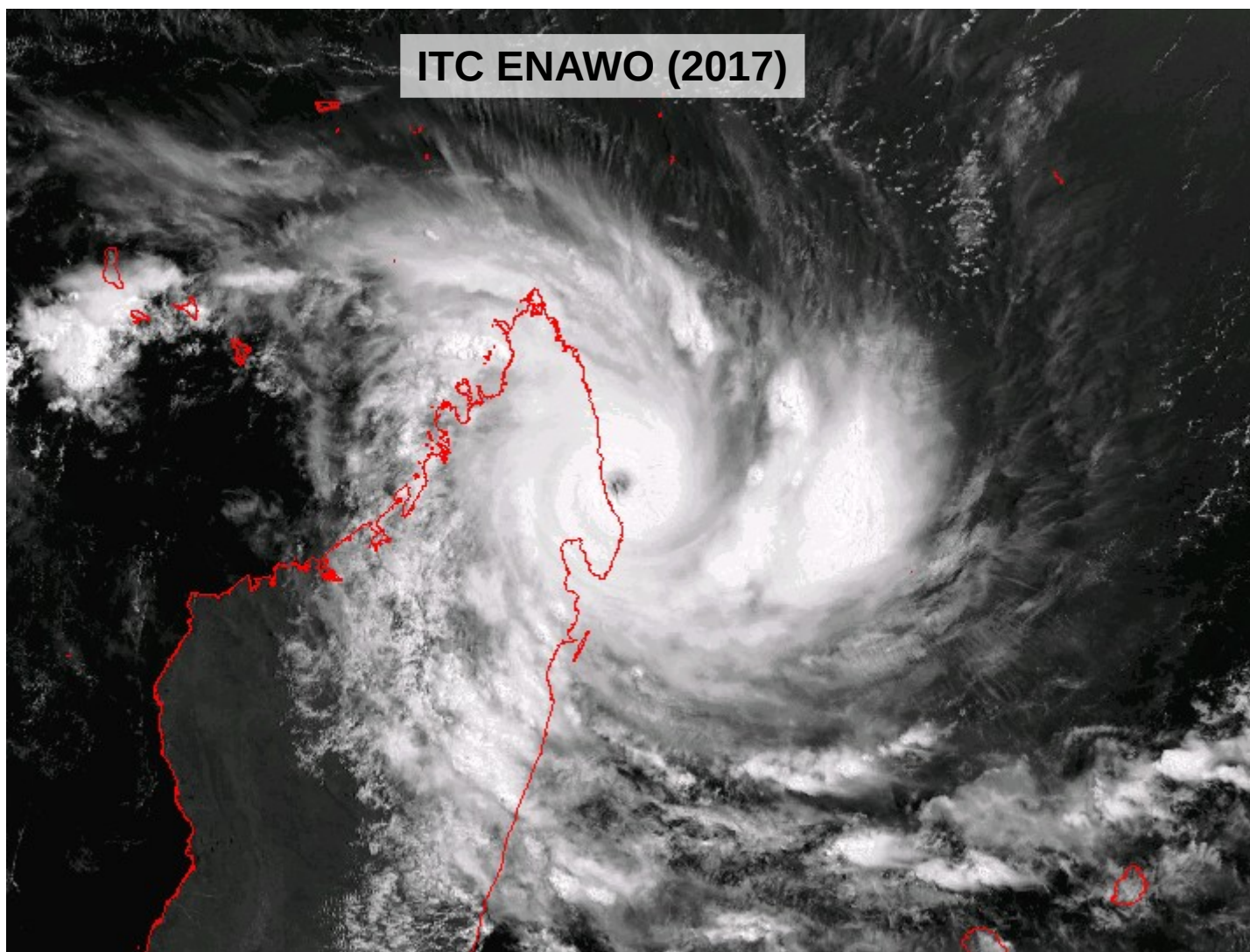


Introduction to Tropical Cyclones – TC 101

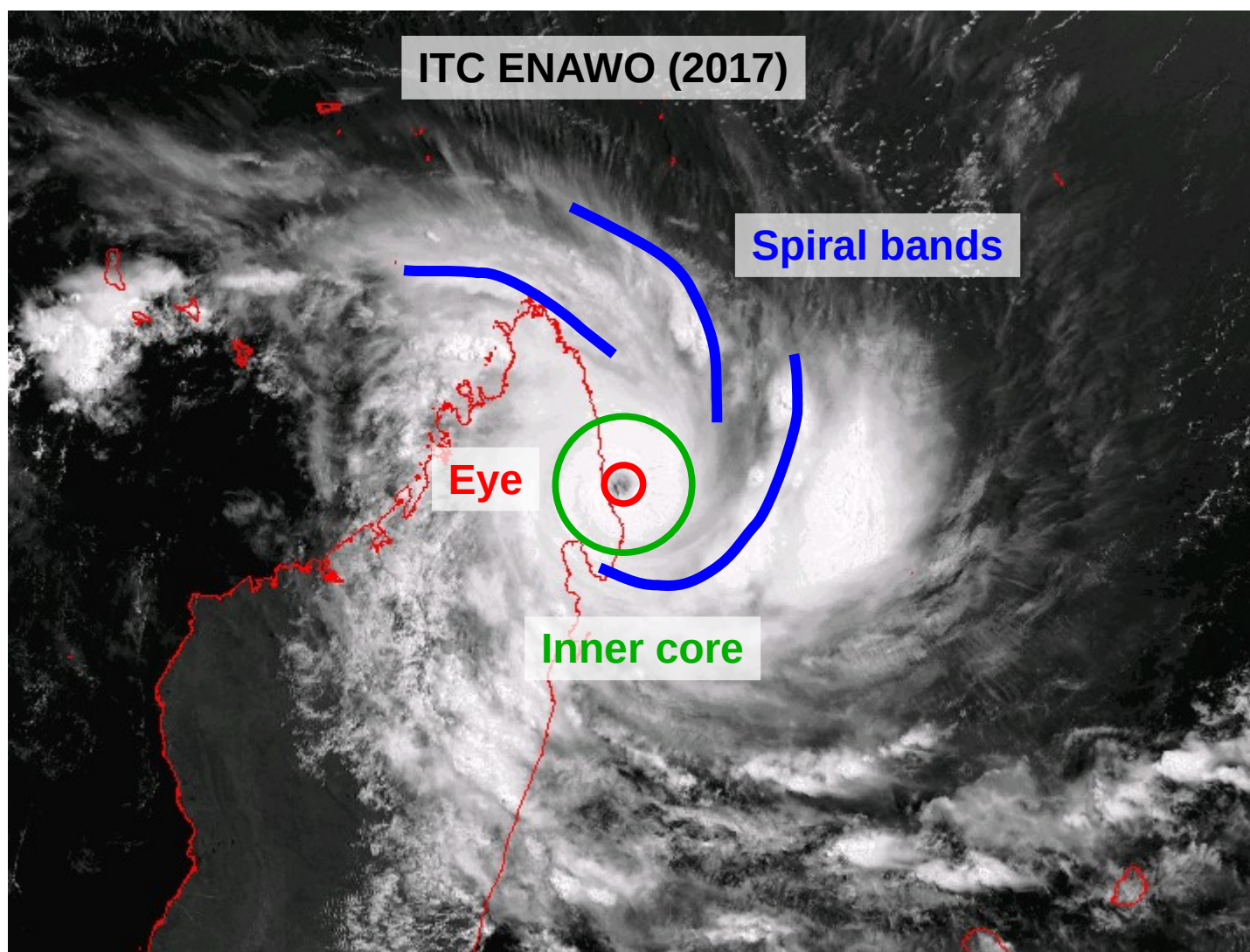
Tarik Kriat / Sébastien Langlade / Adrien Colomb
RA I Training Course on Tropical Cyclones – 11th session
September 2023

1. What is a Tropical Cyclone ?

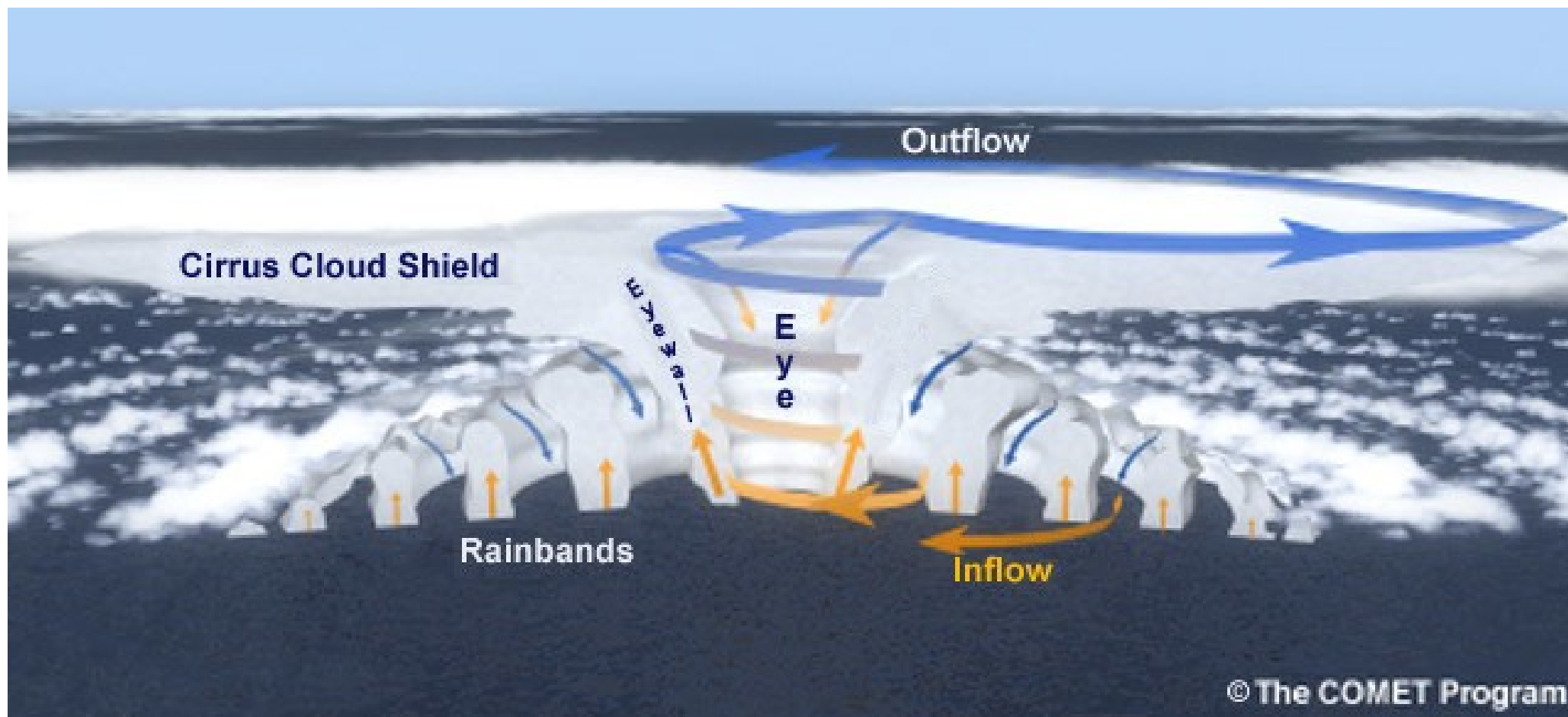
What is a Tropical Cyclone ?



What is a Tropical Cyclone ?

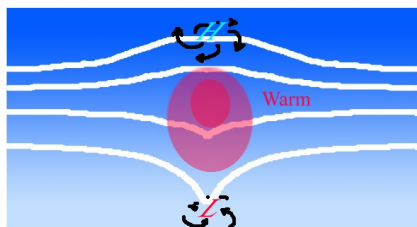
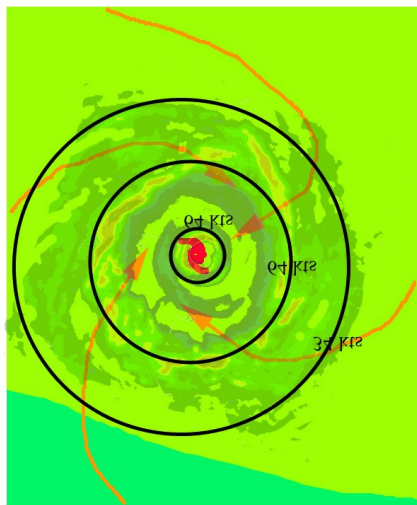


What is a Tropical Cyclone ?

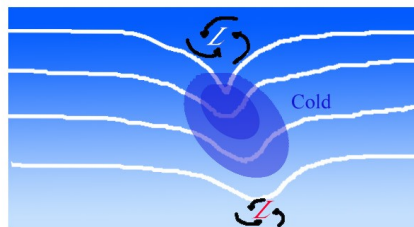
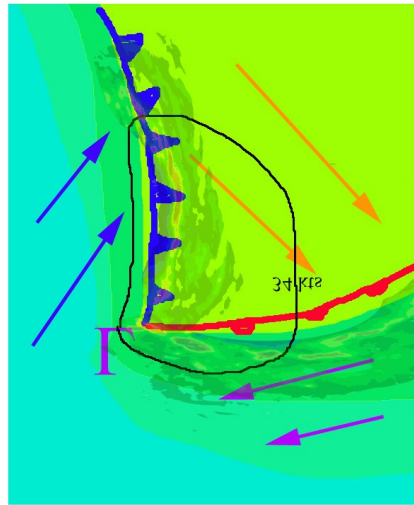


What is a Tropical Cyclone ?

Tropical Cyclones are **warm core** , **non frontal**, low pressure system over sea with a closed and organized circulation



Tropical Cyclone



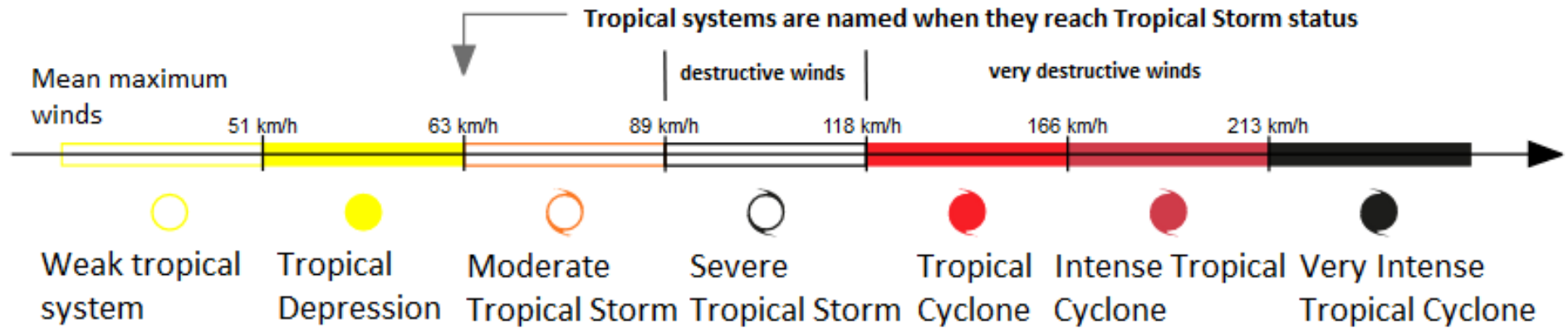
Extratropical Cyclone

Merrill 1993

- Warm core
 - Hot temperature (or humid) anomaly
- Non frontal
 - Weak thermodynamic gradients
 - No baroclinity
 - Central symmetry
 - Isolines // Wind

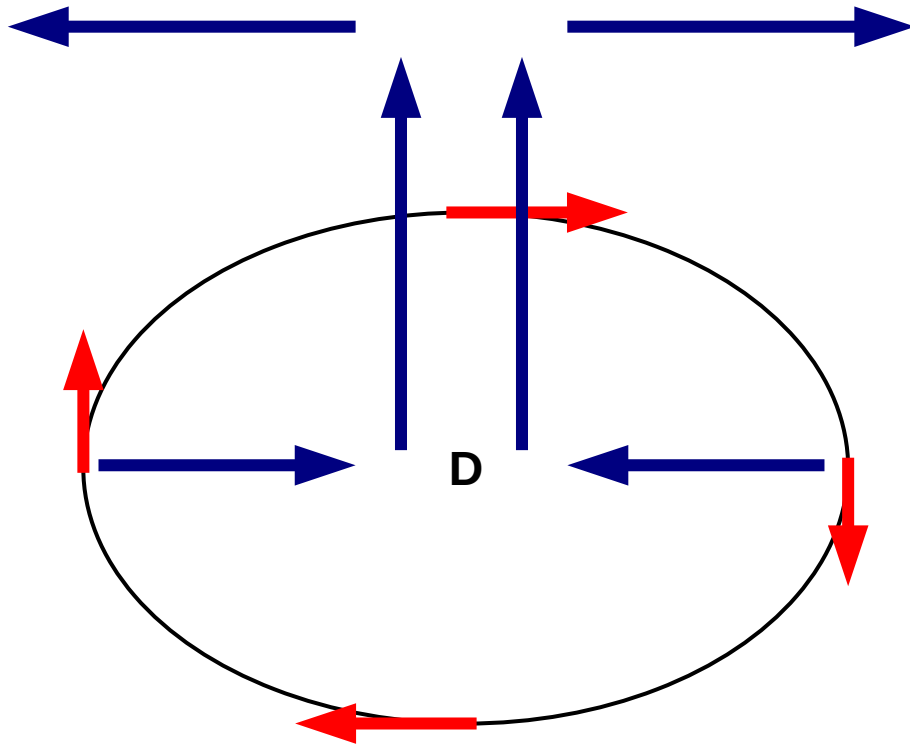
A tropical system is defined by the strength of the mean maximum winds over sea (10 min average in SWIO)

What is a Tropical Cyclone ?



Mean winds (kt)	<28	28-33	34-47	48-63	64-89	90-119	≥ 120
Gusts (km/h)	70	80	85-125	125-165	170-235	235-300	≥ 300
Beaufort	≤ 7	7	8-9	10-11	12	12	12
Saffir-Simpson				TS-Cat1	Cat1-Cat3	Cat3-Cat4	Cat4-Cat5

Primary and Secondary circulations

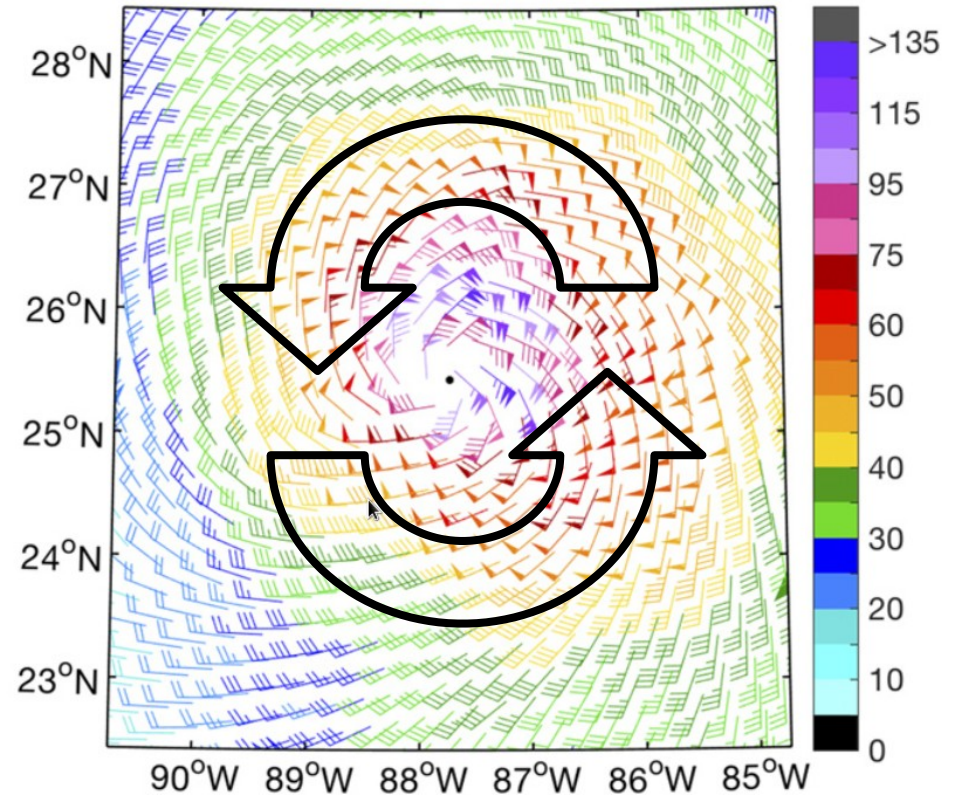
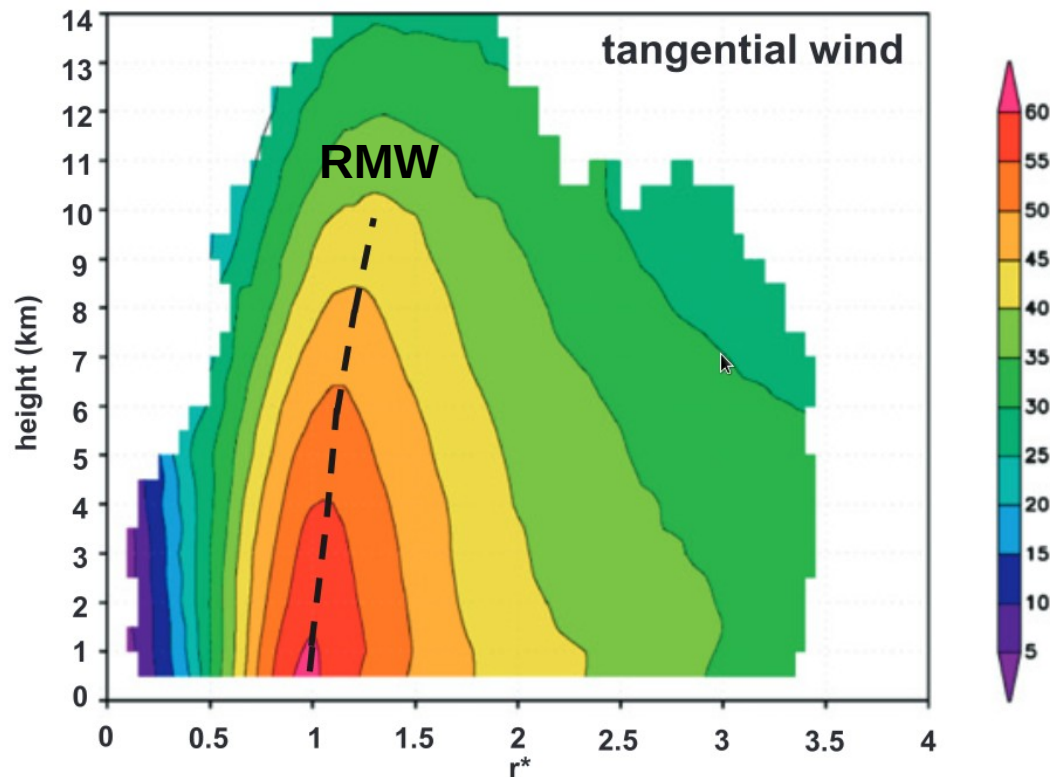


Wind \vec{V}

Tangential wind V_θ : **primary circulation**

Radial wind V_r : **secondary circulation**

Primary circulation

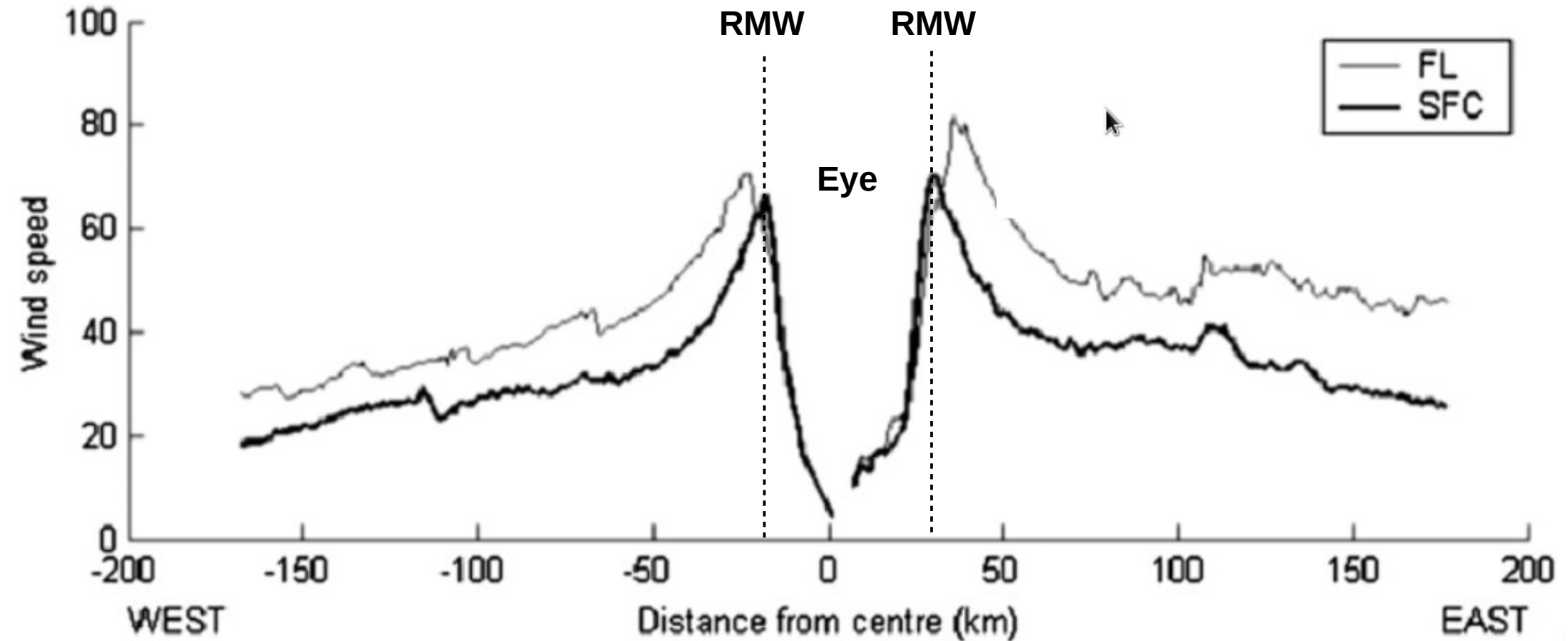


Hurricane Katrina (Northern Hemisphere)

- Maximum winds near the surface
- Asymmetries : Movement, Shear, Intensity, Friction (land), Environnement..

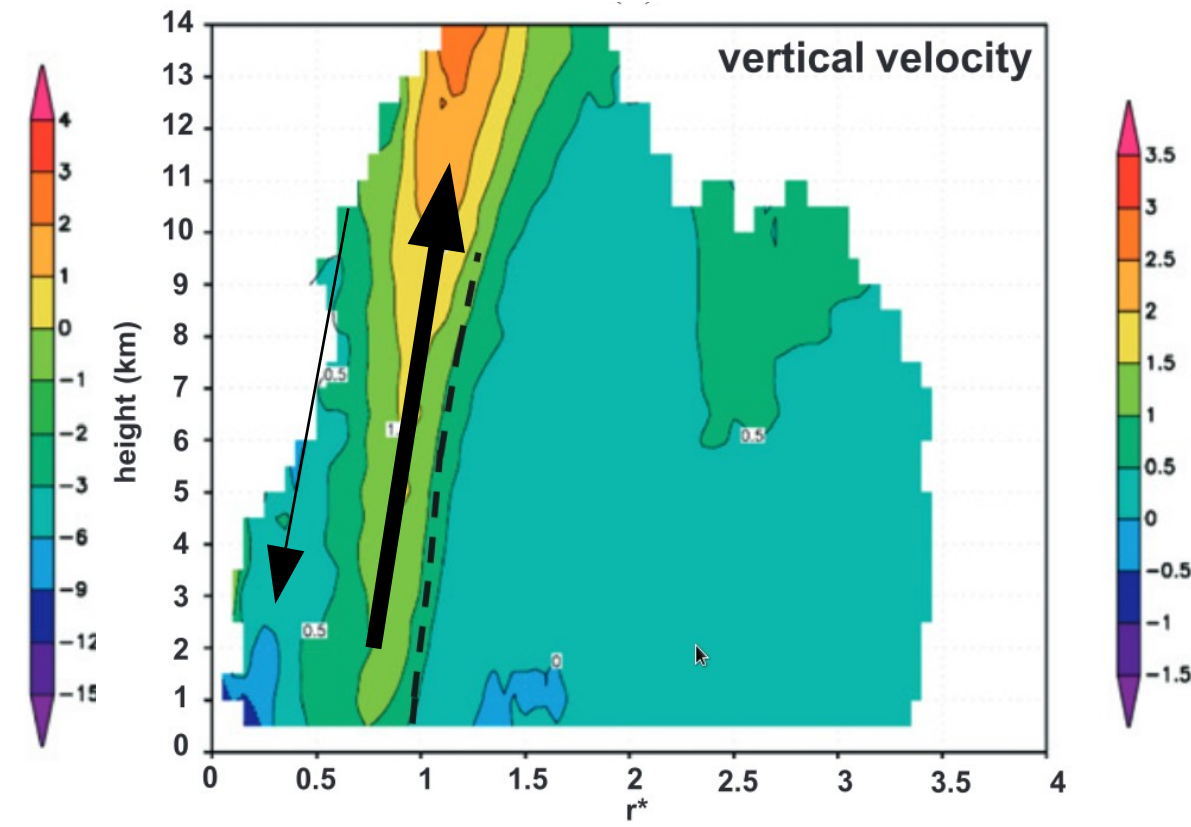
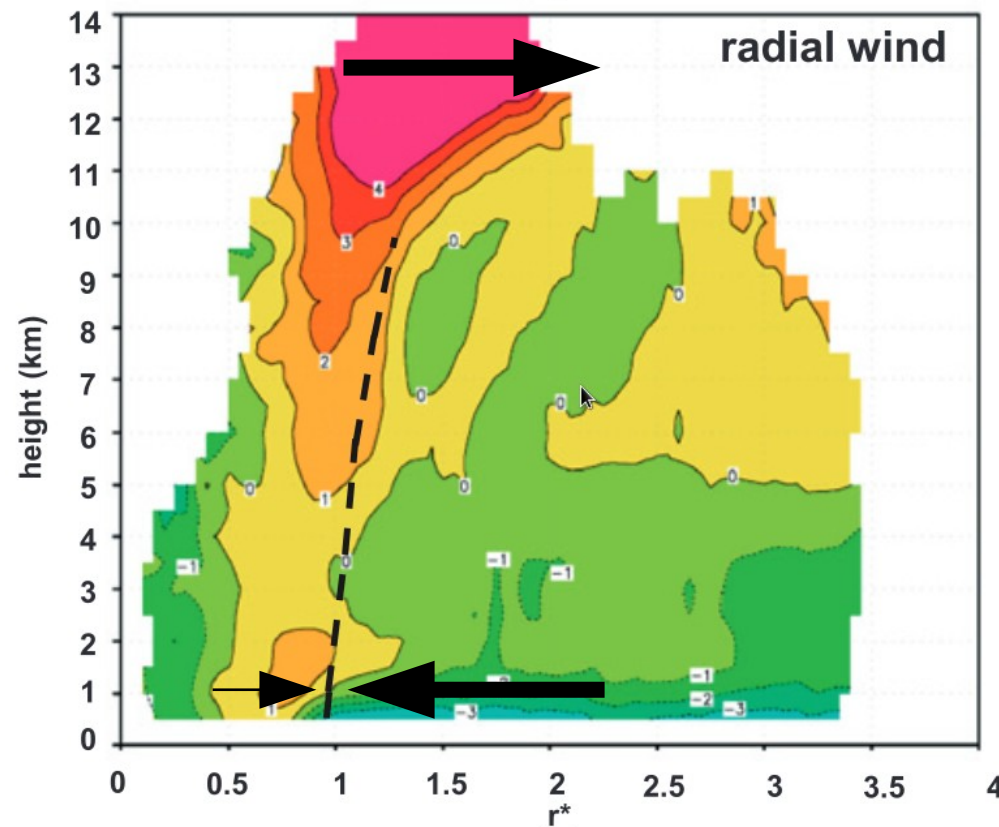
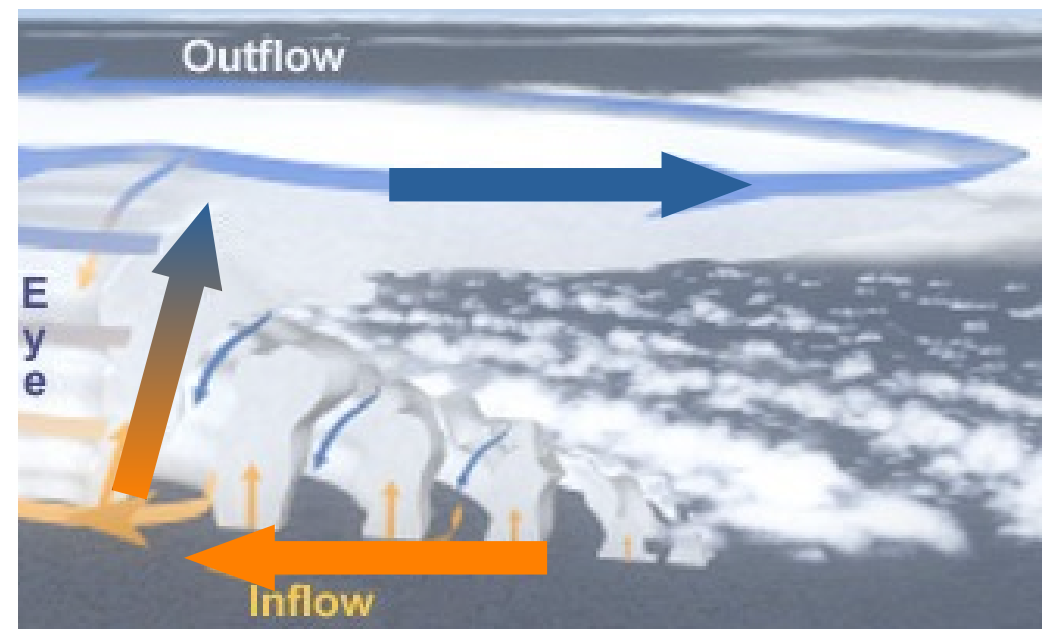
Primary circulation

RMW = Radius of Maximum Winds

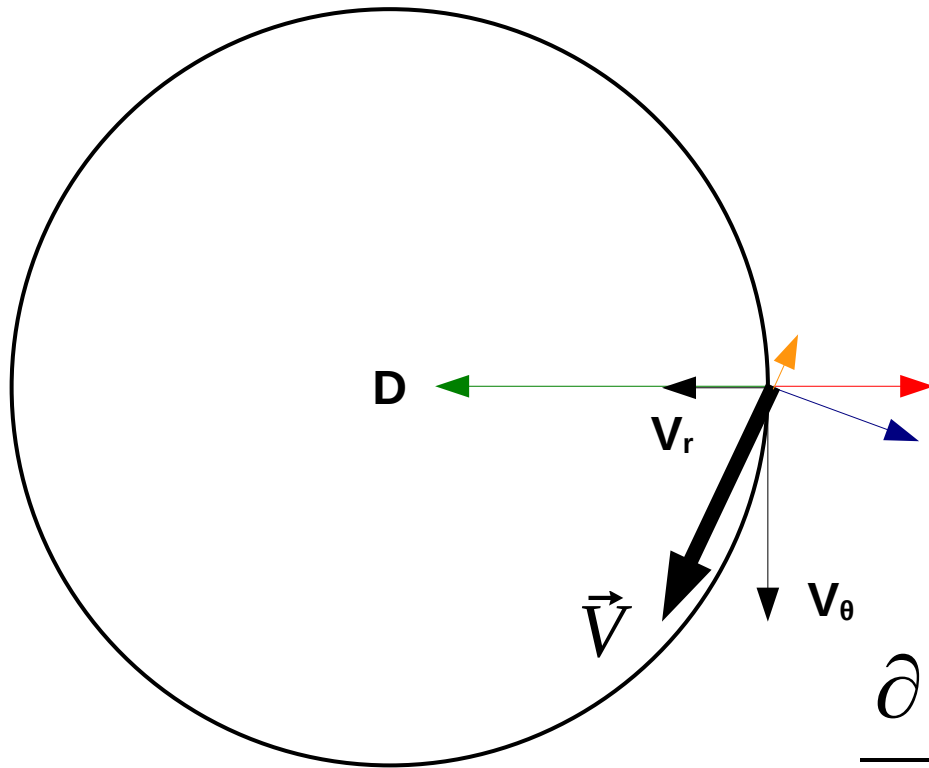


Secondary circulation

- Lower inflow / upper outflow
- Updrafts mostly in the eyewall



Cyclostrophic / geostrophic balance



Wind \vec{V}

Tangential wind V_θ : **primary circulation**

Radial wind V_r : **secondary circulation**

Friction (F)

Coriolis force (f)

Pressure gradient (P)

Centrifugal force

**Geostrophic
balance**
**Cyclostrophic
balance**

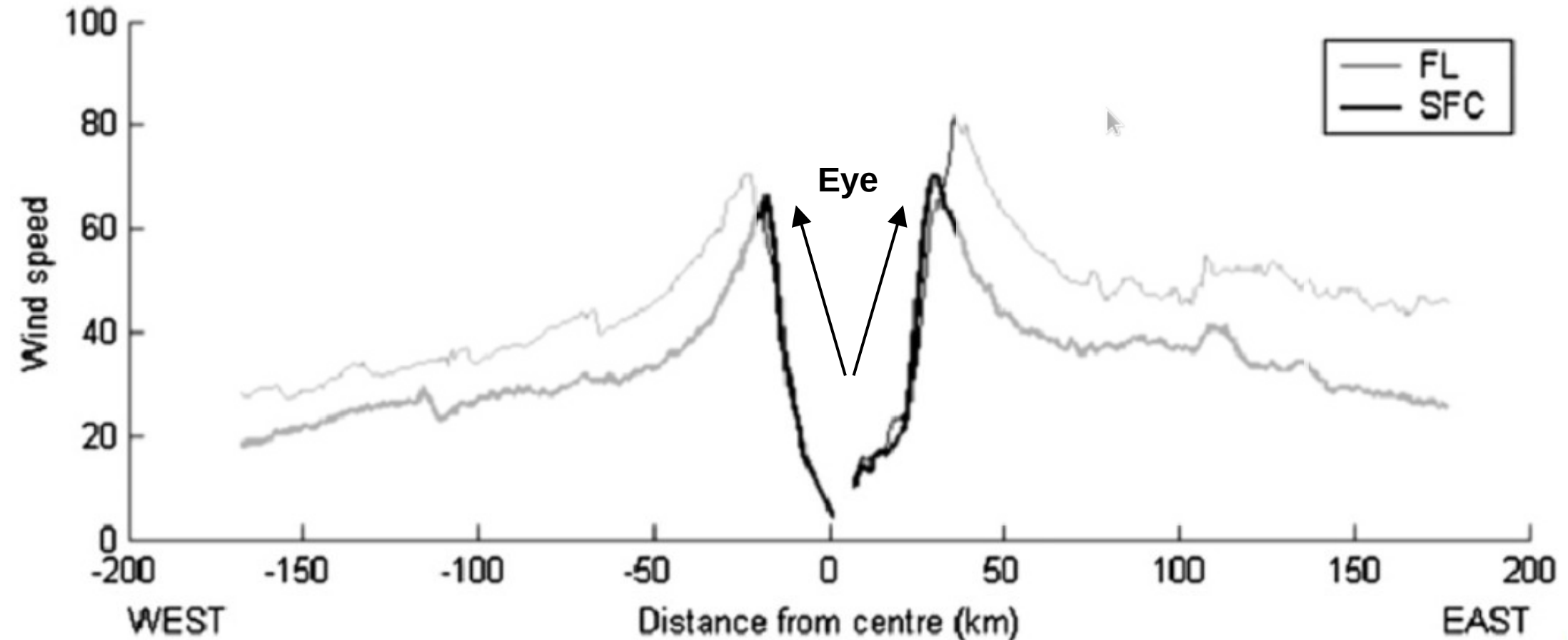
$$\frac{\partial V_r}{\partial t} = \frac{V_\theta^2}{r} + fV_\theta - \frac{1}{\rho} \frac{\partial P}{\partial r} + F_\theta = 0$$

Primary circulation

- Close to the center

$$\frac{\partial V_r}{\partial t} = \frac{V_\theta^2}{r} + \cancel{fV_\theta} - \frac{1}{\rho} \frac{\partial P}{\partial r} + \cancel{F_\theta} = 0$$

- Cyclostrophic balance $V^2 = \frac{r}{\rho} \frac{\partial P}{\partial r}$

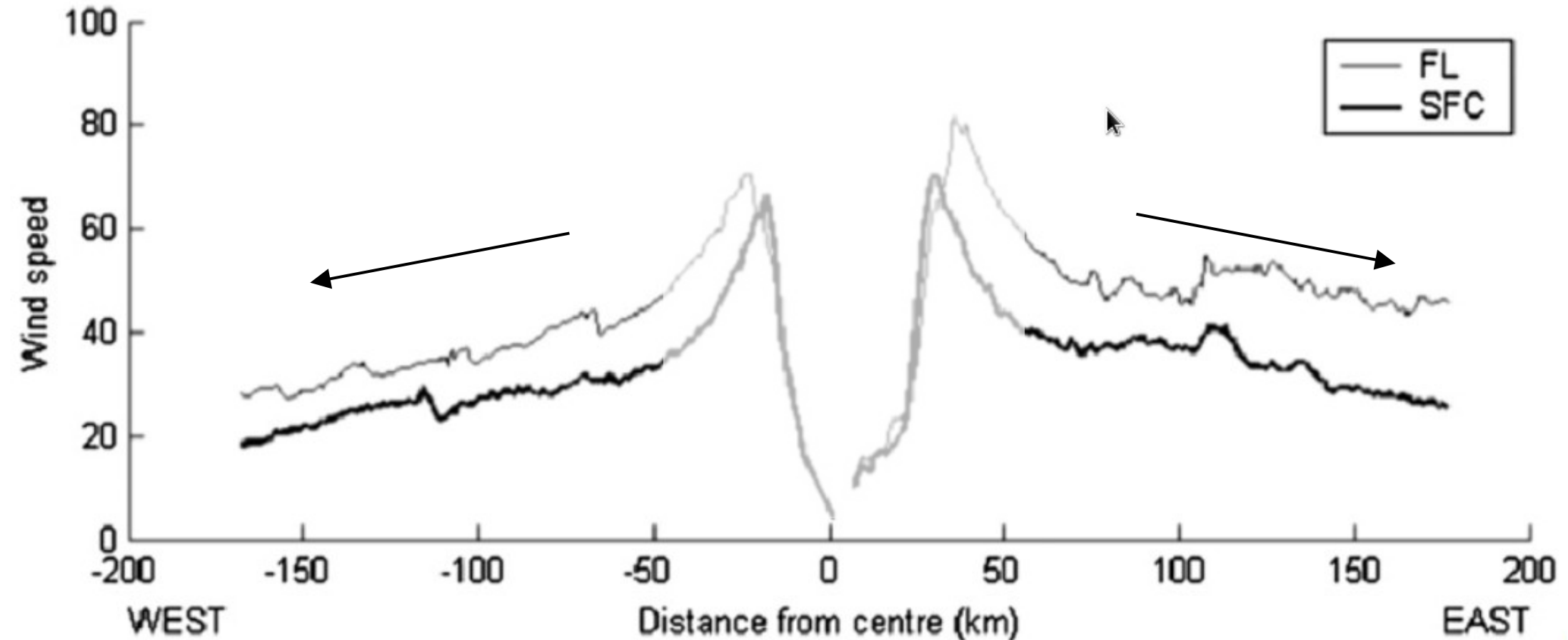


Primary circulation

- Far from the center

$$\frac{\partial V_r}{\partial t} = \cancel{\frac{V_\theta^2}{r}} + fV_\theta - \frac{1}{\rho} \frac{\partial P}{\partial r} + \cancel{F_\theta} = 0$$

- Geostrophic balance $V = \frac{1}{f\rho} \frac{\partial P}{\partial r}$



Eyewall building

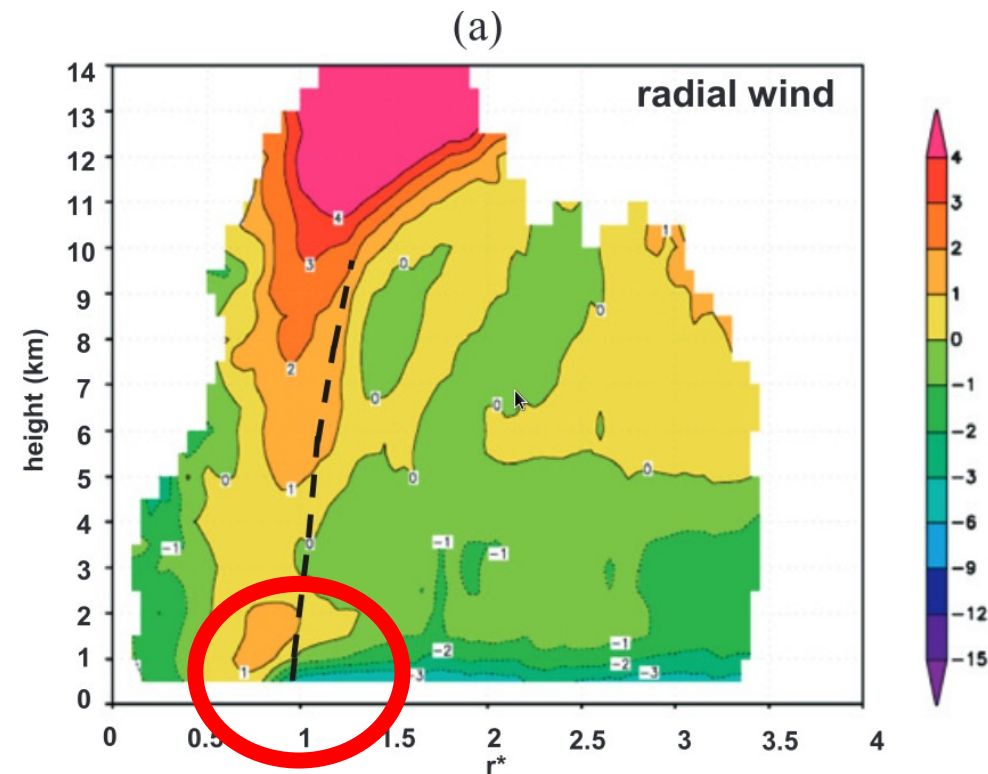
When V_θ becomes too strong (Supergradient wind), pressure gradient is not able to balance the other forces (max 5-10hPa/km).

$$\frac{\partial V_r}{\partial t} = \frac{V_\theta^2}{r} + fV_\theta - \frac{1}{\rho} \frac{\partial P}{\partial r} > 0$$

→ V_r increases, V_r is negative so the inflow slows down

→ Updrafts and convection get stronger

→ Intensification

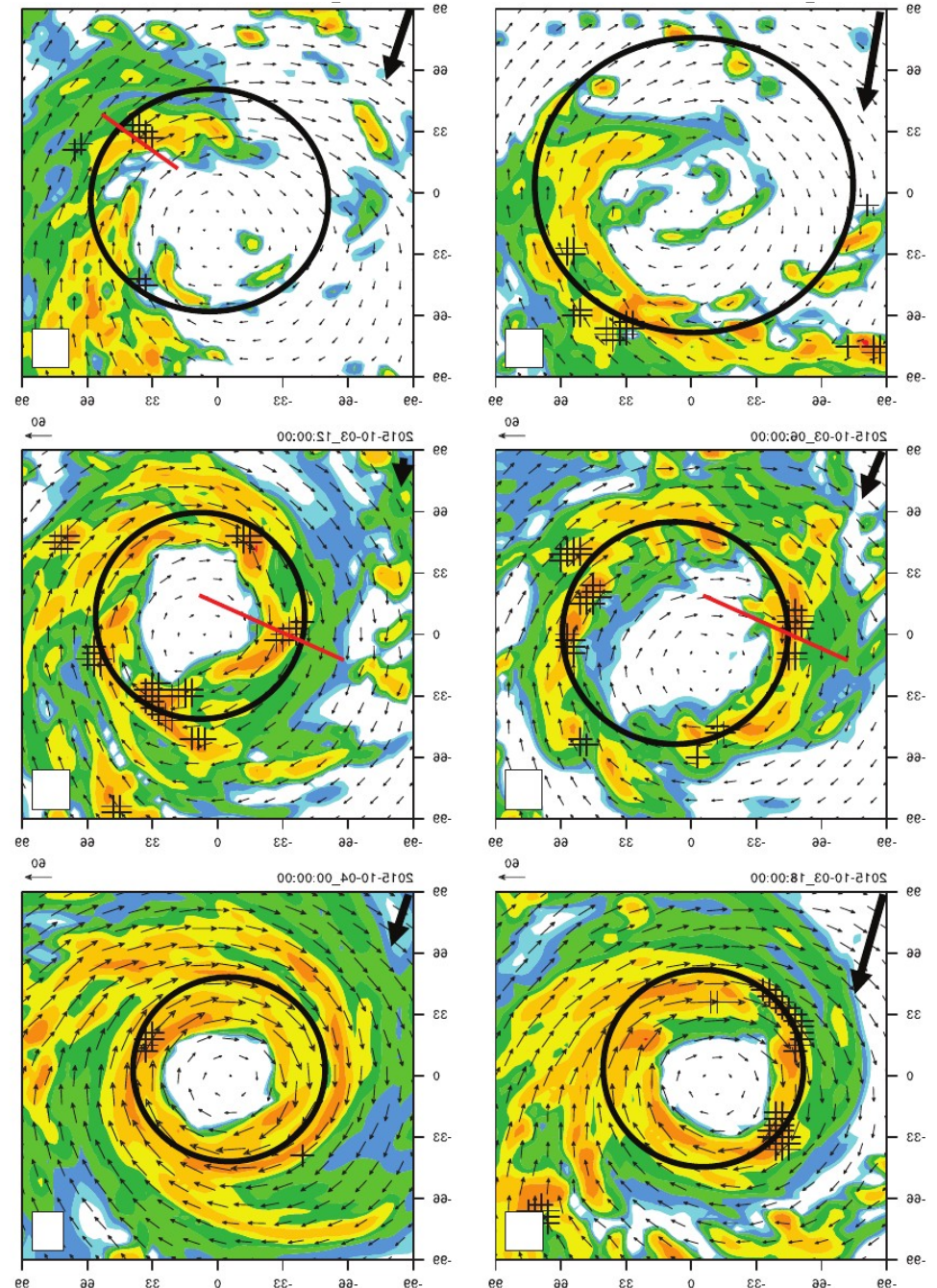


Eyewall building

Convection gets stronger and closer to the center as the TC intensify.

Convective bands progressively wraps around the area of convergence (radius of maximum winds) and forms the eye.

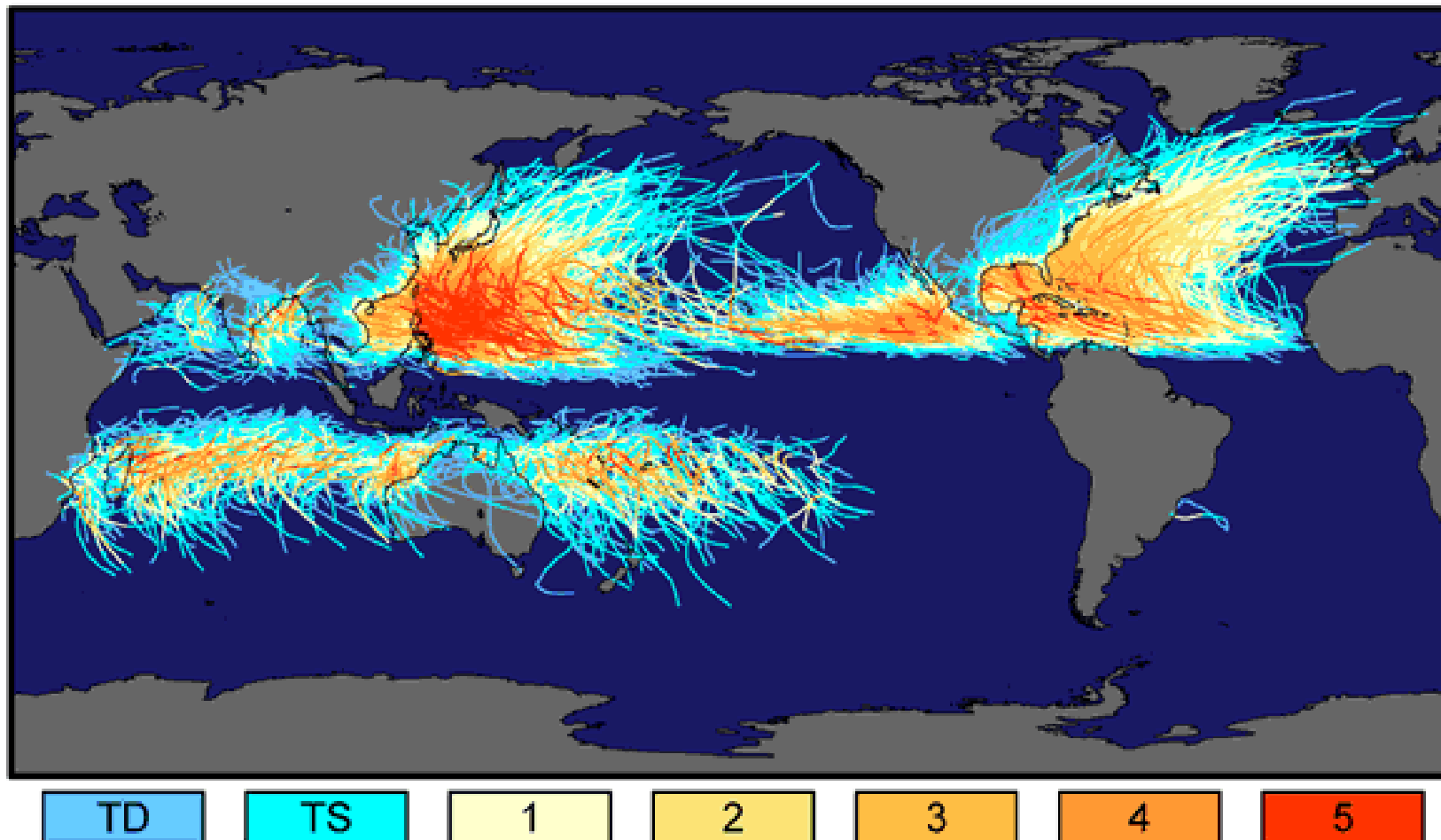
The eye appears on satellites images when it reaches the tropopause.



2. Tropical Cyclone climatology

Tropical cyclone climatology

Tracks and Intensity of Tropical Cyclones, 1851-2006



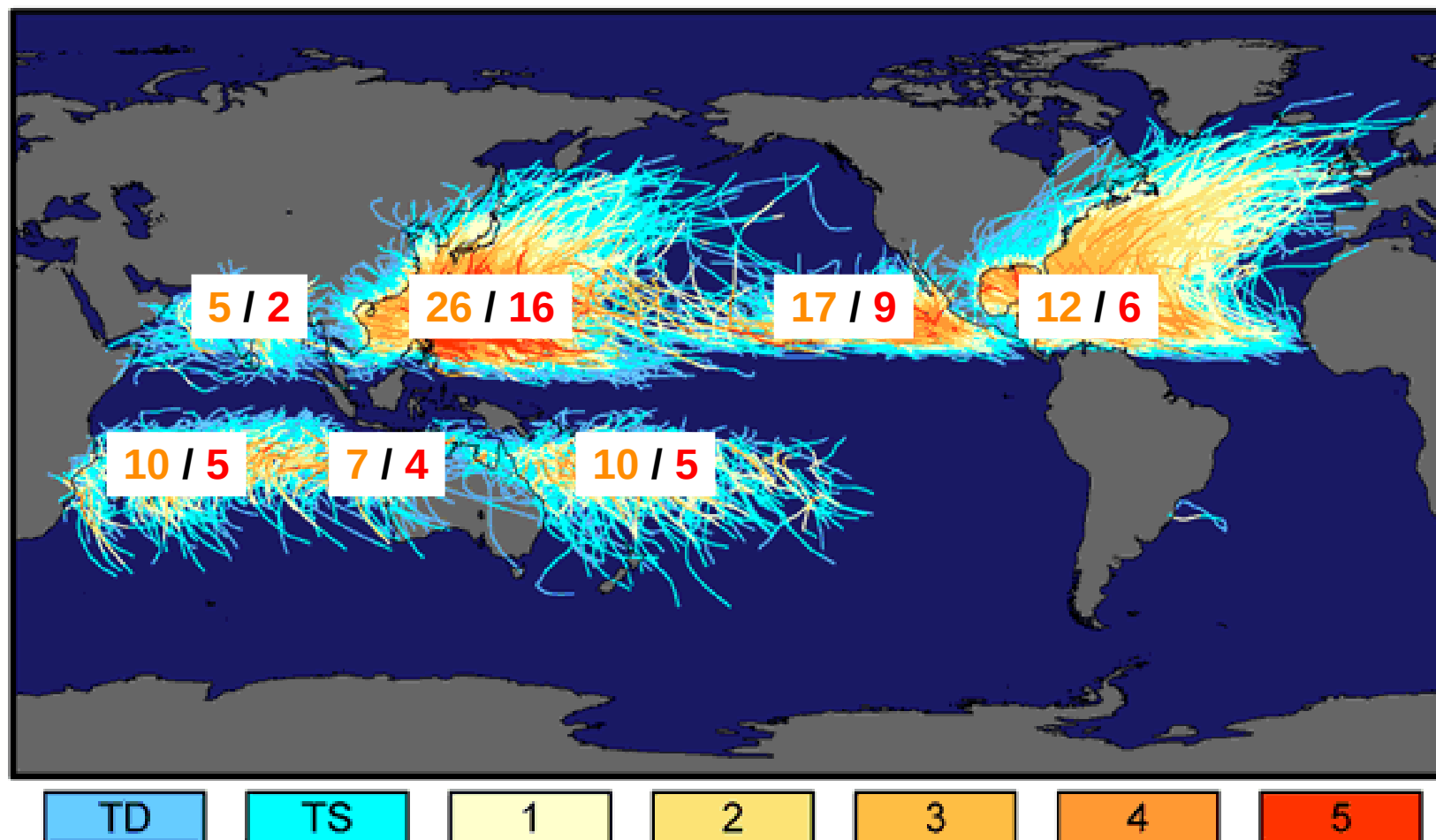
Saffir-Simpson Hurricane Intensity Scale

Robert A. Rohde, UC Berkeley / NASA's Earth Observatory

87 TS / 47 TC worldwide

Tropical cyclone climatology

Tracks and Intensity of Tropical Cyclones, 1851-2006

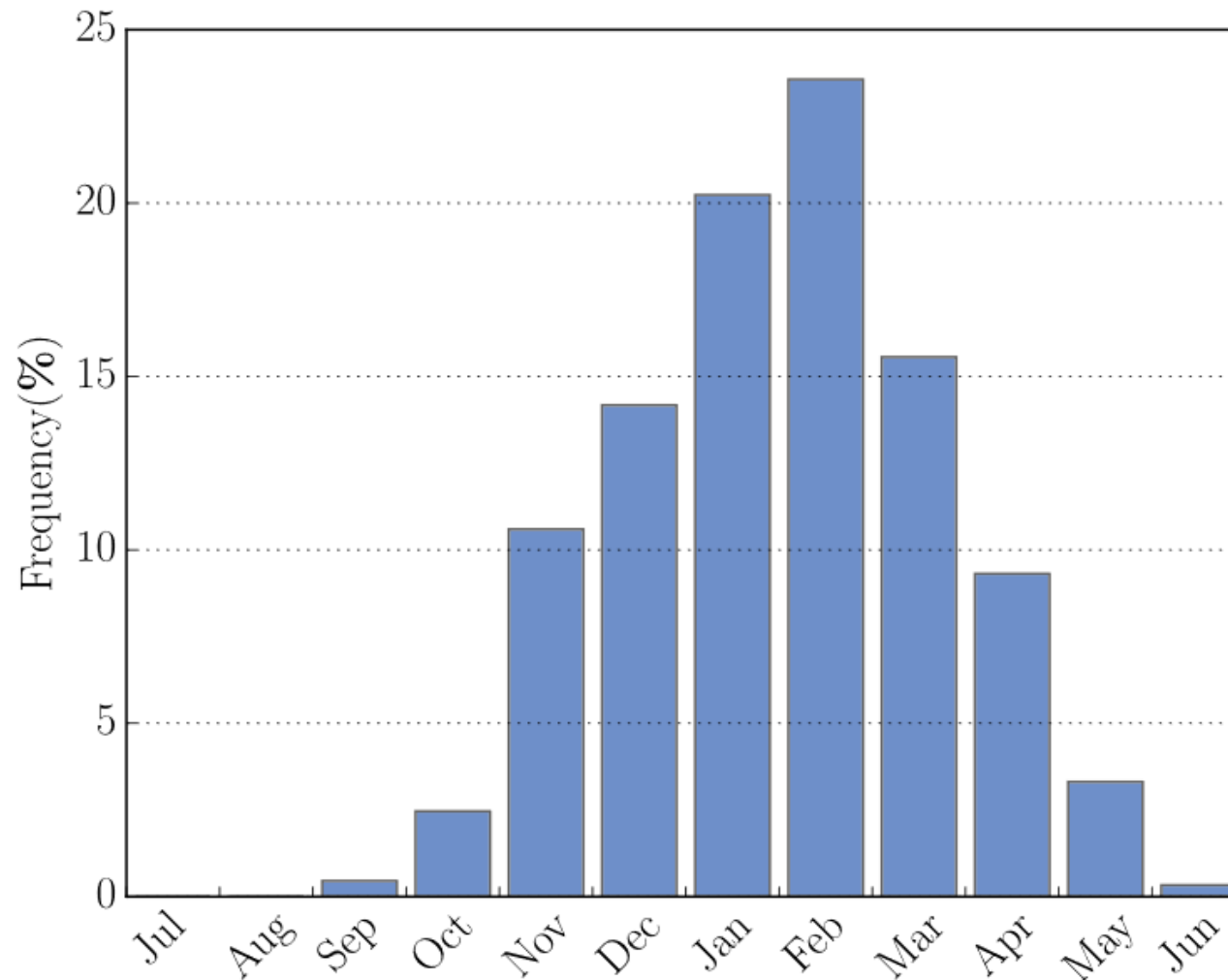


Saffir-Simpson Hurricane Intensity Scale

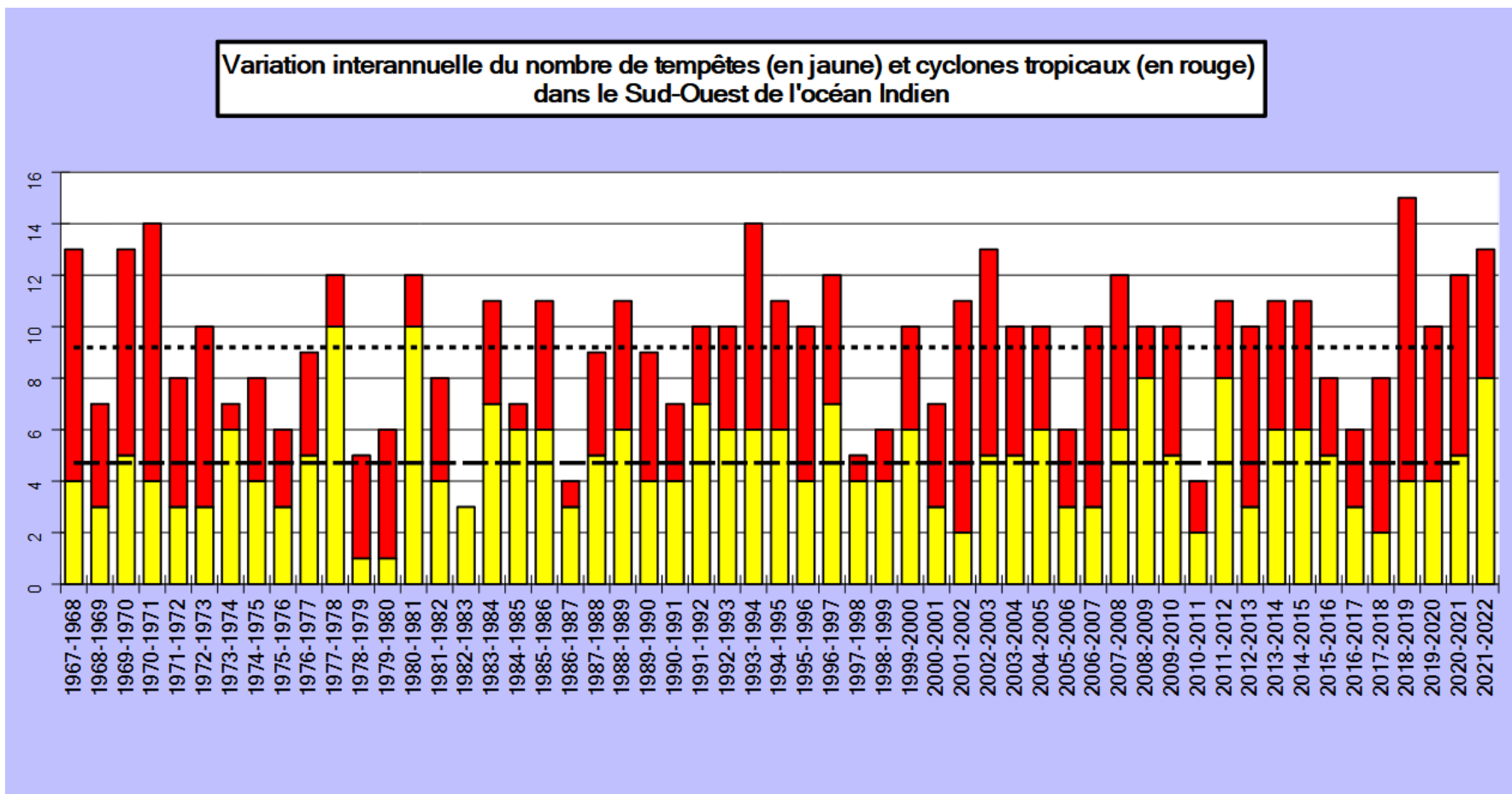
Robert A. Rohde, UC Berkeley / NASA's Earth Observatory

3. South-West Indian Ocean climatology

South-West Indian Ocean climatology

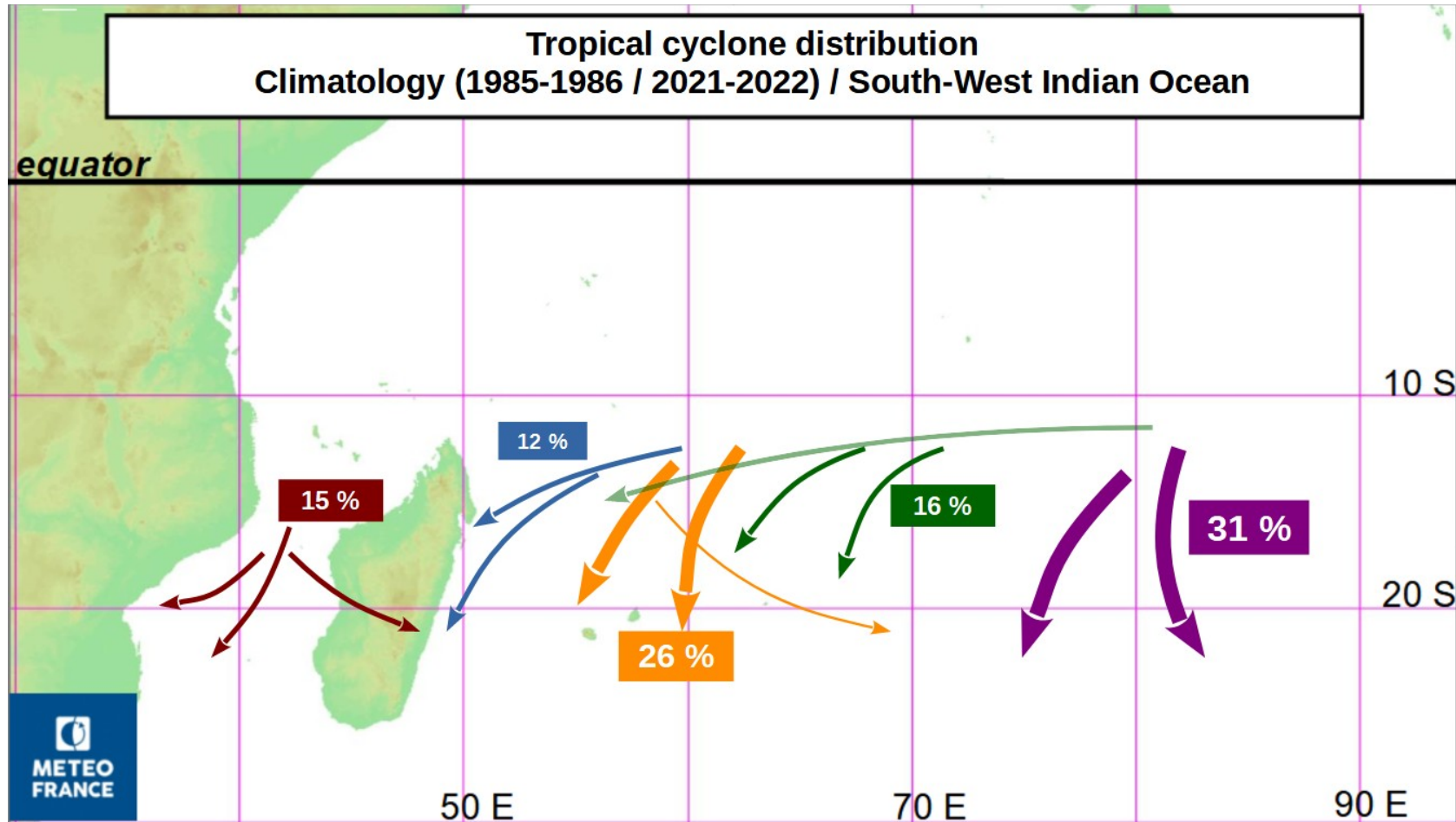


South-West Indian Ocean climatology



12 systems monitored every year,
10 Storms / **5** Cyclones / **3** ITC / **0,5** VITC

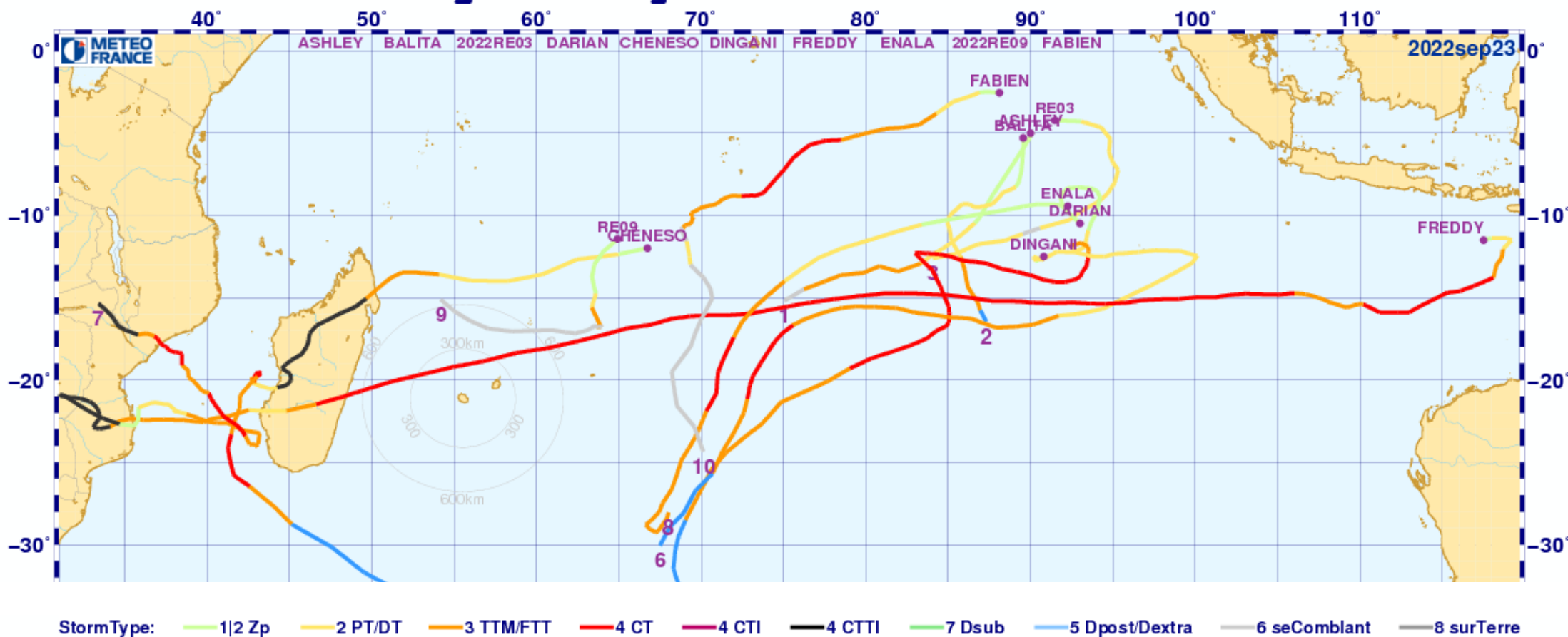
South-West Indian Ocean climatology



Usual tracks

South-West Indian Ocean climatology

activité cyclonique de la saison 2022-2023

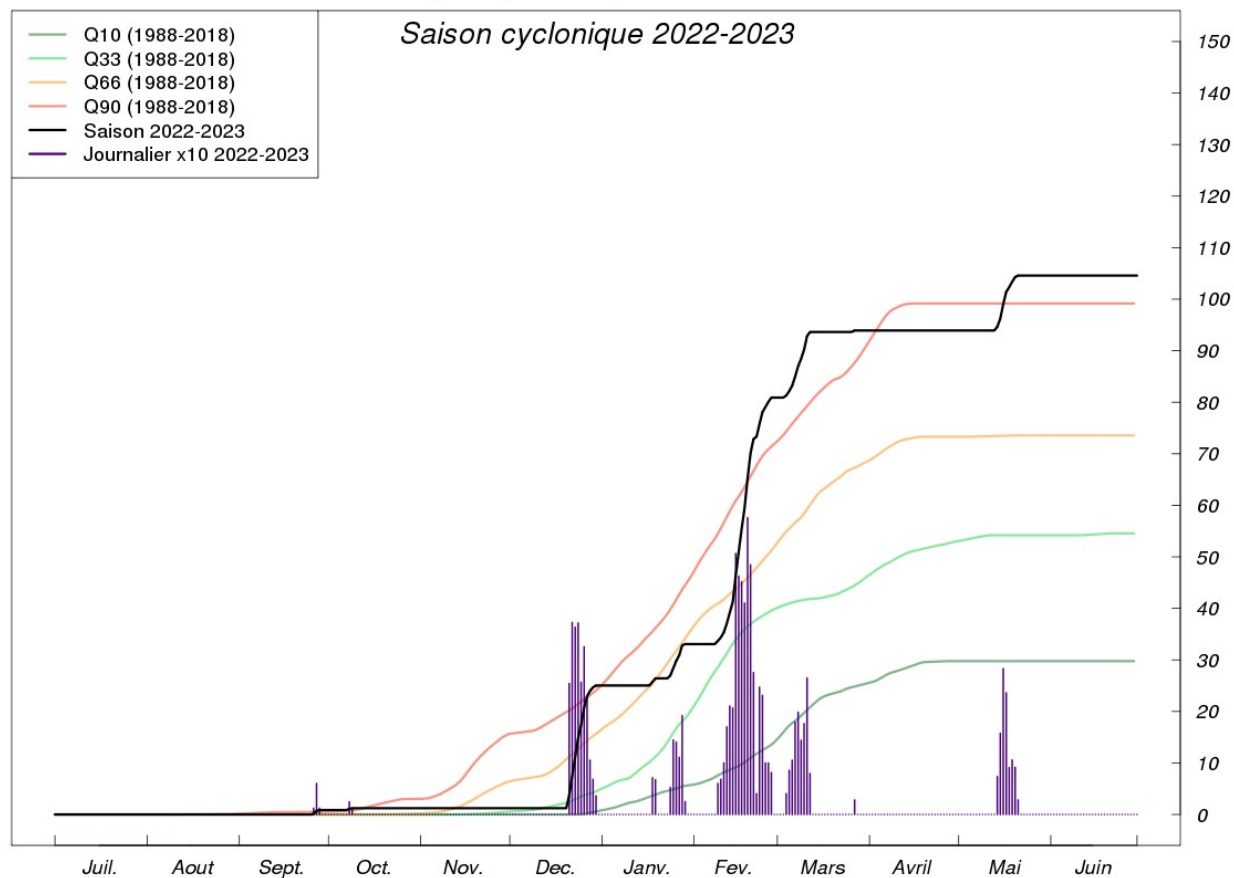


Season 2022-2023 – 9 MTS / 6 TC / 3 ITC / 2 VITC

South-West Indian Ocean climatology

Accumulated cyclone energy

Energie cyclonique accumulee



Season 2022-2023 – Activity above normal