What benefit from ground-based microwave radiometers to better forecast fog events ?

P.Martinet[1], F.Burnet[1], D.Cimini[2], G.Cayez[1], B.Ménétrier[1], Y.Michel[1]
And many others (for technical deployment)

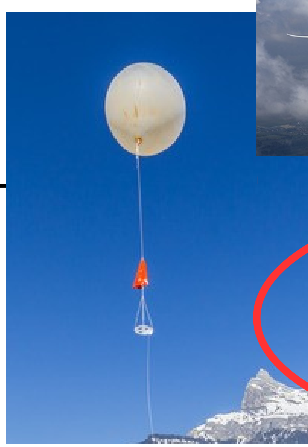
1 : Météo-France, CNRM (GMEI/GMAP)
2 : CNR-IMAA

ISTP2019, 20-24 May 2019

Motivation of the study

Aircraft

Balloon



PBL : observation gap
temperature and humidity
and microphysics 24/24

Weather station

Remote sensing :

- Degraded **fog forecast** due to degraded **initial conditions** of the model in the BL

Fog

What can we expect from the assimilation of MWR observations to improve fog forecasting ?

The Bure field experiment : winter 2016-2017

- Continental site (388 m altitude) in the North-East of France

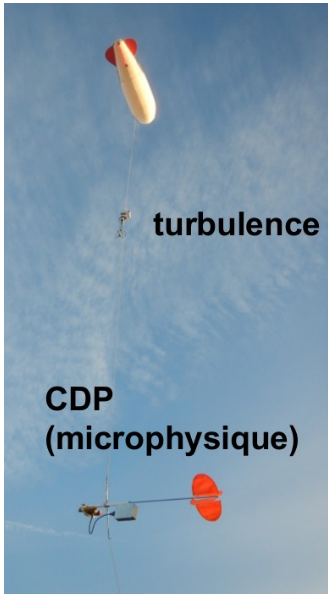
  - **120 m instrumented tower** for **microphysical** measurements (cloud particle counter, liquid water content (PVM100), cloud particle spectrometer (Welas)) + **visibility** + meteorological parameters (T, Q, winds) at 120m, 50m and 10 m

2 IOPs with tethered balloon (turbulence and CDP measurements) + 21 RS

Turbulence

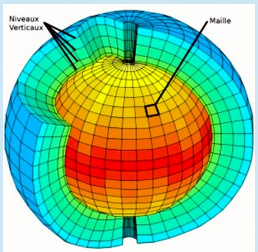
- UAVs : Xeno (high temporal frequency T, Q measurements)

Ceilometer and microwave radiometer



Methodology: 1D-Var retrievals

Model Space: T, Q, LWC

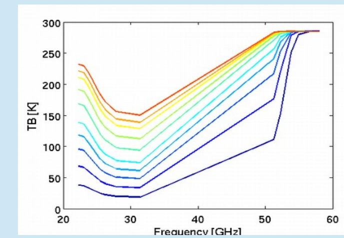


x_b= Background

1h AROME forecast

Radiative Transfer (F)
RTTOV-gb [1]

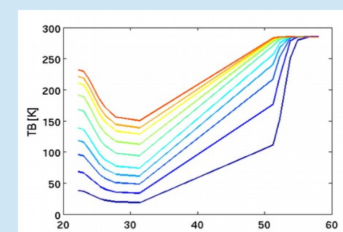
BT simulation (F(x))



Minimization of the cost function J:

$$J(x)=(x-x_b)^T B^{-1}(x-x_b)+(y-F(x))^T R^{-1}(y-F(x))$$

Observation : y



Iterative minimization
Adjustment of the background profile

1 ***F. De Angelis et al 2016***: *RTTOV-gb - Adapting the fast radiative transfer model RTTOV for the assimilation of ground-based microwave radiometer observations, GMD, doi:10.5194/gmd-9-2721-2016*
Martinet et al 2015 *: 1D-Var temperature retrievals from microwave radiometer and convective scale model, Tellus A 2015, 67, 27925, http://dx.doi.org/10.3402/tellusa.v67.27925*
Martinet et al 2017 *: Combining ground-based microwave radiometer and the AROME convective scale model through 1DVAR retrievals in complex terrain: an Alpine valley case study, Atmos. Meas. Tech., 10, 3385–3402, 2017 https://doi.org/10.5194/amt-10-3385-2017*

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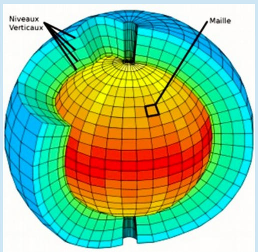

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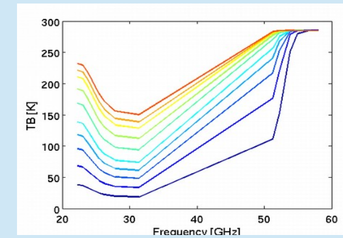
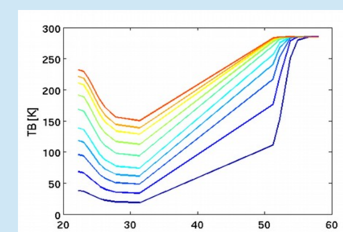


Minimization of the cost function J:

$$J(x) = (x - x_b)^T B^{-1} (x - x_b) + (y - F(x))^T R^{-1} (y - F(x))$$

Observation : y



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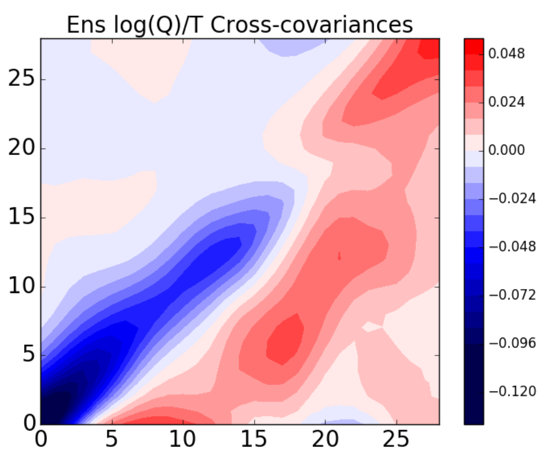
Adjustment of the background profile



- Strong positive correlations between temperature and humidity background errors derived with an ensemble of 25 AROME 3D-Var analyses

Ménétrier and Montmerle 2011 : Heterogeneous background-error covariances for the analysis and forecast of fog events, Q. J. R. Meteorol. Soc. 137: 2004–2013, October 2011 B

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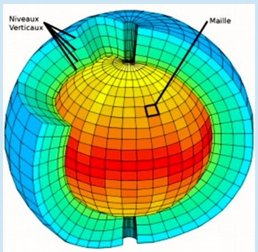

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1h AROM

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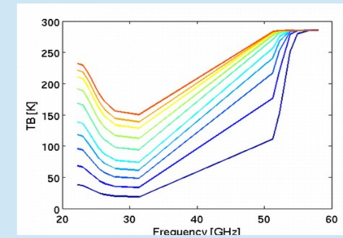

POSTER : Towards data assimilation of a European network of ground-based microwave radiometers into numerical weather prediction

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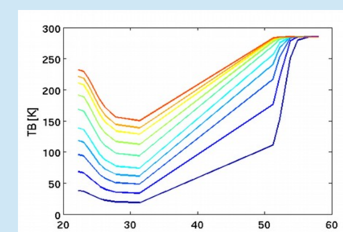

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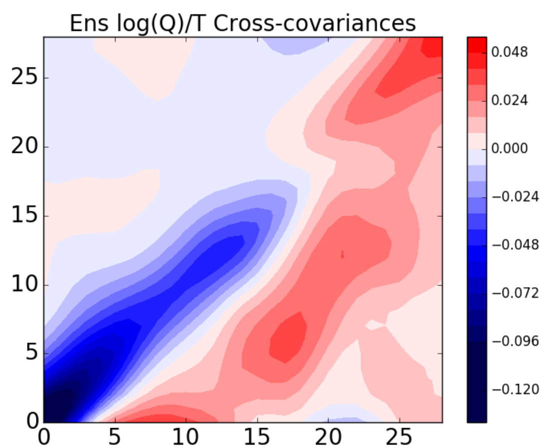

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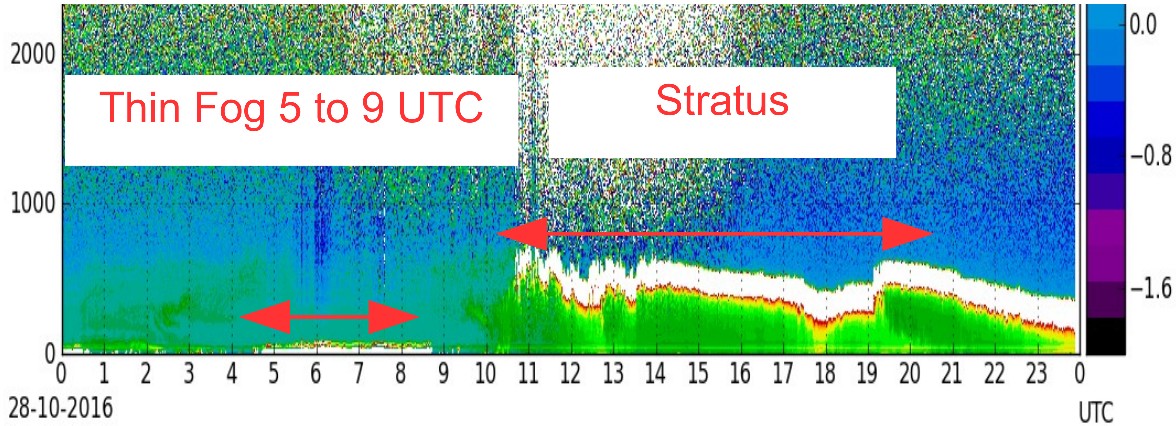
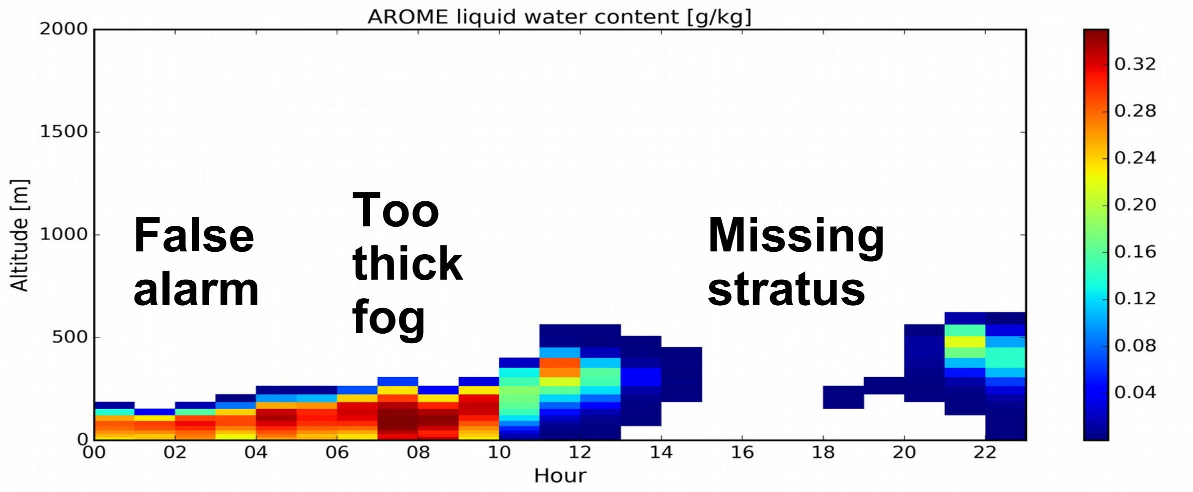
Very thin radiative fog : 28102016

Ceilometer cloud base



Liquid water content AROME



- **Temporal** errors
- Large **overetimation** of the **fog thickness**
- Wrong **dissipation** of the stratus cloud in the afternoon

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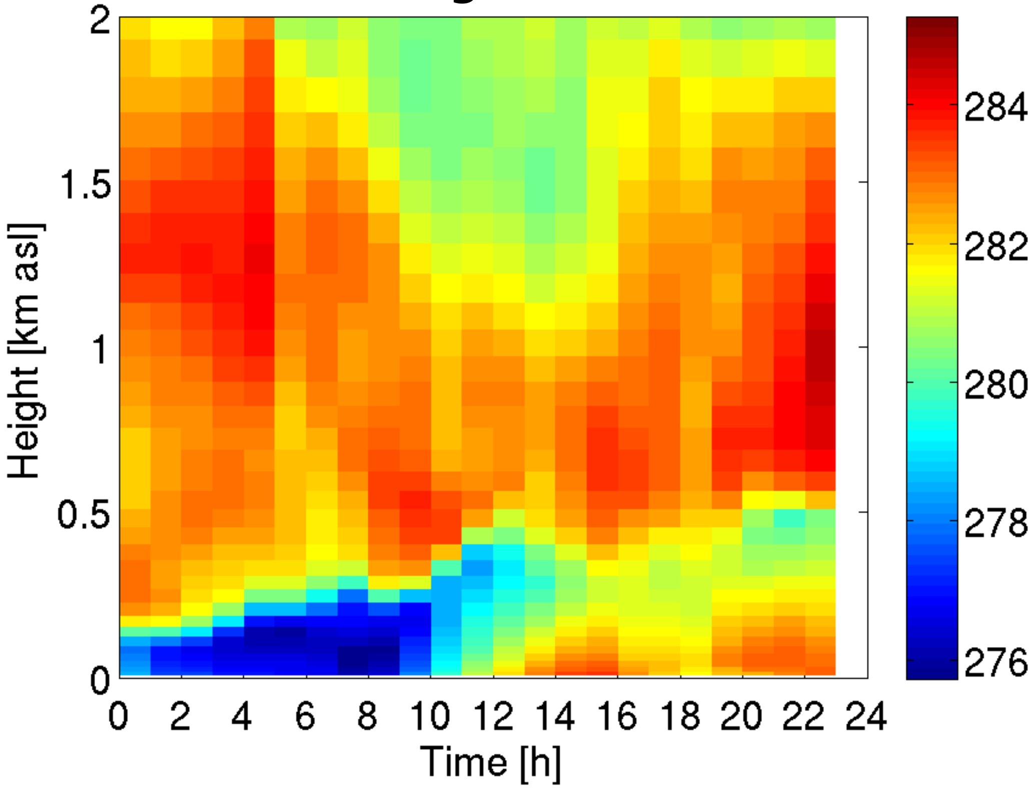
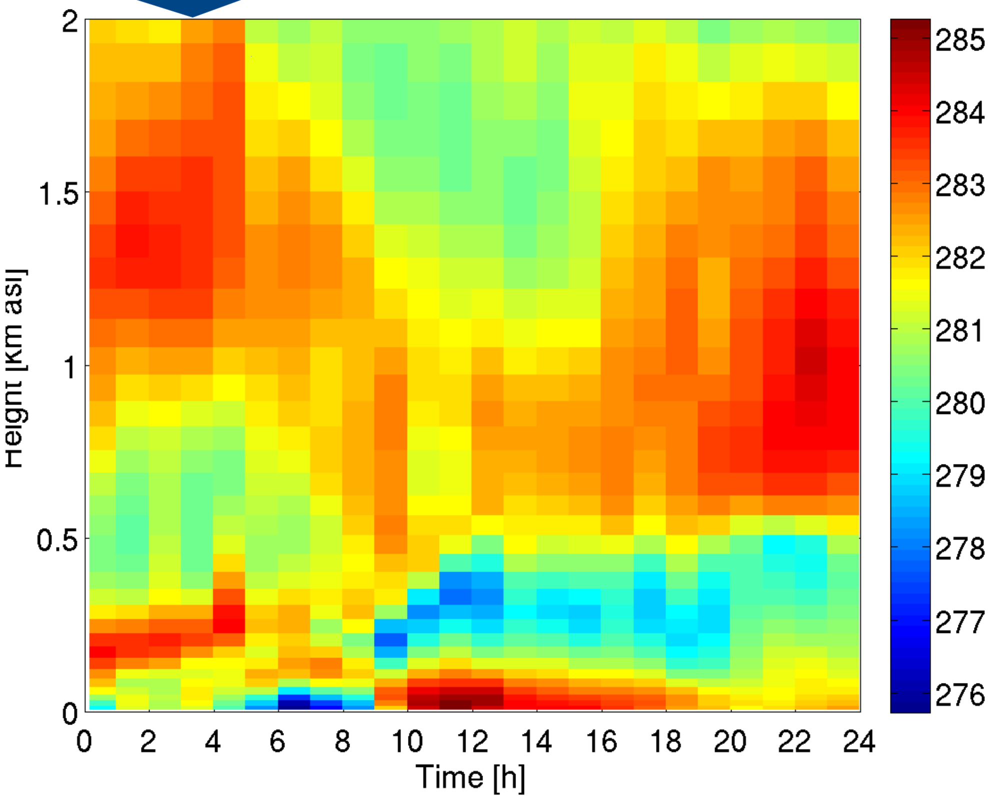
Temperature profile retrievals

+ MWR

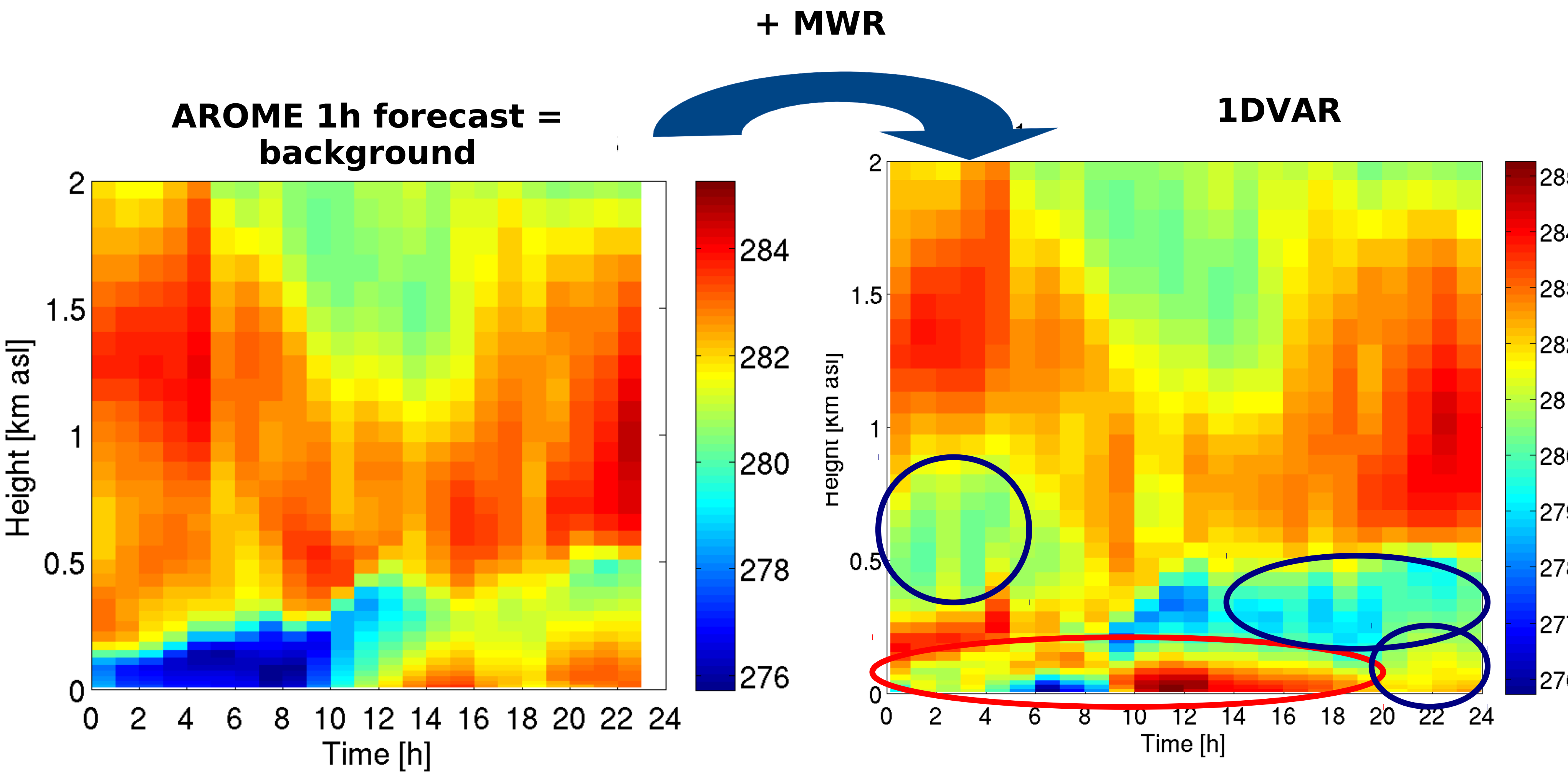
AROME 1h forecast = background



1DVAR



Temperature profile retrievals

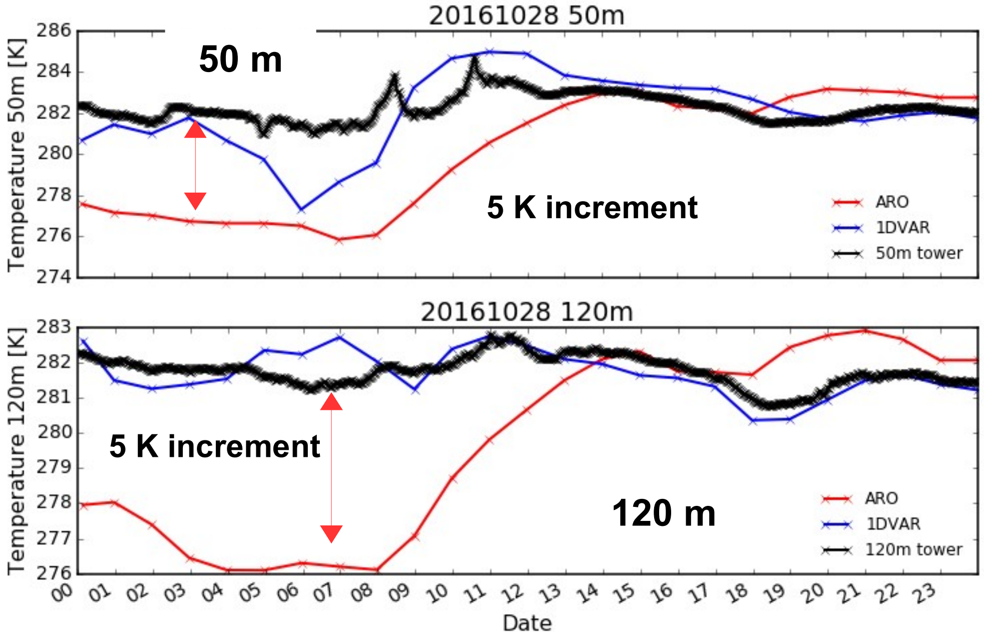


- **Warming** up to 5 K **before** and **during** the fog event
- **Cooling up** to 2 K above 500m and at surface during stratus lowering

Temperature profile retrievals : validation with in-situ measurements

- ARO
- Tower
- 1DVAR

Comparison of temperature diurnal evolution at two levels (50 and 120m)



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Temperature profile retrievals : validation with in-situ measurements

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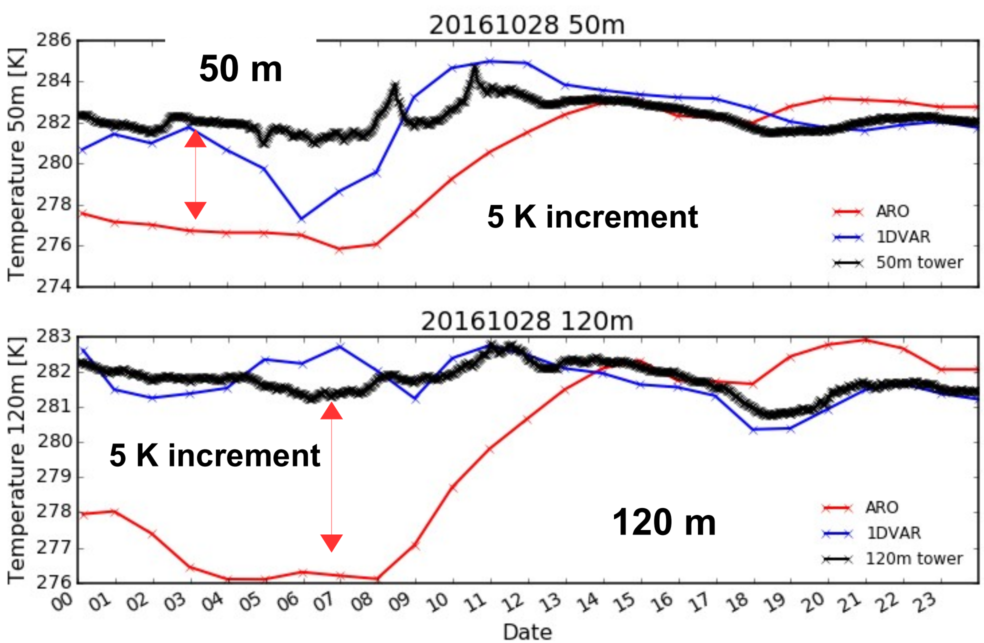
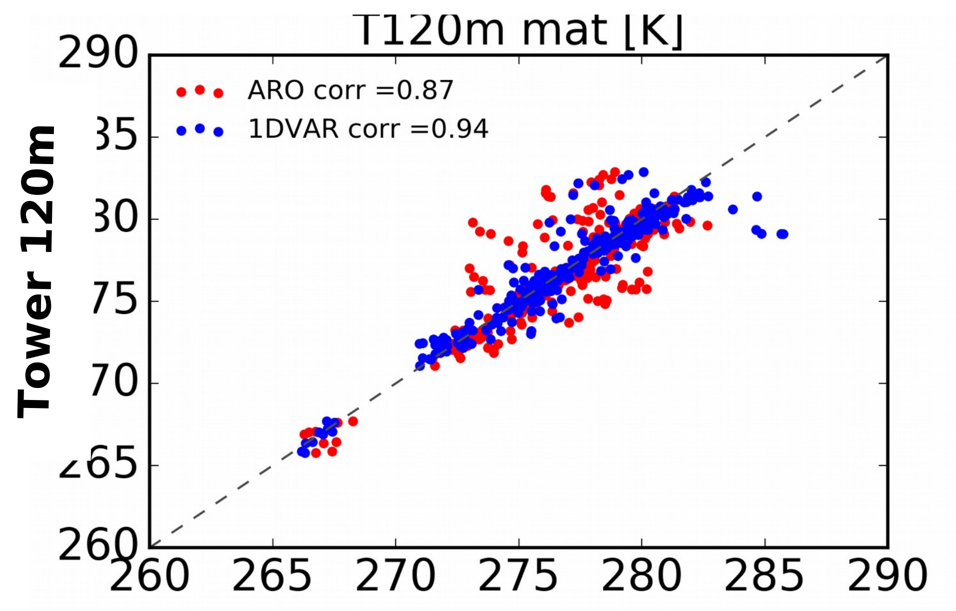


Scatterplot between tower measurements at 120m and AROME forecast or 1DVAR For all fog cases from 01/10/2016 to 31/03/2017



- Large **improvement** of the temperature **diurnal** cycle in the 1DVAR compared to AROME 1h forecasts
- Correlation coefficients increased from **0.87** to **0.94** (all fog cases compared with tower measurements)

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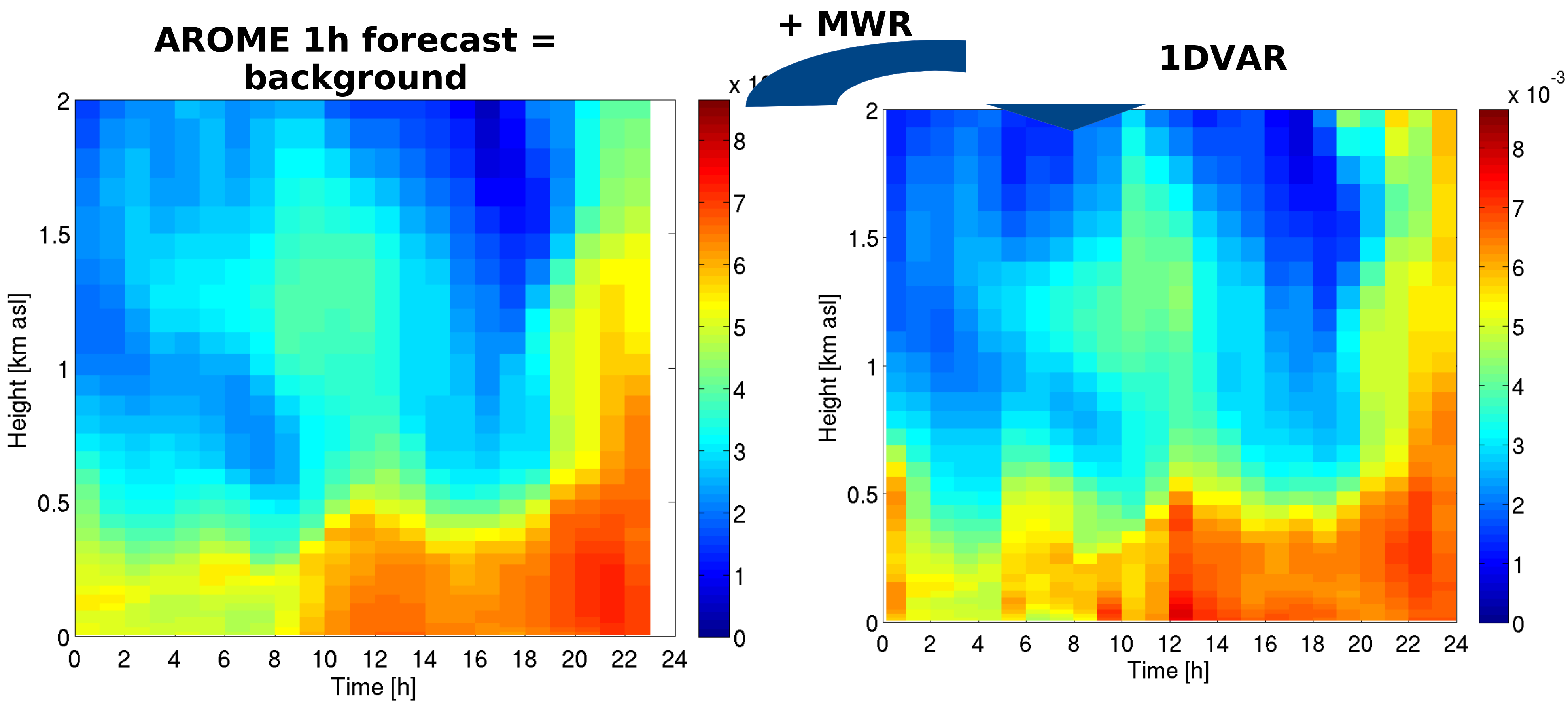
Specific humidity retrievals

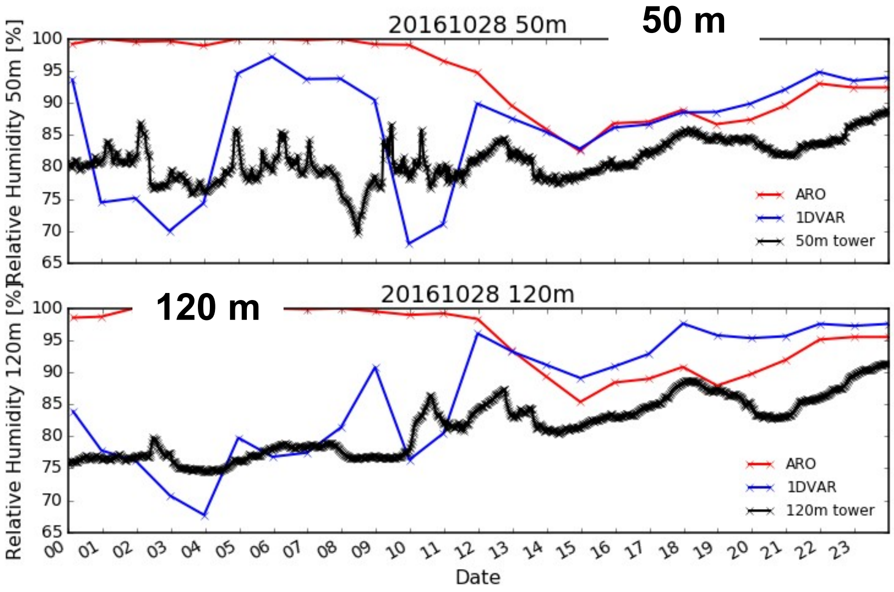


- Humidity increments less significant compared to temperature
- Humidity increase during fog events : **impact of positive cross-correlations**
- Neutral impact statistically

Relative Humidity retrievals : validation with in-situ measurements

- ARO
- Tower
- 1DVAR

Comparison of relative humidity diurnal evolution at two levels (50 and 120m)



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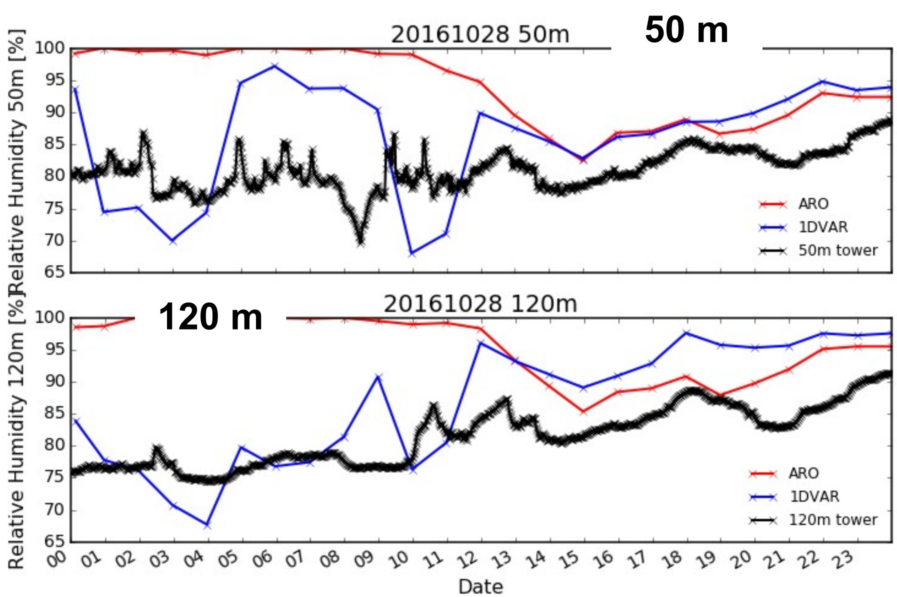
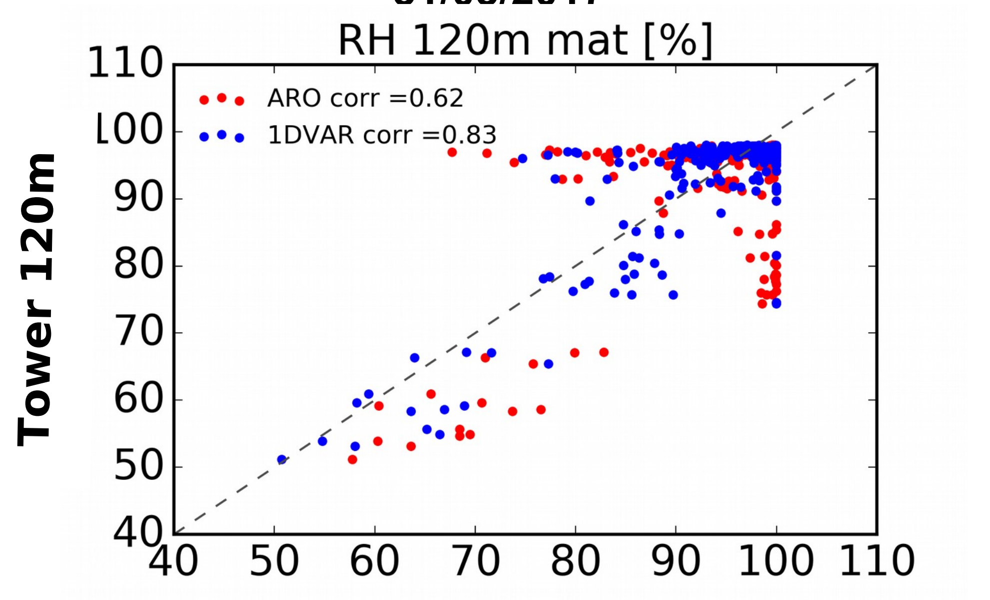
Relative Humidity retrievals : validation with in-situ measurements

Comparison of relative humidity diurnal evolution at two levels (50 and 120m)



Scatterplot between tower measurements at 120m and AROME forecast or 1DVAR For all fog cases from 01/10/2016 to 31/03/2017



- Overall improvement of the diurnal cycle in relative humidity
- Decrease from saturated values to unsatured (~80%) : would impact the fog thickness
- Correlation coefficients increased from 0.62 to 0.83 (all fog cases)

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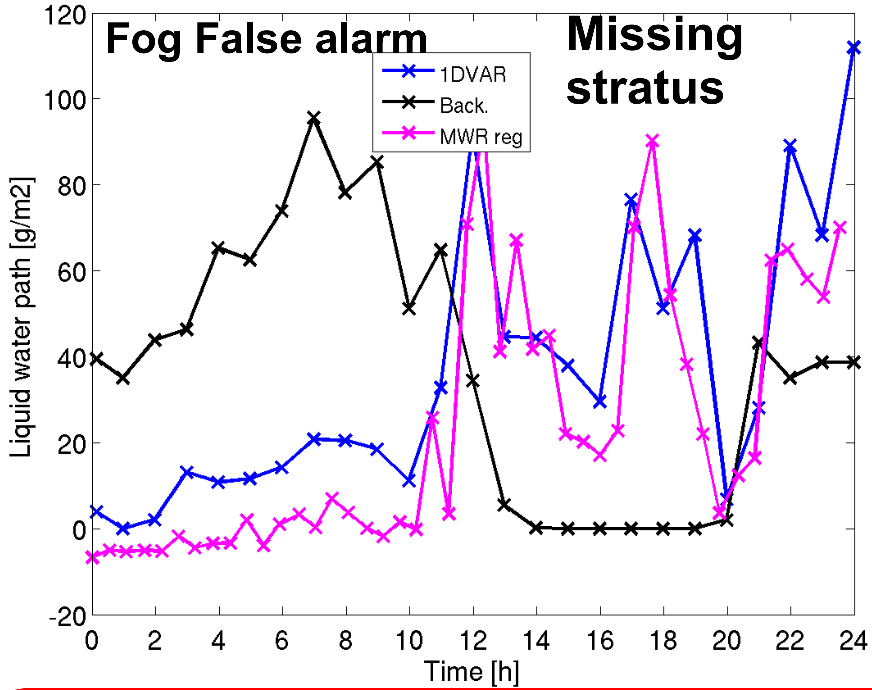
Liquid water path retrievals

LWP MWR (regression)
AROME
1DVAR

Comparison of LWP diurnal evolution

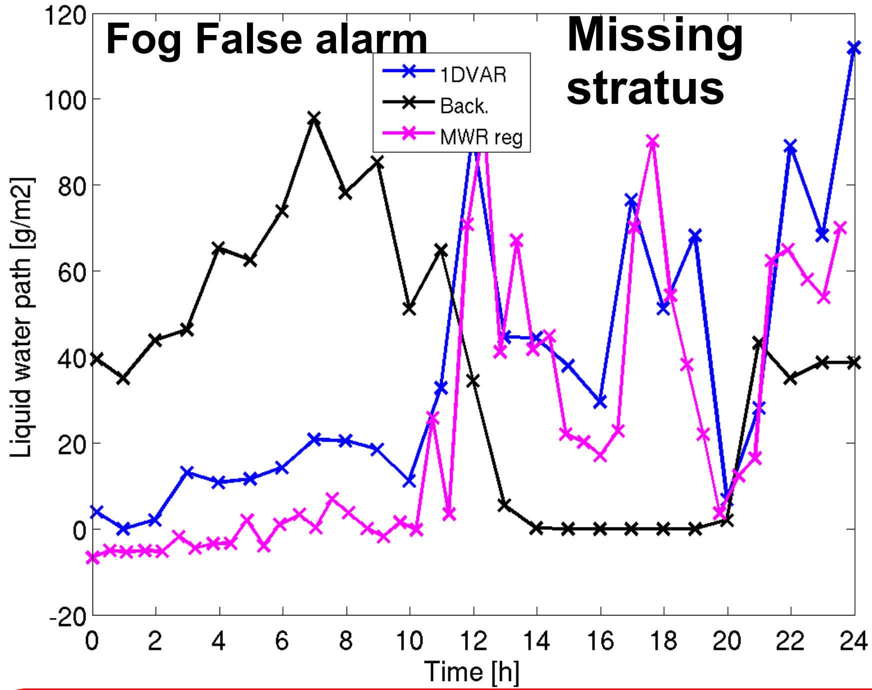


- Large decrease of LWP values before and during the fog event (in agreement with in-situ CDP measurements)
- Large increase during missing stratus

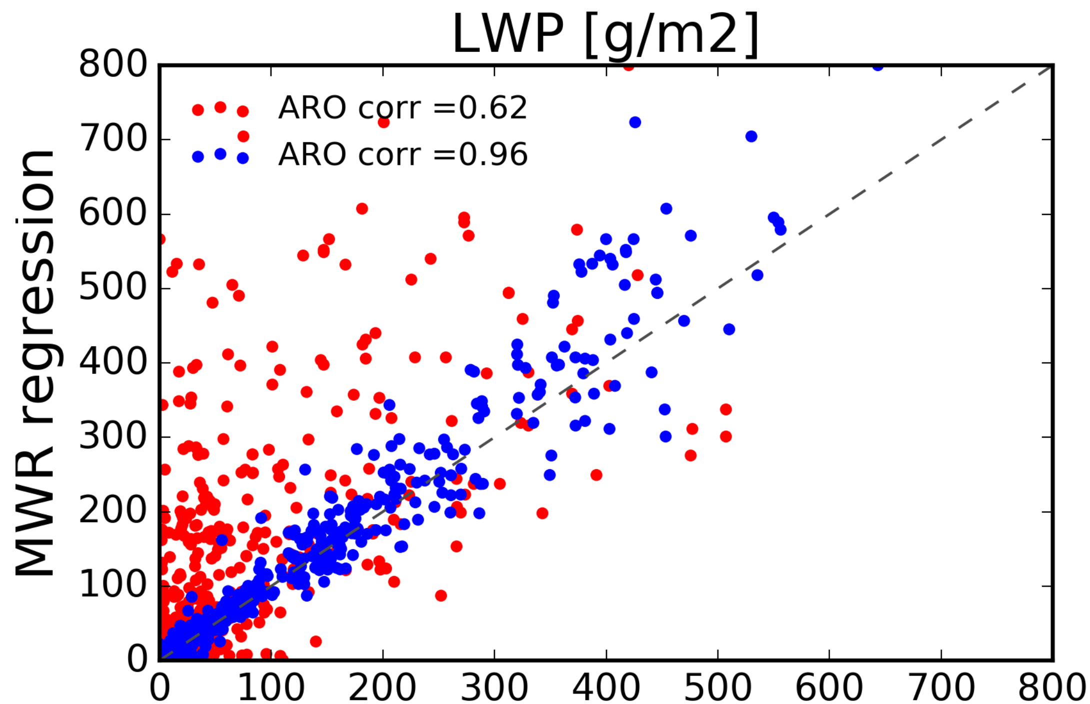
Liquid water path retrievals

LWP MWR (regression)
AROME
1DVAR

Comparison of LWP diurnal evolution



Scatterplot between MWR LWP retrieved by regressions and AROME forecasts or 1DVAR For all fog cases from 01/10/2016 to 31/03/2017



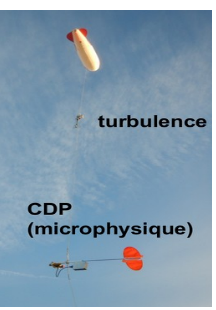
- Large decrease of LWP values before and during the fog event (in agreement with in-situ CDP measurements)
- Large increase during missing stratus

- Large increase of the correlation coefficients during fog from **0.62** to **0.96**

A regional scale ground-based MWR network to study potential fog forecast improvement (SOFOG3D field experiment winter 2019-2020)

- Improve our understanding of fog **processes**, **modelling** and **forecasts** : deployment of a large set of instruments including new and innovative instrumentation (in-situ and remote sensing)
- Opportunity for data assimilation trials (3D-EnVar) by building a regional scale MWR network

8 MWR (Météo-France, ONERA, LA, University of Cologne, MeteoSwiss, ATTEX, RPG)



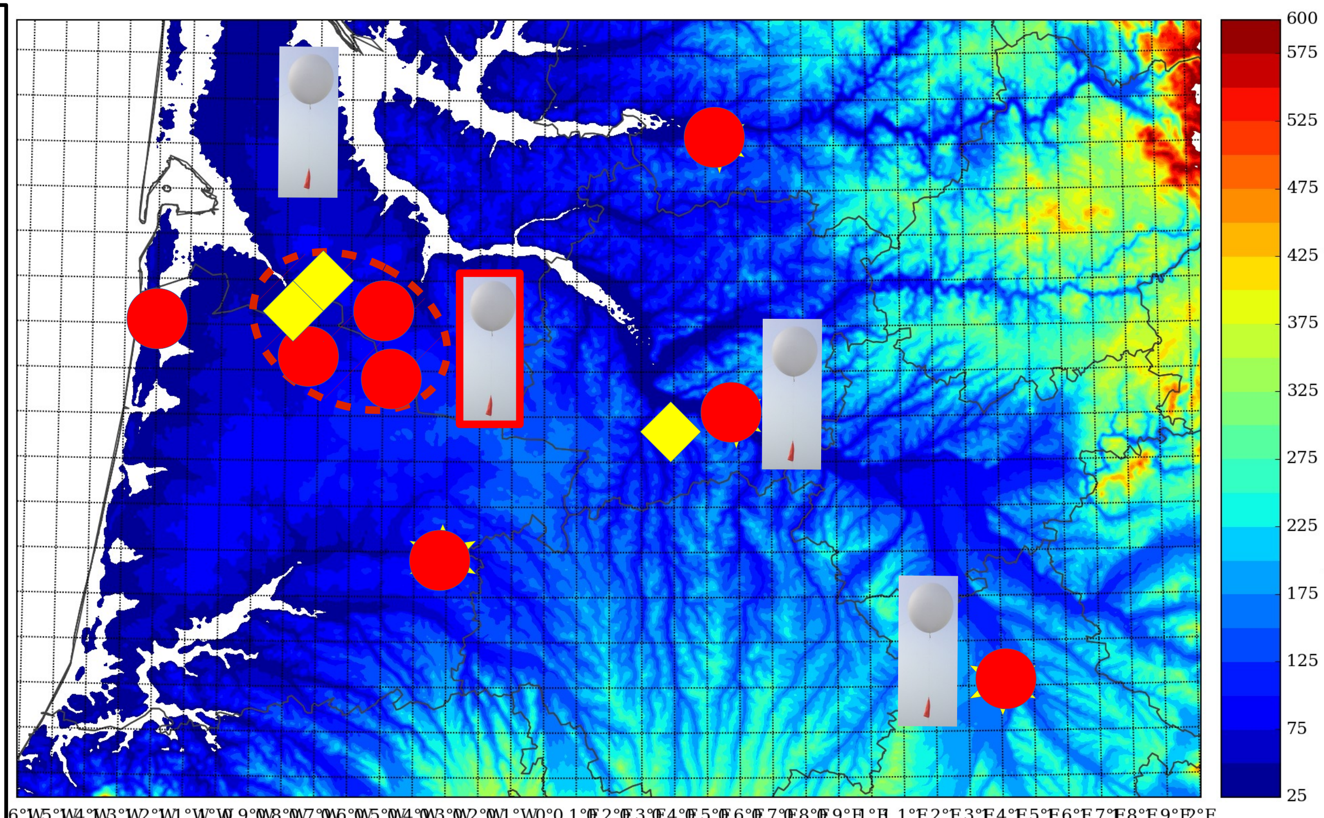
-~ 100 Radiosonde (every 4 to 6 hours during IOPs)

- Tethered balloon : microphysics profiles, aerosols, CCN, T/Q, turbulence

- UAVS (spatial heterogeneity, T, Q, aerosols, extinction)

- Towers (T, Humidity, microphysics)

Domain of the AROME model at 500m resolution



3 cloud radars BASTA (scanning and vertically pointing)

+ ceilometer + Doppler lidars + aerosol lidar etc..

Conclusions

Main Results

- Significant improvement in the temperature profile analysis is expected during fog events (differences up to 5K, RMSE decrease from 2.1 K to 0.5 K)
- Temperature diurnal evolution at 50 and 120 m significantly improved after the 1DVAR (5K increment on 20161028)
- Most of the impact in specific humidity comes from the correlation in the background error covariance matrix
- Relative humidity : large improvement in the correlation with respect to in-situ tower measurements
- Significant improvement in the LWP initial state

Future Prospects

- Validation of the LWP with cloud particler counter profiles of liquid water content inside the fog layer (tethered balloon)
- Synergy with the 94 GHz cloud radar BASTA to retrieve the liquid water content profile (**A. Bell poster**)
- Data assimilation studies in the context of the SOFOG3D experiment and validation with in-situ/remote sensing and satellite observations.

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