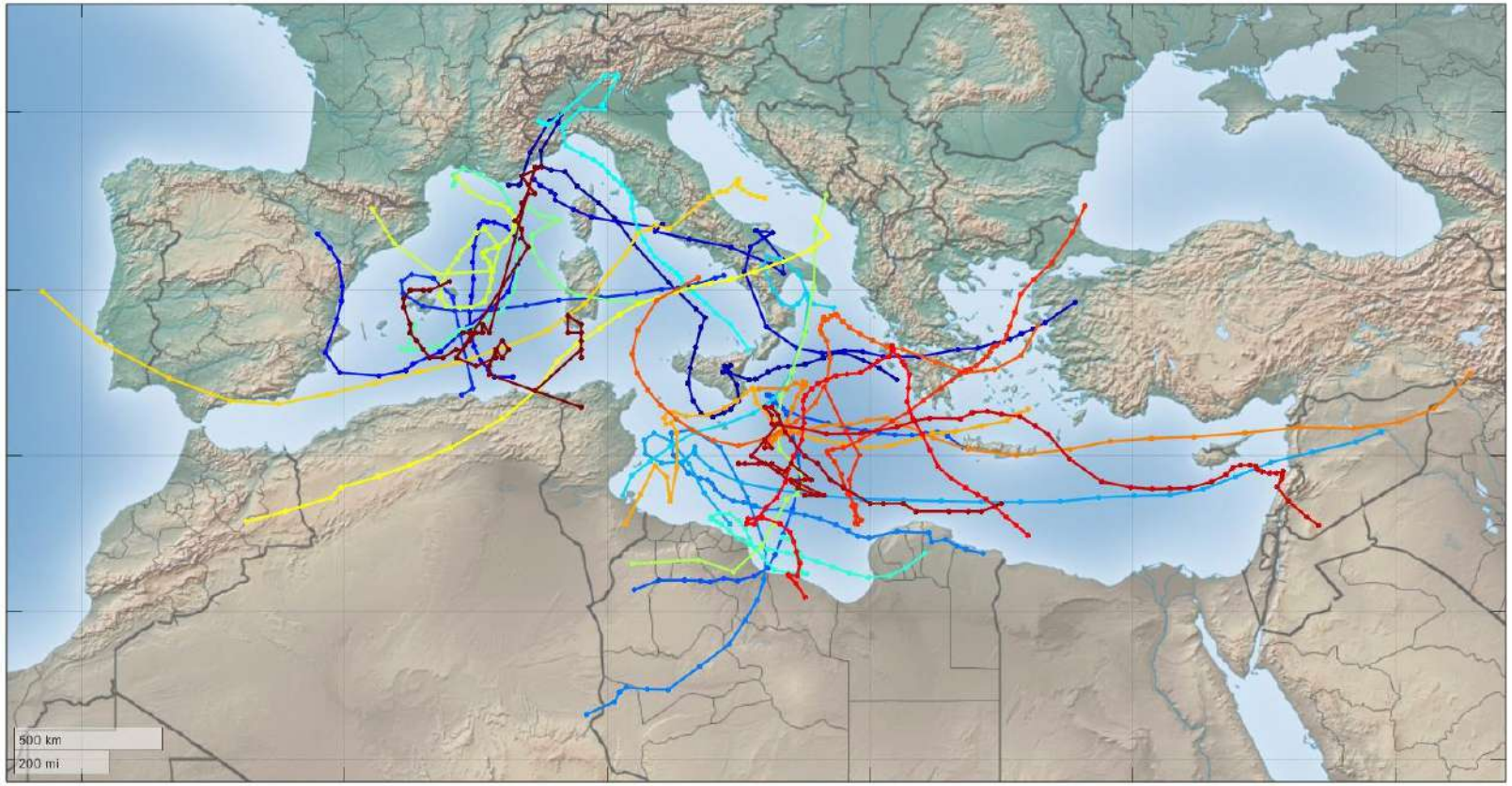
PMW Methods – Eye Detection



PMW Methods – Eye Detection



Observational Dataset



Tracks of the 23 case-studies cyclones.
Dataset provided by MedCyclones COST Action - WG1

Total of parsed satellite overpasses = 447

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

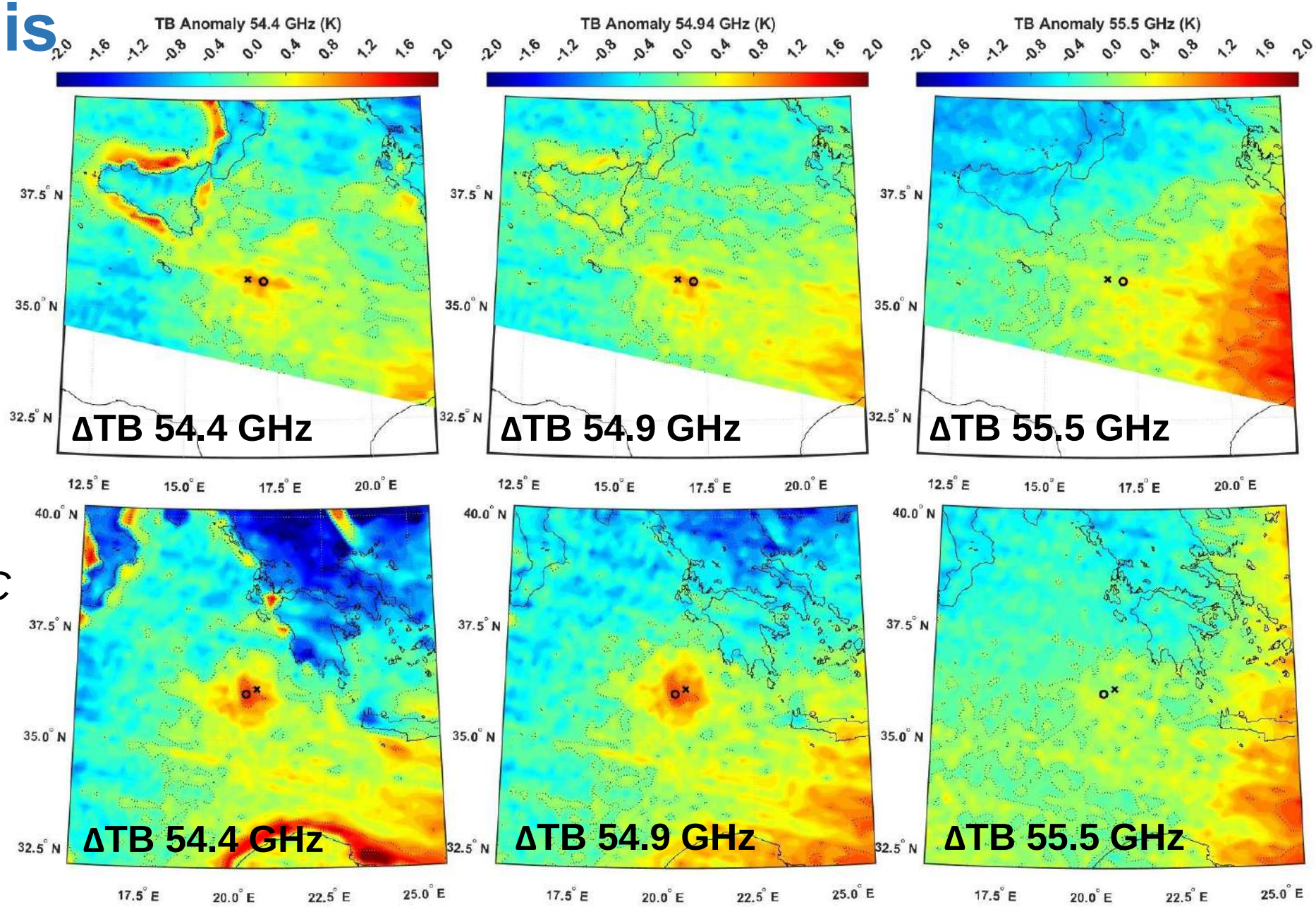
Trixie (October 2016)

ATMS – SNPP
30/10/16 00:55 UTC

Development stage:
- ***shallow***
- **irregular**
- **weak**

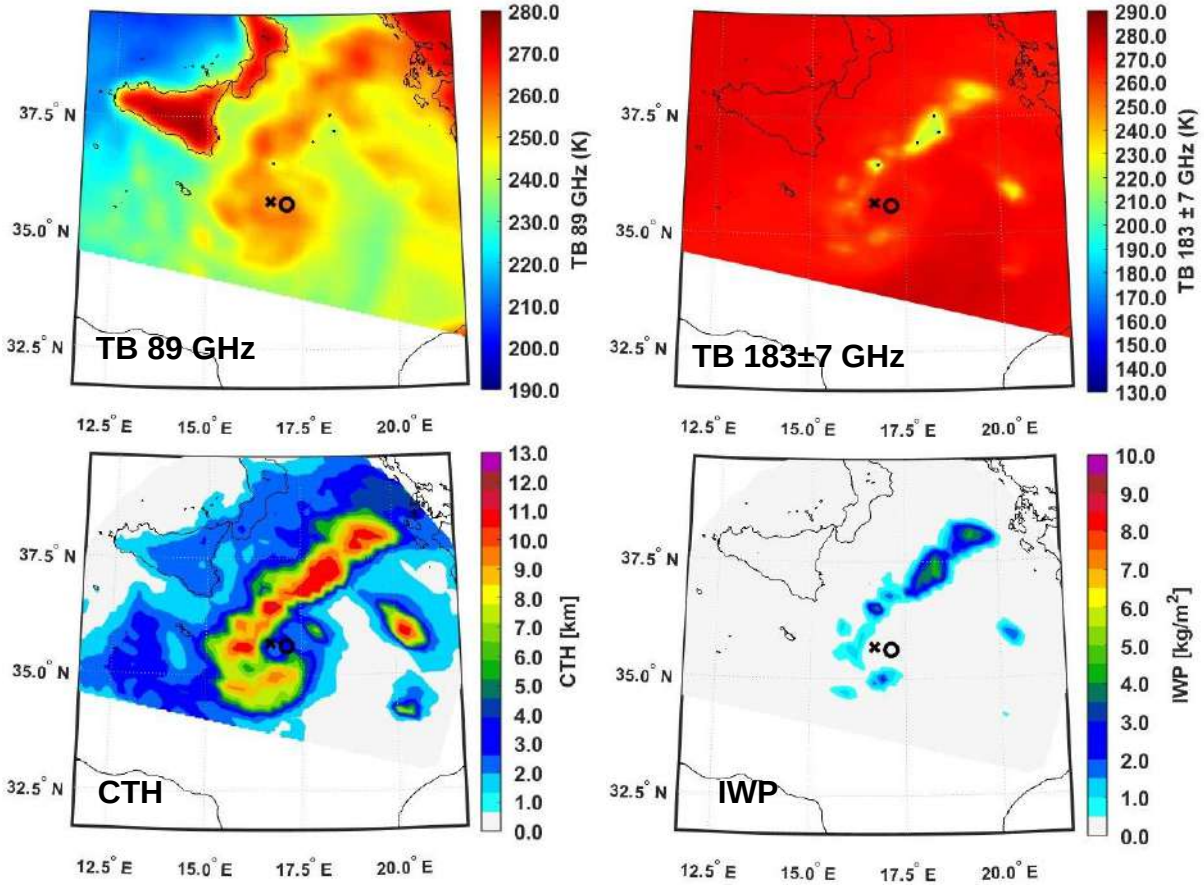
ATMS – SNPP
31/10/16 00:38 UTC

Mature stage:
- ***shallow***
- **symmetric**
- **intense**



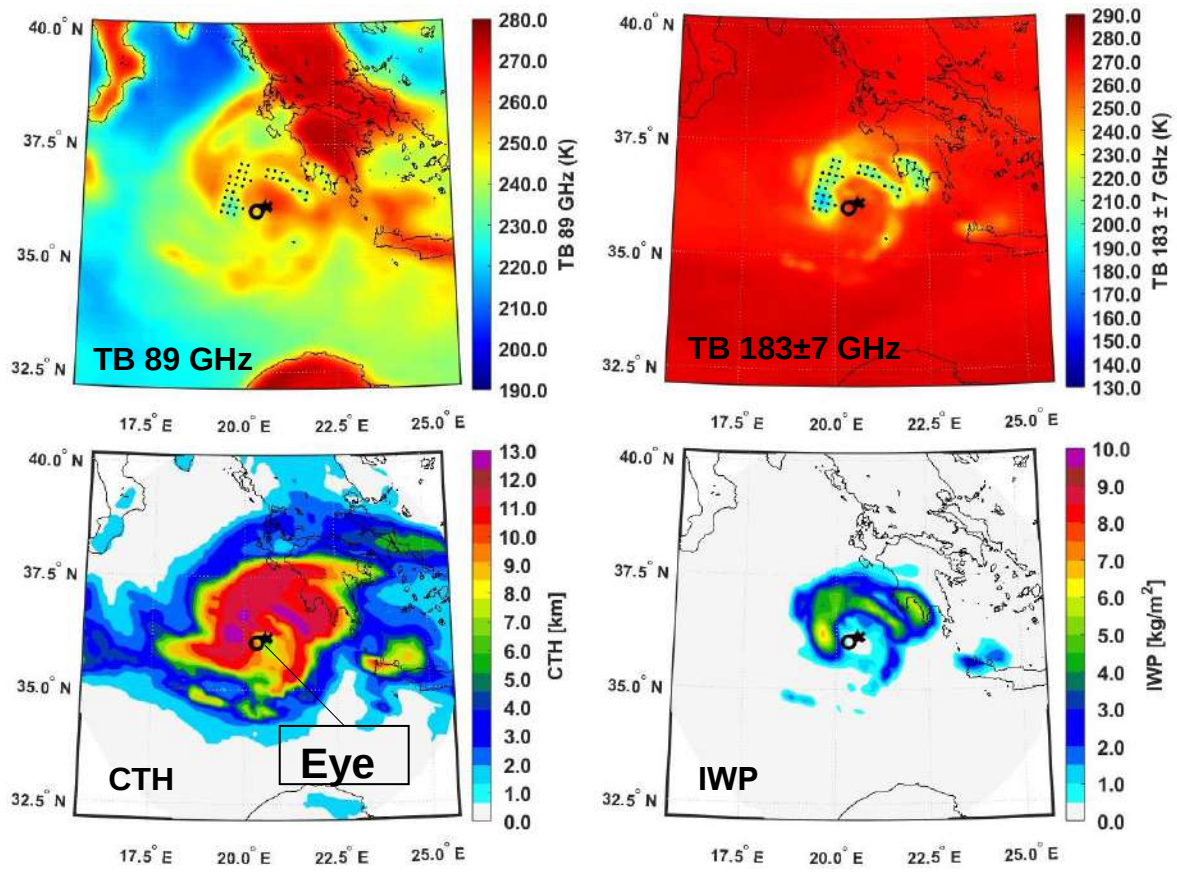
Results: Trixie Analysis (October 2016)

Developement Stage



- Circulation not completely organized
- **DC** almost **absent,** far from the centre
- **Low CTH** near the centre (< 7 km)
- **Very low IWP** near the centre (<1.5)

Mature Stage



- **Organized cloud**, spiraling external rainbands
- **Extensive 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)
- **Closed eye**

Results: Warm Core Analysis

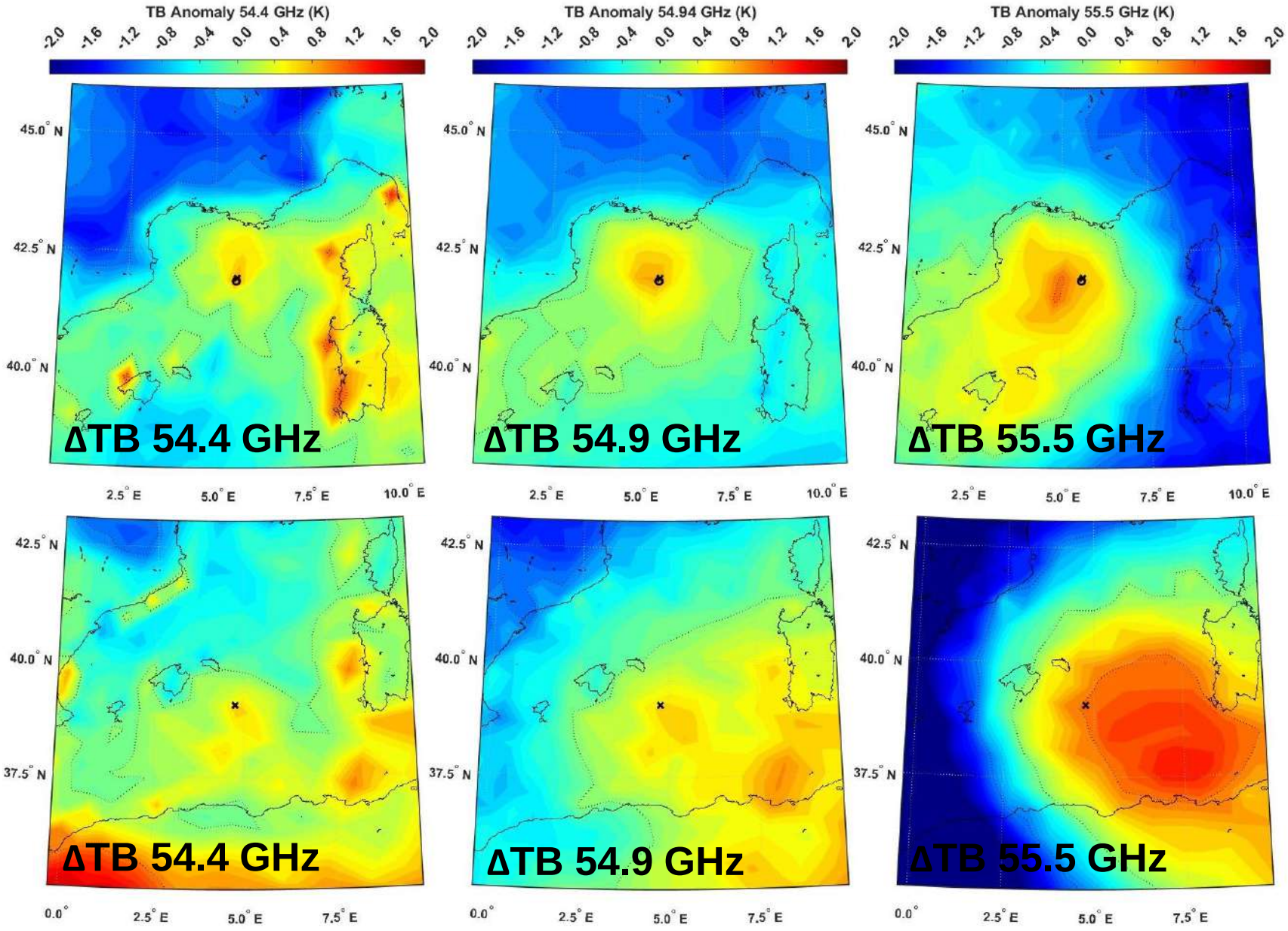
ATMS – SNPP
30/10/16 00:55 UTC

Development stage:
- ***shallow***
- **irregular**
- **weak**

ATMS – SNPP
31/10/16 00:38 UTC

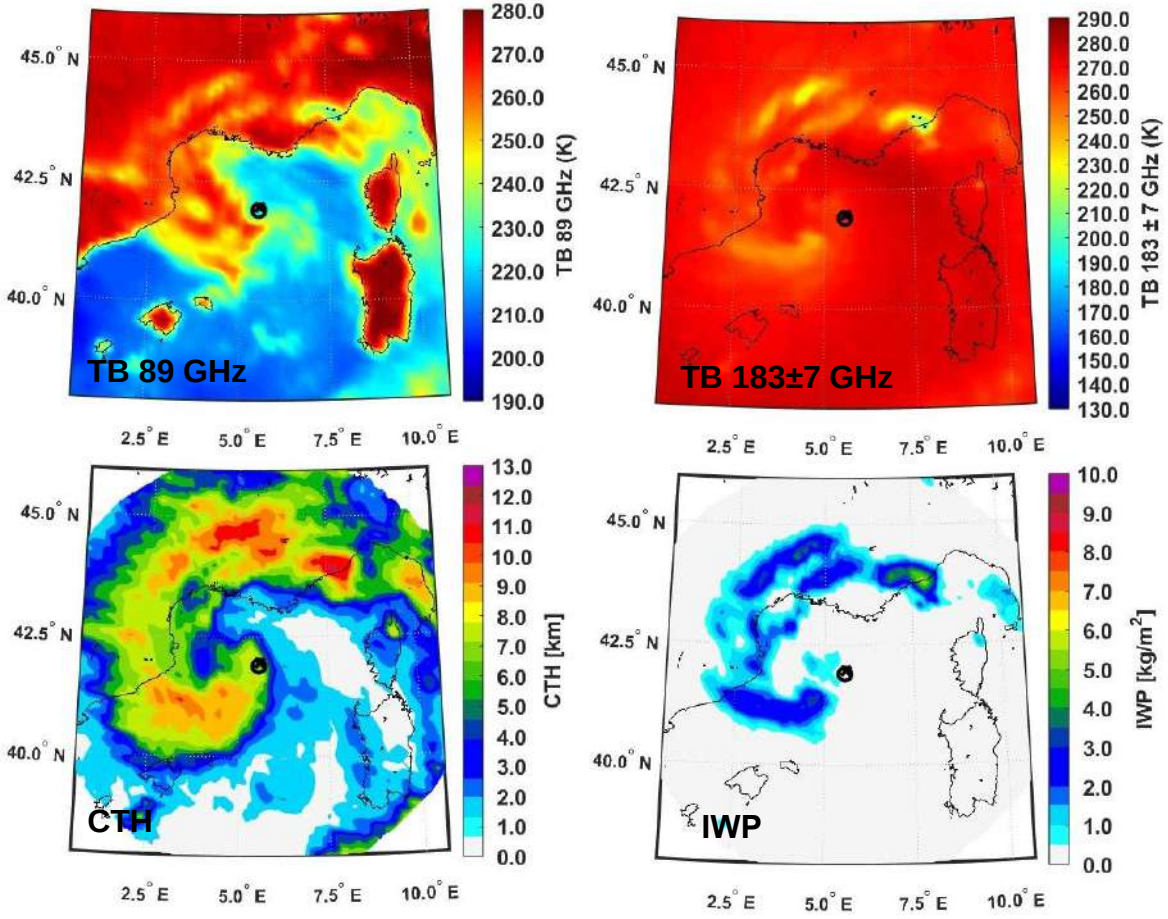
Mature phase:
- **Irregular**
- **indication of top-down development**

Fernando (May 2003)



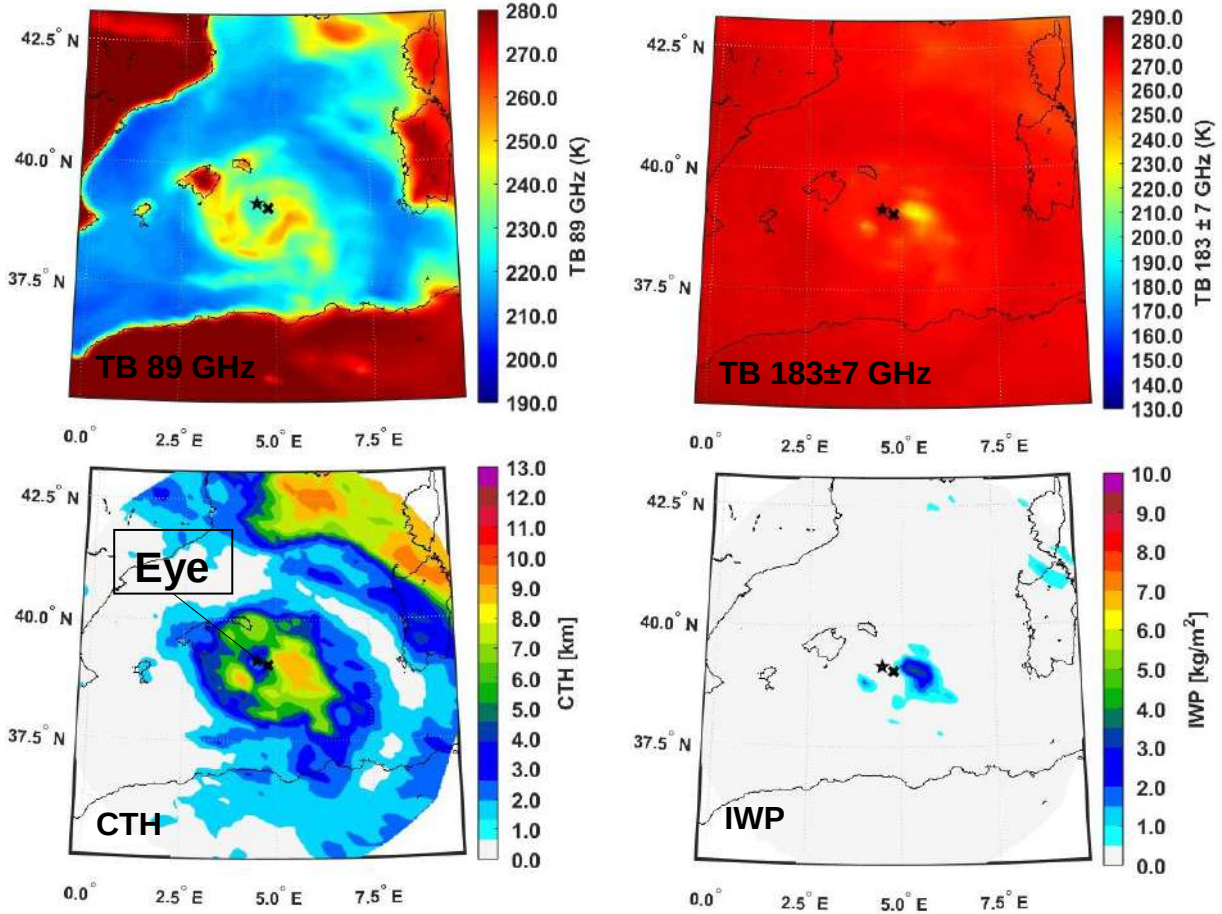
Results: Fernando Analysis (May 2003)

Development Stage



- Circulation not completely organized
- **DC** almost **absent,** far from the centre
- **Low CTH** near the centre (< 7 km)
- **Very low IWP** near the centre (<1.5)

Mature Stage



- **Organized cloud**, spiraling external rainbands
- **DC absent within 100 km** from the centre
- **Low CTH** near the centre (< 7 km)
- **Low IWP** near the centre (< 2.5)
- **Closed eye**

Results: Classification

CATEGORY «A» Tropical Transition	CATEGORY «B» Baroclinic, warm-cored systems
• 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 occurrence: **Sept. - Nov.** • Location of occurrence: **central Med., Ionian Sea**	• Persistent, shallow/deep, **top-down developed WC** • **Absent or very scarse DC** in mature stage; persistent stratospheric intrusion • (→WC has a baroclinic origin) • «Closed» eye in mature stage
• Rolf (2006/11) • Trixie (2016/10) • Numa (2017/11) • Zorbas (2018/09) • Ianos (2020/09) • **Apollo**** (2021/10)	• Fernando (2003/05) • Unnamed (2007/11) • Unnamed (2008/12) • Unnamed (2012/04) • Ilona (2014/01) • Qendresa (2014/11)

Conclusions

- **Satellite passive microwave** (**PMW**) **radiometry** provides useful measurements for identification and characterization of **phenomenological features** and **physical processes** of *Medicanes*, and they **complement model-based analysis**

- New algorithm for the **eye feature detection** improves the identification of **the mature stage and tracking**

Outlooks:

  - **Limitations** in eye feature detection due to **PMW low resolution and/or strong asymmetry in the cloud properties** →Future development with **multi-sensor techniques** (MW/VIS/IR)

  - **Air-Sea Interaction** to be analyzed through **satellite-based products**

Results: Warm Core Analysis

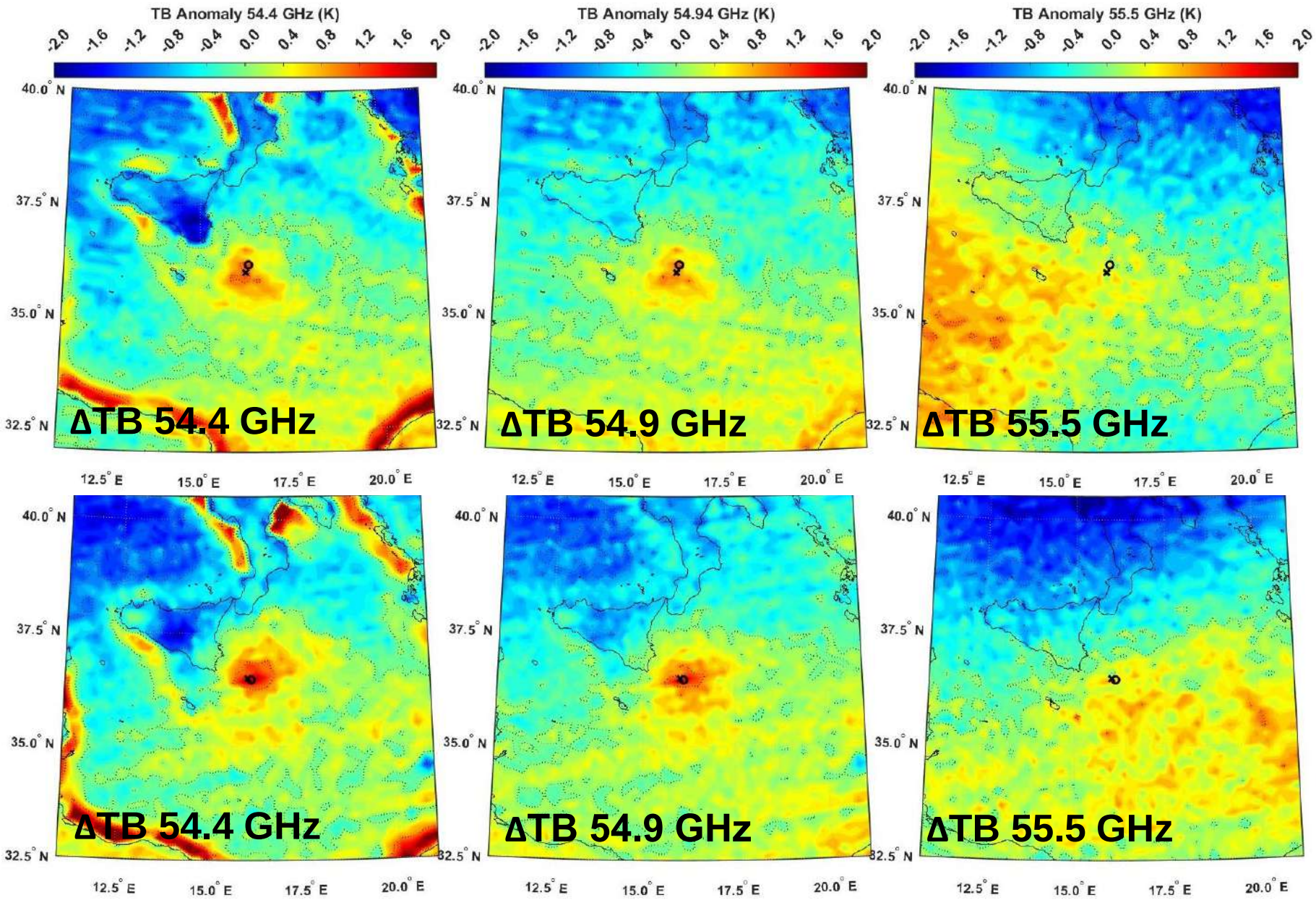
Apollo (October 2021)

ATMS – SNPP
29/10/21 00:40 UTC

Mature stage 1:
- ***shallow***
- **medium-intensity**
- **vertically aligned**

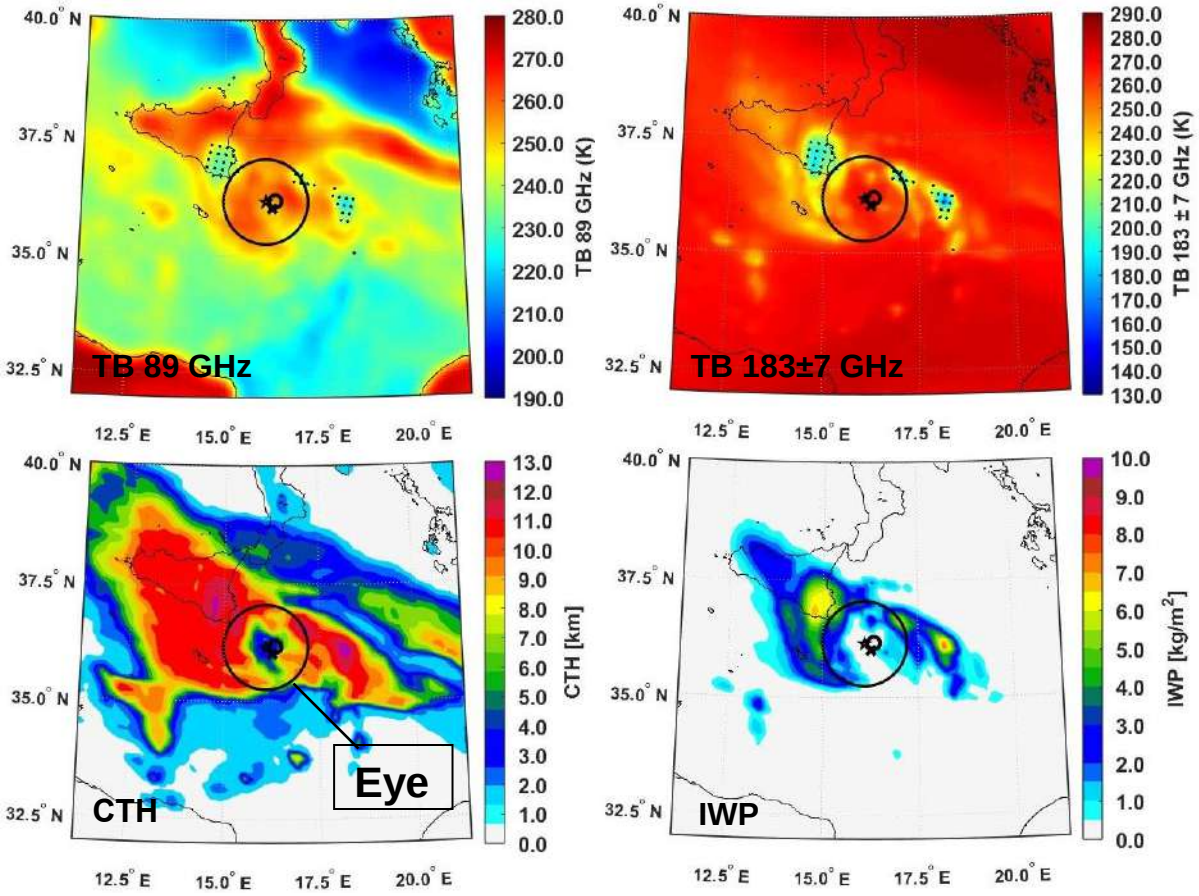
ATMS – SNPP
29/10/21 12:00 UTC

Mature stage 2:
- ***shallow***
- **intense, symmetric**
- **vertically aligned**



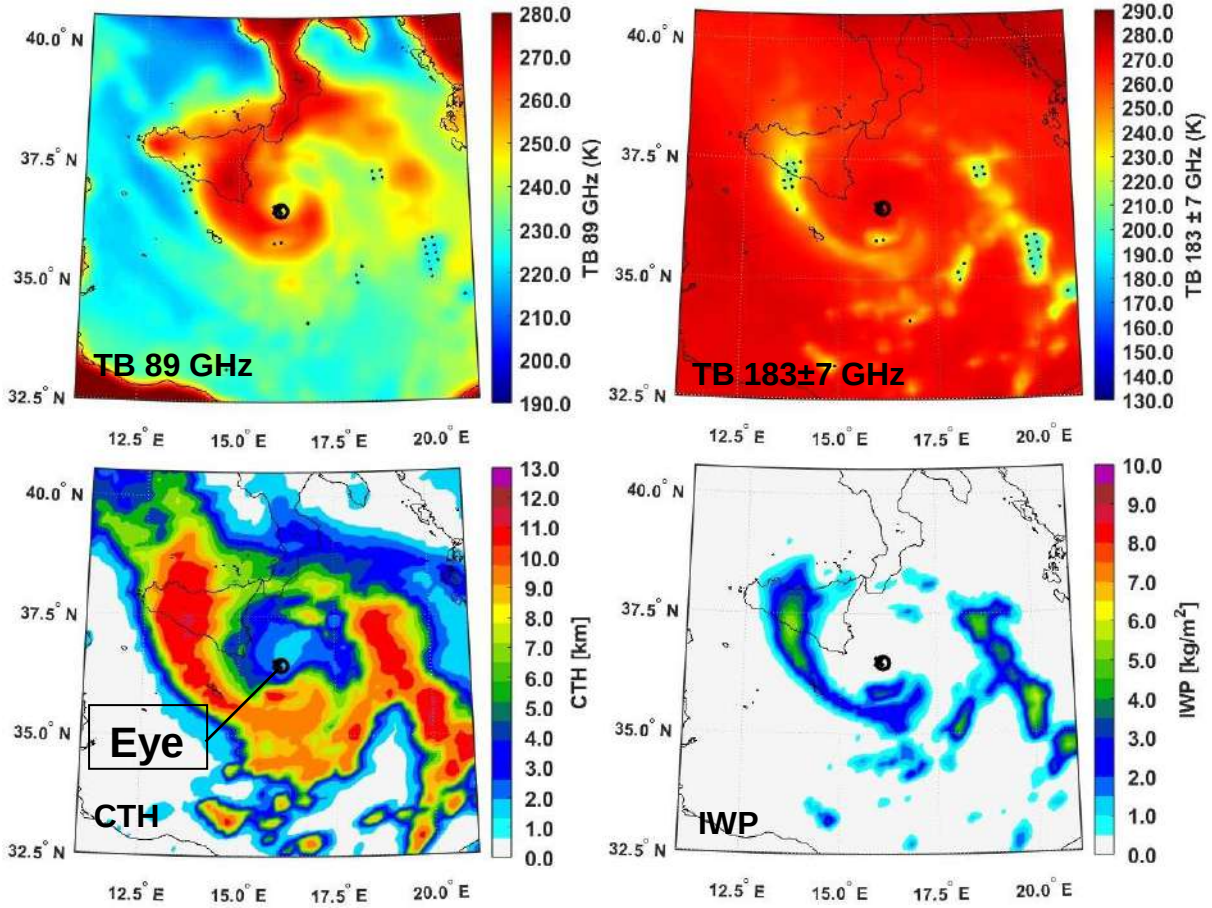
Results: Apollo Analysis (October 2021)

Mature Stage 1

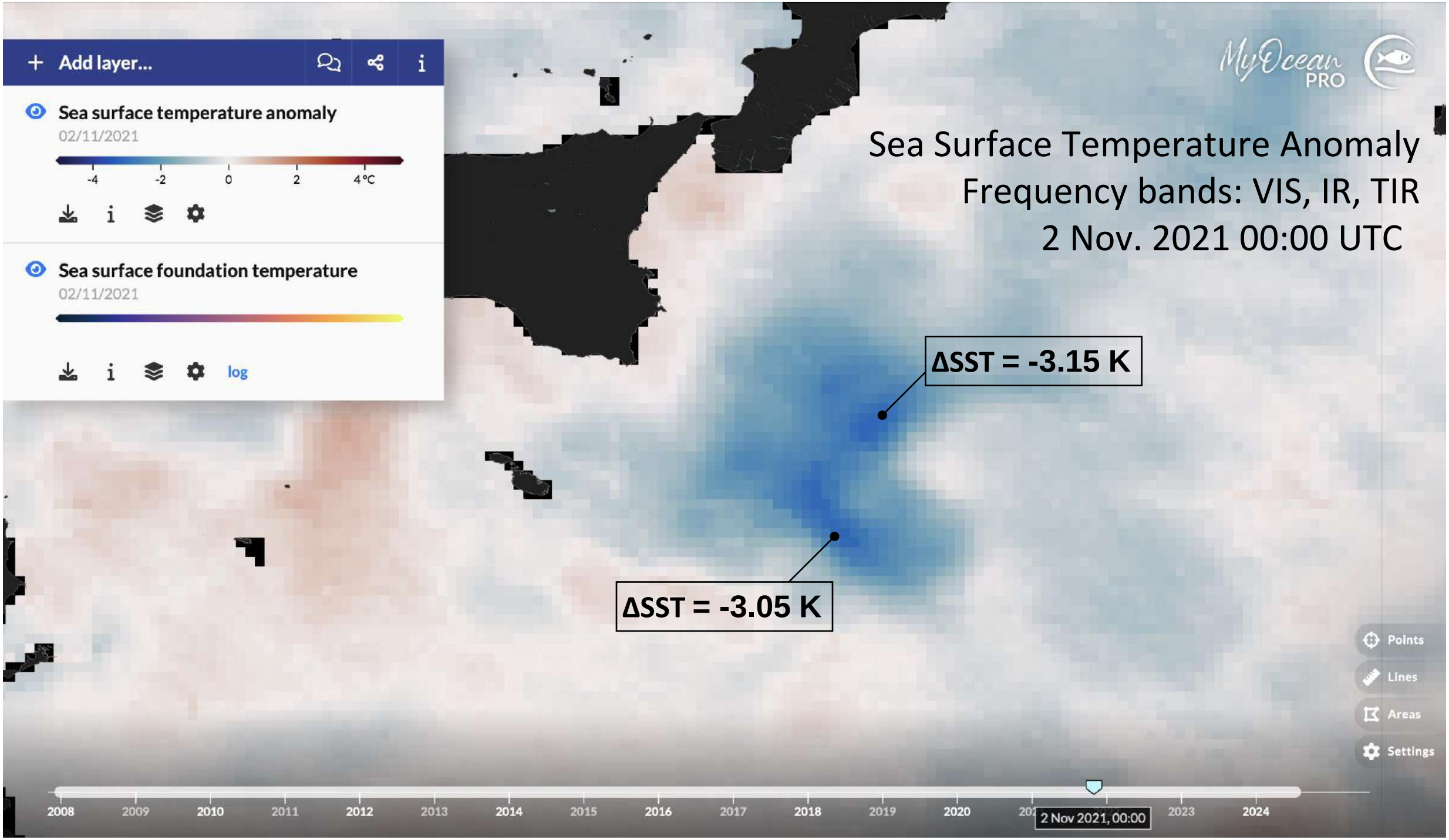


- **Organized cloud**, spiraling external rainbands
- **DC within ~150 km** from the centre
- **Closed eye**

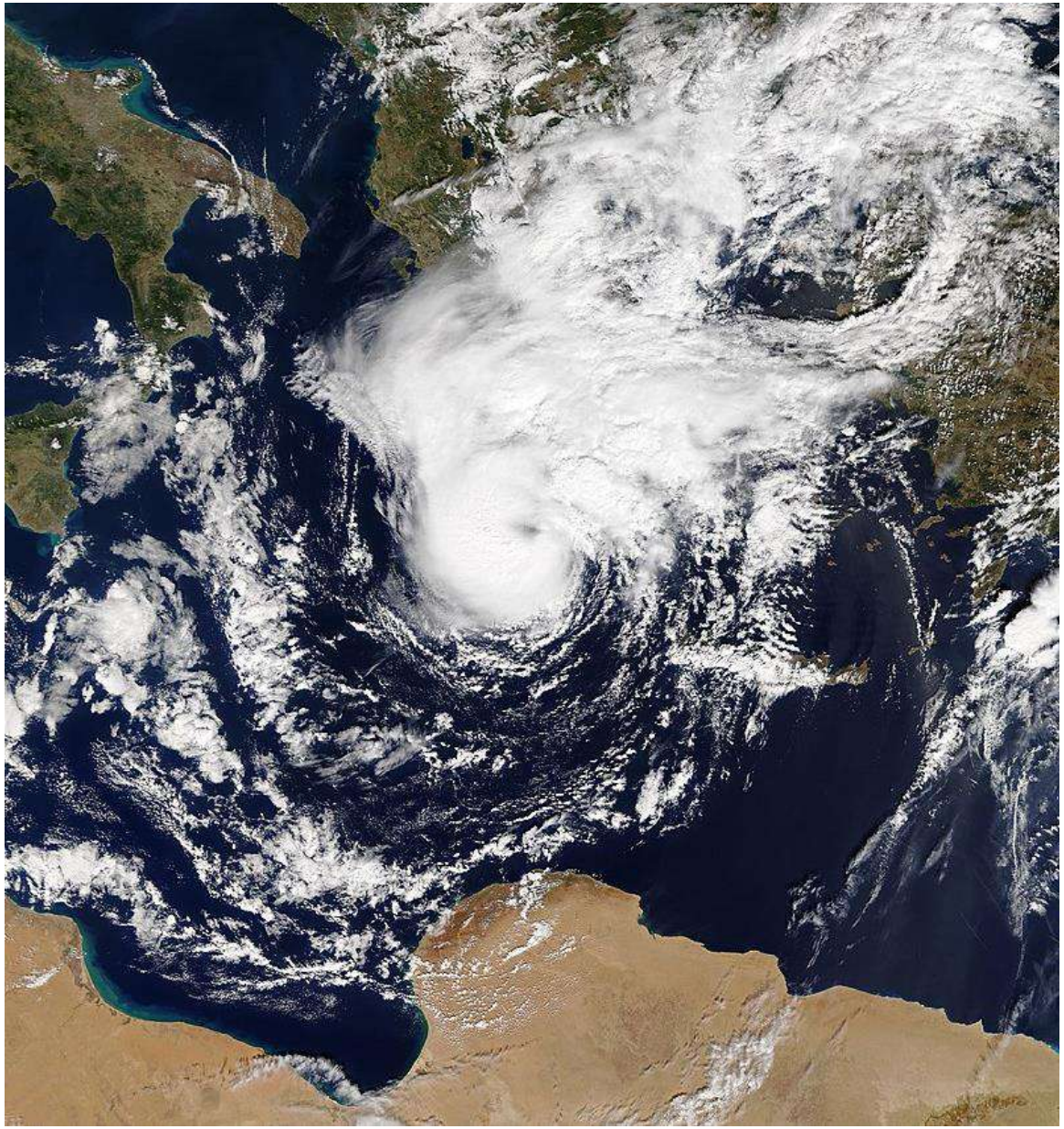
Mature Stage 2



- **Organized cloud**, spiraling external rainbands
- **DC** almost **absent within ~150 km** from the centre
- **Closed eye**

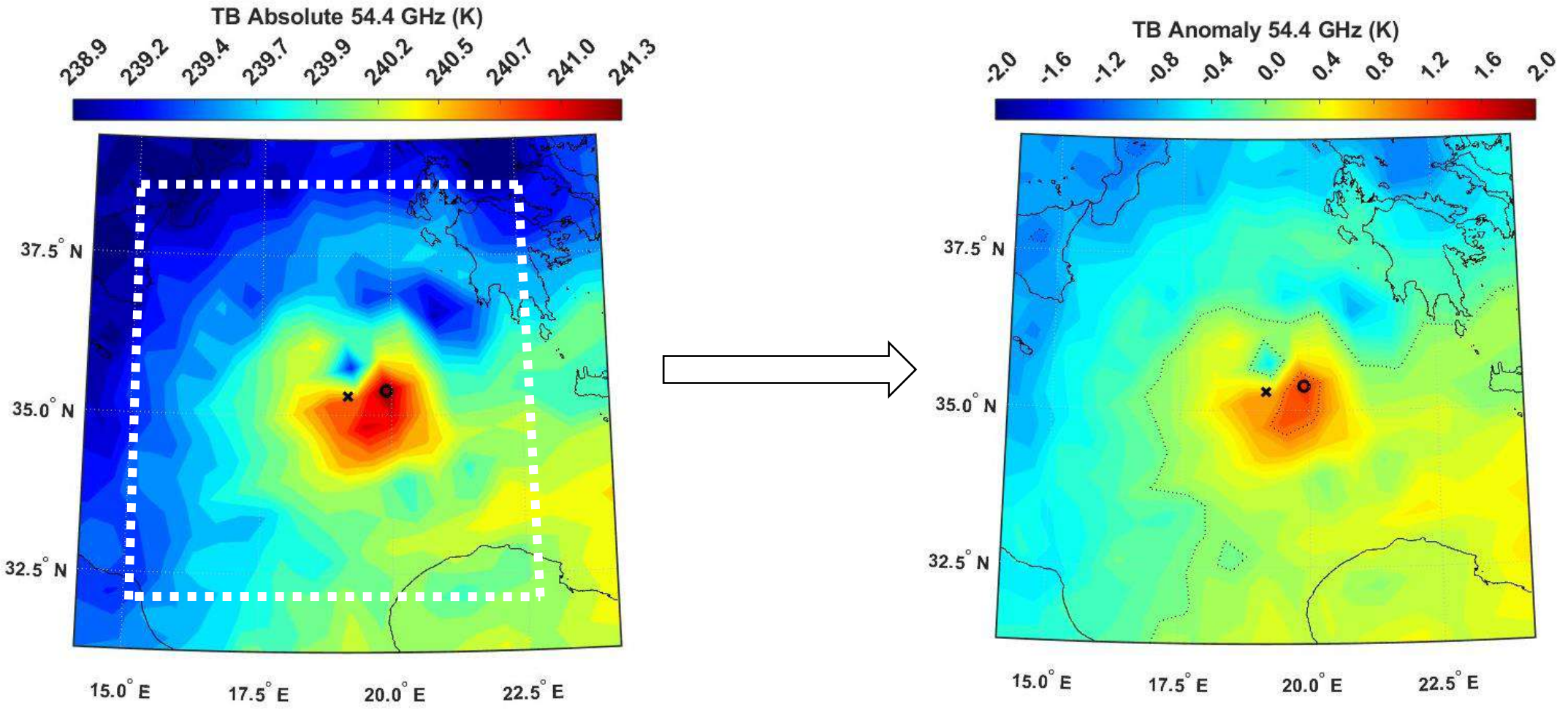

+ Add layer...
Sea surface temperature anomaly
02/11/2021
-4
-2
0
2
4°C
Sea surface foundation temperature
02/11/2021
log
MyOcean PRO
Sea Surface Temperature Anomaly
Frequency bands: VIS, IR, TIR
2 Nov. 2021 00:00 UTC
ΔSST = -3.15 K
ΔSST = -3.05 K
Points
Lines
Areas
Settings
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2 Nov 2021, 00:00
2023
2024

Thank you for your attention!



Back Up Slides

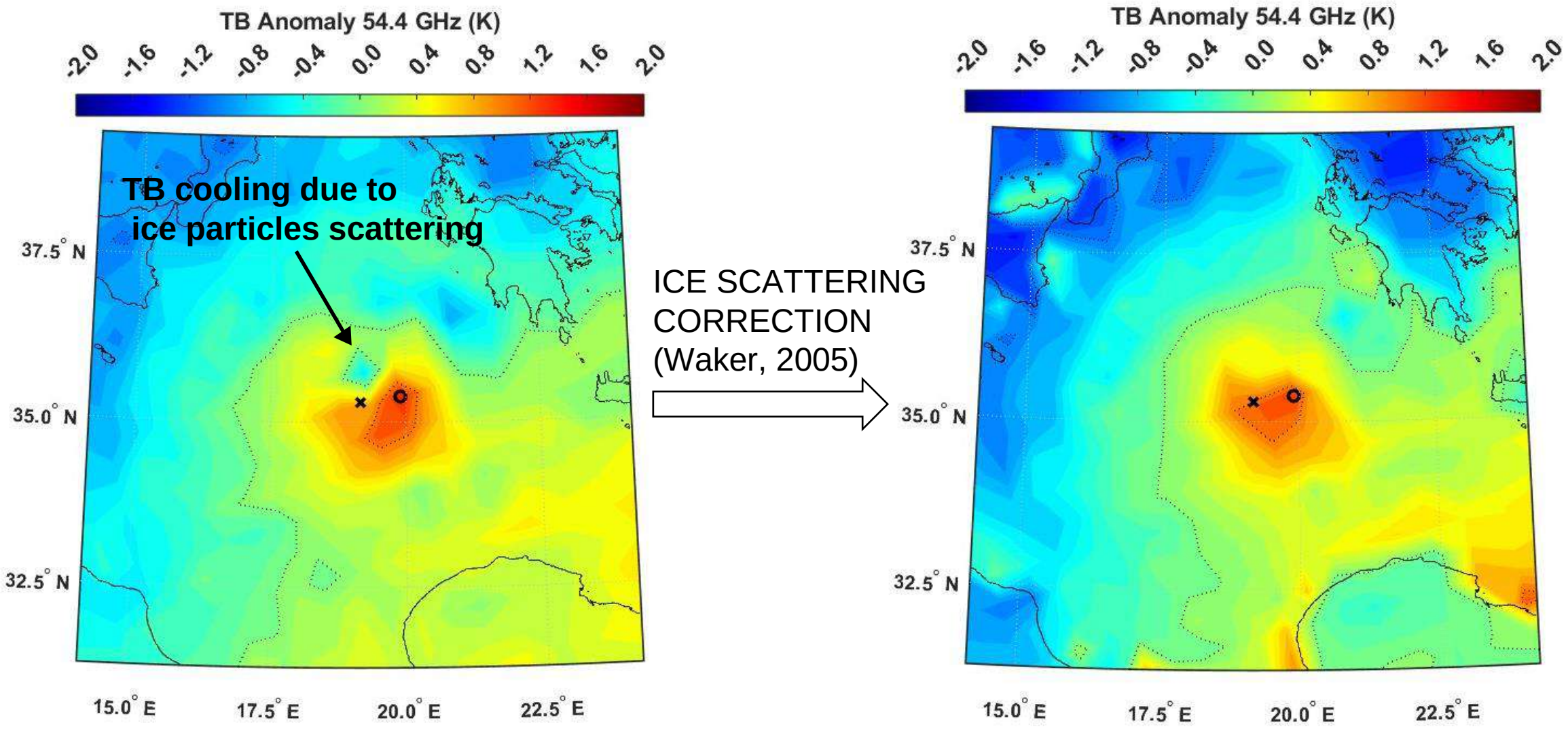
PMW Methods – Warm Core Detection and Analysis



- A 7°x7° area around the min MSLP is considered
- A mean TB (TB_{mean}) is calculated (land/coastal pixels are excluded)

$$\mathbf{TB_{anomaly} = TB - TB_{mean}}$$

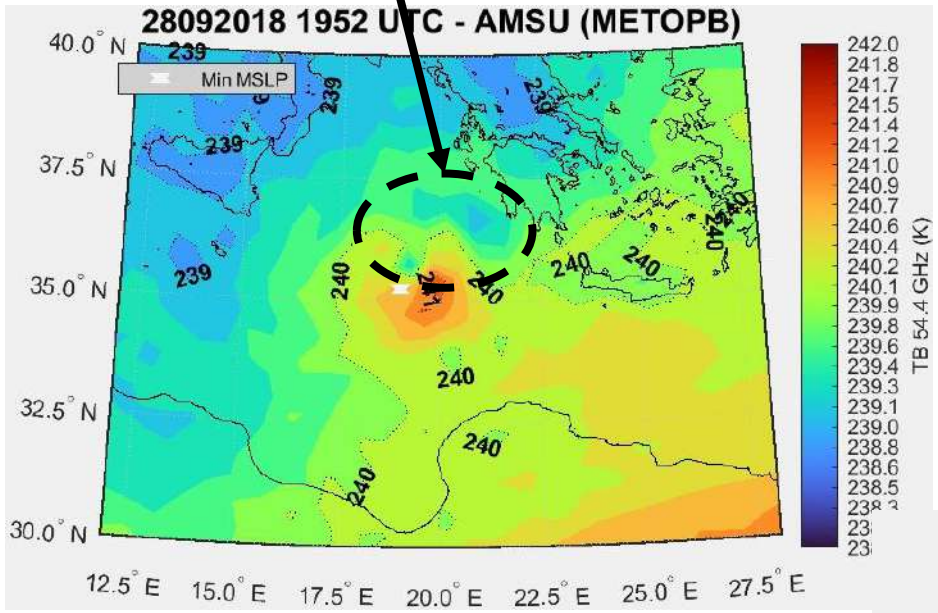
PMW Methods – Warm Core Detection and Analysis



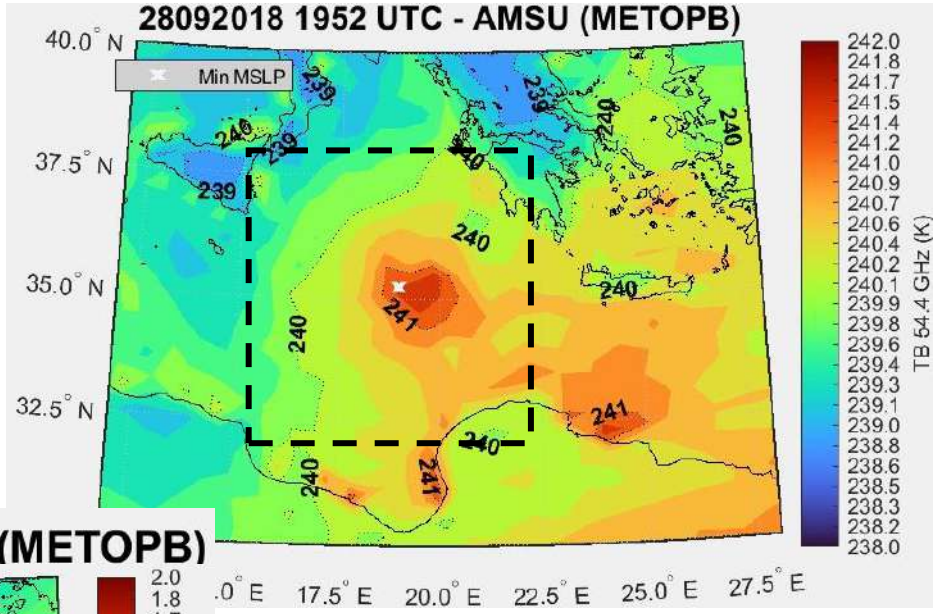
Warm Core analysis – TB anomaly

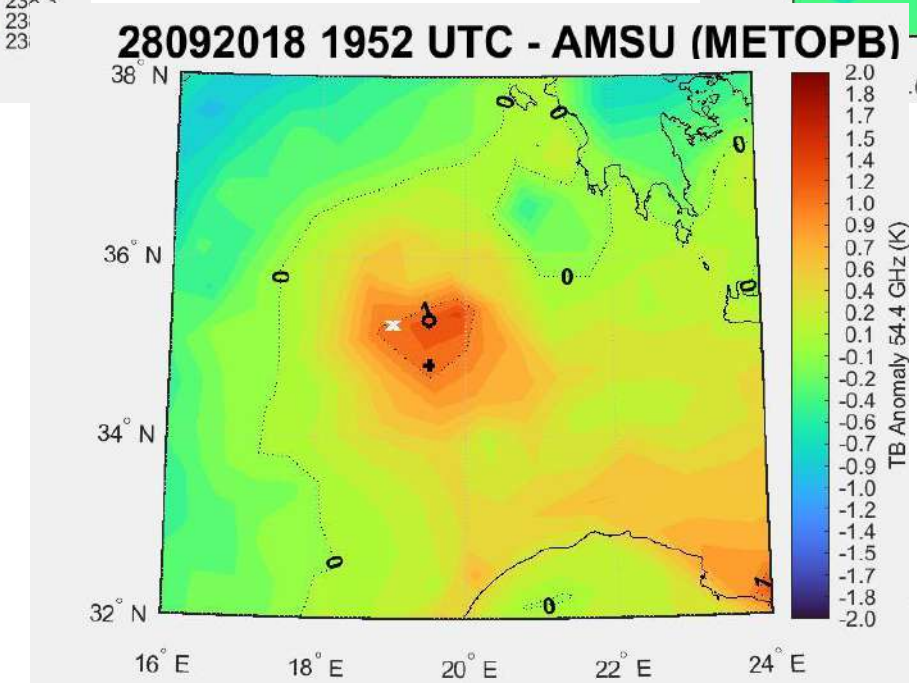
- Brightness temperature(TB) **measured** at 54.4 GHz ~400 hPa
- Cooling due to the scattering of ice particles

- TB corrected for ice scattering at 54.4 GHz ~400 hPa



Scattering Correction
Methodology developed in Wacker (2005) PhD thesis for TC





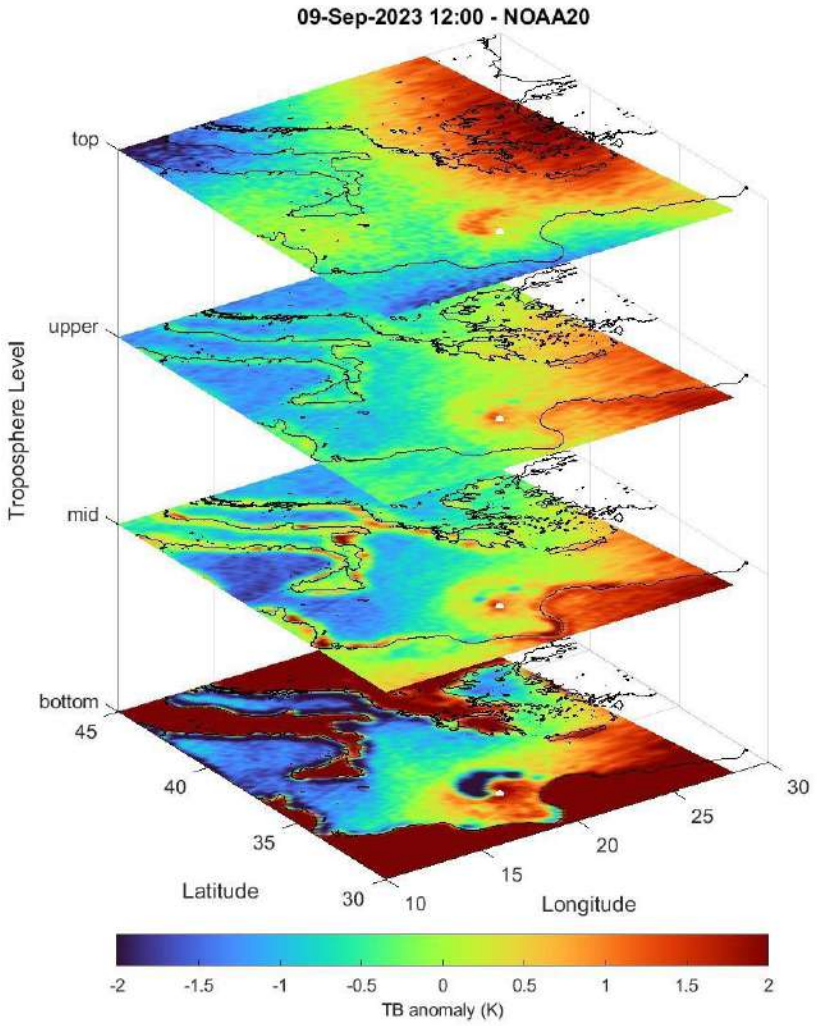
- A 7°x7° area around the min MSLP is considered
- A mean TB (TB_{mean}) is calculated (land/coastal pixels are excluded)
- $TB_{anomaly}$=TB-TB_{mean} (for each pixel over sea)

- This operation is repeated also for channels at 54.94 and 55.5 GHz (~250 and 200 hPa, respectively)

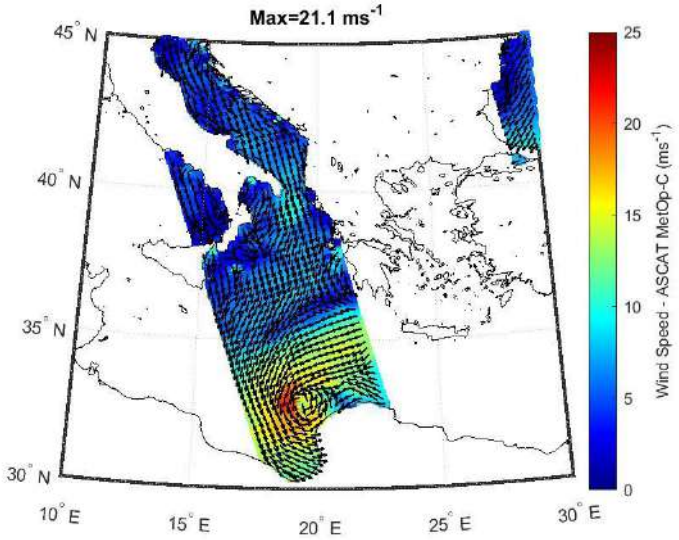
Storm Daniel

MetOp-C on 9 September 2023, at 19:21 UTC

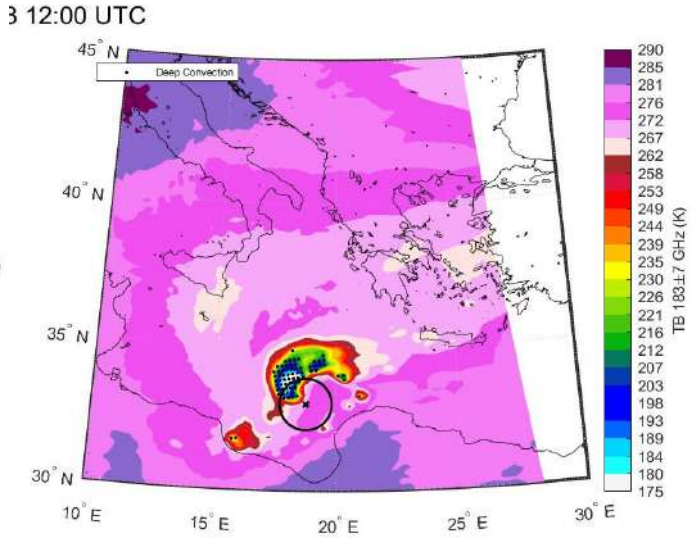
Warm core



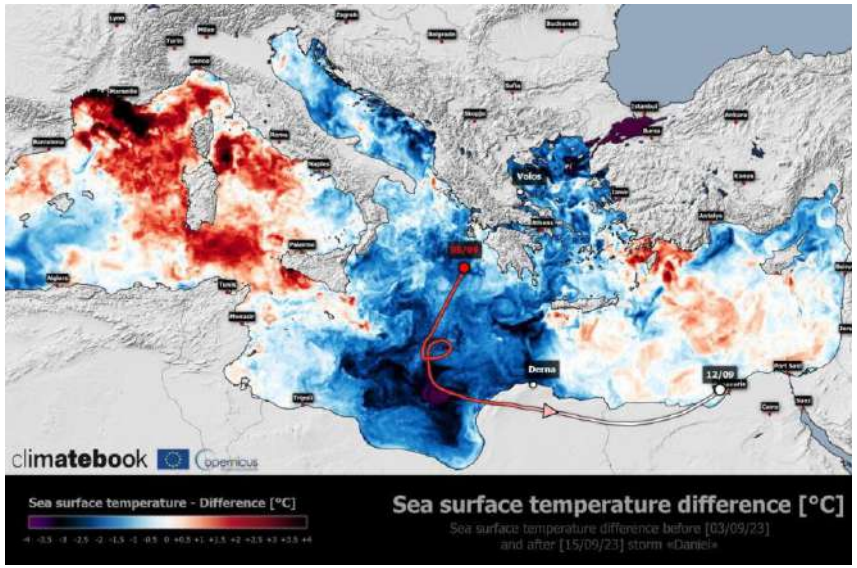
TB anomalies (K) from ATMS. The white dot indicates the position of the MSLP



OSI SAF ASCAT near-surface wind



TB 183+-7 GHz+ Deep convection



SST difference between 3 and 15 September 2023 and the track of Storm Daniel between 5 and 12 September 2023 (Courtesy of Climatebook.gr)

Daniel exhibit TLC features when it hits Lybia coast (axi-symmetric deep warm core, DC close to the center, strong rotation winds, closed eye)