Caractérisation 3D des brouillards : observations de la campagne SOFOG3D :

SOuth west FOGs 3D experiment for processes study

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Toute l'équipe technique du CNRM/GMEI et beaucoup d'autres...

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

Journée scientifique du SIRTA, 16/09/2022

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

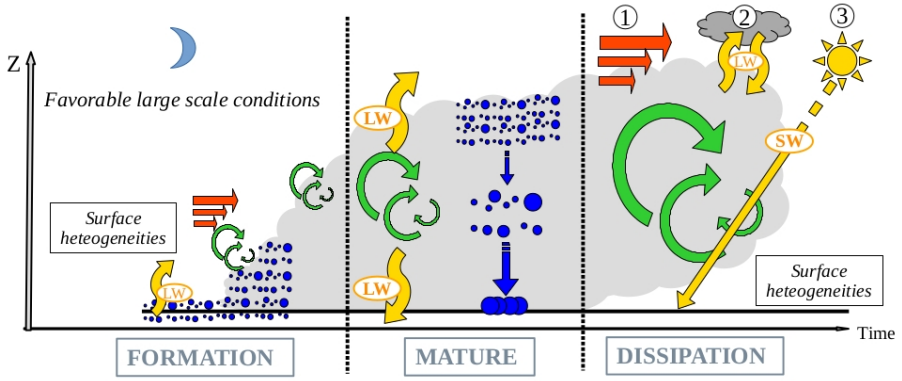
- **Collaborations :**
  - Météo France :
    - CNRM : **GMEI & GMME & GMAP & CEMS**
    - ENM (forecast), DSO (lidar, RS)
  - ANR :
    - IPSL/LMD (M. Haeffelin) et LATMOS (J. Delanoë)
    - UKMO (J. Price)
    - MWR network (TOPROF) : Univ Cologne, MeteoSwiss, RPG & Attex
  - ONERA, IRSN, LAERO

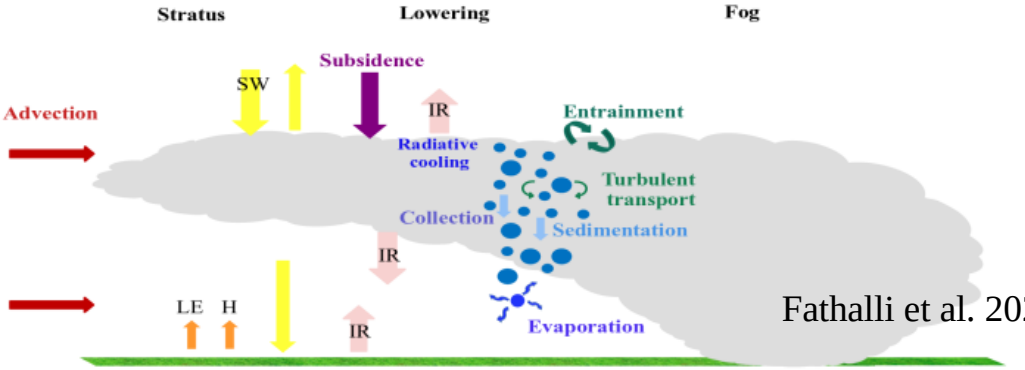
ANR SOFOG3D – 5 years (01/10/2018-30/09/2023)

- **Provide a 3D caracterization 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 ?
    - Impact of entrainment and turbulent mixing at the top of the fog layer
  - Microphysics **:**
    - **Is transition between thin and thick fog mainly driven by microphysics ?**
    - Impact of aerosols, evaluate improvement of the two-moment scheme LIMA
  - **Stratus to fog transition :** do microphysics and local processes influences St lowering or is it mainly driven by large scale conditions ?

- **Data assimilation of local observations : MWR network & synergy with radar 95GHz**





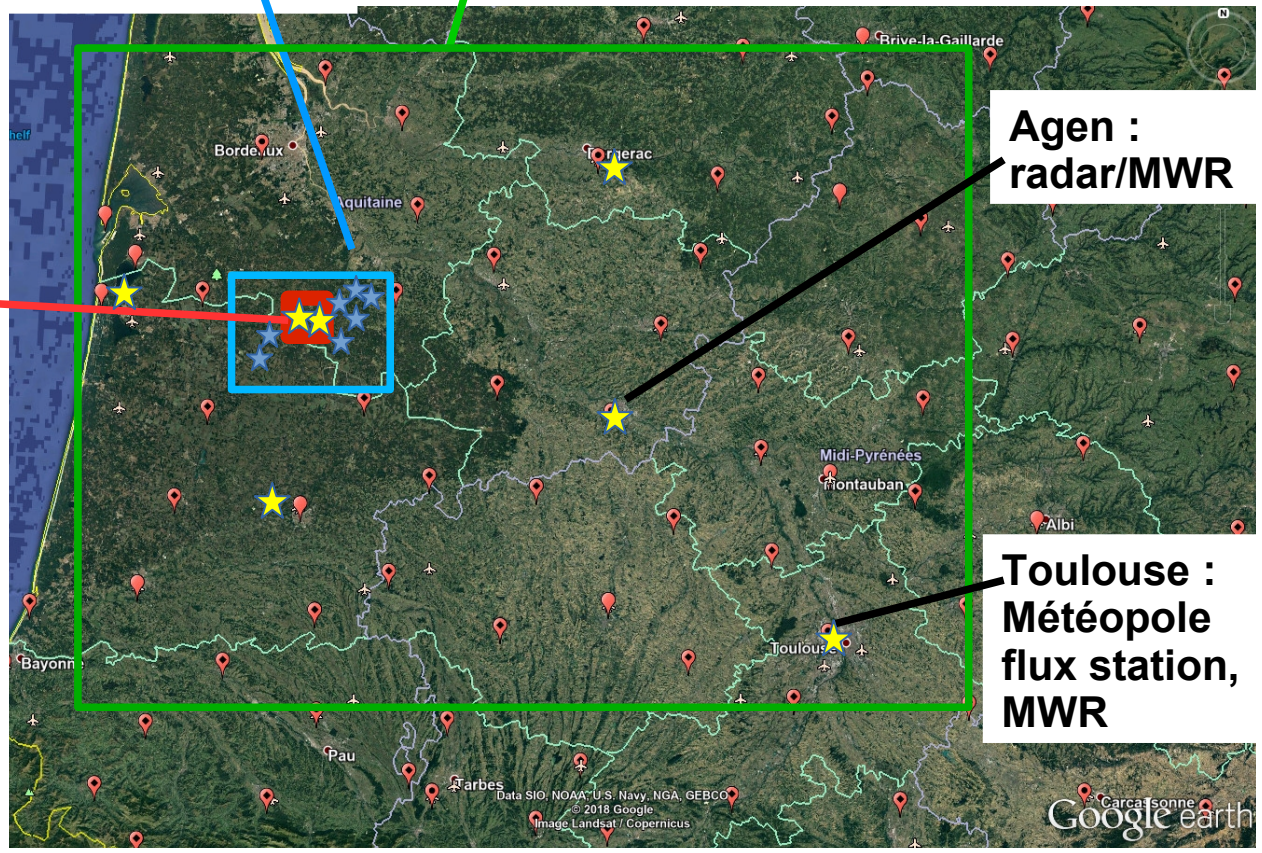
Fathalli et al. 2022

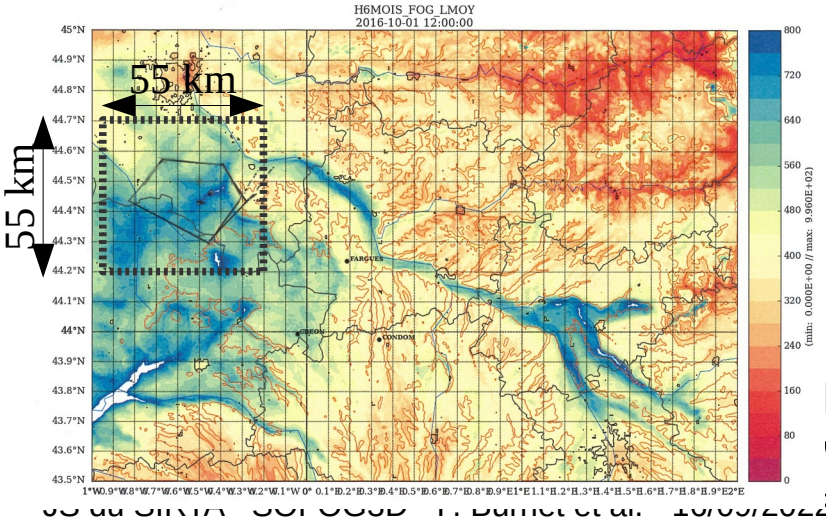
SOFOG3D Experimental strategy : winter 2019-2020

Surrounding domain 30 x 50 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

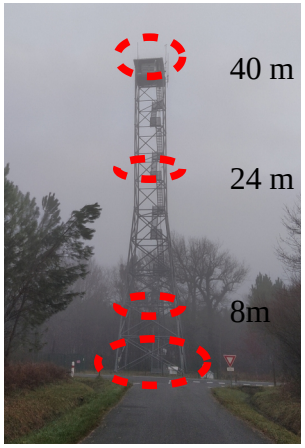
Super-site 10 x 10 km:
- **radar/MWR/lidars**
- **tethered balloon ; UAVs fleet**
- 10 met. stations ; **50 m mast (2)**
- sites with **different vegetation types**: heat and turbulent fluxes, radiation budget, aerosol and fog microphysics, water deposition, visibility, 3 ceilometers





Hours of fog occurrence AROME winter 2016-17 (Y. Seity)

SOFOG3D Super-site experimental strategy :



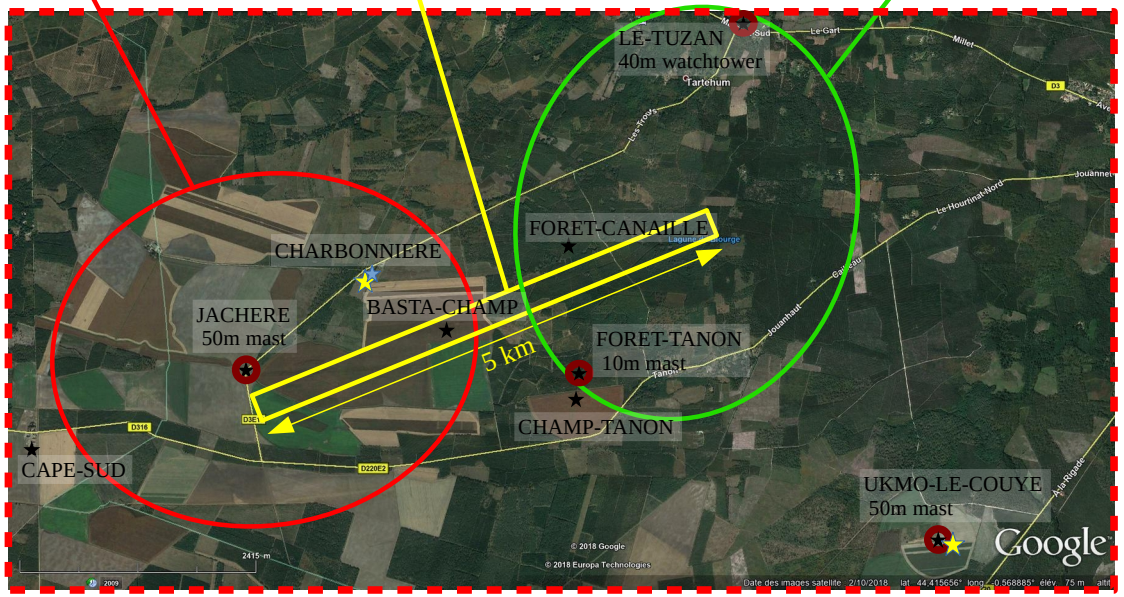
Super-site 6 x 10 km

- zone d'opérations ballon captif, drones et RS
- 2 radars nuage, 3 MWR, lidars aérosols et vent, 3 télémètres,
- container aérosols, microphysique, 9 stations météo., mâts de 10m et 50m, et une seconde tour de guet de 40m instrumentée.

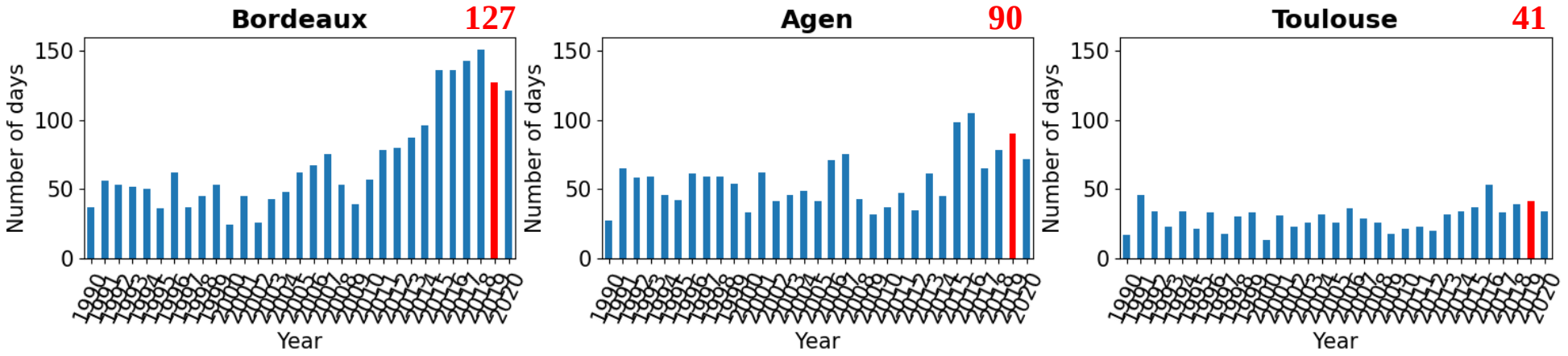
Surfaces cultivées

Zone de vol des drones

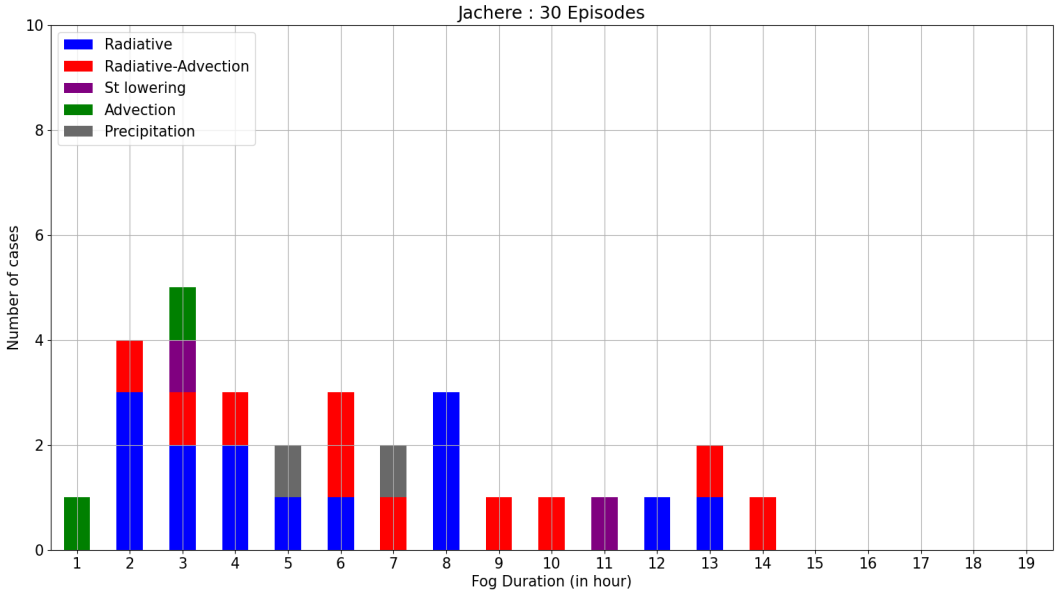
Forêt de pins des Landes



Nombre d’épisodes hiver par sites :



Super-Site 2019/2020 : 30 épisodes



- 14 radiatif
- 10 radiatif-advectif
- 2 advection
- 2 affaissements de St
- 2 précipitation

Formation en moyenne entre 22h et 00h
Dissipation entre 6h et 8h

(T. Costabloz)

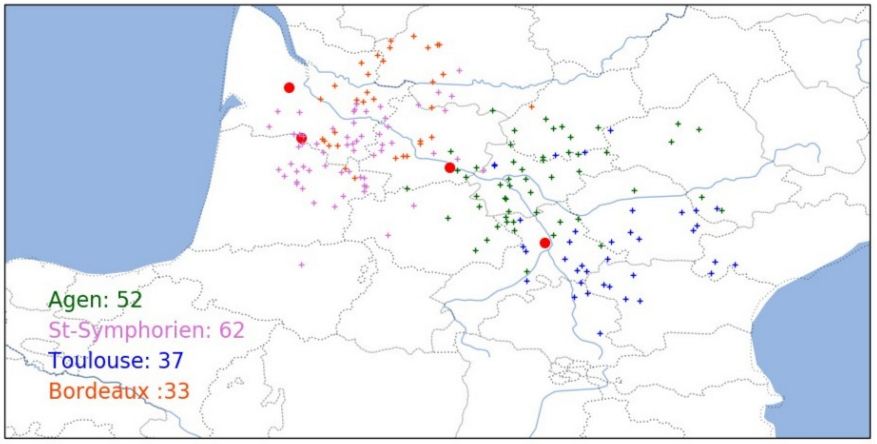
IOP overview : 01/12/2019 => 12/03/2020

- **15 IOP => 20 nights of tethered balloon operations + RS:**
  - 5 without fog (or just mist)
  - 8 thin fogs with width H ≤ 50 m
  - 4 medium with 80 ≤ H ≤ 180 m
  - 3 thick H ≥ 200 m : **IOP-6, 11 and 14**

  } **15 fog events**

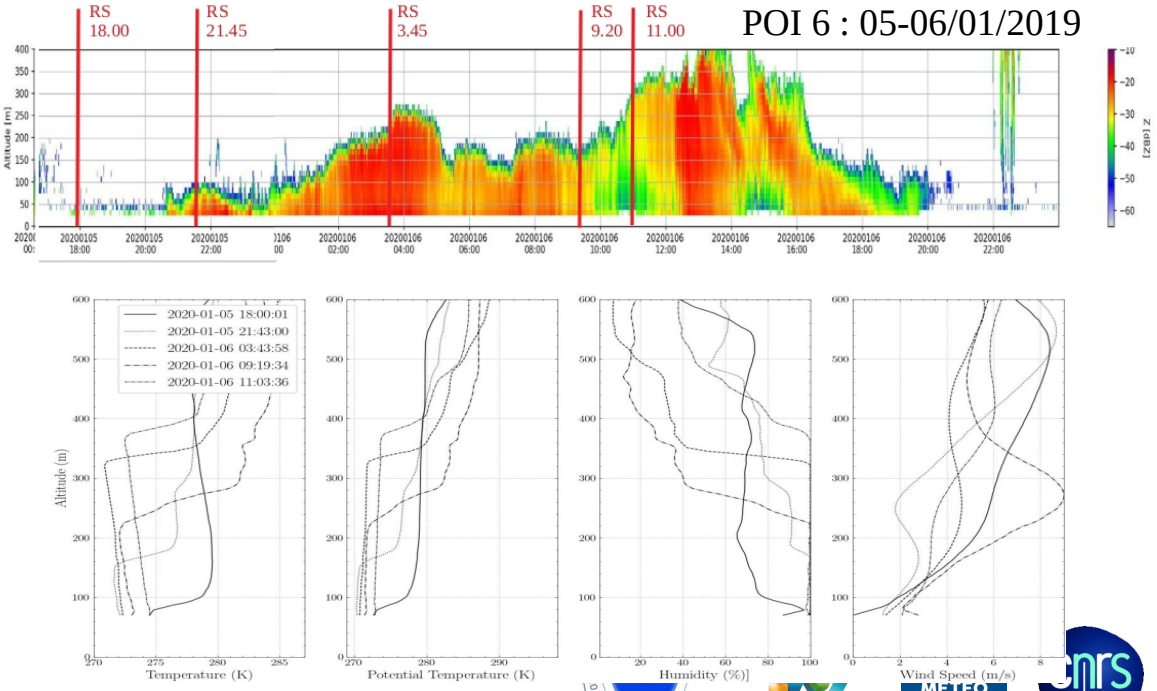
  5-6 Jan. (250m), 8-9 Feb. (250m) and 8-9 March (200m)

- **184 RS** over the whole domain



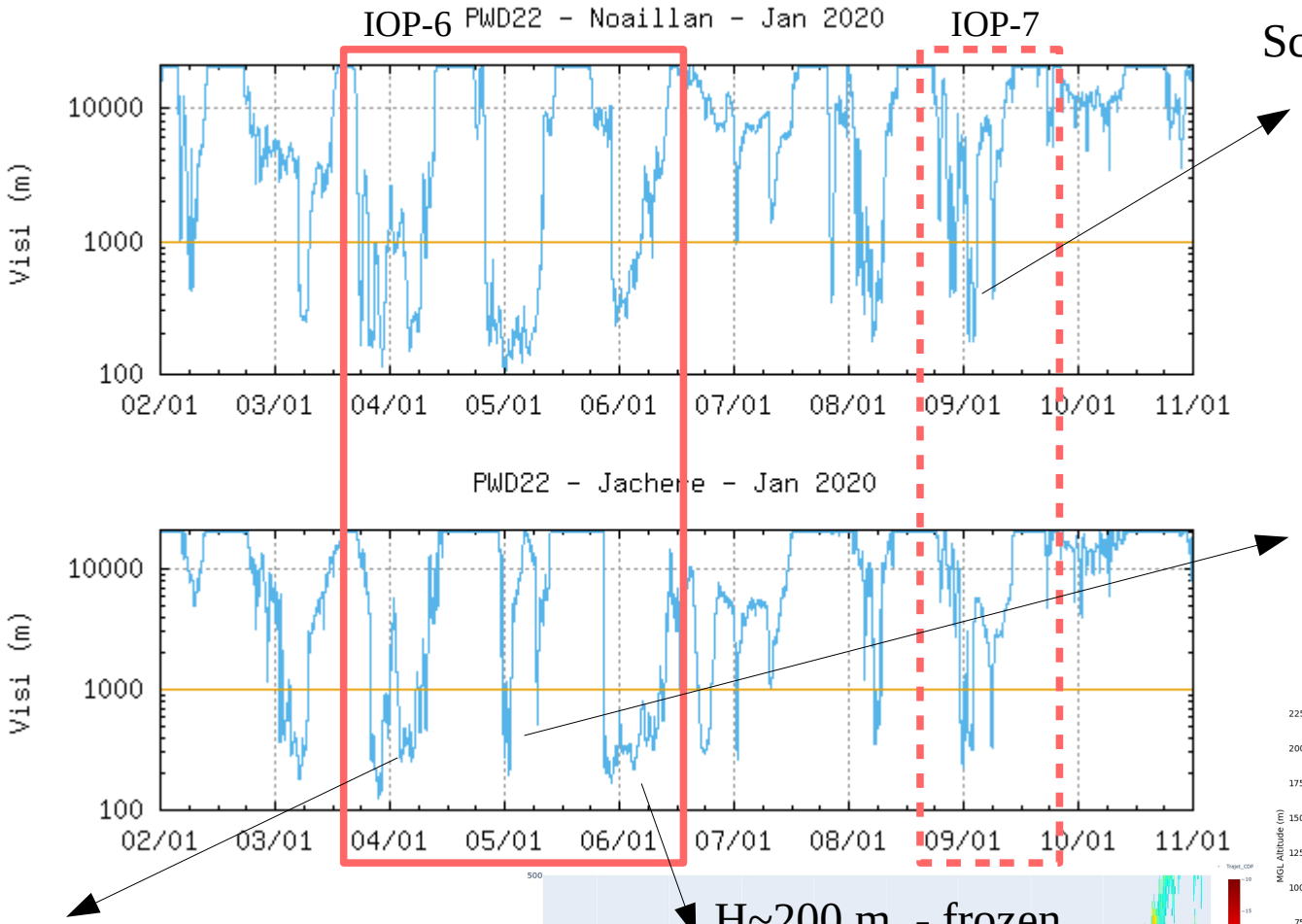
(A. Roy)

POI 6 : 05-06/01/2019



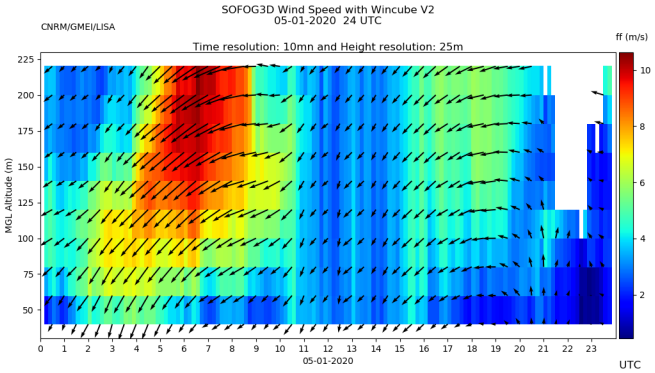
IOP-6 : from January 4 to 7, 2020

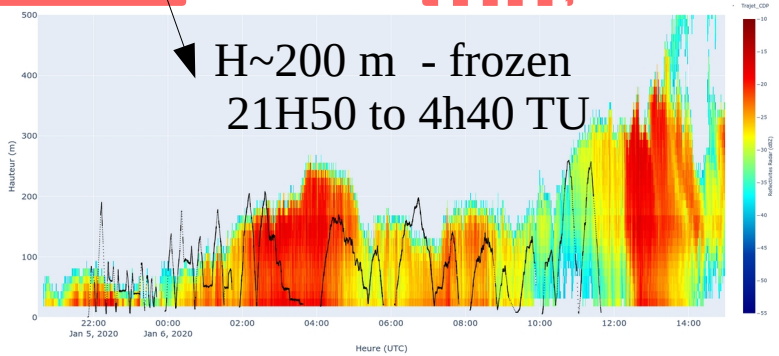
- 3 days of tethered balloon operations : large differences Noaillan / Super-site



Sc stops the fog developpement :

H~35 m ; 0h15 to 2h TU
Nocturnal jet stops the fog developpement :

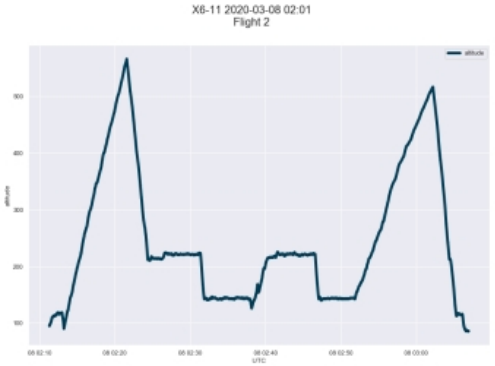


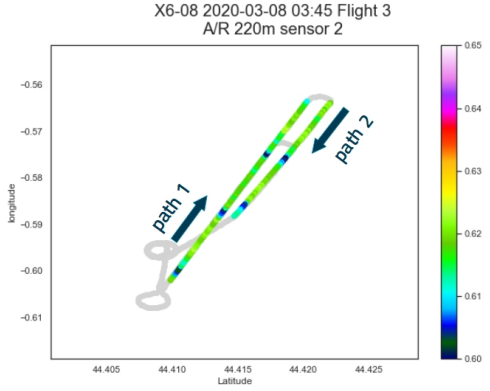


H~100m then St :
(21h30)- 3h30 to 9h TU
Clouds above 0.5-2 km

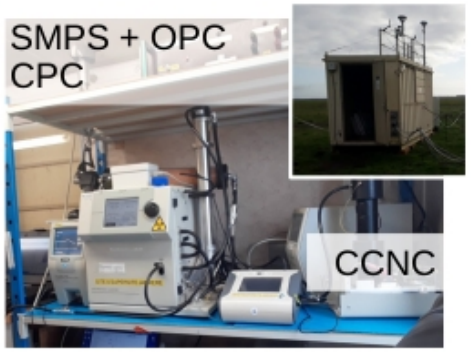
Une grande base de données in situ et télédetection

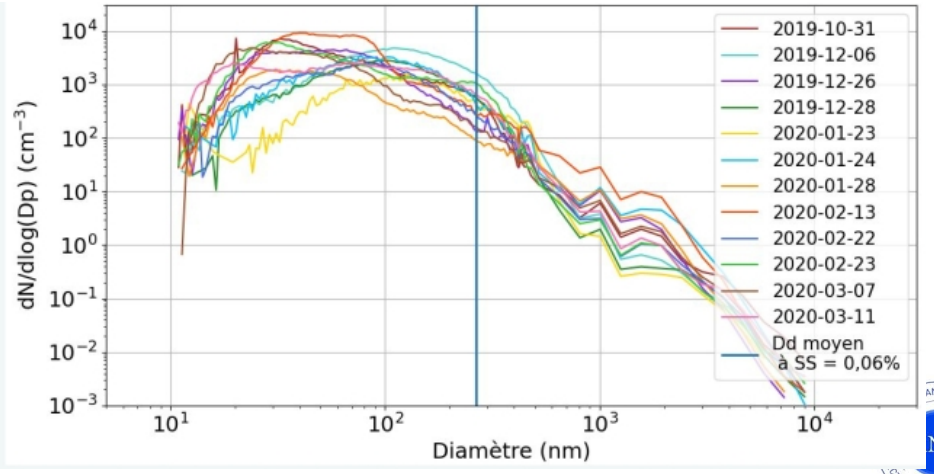
- 7 POI avec mesures UAV - G. Cayez / G. Roberts

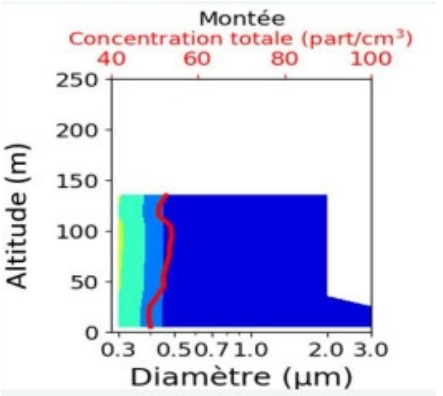


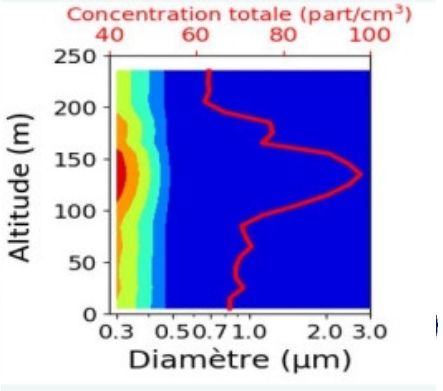


- Propriétes physico-chimiques des aérosols et CCN - C. Denjean
  - concentration plutôt faible ($\overline{Na}$ ~ 2500 cm^{-3})
  - 0.19 < κ < 0.38 => impact des organiques







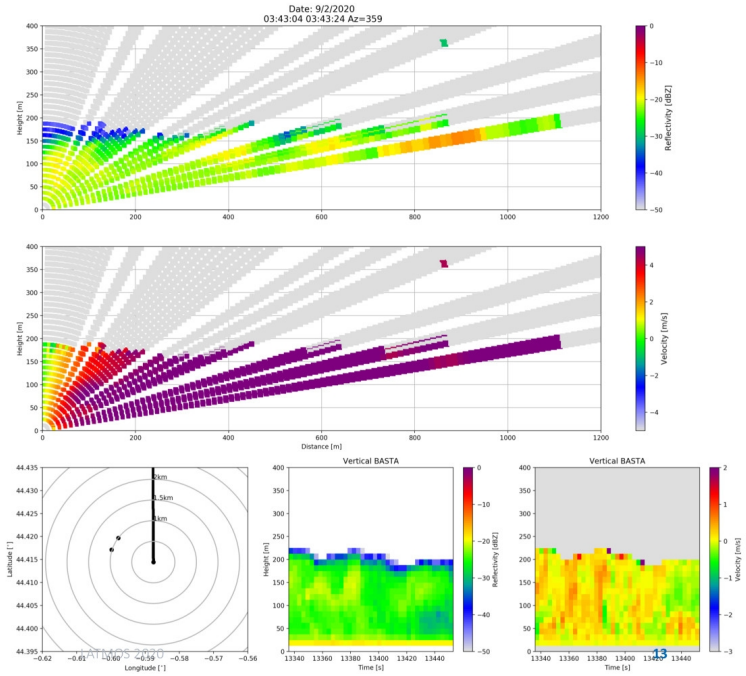


Une grande base de données in situ et télédetection

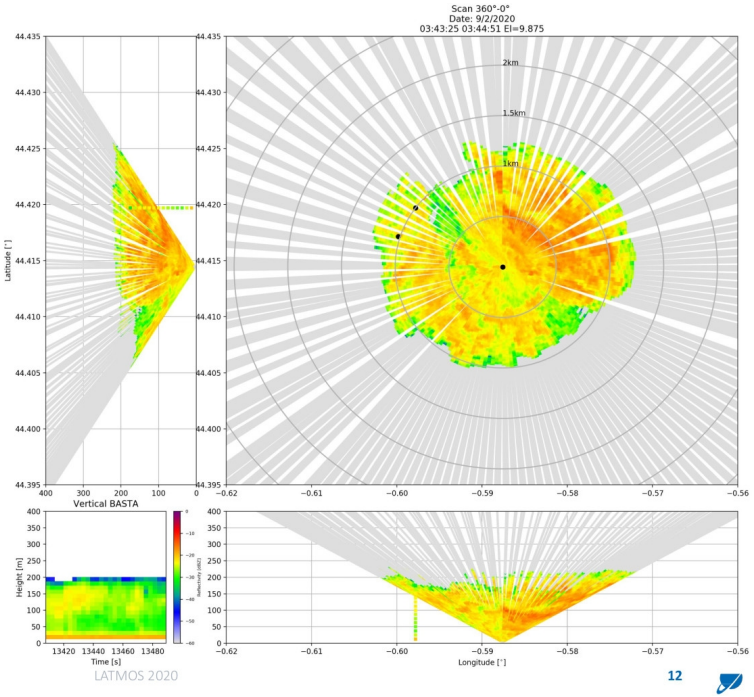
- Turbulence et flux de surface - G. Canut / A. Roy
  - seuil de variance verticale >> LANFEX

- Radars BASTA – Task 2
  - Exploration volumique : J. Delanoë / S. Jorquera (IPSL/LATMOS)

RHI : azimuth fixe



MAPS : élévation fixe

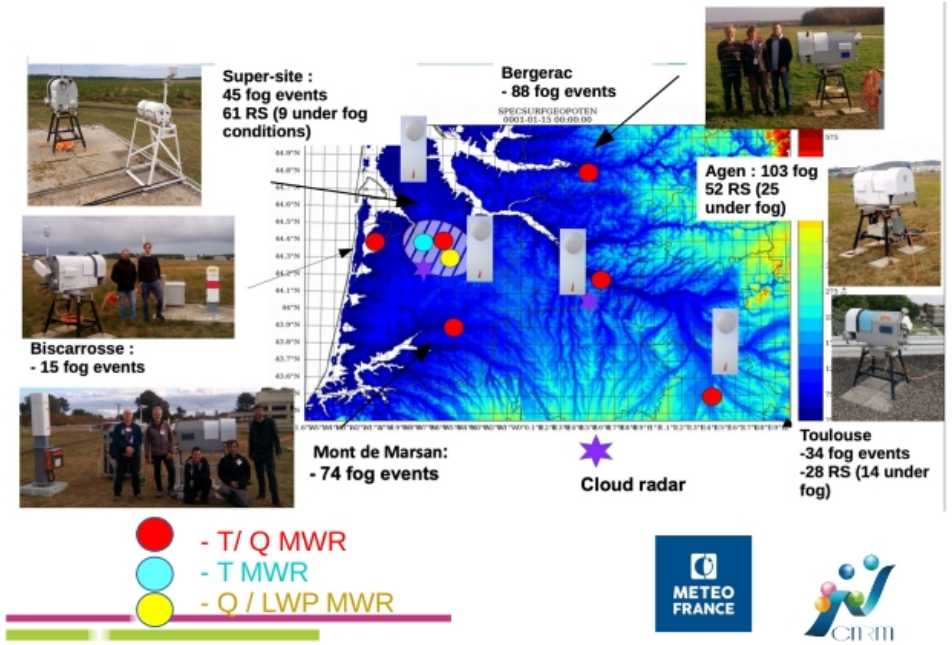


Microwave radiometers network - Task5

- PROBE Cost Action (P. Martinet)

- European collaboration during SOFOG3D : deployment of a dense MWR network of **8 units** located in **6 sites** in a **300 km x 300 km domain** (Météo-France, University of Cologne, Laboratoire d'Aérologie, ONERA, RPG, Attex)

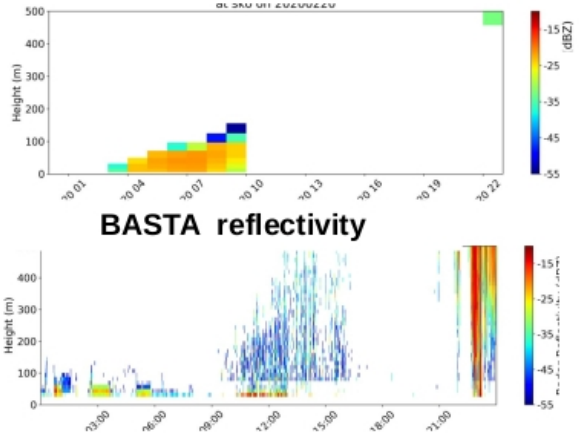
- Real data assimilation experiments (3D-EnVar / 4D-EnVar) during the winter 2019/2020 starting 01/06/2021



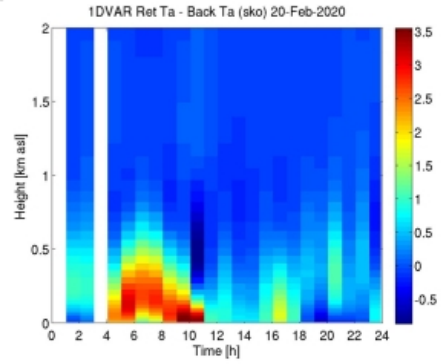
False alarm - 20/02/2020

- First data assimilation trials in a **1D-Var** scheme have demonstrated the high **potential** for NWP models during fog conditions (*Martinet et al 2020*)

Simulated reflectivity from AROME



DT= T1dvar - Tbackground

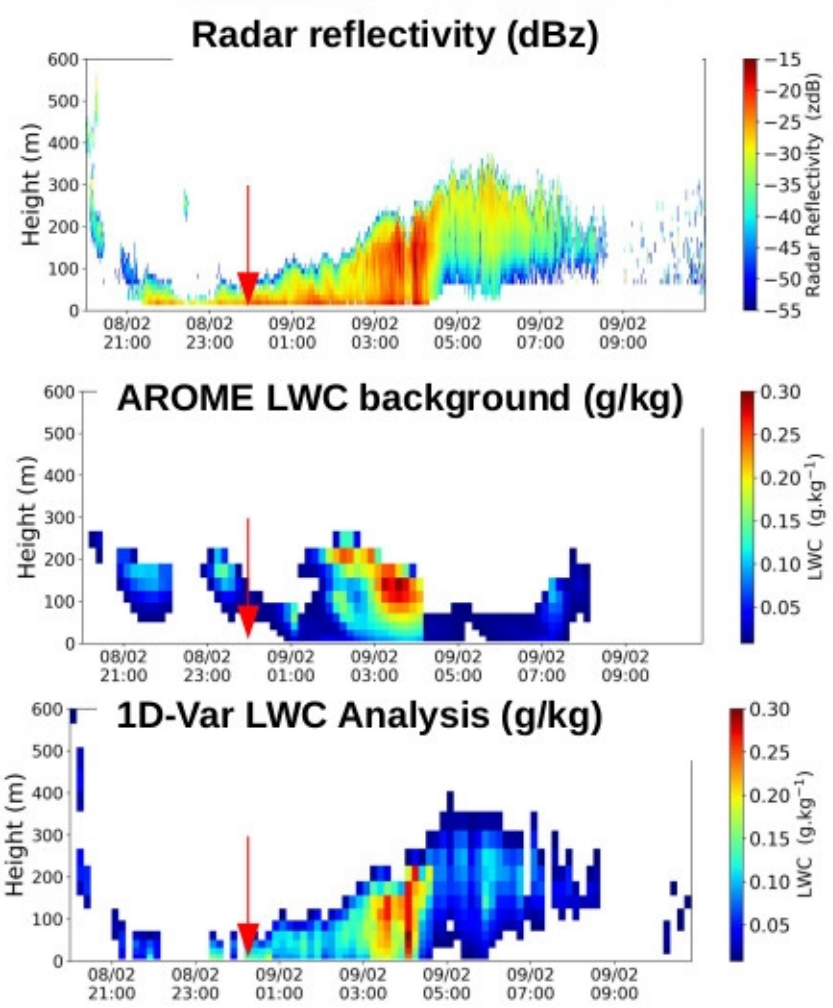


- Large temperature increments (1DVAR minus AROME up to 3.5 K) : should limit the temperature cooling and the saturation in the model (case study of fog false alarm)

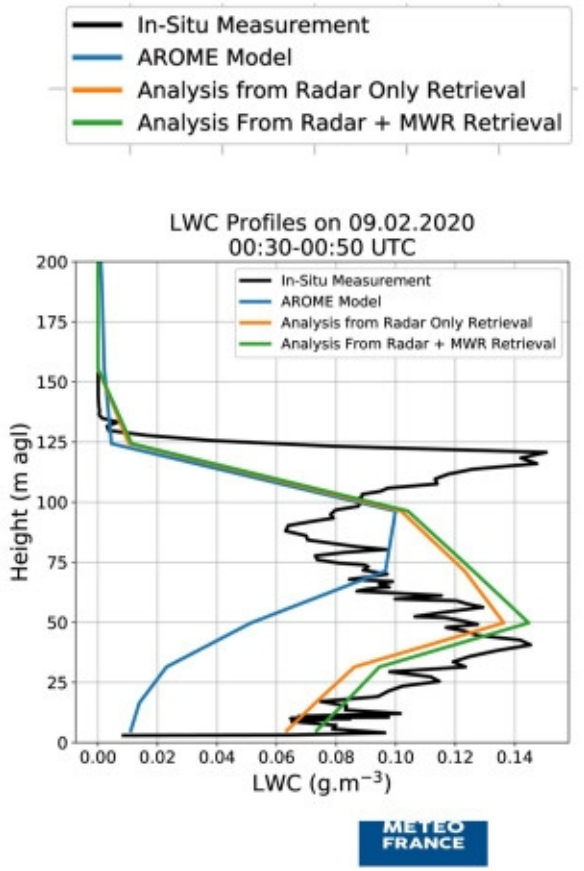
Synergie Radar / radiomètre - Task5

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

(A. Bell, P. Martinet et O. Caumont) – Bell et al. ACP 2022

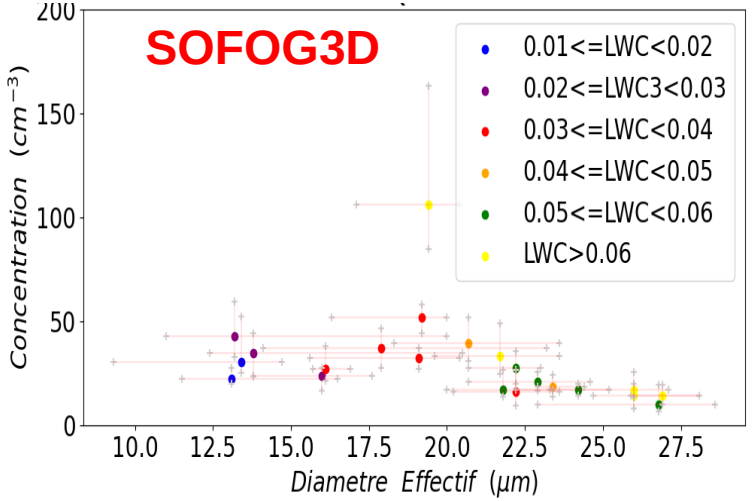


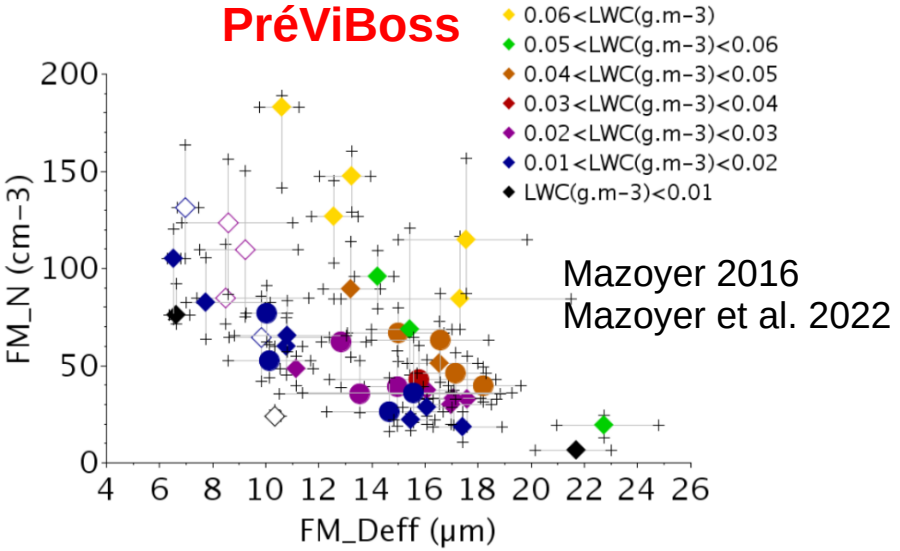
- Significant temporal and fog top heights errors in the AROME background profiles (nearest in time).
- 1D-Var retrievals much more **consistent** with the observed fog structures compared to the BASTA cloud radar.
- Good agreement between 1D-Var retrievals and in-situ CDP measurements



Propriétés microphysiques

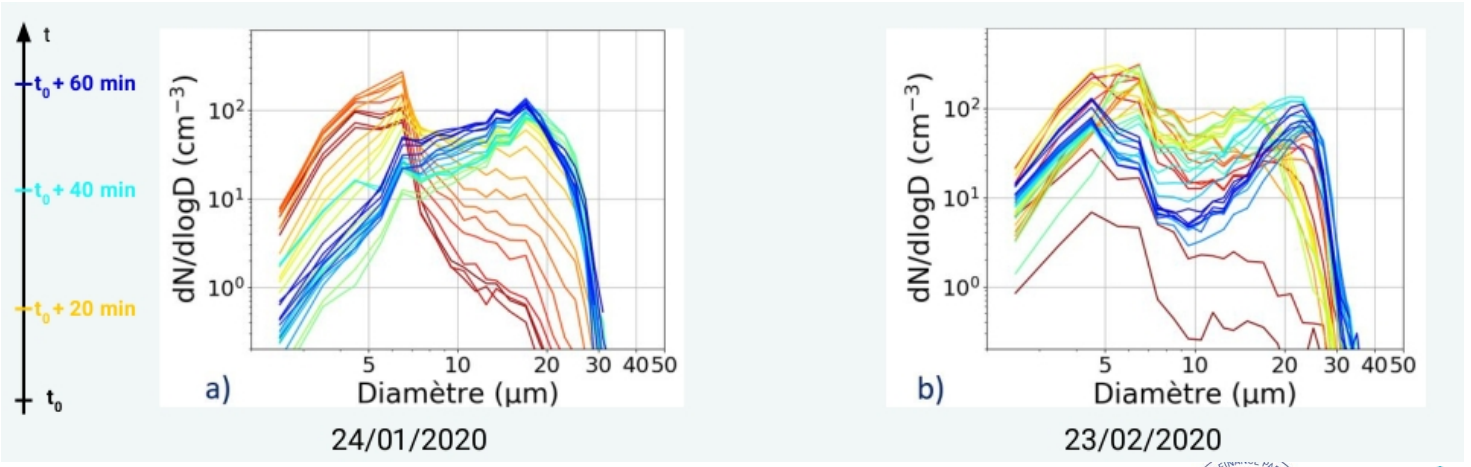
- Caractérisation 3D (thèse T. Costabloz) :
  - Faible CDNC & grosses gouttelettes :



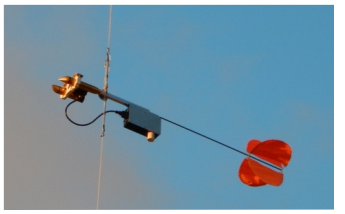


Mazoyer 2016
Mazoyer et al. 2022

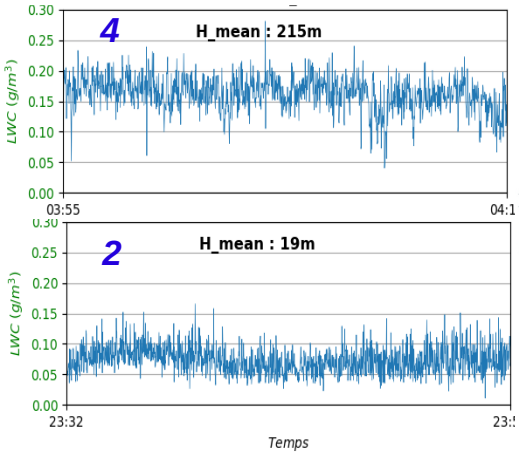
  - Beaucoup d'épisodes avec distributions bimodales :

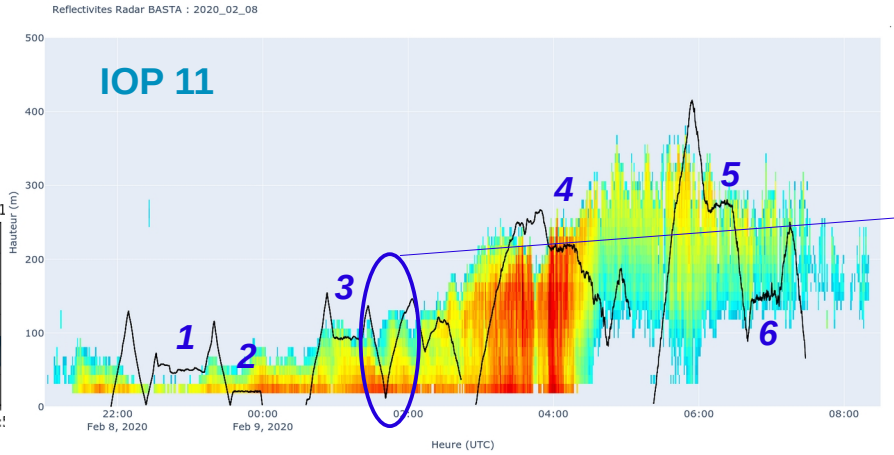


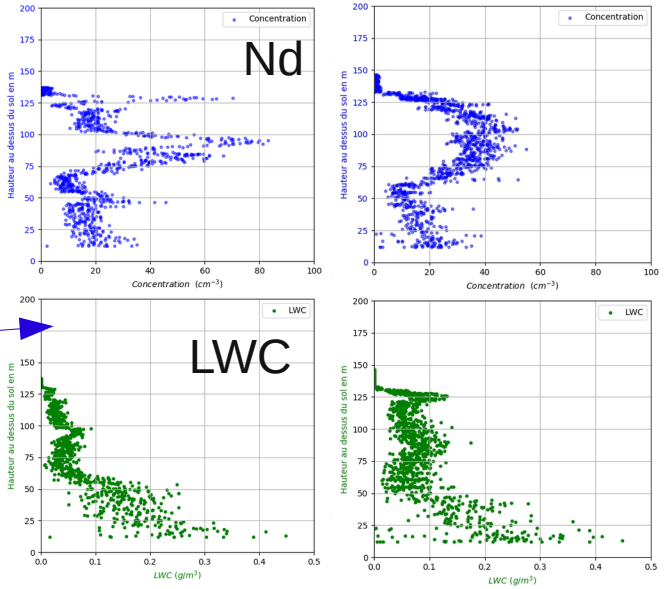
Profil vertical des propriétés microphysiques



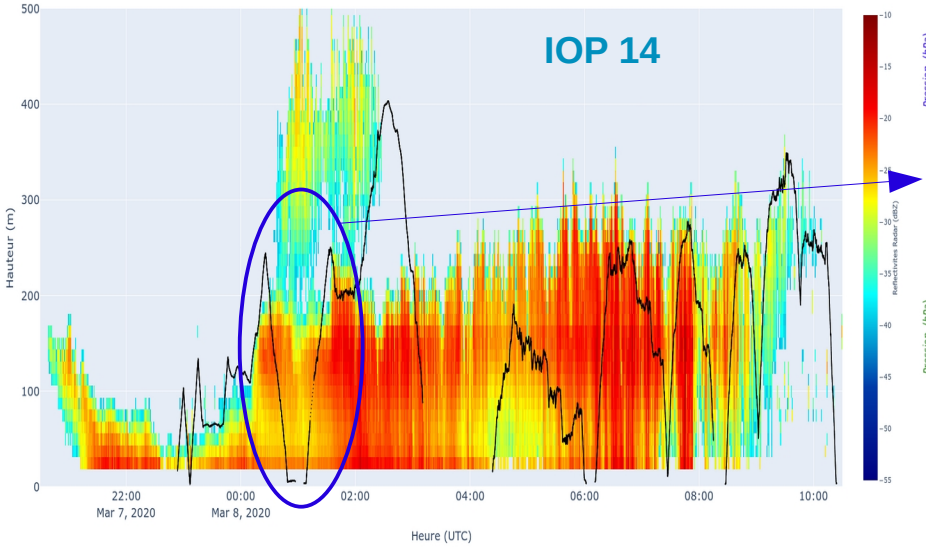
- CDP sous ballon captif : contraste paliers / sondages

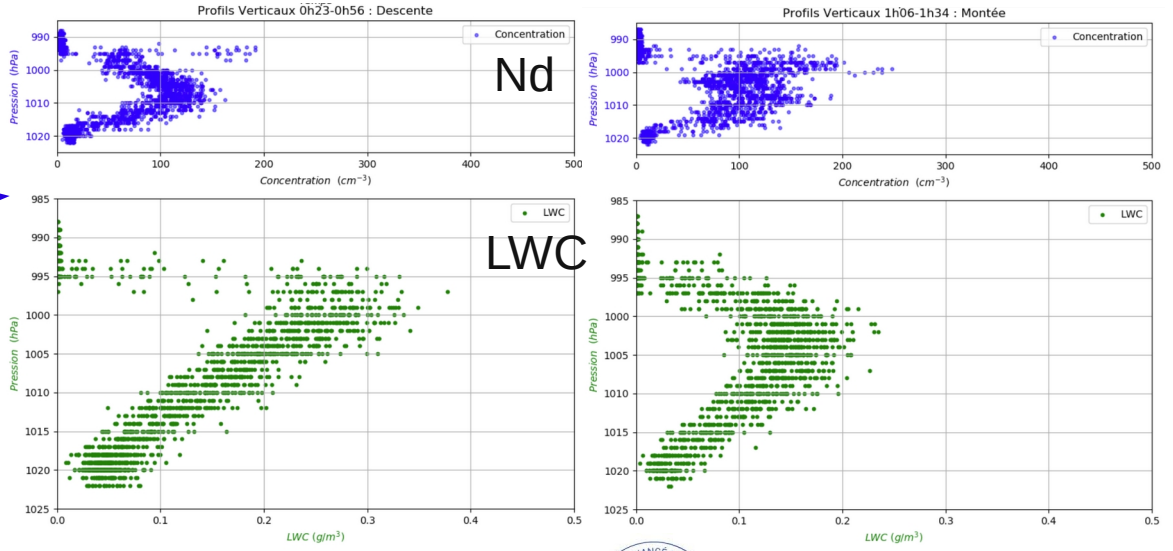




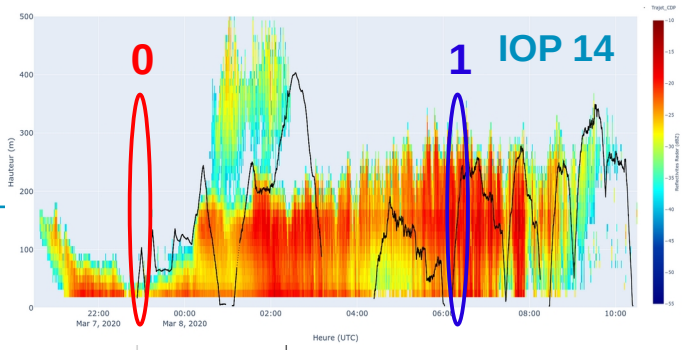


- Transition fin -> développé

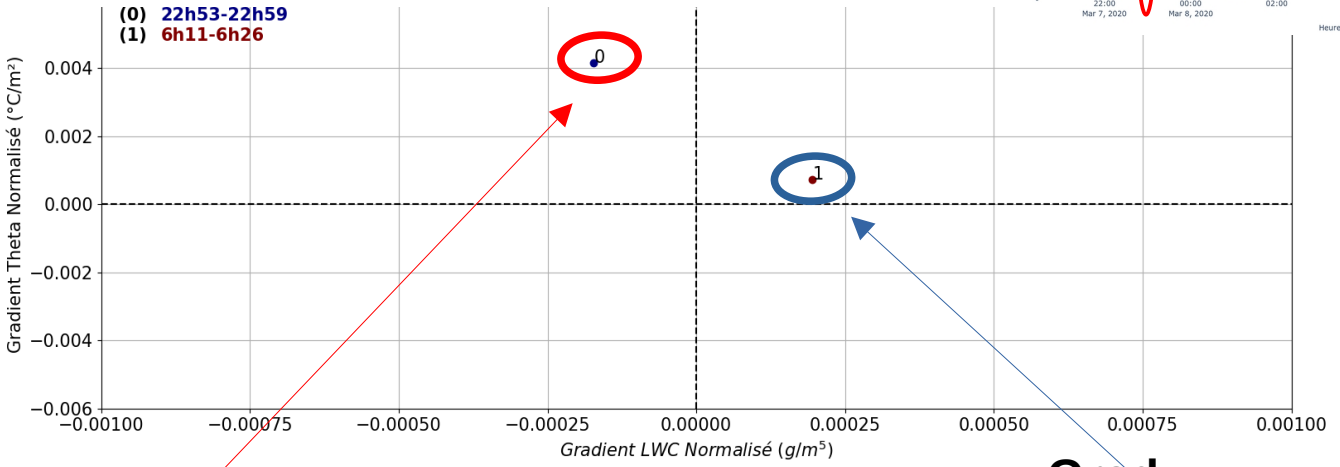




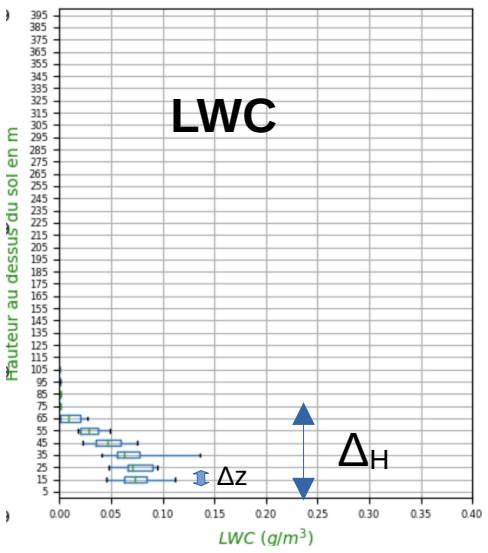
Transition fin -> développé

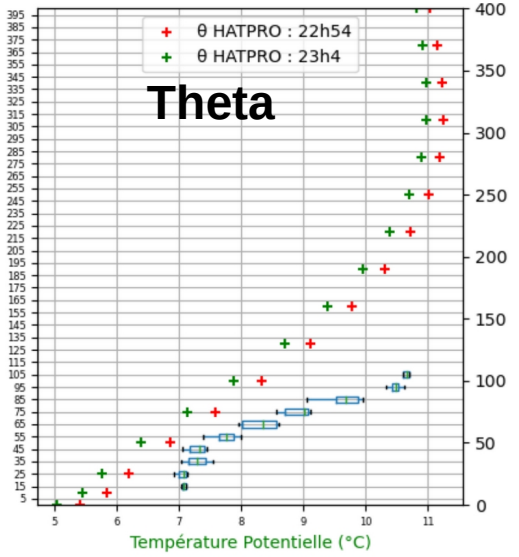


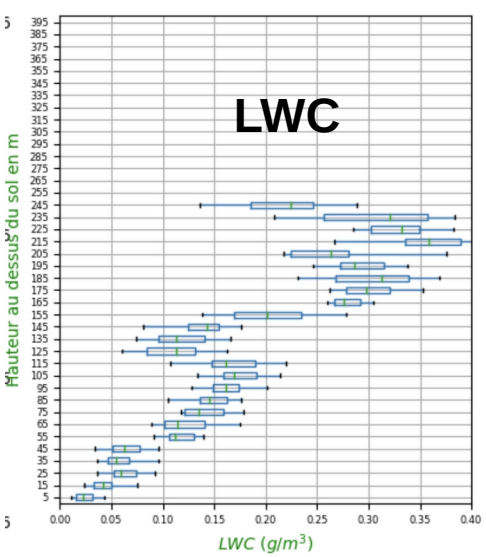
$$\mathbf{Grad_{Norm\ Theta}} \quad \frac{\sum \frac{\theta_{z+1}-\theta_z}{\Delta_z}}{\Delta_H}$$

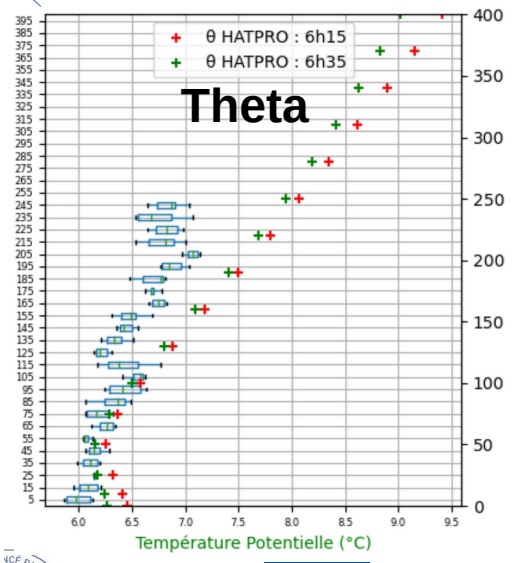


$$\mathbf{Grad_{Norm\ LWC}} = \frac{\sum \frac{LWC_{z+1}-LWC_z}{\Delta_z}}{\Delta_H}$$



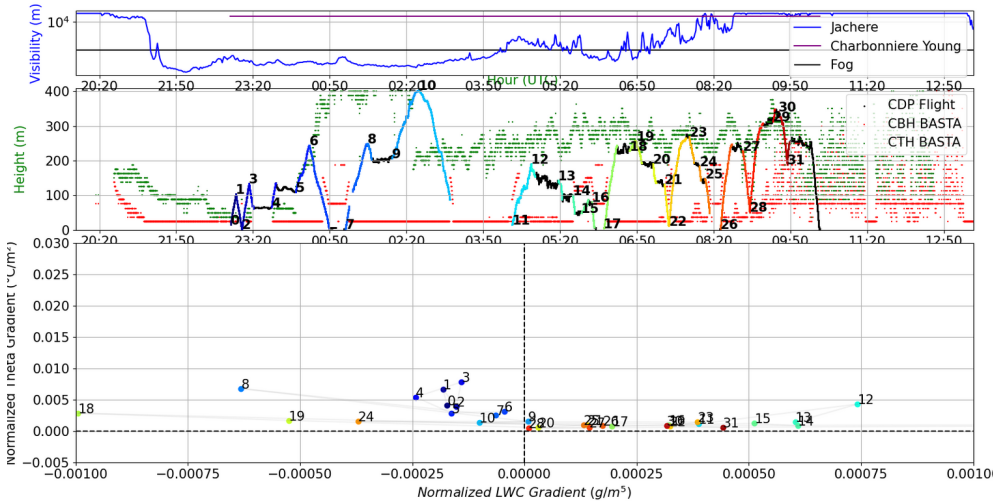




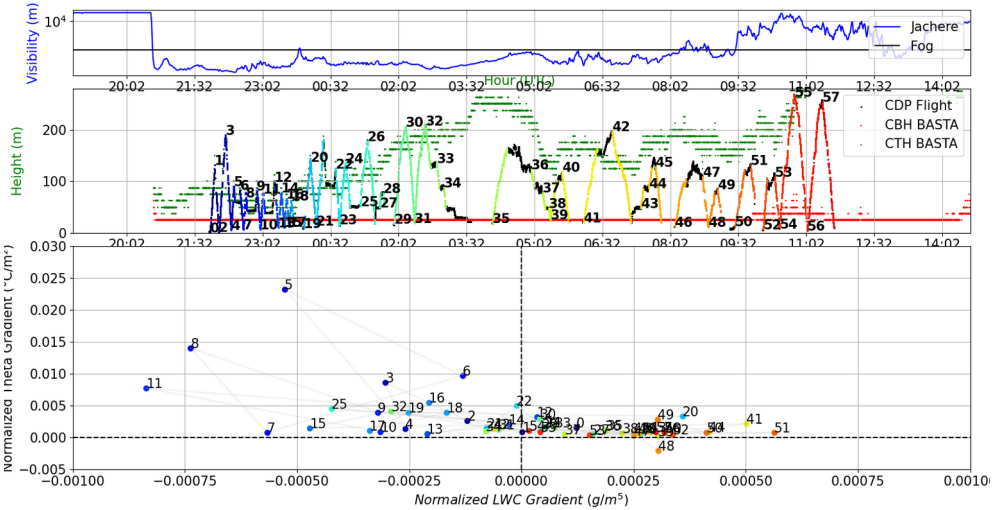


Transition fin -> développé

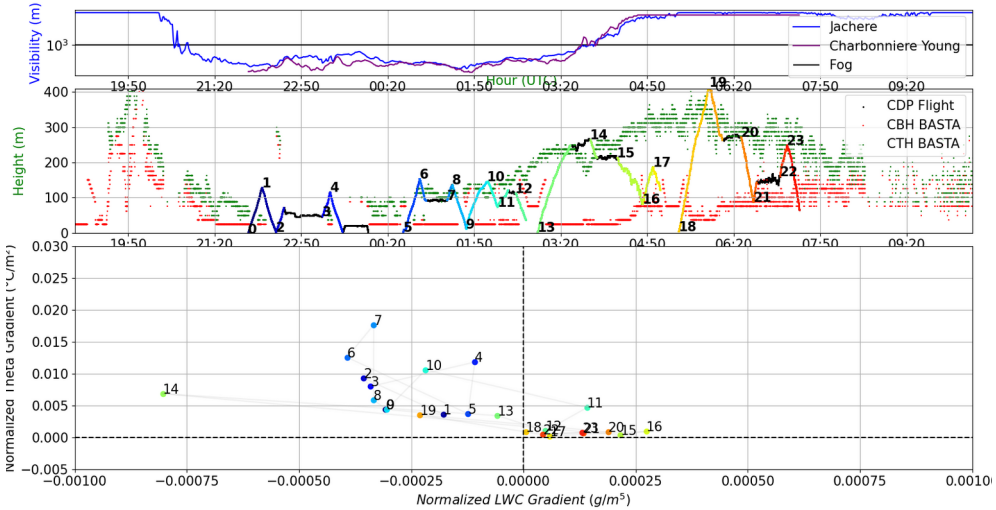
POI 14



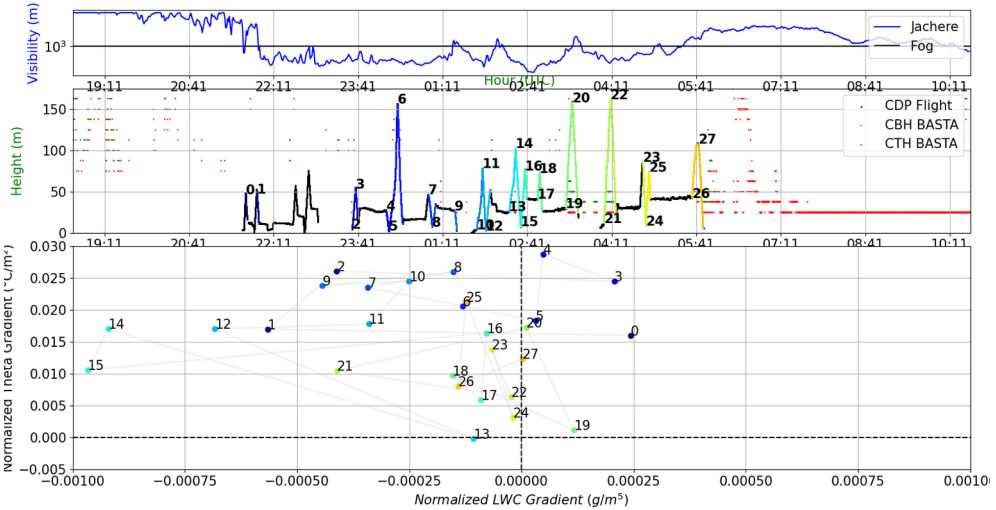
POI 6



POI 11

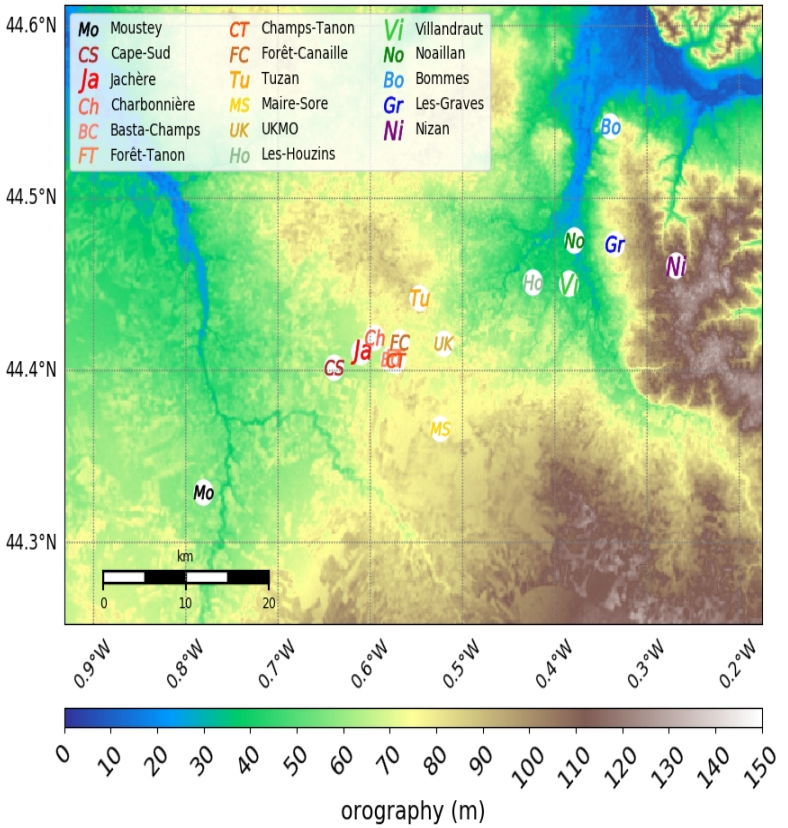


POI 2 : cas stable sans transition

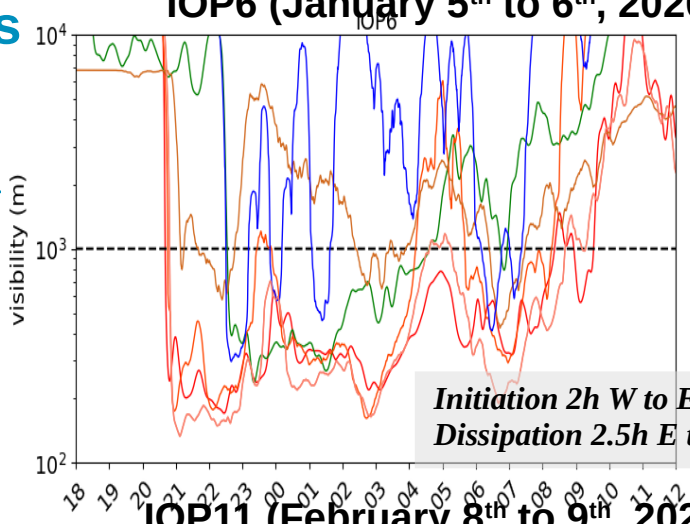


Impact of surface heterogeneities on the fog life cycle

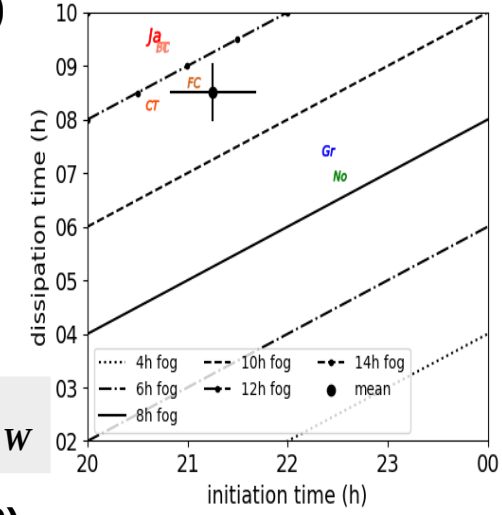
Marie Taufour, *Christine Lac, Quentin Rodier*



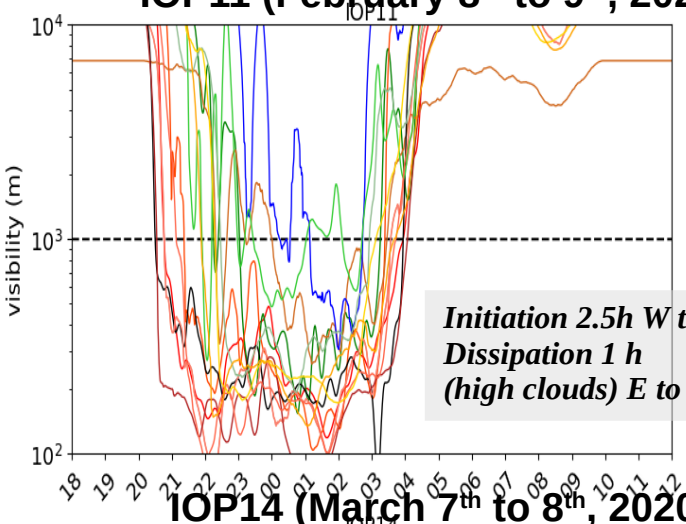
IOP6 (January 5th to 6th, 2020)



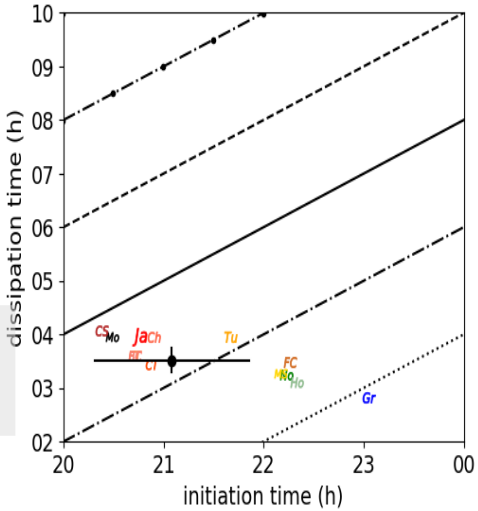
Initiation 2h W to E
Dissipation 2.5h E to W



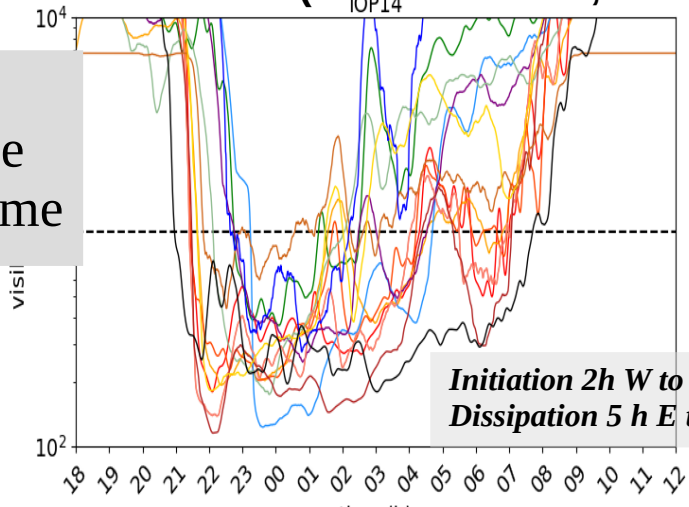
IOP11 (February 8th to 9th, 2020)



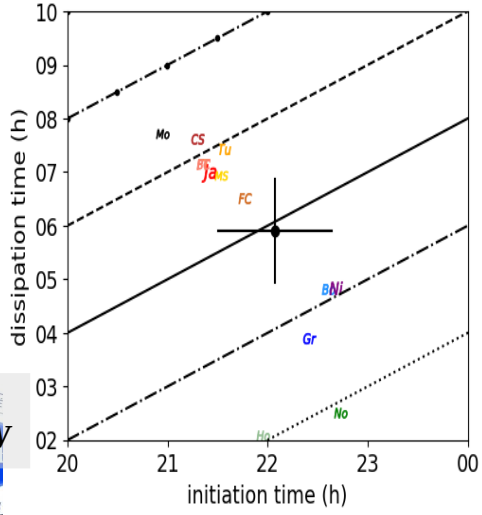
Initiation 2.5h W to E
Dissipation 1 h
(high clouds) E to W



IOP14 (March 7th to 8th, 2020)



Initiation 2h W to E
Dissipation 5 h E to W

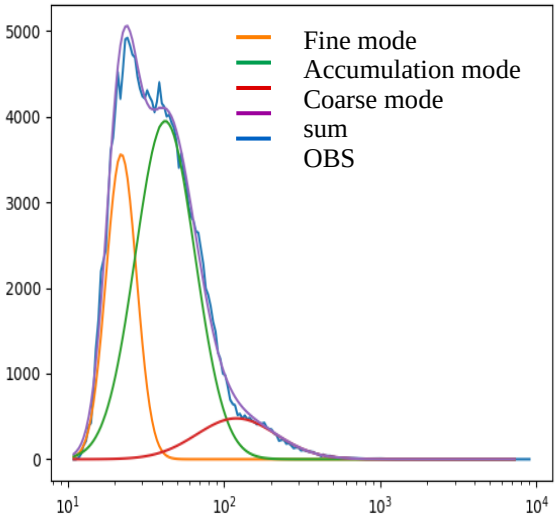


Observations of 3 IOP :
West-East gradient in the initiation time
East-West gradient in the dissipation time

Meso-NH reference simulation

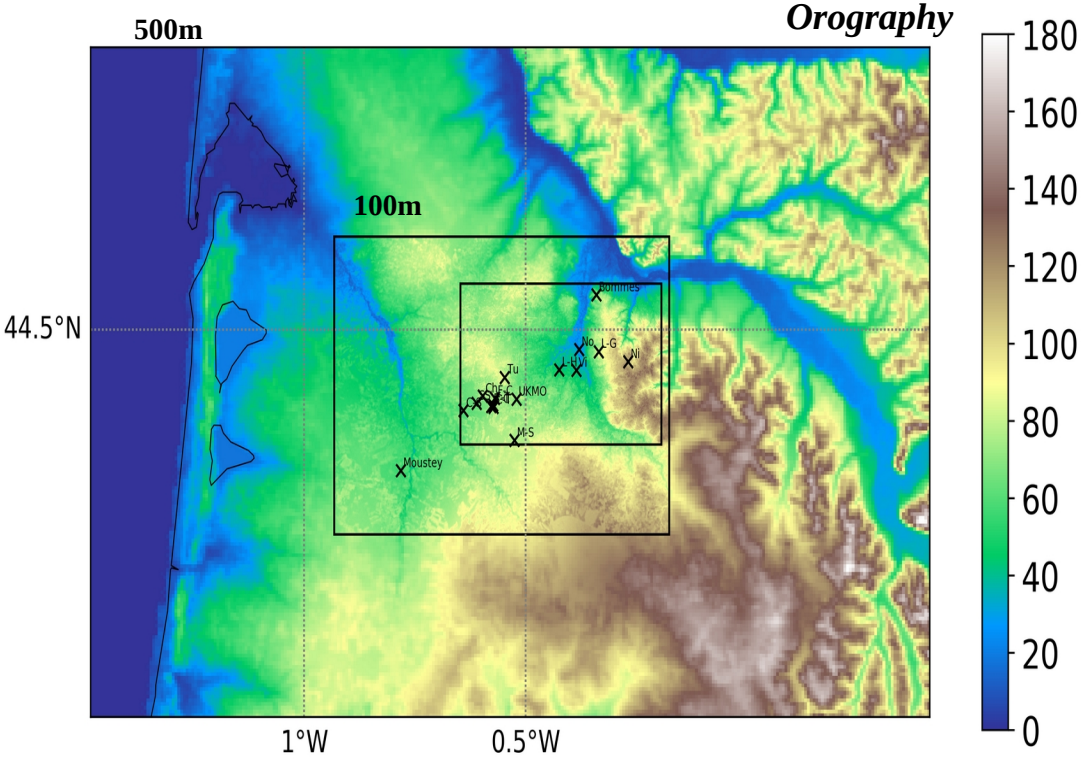
- Initiation : **AROME analyses (1.3 km)** at 15h
- Lateral Boundary conditions : hourly AROME analyses
- Run **2-way grid nesting** **500m → 100m**
- Advection : Runge-Kutta fourth-order centred scheme for wind
- Orography : **SRTM 90m (dad 500m) 30m (sons : 100m/20m)**
- Land cover / surface : **ECOCLIMAP database at 1 km**
- Surface scheme : **ISBA-DIF**
- Shallow convection scheme : **EDMF for 500m domain**
- EcRad
- Turbulence: **ADAP** 1D at 500m, 3D at 100m/20m
- Cloud scheme at 500m
- Microphysical scheme : **LIMA**

***REF** aerosol loading based on observations*

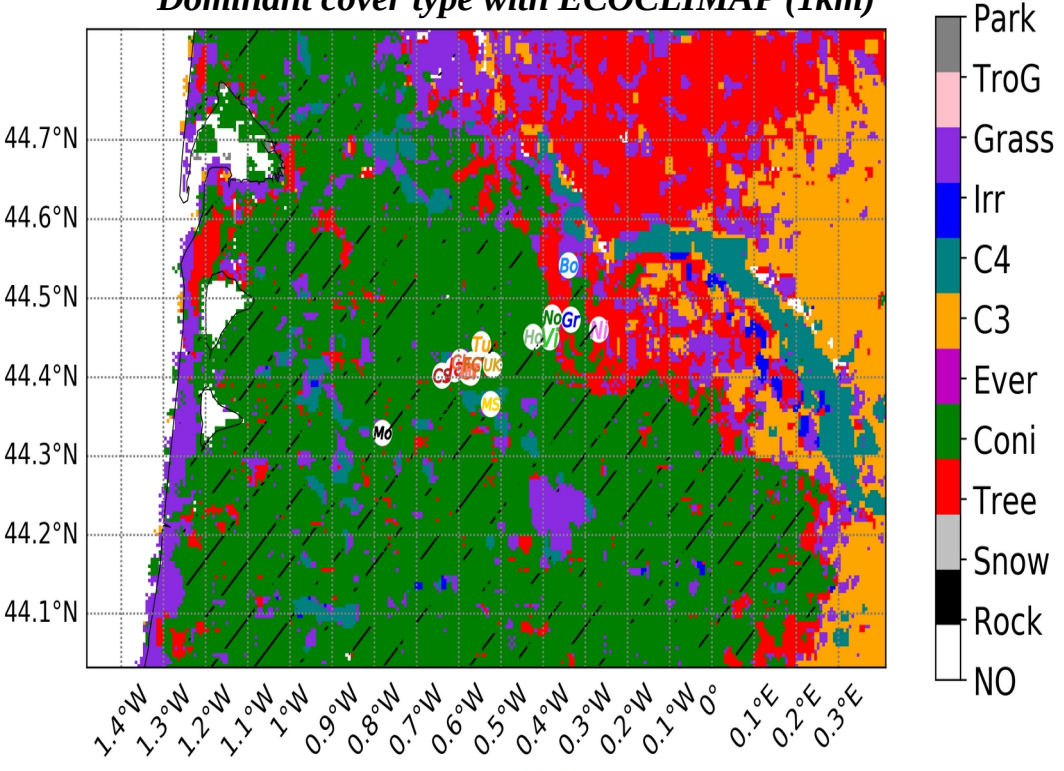


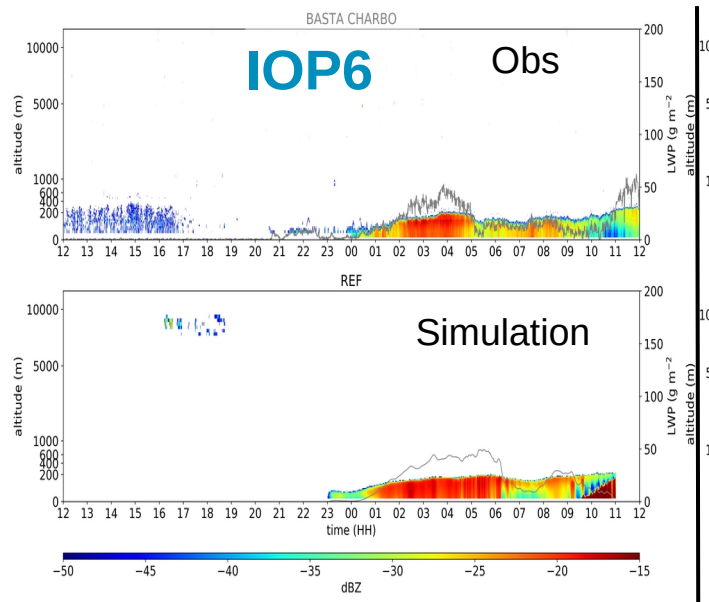
Mainly coniferes over the area

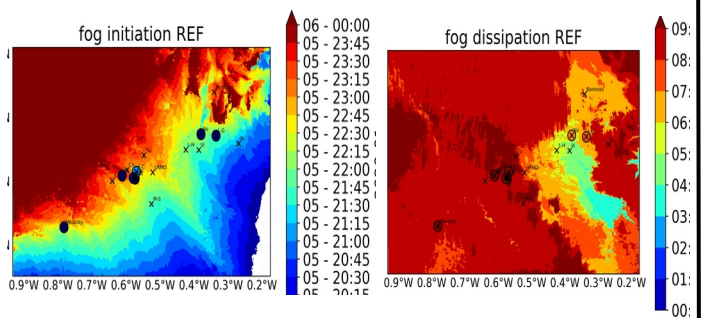
Orography

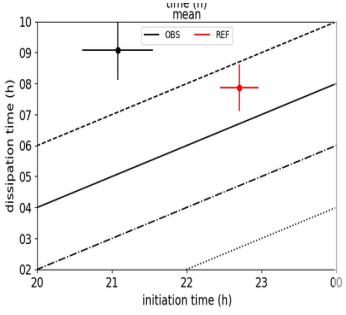


Dominant cover type with ECOCLIMAP (1km)



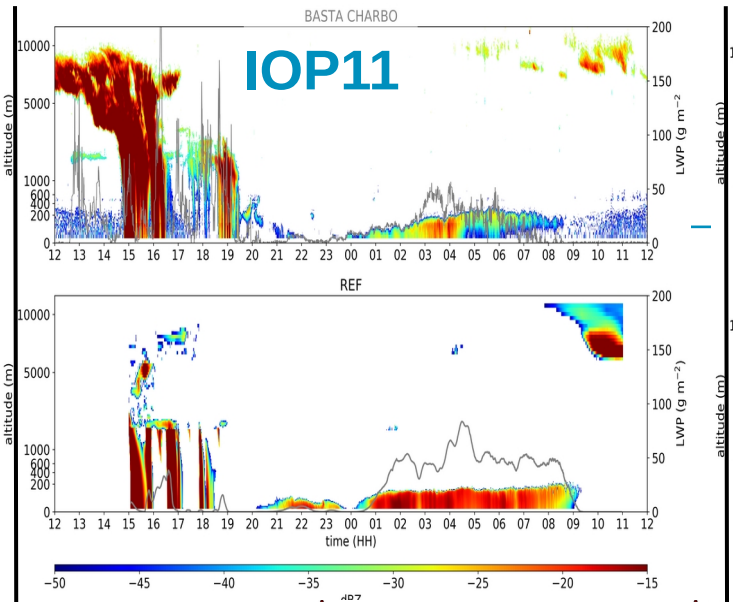


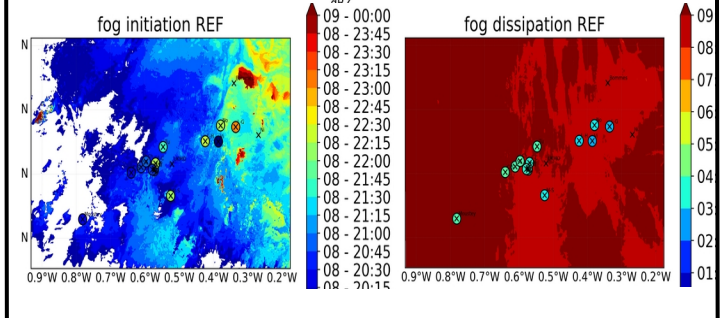


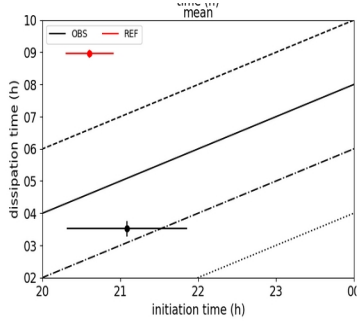


Formation ~1.5h too late.
No W-E gradient

Dissipation ~1h too early.
Some E-W gradient

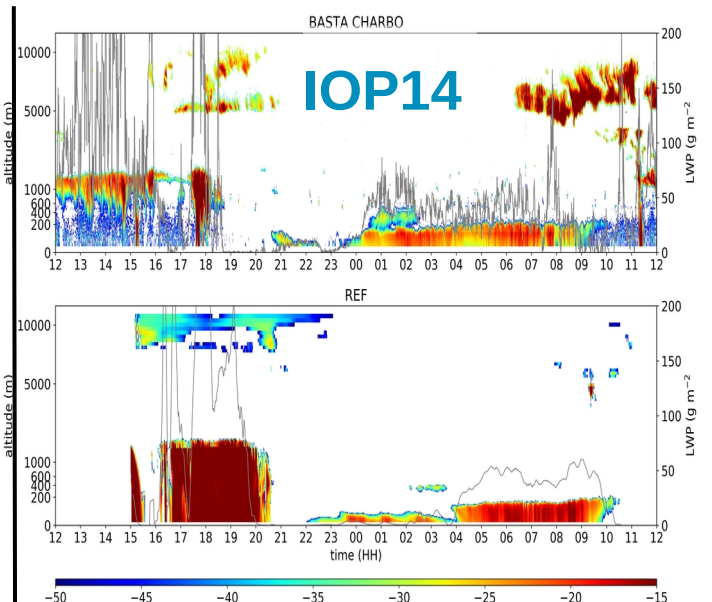


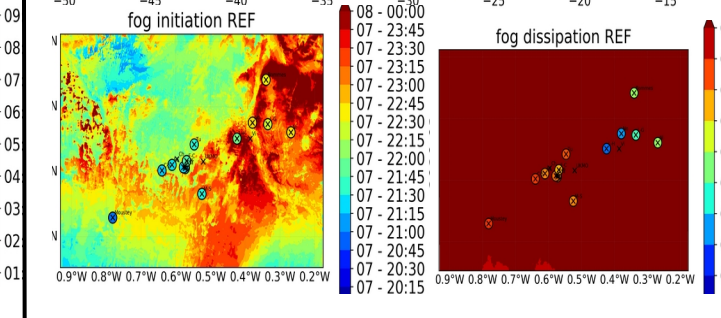


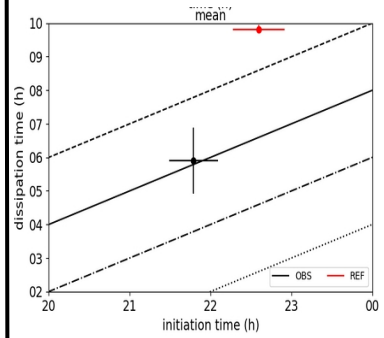


Correct formation time
W-E gradient

Dissipation 5h too late due to the absence of high clouds in the simulation → No E-W gradient







Formation ~1h too late
W-E gradient

Dissipation 4h too late mainly due to the absence of high clouds in the simulation → No E-W gradient

Simulations of 3 IOP : Major challenge to represent the horizontal variability of the fog life cycles
- Initiation quite correctly reproduced with a W-E gradient in 2 IOPs
- Dissipation more difficult with higher clouds in 2 IOPs – Correct in IOP6

Bilan / Perspective

- Suivi du projet :

  => **http://www.umr-cnrm.fr/spip.php?article1086 -> suivi du projet**

  - **Final Science meeting => Toulouse, printemps 2023**
- Base de données sur AERIS en cours d'alimentation

  => https://sofog3d.aeris-data.fr/
- Publications en cours
  - Bell et al. 2022, Martinet et al. 2022, Vishwakarma et al. 2022, in press /review
  - Antoine et al., Burnet et al., Costabloz et al, Thomas et al. ... en préparation
- Thèses et post-doc :
  - FCPLR Salomé Antoine (2019/2022) : validation AROME 500m
  - FCPLR Théophane Costabloz (2021/2024) : propriétés microphysiques 3D
  - Post-doc Marie Taufour (12/2022) : LES Méso-NH impact des hétérogénéités
  - Post-doc Cheik Dione (LMD) (06/2023) : étude de processus - dissipation
  - Post-doc Maroua Fathalli (06/2023) : affaissement de Stratus => poster

Summary

- 15 fog events sampled with the tethered balloon (20 nights of operations, 180 RS)

  => **3 main events (IOP 6, 11 and 14)** but many interesting thiner cases
- Despite technical failures and difficult weather conditions :
  - synergy 94 GHz radar, MWR and in situ profiling with microphysics and turbulence
  - volume sampling with scanning radar and UAV flights with ~5 km legs
  - MWR network (6 sites) for assimilation

  => **promising data set to document 3D heterogeneities and conduct process studies**
- large amount of data to process, validate and analyze... will take some time
- **Many thanks** to all people involved in preparation, forecasts, operations, processing....