The SOFOG3D MWR network : on-going activities

Task5 : Data assimilation and forecast

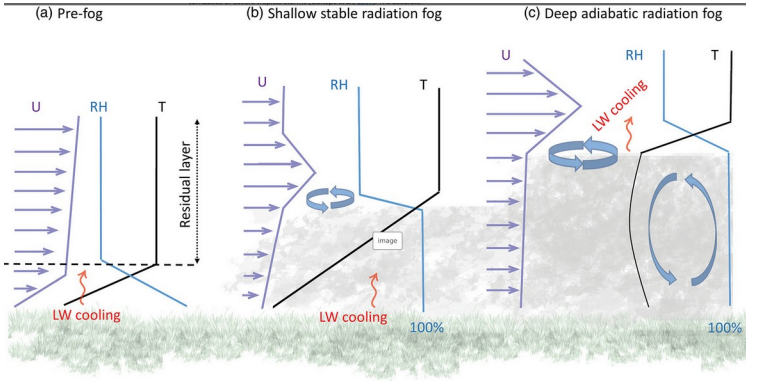
P. Martinet, A. Kremer, U. Löhnert, Donatello Gallucci, Domenico Cimini, E. Orlandi V. Unger, Constanze Seibert, Thomas August and all WP5 partners

The SOFOG3D MWR network : context

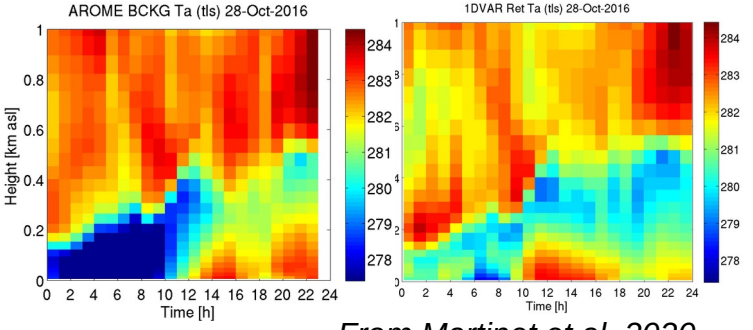
- Fog formation and fog lifecyle are driven by complex physical processes : radiative processes, turbulence, subsidence, advection etc..

- For radiation fog : an accurate initialisation of temperature, humidity and wind profiles within the boundary layer is key to be able to saturate the stable pre-fog layer and move to an optically thick fog.

- Previous studies have highlighted the need of continuous observations of temperature profiles within the ABL for the AROME model



From Smith et al, 2018

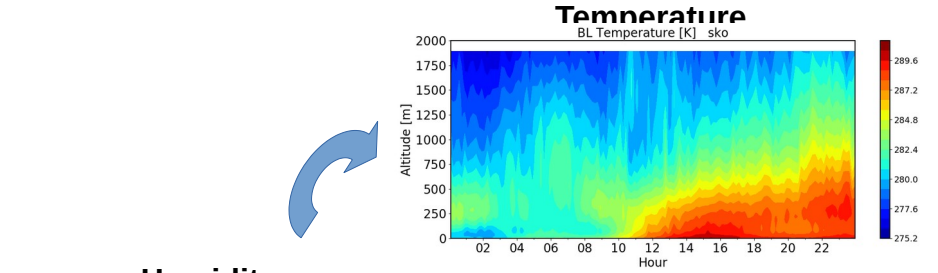


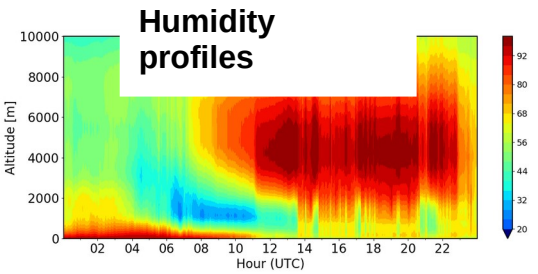
From Martinet et al, 2020

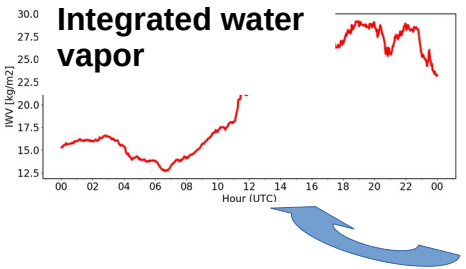
- Bure radiation fog 25/10/2016 : background temperature (left) and 1D-Var analysis increment (right)
- Thick fog in the AROME model due to false alarms

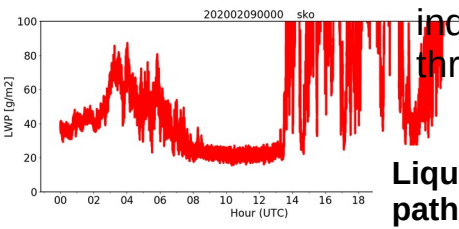
MWR : continuous temperature, humidity and LWP profiling

- 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 profile** : well resolved in the BL (~50 to 150m resolution)
- Measurements of reference for the **IWV** (0.5 to 1kg/m²) and the **LWP** (10 to 20 g/m² error)





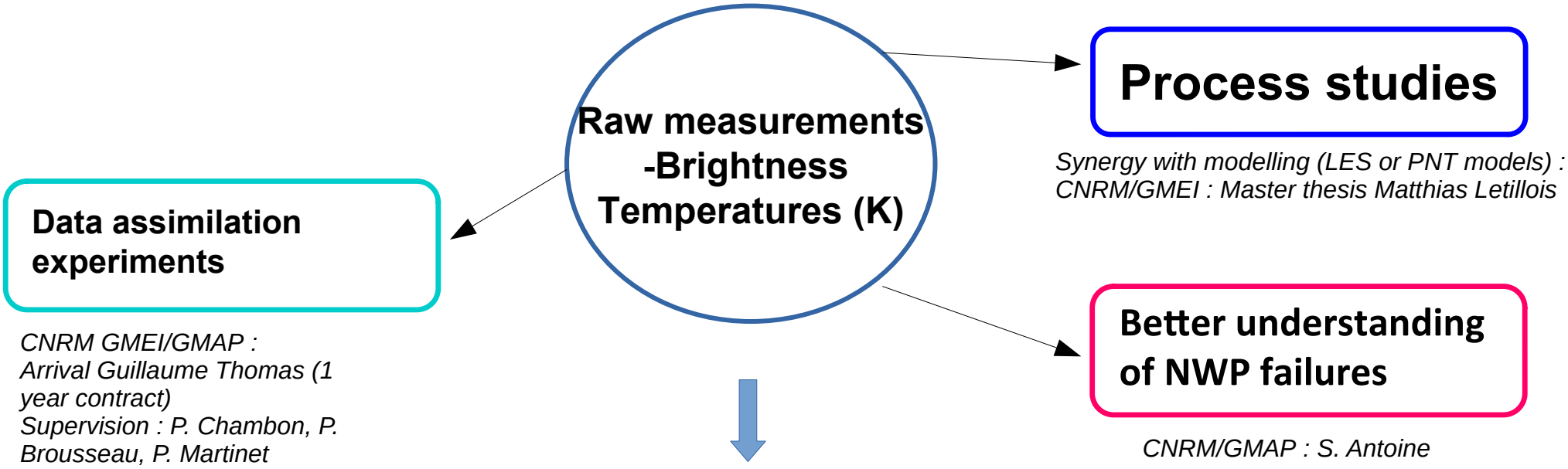




→ IR radiometer when available
+
→ LV3 products : boundary layer height / stability indices/ fog threat

Liquid water path

Usefulness of MWR data

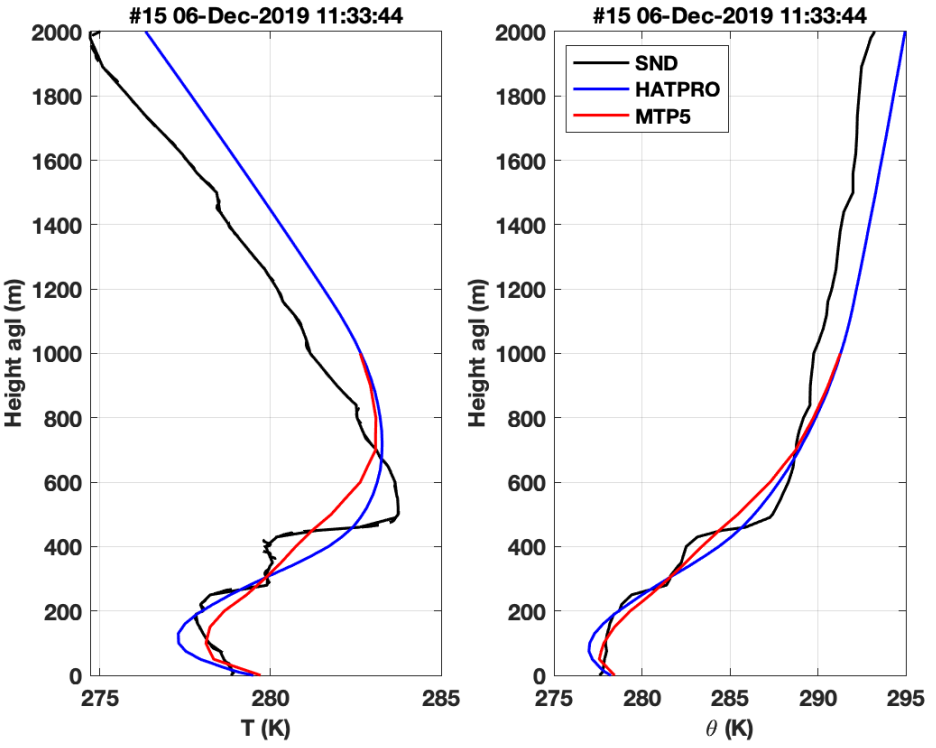


Part I : Temperature, humidity and LWP retrievals

Preparation of the temperature database

- Evaluation of temperature and humidity profiles by different retrieval algorithms : **neural networks** trained with AROME (RPG collaboration), **quadratic regression** trained with COSMO (University of Cologne), **1D-Var**

Temperature profiles from two colocated MWR
HATPRO, MTP-5
Vs radiosondes (61 match-ups)



D.Cimini courtesy

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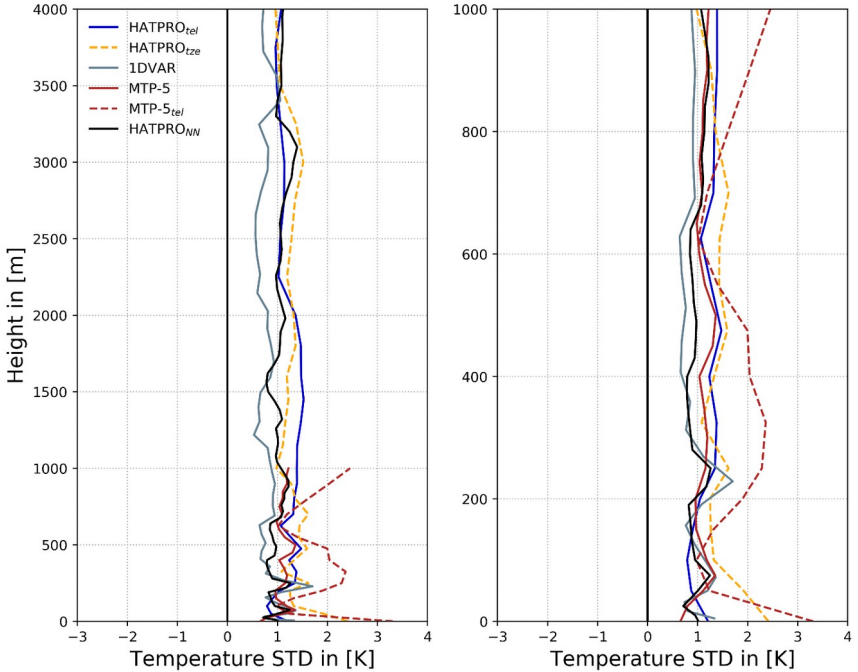

A. Kremer courtesy

Statistics with all RS :

- Similar variance for all retrievals below 250m
- Quadratic regression from Cologne : sligthly better at 150m
- 1D-Var and NN with lowest variance above 250m

In-cloud statistics

- Lowest variance for regression
- Highest variance with 1D-Var !

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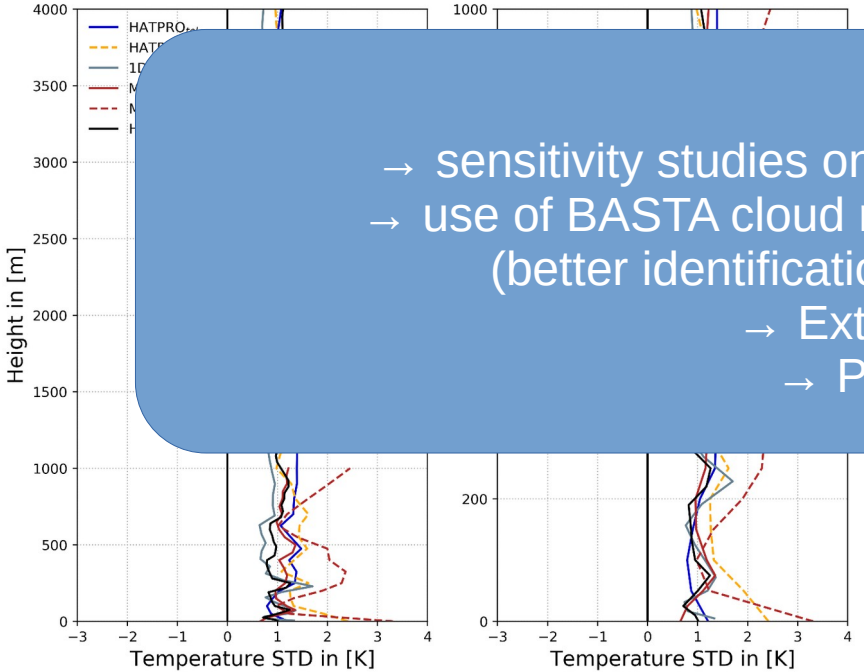


A. Kremer courtesy

Statistics with all RS :

Next steps :

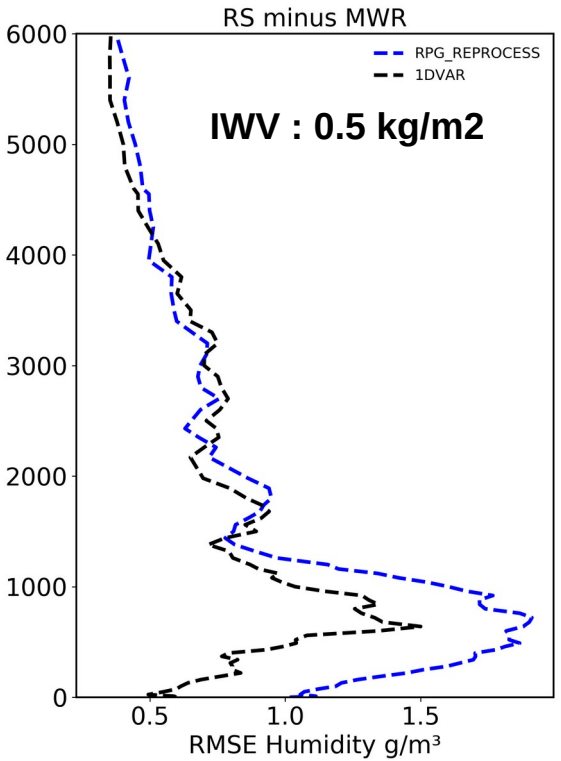
→ sensitivity studies on the 1D-Var (bias-correction/B matrix)
→ use of BASTA cloud radar to improve the in-cloud statistics (better identification Of cloud top height and base)
→ Extend to the Agen site
→ Potential publication

- Lowest variance for regression
- Highest variance with 1D-Var !

Preparation of the humidity database

RMSE RS - MWR

G5 super-site (61 RS, 9 fog)



- RMSE Q : 0.5 to 1.5 g/m3
- Z< 2 km : 1D-Var performs better with improvement up to 1 g/m3
- Z > 2 km : similar accuracy
- Similar accuracy in IWV

NN initial

AERIS database

- Temperature and humidity retrievals (profiles and IWV) have been delivered on the AERIS dabase
- RPG Neural network chosen for their robustness
- After more investigation, 1D-Var retrievals could be transferred in a second time

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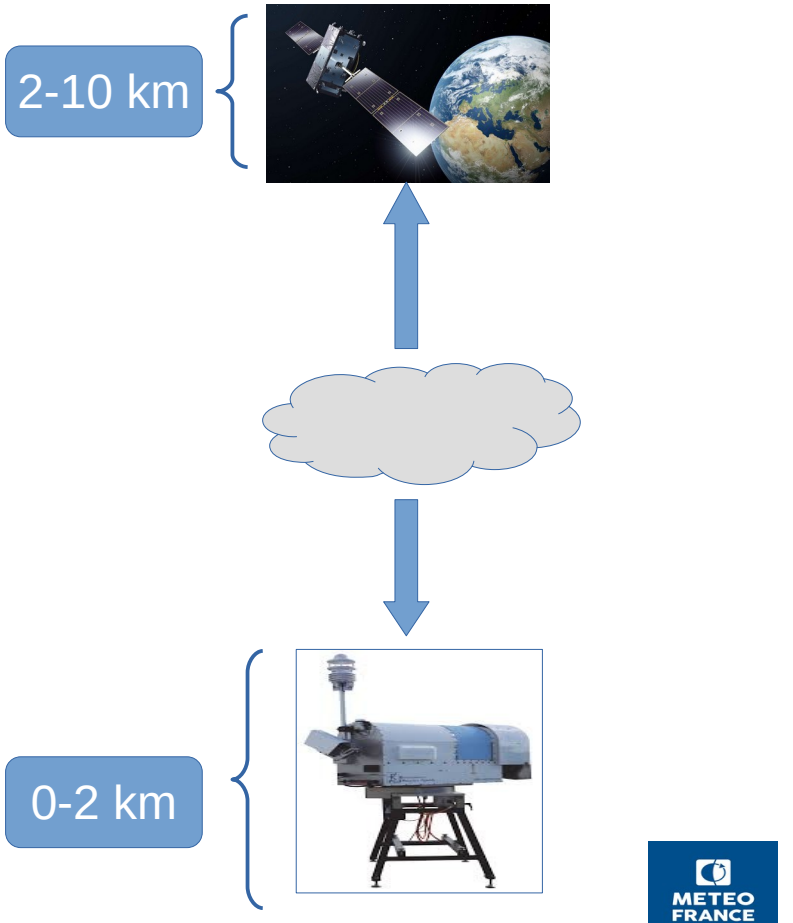
SOFOG3D T/Q profiles : on-going activities with satelitte data monitoring and synergy with MWR : Constanze Seibert (EUMETSAT) , T. August (EUMETSAT), P. Martinet (CNRM) & U. Löhnert (U. Cologne)

- Investigate the usefulness of operational ground-based MWR network for daily monitoring of level2 profiles from IASI/AMSU on Metop satellite.
- Better understanding of spatial and temporal errors in the current monitoring of IASI data (based on scarce RS)
- Despite a degraded vertical resolution, can low temperature inversions during stable condition be detected in IASI lv2 products
- Perspective : combination of IASI + MWR to improve the temperature profile accuracy above low clouds



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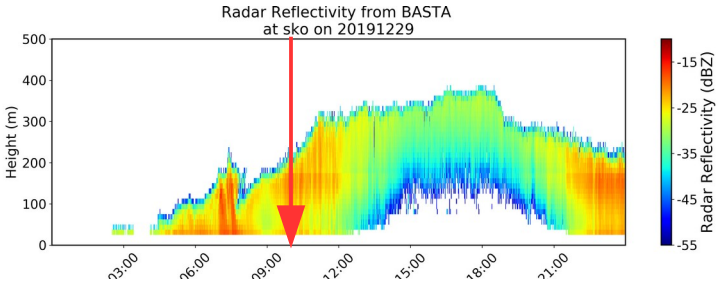
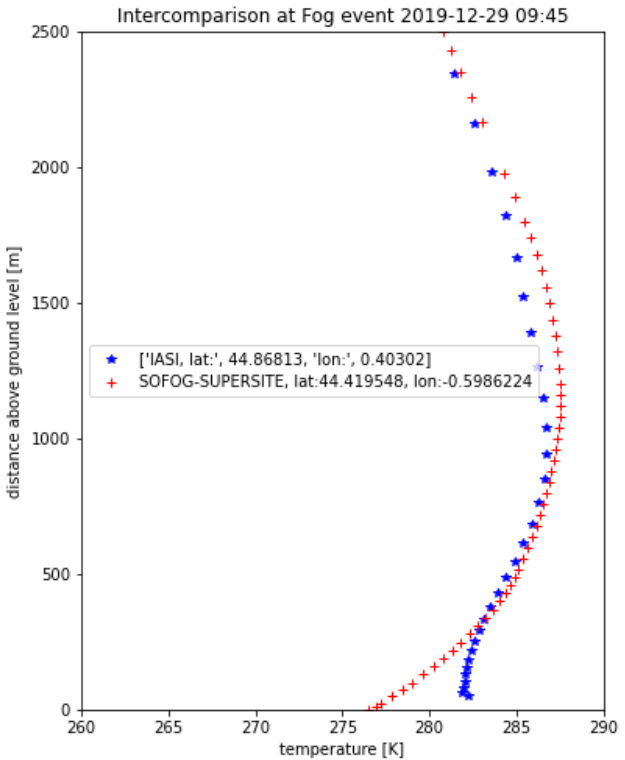
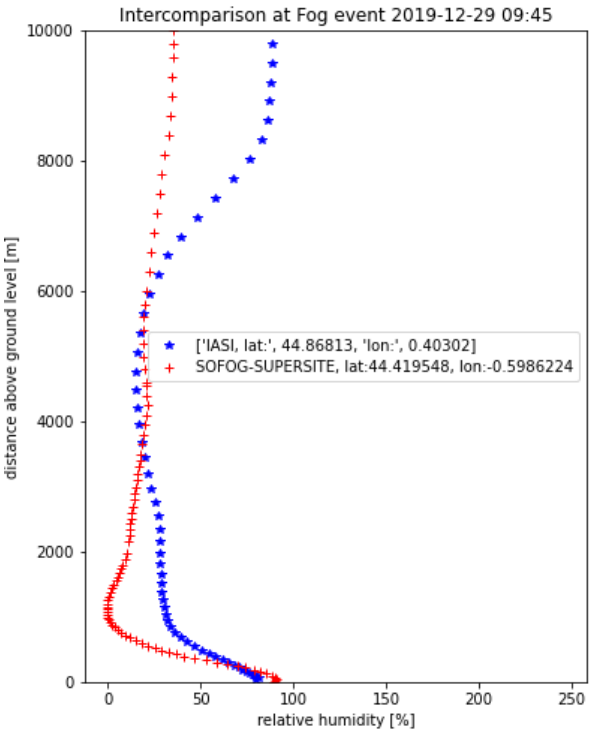
- First co-location IASI / MWR during SOFOG3D data



- Thick fog at super-site
- Low temperature inversion much smoother with IASI but good agreement above 500m
- Significant differences in relative humidity

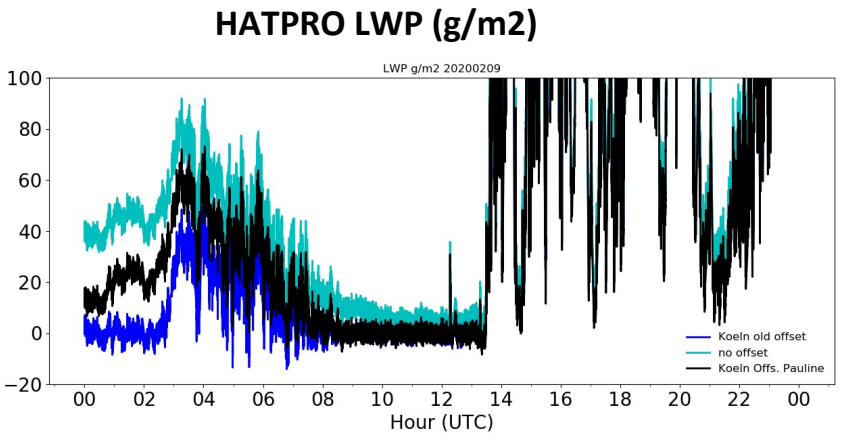




C. Seibert courtesy

Preparation of the database : liquid water path (LWP)

- Fog LWP is key for the fog lifecycle affecting its radiative properties and dissipation
- 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
- Last meeting : proposal of a new bias correction
- When preparing the AERIS database : investigation into much larger offset correction observed for MWR of last generation compared to previous instruments.



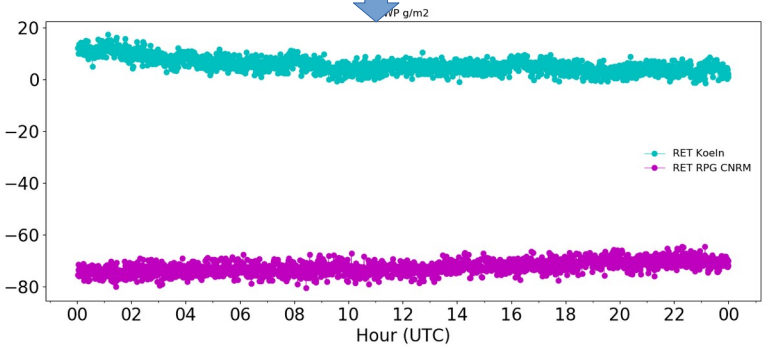
LWP new offset LWP old offset

LWP no offset

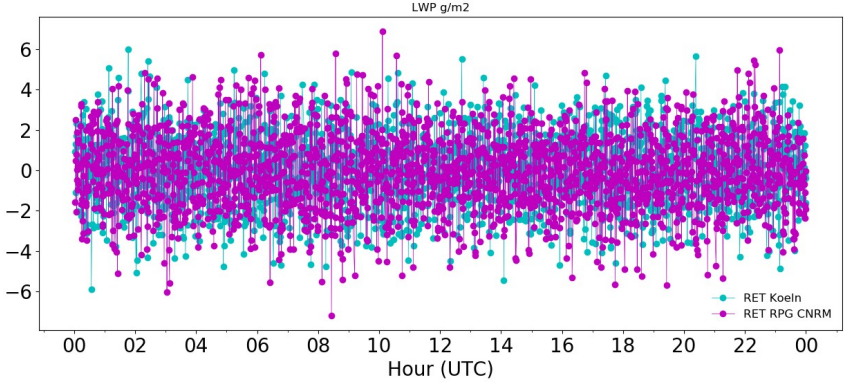
Investigation into LWP offset corrections

- Large negative offset in LWP observed for the HATPRO G5
- Investigation showed that the problem was in the NN training and new values of expected instrumental errors
- The offset correction homogeneizes the absolute values whatever the retrieval algorithm.

Before offfset correction :



After offset correction :



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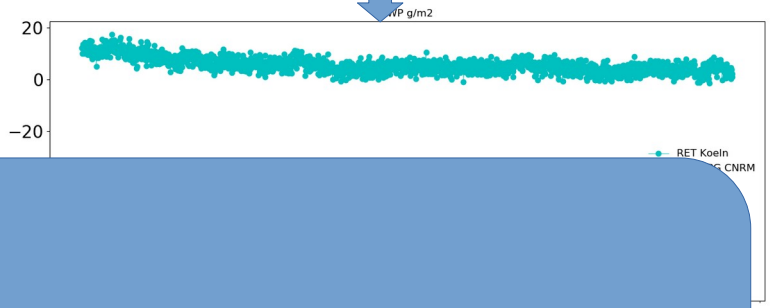
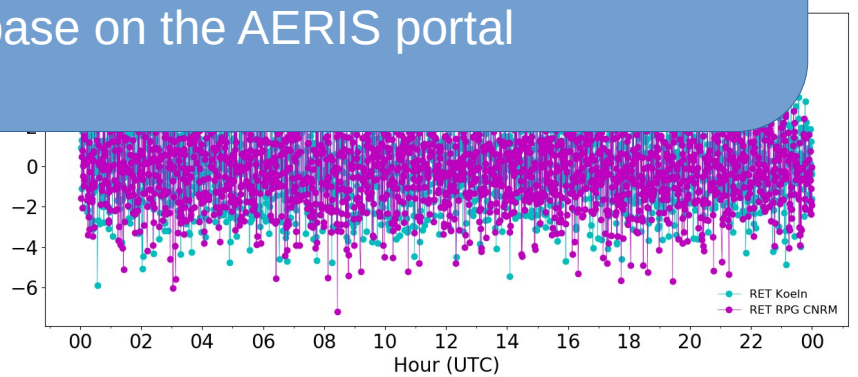


Next steps :

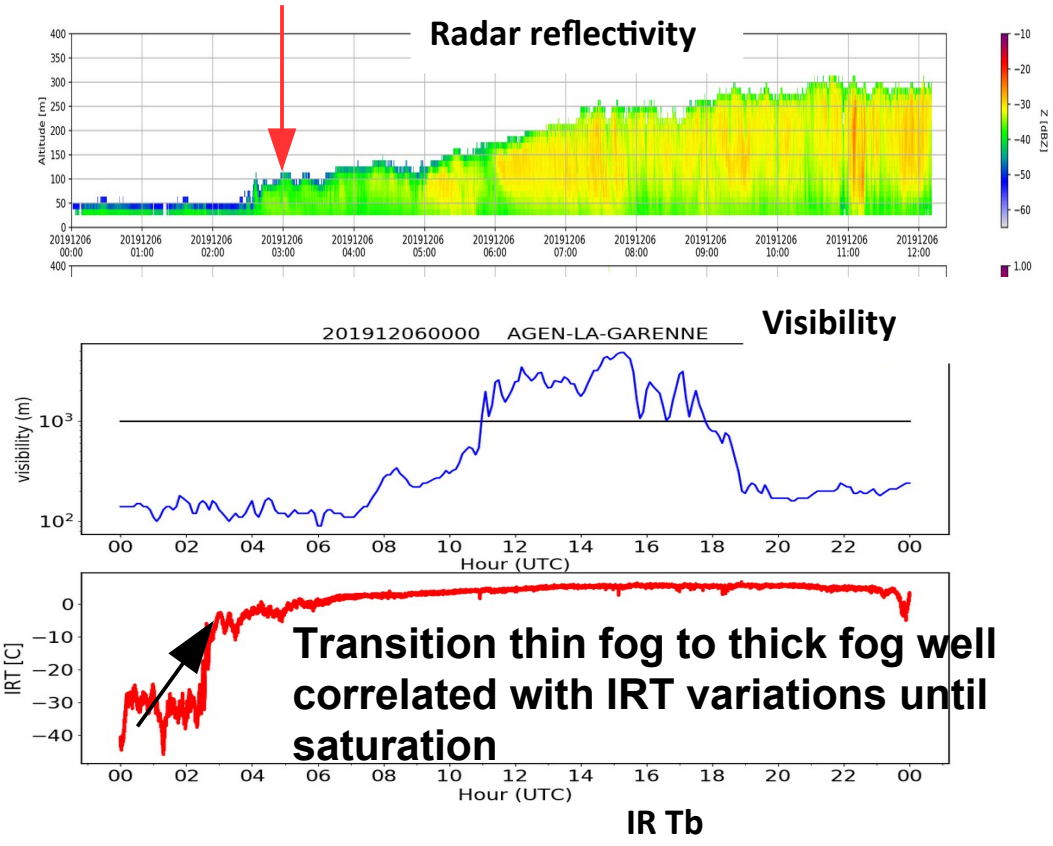
→ confidence in the LWP products
→ implementation of the offset correction for all sites
→ deliverable of the LWP database on the AERIS portal



Improvement of the LWP retrievals for low LWP values with IR synergy (D. Gallucci, D. Cimini, P. Martinet)

- IRT observations : available everywhere except for the MWR of the University of Cologne.
- Potential to make an analysis over ~ 300 cases of fog events taking into account all sites (probably a bit lower due to missing data from Mont-De-Marsan)

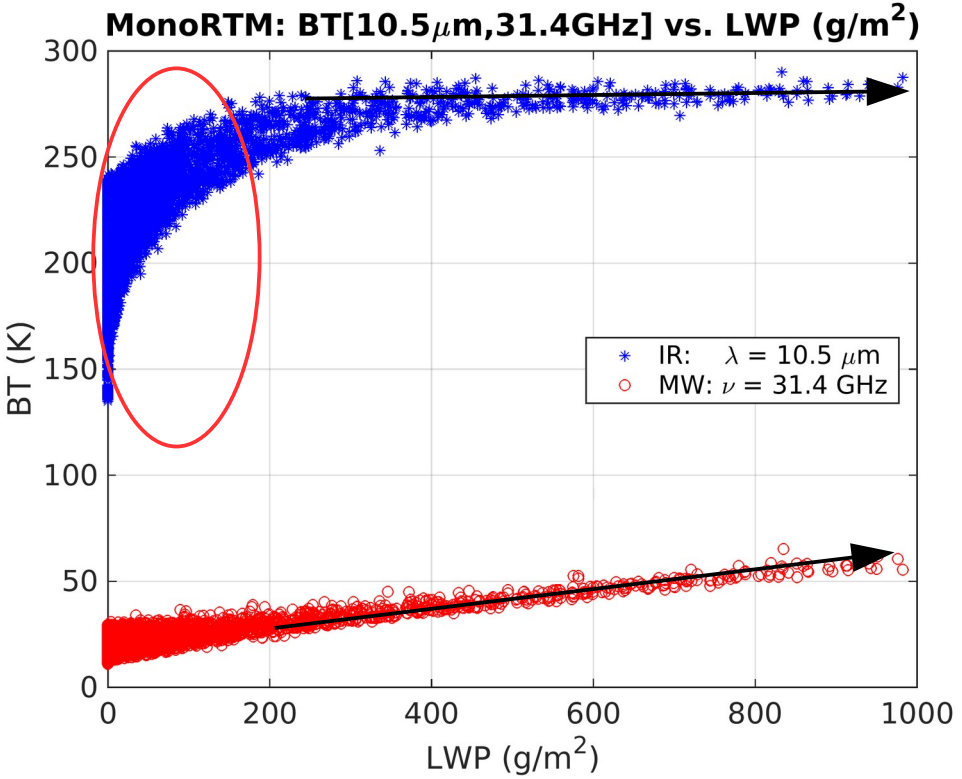
Fog optically thick at IR



Improvement of the LWP retrievals for low LWP values with IR synergy (D. Gallucci, D. Cimini, P. Martinet)

- Higher sensitivity of IR for low LWP < 150 g/m2
- Saturation of the IR signal for LWP > 150 g/m² while the MW shows a linear dependence to the LWP

Investigation into the IR synergy to improve low LWP retrievals



D. Gallucci courtesy

Improvement of the LWP retrievals for low LWP values with IR synergy (D. Gallucci, D. Cimini, P. Martinet)

- Use of the AROME database to train new linear / quadratic regressions
- Sensitivity studies of the retrieval accuracy to the training database and instrumental errors

Train (whole LWP) and test (LPW < 0.1 mm)

	14MW	7MW (WV)	14MW-IR	14MW-IR-IR^2
rmse (g/m2)	**17.60**	18.50	17.23	**17.16**
correlation	**0.86**	0.84	0.83	0.83

Train and test over LWP < 0.1 mm

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rmse (g/m2)	**12.32**	13.68	9.08	**8.19**
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- 30 % improvement in the LWP RMSE when only low LWP values are used in the training
- 50 % improvement in the LWP RMSE when only low LWP values used in the training and IR used and increase correlation (0.88 → 0.99)

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Improvement of the LWP retrievals for low LWP values with IR synergy (D. Gallucci, D. Cimini, P. Martinet)

Next steps :

→ apply new retrievals on real SOFOG3D measurements
→ quantify the improved accuracy compared to in-situ measurements

Part II : Data assimilation experiments

Data assimilation OSE : objectives

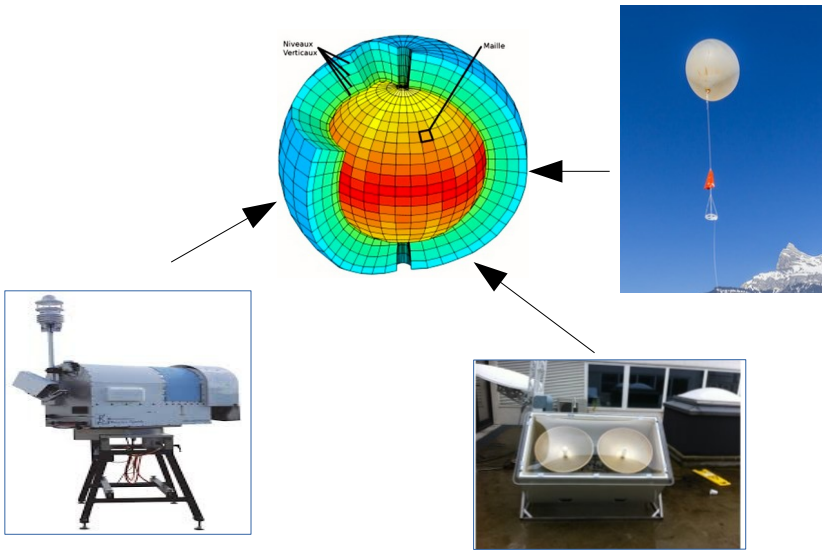
Focus data assimilation

→ 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 ?

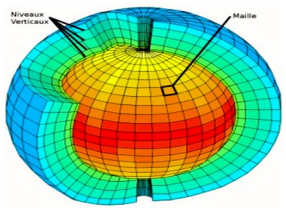
3D-EnVar / 4D-EnVar



Future data assimilation OSE : post-doc Guillaume Thomas (01/06/2021 → 31/05/2022)

- OSE starting with the assimilation of temperature profiles and IWV (humidity profiles to be discussed) : start with **Neural Network retrievals** and then switch to **1D-EnVar**
- Depending on time : possibility to include LWP or LWC retrieved from MWR and cloud-radar synergy

3D-EnVar AROME



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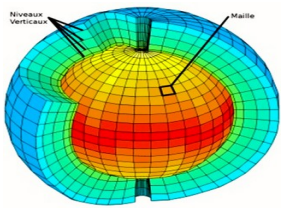
Conf 2

3D-EnVar AROME



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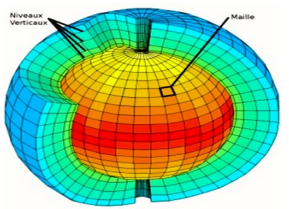
- Intensive Radiosondes

Conf 3

3D-EnVar AROME



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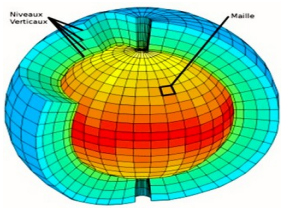
- MWR retrieved profiles at the same temporal resolution as RS

Conf 4

4D-EnVar AROME



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- MWR retrieved profiles at high temporal resolution **~ 10min**

Future data assimilation OSE : post-doc Guillaume Thomas (01/06/2021 → 31/05/2022)

Next steps :

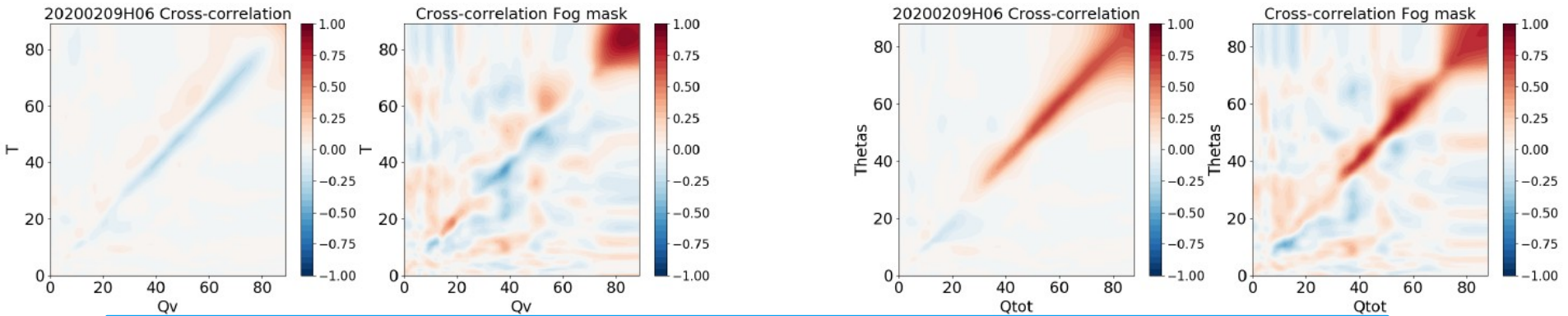
→ run a control 3D-Var AROME experiment : on-going
→ preparation of the MWR level2 data in an adapted file format
→ launch the first DA tests with one observation

Other on-going projects : Conservative variables for fog data assimilation : A. Barbu, P. Marquet, J-F. Mahfouf, P. Martinet

- M2 internship : Alina Barbu, P. Marquet, J-F. Mahfouf, P. Martinet : Use of conservative variables as new control variables : specific entropy and total water vapour
- Less variability in background-error-covariance structures with weather events => should avoid larger increment errors due to wrong vertical and corss-correlations currently used in background error covariance matrices.

Usual T / Qv variables

New Thetas / Qtot variables



- When usual variables show large differences in cross-correlation between fog conditions and other meteorological situations, thetas and Qtot show less variability

Other on-going projects : evaluation of atmospheric stability (D. Cimini)

- Investigate MWR performances in retrieving atmospheric stability during the SOFOG3D experiment.
- The aim is to provide an assessment for wind energy scientists, who use atmospheric stability as a proxy for the energy yield.

MWR temperature retrievals agree with radiosonde measurements within

1 K rms below 500 m

1.5 K rms below 1 km

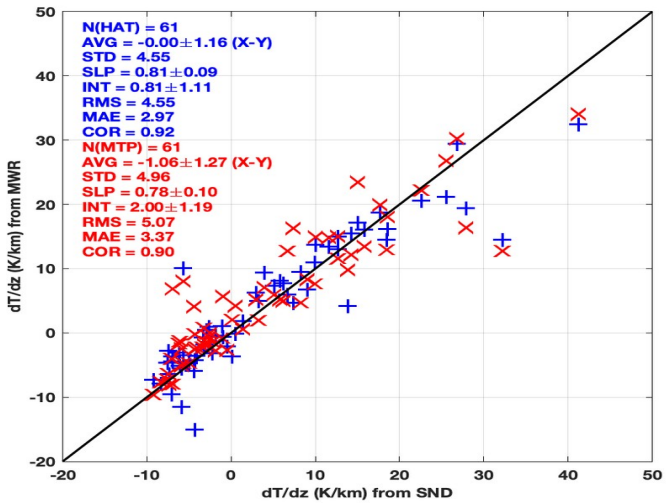
Temperature gradients agree with reference values with

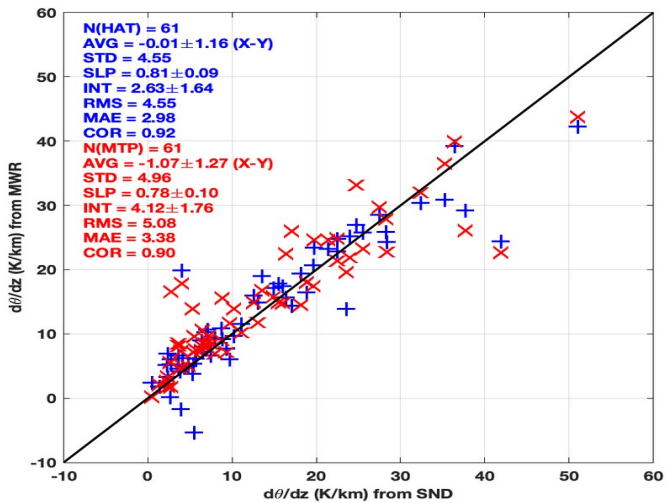
MAE ~3 K/km

bias <1 K/km

0.9 correlation.

Temperature and potential temperature gradients





Results from SOFOG3D are consistent with those from other datasets (ARM, XPIA)
Different climatologies (mountain, rural, marine) lead to similar performances
MWR performances seem mostly independent from the conditions

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MWR network next steps

Retrievals of thermodynamic And microphysics

- Optimization of 1D-Var retrievals (bias correction and B matrix)
- More in depth evaluation of in-cloud / in-fog temperature profiles retrievals
- Preparation of a scientific paper
- Analysis of IR synergy to improve low LWP retrievals and validation with in-situ measurements (CDP on tethered balloons)

Data assimilation

- 3D-Var / 3D-EnVar / 4D-EnVar data assimilation studies with the AROME model. Experiment already in preparation : G. Thomas

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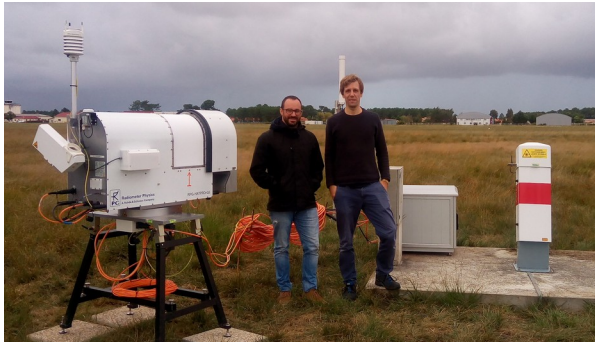
MWR network next steps

Process-studies

- Documentation of fog properties between the different sites : temporal evolution of temperature and humidity, evolution of temperature and humidity vertical gradients, inversion strengh and LWP
- Link with other variables : fog top and Doppler velocity from BASTA cloud radar + dynamics from Doppler lidar+aerosol activation from CL31 backscattering profiles

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



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