

Genesis of a tropical system

Cyclogenesis & tropical waves

Adrien Colomb

*9th WMO tropical cyclone training in the SWIO
04/11/19 - St Denis de la Réunion*

Genesis of a tropical system

Cyclogenesis & tropical waves



I)Cyclogenesis processes

- 1)Environmental influences
- 2)Physical mechanisms

II)Large-scale influences

- 1)Basin configurations
- 2)Tropical Waves

III)Operational practices

Cyclogenesis Processes

Cyclogenesis

Definition : A tropical cyclogenesis is complete when the low becomes self-sustained and does not need help from the environment to develop, through environmental forcings. In operations, cyclogenesis is deemed complete when the system reaches the « moderate tropical storm » stage (max winds > 35kt).

Necessary conditions :

- ✓ Sufficient oceanic energy [SST > 26°C on at least 60-m depth]
- ✓ Layerwise instability
- ✓ Mid-level moisture (On a 700/500 hPa layer)
- ✓ Latitude > 5°
- ✓ Low-level vorticity (precursor)
- ✓ Low wind-shear (**lower than 15kt**)

Thermal potential

Dynamical potential

Cyclogenesis

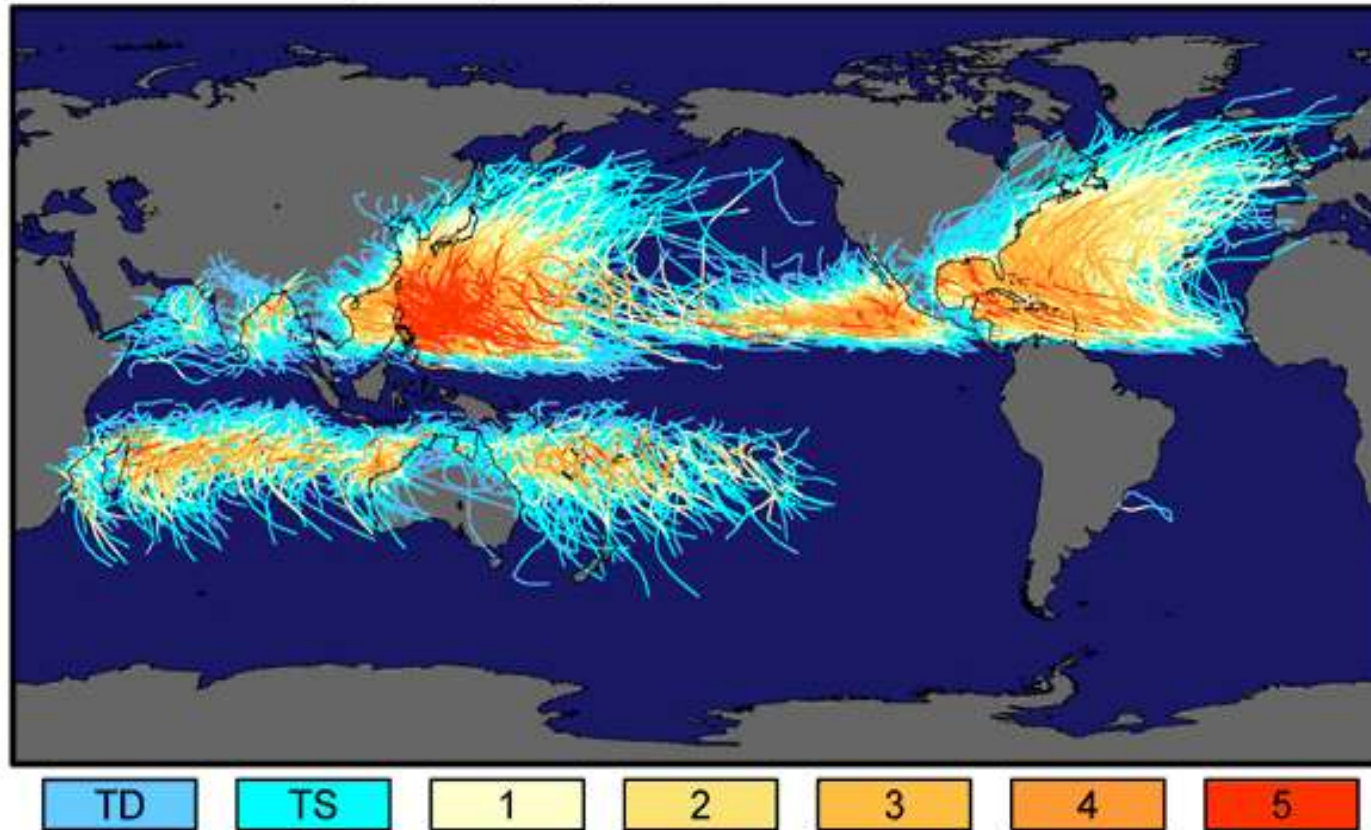
Tropical cyclone classifications									[hide]
Beaufort scale	1-minute sustained winds (NHC/CPHC/JTWC)	10-minute sustained winds (WMO/JMA/MF/BOM/FMS)	NE Pacific & N Atlantic NHC/CPHC ^[26]	NW Pacific JTWC	NW Pacific JMA	N Indian Ocean IMD ^[13]	SW Indian Ocean MF	Australia & S Pacific BOM/FMS ^[19]	
0–7	<32 knots (37 mph; 59 km/h)	<28 knots (32 mph; 52 km/h)	Tropical Depression	Tropical Depression	Tropical Depression	Depression	Zone of Disturbed Weather	Tropical Disturbance Tropical Depression Tropical Low	
7	33 knots (38 mph; 61 km/h)	28–29 knots (32–33 mph; 52–54 km/h)				Deep Depression	Tropical Disturbance		
8–9	34–37 knots (39–43 mph; 63–69 km/h)	30–33 knots (35–38 mph; 56–61 km/h)	Tropical Storm	Tropical Storm	Tropical Storm	Cyclonic Storm	Moderate Tropical Storm	Category 1 Tropical Cyclone	
9–10	38–54 knots (44–62 mph; 70–100 km/h)	34–47 knots (39–54 mph; 63–87 km/h)				Severe Tropical Storm	Severe Cyclonic Storm		Severe Tropical Storm
12+	64–71 knots (74–82 mph; 119–131 km/h)	56–63 knots (64–72 mph; 104–117 km/h)	Category 1 Hurricane	Typhoon	Typhoon	Very Severe Cyclonic Storm	Tropical Cyclone	Category 3 Severe Tropical Cyclone	
	72–82 knots (83–94 mph; 133–152 km/h)	64–72 knots (74–83 mph; 119–133 km/h)	Category 2 Hurricane						
	83–95 knots (96–109 mph; 154–176 km/h)	73–83 knots (84–96 mph; 135–154 km/h)	Category 3 Major Hurricane						
	96–97 knots (110–112 mph; 178–180 km/h)	84–85 knots (97–98 mph; 156–157 km/h)	Category 4 Major Hurricane						
	98–112 knots (113–129 mph; 181–207 km/h)	86–98 knots (99–113 mph; 159–181 km/h)	Category 5 Major Hurricane						
	113–122 knots (130–140 mph; 209–226 km/h)	99–107 knots (114–123 mph; 183–198 km/h)	Super Typhoon	Super Cyclonic Storm	Very Intense Tropical Cyclone	Category 5 Severe Tropical Cyclone			
	123–129 knots (142–148 mph; 228–239 km/h)	108–113 knots (124–130 mph; 200–209 km/h)							
	130–136 knots (150–157 mph; 241–252 km/h)	114–119 knots (131–137 mph; 211–220 km/h)							
	>137 knots (158 mph; 254 km/h)	>120 knots (140 mph; 220 km/h)							

In each cyclonic basin, a different classification...

... and even different wind averages (10mn ≠ 1mn) !

Cyclogenesis

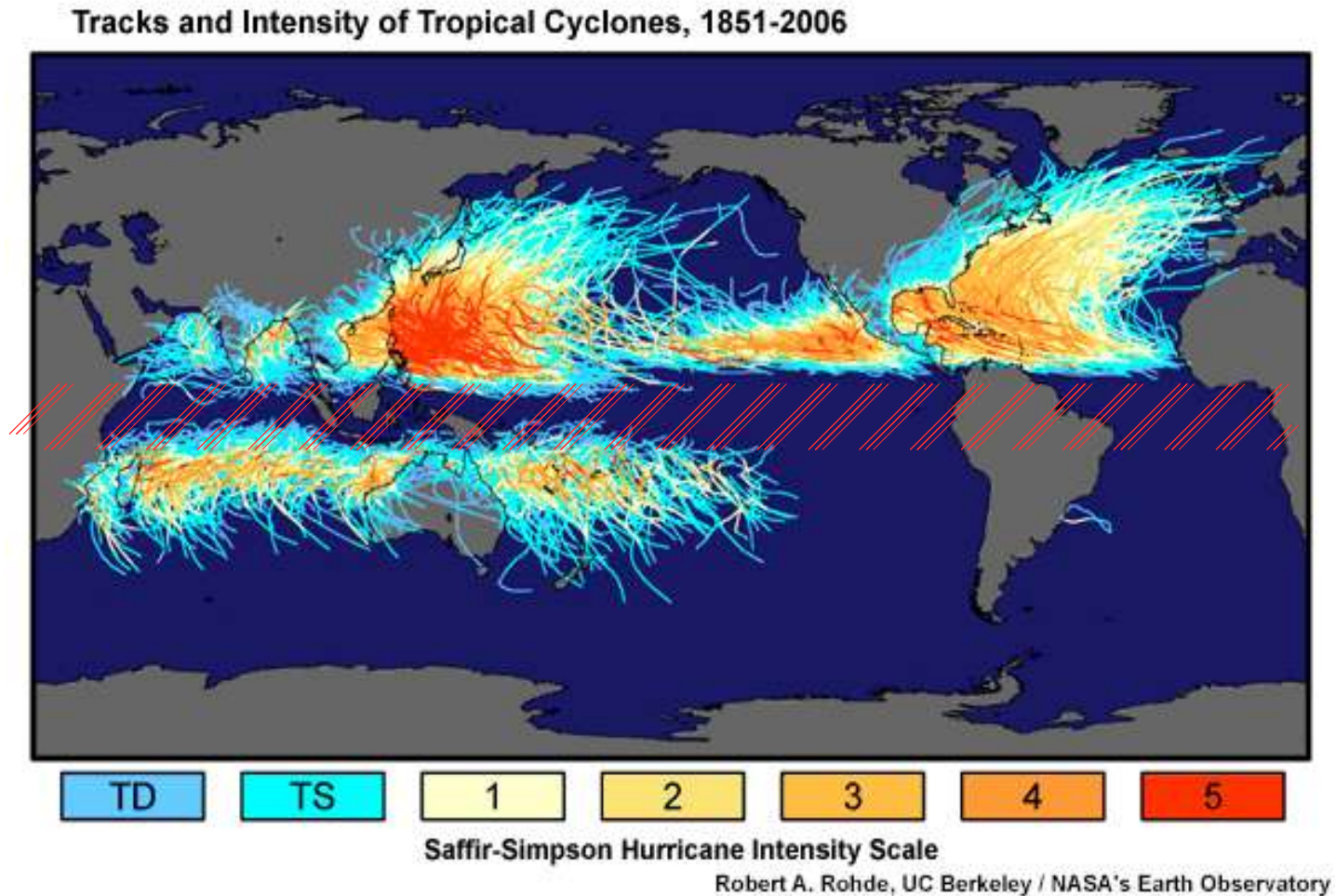
Tracks and Intensity of Tropical Cyclones, 1851-2006



Saffir-Simpson Hurricane Intensity Scale

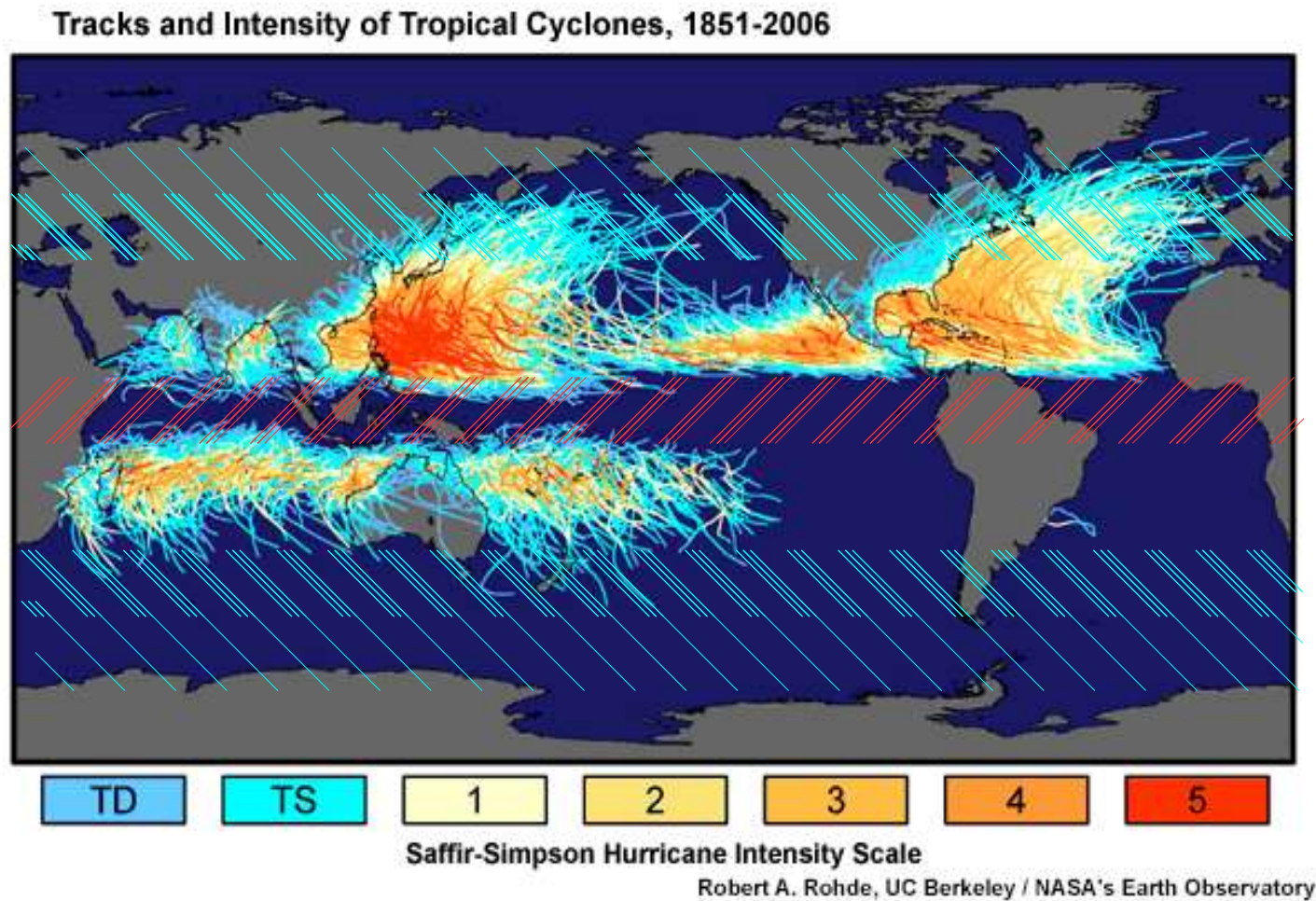
Robert A. Rohde, UC Berkeley / NASA's Earth Observatory

Cyclogenesis, latitude



Near the equator → Coriolis is too weak

Cyclogenesis, SST



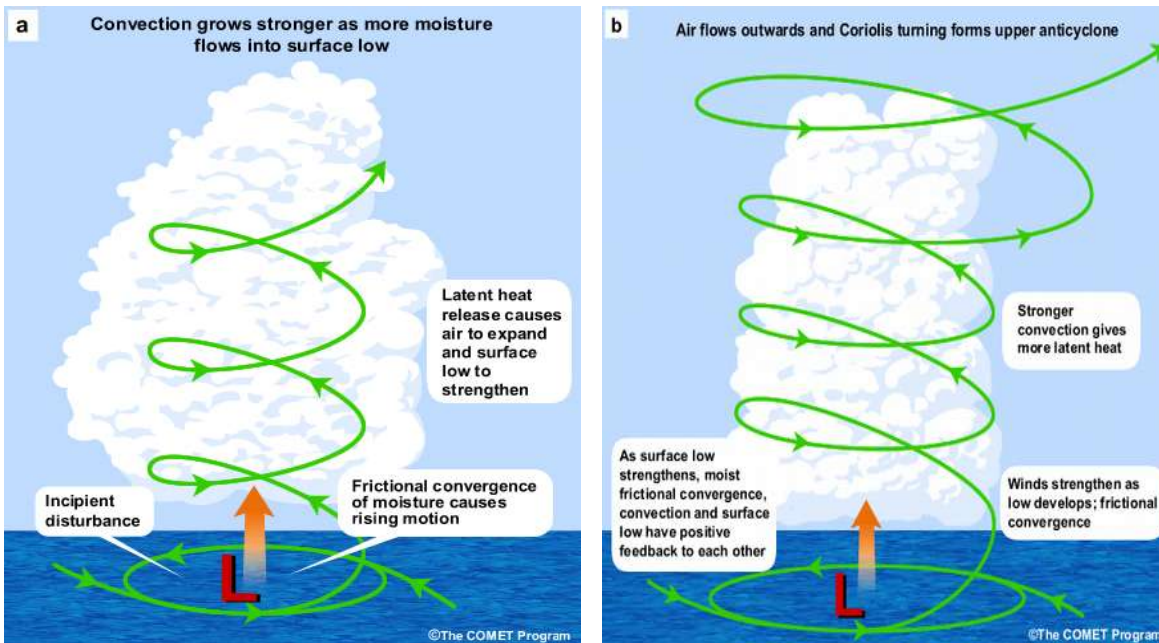
Within the mid-latitudes → SSTs are too low

Intensification mechanisms of warm-core vortices

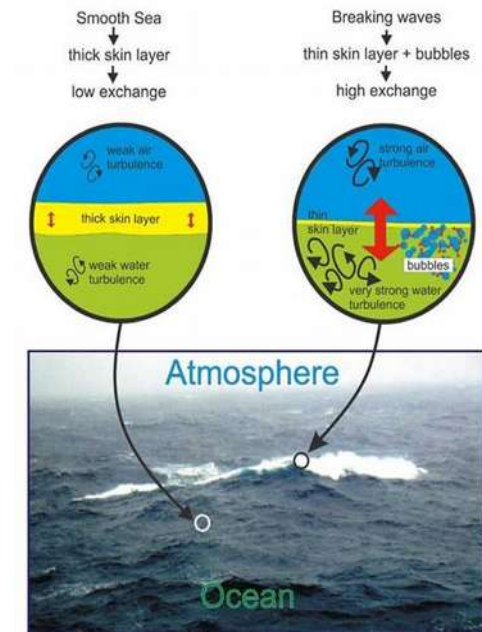
Favorite

CISK vs WISHE

(Conditional Instability of the Second Kind)



(Wind-Induced Surface Heat Exchange)



Surface convergence induced by convection & a low-level precursor

Updrafts

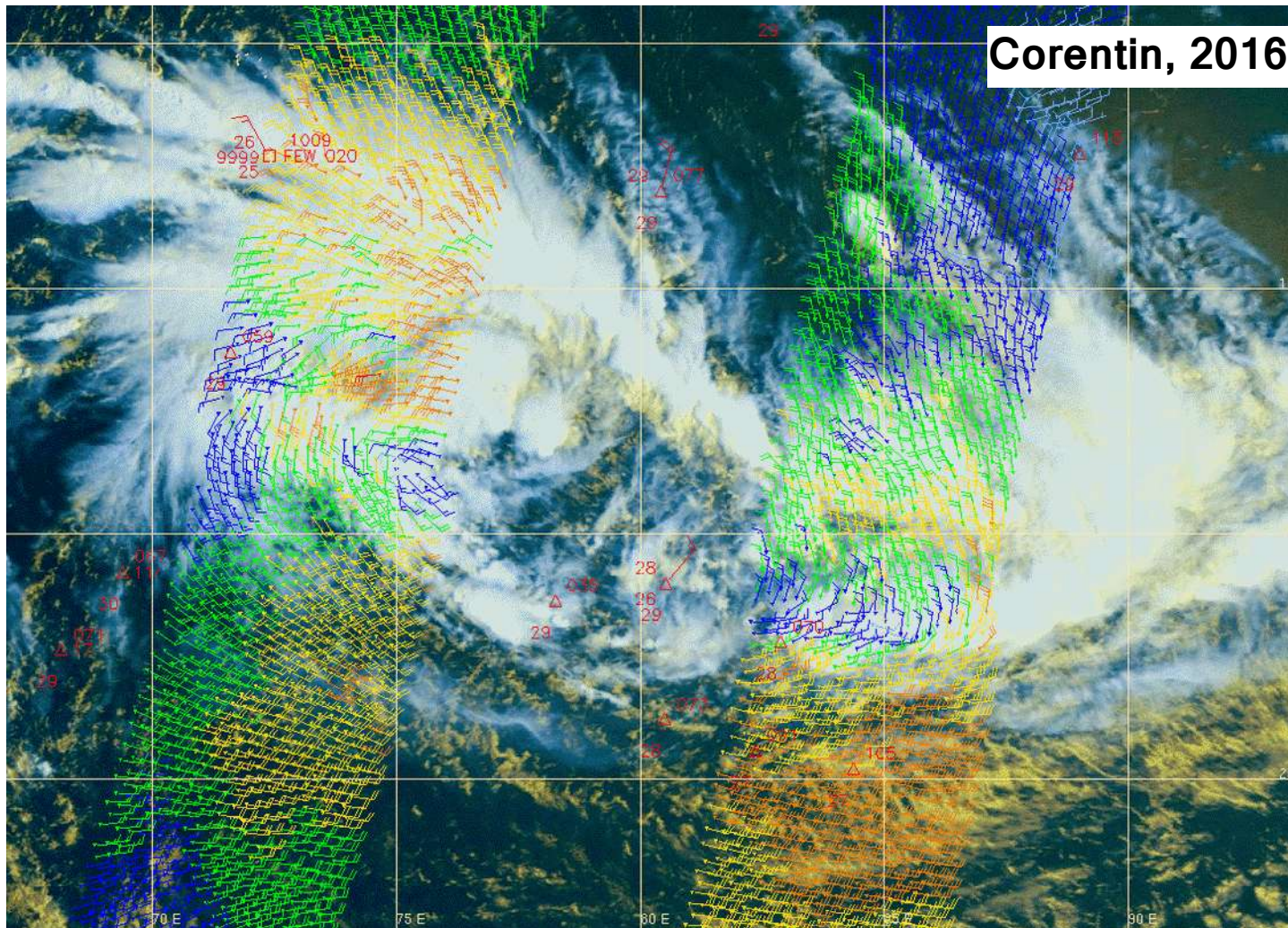
Latent heat release at mid-levels

Updrafts

Heat transfer Ocean->Atmosphere

System intensity (Wind strength and radii)

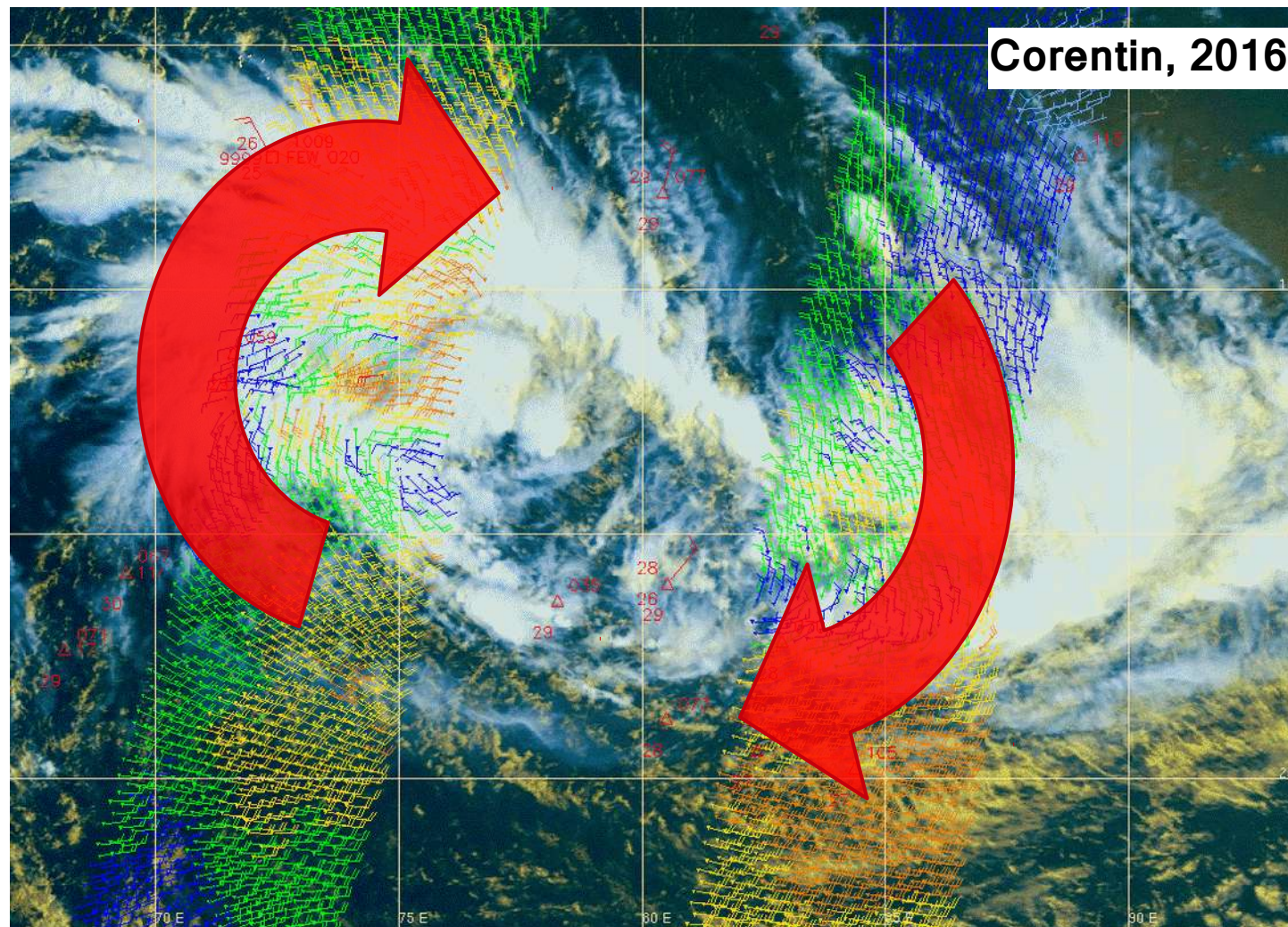
Low-level convergence : the spark to initiate cyclogenesis



A TC needs environmental convergence to develop during the early stages of its formation.

Mature TCs generate their own surface convergence and this parameter does not significantly influence their intensity anymore.

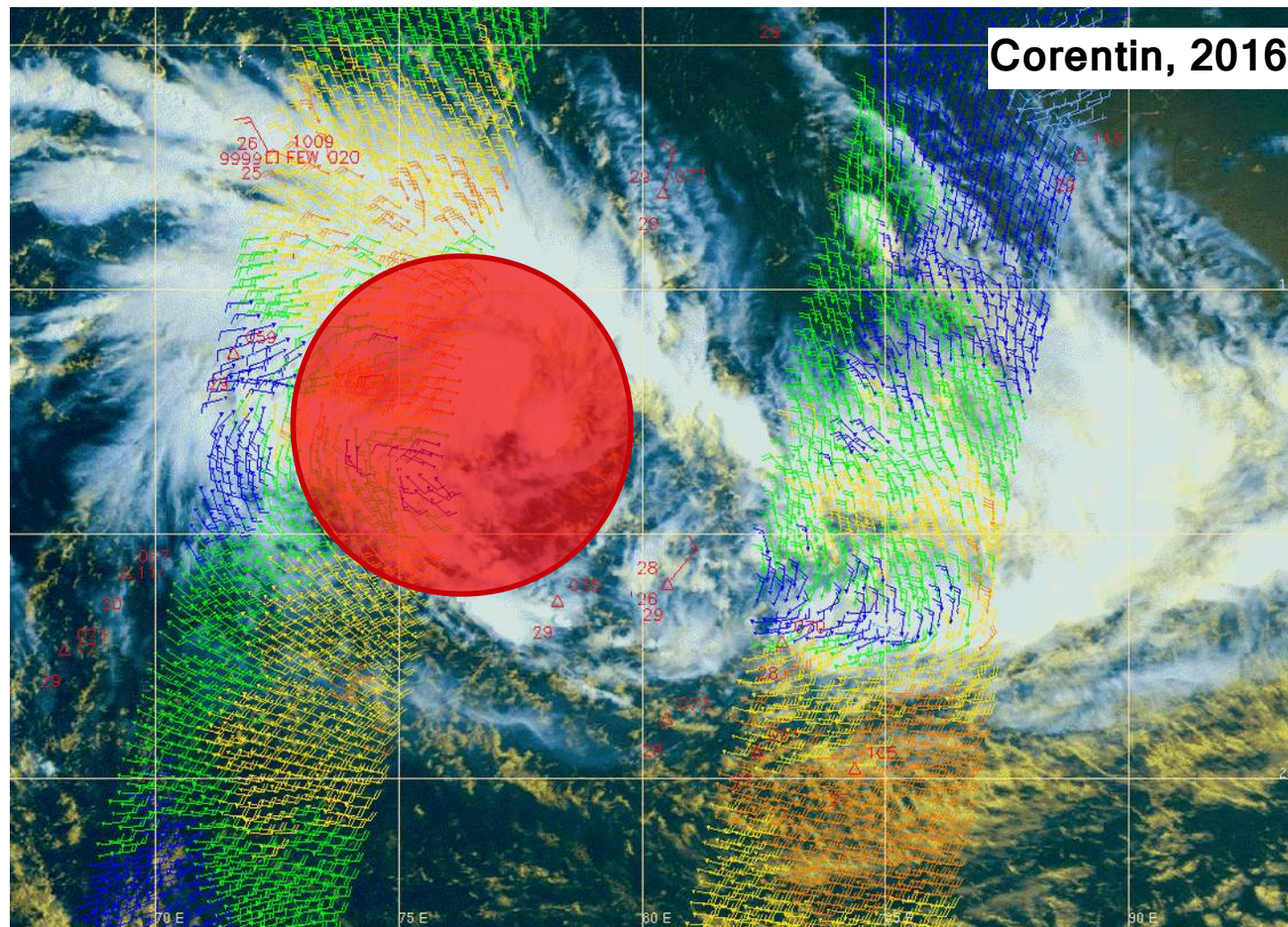
Low-level convergence : the spark to initiate cyclogenesis



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Mature TCs generate their own surface convergence and this parameter does not significantly influence the intensity anymore.

Low-level convergence : the spark to initiate cyclogenesis



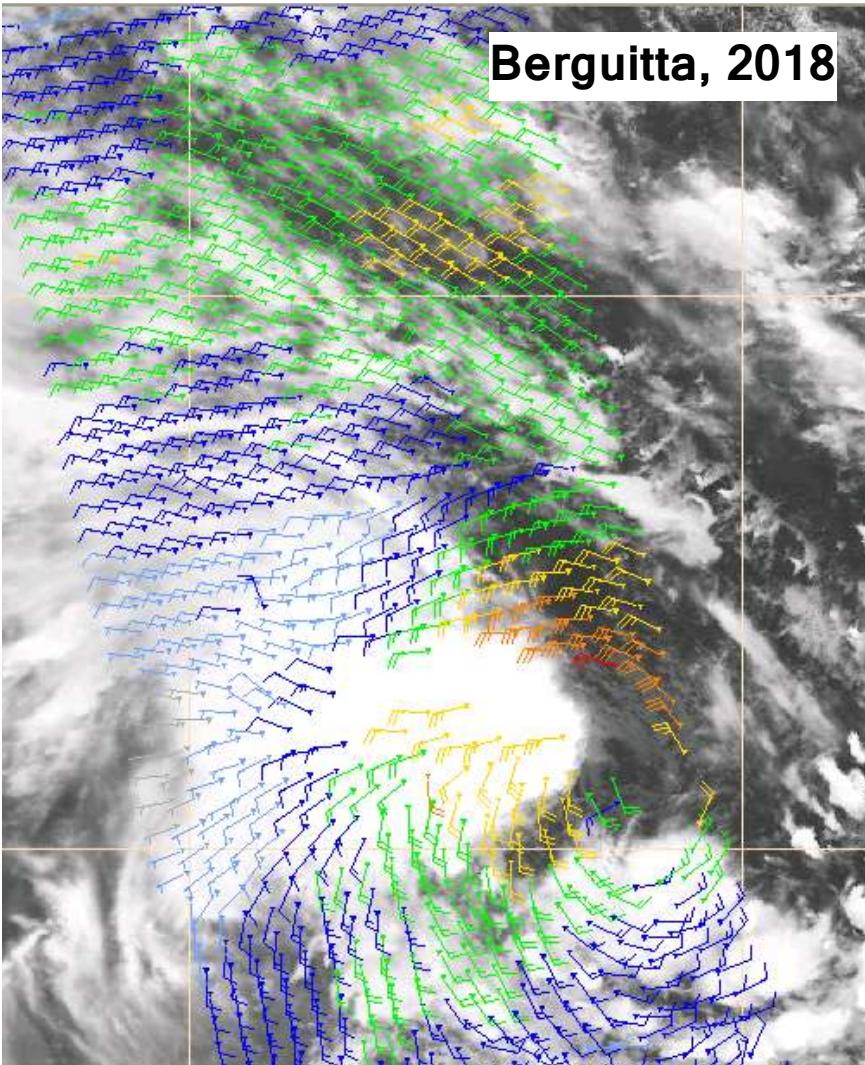
Surges of environmental winds allow to maintain deep convection in locations where previous convective bursts created high local vorticities.

Low-level convergence : the spark to initiate cyclogenesis

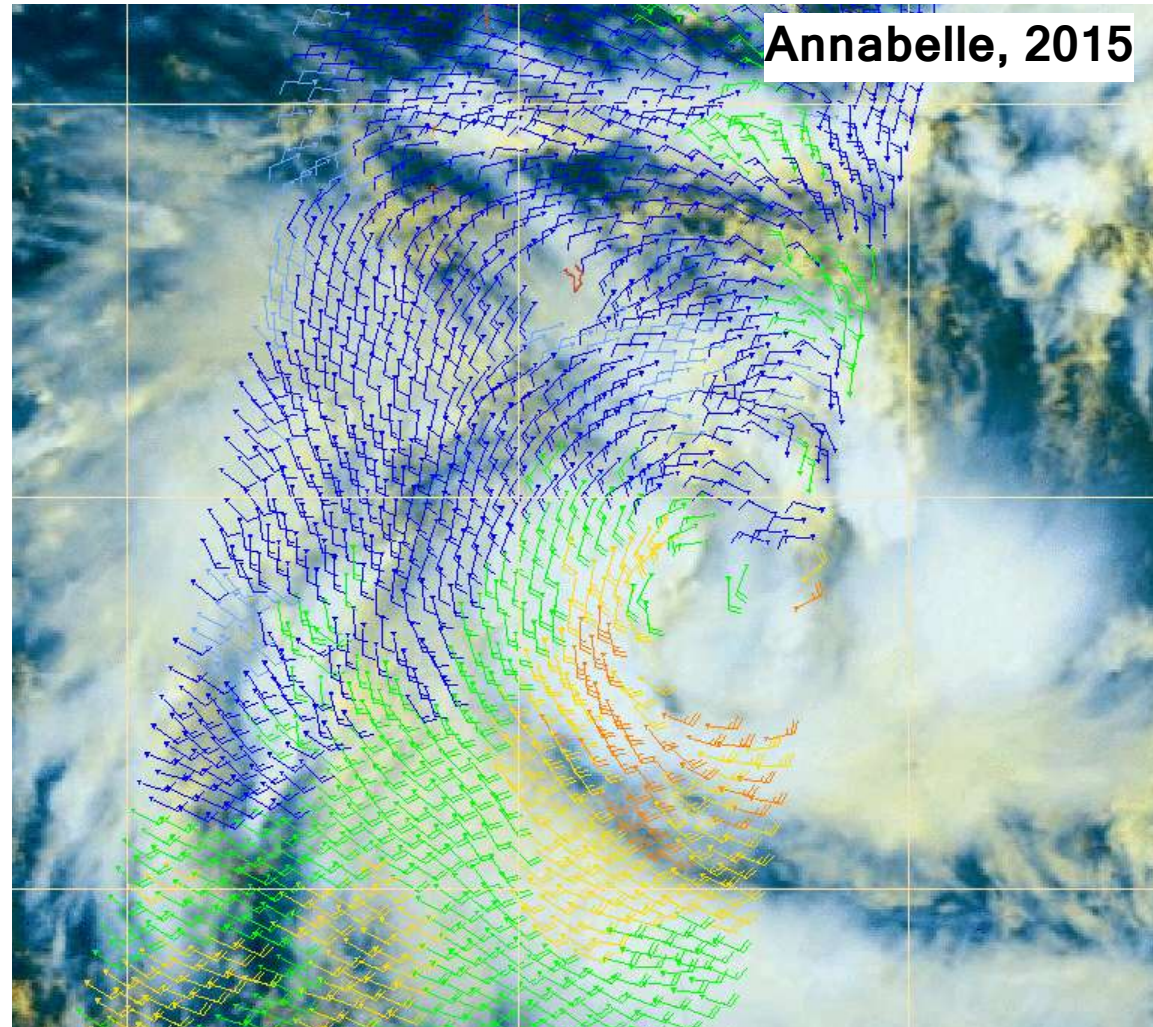
Surges of environmental winds can occur **on either side** of the circulation :

Equatorward (westerly surges = monsoon) or **Poleward** (strengthening trade winds)

Berguitta, 2018



Annabelle, 2015

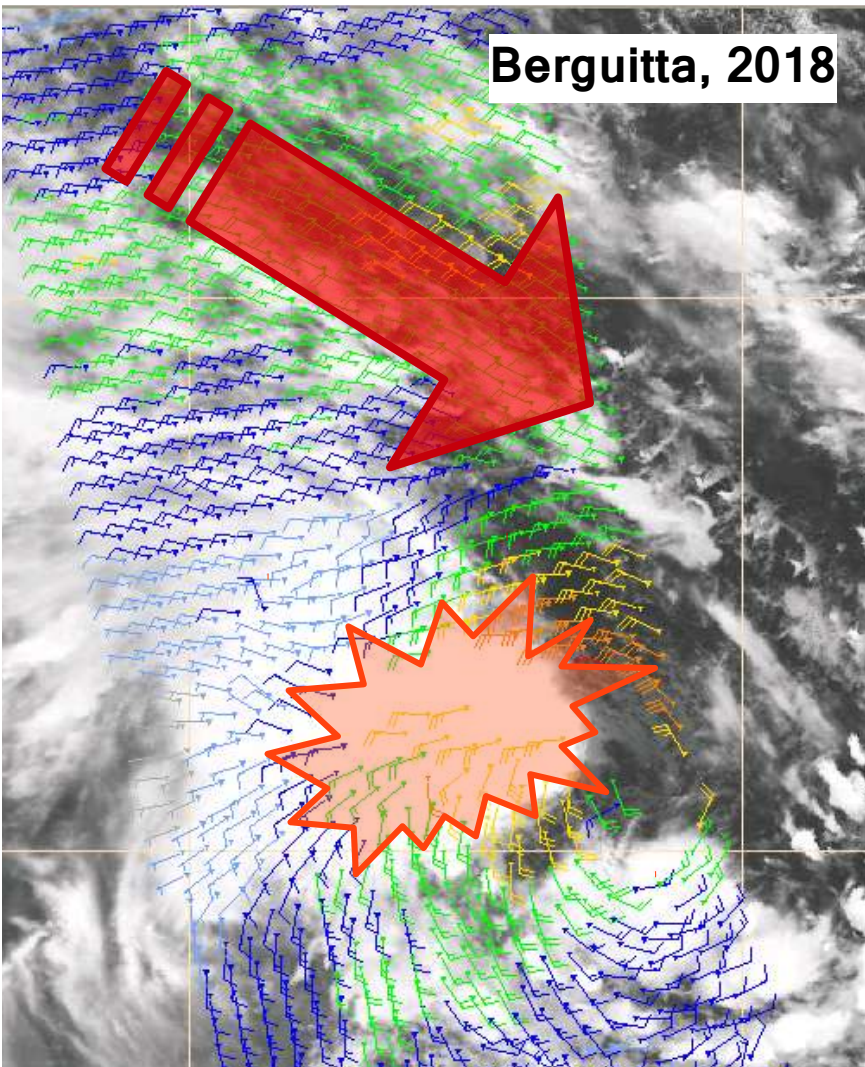


Low-level convergence : the spark to initiate cyclogenesis

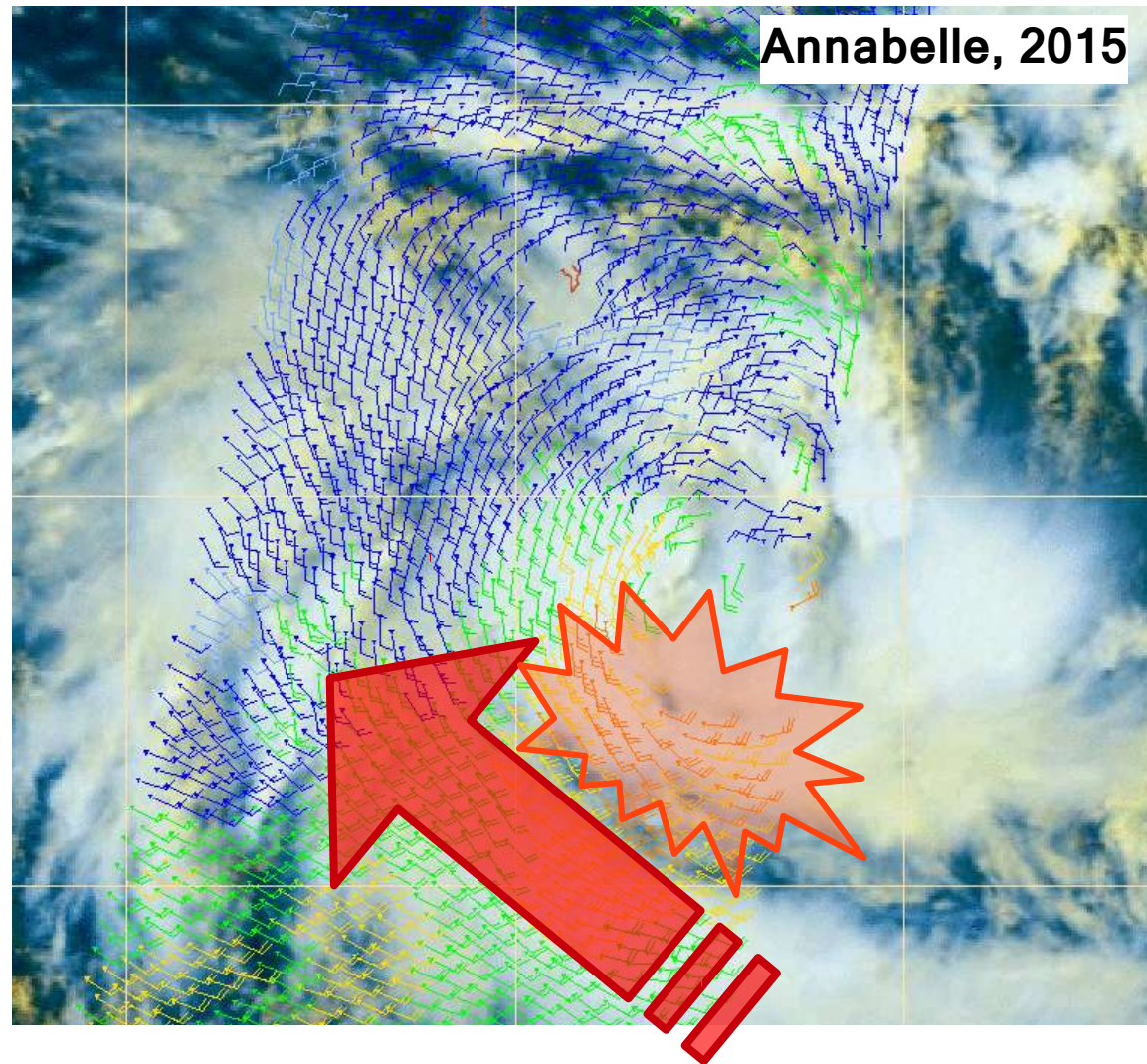
Surges of environmental winds can occur **on either side** of the circulation :

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Berguitta, 2018



Annabelle, 2015



II) Large-scale influences

La Cyclogenèse, configurations de bassin

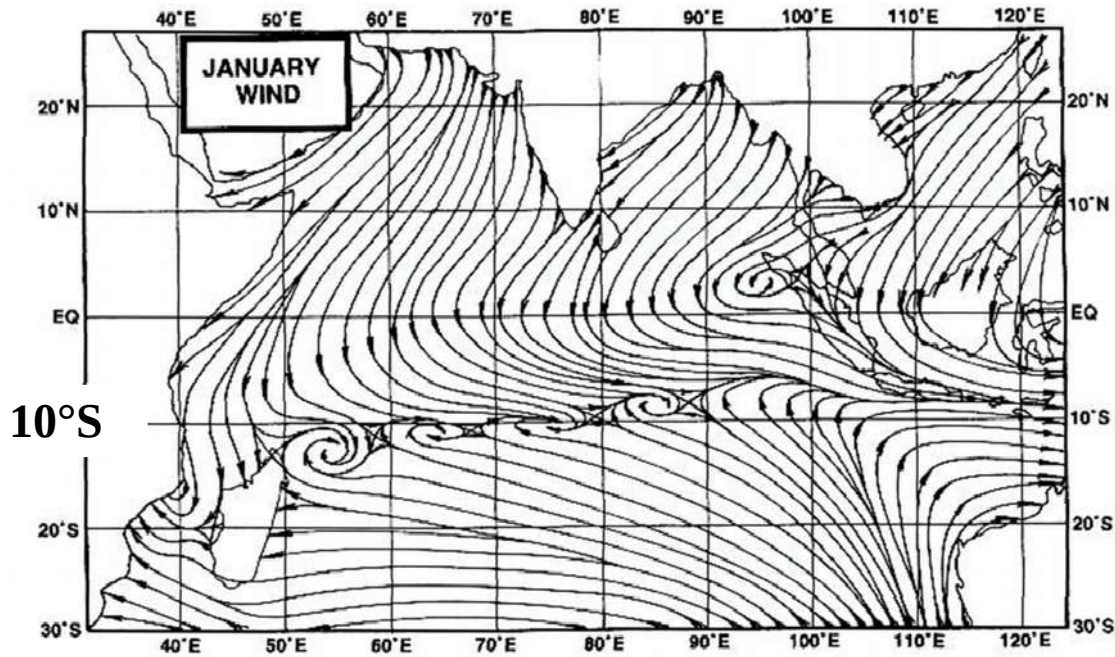
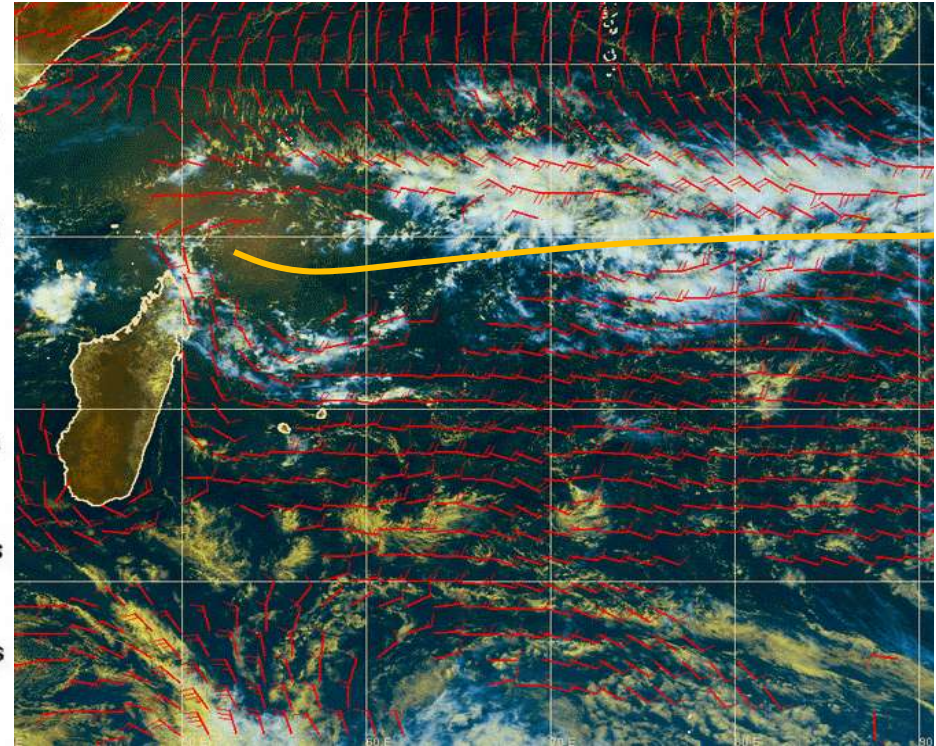
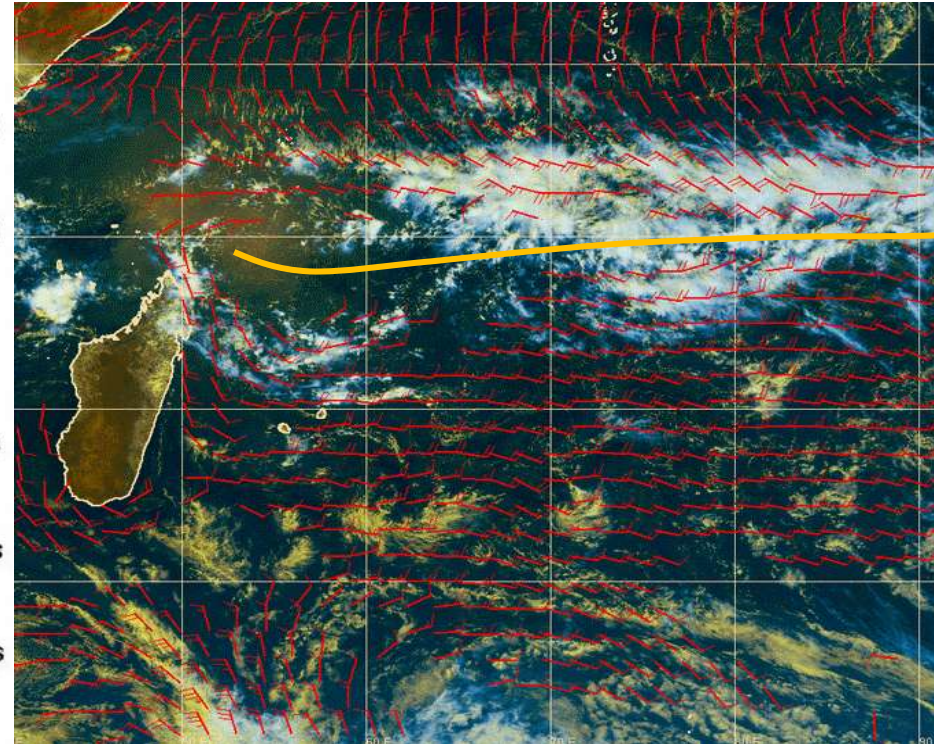
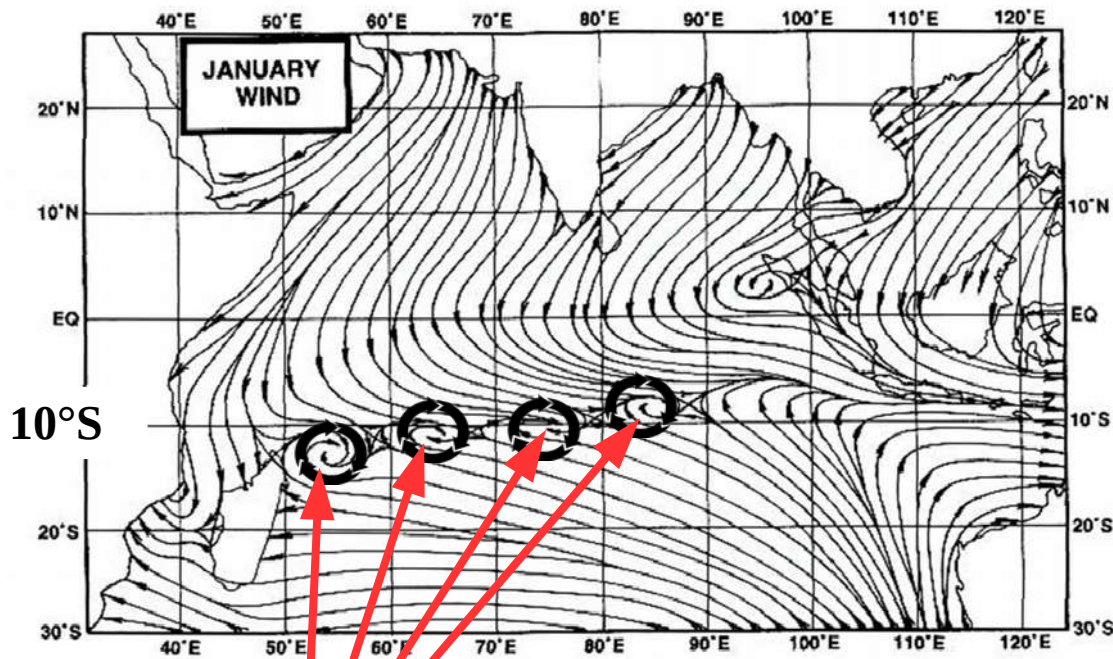


Figure 2.6. Mean surface level streamline analyses over the Indian Ocean for January (Sadler, 1975).



La Cyclogenèse, configurations de bassin

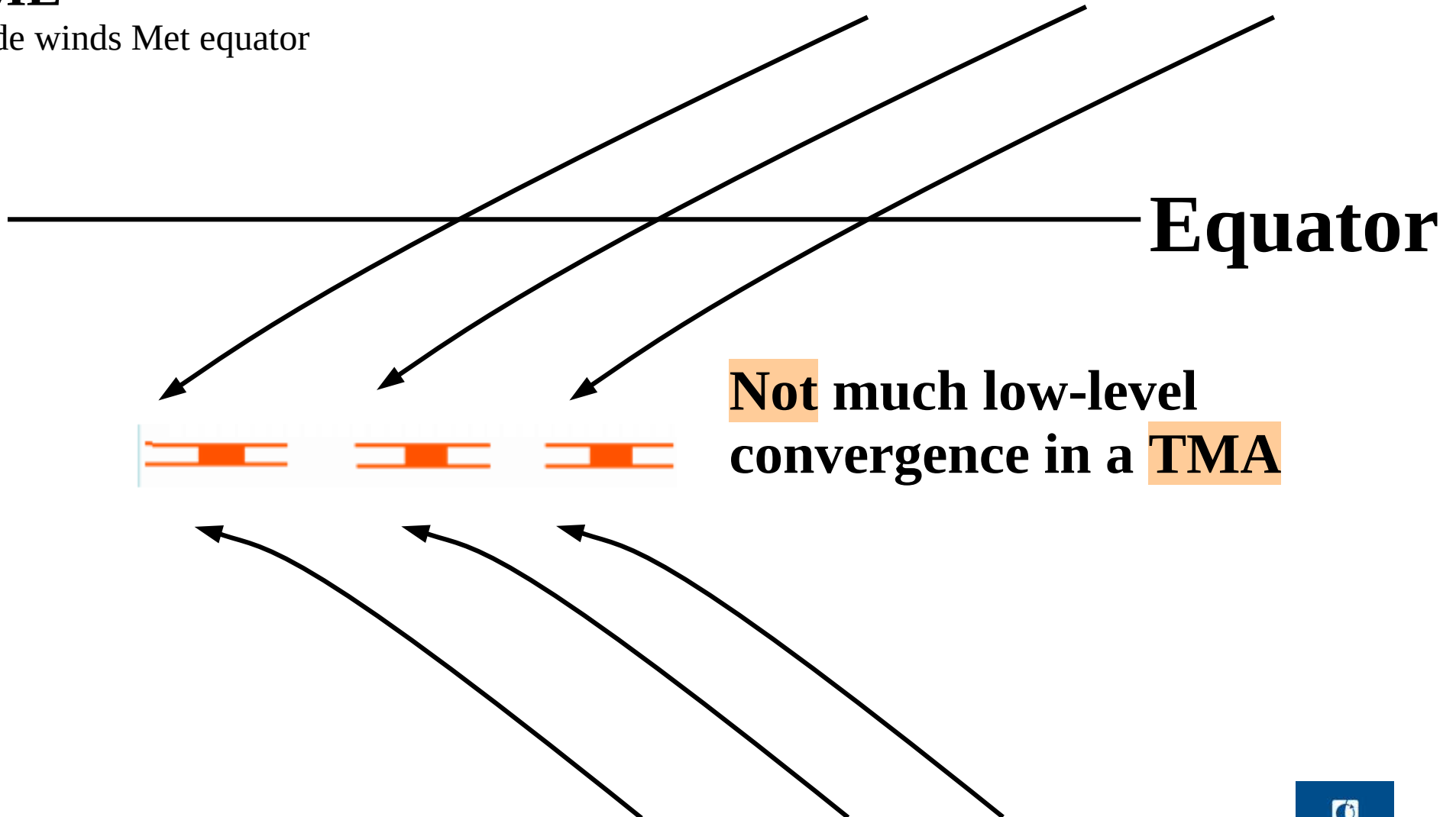


Lots of potential precursors nested within a Monsoon trough

Modèles conceptuels

TME

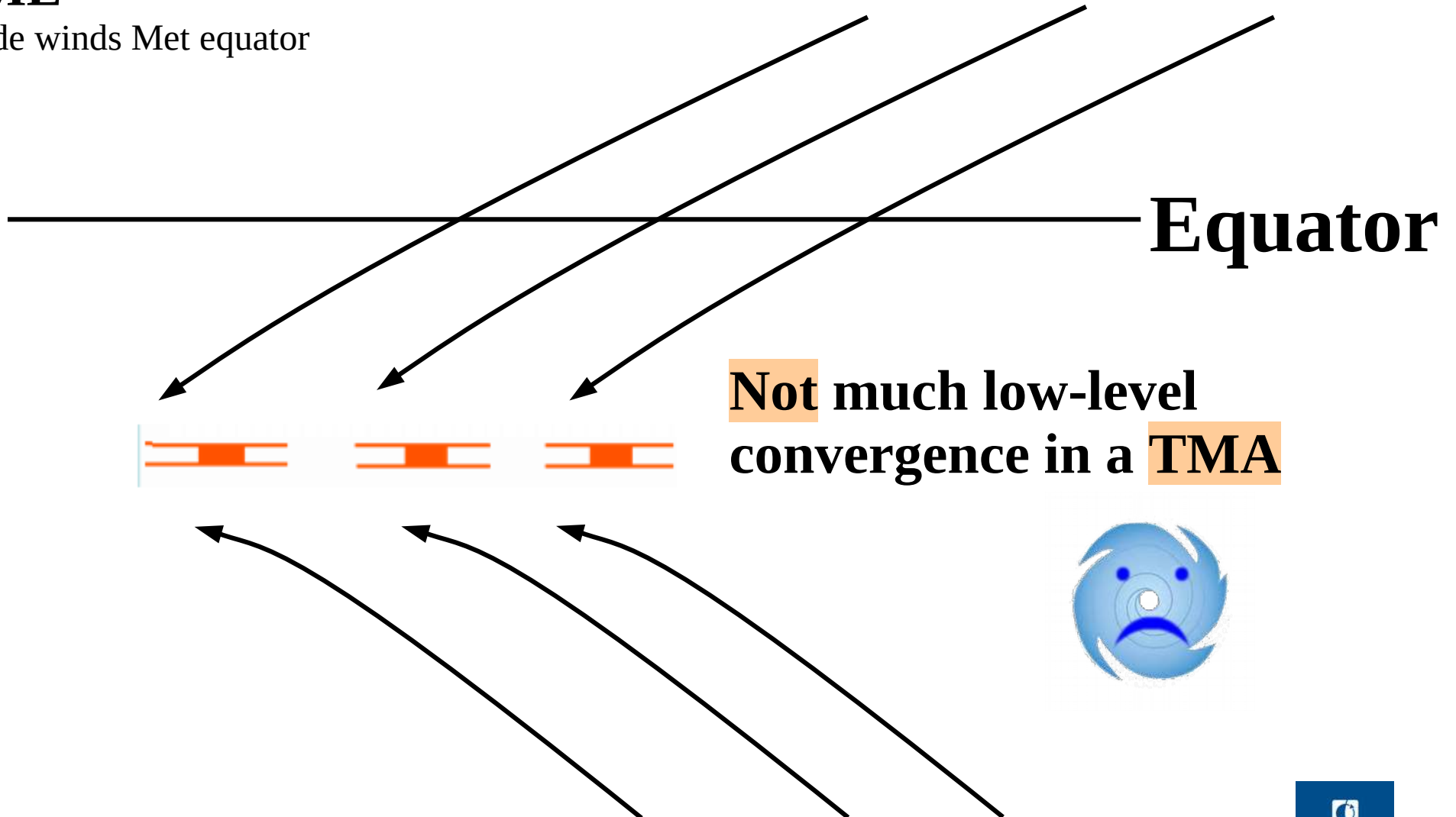
Trade winds Met equator



Modèles conceptuels

TME

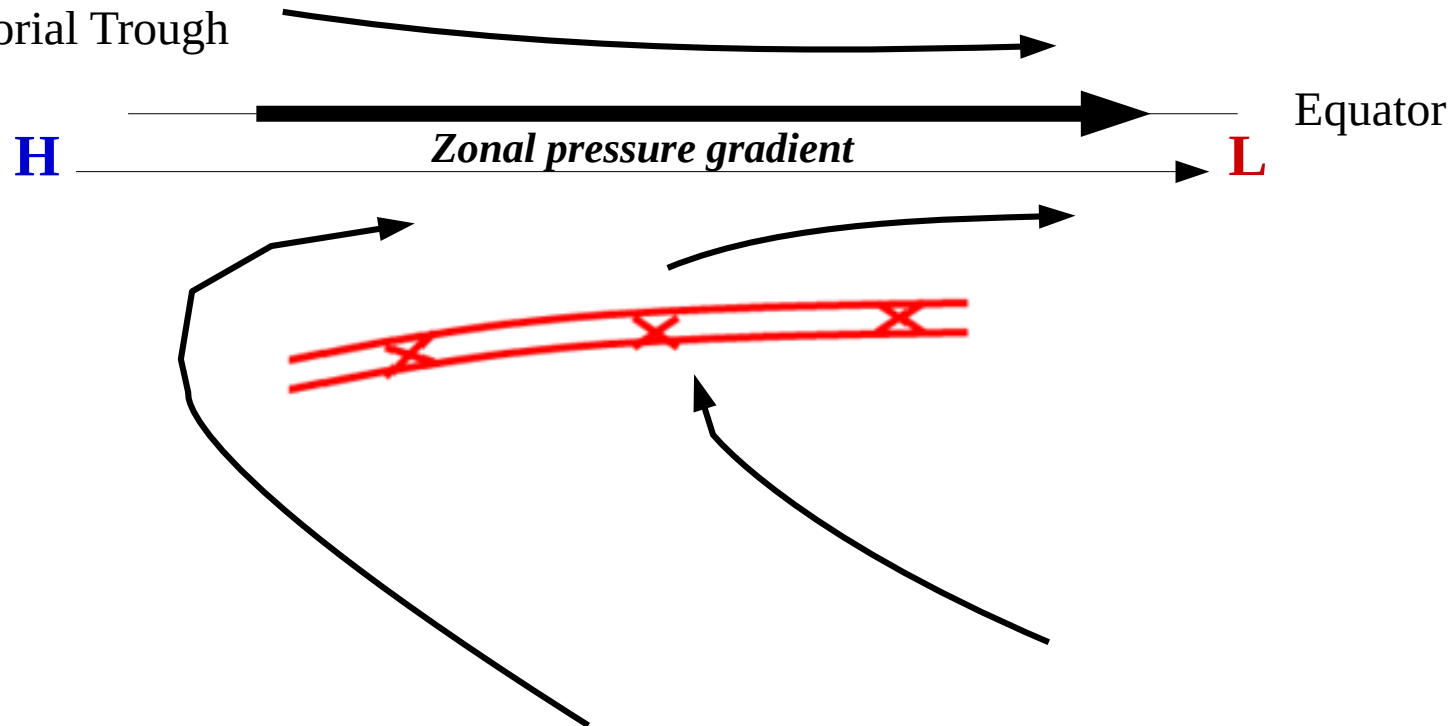
Trade winds Met equator



Modèles conceptuels

NET

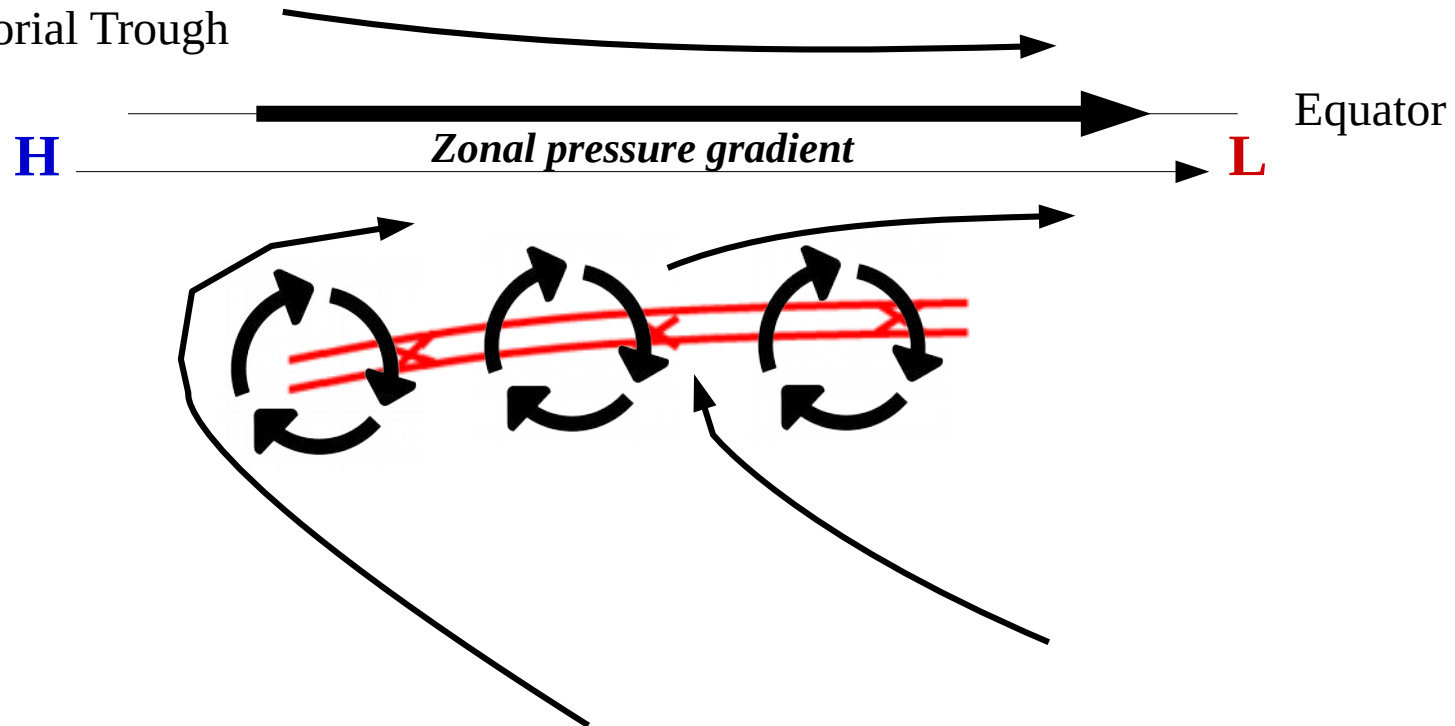
Near Equatorial Trough



Modèles conceptuels

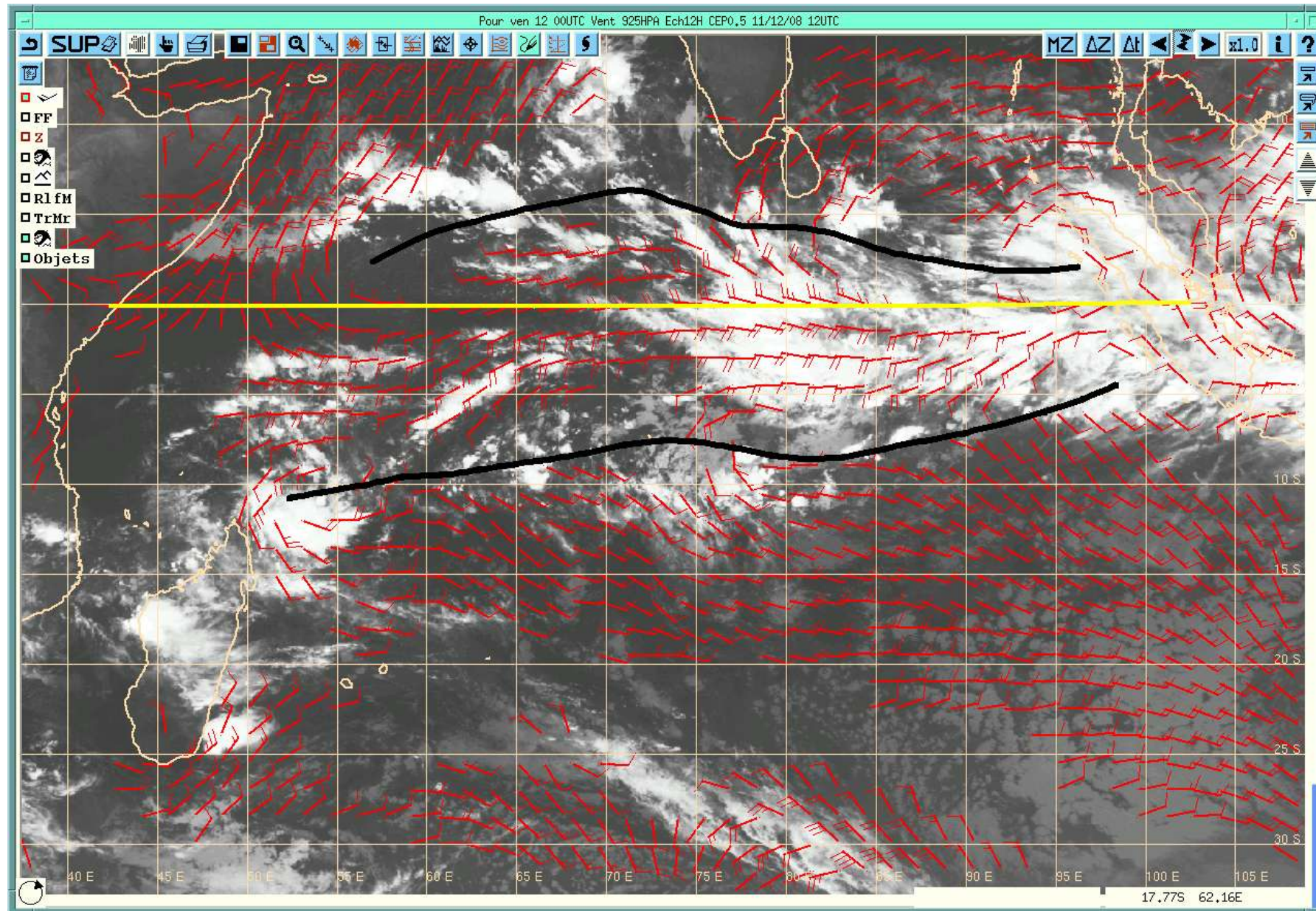
NET

Near Equatorial Trough

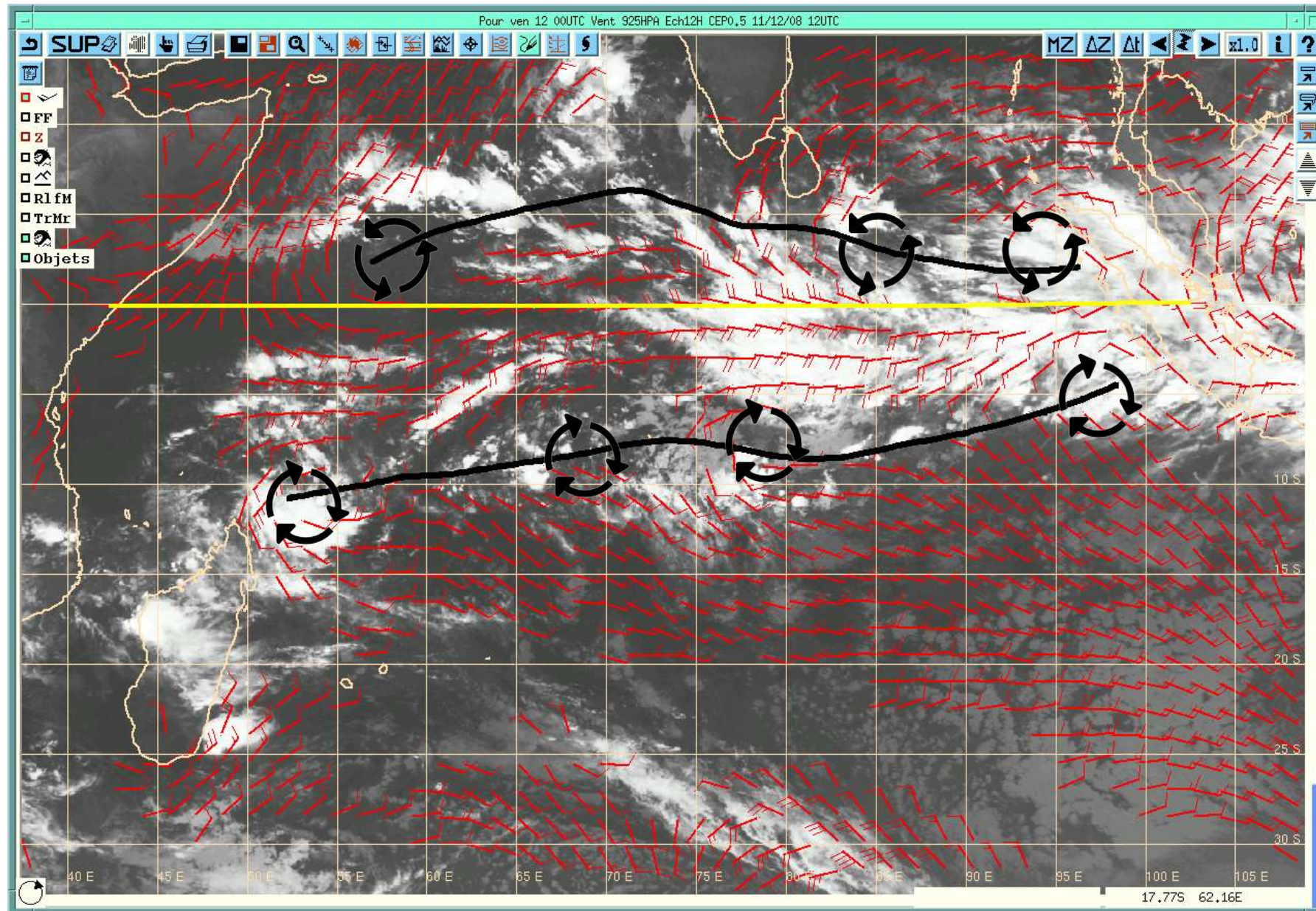


Some precursors are also nested within NETs

NET & Cyclogenesis



NET & Cyclogenesis



Basin configuration & Cyclogenesis

Some of the basin configurations favor cyclogenesis by providing :

- ✗ A high mid-level moisture
- ✗ Pre-existing low-level environment
- ✗ Favorable upper conditions (Low vertical wind shear and poleward divergence)

Monsoon Trough & Near Equatorial Trough



TD 1

Find today's basin configuration

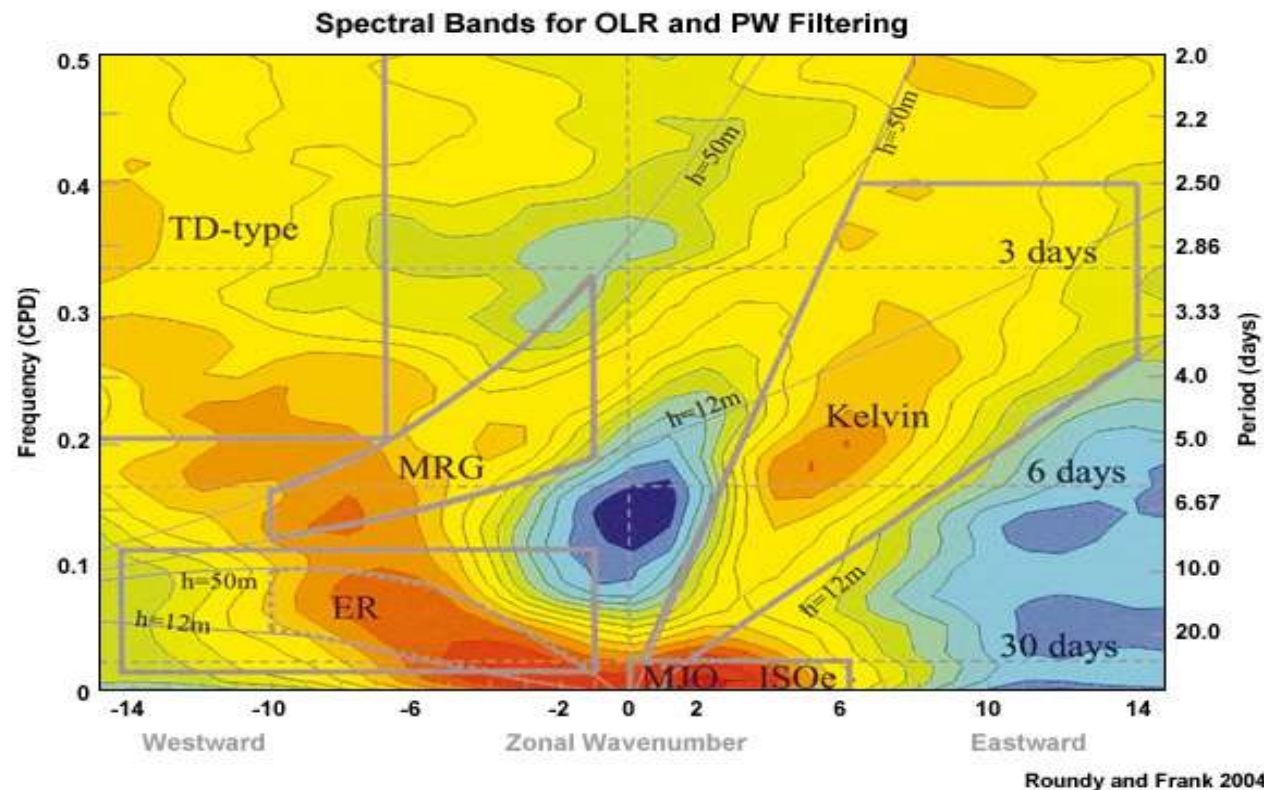


What to look at : - Satellite image (MSG1)
- 925 hPa winds (streamlines if possible)

Tropical Waves

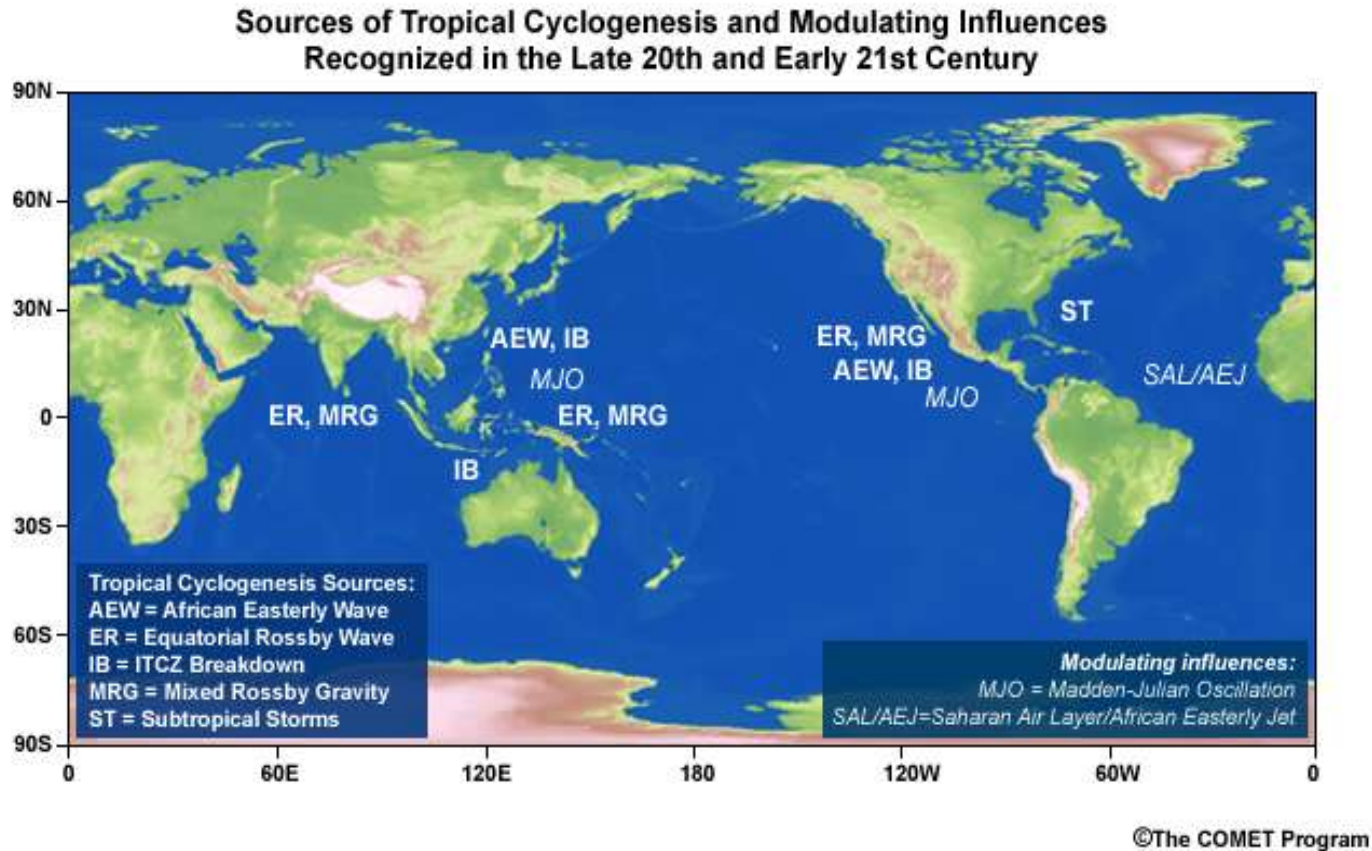
Le rôle des ondes tropicales

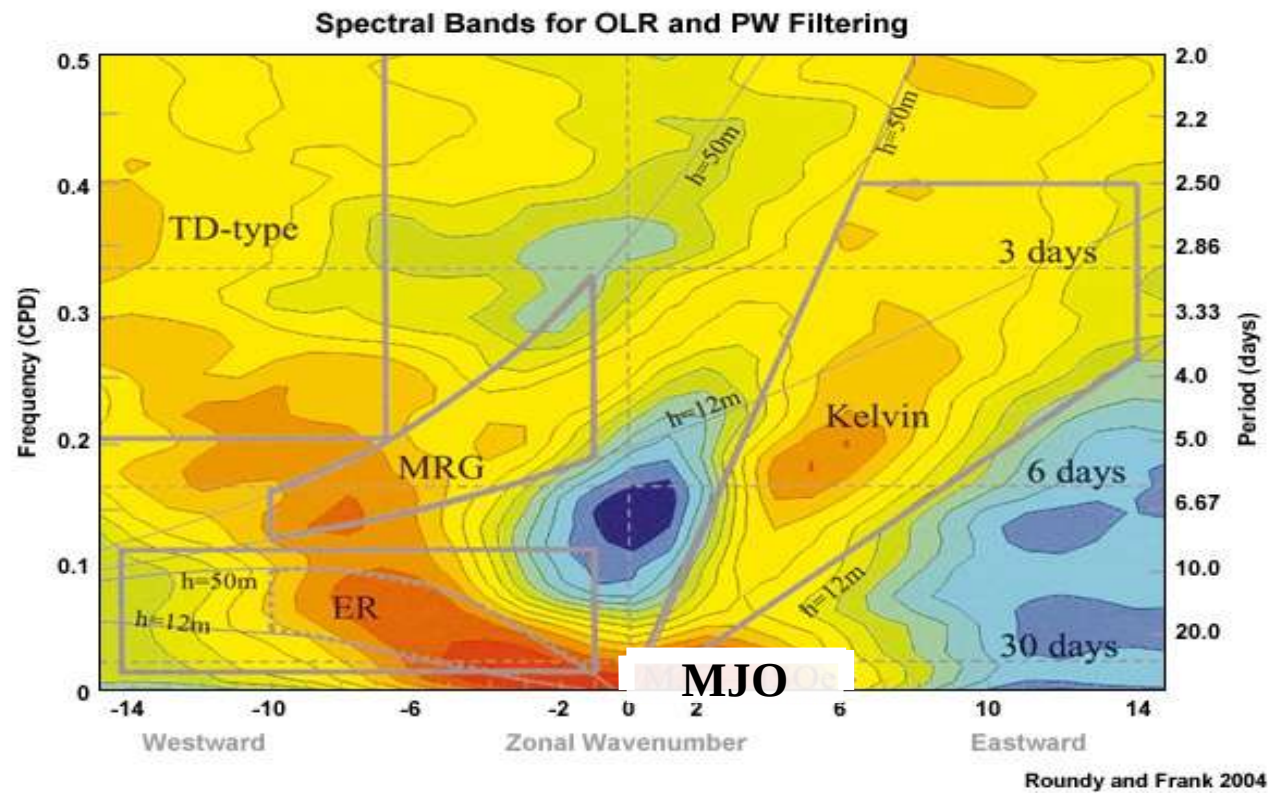
Definition : A tropical wave materializes the propagation of an atmospheric disturbance at the planetary scale. It is coupled with convection : strong convective bursts are creating it and the wave propagation favors deep convection in return. It remains channeled along the equator ($\pm 15^\circ$) by the equatorial wave guide.



Tropical waves bring predictability at the monthly scale

Le rôle des ondes tropicales





Tropical Waves bestiary

Madden Julian Oscillation (MJO)

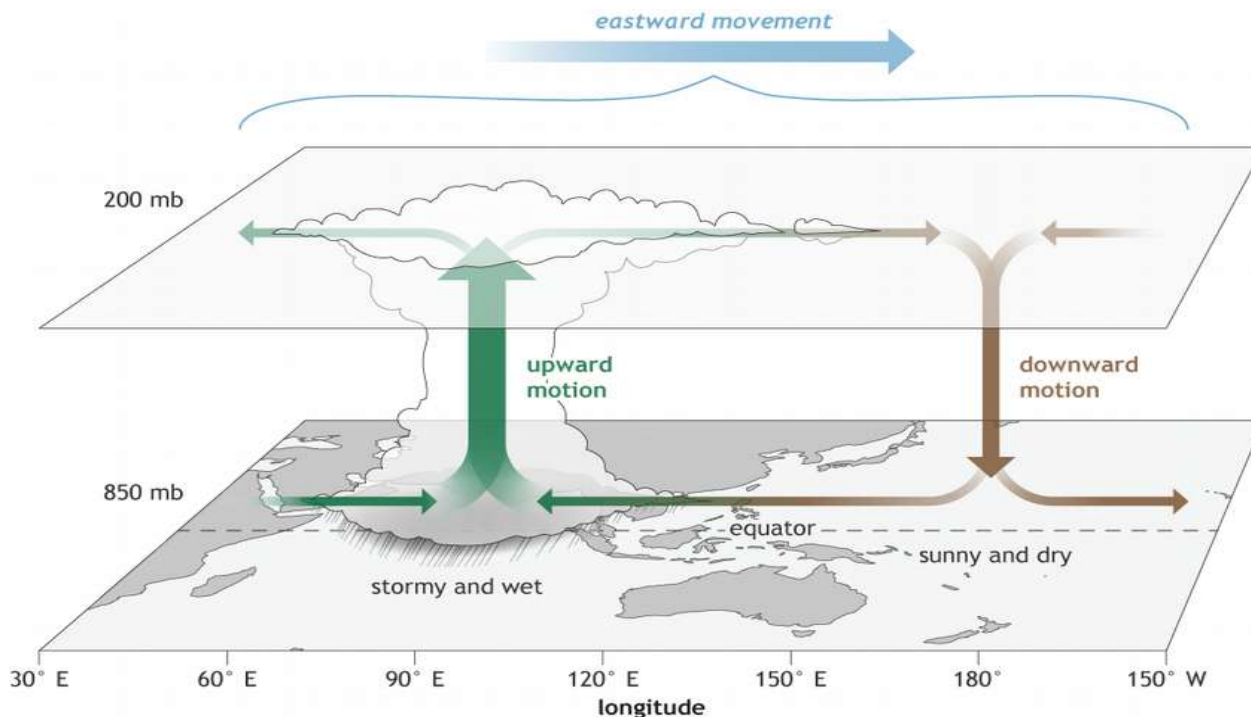
Propagation : Eastward

Period > 30 days

Monitoring parameters : Positive 200-hPa divergence anomaly, RMM index

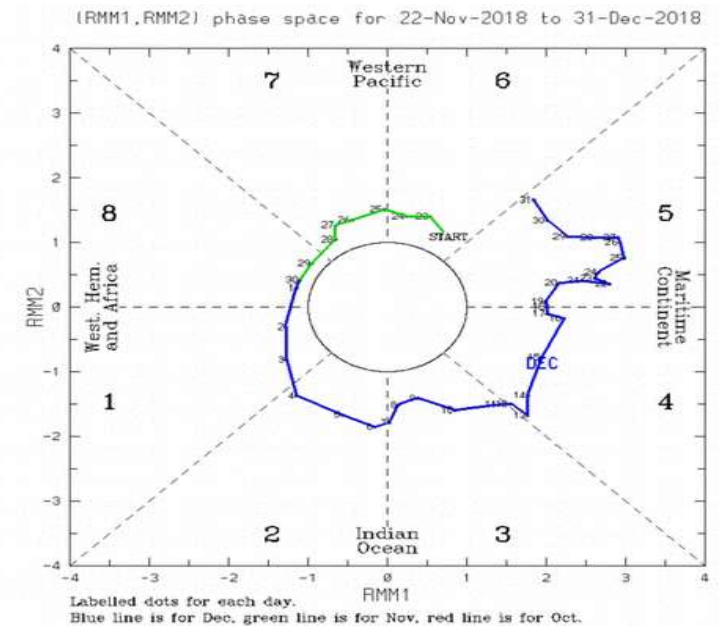
Main consequences : Strengthened deep convection and favored cyclogenesis during ± 1 month on the basin.

Interaction with other waves : triggers “scout” Kelvins



Madden-Julian Oscillation

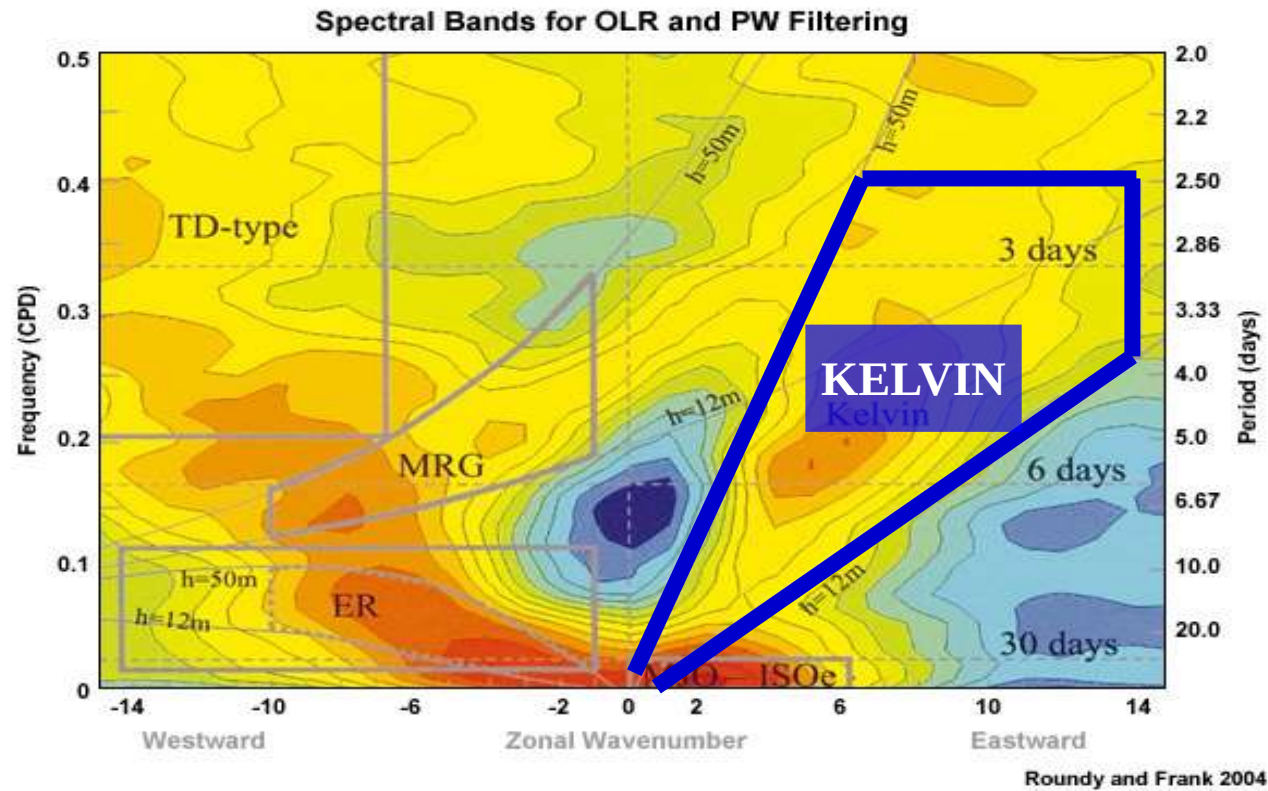
NOAA Climate.gov



RMM - BOM



Kelvin wave



Tropical Waves bestiary

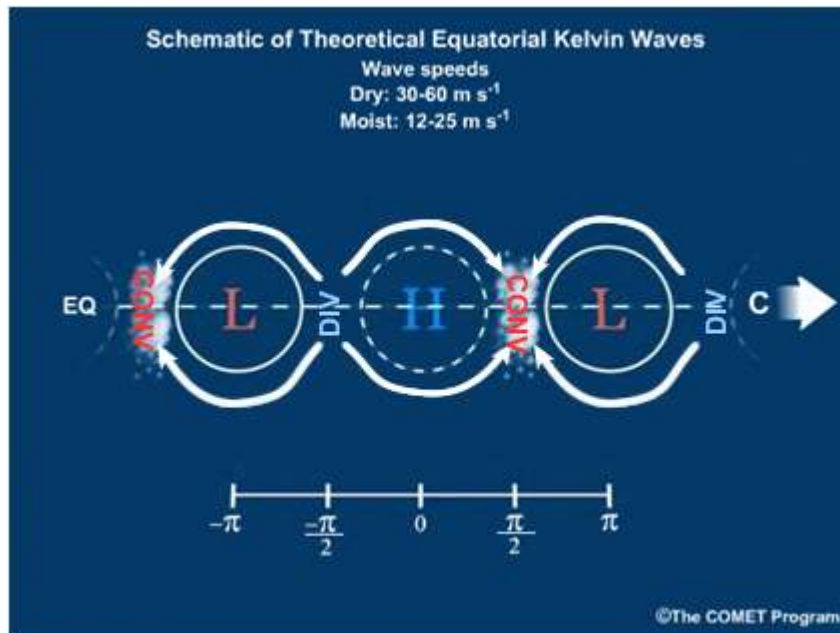
Kelvin wave

Propagation : Eastward

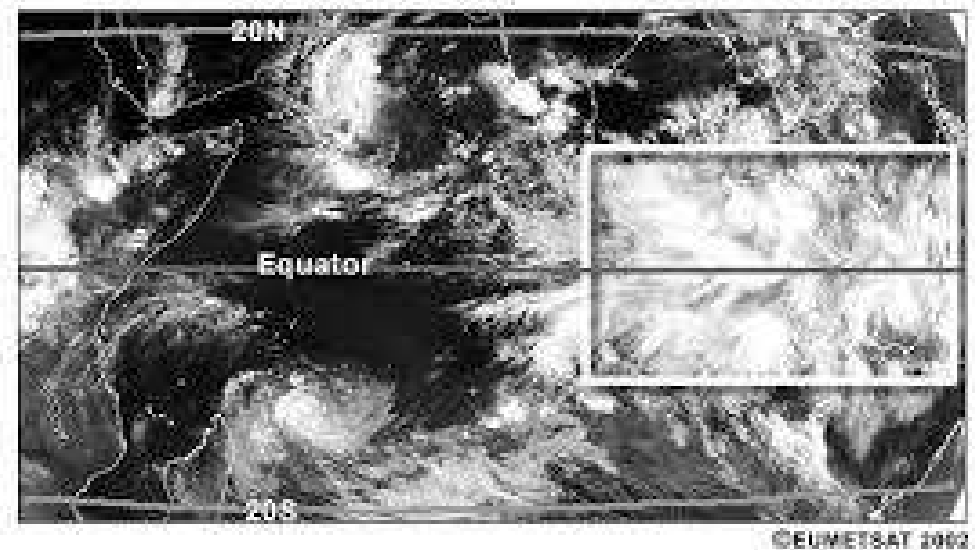
Period $\approx 3/7$ days

Monitoring parameters : 200-hPa divergence, U850 (850-hPa zonal wind)

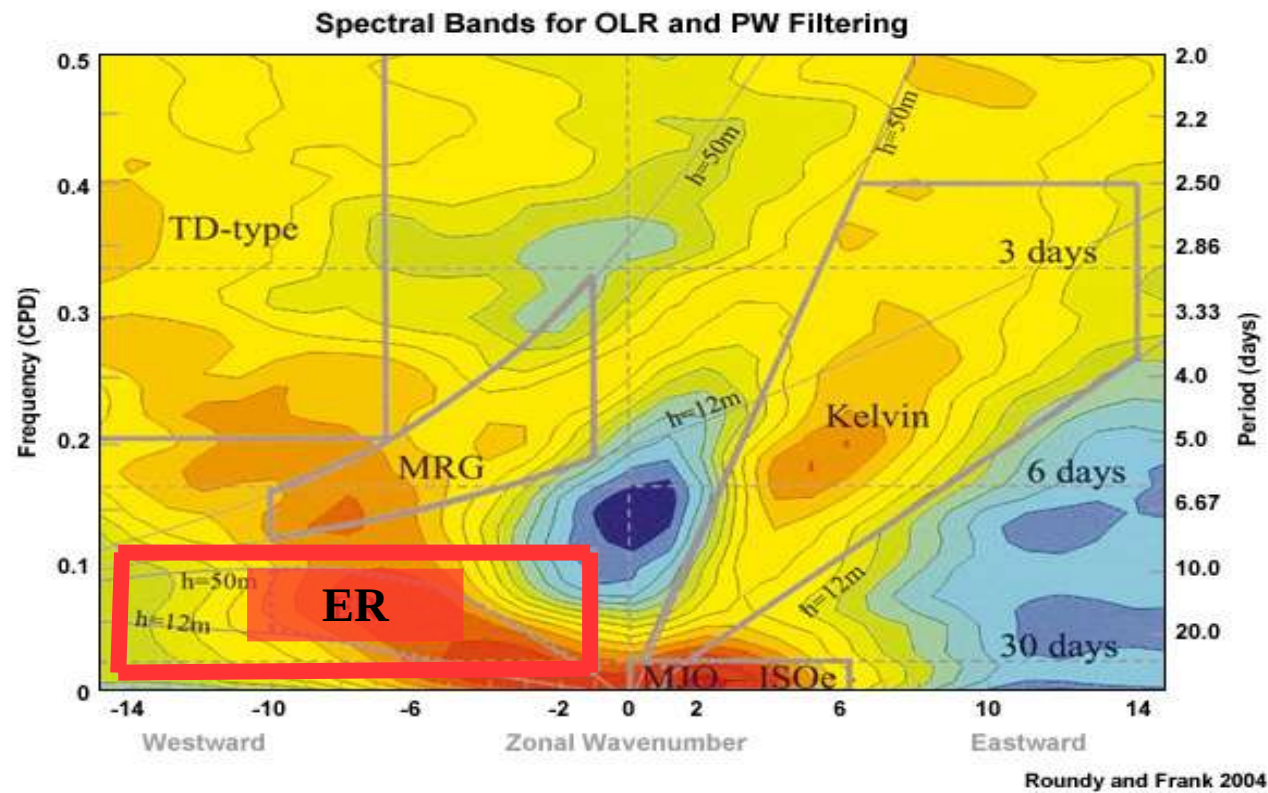
Main consequences : Westerlies burst at the equator, enhanced deep-convection, etc...



Satellite Infrared Image, 18 UTC 7 May 2002



Equatorial Rossby



Tropical Waves bestiary

Equatorial Rossby wave (ER)

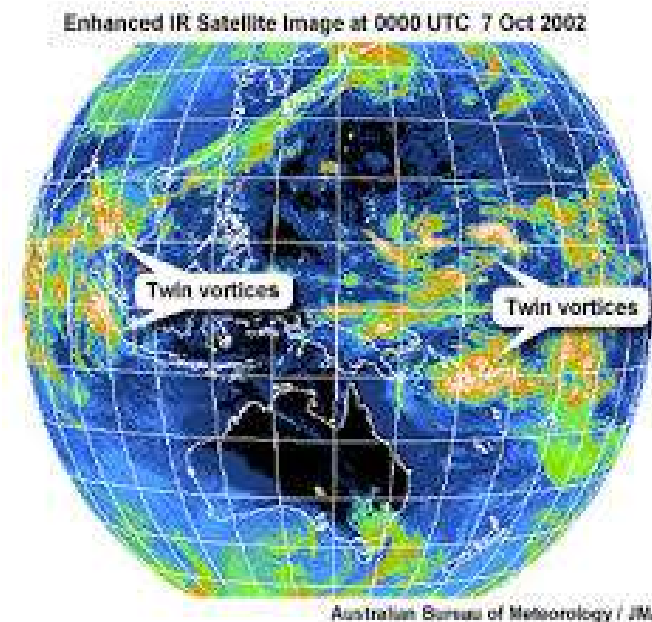
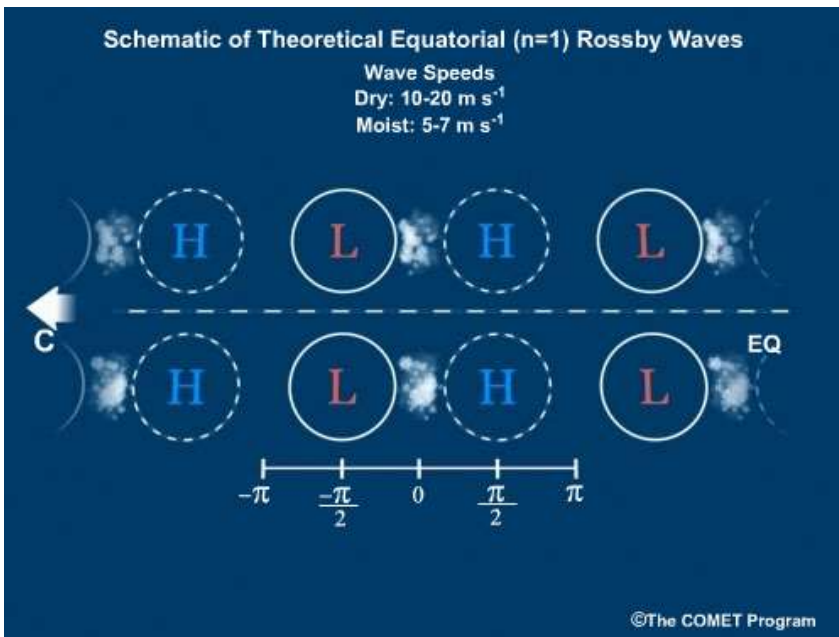
Propagation : Westward

Period \approx 10/20 days

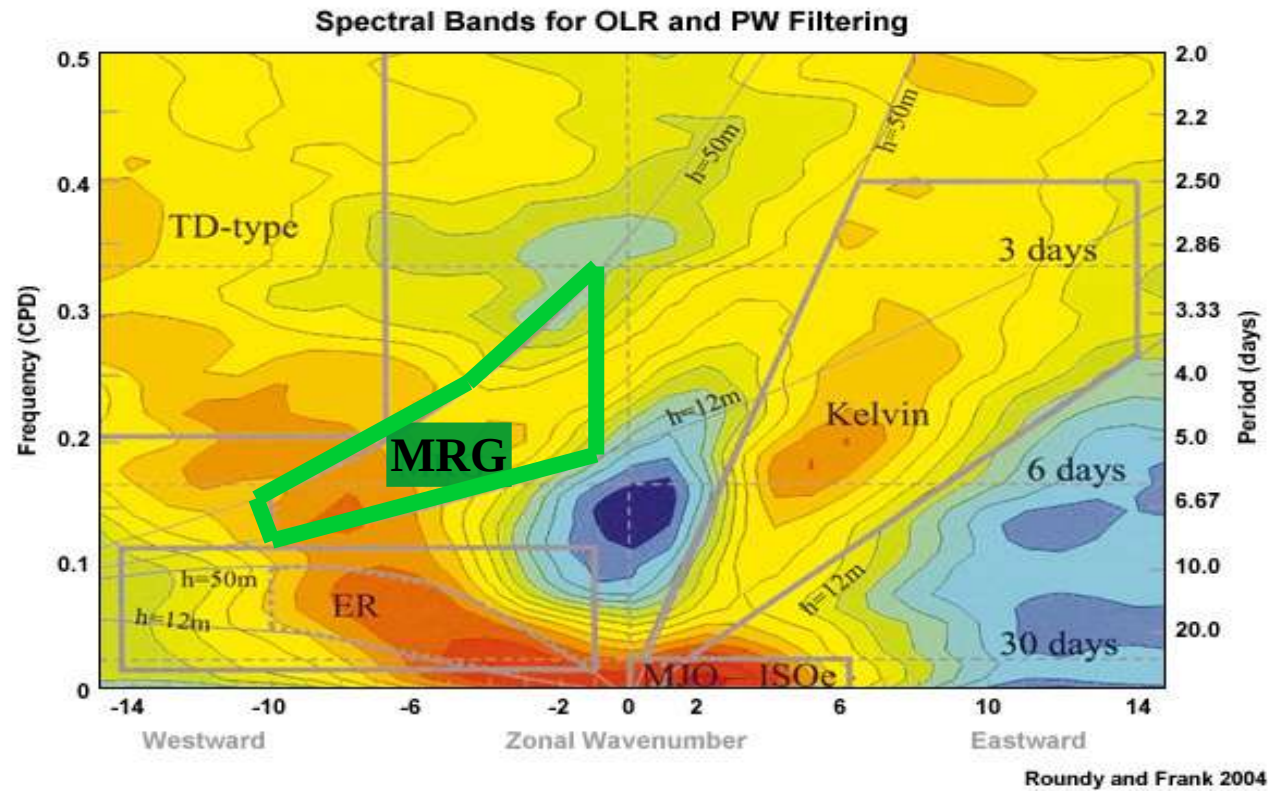
Monitoring parameters : V850 (850-hPa meridian wind), Low level vorticity

Main consequences : Symmetrical cyclonic vortices / Equator ; may serve as precursor

Lien avec les autres ondes : Especially favorable to cyclogenesis if crossing path with a Kelvin



Mixed Rossby-Gravity



Tropical Waves bestiary

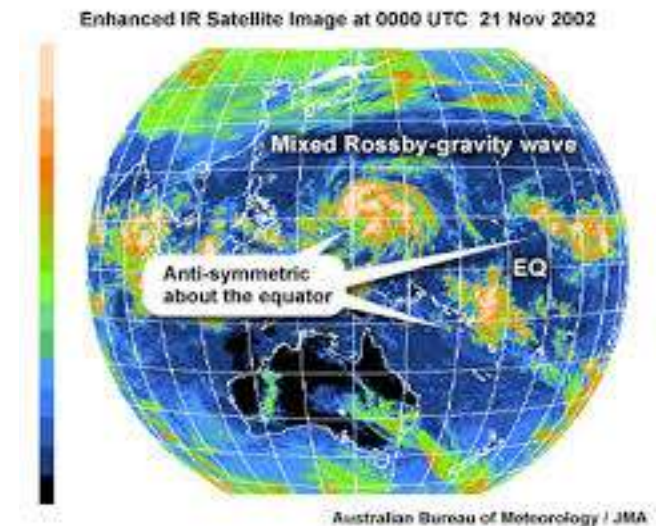
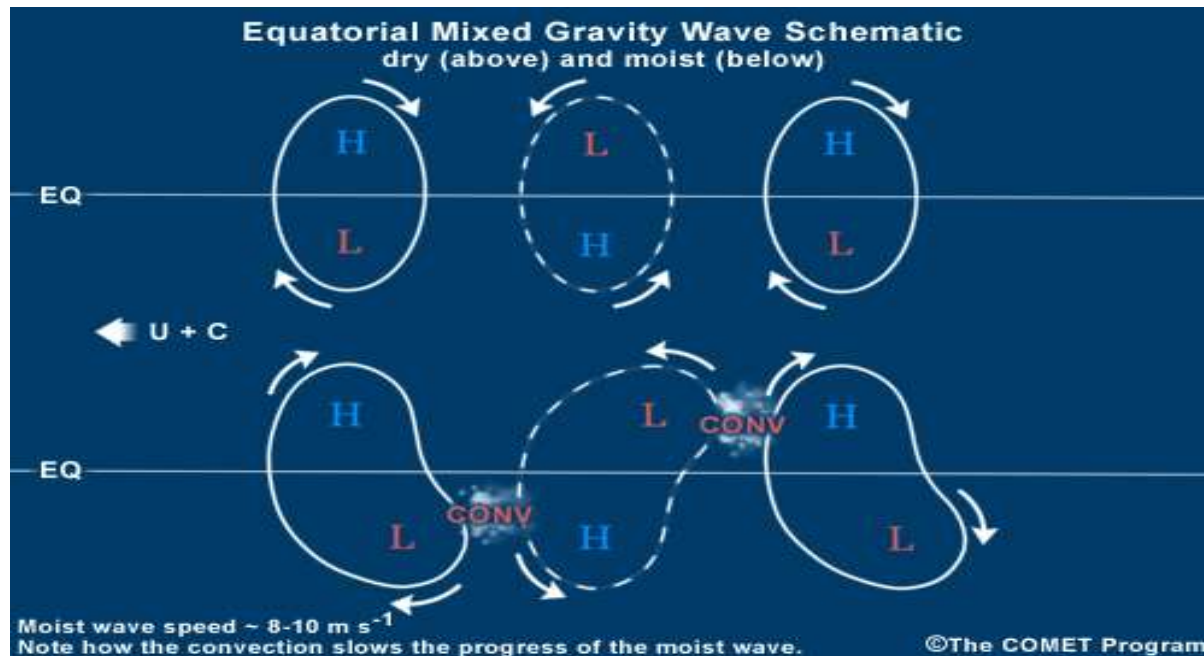
Mixed Rossby-Gravity (MRG)

Propagation : Westward

Period \approx 3/6 days

Monitoring parameters : V850 (850-hPa zonal wind), Low-level vorticity

Main consequences : Antisymmetrical vortices / Equator



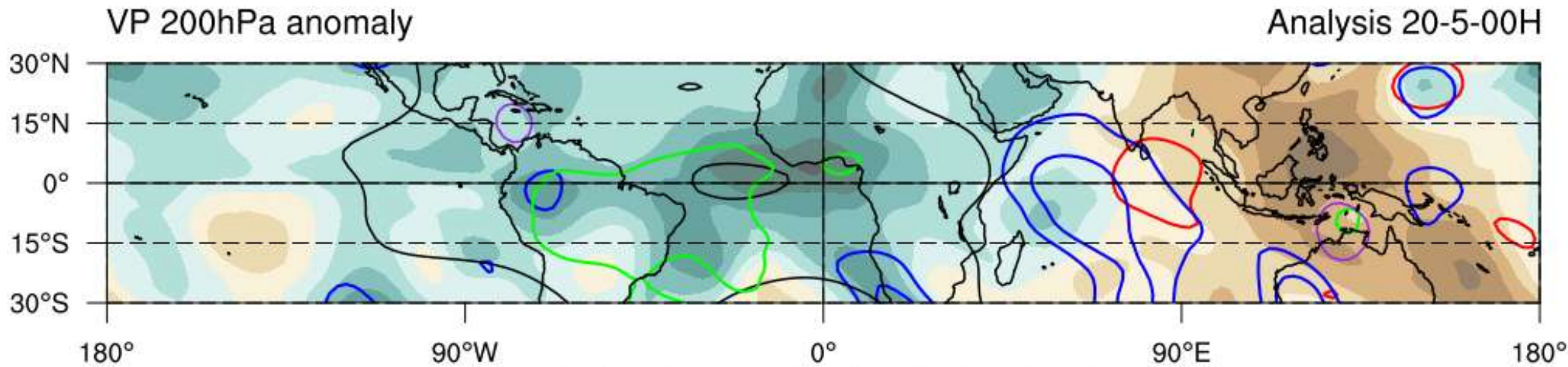
Tropical waves tools

Filtering : the operational tool for tropical wave **monitoring**

NCICS filters

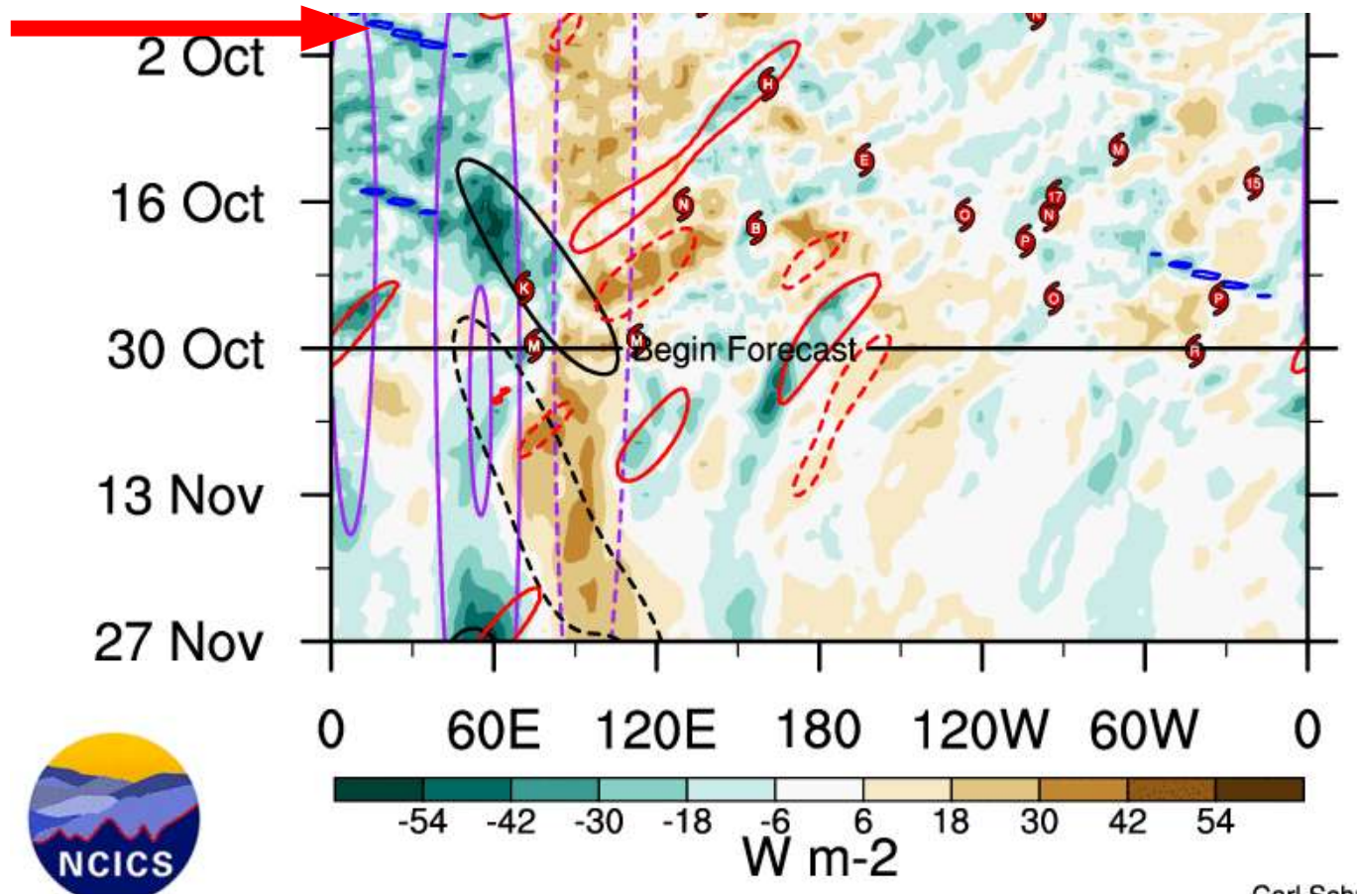
Ventrice's Filters

Filtered OLR, observation data

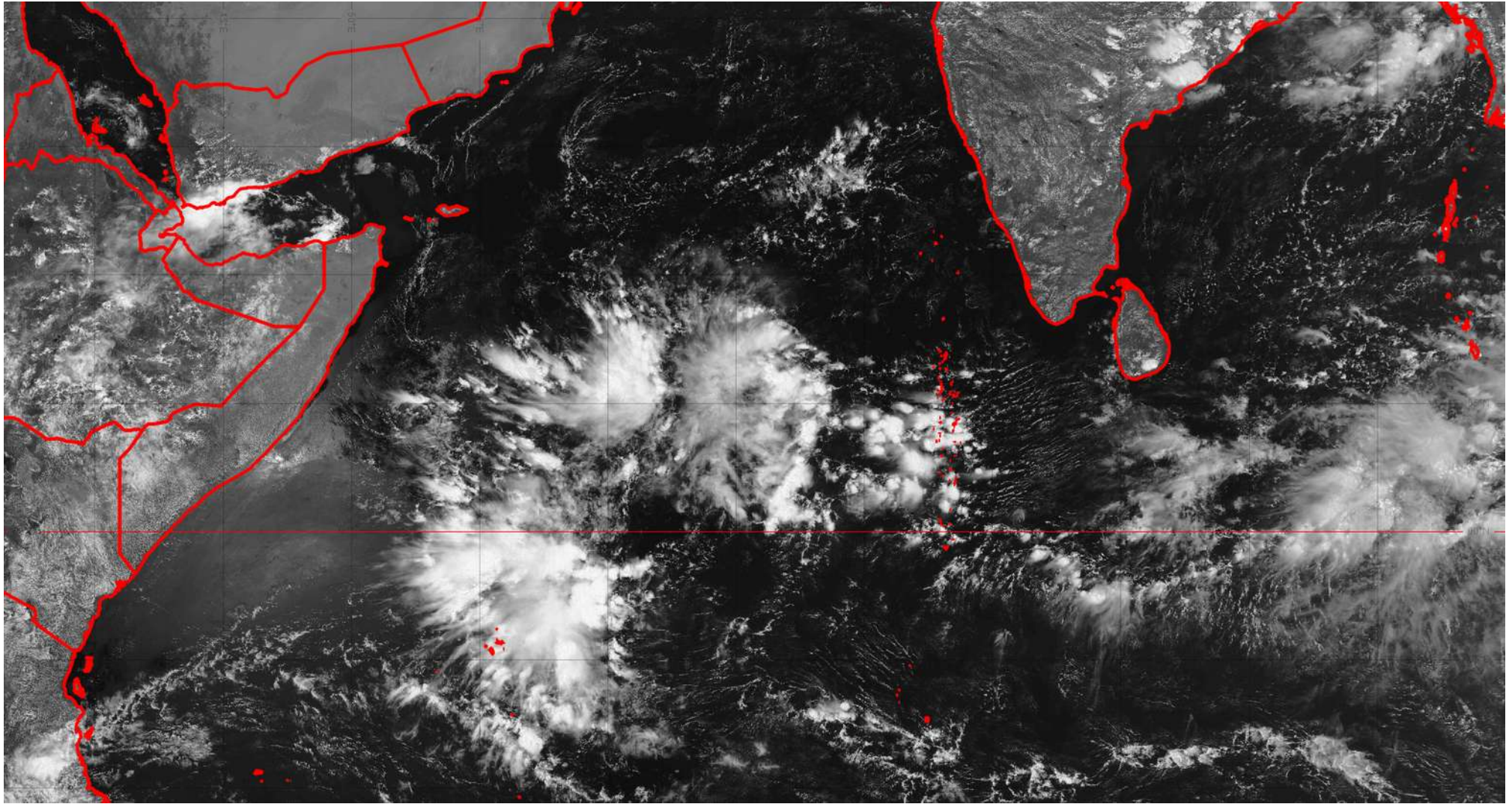


Forecasting by filtering model fields (Divergence, Wind)

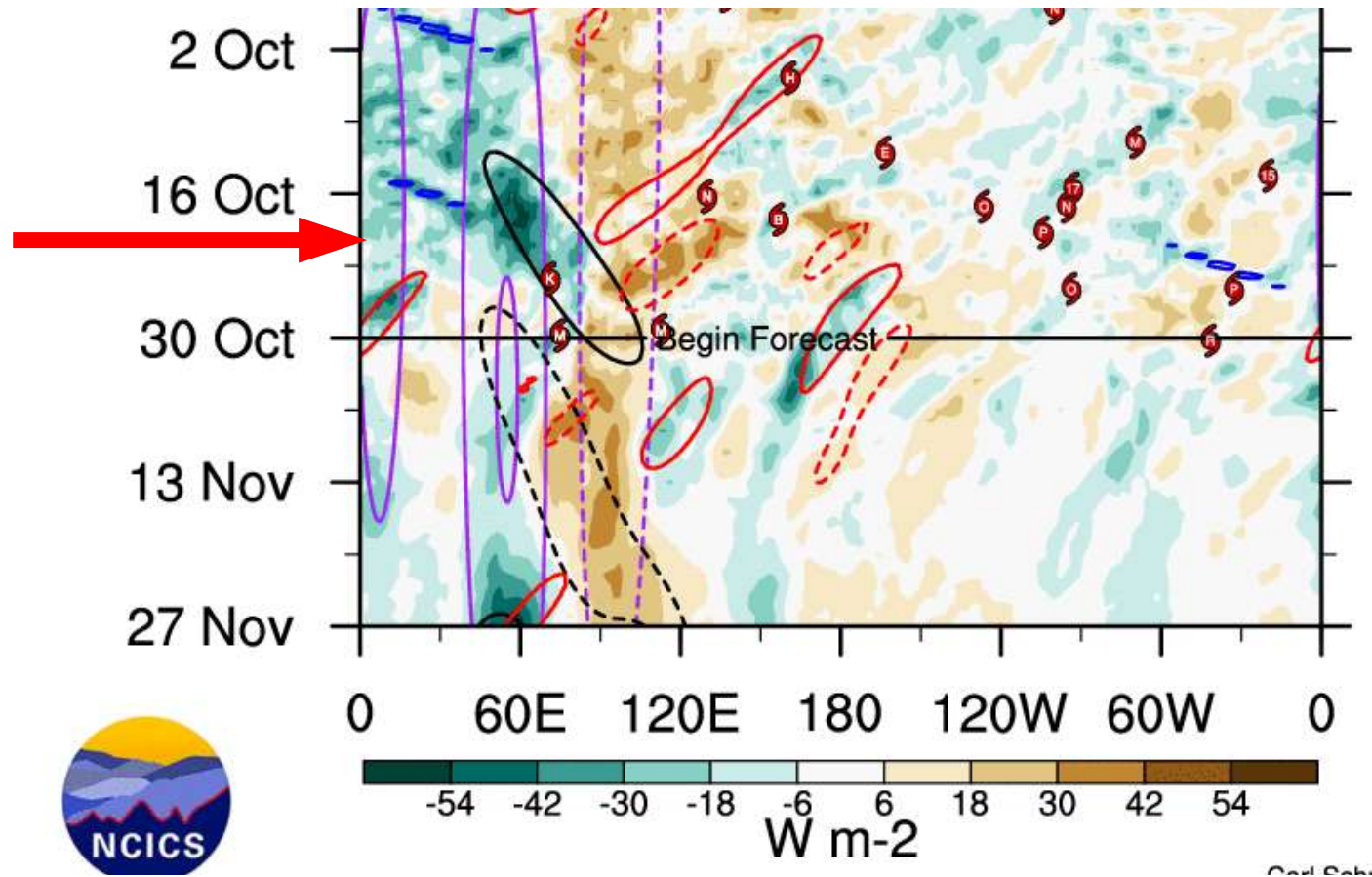
Last fortnight, on the North Indian...



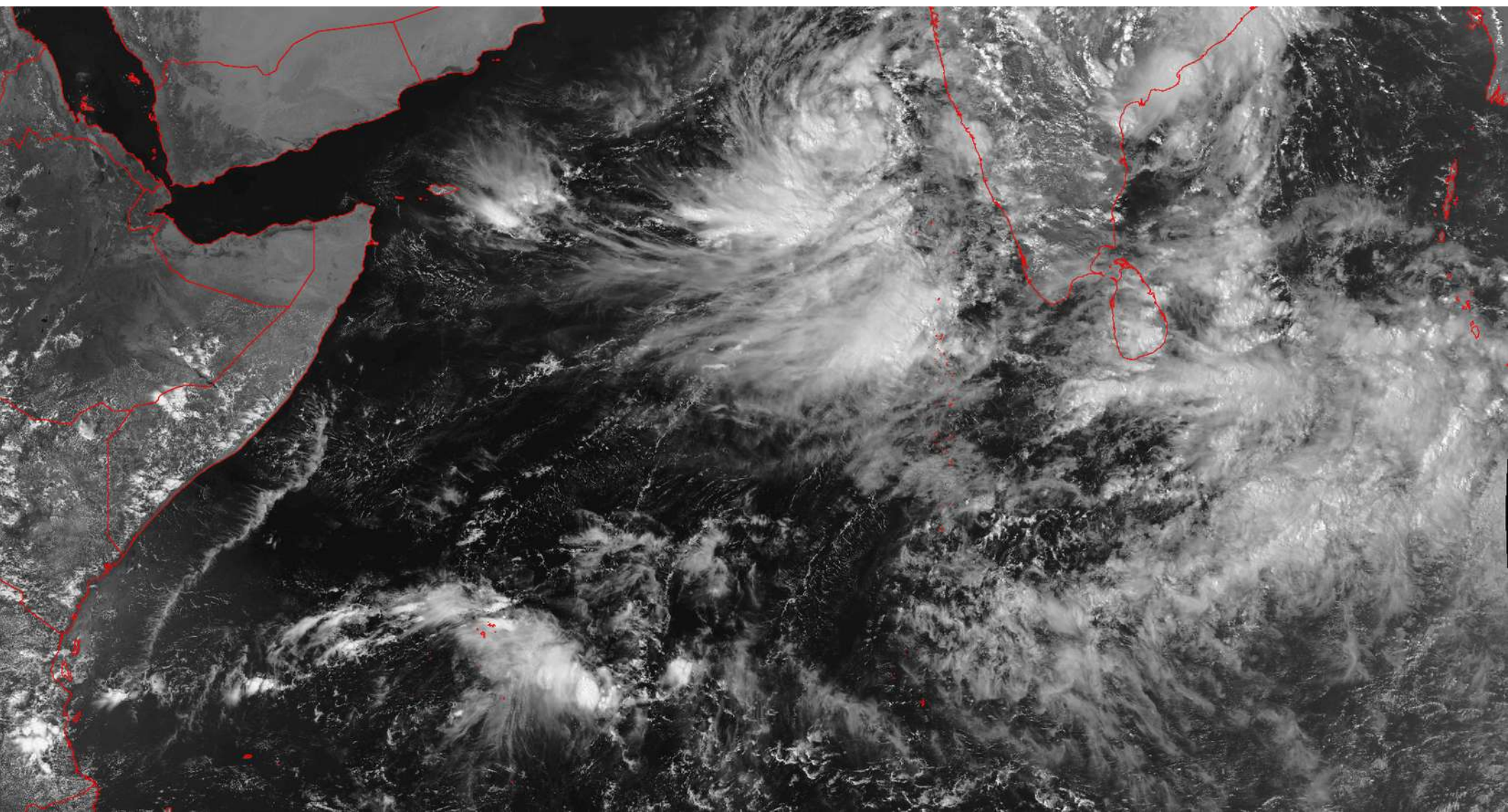
Last fortnight, on the North Indian...



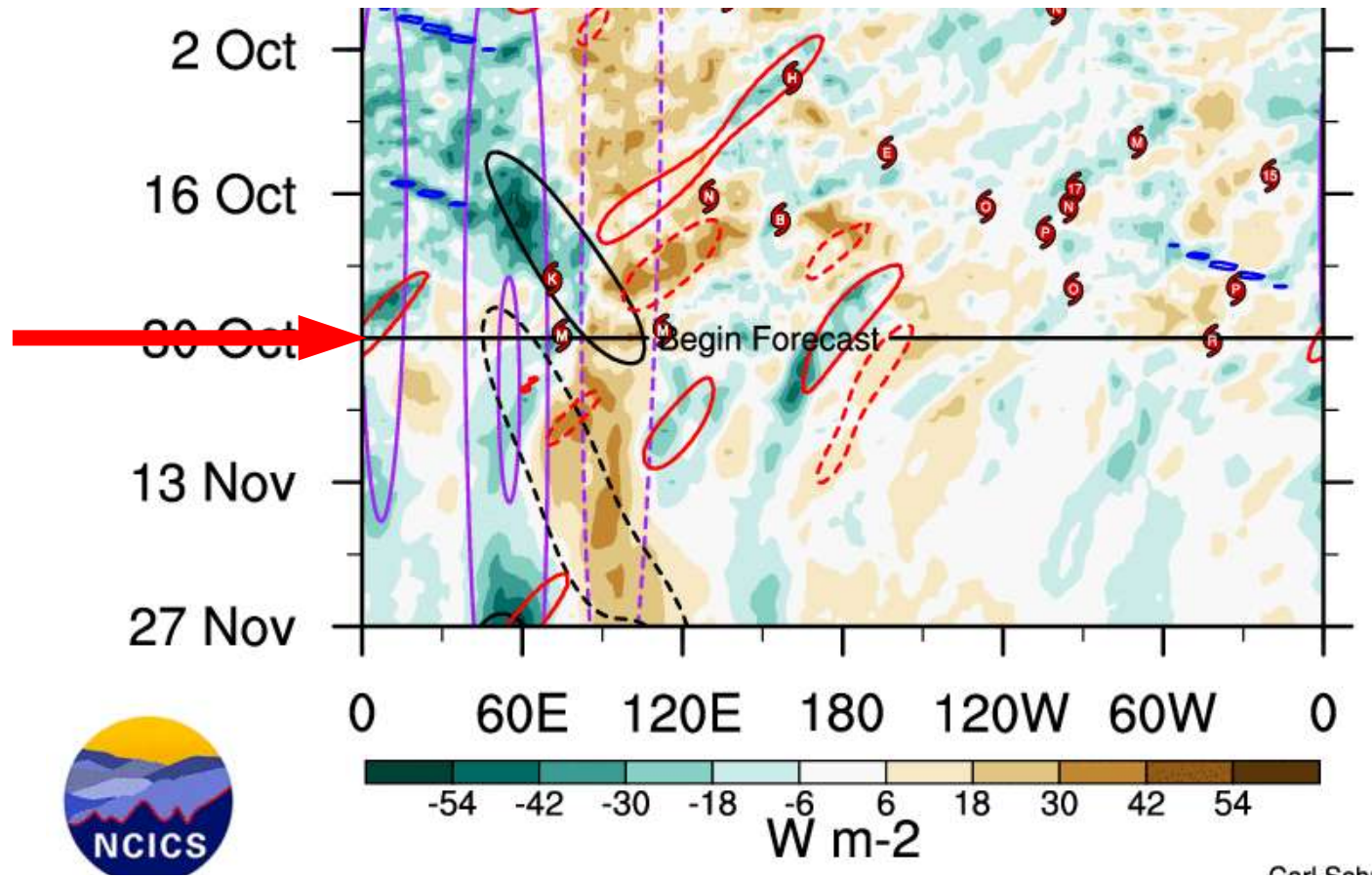
Last fortnight, on the North Indian...



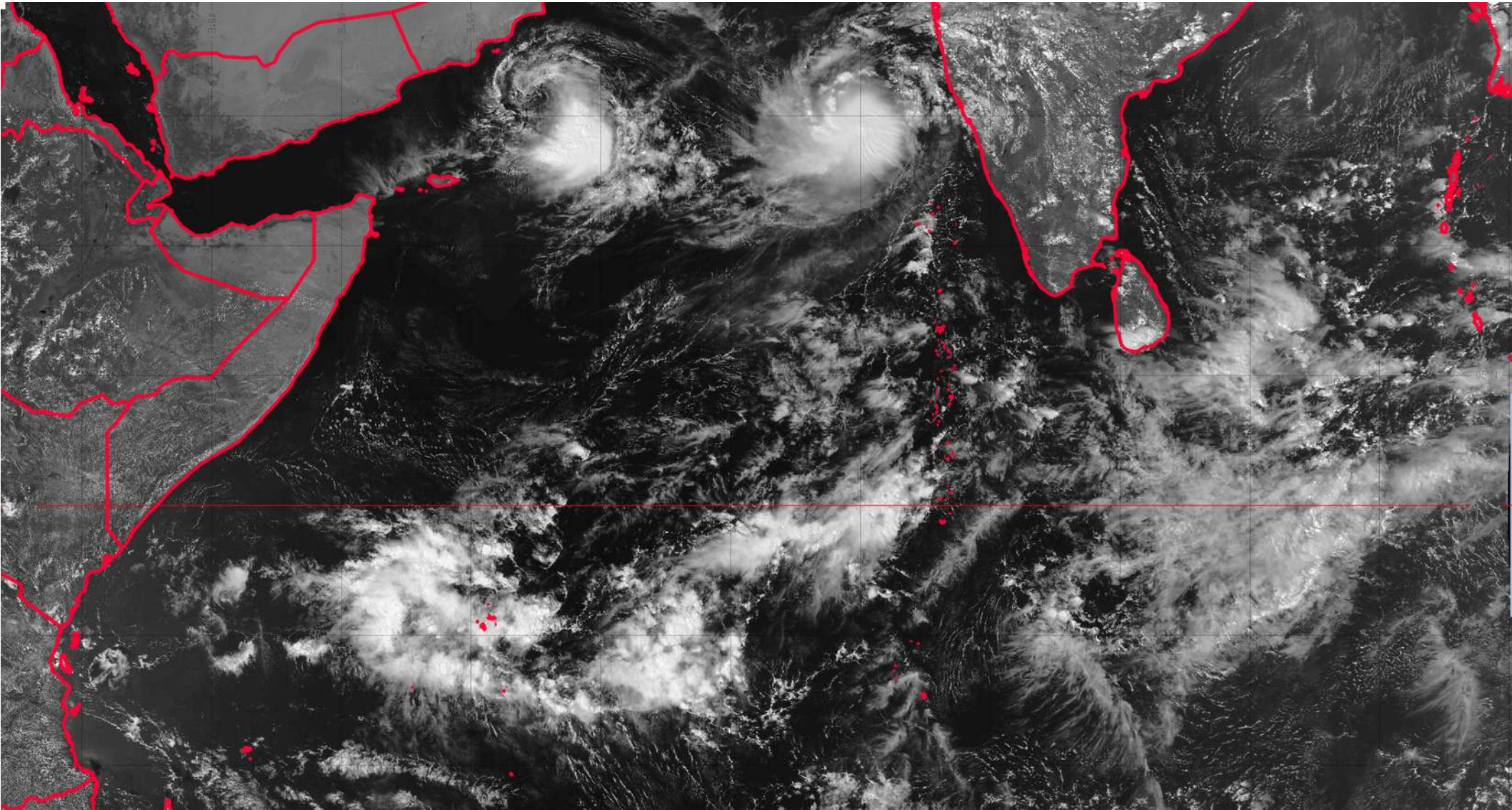
Last fortnight, on the North Indian...



Last fortnight, on the North Indian...



Last fortnight, on the North Indian...



Genesis of a tropical system
Cyclogenesis & tropical waves

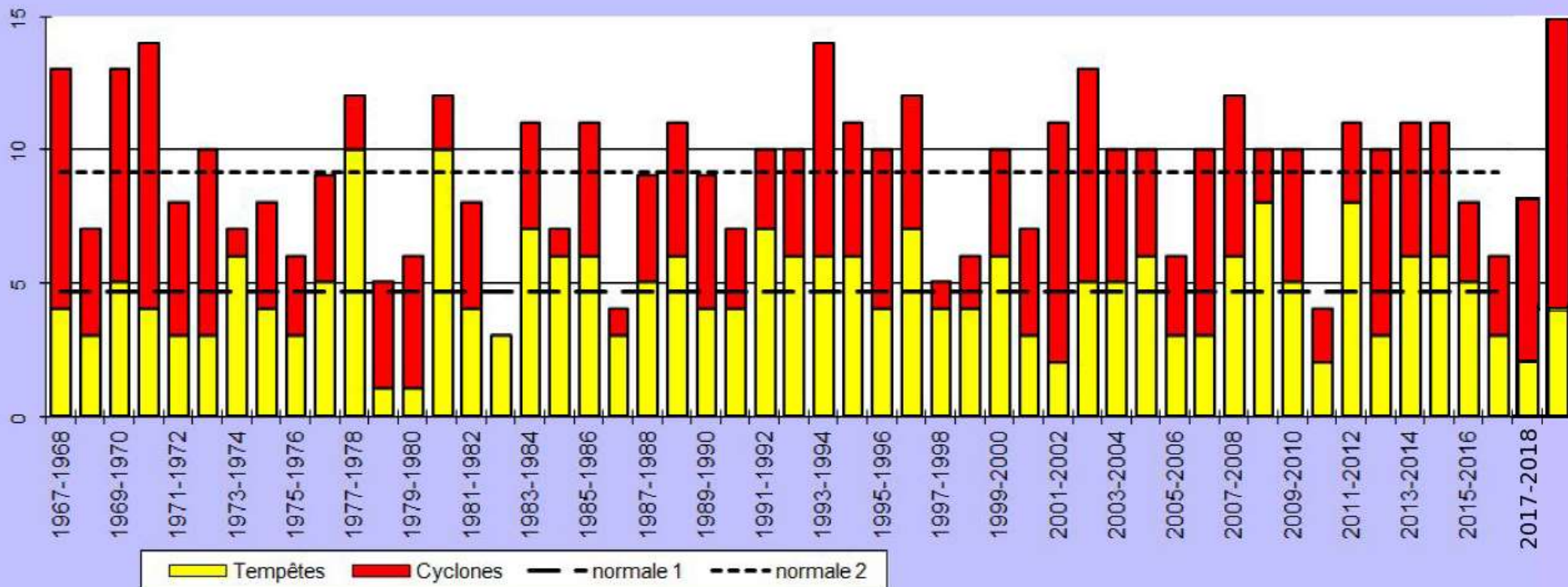


**METEO
FRANCE**

SWIO climatology & Operational practices

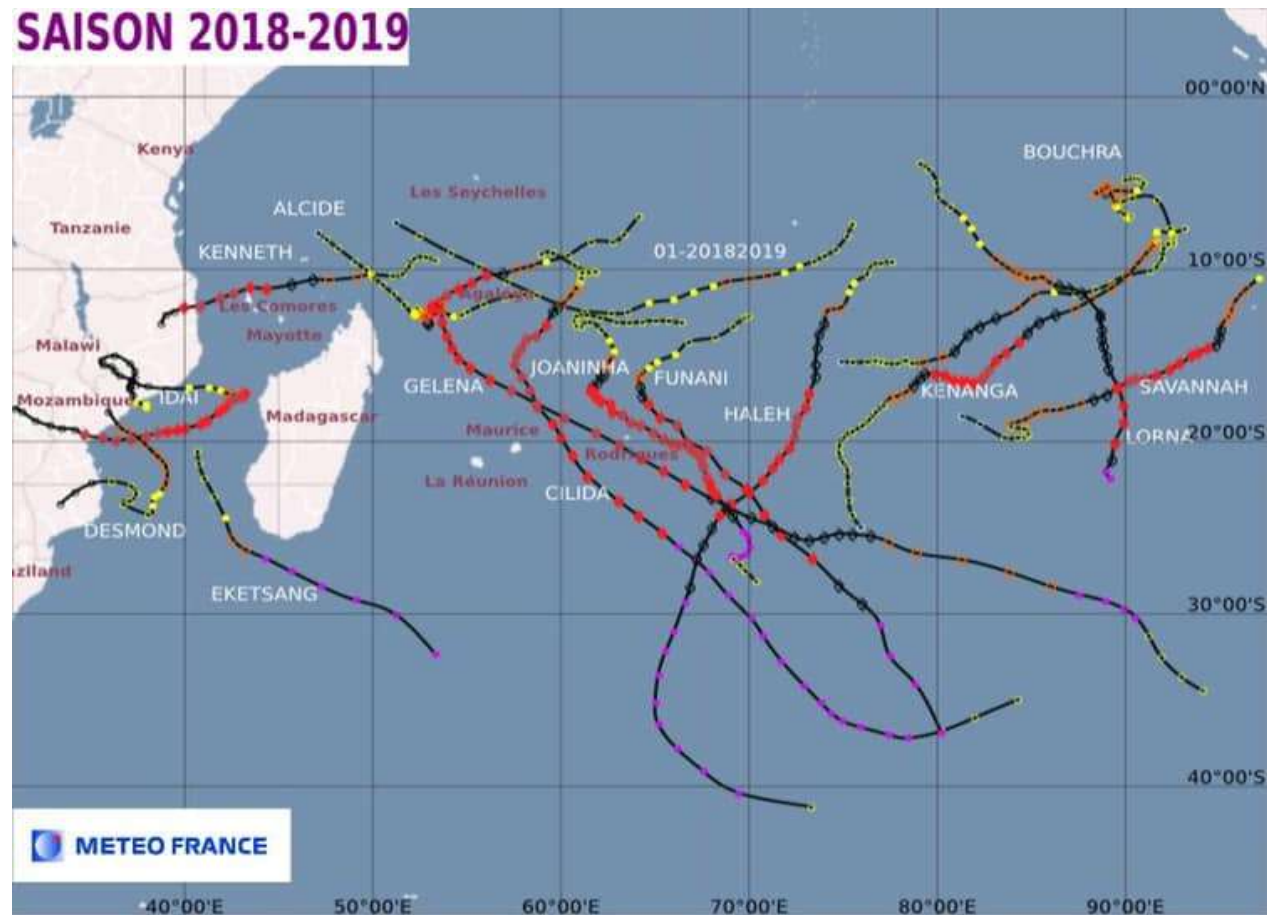
Climatology of Cyclogenesis in the SWIO

Variation interannuelle du nombre de tempêtes (en jaune) et cyclones tropicaux (en rouge) dans le Sud-Ouest de l'océan Indien



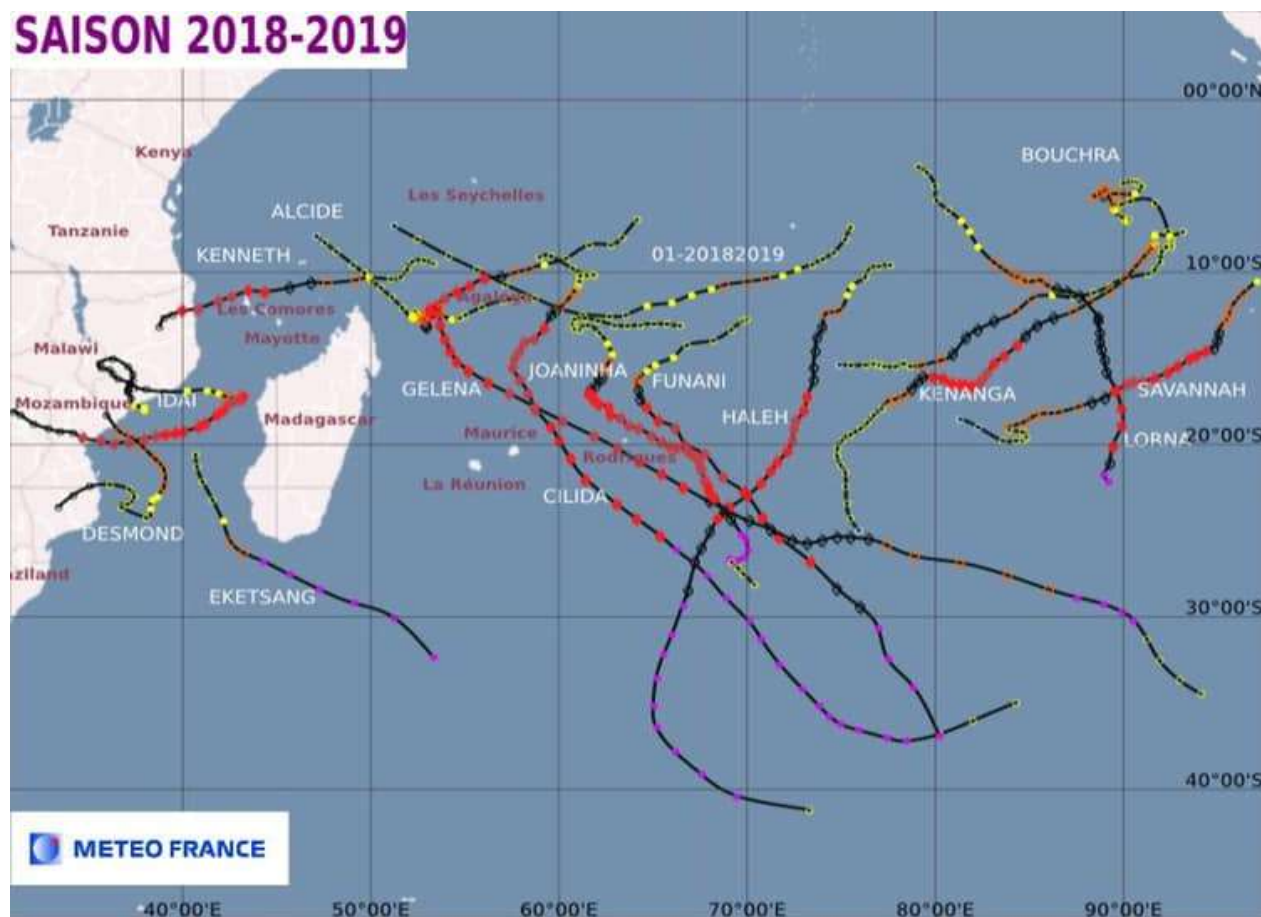
9 systems on average every year, including **5** storms & **4** cyclones

Cyclogenesis in the SWIO



2018/2019 Season : **15** systems including **11** cyclones
(**10 ITC !!!**)

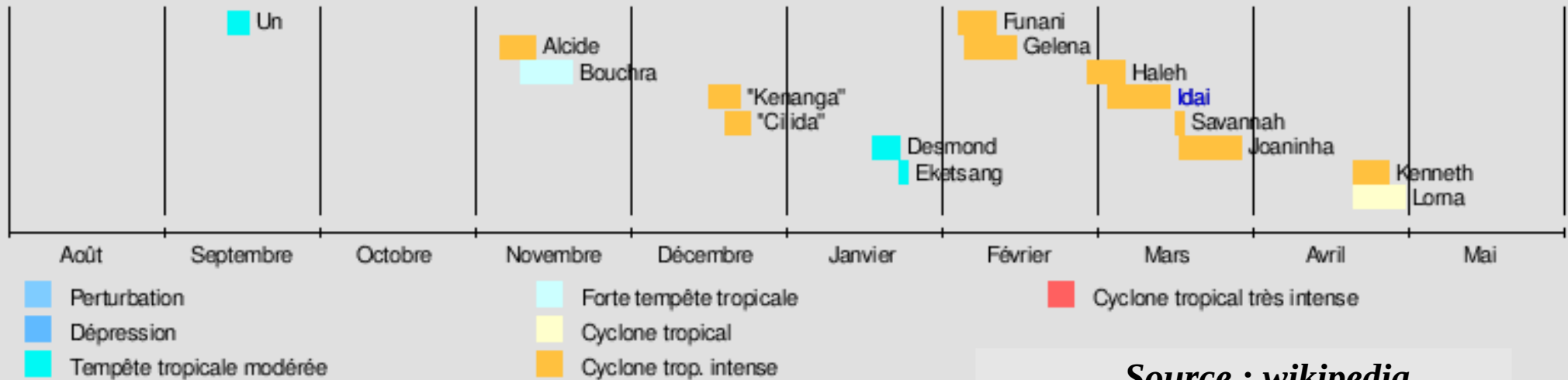
Cyclogenesis in the SWIO



2018/2019 Season : **15** systems including **11** cyclones
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RECORD **RECORD** **RECORD**

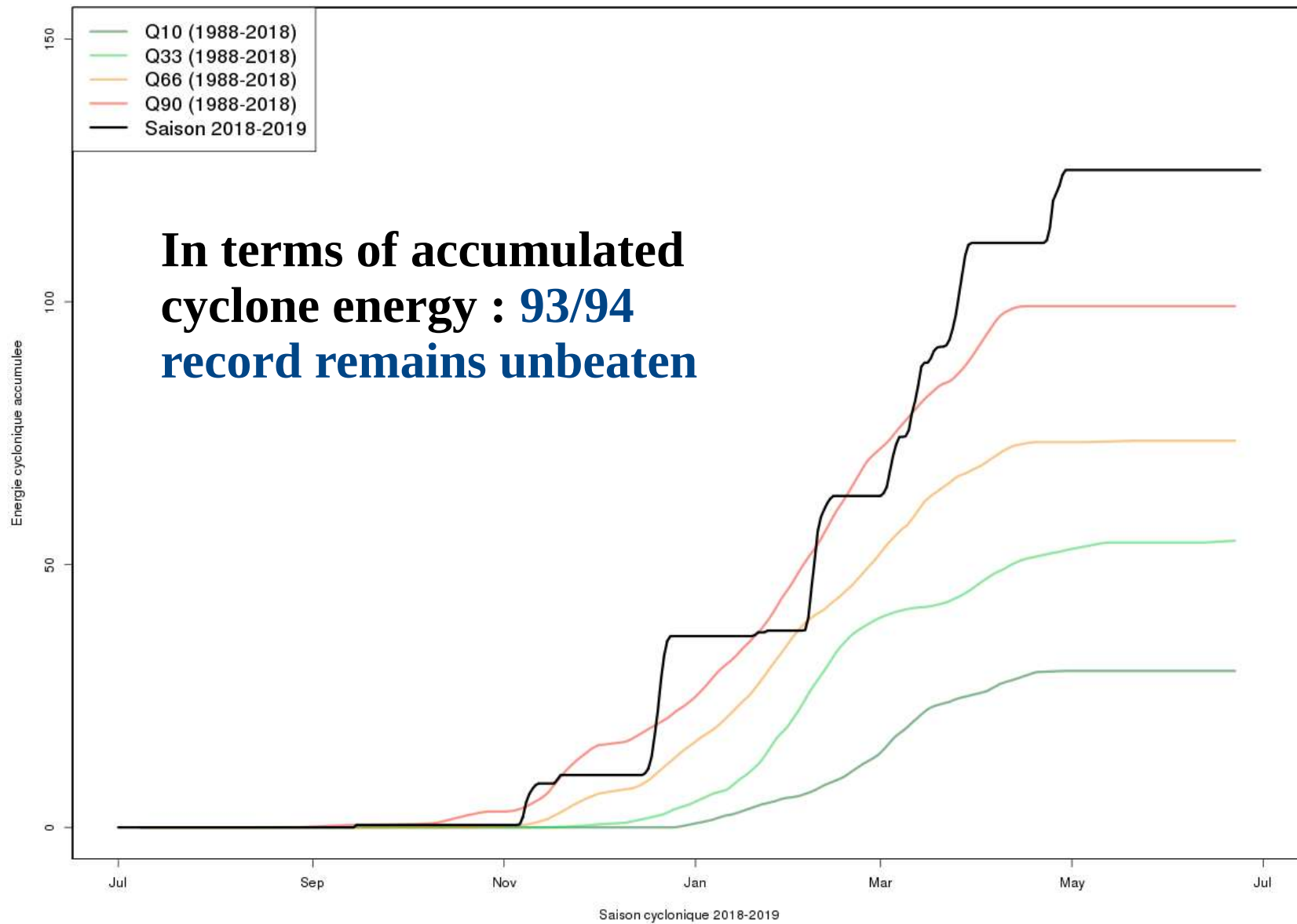
Cyclogenesis in the SWIO



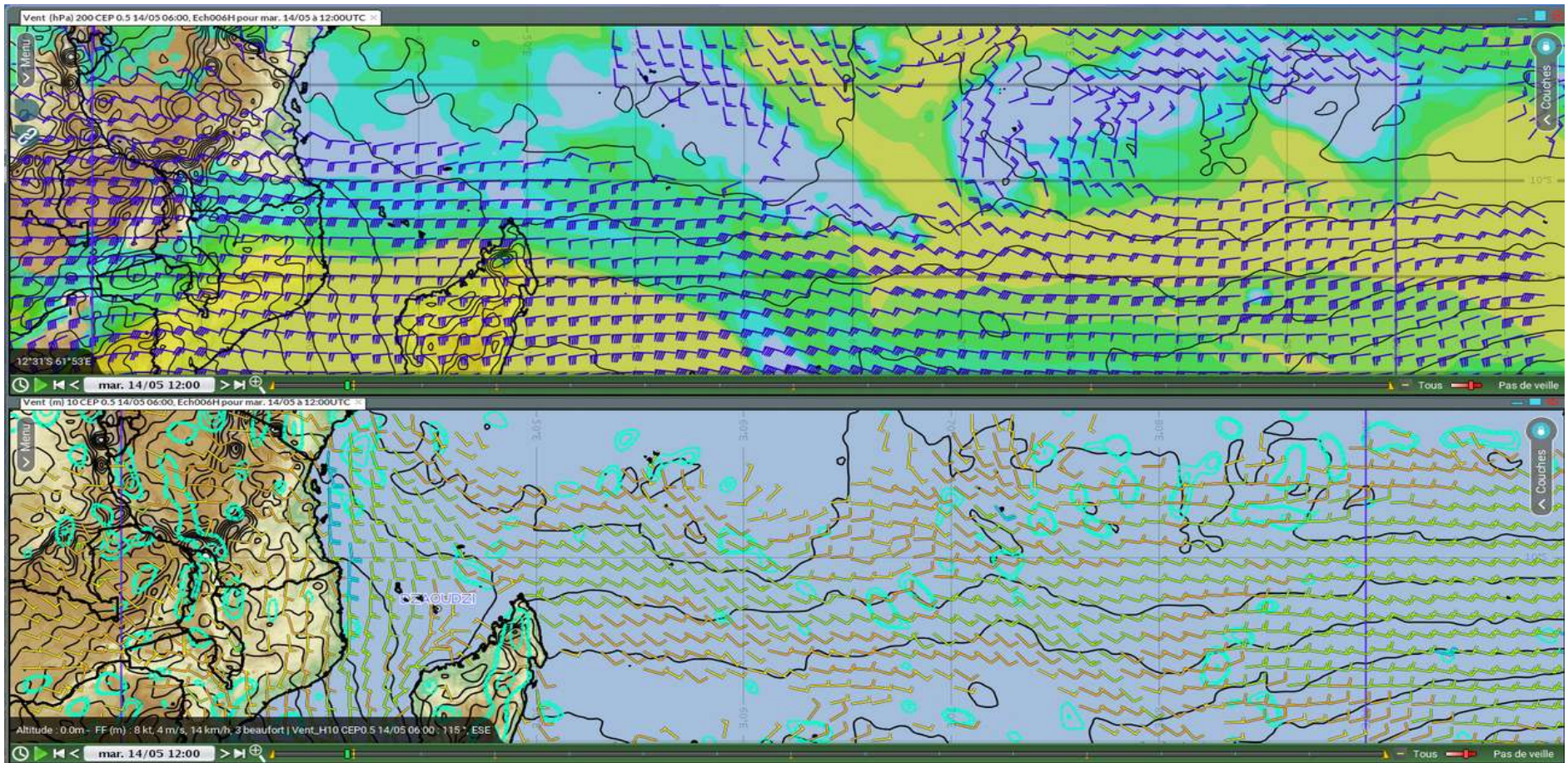
Source : wikipedia

39 cumulated days of cyclonic activity : new record !

Cyclogenesis in the SWIO



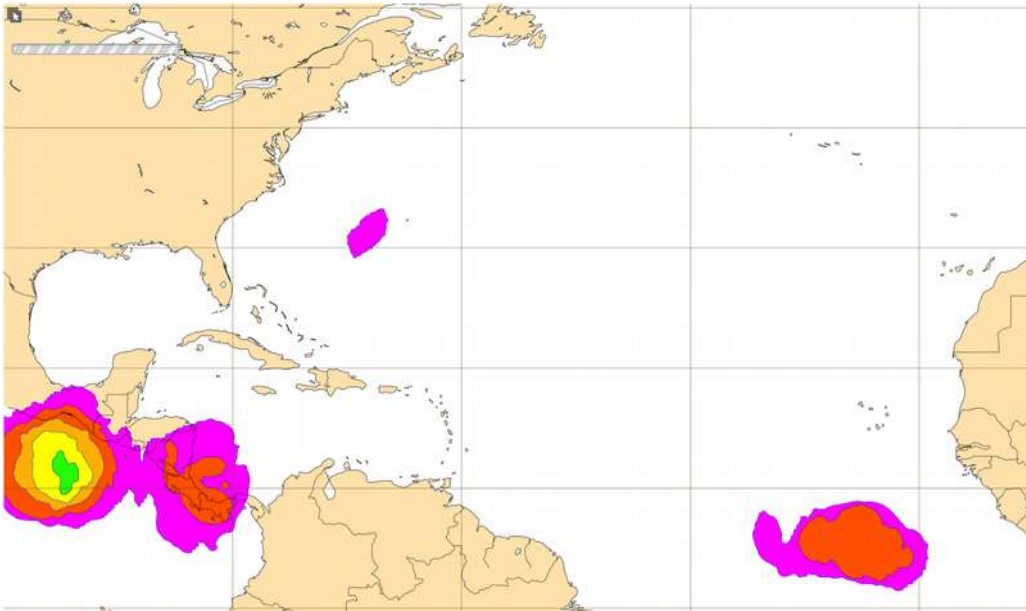
Cyclogenesis : Numerical prediction



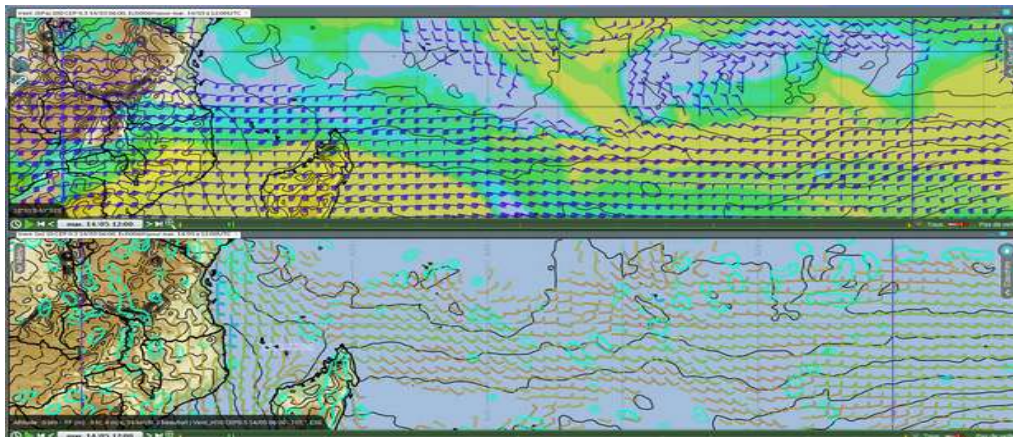
Model fields to subjectively evaluate the environment :

- ↑ Upper levels : Divergence and 200-850 hPa wind shear
- | Mid levels : Air moisture (500 hPa) and 500-850 wind shear
- ↓ Low levels : Convergence (important at early stage)

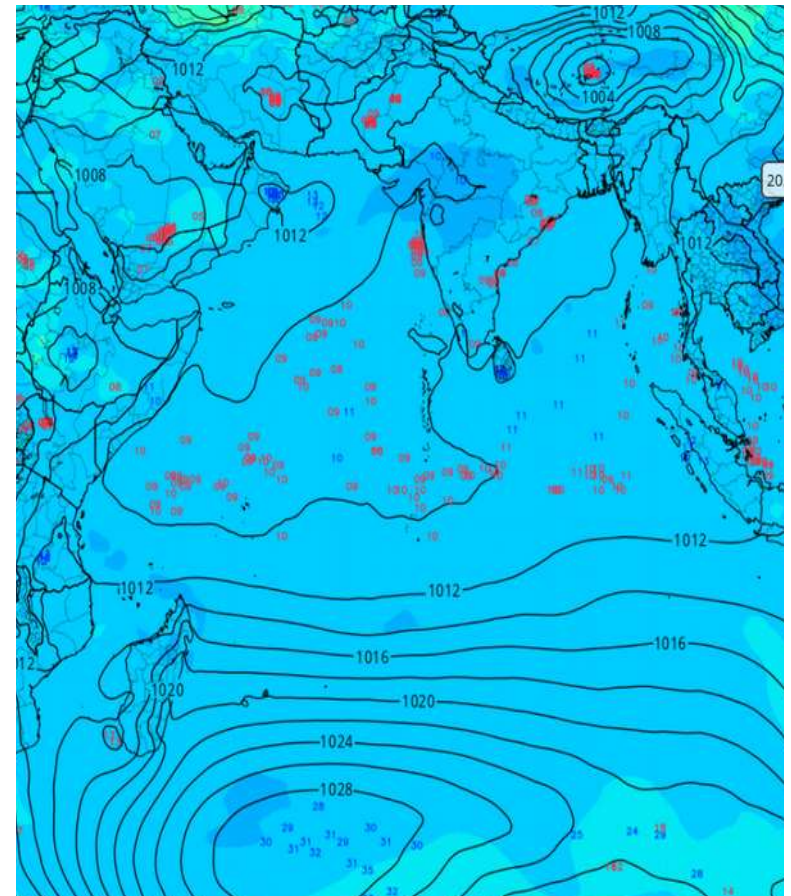
Cyclogenesis : Numerical prediction



Tropical Storm Strikes



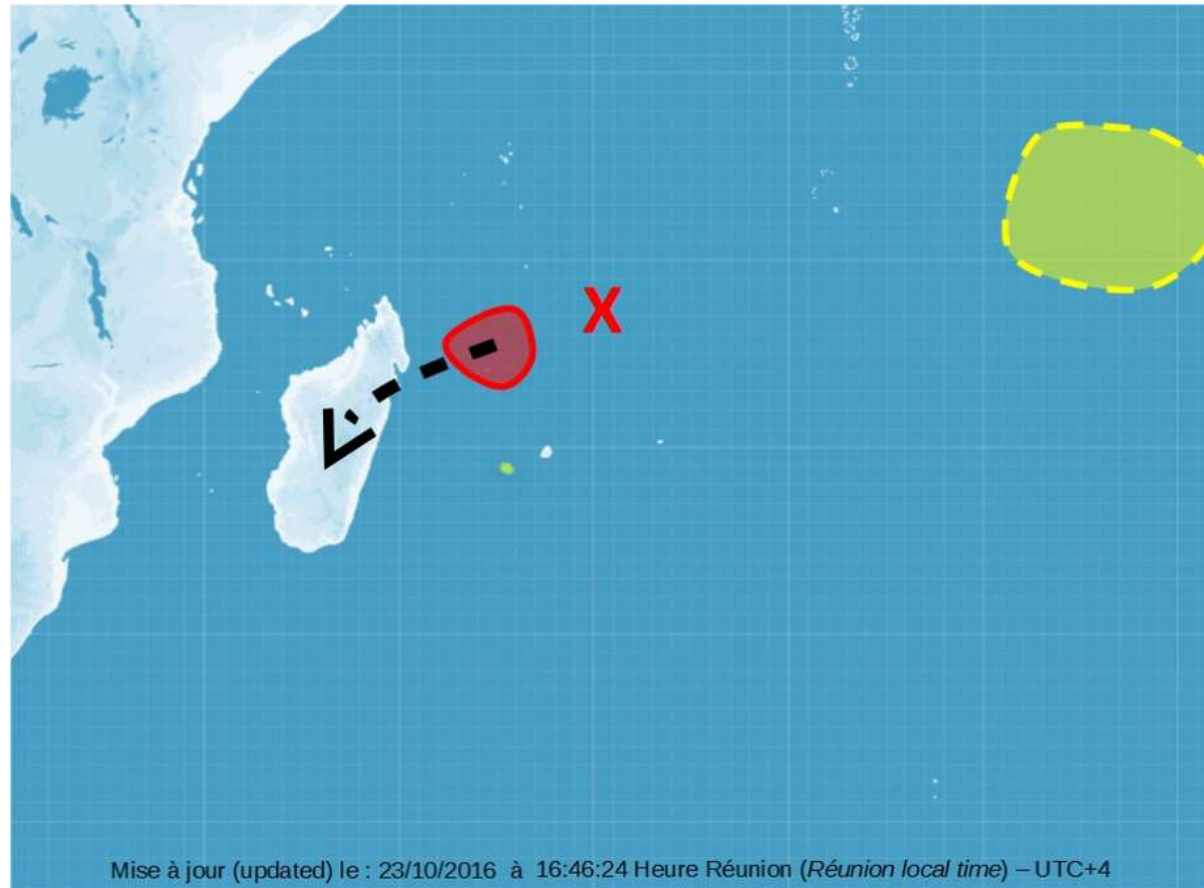
Model fields to subjectively evaluate the environment



GEFS members SLP

Cyclogenesis : RSMC products

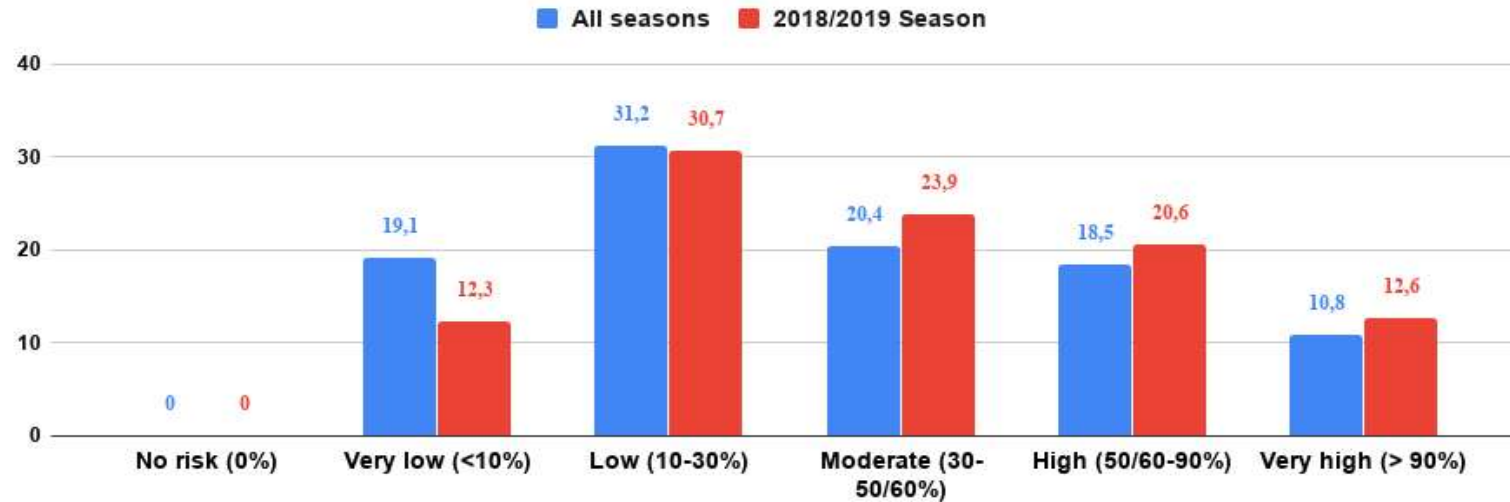
ITCZ bulletin : a 5 Days outlook



Cyclogenesis map
(subjective risk assessment by RSMC forecasters)

Cyclogenesis : RSMC stats

Class usage rates (%)



Fiability of Cyclogenesis Forecasts

