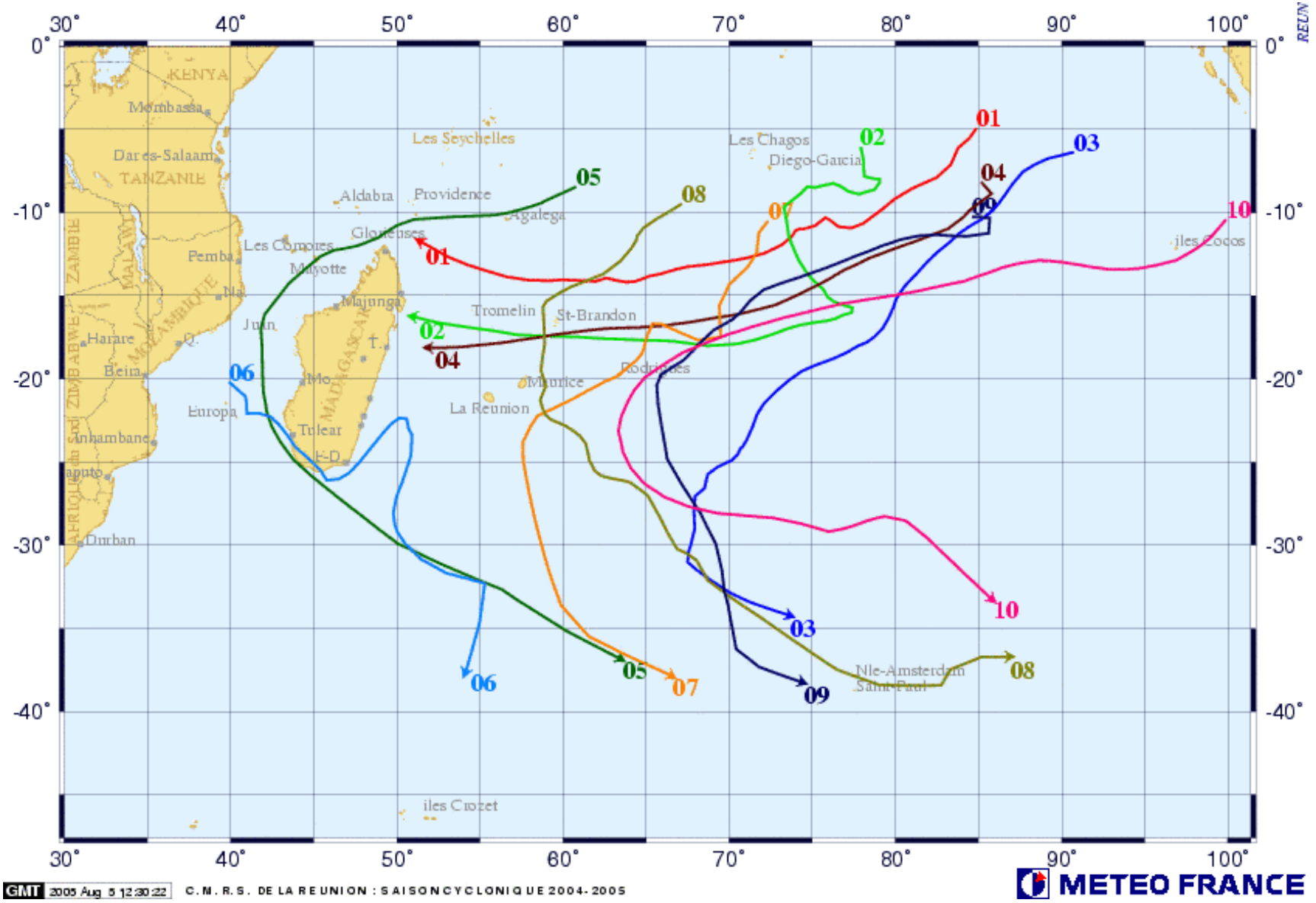
Mechanisms governing TC tracks

Steering flow, Beta effect

Sébastien Langlade Tarik Kriat Adrien Colomb

RA I WMO training course on tropical cyclones 2023

TC season 2004-2005 tracks



Mechanisms governing TC tracks

Steering flow, Beta effect

I) Mechanisms governing tracks

1) Steering flow
2) Bêta effect
3) Fujiwahra effect, islands/land effects

II) Differents types of guidance

1) Deterministic
2) Ensemble forecast
3) Consensus

I)Méchanisms

What's govern TC track ?

- To a first approximation, TC motion is governed by **conservation of relative vorticity** within the large scale steering flow (advection of the vortex within the large scale flow)
- Second order includes the Beta term (**conservation of absolute vorticity**).
- Divergence term (wavenumber 1 asymmetry in convection, interaction with orography, friction)
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→ **3D dynamical model includes all of these terms.**

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$T \sim \frac{L}{V} \sim 5 \times 10^4 \quad sec$

$\zeta \sim \frac{V}{L} \sim 2 \times 10^{-5} sec^{-1}$

$\delta \sim \frac{U}{L} \sim 2 \times 10^{-6} sec^{-1}$

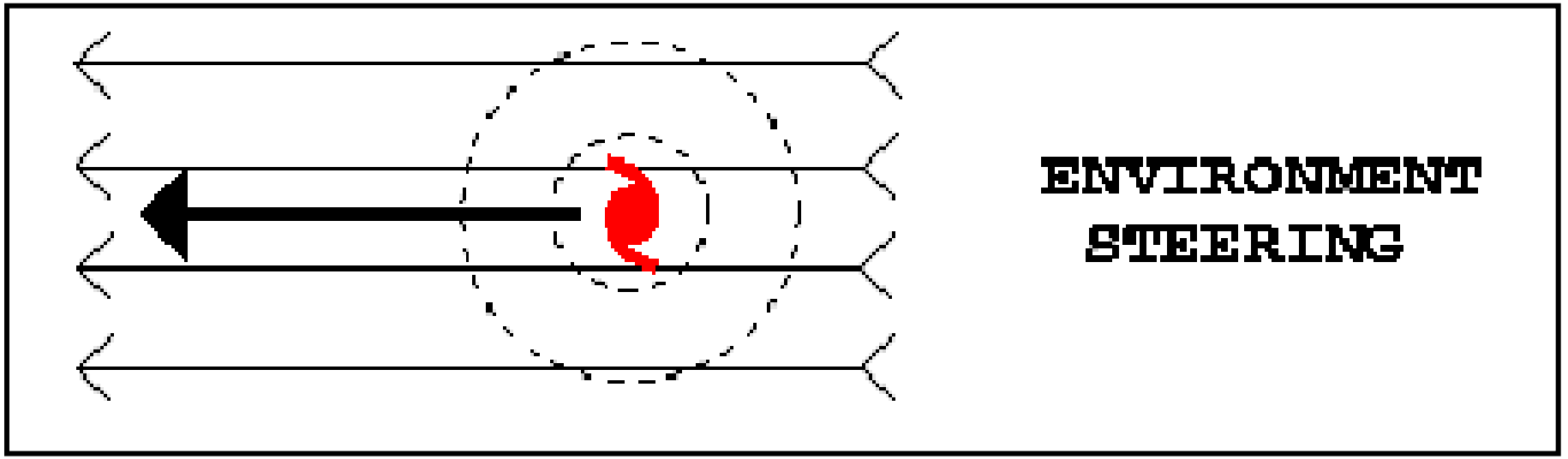
$\omega \sim \delta \Delta P \sim 0.2 \quad Pa/sec$

$$\frac{\partial \zeta}{\partial t} = -V \cdot \nabla \zeta - \omega \frac{\partial \zeta}{\partial P} - \beta v - (\zeta + f)\delta - k \cdot \nabla \omega \times \frac{\partial V}{\partial P}$$

(1) (1) (4) (2) (3) (4)

4×10^{-10} 4×10^{-10} 4×10^{-11} 2×10^{-10} 1×10^{-10} 4×10^{-11}

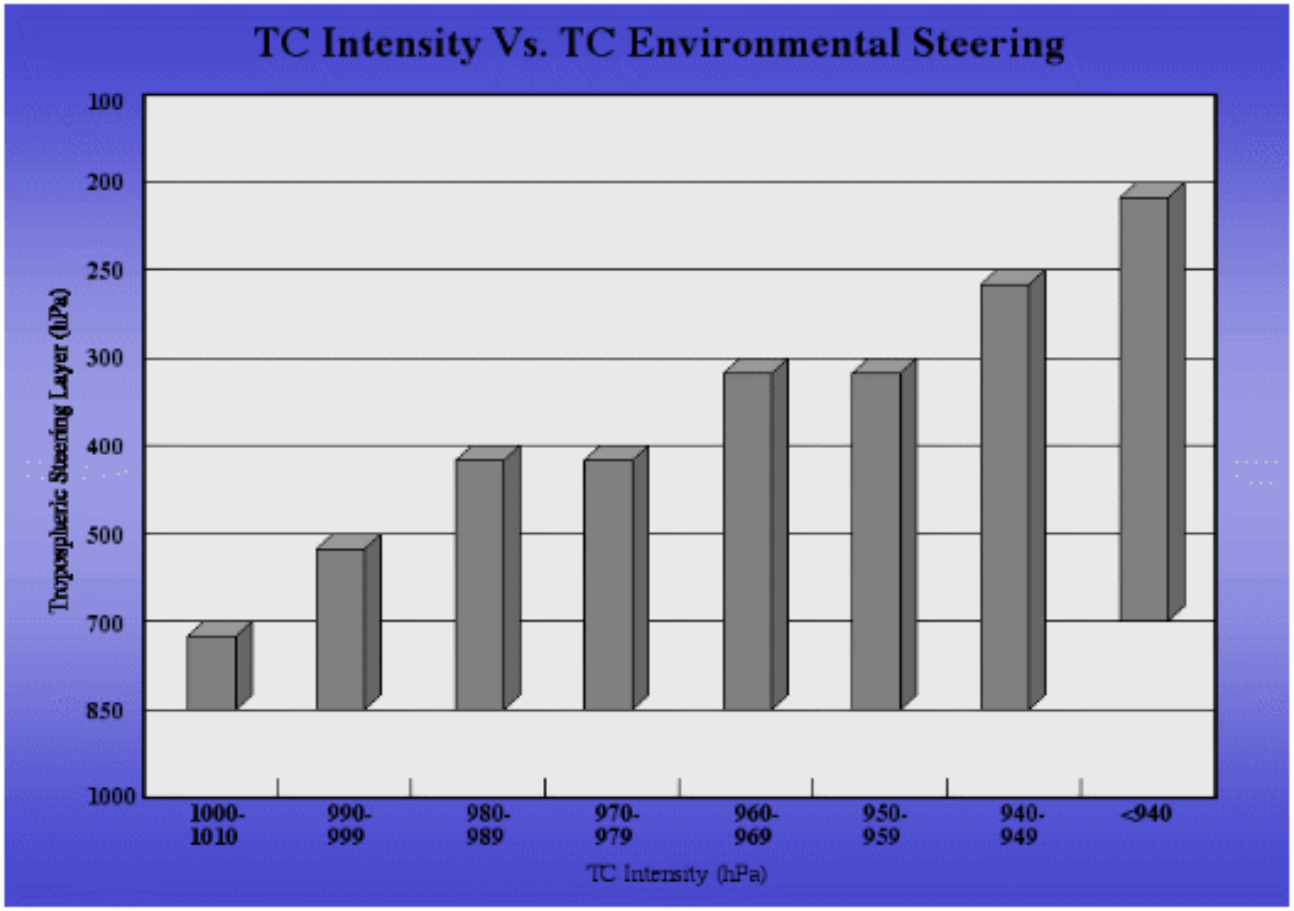
Advection by the steering flow



→ A TC is steered by the horizontal wind characterizing the environment in which it is located

Level of the steering flow

Steering flow level depends on the intensity of the system



Source : Velden and Leslie (1991)

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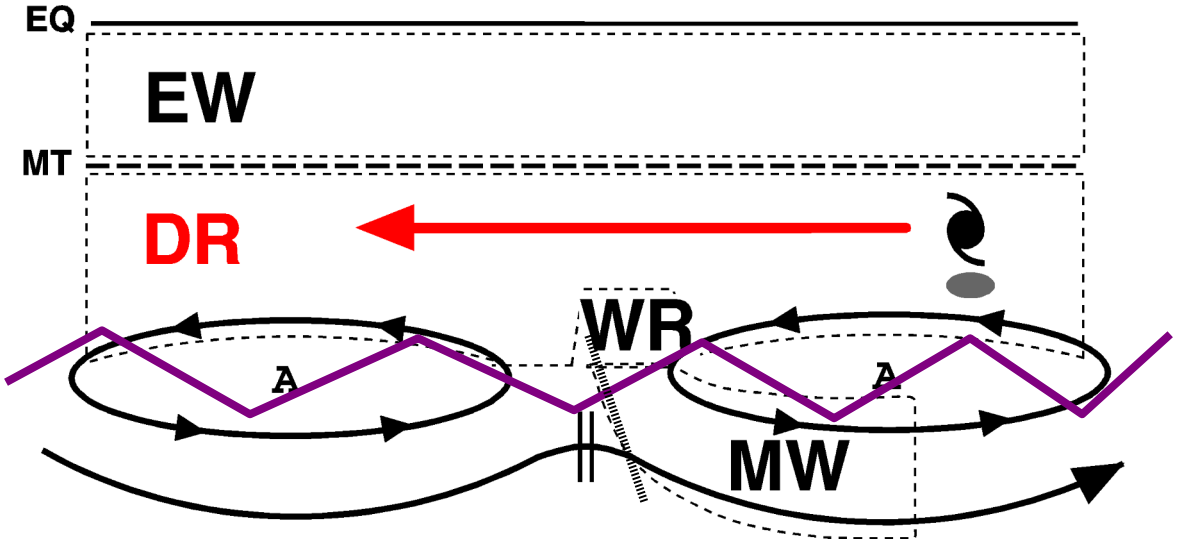
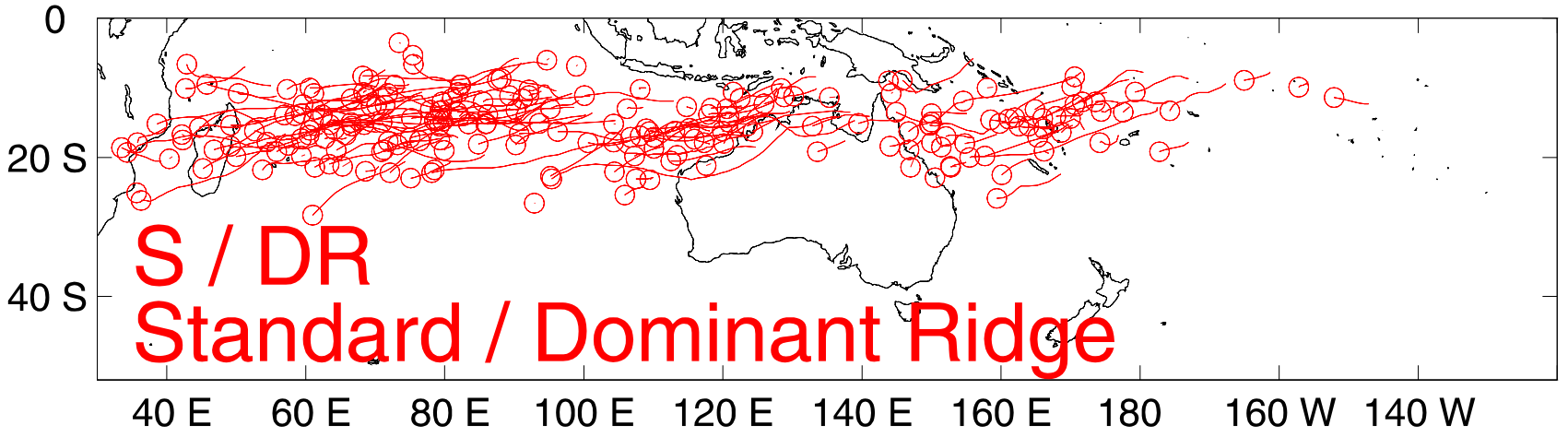
Level of the steering flow

Steering flow level depends on the intensity of the system

Early stage Tropical Depression	**850/700 hPa**
Tropical Storm	**700/500 hPa**
Tropical Cyclone	**500/400 hPa**
ITC / VITC	**500/300 hPa**

Effet de l'environnement





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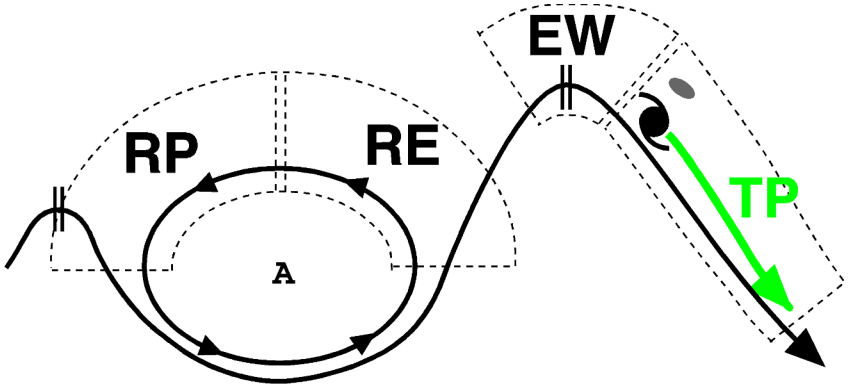
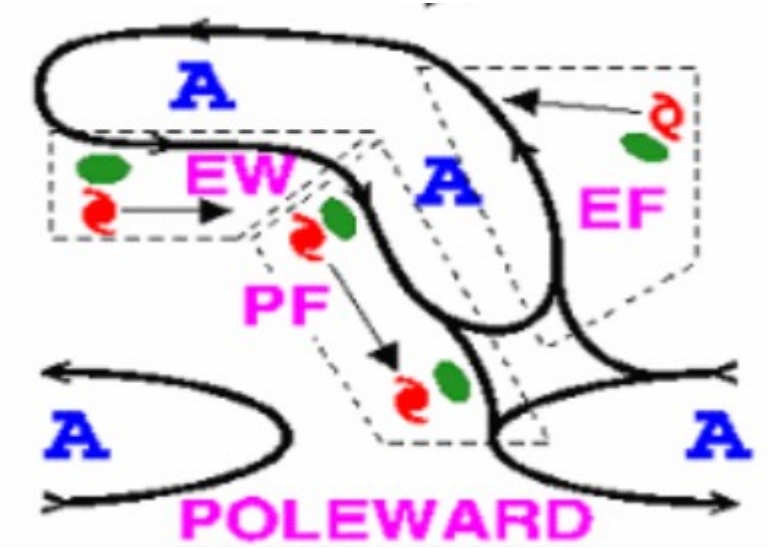
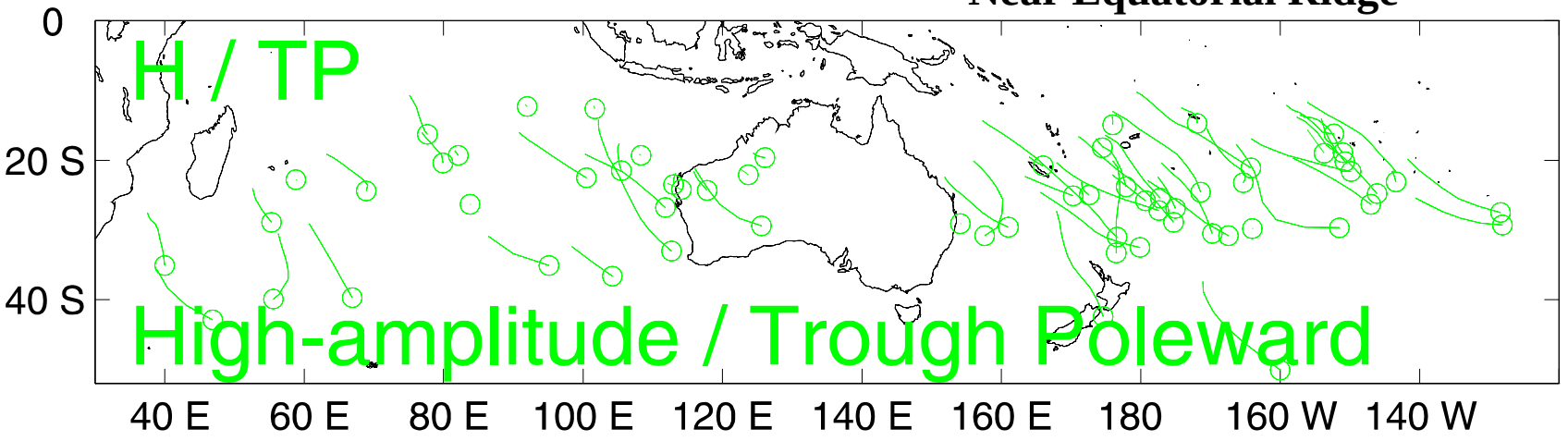


High Amplitude Trough



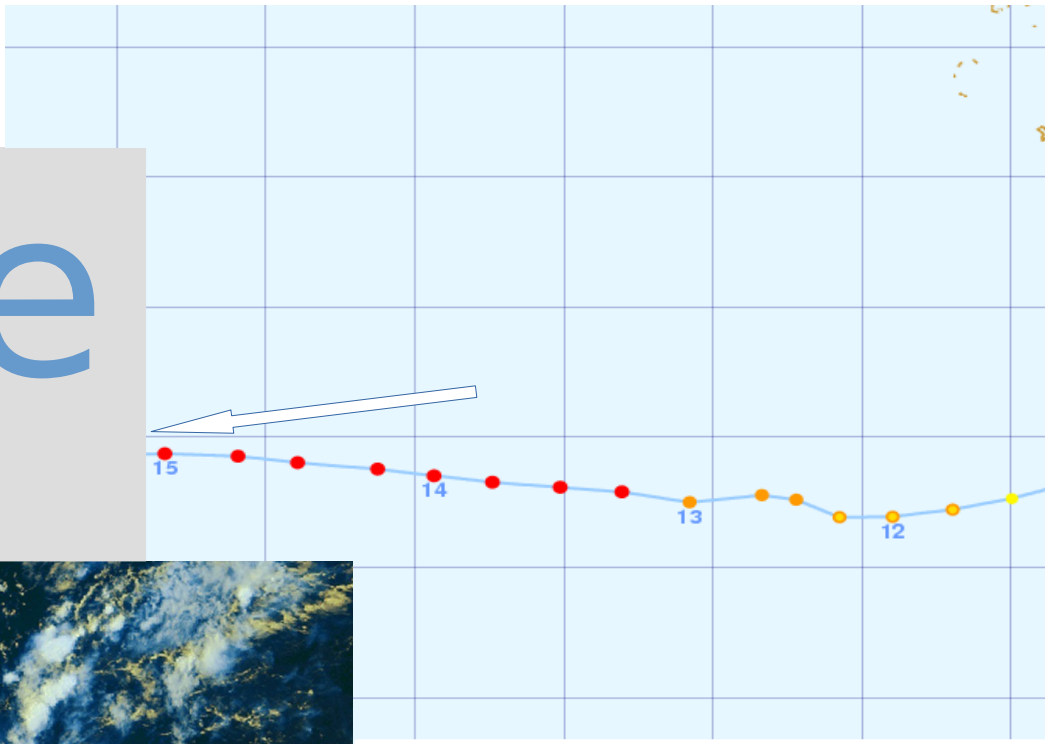
Near Equatorial Ridge

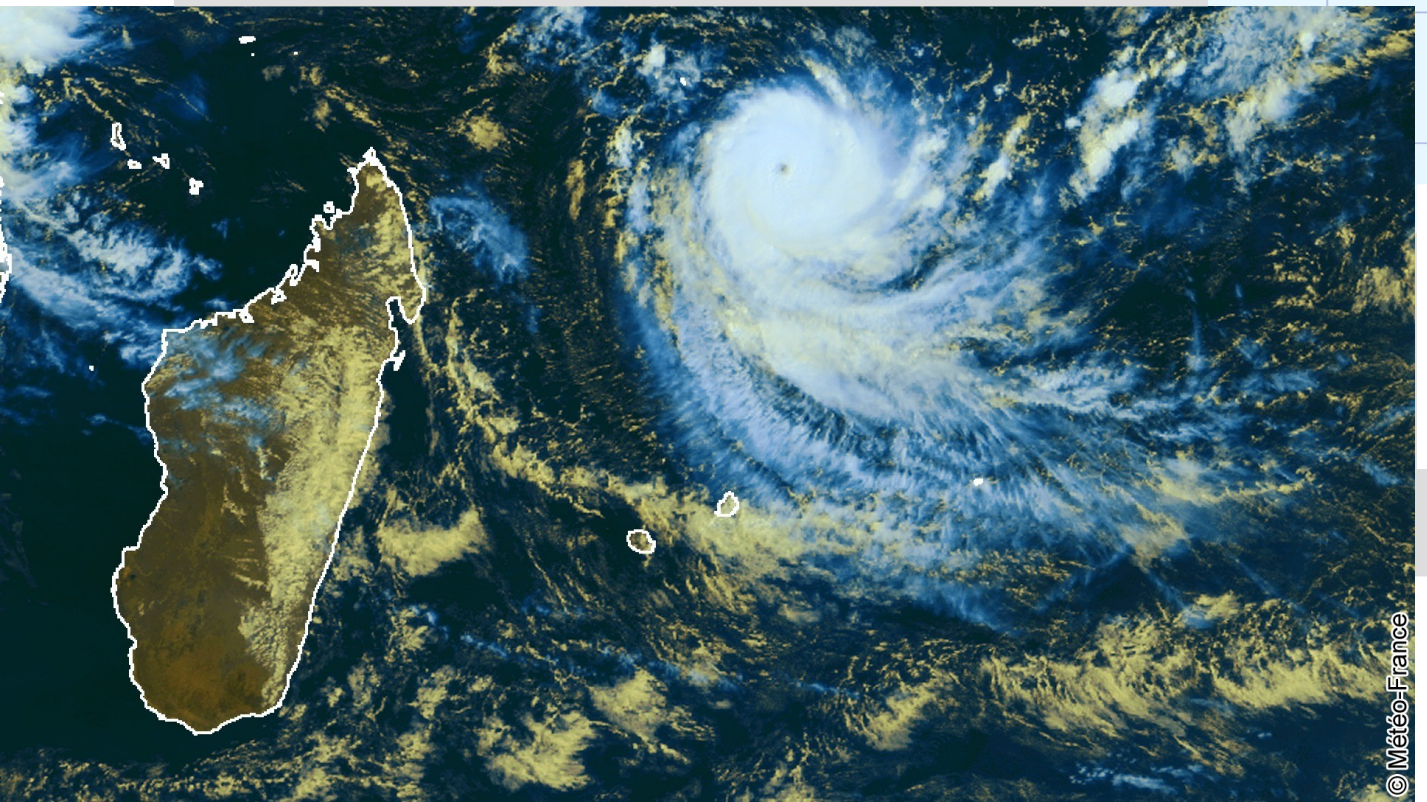


Exercise

Identify the level of the steering flow and recognize the synoptic actors that are driving it !

Exercise





15/04/16 at 12Z :
CTI Fantala (Vmax :110 kt)
Forward motion : westwards (263°) at 16 km/h

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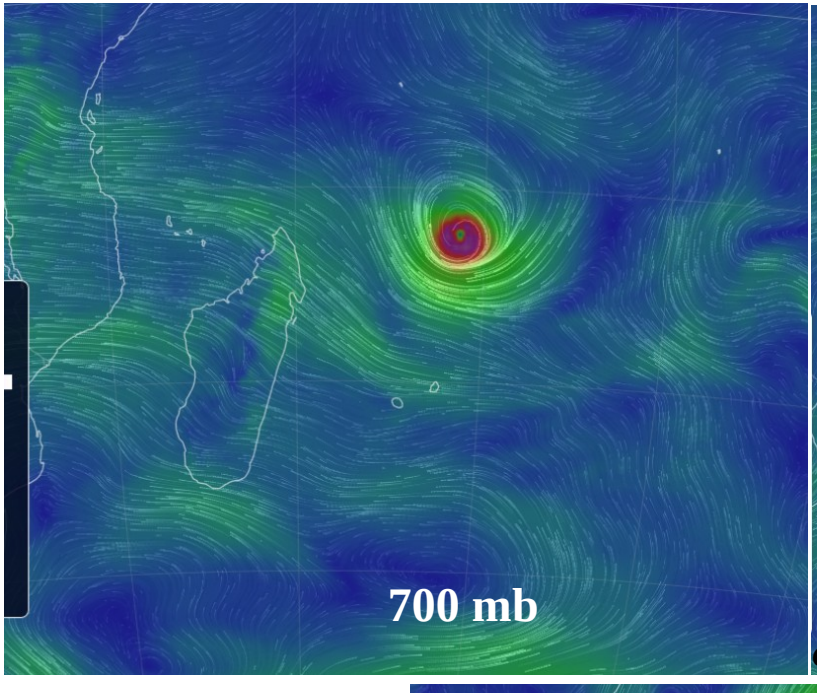
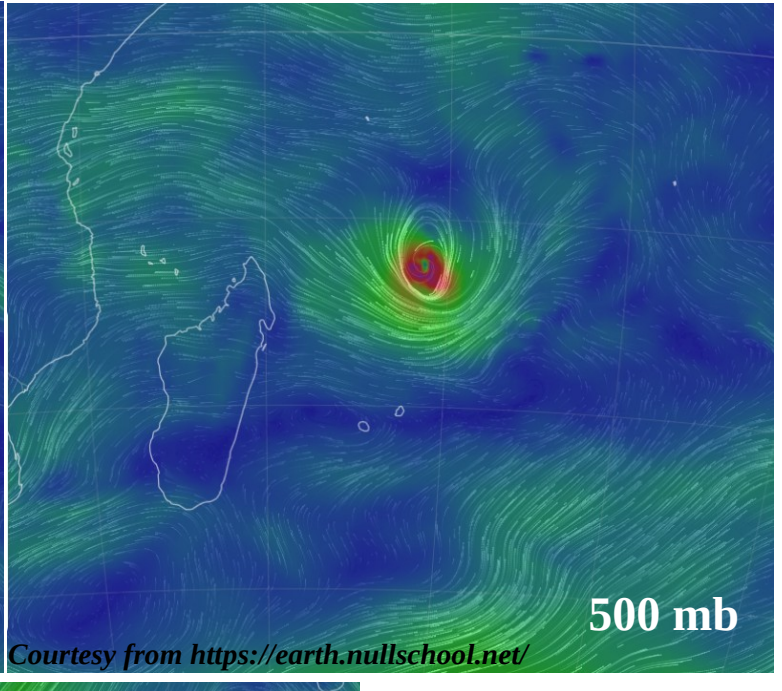
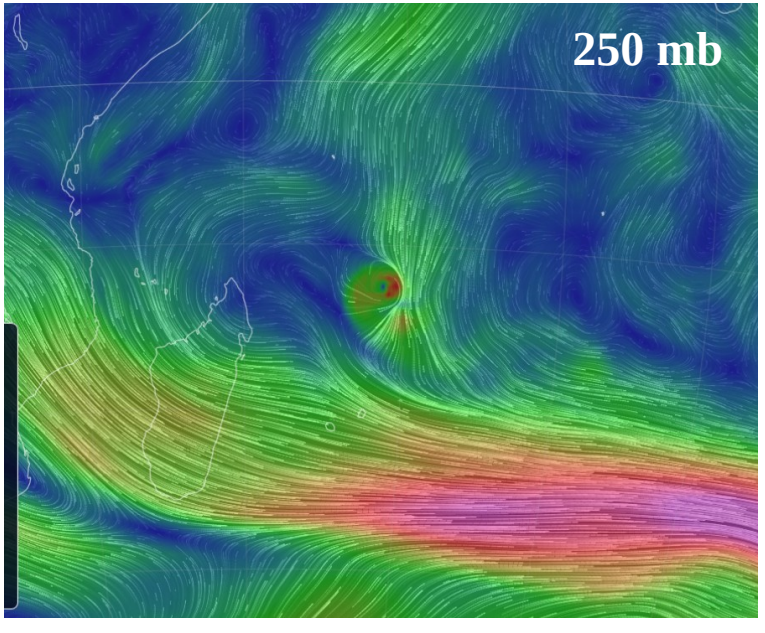
Which levels is appropriate for steering flow based on current forward motion and intensity ?

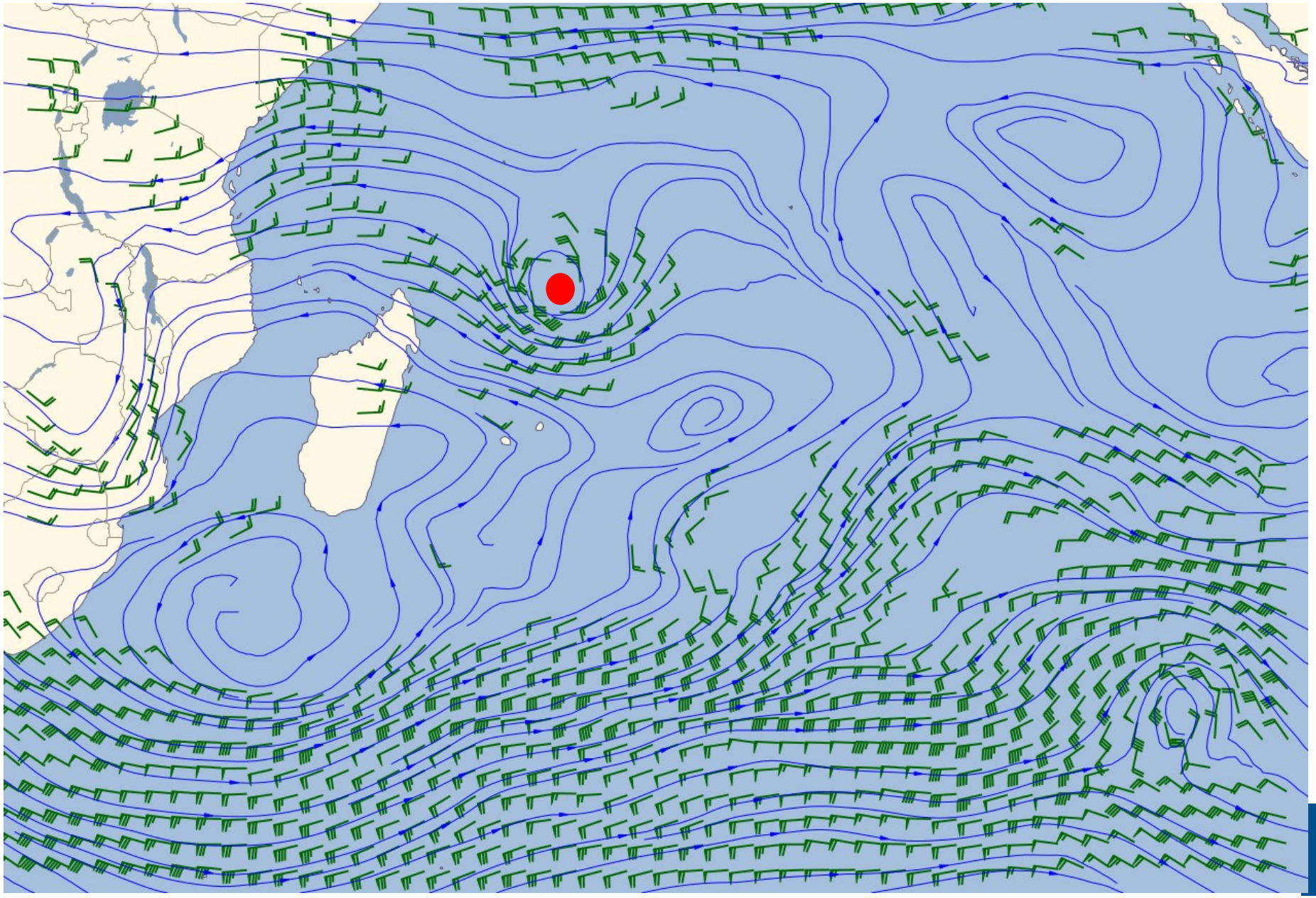




Courtesy from https://earth.nullschool.net/



Situation at 500 hPa the 15/04/16 at 12Z (Fantala position in red)



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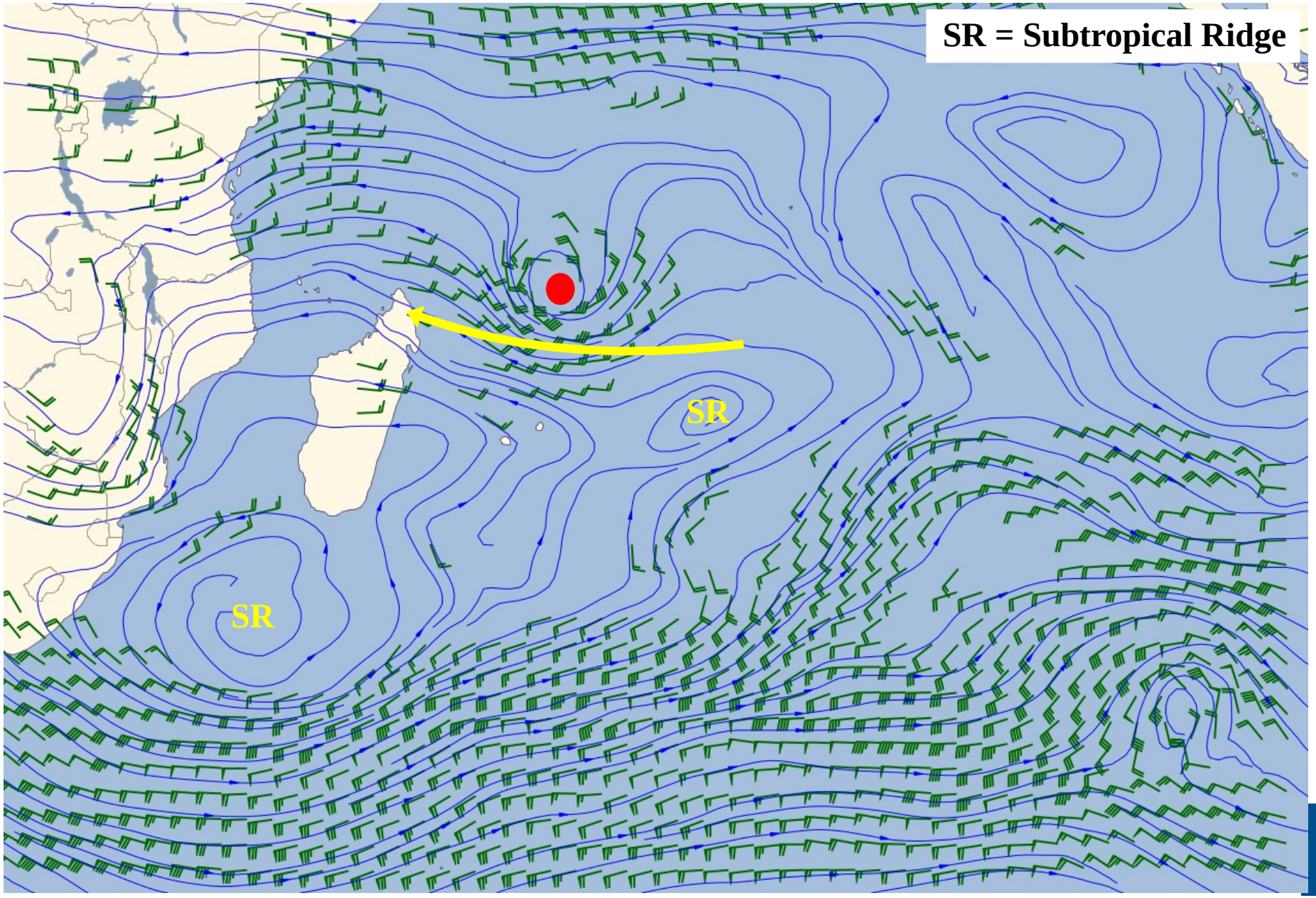
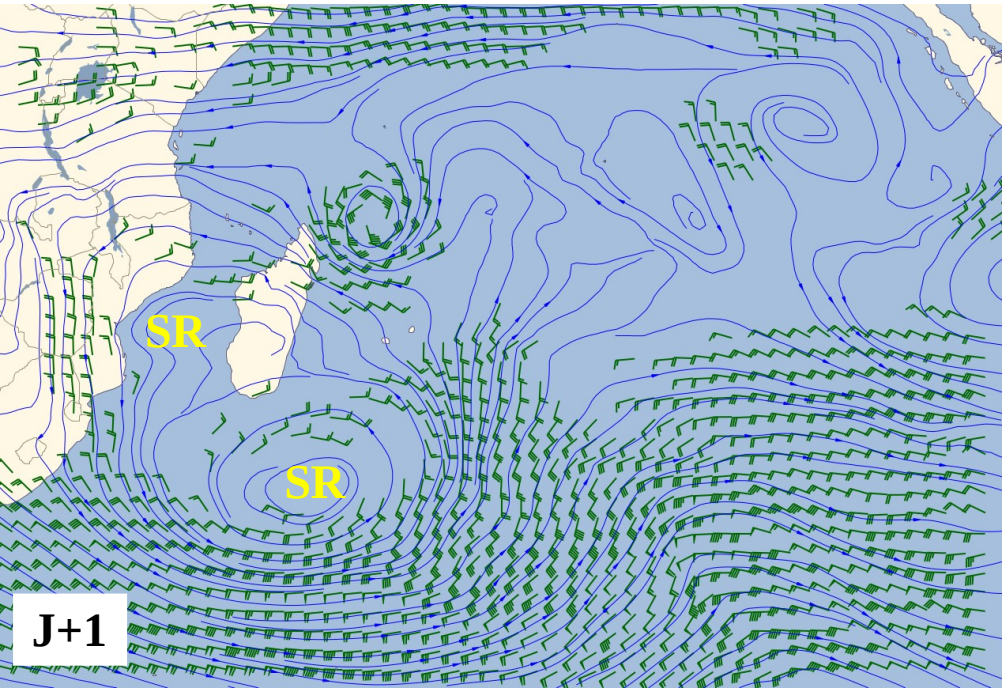
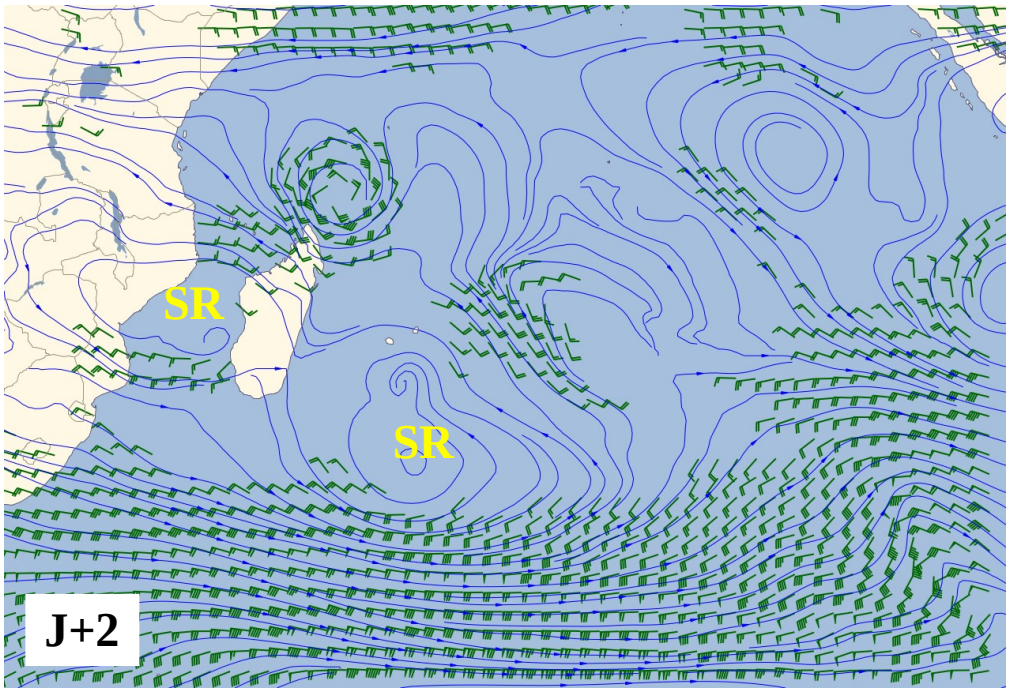
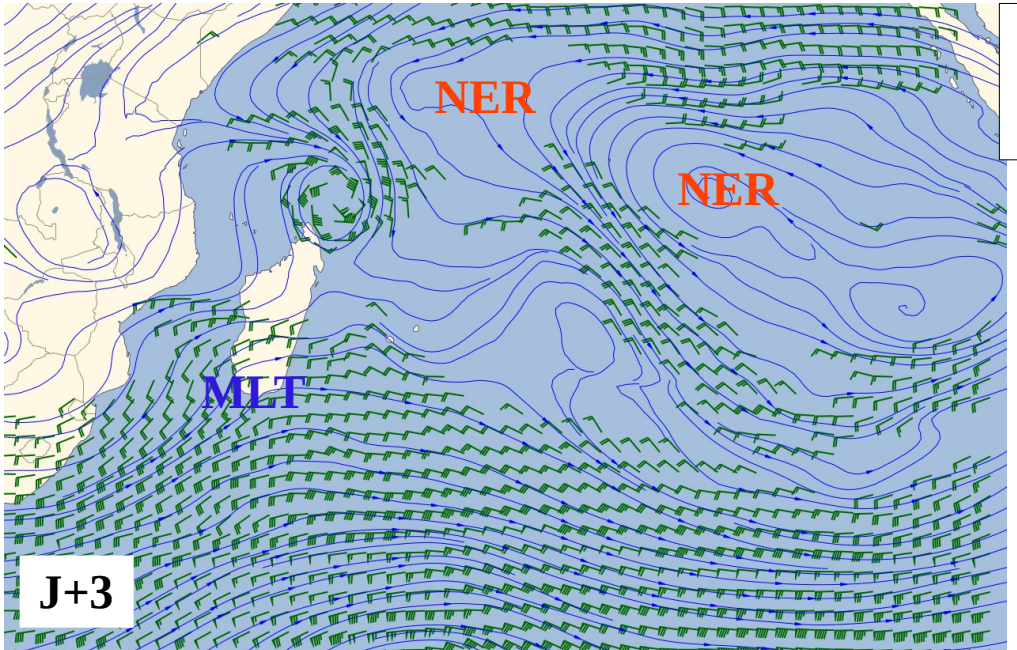


Forecast of the 500 hPa wind up to day3 (1 picture / day)







SR = Subtropical Ridge
NER = Near Equatorial Ridge
MLT = Mid-levels Trough

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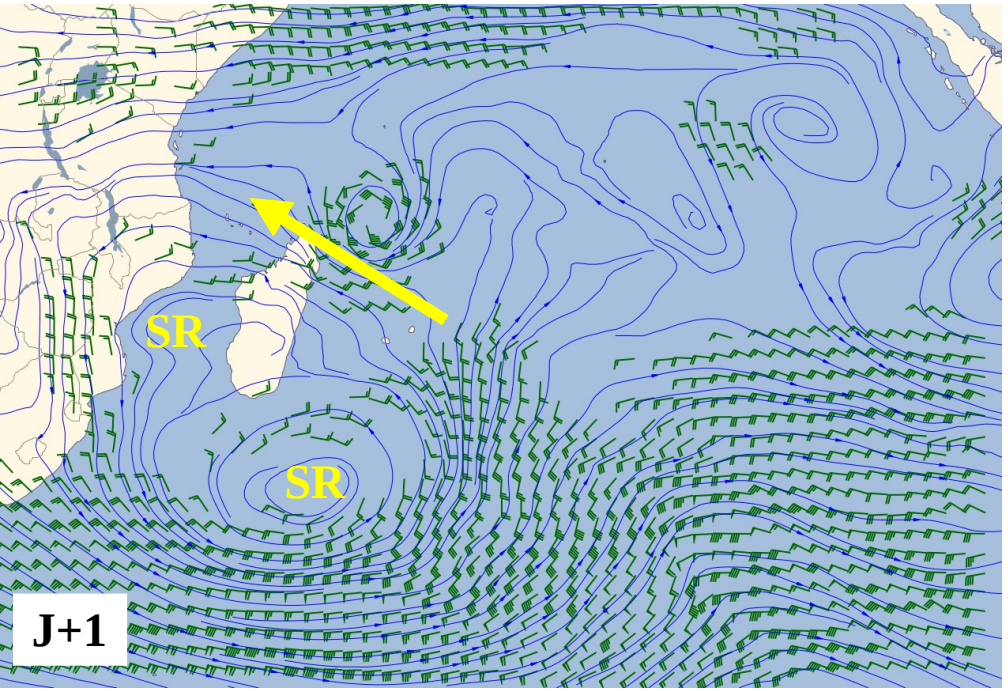

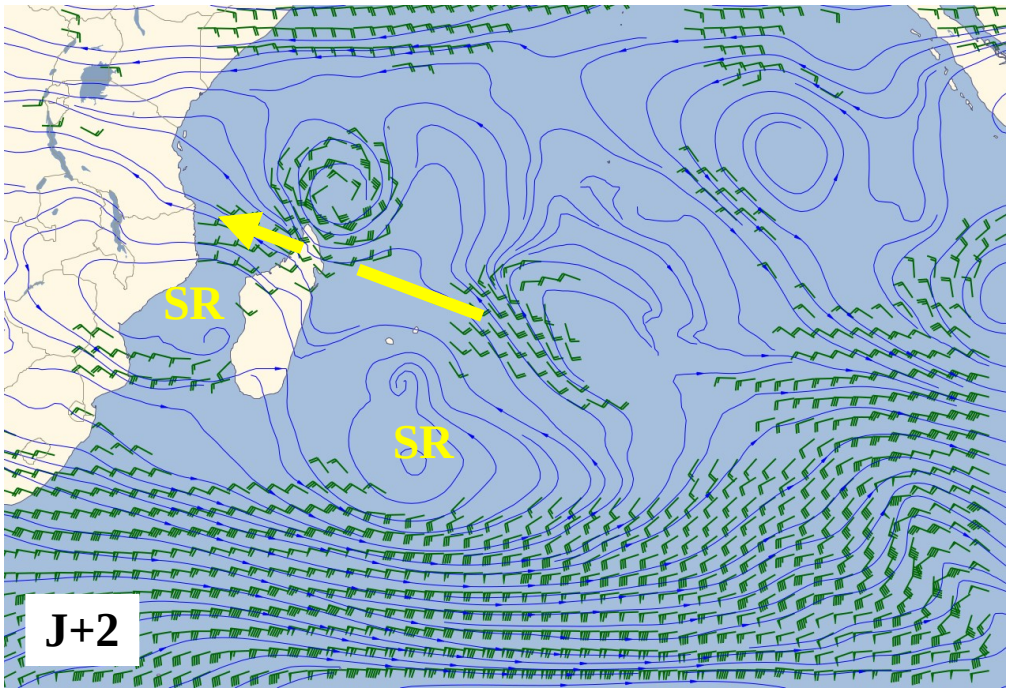

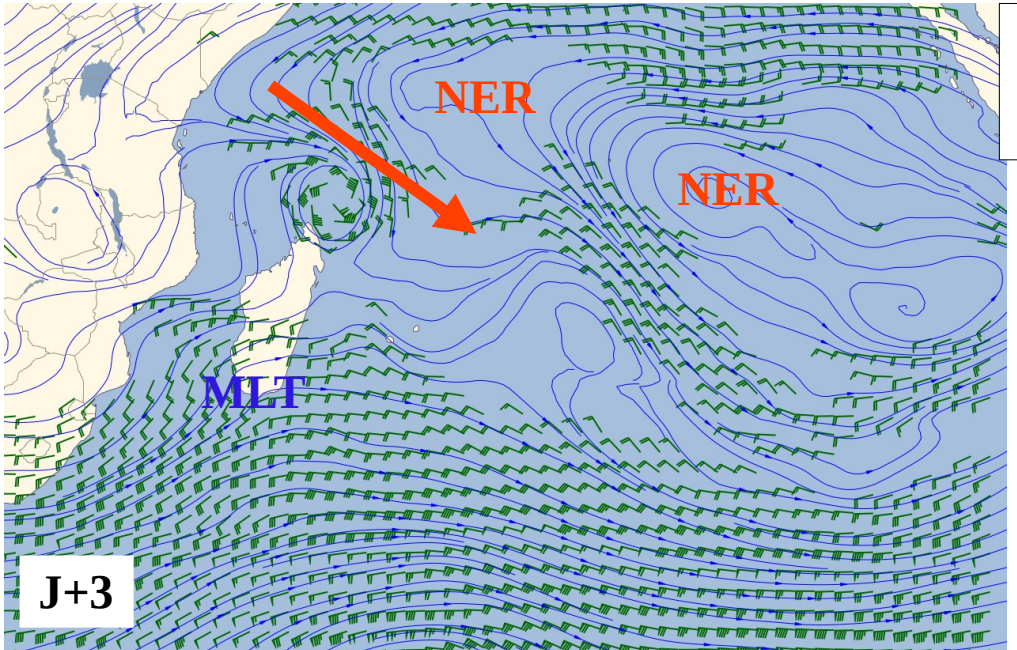

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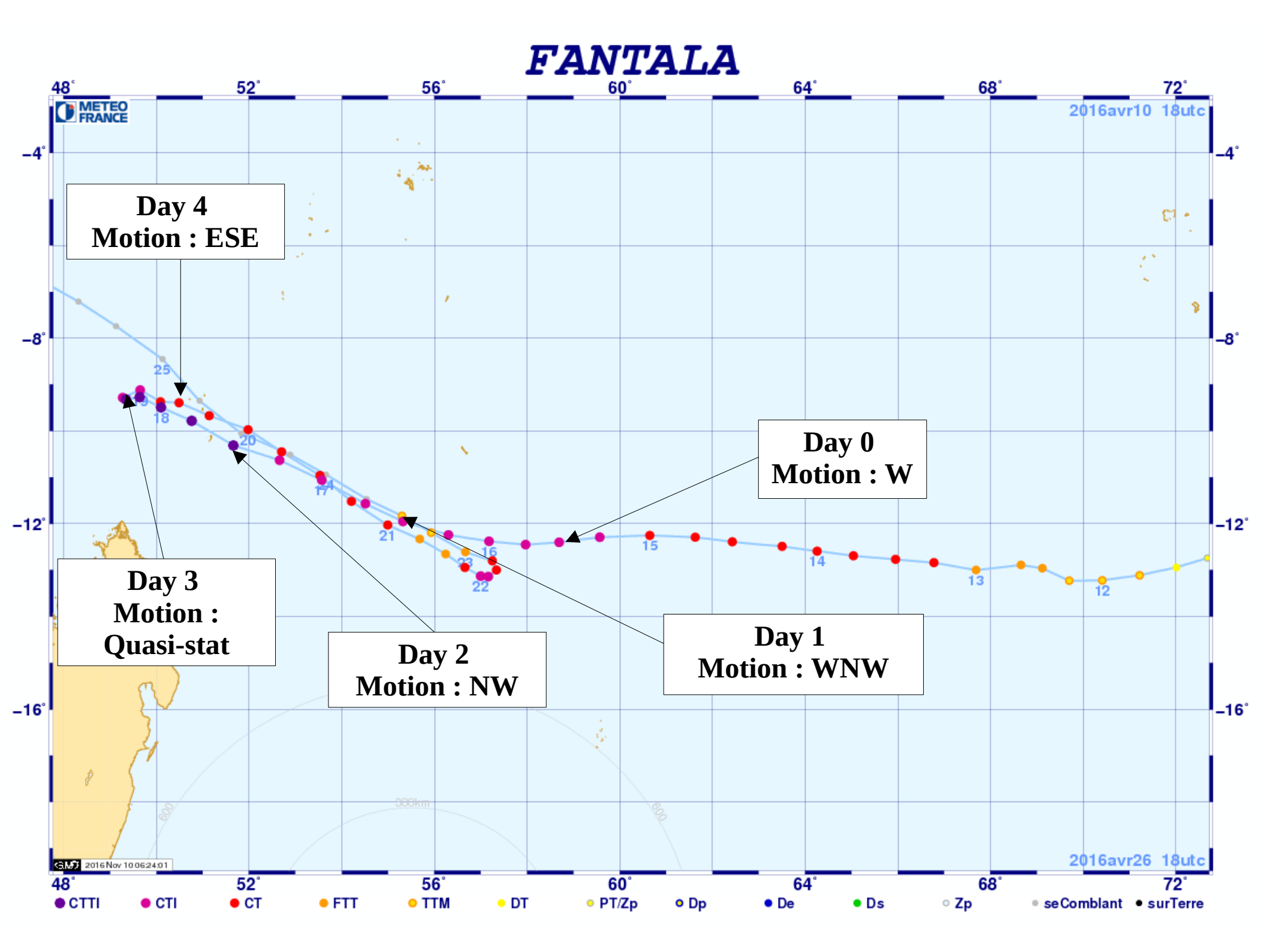
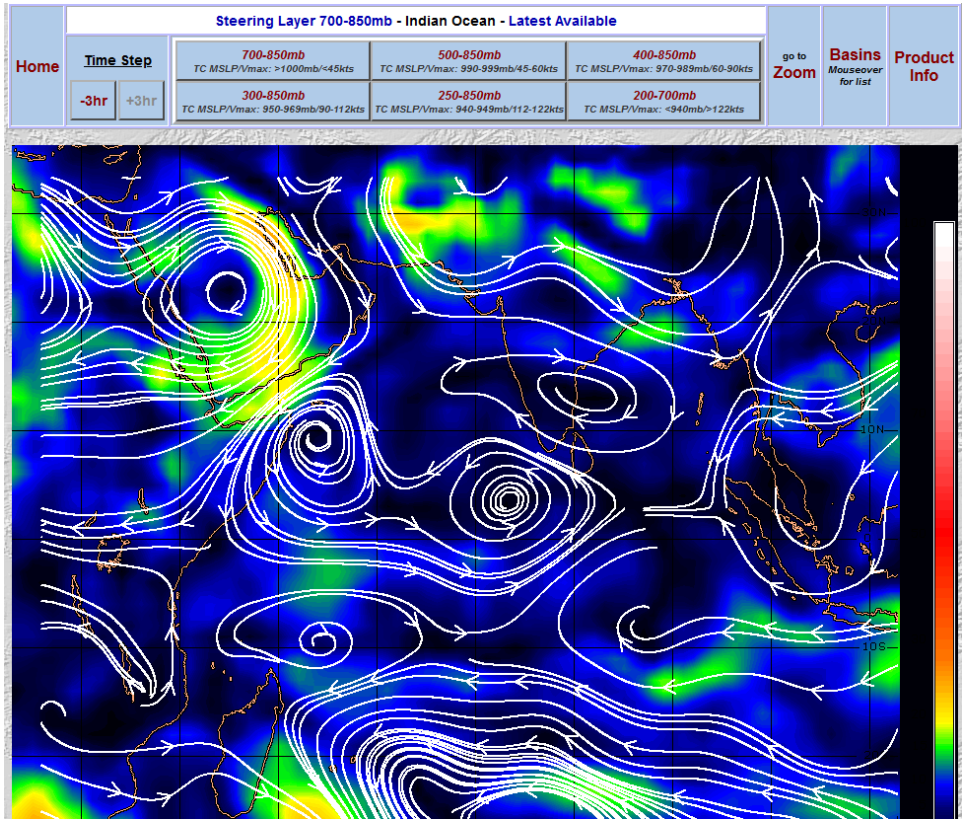
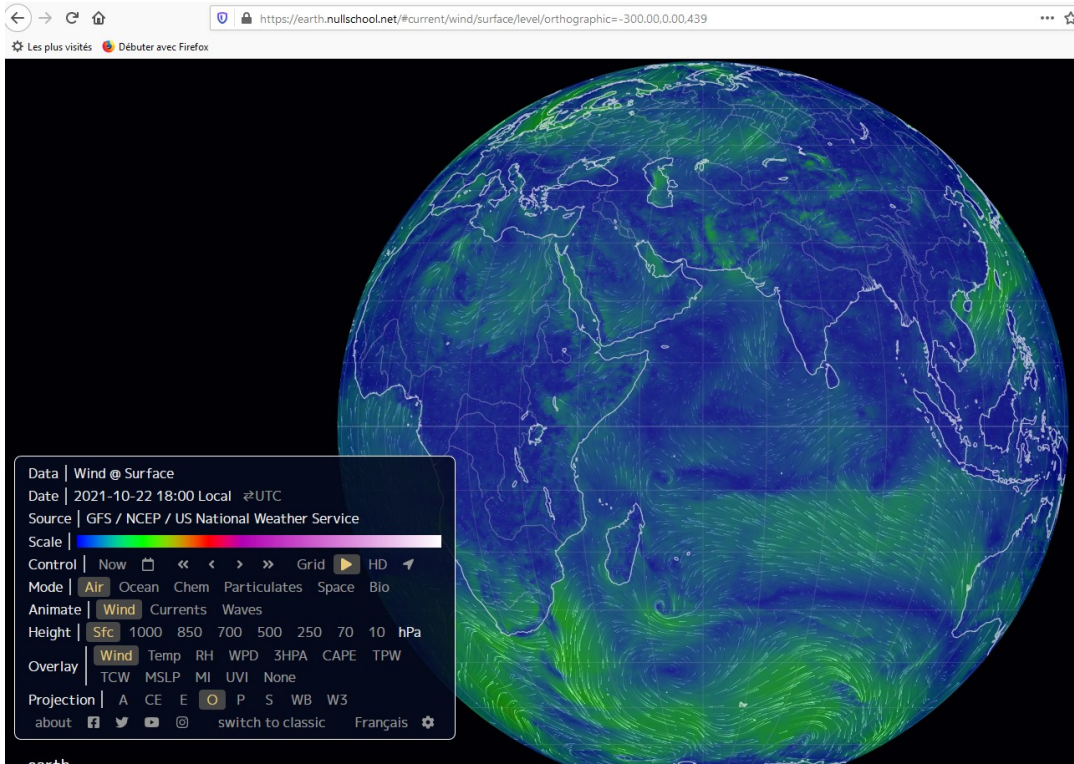

FANTALA
METEO FRANCE
2016avr10 18utc
2016avr26 18utc
48°
52°
56°
60°
64°
68°
72°
-4°
-8°
-12°
-16°
Day 4
Motion : ESE
Day 0
Motion : W
Day 3
Motion :
Quasi-stat
Day 2
Motion : NW
Day 1
Motion : WNW
CTTI
CTI
CT
FTT
TTM
DT
PT/Zp
Dp
De
Ds
Zp
seComblant
surTerre

Useful websites



Observed deep layer winds - CIMSS



Earth nullschool (or windy) for forecast windfield

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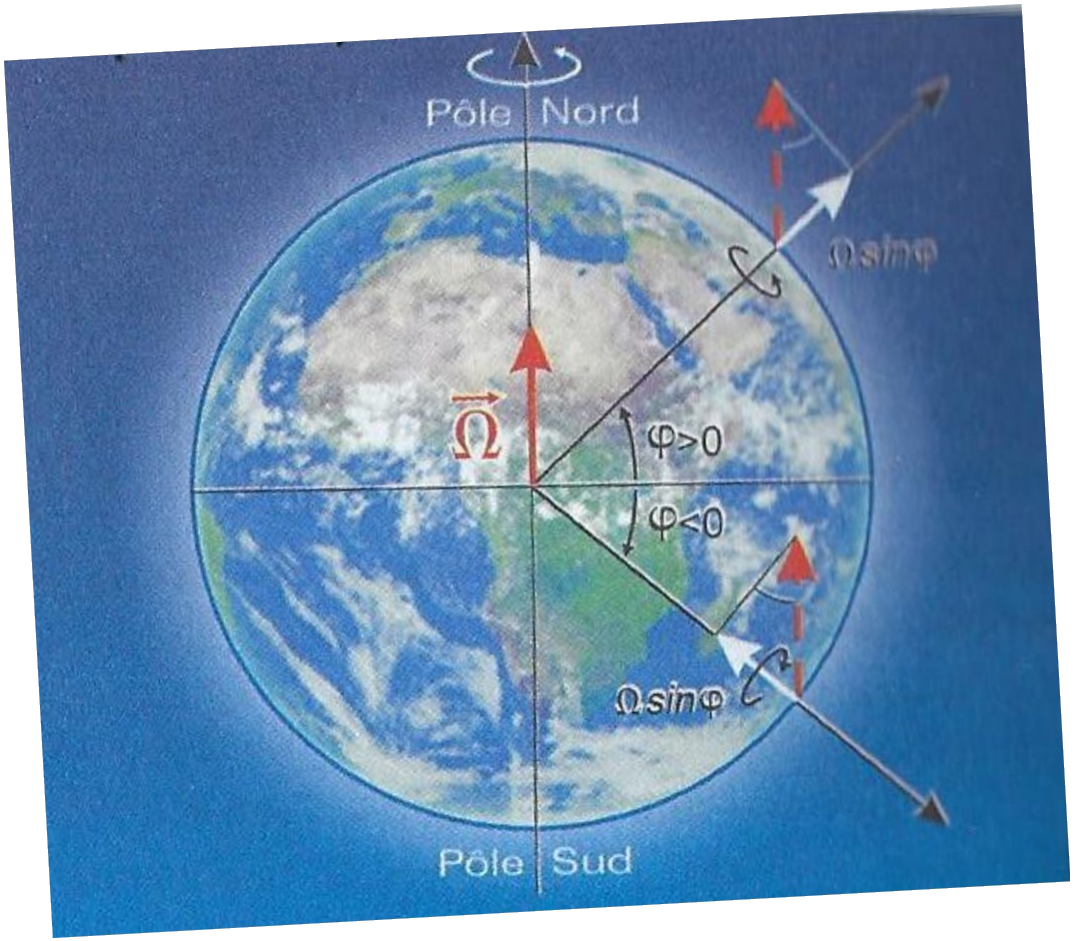
β effect

- **Reminder on the planetary vortex**



$$f = 2\,\Omega \sin\varphi$$

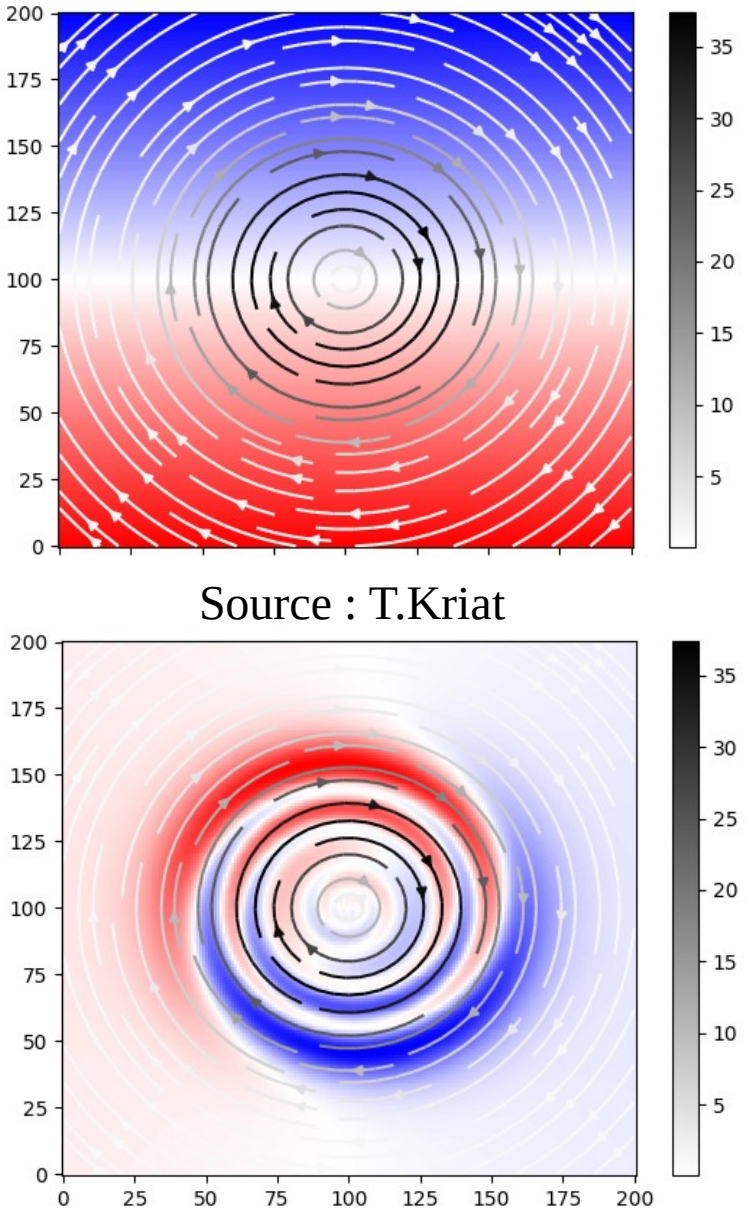
Source: S.Malardel

β effect

- The circulation of a TC, combined with the North-South variation of the Coriolis parameter, induces asymmetries known as **Beta Gyres.**

- Beta Gyres produce a net steering current across the TC, generally towards the NW (northern hemisphere) or towards the SW (southern hemisphere). This motion is known as the **Beta Drift.**

- **15/20 %** of TC motion **(2-4kt), d**epend on outer wind structure – **more pronounced effect for large TCs,** taken into account by NWP models



Source : T.Kriat

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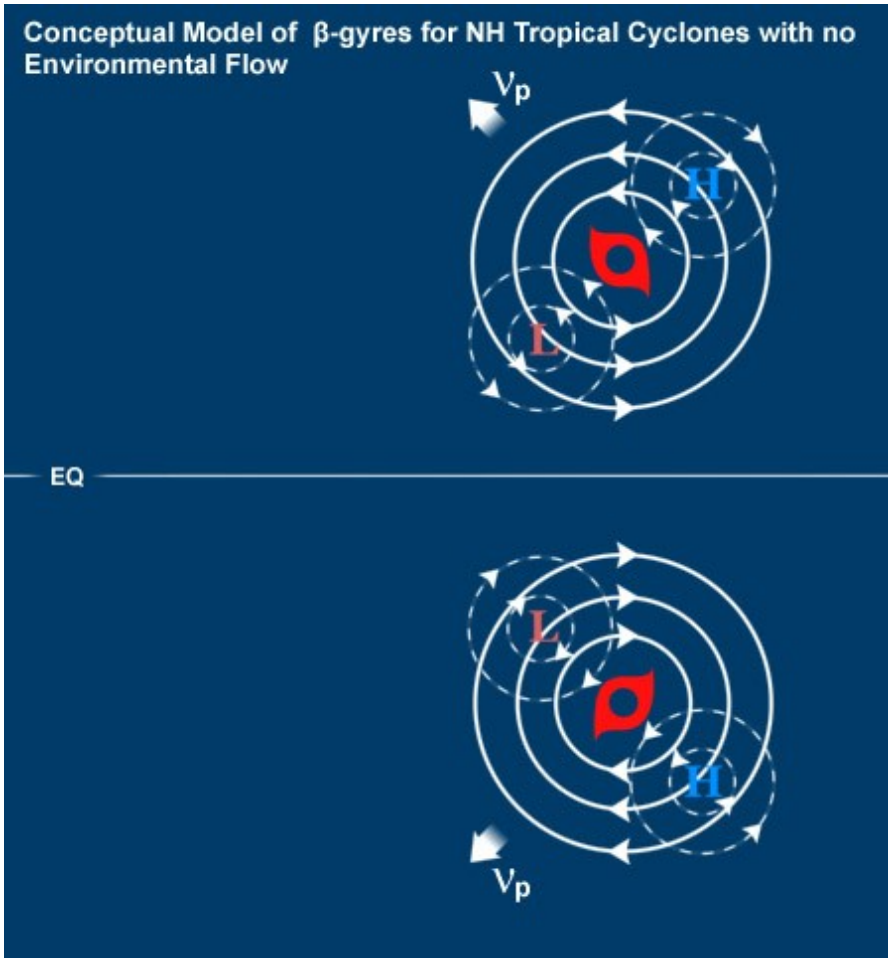

Source : Comet Program

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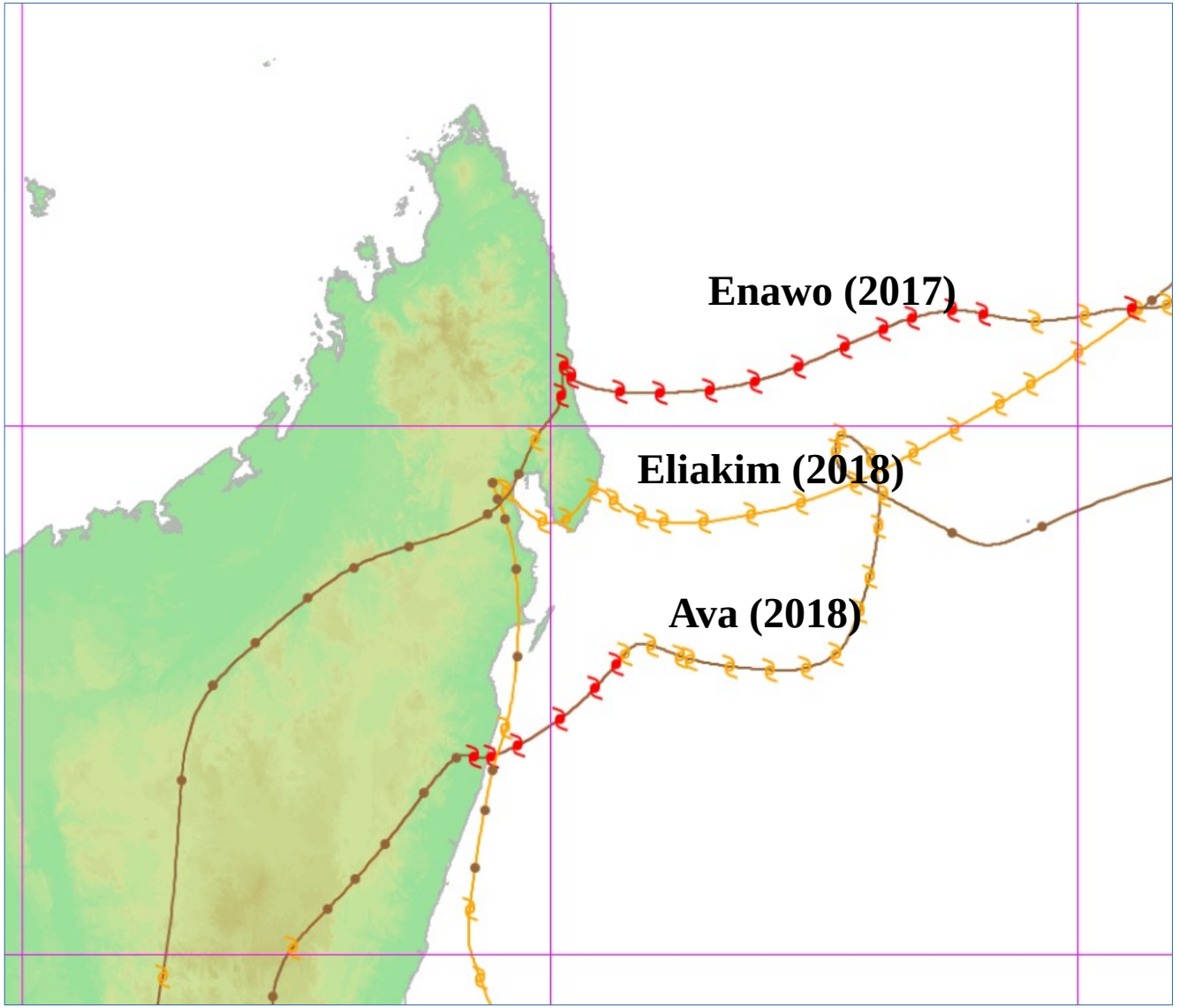
4×10^{-10} 4×10^{-10} 4×10^{-11} 2×10^{-10} 1×10^{-10} 4×10^{-11}

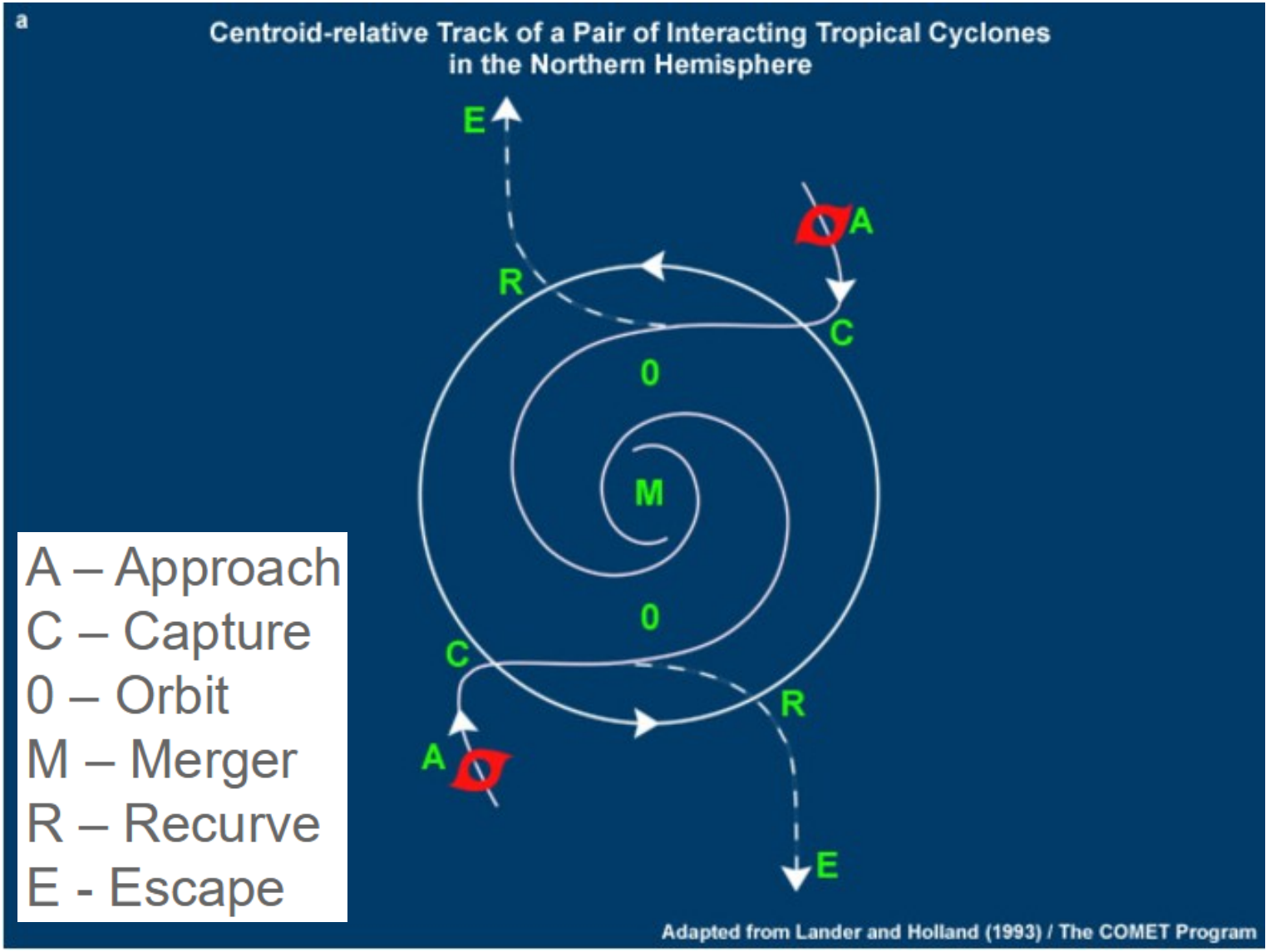
Effect of the relief of an island on the track



→ A deviation to the right (equatorward deviation) is noticed for recurving TS/TC that made landfall over the north-eastern coasts of Madagascar

→ Reasons are unclear and apparently at odd with observations from the North-Western Pacific (Taïwan and Philippines), were a polewards deviation is noticed (Yeh and Elsberry, 1993)

Effet Fujiwhara

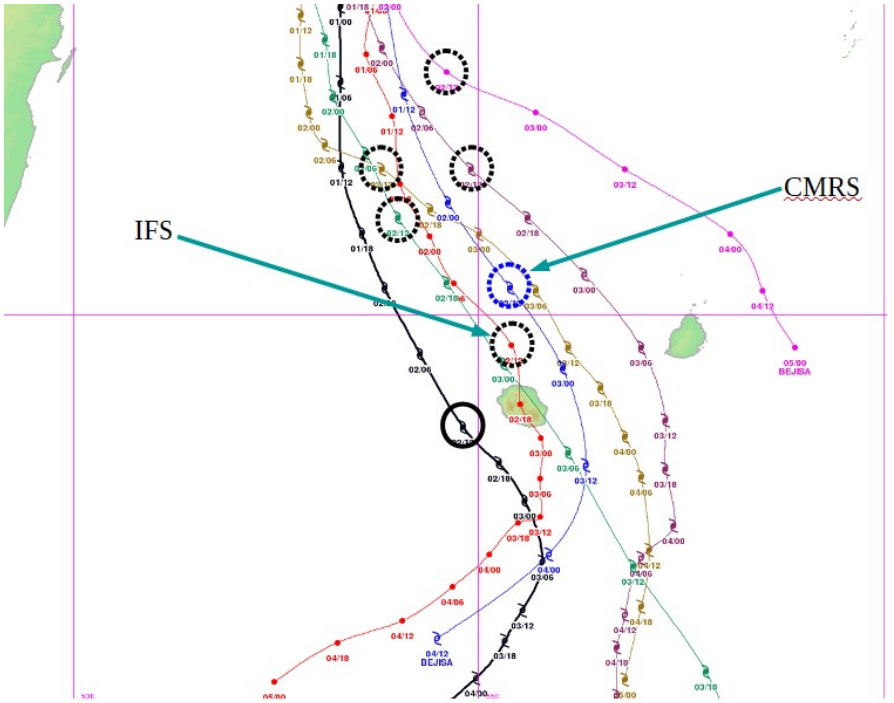


- **Interaction binaire entre 2 systèmes** = le flux directeur de l'un est donné par la circulation dépressionnaire de l'autre …
- Dépend de la taille des systèmes et de la distance de séparation (moins de 1000 km en général)

II) Guidances

Differents types of « guidance »

- **Deterministic models**



Prévision à J+3 pour le cyclone Béjisa (30/12/13 à 12Z)

Use :

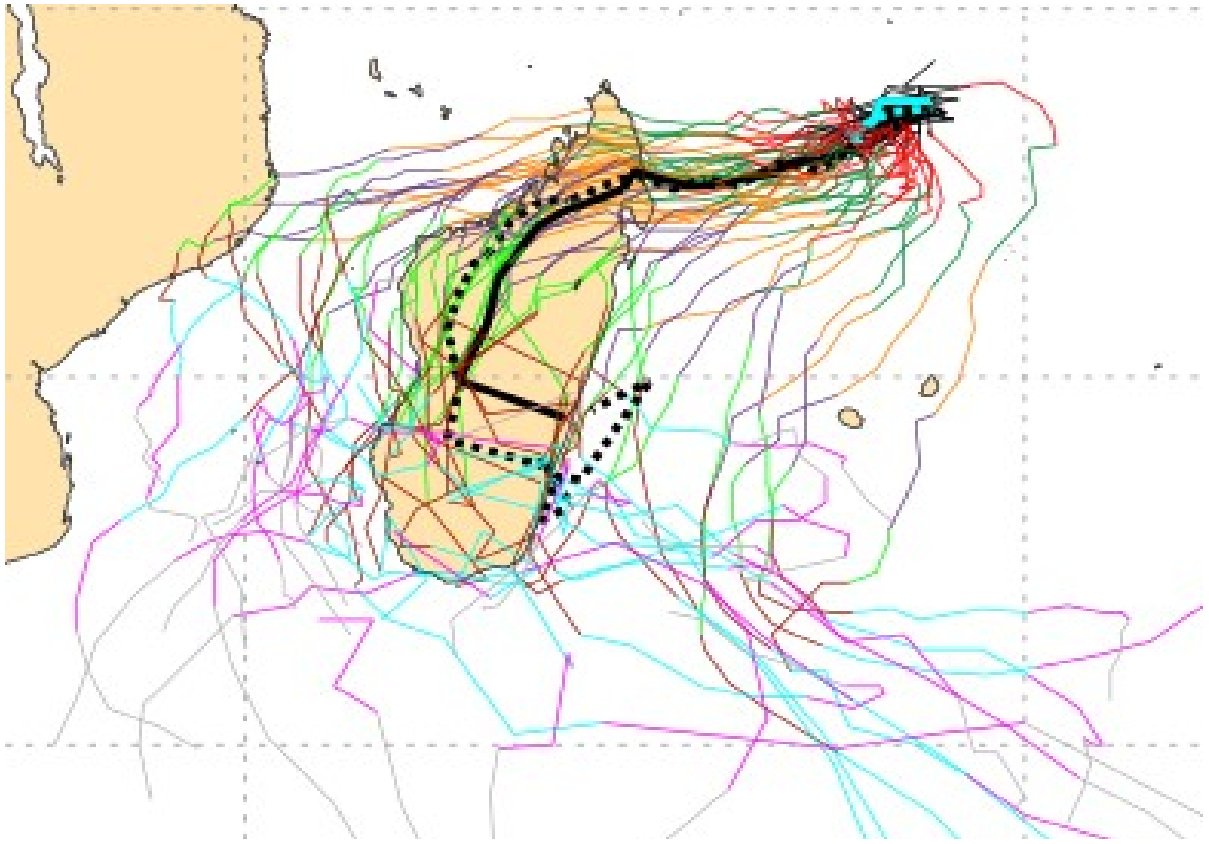
- Identify the dominant scenario(s)
- Evaluate the influence of the environment
- Serve as a basis for model consensus

Criteria for choosing a model :

- Climatological skill
- Quality of the position/intensity analysis
- Representation of the environment
- Skill over the current system

Differents types of « guidance »

Ensemble forecast



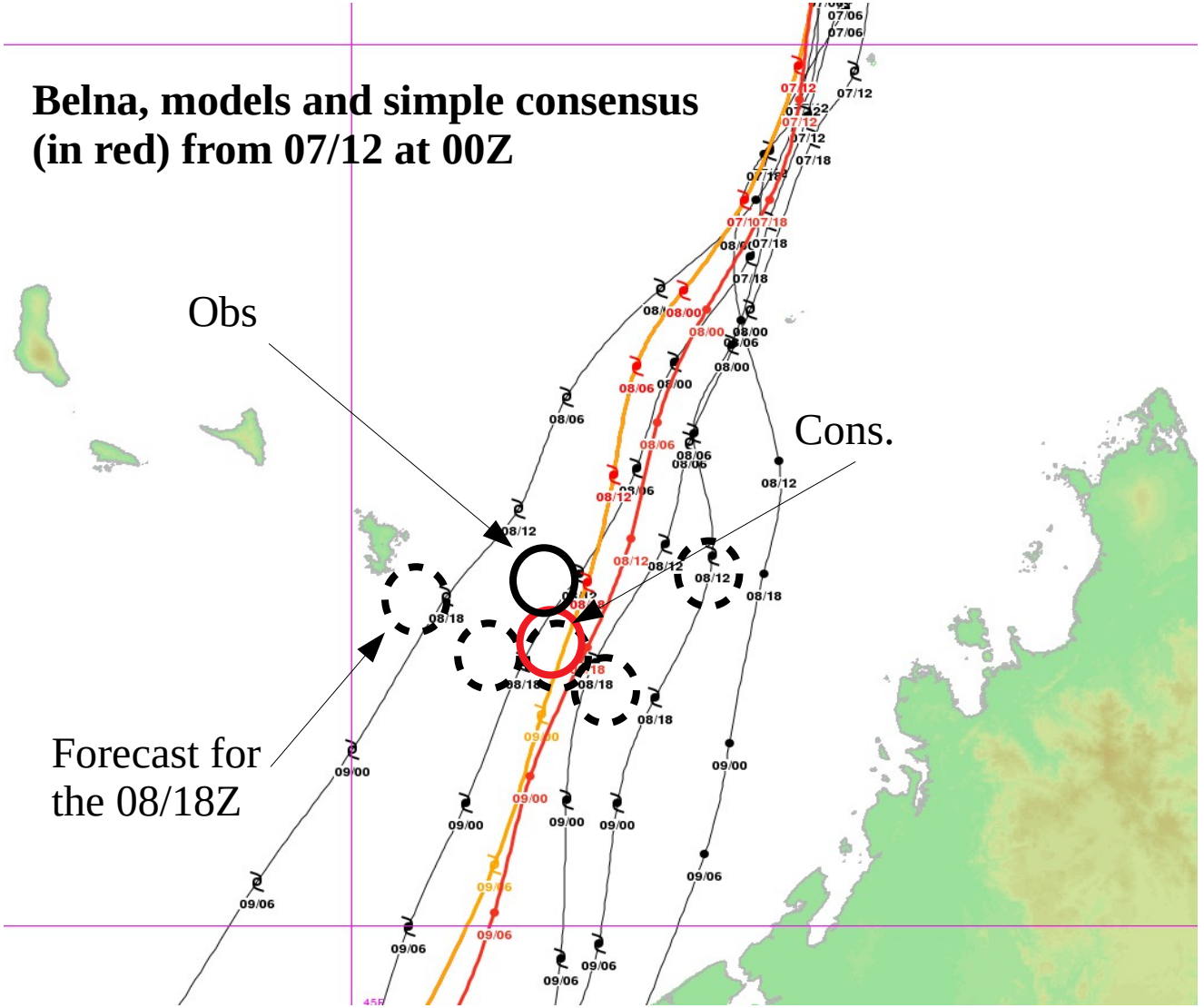
Use :

- Identify the dominant scenario(s)
- Give weight to the different scenarios of the determinists
- Evaluate the dispersion (confidence in the track)
- RSMC La Reunion: EPS is a component of the uncertainty cone

Main used : EPS (EURO), GEFS (US), MOGREPS (UK), PEARP (FR)

Differents types of « guidance »

Models consensus



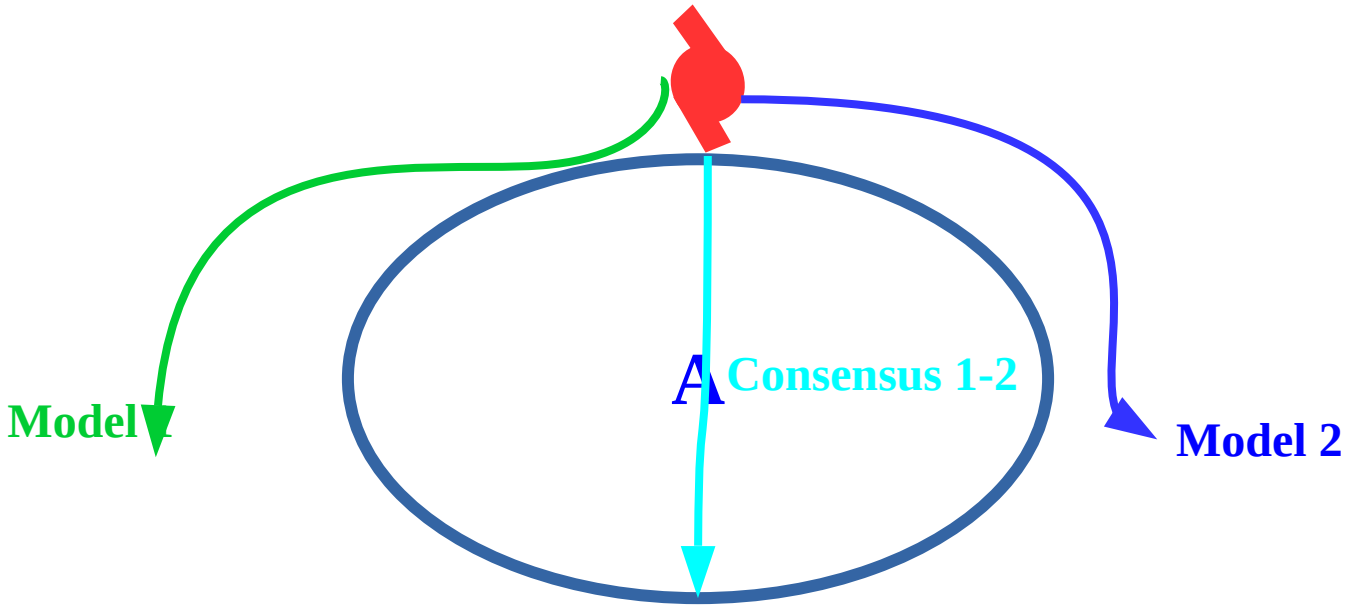
Construction :

- From the available models with "weights" depending on the skills of the previous years
- Simple average from the most relevant models on the situation of the day, according to the forecaster.
- Often the best option

Differents types of « guidance »

Models consensus

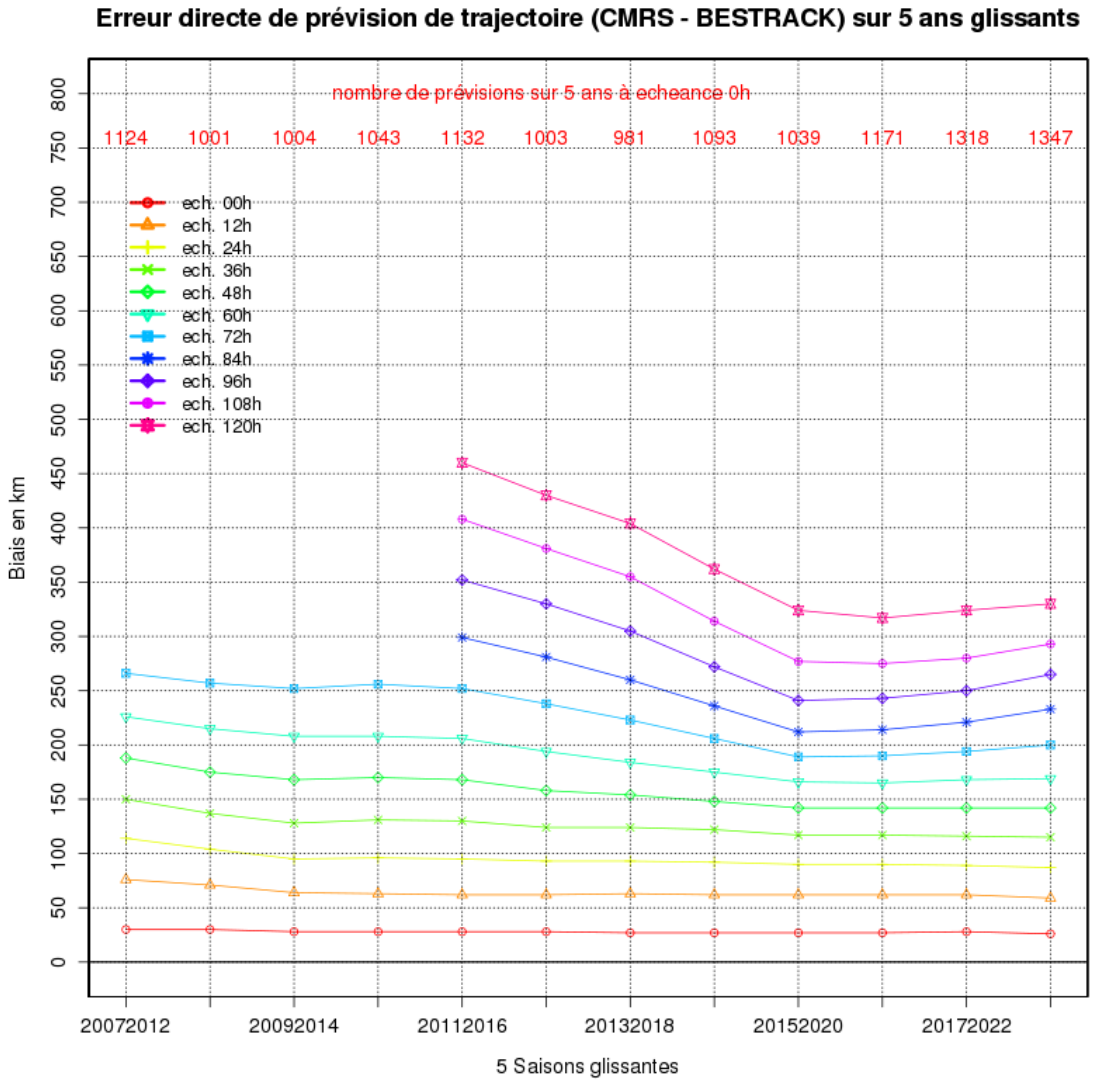
Beware ! Limits of use : at the end of the forecast period, it happens that the deterministic models diverge significantly, especially for extratropicalisation. The consensus is no longer very realistic at this point...



You have to choose between 1 and 2, consensus makes no sense !

RSMC La Reunion track forecast

5 years running mean direct position error (RSMC forecast – Best-track)



Errors in km

5 running seasons

To be remembered, the orders of magnitude of the average errors

- at 24h : **85 km**
- at 48h : **140 km**
- *at 72h* : **200 km**
- *at 96h* : **265 km**
- *at 120h* : **330 km**

→ Slight deterioration of track performance from day 3 to day 5 in the last few years !

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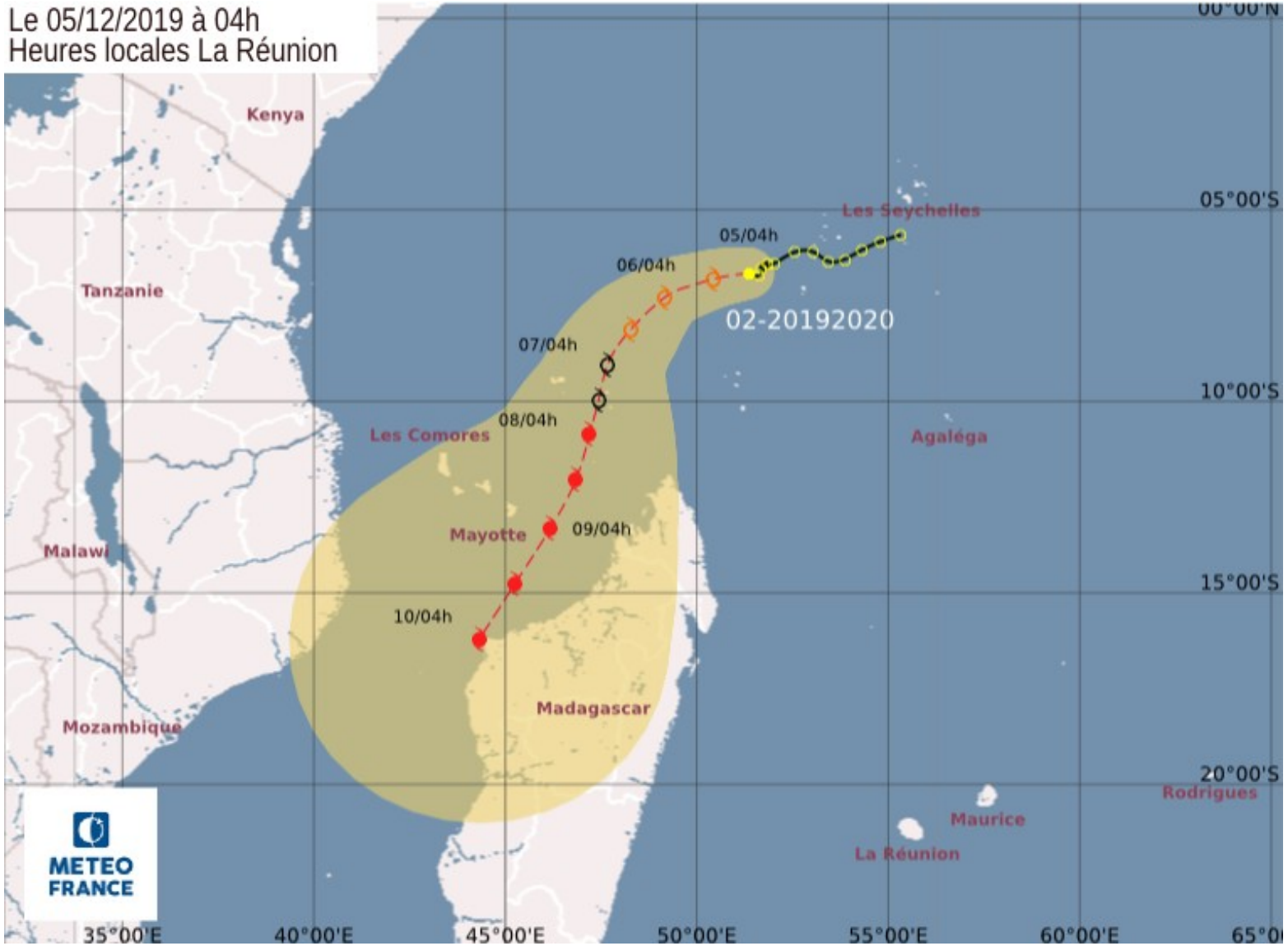
RSMC La Reunion uncertainty cone



→ Brown area around the track forecast

→ Show the area where there is 3 chances over 4 that the real track occurs.

→ It's only the TS/TC center ! Storm size and associated rainfalls are not taking into account …

→ based on climatological RSMC track errors and european ensemble forecast (EPS)

→ **Therefore the width of the cone may vary depending on the predictability of the situation**

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