



Some results from the SOutH west FOGs 3D experiment for processes study (SOFOG3D) project

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Météo-France/CNRM - ¹IPSL/LMD - ²IPSL/LATMOS - ³UKMO

9th IFDA, Fort Collins, CO - 28/07/2023

Context

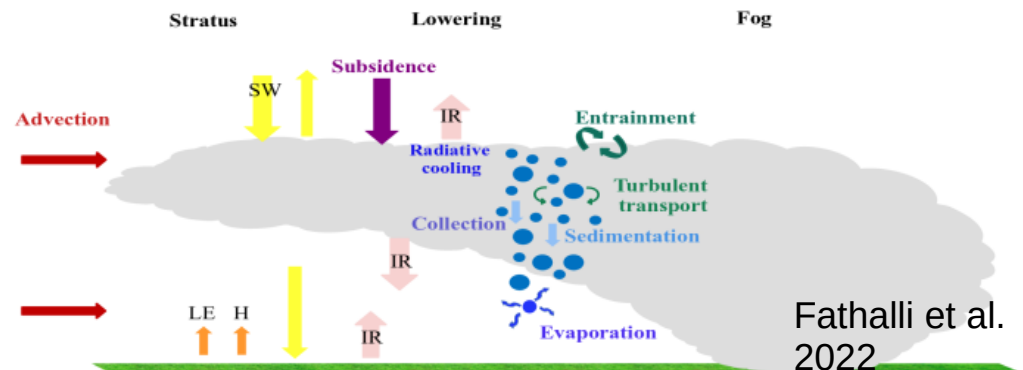
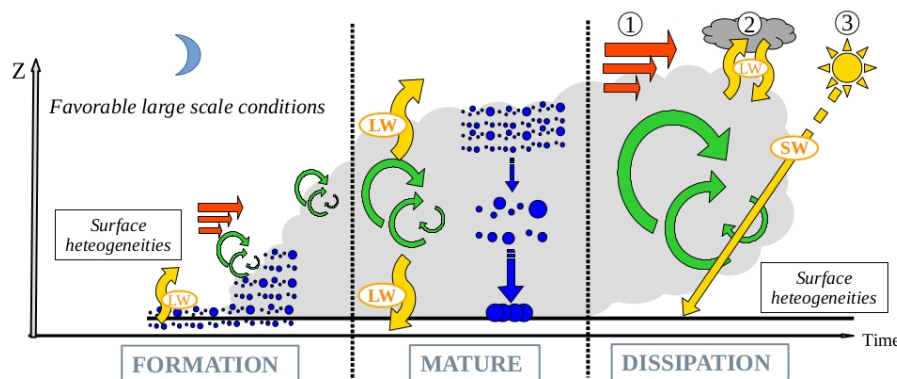


- High **economical impact** of **fog** on **transport** :
a specific research action started at Météo France for 5 years (COP 2017-2021)
=> Development of a high resolution version of the NWP model AROME-500m
- **SOFOG3D field experiment & ANR project**
 - Evaluation/validation of AROME-500m
 - improve our understanding of fog **processes to derive refined parameterizations** :
=> 3D high resolution LES simulations & experimental studies
 - new data assimilation tests
- **Collaborations :**
 - Météo France :
 - CNRM : GMEI & GMME & GMAP & CEMS
 - ENM (forecast), DSO (lidar, RS)
 - ANR :
 - IPSL/LMD (M. Haeffelin) and LATMOS (J. Delanoë)
 - UKMO (J. Price)
 - MWR network (TOPROF) : Univ Cologne, MeteoSwiss, RPG & Attex
 - ONERA, IRSN, LAERO



Objective and main scientific questions

- Provide a **3D characterization of fog layer properties** with detailed observations of dynamics, radiation, microphysics and surface fluxes
- Processes study using **synergy between 3D high-resolution LES and detailed observations**
 - Dynamics : **impact of surface heterogeneities** on the spatio-temporal variability of the fog ?
 - Microphysics : **transition between thin and thick fog**, impact of aerosols ?
 - **Stratus to fog transition** : microphysics and local processes vs large scale conditions ?
- **Data assimilation of local observations : microwave radiometer (MWR) network & radar 95GHz**
- ANR funding : 5 years project (2018-2023)



Fathalli et al. 2022

SOFOG3D Experimental strategy

- 6 month experiment : Fall-winter 2019-2020
- 3 nested domains

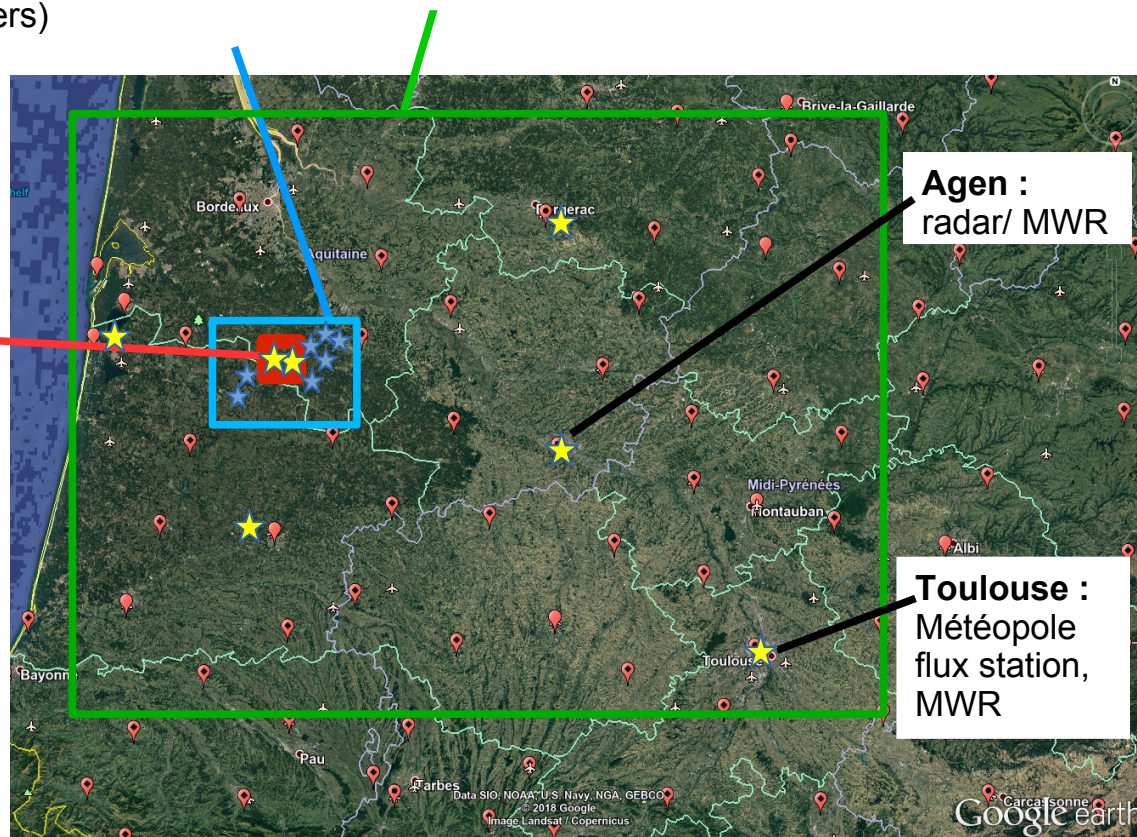


Surrounding domain 50 x 30 km
with increased density in-situ sensors network (+7 surface met. stations, visibility, +2 ceilometers)

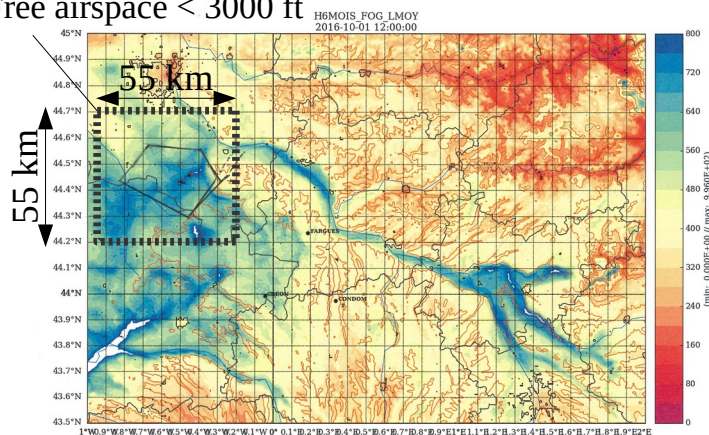
Larger domain 300 x 200 km (AROME-500m model) with in-situ sensors (~ 50 surface meteor. stations) and MWR (6 sites) networks

Super-site 10 x 6 km:

- radar/MWR/lidars
- tethered balloon ; UAVs fleet
- 10 met. stations ; 50 m mast (2)
- sites with **different vegetation types:** heat and turbulent fluxes, radiation budget, aerosol and fog microphysics, water deposition, visibility, 3 ceilometers



Free airspace < 3000 ft



Hours of fog occurrence
AROME winter 2016-17

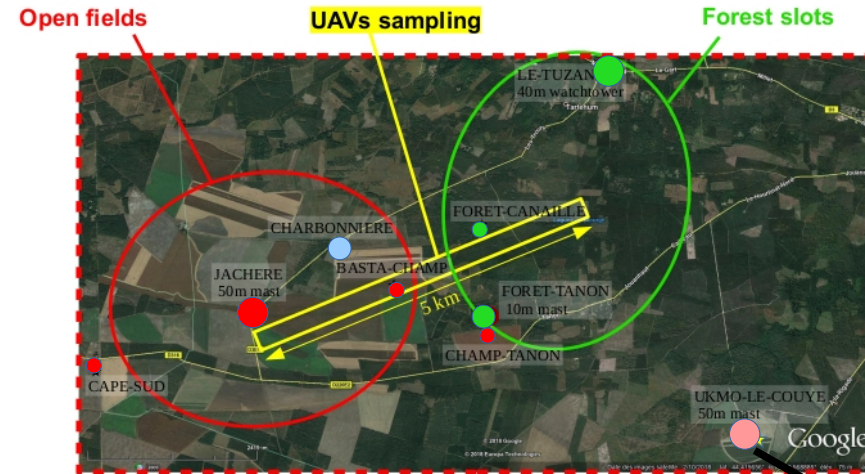
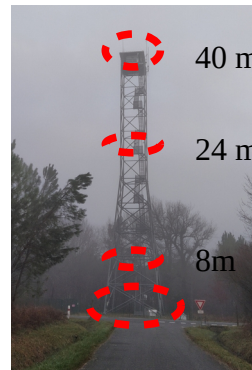
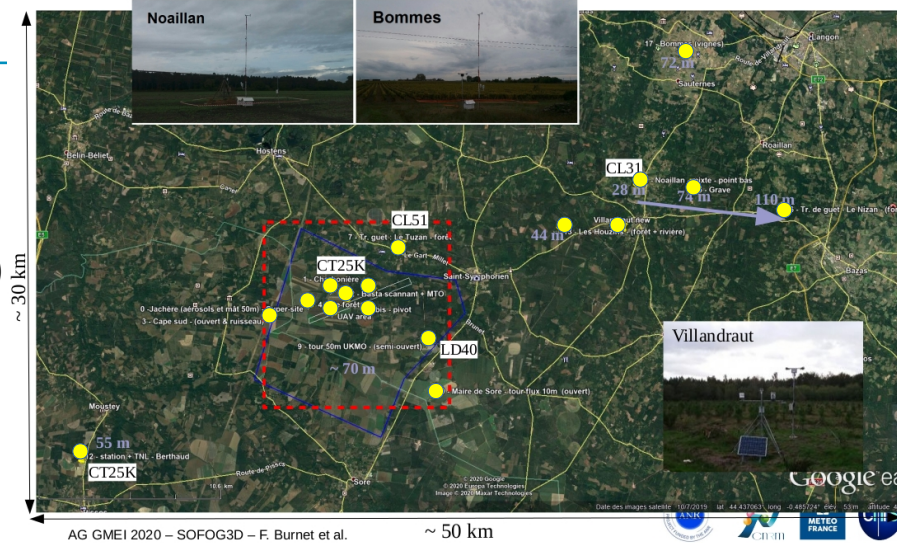


Observationnal set-up

- **Surface network => contrast open fields / pine forest**
 - 17 stations with 2 50m-masts
- Combine remote sensing (radar, MWR, lidar, ceilometer,...) and in situ (fluxes, aerosols, microphysics,...)
- Automatic systems and IOP triggered on forecasts :
 - tethered balloon, RS and UAV

SOFOG3D surrounding domain : 7 sites (+ 10 super-site)

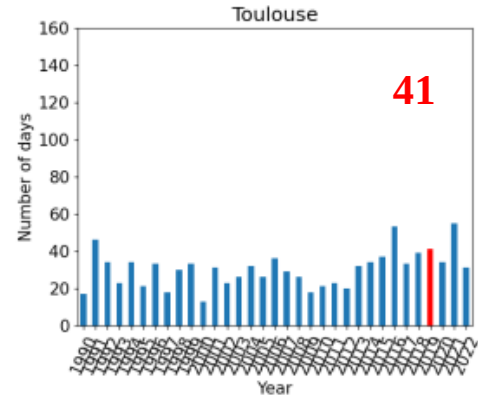
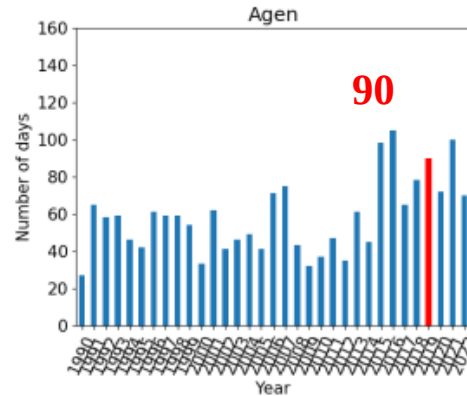
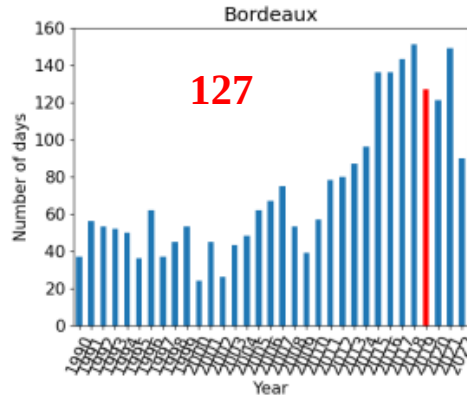
=> sol : 2 stations UMKO + 5 stations SAMHA de 4M + tour du Nizan



Fog occurrence and classification

- Number of foggy days per autumn-winter (Sept.-March) since 1990 :

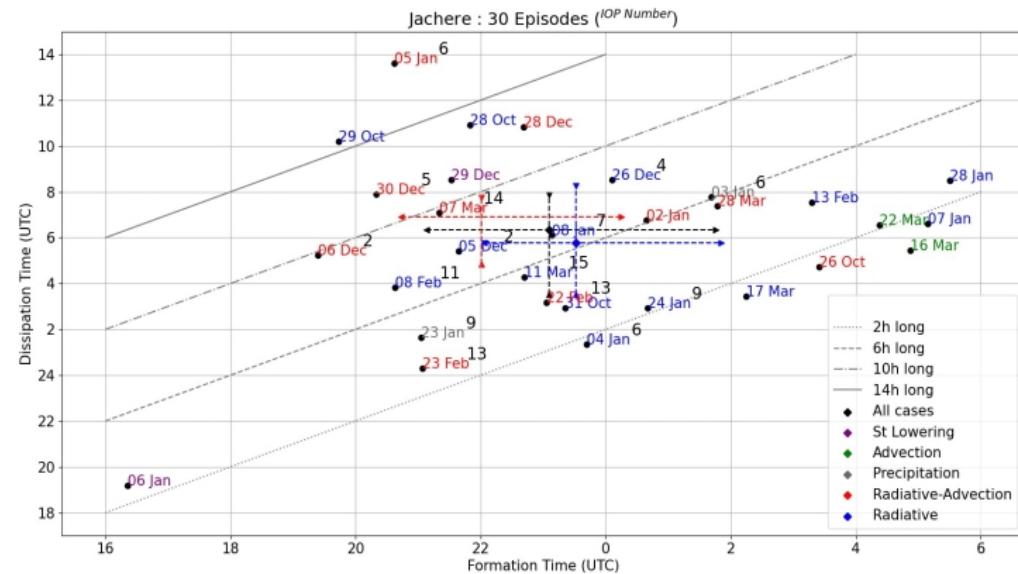
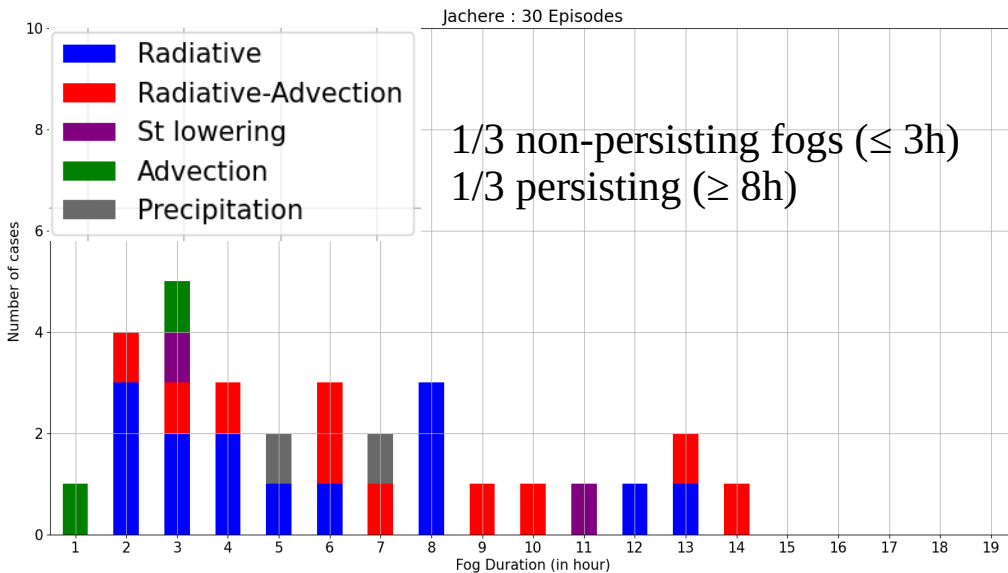
**SOFOG3D
2019-2020**



- 30 fog events at the super site (less than expected)**

- 14 radiation and 10 radiation-advection
- 2 advection, 2 St lowering and 2 precipitation

- Fog forms and dissipates at anytime during the night

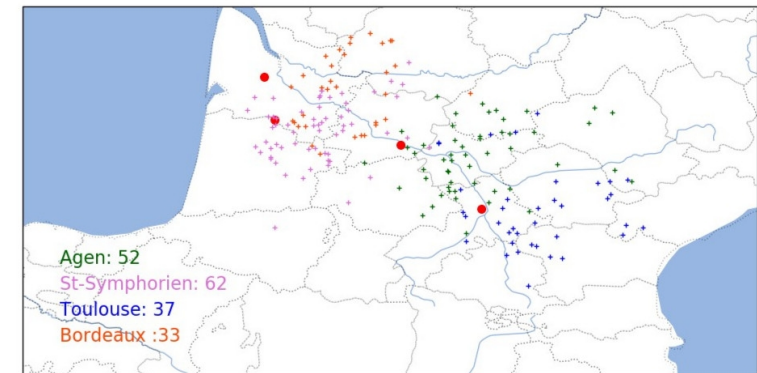
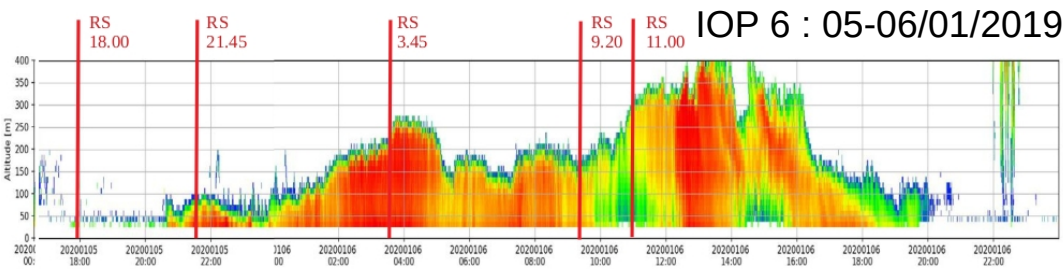


IOP overview : 01/12/2019 => 12/03/2020

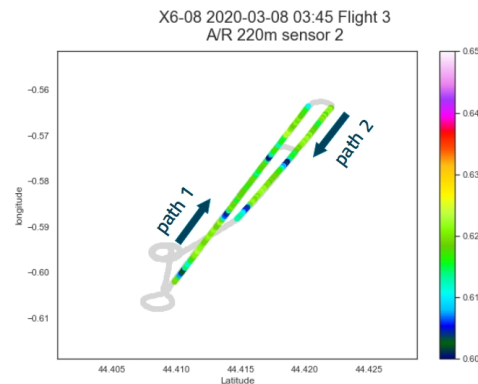


- **15 IOP => 20 nights of tethered balloon operations + RS:**
 - 5 without fog (or just mist)
 - 8 thin fogs with width $H \leq 50$ m
 - 4 medium with $80 \leq H \leq 180$ m
 - 3 thick $H \geq 200$ m : **IOP-6, 11 and 14**
- 15 fog events**
- 5-6 Jan. (250m), 8-9 Feb. (250m) and 8-9 March (200m)

- **184 RS** over the whole domain

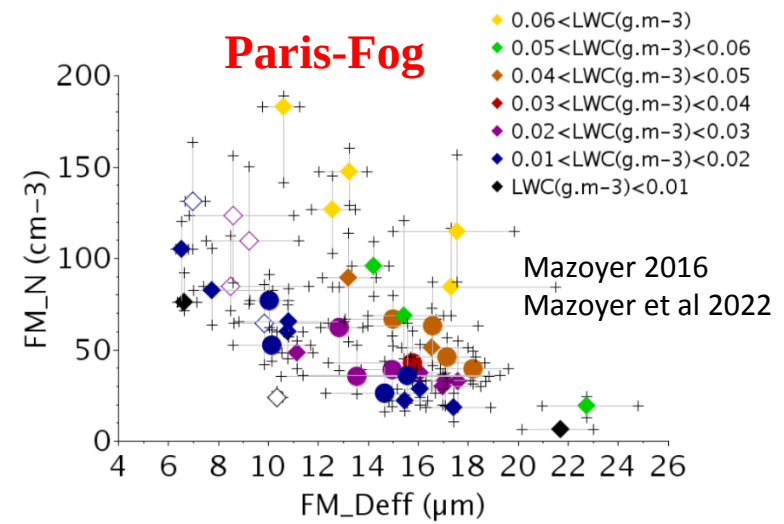
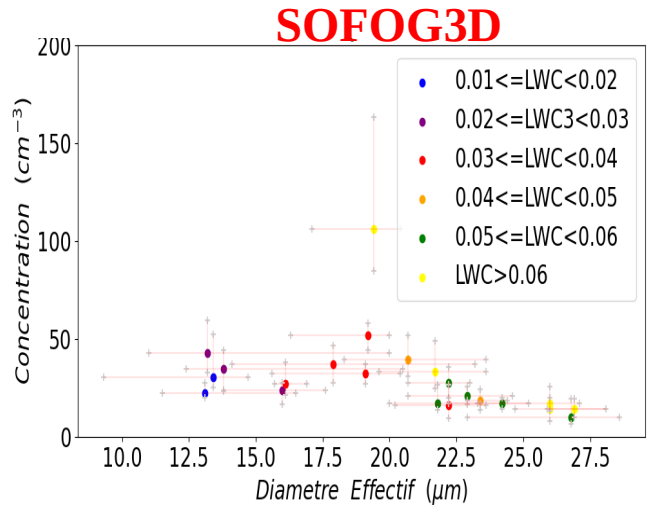


- **7 IOP with UAV flights - 5 km legs**

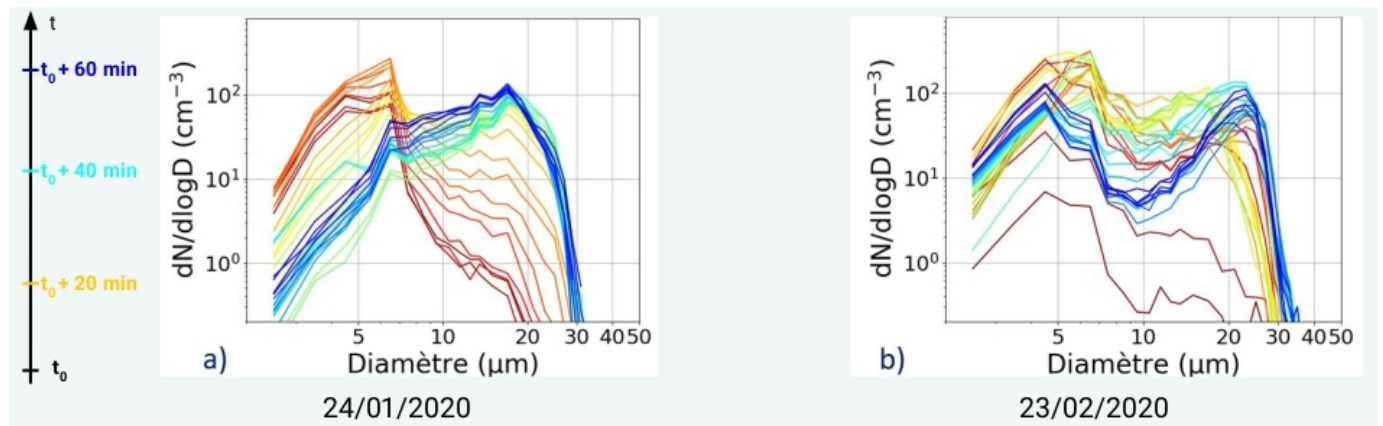


Microphysics properties :

- FM120 measurements at Jachère site : **low CDNC (< 50 cm⁻³) of large droplets**

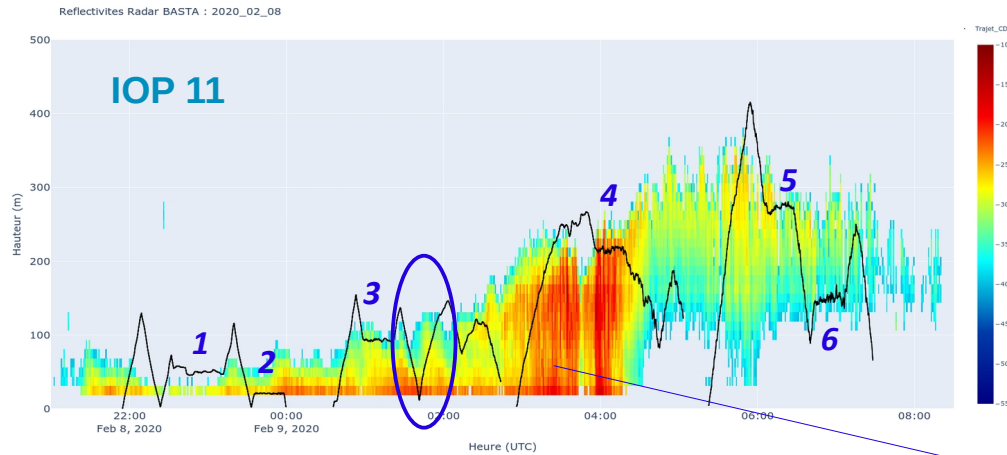


Many bimodal droplet size distributions

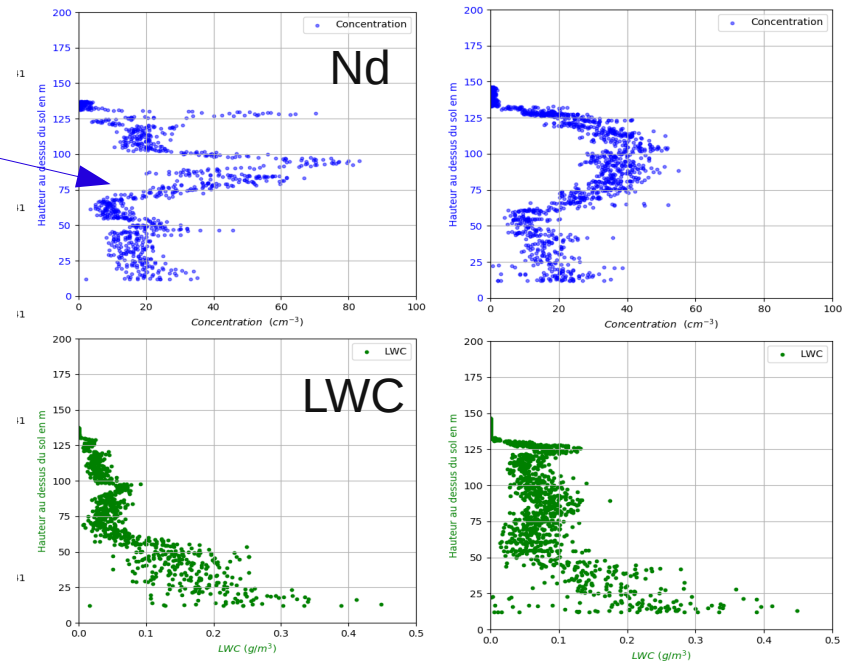


Vertical profiles of fog microphysics

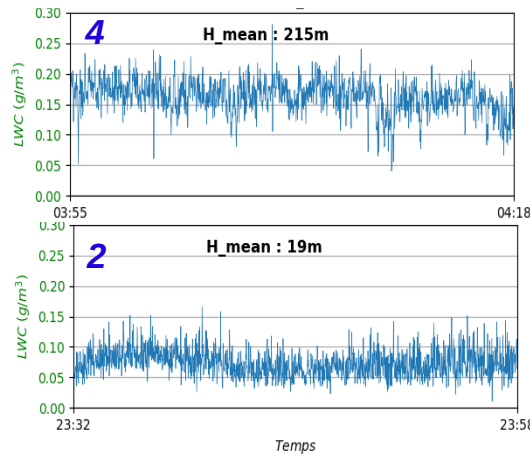
- CDP below tethered balloon : contrast constant leg / profiles



Vertical profiles :



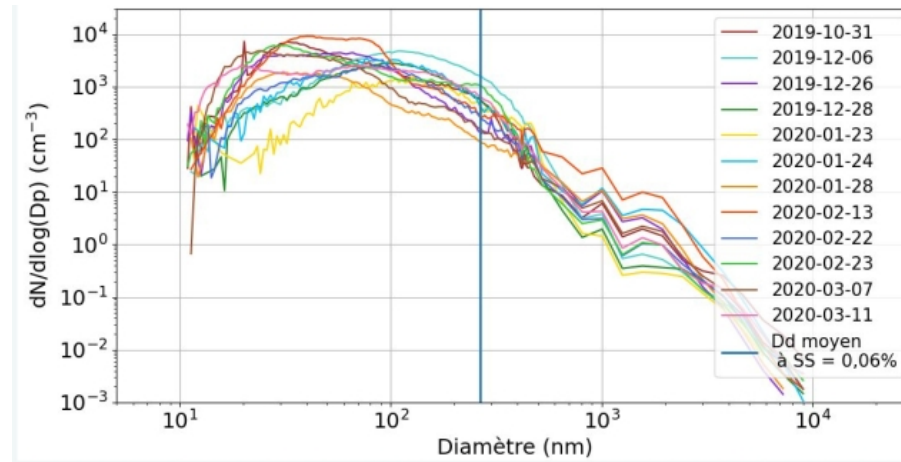
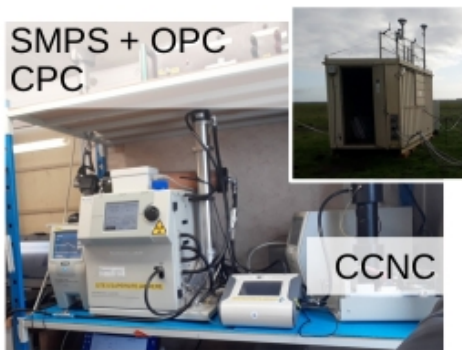
Constant altitude leg
25 min long :



- Life cycle and thin to thick transition => T. Costablos presentation

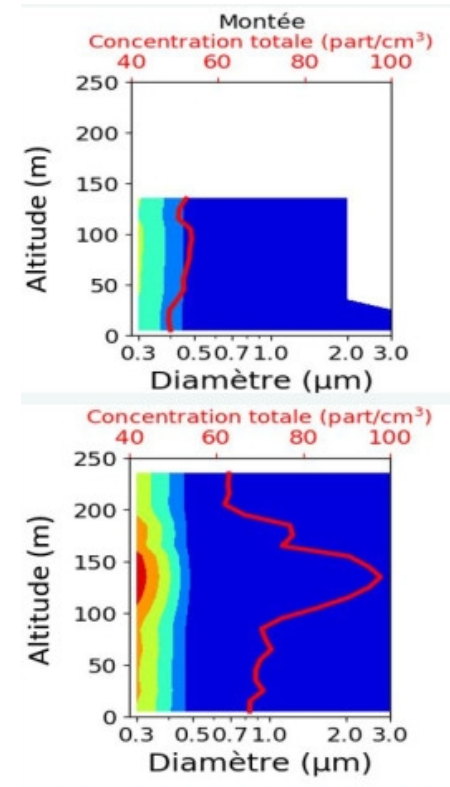
Impact of aerosols :

- **Microphysics, radiatives and hygroscopic properties of aerosols**
 - low concentration ($\overline{Na} \sim 2500 \text{ cm}^{-3}$)
 - $0.19 < \kappa < 0.38 \Rightarrow$ impact of organics

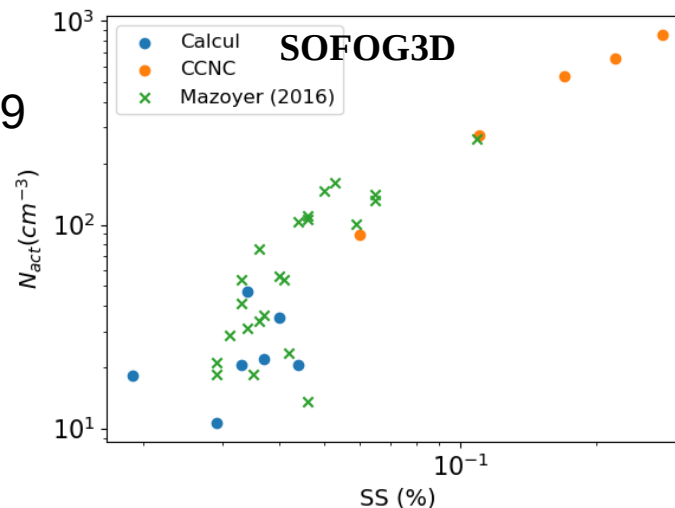


Vertical variability

OPC below tethered balloon before fog event



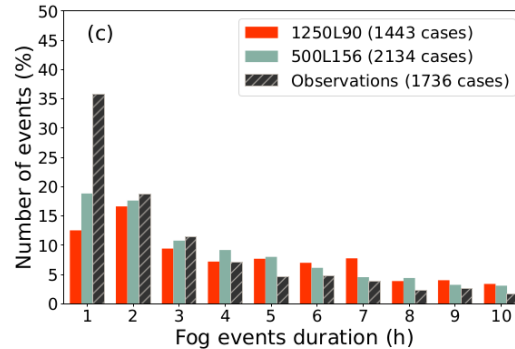
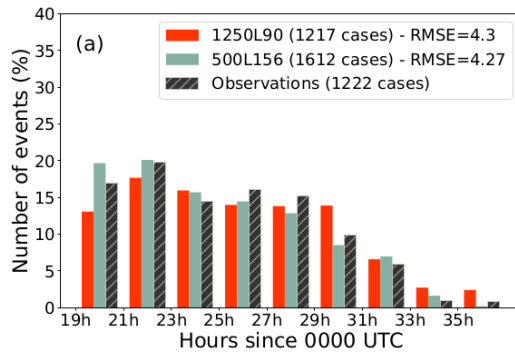
- **Nact vs. Supersaturation**
following Mazoyer et al. 2019
 - $N_{act} < 50 \text{ cm}^{-3}$
 - $SS < 0.05\%$



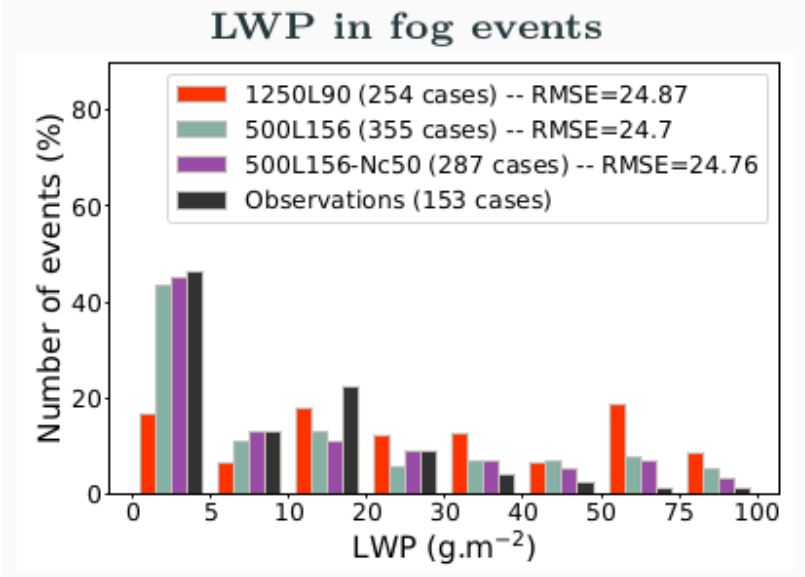
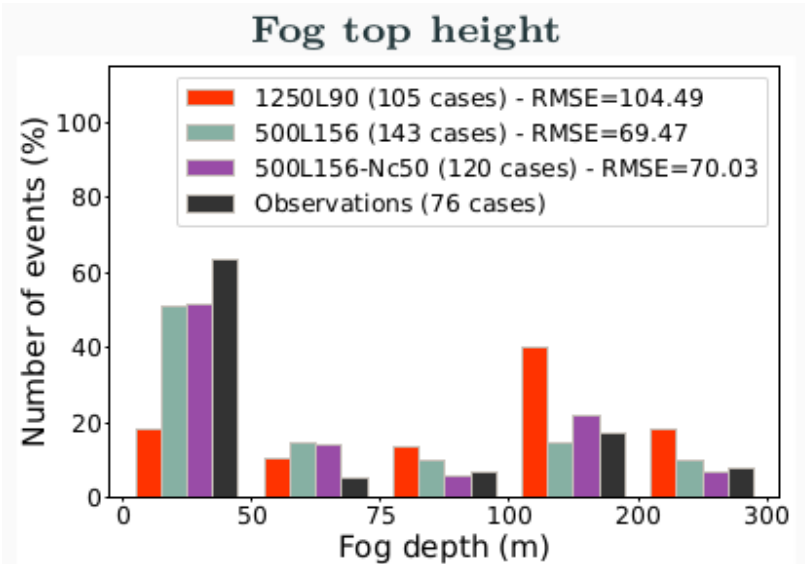
AROME-500 evaluation

Antoine et al. 2023
WAF-D-22-0215

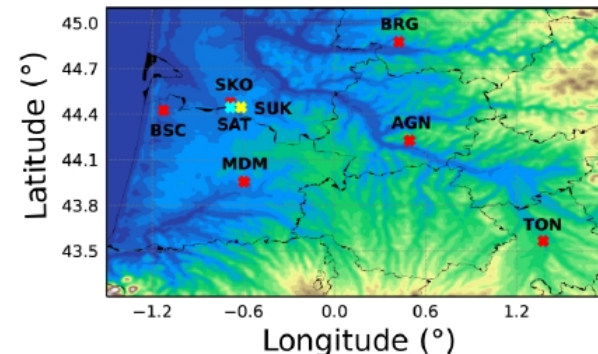
Configurations	1250L90 Reference (\approx AROME-France)	500L156 Adapted to fog	500L156-Nc50
Horizontal resolution	1250 m	500 m	500 m
Number of vertical levels	90	156	156
First level height	5 m	1 m	1 m
Initialisation and coupling	AROME-France forecasts		
Micophysical scheme	ICE3	LIMA	ICE3
Droplet deposition	No	Yes	Yes
ICE3 droplet concentration	300 cm^{-3}	-	50 cm^{-3}



- Simulations at 0h UTC for 48h every day
- Over all sites for the entire night (+18 to +36h) :
 - Increase of the detection rate 63 vs **74** %
 - but also of the false alarm rate 35 vs **44** %
- more fog with low LWP and thin layer
less fog with high LWP and thick layer
 - linked to reduced CDNC values
- Reduction of the fog formation delay (turbulence)



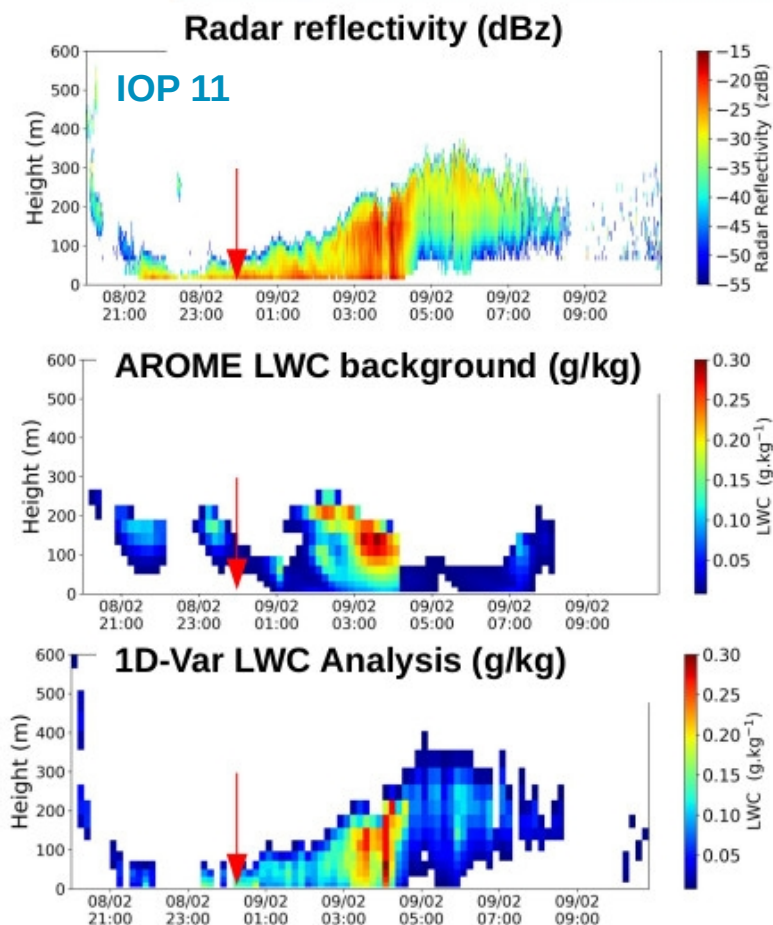
New data assimilation in AROME



- **3D-Var assimilation of MWR temperature profiles :**

- 8 MWRs deployed at 6 sites (Martinet et al. 2022)
- **significant improvement of the temperature profiles biases** in the first 2 km of altitude and for several hours (Thomas et al. 2023 in prep.)

- **1D-Var assimilation of combined cloud radar Z and MWR BT**

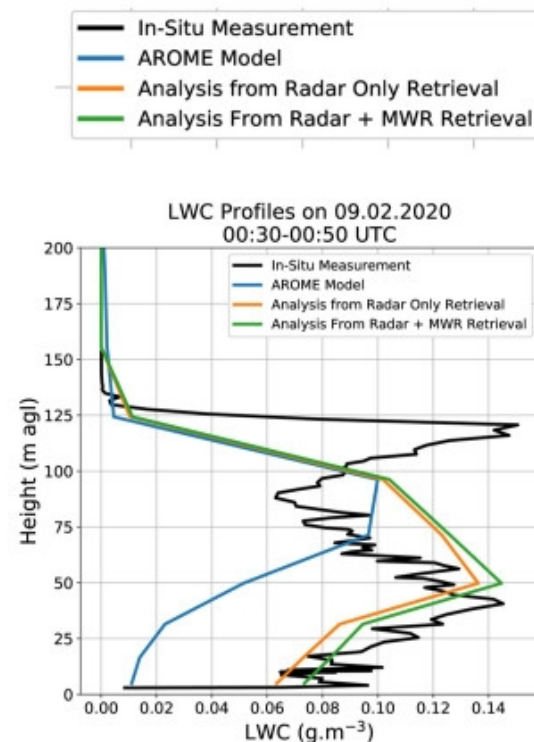


- Significant temporal and fog top heights errors in the AROME background profiles (nearest in time).

- 1D-Var retrievals much more **consistent** with the observed fog structures compared to the BASTA cloud radar.

- Good agreement between 1D-Var retrievals and in-situ CDP measurements

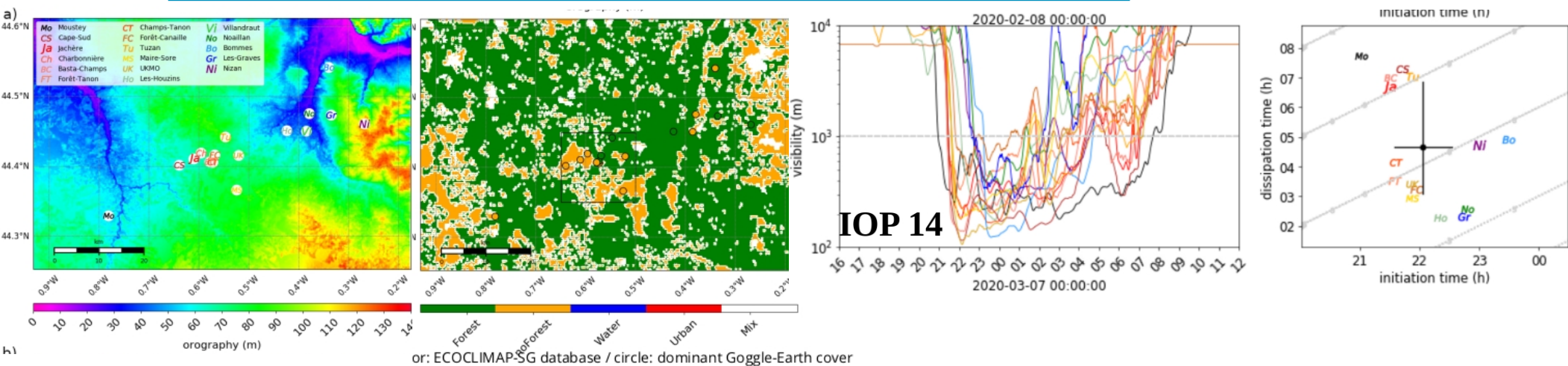
(Bell et al. ACP 2022)



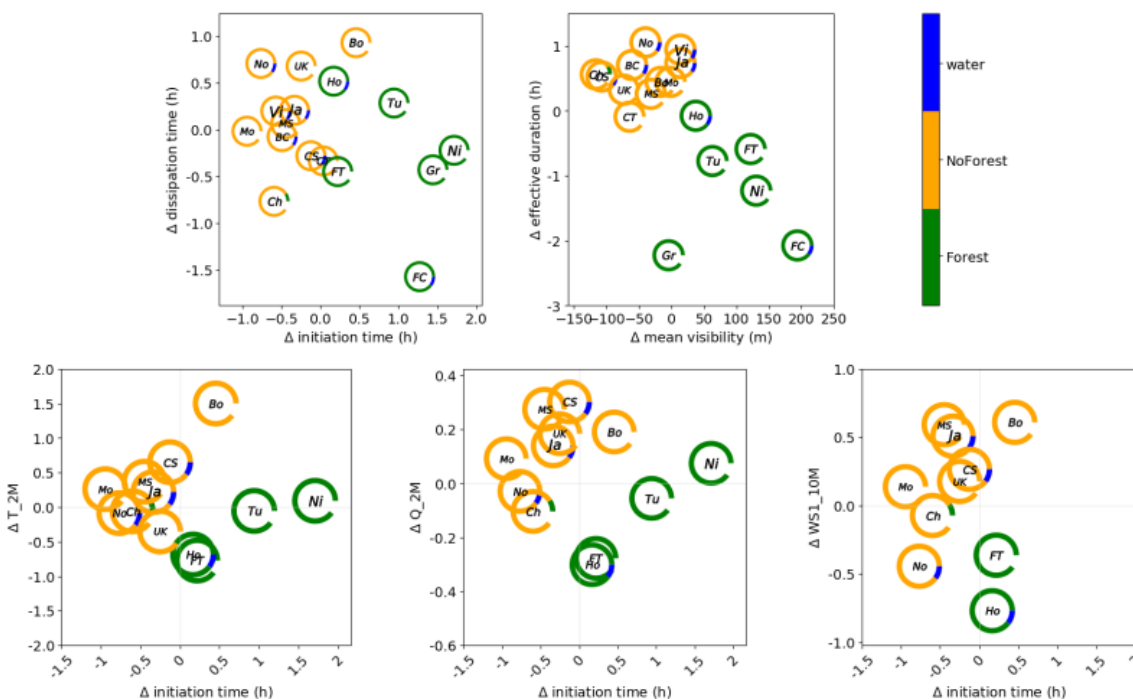
METEO FRANCE

Impact of surface heterogeneities

Taufour et al. 2023
in prep.



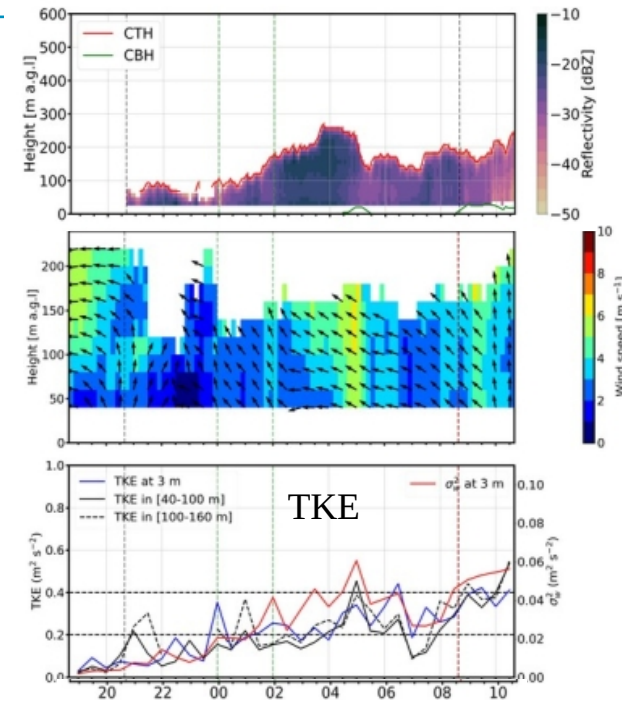
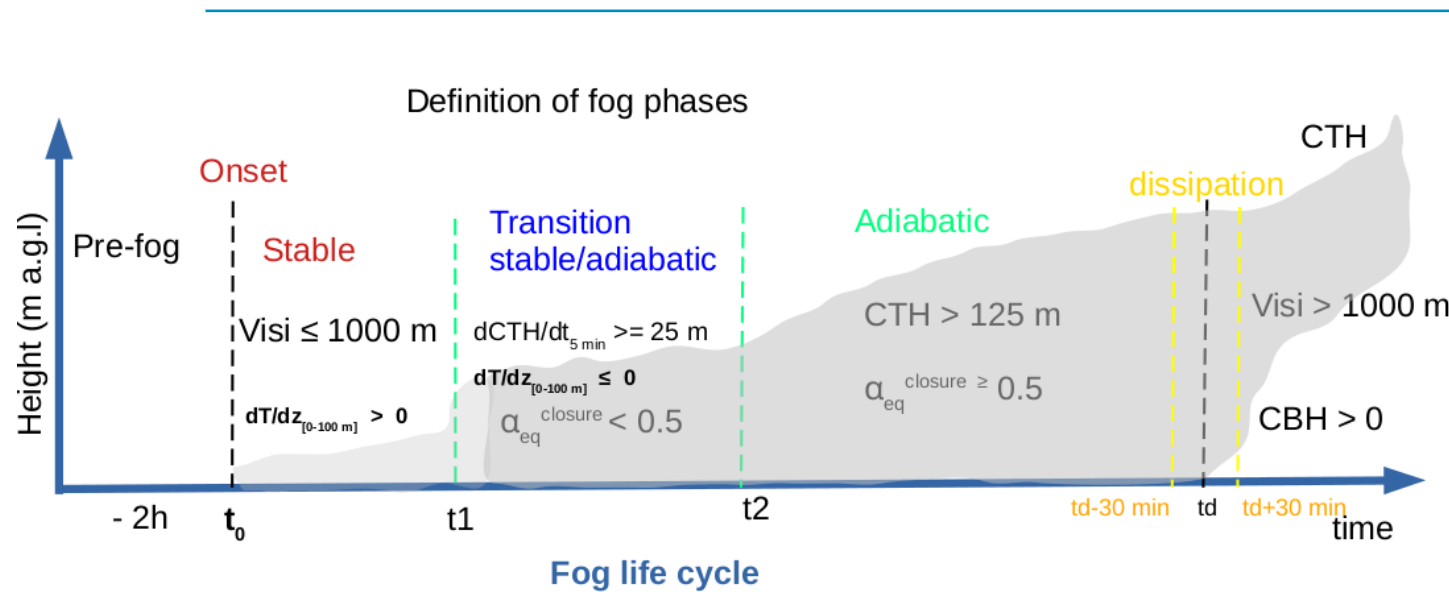
Comparison between forest and non-forest sites from the whole measurement database



- Delayed initiation on forest sites
- No impact of ground cover during dissipation
- Shorter fog durations in forest
- Higher visibilities (3m) in the forest
- Lower temperatures, humidities and wind speeds at the forest sites during the three hours preceding the fog formation

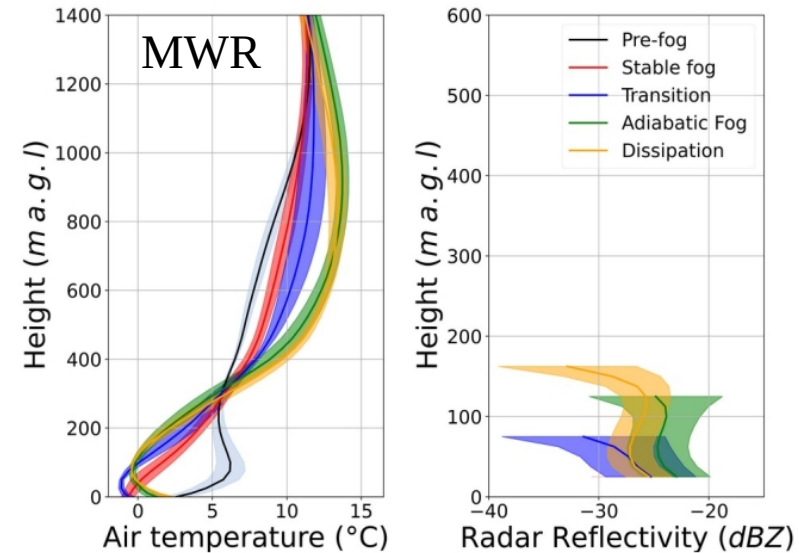
Role of thermodynamics and turbulence

Dione et al., 2023, ACPD



- Analysis of the 4 deepest fogs from remote sensing
 - radar, MWR, wind lidar and ceilometer
- Longer duration for stronger temperature inversion
- Thin to thick transition :
 - TKE increases to 0.2-0.4 m²s⁻²
- Dissipation : TKE > 0.4 m²s⁻²
 - mechanical for nighttime, thermal for daytime
- Nowcasting with the adiabatic conceptual model

IOP 6



Summary

- More details See <http://www.umn-cnrm.fr/spip.php?article1086>
- **6 month campaign provided a large amount of data** <https://sofog3d.aeris-data.fr/catalogue/>
- On going / future work
 - Presentations of T. Costabroz and M. Fathalli this session
 - Contrasting fog life cycle open site / forest (Thornton et al., QJRMS in review)
 - LWC profile retrieval from cloud radar (Vishwakarma et al. AMT 2023)
 - Meso-NH simulations at 100m resolution already performed for the 3 IOP 6, 11 & 14
 - UKMO modeling work with simulations with UM (McCabe et al in prep.)
 - LWC deposition (Price et al. in prep)
 - volume sampling with scanning radar and UAV flights with ~5 km legs to be analyzed
- **Many thanks** to all people involved in preparation, forecasts, operations, processing...

