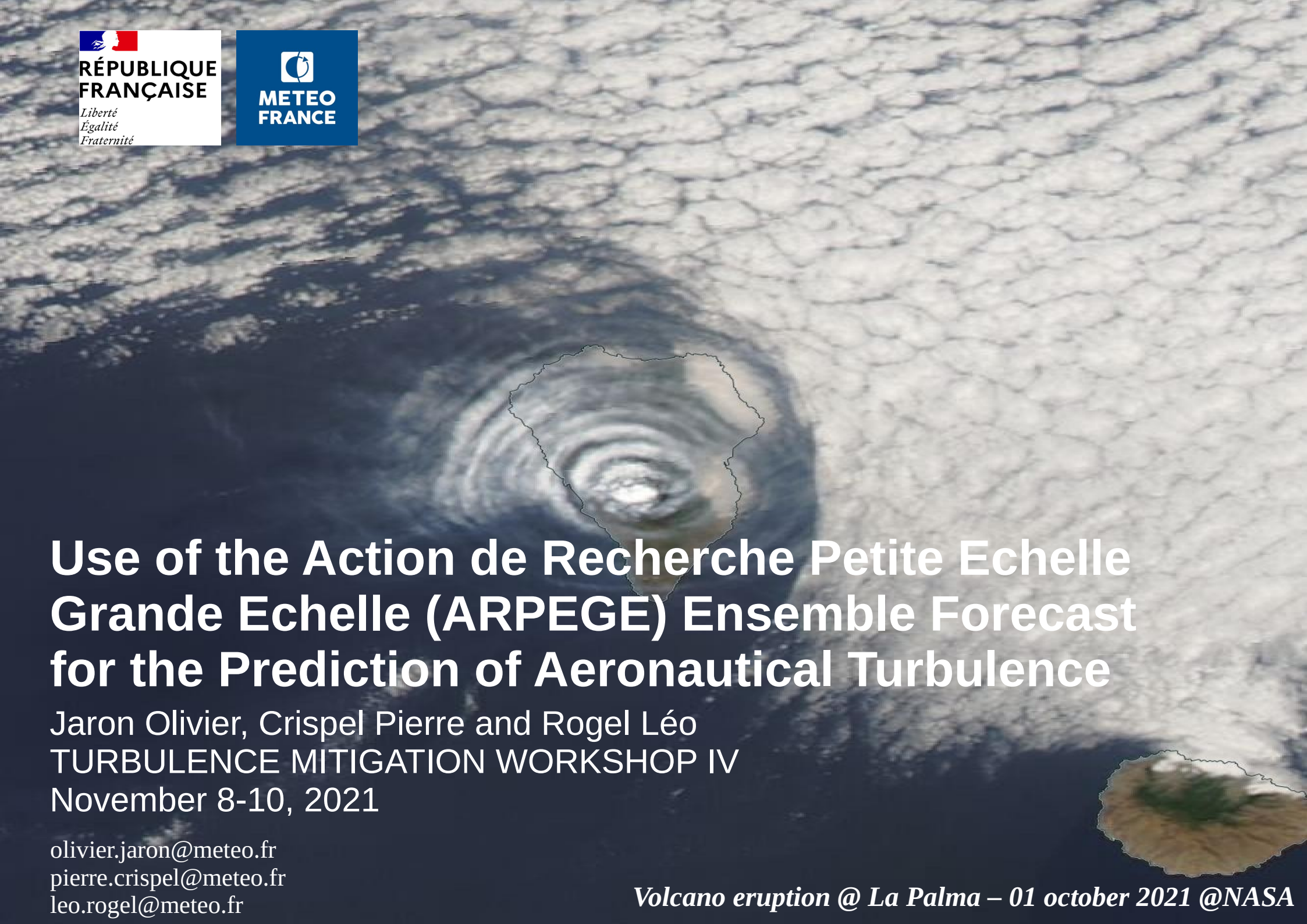

Use of the Action de Recherche Petite Echelle Grande Echelle (ARPEGE) Ensemble Forecast for the Prediction of Aeronautical Turbulence

Jaron Olivier, Crispel Pierre and Rogel Léo

TURBULENCE MITIGATION WORKSHOP IV
November 8-10, 2021

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Volcano eruption @ La Palma – 01 october 2021 @NASA

A Short Plan

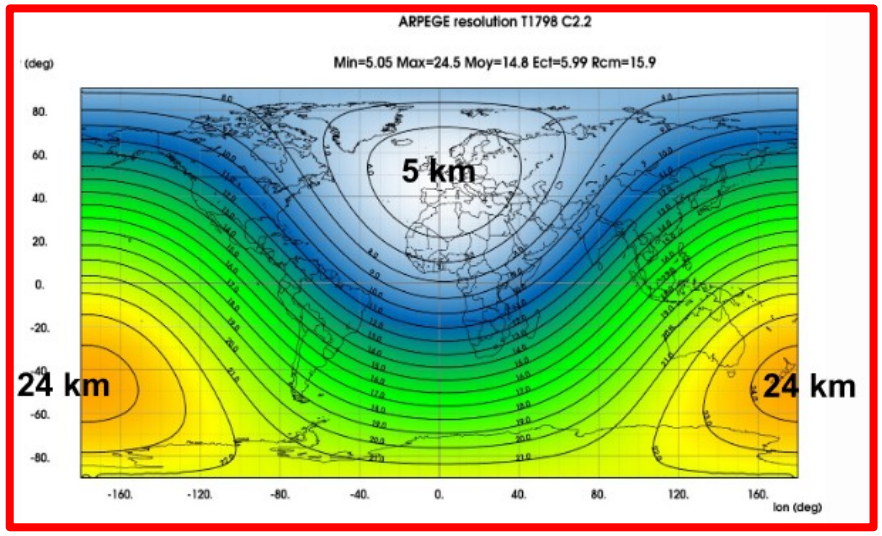
1) **Ensemble Forecast of Turbulence :**
   from raw data to end-user products

2) **Convection Induced Turbulence :**
   a try

3) **Improve TKE representation :**
   a PhD work

EDR Diagnostic (EDRD) on ARPEGE deterministic model

- GTG Method (Sharman et al.)
- Diagnostics computed on model grid (spherical geometry) Remapped in ‘edr units’ w/ 1yr climatology (2018)
- Outputs every 1h on a lat/lon 0.25° grid, Δ10FL, refreshed every 6h (*oper since mid-2019*)



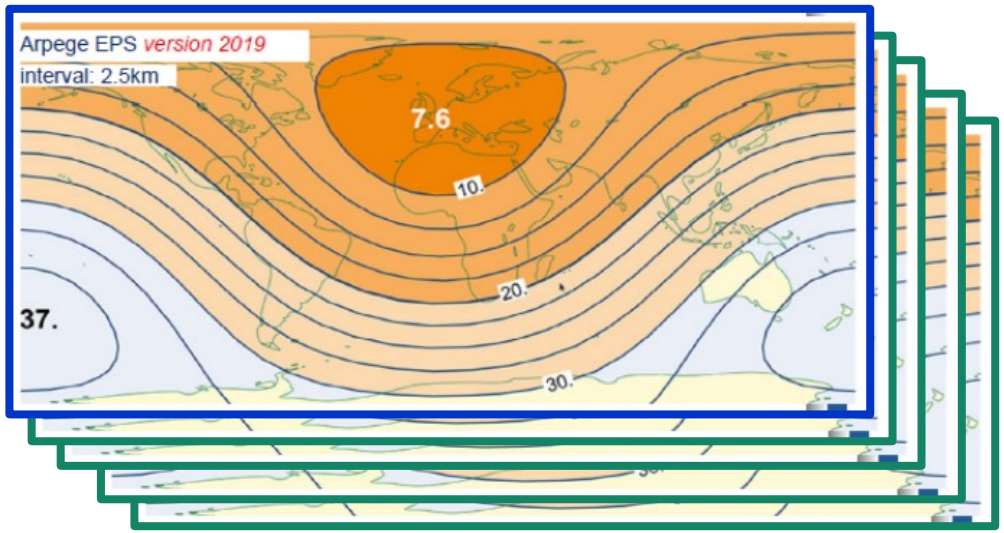
Level	Combination of diagnostics	AUC* for MOG
HIGH	{DEF/Ri, TKE, Ω² ,..}	0.805
MED	{TKE, Ω²,...}	0.784
LOW	{TKE, Wind Speed,..}	0.701

** : first semester of 2019, MADIS Database, obs assoc. w/ the closest model point on grid 0.025° / 60 levels, +/- 30 min 1 run / day (00h), lead times 6h, 9h ,12h ,15h, 18h*

Motivation to use EDRD Ensemble Forecast

- Improve turbulence forecast **skills**
- Assess **confidence** in the forecast
- Other works :
  - **Nowcasting :** select the best scenario (based on the latest available observation)
  - **CIT** : better convection forecast with ensemble

- **1 control member** + **34 perturbated members**
- **EDRD** of each member computed **on the fly** with the ARPEGE postprocessing soft (FullPos)
- **Statistics** computed with a parallel workflow on HPC in Python
- Operational early 2022

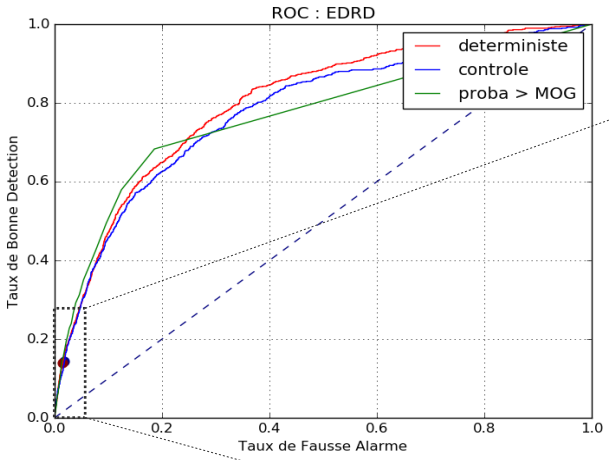


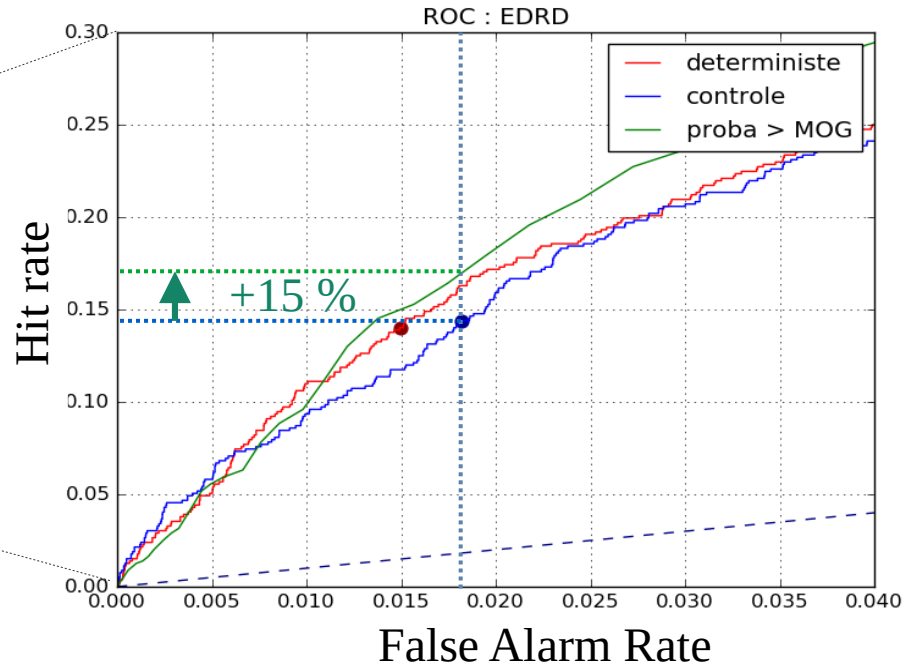
1+34 members, 90 vertical levels, set of 10 physical packages

Evaluation of the ensemble to predict CAT w/ EDRD

- For this study, **ENS** has a lower resolution than determ. model :
  - Climatologies of selected diagnostics are recomputed
  - We use the same combination than for the **determ.** model

- ***ENS** will have the <u>same resolution</u> than **determ**. in early 2022*



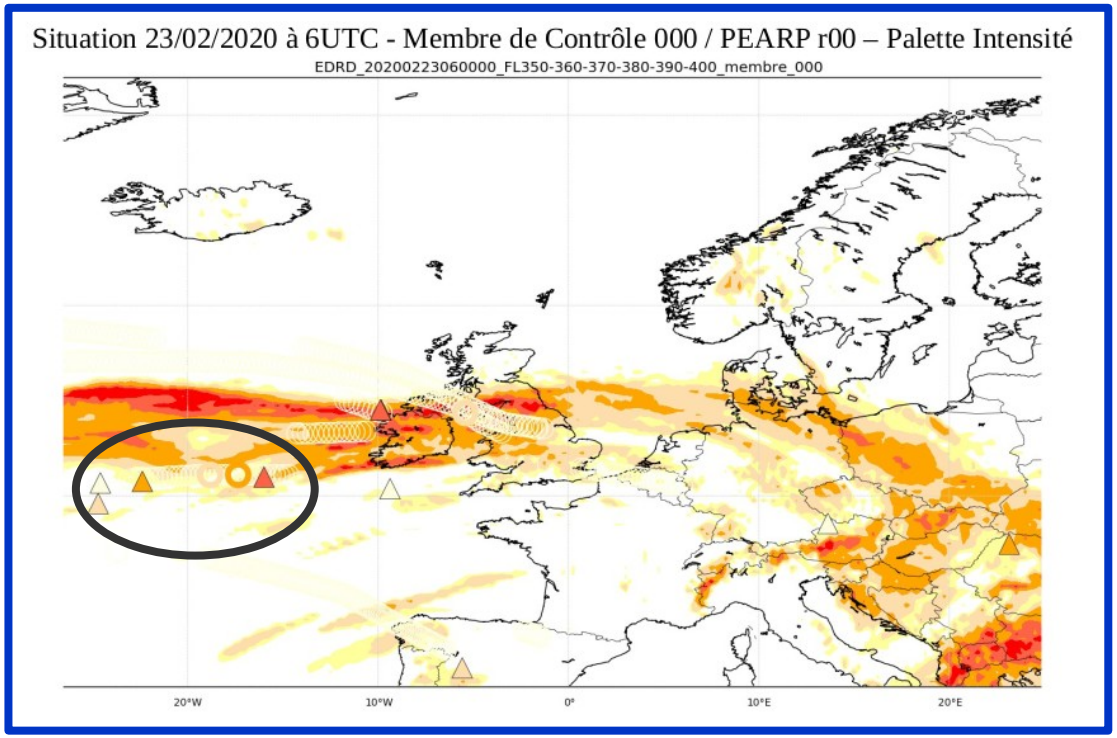


*Second mid-2022, one run, on lead time (**12h**).*
% MOG = 1 % of total obs.

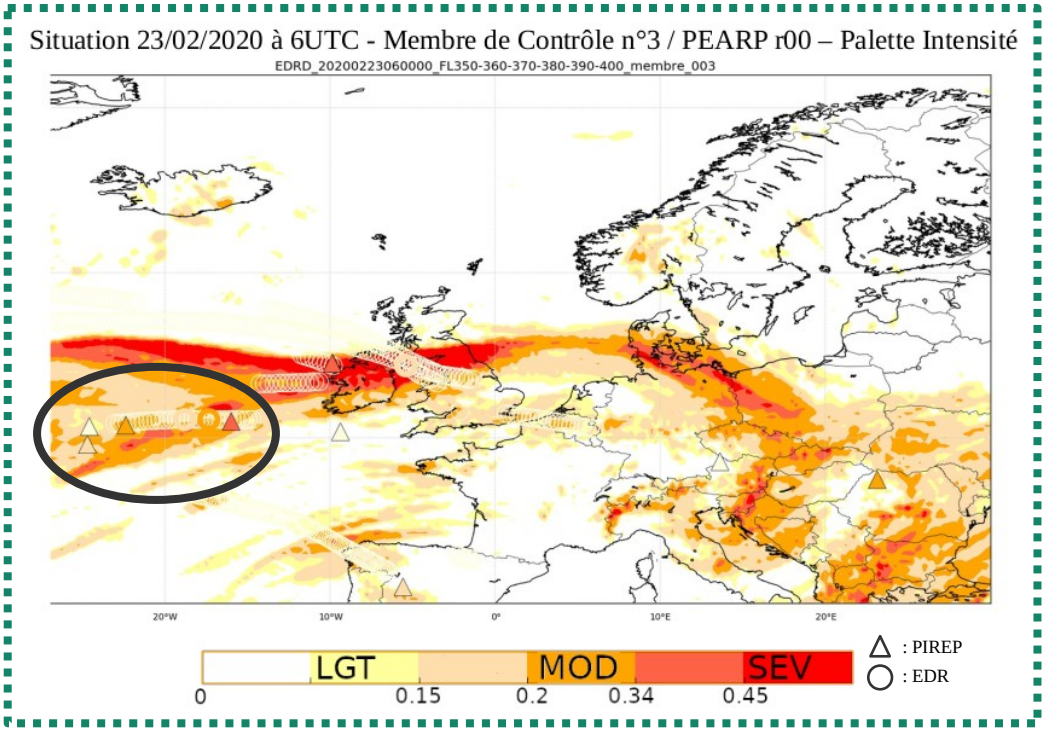
Hit rate +15 % for **ENS** compared to the **single non perturbated (control) member**

Higher resolution **determ. model** has a better skill, but **ENS** has an even better result

Exemple of dispersion of EDRD @ +6H

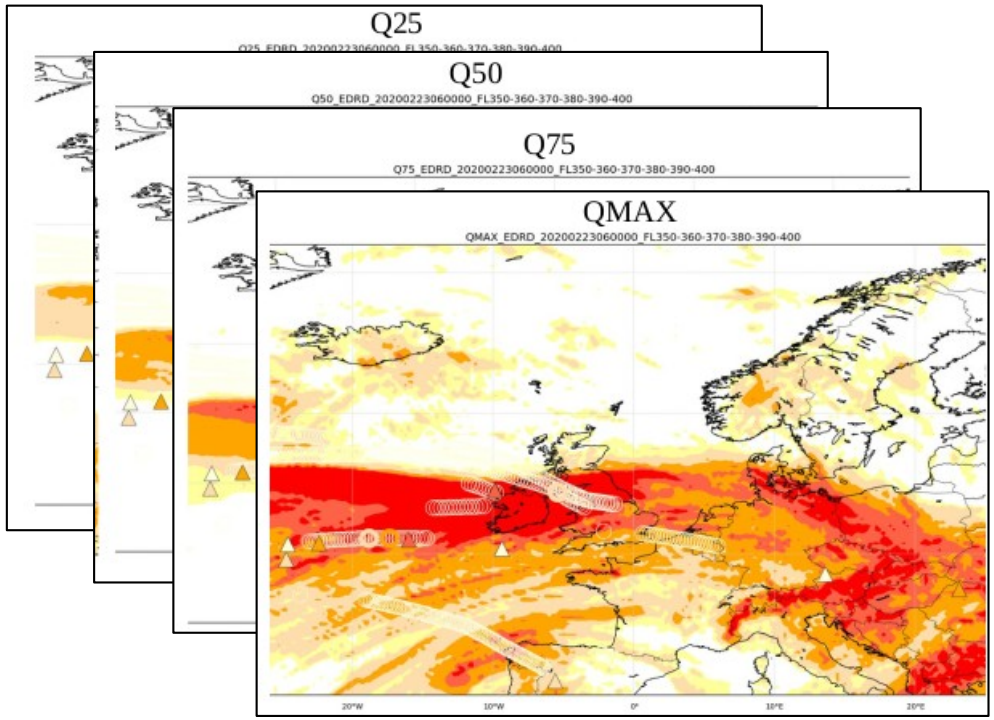


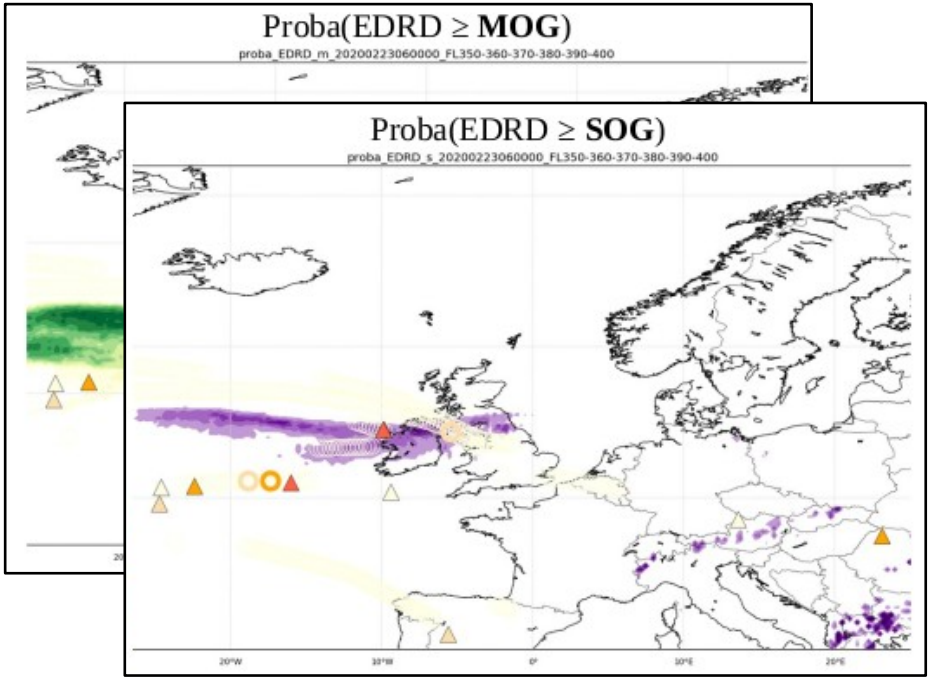
Control member



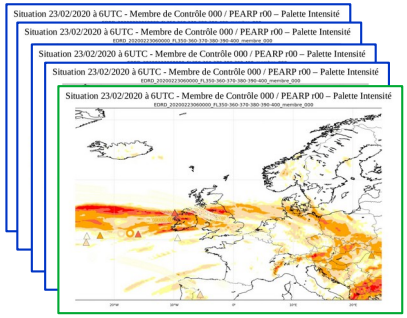
Perturbated member N°3

Statistics production for forecasters

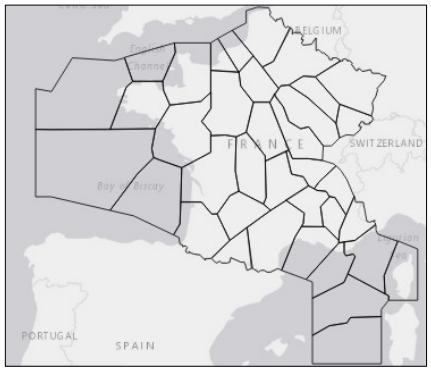




End-user production for air traffic control

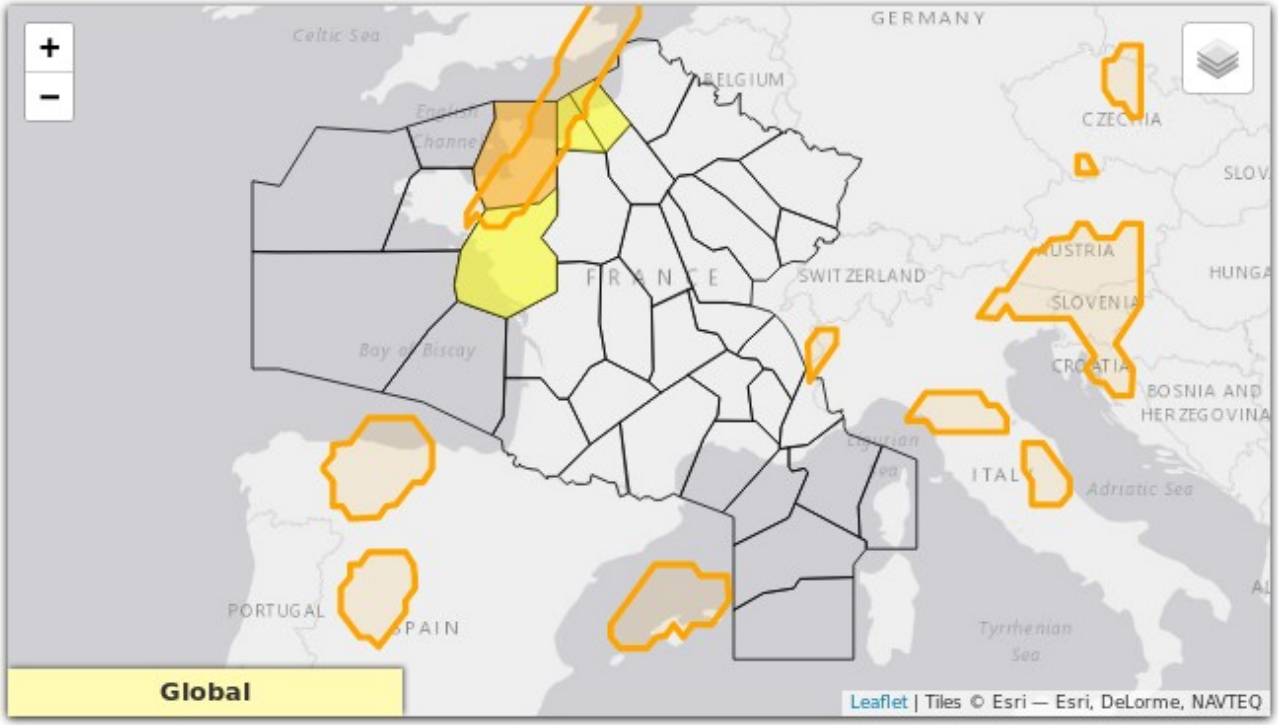


EDRD ensemble forecast



Air traffic control sectors

Risk matrix



CRNA	Secteur	2021-11-04				2021-11-05		
		12 UTC	15 UTC	18 UTC	21 UTC	00 UTC	03 UTC	06 UTC
LFBB	H5							
LFBB	L5							
LFBB	N5							
LFBB	P4							
LFBB	R5							
LFBB	T4							
LFBB	X5							
LFBB	Z5							
LFEE	HE							
LFEE	HH							
LFEE	HN							
LFEE	HR							
LFEE	KD3							
LFEE	KF							
LFFF	HP							
LFFF	QU							
LFMM	A4							
LFMM	B4							
LFMM	DH							
LFMM	E3							
LFMM	F4							
LFMM	G4							
LFMM	K3							
LFMM	M4							
LFMM	W3							
LFMM	Y4							
LFMM	ZH							
LFRR	AU							
LFRR	GU							
LFRR	JU							
LFRR	KU							
LFRR	MU							
LFRR	NU							
LFRR	VU							
LFRR	WU							
LFRR	XU							
LFRR	ZU							

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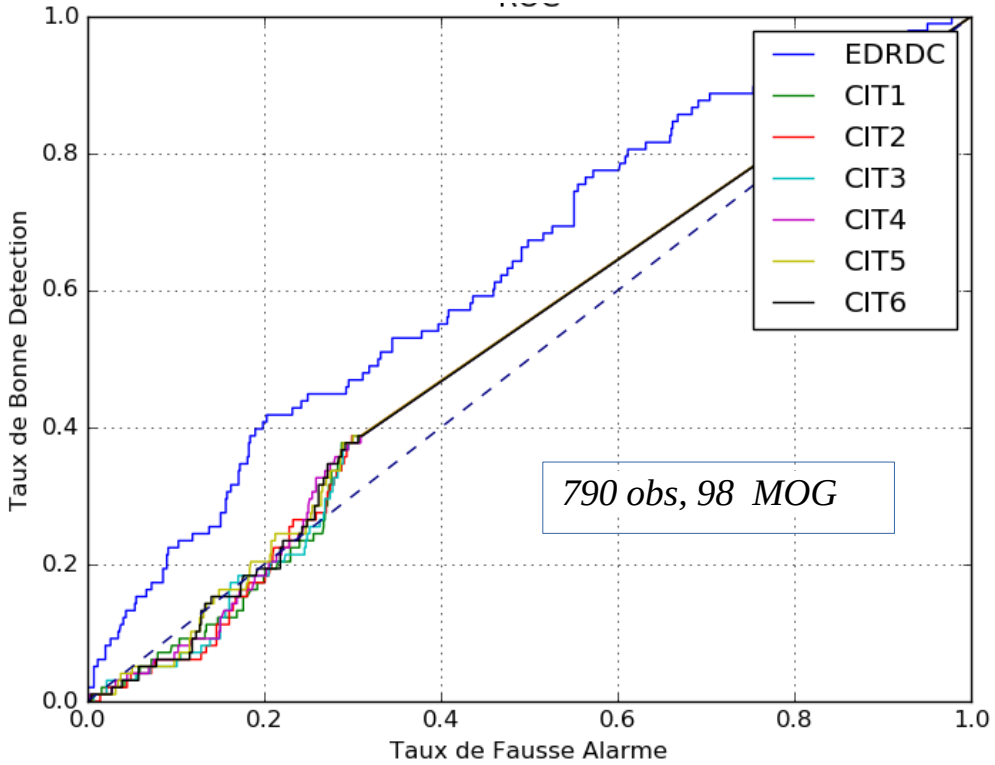
Works on CIT diagnostics

- 6 new diagnostics computed with the **deterministic** model



Period May → Nov 2020

Distance max Obs to Cell = 25km

Diag.	Description
EDRD	EDR Diagnostic (combination)
CIT1	Value of 2D CAPE*, raised through vertical up to (Presure of summit of convection * 0.9 (10 %)
CIT2	CIT1 * Vertical Windshear^2
CIT3	CIT1 * Vertical Windshear
CIT4	Value of 2D CAPE*, raised through vertical up to (Presure of summit of convection * 0.9 (10 %) with lineare deggresivity
CIT5	CIT4 * Vertical Windshear^2
CIT6	CIT4 * Vertical Windshear

*CAPE issued from deep convection scheme, avalaible when scheme is activated

Deterministic CIT indices has no skill to predict CIT :

- Scores are sensible to uncertainty linked to deterministic convection forecast
- Future work to be conducted with ensemble forecast

A Short Plan

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a try

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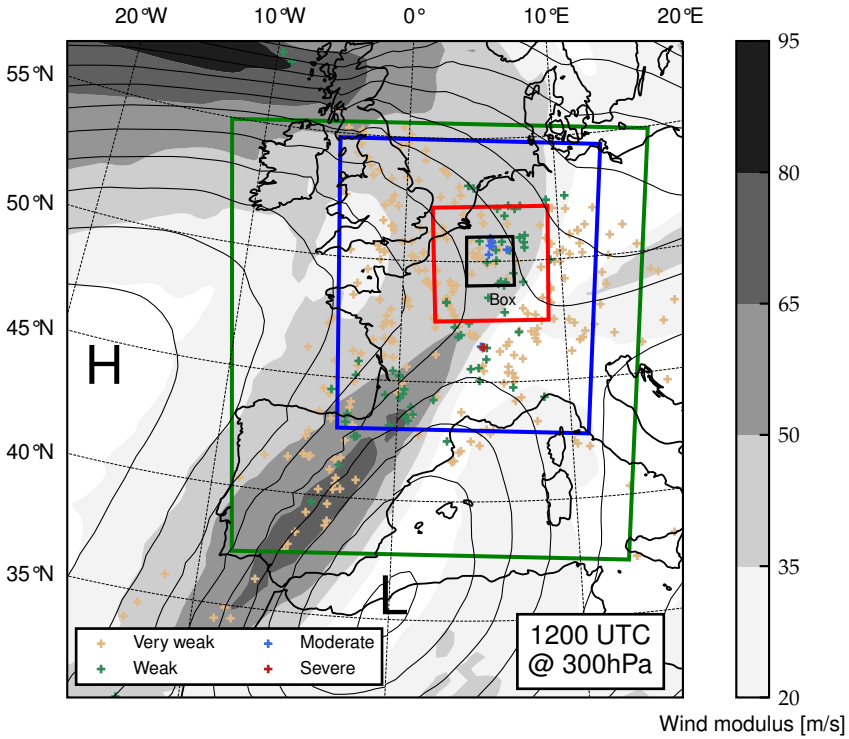
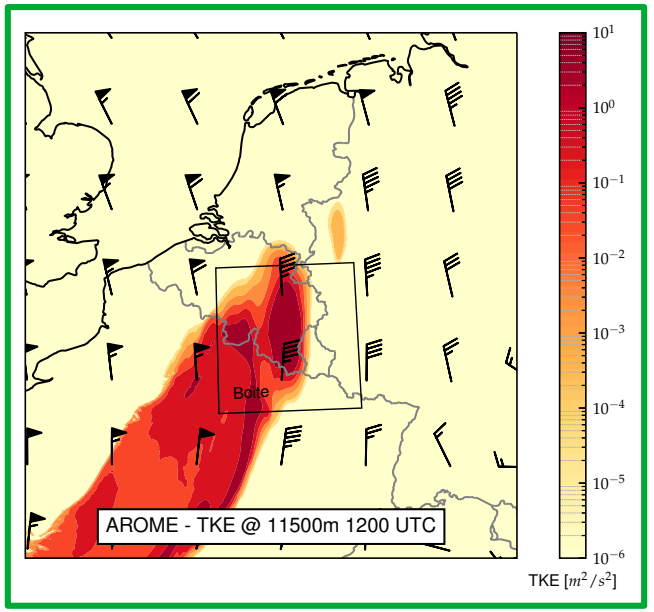
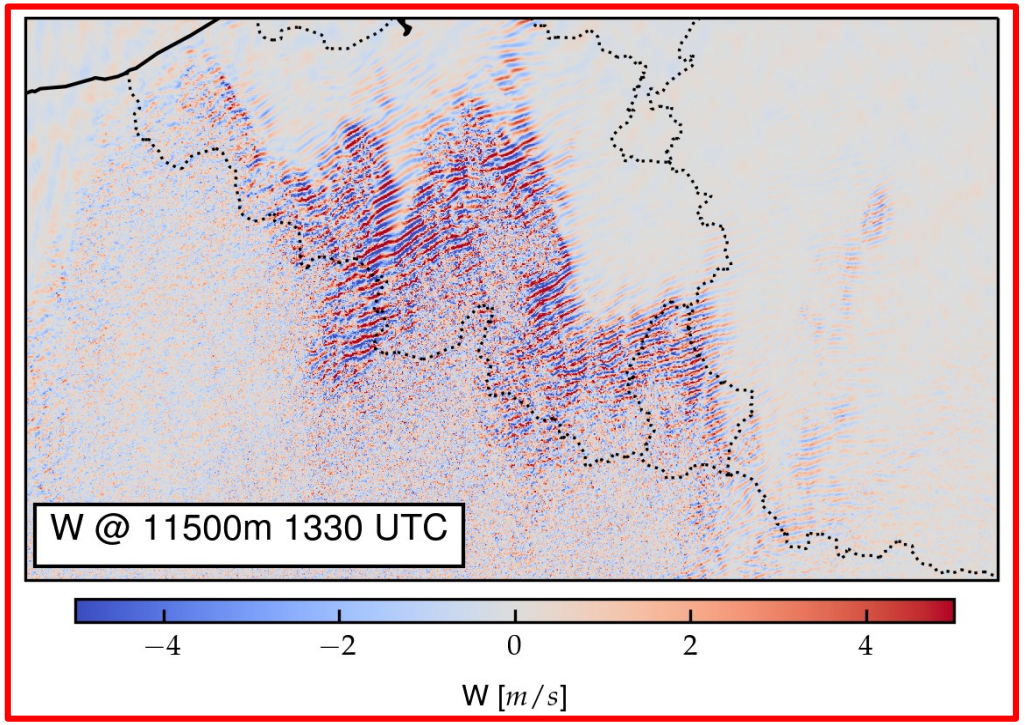
Clear Air Turbulence (CAT) and gravity waves (Léo Rogel PhD)





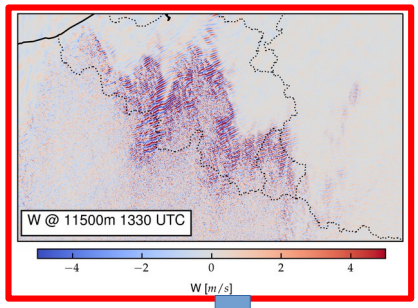
Production of sub-grid TKE ***(Arome 1.3km)***

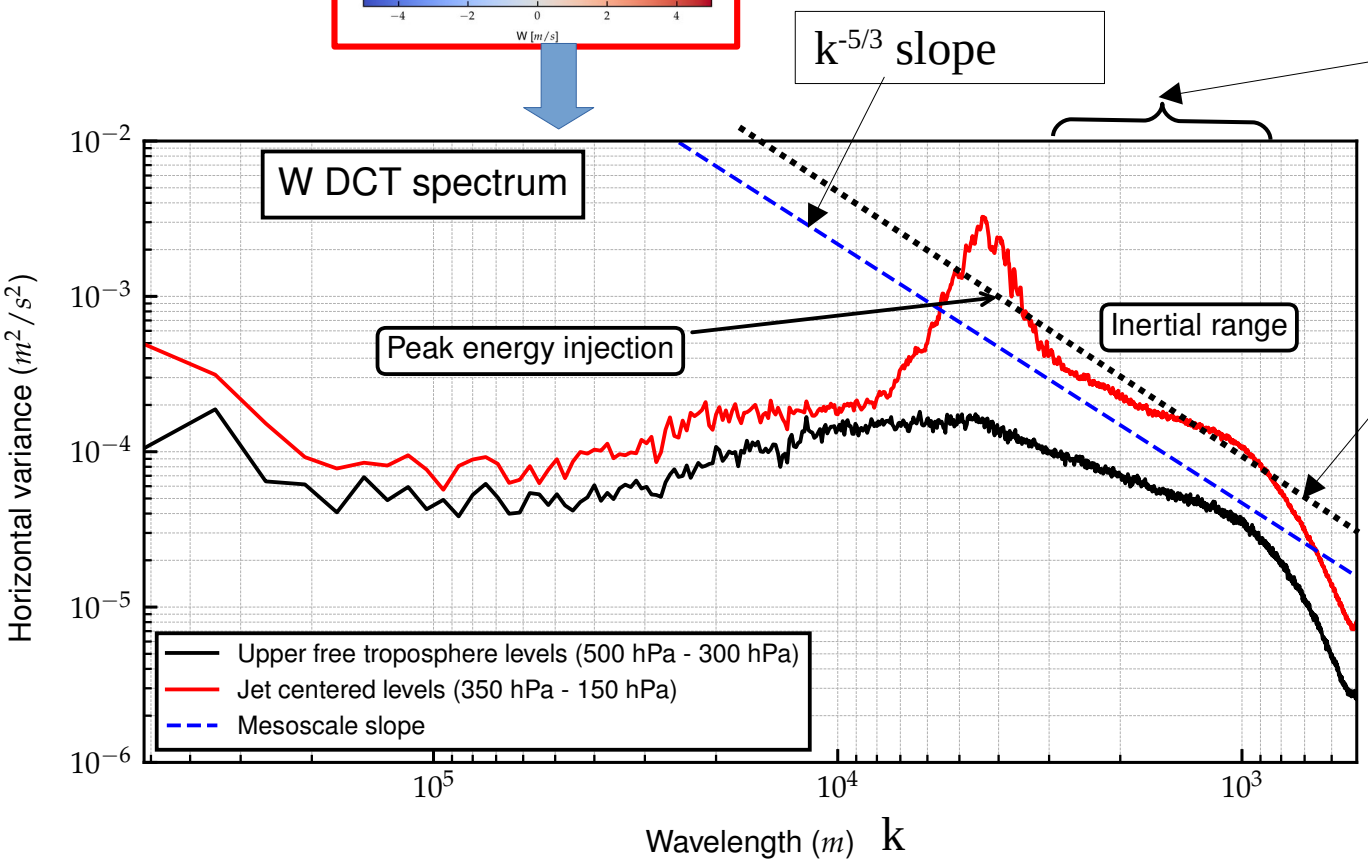
Vertical velocity Waves from jet ***(MesoNH 260m)***



- MOD auto. reports over Belgium due to jet streak
- Modeled with **Arome 1.3km**, **MesoNH 1.3km** and **MesoNH 260m (LES)**.
- **LES** simulations allow to solve internal gravity waves linked to the jet (λ ~ 4,5km)
- Results of LES used as proxy to **improve turbulence parametrization**

From LES power spectra to EDR (Léo Rogel PhD)





For inertial range :
(Sharman et al., 2014)

$$F_N(k) \approx \frac{12}{55}\alpha\varepsilon^{2/3}k^{-5/3}$$

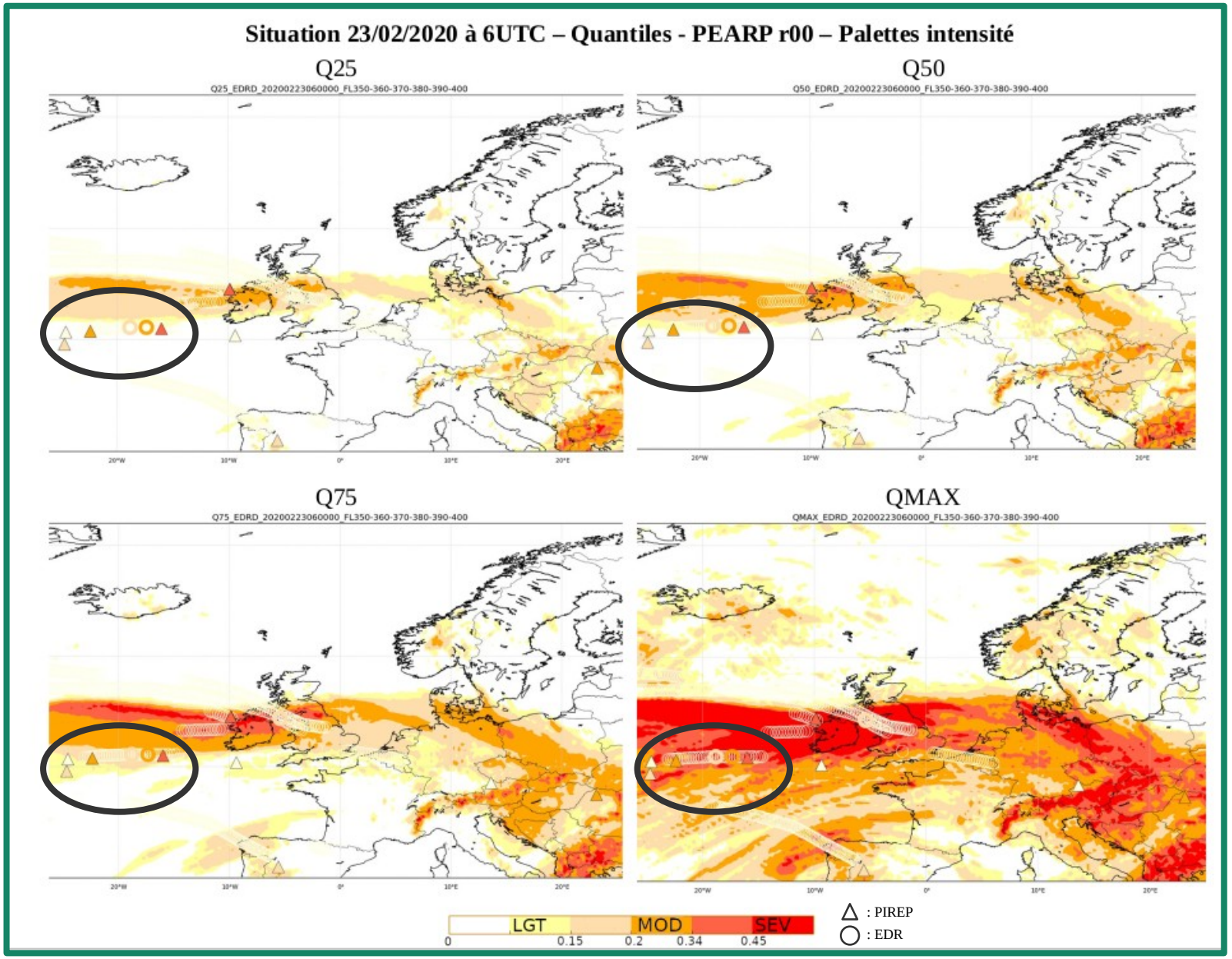
$\varepsilon^{1/3}$ = EDR

@aviacionhr_info

Thank you

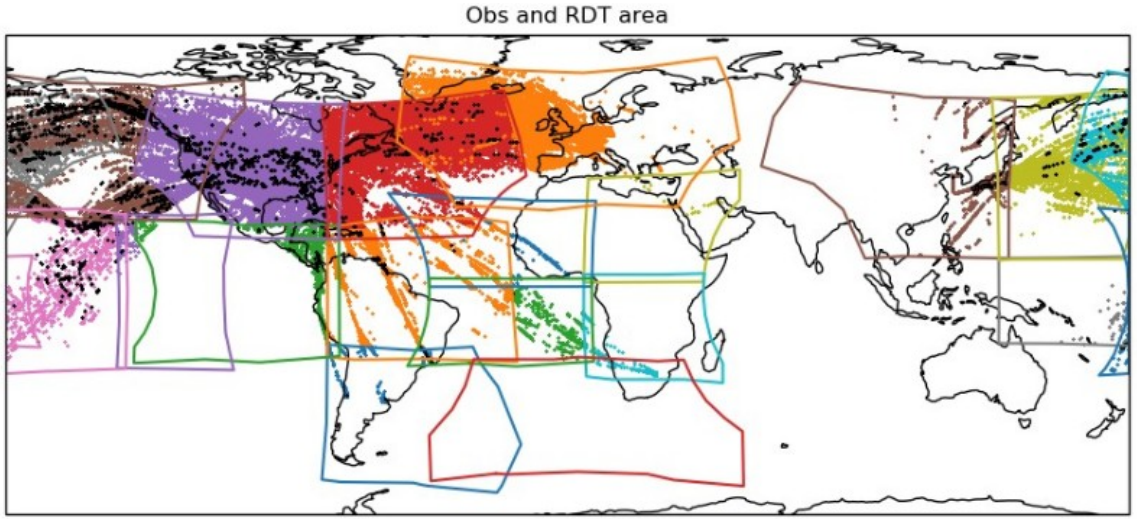
Questions ?

Exemple of dispersion of EDRD @ +6H

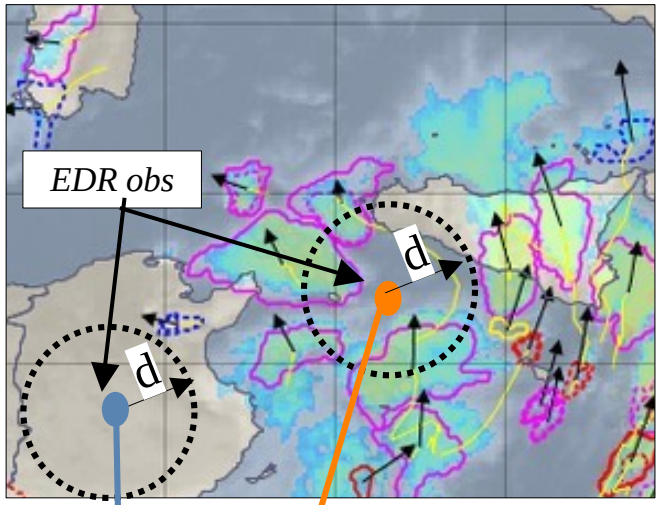


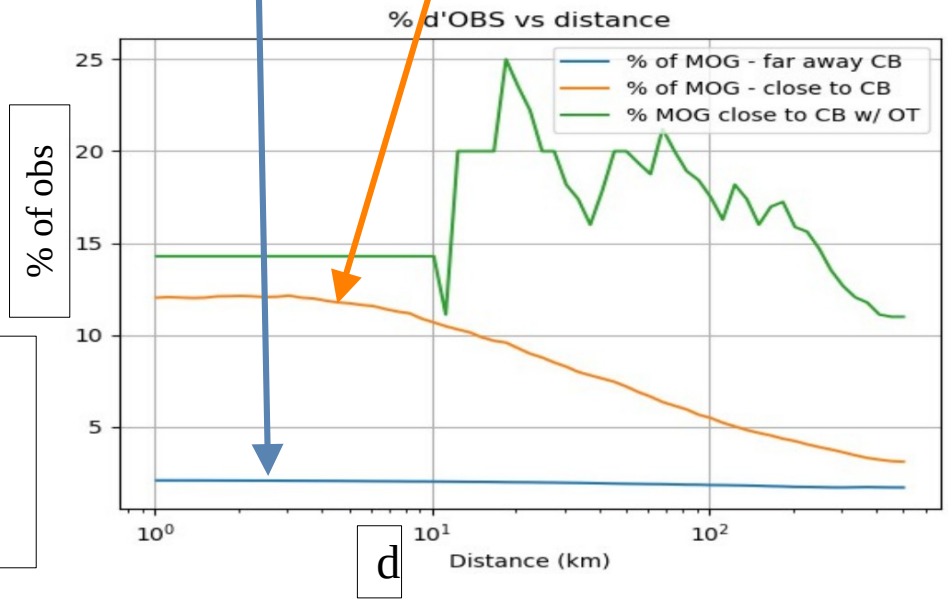
Convective Induced Turbulence : discrimination of observations

- Predicting convection is not a strong point of global models
- **Discrimation of observations** according to the convection
  - Use of RDT cells
  - Sorting data CAT / CIT
  - Evaluate dedicated indices to forecast CIT
- 1 sep. → 31 dec 2019 : 230 000 obs



IR imagery + Rapid Developping Storms cells





5% of obs. are within 30km of a cell, **2 %** over an avil
% of MoG increases from 2% to
8% if d<30km
12 % over an anvil