WP3 : 3D Large Eddy Simulations (LES) and impact of heterogeneities

Leader : C. Lac (CNRM)

Photo F. Burnet

Task 3.1 : LES and validation (T0+24 - T0+36)

- Run of the most documented cases with **Meso-NH model** from **AROME analysis** with **grid-nesting** downscaling up to 5m resolution → **Post-Doc 12 months**

Tests of the recent advances in parametrizations :

- **SURFEX** (Masson et al., 2013) ISBA-Diff – ISBA-MEB (Boone et al., 2017) vegetation scheme – HR surface data base

- Radiation : **ecRad** (Hogan and Bozzo, 2016) with 14 SW bands and improved radiative optical properties (Jahangir et al.)

- Microphysics : **LIMA** 2-moment scheme (Vié et al., 2016)

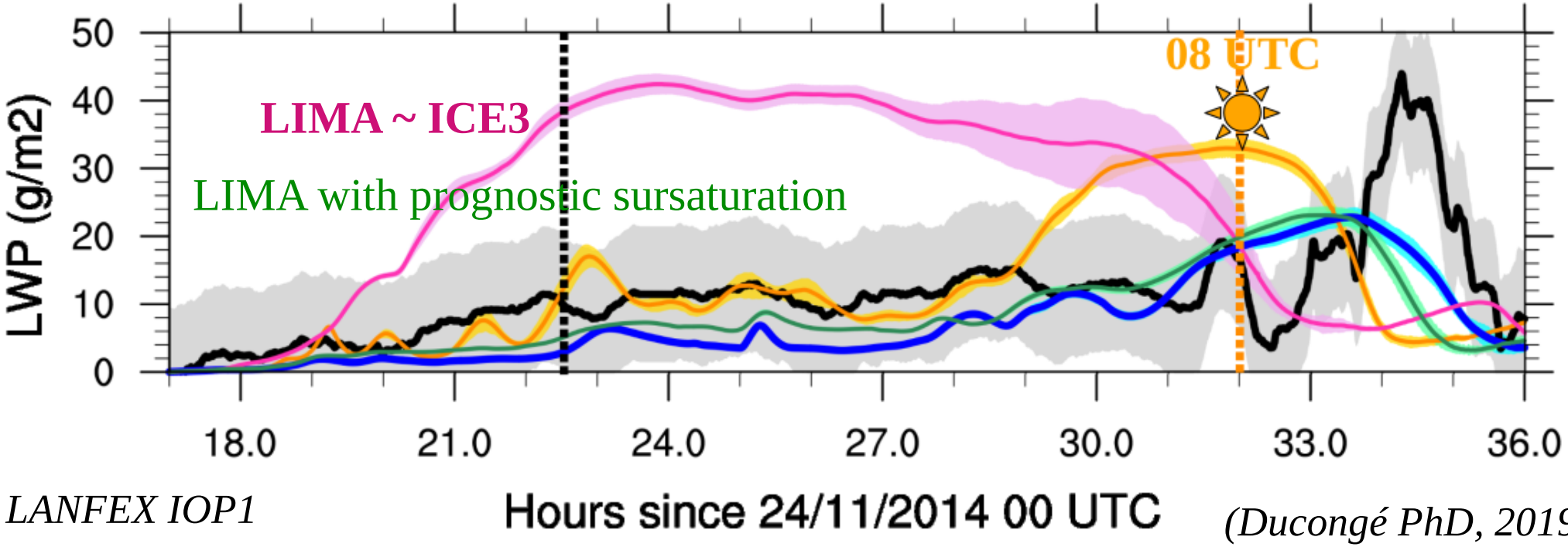
  Initialization of aerosols from OPC and SMPS

Recent improvement of the activation process in LIMA

$$\frac{dS}{dt} = \psi_1 w - \psi_2 \frac{dr_c}{dt} + \psi_3 \frac{d\theta}{dt} = 0 \longrightarrow \mathbf{S_{max}} \longrightarrow \mathbf{N_{CCN,\ activés}}$$

$$\frac{dS}{dt} = \psi_1 w - \psi_2 \boxed{\frac{dr_c}{dt}} + \psi_3 \boxed{\left.\frac{d\theta}{dt}\right|_{RAD}}$$

: corrections proposed by Thouron et al. (2012)



LANFEX IOP1

(Ducongé PhD, 2019)

Task 3.2 : Impact of heterogeneities (T0+30 - T0+42)

- To better understand how surface heterogeneities interact with turbulence :

  - Are the heterogeneities in the fog life cycle between the sites a consequence of vegetation heterogeneities ? LES and observations

  - What is the impact on TKE budget ? anisotropy of turbulence ? Surface energy budget ?

  - Use Meso-NH-SURFEX as a laboratory : impact of modification of vegetation characteristics on the fog life cycle

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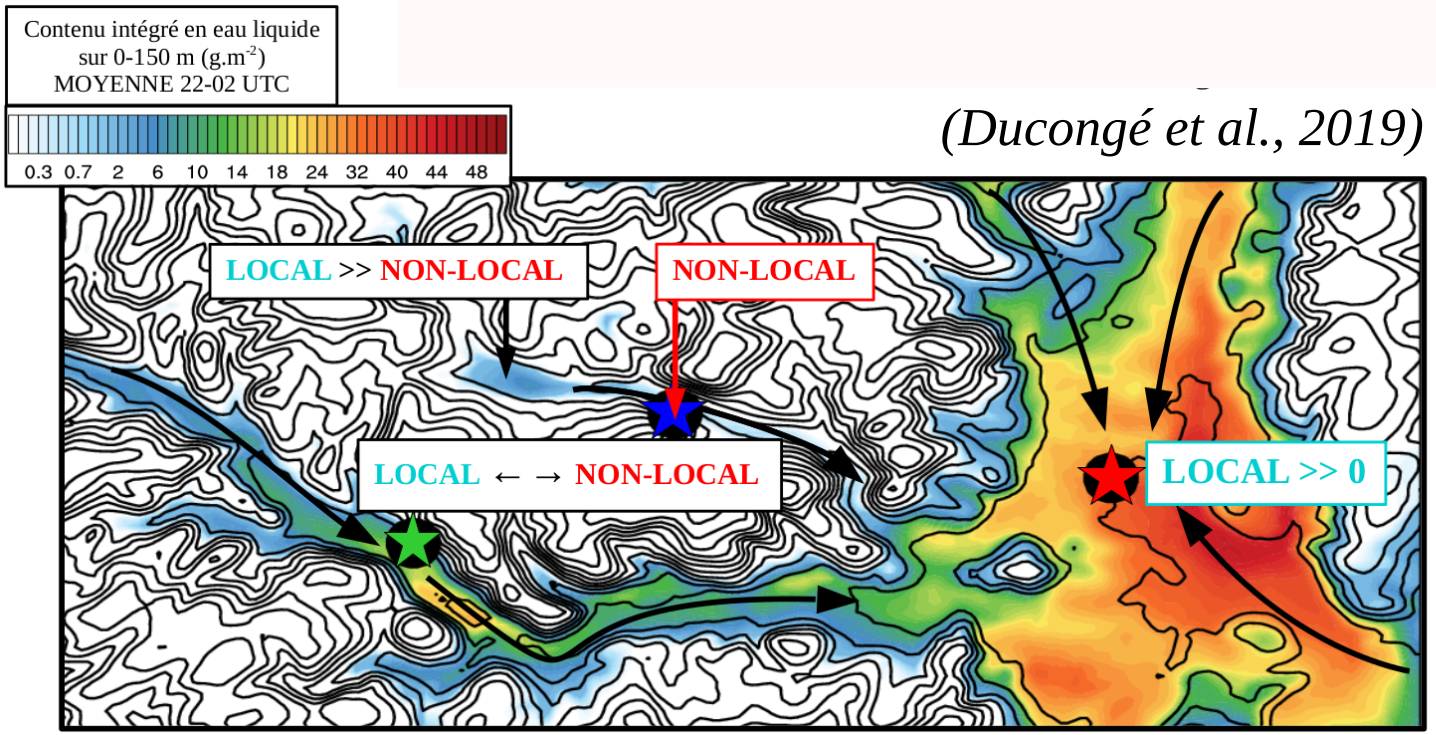
Task 3.3 : Impact of orography and advective processes (T0+30 - T0+42)

- Local circulations studied with scanning Doppler wind lidar, Doppler wind lidar profiler (Sabatier et al., 2018), scanning 95GHz Doppler radar.

- LES to quantify local and non-local contributions to the cloud mixing ratio budget



(Ducongé et al., 2019)

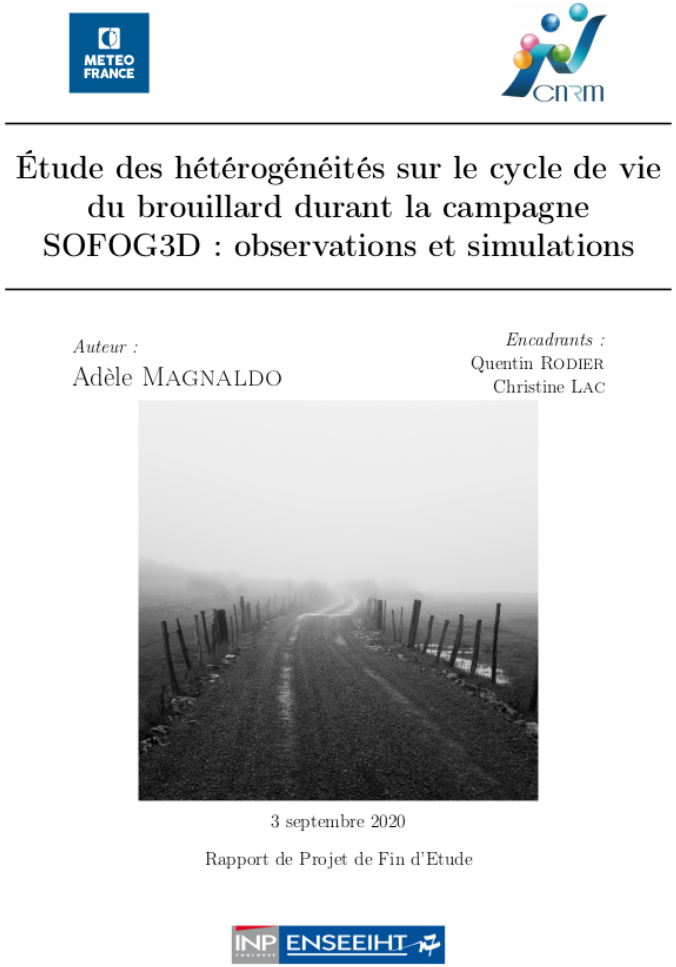
Towards Large-Eddy Simulations of surface heterogeneities impact on fog with Meso-NH

Quentin Rodier, Marie-Adèle Magnaldo, Christine Lac

SOFOG3D data & science meeting
9 november 2020

First results for T 3.1 and 3.2 :

- Work from Marie-Adèle Magnaldo
  (March → August 2020 master's thesis), CNRM



Étude des hétérogénéités sur le cycle de vie du brouillard durant la campagne SOFOG3D : observations et simulations

Auteur : Adèle MAGNALDO

Encadrants : Quentin RODIER, Christine LAC

3 septembre 2020

Rapport de Projet de Fin d'Etude

INP ENSEEIHT

Objectives

- Identify the IOPs with heterogeneities of the fog life cycle between the sites
- Statistical evaluation of the heterogeneities during the campaign → Select one IOP representative of the statistics with numerous measurements
- Configure Meso-NH with refining resolution and run a reference simulation
- Are the heterogeneities reproduced at 100m ?
- Outlook

Outline

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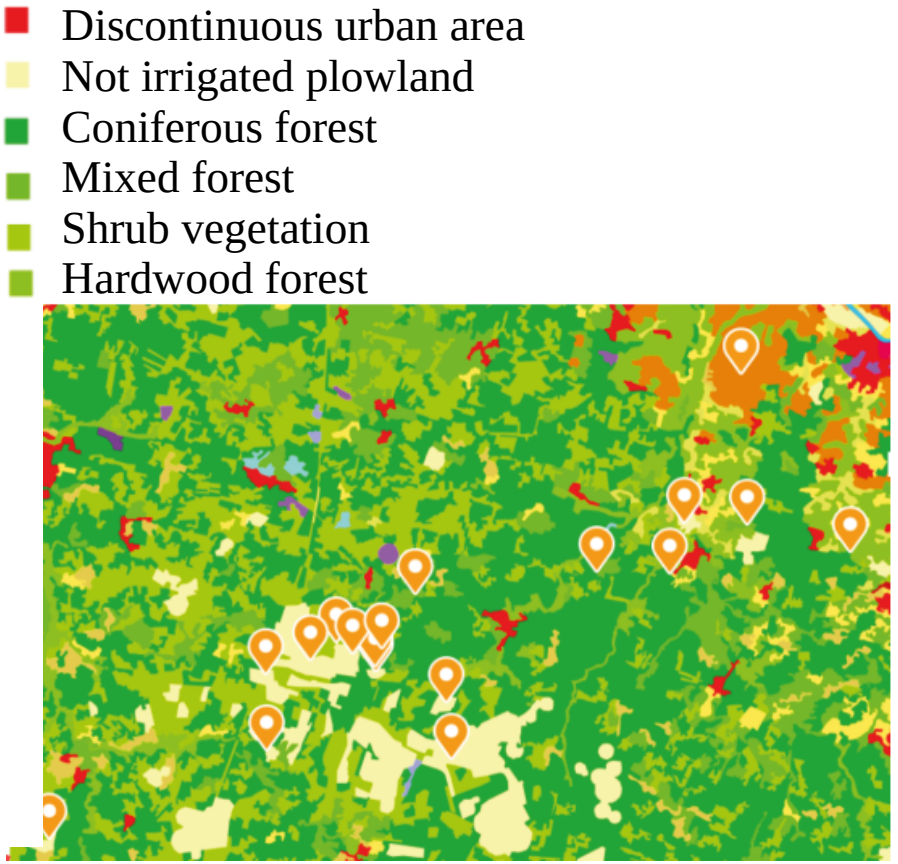
IOPs with heterogeneities

- 15 IOPs
- 3 observed deep fog (height > 200m) : IOP6 (5-6 Jan.), IOP11 (8-9 Feb.), IOP14 (7-8 Mar.)
- Focus on **4** ground stations



(ref : Geoportail.gouv.fr)

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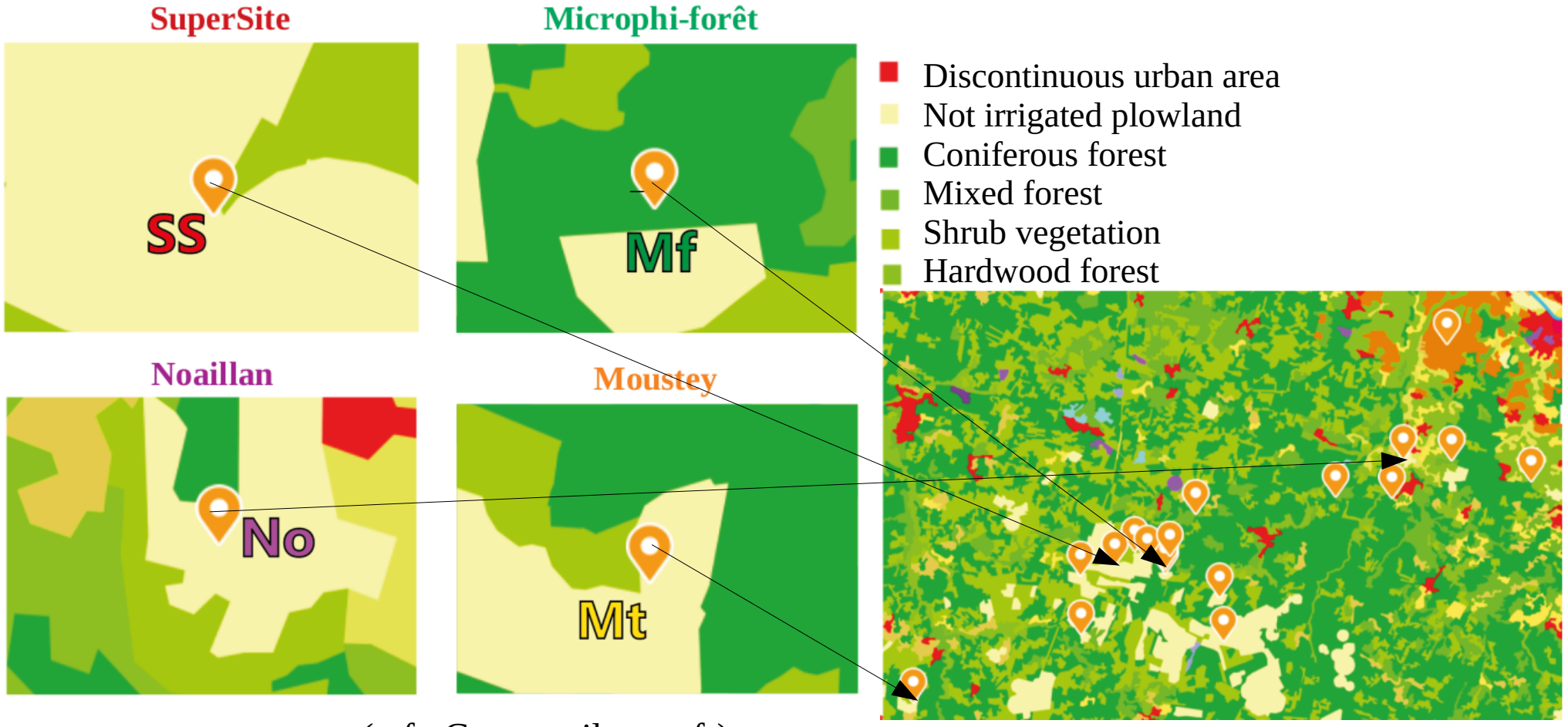

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IOPs with heterogeneities

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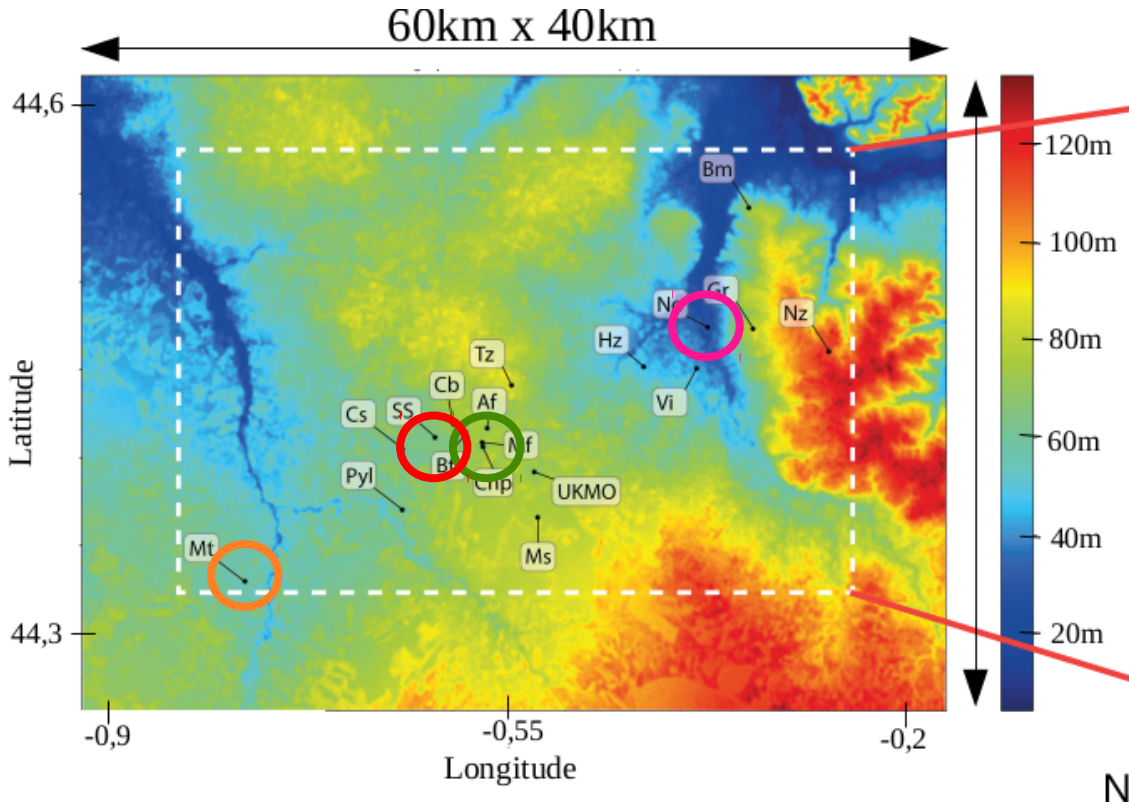
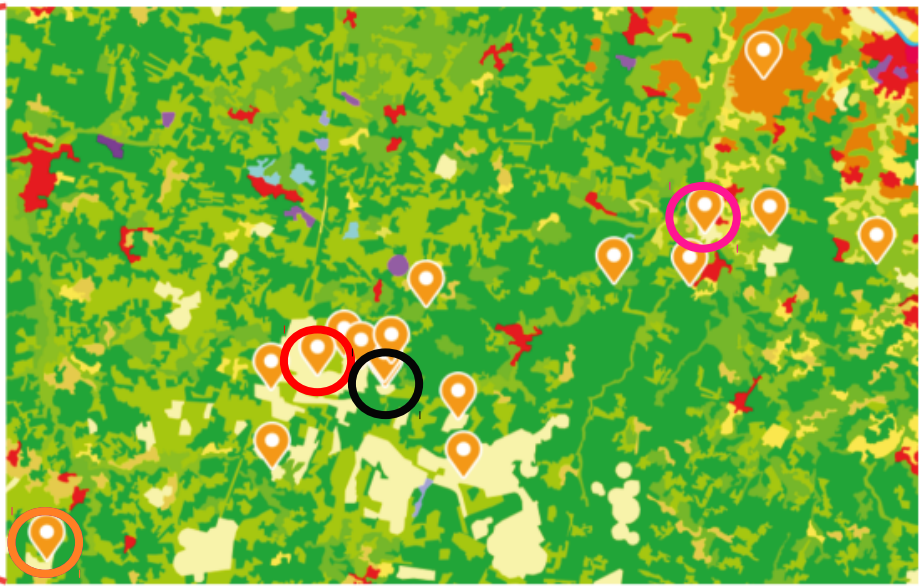


Orography from 90m resolution SRTM



Nature des sols des différents sites instrumentés

Land cover

- SuperSite and Microphi-foret very close
- Noaillan down to a small river valley

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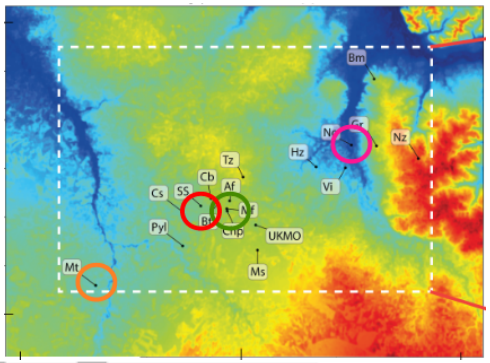
Selection of an interesting case

- POI 6 : 5-6 Jan.



Visibility (m)

10^4

10^3

10^2

formation
3h shift

dissipation

SuperSite (2m)
Microphi-foret (10m)
Noaillan (2m)
Moustey (2m)

21:00:00 00:00:00 03:00:00 06:00:00 09:00:00 12:00:00 15:00:00 18:00:00 21:00:00

UTC time

Fog lifetime : **Noaillan** < **Microphi-foret** ~ **SuperSite** < **Moustey**
Mean visibility (< 1km) : **Noaillan** > **Microphi-foret** ~ **SuperSite** ~ **Moustey**

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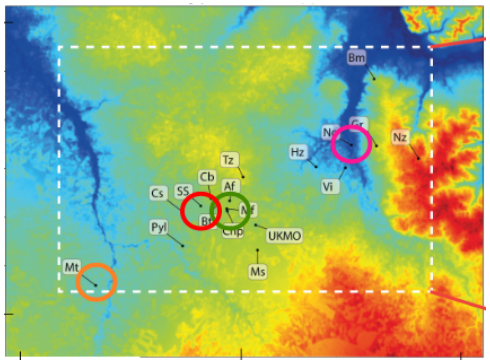
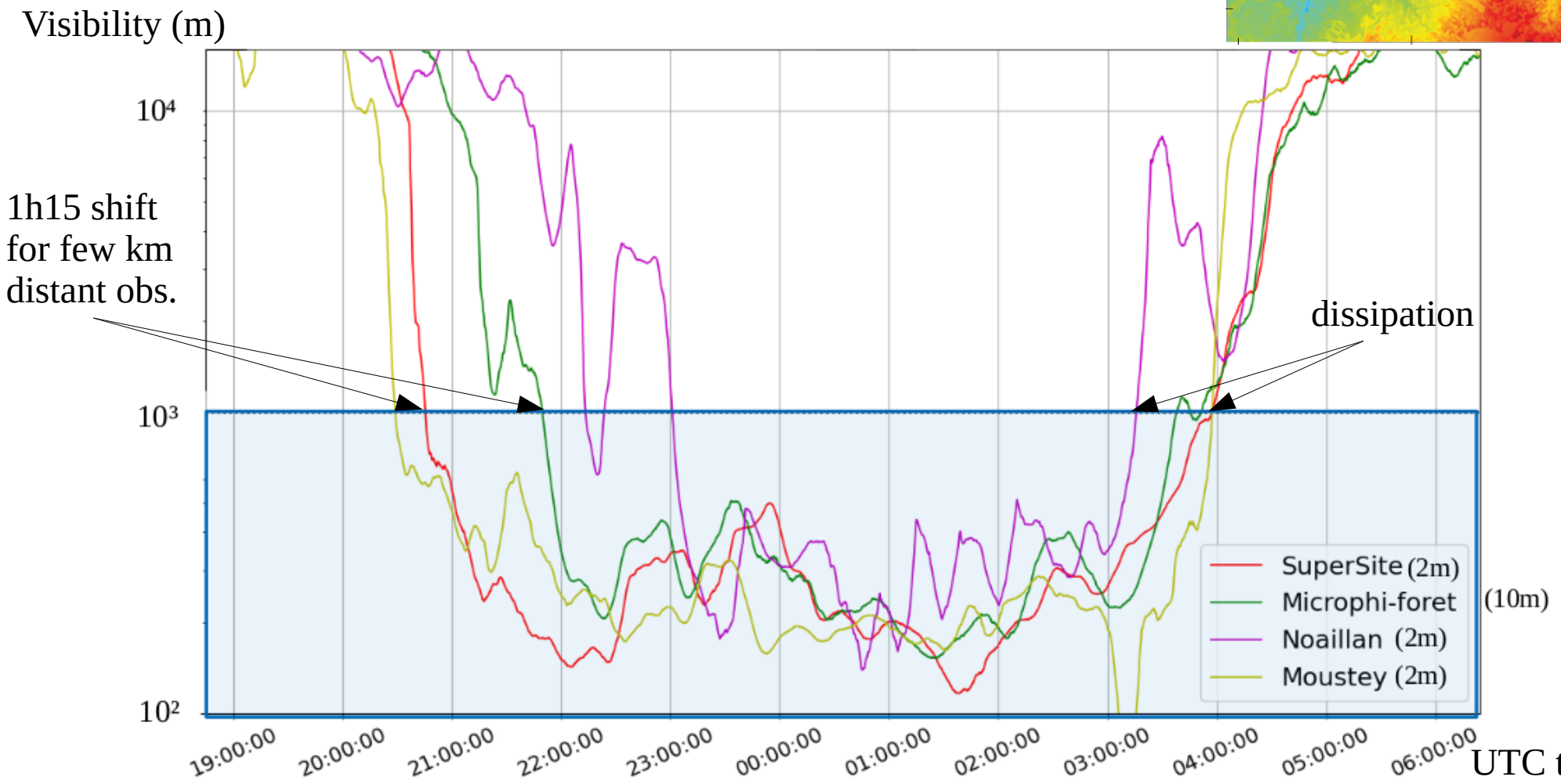
Selection of an interesting case

- POI 11 : 8-9 Feb.





Fog lifetime : **Noaillan** < **Microphi-foret** < **SuperSite** < **Moustey**
Mean visibility (< 1km) : **Noaillan** > **Microphi-foret** ~ **SuperSite** ~ **Moustey**

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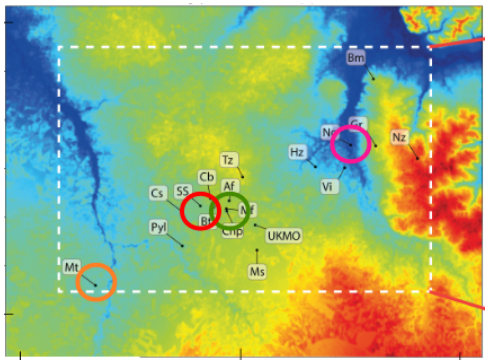
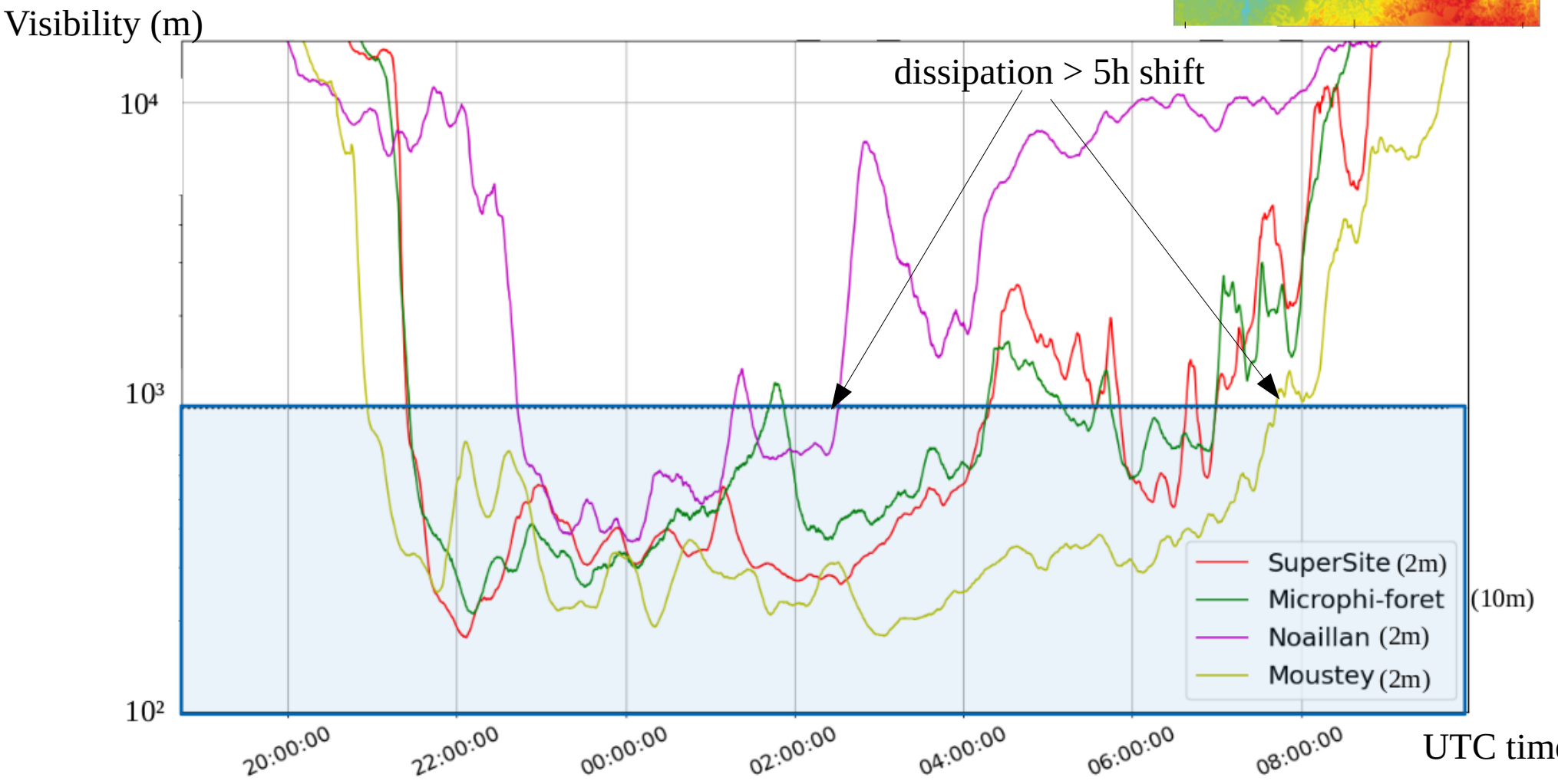
Selection of an interesting case



- POI 14 : 7-8 March



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Mean visibility (< 1km) : **Noaillan** > **Microphi-foret** ~ **SuperSite** > **Moustey**

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Outline

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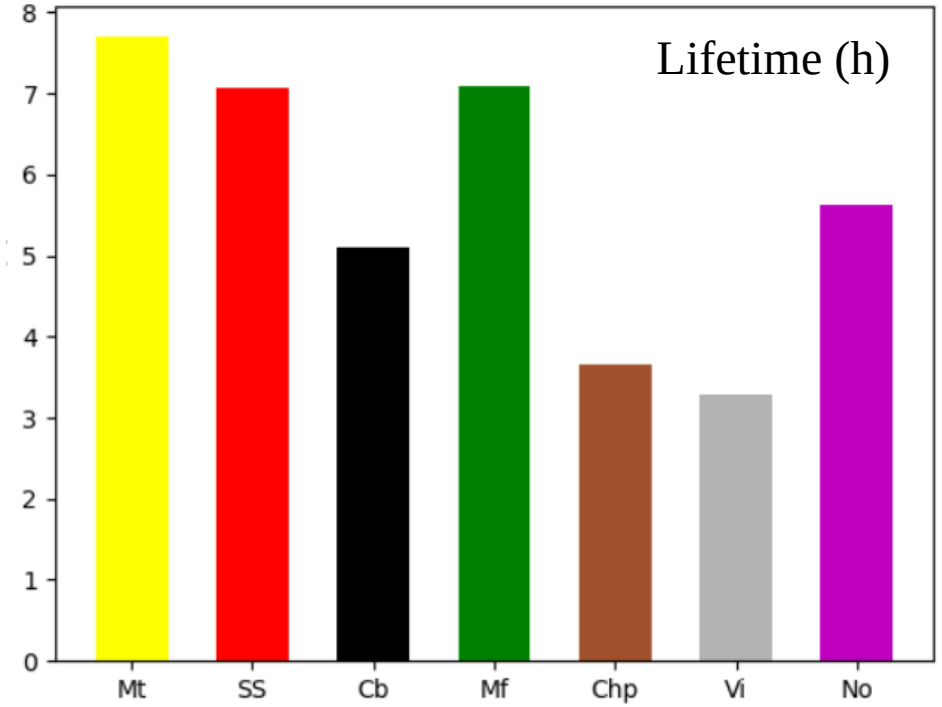
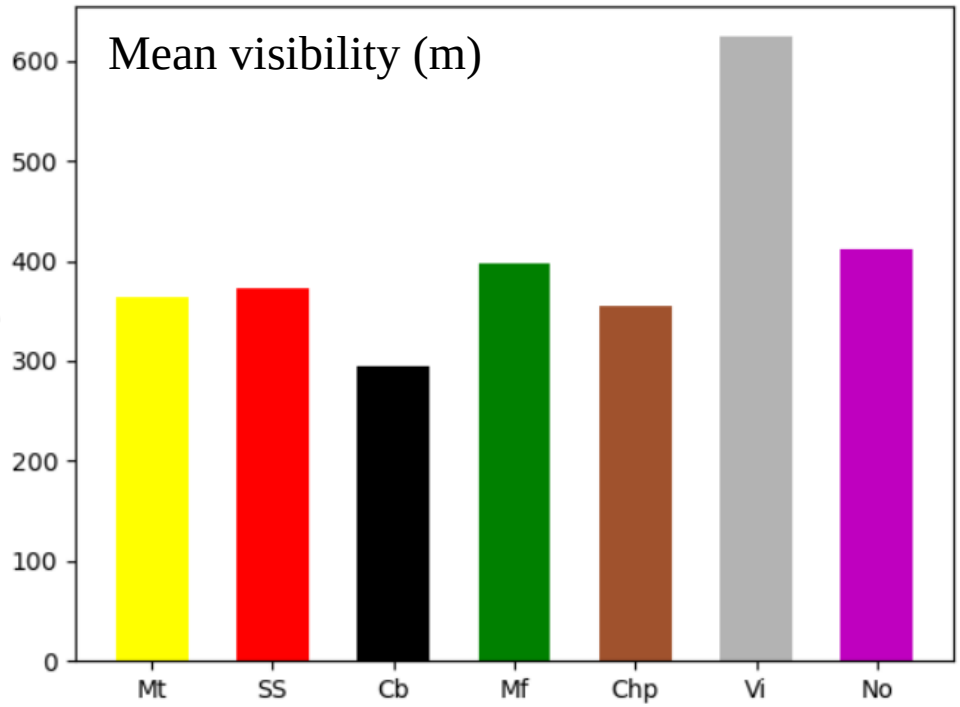
Selection of an interesting case

- Statistical metrics for the longest fogs (> 3h without intermittency)
  ⇒ 6 events





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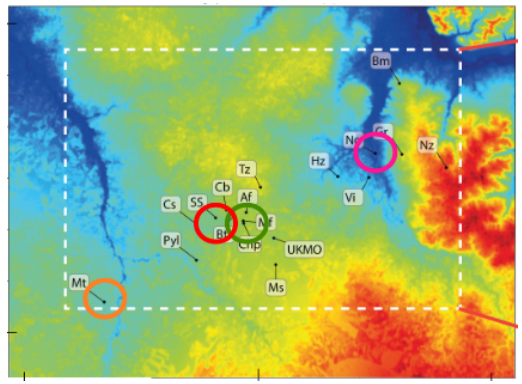

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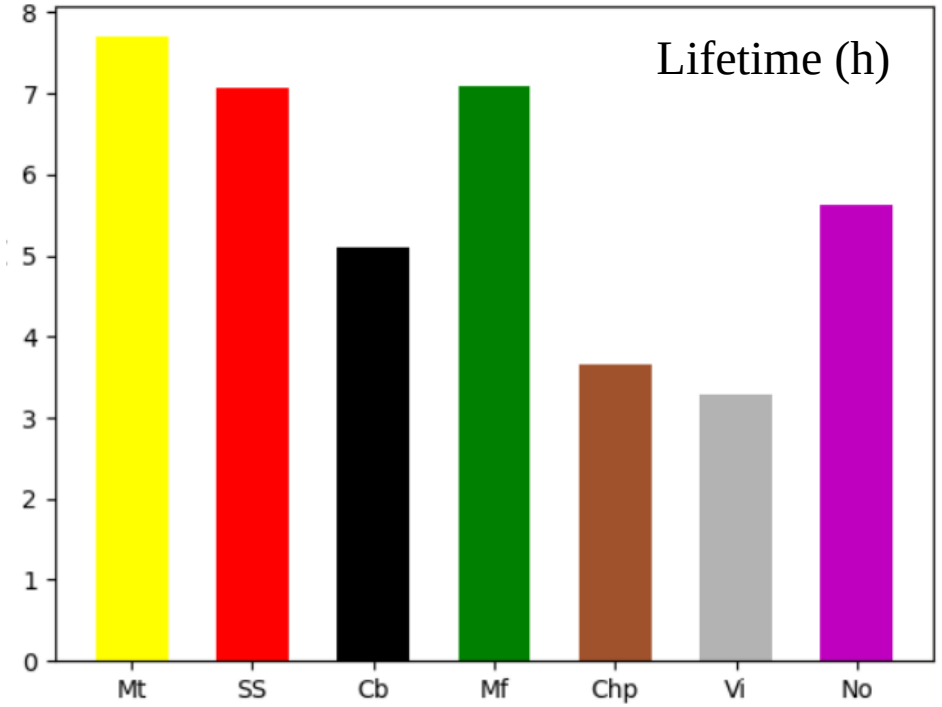

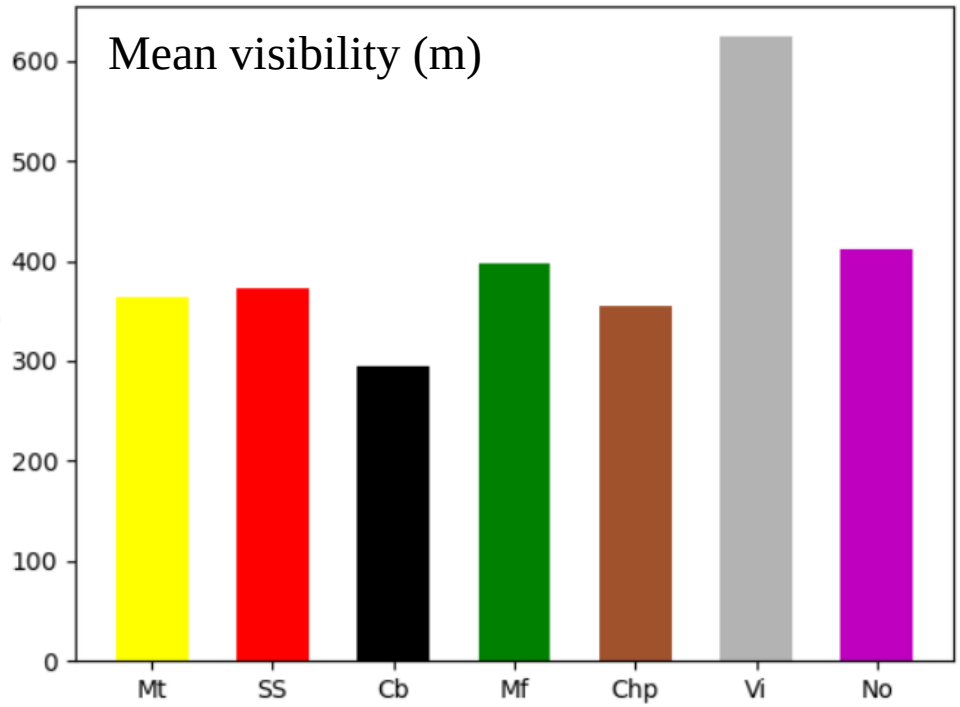

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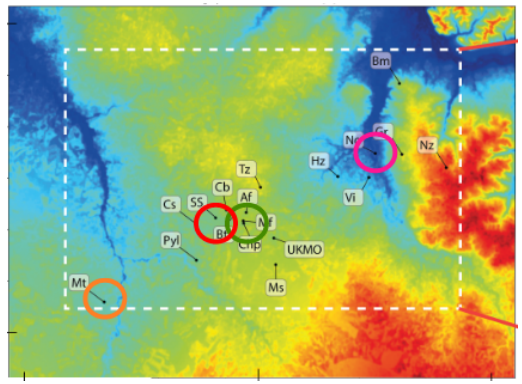

- The 3 selected IOPs are in agreement with the statistics
- **IOP14** presents strong heterogeneities and numerous available observations (UAV, tethered balloon with turbulence ...)

Outline

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  - Méso-NH 500m *vs* AROME 500m

  - Méso-NH 100m
- Are the heterogeneities reproduced at 100m ?
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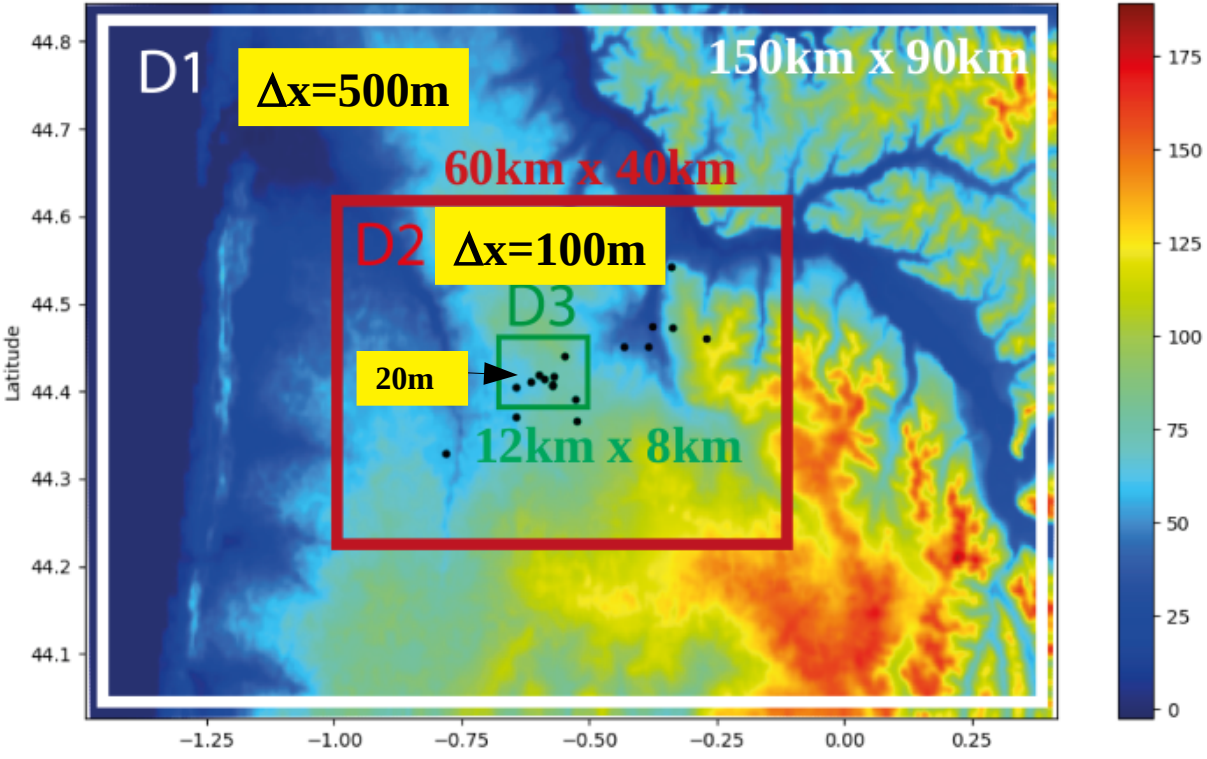
Fine scale Simulations of POI 14

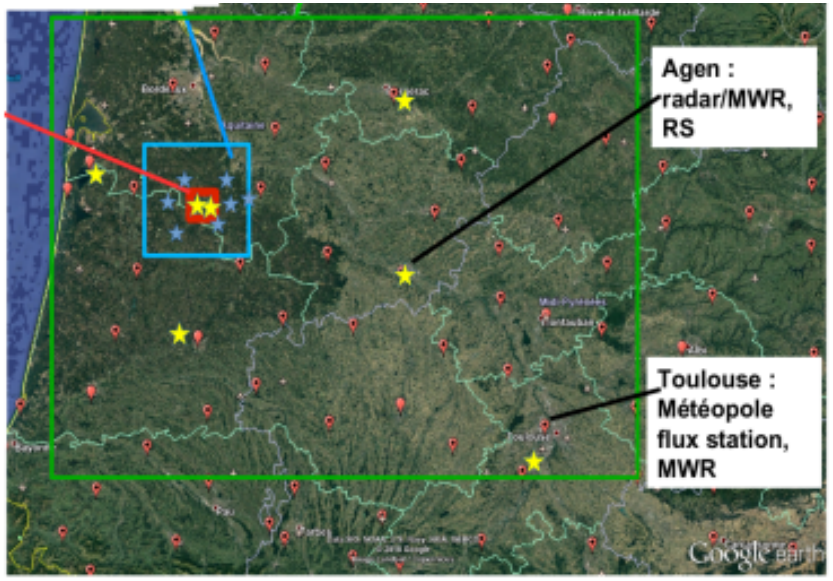
- Downscaling approach towards the LES of stable boundary layer which needs metric resolution
- 3 Méso-NH simulations

- D1 : 500m hor. Resolution ~ AROME-SOFOG
- D2 : 100m
- D2-D3 : two-way grid-nesting 100m + 20m



Orography (m)

AROME domain



Meso-NH configuration

- Surface : fully coupled with SURFEX (Masson et al. 2013) : ISBA-3L, TEB

- Microphysics : one-moment ICE3

  (prognostic mixing ratios + fixed droplets concentration = 300cm^{-3})

- Turbulence (Cuxart et al. 2000) : TKE + mixing length

  1D for MESONH-500 with BL89

  3D for MESONH100 and MESONH100-20 with Deardorff

- Radiation : ECMWF with RRTM for LW and Fouquart-Bonnel for SW

- Vertical resolution is 2,3m at the ground (138 levels)

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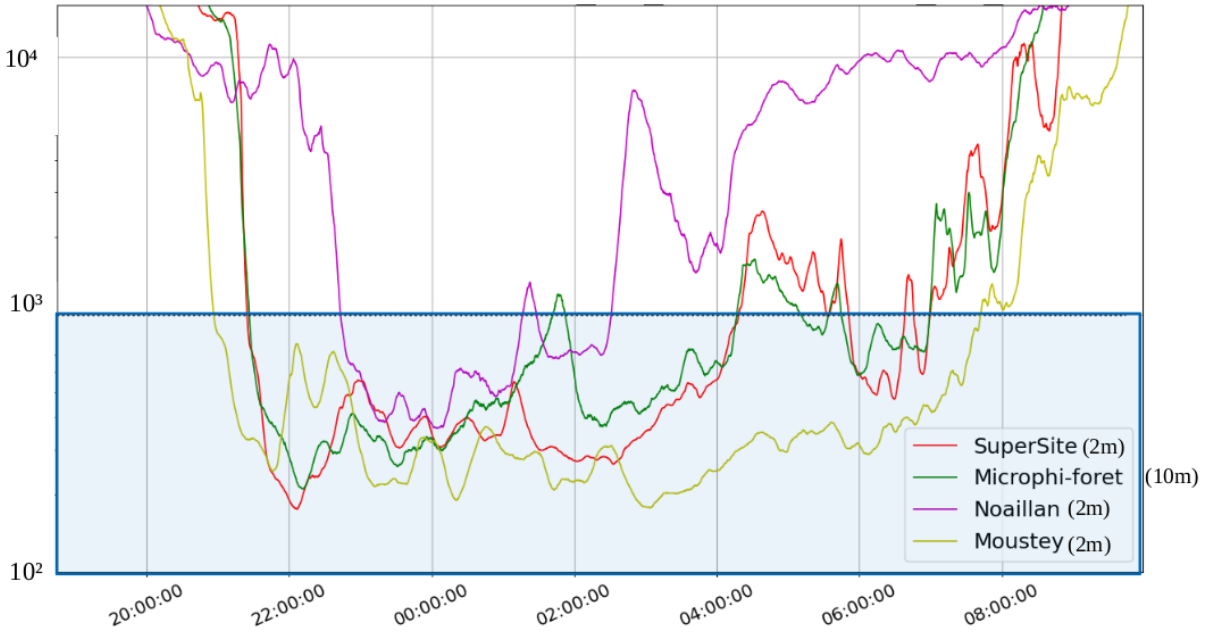
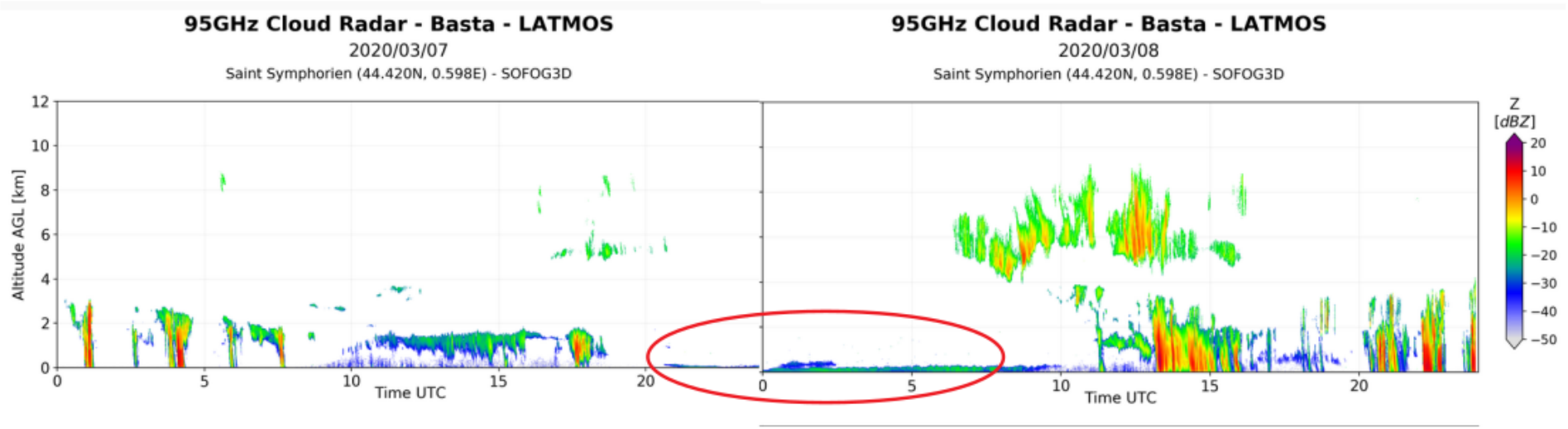
Observations at the SuperSite



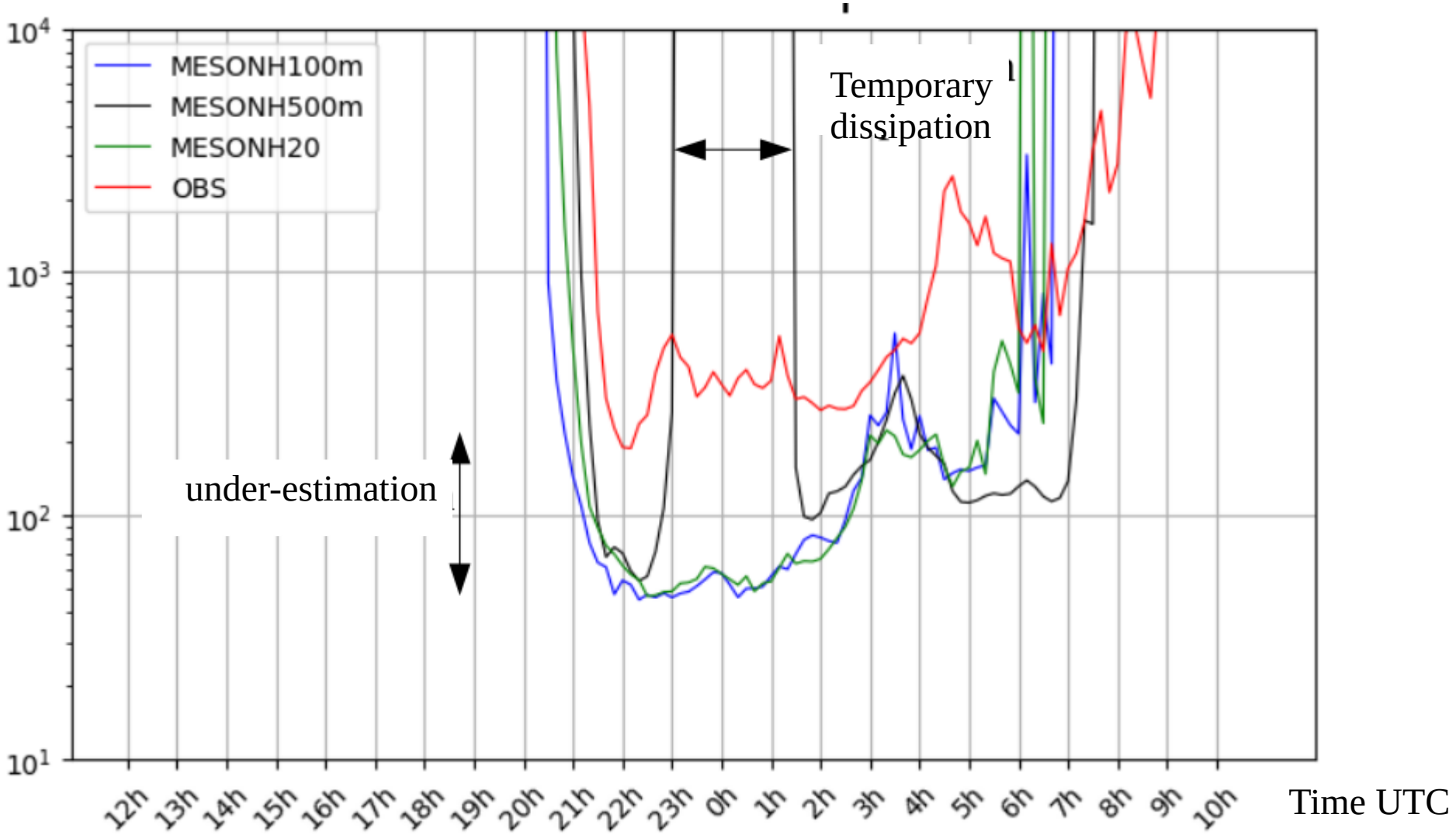
- Beginning of the fog = **21h30**
- End of the fog = **7h**

- Radar : **no cloud above** the fog



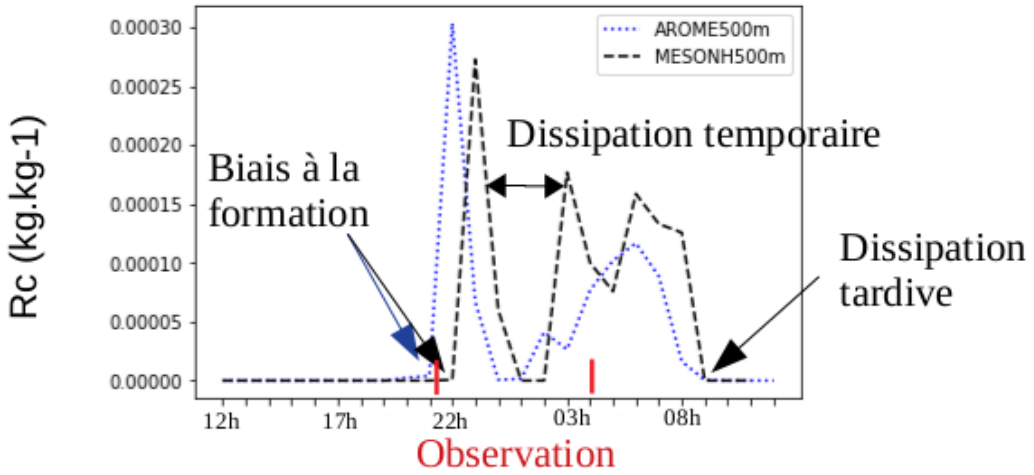
Horizontal resolution sensitivity of MNH at Supersite

Visibility (m) from Kunkel



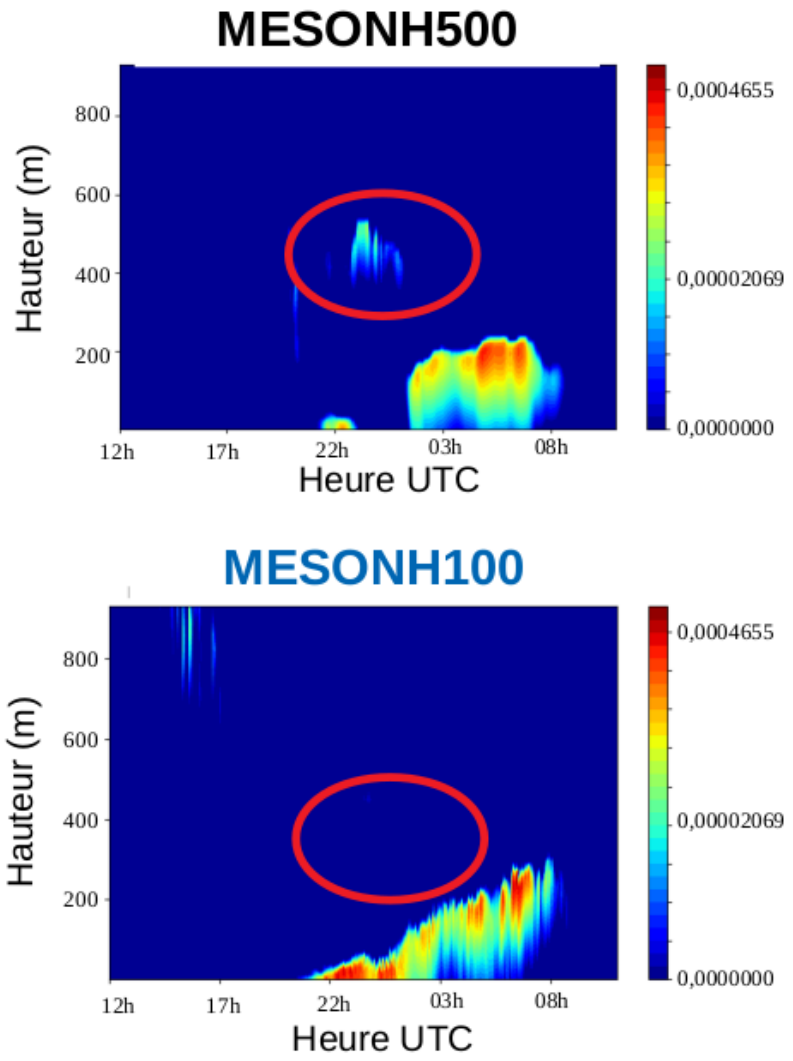
- The visibility is under-estimated (Kunkel formula)
- MESONH-500 shows a temporary dissipation

MESONH500 vs AROME500 vs SuperSite



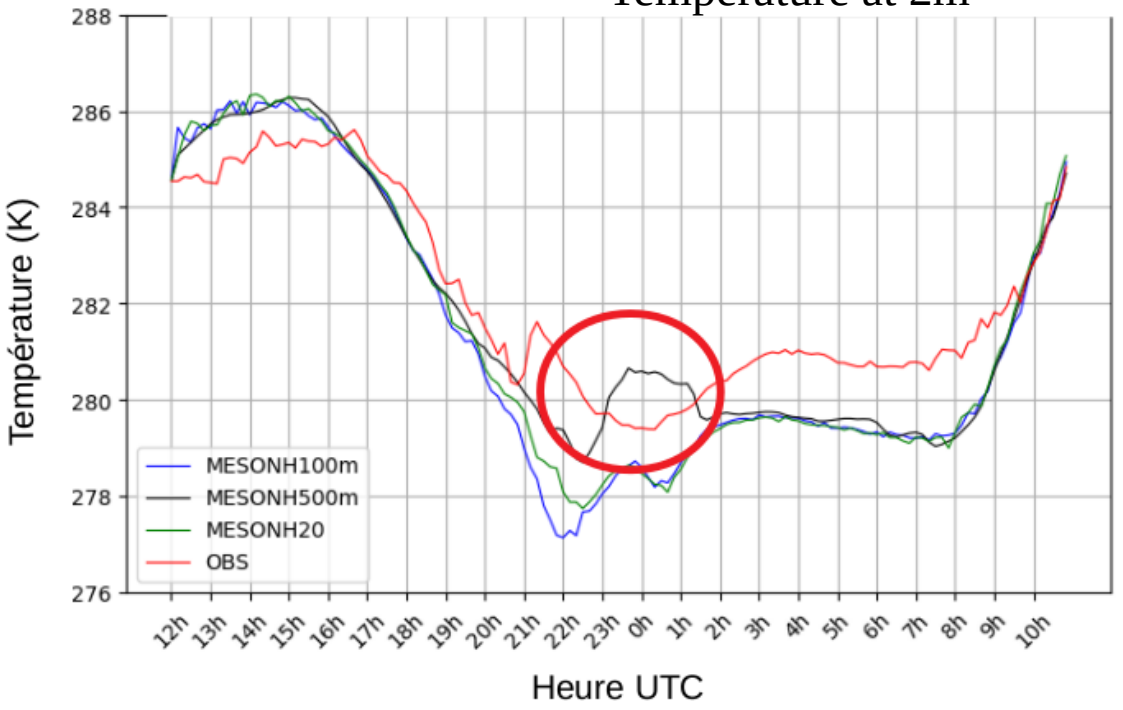
- The temporary dissipation also exists in AROME 500.

MESONH500 vs AROME500 vs SuperSite



Cloud mixing ratio (kg/kg)

Temperature at 2m



- The temporary dissipation can be explained by clouds formed above the fog at 500m but not at 100m
- These clouds do not exist (radar)
- A resolution of 100m is necessary

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  - Méso-NH 500m *vs* AROME 500m

  - Méso-NH 100m
- **Are the heterogeneities reproduced at 100m ?**
- Outlook

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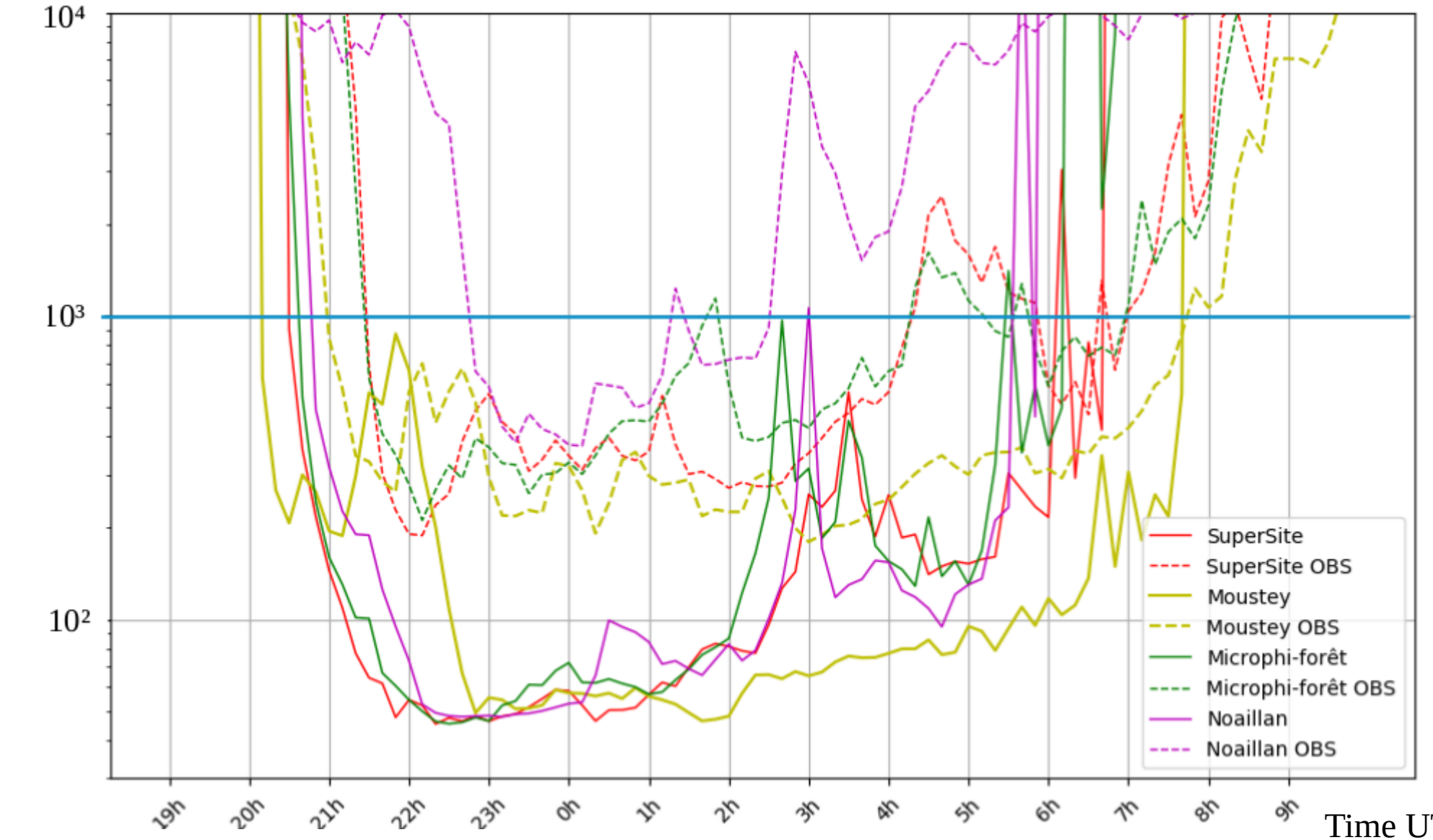
Visibility at 100m *vs* OBS at 2m for POI14

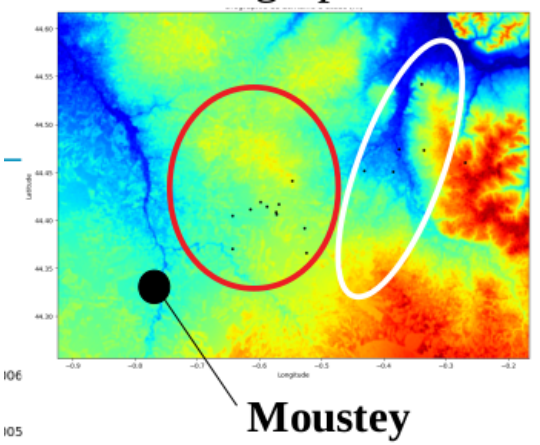


Time UTC

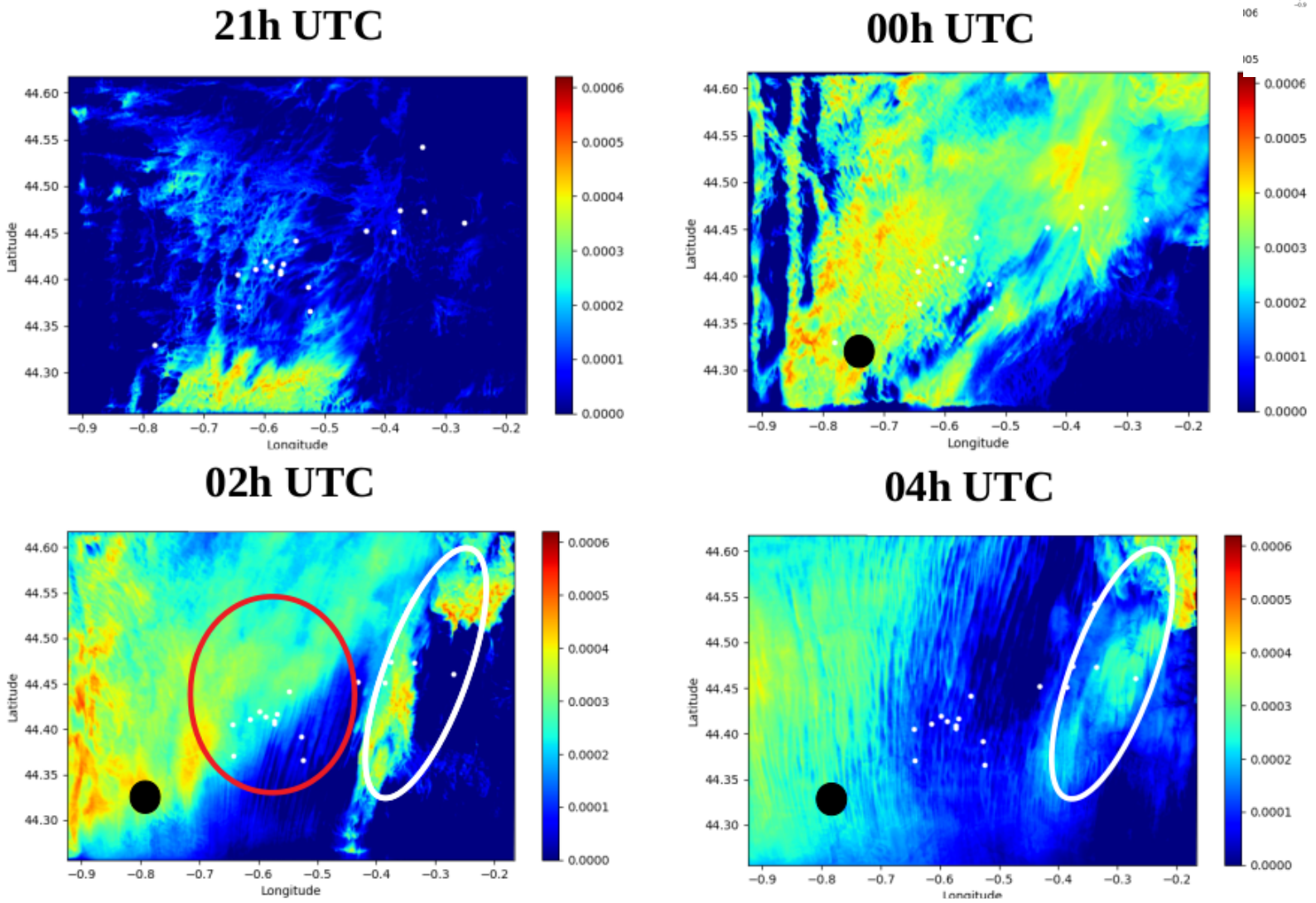
Visibility (m)

Satisfying variability but underestimation of the visibility (⇒ Kunkel formula, 1-moment)

Impact of orography



Cloud mixing ratio at 2m (kg/kg)

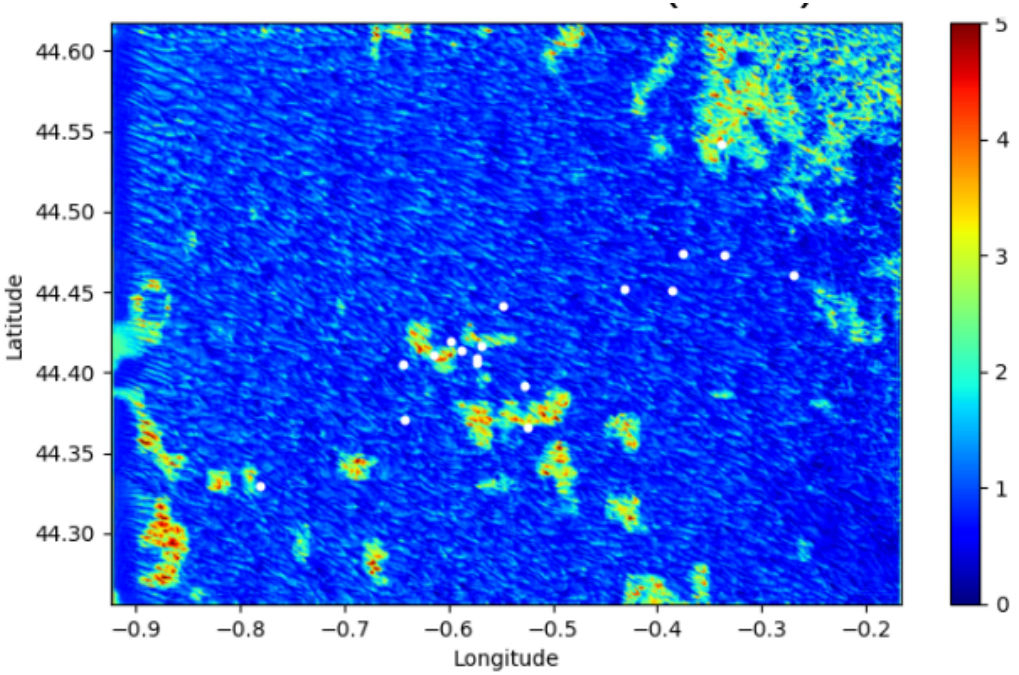


The orography can explain the longer duration and the lower visibility at Moustey (river valley) compared to the Supersite

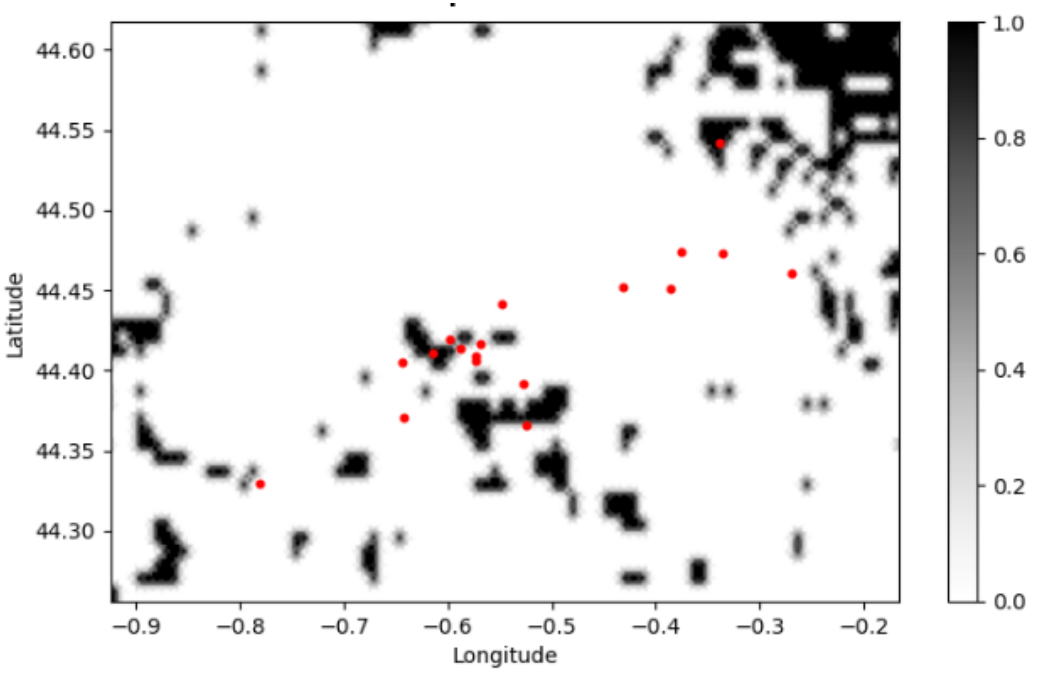
Impact of land cover on wind speed

Database used : Ecoclimap II (1 km global resolution)

Wind speed at z=2m



Agricultural fields + shrubs fractions



⇒ The wind speed increases where rugosity drops

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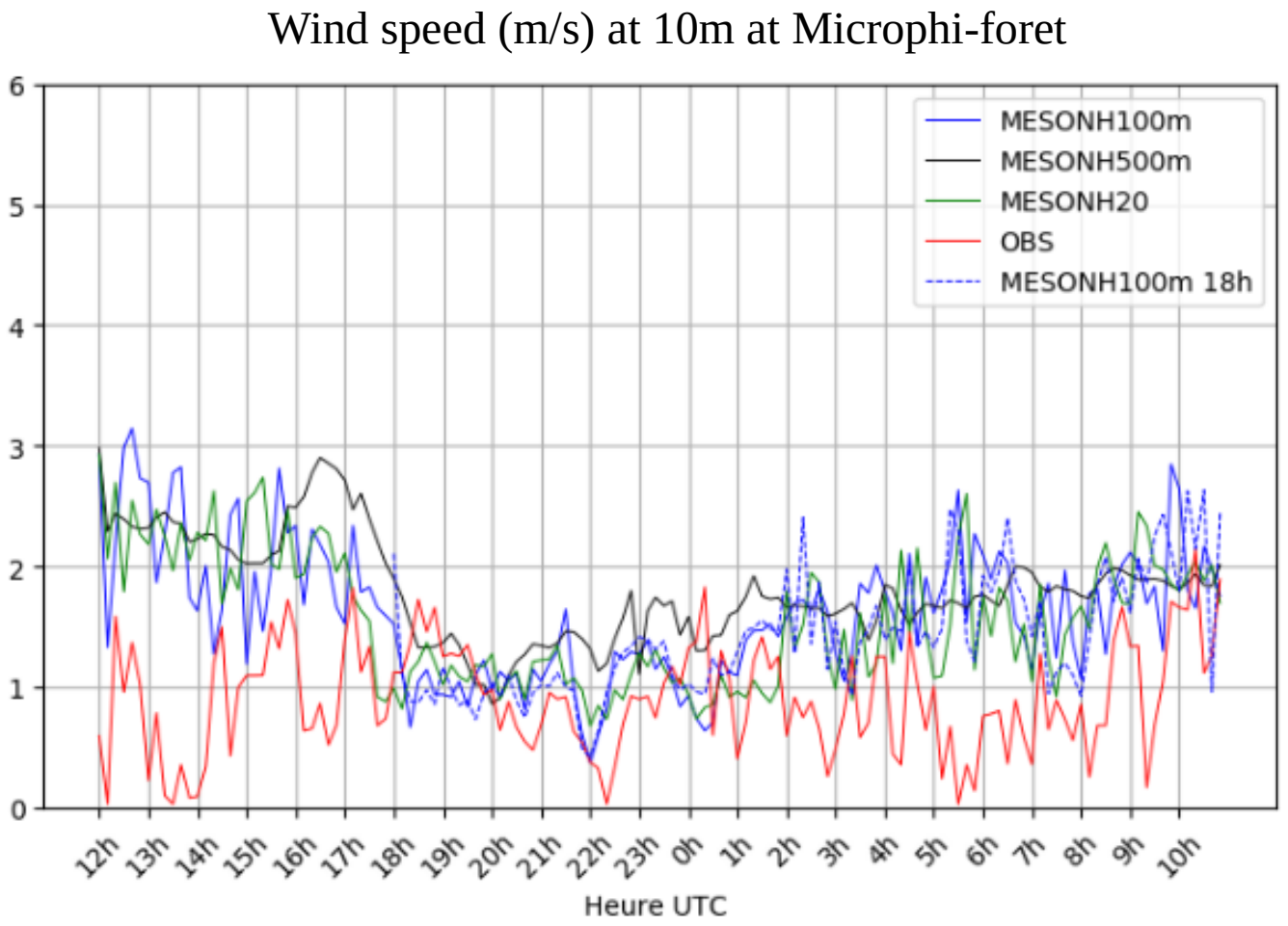
Impact of land cover on wind speed



⇒ However, the wind speeds is overestimated over the forest

⇒ need a better resolution of land cover and the forest drag

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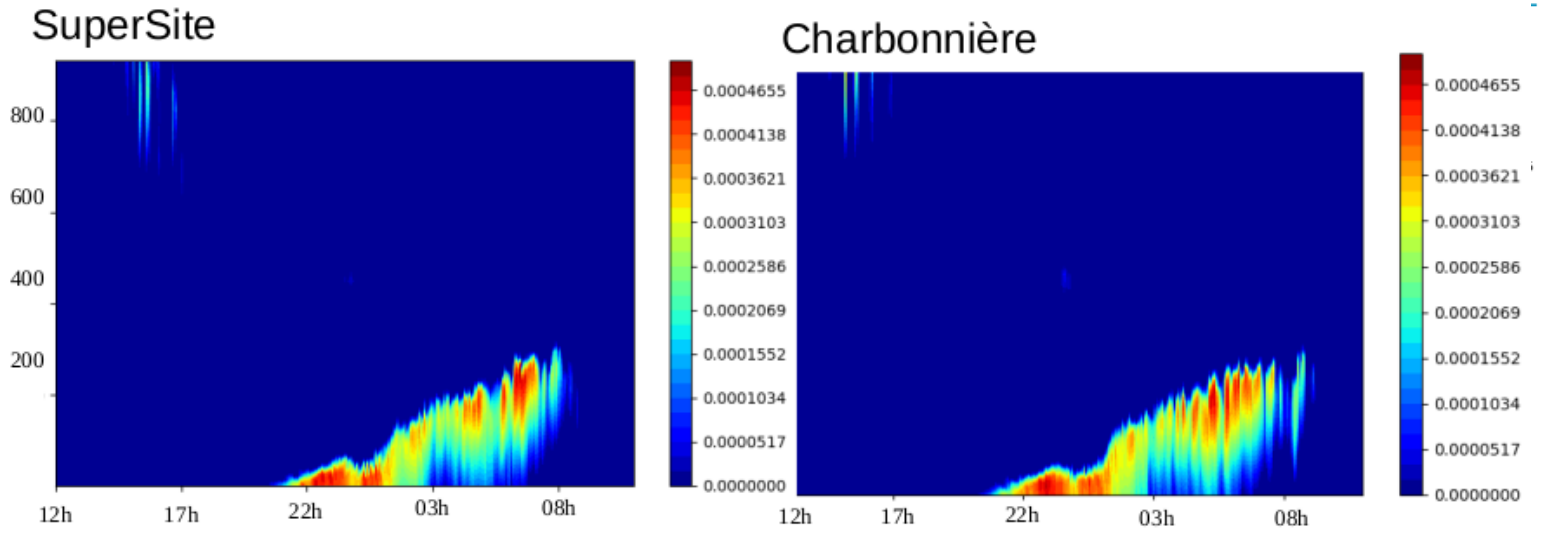
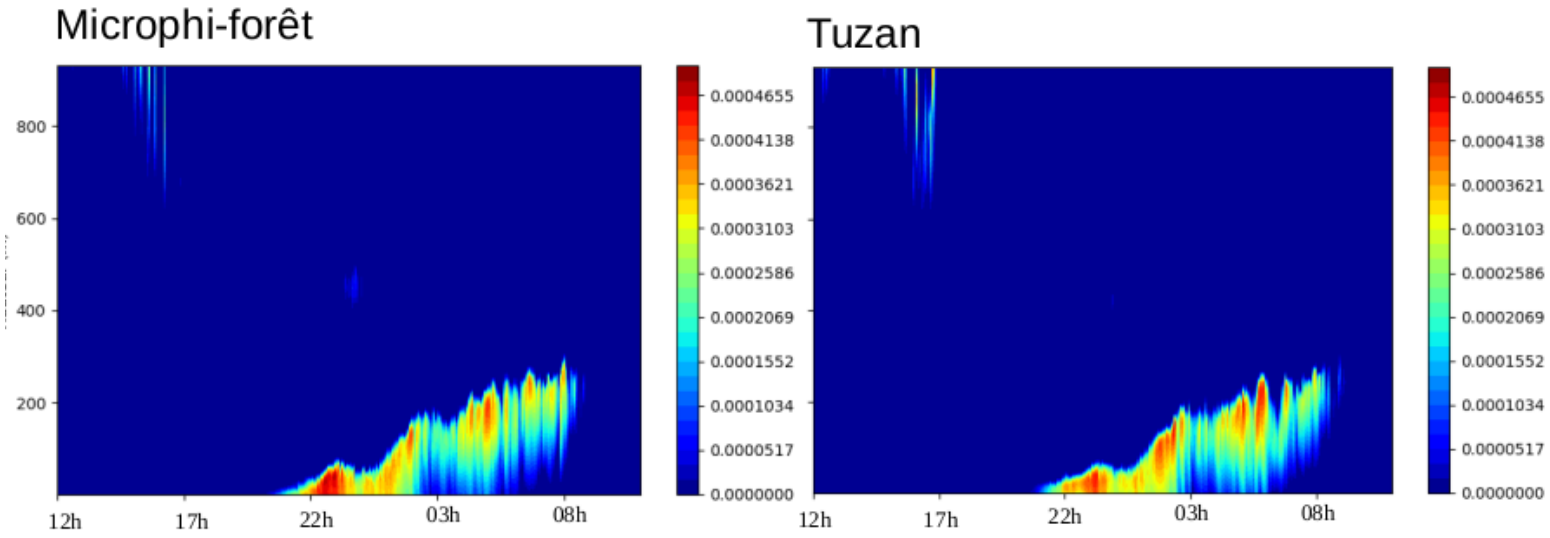
Impact of land cover on cloud mixing ratio

- In agricultural fields



- In forests



Low impact on these 4 sites

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Conclusion

- The IOP14 as a deep (~200m) and long (> 6-7h) fog is an interesting case to study fog heterogeneities between sites
- The 500m resolution with MesoNH and AROME produces a fog disruption due to unrealistic upper level clouds
- Higher resolution seems promising to reproduce heterogeneities between sites
- The simulated visibility variability is well represented at 100m resolution but needs a 2-moment scheme to be more realistic (impact of droplet concentration variability)

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Outlook (Postdoc position open)

- Sensitivity study to :
  - Tree drag parametrization
  - Higher resolution land cover with Ecoclimap-SG (300m) and LAI with LDAS (Land Data Assimilation System)
  - Orography at 30m resolution with new SRTM-30m
  - Microphysics with LIMA (+ initialization from observed aerosols)
  - Turn on droplets deposition on trees and grass
- Towards LES resolution (20m + 5m)
- Complete the analysis with turbulence and microphysics observations from UAV, tethered balloon, MWR
- Run the LES configurations to other POIs

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