Impact of vertical resolution on AROME fog prediction

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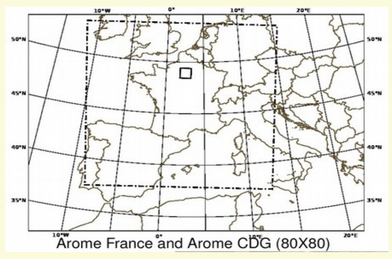
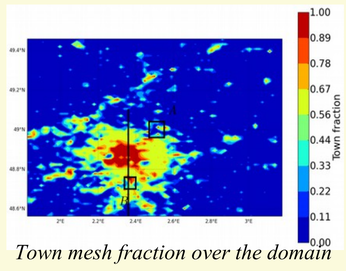
Abstract

The impact of vertical resolution on the fog forecasting in the kilometric scale model AROME (Seity al al. 2011, Brousseau et al. 2016) has been studied at the Paris Charles-de-Gaulle airport.

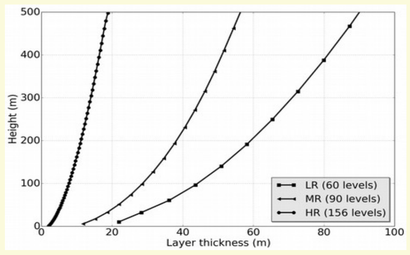
Vertical resolution impacts both the onset time, the spatial development and also the physical processes involved at the fog onset. It has been shown that a finer vertical resolution leads to the simulation of more local fog events than a coarser vertical resolution. In spite of the increase of good detections with a finer vertical resolution, the overall forecast quality does not change because of more frequent false alarms. Furthermore, these simulations emphasize that the model overestimates the cloud base height whatever the vertical resolution.

Two methods representing the surface boundary layer and allowing a finer vertical resolution at a low computational cost have been avaluated. The best method is based on the surface boundary layer prognostic scheme "Canopy", which improves the physical behavior of the model during the onset of radiation fogs. However, the limits of the method are reached when the onset is impacted by local circulations.





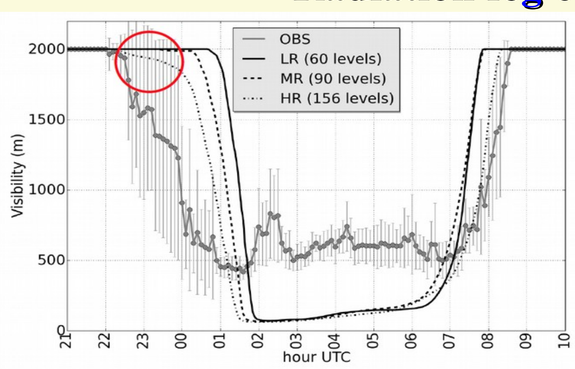
Town mesh fraction over the domain



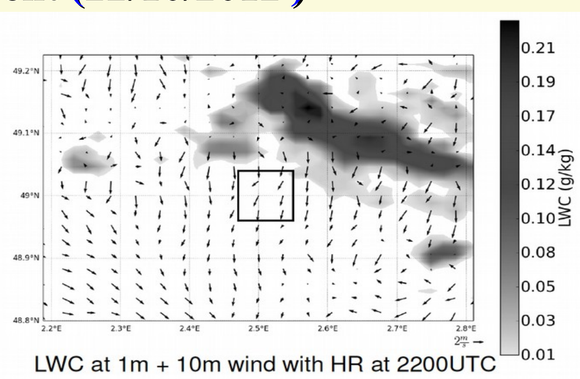
LR : 60 levels with first level at 10m (old oper)
MR : 90 levels with first level at 5m (oper)
HR : 156 levels with first level at 1m

← Paris Charles-de-Gaulle airport

Radiation fog event (22/10/2012)

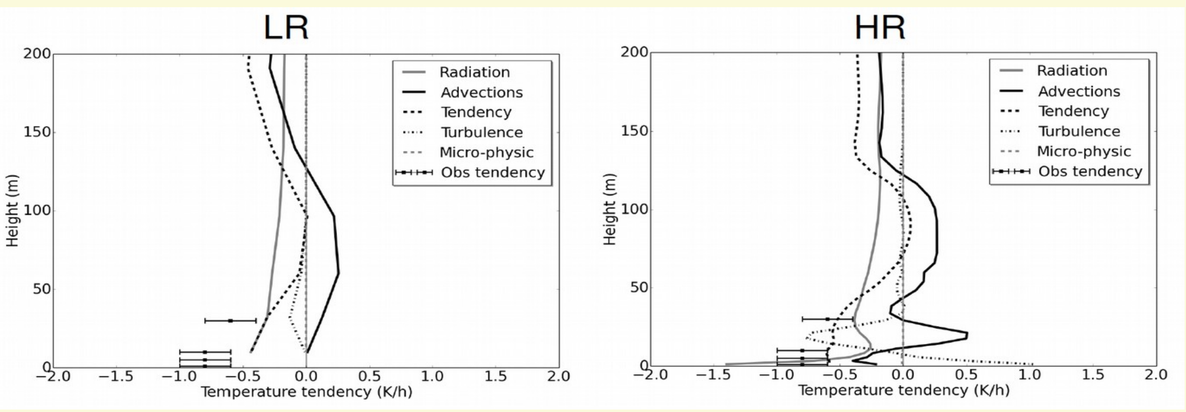


Visibility on the airport area

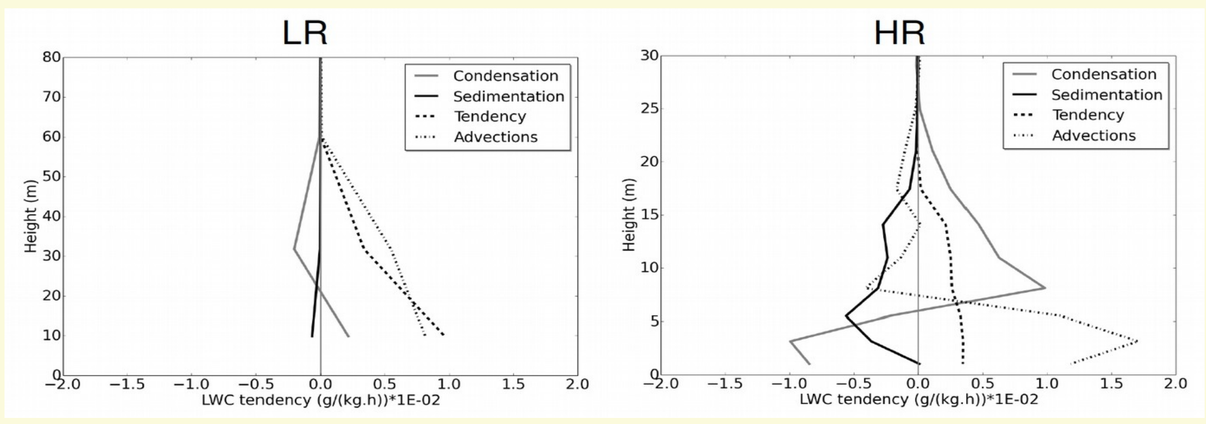


LWC at 1m + 10m wind with HR at 2200UTC

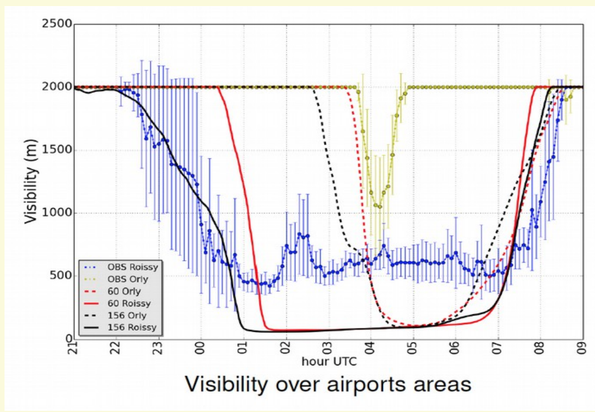
- HR visibility simulation during the formation phase is in better agreement with observations than MR/LR
- Local circulations close to the surface are more pronounced with HR
- MR and LR have similar behavior



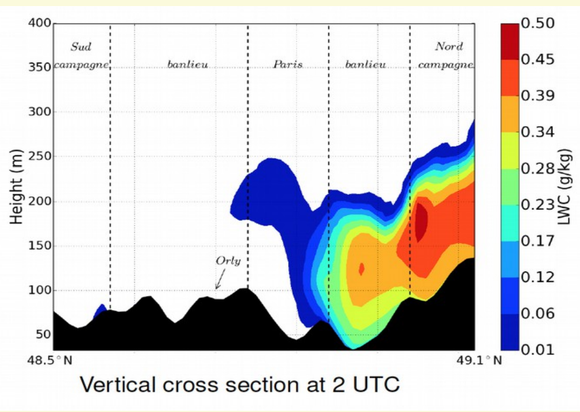
Caption: Temperature budget (K/h) for LR and HR configurations at 2200 UTC. Solid gray, solid black, dashed black, dotted black, and dashed gray curves correspond, respectively, to the radiation, advection, tendency, vertical turbulence, and microphysical terms. Observed tendencies at 1, 5, 10, and 30m are represented by the black squares. The accuracy is represented by the error bar.



Caption: Liquid water budget (g/kg/h) for LR at 0100 UTC and HR at 2300 UTC. Solid gray, solid black, dashed, and dotted curves correspond, respectively, to the condensation, sedimentation, tendency, and advection terms.



Visibility over airports areas

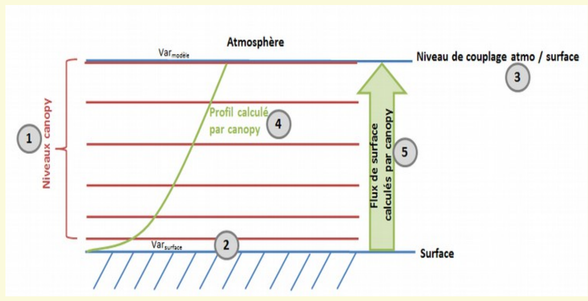


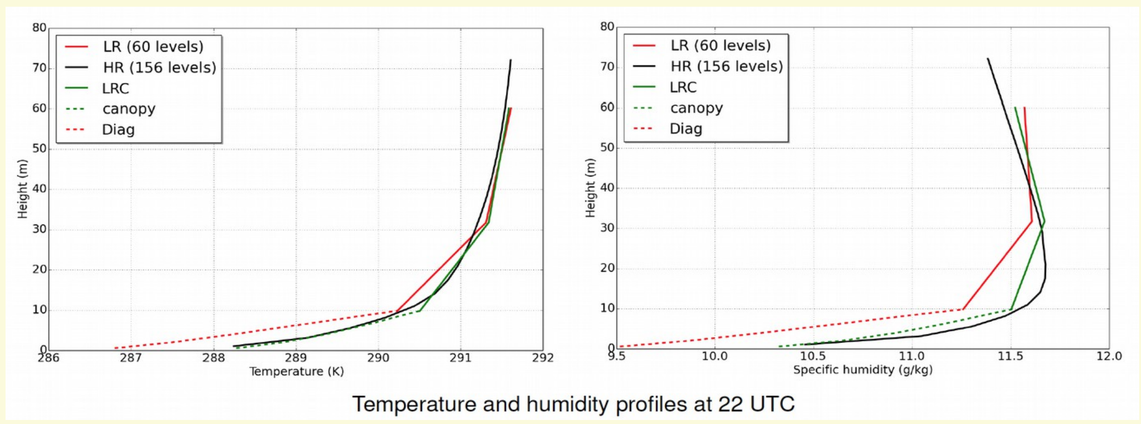
Vertical cross section at 2 UTC

- Fog becomes a stratus above Paris
- At Orly this event is a Cloud-Base-Lowering fog and HR brings nothing more

Parameterization of a fine vertical resolution

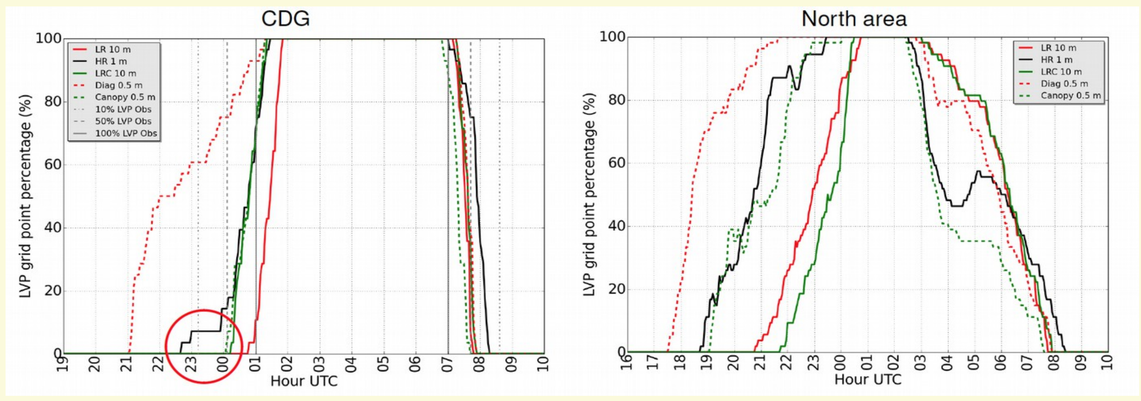
The first method is a simple vertical interpolation "Diag" based on stability functions. The second method uses the "Canopy" scheme (Masson and Seity, 2009): a prognostic TKE scheme which interacts with the surface. In the both cases an adjustment to saturation has been introduced.





Temperature and humidity profiles at 22 UTC

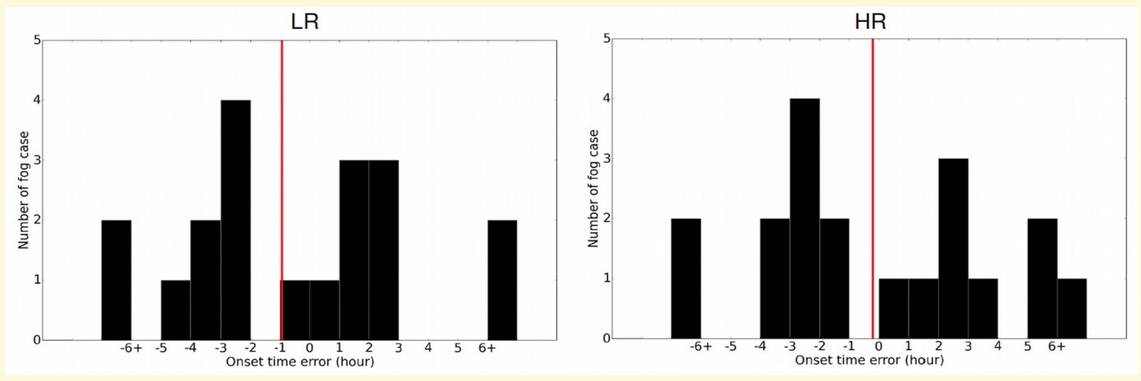
- "Canopy" scheme improves Low Resolution profiles and reconstructs good profiles below the first level



Caption: Temporal evolution of the percentage of grid points under foggy conditions at CDG (left) and a little further North (right)

- "Diag" method brings nothing more. "Canopy" improves onset of radiation fog. At CDG, at the beginning, fog is radiation/advective

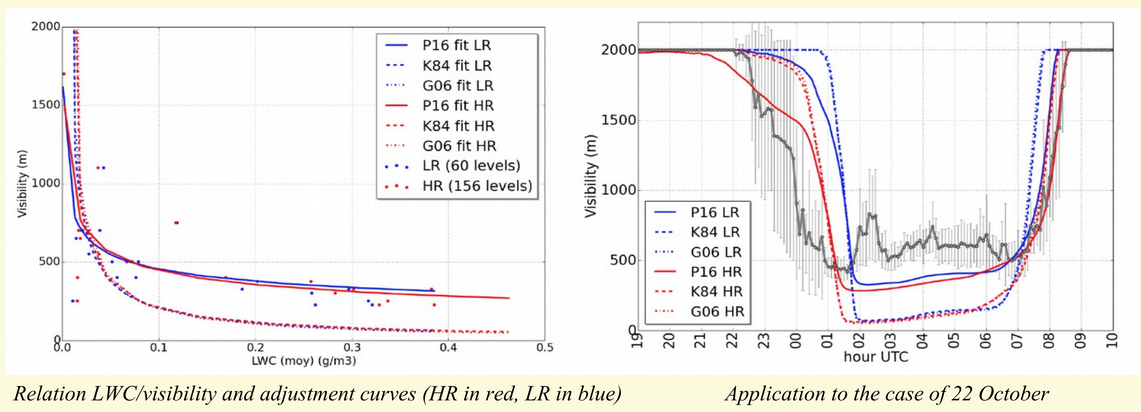
Statistical study over the 2011-2012 winter season



Frequency distribution histogram of the onset time error

- The statistical study confirms that high vertical resolution simulates fog earlier
- On the other hand, high resolution does not improve the forecast quality
- The Cloud-Base-Lowering fogs are not well simulated by the model no matter what vertical resolution is used
- Arome model predicts low clouds but the height of ceiling is not well simulated

Adjustment of the Kunkel's visibility formula



Relation LWC/visibility and adjustment curves (HR in red, LR in blue) *Application to the case of 22 October*

- Arome predicts a too large LWC near the surface. It's possible to adjust Kunkel's formula (1984)

Conclusions and perspectives

- A fine vertical resolution near the ground is necessary to have a good representation of various meso-scale processes involved during the fog formation phase
- The fine vertical resolution simulates stronger horizontal heterogeneities and consequently more fog events over the winter season but it doesn't improve the quality (too many false alarms)
- In case of radiation fog the "Canopy" scheme improves the chronology of fog formation and increases horizontal heterogeneities
- Cloud-Base-Lowering fogs are not well simulated by Arome
- Arome predicts too large LWC near the surface but it's possible to adjust a formula of the Kunkel's type

- Parameterize radiative effects of LWC produced by "Canopy"
- Parameterize horizontal advection in "Canopy", if possible (?)
- Study the inacurate lowering of stratus in Arome
- Improve micro-physics, in particular the interaction between cloud liquid water and vegetation and buildings

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