Fog process studies with AROME-EPS model

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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

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
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

Relevés de visibilité sur le réseau MF, domaine SO. Date: 2020-01-06 10:00:00
Visual identification with hourly minimum visibility parameter

Date: 6 January 10h UTC

ARO-EPS minimum visibility 1h

Minimum visibility 1h observed

Relevés de visibilité sur le réseau MF, domaine SO. Date: 2020-01-06 10:00:00
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

Most interesting IOPs based on:
- 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?

IOP4.1, IOP4.2
IOP6.3
Example with IOP4.1

IOP9.1, IOP14

IOP11, IOP13.2

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

Difficulties in finding one member of ARO-EPS which has both:

- 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 $\rightarrow$ fog vertical structure needed

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

![Radar reflectivity observation](image1)

![Radar reflectivity simulation](image2)

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

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility &lt; 600 m</td>
<td>Score = 0</td>
<td>the simulated shape is disjoint from the observed shape</td>
</tr>
<tr>
<td>Cloud ceiling &lt; 200 ft</td>
<td>Score = 1</td>
<td>the simulated shape is identical to the observed shape</td>
</tr>
</tbody>
</table>

Jaccard score = \( \frac{\text{Intersection}}{\text{Union}} \)

Calculation of GFR, FAR and HSS

→ Calculation of GFR, FAR and HSS

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)

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

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

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

Difference direction variation modelised / wind direction variation observed
3) Analysis of Initial Conditions for several thermodynamic parameters

Wind strength profile

- Growth of dispersion with altitude
- Differences of wind strength 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