Application of a high-resolution ensemble prediction system to the prediction of tropical cyclones over the West Indies basin

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1. The French TIREX project

Sharing learning from post-disaster research for strengthening individual and collective response and adaptation capacities in the context of climate change (Leeward Islands - 2017 hurricane season)

The TIREX project is built on an interdisciplinary approach involving geography, geomorphology, spatial analysis and remote sensing techniques, political sciences, information and communication, sociology, scientific mediation, climate modelling and climatology.

Within this project, **Météo-France will examine the potential benefit of a high-resolution ensemble prediction system (EPS)** to better forecast cyclones track/intensity and improve decision making, with a specific focus on the three hurricanes of September 2017, Irma, Jose and Maria.

2. Arome Overseas

- Five NWP systems based on the French Arome model have been deployed in early 2016 over the main French overseas territories: West Indies, French Guiana, La Réunion, New Caledonia and French Polynesia.
- The Arome model has a non-hydrostatic dynamical core and detailed moist physics designed for kilometric-resolution forecasts; the vertical resolution is characterized by 90 vertical layers starting at 5m, and a regular 2.5km resolution is used on the horizontal, allowing explicit deep convection.
- Arome is coupled to a 1D-ocean model, initialized by Mercator-Ocean global model.
- For the atmospheric initial conditions and coupling, this tropical version of Arome uses the deterministic global model from ECMWF (HRES).
- Forecasts up to +48h are run four times a day and are extended up to +78h in case of tropical cyclone threat.

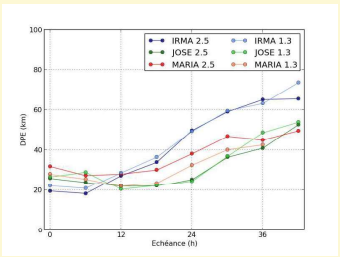


Figure: Mean Direct Position Error according to forecast lead time for the three hurricanes and the two versions of Arome-West Indies.

These new models bring an important added value for both weather and cyclone forecasting (Faure *et al.*, 2019). **For the TIREX project, a high-resolution version of Arome-West Indies with a 1.3km horizontal resolution has been compared to its operational counterpart** for the hurricanes Irma, Jose and Maria. Both versions perform well on trajectory forecasts. With respect to the intensity, the high-resolution version is a bit more realistic.

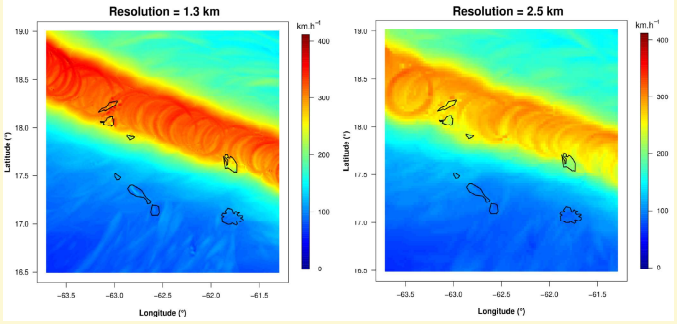


Figure: Maximum of wind gusts on 24h forecast for the two versions of Arome-West Indies for hurricane Irma. Forecasts start on 5 Sept. 2017 at 18 UTC. Wind gusts reached 321 km/h on Saint-Barthélémy according to an unoffical station, and mean wind reached 295 km/h.

3. Arome Overseas EPS

A prototype of high-resolution EPS based on Arome Overseas has been developed (Bousquet et al., 2019). The configuration is mostly an adaptation from the Arome-France EPS which has been running operationally over France since 2016. The main characteristics are the following :

- 12 perturbed members (no control) at 2.5km
- Initial perturbations and boundary conditions are determined from a clustering of ECMWF-EPS members (Bouttier and Raynaud, 2018)
- Model errors are accounted for with the Stochastically Perturbed Physics Tendencies (SPPT) approach (Bouttier *et al.*, 2012)
- Random perturbations are added to the SST and ocean mixed layer (Bouttier *et al.*, 2016).

4. Probabilistic prediction of Hurricane Maria

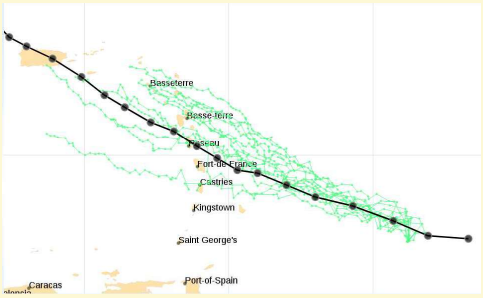


Figure: Trajectories predicted by the Arome-EPS started on 17/09/2017 at 00UTC (green) and best track (black).

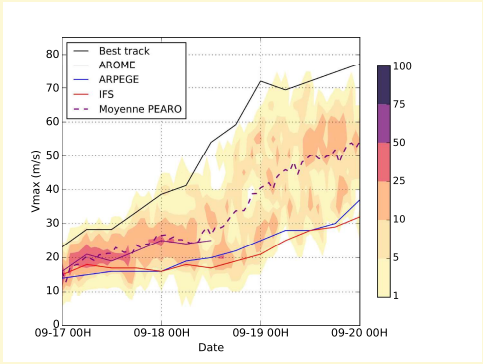
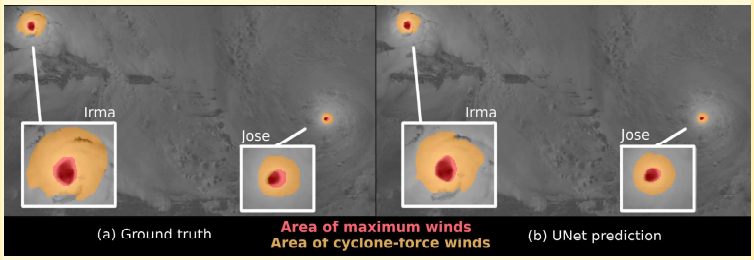


Figure: Probabilities of maximum wind derived from the Arome-EPS started on 17/09/2017 at 00UTC.

- The Arome-EPS improves the intensity of maximum winds compared to the global EPS from ECMWF and Météo-France.

5. Tropical Cyclone Object Identification with Neural Nets : the TCOINN tool

- Detect tropical cyclone objects from Arome outputs using Convolutional Neural Networks (CNNs)
- 3 target objects : area of cyclone-force winds, area of maximum winds and cyclone center
- Based on U-Net (Ronneberger et al., 2015), a commonly-used CNN for segmentation problems
- U-Net inputs : Arome forecasts of 10-m wind speed and Z850
- Training database : 150 cases (West Indies basin) manually labeled



- Very encouraging results : no miss (multiple cyclones well detected) and no false alarms
- Results should be further improved with a larger training dataset and clear labeling rules
- Transfer learning between different Overseas domains seems promising : the CNN trained over West Indies outputs performs well when applied to Indian Ocean basin outputs
- Use of TC objects in forecast verification and in the design of innovative probabilistic products will be examined.

6. Conclusions

- The Arome-EPS provides promising results on the 2017 hurricane season
- A comprehensive evaluation will be performed on a wider range of hurricane and non-hurricane events
- Tuning of clustering and surface perturbations will be further investigated
- Development of innovative EPS products and vizualization tools is planned with the support of experts in risk mapping

References

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