Formation of fog due to stratus lowering: An observational and modelling case study

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Introduction

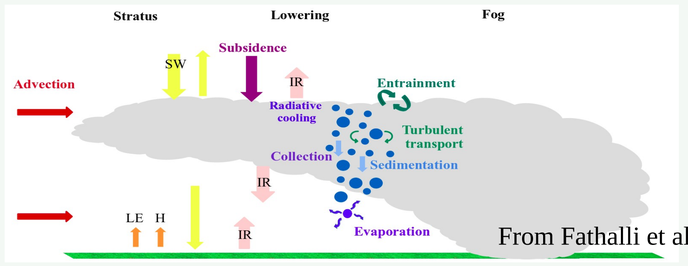
Context

- Fog=Strong disruption of aviation, marine and land transportation.
- **NWP** models: difficulties to correctly forecast stratus lowering **(STL)** (Philip et al. 2016)

Scientific questions

- What are the main processes leading to fog by STL?
- What is the impact of microphysics? Does a 2- moment versus a 1-moment microphysical scheme induce substantial changes ?

What are the processes leading to stratus lowering ?



From Fathalli et al. 2022

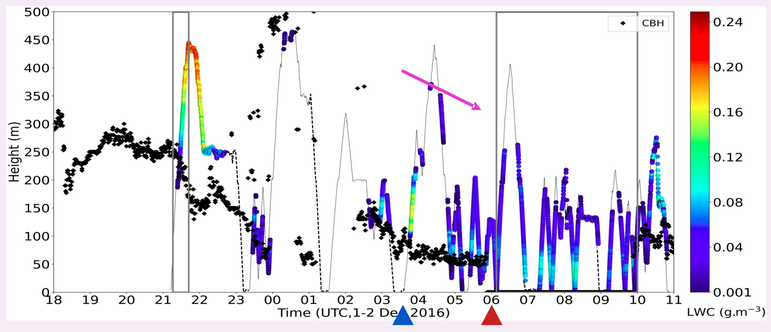
Methods

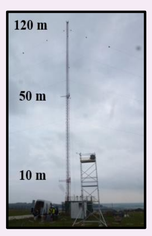
- Analysis of data collected during the field campaign **BURE** (Martinet et al.,2020, Burnet et al. In prep) (2015/2017) realized at the Observatoire Pérenne de l'Environnement (OPE) of ANDRA located in North-East of France, in collaboration with IRSN.
- **Numerical simulation** of a **STL event of BURE** with **Meso-NH** model and a two moment microphysical scheme at high resolution.

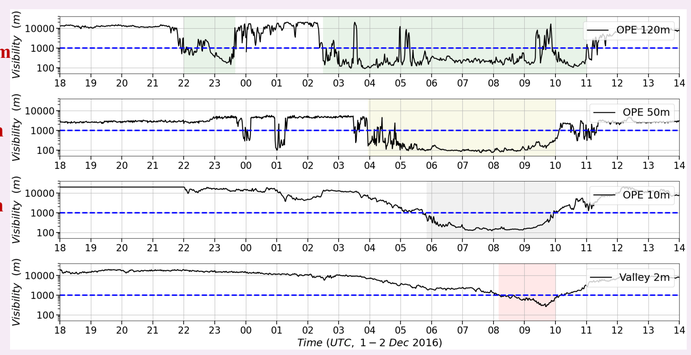
Observations

IOP 2 : 1st and 2nd December 2016 — **Stratus** **Drying period** **Stratus lowering** **Fog**

Tethered balloon path Associated with liquid water content calculated from CDP







Time series of visibility at 10m, 50m and 120m in OPE and at 2m in valley.

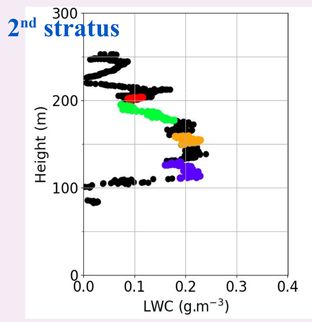
Cloud life cycle (4 phases)

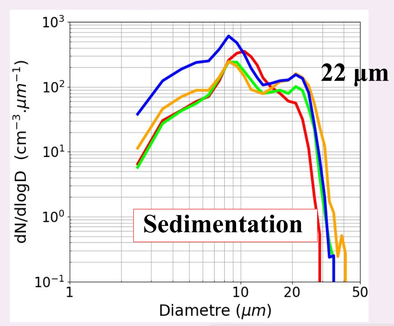
- Stratus base: From 300 m to 120 m

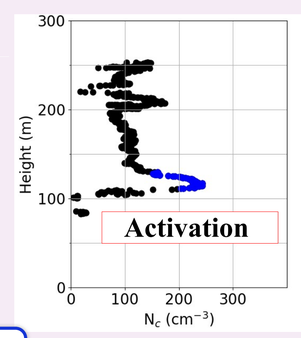
- Stratus base: From 500 m to 800 m
- Increase in visibility at 120 m

- Stratus base: From 160 m to 0 m
- Decrease in visibility at three level

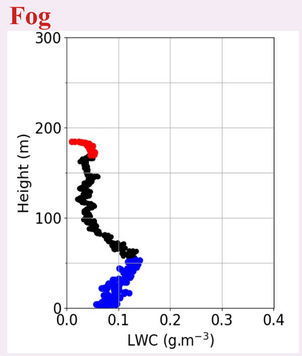
Microphysical properties derived from CDP measurements



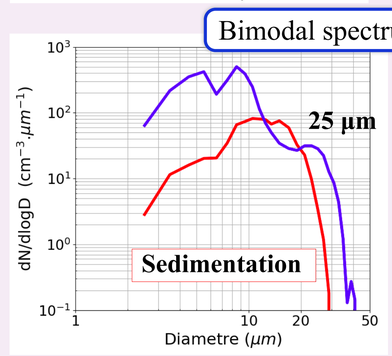


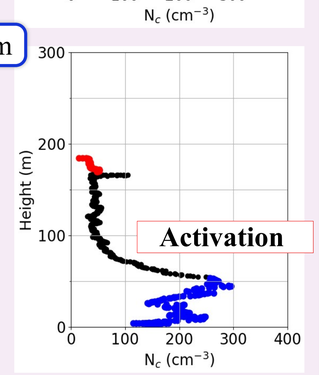


Fog



Bimodal spectrum



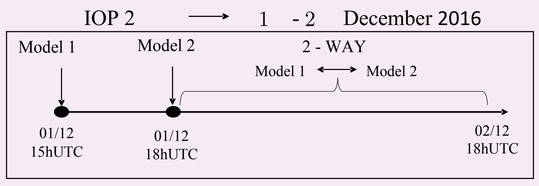


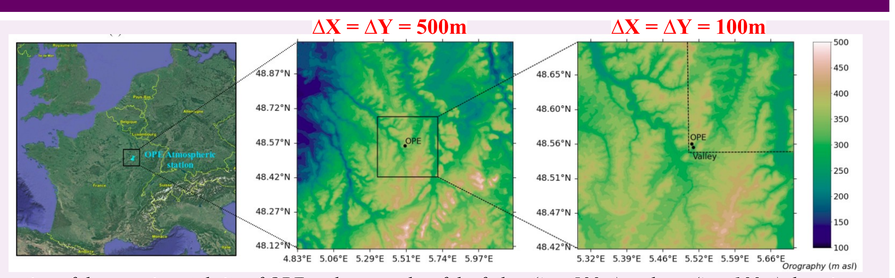
Simulation of IOP 2 (1st- 2nd Dec 2016) -Meso-NH model

Numerical set-up

- Horizontal grid resolution: 500 m and 100 m two-way nested grids.
- 150 vertical levels: 0 to 3250 m (from 1.5 to 50 m of resolution).
- Initial/coupling conditions: Analyses produced from NWP French model (**AROME**).
- Microphysics scheme: 1-moment (**ICE3**, Pinty and Jabouille, 1998) and 2-moment (**LIMA**, Vié et al., 2016) microphysical schemes.

Meso-NH mesoscale non-hydrostatic model (Lac et al,.2018)



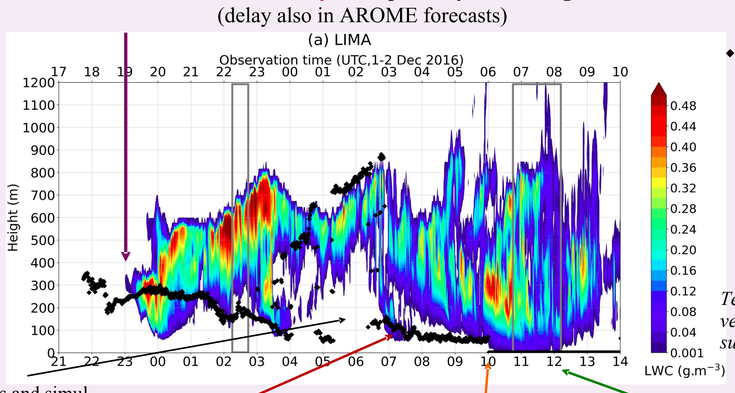


Location of the experimental site of OPE and orography of the father (Δx=500m) and son (Δx=100m) domains.

Reference numerical simulation LIMA(two-moment)

- Prognostic evolution for the droplet and aerosol concentrations.
- Activation of multimodal aerosols
- Initialization of aerosols from in-situ measurement (OPC and SMPS) with 3 modes.

Stratus formation at 23 UTC with a delay of 5h partially due to large scale conditions
(delay also in AROME forecasts)



◆ Cloud base height from ceilometer

Temporal evolution of simulated vertical profile of LWC with LIMA superimposed with the observed CBH.

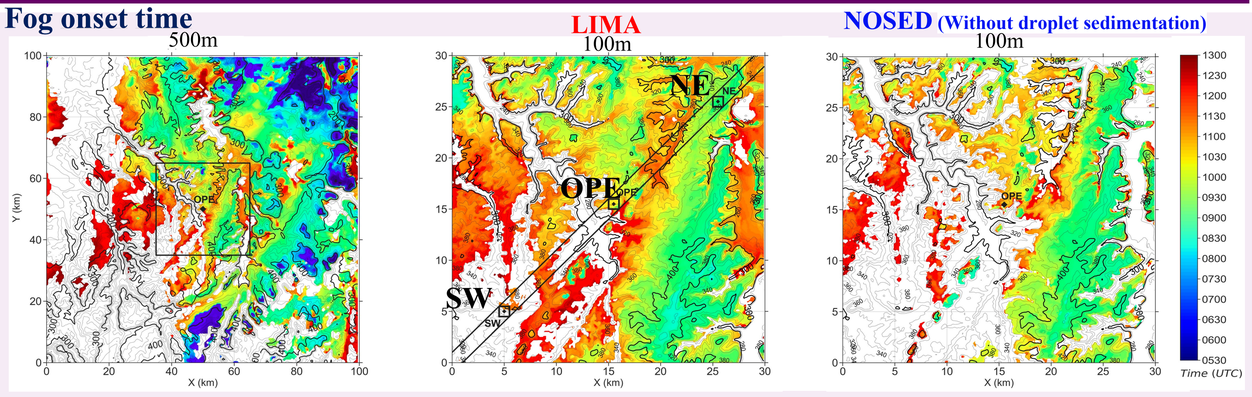
Drying period in obs and simul

Stratus lowering slowly — **Fog formation** with a **delay 4hour** — **Fog dissipation too early**

➢ REF **reproduces well** the cloud life cycle (3 phases)

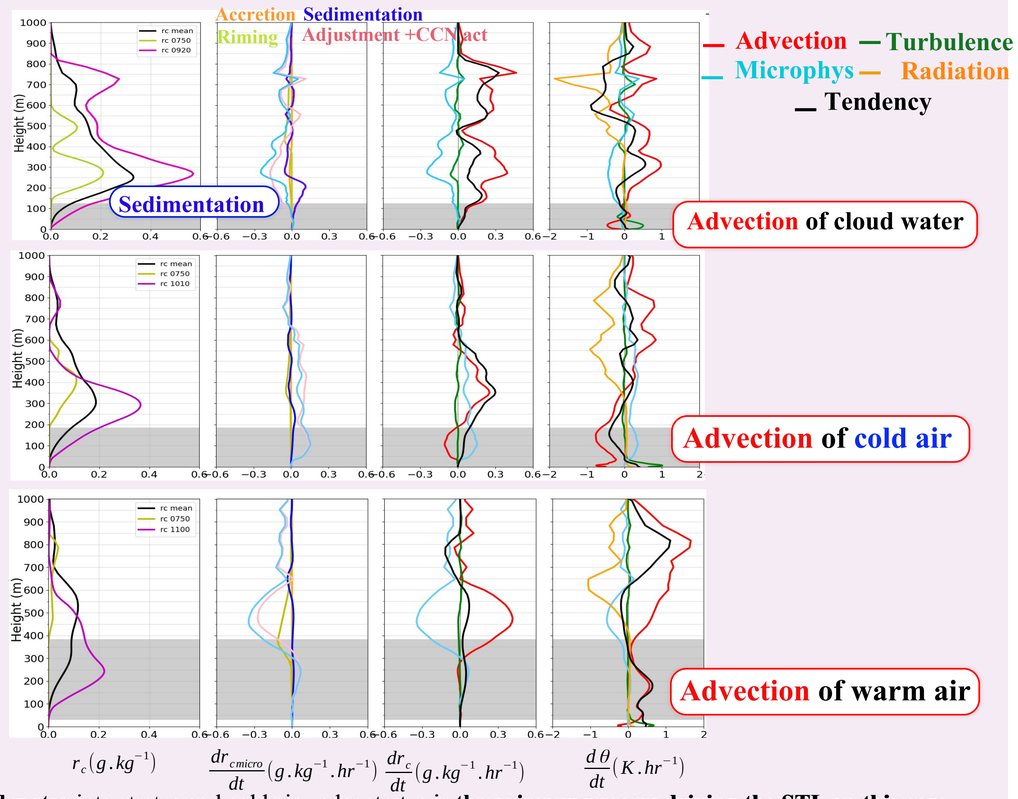
Analysis of Stratus Cloud Lowering

Fog onset time



72 % of the domain — **47 %** of the domain

Budget analysis

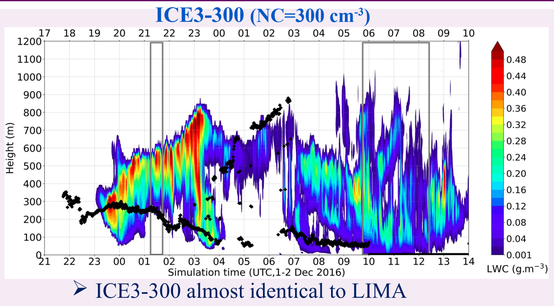


$r_c(g.kg^{-1})$ $\frac{dr_{cmicro}}{dt}(g.kg^{-1}.hr^{-1})$ $\frac{dr_c}{dt}(g.kg^{-1}.hr^{-1})$ $\frac{d\theta}{dt}(K.hr^{-1})$

➢ **Advection** of **cloud water** into stratus and cold air under stratus is **the primary process driving the STL on this case**.
➢ **Sedimentation** is **the second process that favors the stratus lowering**

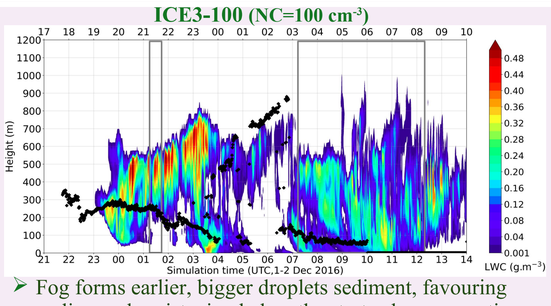
Impact of the microphysics: sensitivity test with ICE3 (one-moment)

ICE3-300 (NC=300 cm⁻³)



➢ ICE3-300 almost identical to LIMA

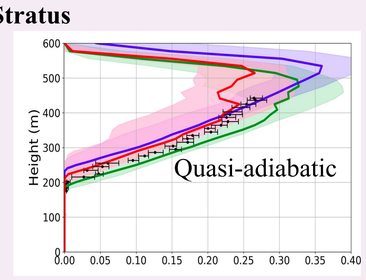
ICE3-100 (NC=100 cm⁻³)

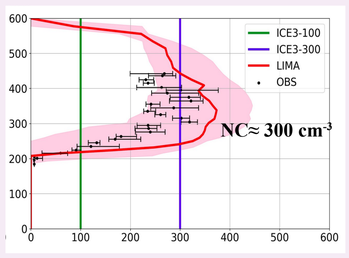


➢ Fog forms earlier, bigger droplets sediment, favouring cooling and moistening below the stratus by evaporation.

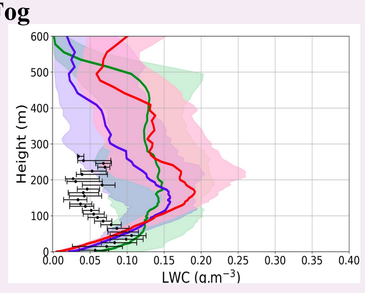
➢ **Microphysics can accelerate the lowering (evaporation of droplets below stratus)**

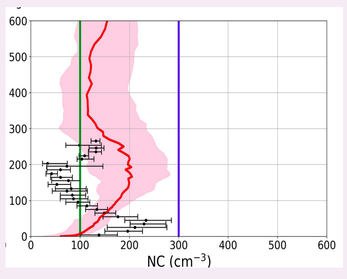
Stratus





Fog





Comparison with CDP measurements

LIMA:

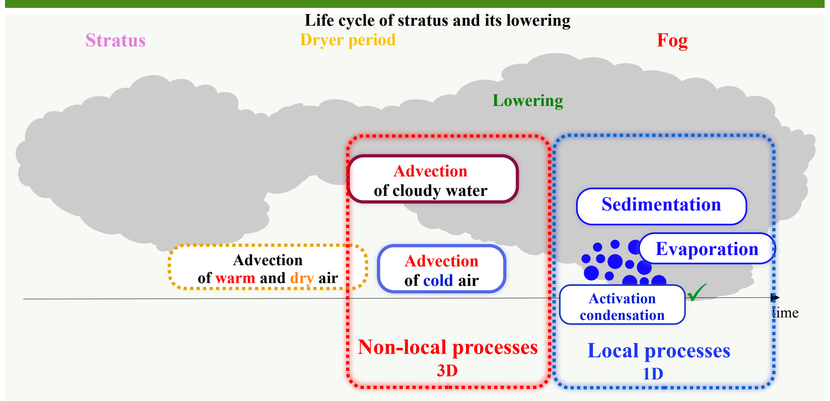
➢ **Differences between stratus and fog fairly well reproduced.**

ICE3:

➢ **NC=100 underestimates NC (stratus)**

➢ **NC=300 correct in stratus but not in fog**

Conclusion



Perspectives

- Investigation 2-3 cases of fog by STL during SOFOG3D:

  - Analysis of observations (radar, ceilometer, radiometer, thermodynamical and microphysical measurements)

  - LES simulations with Meso-NH and validation of the microphysics

  - Process study

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Vié, B et al. "LIMA (v1. 0): A quasi two-moment microphysical scheme driven by a multimodal population of cloud condensation and ice freezing nuclei." GMD (2016).
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