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# Unprecedented observations of Medicane precipitation structure from the GPM constellation

ISAC

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# Medicane (Mediterranean Hurricane)

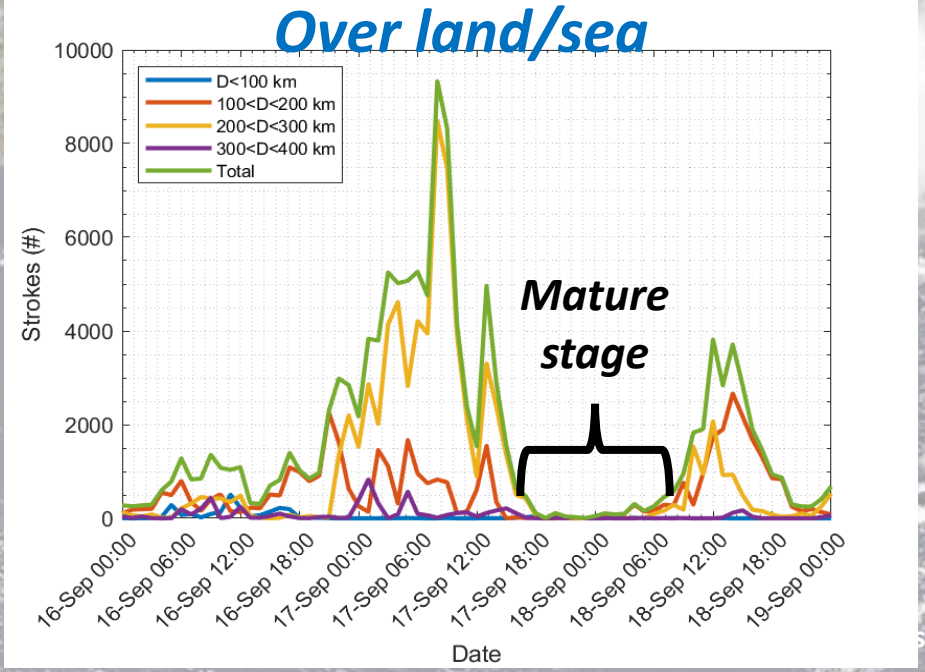
- **Mesoscale cyclones typical of the Mediterranean area which have some tropical-like cyclone (TLC) features during their mature stage (i.e., axi-symmetric barotropic structure, weak vertical wind shear and a warm core anomaly)**
- **They are often associated to heavy rainfall and flooding, intense wind, and high waves and storm surges**
- **Satellite imagery have favored the clear identification and characterisation of Medicanes:**
  - **quasi-cloud-free calm eye, spiral-like cloud bands elongated from the center, strong winds close to the vortex center**
  - **stronger convection and lightning activity prior to the medicane maximum intensity (i.e., during development phase) (e.g., Miglietta et al., 2013)**
  - **only a fraction of these cyclones experiences long-lasting intense convective activity close to their centers (Dafis et al., 2021);**
- **With the advent of the GPM mission era it has become possible to analyze in detail the precipitation structure of medicanes as they form, develop and evolve up to their mature phase (Panegrossi et al., 2016, Marra et al., 2019)**

# Medicane Ianos

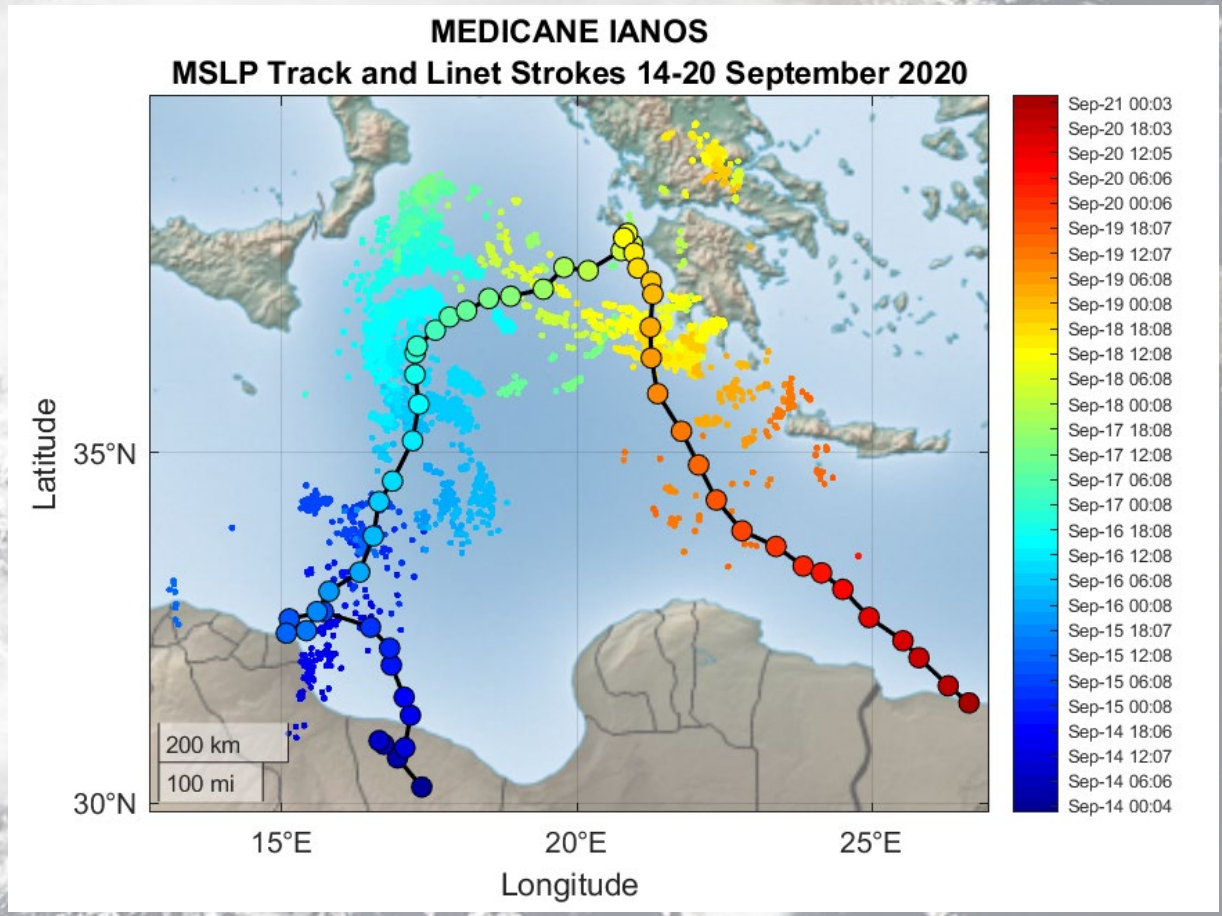
- Medicane Ianos occurred over Southern Mediterranean Sea in mid-September 2020. It has been classified as the most intense medicane: MSLP 984 hPa, wind gusts up to 54 $ms^{-1}$, 650 mm of accumulated rain (Lagouvardos et al., 2021). It exhibits TLC features during its mature phase (Comellas Prat, 2021)

- **Lagouvardos et al. (2021) identified deep convection in proximity of the medicane core during Ianos mature phase, although no lightning activity was observed at that stage**

***Over land/sea***




***Best track***



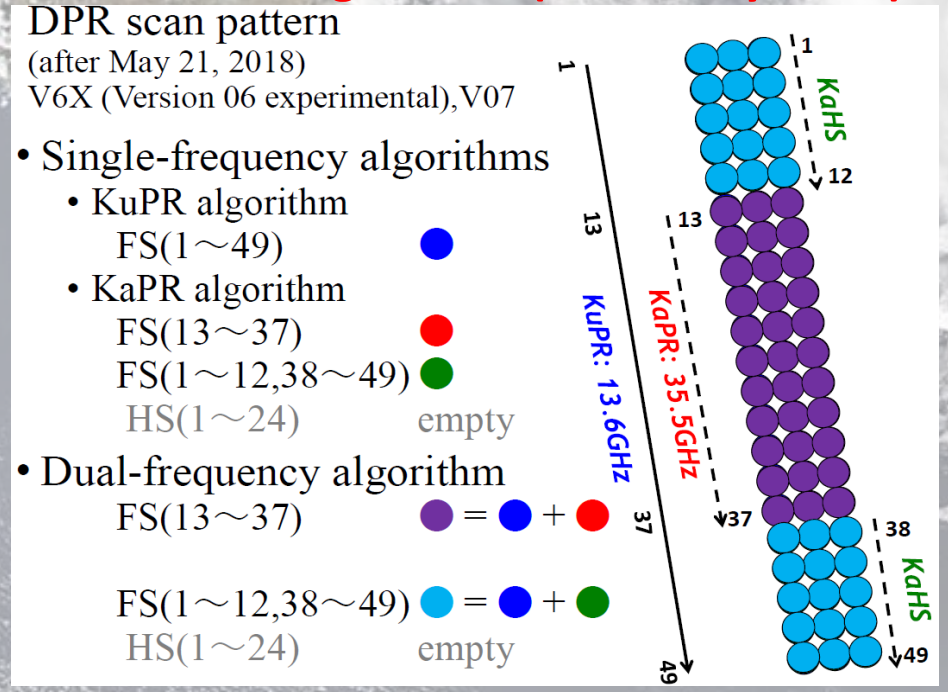

**Position of the minimum MSLP, and total number of strokes as detected by the LINET network within a time interval of ±30 minutes and within a 200 km radius from the position of the minimum MSLP (14 - 20 September 2020 )**

# GPM-Core Observatory

## Dual-frequency Precipitation Radar (DPR)

- Ku-band (13.6 GHz), Ka-band (35.5 GHz)
- Dual-frequency + single-frequency based products
- Each scan provides vertical profiles at 5 km horizontal (125 m vertical) resolution (3D view of precipitation)
- Reflectivity, precipitation rates, LWC, DSD parameters, etc.

**New scanning modes (since May 2018)**




## GPM Microwave Imager (GMI)

- Conical-scanning PMW radiometer
- 10 dual-polarization channels (10-166 GHz), 3 single-polarization water vapour channels
- 904 km swath, high spatial resolution (from 4x7 km at higher frequencies to 19x32 km at lower frequencies)
- Main output: brightness temperature (TB)

## Channels used and their properties

| *GMI channel* | *TB Warmer than background* | *TB Colder than background* |
|---|---|---|
| *37 GHz* | Emission from raindrops (rain) | Scattering by large and dense ice hydrometeors (e.g. hail – deep convection) |
| *89 GHz* | Emission from cloud liquid water (and water vapour) | Scattering by precipitating heavily rimed ice (e.g., graupel – convection/deep convection) |
| *166 GHz* | Emission from water vapour (and cloud liquid water) | Scattering by less dense ice (snowflakes and aggregates – stratiform/convective precip) |

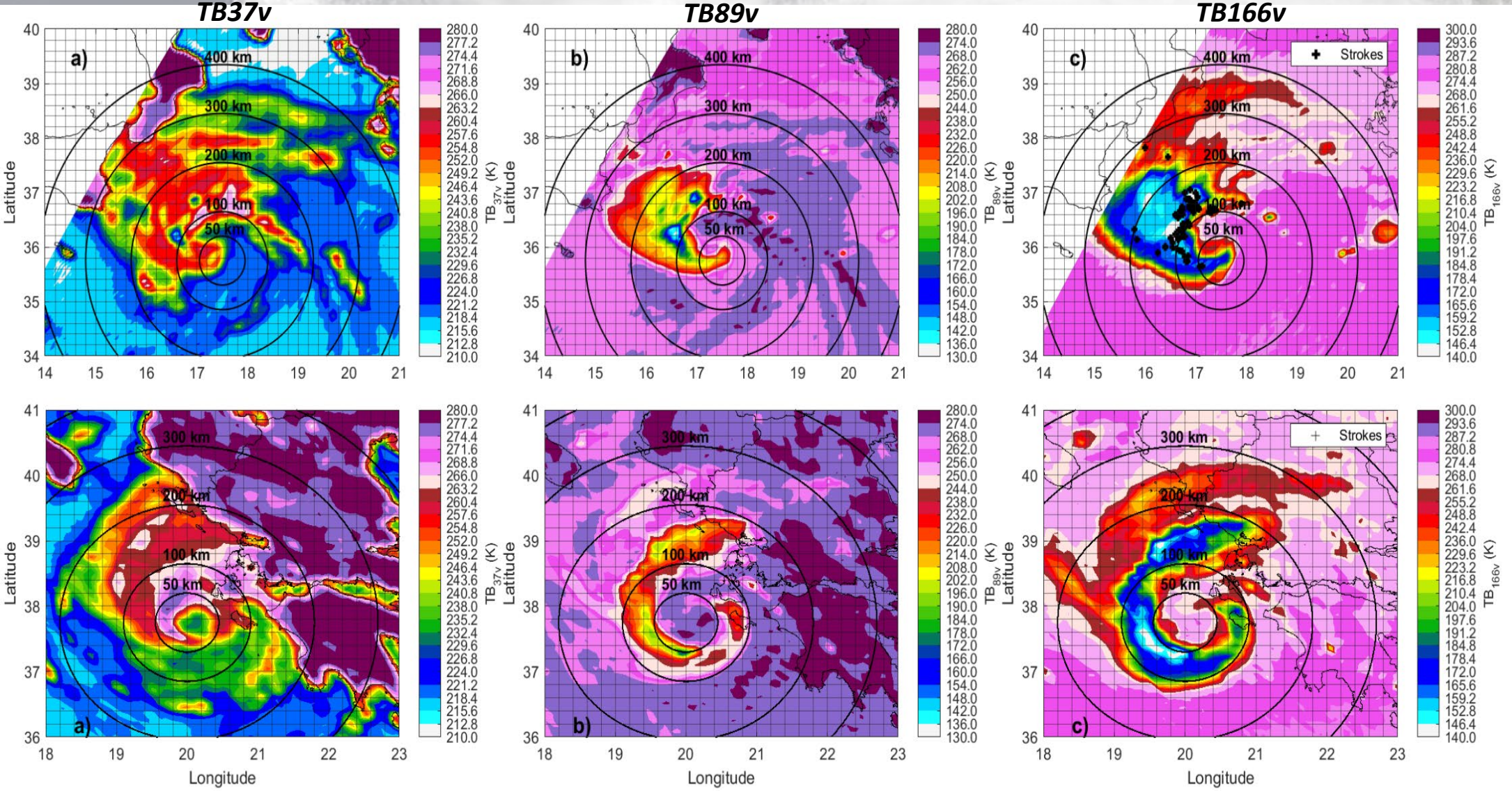
**Product used:**

- 2B-CMB product V06A providing corrected reflectivity profiles at Ku and Ka band, and different cloud and precipitation variables,
- GMI brightness temperatures (L1C product V05A)
- Lightning Strokes from the LINET ground-based network (Betz et al., 2004)

# Passive MW analysis - GMI

## GMI TB imagery

*L. P. D'Adderio, D. Casella, S. Dietrich, P. Sanò, G. Panegrossi, 2022. GPM-CO observations of Medicane Ianos: Comparative analysis of precipitation structure between development and mature phase, Atmos. Res., https://doi.org/10.1016/j.atmosres.2022.106174.*




**16 Sept 2020**
**13:40 UTC**
**Development phase**

**(* LINET Strokes)**

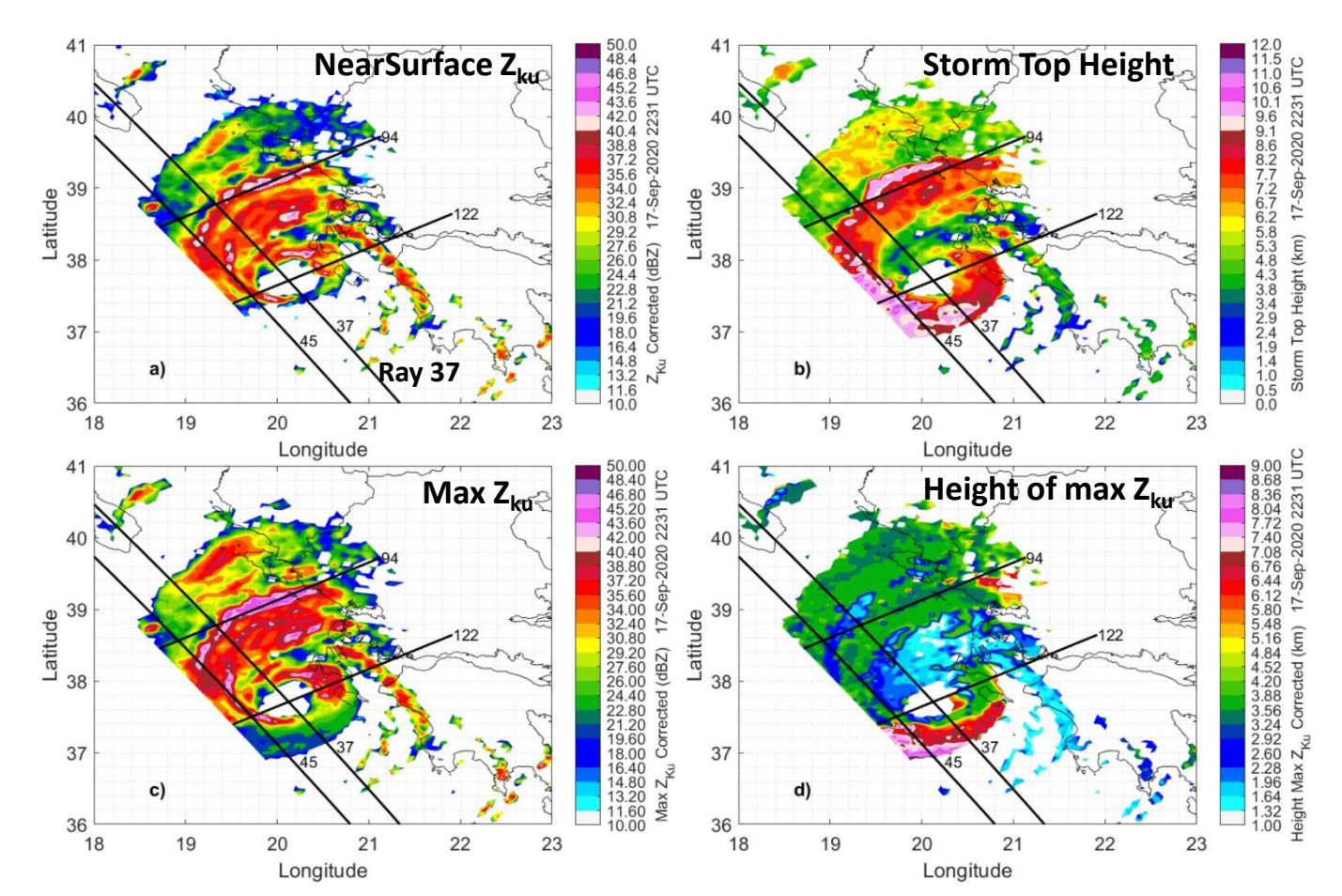
**17 Sept 2020**
**22:30 UTC**
**Mature phase**

**(* LINET Strokes)**

**analogous to TC Cecil and Zipser, (1999)**

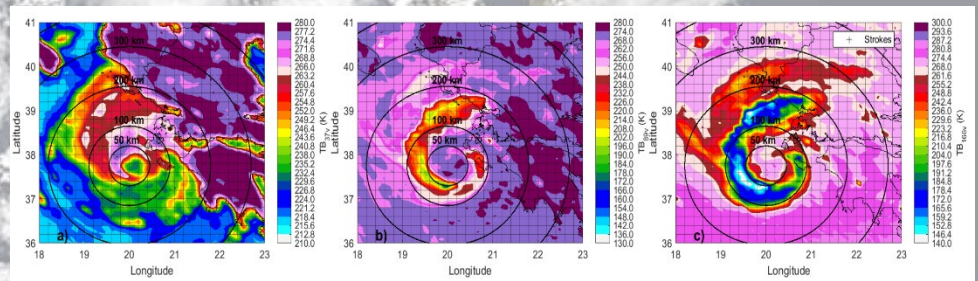
# DPR analysis

## GPM-CO overpass on 17 September 2020, 22:30 UTC – Mature stage




- $Z_{Ku}$ generally around 30 dBZ, only 6.5% of footprints > 40 dBZ
- Max Zku < 45 dBZ
- **Storm top height generally below 9 km (except for the convective cores or high-base not precipitating clouds reaching 11 km)**
- Mostly stratiform precipitation, Intense shallow precipitation around the eye (STH < 4-5 km, freezing level), limited areas show deep convection properties

### GMI TB imagery

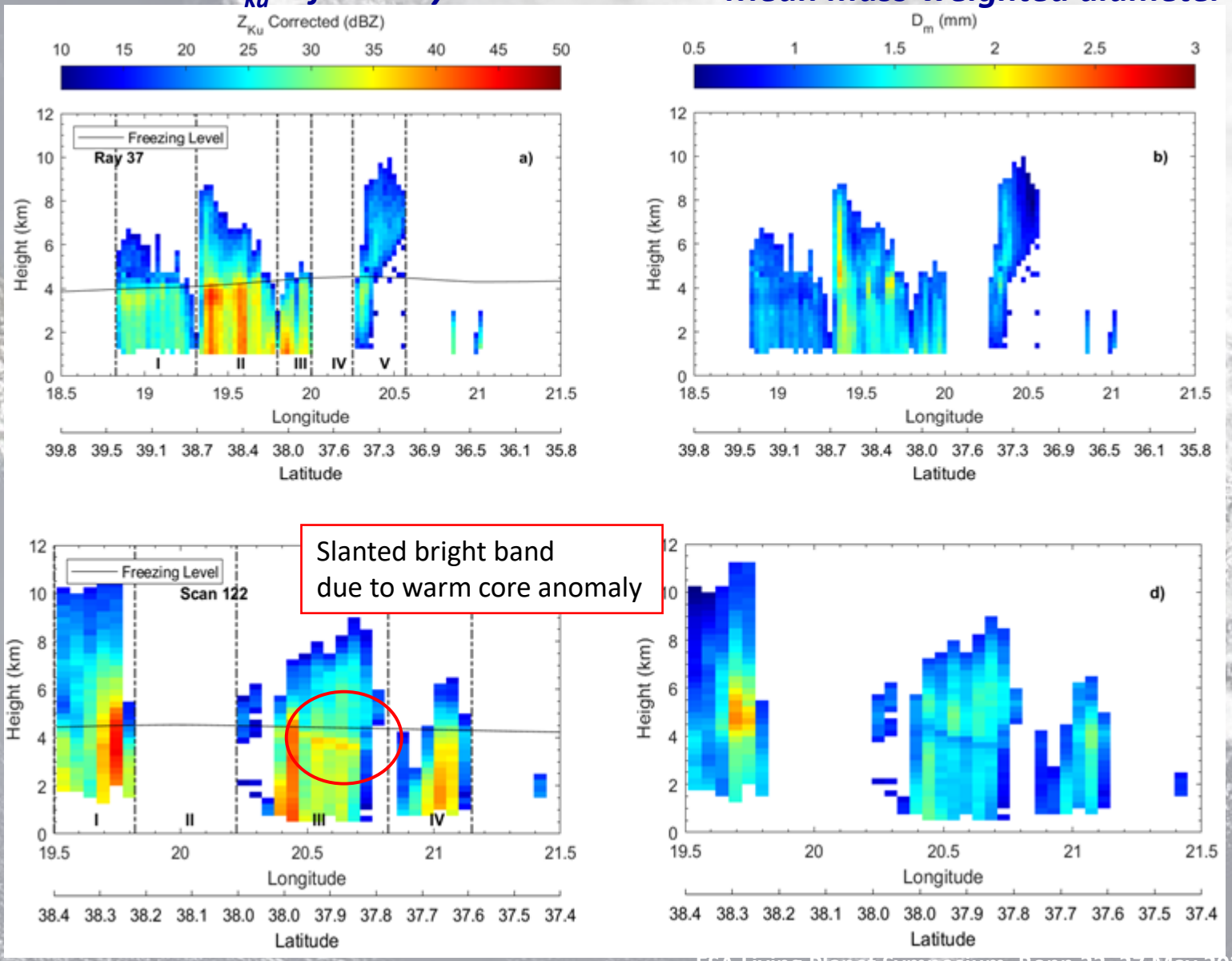


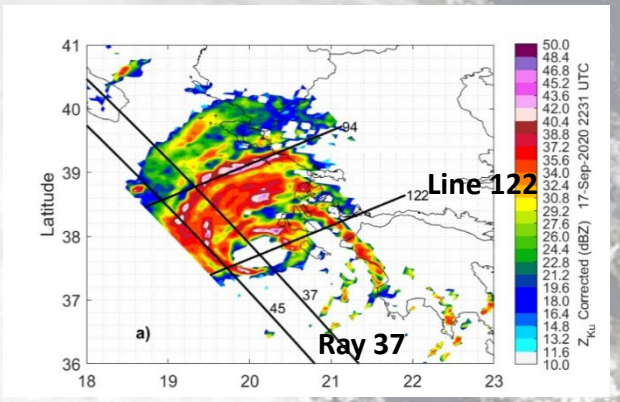

*L. P. D'Adderio, et al. 2022 Atmos Res*

# DPR vertical cross section

**17 September 2020, 22:30 UTC**

***$Z_{ku}$ reflectivity*** ***Mean mass-weighted diameter***




**Zone I: stratiform precipitation**
**Zone II: moderate embedded convection**
**Zone III: shallow/warm rain region**
**Zone IV: Ianos eye**
**Zone V: non-precipitating high-level cloud**

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**Zone I: convective core**
**Zone II: Ianos eye**
**Zone III: stratiform precipitation with embedded convection**
**Zone IV: shallow precipitation**

$D_m$ generally < 1.5 mm
In deep convective region max $D_m$ = 2-2.5 mm at 4 - 6 km (collisional breakup)

*L. P. D'Adderio, et al. 2022 Atmos Res*

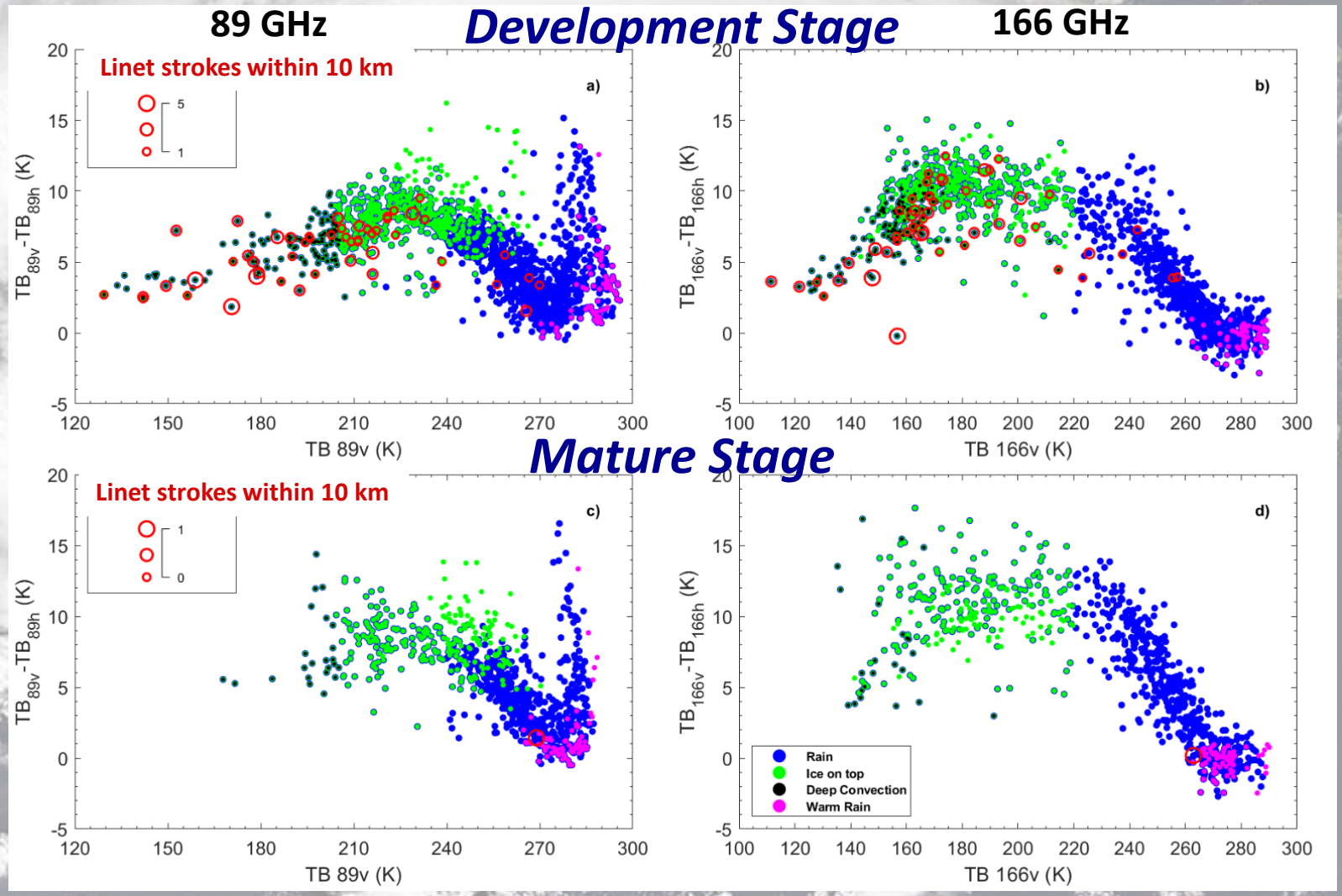
# GMI classification

- **ΔTB-$TB_v$ relationship highlights different precipitation processes (Bell shape curve *Gong and Wu 2017)***

- **Different thresholds on TB/ΔTB/PCT to classify each satellite footprint according to its microphysical/precipitation properties**

***Four classes are identified***

| Precipitation Class | Threshold |
|---|---|
| Rain | $\Delta TB_{37}$<30 K |
| Deep Ice on top | $TB_{166}$<220 K |
| Deep Convection | $PCT_{89}$<210 K |
| Warm Rain | $TB_{37}$>268 K & $TB_{166}$>261 K |

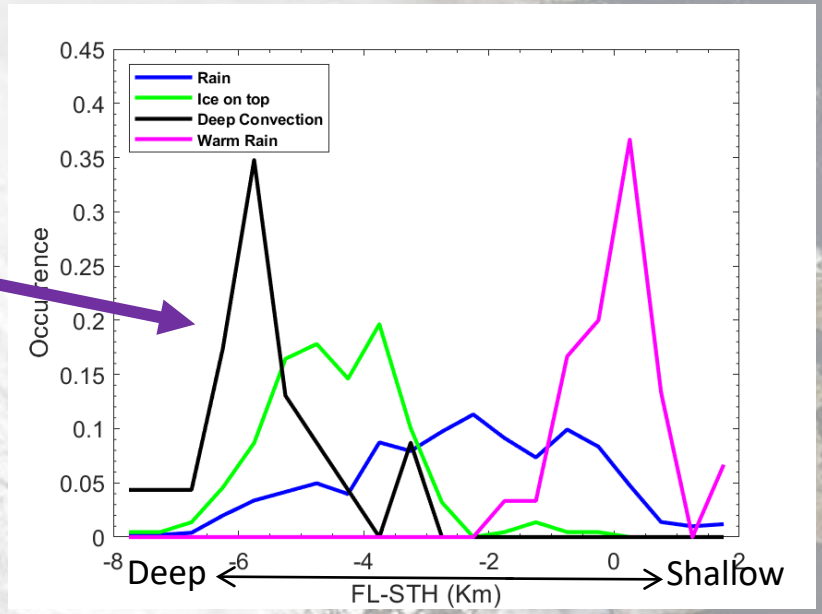



*$PCT_{89}$ < 210K deep convection (upper limit of top 1% class from Hourngir et al., 2021)*

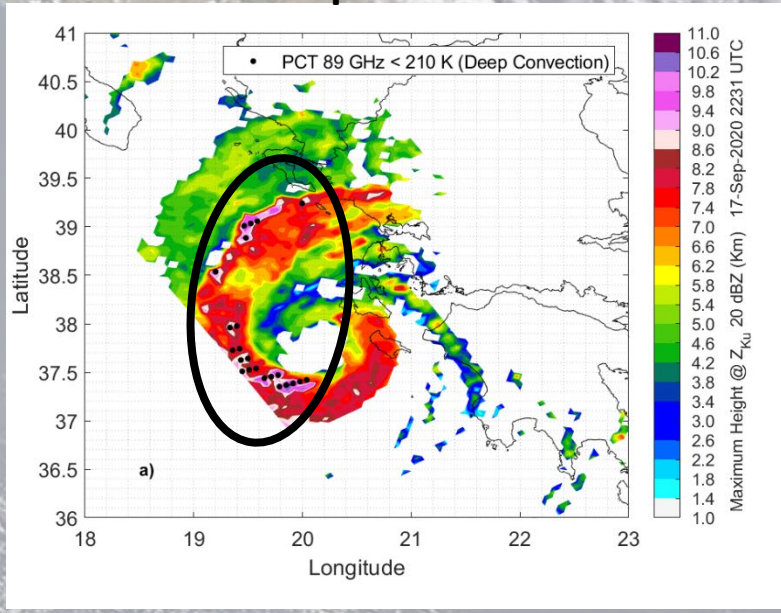
*L. P. D'Adderio, et al. 2022 Atmos Res*

# DPR/GMI combined analysis

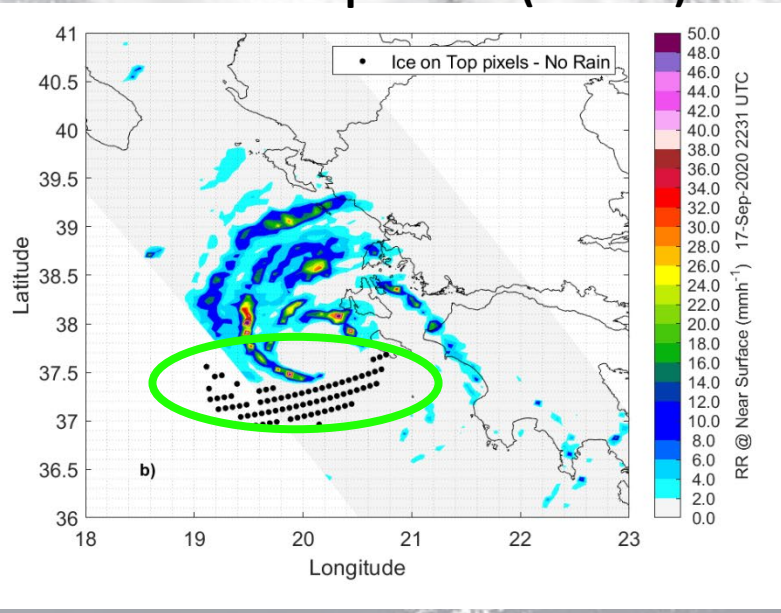
- **Verification of GMI-based classification with DPR data**
- **Distribution of the difference between freezing level (FL) and storm top height (STH) as retrieved by DPR for the four classes labelled by GMI analysis**




**DPR 20BZ <echo top height and GMI-based deep convection**




**DPR Near surface Rain rate and GMI-based deep clouds (no rain)**




**The "Deep Convection" GMI-based pixels perfectly match with cores showing highest 20 dBZ echo top height**

**The "No Rain with ice on top" GMI-based pixels perfectly match with area not reporting rain at Near Surface level**



*L. P. D'Adderio, et al. 2022 Atmos Res*

# Warm Core analysis Introduction

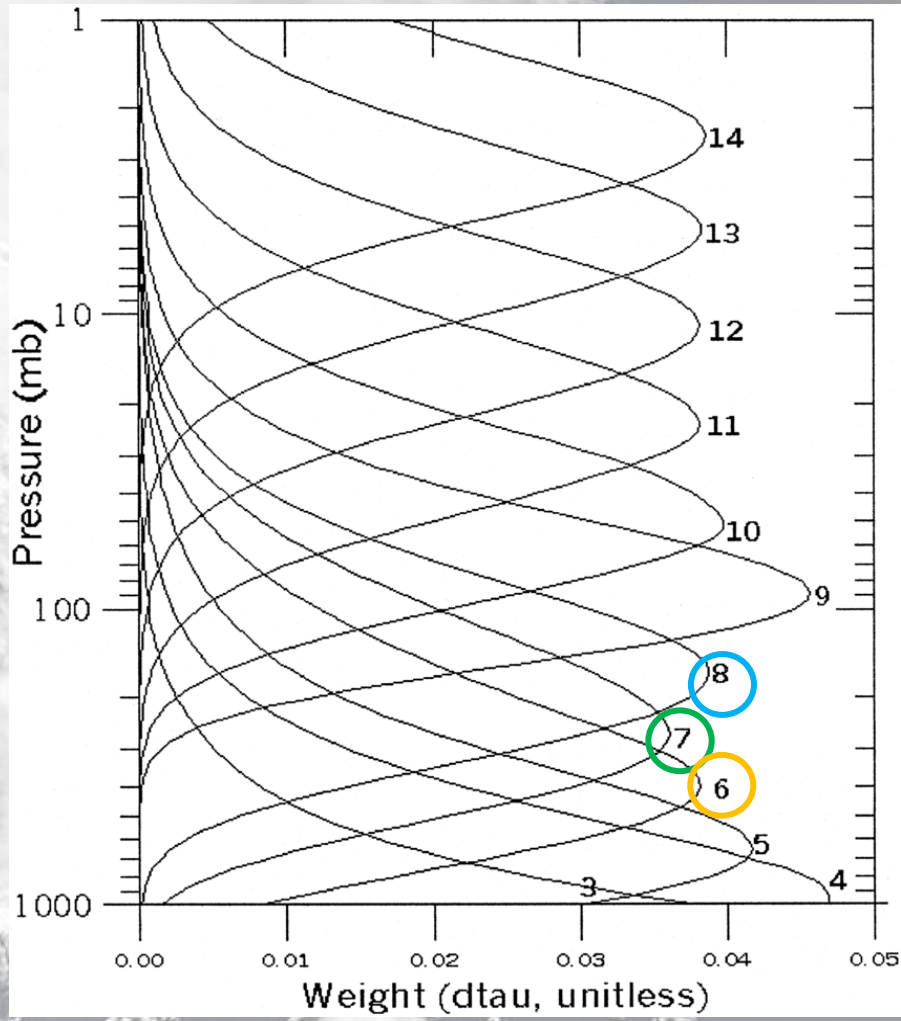
- ***Satellites: AMSU-A, ATMS***

- **Brightness Temperature (TB) anomaly: TB-$TB_{mean}$ (calculated over the whole domain). TB corrected for limb effect (related to the cross-track scanning mode).**

- **Three channels: 54.4 (ch6), 54.94 (ch7) and 55.5 (ch8) GHz.**

- **Channels 6-8 are used to reconstruct the hurricanes track.***

- **In presence of clouds, additional effects (e.g. ice scattering) have to be considered in the TB calculation (to be investigated).**




*Velden, C. S., & Herndon, D. (2020). A Consensus Approach for Estimating Tropical Cyclone Intensity from Meteorological Satellites: SATCON, *Weather and Forecasting*, *35*(4), 1645-1662. Retrieved Apr 26, 2022, from https://journals.ametsoc.org/view/journals/wefo/35/4/wafD200015.xml

Velden, C. S., & Herndon, D. (2012). Estimating TC Intensity Using the SSMIS and ATMS Sounder. https://apps.dtic.mil/sti/pdfs/ADA561820.pdf

# Warm Core analysis
# GPM constellation

## AMSU-A satellite

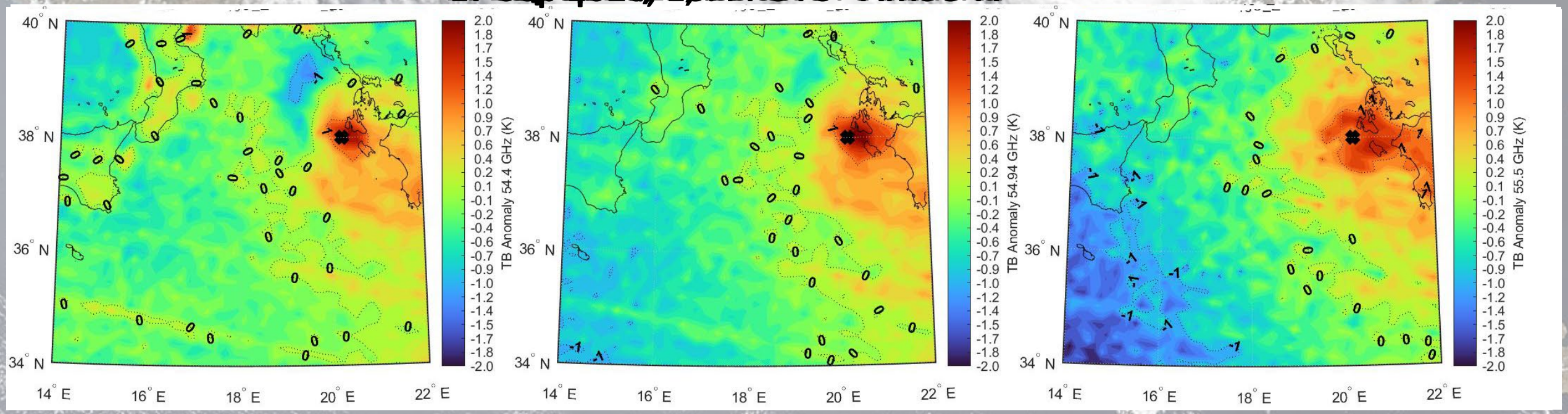
- *20 channels (frequencies) in total*
- *3 frequencies considered: 54.4, 54.94 and 55.5 GHz*

## ATMS satellite

- *22 channels (frequencies) in total*
- *3 frequencies considered: 54.4, 54.94 and 55.5 GHz*

**Weighting function peaking in the 350-100 hPa range, where the warm core is observed and the clouds have a low impact on the measurements**

**These channels are deeply used to identify the hurricanes warm core**

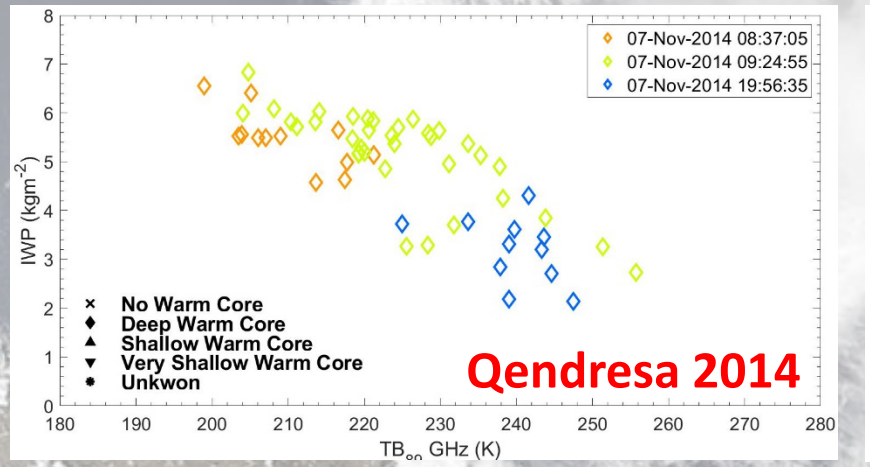


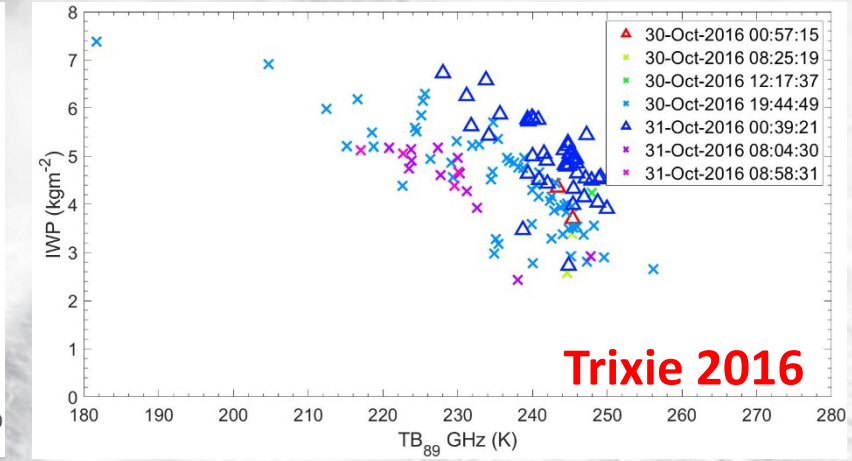
# Warm Core analysis - Properties

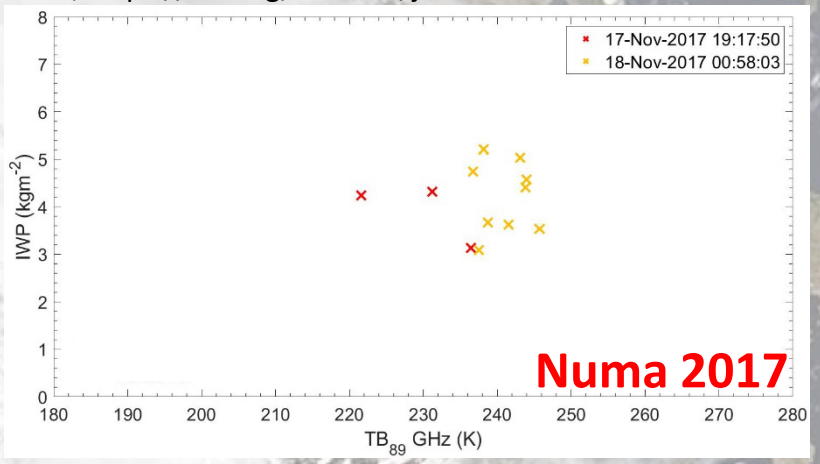
## Ice Water Path (IWP)

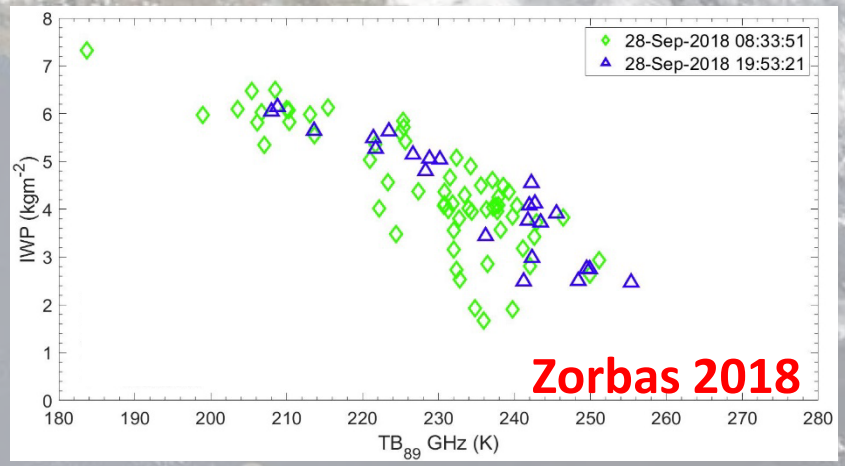
- **Analysis of Ice Water Path (IWP) for deep convection pixels through the medicane evolution**

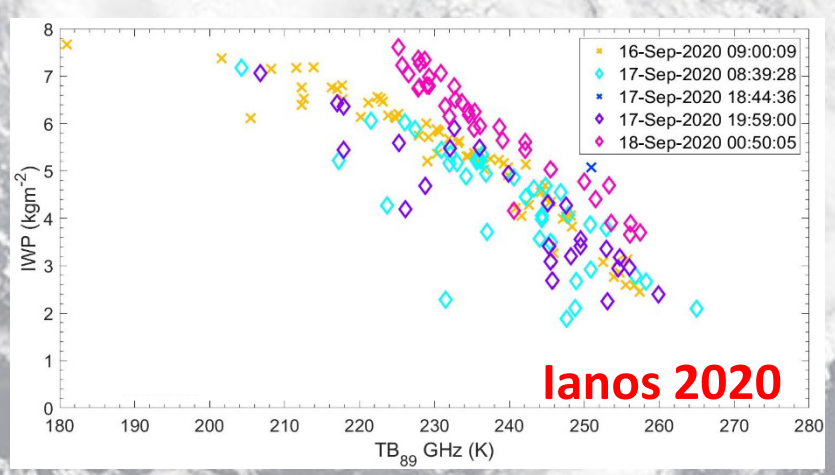
Rysman J.-F., Claud C., Dafis S., 2021. Global monitoring of deep convection using passive microwave observations, Atmos. Res., 247, https://doi.org/10.1016/j.atmosres.2020.105244.

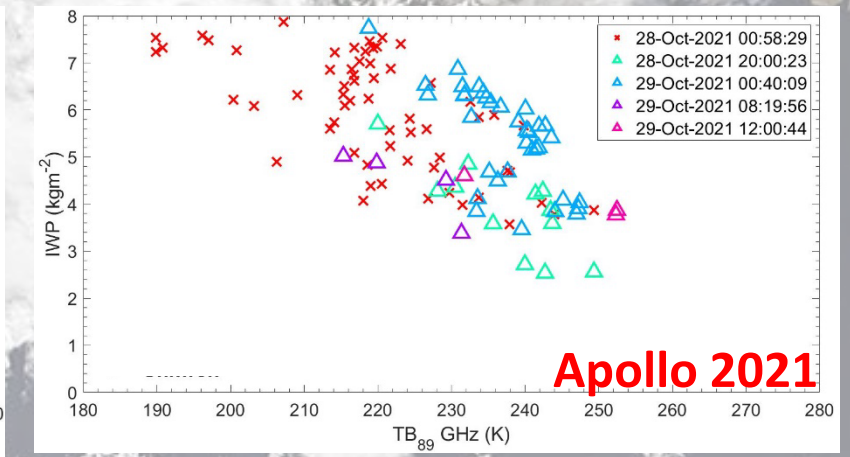



- Medicane Ianos show a bi-modal distribution of IWP with respect to TB @ 89 GHz depending on the medicane stage (i.e. development vs mature stage).
- Similar properties (but less evident) are shown by medicanes Trixie and Apollo
- Additional data have to be investigated for the other medicanes.

## Only Deep Convective pixels

Funatsu, B. M., Claud, C., and Chaboureau, J.-P. (2007), Potential of Advanced Microwave Sounding Unit to identify precipitating systems and associated upper-level features in the Mediterranean region: Case studies, *J. Geophys. Res.*, 112, D17113, doi:10.1029/2006JD008297.

# Conclusions

- **GPM-CO provides evidence of Ianos exceptional intensity, tropical-like characteristics during its mature phase, and its similarities with tropical cyclones.**
- **Passive microwave measurements (GMI) reveals different precipitation structures and microphysics processes between development and mature phase, confirmed by DPR measurements (for the first time during TLC phase).**
- **Shallow precipitation/warm rain processes are observed in the inner region around the medicane eye.**
- **Substantial drop in lightning activity during Ianos mature phase (in presence of deep convection).**
- **GPM constellation is used to detect the medicane(s) warm core and estimate its depth.**
- **The IWP seems to be related to different cloud microphysical properties depending on the medicane stage.**

**Future Work: contribute to MedCyclone Cost Action Initiative on Medicane definition**

- ***Trying to automatize the detection and the depth estimation of the warm core***
- ***Further analysis considering additional PMW channels and numerical models***

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EGU

# 17TH PLINIUS CONFERENCE
## on Mediterranean Risks

18 - 21 October 2022
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www.meetings.copernicus.org/plinius17

ISAC

Ideazione e realizzazione Alessandro Ciarravano

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17th Plinius Conference on Mediterranean Risks
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Villa Mondragone Congress and Event Center
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Sessions:

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4. Socio-economic impacts: exposure, vulnerability, prospectives, and adaptation
5. Safeguarding and management of cultural and natural heritage at risk from climate extreme events
6. Natural hazards for ecosystems and agriculture
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**Abstract submission deadline: 3 June 2022**