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Diversity of Tropical Cyclone structures

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RA I Training Course on Tropical Cyclones – 11th session

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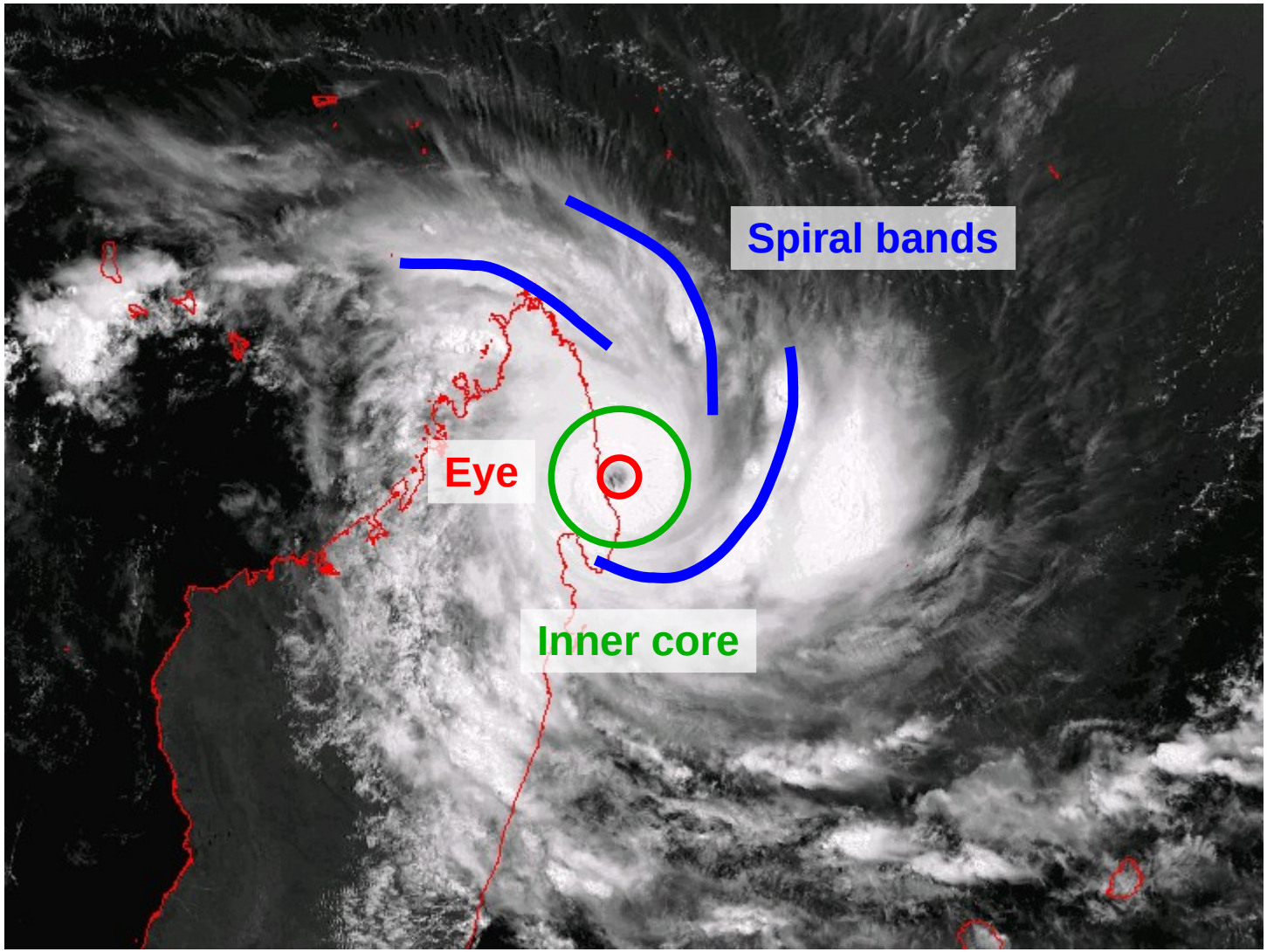
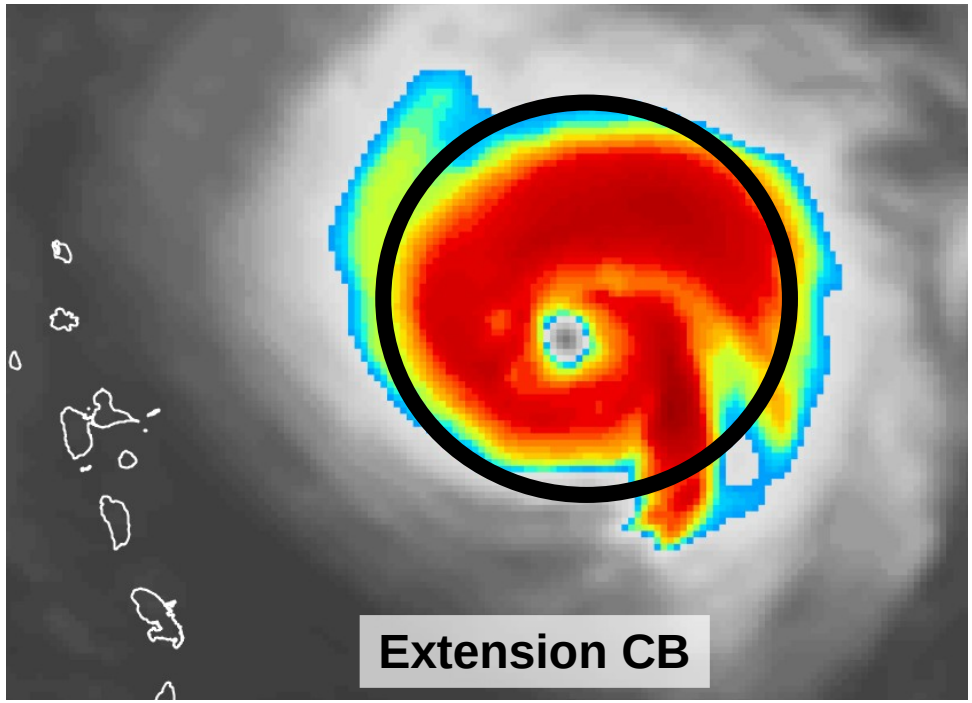
What is a Tropical Cyclone ?

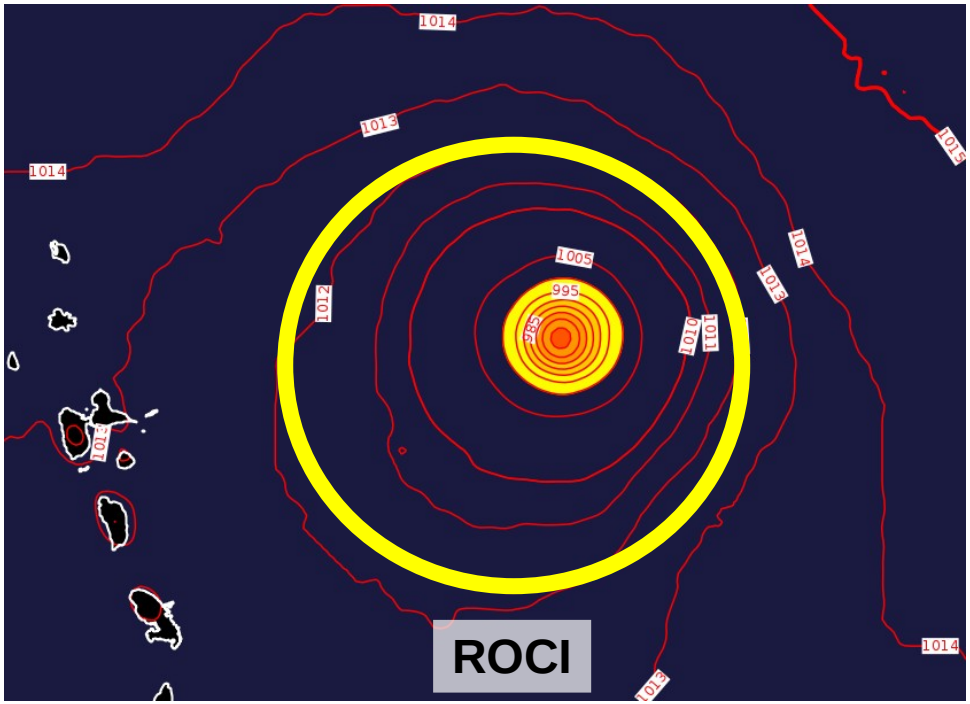


1. Size and Wind/Pressure relationship

The tropical cyclones sizes

- ROCI / RPIF (Radius of the Outermost Closed Isobar / Rayon de la Première Isobare Fermée), first historical measure
- Deep convection extension

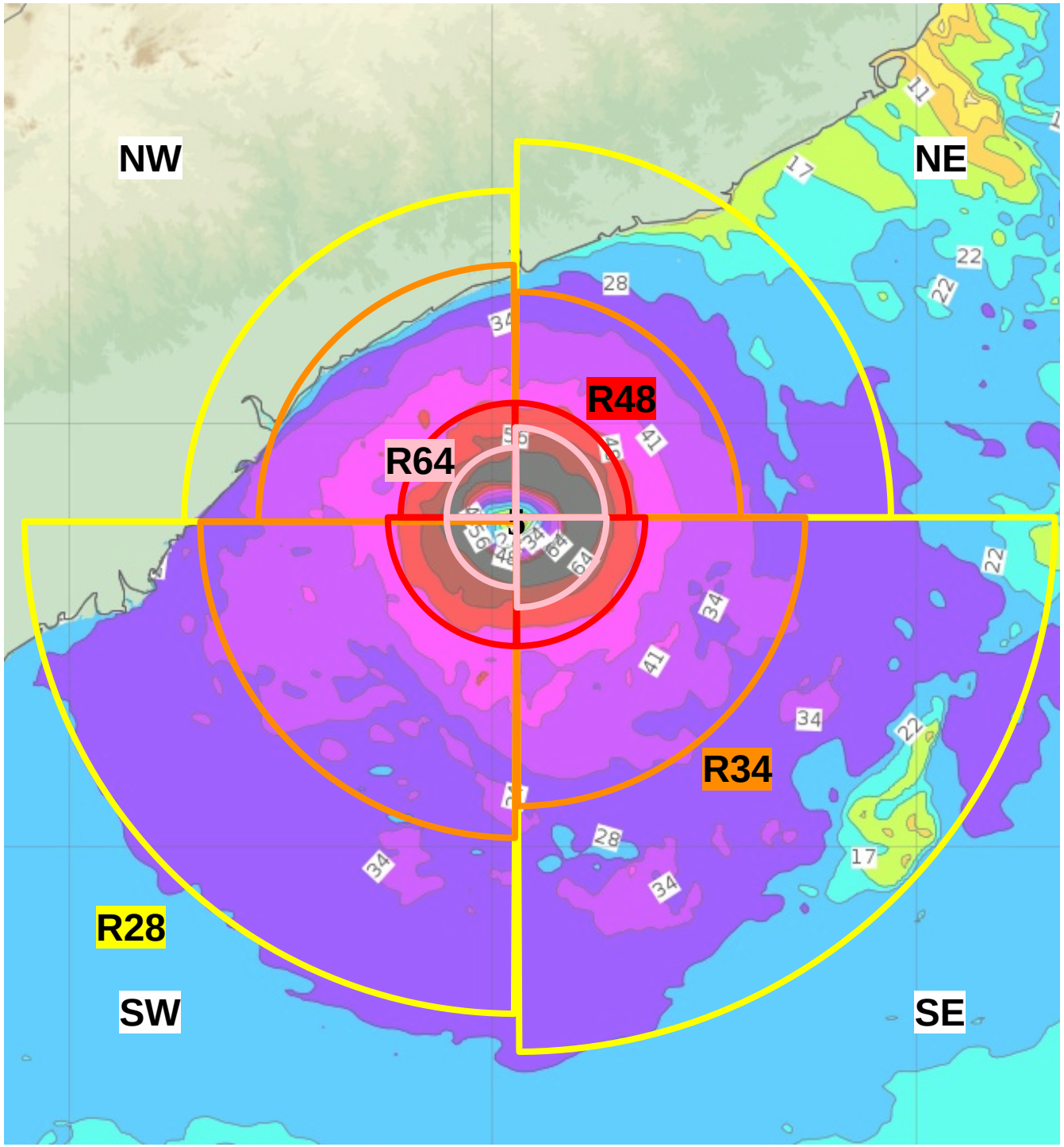




ROCI

Wind radii

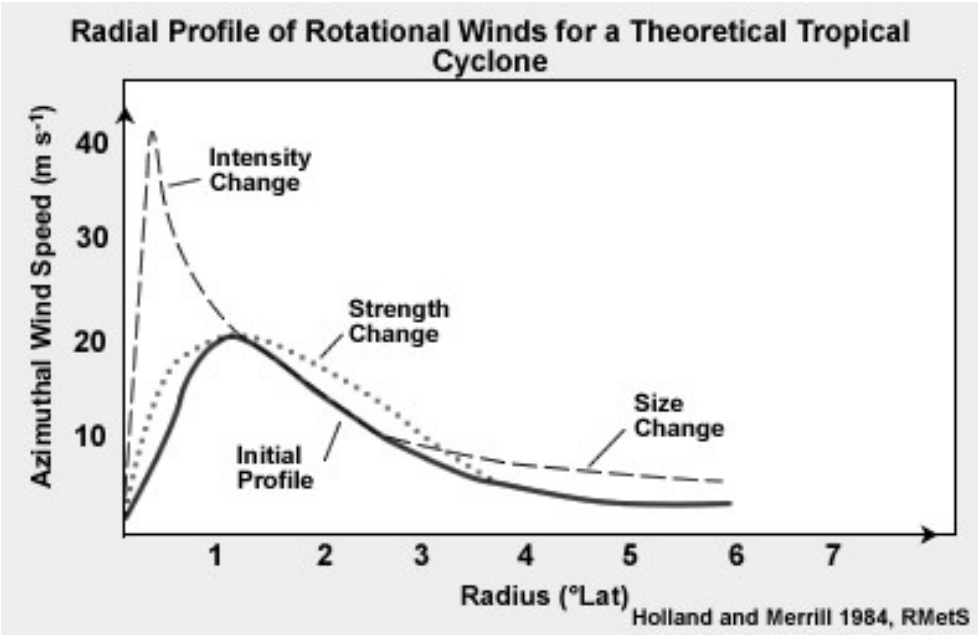
- Extent of specific windfield
- In the SWIO, we use the thresholds : 28kt, 34kt, 48kt and 64kt
- Defined in 4 quadrants (NW/NE/SE/SW)

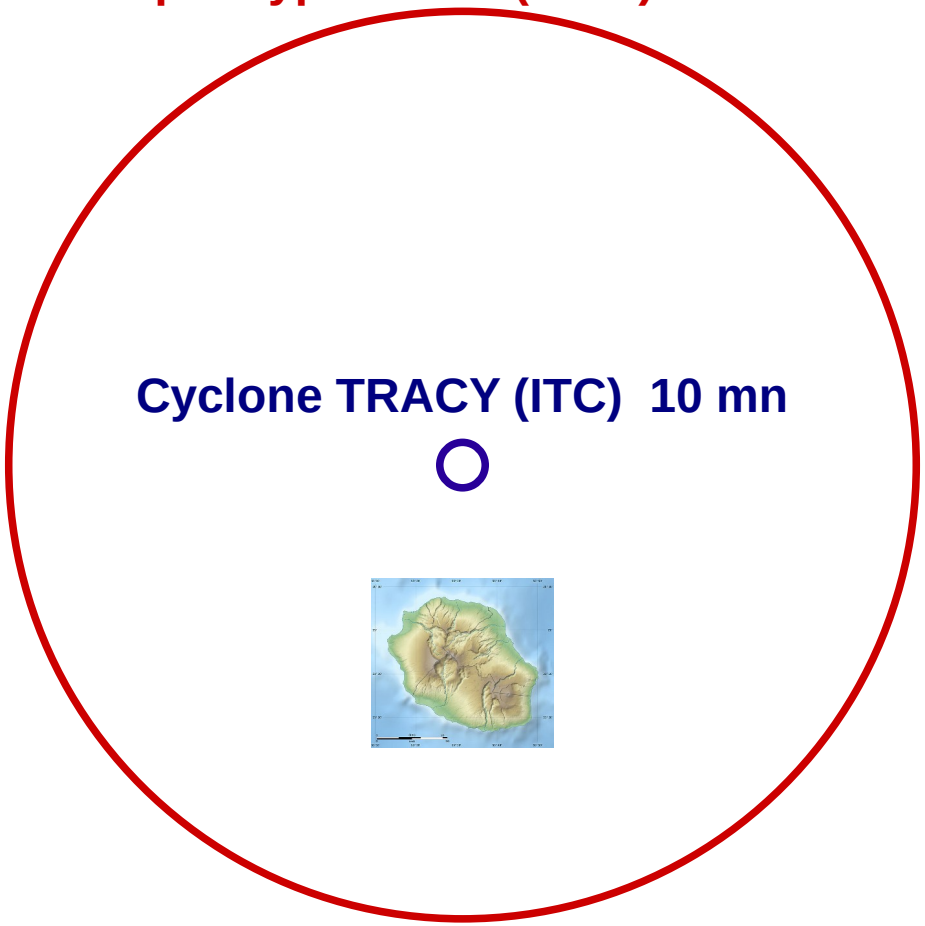


Tropical cyclone size

Size ≠ Intensity

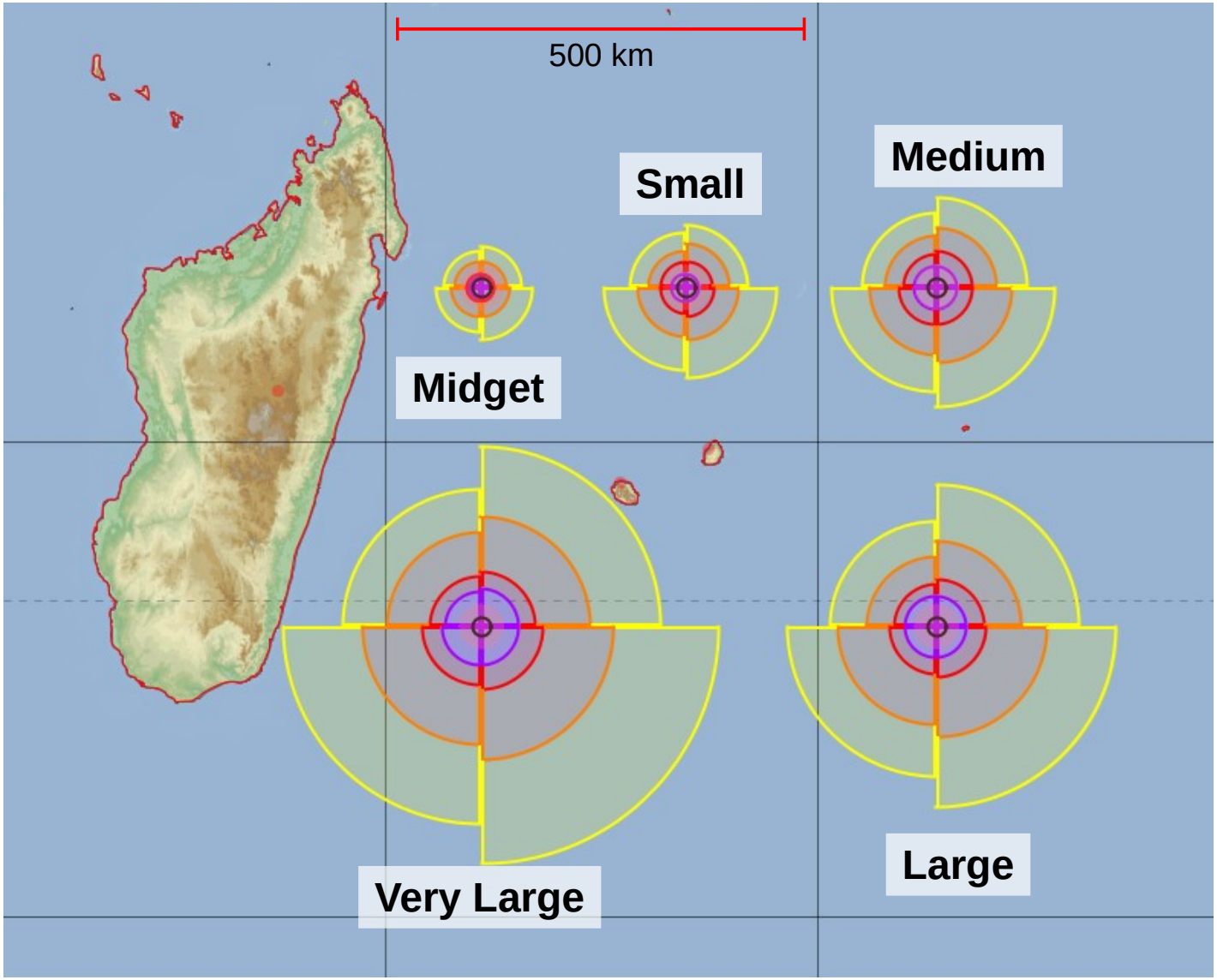
Size matters for the impacts (swell, storm surge, rainfalls, winds ..)





Storm force (>48kt) windfield (R50)

SWIO wind radii climatology



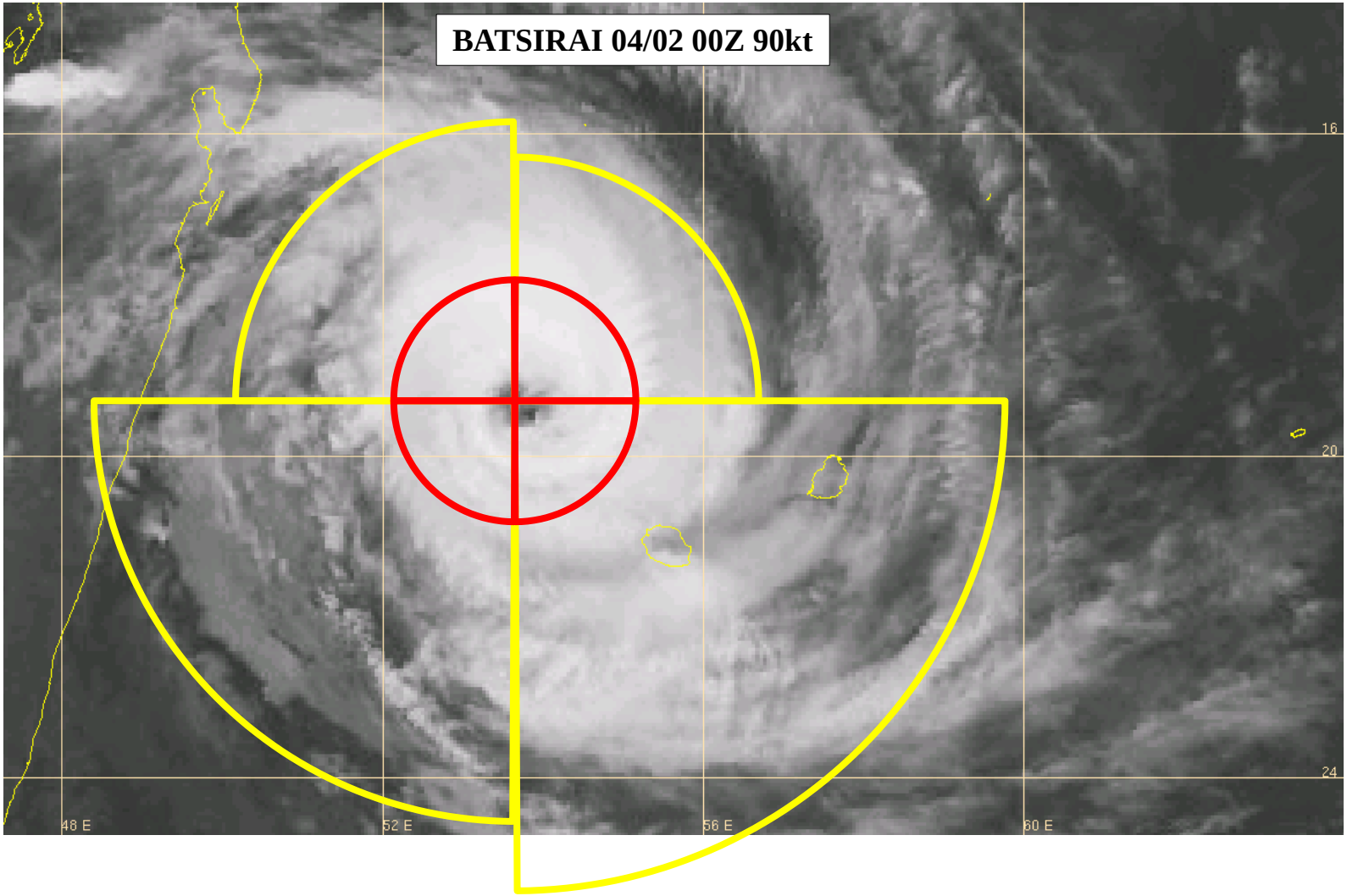
Midget R34 ≤ 50 km

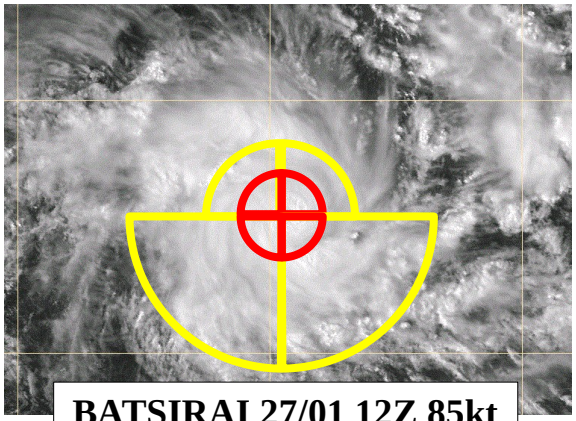
Very Large R34 ≥ 200-250km

TC size is driven by :

- Cyclogenesis environment and initial size
- Motion
- Current environnement (shear, dry air, subtropical ridge,...)
- ERC

SWIO wind radii : BATSIRAI

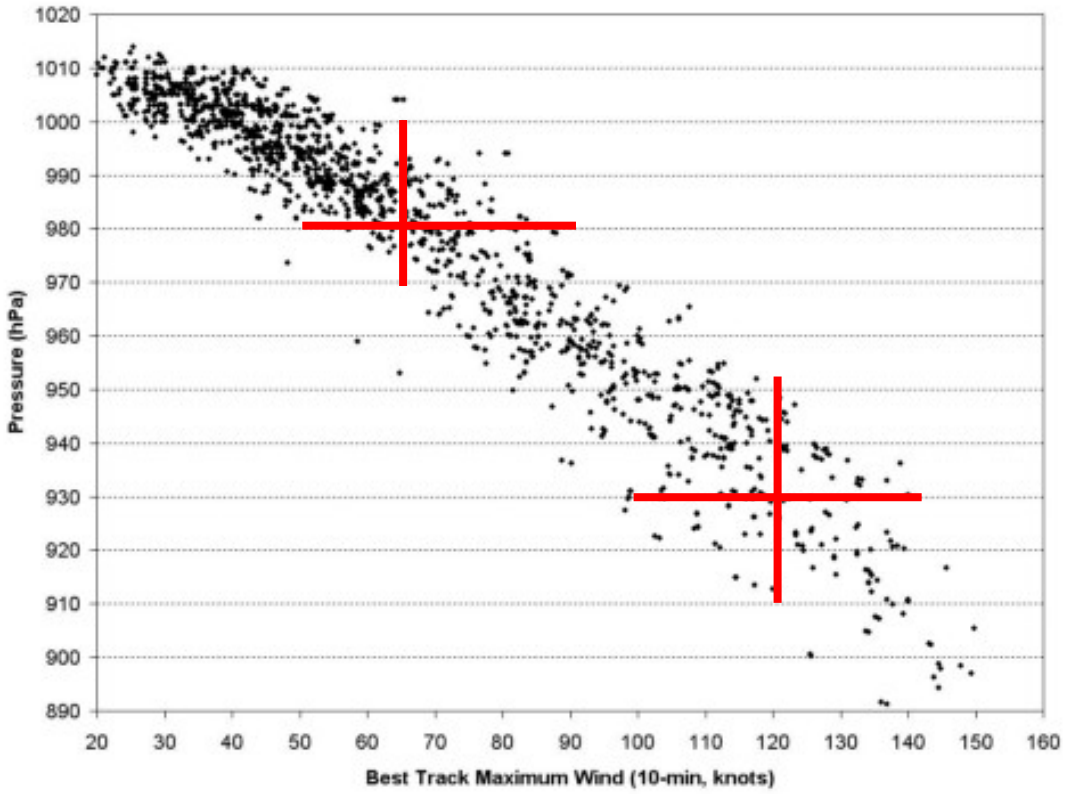




28kt radii (7 Beaufort)
50kt radii (10 Beaufort)

Wind / Pressure relationship

Fig. 1 Scatter diagram of the maximum ten-minute mean wind versus the minimum pressure from reconnaissance-based best track data, Atlantic basin, 1998-2007.



Central pressure does not only depend on the intensity :

- Vmax = 65 kt (CT)

→ 970 hPa <Pmin< 1000 hPa

- Vmax = 120 kt (CTTI)

→ 910 hPa <Pmin< 950 hPa

- Pmin = 980 hPa

→ 45 kt (TTM) <Vmax< 85 kt (CT)

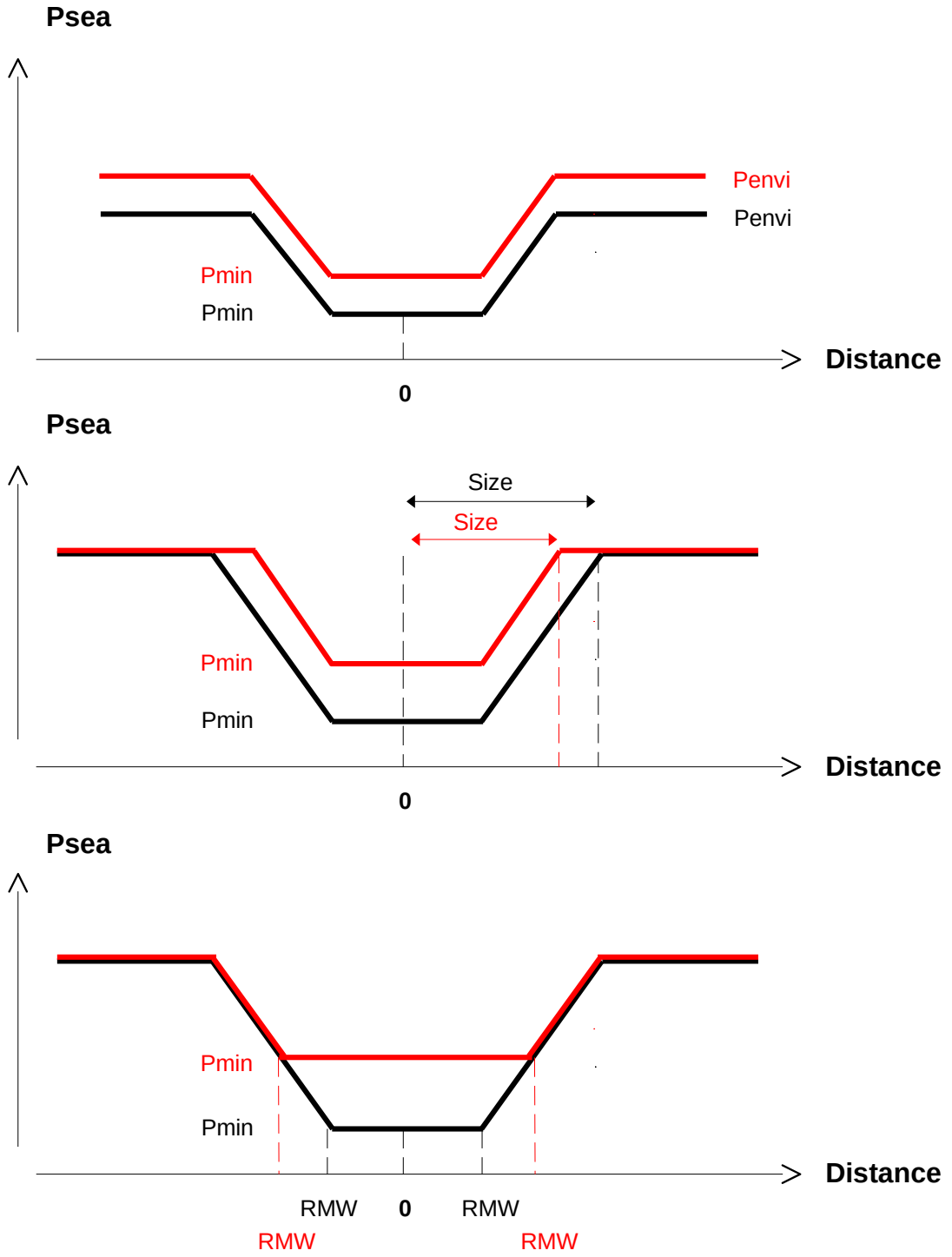
- Pmin = 930 hPa

→ 100 kt (CTI) <Vmax< 140 kt (CTTI)

Wind / Pressure relationship

Several factors influence the W/P relation

- Environmental pressure (P_{min} ↑ si P_{envi}↑)
- Size (P_{min} ↑ si Size↓)
- RMW (P_{min} ↑ si RMW↑)
- Latitude (P_{min} ↑ si |Lat|↓)
- Motion speed (P_{min} ↑ si Speed↑)



Size + W/P relationship – In operations

- Use mainly the values from RSMC bulletins and products

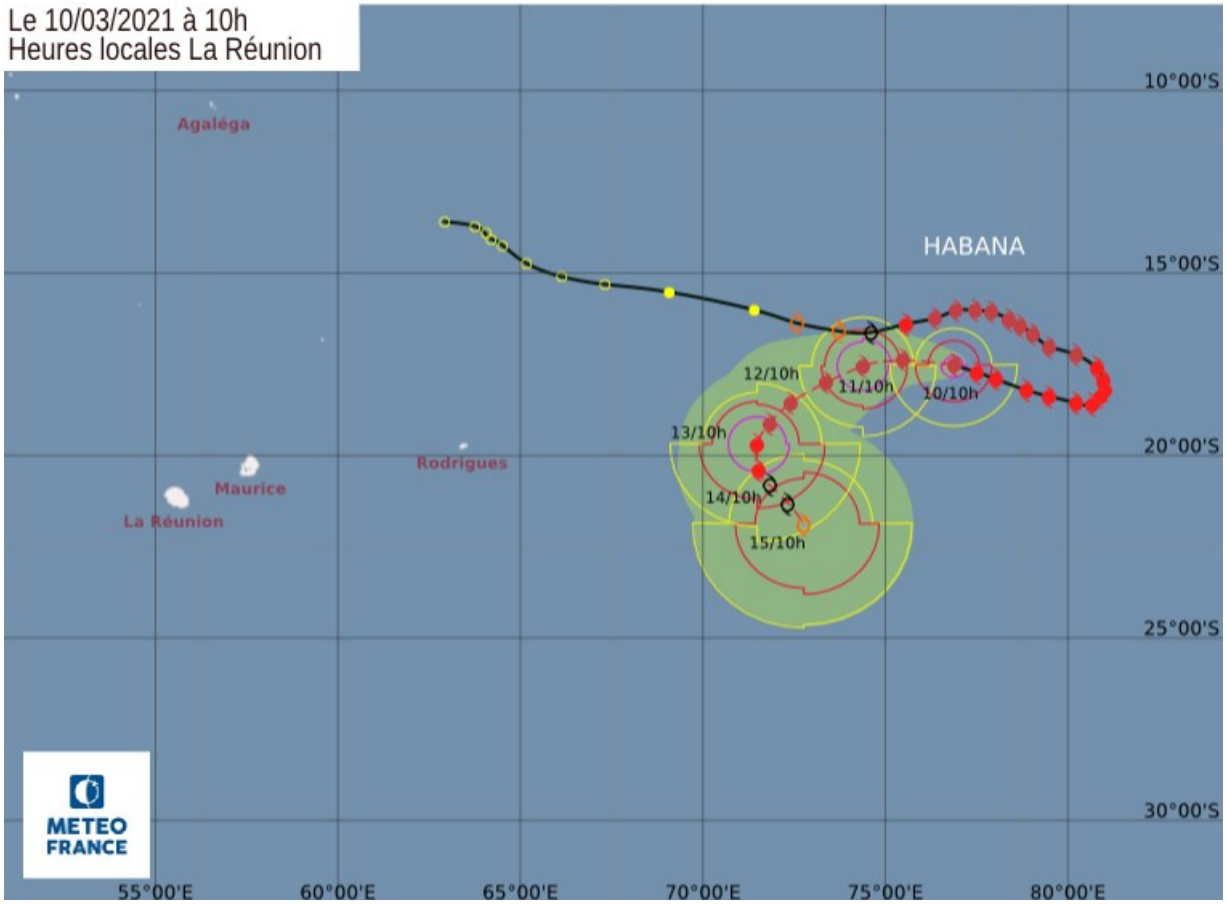
WTIO 30 WTIO 31

4.A CENTRAL PRESSURE: 967 HPA
5.A MAX AVERAGE WIND SPEED (10 MN): 100 KT
RADIUS OF MAXIMUM WINDS (RMW): 15 KM

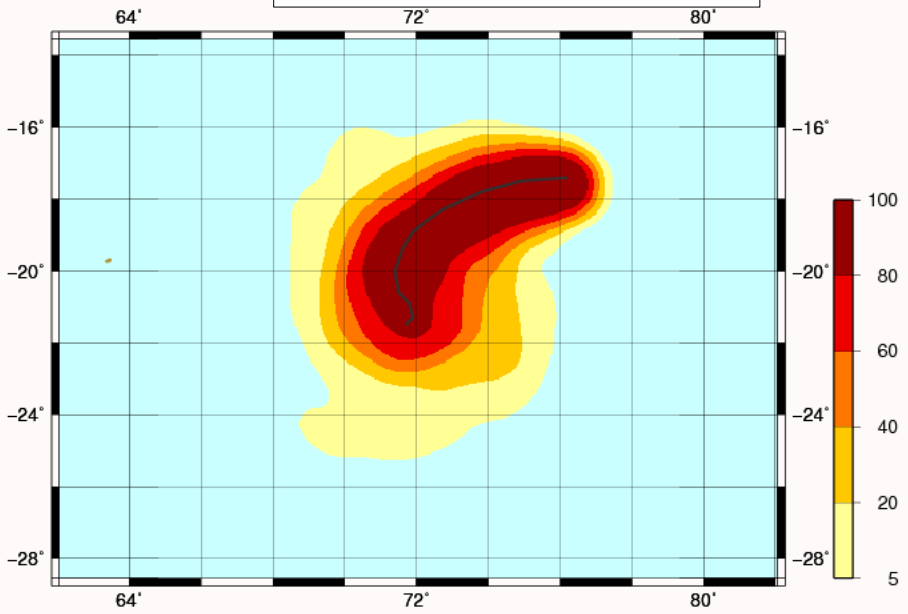
6.A EXTENSION OF WIND BY QUADRANTS (KM):
28 KT NE: 110 SE: 150 SW: 110 NW: 165
34 KT NE: 75 SE: 75 SW: 75 NW: 75
48 KT NE: 45 SE: 45 SW: 50 NW: 45
64 KT NE: 30 SE: 30 SW: 30 NW: 30

1.B FORECASTS (WINDS RADII IN KM):
12H: 2021/03/06 00 UTC: 16.1 S / 77.2 E, VENT MAX= 110 KT, INTENSE TROPICAL CYCLONE
28 KT NE: 110 SE: 130 SW: 150 NW: 100
34 KT NE: 95 SE: 75 SW: 85 NW: 85
48 KT NE: 65 SE: 55 SW: 65 NW: 65
64 KT NE: 35 SE: 35 SW: 35 NW: 45

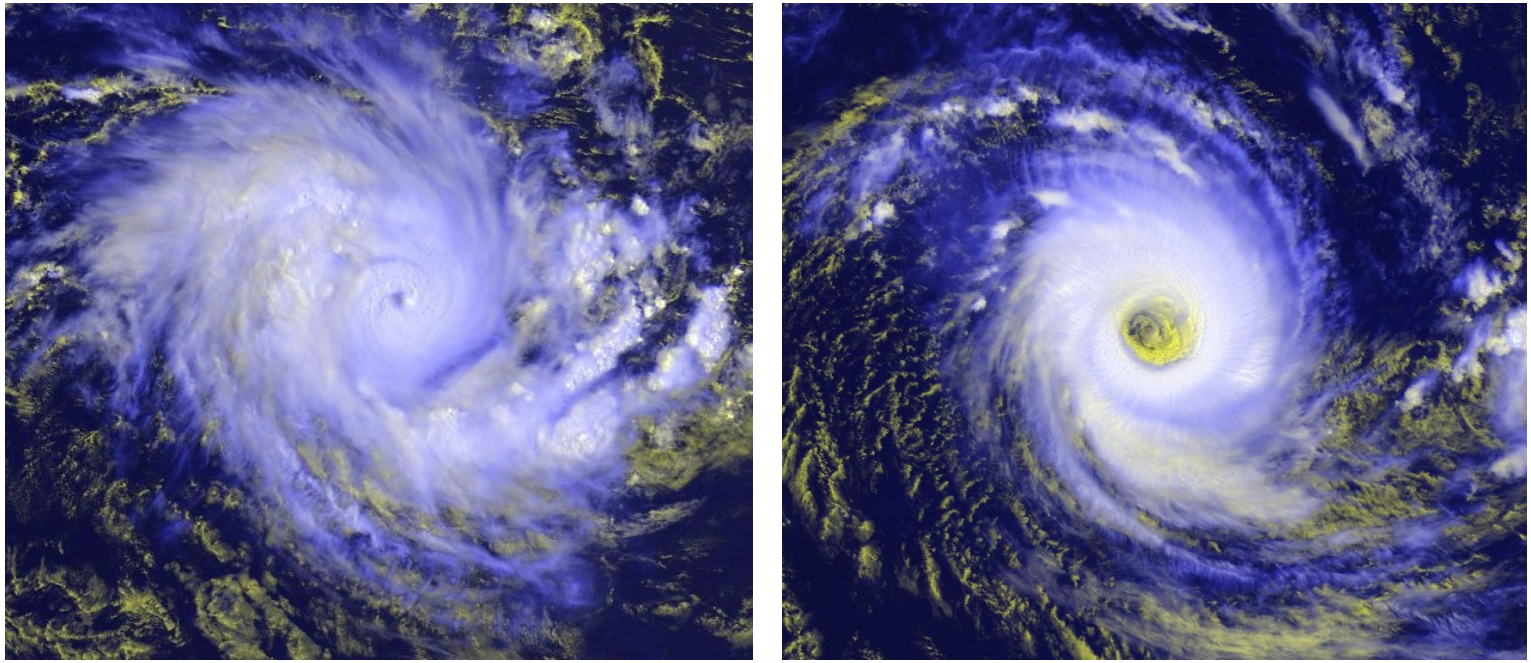
24H: 2021/03/06 12 UTC: 16.0 S / 78.2 E, VENT MAX= 100 KT, INTENSE TROPICAL CYCLONE
28 KT NE: 95 SE: 150 SW: 165 NW: 130
34 KT NE: 85 SE: 85 SW: 95 NW: 85
48 KT NE: 55 SE: 65 SW: 65 NW: 55
64 KT NE: 35 SE: 30 SW: 35 NW: 35



Probability of wind exceeding 34kt



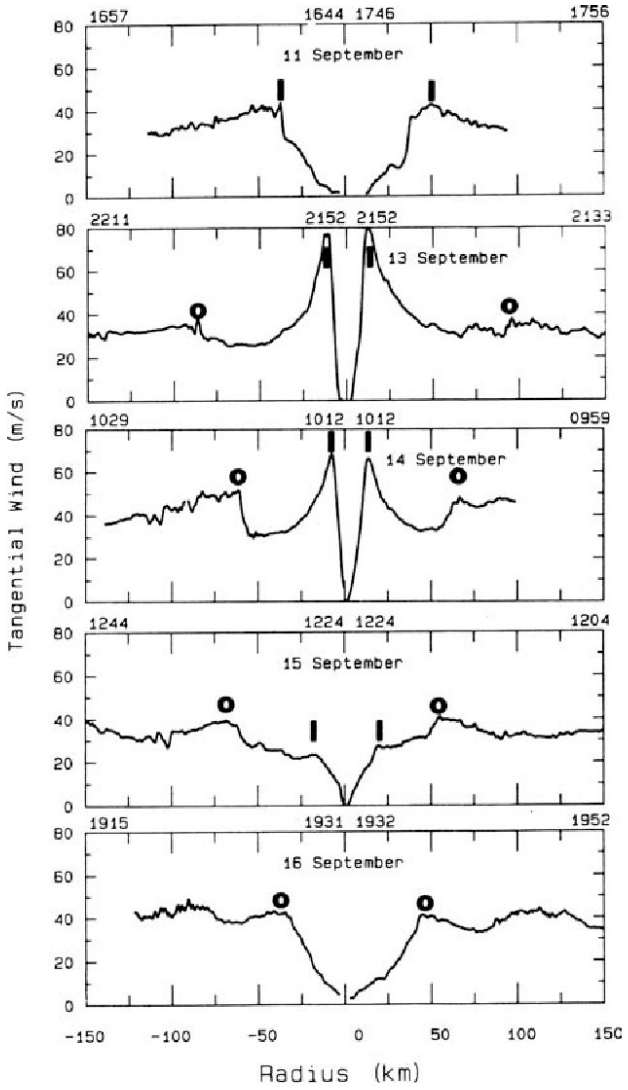
2. Eyewall Replacement Cycle (ERC)



CEBILE (2018) evolution in 48h

Eyewall Replacement Cycle (ERC)

Evolution of the wind profile



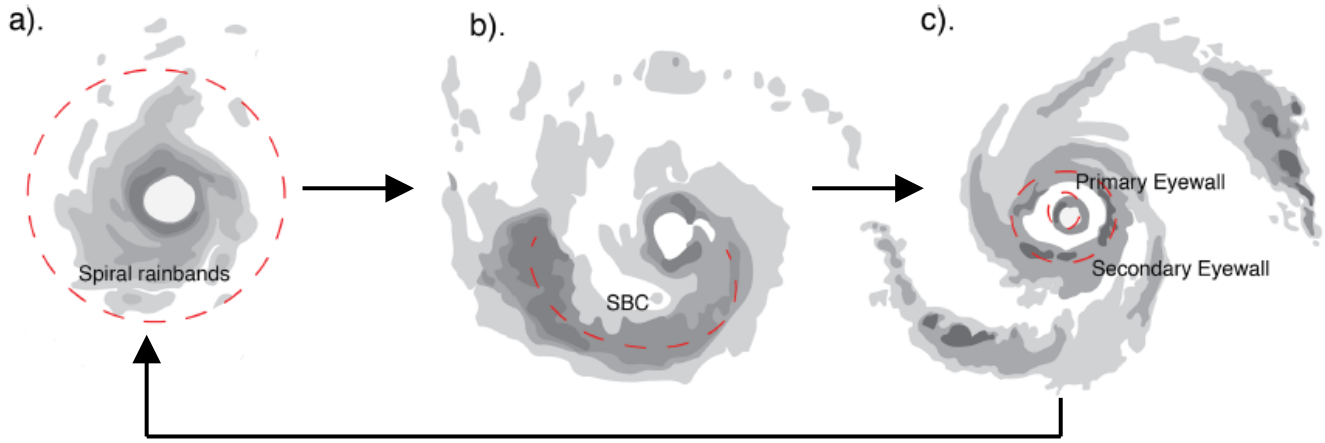
From Black & Willoughby 1992

Progressive building of an outer eyewall around the first eyewall

Tightening of this secondary eyewall and disappearance of the initial eyewall

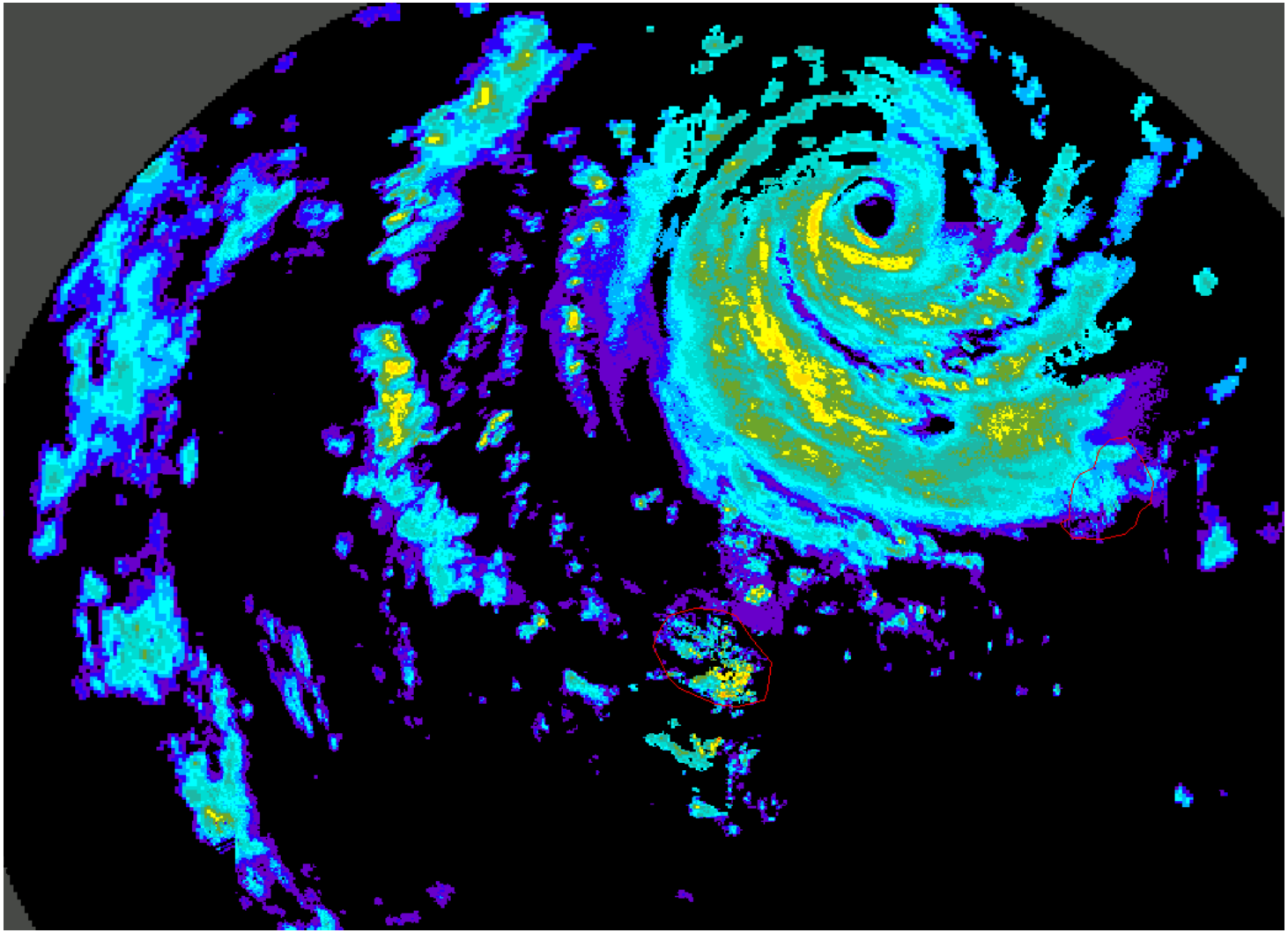
TC are often bigger (size) at the end

Evolution of the convective structure

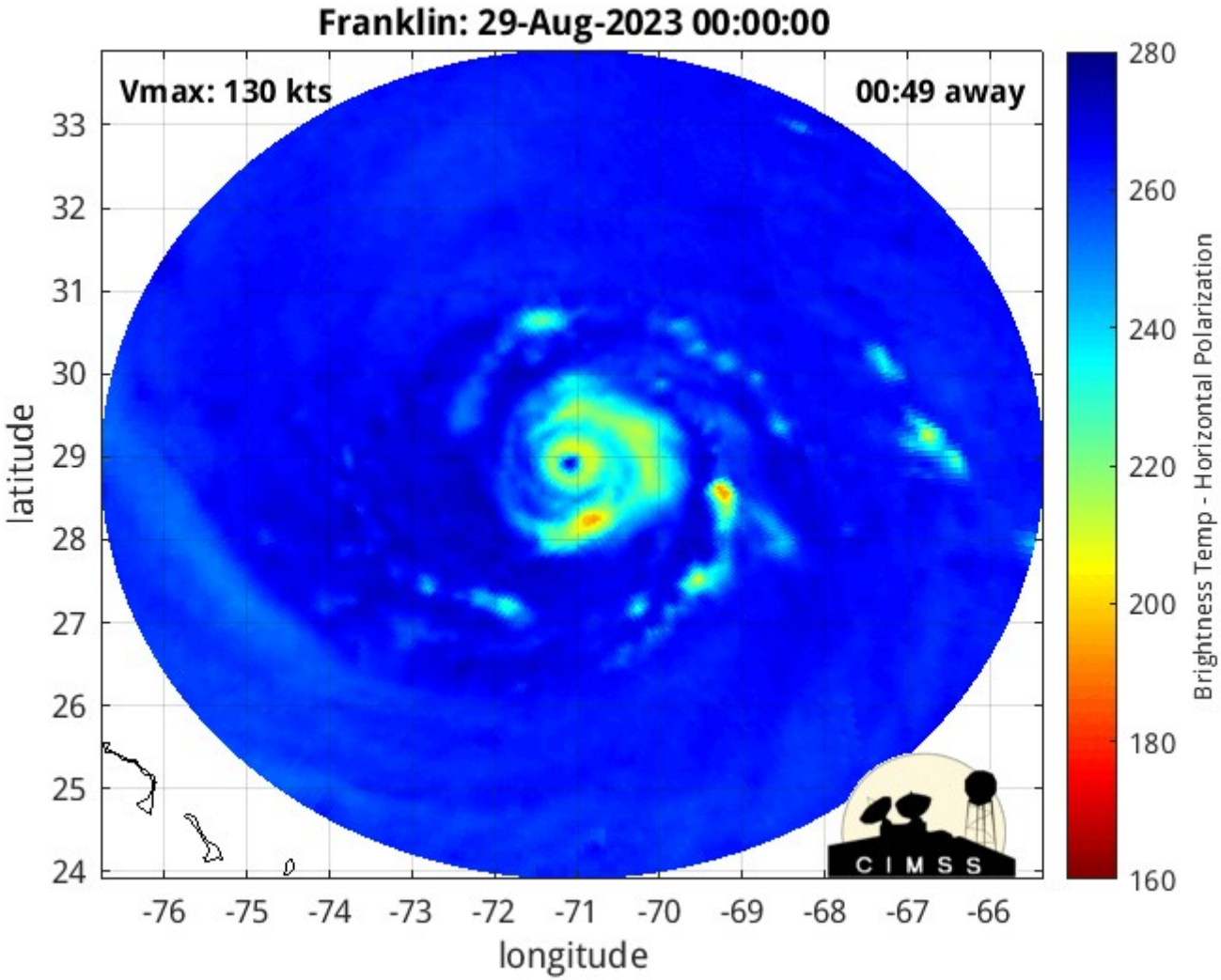


From Vaughan et al 2019 (The Stationary Banding Complex and Secondary Eyewall Formation in Tropical Cyclone)

ERC : BATSIRAI

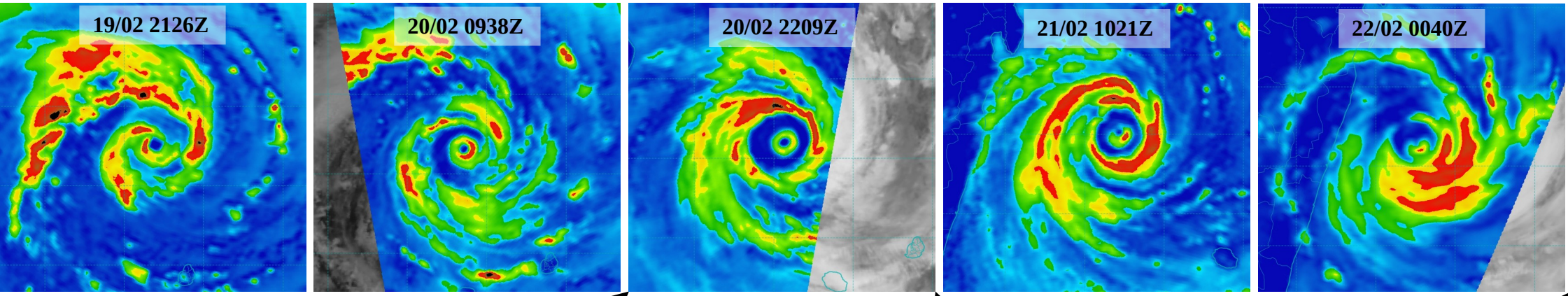


ERC : FRANKLIN



ERC : EMNATI

955hPa / 75 kt ↑ **935hPa / 95 kt →** **950hPa / 80 kt ↓** **952hPa / 75 kt →** **948hPa / 80 kt -**

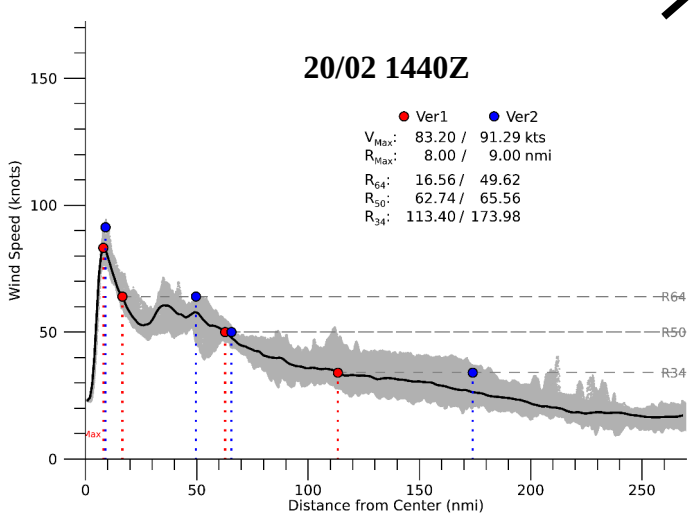


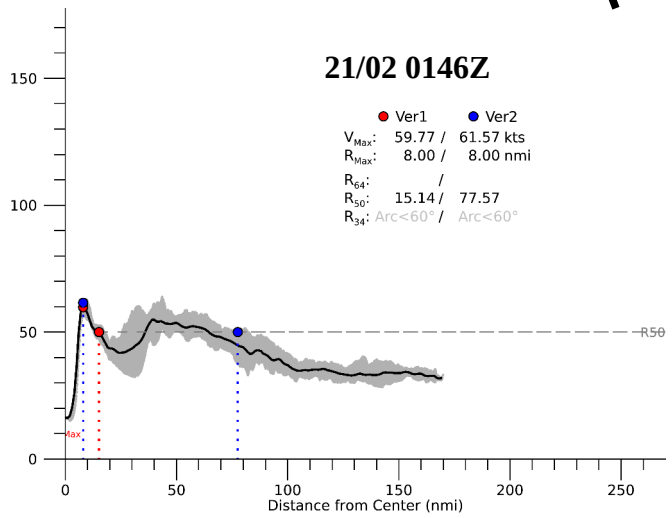
Building of the outer eyewall

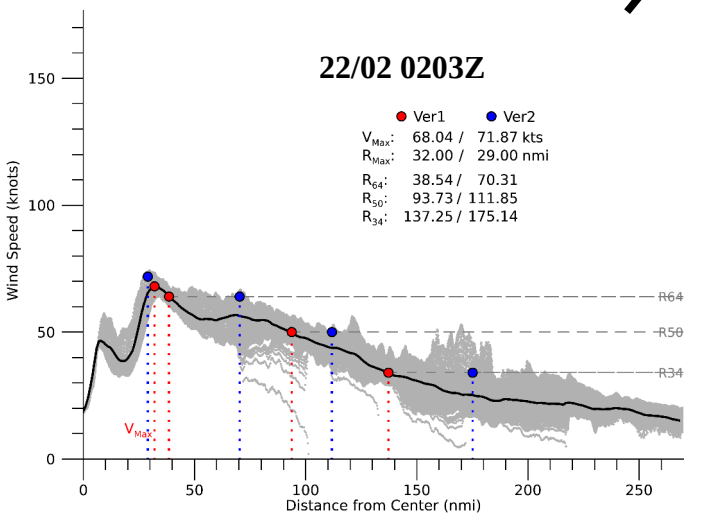
Weakening of the inner eyewall

V_{max} is on the outer eyewall

Inner eyewall disappear

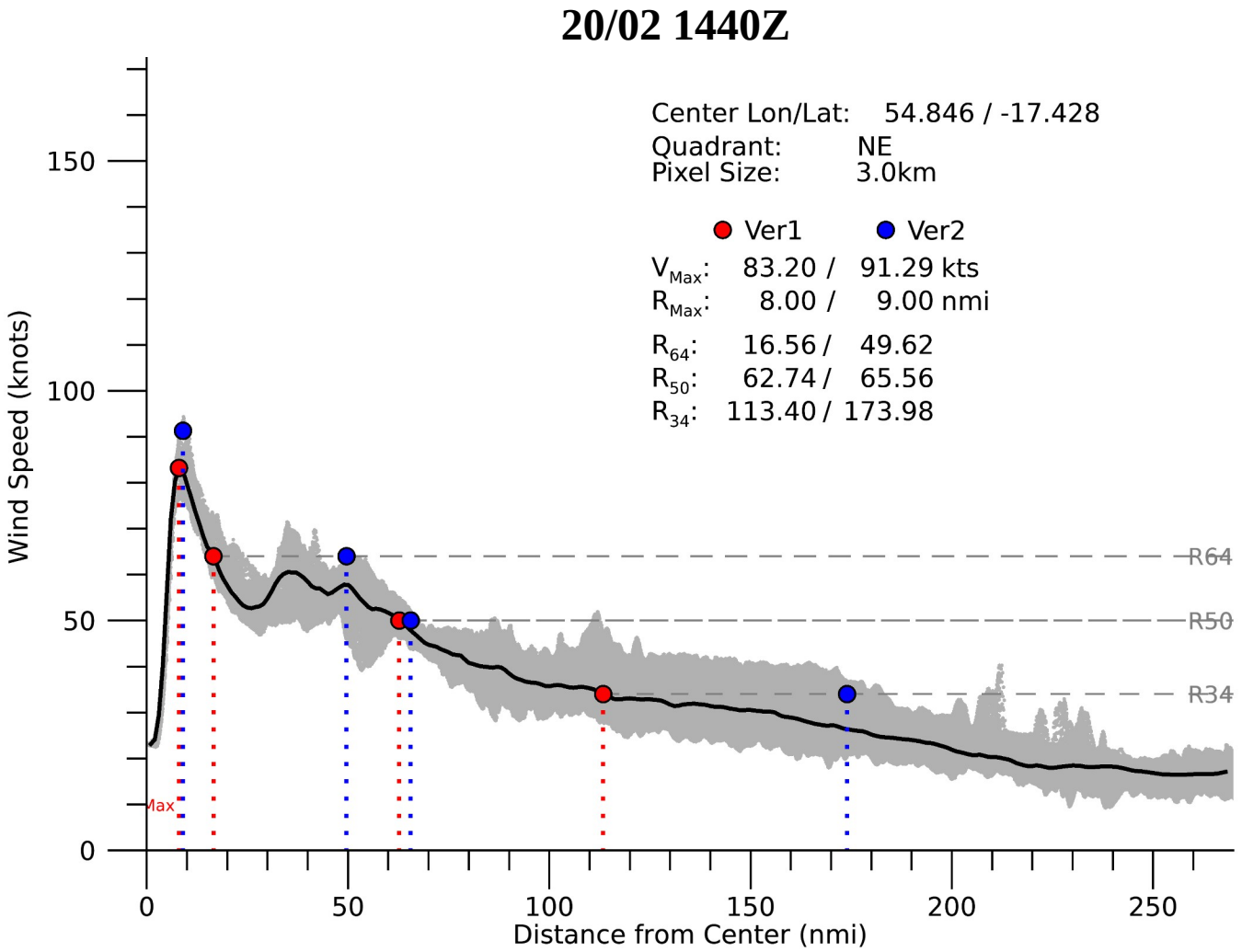






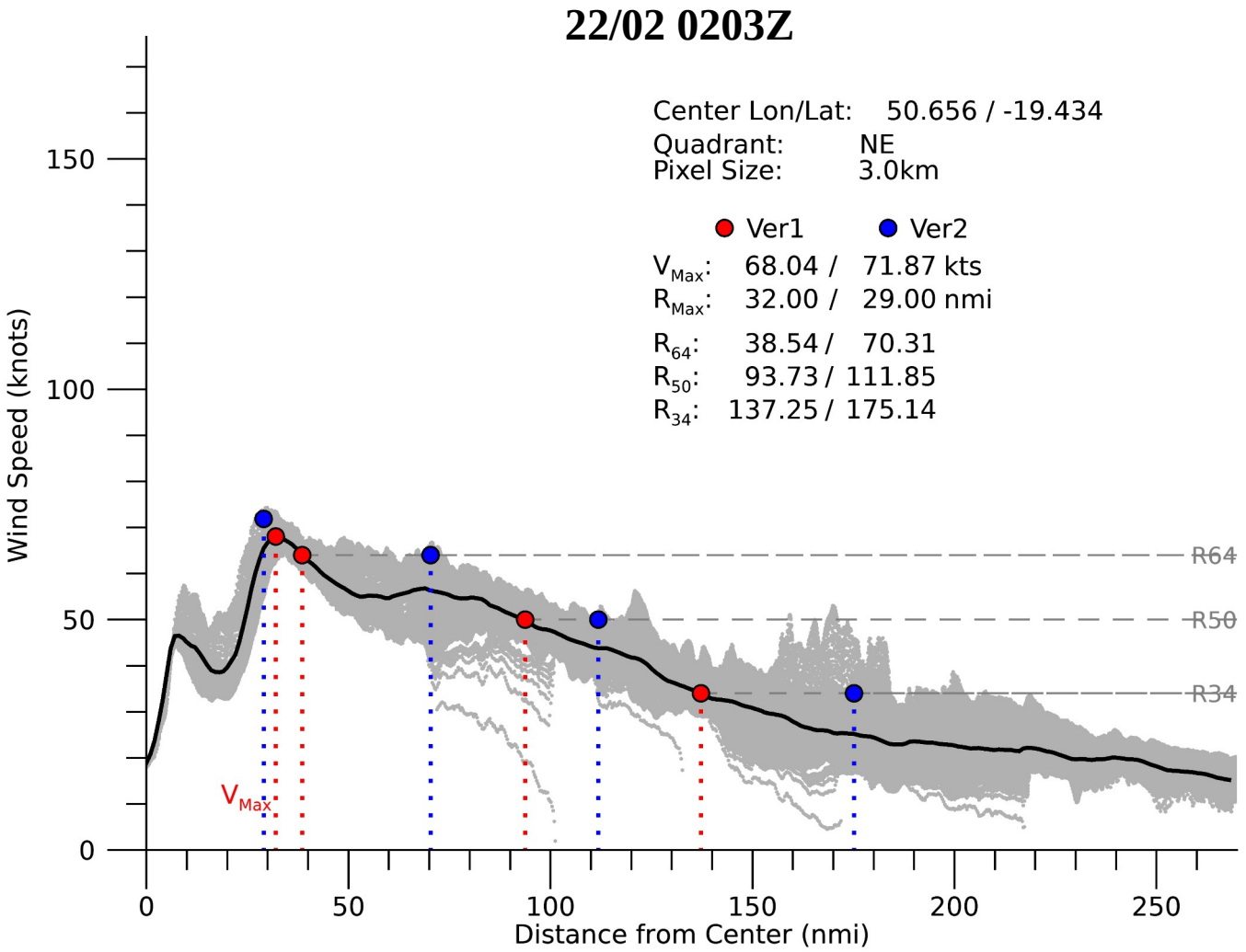
ERC : EMNATI

Increase of the TC size

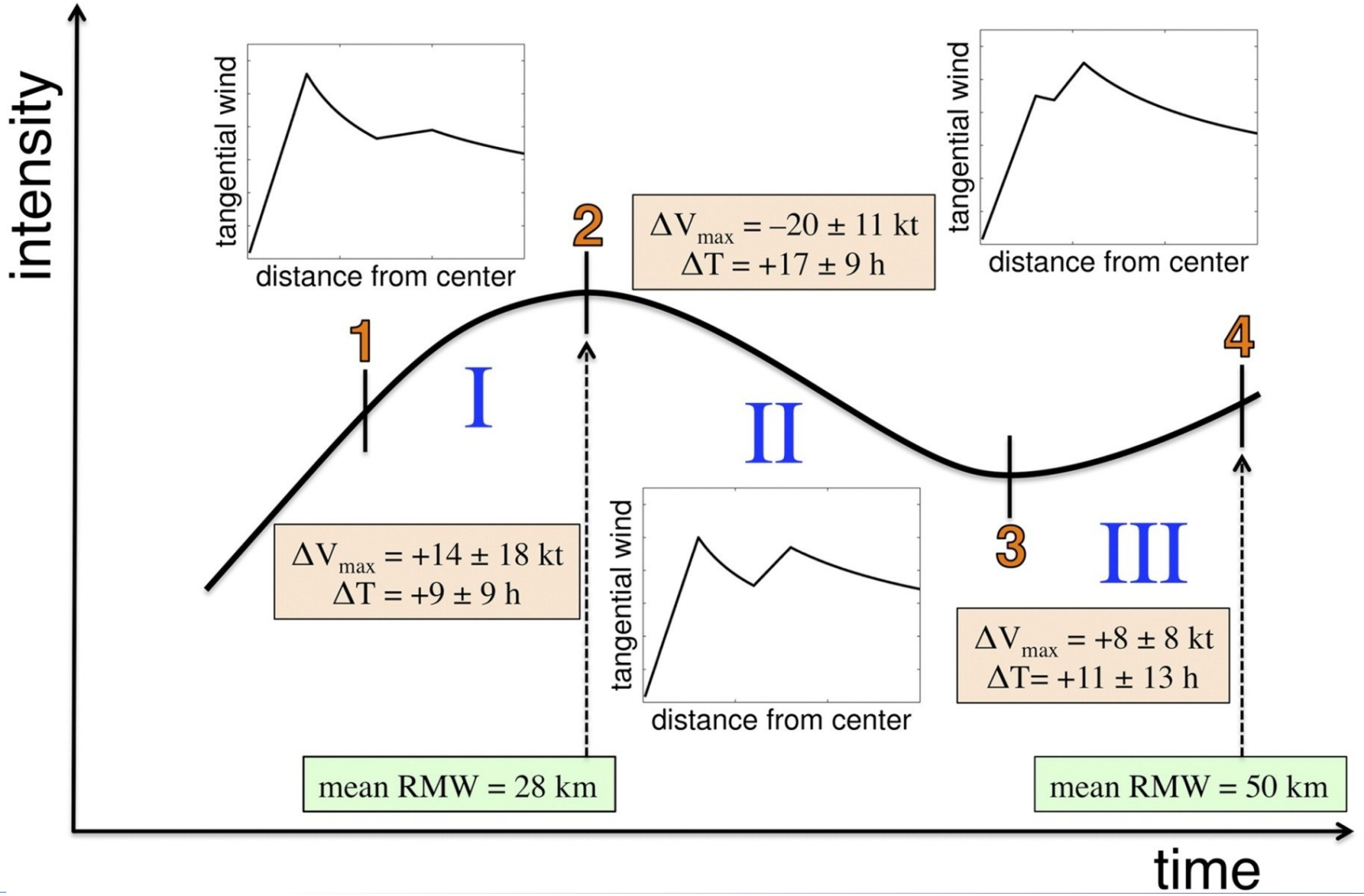


ERC : EMNATI

Increase of the TC size



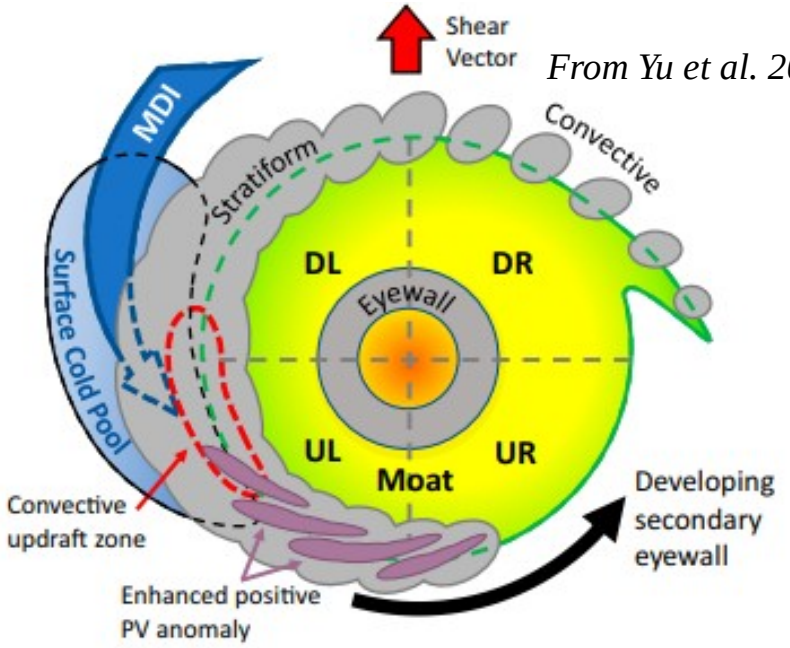
ERC consequences on intensity



ERC causes

The mechanism that triggers the start of an ERC is not entirely understood :

- The formation of the secondary eyewall may be favored in slightly sheared cases (*Yu et al. 2021, Wang and Tan 2022, ..*)
- It is a frequent phenomenon for intense and very intense tropical cyclones



From Yu et al. 2021

FIG. 13. A schematic diagram that illustrates the role of the stationary rainband complex in the SEF process. The gray and purple

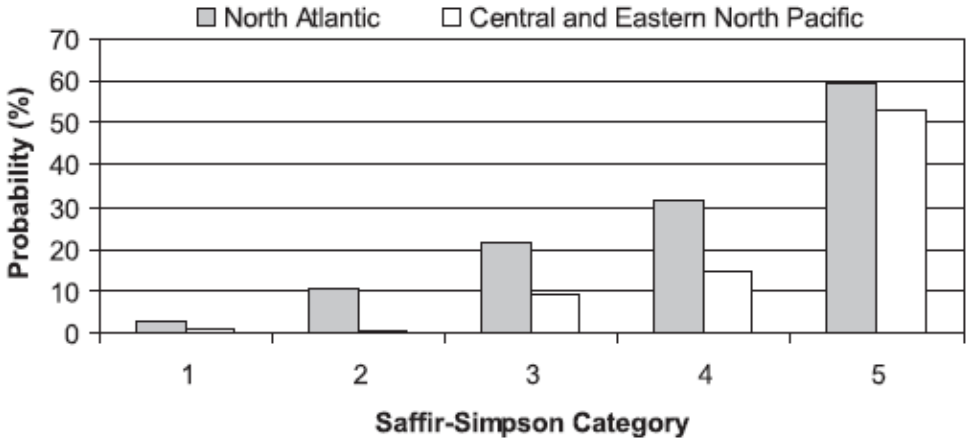
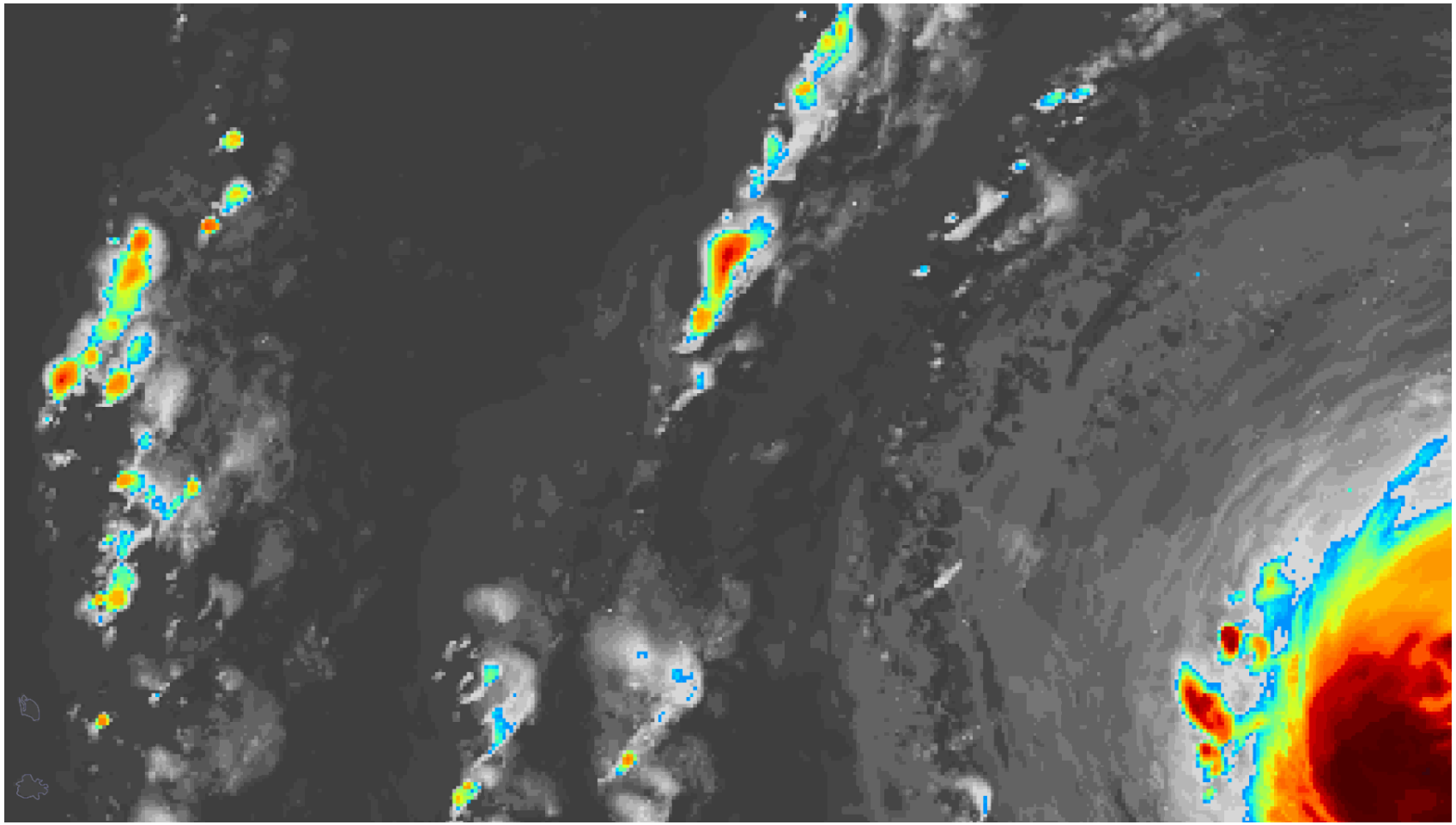


FIG. 6. Climatological probability, based on counts, of secondary eyewall formation as a function of current intensity (grouped by Saffir–Simpson category). The values reflect the climatological probability, for any time that a hurricane is over water, that secondary eyewall formation is imminent.

From Kossin et al. 2009

ERC forecast

Arome IO is able to forecast an ERC but it is not reliable yet.



ERC forecast – In operations

- Microwave imagery from NRL https://www.nrlmry.navy.mil/TC.html
- CIMSS MPERC http://tropic.ssec.wisc.edu/real-time/archerOnline/web/index_erc.shtml
  - CEBILE