# A dedicated convection- permitting ensemble in the operational NWP systems at Météo-France for the tropics

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# Extreme events in tropics


*Tropical cyclone impacts :*

***IRMA (2017)***


***BATSIRAI (2022)***

**Madagascar, 06/02/22, gusts 250 km/h**

courtesy : DR / Réunion La 1ère

**Saint-Martin, 06/09/17, gusts 320 km/h**

courtesy: Lionel Chamoiseau / AFP

*Objective of Météo-France's **RSMC** : **ensure security of person and protection of property :***

➡ **Observe + Understand + Forecast + Alert**

# Need of quantifying convective-scale uncertainty

- Assessment of uncertainty sources : initial conditions and lateral boundary conditions and modeling errors (***joint works between LACy** and **CNRM/GMAP**)*
  - Implementation of perturbation methods to gather uncertainties → first prototype of a high-resolution EPS for the French over-seas territories (PE Arome-OM).
  - This system is operationnal and based on the first version of Arome EPS for France.

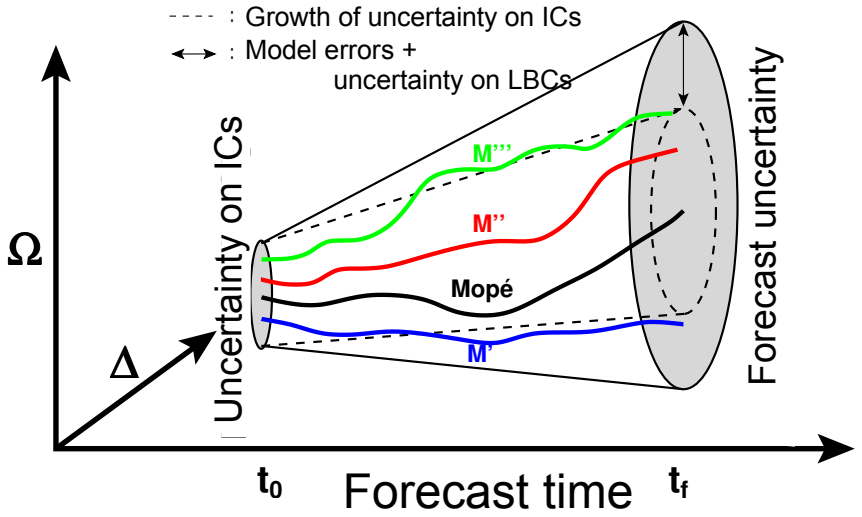
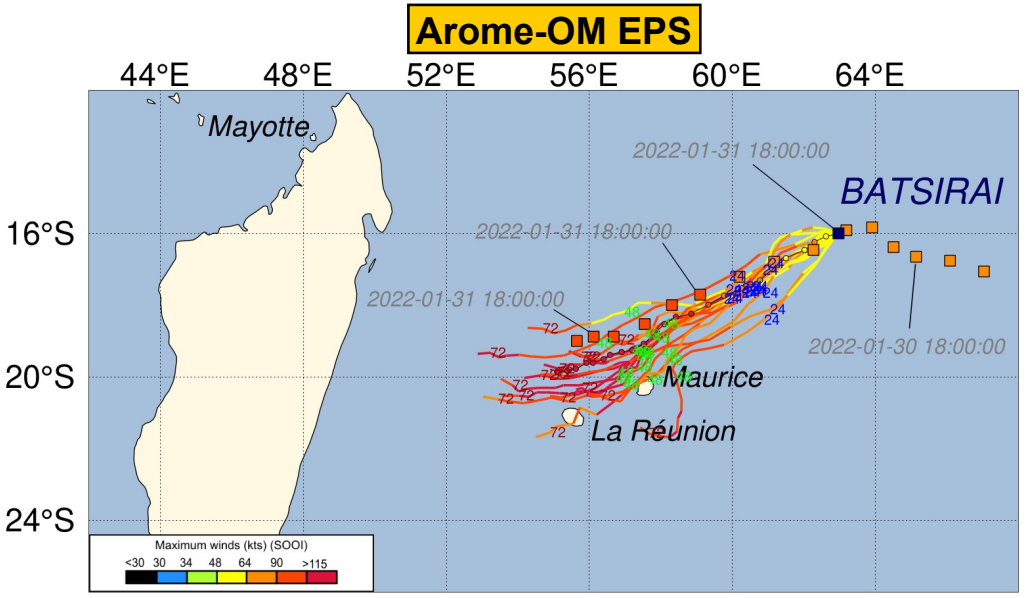



*Illustration of how error growth impacts forecast in a high-resolution (LAM) ensemble prediction system.*




*Track-Intensity plume from Arome-OM EPS (Indian basin). Forecast starts at 18 UTC on 31/01/22*

# Outlines

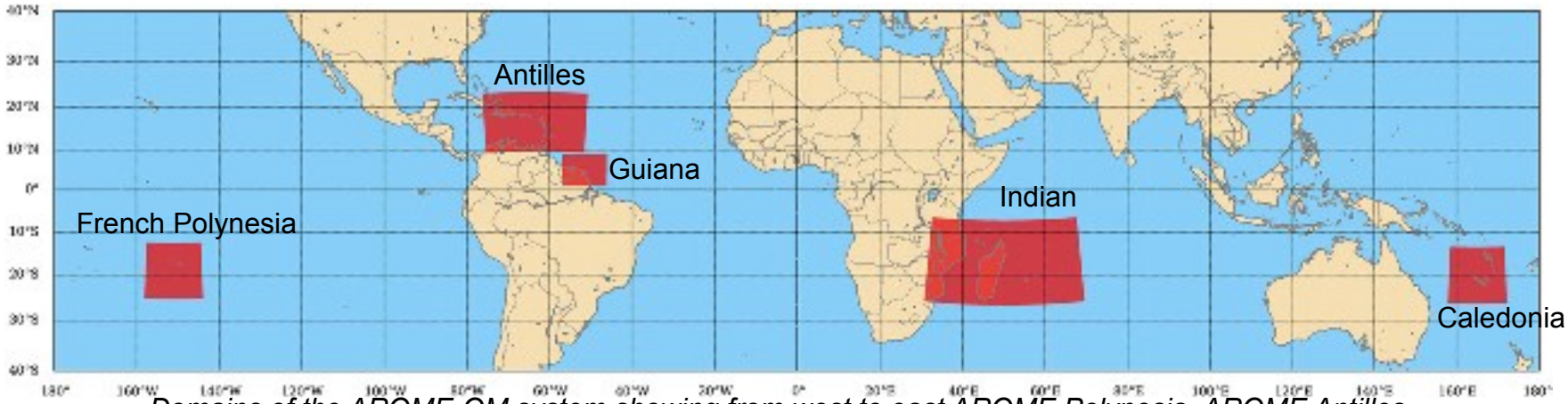
1. A brief remind of the operational suite for the French oversea regions with Arome

2. Design of Arome-OM EPS

3. Overall performance of Arome EPS : focus on tropical cyclone activity over the SWIO basin

4. Conclusions and future works

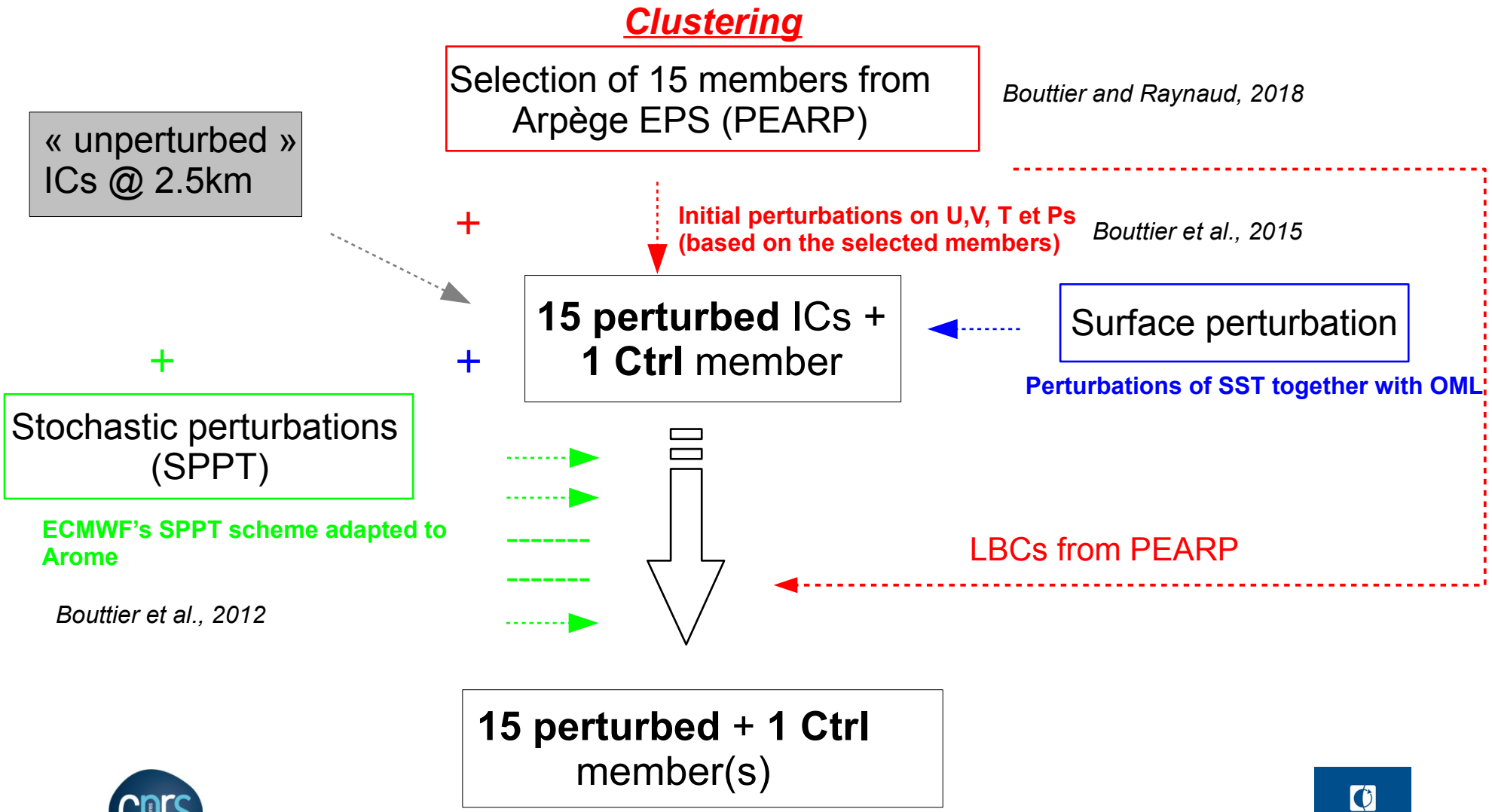
# Operational suite with Arome-OM




*Domains of the AROME-OM system showing from west to east AROME Polynesia, AROME Antilles , AROME Guiana , AROME Indian, and AROME Caledonia, respectively (**Faure et al., 2020**)*

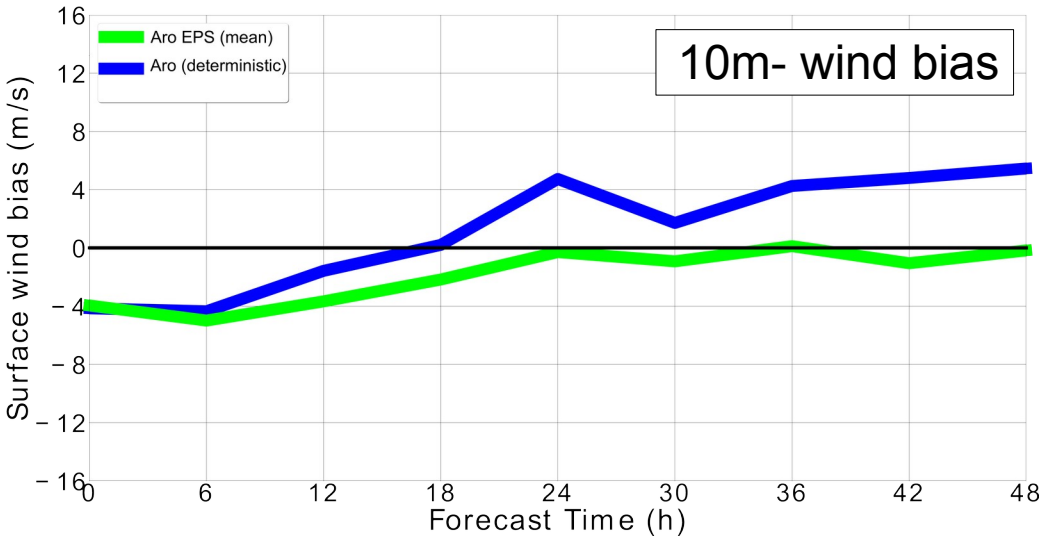
- A first version of the AROME-OM system was operationally implemented at Météo-France since **2016**, including **5 domains** with a **horizontal resolution of 1.3km**.
- The AROME-OM system is mostly based on the **AROME-France** configuration run operationally centered over France.
- **No data assimilation** in the AROME-OM system : ICs and LBCs mostly come from **ECMWF IFS** model. It is coupled with the **1D ocean** Mercator global model PSY4.
- Since February 2023, **5 new high-resolution EPS have been declared operationnal**, run twice a day with a horizontal resolution of **2.5km** , up to a lead time of 48h (extended mainly during **tropical cyclone warnings**),...

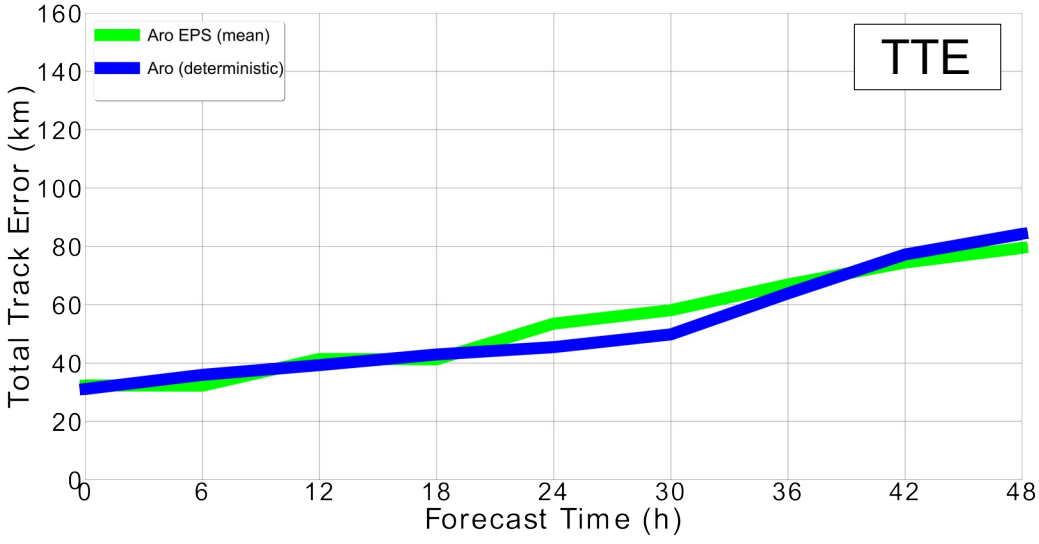
# Design of the operationnal Arome-OM EPS



# Overall performance of Arome-OM EPS (EPS vs. deterministic)

- Near-surface wind **errors** and **bias** for 4 TCs over the SWIO basin (**Batsirai**, **Emnati** and **Gombe**).
- **Track errors** are about **80-100** km at 48h forecast time (~ state of art in terms of forecast track).
- Some issues for **initial intensity** especially for intense TCs (dowscaling IFS), but forecast is still **improved** as forecast time increasing.



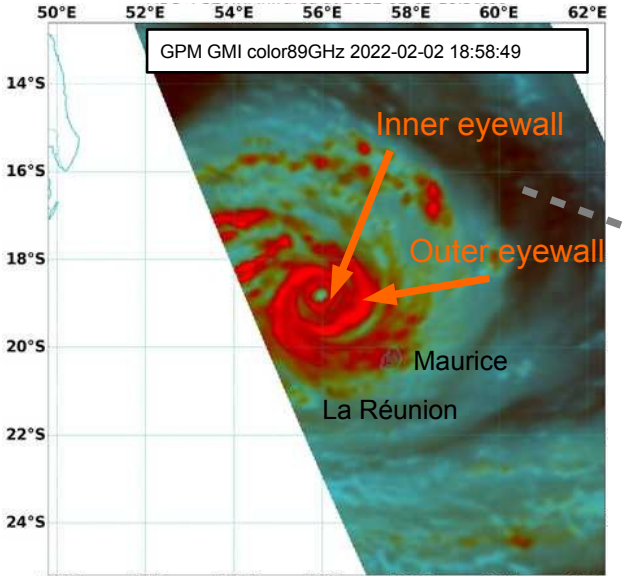



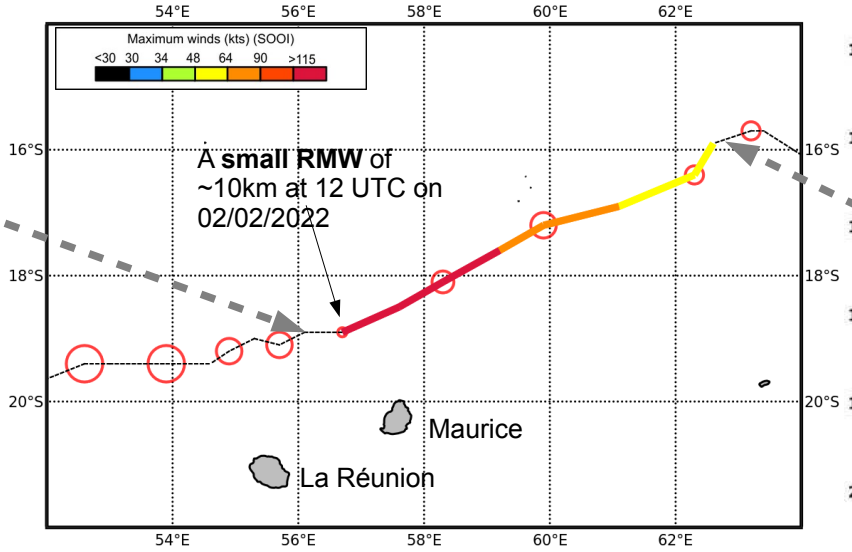

*Time-series of **near-surface wind bias** and **total track errors** for 3 TCs (Batsirai, Emnati et Gombe) during the 2022 TC season over the SWIO basin. 15 runs are considered and combined here.*

# Observed RI and ERC in Batsirai

- Batsirai underwent a **rapid intensification** (RI), evolving from a very **asymmetric** convective structure, then towards a **very organized** and powerfull / symmetric cyclone with a **concentric eyewall** structure.
- Then, an **Eyewall Replacement Cycle** (ERC) occured while passing near ~150km N of the islands.
- This ERC was well observed from the **ground-based Doppler radar** in La Réunion.
- So were these RI and ERC events **predictable** based on Arome-OM EPS ?

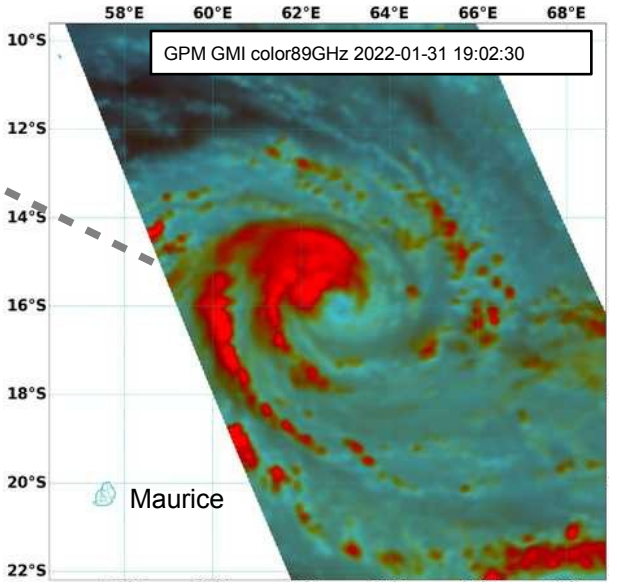
**Concentric eyewall structure**



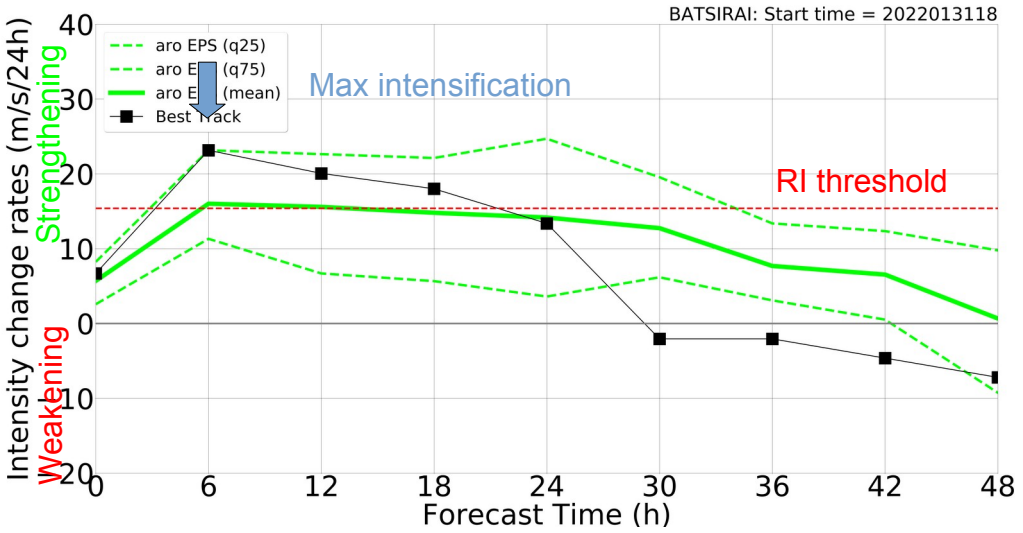

*Analysed radii of maximum wind (RMW, cercles) + track (coloured line = RI).*

**Asymmetric structure**

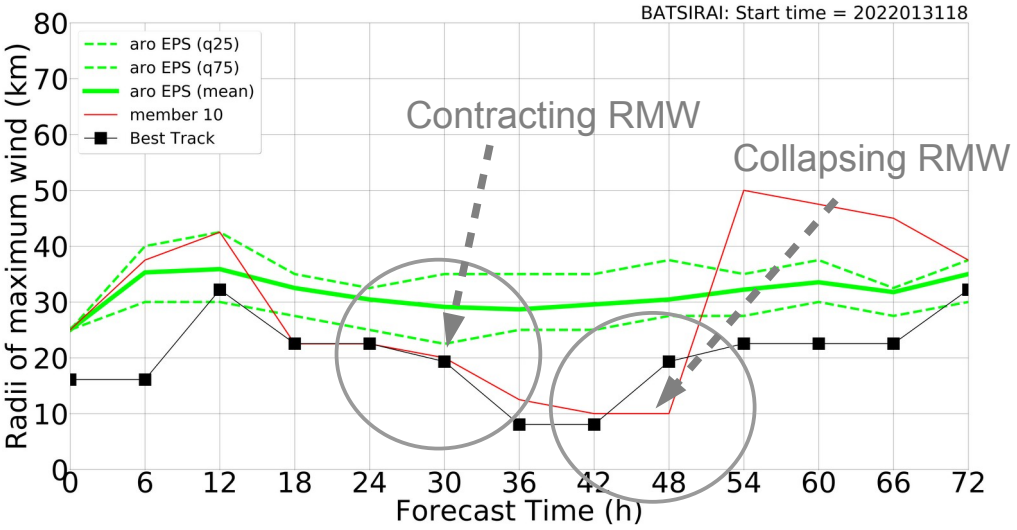


# Batsirai's simulated intensity and size

How does Arome-OM EPS predict both Batsirai's intensity and structure (run on 31/01 at 18:00 UTC) ?




*Time-series of the simulated intensity change rates as a function forecast time. The run starts at 18:00 UTC on 31/01/22*

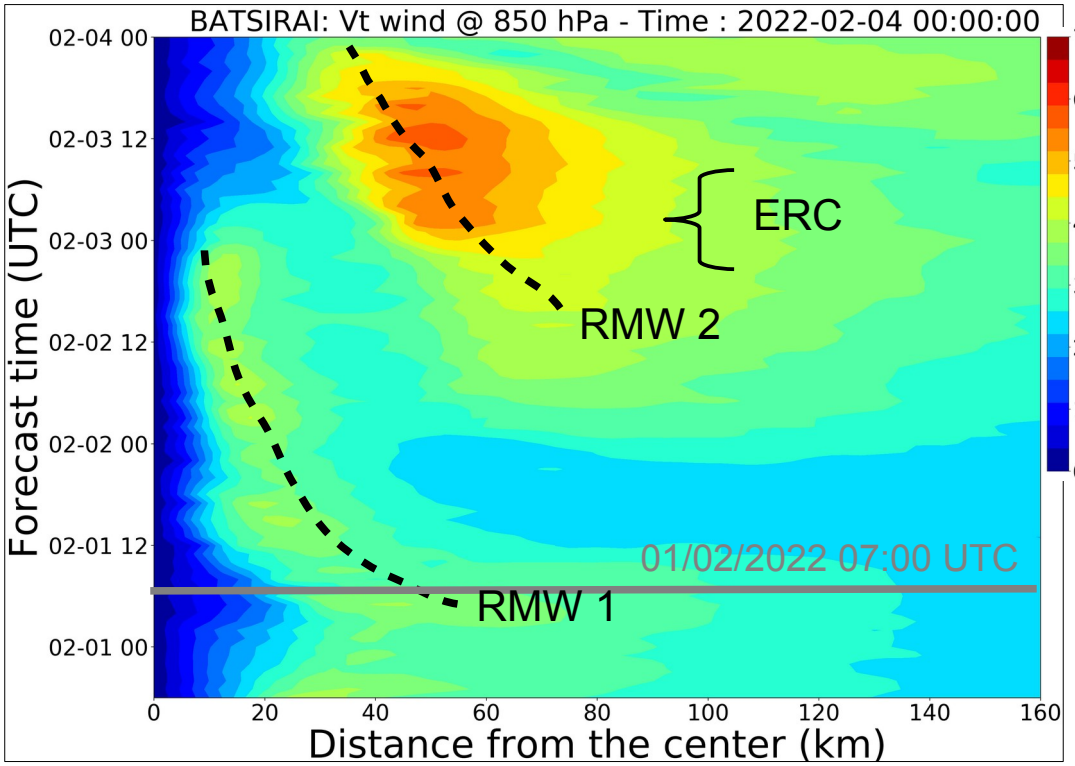



*Time-series of the simulated intensity change rates as a function forecast time. The run starts at 18:00 UTC on 30/01/22*

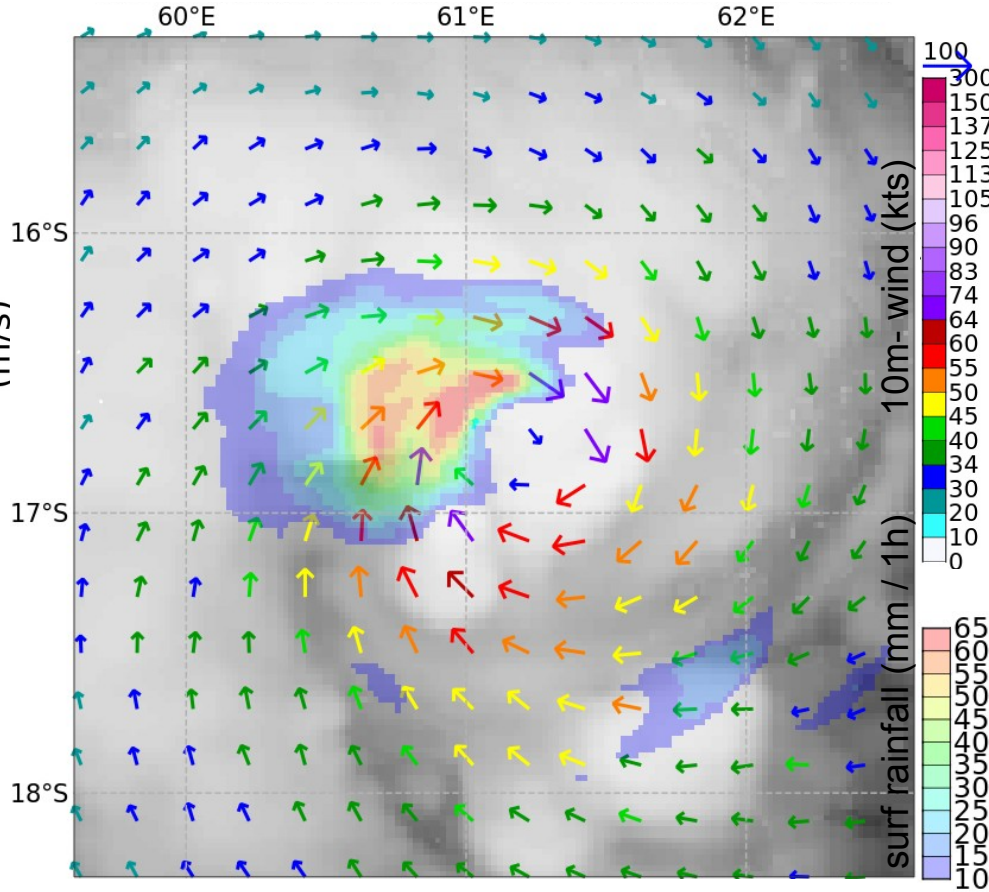
- The ensemble captures fairly well **intensity fluctuations** (some weakening) around 24h after the intensification peak (intensification is still a bit too lasting ?)
- **Member 10** from this run is the only good illustration of the right (or **realistic**) scenario : a structure with a very **small RMW** evolving towards an **ERC**.

# Overview of TC's inner-core structure from MB10

*Hovmöller diagram of tangential wind. The dashed lines show contraction of the RMWs.*



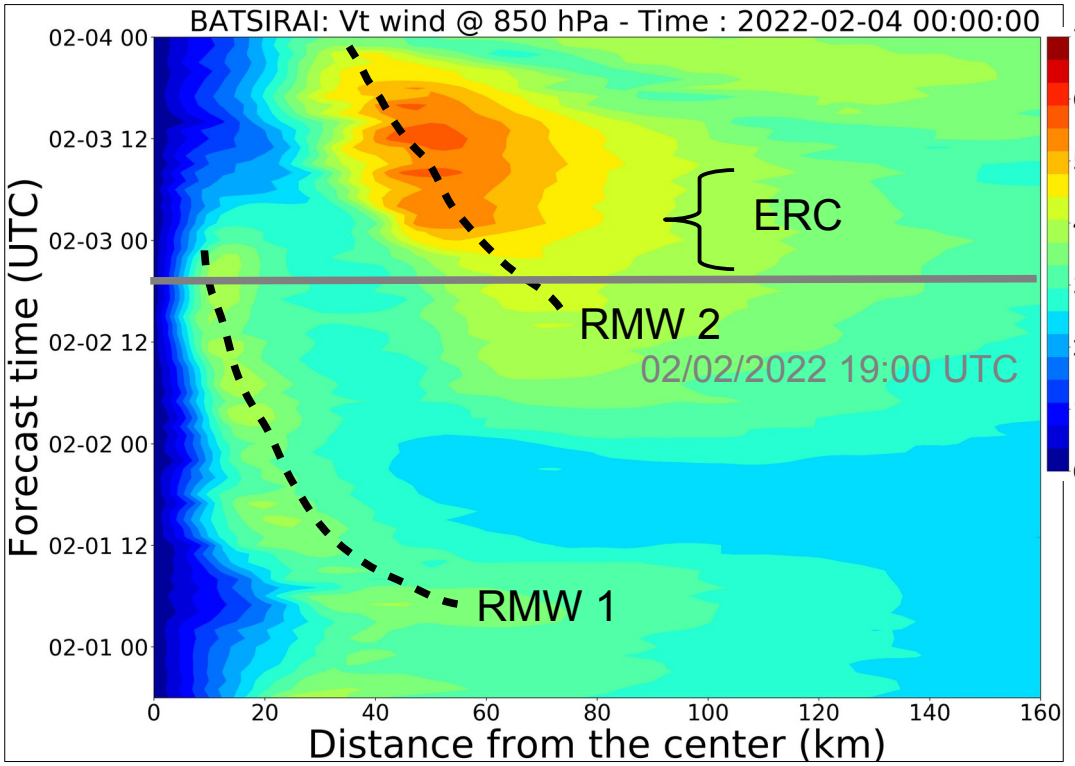

*Storm-centered plot of simulated IR 10.8 µm BT + 1h-surface precip (coloured shades) and 10m- wind (arrows).*




- Evident **sequence of ERC** : contracting RMW 1 (60km → ~15km) + RMW 2 appearing between 60-80 km. RMW 1 collapses and strengthening can resume.
- **Asymmetric structure** around 07:00UTC on 01/02/2022 : **southeasterly wind shear** impacting Batsirai.

# Overview of TC's inner-core structure from MB10

*Hovmöller diagram of tangential wind. The dashed lines show contraction of the RMWs.*

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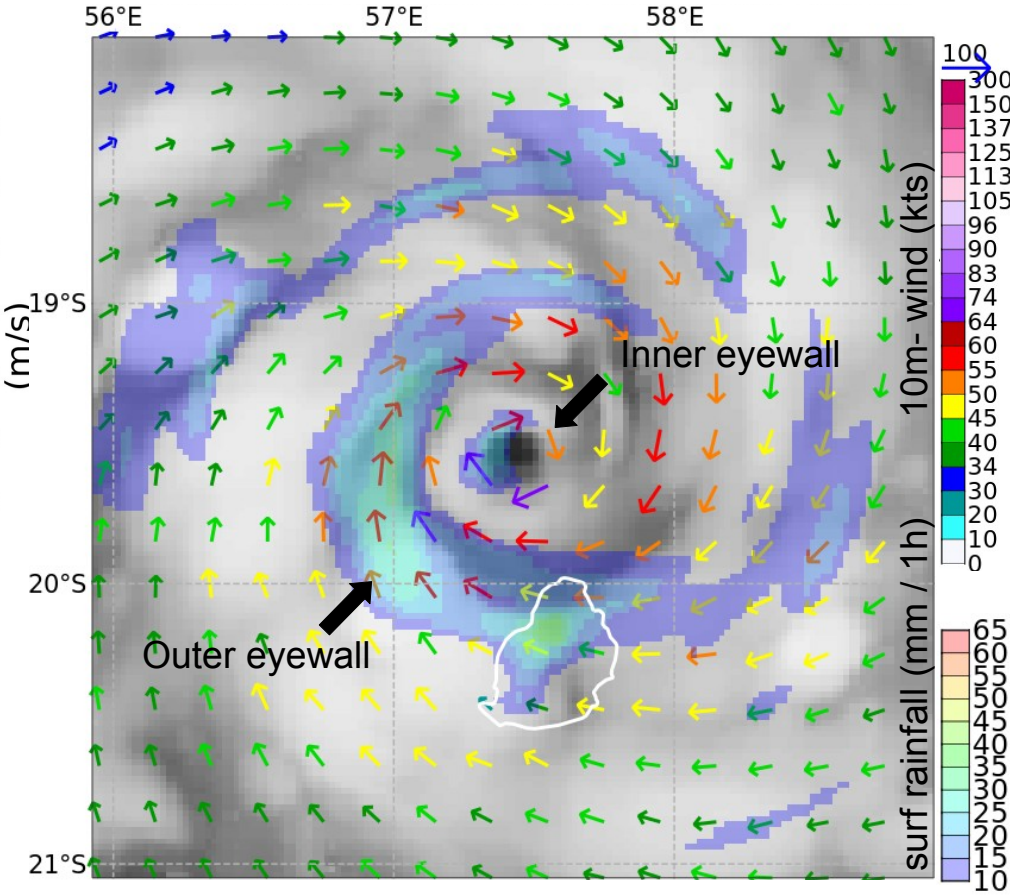
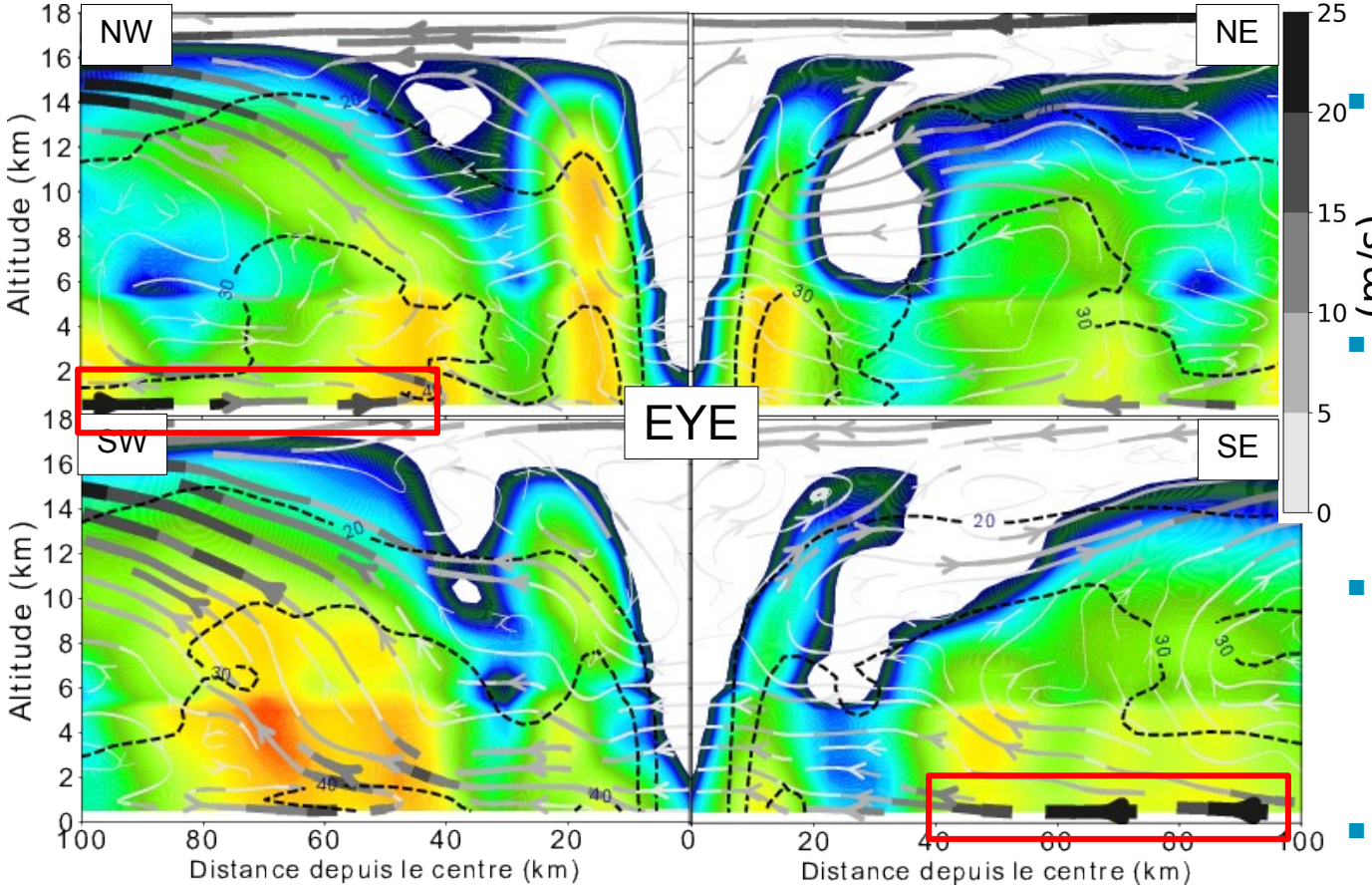



- Evident **sequence of ERC** : contracting RMW (60km → ~15km) + a 2nd max appearing between 60-80 km. The inner RMW collapses and strengthening can resume.
- Around 12:00 UTC on 02/02, a **double ring pattern** of strong precipitation forms just before the ERC.

# Overview of TC's inner-core structure from MB10



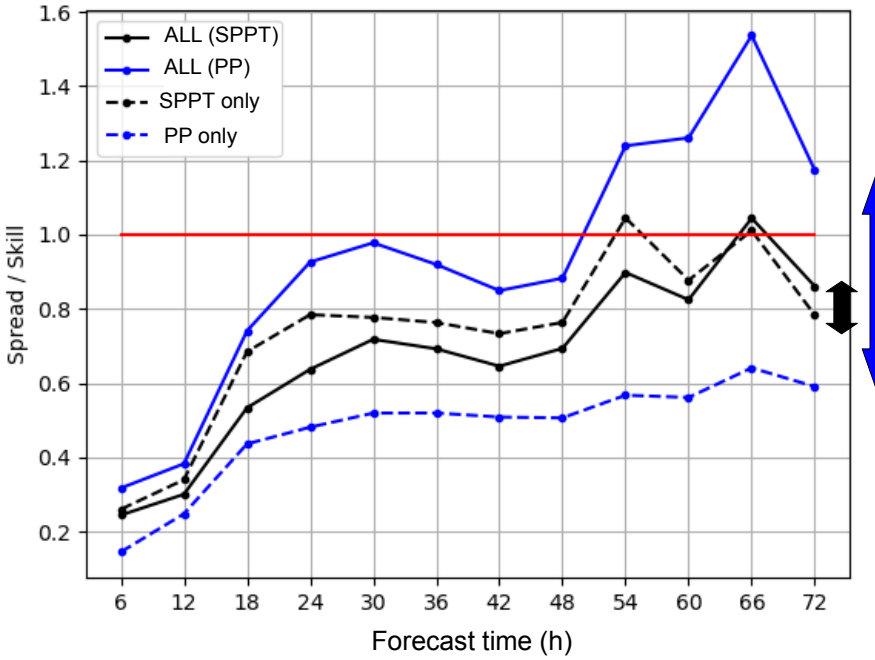

*Vertical cross-section of simulated radar reflectivities (dBZ, coloured shades), tangential wind (m/s, dash lines) and radial and vertical winds (m/s, streamlines), azimuthaly averaged by quadrant.*

- **A well-organized concentric structure** is clearly visible, with decaying convective activity within the inner eyewall.
- Northeasterly wind shear is still impacting the simulated TC as the **upper-level outflow** remains **asymmetric**.
- Outer rainbands form and **intercept** most of the **low-level inflow**, favouring the decline of the inner eyewall.
- ERC with the good size are quite **rare situations** in Arome-OM EPS → need to improve their representation to better tackle **TC predictability**.

# Some research topics with Arome-OM EPS

- **Léna Dziura**'s thesis → **perturbation parameter (PP)** approach to better document model errors with a focus on oceanic surface flux scheme (*Coll.* CNRM/GMAP and LACy).
- Comparison **SPPT** vs. **PP** (~20 case studies over Atlantic, SWIO and South Pacific basins).

- For **PP**, adding the other uncertainty sources **significantly increases** spread/skill ratio.
- Surprisingly, **not much difference** between **SPPT only** compared to **all perturbations** (SPPT only even looks like virtually better than ALL (SPPT).
- Léna is evaluating **significativity** and possible impacts on other **TC's fine-scale features**.




***Spread-Skill ratio*** *of Pmin for* ***hurricane Laura****.*
*Forecast starts @ 00 UTC on 24/08/2020.*

# Conclusions

- **5 new AromeOM EPS** are now **operationnal** at Météo-France for the French oversea regions.
- Numerous feedback (subjective evaluation) and **great interest from forecasters** !
- An « object-oriented » approach has been used to detect, « track » and make an ensemble analysis of « **meteorological objects** » (e.g. TC position, intensity, sizes, convective structures,...)
- Arome-OM EPS has « fair » characteristics (in terms of spread vs. skill) and it is able to capture some part of the **predictability** associated with **rapid intensification** in TC (e.g. Batsirai case)
- Results regarding parameter perturbation for near-surface flux scheme look like **very promising** especially for **TC prediction** → could provide more spread within this part of troposphere and **better document uncertainty**.

# Future works

- **Léna Dziura**'s thesis → dynamical perturbation : **STOCHDP** scheme from ECMWF has been already implemented in Arome-OM (*thanks to S. Malardel and S-J Lock !*) and some tests have been carried out for **TC cases**.
- There are sometimes a few cases of **over-intensification**, especially for strong TCs → improvement of the 1D ocean model (implementing **Ekman transport**)
- Arome-OM EPS still suffers from an **issue of initial intensity** (especially for strong and/or small TCs), and probably it could benefit from works currently ongoing on **EDA** for the Arome-OM model (*S. Malardel*)
- An « object-oriented » approach → better document **variability** of **fine-scale features** and **mechanisms** involved in TCs → How it could be **useful** practically for operationnal forecast ?

# Thank you for your attention !

# Any questions ?