Satellite-based analysis and characterization of medicanes' surface wind field

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Medicanes

Mediterranean cyclones showing tropical-like characteristics during their mature phase:

- strong near-surface wind field with **closed cyclonic structure**;
- **quasi-calm cloud free eye** in its center;
- **spiraling heavy rain bands** around the center.

Tropical transition: the deep warm core originates from diabatic processes and deep moist convection (DC) can be found in proximity of the center.

Deep convection due to low-level diabatic processes consists in strong vertical motions close to the Medicane's center warming the core of the Medicane in great vertical extent through latent heat release in moist ascent (Panegrossi et al., 2023).

Objective of the work

- **<u>surface wind field characterization</u>** during the whole lifecycle of a medicane **<u>through the definition of a Radius of Maximum Wind</u>** (RMW), similarly to what has already been done for tropical cyclones (Rogers and Reasor, 2013);
- highlight the differences in terms of surface wind field between the development and the tropical-like phase;
- analyse the behaviour of RMW in the presence of WC.

Data

Sea surface wind vector (speed and direction): ASCAT scatterometers on board Metop satellites

Mean Sea Level Pression (MSLP): hourly estimates at 0.25° by ERA5 reanalysis

Brightness Temperature (TB): AMSU-A/B/MHS passive microwave radiometer on board Metop satellites

The TB is a measurement of the amount of microwave radiation traveling upward from the Earth's surface to the satellite and interacting with hydrometeors present in the atmosphere (absorption, emission, scattering, etc.). It is expressed in terms of the temperature of a perfectly absorbing surface (equivalent black body).

Instruments

ASCAT

Full name	Advanced Scatterometer
Purpose	Sea surface wind vector. Also large-scale soil moisture
Short description	C-band (5.255 GHz), 1 MHz bandwidth, side looking both left and right. 3 antennas on each side
Scanning Technique	Two 550-km swaths separated by a 700-km gap along-track. 3 looks each pixel (45, 90 and 135° azimuth)
Resolution	12.5 km
Coverage / Cycle	Global coverage in 1.5 days

AMSU-A / AMSU-B/MHS

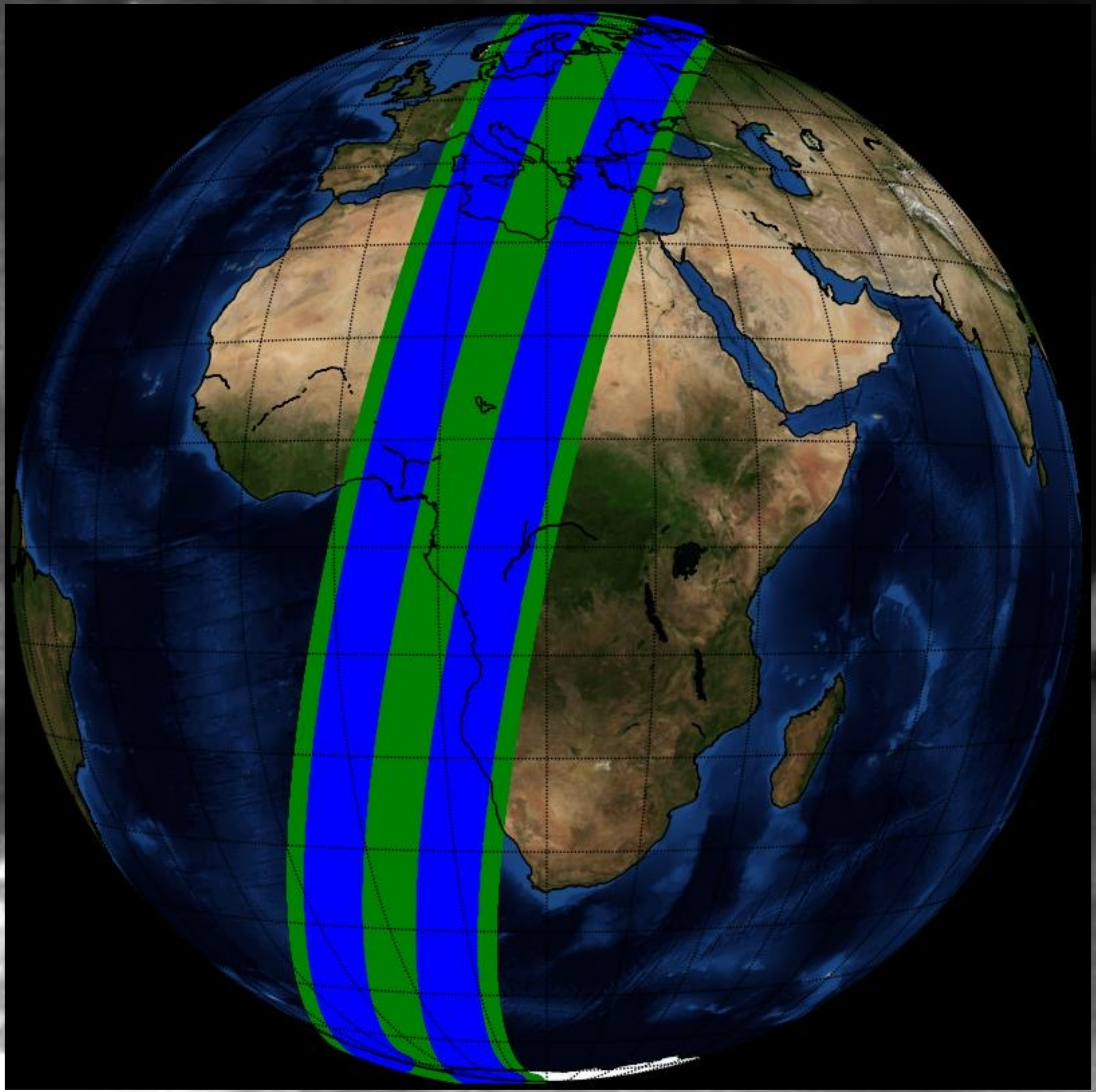
Full name	Advanced Microwave Sounding Unit - A
Purpose	Temperature sounding in nearly-all-weather conditions
Scanning Technique	Cross-track: 30 steps of 48 km s.s.p., swath 2250 km - Along-track: one 48-km line every 8 s
Resolution	48 km IFOV
Coverage / Cycle	Near-global coverage twice/day
Frequency	15 channels from 23 to 89 GHz

ASCAT scenes are observed also by AMSU-A/B/MHS onboard the same platform.

Instruments

AMSU-B

ASCAT



ASCAT does not detect the medicane when it is located between its two swats

Dataset

ASCAT data availability is investigated for **all Medicanes occurred from 2011 to 2023**

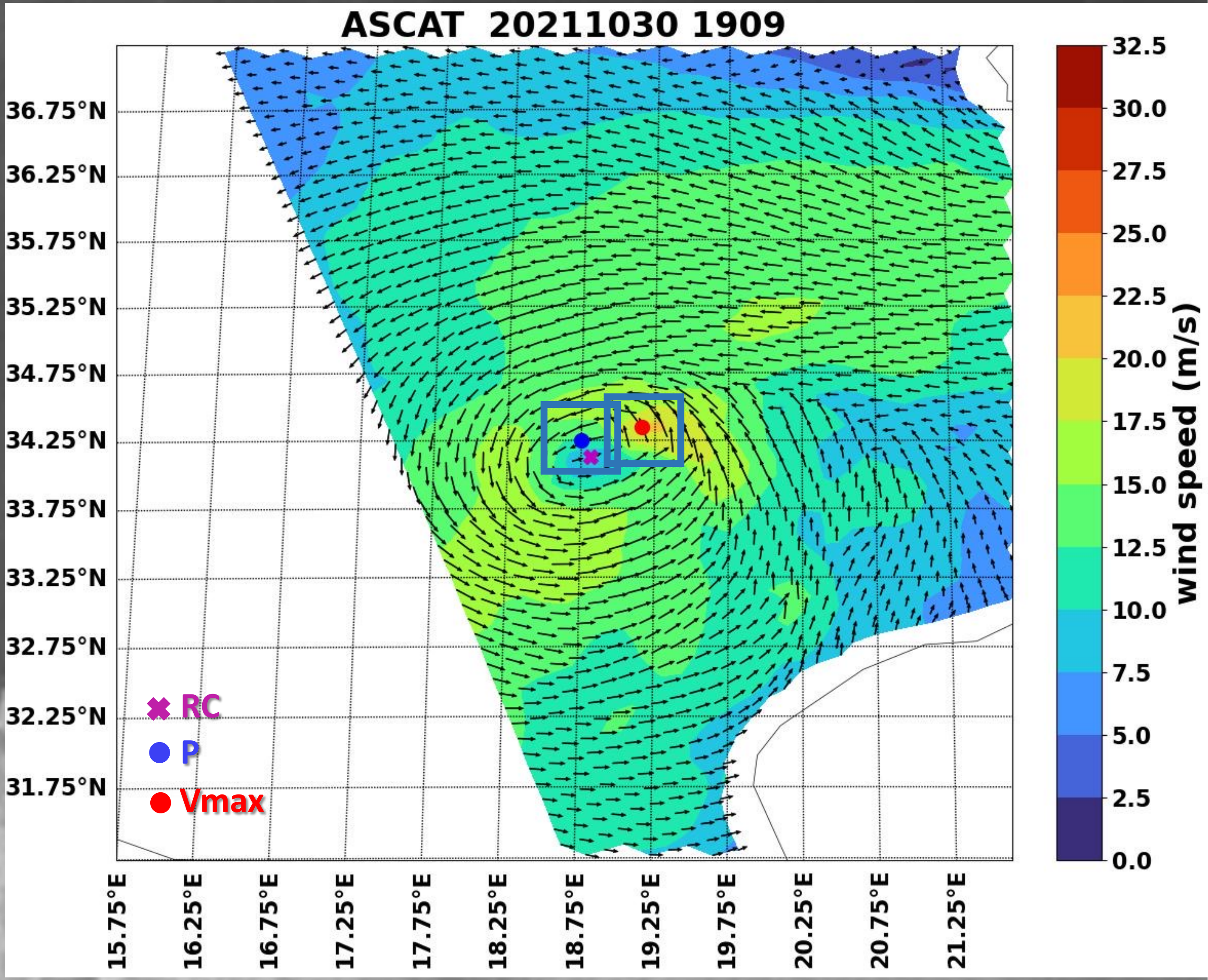
Medicane	Duration	Useful overpasses (*)
Rolf	20111105-09	2
Qendresa	20141106-09	2
Trixie	20161028-31	6
Zorbas	20170927-29	4
Numa	20171115-19	5
Ianos	20200916-19	3
Apollo	20211026-31	9
Blas	20211107-15	10
Juliette	20230227-20230303	5
Daniel	20230905-10	3

(*) if the ASCAT swat covers the entire area affected by the medicane

Medicane Rotational Center Automated Detection (MeRCAD)

Rotational center (RC) detection:

- within two 0.5° boxes around the minimum MSLP (P) and the maximum wind speed (Vmax)
- wind speed < 12 m/s
- standard deviation of the wind direction computation in a 2X2 moving window inside each box
- the position of the pixel with standard deviation belonging to the 90th percentile closest to P is detected in each box
- finally, between the two pixels thus detected, RC corresponds to the pixel with the minimum wind speed



RMW computation and analysis

- **RMW computation:** similarly to what is done for tropical cyclones (Rogers and Reasor, 2013) the RMW has been defined as the distance between the band of the maximum winds and RC
- **Identification of the RMW behavior in relation to the WC and DC**

Methodology

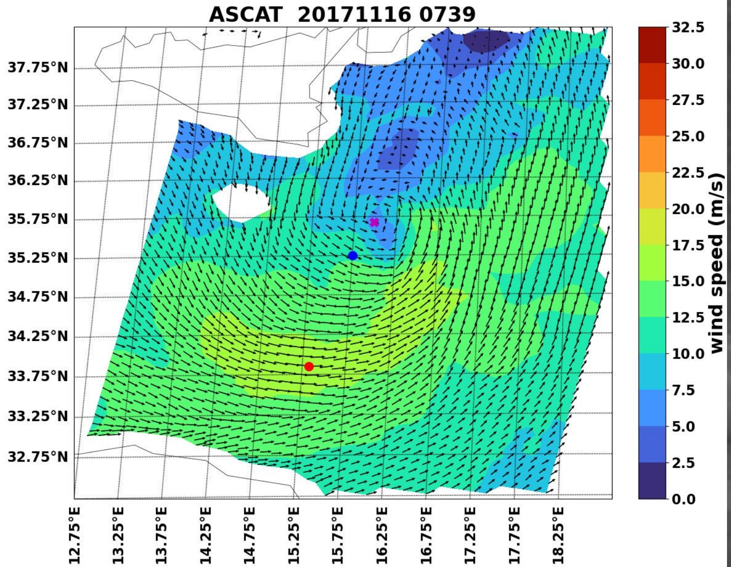
Deep convection detection is based on the 183.31 GHz channels: $\Delta T35 < T0$; $\Delta T34 < T0$; $\Delta T45 < T0$ (Hong et al., 2005; Rysman et al., 2017), where:

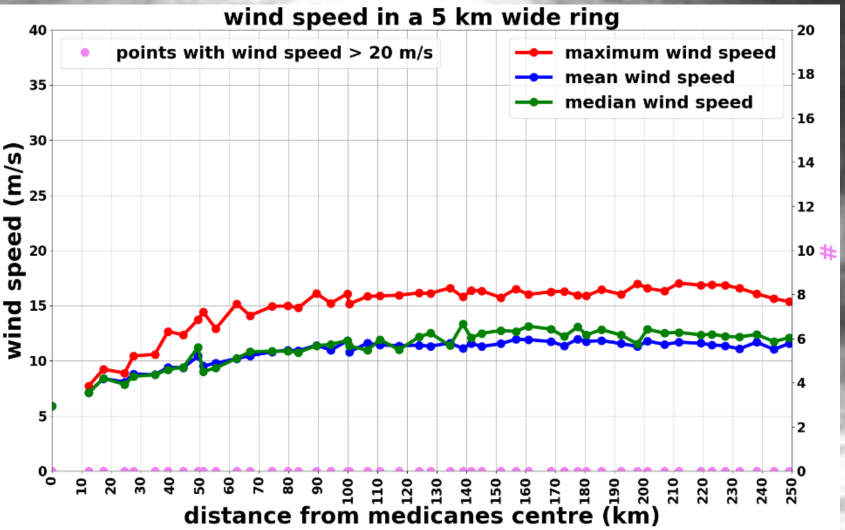
- $\Delta T35 = TB(183.3+-1)-TB(190.3)$
- $\Delta T34 = TB(183.3+-1)-TB(183.3+-3)$
- $\Delta T45 = TB(183.3+-3)-TB(190.3)$
- $T0 = 0.04761 - 0.01678 * \theta + 0.00599 * \theta^2$, where θ is the viewing angle

The **WC identification** is based on the analysis of the TB warm anomaly measured by the AMSU and ATMS 54 GHz oxygen absorption band channels (54.4, 54.94, and 55.5 GHz) (Panegrossi et al., 2023).

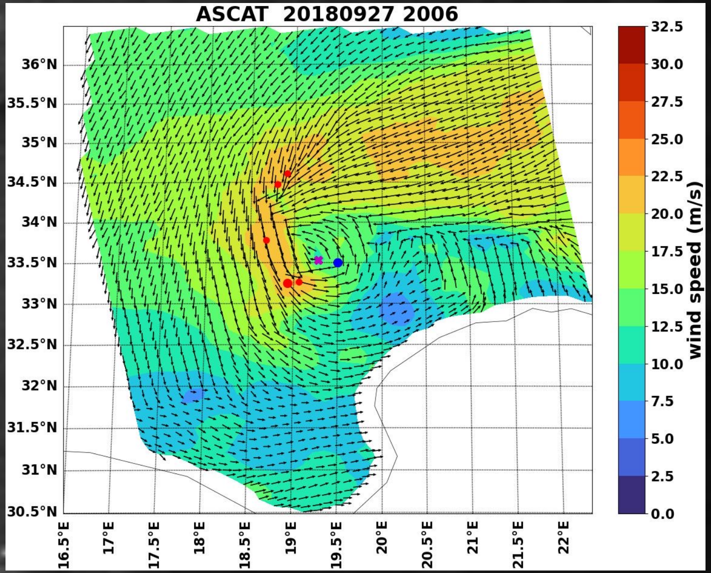
Wind speed field for development phase

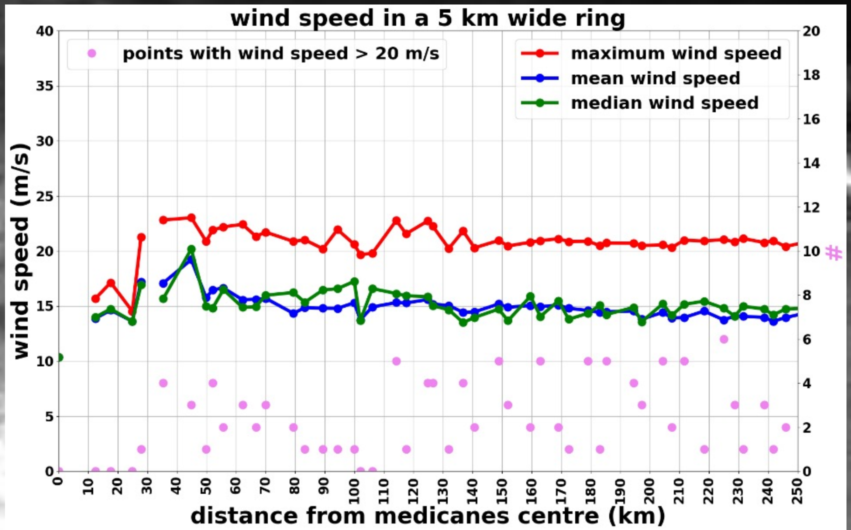
Numa



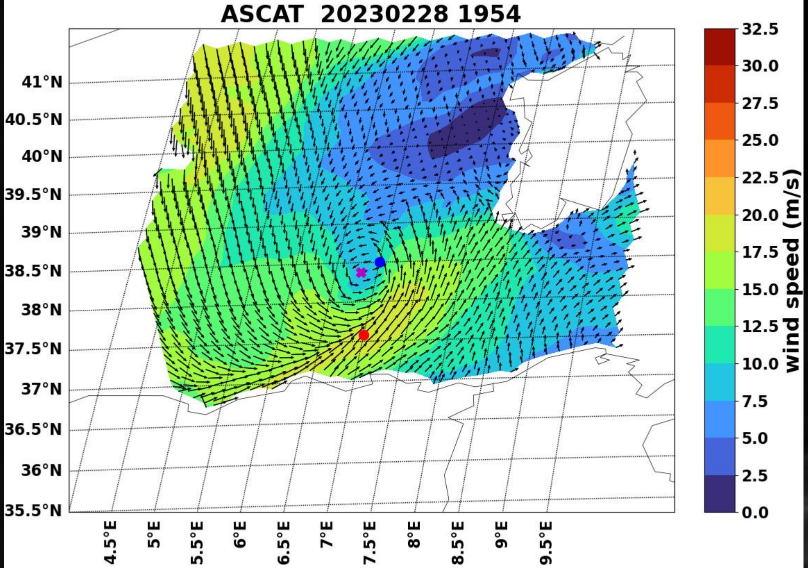


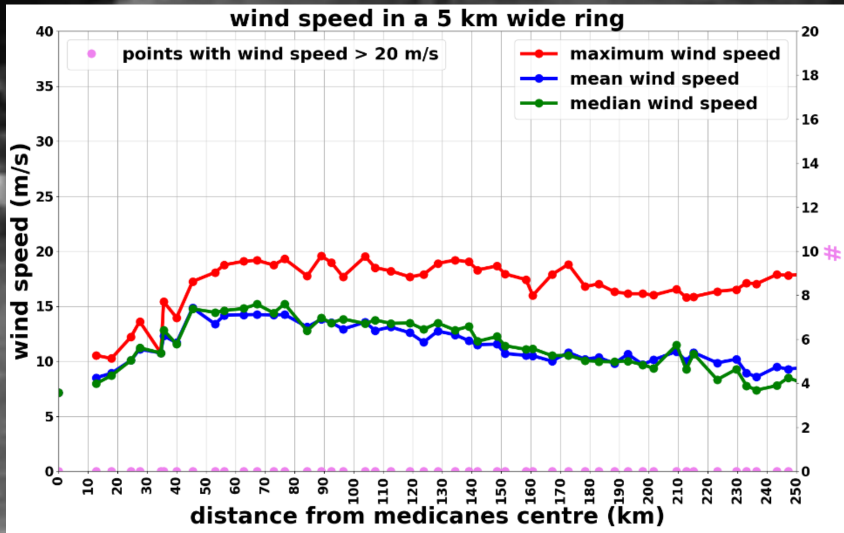
Zorbas





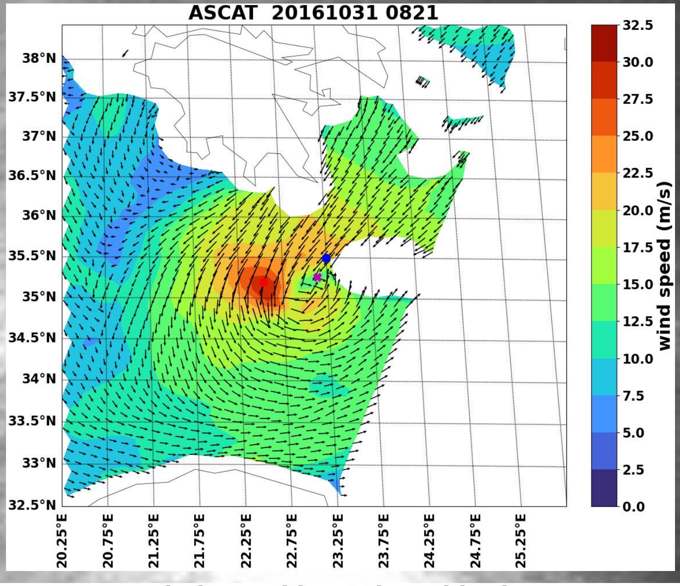
Juliette



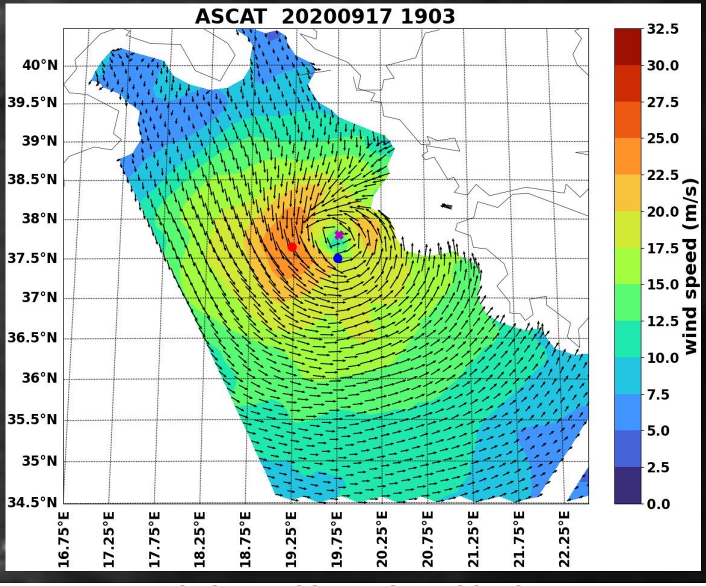


Wind speed field for mature phase

Trixie



Ianos



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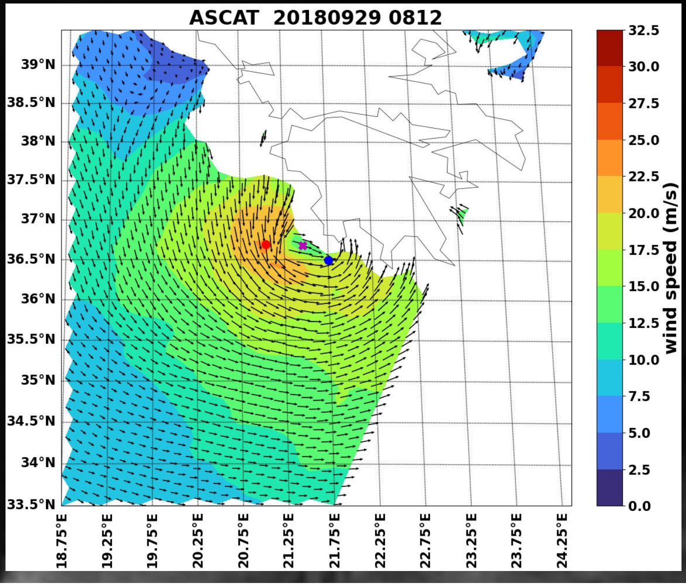
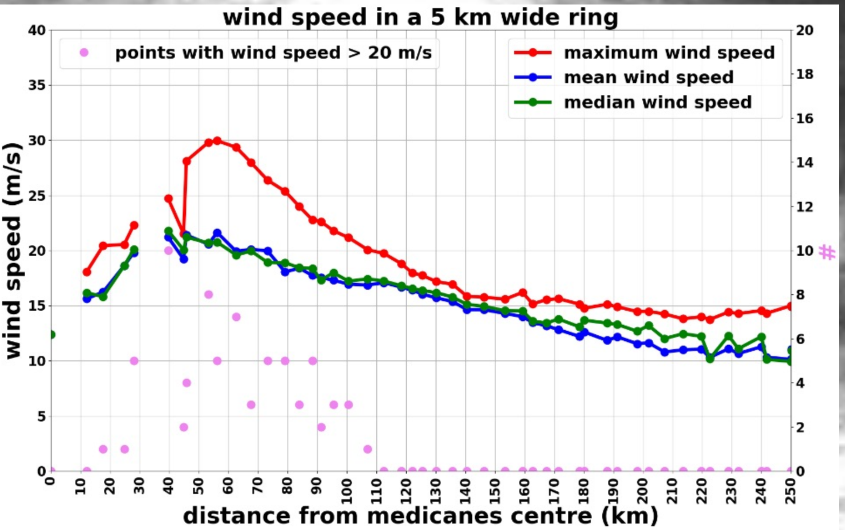
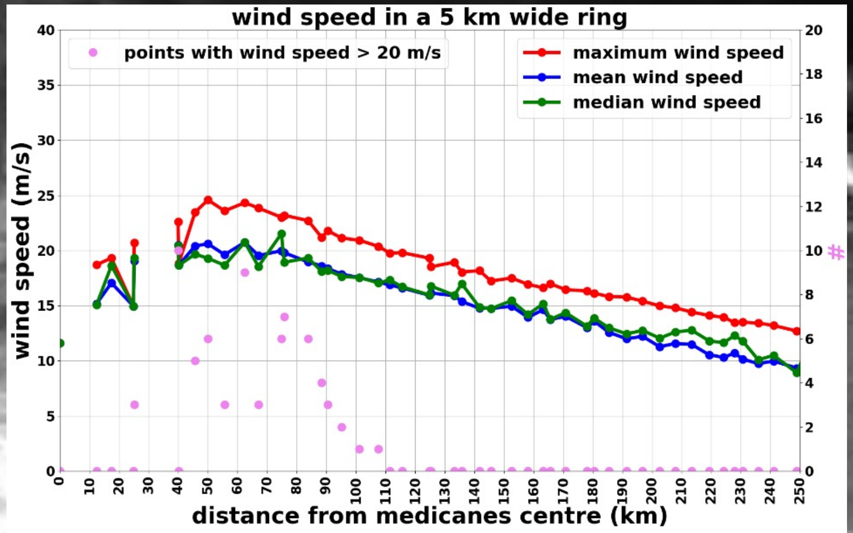
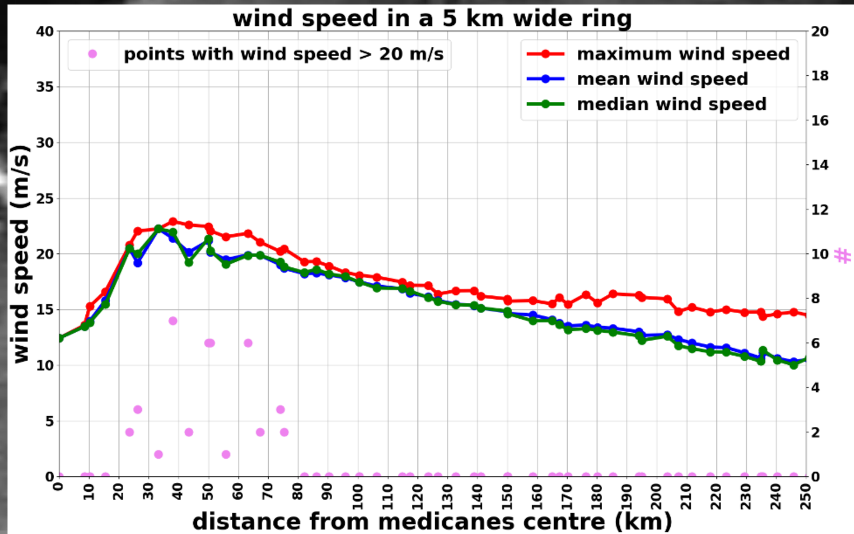
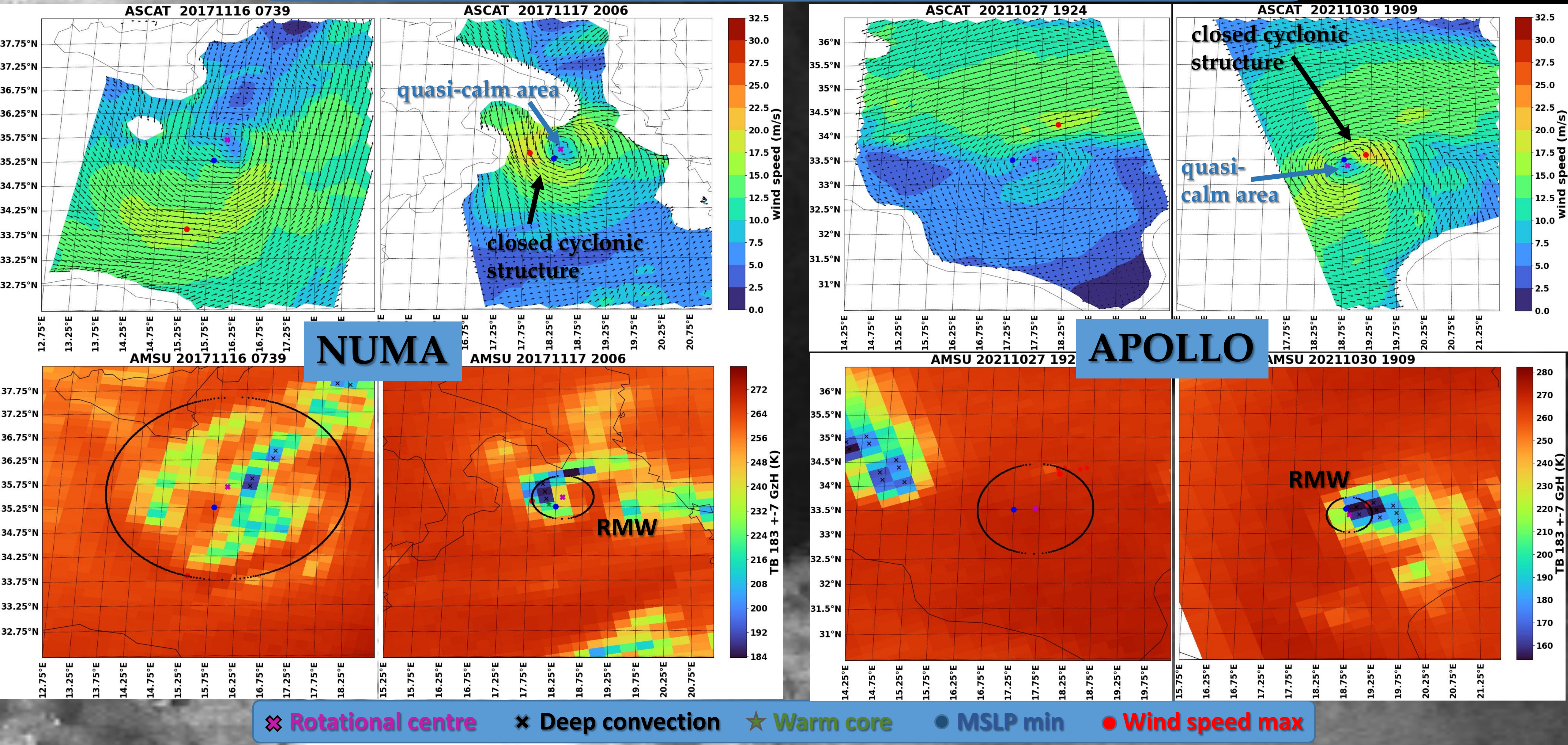




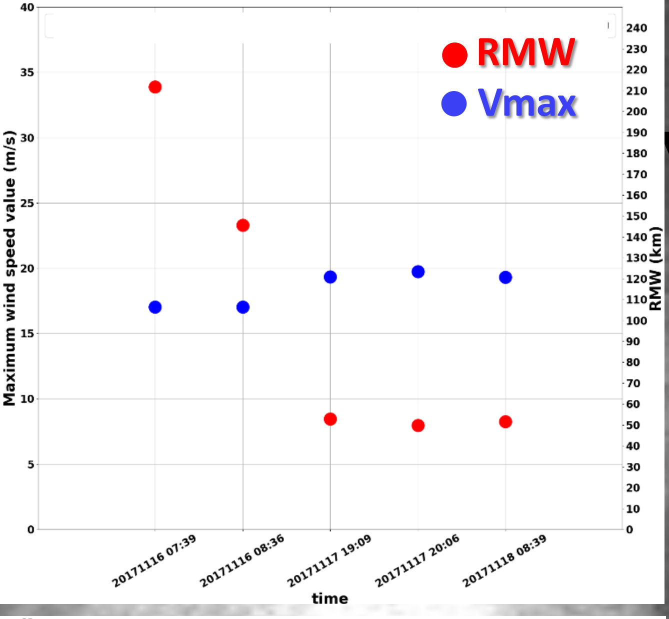


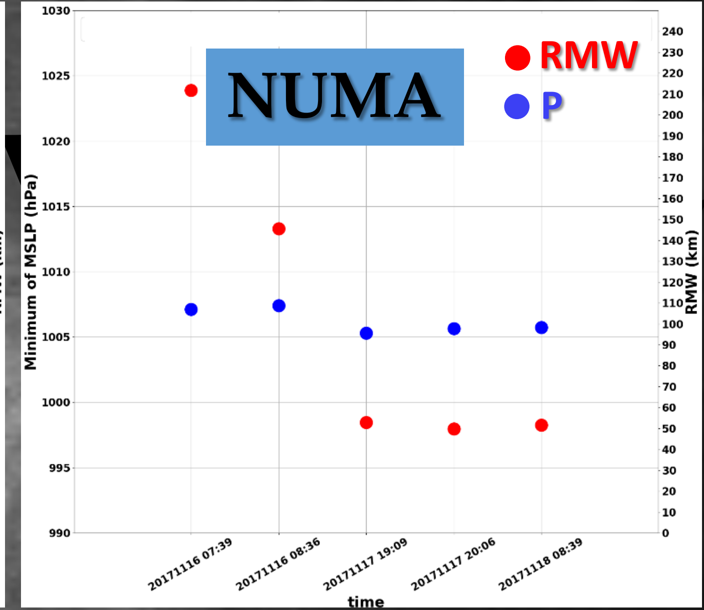


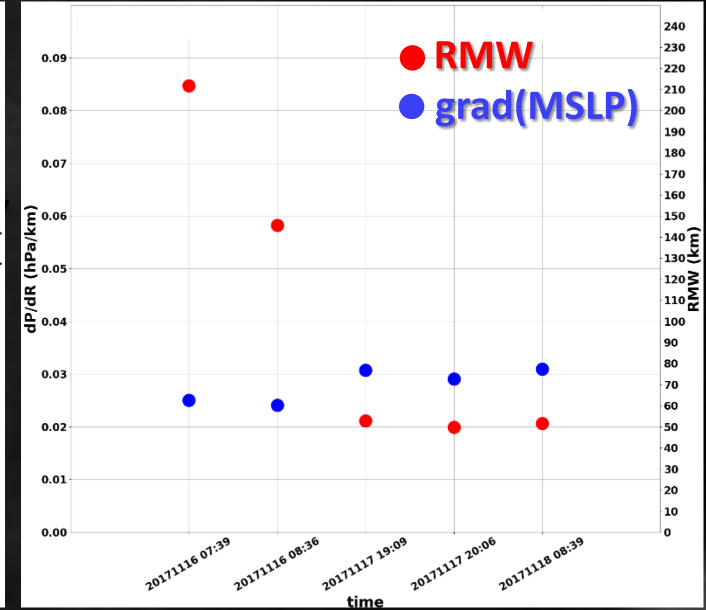
Development vs mature phases



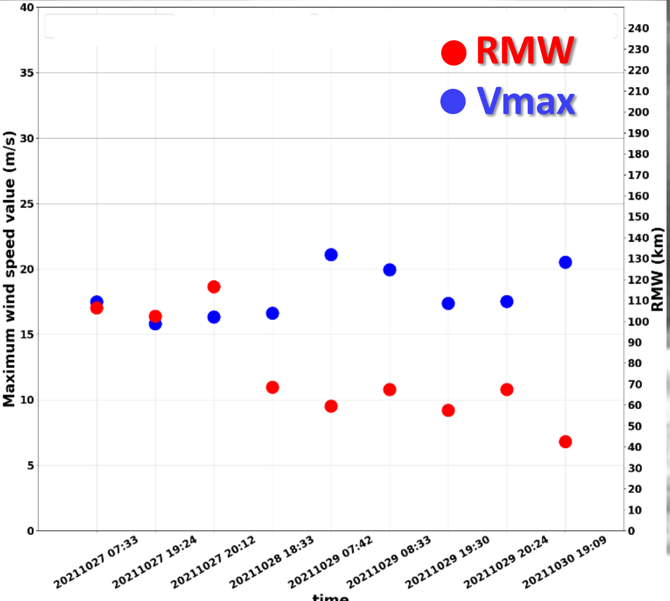
RMW vs Vmax, P, and grad(MSLP)

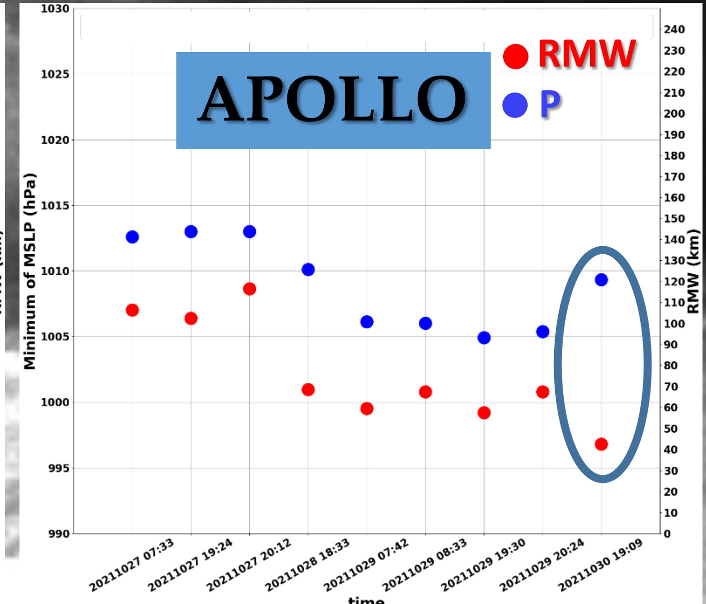


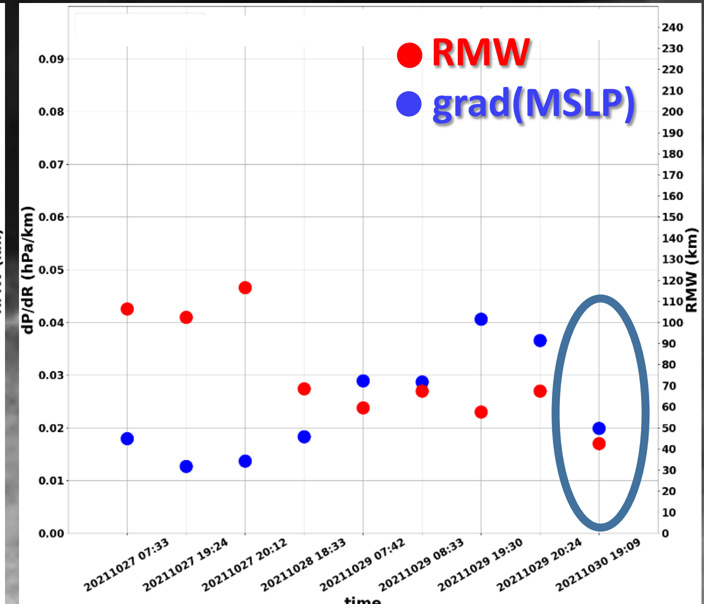




In general, RMW decreases as the medicane intensify as showed by the increase of both M and grad(MSLP), and the decrease of P.





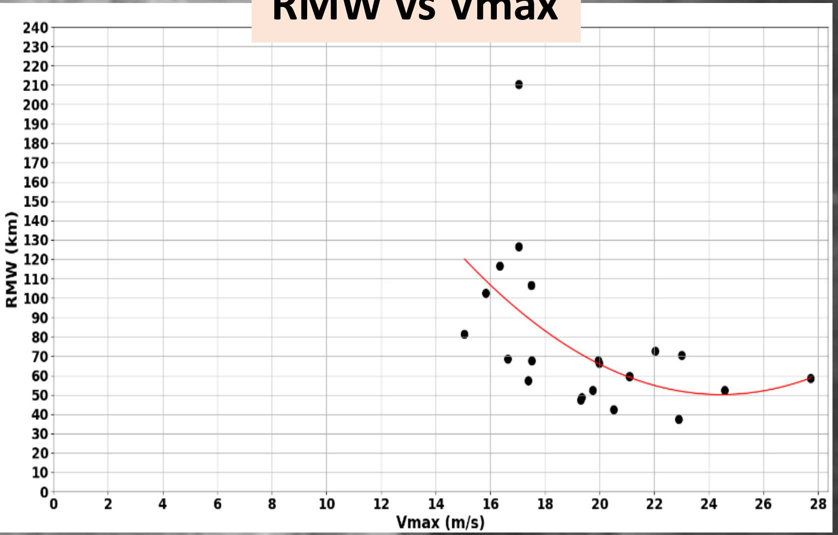


grad(MSLP) = dp/dR
dp = max(MSLP) – min(MSLP)

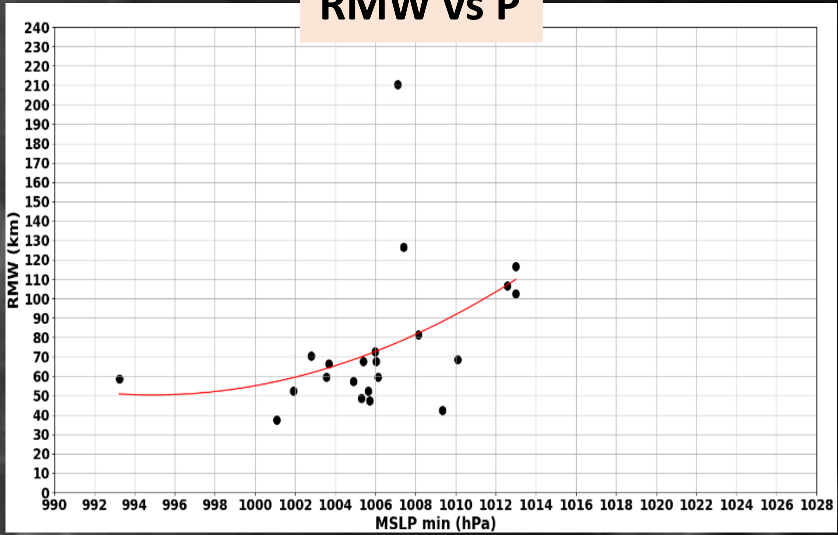
RMW vs Vmax, P, and grad(MSLP)

ALL MEDICANES

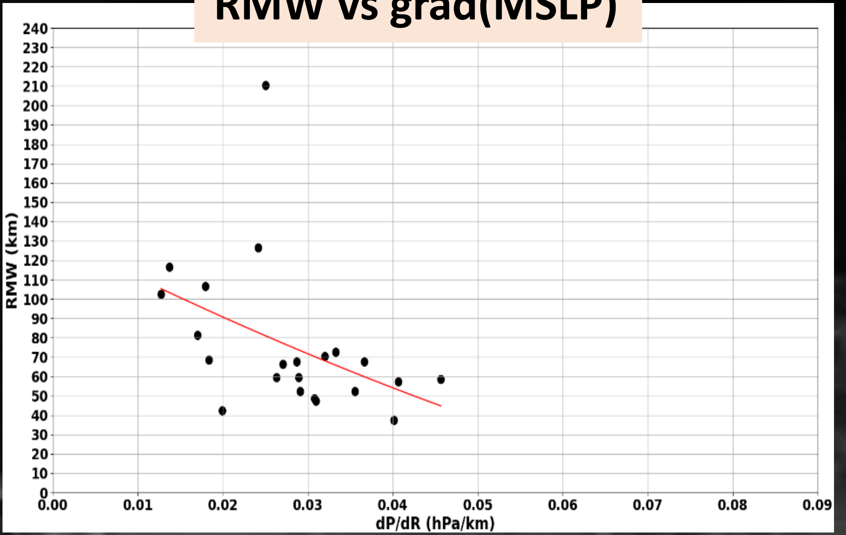
RMW vs Vmax



RMW vs P



RMW vs grad(MSLP)



The greater the maximum speed
The greater the grad(MSLP)
The lower the minimum of MSLP

The smaller the RMW

Satellite-based RMW provides additional information on the Medicanes' intensification phase

Comparison between the use of ERA5 and WC center for RC estimation

TRIXIE

P-RC (km)	RMW (km)	WC-RC (km)	DATE TIME
30.44	134.5	41.5	2016-10-28 19:40
38.57	191.9	-	2016-10-28 20:26
26.15	91.0	-	2016-10-30 08:25
40.91	79.5	-	2016-10-30 09:19
28.5	52.5	-	2016-10-31 08:59

NUMA

P-RC (km)	RMW (km)	WC-RC (km)	DATE TIME
52.2	211.7	-	2017-11-16 08:19
64.7	126.5	-	2017-11-16 09:14
17.0	48.8	-	2017-11-17 19:17
24.5	49.8	26.6	2017-11-17 20:13
8.7	47.5	-	2017-11-18 09:18

IANOS

P-RC (km)	RMW (km)	WC-RC (km)	DATE TIME
40.5	72.5	-	2020-09-16 08:13
19.5	68.5	36.6	2020-09-16 20:19
32.3	52.5	84.8	2020-09-17 19:11

ROLF

P-RC (km)	RMW (km)	WC-RC (km)	DATE TIME
17.7	82.8	55.6	2011-11-06 09:20
57.6	90.8	86.0	2011-11-08 10:18
18.3	55.9	-	2011-11-08 19:58

APOLLO

P-RC (km)	RMW (km)	WC-RC (km)	DATE TIME
69.8	106.7	-	2021-10-27 08:13
38.1	102.5	-	2021-10-27 19:32
37.3	116.5	-	2021-10-27 20:20
36.6	68.5	-	2021-10-28 18:42
7.9	59.5	29.1	2021-10-29 08:20
9.2	62.9	-	2021-10-29 09:12
12.1	57.5	-	2021-10-29 19:39
15.7	69.4	-	2021-10-29 20:31
14.8	39.7	-	2021-10-30 19:18

ZORBAS

P-RC (km)	RMW (km)	WC-RC (km)	DATE TIME
143.1	67.5	-	2018-09-27 07:53
20.7	70.5	77.5	2018-09-27 20:14
32.7	37.5	-	2018-09-29 08:52

The distance between P and RC tends to decrease as RMW decreases and during mature phase.

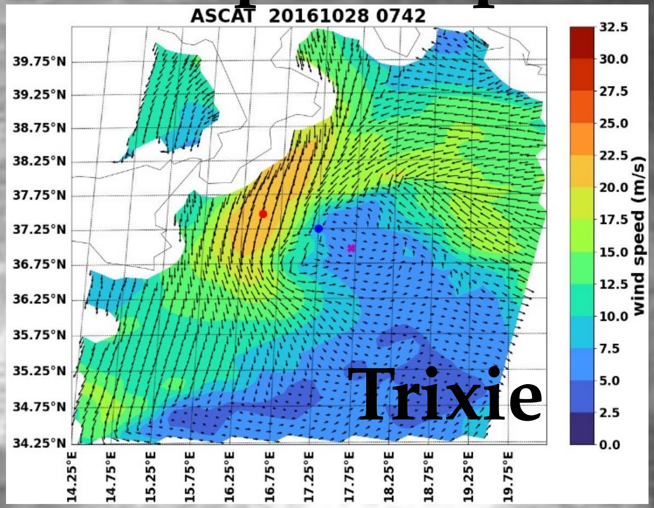
Generally the WC center falls within the RMW, <u>however at larger distances from RC with respect to P.</u>

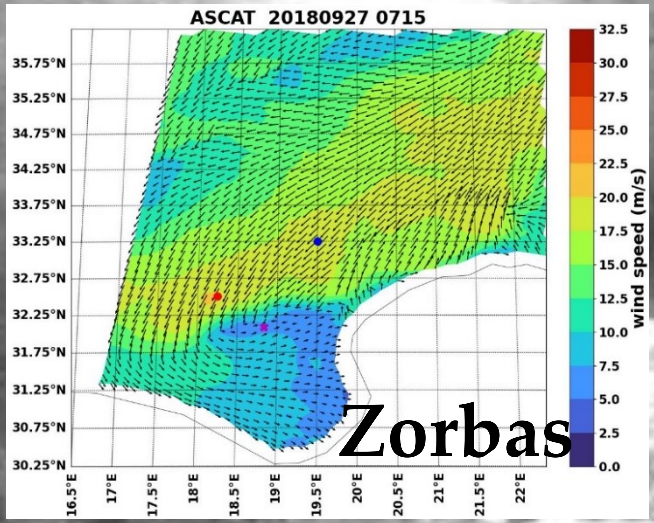
development phase

mature phase

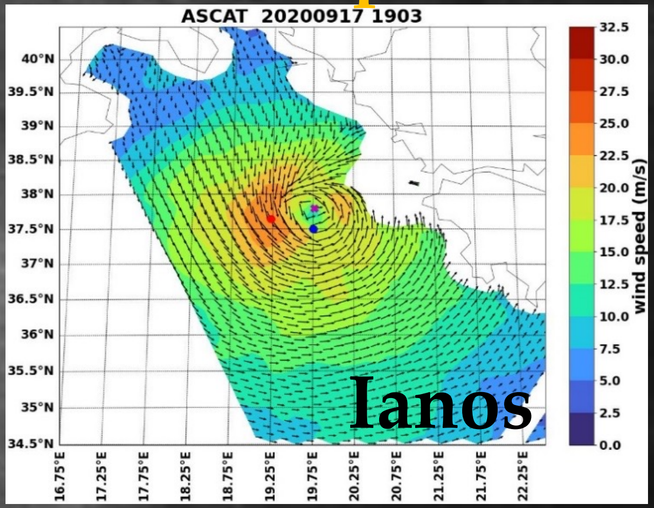
Critical issues

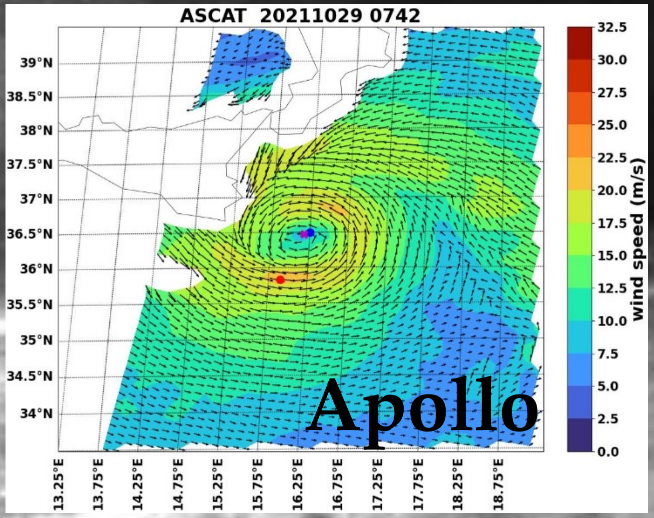
Development phase





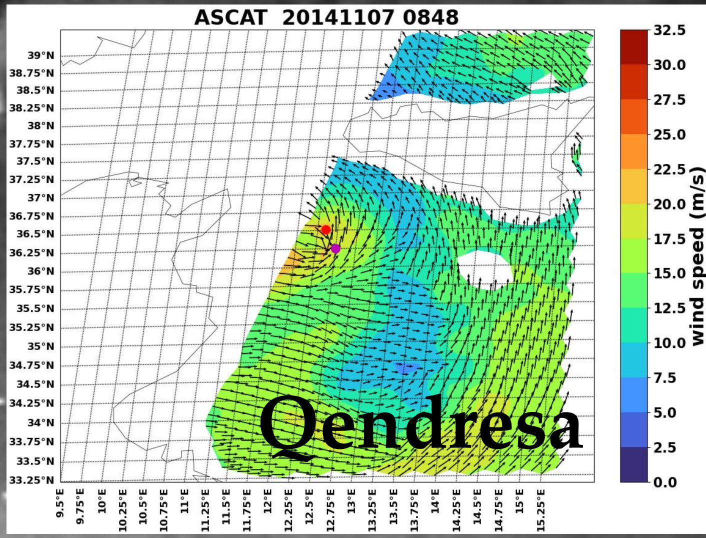
Mature phase





- The RC estimate is more reliable when the medicane is in its mature phase
- In the development phase is more correct to talk about distance between RC and maximum wind speed
- In the mature phase, the cyclonic vortex is closed and the radius can be estimated

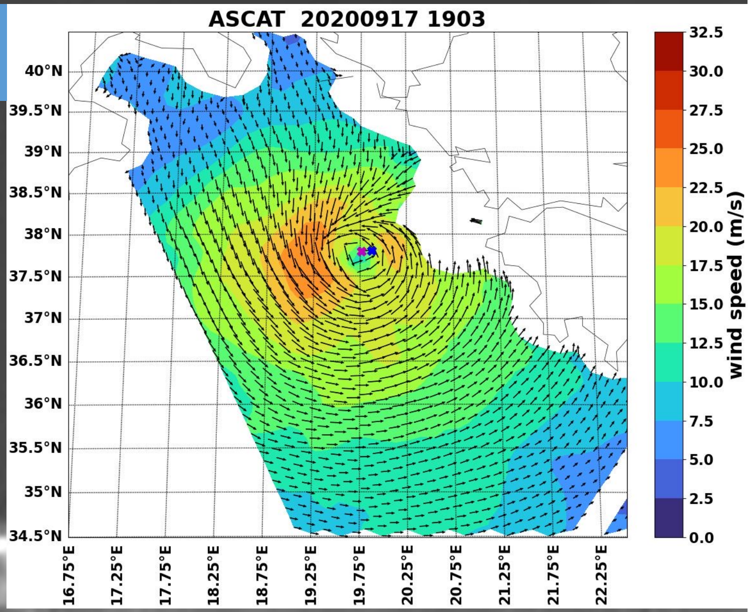
When ASCAT partially detects a medicane, the RMW cannot be estimated



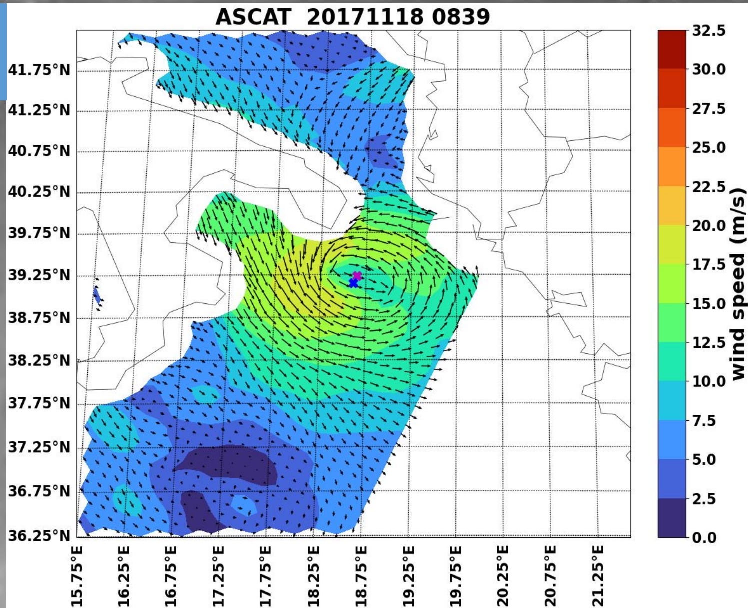
ARCHER vs MeRCAD

The Automated Rotational Center Hurricane Eye Retrieval (ARCHER) algorithm, developed by the TC group at CIMSS/University of Wisconsin-Madison, is widely used for the correct identification of a TC's center of rotation (Wimmers and Welden, 2016).

IANOS



NUMA



✖ MeRCAD

✖ ARCHER

The RCs identified by ARCHER and MeRCAD are very close to eachother.

Conclusions and further developments

AIM OF THE WORK: medicanes' wind field characterization through ASCAT RMW based on new method for RC detection (MeRCAD)

RESULTS:

- **RMW decreases as the medicane intensify** (as wind speed and MSLP gradient increase, or the minimum MSLP decreases); **MeRCAD RMW analysis can be used as proxy of medicanes intensification**;
- generally, the distance between ERA5 minimum MSLP and the RC decreases as RMW decreases and during mature phase;
- in most cases WC center falls within the RMW, even if at larger distances from RC with respect to P.

FUTURE DEVELOPMENTS:

- use of Sea surface wind field collected by the Wind Radar (WindRAD) onboard Feng Yun FY-3E satellite series;
- comparison with RC based on CTH field;
- ARCHER will be applied to all dataset (first application to Medicanes).

Thanks for the attention

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