A Dedicated Convection-Permitting Ensemble in the Operational NWP Systems at Météo-France for the Tropics

Olivier Nuissier[1], Tom Rémond[4], Tarik Kriat[2], Adrien Colomb[3] and Sébastien Langlade[2]

[1] Centre National de Recherches Météorologiques Météo-France (Météo-France and CNRS), Toulouse, France.
[2] RSMC – La Réunion Tropical cyclone centre (Météo-France), La Réunion Island, France.
[3] Laboratoire de l'Atmosphère et des Cyclones, (Météo-France and Université de la Réunion, La Réunion Island, France.
[4] DIRCE/SERVICES (Météo-France), Bron, France.

Introduction

Tropical cyclone (TC) intensity change forecast is quite crucial, especially when such phenomena are approaching coastal-island regions. Complex interactions between both environmental (large-scale) external factor and internal (fine-scale) mechanisms strongly control TC predictability, and therefore our ability to properly predict **intensity changes**. The **French Overseas territories**, present in most of TC basins (North Atlantic, South West Indian Ocean and South Pacific), are largely concerned by TC hazards. In order to provide ever more effective guidance to **RSMC – La Réunion** TC center, weather numerical prediction systems at the French Weather Service, **Météo-France**, have been improved, notably the Arome Overseas operational deterministic chain, and very recently, for operations in 2023, its ensemble prediction system called **AROME-OM EPS**. The AROME-OM model described by *Faure et al. (2020)* has a horizontal resolution of **2.5km** and is operated twice daily across five tropical domains.

The objective of the present study is to assess the performance of the AROME-OM EPS for TC prediction focussing on reforecasts of TC events that occurred in the **southwest Indian Ocean** (SWIO) during the 2022-2033 TC seasons. Special attention is paid to the predictability of TC **Batsirai (2022)**. An analysis of a few synoptic-scale environmental and TC-scale variable calculation has been performed in a **probabilistic framework** in order to assess the ability of AROME-OM EPS in providing guidance of possible scenarios of Batsirai while approaching Mauritius and La Réunion islands.

The AROME-OM Ensemble Prediction System

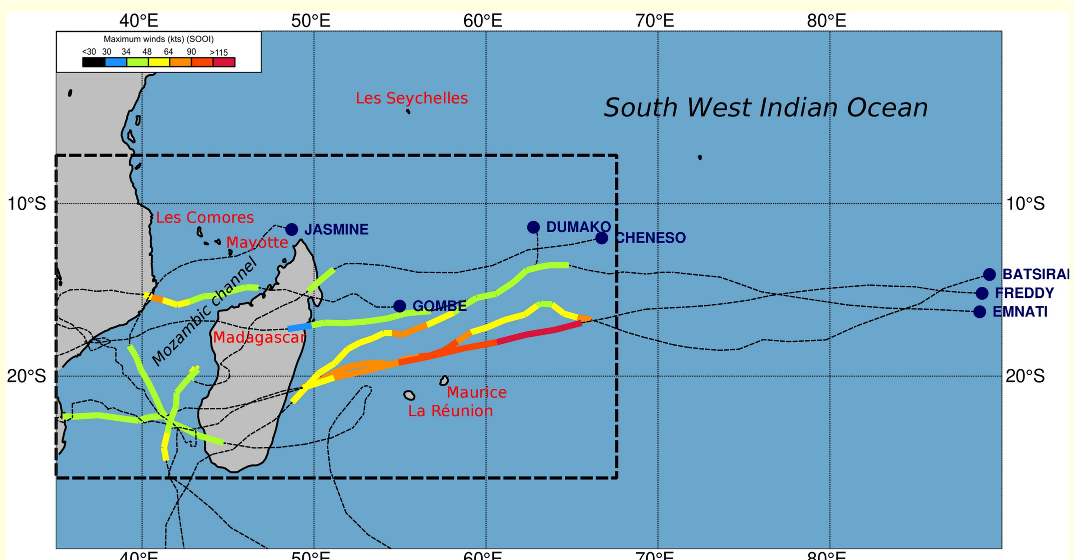

Fig.1 : Best-Track colored by intensity of the case studies retained during the 2022-2023 TC season. The black rectangle shows the AROME-OM EPS domain for the southwest Indian Ocean (SWIO).

The AROME-OM EPS ensemble set-up is the following :

i) The ensemble runs comprise 15 'perturbed' + one control 'unperturbed' member (16 members) up to 72 h forecast range

ii) Lateral Boundary Conditions (LBC) are provided by a subset of about fifteen members of the ARPEGE EPS called **PEARP** (*Descamps et al., 2015*), selected according to a clustering approach.

iii) Initial perturbations from PEARP are downscaled on the 2.5 km AROME-OM grid and added to AROME-OM analysis (zonal and meridional wind, temperature and surface pressure).

iv) Atmospheric model errors are represented by the stochastic perturbation of physics tendencies (SPPT) scheme from ECMWF and adapted for the AROME model (*Bouttier et al. (2012)*)

v) Surface (continental) and sea surface temperature (SST) and ocean (temperature) conditions of the AROME model are also perturbed using the same 2D horizontal random pattern.

Overall performance of AROME-OM EPS

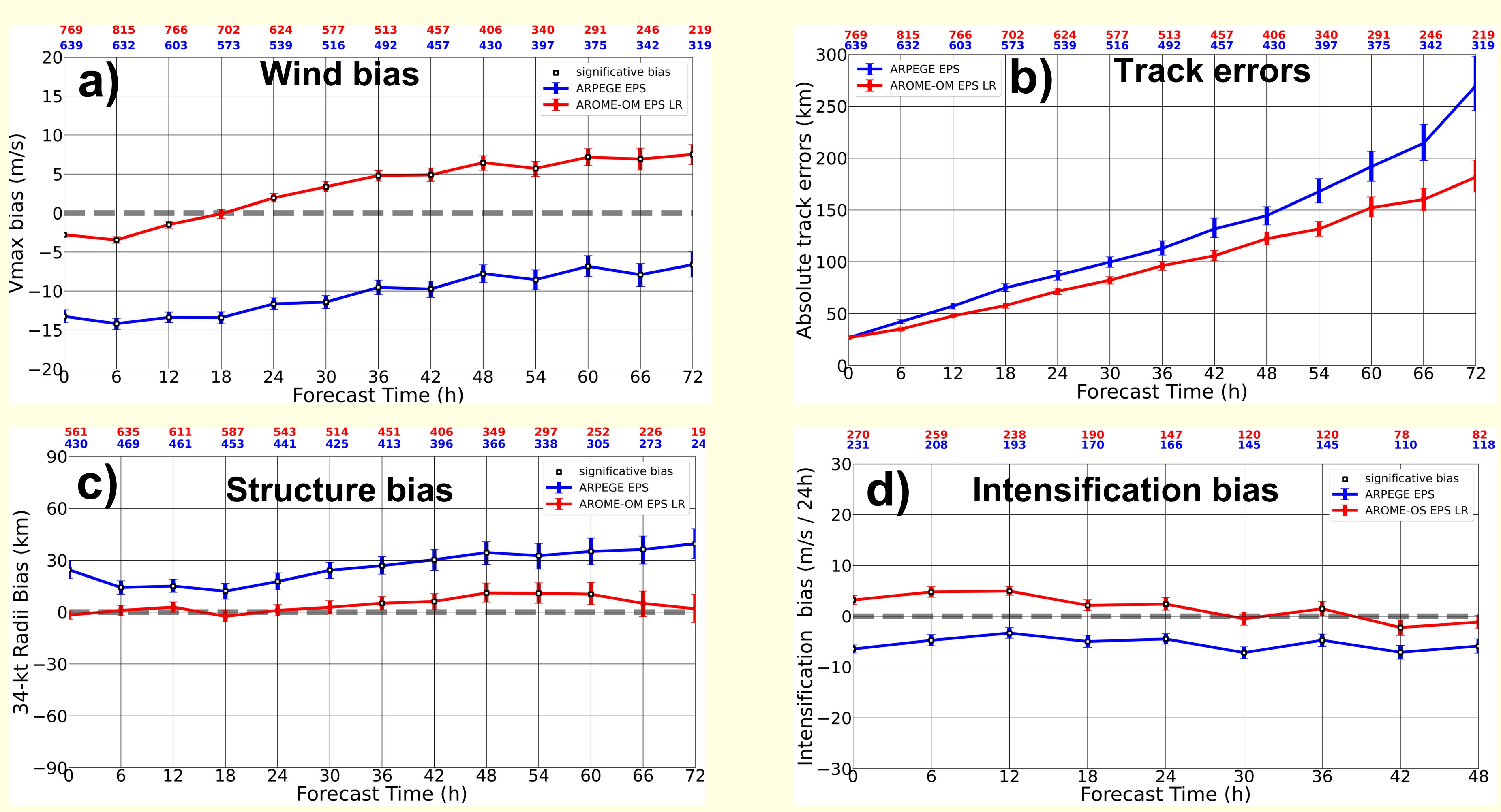

*Fig.2 : **a)** Maximum wind bias, **b)** Absolute Track errors, **c)** Tropical storm wind radii bias, and **d)** Intensification (ΔVmax over the next 24h >0) bias from **AROME-OM EPS** (red) against its coupler **PEARP** (blue) as a function of forecast time (h). The error bars show the 95% confidence interval.*

Although AROME-OM EPS overestimates intensity at longer range, intensity biases are significantly reduced compared with PEARP, which tends to underestimate TC intensity at all lead times (Fig. 2a). Contrary to what one would expect, absolute track errors are improved for AROME-OM EPS against PEARP (Fig. 2b). It could be due to much better initial conditions in AROME-OM analysis that could imply better interaction between the TC's vortex and its environmental steering flow.

Regarding surface wind structures (tropical storm wind radii), AROME-OM EPS biases are quite reduced, although being slightly positive between 36h and 60h. Broadly speaking, AROME-OM EPS has a much better handle on TC intensification (Fig. 2d). Standard deviation (not shown) is also in the same lines than biases presented here.

References

- Faure, G., P. Chambon, and P. Brousseau, 2020: Operational Implementation of the AROME Model in the Tropics: Multiscale Validation of Rainfall Forecasts. *Wea. Forecasting*, 35, 691–710, https://doi.org/10.1175/WAF-D-19-0204.1.
- Descamps, L., Labadie, C., Joly, A., Bazile, E., Arbogast, P. and Cébron, P. (2015), PEARP, the Météo-France short-range ensemble prediction system. *Q.J.R. Meteorol. Soc*, 141: 1671-1685. https://doi.org/10.1002/qj.2469
- Bouttier, F., B. Vié, O. Nuissier, and L. Raynaud, 2012: Impact of Stochastic Physics in a Convection-Permitting Ensemble. *Mon. Wea. Rev.*, 140, 3706–3721, https://doi.org/10.1175/MWR-D-12-00031.1.
- DeMaria, M.; Kaplan, J. A Statistical Hurricane Intensity Prediction Scheme (SHIPS) for the Atlantic Basin. Weather Forecast. 1994, 9, 209–220.
- Hazelton, A. *et al*. (2021) : Understanding the Processes Causing the Early Intensification of Hurricane Dorian through an Ensemble of the Hurricane Analysis and Forecast System (HAFS). *Atmosphere*, 12, 93. https://doi.org/10.3390/atmos12010093

Cases studies and methodology

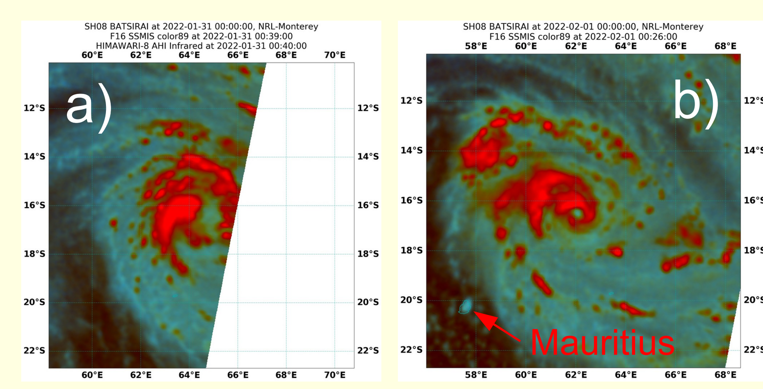

*Fig3: Microwave satellite image of TC Batsirai observed on : (**a**) 31/01/22 @ 00UTC and (**b**) 01/02/22 @ 00UTC, respectively.*

Tab1: List of cases, date ranges considered and maximum wind reached by each system.

Name Storm	Number of runs	First/last start time	Maximum observed intensity (kt)
BATSIRAI	13	31/01/2022 - 06/02/2022	**110**
DUMAKO	4	13/02/2022 - 15/02/2022	45
EMNATI	11	17/02/2022 - 22/02/2022	95
GOMBE	5	08/03/2022 - 10/03/2022	85
JASMINE	5	24/04/2022 - 26/04/2022	60
CHENESO	9	18/01/2023 - 27/01/2023	75
FREDDY	9	19/02/2023 - 11/03/2023	120

In order to assess the overall performance of AROME-OM EPS for TC prediction, a statistical analysis of intensity, track, and structure errors was performed for 7 storms that occurred in the simulation domain during 2022-2023 TC seasons. AROME-OM EPS and its driving model (PEARP) are verified RSMC La Réunion Best-Track (BT) database. In order to fairly compare both ensembles, model fields are interpolated onto the same grid with a horizontal resolution of 0.025°.

Special attention is paid on TC Batsirai (2022). After having impacted by vertical wind shear and dry air (Fig 3a), Batsirai found very favorable conditions over the SWIO basin and became a powerful TC (Fig 3b). It moved very close to both Mauritius and La Réunion islands, before hitting Madagascar very hard.

Predictability of TC Batsirai (2022)

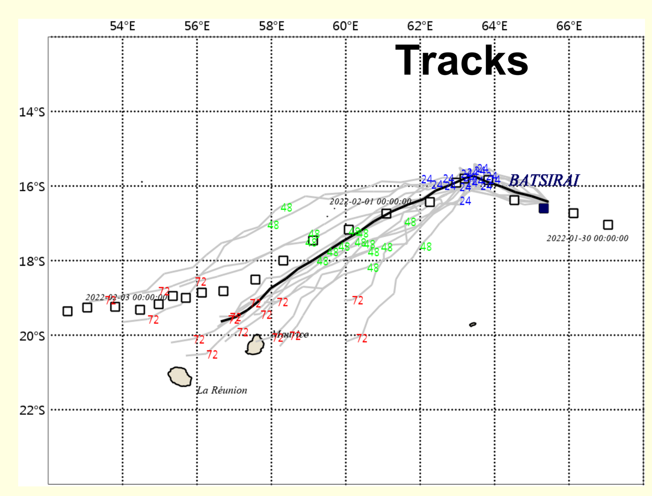

*Fig.4: 72-h tracks of TC Batsirai started on 31/01/22, at 1800 UTC. **Squares** show the **Best Track**. Thick line highlights the ensemble mean. Number labels mark TC position at **24h**, **48h** and **72h**, respectively.*

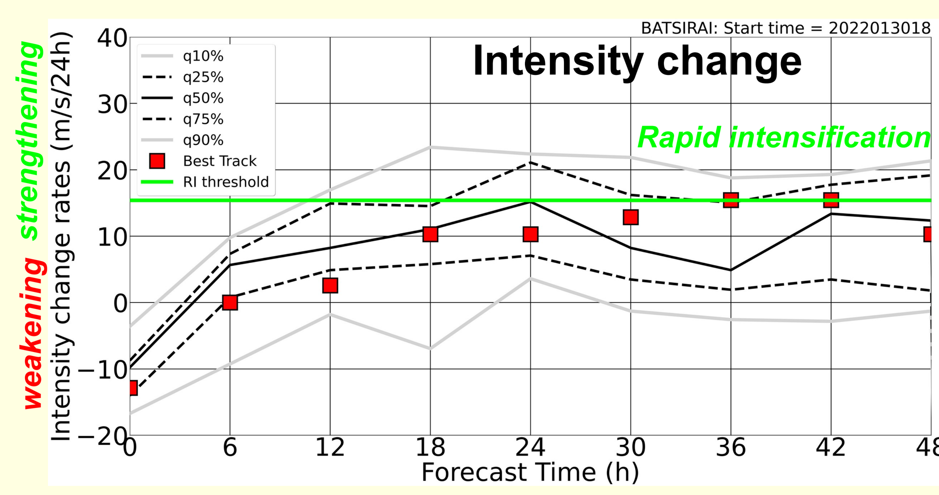

*Fig.5: Time-series of Batsirai's predicted intensity change. Forecast starts on 31/01/22, at 1800 UTC. The lines indicate different percentile thresholds. **Red squares** show the **BT**. The green line highlights the rapid intensification (RI) threshold.*

Based on this specific run (31/01/22 at 18UTC), AROME-OM EPS already showed two possible track scenarios : either moving southwest very close to Mauritius and La Réunion, or more west-southwest a bit away from the islands (Fig. 4). One of the key parts of TC intensity change prediction is also to correctly predict its (rapid) intensification. AROME-OM EPS enables to capture fairly well the **Batsirai's RI** almost 30h-36h ahead (Fig. 5).

A few variables, similar to those used to drive the Statistical Hurricane Intensity Prediction Scheme (SHIPS) (*DeMaria et al., 1994; Hazelton et al., 2021*), have been calculated. The decrease of spread on inner-core structure metrics (including **vortex tilt**) and on the related convective structure suggested a very favorable configuration (upshear convection triggering along the RMW) and less uncertainty for a **scenario of a powerful intensifying** TC approaching the islands (Fig. 6).

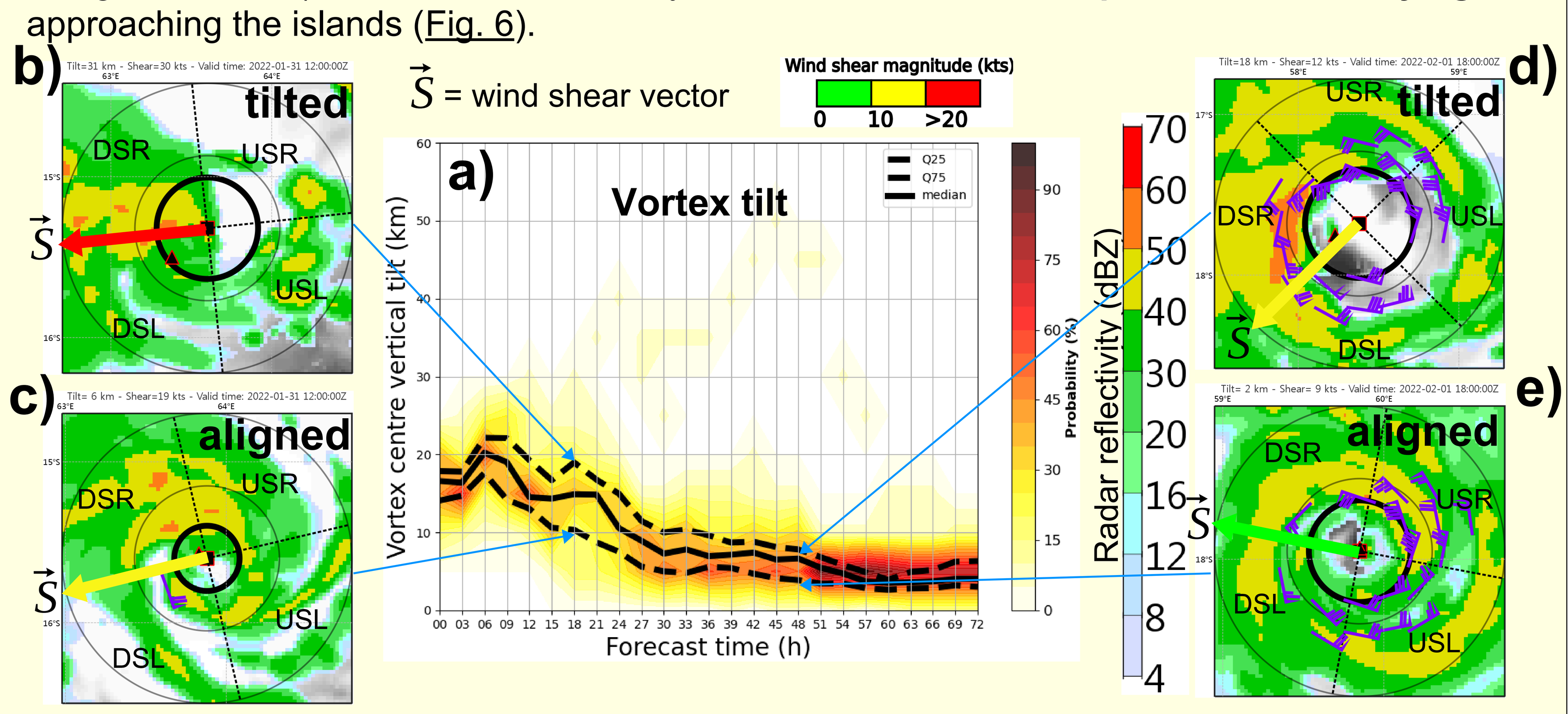

*Fig.6 : **a)** Probability of vortex center tilt (surface-5km) from 0 to 72h forecast time, started on 31/01/22, at 1800 UTC. Simulated convective structure (radar reflectivity, dBZ) for the representative tilted (aligned) member at 18h (**b – c**) and at 48h (**d – e**). S stands for the deep-layer wind shear (850-200 hPa). The cercle shows the mean radius of maximum wind (**RMW**)*

Météo-France, DESR/CNRM/GMAP, 42 Avenue Coriolis, 31057 Toulouse Cedex 1, FRANCE
Tel: 33 5 61 07 98 65 Fax: 33 5 61 07 96 26
Email: olivier.nuissier@meteo.fr