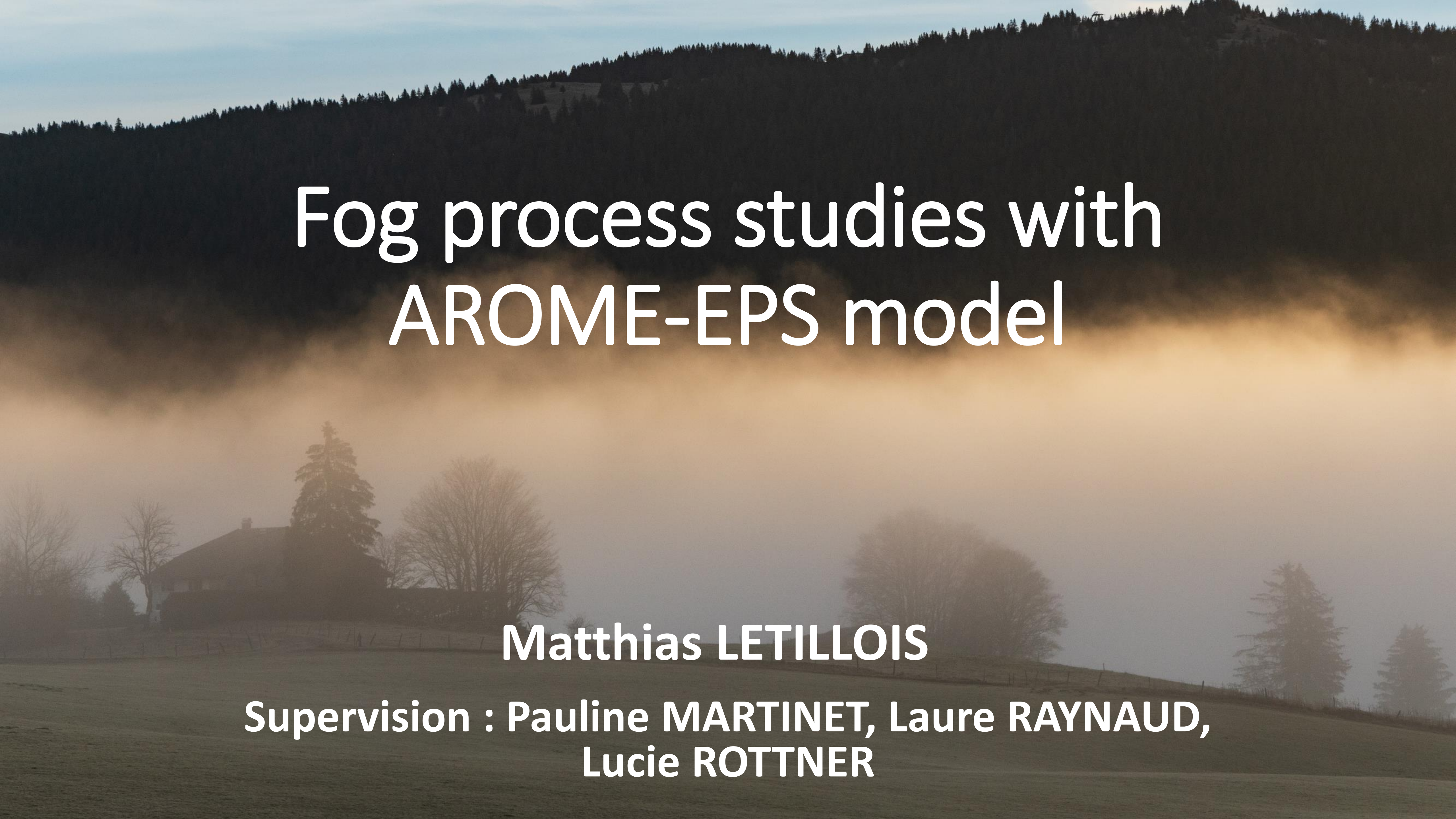

Fog process studies with AROME-EPS model

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Scientific questioning

With the operational AROME-EPS (analysis as a set of determinist models) :

- Which source of error is dominant in the fog forecasts of the AROME model: physical settings, initial conditions, surface conditions, lateral couplings ?
- Which model variables, whose errors in the initial conditions, have the greatest impact on the quality of the fog forecast ?

Objectives

Step 1 : Identification of few IOPs for which one or several ARO-EPS members show a significantly better fog forecast than other members.

- ✓ **Regional scale :** capability to correctly reproduce the fog spatial distribution at surface by comparing observed visibility versus simulated visibility
- ✓ **Local scale :** capability to correctly reproduce the fog lifecycle and vertical structure focusing on the SOFOG3D super-site

Step 2 : Sensitivity analysis on fog forecasting

- ✓ Research of most impactful errors in initial conditions
- ✓ Evaluate the respective weight of the perturbations of initial conditions versus physical parameterizations

Available data

Regional scale study

Observation data :

- Visibilimeters (RADOME network + super-site) : 18 stations

AROME-EPS model data :

- Parameter at surface :
  - Minimum visibility 1h

« Surface » data → Spatial distribution at regional scale

Available data

Local scale study

Observation data :

- MW Radiometers super-site (T, RH profiles, IWV, LWP)
- 95 GHz Cloud Radar BASTA (fog structure)
- Radiosondes
- LIDAR data (wind strength, wind direction)

AROME-EPS model data :

- Parameter profile :
  - T, RH, Wind strength, Wind direction …
  - BASTA profile modelling (reflectivity profile)

« Vertical structure » data → local scale : SOFOG3D super-site

Section 1

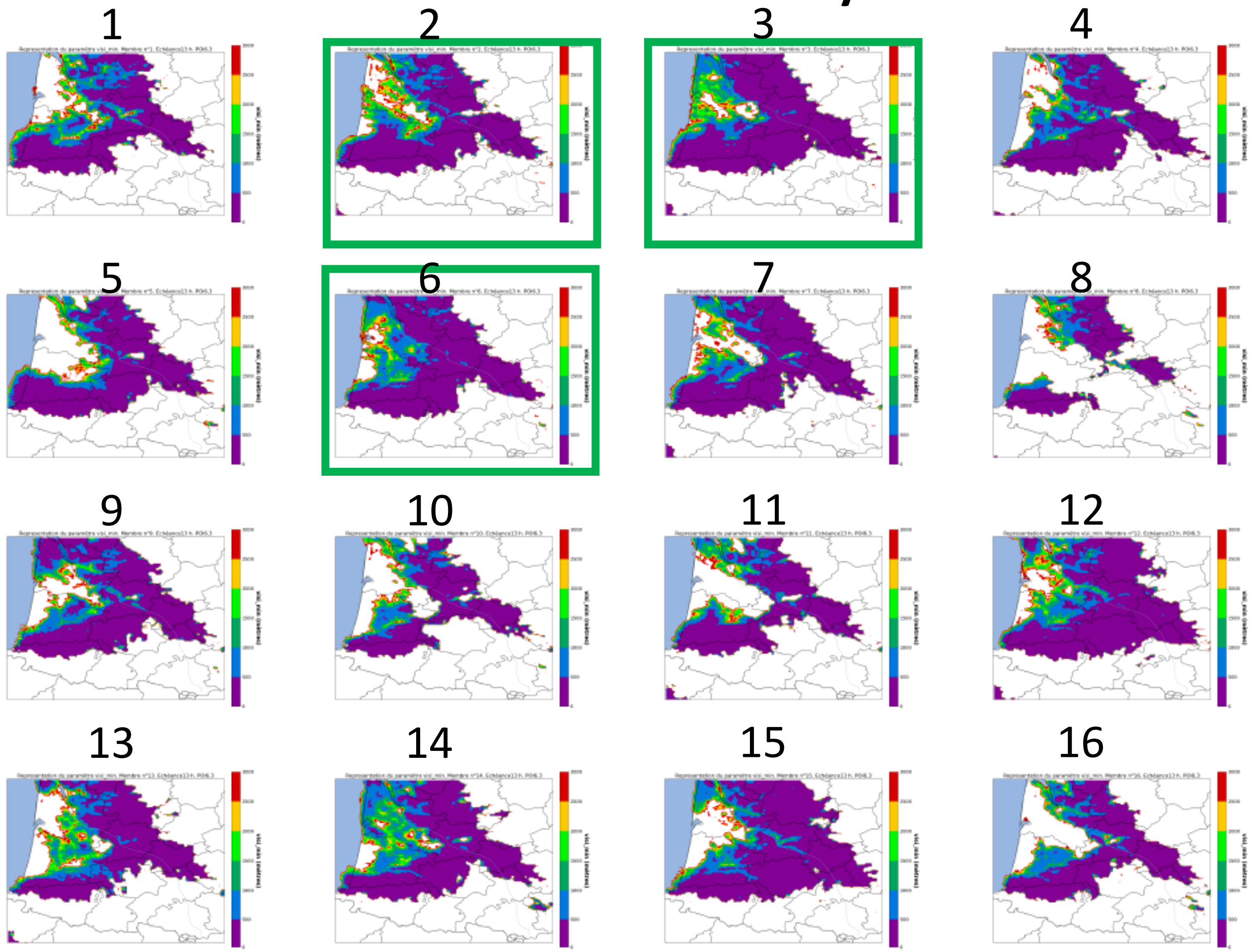
Identification of few IOPs for which one or several ARO-EPS members show a significantly better fog forecast than other members

Regional scale

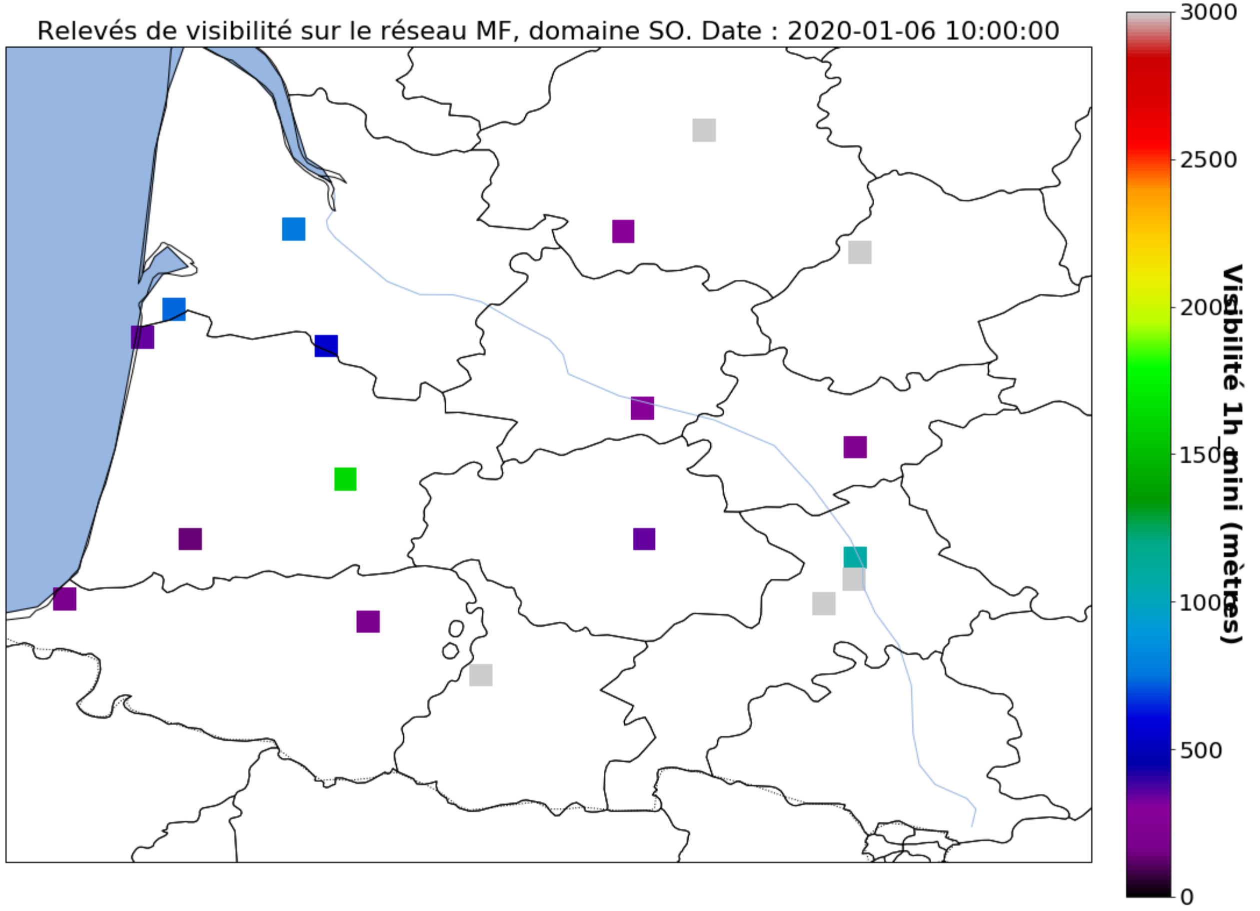
Visual identification with hourly minimum visibility parameter

Date : 6 January 10h UTC

ARO-EPS minimum visibility 1h



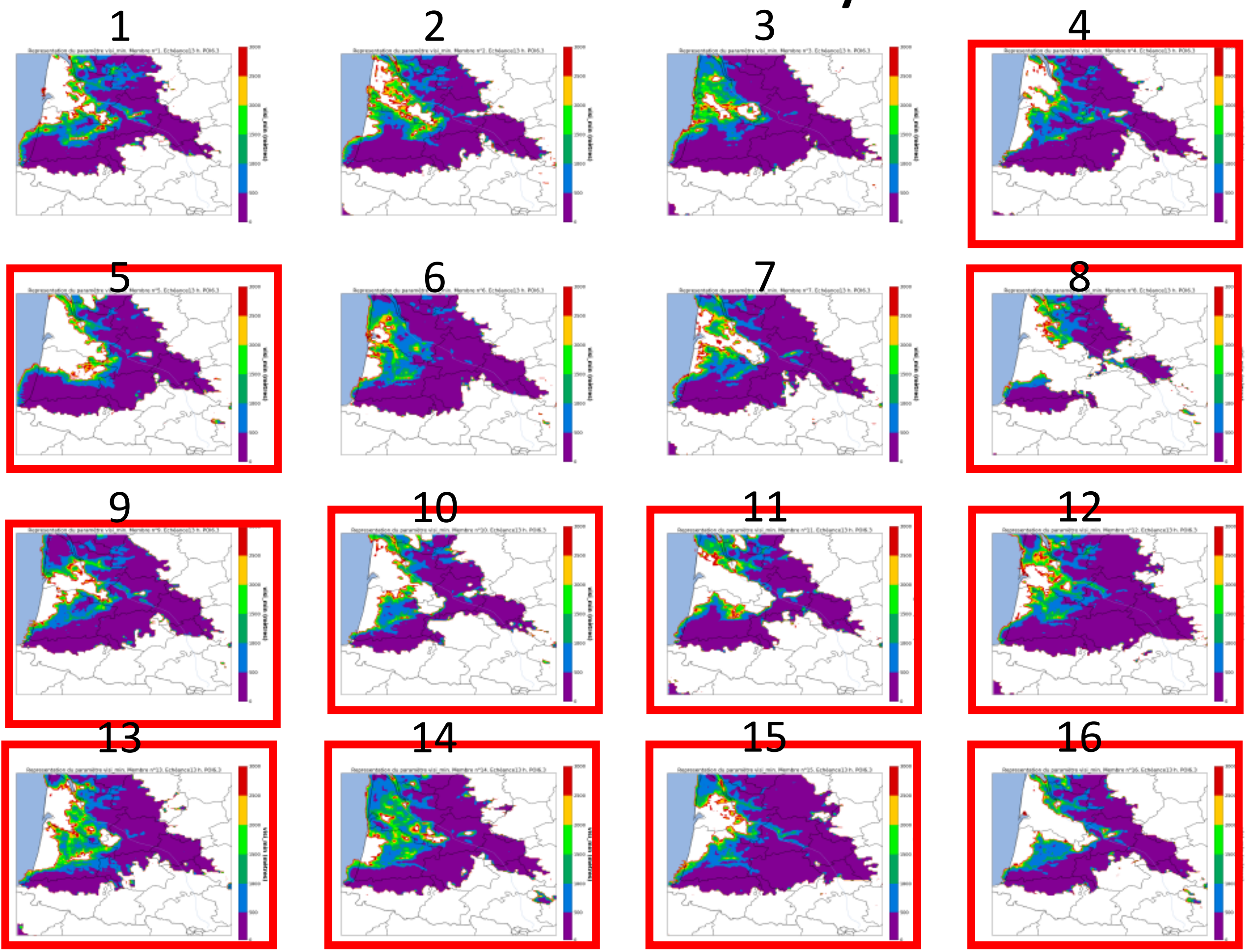
Minimum visibility 1h observed



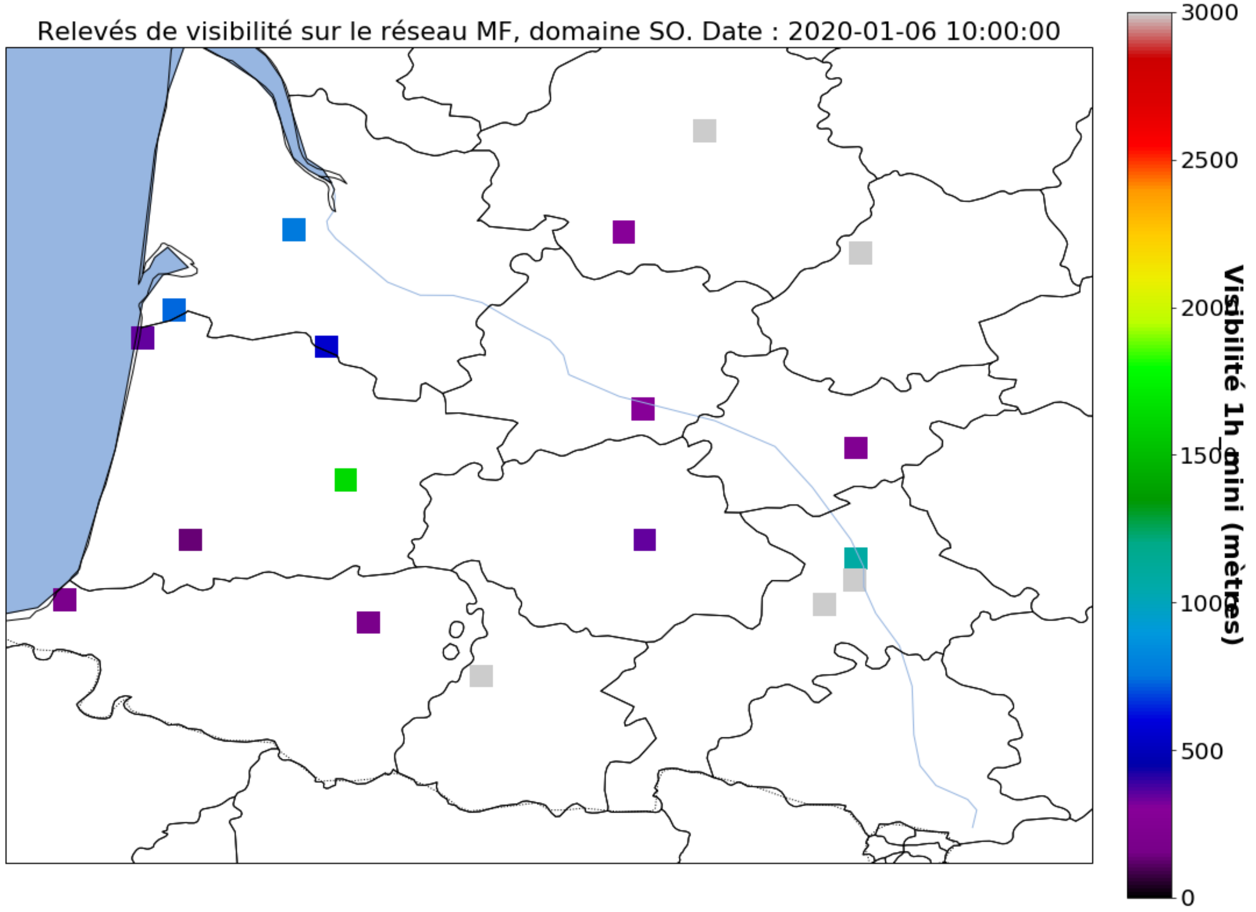
Visual identification with hourly minimum visibility parameter

Date : 6 January 10h UTC

ARO-EPS minimum visibility 1h



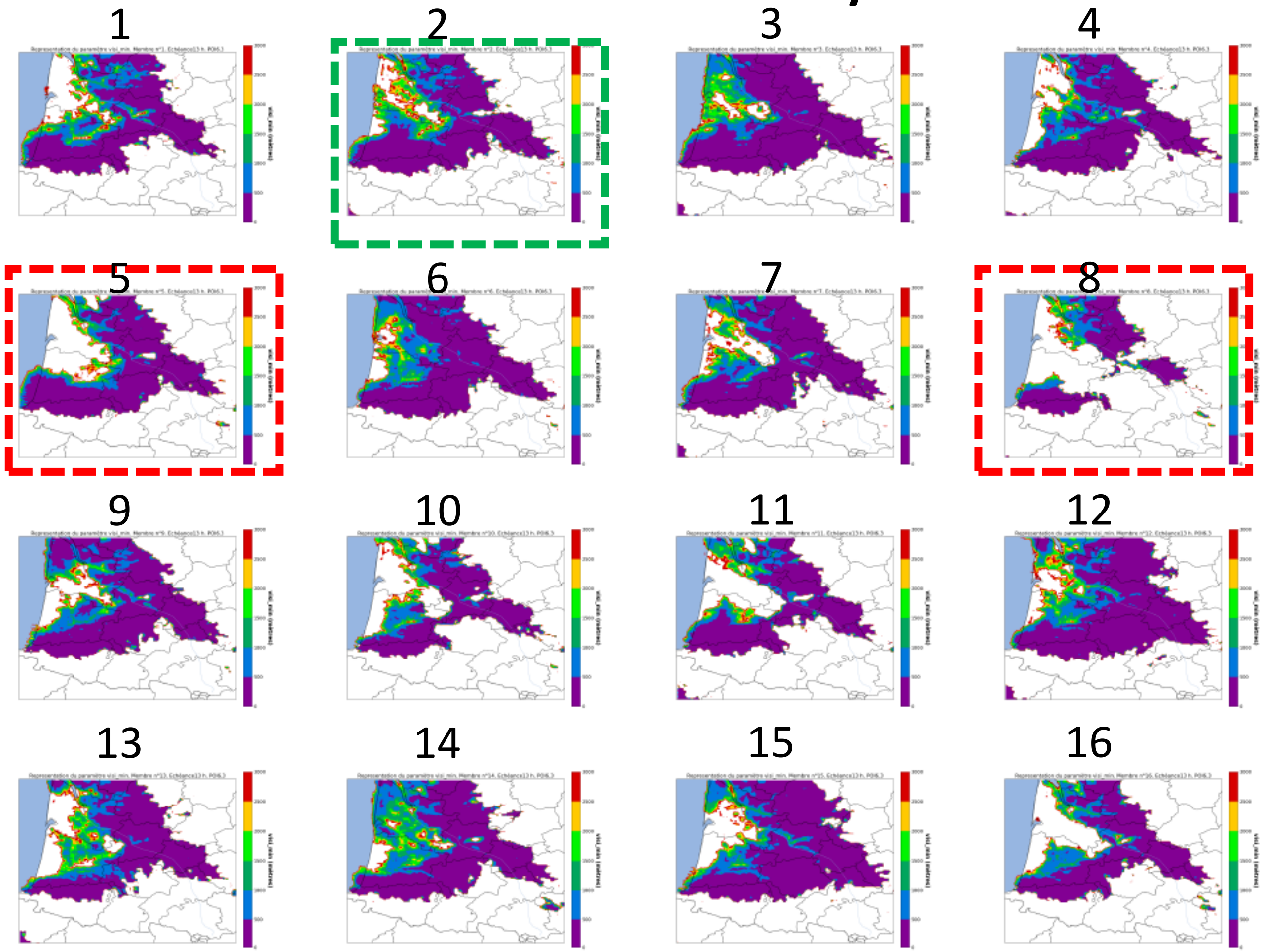
Minimum visibility 1h observed



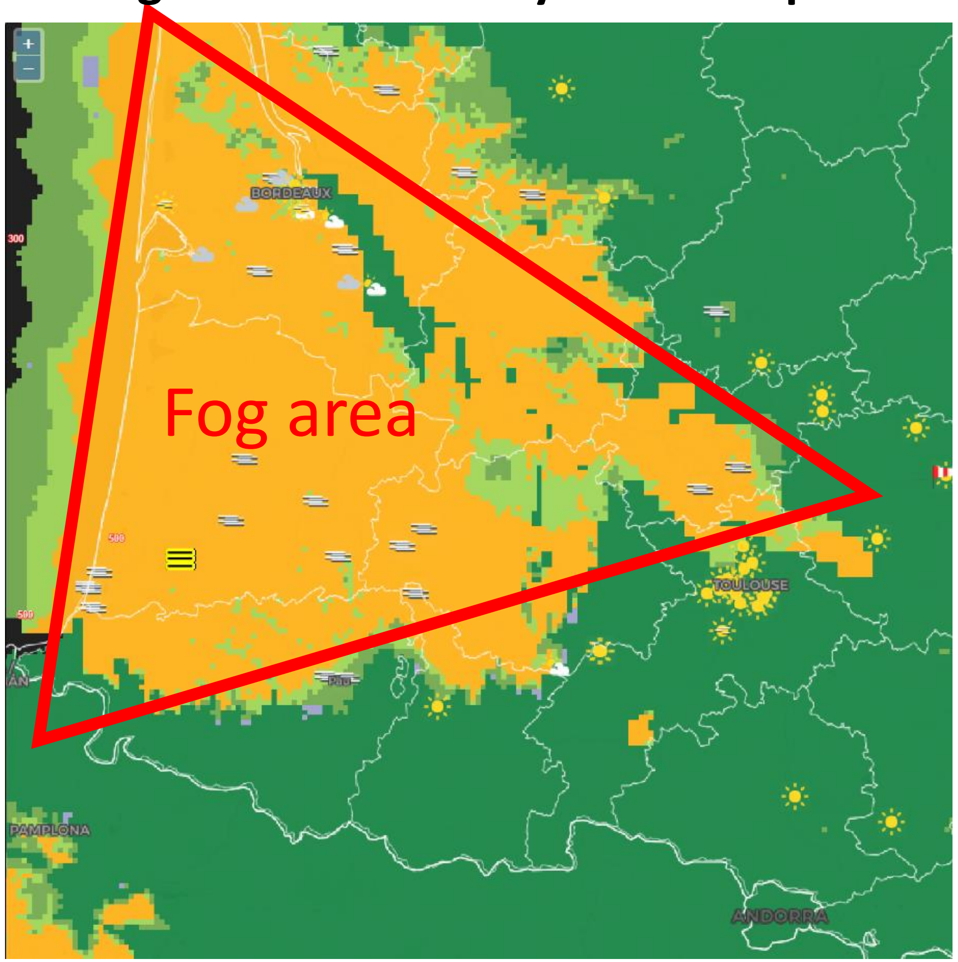
Visual identification with hourly minimum visibility parameter

Date : 6 January 10h UTC

ARO-EPS minimum visibility 1h



Fog area observed by CARIBOU product



Significant differences in location of fog weaknesses

Study results on 7 IOPs (thick fog cases)

Ranking of the IOP's studied : regional scale

IOP4.1, IOP4.2
IOP6.3
(December 2019)
(January 2020)

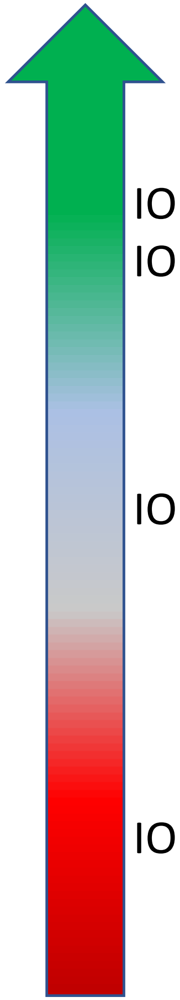
IOP9.1, IOP14
(January, March 2020)

IOP11, IOP13.2
(February 2020)

<u>Most interesting IOPs based on:</u>

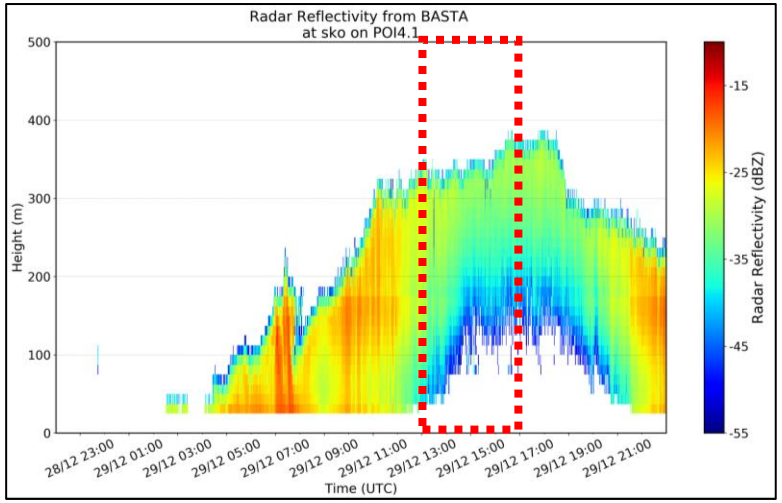
- ✓ Relevantly better fog forecast at surface for one or several members of ARO-EPS
- ✓ Sharp distinction « wrong members » / « good members »
- ✓ Agreement observed visibility / simulated visibility for “good members” on super-site

Agreement regional scale /local scale ?

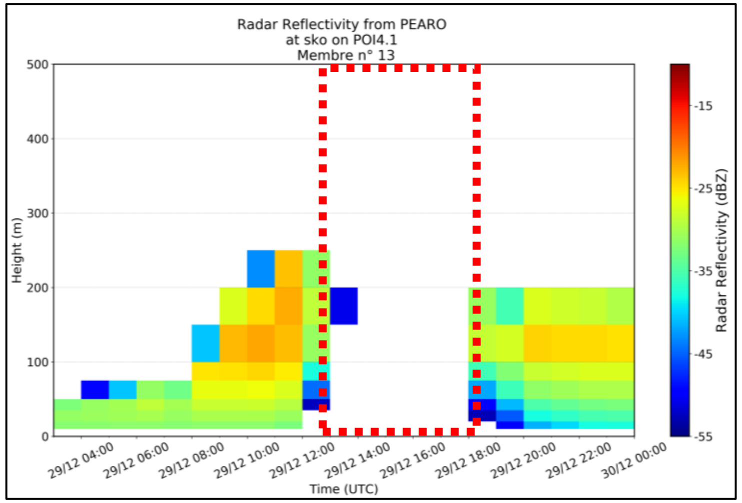


Example with IOP4.1

Cloud Radar reflectivity observed



Best ARO-EPS member at regional scale



→ Wrong stratus dissipation forecasting by the best member at regional scale

<u>Difficulties in finding one member of ARO-EPS which has **both** :</u>

- ❑ Good fog surface spatial representation at regional scale
- ❑ Good ability to reproduce fog lifecycle at the super-site

Section 2

Identification of few IOPs for which one or several ARO-EPS members show a significantly better fog forecast than other members

Local scale

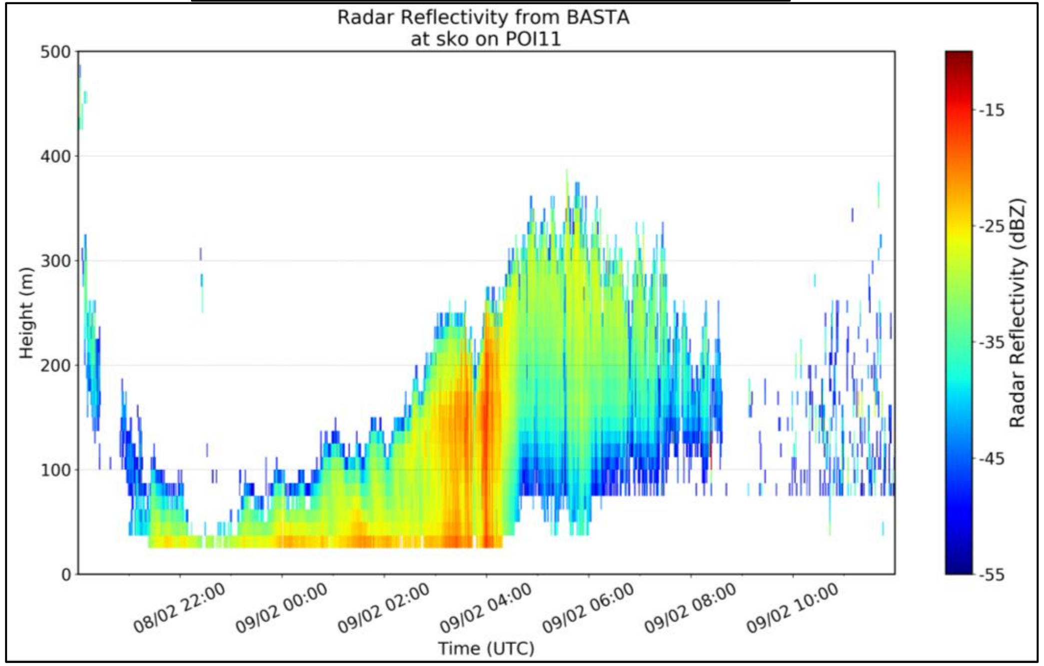
2) Analysis of fog vertical structure on super-site with ARO-EPS

Data used to validate fog forecast validation

- ❑ **Minimal visibility at surface** : not the best parameter to validate the fog forecast → fog vertical structure needed

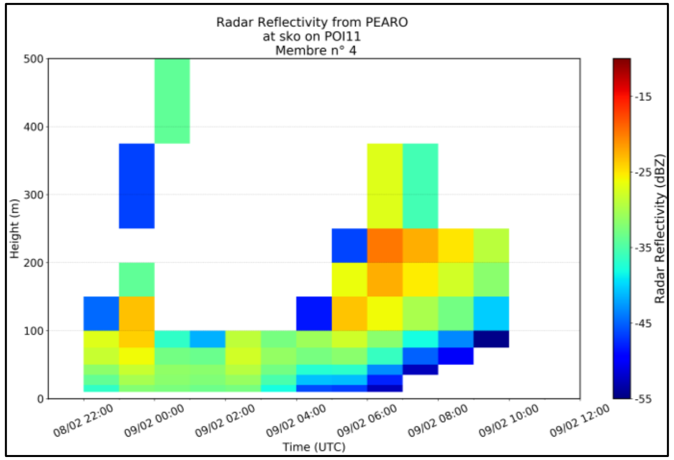
- ➢ Use of BASTA cloud radar observations and simulated reflectivity (cf A. Bell presentation) : IOP11 selected

Radar reflectivity observation

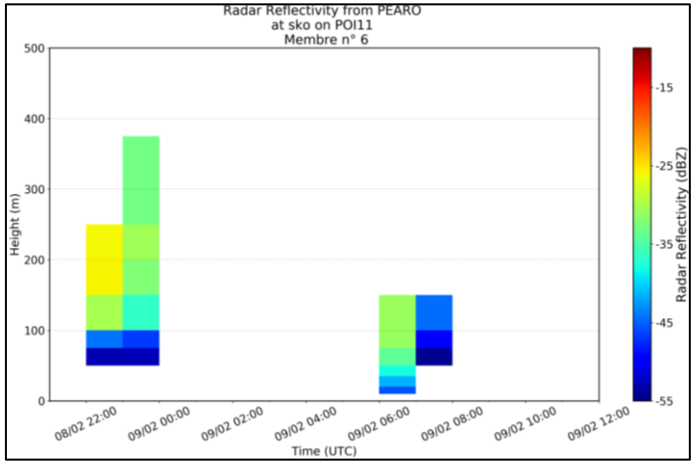


Radar reflectivity simulation

Member n°4



Member n°6



2) Analysis of fog vertical structure on super-site with ARO-EPS

How to quantify member(s) with the most accurate fog forecast?

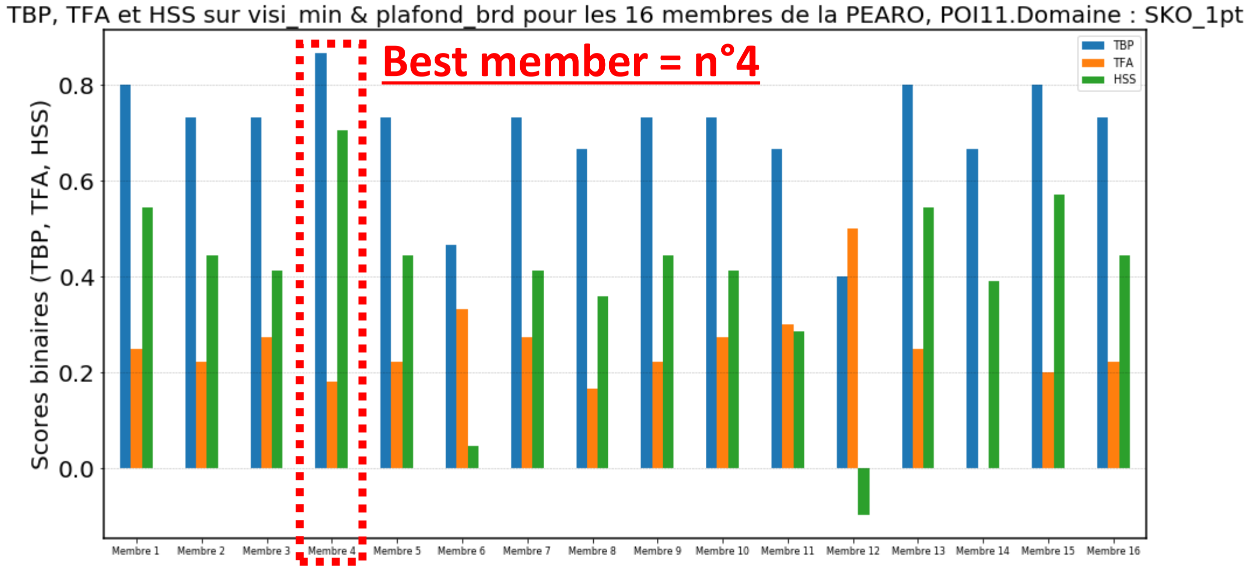
Contingency table with Airport LVP conditions

Conditions :

✓ Visibility < 600 m

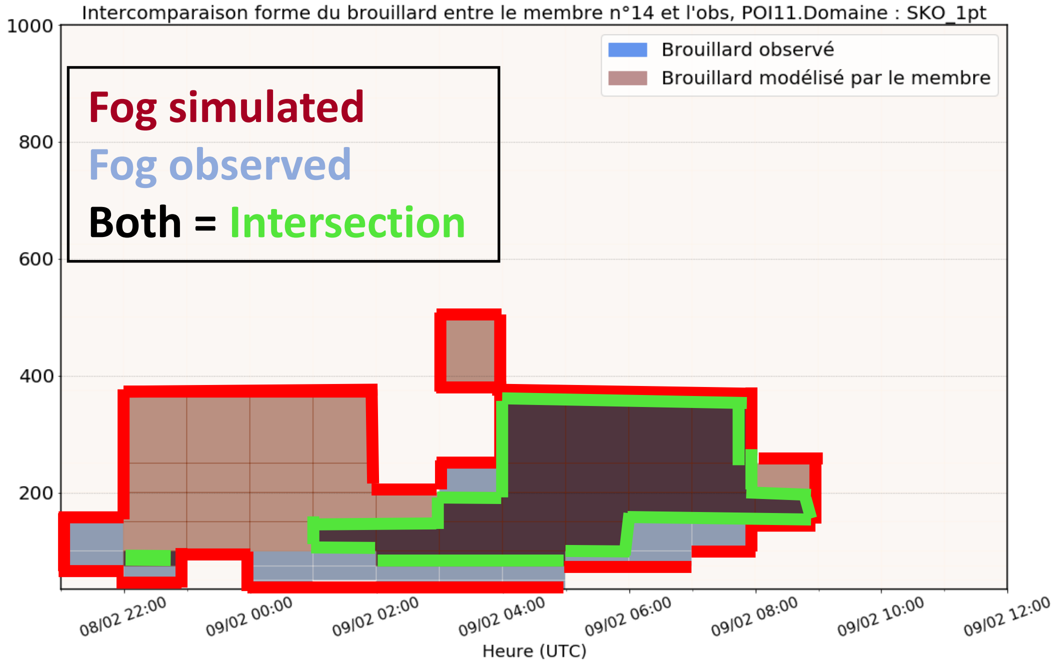
OR/AND

✓ Cloud ceiling < 200 ft



→ Calculation of GFR, FAR and HSS

$$\text{Jaccard score} = \frac{\textit{Intersection}}{\textit{Union}}$$

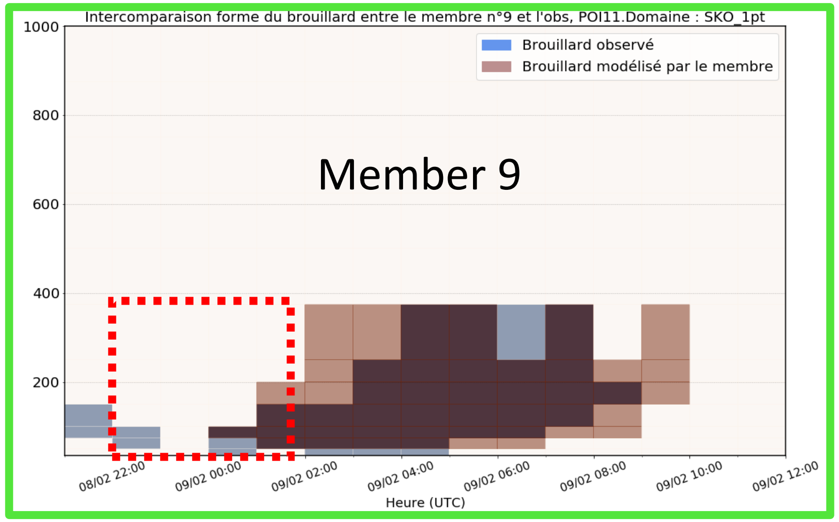


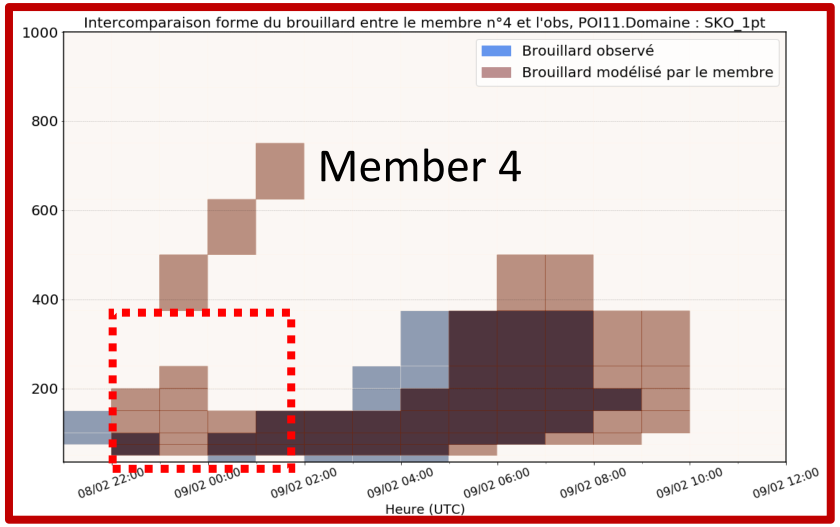
Score = 0 : *the simulated shape is **disjoint** from the observed shape*

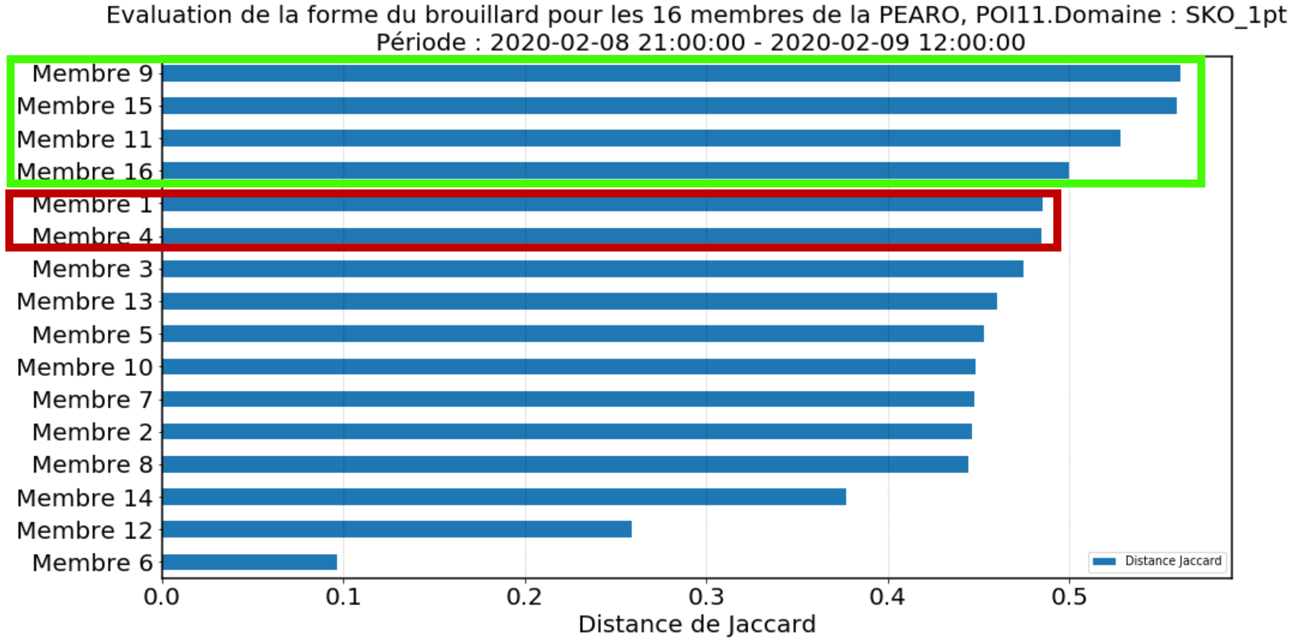
Score = 1 : *the simulated shape is **identical** to the observed shape*

2) Analysis of fog vertical structure on super-site with ARO-EPS

Results with Jaccard score for IOP11 (8-9 February)







<u>Results with ARO-EPS model, run 21z 8/2/20</u>

Best members in Jaccard score can be separated in two groups :

→ Beginning of fog formation between **H+2 and H+4 (23h UTC – 1h UTC)**

→ Fog formation **since H+1 (22h UTC)**

Section 3

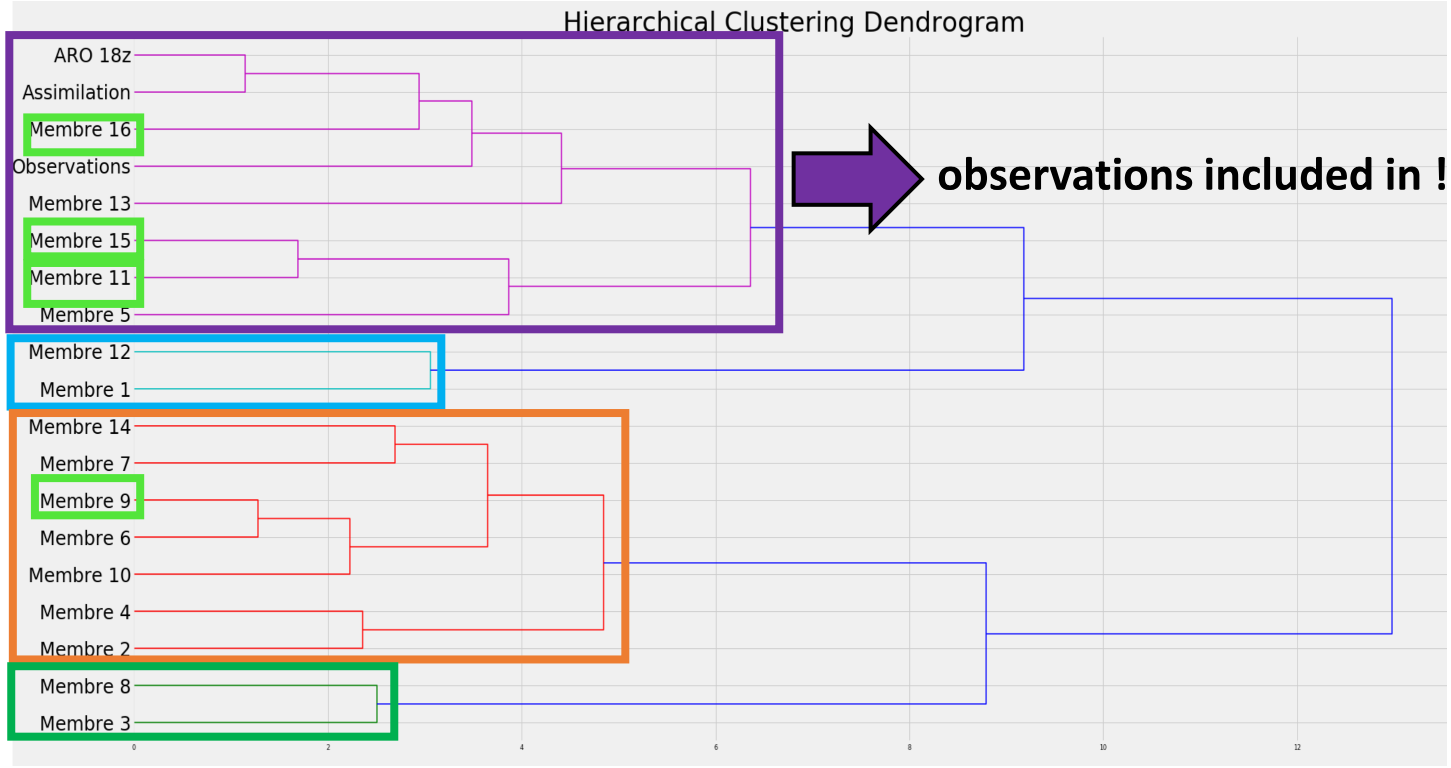
Research of most impactful errors in initial conditions

Local scale

3) Analysis of Initial Conditions for several thermodynamic parameters

Temperature profile

Method : **Ascending Hierarchical Clustering**
- Linkage criterion : Ward
- Affinity : Euclidean



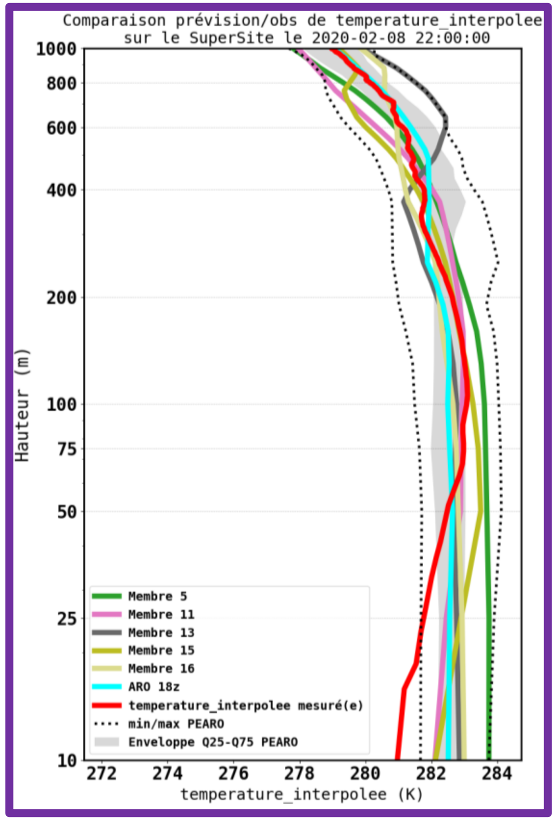
observations included in !

Temperature profiles **at the beginning of IOP11** study
→ Division into 4 clusters

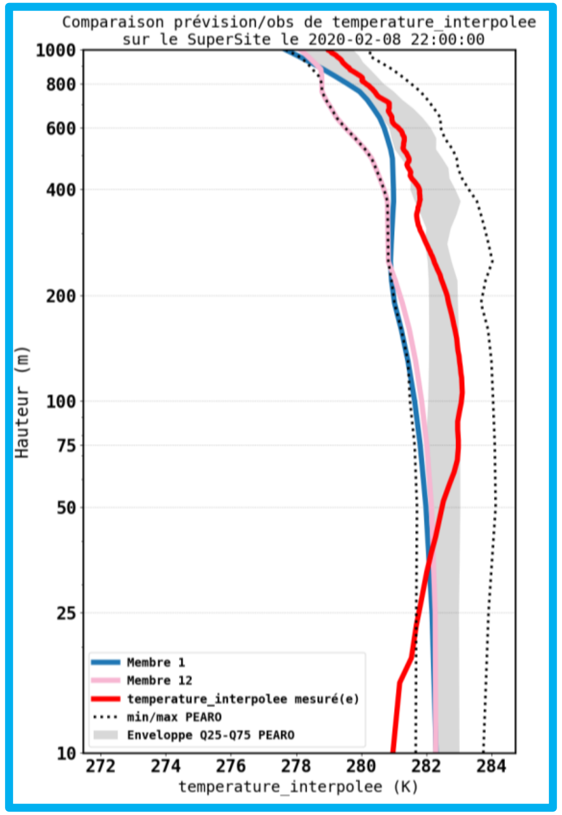
- ➢ First impression : « good Jaccard score » members are mostly well placed (in right cluster)
- ➢ Good indicator of the importance of the temperature profile on the fog forecast

3) Analysis of Initial Conditions for several thermodynamic parameters

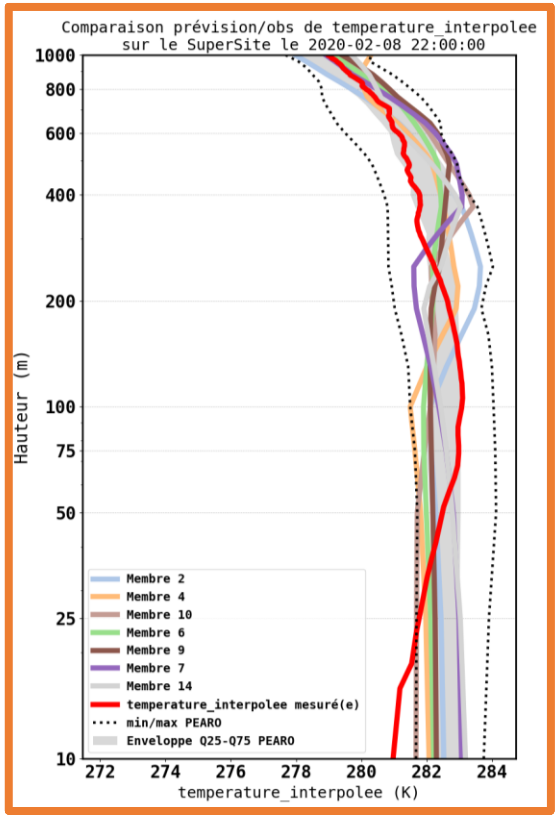
Temperature profile



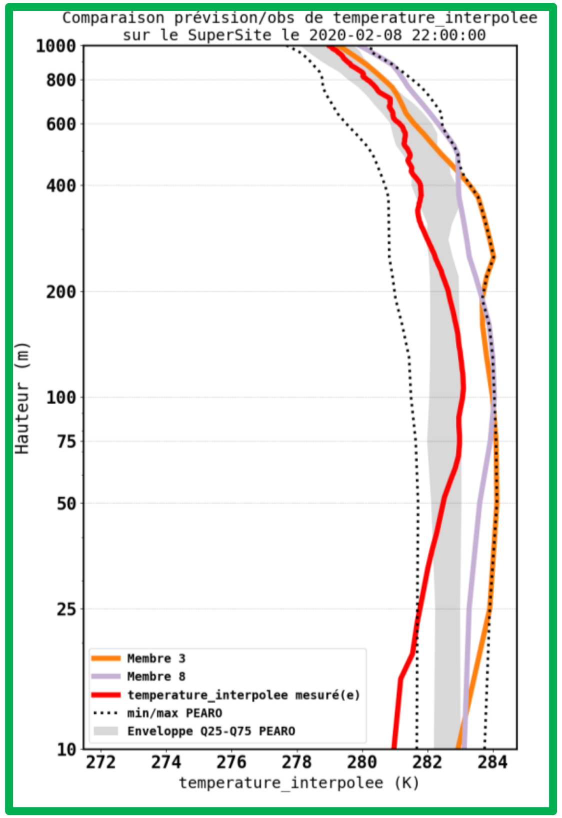
- Thermal inversion ok



- No thermal inversion
- Unstable profile



- Thermal inversion too high



- Profile shape ok
- Warm bias (+1.5K)

3) Analysis of Initial Conditions for several thermodynamic parameters

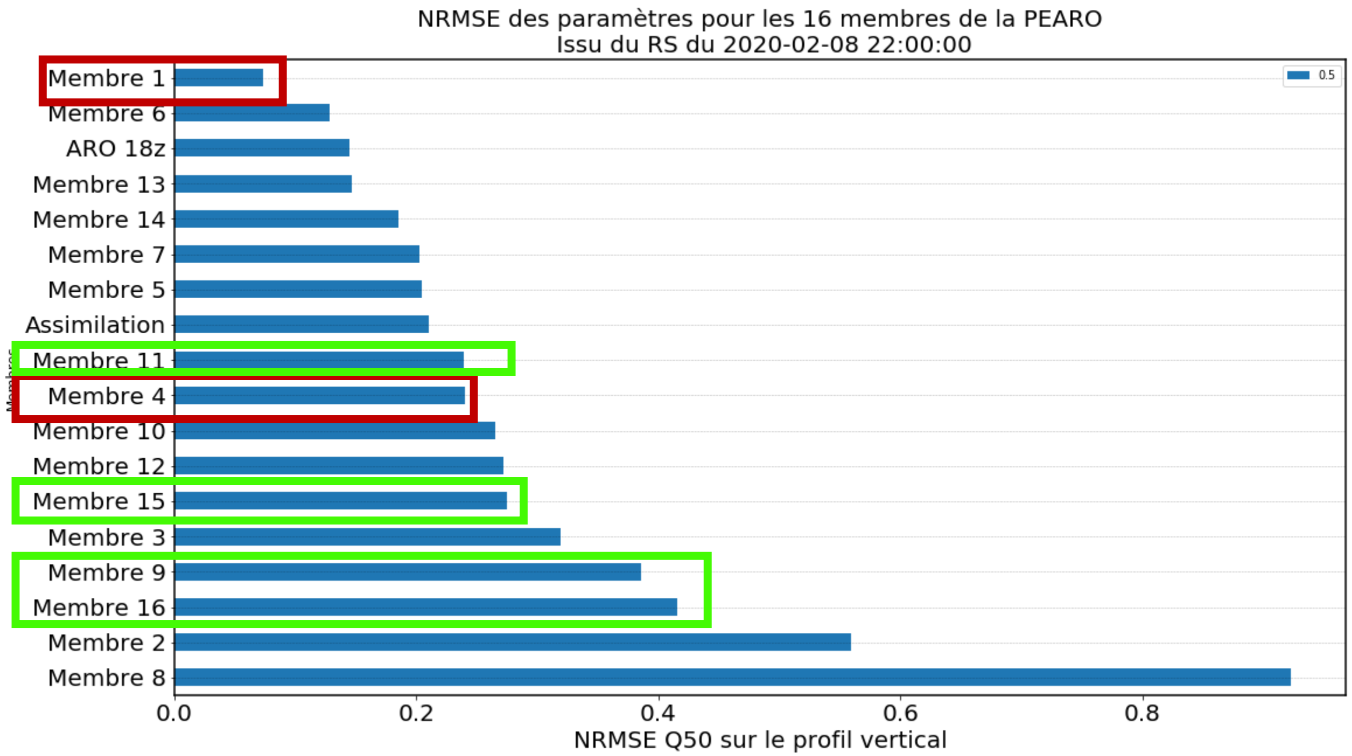
Relative humidity profile

Calculation of the RMSE for one time step (8/2/20 22h UTC) :

- ❑ Vertical levels selection
- ❑ Calculation of RMSE for each vertical level

- ❑ Quantile calculation on all vertical RMSE values

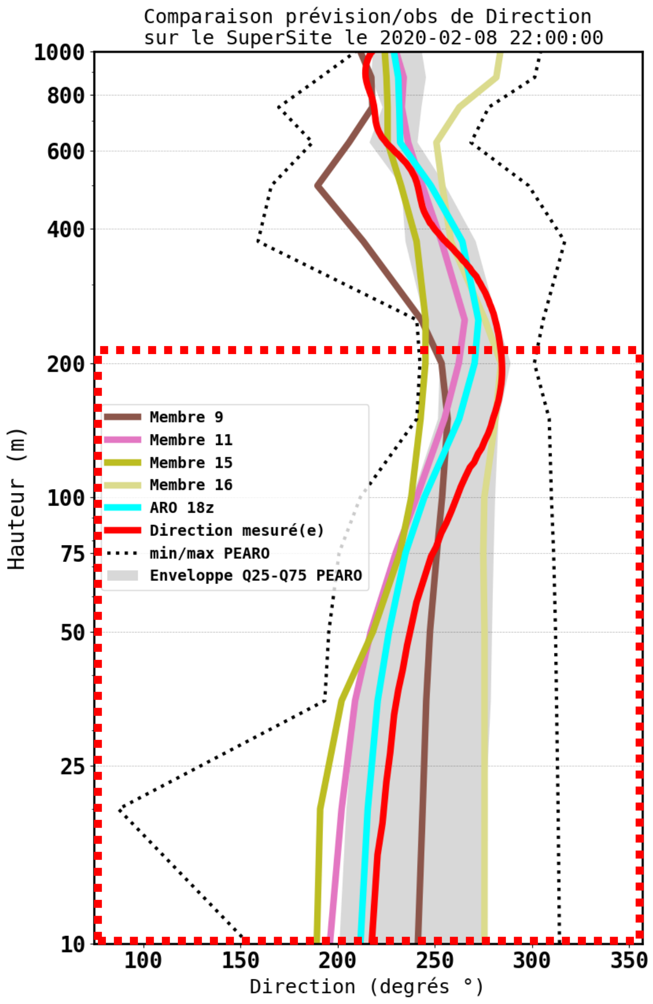
1 RMSE value for all vertical profile

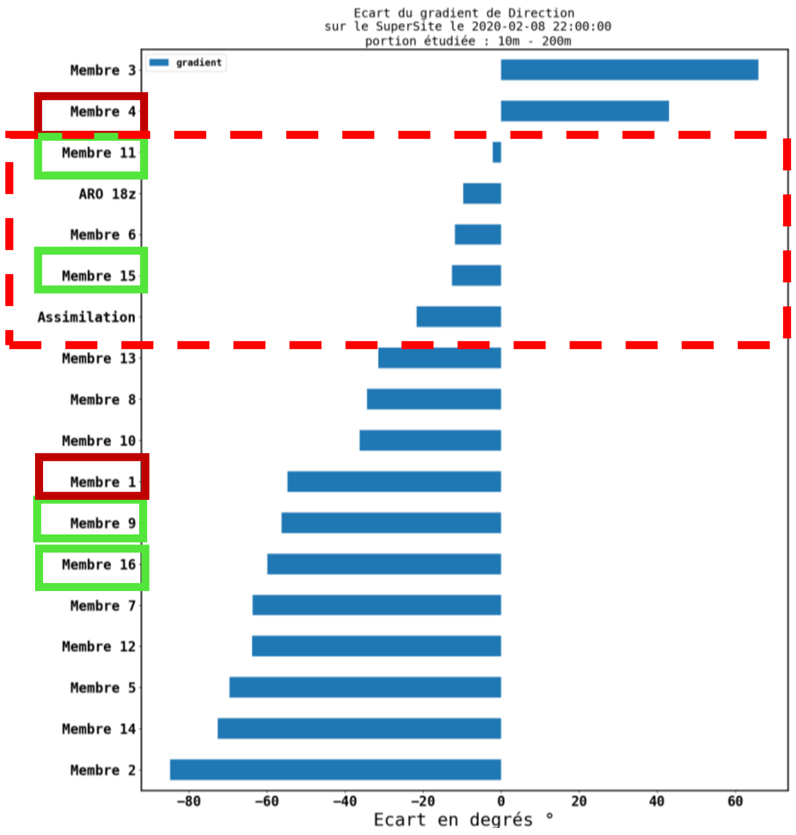


- « good Jaccard score » members in the worst half of the ARO-EPS members, except for the member n°1
- At first sight, compliance with RH values is less important than temperature

3) Analysis of Initial Conditions for several thermodynamic parameters

Wind direction profile



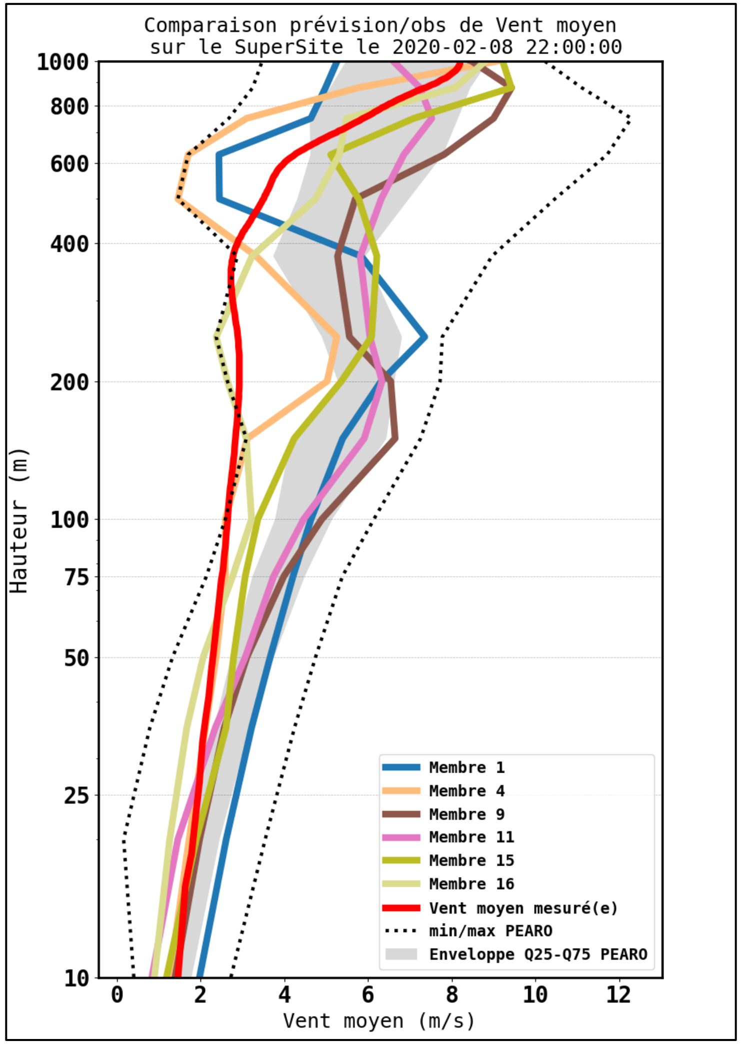


Difference direction variation modelised / wind direction variation observed

- Importance of well representation of wind direction variation = good modelization of turbulence inside fog

3) Analysis of Initial Conditions for several thermodynamic parameters

Wind strength profile



- ➢ Growth of dispersion with altitude
- ➢ Differences of wind strengh among « good Jaccard score » members
- ➢ **Compliance with the wind profile → not a condition for a good vertical fog structure**

4) Prospects

Next steps :

- ❑ Removal of the temperature (+ relative humidity) perturbation and evaluate how much impact on fog forecast
- ❑ Removal of the physical perturbations to quantify the respective weight of the perturbations of initial conditions versus physical parameterizations