Two satellite-based methodologies for the automated detection of the center of rotation in Mediterranean tropical-like cyclones

Stefano Sebastianelli[1], Giulia Panegrossi[1], Leo Pio D'Adderio[1] , Paolo Sanò[1], Daniele Casella[1], and Derrick Herndon[2]
[1]Institute of Atmospheric Sciences and Climate, National Research Council of Italy, CNR-ISAC, Rome, Italy
[2]Cooperative Institute of Meteorological Satellite Studies (CIMSS) - University of Wisconsin-Madison
e-mail: s.sebastianelli@isac.cnr.it

DEFINITION OF MEDICANES

Mediterranean cyclones showing tropical-like characteristics during their mature phase are characterized by: **ring-shaped closed cyclonic circulation with strong near-surface wind field**; **quasi-calm cloud free eye in its center**; **spiraling heavy rain bands around the center, and a warm core (WC).** The warm core may originates from baroclinic processes but during their evolution some medicanes exhibit an axi-symmetric WC originating from diabatic processes from which they extract the energy to self-sustain associated to deep convection close to the center (Panegrossi et al., 2023).

OBJECTIVES

- **development of the Medicane Rotational Centre Automated Detection (MeRCAD) new algorithm** to correct identify the Rotational Center (RC) of a medicane;
- **comparison between MeRCAD and the Automated Rotational Center Hurricane Eye Retrieval (ARCHER)** algorithm;
- **calculation of the Radius of Maximum Wind (RMW) based on the RC identification for the sea surface wind field characterization in the tropical-like phase**, similarly to tropical cyclones (Rogers and Reasor, 2013);
- comparison between development and mature phase of medicane.

DATASET

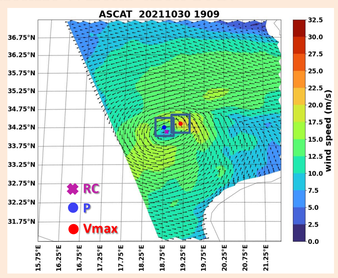
- **Sea surface wind speed and direction** → OSI SAF product from ASCAT on board Metop satellites
- **Mean Sea Level Pressure (MSLP)** → hourly estimates by ERA5 reanalysis
- **Brightness Temperature (TB)** → AMSU-A/B/MHS passive microwave radiometer on board Metop satellites

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

10 Medicanes occurred **from 2011 to 2023** are analysed according to the ASCAT useful overpasses' avaibility.

MeRCAD METHODOLOGY

- minimum of ERA5 MSLP = P; maximum of ASCAT wind speed = Vmax;
- identification of two boxes of 0.5° surrounding P and Vmax;
- computation of the wind speed standard deviation in a 2x2 pixel moving window inside each box;
- selection of the ASCAT pixel closest to P where the standard deviation belongs to the 90th percentile and wind speed < 12 m/s for each box;
- between the two pixels thus detected, the RC corresponds to the pixel with the minimum wind speed;
- **RMW computation:** as the distance between the band of the maximum winds and RC.



CONCLUSIONS

- **These preliminary results indicate that the greater the maximum sustainable wind the better the agreement between MeRCAD and ARCHER, especially in the mature phase;**
- **MeRCAD RMW analysis can be used as proxy of medicanes intensification**;
- generally, the distance between P and RC decreases as RMW decreases and during the mature phase;
- in most cases WC center falls within the RMW, even if at larger distances from the RC with respect to P.

FUTURE DEVELOPMENTS

- data provided by the Wind Radar (WindRAD) onboard of Feng Yun FY-3E satellite series will be used;
- ARCHER will be applied to all medicanes since year 2000;
- wind field characterization based on ARCHER RC.

ACKNOWLEDGMENTS

This work is part of the ESA project "Earth Observations as a cornerstone to the understanding and prediction of tropical-like cyclone risk in the Mediterranean (MEDICANES)".

REFERENCES

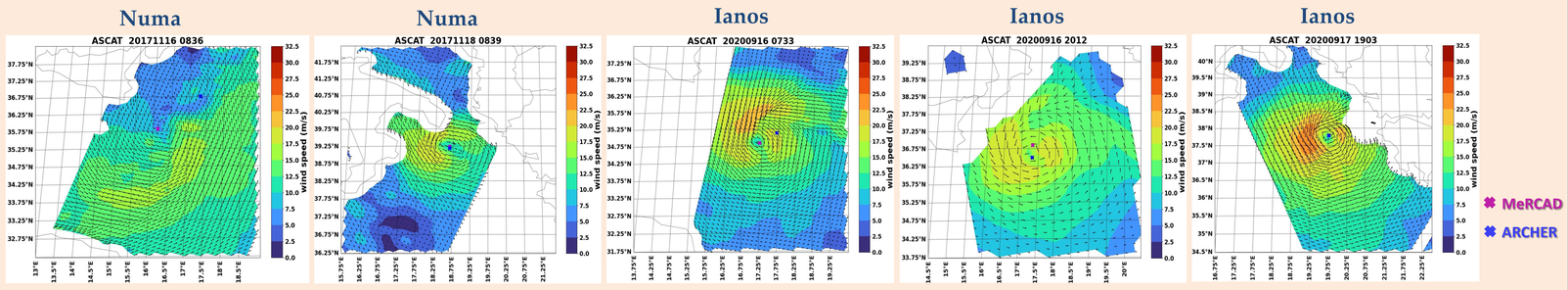
- Panegrossi, G.; D'Adderio, L.P.; Dafis, S.; Rysman, J.-F.; Casella, D.; Dietrich, S.; Sanò, P.Warm Core and Deep Convection in Medicanes: A Passive Microwave-Based Investigation. Remote Sens. 2023, 15, 2838. https://doi.org/10.3390/rs15112838
- Rogers, R., Reasor, P., & Lorsolo, S. (2013). Airborne Doppler observations of the inner-core structural differences between intensifying and steady-state tropical cyclones. *Monthly Weather Review*, *141*(9), 2970-2991.
- Hong, G., G. Heygster, J. Miao, and K. Kunzi (2005), Detection of tropical deep convective clouds from AMSU-B water vapor channels measurements, J. Geophys. Res., 110, D05205, doi:10.1029/2004JD004949.
- Rysman, J. F., Claud, C., & Delanoë, J. (2016). Monitoring deep convection and convective overshooting from 60 S to 60 N using MHS: a Cloudsat/CALIPSO-based assessment. IEEE Geoscience and Remote Sensing Letters, 14(2), 159-163.
- Wimmers, A. J., & Velden, C. S. (2016). Advancements in objective multisatellite tropical cyclone center fixing. Journal of Applied Meteorology and Climatology, 55(1), 197-212.

RESULTS

MeRCAD vs ARCHER (Ianos and Numa case studies)

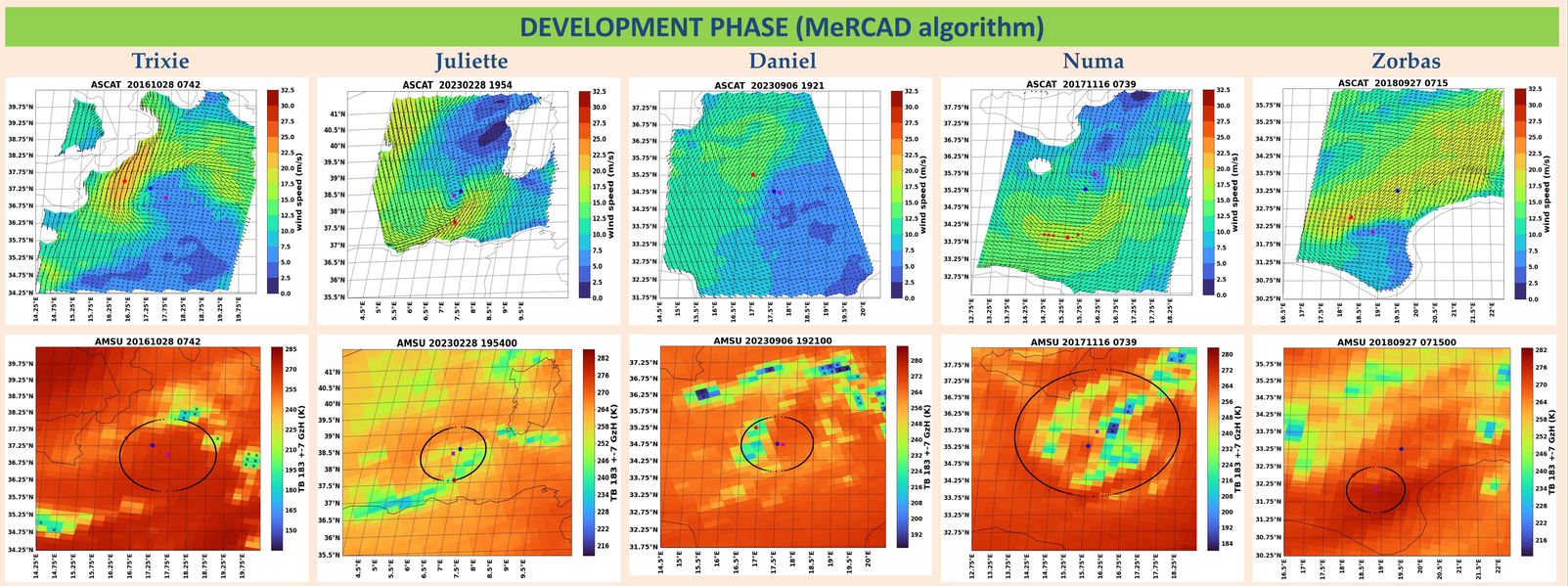
The Automated Rotational Center Hurricane Eye Retrieval (ARCHER) algorithm, developed by the TC group at CIMSS/University of Wisconsin-Madison, is widely used for the correct identification of a TC's center of rotation (Wimmers and Welden, 2016). In this study it **is applied to medicanes for the first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

Medicane	Phase	Time	Vmax (m/s)	Lat RC MeRCAD	Lon RC MeRCAD	Lat RC ARCHER	Lon RC ARCHER	Distance (km)
Numa	development	20171116 07:39	17.03	35.68	15.98	-	-	-
Numa	development	20171116 08:36	17.04	35.82	16.14	36.77	17.31	148.88
Numa	mature	20171117 19:09	19.34	39.16	18.41	-	-	-
Numa	mature	20171117 20:16	19.74	39.20	18.37	-	-	-
Numa	mature	20171118 08:39	19.31	39.24	18.65	39.19	18.65	5.56
Ianos	mature	20200916 07:33	22.04	34.84	17.18	35.14	17.67	55.74
Ianos	mature	20200916 20:12	19.97	36.85	17.32	36.50	17.32	38.93
Ianos	mature	20200917 19:03	24.57	37.79	19.76	37.79	19.76	0.00



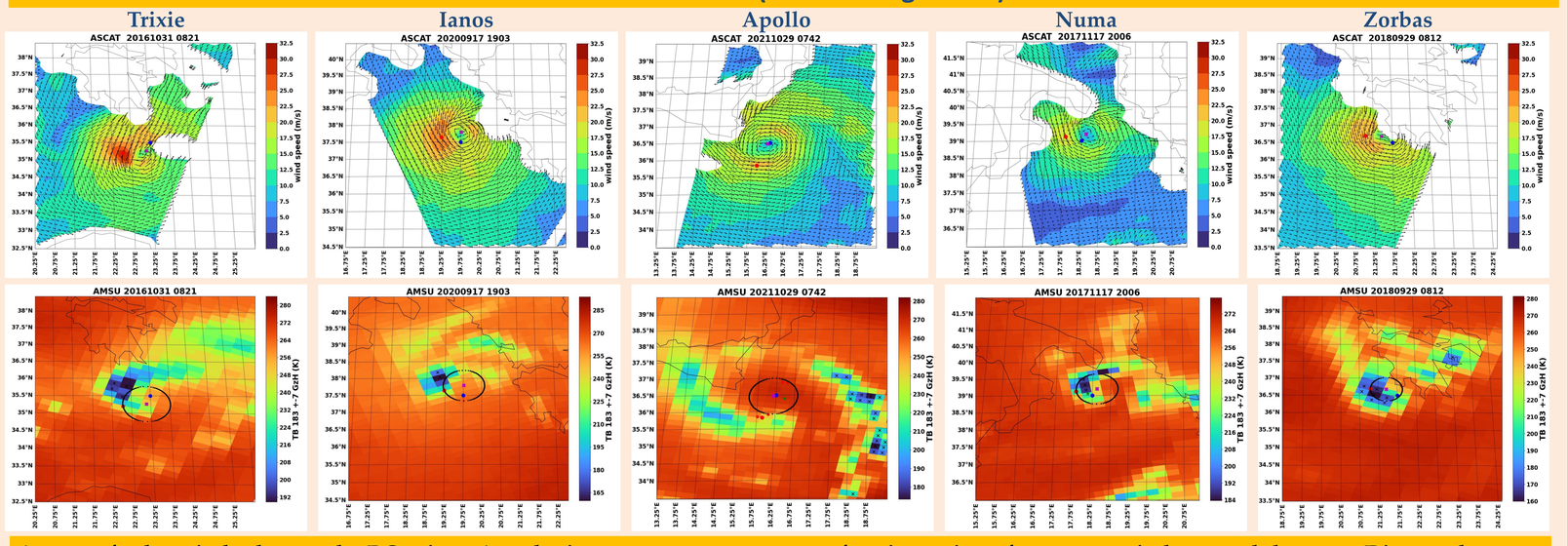
There is not always a good agreement between the position of the RC computed by MeRCAD and ARCHER. Sometimes ARCHER is unable to estimate the position of RC. **It seems that the greater the maximum sustainable wind the better the agreement between MeRCAD and ARCHER, especially in the mature phase.**

DEVELOPMENT PHASE (MeRCAD algorithm)



A wide area of calm winds near the center exists rather than an <<eye>>, so it is more difficult to identify the RC • The cyclonic vortex structure of strong winds is not present at this stage • Distance between band of maximum winds and RC is higher than in mature phase (ellipse) • Wind speed is lower than in mature phase.

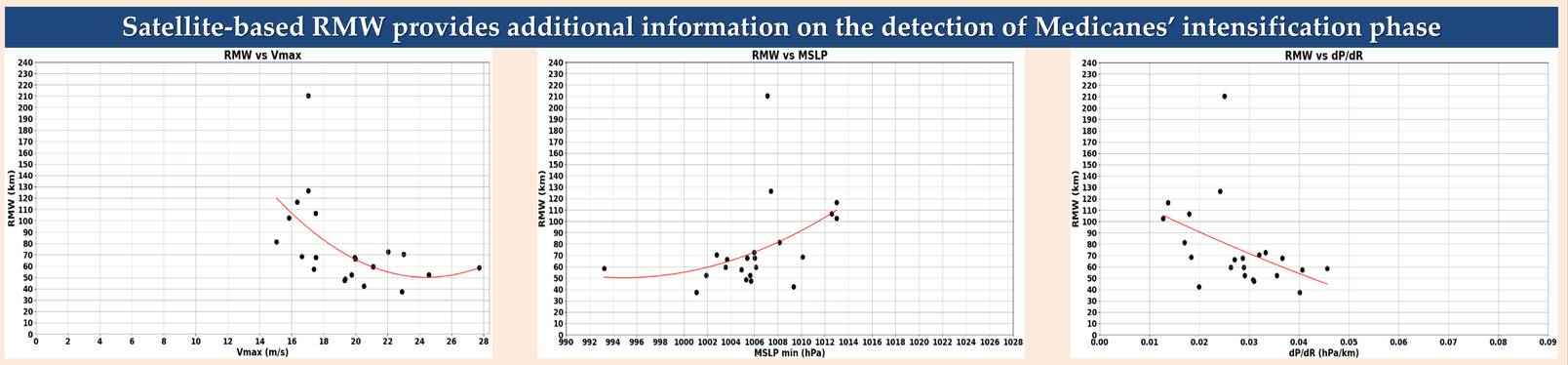
MATURE PHASE (MeRCAD algorithm)



An eye of calm winds close to the RC exist • A cyclonic vortex structure appears forming a ring of strongest winds around the eye • Distance between band of maximum winds and RC (RMW) is shorter than in development phase (ellipse) • Wind speed is greater than in development phase • WC due to diabatic heating (with deep convection in proximity of the center) may occur at distances shorter than the RMW.

RC DC WC P Vmax

Satellite-based RMW provides additional information on the detection of 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

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

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

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

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

development phase
mature phase

In most cases the WC center is located at shorter distances than RMW, even if at larger distances from RC with respect to P. Generally, the distance between P and RC decreases as RMW decreases and during mature phase.