Towards a dedicated convection-permitting ensemble in the operational NWP systems at Météo-France for the tropics

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Outlines

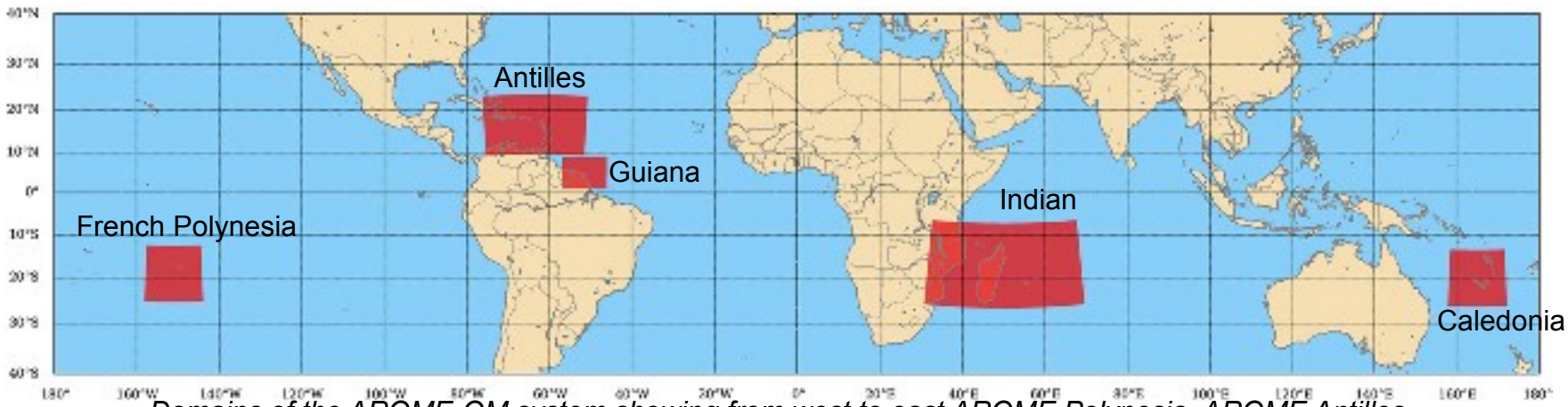
1. A brief remind of the operational suite for the French oversea regions with Arome

2. A dedicated prototype of EPS with Arome

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

4. Conclusions and future works

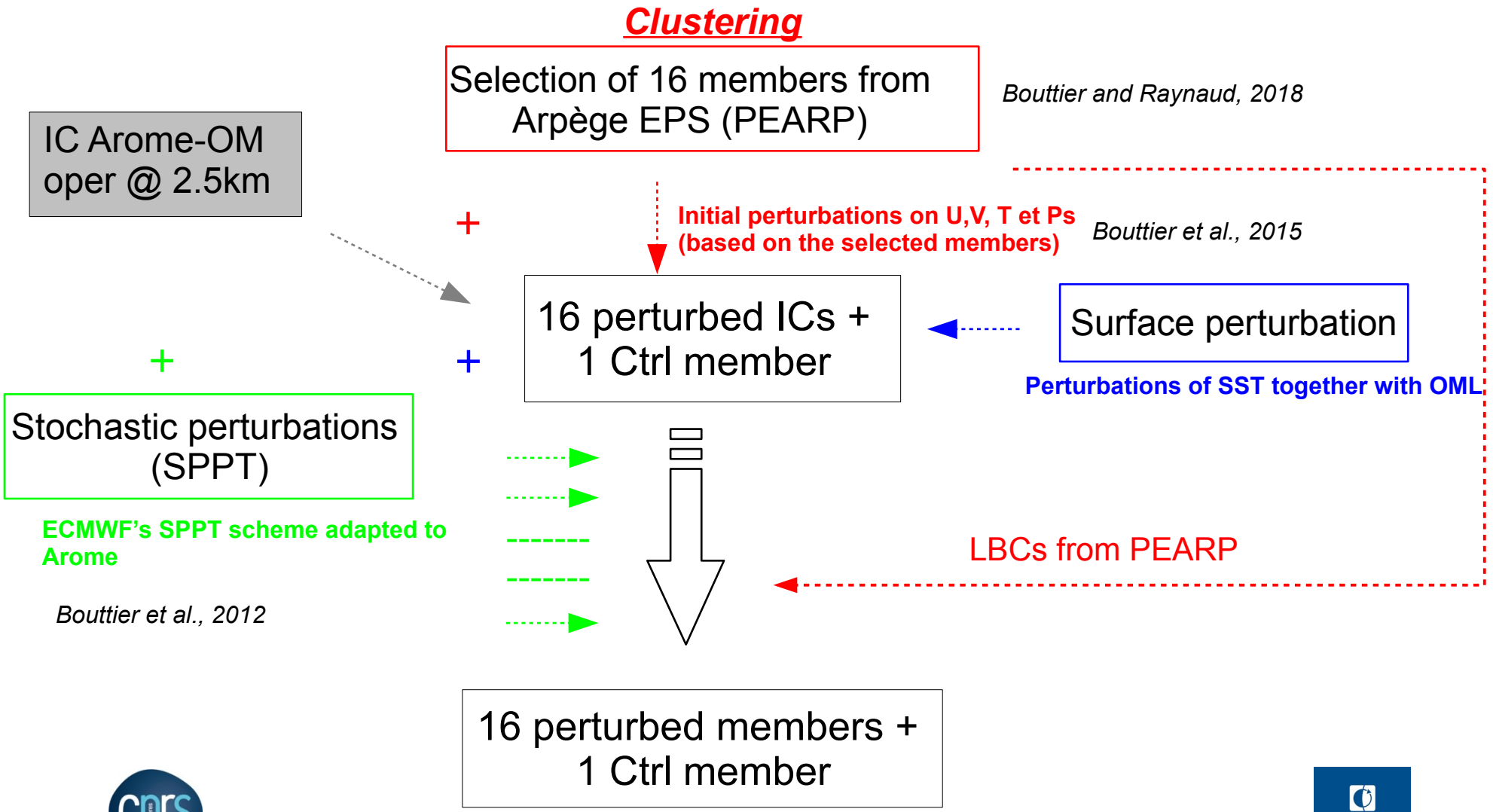
Operational suite with Arome-OM



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 in **February 2016**, including **5 domains** with a **horizontal resolution of 2.5km**.
- The AROME-OM system is mostly based on the **AROME-France** configuration run operationally centered over France (a horizontal resolution of **1.3km** is currently evaluated).
- **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.
- It is run four times a day, at 0000, 0600, 1200, and 1800 UTC, up to a lead time of 48h…, but **up to 78h on demand** (mainly during tropical cyclone warnings).

Design of a future EPS with Arome-OM



The experimental suite with Arome-OM EPS

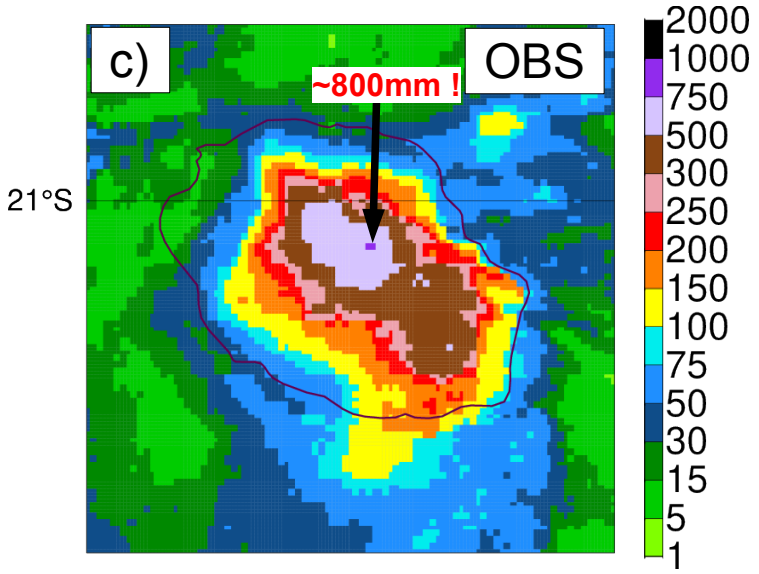
- Several experimental sets of Arome-OM EPS are carried out since 2020, with **daily runs** in near **real-time** for the 5 Arome domains.
- Arome-OM EPS is run each day at 06:00 or 18:00 UTC, up to a lead time of 48h. Forecast times have been also extended up to **+72h** on demand during **TC alert**.
- A few products are made available and are **subjectively evaluated by forecasters** in routine (as far as possible).
- Common **probabilistic outputs** are produced **at gridpoints** (quantiles and probability of exceeding thresholds of accumulated rainfall, mean wind and gusts, individual thumbnails for members,…)
- **Specific products** are also generated for **TC forecast purposes** (« tracking » of **TC's characteristics**) : plumes of track – intensity, strong wind radii, environmental wind shear, inner-core structures,...
- This « **object-oriented** » approach is also used to assess TC's predictability.

Focus on a heavy precipitation event over La Réunion island

Flooding event in La Réunion (2-4/04/2022). © Mussard Anny and Eloïse Bentz.

Flooding event in La Réunion (2-4/04/2022). © Brancalin Sandrine.

- **A near-record heavy precipitation event** occured in La Réunion by the beginning of April 2022.



*24h- accumulated surface precipitation of the upper 10th percentile from Arome-OM EPS valid for the 03/04 at 18:00 UTC : **a)** starting at 18:00 UTC on 31/03 and **b)** starting at 18:00 UTC on 01/04, respectively. Panel **c)** shows the corresponding estimation from radar observations.*

Focus on a heavy precipitation event over La Réunion island

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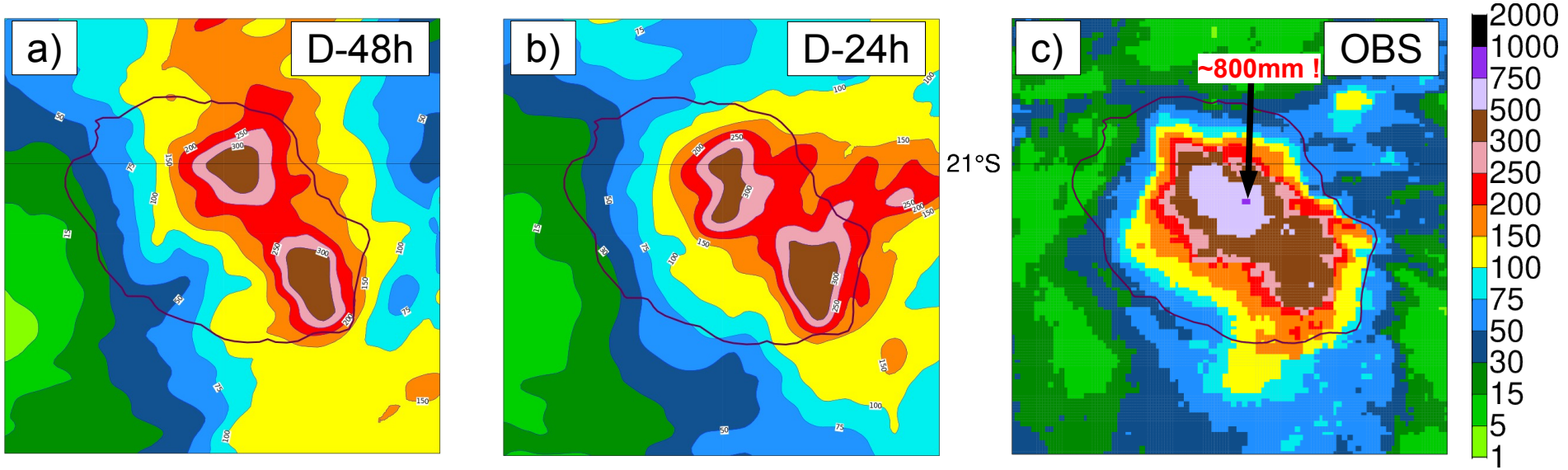
Flooding event in La Réunion (2-4/04/2022). © Brancalin Sandrine.

- **A near-record heavy precipitation event** occured in La Réunion by the beginning of April 2022.
- Arome-OM EPS (q90) captured fairly well the **strongest rainfall**, with a signal clearly visible **48h before the event**..



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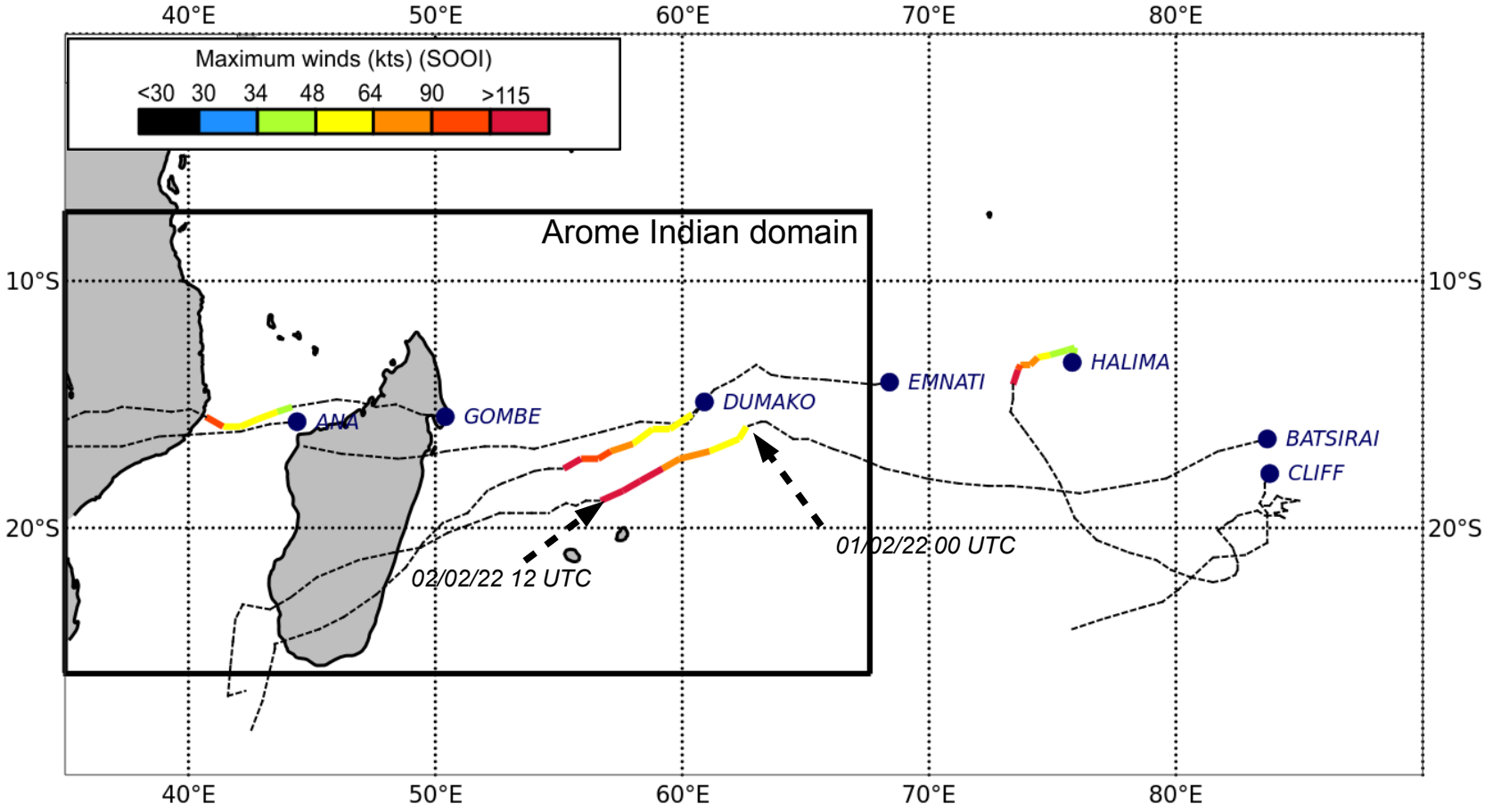
Overview of tropical cyclone activity over the SWIO basin (2022)

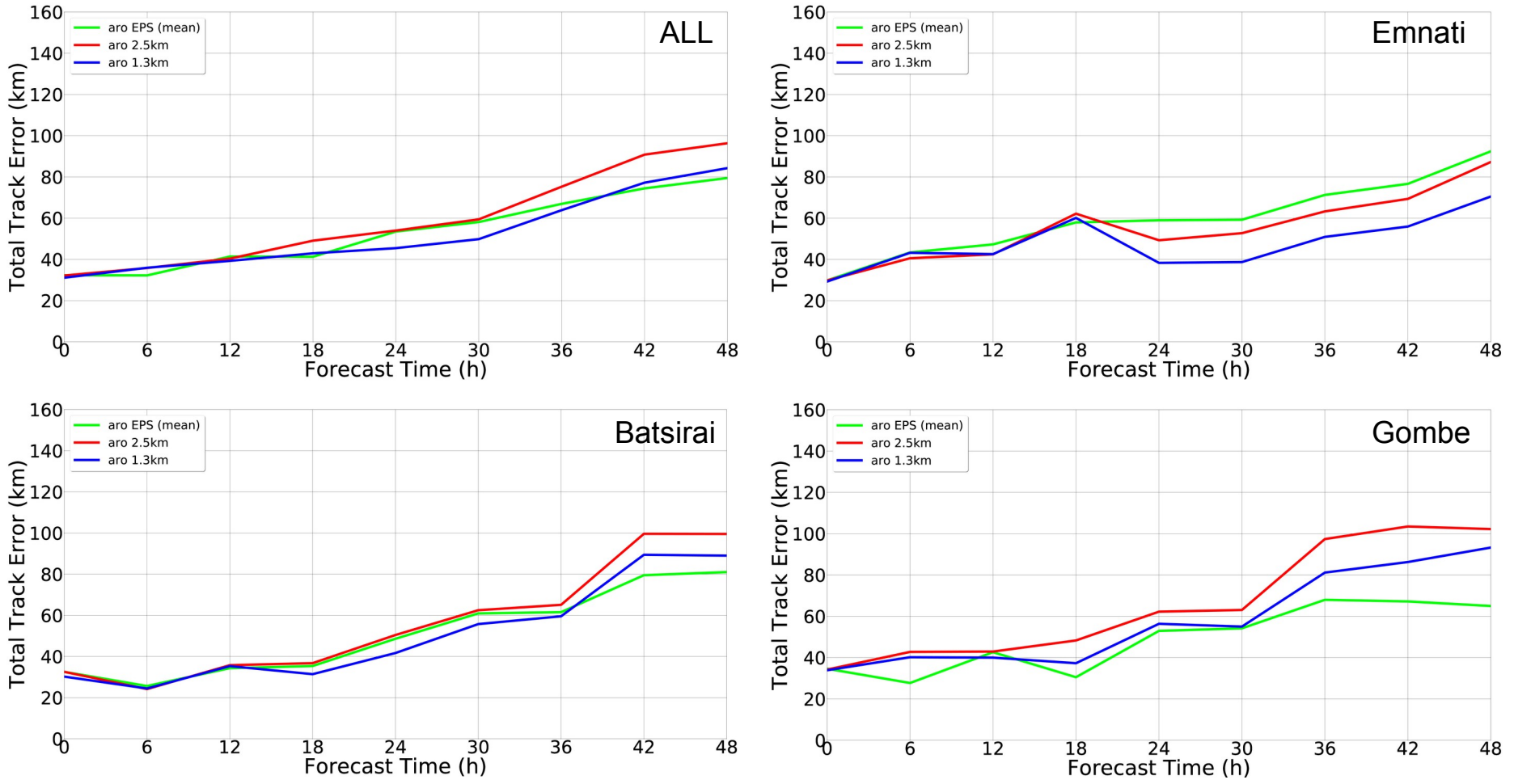
- **13 TCs** formed over the SWIO basin (season is « officially » over).
- **4 TCs** underwent a rapid intensification (RI, >30 knots (or ~15.4 m/s) in 24h).



Best-Track analysis (BT) for SWIO basin's TCs in 2022. Coloured thick lines indicate the RI periods for each TC. The rectangle represents the Arome Indian domain.

Overall performance of Arome-OM EPS (EPS vs. deterministics)

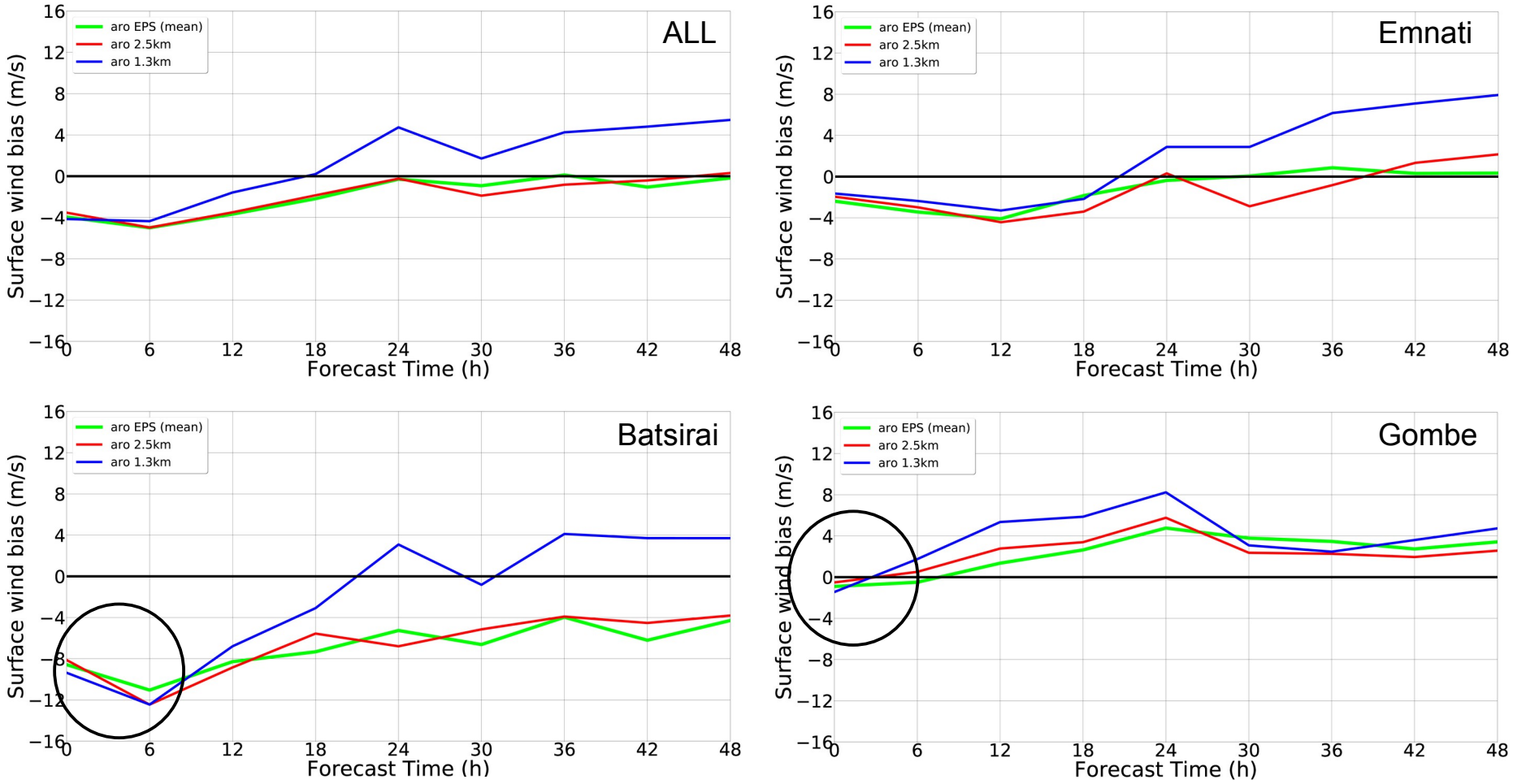
Some objective scores : total track errors (15 runs considered so far) :



Time-series of total track errors as a function of forecast time : for all TCs (ALL), Batsirai, Emnati and Gombe, respectively.

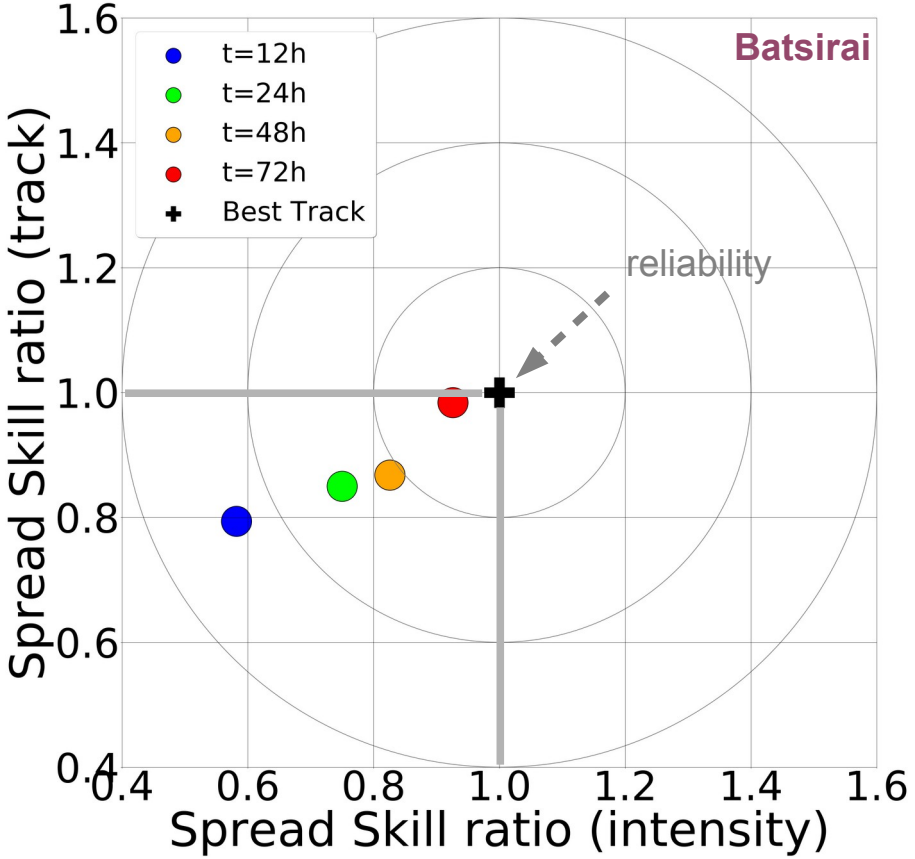
Overall performance of Arome-OM EPS (EPS vs. deterministics)

Some objective scores : 10m- wind bias (15 runs considered so far) :



Time-series of near-surface wind bias as a function of forecast time : for all TCs (ALL), Batsirai, Emnati and Gombe, respectively.

Ensemble spread vs. mean error (track vs. intensity)

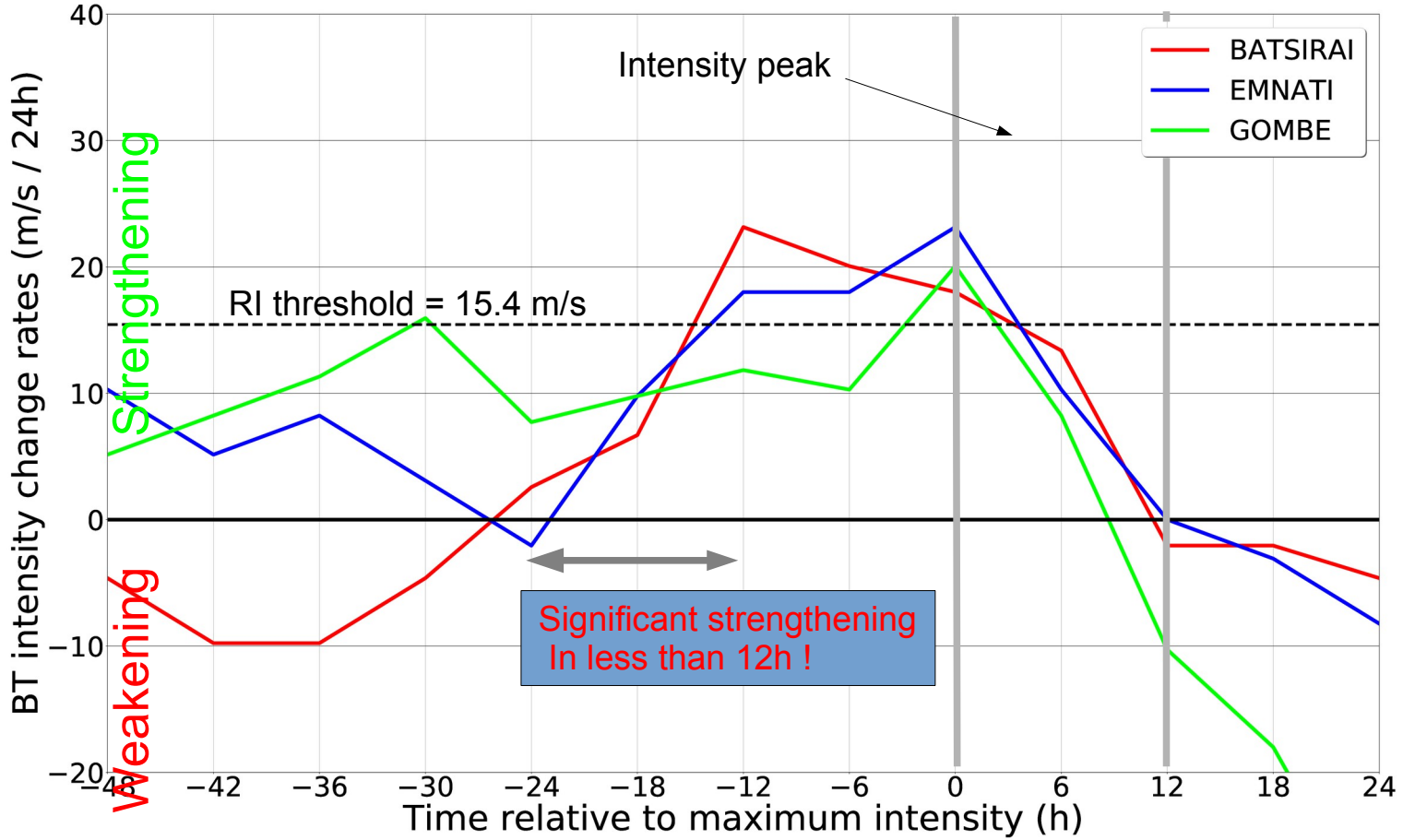


Spread / Skill ratio for track as a function of Spread / Skill ratio for intensity. The fill coloured cercles stand for forecast times and the cross indicates the BT.

- The **spread / skill ratio** (ensemble spread vs. rmse ; < 0 = underdispersive ensemble ; **1 = reliable ensemble**).
- Despite significant bias on initial intensity forecast becomes **more reliable at longer range**.
- At 72h the SS ratio reaches a value near 1 for the track forecast meaning **improvement** at this time.
- Reliability on intensity increases **much faster** (~ twice more) than for track while forecast time increasing.

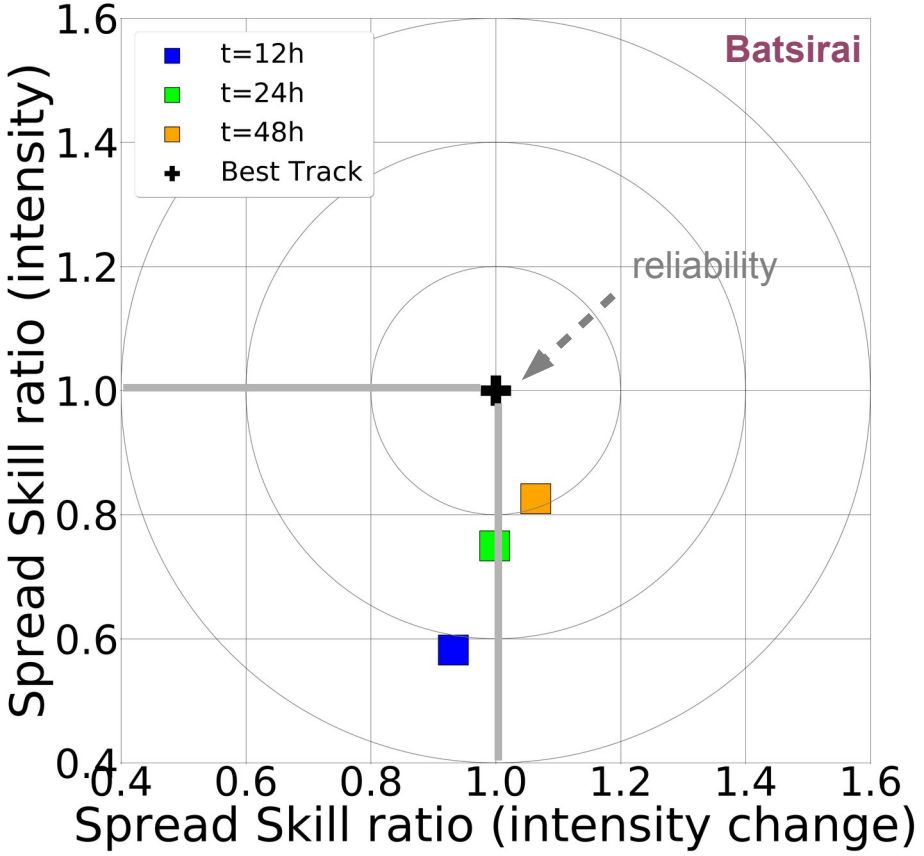
Observed intensity change rates

- Both Batsirai and Emnati **strengthened notably** just before their intensity peaks.
- Were these RI events predictable based on Arome-OM EPS ?



Time-series of intensity change rates as a function of forecast time (relative to intensity peaks).

Ensemble spread vs. mean error (intensity vs. intensity change)

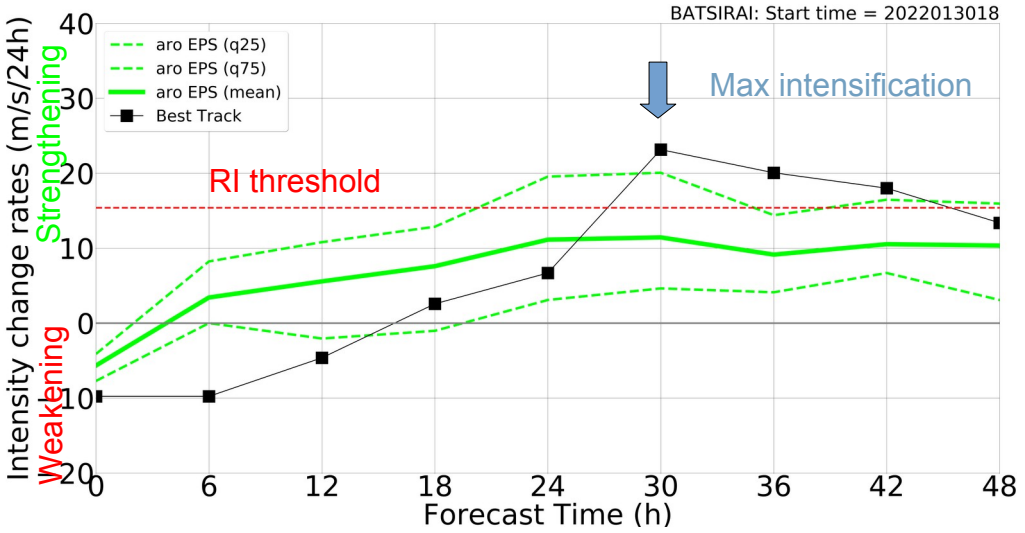


Spread / Skill ratio for track as a function of Spread / Skill ratio for intensity. The fill coloured cercles stand for forecast times and the cross indicates the BT.

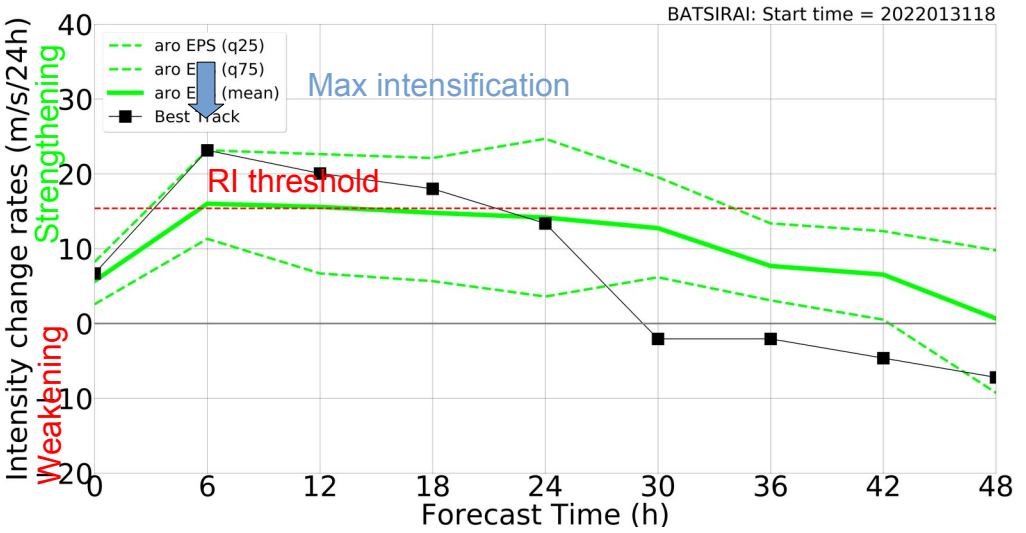
- The **spread / skill ratio** (ensemble spread vs. rmse ; < 0 = underdispersive ensemble ; **1 = reliable ensemble**).
- Contrary to intensity, reliability on intensity change forecasts seems already **very good** even at **shorter forecast times**.
- However, reliability on intensity change seems **decreasing at long-term** (**ratio > 1**), maybe due to overdispersion and/or loss of skill.
- Despite underestimated initial intensity, Arome-OM EPS captures fairly well **intensity changes**.

Batsirai's simulated intensity change

How does Arome-OM EPS predict Batsirai's RI (runs on 30/01 and 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 30/01/22

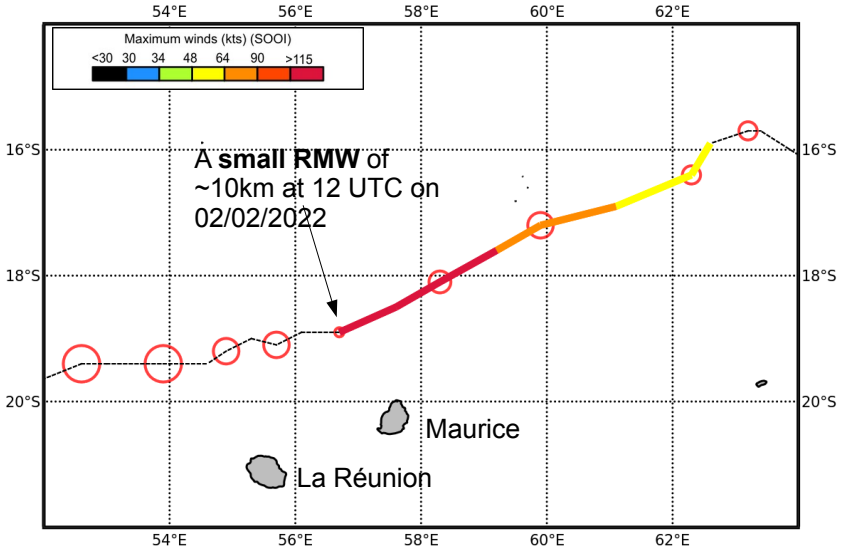


Time-series of the simulated intensity change rates as a function forecast time. The run starts at 18:00 UTC on 31/01/22

- AROME-OM EPS is able to capture fairly well the **sharper increase intensity** seen in BT.
- The ensemble also captures (but not fully) **intensity fluctuations** (some weakening) around 24h after the intensification peak (intensification is still a bit too lasting ?).

An observed ERC in Batsirai

- An **Eyewall Replacement Cycle** (ERC) occured while passing near ~150km N of the islands.
- By the beginning of the RI, Batsirai had a very **asymmetric** convective structure, that evolved towards a **very organized** and powerfull and symmetric cyclone with a **concentric eyewall** structure.
- This ERC was well observed from the **ground-based Doppler radar** in La Réunion.
- So was this ERC event **predictable** based on Arome-OM EPS ?



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

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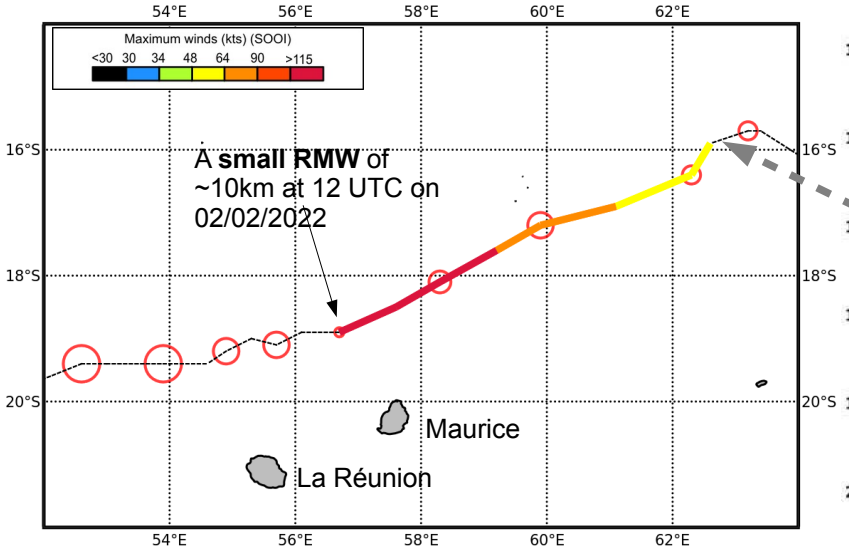

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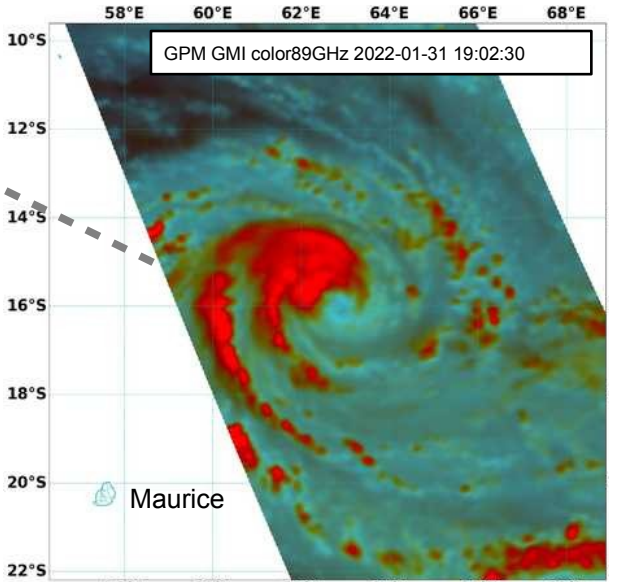
Asymmetric structure



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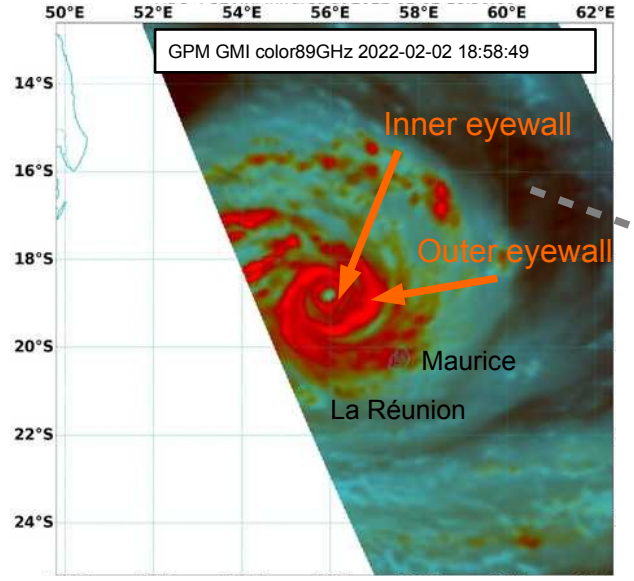
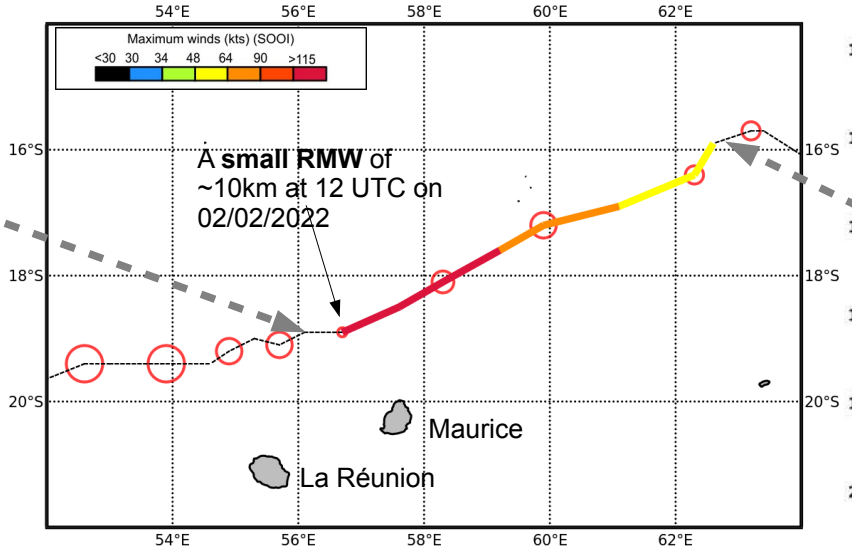
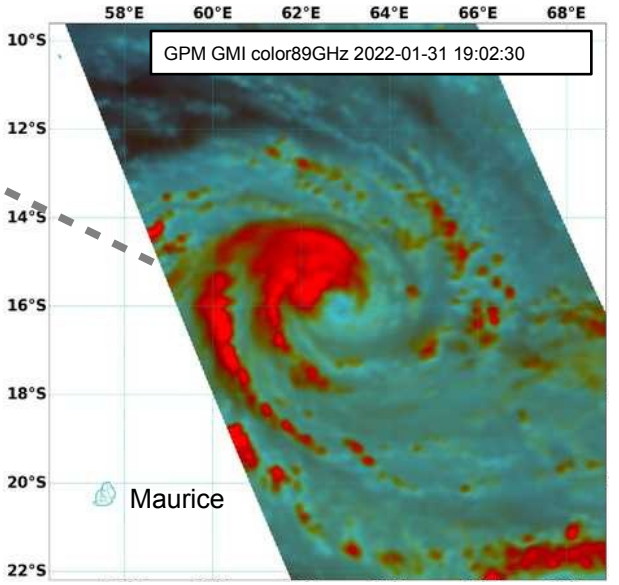
Concentric eyewall structure





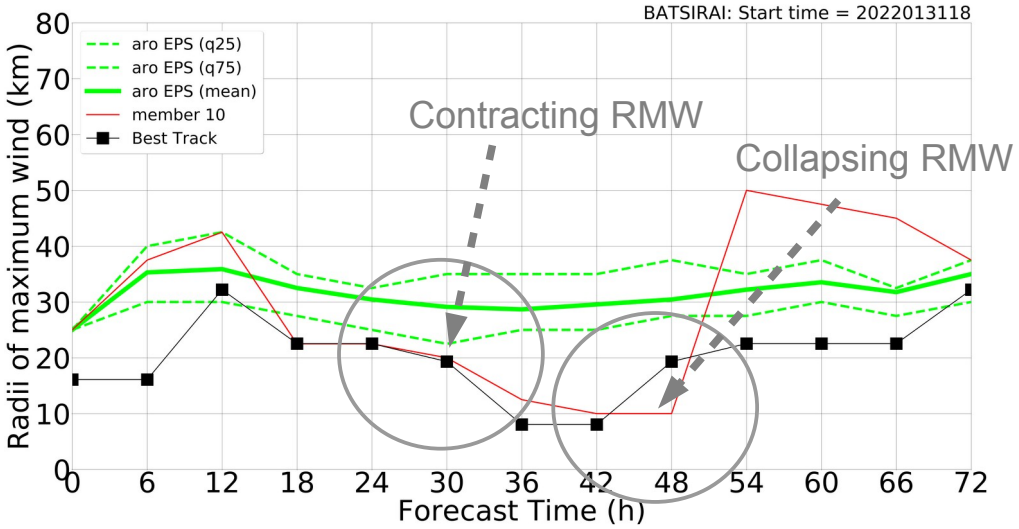
Analysed radii of maximum wind (RMW, cercles) + track (coloured line = RI).

Asymmetric structure



Batsirai's simulated sizes

How did Arome-OM EPS predict Batsirai's size (run at 18:00 UTC on 31/01) ?



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

- **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**.

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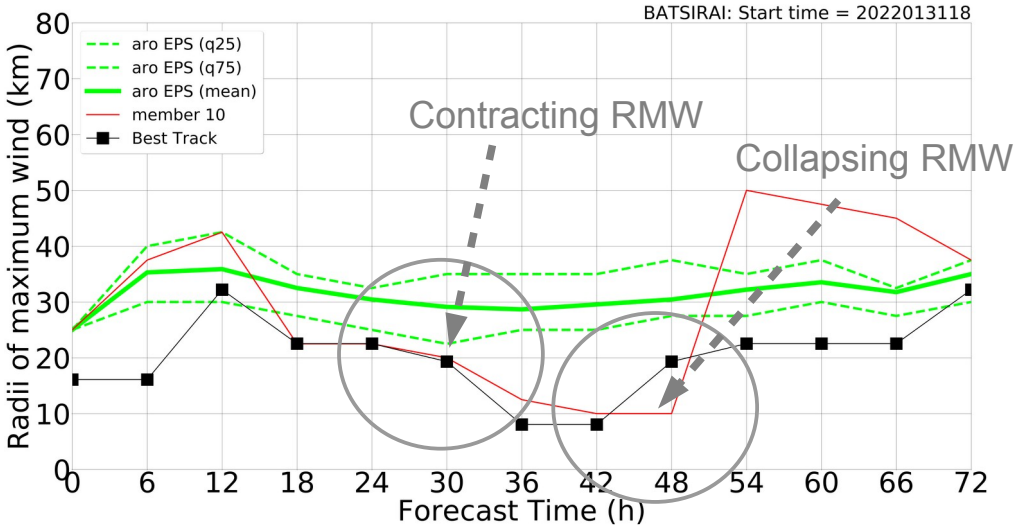
How did Arome-OM EPS predict Batsirai's size (run at 18:00 UTC on 31/01) ?



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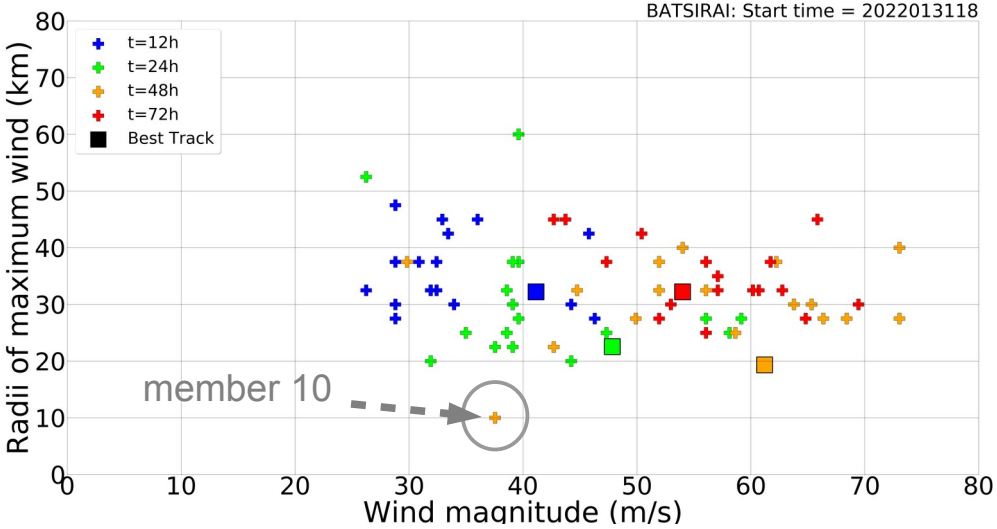
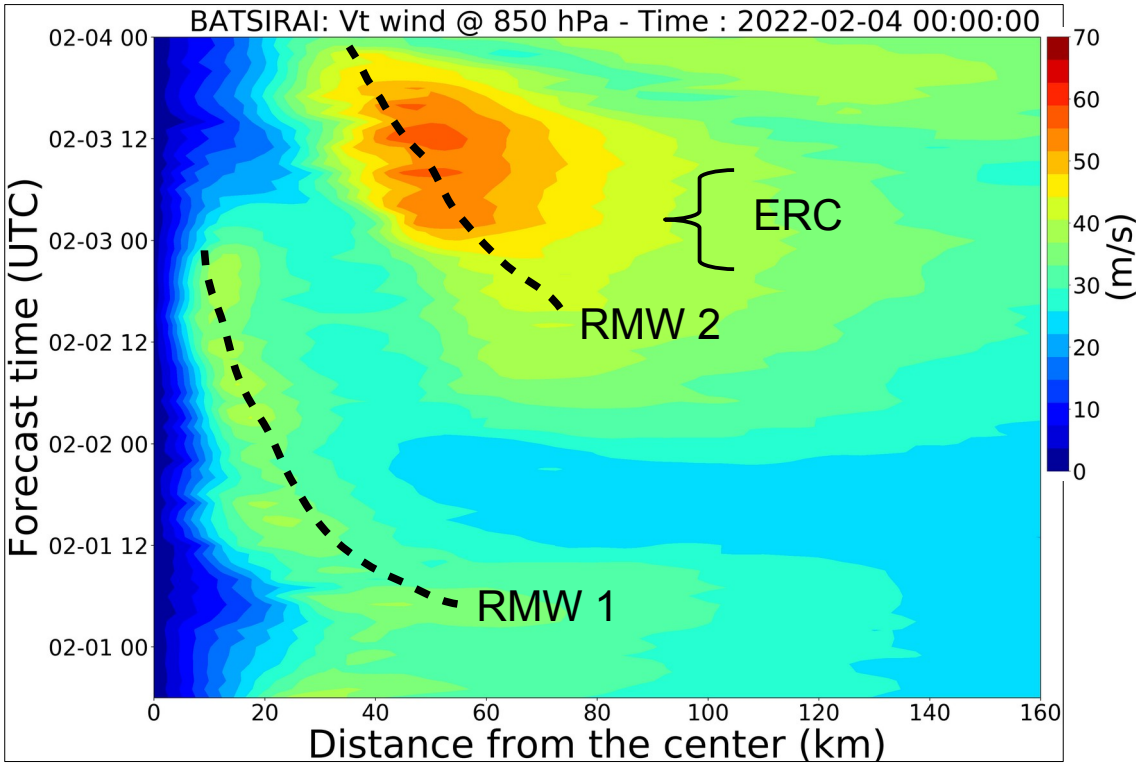


RMW (km) as a function of intensity (m/s). Coloured crosses indicate the forecast time, and the corresponding BT are the squares.

- **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**.
- Globally spoken lack of significant spread on the simulated **RMWs** (strongest winds are located at too larger radii compared to BT).

Overview of TC's inner-core structure from MB10

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



- Evident **sequence of ERC** : contracting RMW 1 (60km → ~15km) + RMW 2 appearing between 60-80 km. RMW 1 collapses and strengthening can resume.

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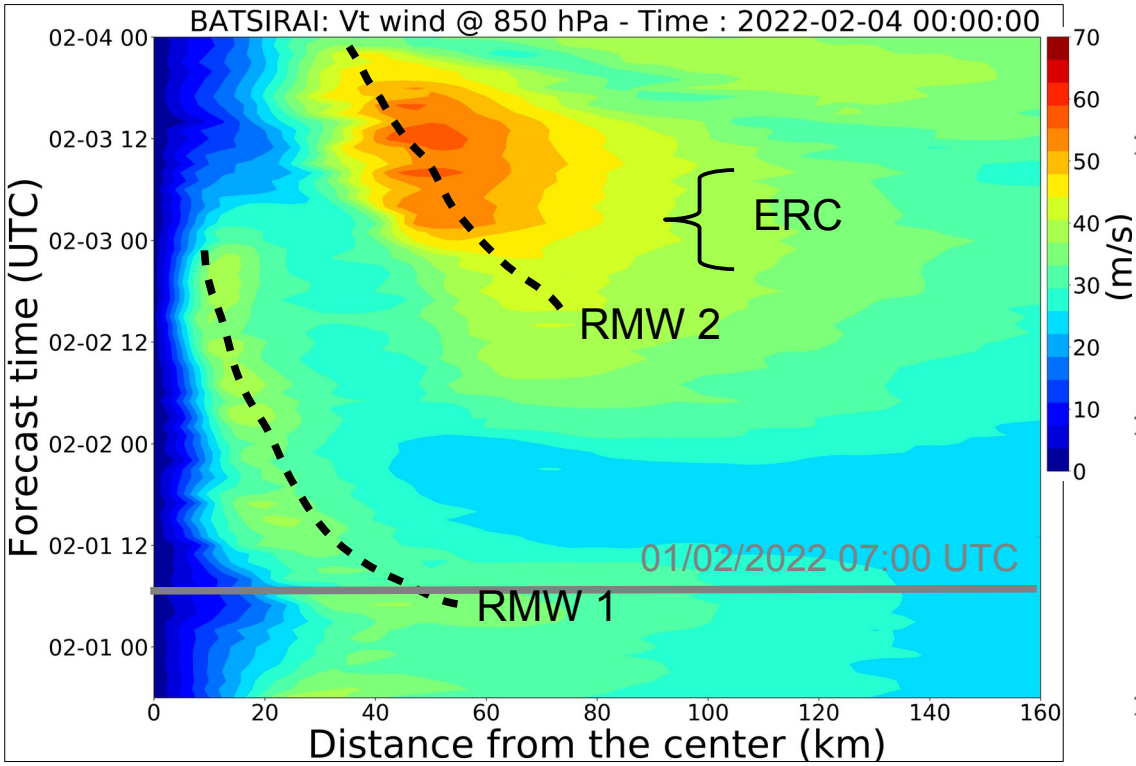
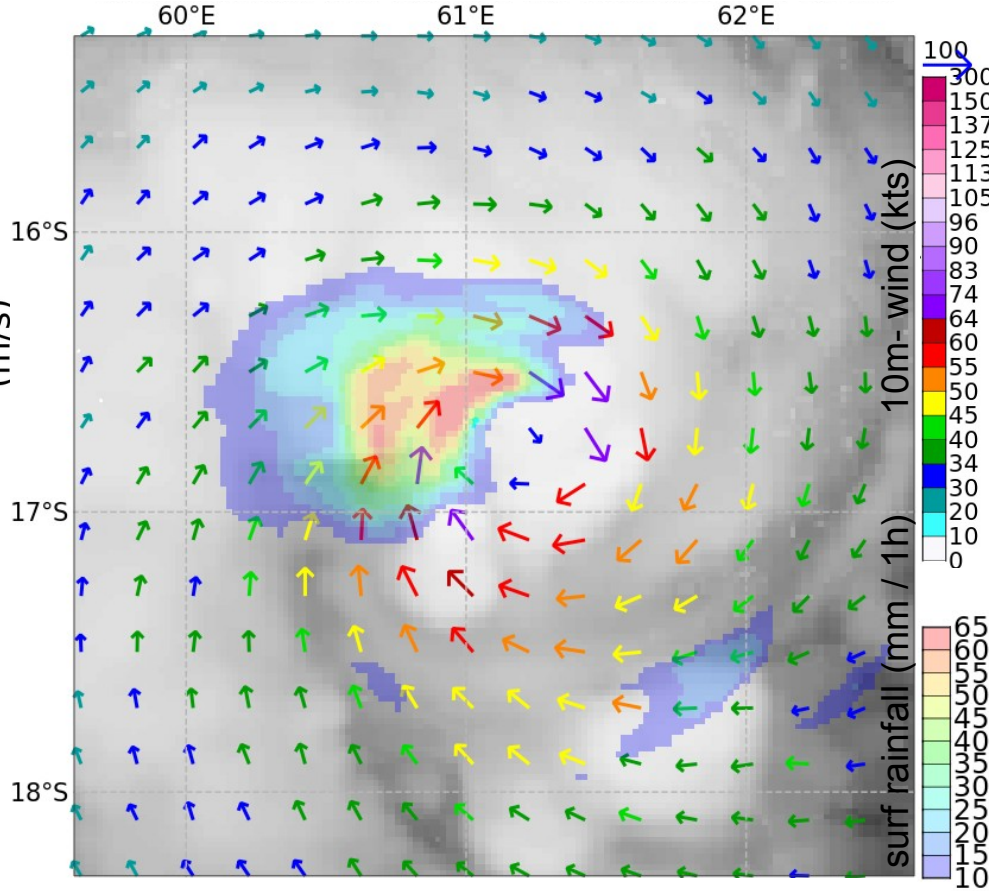


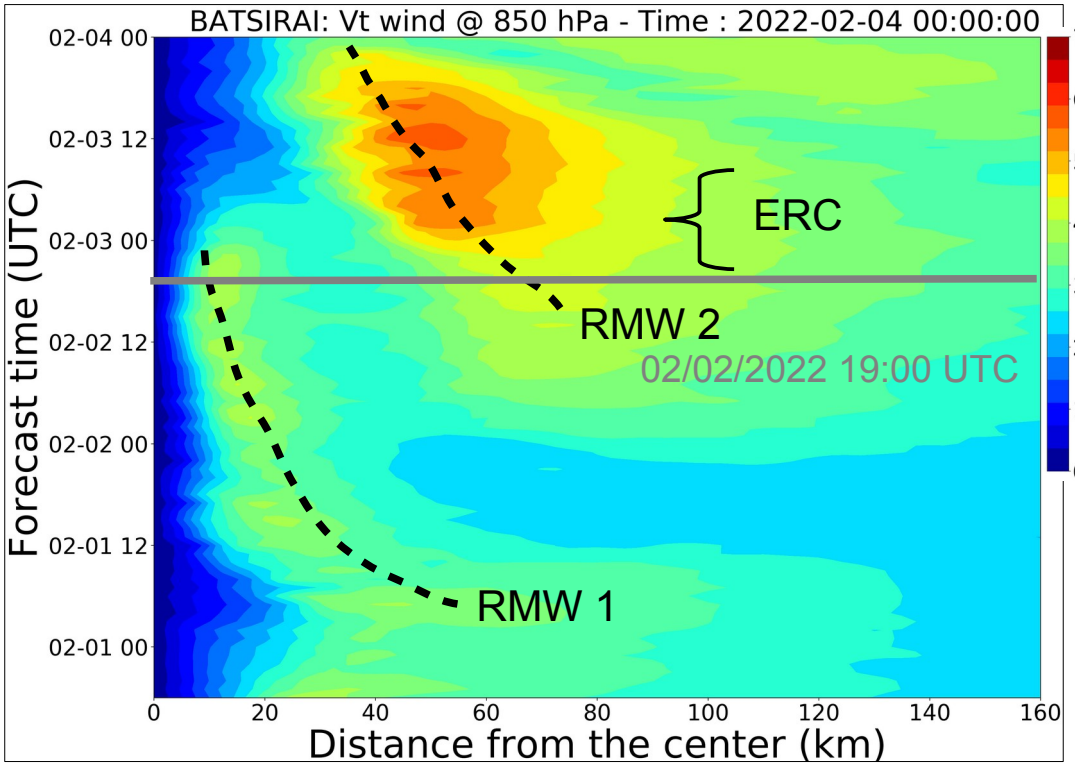
Storm-centered plot of simulated IR 10.8 µm BT + 1h-surface precip (coloured shades) and 10m- wind (arrows).



- 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 07:00 UTC on 01/02/2022 : **northeasterly 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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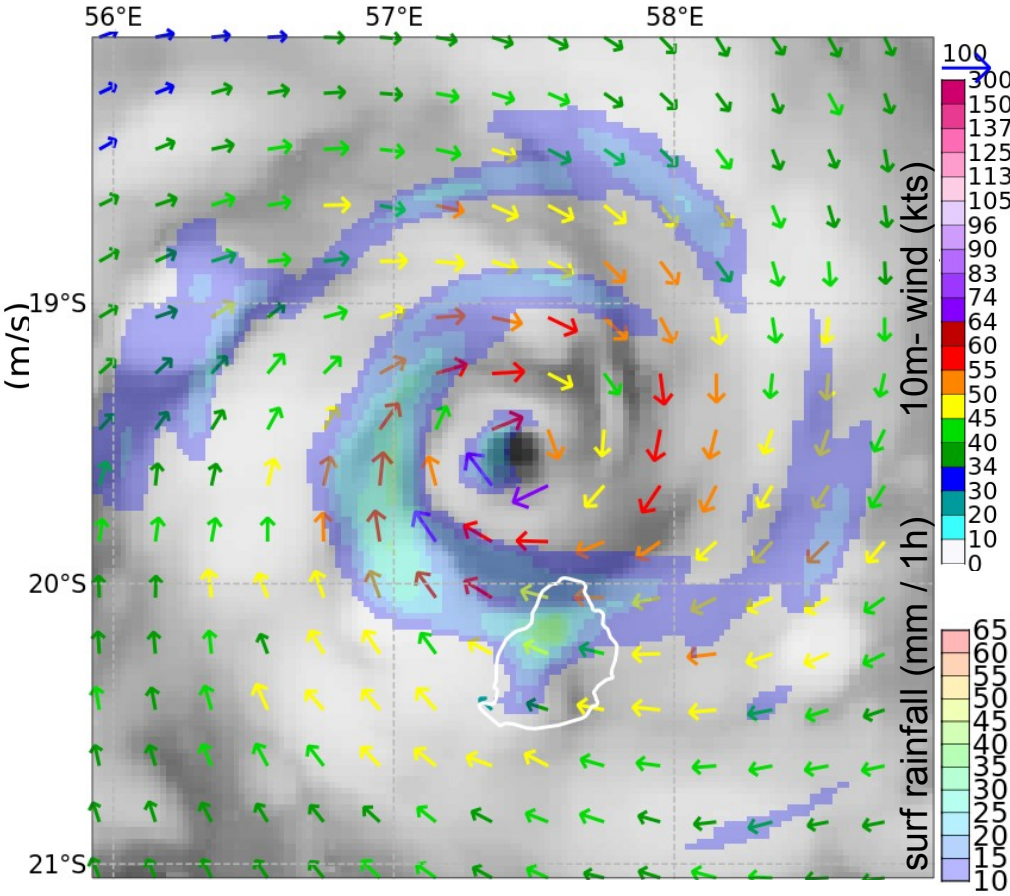
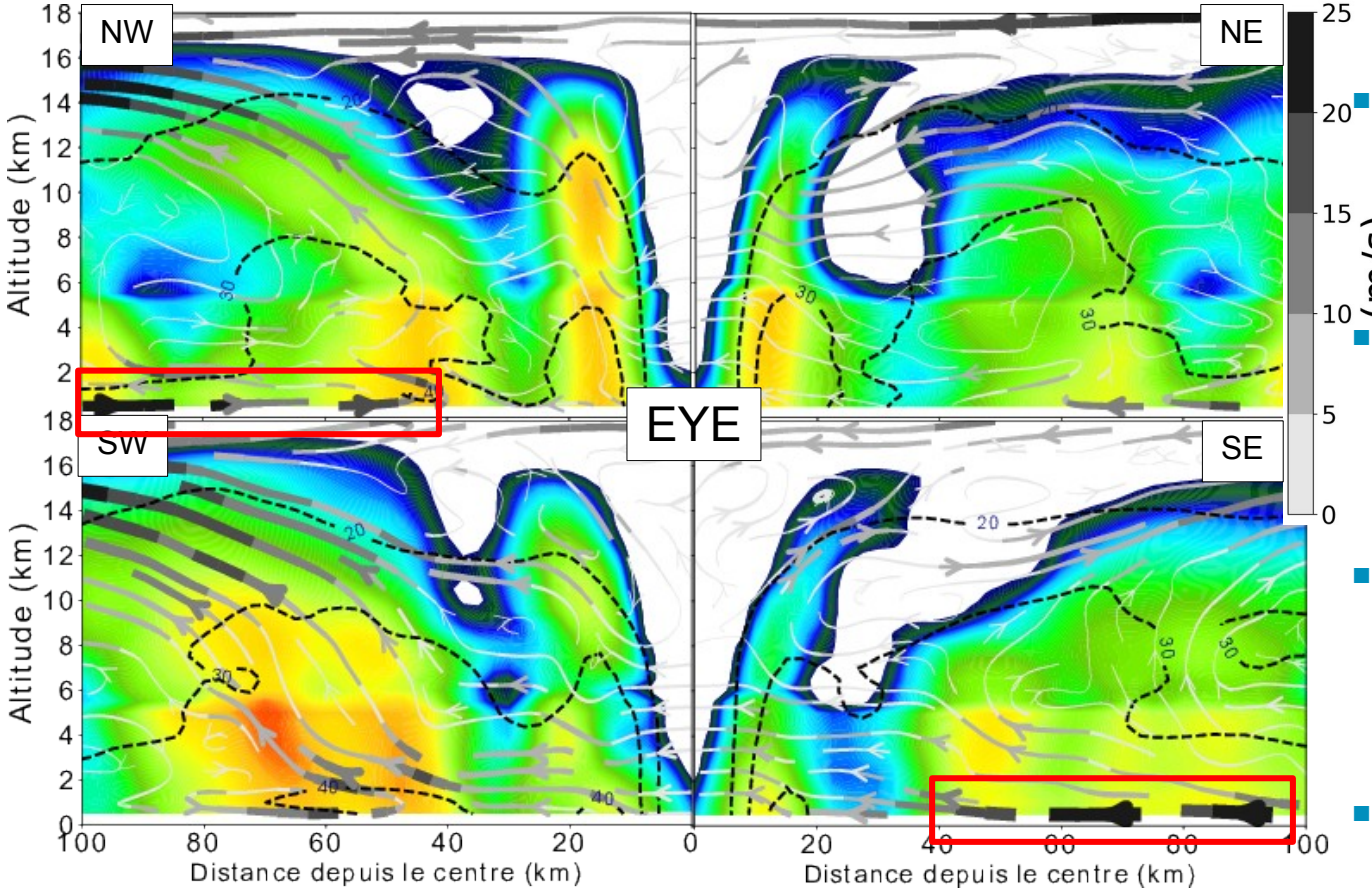


- Evident **sequence of ERC** : contracting RMW (60km → ~15km) + a 2nd max appearing between 60-80 km. The inner RMW collapses and strengthening can resume.
- Around 12:00 UTC on 02/02, a **double ring pattern** of strong precipitation forms just before the ERC.

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**.

Conclusions and future works

- 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 « good » spread (compared to ensemble errors) for track and it is able to capture some part of the **predictability** associated with **rapid intensification** in TC.
- However, it still suffers from an **issue of initial intensity** (especially for strong TCs), and probably it could benefit from works currently ongoing on **EDA** for the Arome-OM model (**better perturbed ICs**).
- These first prototypes of Arome-OM EPS will be improved, evaluating another **perturbations** for model errors ; as perturbed parameters (e.g. Meryl Wimmer's talk) and model's dynamic (Léna Dziura's thesis).
- First results with Arome-OM EPS are encouraging : highly feedback and **great interest from forecasters** !

Thank you for your attention !

Overall performance of Arome-OM EPS (EPS vs. deterministics)

Some objective scores : total track errors (15 runs considered so far) :