The International SOFOG3D experiment

Task5 : Data assimilation and forecast

P. Martinet, A. Kremer, U. Löhnert, V. Unger, E. Orlandi and all WP5 partners

The SOFOG3D MWR network : context

- Built thanks to a strong international collaboration (TOPROF and PROBE Cost actions) : University of Cologne, MeteoSwiss, ONERA, Laboratoire d'Aérologie, manufacturers (RPG / ATTEX).
- Use for : data assimilation trials, process study, evaluation of NWP model

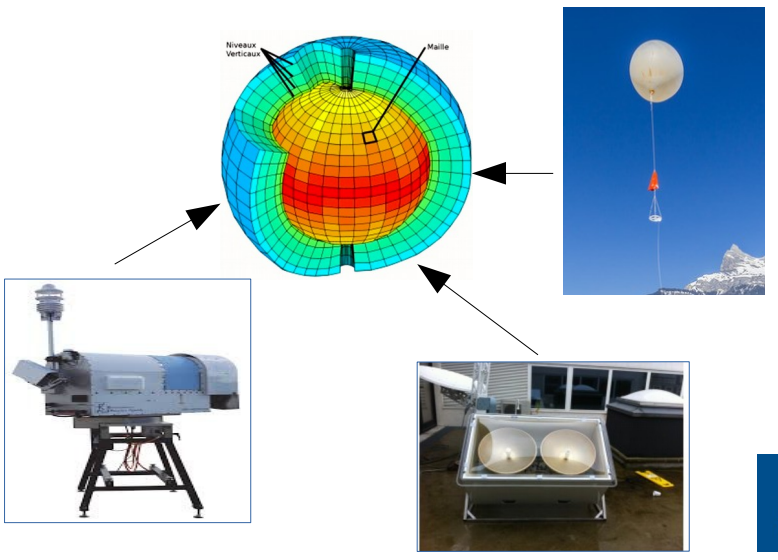
Focus data assimilation

→ What variables/parameters about fog forecasts are improved thanks to the assimilation of a MWR network ?

→ What are the most relevant meteorological quantities to be initialized (temperature, humidity, hydrometeors) for improving fog forecasts ?

→ What is the most important parameter between vertical or temporal resolution to improve fog forecasts ?

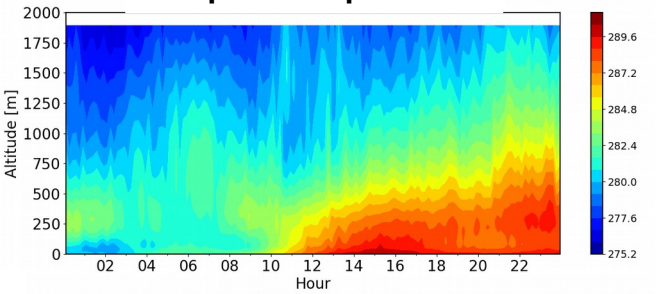
3D-EnVar / 4D-EnVar



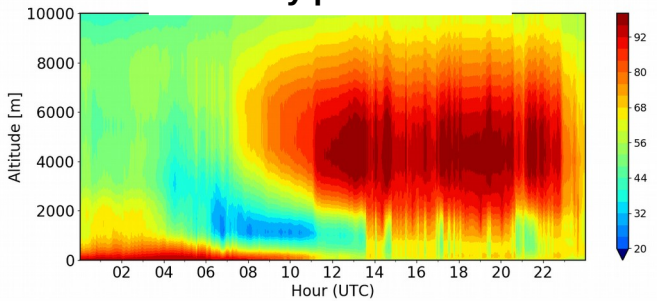
MWR : instrument and main products

- Measurement of the downwelling radiative emission of the atmosphere in two spectral bands :
  22 - 31 GHz : water vapor, liquid water content
  51 - 60 GHz : temperature
- Elevation scans to increase resolution of temperature profiles
- Continuous measurements : clear-sky / cloudy-ky

Temperature profiles

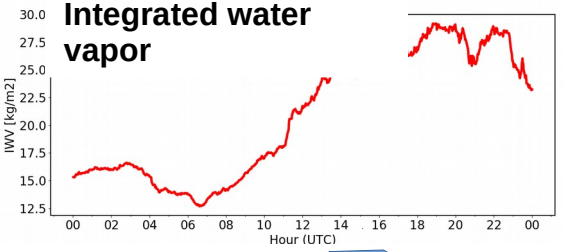


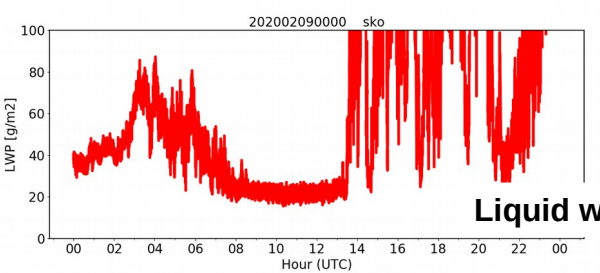
Humidity profiles



→ IR radiometer when available
+
→ LV3 products : boundary layer height / stability indices/ fog threat

Integrated water vapor



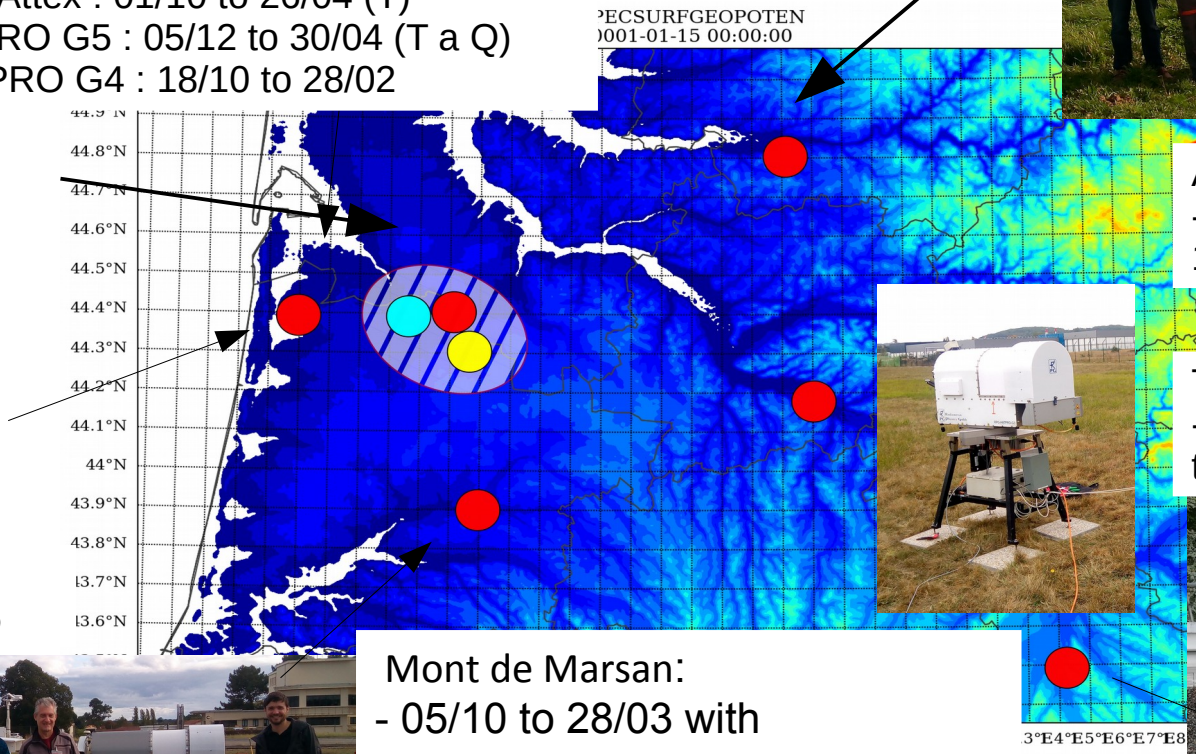


Liquid water path

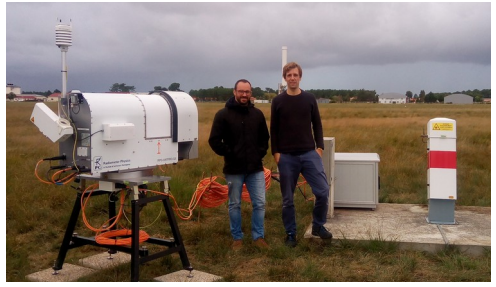
MWR network : the database

Bergerac
- HATPRO G2 : 17/12 to 11/06

Super-site :
MTP-5 Attex : 01/10 to 26/04 (T)
- HATPRO G5 : 05/12 to 30/04 (T a Q)
- HUMPRO G4 : 18/10 to 28/02



Agen
- HATPRO G3
14/10 to 22/04



Biscarrosse :
- HATPRO G5: 20/10 to 15/06

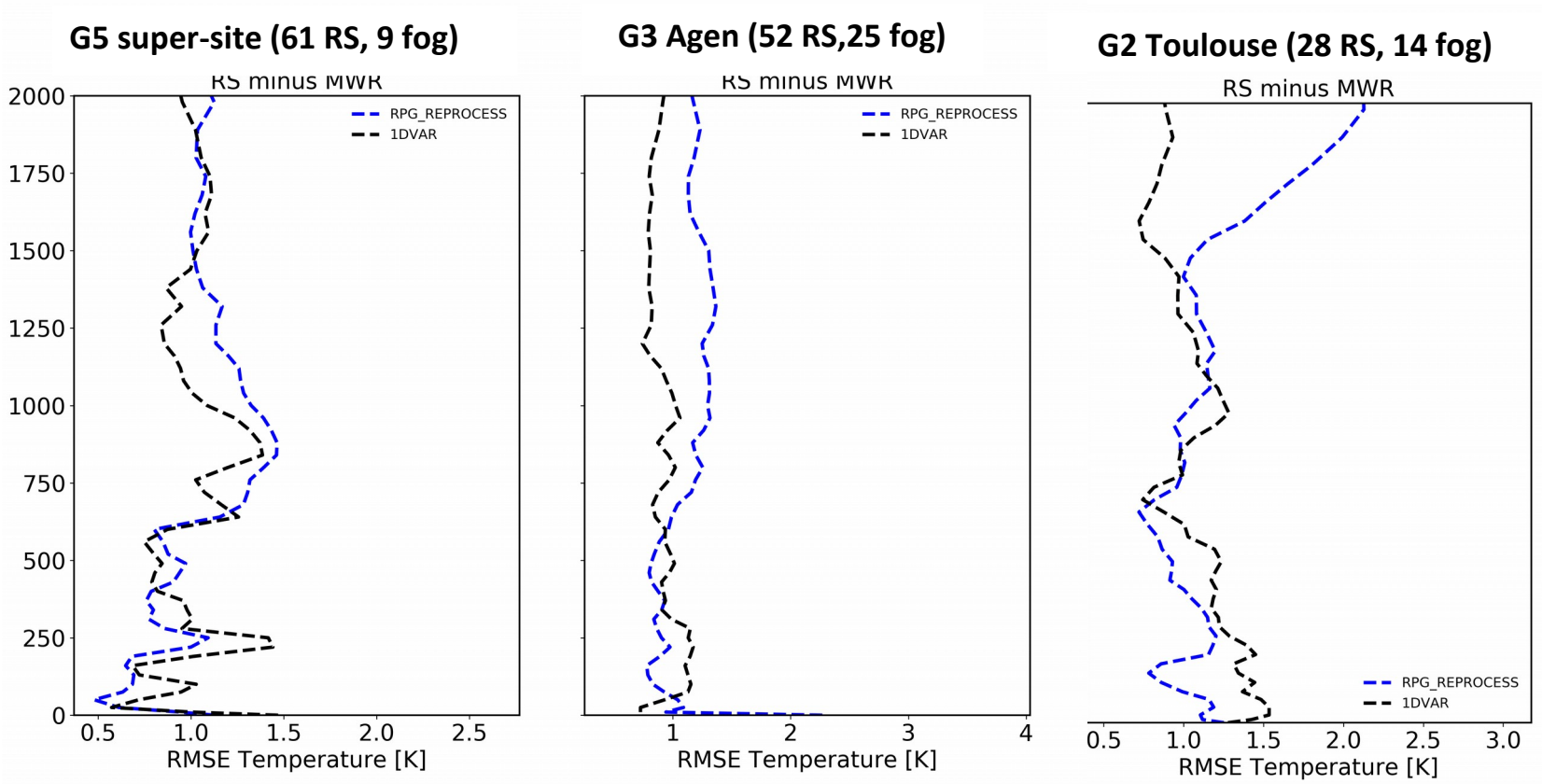
Toulouse
- HATPRO G2 : 01/07
to 22/04

Mont de Marsan:
- 05/10 to 28/03 with
breakdowns :
-26/10 to 03/11, **23/12 to 31/01,**
13/02 to 19/02, 04/03 to 12/03

Retrieval inter-comparisons : A. Kremer (University of Cologne)

RS validation : Temperature profiles

RMSE RS - MWR



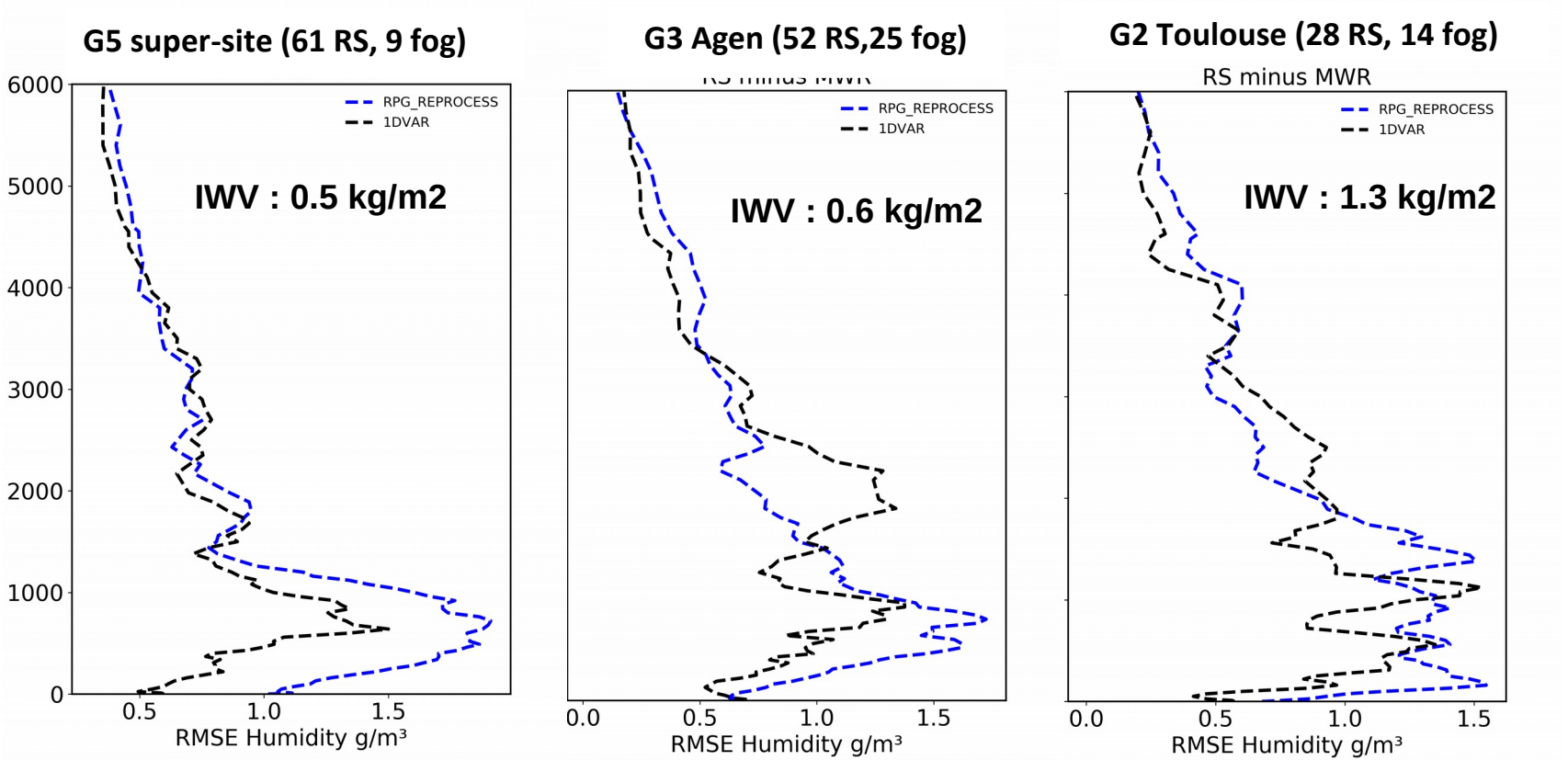
- RMSE T : 0.5 to 1.5 K
- RPG NN improved with new coefficient generation
- Z < 700m : NN perform better
- Z > 700m : 1D-Var perform better

NN initial

1D-Var (no bias correction!)

RS validation : Humidity profiles

RMSE RS - MWR



NN initial

1D-Var (no bias correction!)

- RMSE Q : 0.5 to 1.5 g/m3
- Z< 2 km : 1D-Var performs better
- Z > 2 km : similar accuracy

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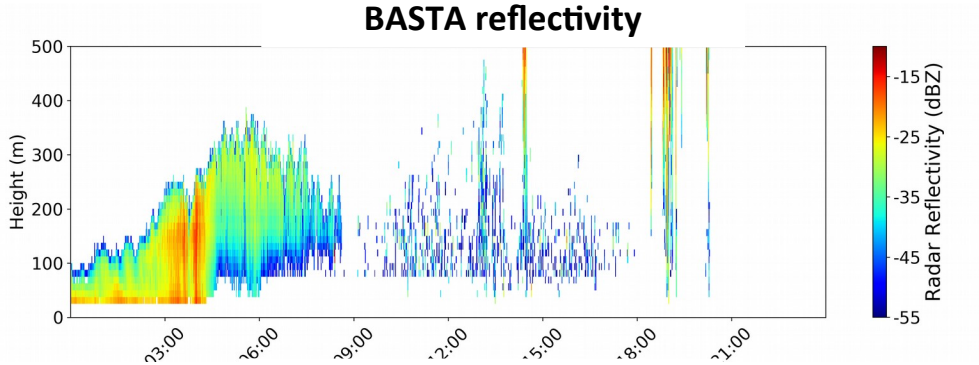
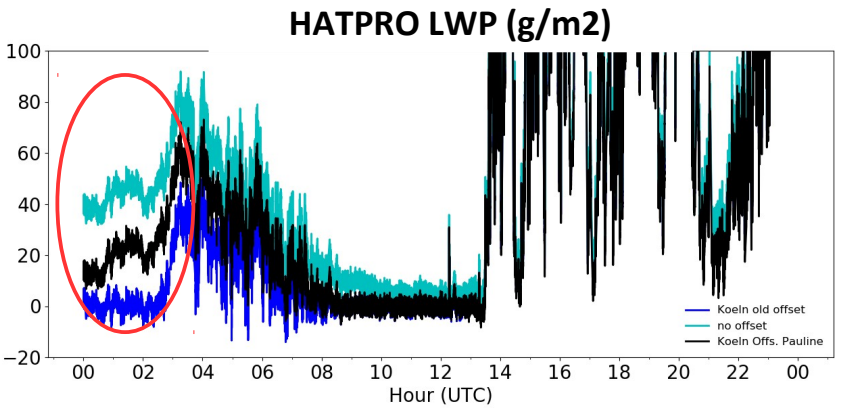
LWP inter-comparison

- Fog LWP is key for the fog lifecycle affecting its radiative properties and dissipation
- MWR provides the most reliable source of LWP measurements
- However MWR LWP uncertainty is around 20 g/m² : not negligible for thin fog
- For low LWP values, LWP uncertainty can be reduced through a bias-correction procedure
- First validation have highlighted problems in the offset correction (removing most of the signal during fog)





LWP new offset

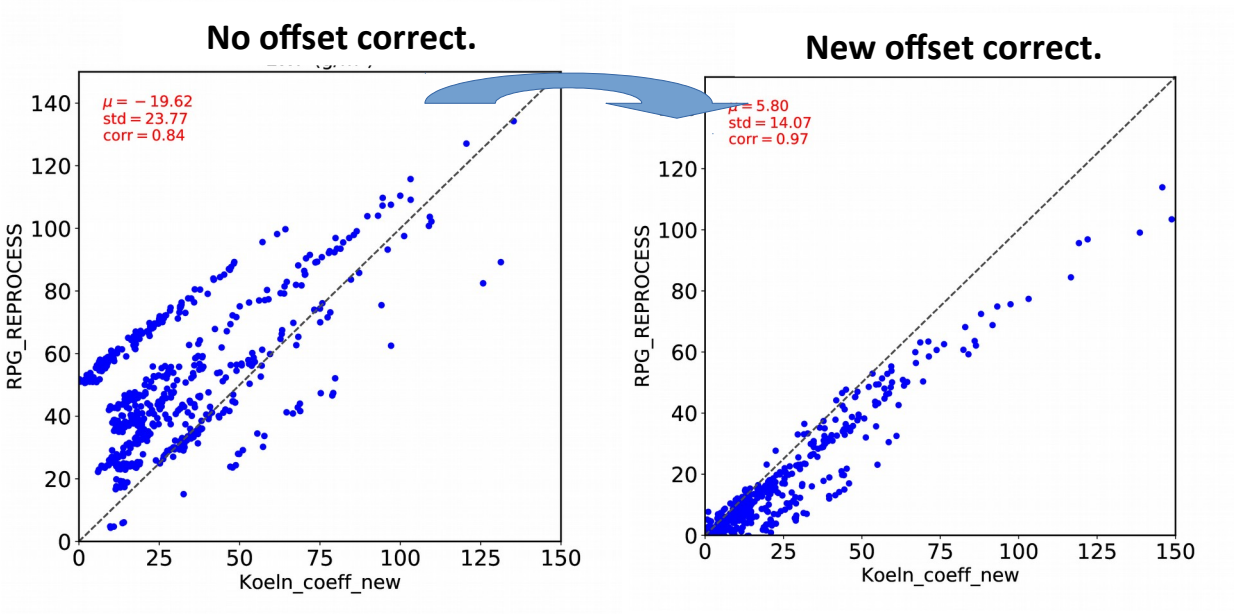
LWP no offset

LWP old offset

LWP inter-comparison

- Initial LWP std threshold used for clear-sky detection too high for fog (median = 2 g/m²)
- New offset correction proposed at the super-site using visibility measurements to identify fog periods

Scatterplot between LWP neural network (y-axis) and LWP quadratic regression (x-axis)

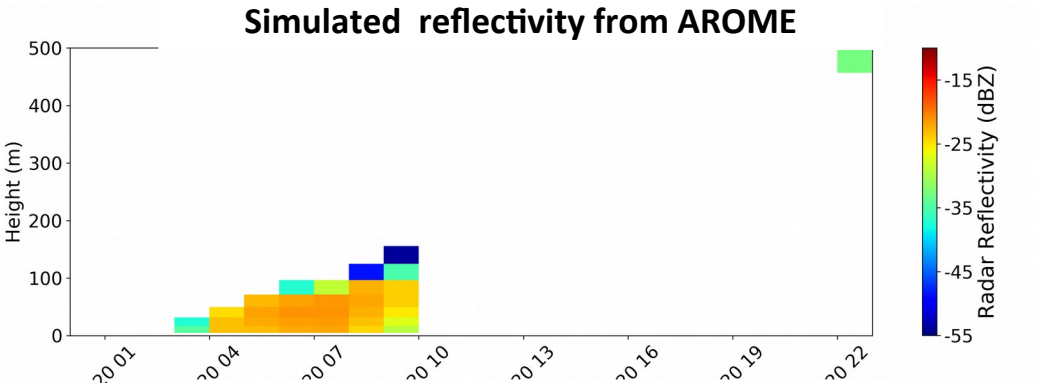


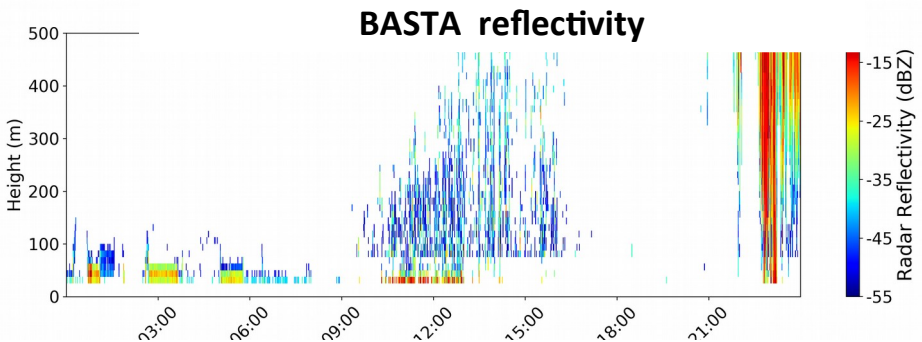
- Much better agreement between the two statistical retrievals using new offset correction
- LWP products for all sites available

Benefit of the MWR network : an insight into future perspectives (data assimilation, fog process studies and model evaluation)

Data assimilation : expected benefit

- IOP du 20/02/2020
- AROME false alarm
- Thick fog (~ 100 m à 8 UTC) in AROME but no fog observed





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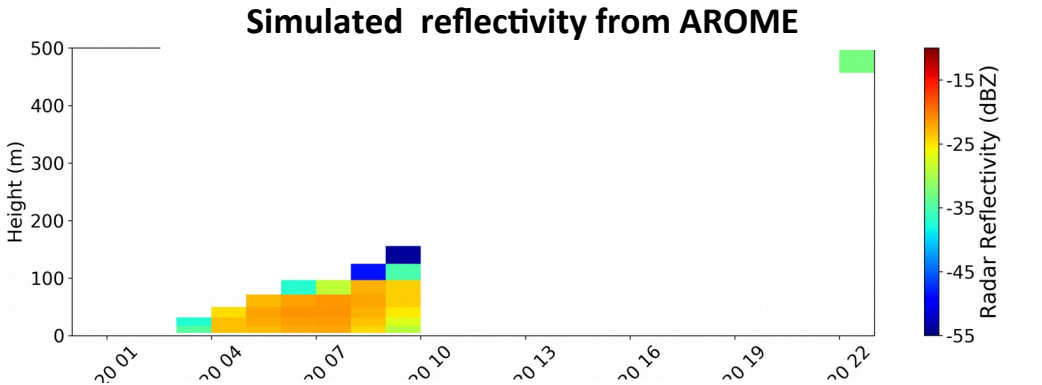
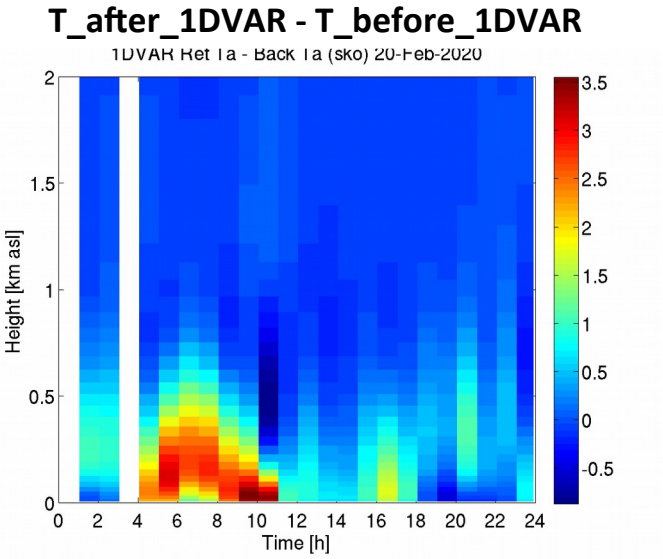


- 1ers preliminary 1D-Var run (no bias correction de biais, diagonal B matrix not adapted to fog)



- Large temperature increments (1DVAR minus AROME up to 3.5 K) : should limit the temperature cooling and the saturation in the model

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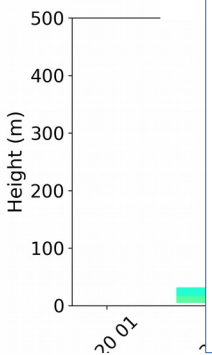
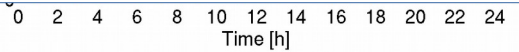
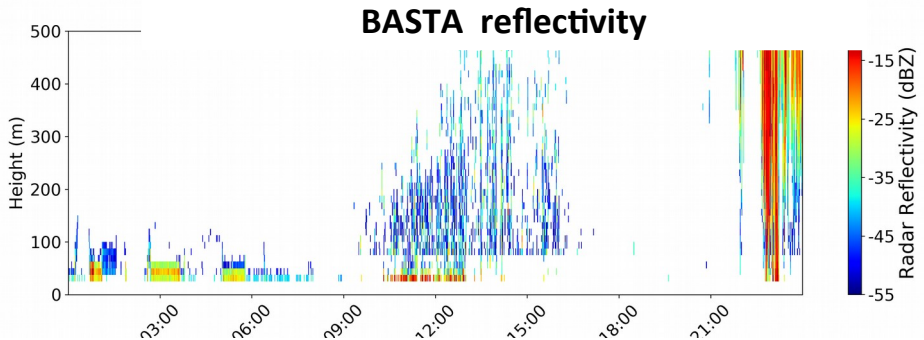
More about expected benefit of MWR data assimilation in the following paper :

Martinet,P et al : Improvement of numerical weather prediction model analysis during fog conditions through the assimilation of ground-based microwave radiometer observations: a 1D-Var study, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2020-166, in review, 2020.







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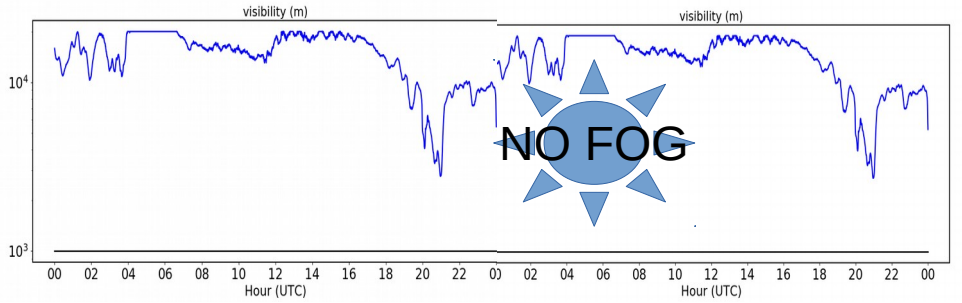
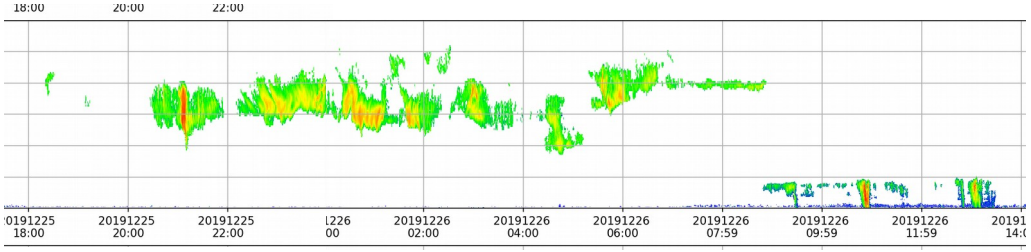
Benefit to fog process studies & better understanding of spatial heterogeneities

IOP4 26/12/2019 : thick fog in Agen versus no fog at the supersite

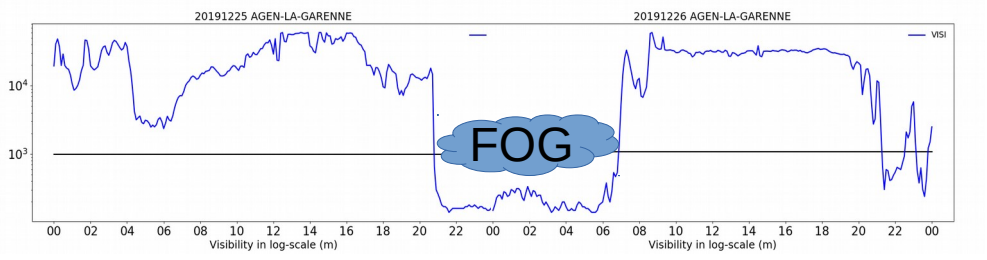


Visibility super-site



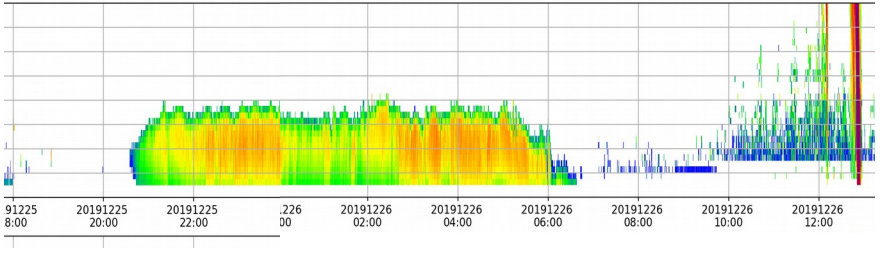
Basta super-site (0-12 km)

High clouds in altitude (20h30 UTC) limit the radiative cooling



Visibility Agen

Fog : 21 UTC to 27/12 07 UTC



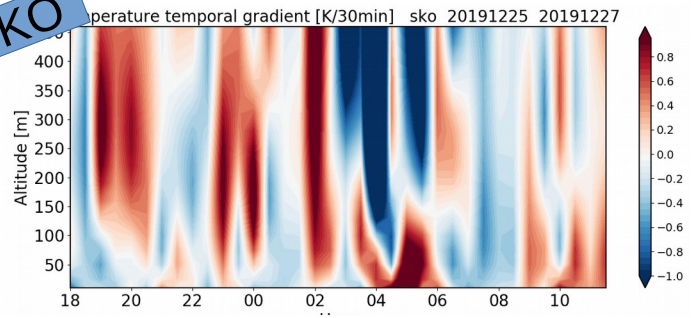
Basta Agen (0-500 m)

150 m thick fog starting at 20h30

MWR data : an added value to fog process studies

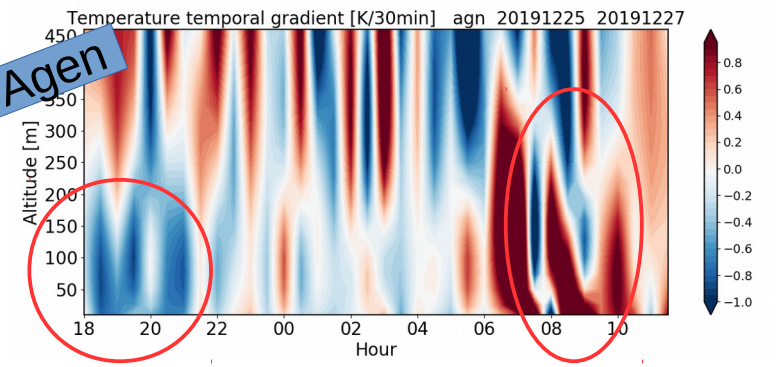
Temperature profiles temporal evolution dK within 30 minutes

SKO



- Larger pre-fog cooling 2 hours before fog in Agen

Agen



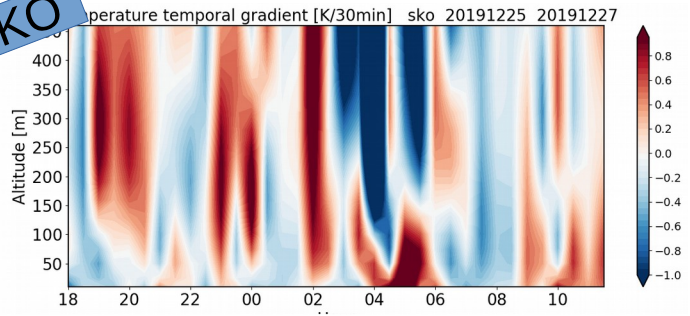
Pre-Fog cooling

Fog dissipation

MWR data : an added value to fog process studies

Temperature profiles temporal evolution dK within 30 minutes

SKO



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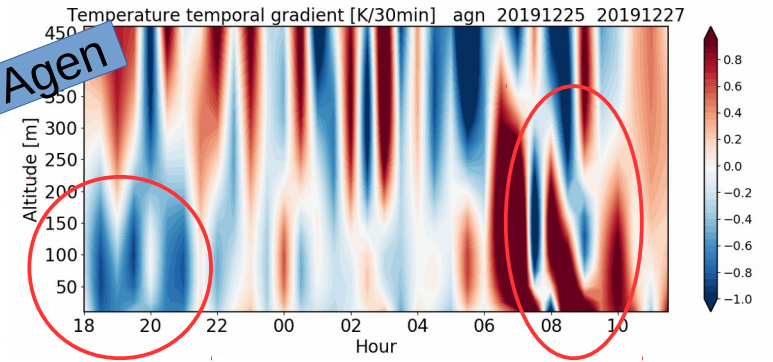
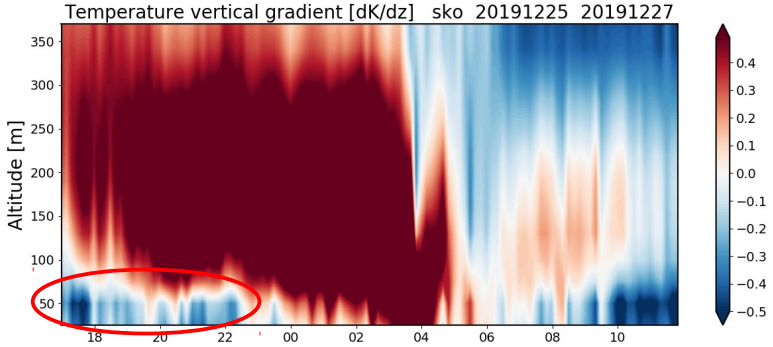


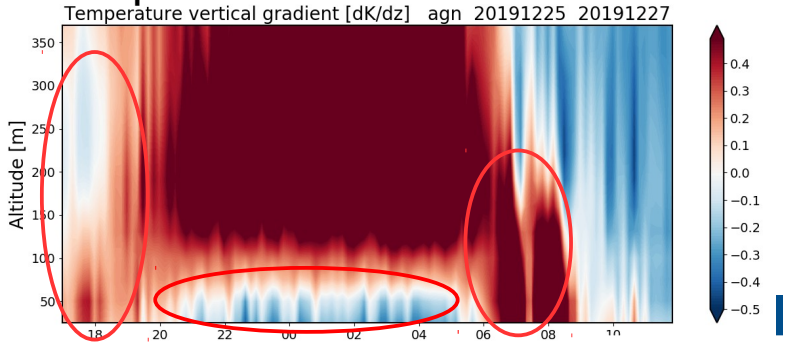
Pre-Fog cooling

Fog dissipation

Temperature vertical gradient (within 30 m bins) temporal evolution



- Un-stable conditions within the first 100m at the super-site until 00 UTC



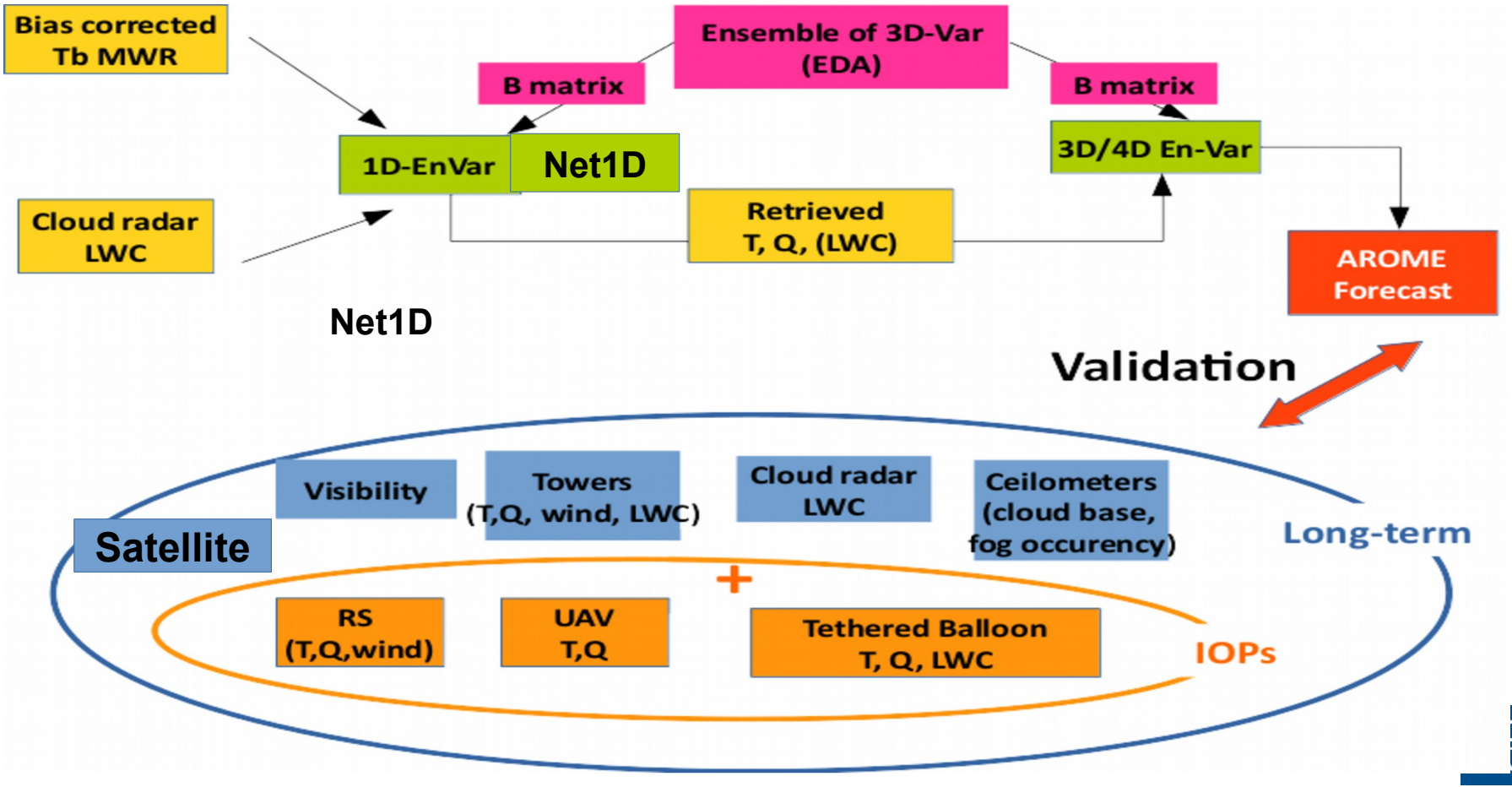
Stable conditions pre-fog

Surface unstability due to warming by fog

Stable conditions After fog

Benefit of the MWR network : future work

WP5 : Summary of the work-plan



New steps

- Optimization of 1D-Var retrievals (bias correction and B matrix)
- Finalization of the database (11/2020 => 04/2021) => AERIS and paper on retrieval inter-comparison
- 3D/4D-EnVar DA experiments, preparation on-going (04/2021 => 04/2022)=> post-doc April 2021 (supervision with. P. Chambon & P. Brousseau)
- Investigation into IR / MWR synergy to improve LWP retrievals (collab. Domenico Cimini) => investigation on-going, potential for PhD Autumn 2021
- Use of MWR data for fog process studies and AROME model evaluation : statistics of fog parameters and their variability + regional-scale variability (temperature & humidity gradients, IWV, and LWP etc.) => 01/2021
- Synergy between ground-based and satellite data : collab. University of Cologne and Eumetsat (M2 internship) : https://eumetsat.jobbase.io/job/iv8b7dox

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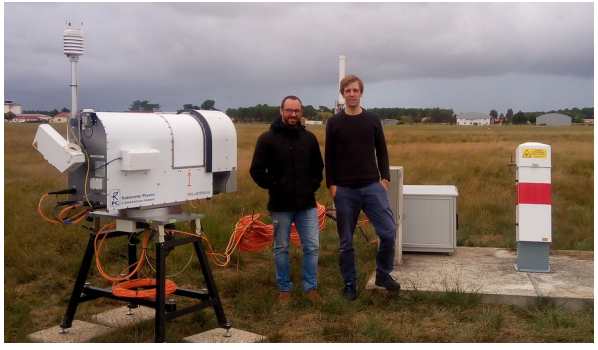
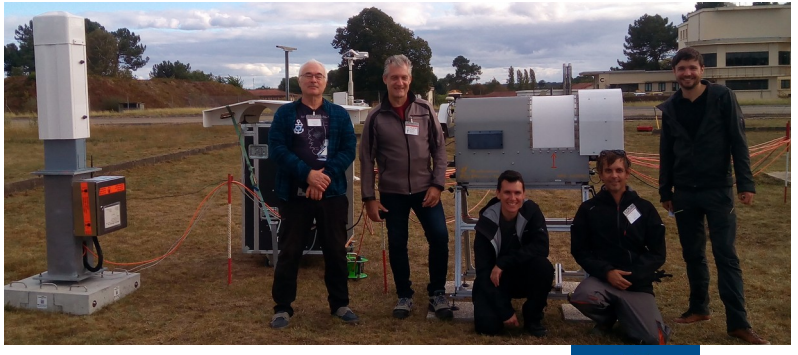
Thanks for your attention and thanks to all the MWR network partners !





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Task progress (Main achievements)

- Evaluation of data quality with respect to RS at the super-site / Agen and Toulouse
- First 1D-Var retrievals with a simple configuration (no bias correction, diagonal B matrix)
- Inter-comparison of several retrieval methods (University of Cologne collaboration)
- Correction of errors in RPG Neural Network retrievals (RPG collaboration)
- Correction of errors in LWP offset correction
- In parallel to the database preparation, preparation of the AROME 3D-EnVar experiment (CNRM/GMAP collaboration)

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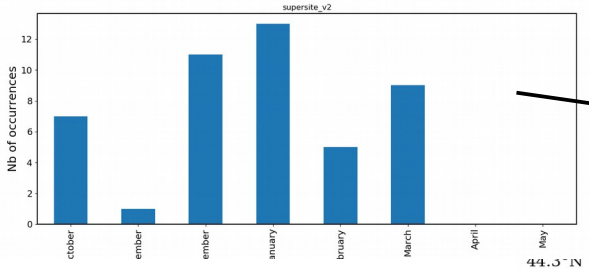
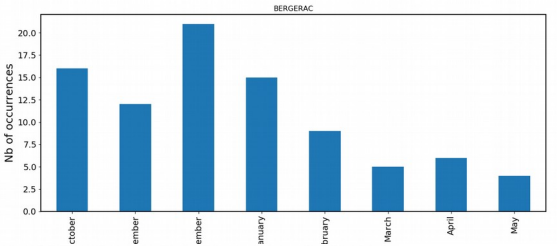
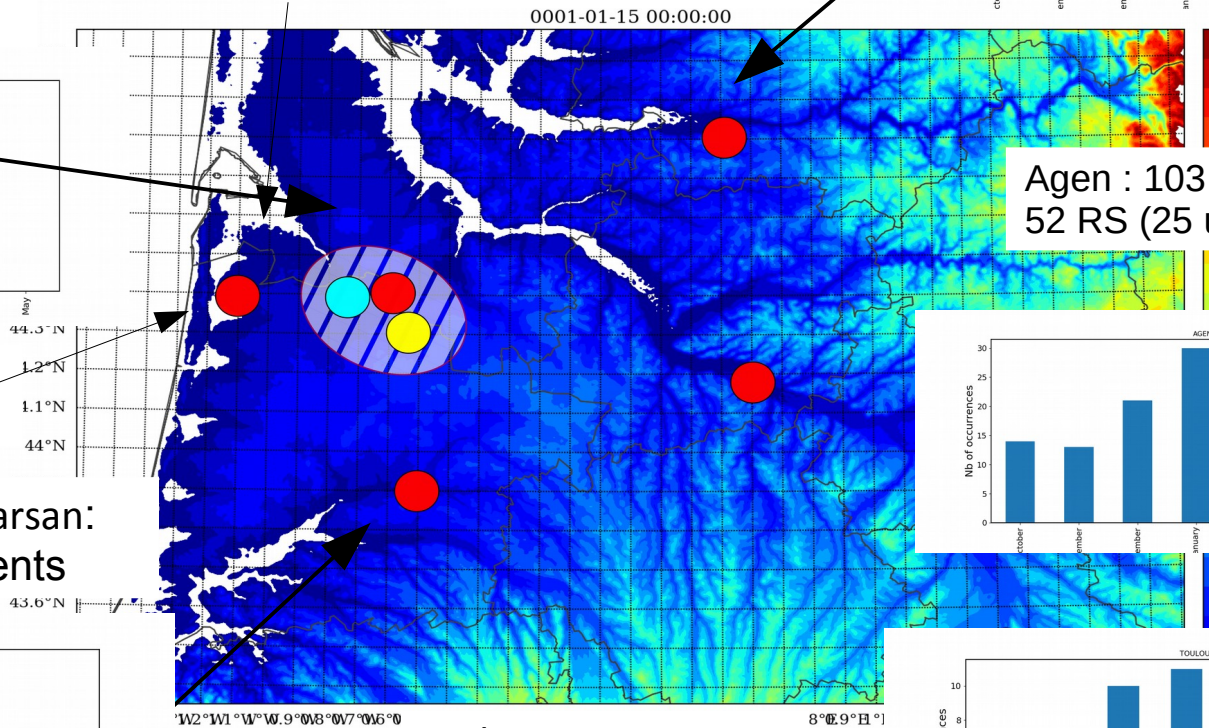
MWR network : fog events and statistics per month

Super-site :
45 fog events
61 RS (9 under fog conditions)



Bergerac
- 88 fog events

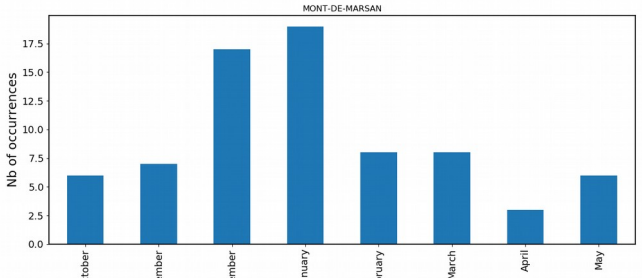




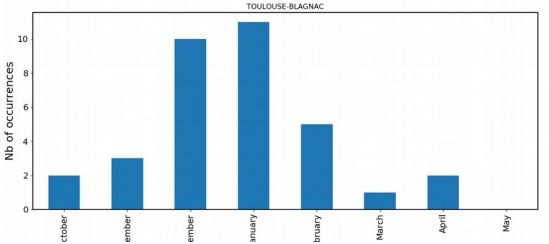
Agen : 103 fog
52 RS (25 under fog)

Biscarrosse :
- 15 fog events

Mont de Marsan:
- 74 fog events



Toulouse
-34 fog events
-28 RS (14 under fog)



Fog occurrence by site and month and fog duration

-Super-site :
46 cas

-Agen :
103 cas

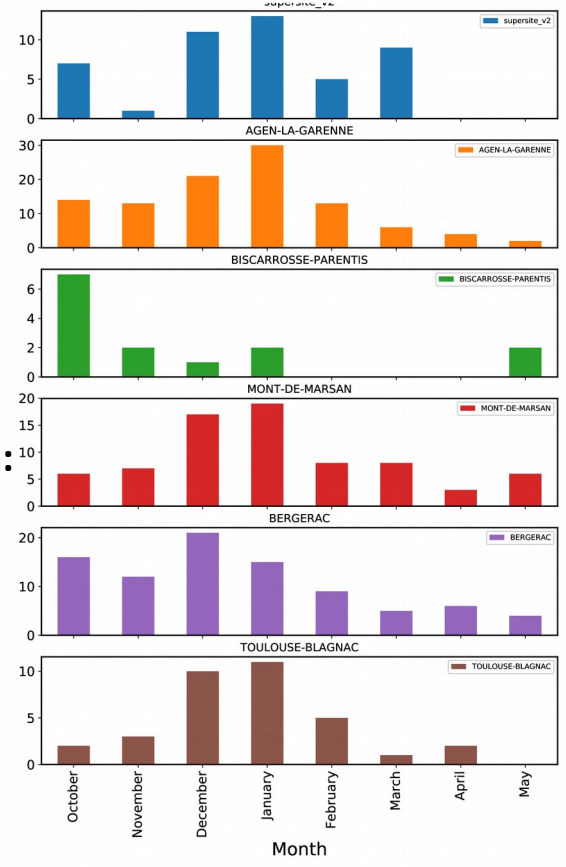
-Biscarrosse :
15 cas

- Mont-de-Marsan:
74 cas

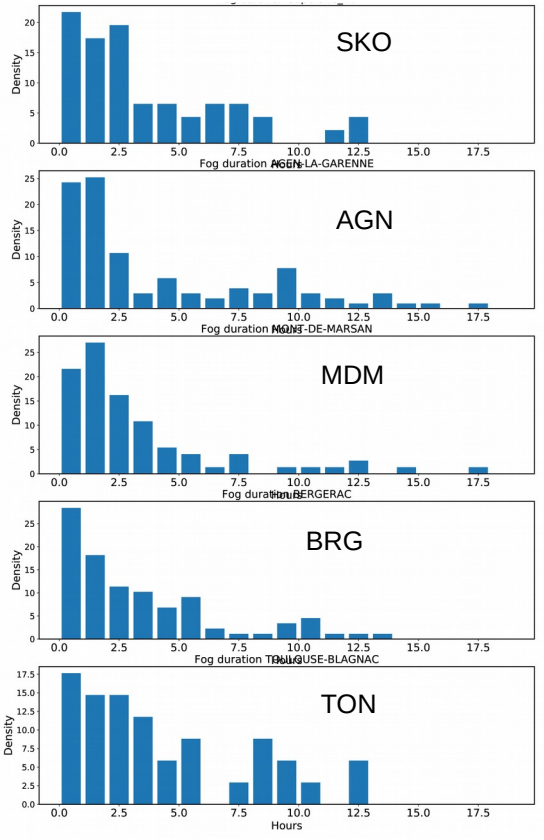
- Bergeac:
88 cas

- Toulouse:
34 cas

Number of fog occurrence by site and month



Fog duration by site



- Most of fog events occur in January / February
- Mean fog duration : 3h30 to 4h30
- 50 % of fog events with lifetime < 2h
- Most persisting fog (> 7 h) : Toulouse and Agen

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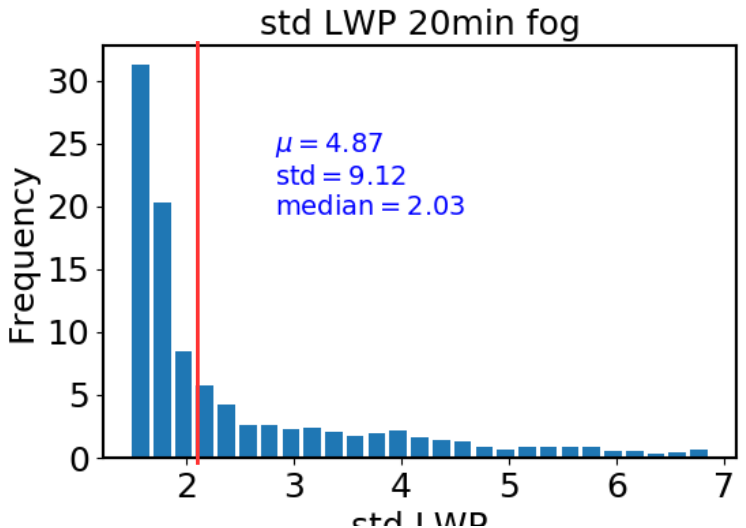
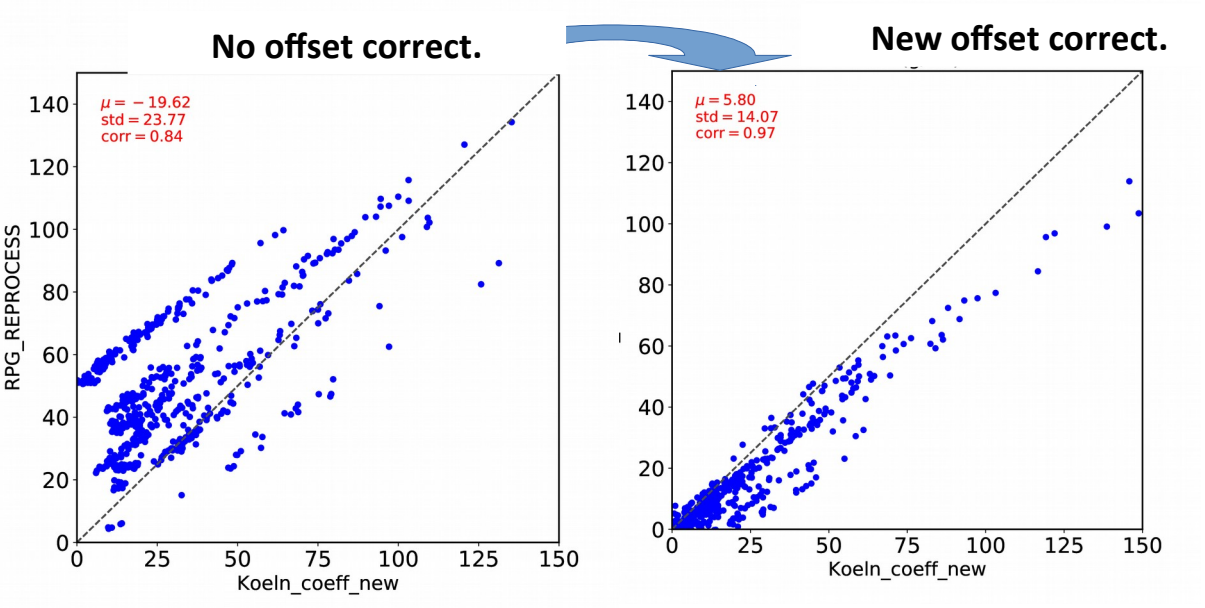
LWP inter-comparison

LWP 20 minutes std during fog events



- Initial LWP std threshold used for clear-sky detection too high for fog (median = 2 g/m²)
- New offset correction proposed at the super-site using visibility measurements to identify fog periods

Scatterplot between LWP neural network (y-axis) and LWP quadratic regression (x-axis)



- Much better agreement between the two statistical retrievals using new offset correction
- LWP products for all sites available