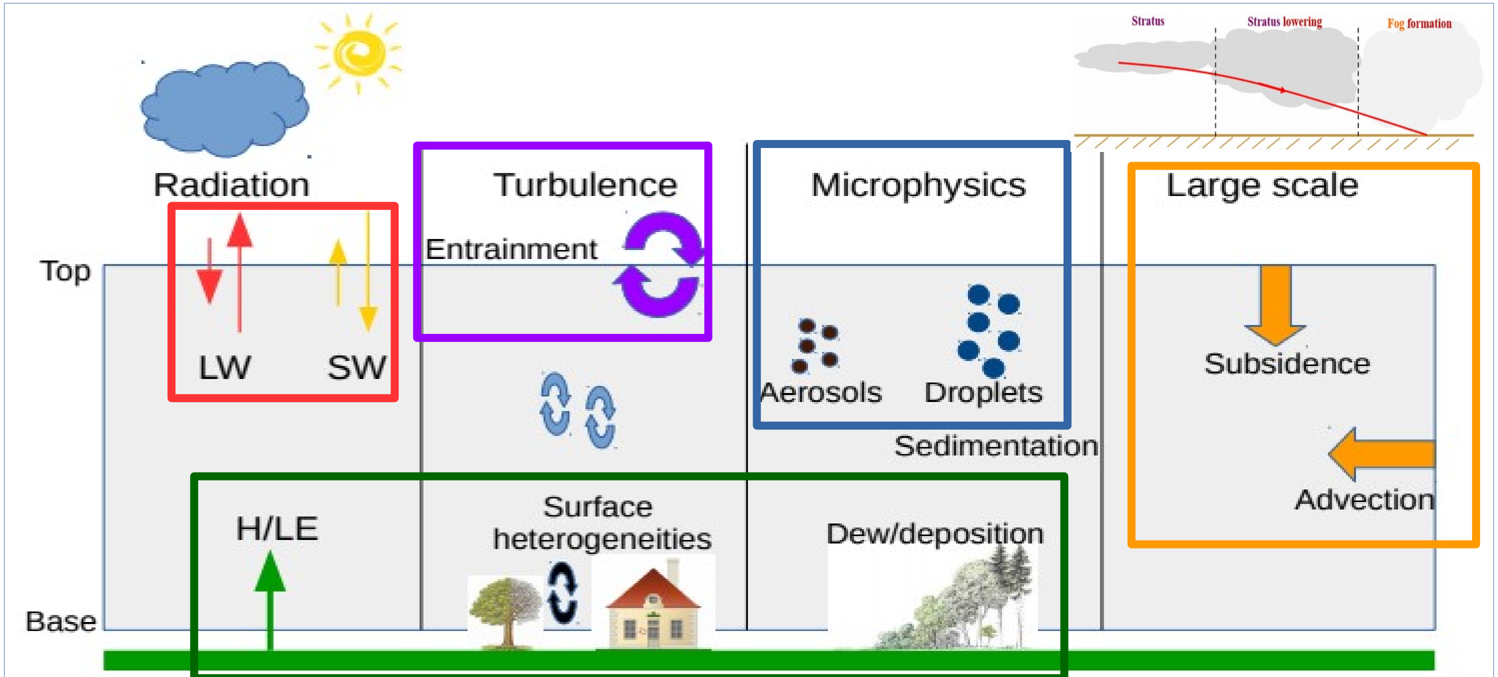
SOFOG3D : Better understanding and forecasting fog

Concerns the main processes and all the fog phases.



Adapted from Waersted et al. (2019)

- To better understand **contrasts** leading to radically different fate in fog life cycles :

  - **Shallow stable** fog *vs* **deep adiabatic** fog
  - **Stratus lowering** into fog *vs* **stratus persisting** aloft
  - Daytime fog **dissipation** or lifting *vs* **persistence**

- 1D and 3D measurements
- Large-Eddy Simulations (LES)
- AROME oper + AROME 500m
- Satellite products

GMEI, GMME, GMAP, CEMS

LES of fog

- Most of the eddies are resolved : Pope (2000) : $TKE_{resolved} > 80\ \%\ TKE_{total}$

  Stable boundary layer : Δx = a few meters *(Beare and McVean, 2004)*

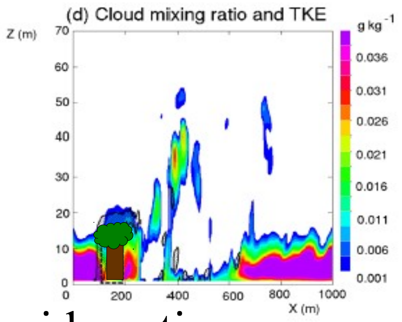
  Importance of the vertical resolution for fog : $\Delta z \sim 1$ m

- First LESs of fog : *Nakanishi (2000), Porson et al. (2011), Bergot (2013)* : with homogeneous canopies

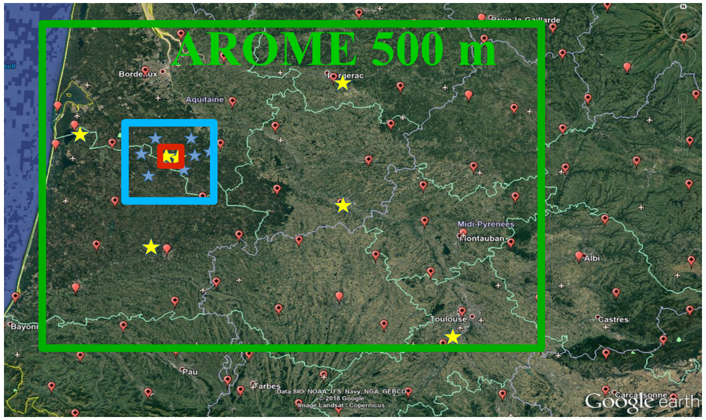
- LESs of fog with surface heterogeneities :

  Bergot et al. (2015), Mazoyer et al. (2017)

SIRTA site



- Since recently, downscaling from AROME analyses with Meso-NH grid-nesting



Δx=100 m+ Δx=20 m + Δx=5 m

ANR Task 3.1 : **LES of the most documented cases** validated with measurements

Surface interactions (Task 3.2)

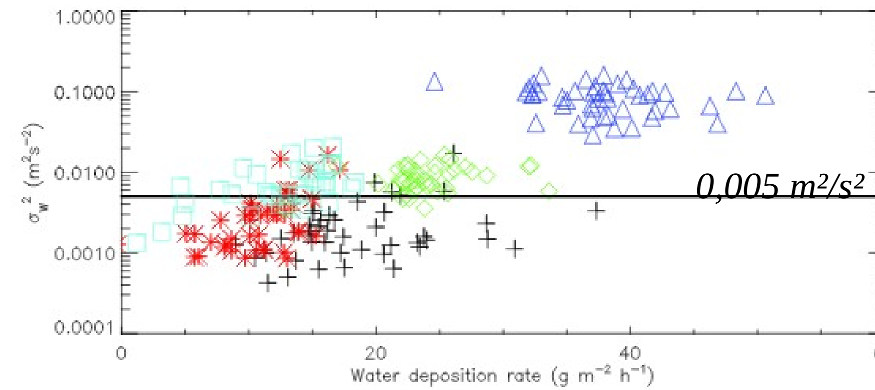
- How **surface and turbulence** interact:

  - Temporal evolution of **TKE** (TKE threshold on formation), budget of TKE

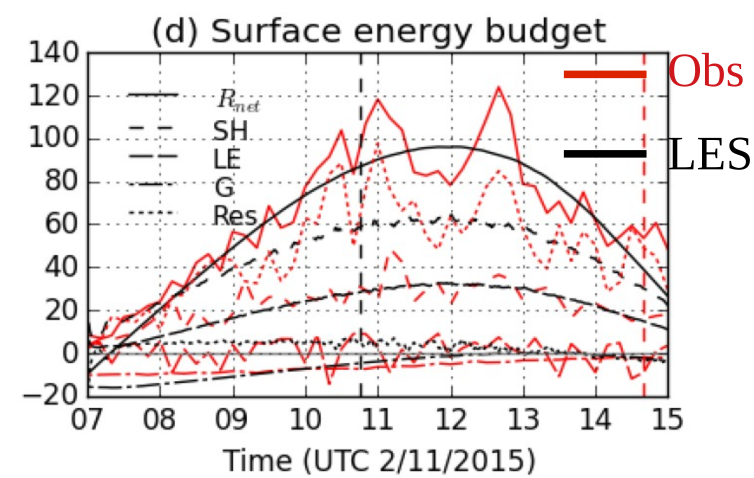
  - **Anisotropy** close to the surface

  - **Surface energy budget** to minimize the non closure, consistency with LES

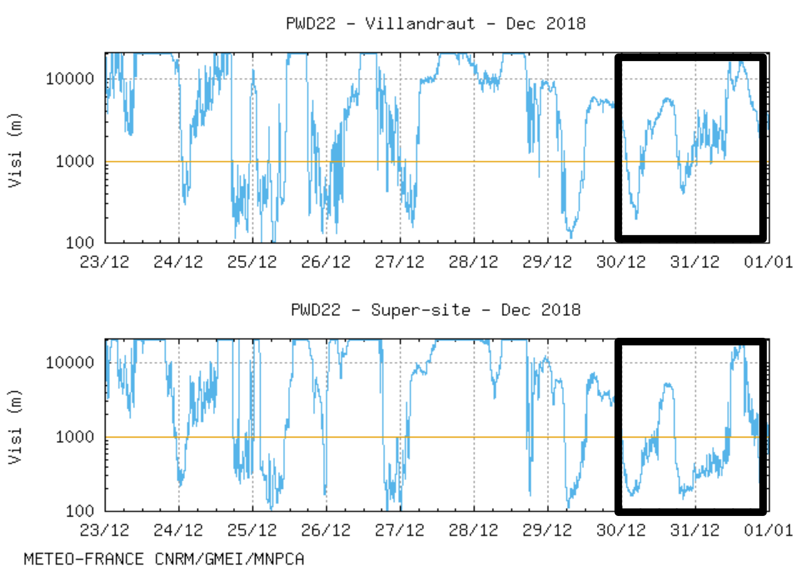
- Role of **surface heterogeneities**, impact of a contrasted surface



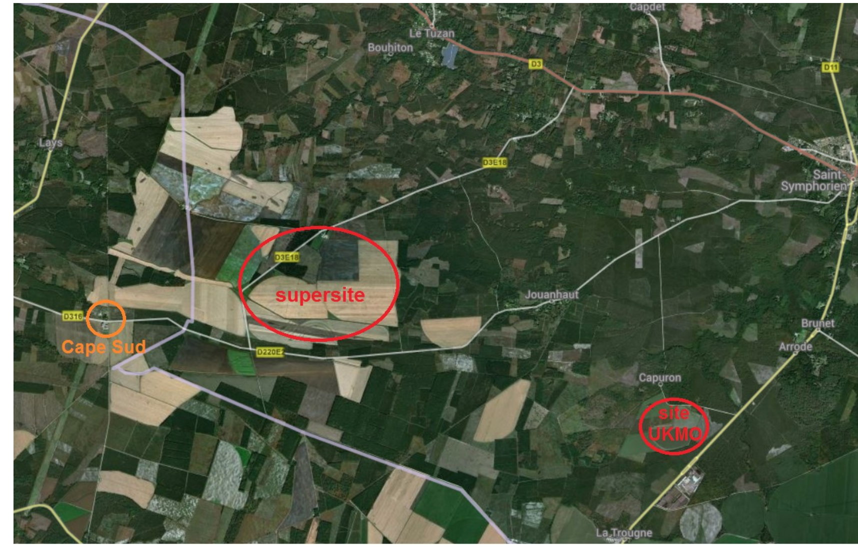
Price, 2019, IOP9 LANFEX



Waersted, 2018



Surface interactions - Tools

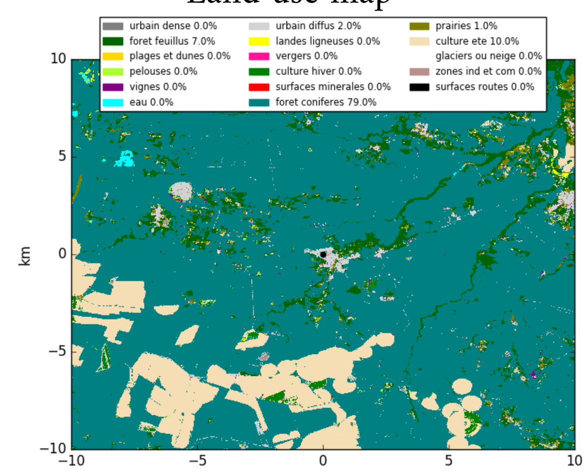


- In situ 3D observation network
- 50m and 10m towers with mean and turbulence measurements
- Vertical profiles with turbulence probe (Gill) above tethered balloon (coupled with microphysics)
- Profil of TKE with wind doppler lidar (0-240 m), mainly before the event
- Network of soil humidity and temperature (we will deploy 10 sites with 3 sensors at 10, 20 and 30 cm of depth)

Sensible fluxes measured on a tethered balloon,
+ (first test with rapid humidity measurement)

- LES : Use Meso-NH-SURFEX as a laboratory : impact of modification of vegetation characteristics on the fog life cycle
- AROME and Meso-NH : impact of fine resolution land use maps (ECOCLIMAP-SG), surface conditions (LDAS)

Land use map



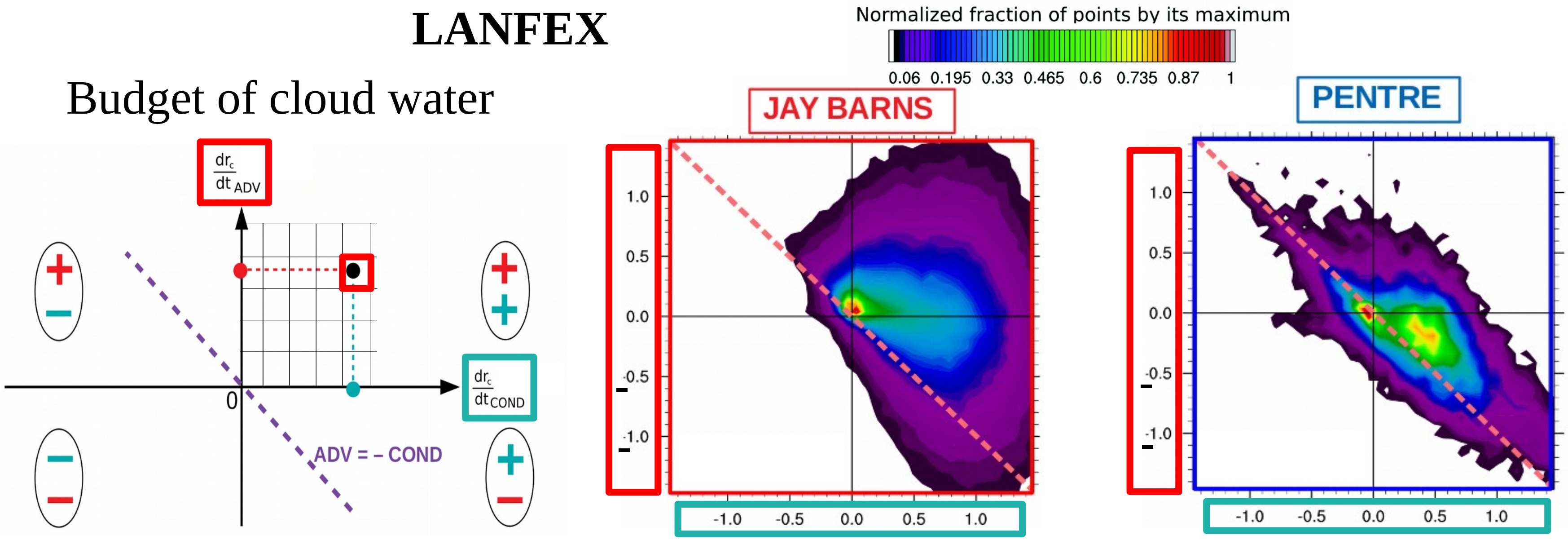
Impact of orography and advective processes (Task 3.3)

- Local circulations studied with scanning Doppler wind lidar, Doppler wind lidar profiler, scanning 95GHz Doppler radar . Thermal IR imaging.

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

LANFEX

Budget of cloud water



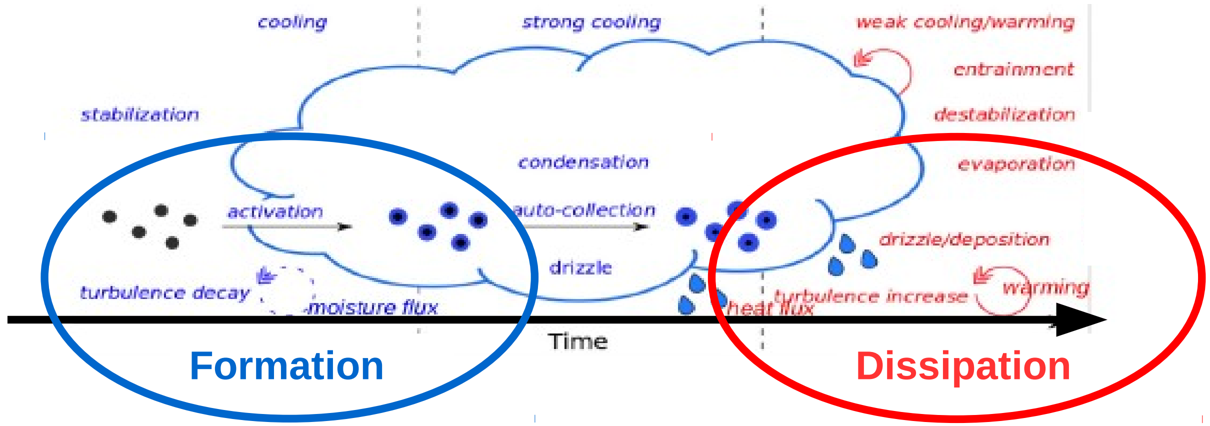
Δx=100 m

LOCAL formation

LOCAL formation
NON-LOCAL destruction
In opposition

Duconge et al., QJRMS, in revision

Aerosols



What is the vertical variability of aerosol activation processes ?

Tethered balloon-born measurements :

Parameters	Instruments
Aerosol size distribution	OPC
CCN concentration	Mini-CCNC
Fog microphysics	CDP

CCN closure study to derivate <u>parameterization of aerosol activation into fog droplets</u>

How aerosol absorbing properties impact fog dissipation ?

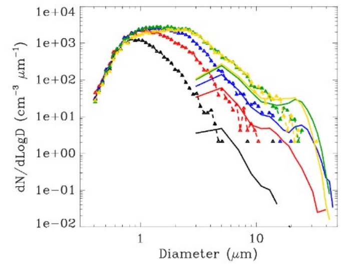
Ground-based measurements :

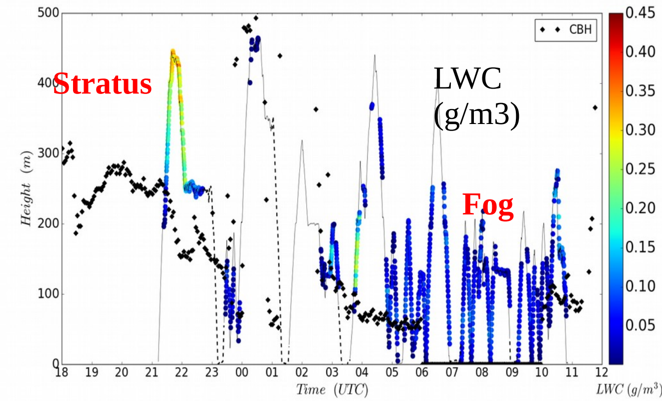
Parameters	Instruments
Aerosol size distribution	SMPS, OPC
Aerosol concentration	CPC
Aerosol optical properties	CAPS, nephelometer
Aerosol hygrosopic properties	Custom-built H-TDMA (h-BC project funded by LEFE)

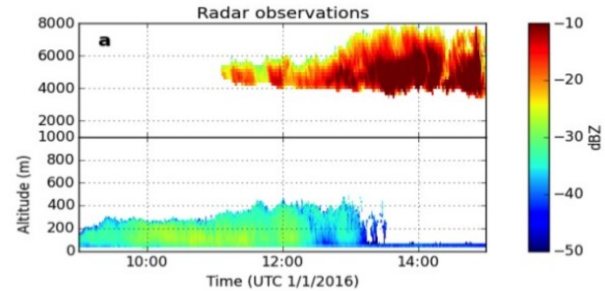
Optical closure study to derivate <u>key radiative parameters</u> in ambient RH conditions

METEO FRANCE

Microphysics

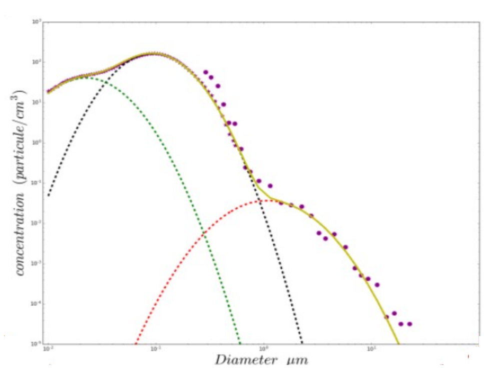


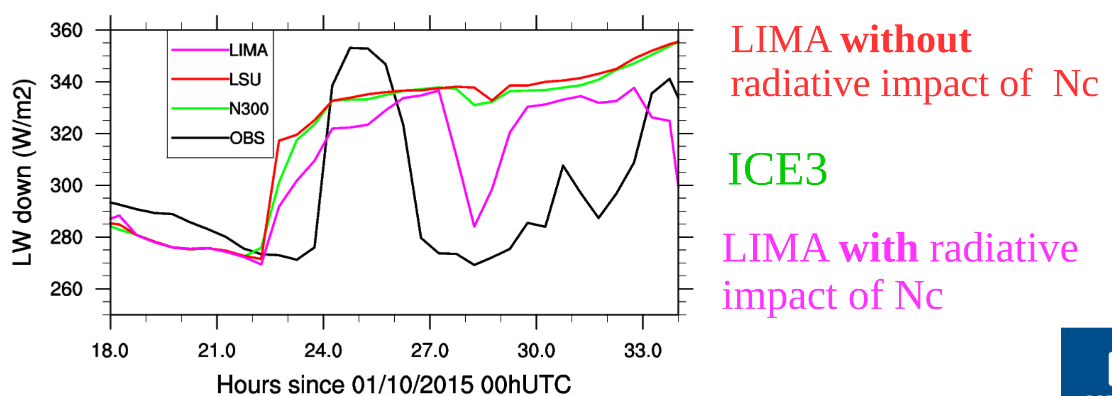




- Characterization of the vertical variability of microphysical fields
- Role of the microphysics in the bifurcation optically thin / thick
- How **turbulence and microphysics** interact ? Simultaneous observations

- Impact of the 2-moment microphysical scheme LIMA with a realistic multi-modal aerosol initialization





Duconge et al., QJRMS, in revision

METEO FRANCE

Microphysics : activation parametrization

- Supersaturation very small in fog :

  Hammer et al. (2014), Mazoyer et al. (2019)

  OBS$_{\text{brouillard}}$: S ~ 0.05 %

- Activation in 2-moment schemes based on adjustment to saturation and a diagnostic of Smax :

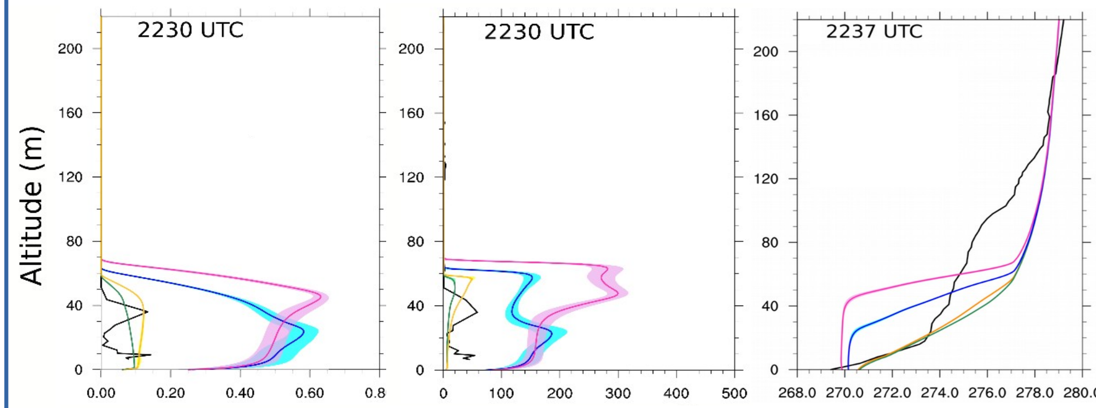
$$\frac{dS}{dt} = \psi_1 w - \psi_2 \frac{dr_c}{dt} + \psi_3 \frac{d\theta}{dt}$$

$$N_{CCN} = C S_{max}{}^k F\left(\mu, \frac{k}{2}, \frac{k}{2}+1, -\beta S_{max}{}^2\right)$$

- Tends to overestimate Smax (LES), and Nc → too rapid transition to thick fog

- A prognostic approach for supersaturation *(Thouron et al., 2012)* seems promising for fog

$$S = \frac{r_v}{r_s} - 1$$

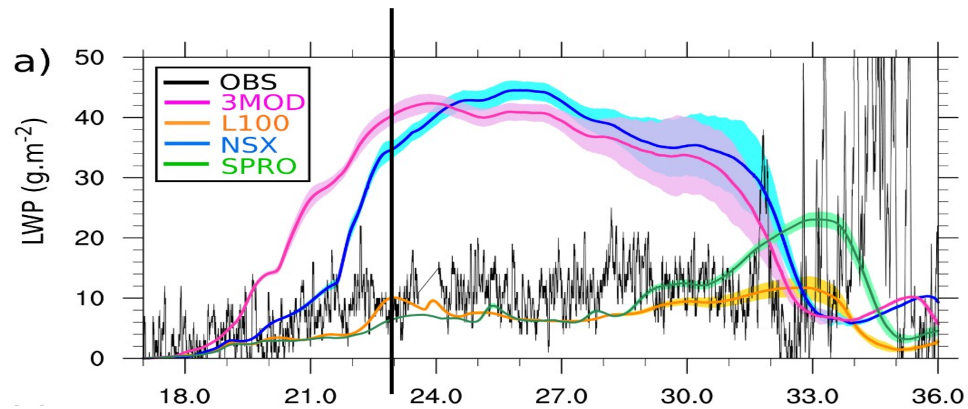


Contenu en eau liquide (g cm^{-3})

Nc : Conc. gouttelettes (cm^{-3})

ϴ (K)

LIMA-REF LIMA-PROGNOS



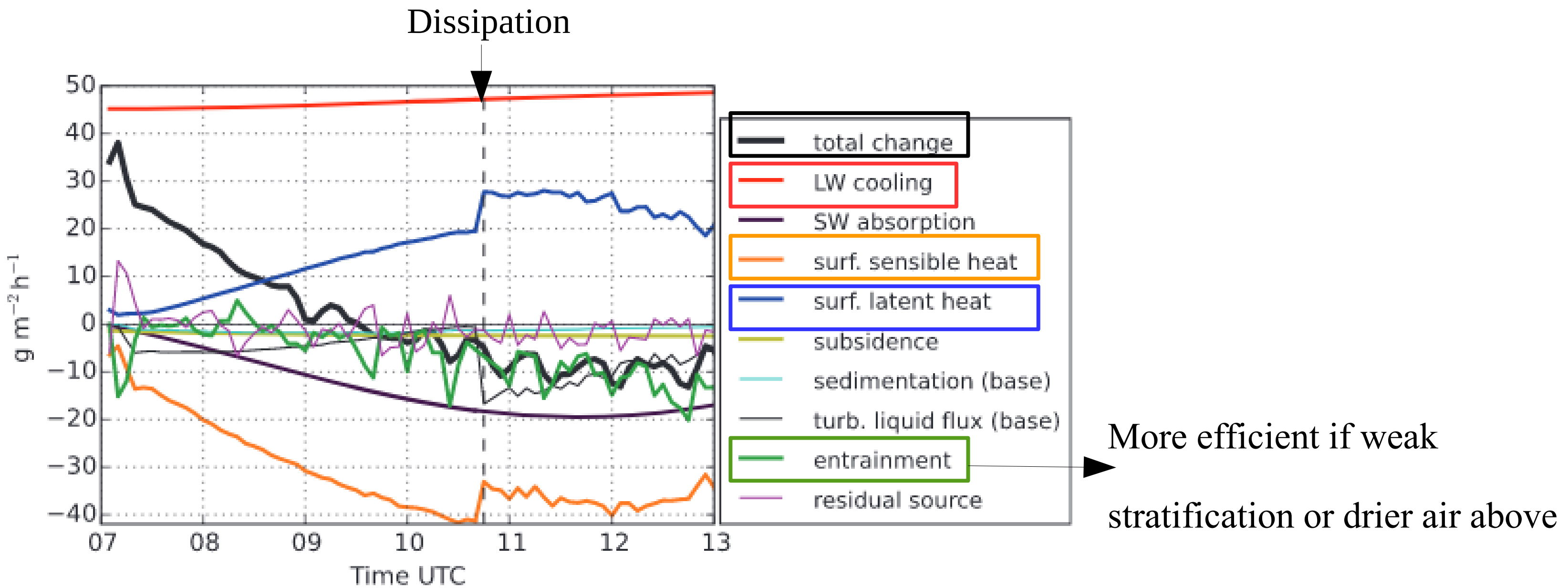
From L. Ducongé ***LANFEX***

Entrainment at fog top (Task 4.1)

- Once fog is thick, quantification of entrainment with thermodynamical and microphysical in-situ observations (tethered ballon, UAV, MWR) and LES budgets :

  - Impact of humidity and temperature profiles above the fog on entrainment

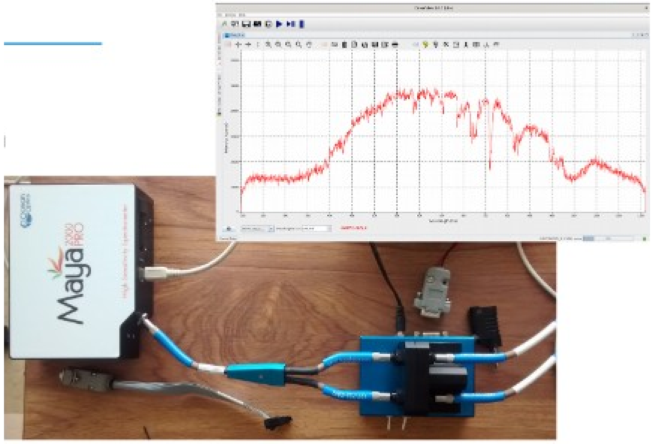
  - Impact of entrainment on microphysics



Budget of LWP, Waersted, 2018

Radiation (Task 4.3)

- Radiation **absorption** : Spectrophotometer measurements : spectral solar irradiance 300-1100nm. Evaluation of the models by spectral band
- Radiative **cooling** (tethered ballon, UAV, MWR) : main source of LWP at the mature stage
- Evaluation/improvement of cloud and aerosols optical properties (thèse de E.Jahangir)
- Evaluation of ecRad radiation scheme



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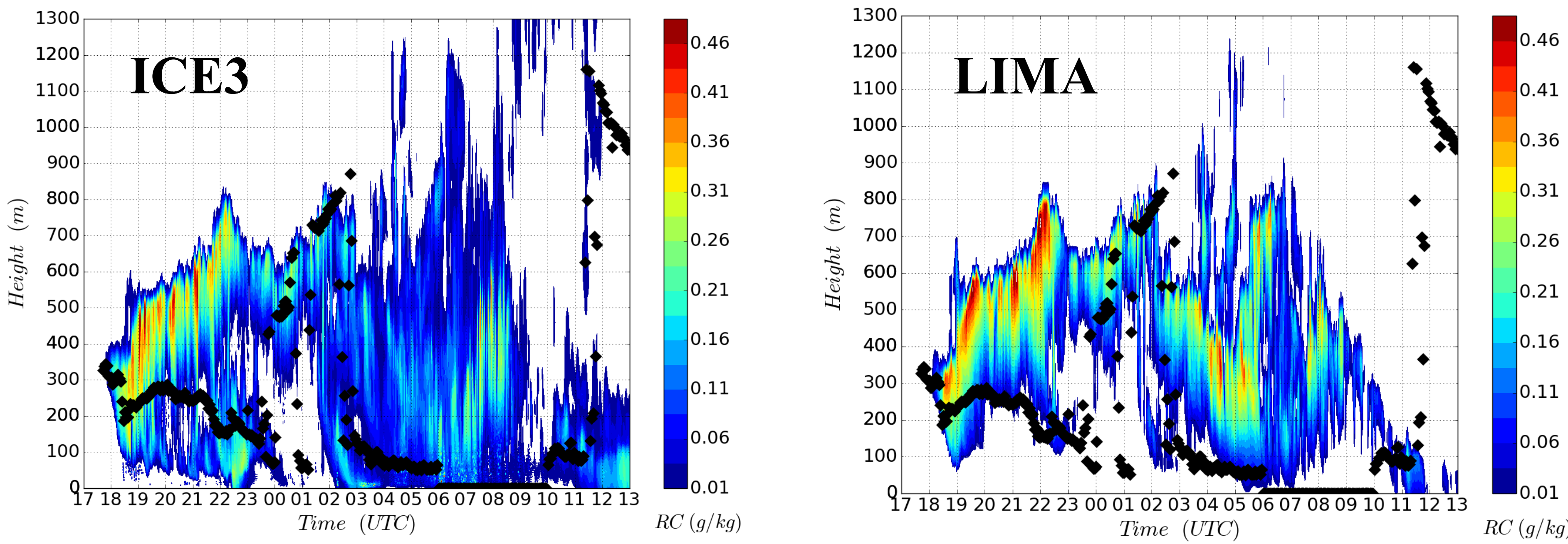
Fog by stratus lowering (Maroua Fathalli PhD, Task 4.2)

- What are the **main processes driving stratus lowering** ?

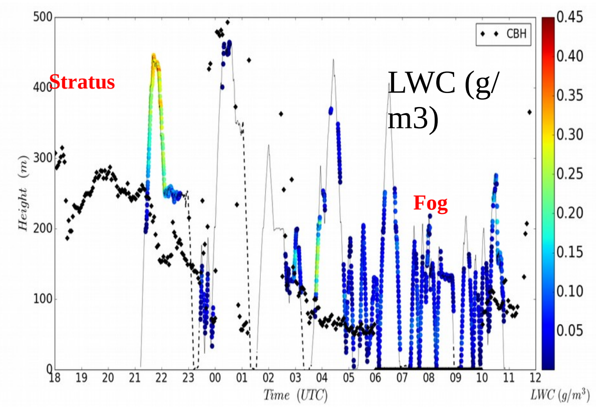
  Microphysics (evaporation of droplets), large-scale conditions above the inversion (subsidence, humidity), below the stratus

BURE : 01-02 december 2016



Cloud mixing ratio (g/kg)

Fog by stratus lowering (Maroua Fathalli PhD, Task 4.2)

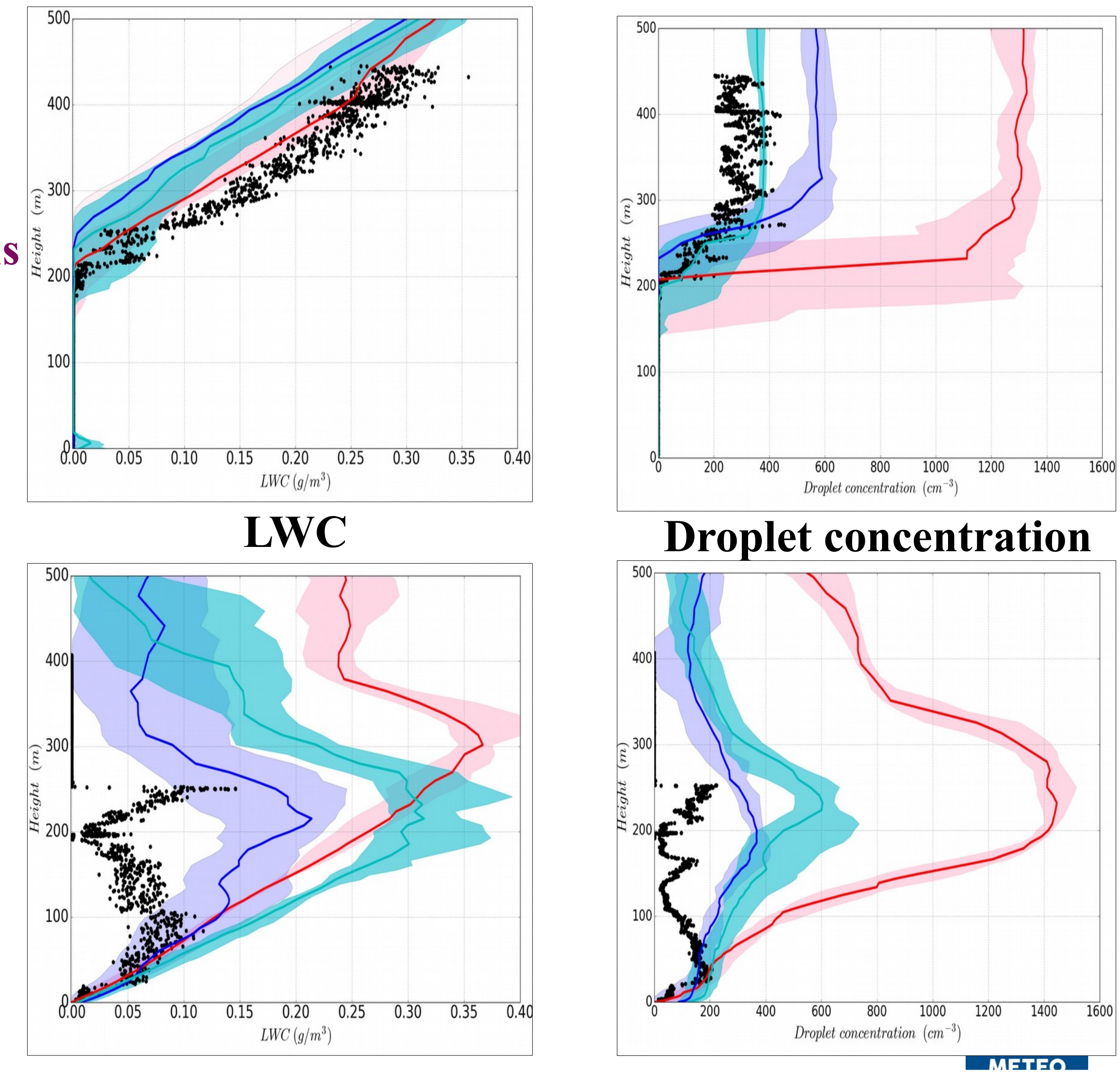


- OBS
- LIMA ref
- LIMA modified
- LIMA with prognostic supersaturation

Microphysical differences between stratus and fog

Stratus

Fog



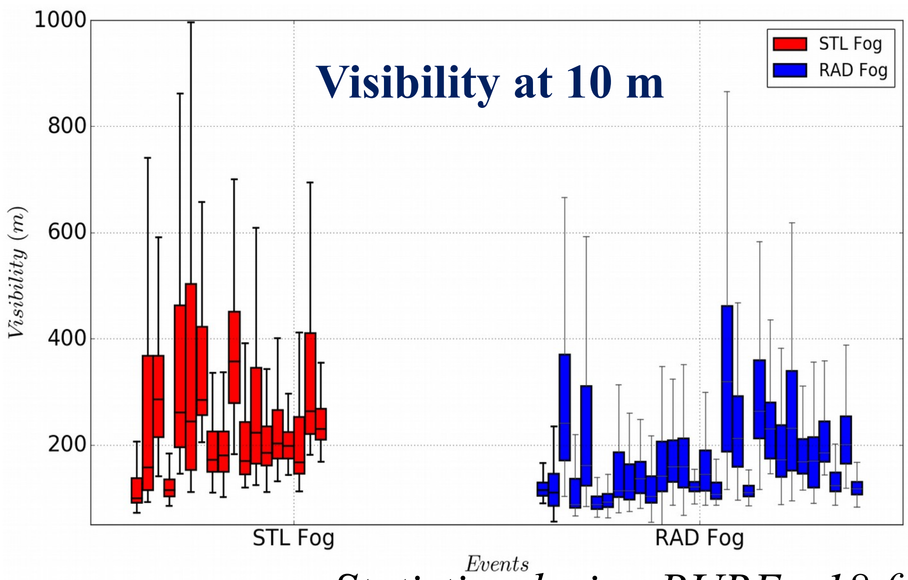
CDP measurements with tethered balloon and LIMA results

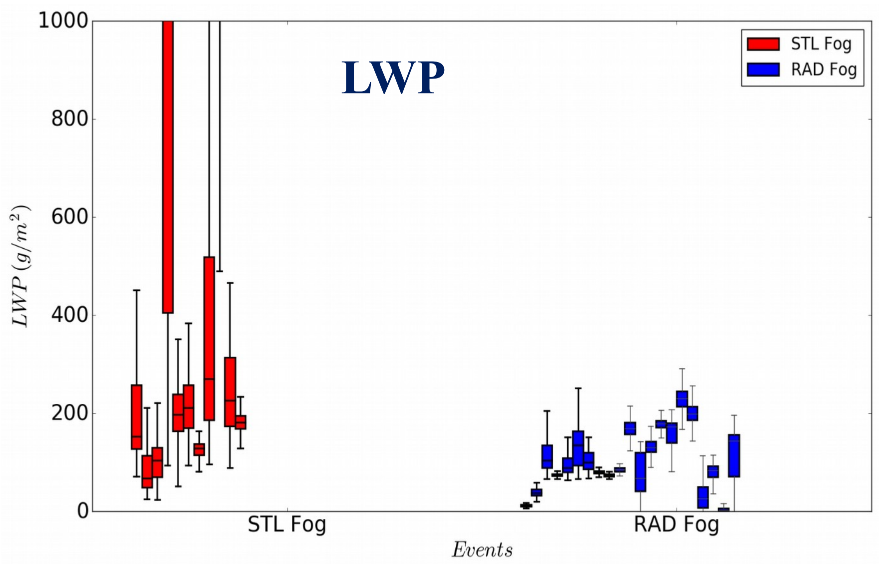
Fog by stratus lowering (Maroua Fathalli PhD, Task 4.2)

- What are the **main processes driving stratus lowering** ?

  Microphysics (evaporation of droplets), large-scale conditions above the inversion (subsidence, humidity), below the stratus

- What are the main differences between **stratus with/without lowering** ?
- Why do **models** so often **miss** them ?
- Are there microphysical differences between **radiative fog** and **fog by stratus lowering**?

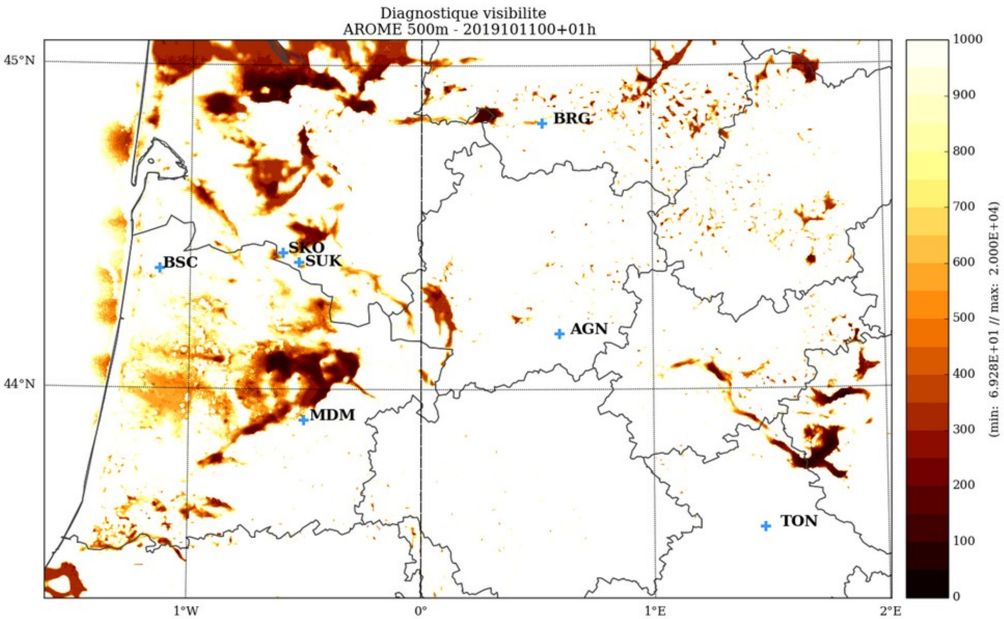




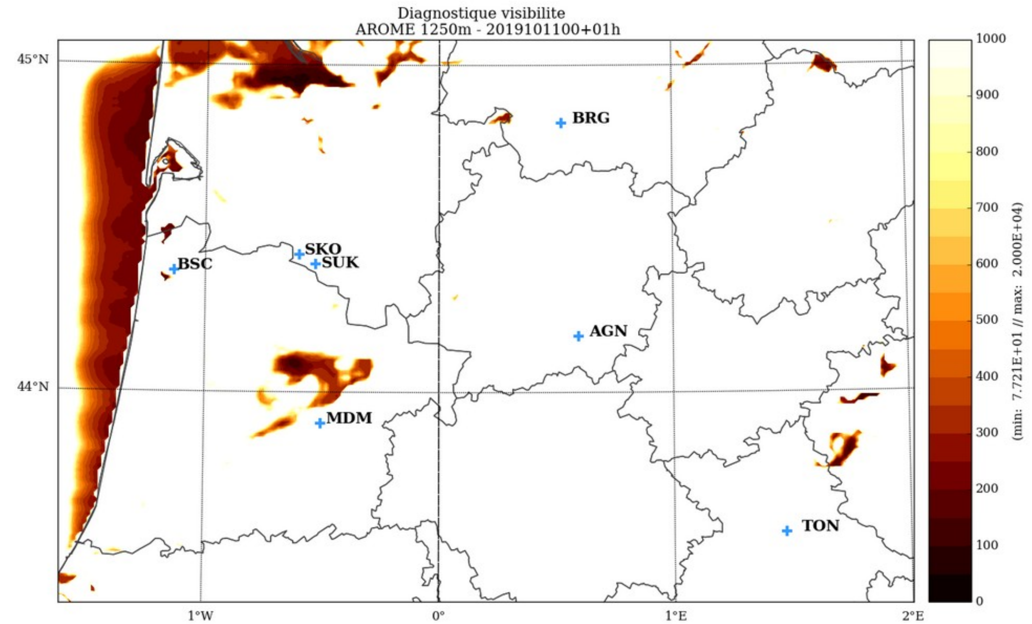
Statistics during BURE : 18 fogs by stratus lowering, 30 radiative fogs

AROME 500m (Salomé Antoine, PhD)

- Runs AROME during the 6 months of experiment :



AROME 500m – 156 levels - Ecoclimap-SG



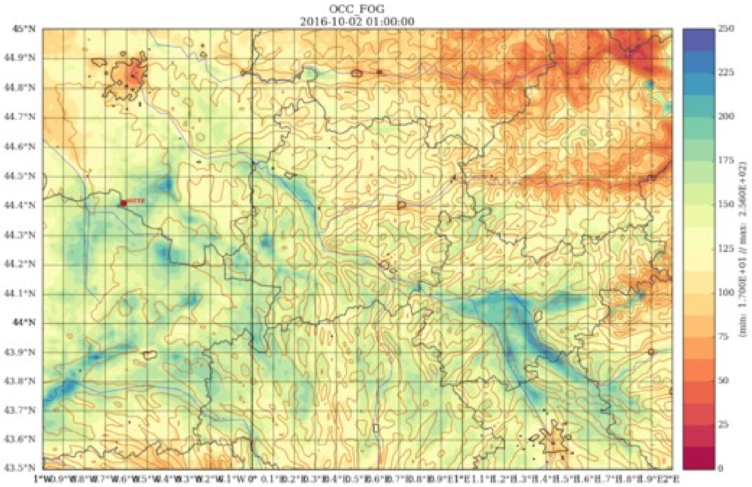
AROME 1250m – SW domain

- How spatial resolution can improve fog prediction ?
- Validation of new physics : LIMA (with realistic aerosol initialization), cloud optical properties, ecRad
- Visibility diagnostics
- Surface : fine scale databases, ISBA-DIF

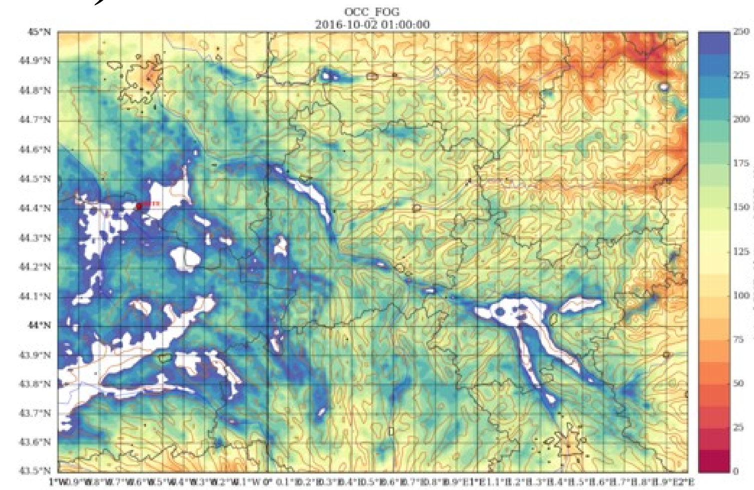
AROME : spatial resolution

Statistics over 6 months :
Occurrence of fog (hours)

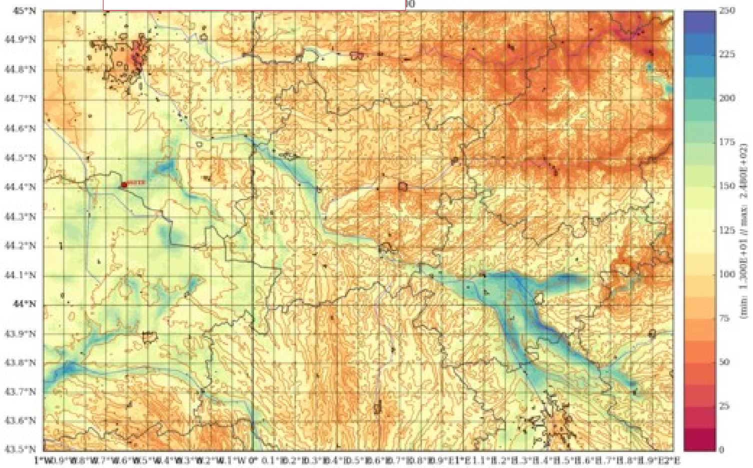
1250m L90



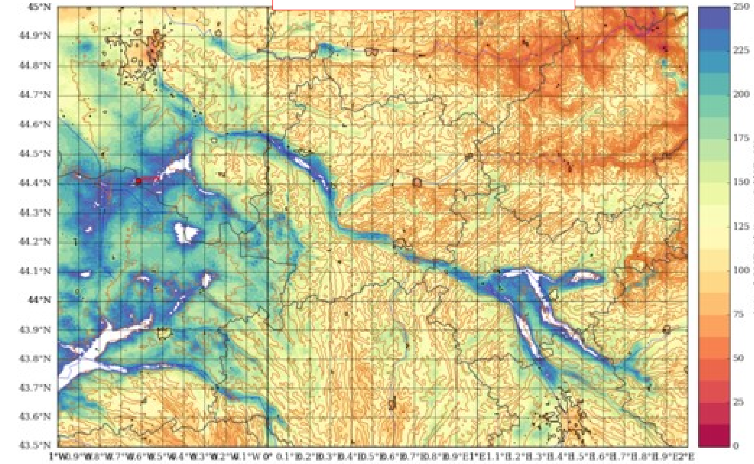
1250m L156



500m L90



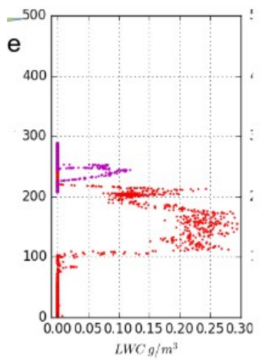
500m L156

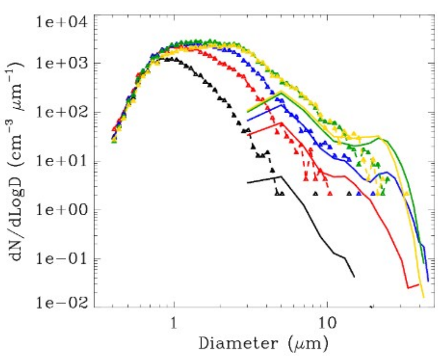


C. Zecchin, Y. Seity

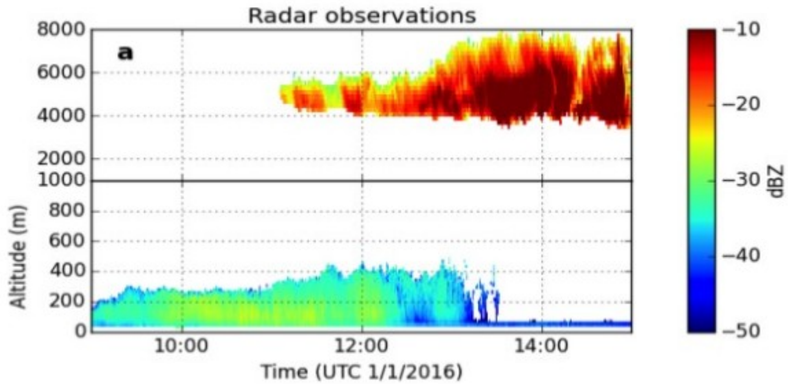
SOFOG3D : une opportunité pour le CEMS/Nuages

- Le CEMS restitue et valide les propriétés macro- et microphysiques des nuages à l'échelle globale (sur l'Europe avec MSG4)
- Le CEMS pourrait donc contribuer à la base de données SOFOG3D par la mise à disposition des propriétés macro- et microphysiques des nuages (sur une zone SW et sur les POI) :
  - Présence et type des nuages
  - Hauteur des nuages
  - Microphysique des nuages (phase thermodynamique,épaisseur optique, contenu en eau/glace,taille effective des particules)
- Sofog3D est également une opportunité pour le CEMS de validation certe locale mais plus précise. Exemple de mesures disponibles (F.Burnet et al.):





IFDA - SOFOG3D project - F. Burnet et al. -



SOFOG3D : une source de validation pour CEMS

- Validation de la présence des brouillards
- Impact des champs de modèles NWP sur la restitution de la hauteur des brouillards (test avec différents modèles à différentes résolutions spatiales)
- Sensibilité de la restitution de la microphysique des brouillards avec la largeur de la distribution de taille de gouttes utilisées dans la diffusion de Mie
- Validation de la taille effective des particules (non effectué à l’échelle globale)
- Validation du contenu en eau des brouillards (effectué à l’échelle globale uniquement au dessus des océans et à certaines heures) et de son cycle diurne