# Understand and quantify the sources of uncertainty that govern the predictability of tropical cyclones at the convective scale with AROME

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# Plan

- Context / Goal
- Perturbation of Semi-Lagrangian advection scheme
- Results on cyclone scores (trajectory and intensity)
- Conclusions and Perspectives

# Context

Several french overseas territories are subject to cyclonic hazards

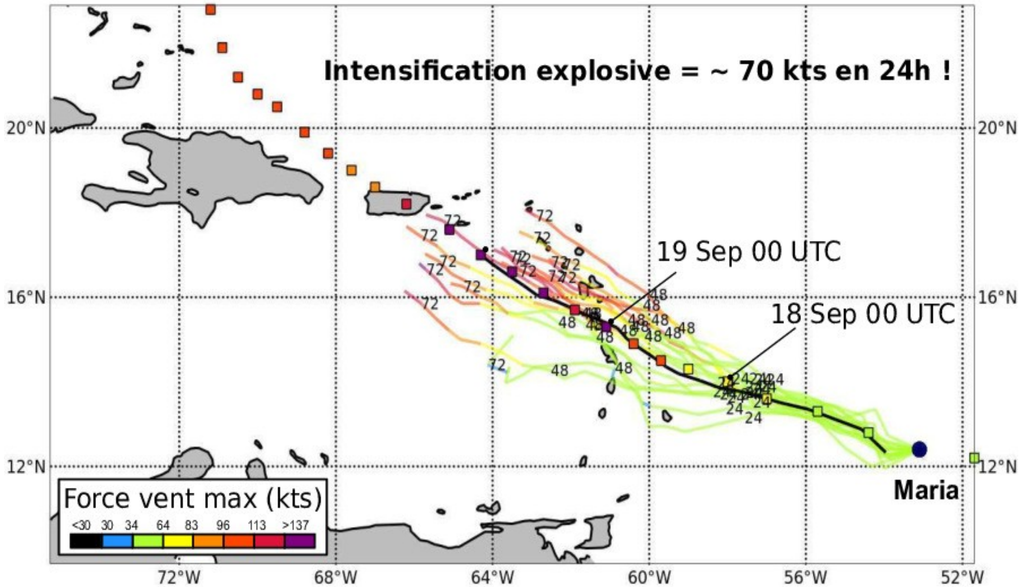
**Extremes** phenomena→ Difficult to predict ! (especially intensity)

Non-linear dynamics, sensitive to fine-scale phenomena (convection processes, turbulence, etc.), initial conditions and coupling.

How can we quantify the uncertainty associated with cyclone forecasts ?

➔ Development of a **High-Resolution Ensemble Prediction System** to assess predictability since 2020 : **AROME-OM-EPS**.

Plumes trajectory – intensity AROME-OM-EPS Antilles 17 Sep 2017 00UTC



# Main Goal

**Improving** the representation of model errors in **AROME-OM-EPS**

I. Another approach to represent uncertainties related to physical processes in the model ?

- Implementation of Parameter Perturbation (PP) method in AROME-OM-EPS

II. How to represent the uncertainties linked to the model dynamics ?

- Sensitivity Analysis on Departure Point Perturbations (DPP) in the Semi-Lagrangian advection scheme
- Implementation of DPP in AROME-OM-EPS over 19 cases, 3 basins during season 2020-2021

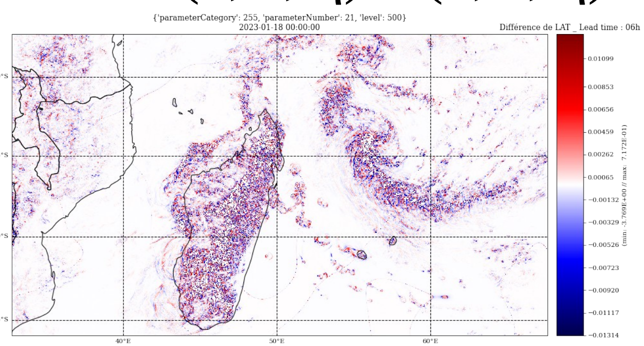
# Perturbation of Semi-Lagrangian advection scheme

# How to perturb Semi-Lagrangian advection scheme ?

<u>S.J. Lock assumption :</u>

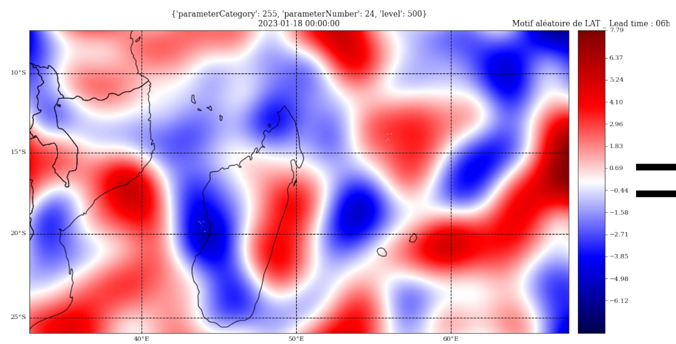
The greater the speed of convergence to determine the position of the Departure Point, the more certain this position is

$Z_{Diff} = \overrightarrow{(u, v, \eta)}_4 - \overrightarrow{(u, v, \eta)}_2$



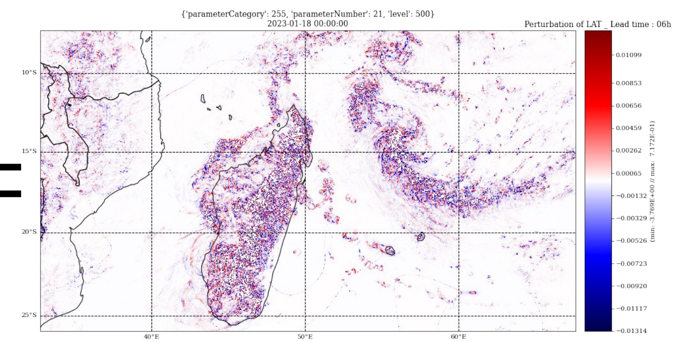

X

$Z_{Rand}$




=

$Z_{Pert}$




$Z_{Pert}$ added to the "final" wind field used to calculate the "final" Departure Point position

# Sensitivity Analysis on DPP

First tests with IFS settings leading to **Numerical crashes** of the model !

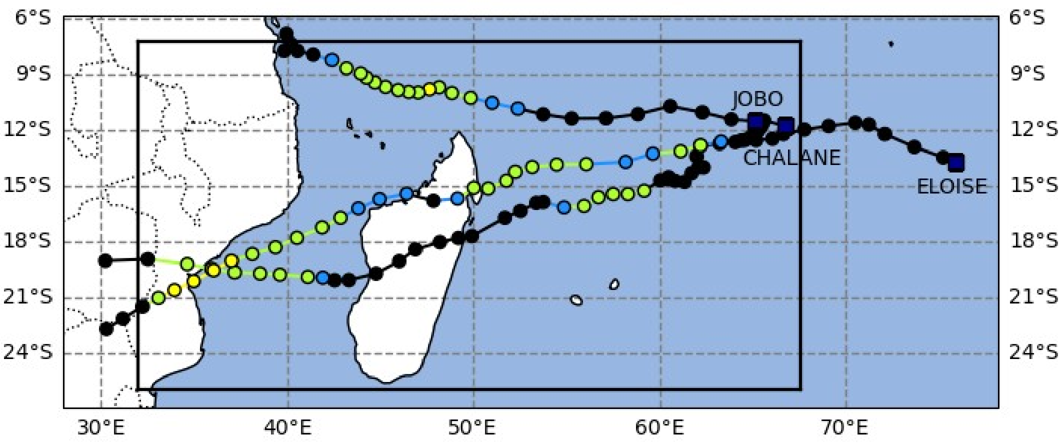
Short sensitivity analysis on :

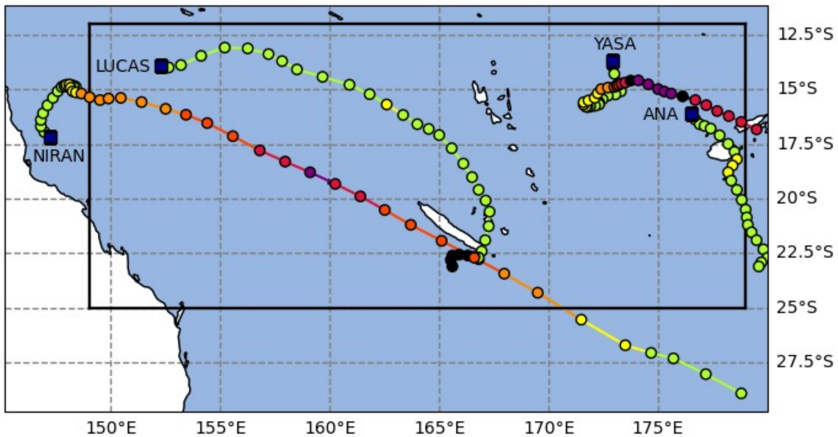
➔ The wind difference ($Z_{diff}$)

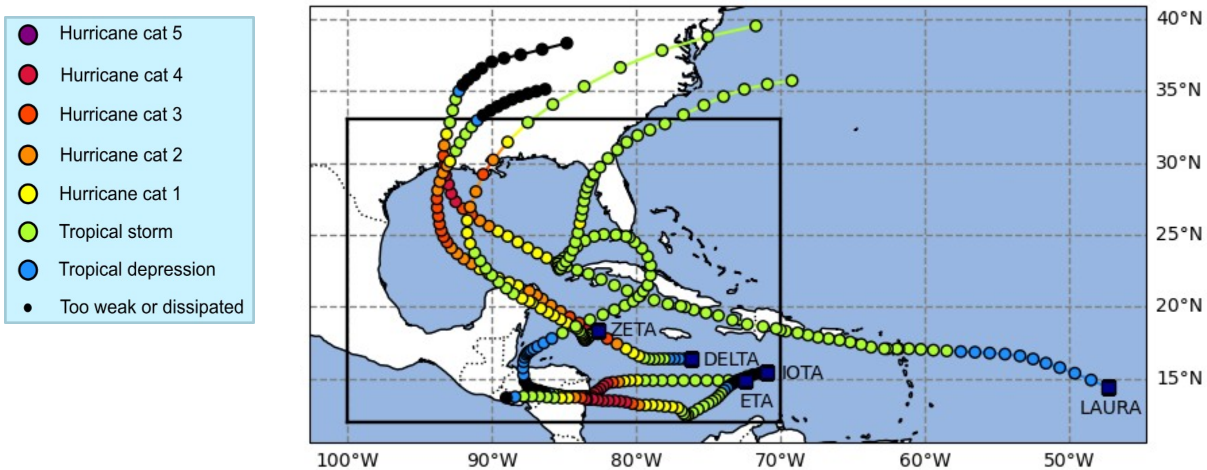
➔ The random pattern ($Z_{rand}$) : spatio-temporal correlation and the amplitude
**SPPT settings kept** (XL_COR = 400km, TAU = 6h, CPERT = 0.3)

# Domains and Cases studies

Selection of 3 domains : - SWIO : South West Indian Ocean (operational)
- SWPO : South-West Pacific Ocean = stretched Caledonia
- GoM : Gulf of Mexico (instead of Antilles)




12 systems (19 runs)
for 2020-2021 season

# Experiments with AROME-OM-EPS

**AROME-OM-EPS** :
Horizontal resolution 2.5km, simple precision, hydrostatism.
IC IFS + ARPEGE-EPS, LBC ARPEGE-EPS. SPPT, final lead-time 72h.

| Name | Perturbations of initial and lateral boundary conditions | Physical model perturbations | Dynamical model perturbations |
|---|---|---|---|
| ILB | Yes | No | No |
| ILB_SPPT | Yes | SPPT | No |
| ILB_DPP | Yes | No | Yes |
| ILB_DPP_SPPT | Yes | SPPT | Yes |

Tracking tool used to evaluate cyclones position and intensity : maximum sustained wind speed at 10m and minimum pressure reduced to sea level

# Intensity and Trajectory Scores

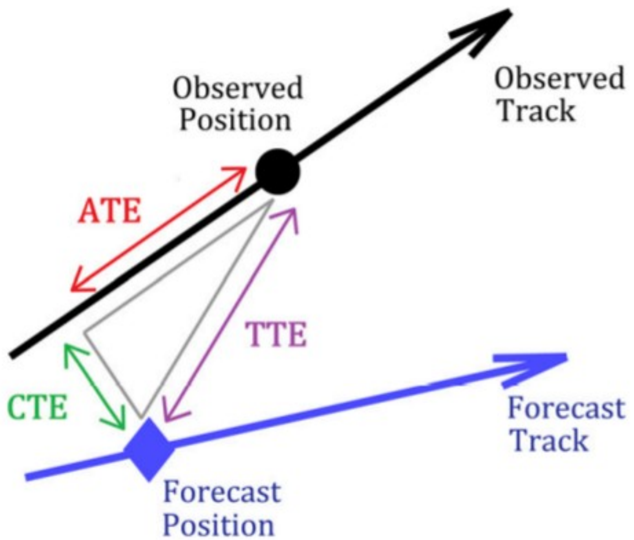
Intensity evaluation :

Spread Skill Ratio (SSR)

$$SSR = \frac{Spread}{RMSE}$$

Trajectory evaluation :

Total Track Error (TTE)



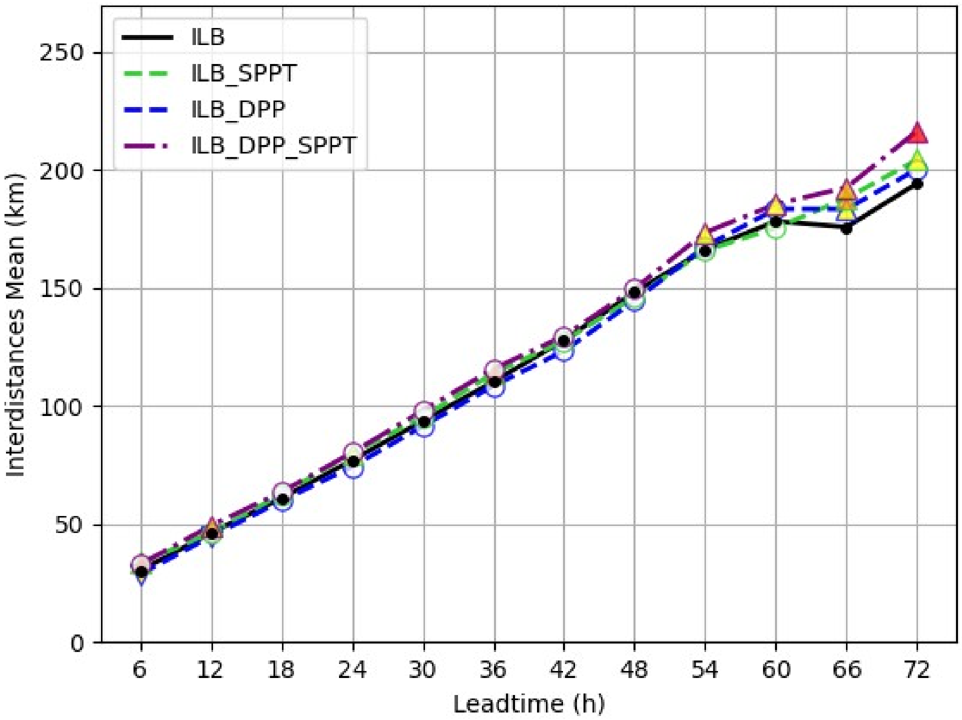

*Leonardo et Colle, 2018*

Computation of $\overline{\text{TTE}}$ mean and mean distances between members of the ensemble

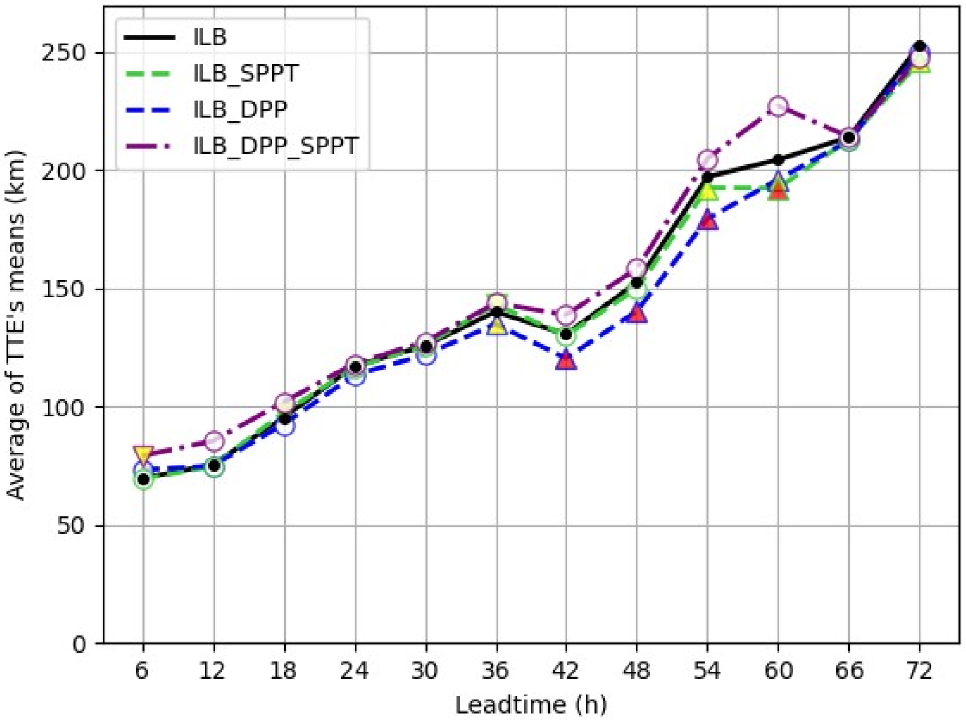
# Results on cyclone scores

# Results : Trajectory

(a) Mean distances : Measure of Spread




(b) $\overline{\text{TTE}}$ mean : Measure of Skill

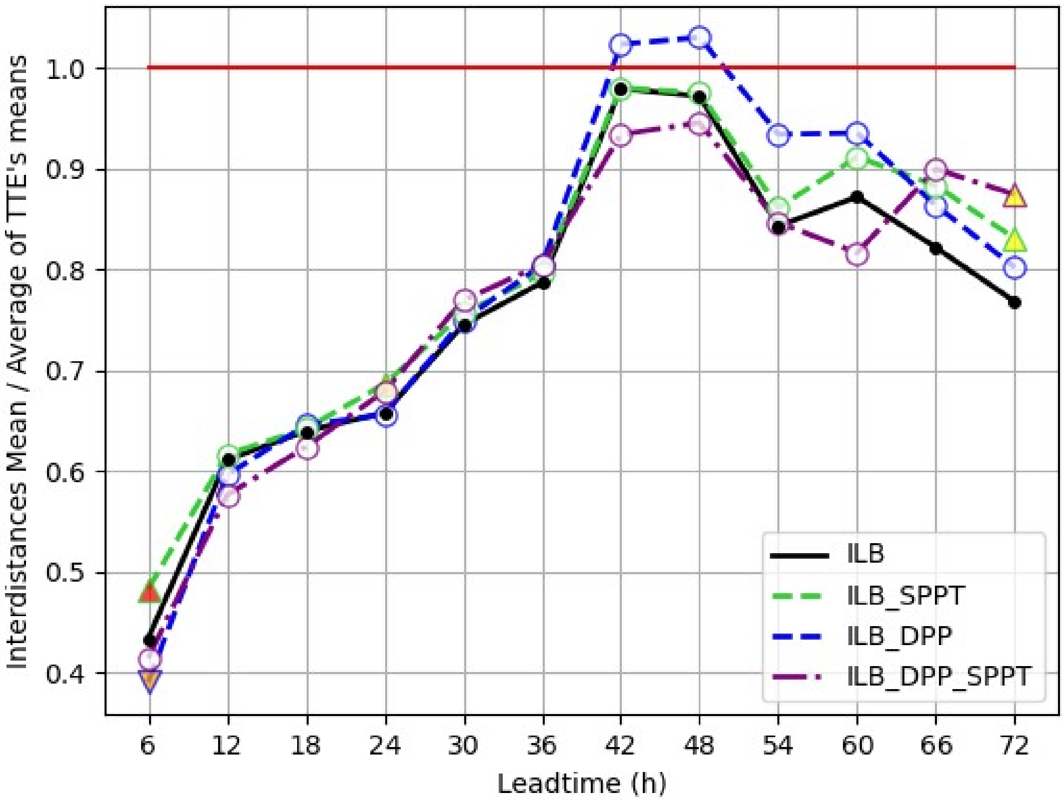



- Overall, no impacts on trajectory dispersion with the addition of model perturbations, except at long leadtime for ILB_DPP_SPPT compared to ILB.

- Better skill for ILB_DPP, no significant impact otherwise.

# Results : Trajectory

(a)/(b) Mean distances / $\overline{TTE}$ mean : Measure of reliability

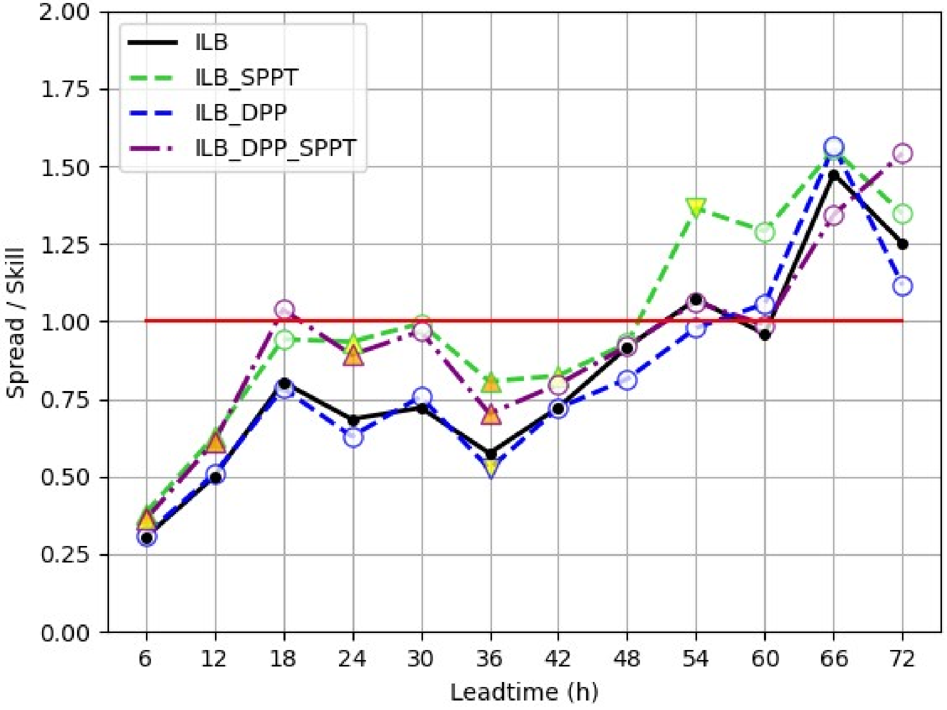



- Ensembles are underdispersive in terms of trajectories, especially for short leadtimes (until 42h, lack of spread).

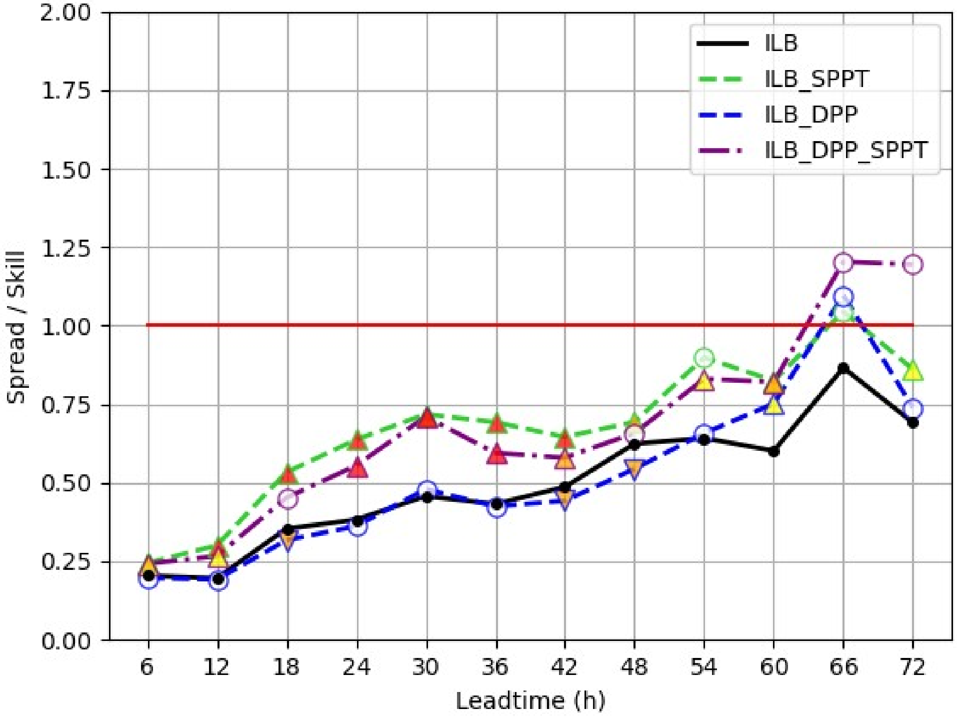
- No significant impacts on trajectory forecasts with the addition of model perturbation.

# Results : Intensity

Maximum Wind speed SSR




Minimal Pressure SSR




- For Pressure, underdispersion observed except for long leadtimes.

- On the contrary, for wind, the SSR is close to 1, especially for experiment with physical model errors.

- Experiments including physical model errors (ILB_SPPT, ILB_DPP_SPPT), show bett

# Conclusions and Perspectives

Conclusions :

- Numerical explosions in the first tests.
- No significant impact of DPP on trajectory : not surprising, already the case for physical perturbation
  → Trajectory spread is driven by large scale (LBC).
- Improvements on intensity scores due to SPPT, no real impact of DPP.
  Model errors mainly dominated by uncertainties due to physical parameterizations ?

Perspectives/Discussion :

- Case study : to see if DPP can have a bigger impact on a particular cyclone than on the entire sample
- Improving settings of DPP ?
- Does DPP have a greater impact on global scores ? (T, HU, wind10m, RR)

# Thank you for your attention !