Recent activities on fog modeling at Météo-France

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PLAN

1. Impact of vertical resolution for fog forecasting with AROME

2. Impact of surface heterogeneities with MESO-NH model used for LES (Understanding the physical mechanisms involved during the fog life cycle is a key point in improving fog forecasting)

3. Perspectives

PLAN

1. Impact of vertical resolution

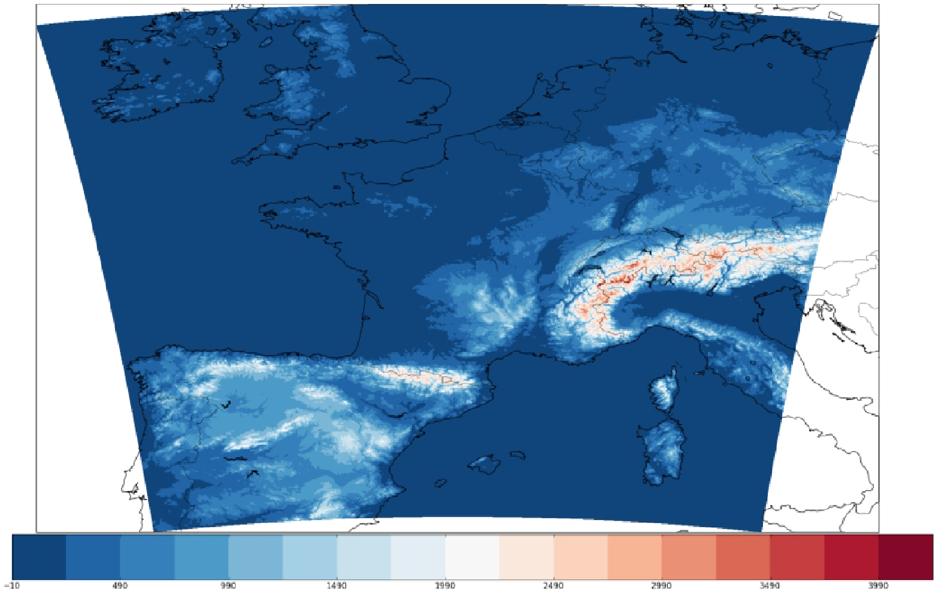
2. Impact of surface heterogeneities

3. Perspectives

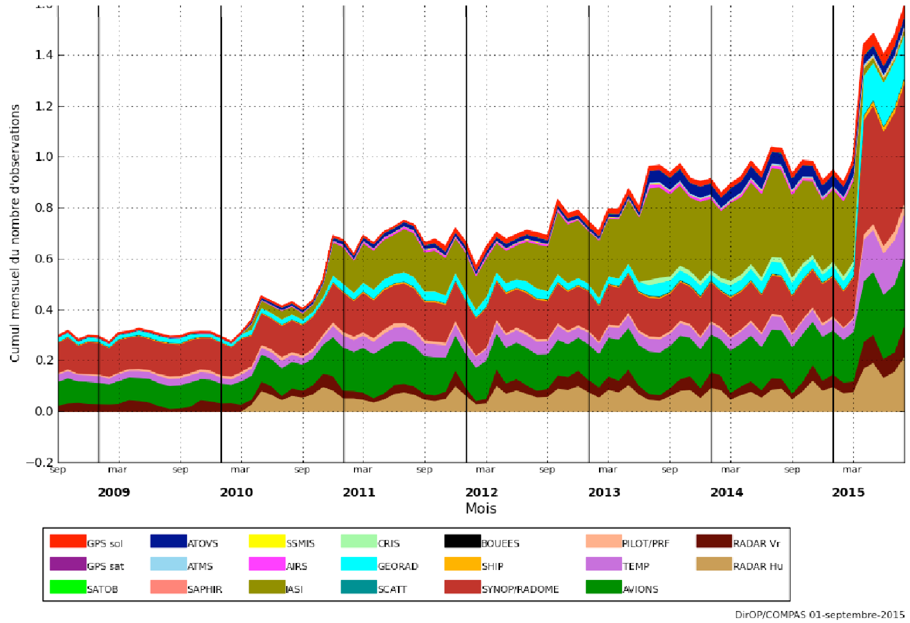
AROME-France operational NWP system

- ✓ Limited area spectral non-hydrostatic convective scale model
- ✓ Operational since December 2008
- ✓ Hourly coupling to global ARPEGE model
- ✓ Since April 2015 : Dx=2.5 -> 1.3 km , 60 -> 90 vertical levels, 3DVar 3h -> 1h cycle

Computational domain



Monthly evolution of observations number



RADARS AIRCRAFTS SYNOP/RADOME

IASI SEVIRI TEMP Ground GPS

AROME Physics

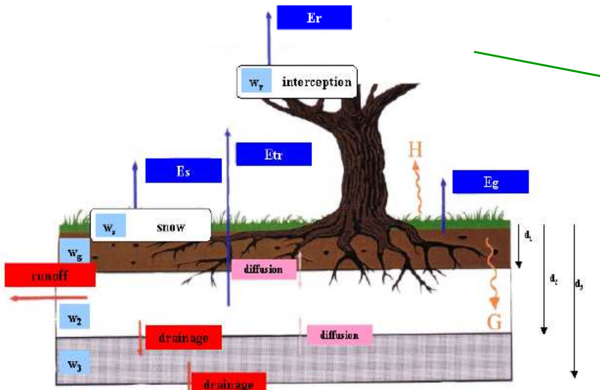
- **TURBULENCE** : 1.5 order closure (Cuxart et al.,2000), Non local mixing length (Bougeault and Lacarrere, 1989)

- **PBL THERMALS** : Dry & moist shallow convection. Surface flux closure. (Pergaud et al, 09)

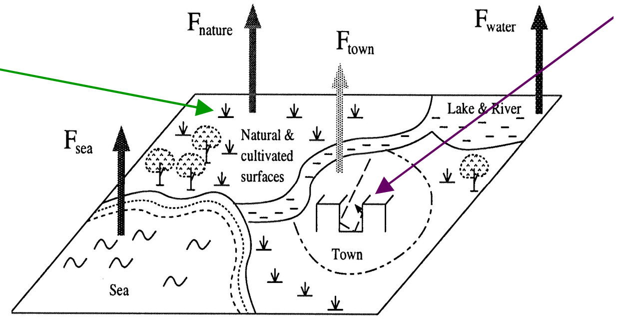
- **RADIATION** : LW and (old) SW ECMWF radiative transfer code

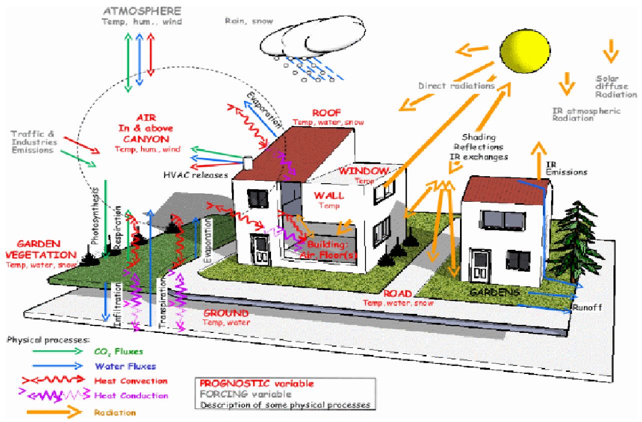
- **MICROPHYSICS** : 1 moment scheme with prognostic cloud mass and droplet sedimentation

- **SURFACE** : SURFEX (Masson et al., 2014)



ISBA (Noilhan and Planton, 1989)

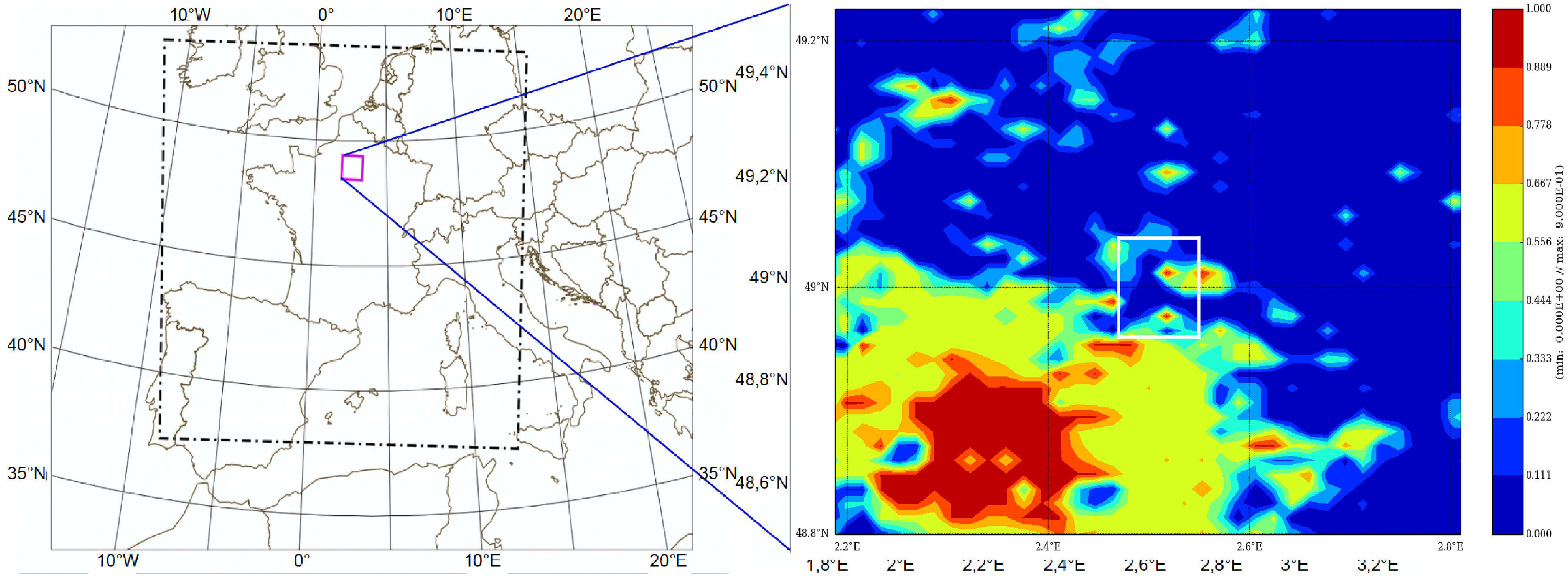




TEB (Town Energy Balance) Masson (2000)

Model configuration

AROME 80*80 grid points centred on CDG airport at 1.3km and 3 vertical resolutions coupled to previous (2.5km) AROME operational system on 2011-2012 winter period.



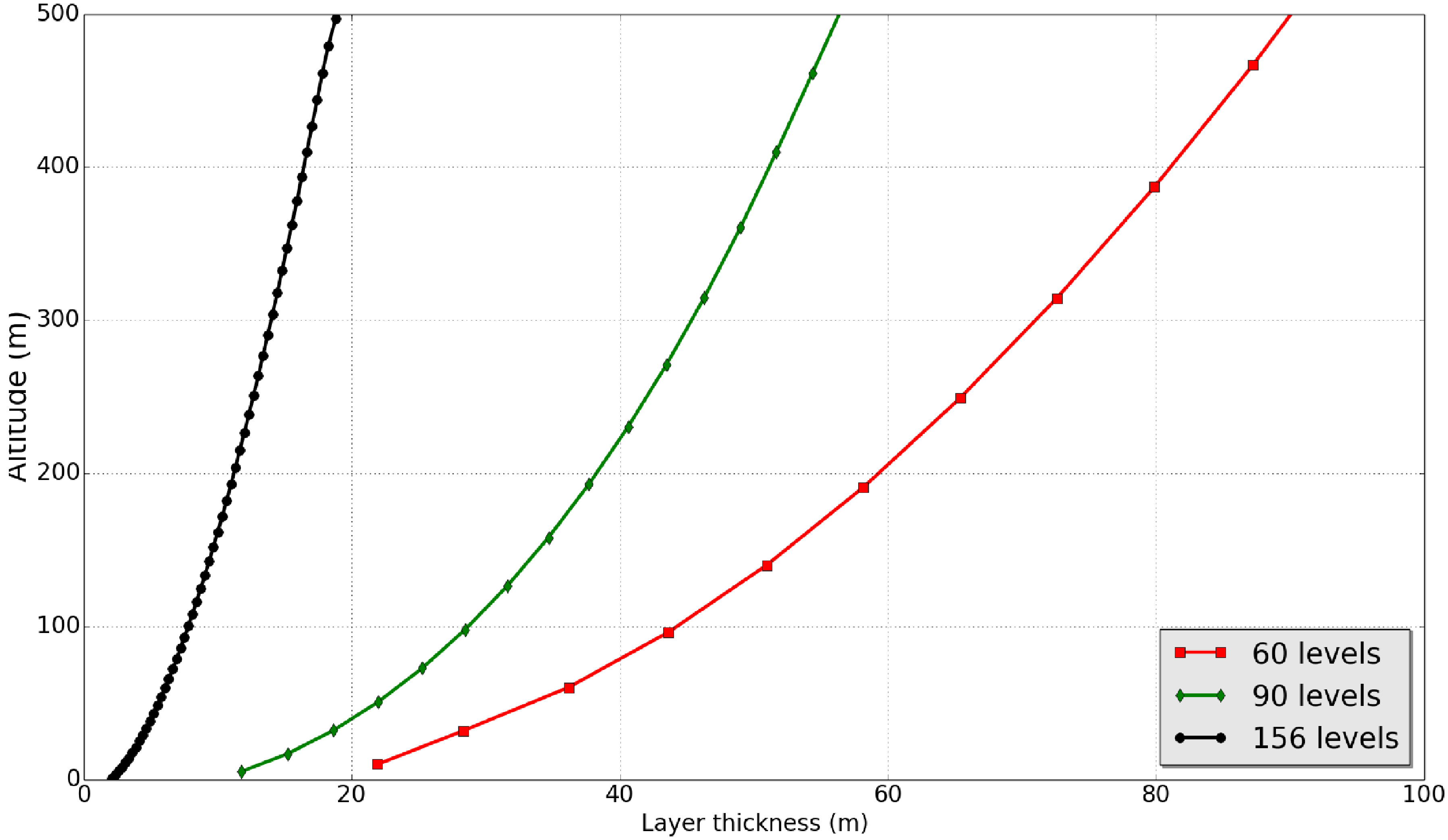
Dashed black square : host model
Solid pink square : studied domain

Normalized town fraction percentage of the calculation area

Observations over CDG airport :

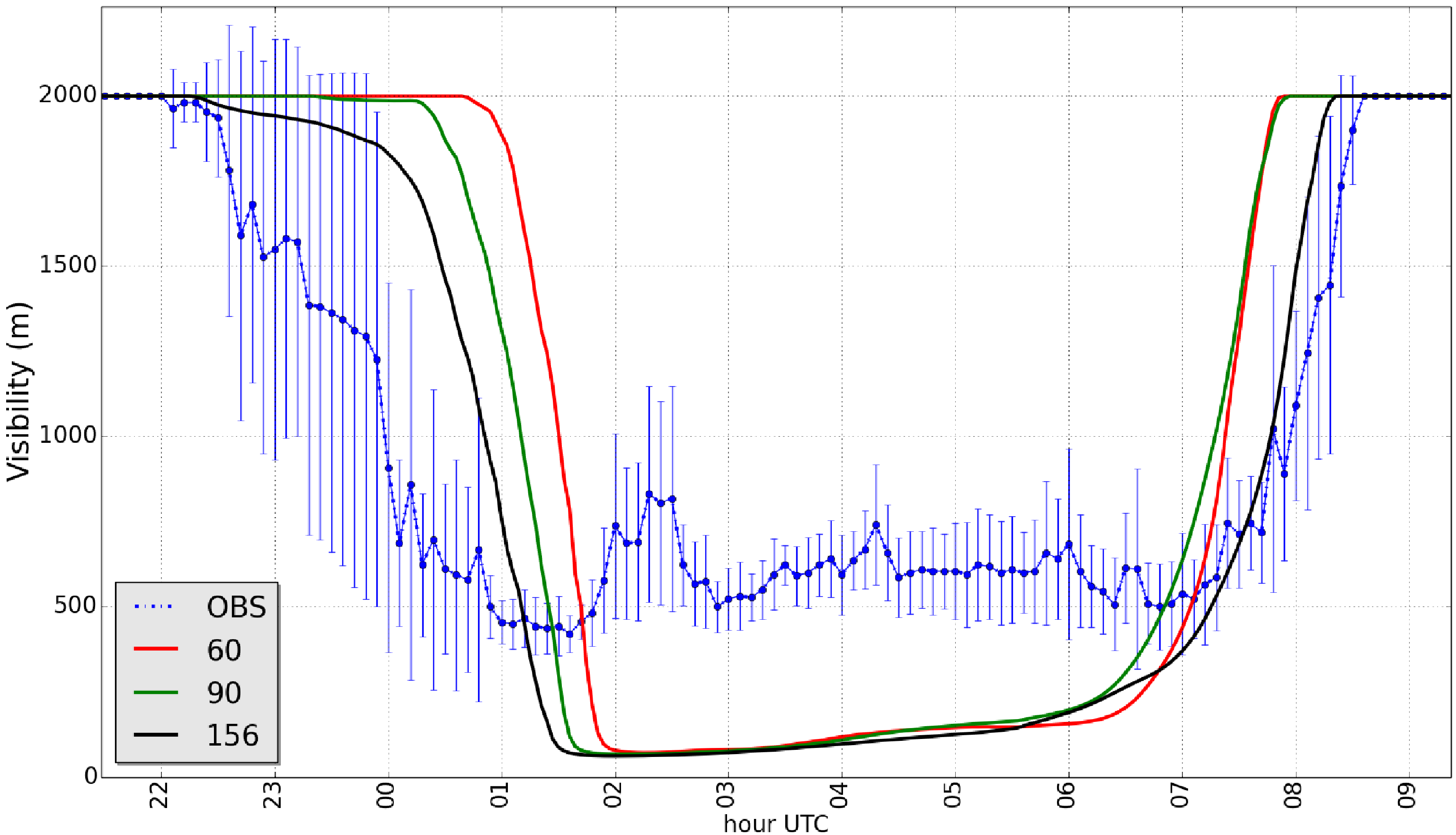
- 30m high mast: temperature and humidity
- Sensors over ground: 12 visibility, 4 ceiling cloud, IR and visible ray, 2m humidity and temperature and 10m wind.
- Sensors under ground : temperature and humidity

3 vertical resolutions (60, 90, 156 levels)



Case study : the 22nd of October 2012

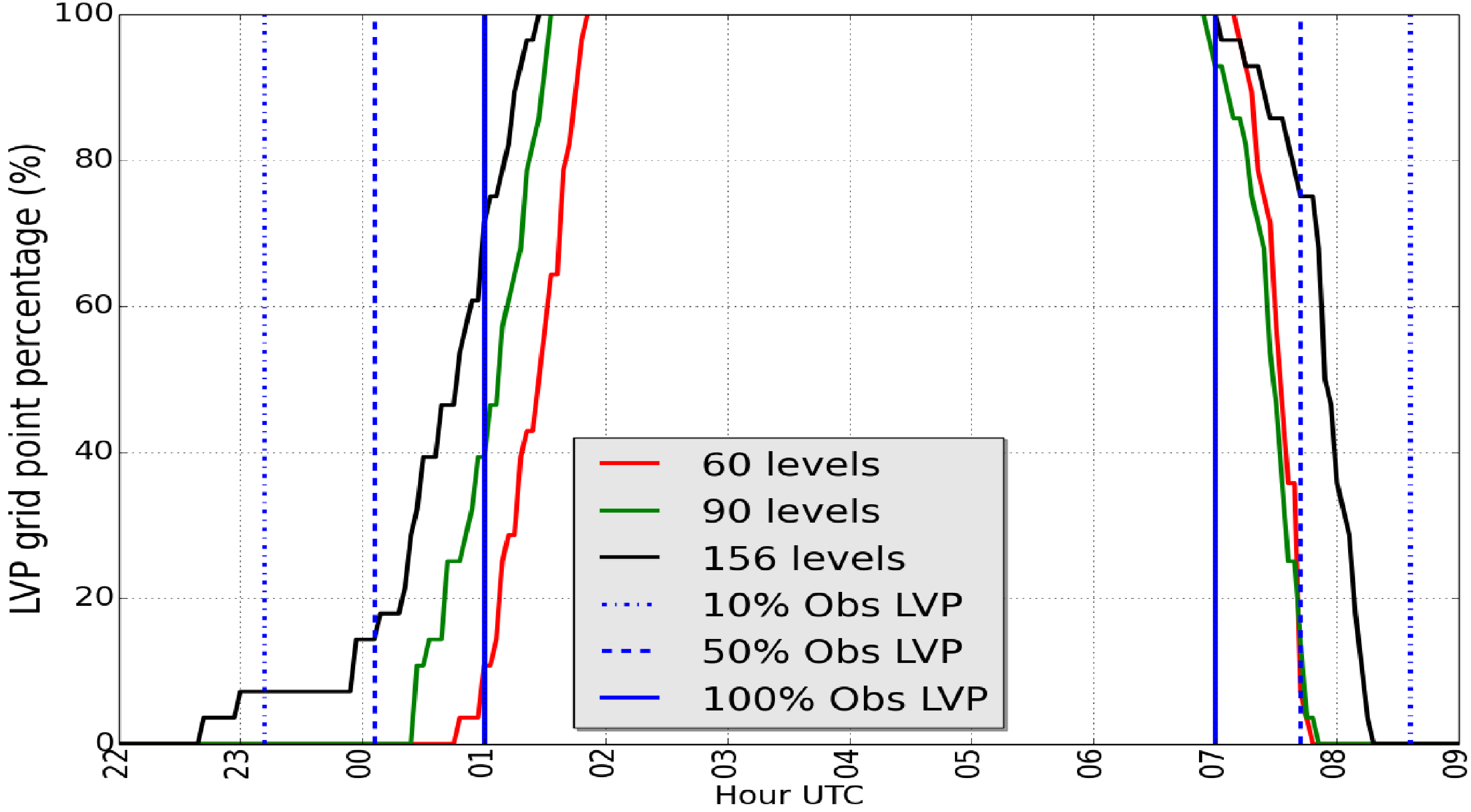
- Clear night and light wind conditions
- High variability between 2200 and 0000 UTC (beginning of fog formation)
- Low Visibility Procedure (LVP) active from 0000 to 0730 UTC, ceiling < 60m and/or visibility < 600m
- Total dissipation after sunrise at 0830 UTC



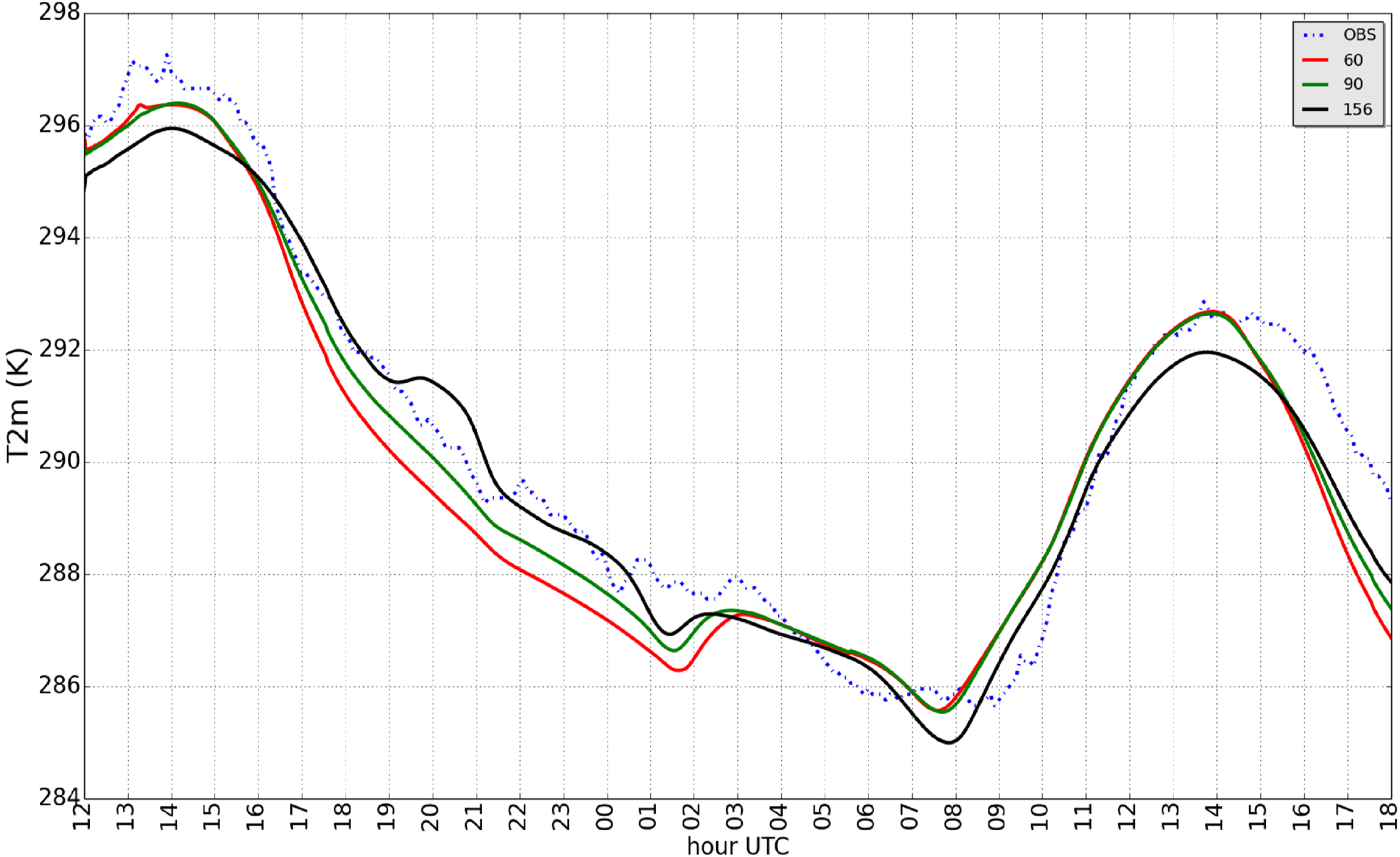
Simulation : 28 grid points average

LVP grid points proportion - 28 grid points

A grid point is LVP when the liquid water content > 1.0E-02 g/kg
- High heterogeneity well represented by High Resolution (HR) configuration (black curve)
- Slow increase of LVP grid points between 2245 and 0000 UTC for HR) better agreement with observations
- Coarser resolutions do not represent correctly this slow increase.
- HR : Slower dissipation rate in better agreement with observations

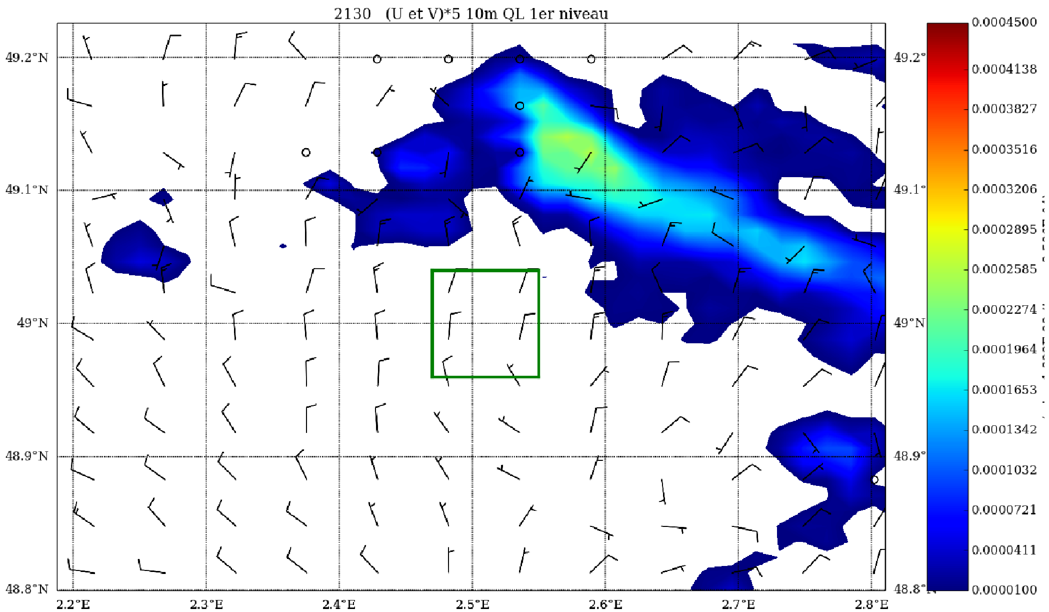


T2m evolution

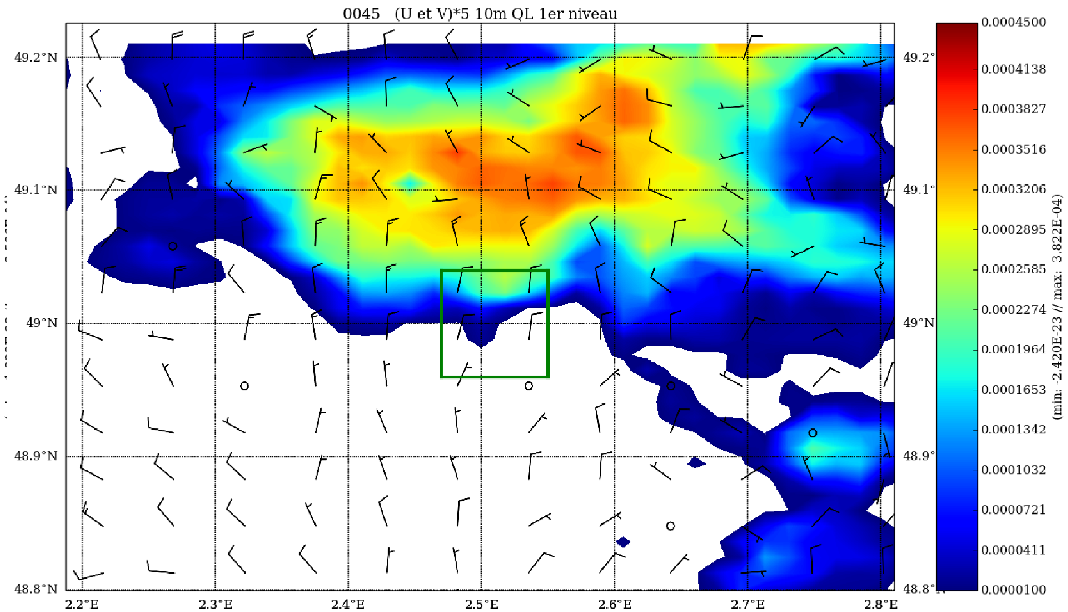


Spatial heterogeneities

Liquid water content at the first model level with barbs at 10m



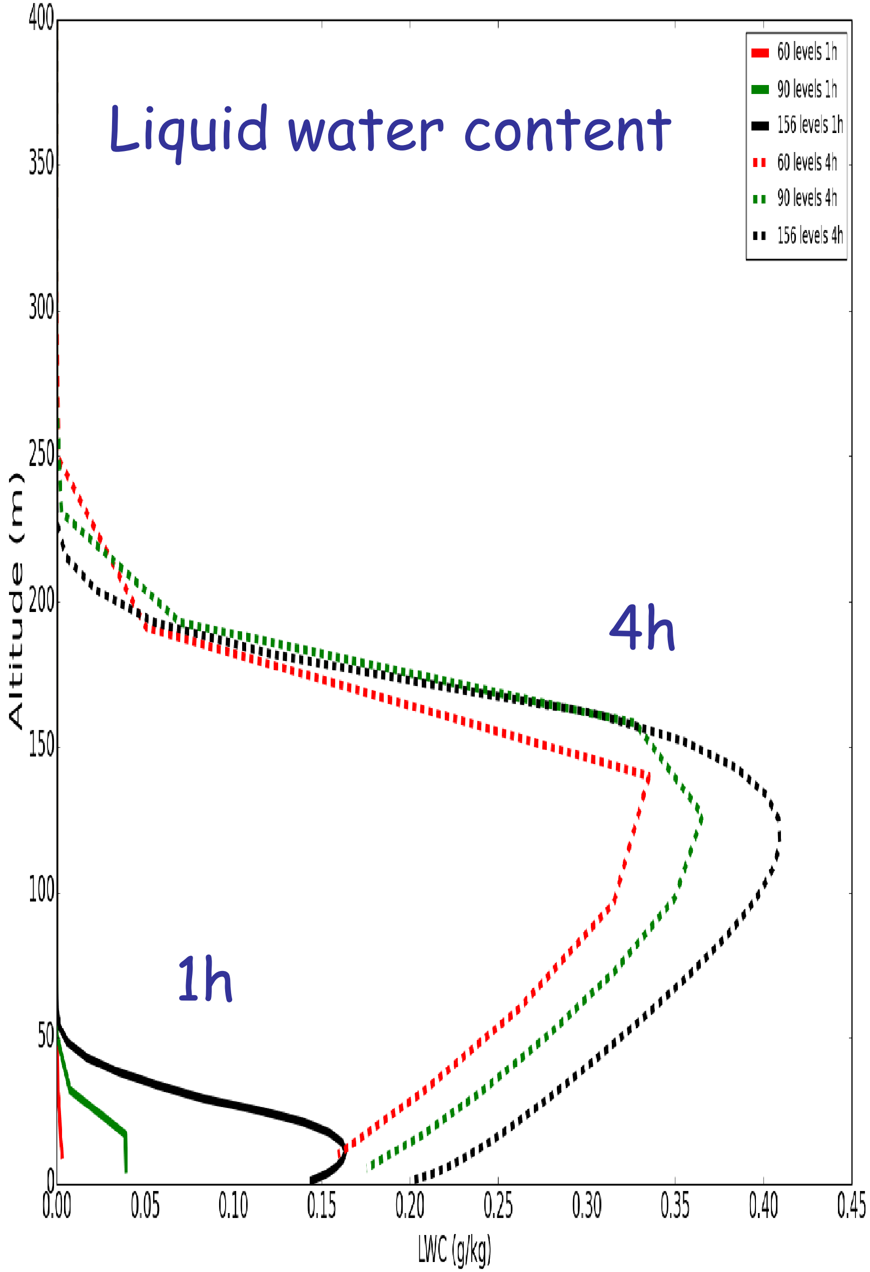
21h30 UTC



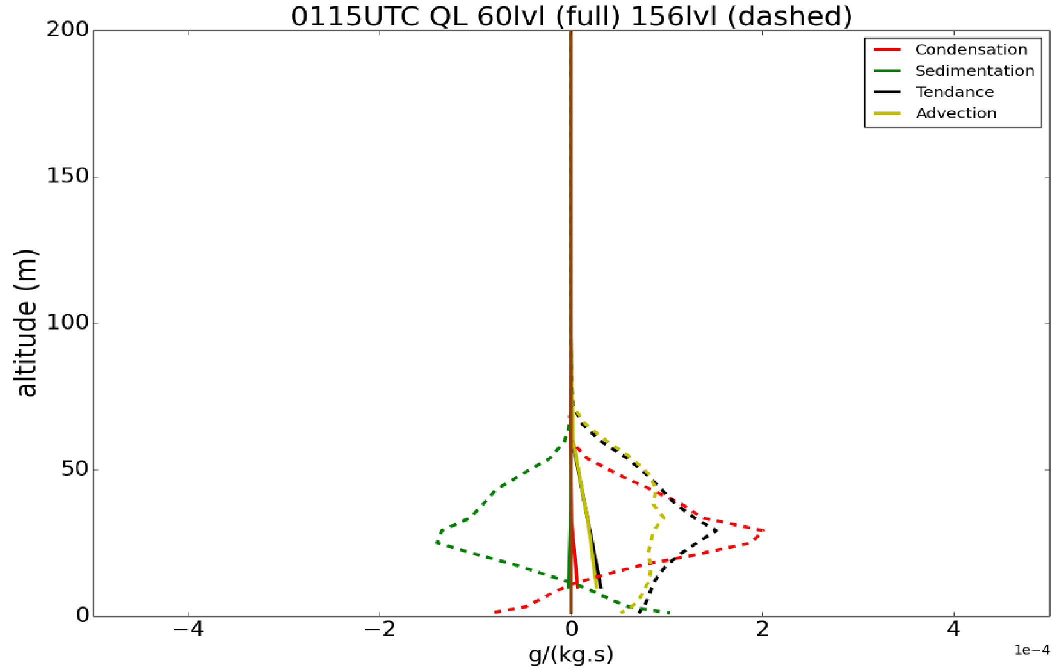
00h45 UTC

METEO FRANCE
Toujours un temps d'avance

Liquid water evolution at CDG



Liquid water content evolution budget



Results on this case study

With high resolution :

- Better representation of high variability at the beginning of fog episode
- Better agreement to observations during formation and dissipation phases
- Earlier and higher liquid water content
- Stronger turbulent mixing (not shown)
- Advection plays an important role

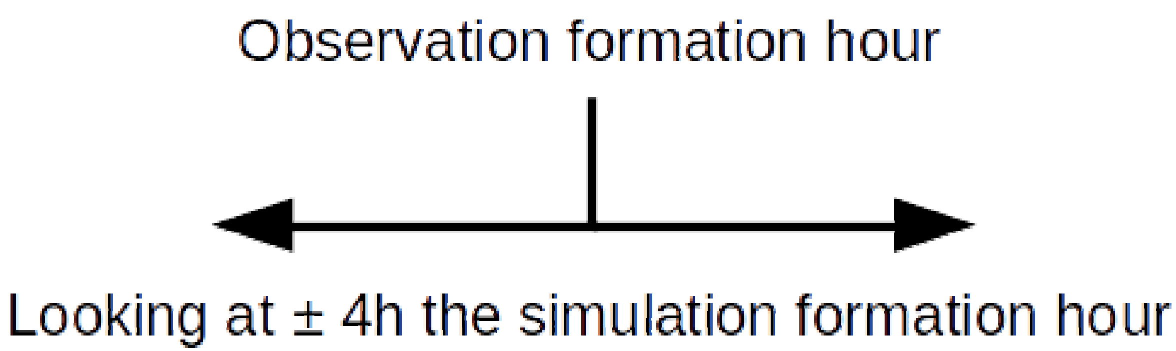
A statistical study : Winter 2011 - 2012

Observation fog events over CDG are defined with Tardif and Rasmussen 2007 method:

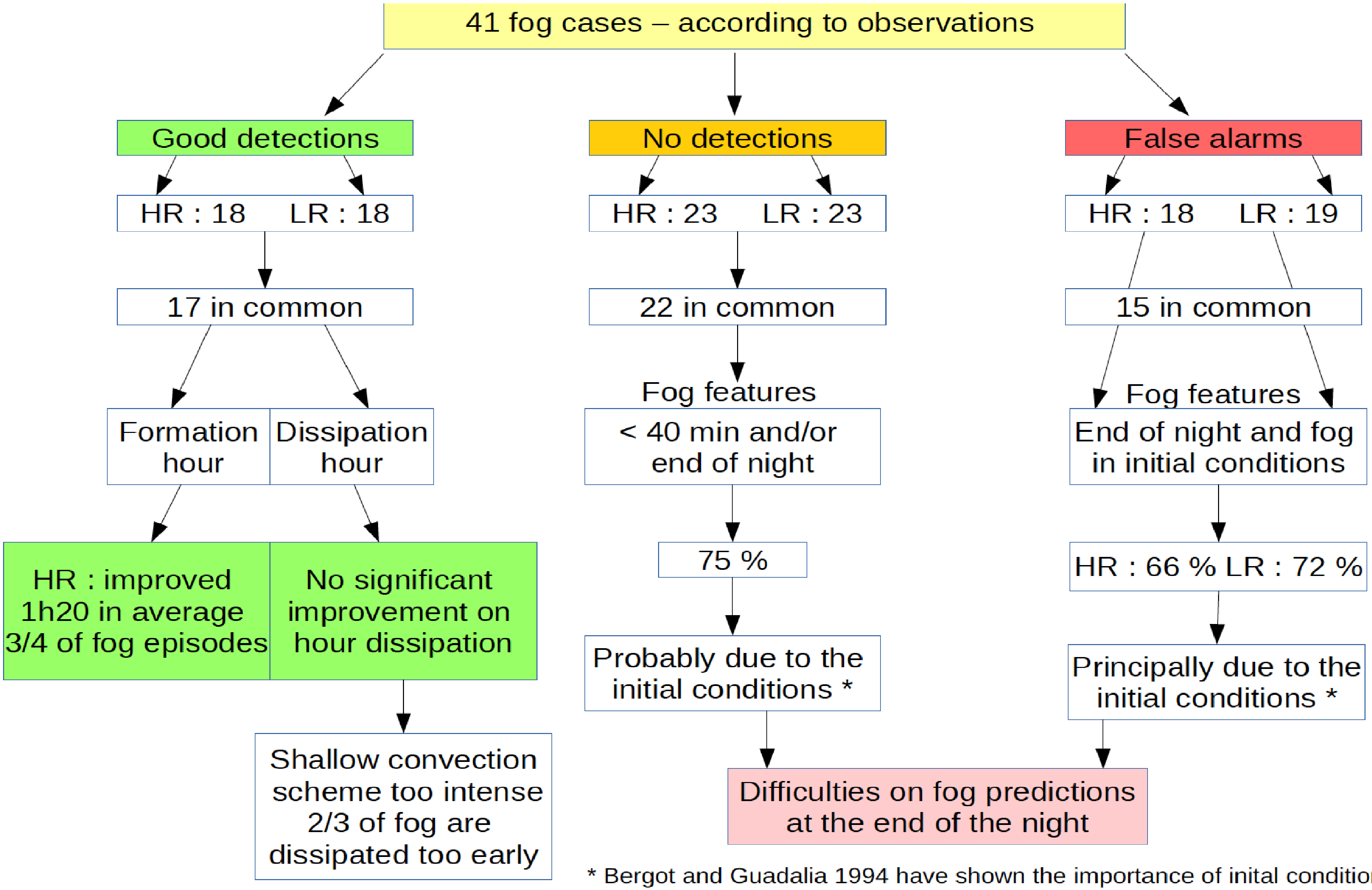
- 40% of events are radiation fogs
- 20% are cloud base lowering fogs
- 10% are advection fog
- 30% undetermined

Formation and dissipation hour of simulations and observations are compared.

Simulation good detection :



A statistical study : Winter 2011 - 2012



* Bergot and Guadalia 1994 have shown the importance of inital conditions on fog predictions

PLAN

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Meso-NH

mesoscale non-hydrostatic model

Non hydrostatic anelastic mesoscale model, jointly developed by CNRM (Météo-France-CNRS) and Laboratoire d'Aérologie (CNRS-UPS) since the 1990's

Open-source code : *http://mesonh.aero.obs-mip.fr/mesonh/*

Applied to a broad range of scales : from 100km of horizontal resolution to the meter and various topics

Sophisticated physics : turbulence 3D, different microphysical schemes

Used for Research (without operational vocation) : 62 laboratories, 540 publications, 120 PhD

Physics implemented in AROME, the NWP model over France (1.3km resolution) (1-moment microphysical scheme, Turb1D, Shallow convection)

Used increasingly on **large grids**, and **very fine resolution (LES)**

Numerical schemes : eulerian, explicit (3rd and 4th order) : good effective resolution

MESO-NH Physics in LES

- **TURBULENCE** : 1.5 order closure (Cuxart et al.,2000), 3D turbulence : Prognostic TKE, Deardorff (1980) mixing length

- **RADIATION** : LW and (old) SW ECMWF radiative transfer code

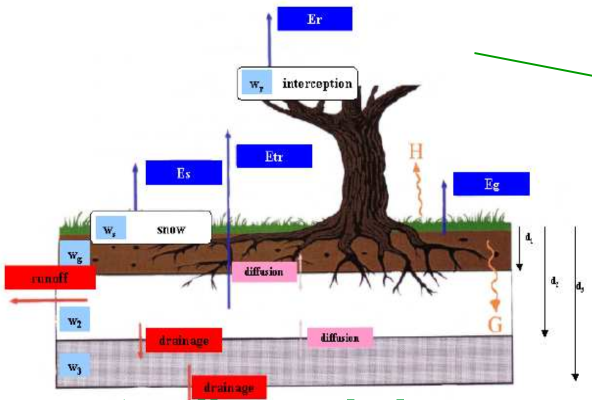
- **MICROPHYSICS** : - 1 moment scheme, with prognostic cloud mass and droplet sedimentation

$$n(D)dD = Ng(D)dD = N\frac{\alpha}{\Gamma(\nu)}\lambda^{\alpha\nu}D^{\alpha\nu-1}\exp\left(-(\lambda D)^{\alpha}\right)dD$$

$\alpha=3$, $\nu=1$ for the droplets

Nc fixed (300 cm^{-3})

- **SURFACE** : SURFEX (Masson et al., 2014)



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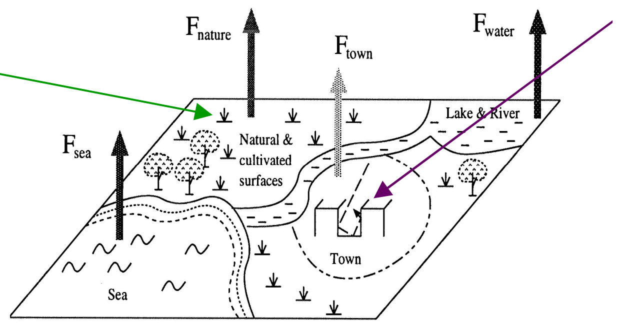
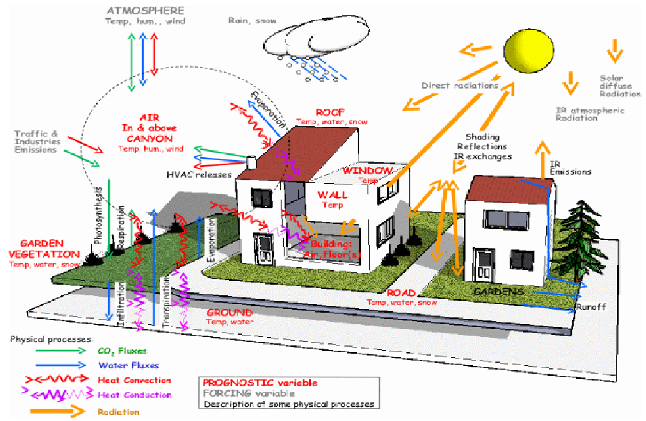
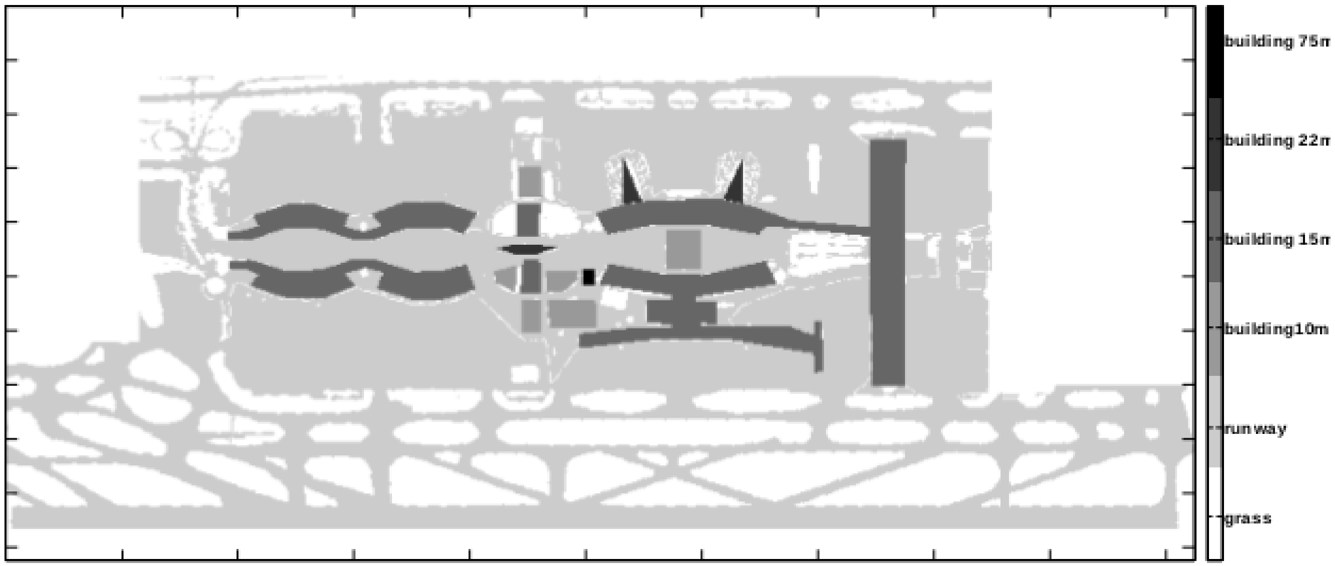




TEB (Town Energy Balance)
Masson (2000)

Effects of small-scale surface heterogeneities on radiation fog : LES at Paris CDG airport

Database from Aéroports de Paris
Surface elements have been built



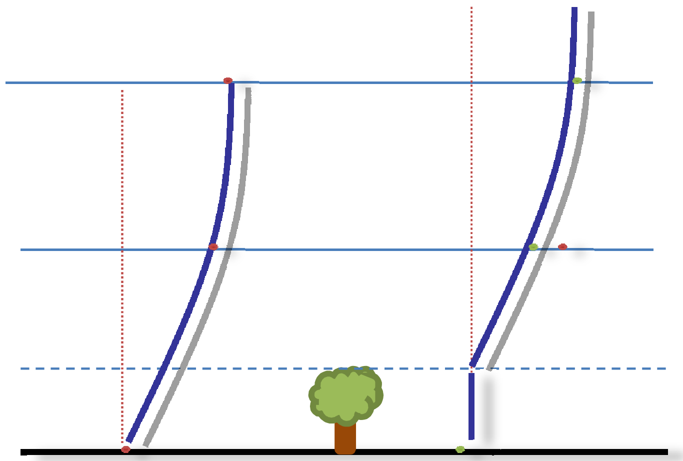
3000×1000
×135
Δx=1.5m
Δz=1m
Flat terrain

Bergot et al., 2014, QJRMS

Small-scale surface heterogeneities : LES at Paris CDG

1. Ground homogeneous and only grass : **REF**

2. Roughness length with TEB : **BLD**

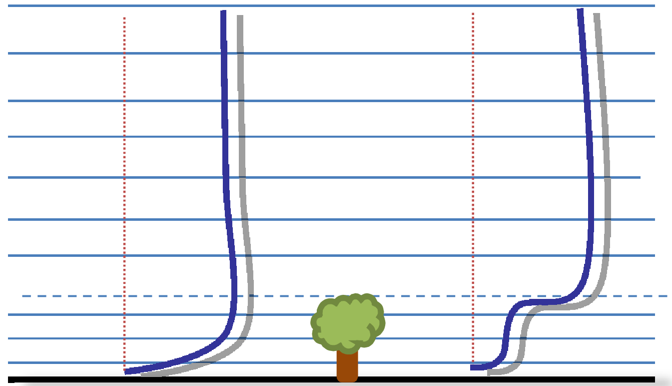


3. Drag force with presence of buildings : **DRAG**
(Aumond et al., 2012, BLM)

$$\frac{\partial U}{\partial t} = F_u - C_d A_f(z) U (U^2 + V^2)^{0,5}$$

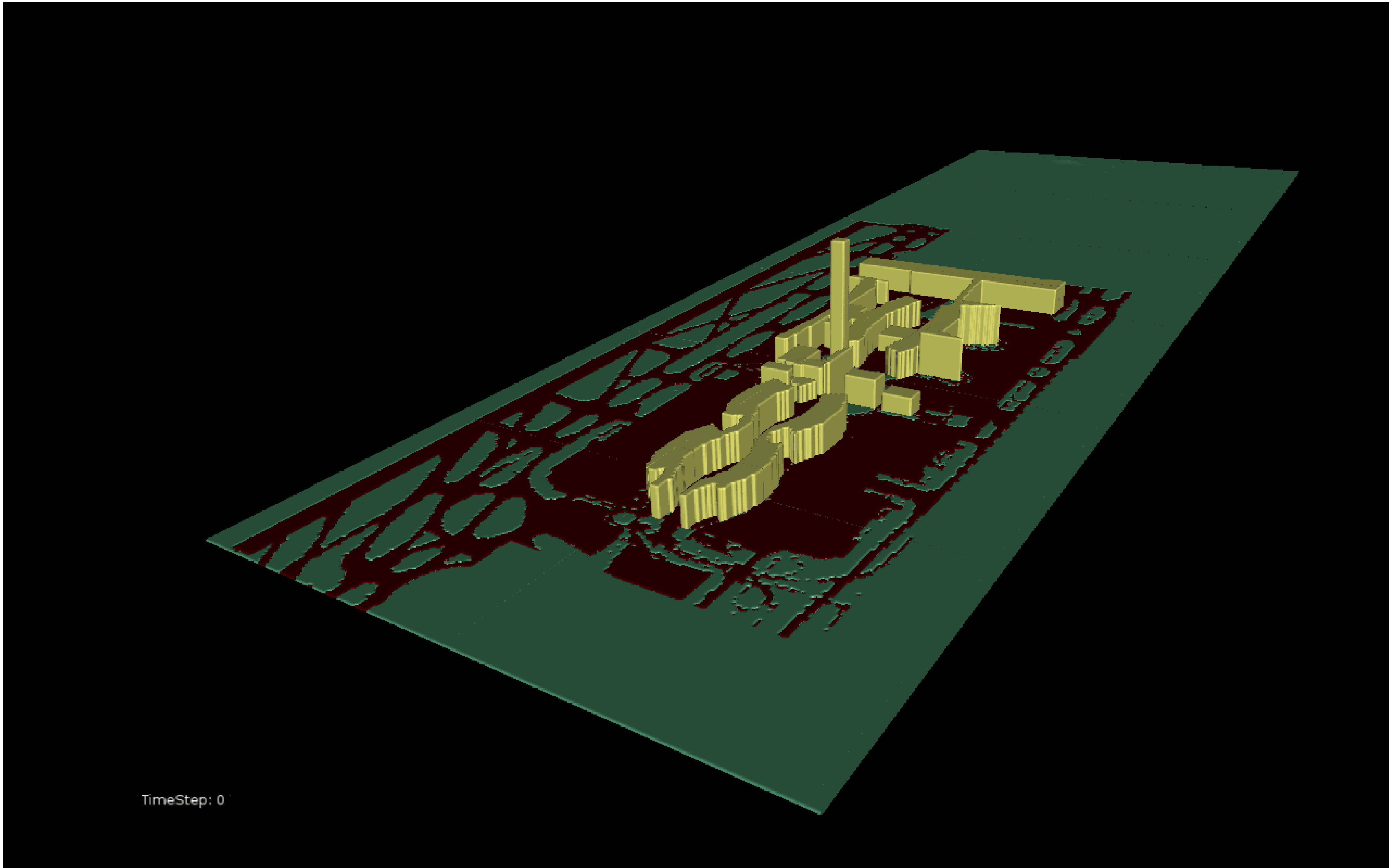
$$\frac{\partial e}{\partial t} = F_e - C_d A_f(z) e$$

A_f= Canopy area density
Building not porous



Becomes necessary at very fine vertical resolution

DRAG simulation : Movie during 1h40min

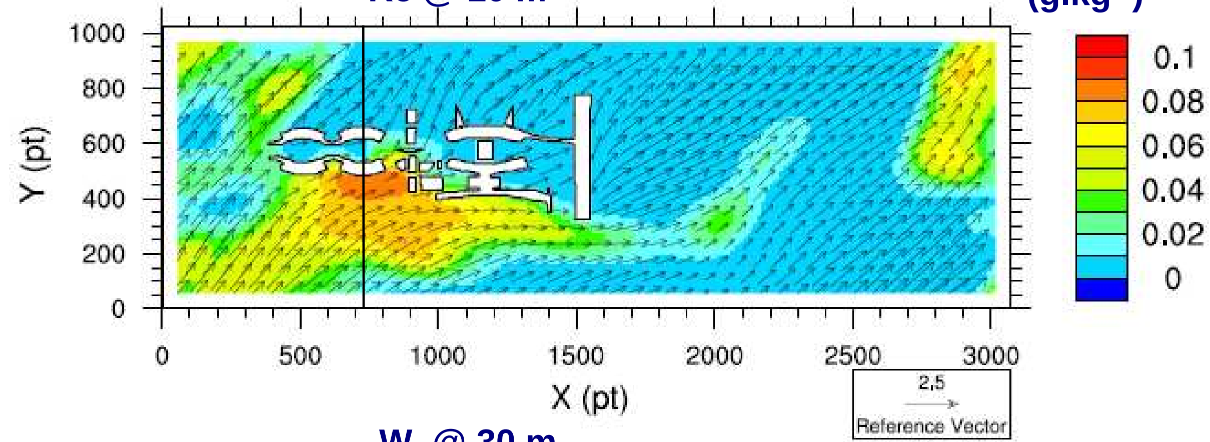


23h15 UTC

Development of the fog

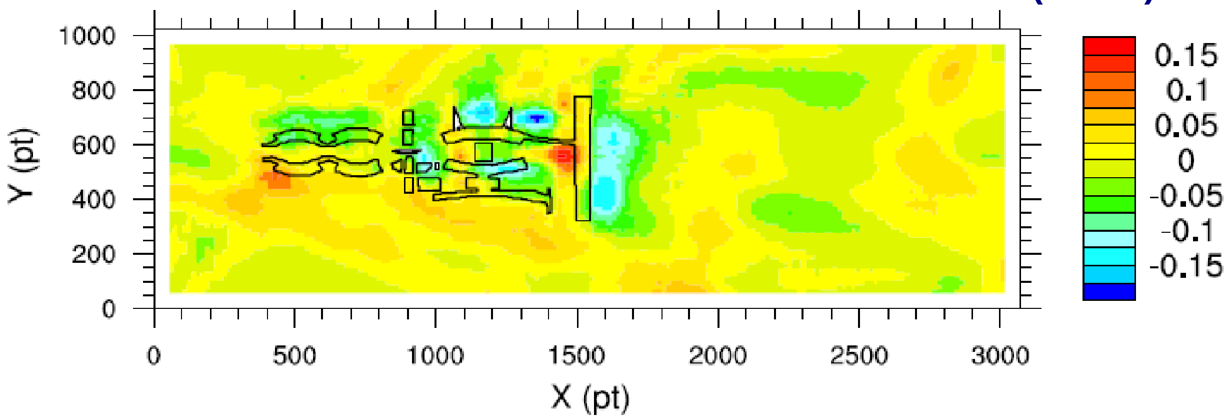
DRAG

Rc @ 10 m



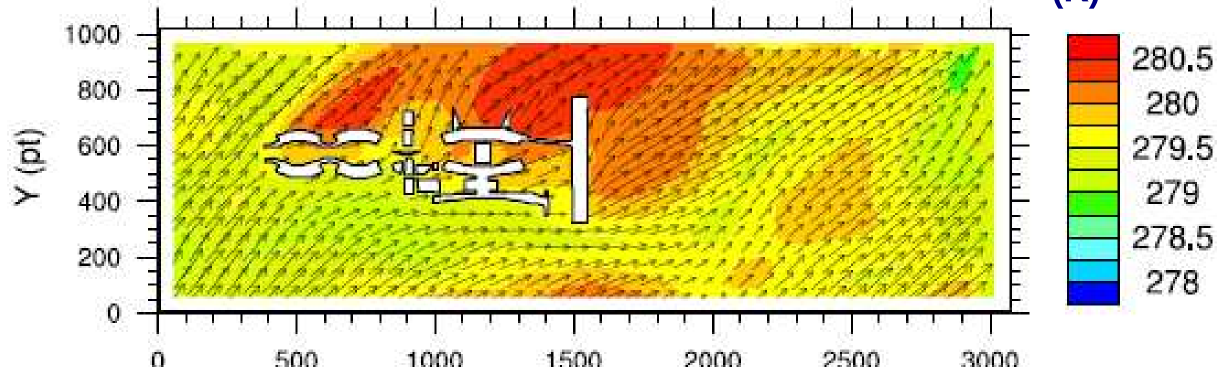
Very heterogeneous fog formation (~1.5 h) : 30 min more than BLD
No fog downstream

W @ 30 m



Ascendance (0.1cm.s^{-1}) upstream and subsidence (-0.1cm.s^{-1}) downstream

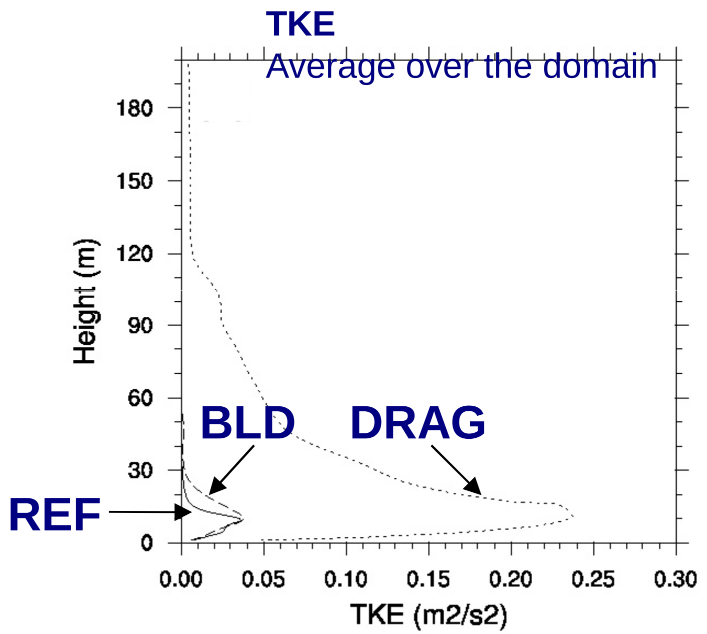
T @ 5 m

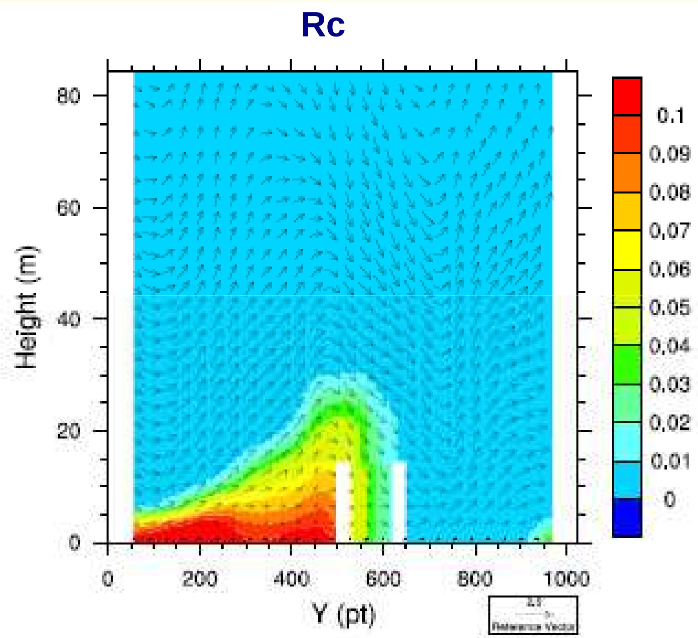


Heating (1K) downstream due to subsidence (adding to anthopogenic heating) delays fog formation

Development of the fog

23h15 UTC





Increased turbulence due to shear reduces the inversion and facilitates the development.
KH instabilities no longer clearly visible during the development.

Mature stage of the fog

Buildings have little impact
Dynamics mainly driven by processes at the fog top

Dissipation stage of the fog (Bergot, 2015, submitted to QJRMS)

No impact of the buildings on the range of dissipation time, but only on horizontal structures at fine scale

Perspectives

- ✓ R&D on modelling fog with AROME and MESO-NH will continue
- ✓ Preparation of future AROME configurations: horizontal and vertical resolutions, physics, etc.
- ✓ Investigate ways to have a finer vertical resolution in the physics, in priority near the ground in a similar way than CANOPY
- ✓ Try to improve initialization of cloud droplet concentration with real time information (CAMS, MOCAGE, ??)
- ✓ Research studies: 2-moments mixed-phase microphysical scheme (Vié et al., submitted du GMD) , aerosols, LES with MESO-NH of radiation fog for process study (Dx~1m, Dz~1m)


Thank you
for
your attention