Data assimilation experiments of the SOFOG3D ground-based microwave radiometer network

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The AROME NWP model

AROME-France
(Seity et al, 2011 : Brousseau et al, 2016)

- Non-hydrostatic operational NWP model since 2008
- Horizontal resolution : 1.3 km
- 90 vertical levels (≈ 50 below 2 km of altitude)
- Three dimensional variational (3D-Var) data assimilation scheme in an hourly continuous cycle.

Example of temperature field forecasted over the AROME domain

Nevertheless, fog forecasts remain challenging.
The SOFOG3D microwave radiometer (MWR) network

SOFOG3D: SOuth west FOGs 3D experiment for processes study (6 months campaign)

HATPRO MWR:
- 2 channels (temperature and humidity)
- Temperature profiles, integrated water vapor, and liquid water path can be retrieved from MWR measurements

MWR network over the SOFOG3D domain.
(From Martinet et al, 2022 (submitted))
## Data assimilation experiment descriptions

As a first approach, only temperature profiles retrieved from MWR observations (altitude <2 km) which passed quality controls have been assimilated every hour.

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<th>THIN</th>
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For these three experiments:
- A climatological **B** matrix
- A diagonal **R** matrix have been used for MWR temperature (same values then radiosounding temperature ones)
Departure statistics

**Innovation (O-B):** Observation – Background

(Background = Short term forecast)

**Analysis residual (O-A):** Observation – Analysis

(Analysis = New initial conditions)
Departure statistics: ALLOBS experiment

Statistics computed for a three month period (December 2019 to February 2020).

Bias reduced by ≈ 40% and standard deviation is divided by ≈ 3.
Departure statistics : THIN experiment

Statistics computed for a three month period (December 2019 to February 2020).

Bias reduced by $\approx 20\%$ and standard deviation by $\approx 30\%$. 
Departure statistics: THIN experiment

Statistics computed for a three month period (Decembre 2019 to February 2020).

Conclusions:

1 – MWR temperature data can be assimilated with the AROME 3D-Var.

2 – ALLOBS presents a better improvement of departure statistics (due to the larger number of observations per profile).

Bias reduced by ≈ 20% and standard deviation by ≈ 30%.
Impact on temperature forecasts:

All MWR stations and all weather conditions (but precipitation).

Mean absolute error computed between forecasted temperatures (from 24h forecasts valid at 00 UTC) and non assimilated MWR temperature profiles.
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Mean absolute error reduction up to 50 % with ALLOBS and up to 30 % with THIN.
Impact on temperature forecasts:

All MWR stations and all weather conditions (but precipitation).

Standard deviation computed between forecasted temperatures (from 24h forecasts valid at 00 UTC) and non assimilated MWR temperature profiles.

Associated standard deviations remain similar.
Impact on temperature forecasts:

At Agen for foggy days (57 observed and simulated).

Mean absolute error computed between forecasted temperatures (from 24h forecasts valid at 00 UTC) and non assimilated MWR temperature profiles.
Impact on temperature forecasts:

At Agen for foggy days (57 observed and simulated).

Mean absolute error computed between forecasted temperatures (from 24h forecasts valid at 00 UTC) and non assimilated MWR temperature profiles.

Up to 10 hours of forecasts, mean absolute error reduction up to 50% with ALLOBS and up to 30% with THIN.
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The most important impacts are situated between the ground and 200 m of height, for the first five hours of forecast.
Case study 1: a fog event at Charbonnières

On the 25th December 2019, a thick fog event was observed at the SOFOG3D super-site, similarly to a large domain of the South-West of France.

![BASTA radar reflectivity observations (20191225)](image-url)
Case study 1: a fog event at Charbonnières

On the 25th December 2019, a thick fog event was observed at the SOFOG3D super-site, similarly to a large domain of the South-West of France.
Case study 1: a fog event at Charbonnières

At 50m upon the ground

At the observed fog base

- At 00 UTC, ALLOBS is slightly warmer than REF and THIN, all being close to OBS.

- Fog formation is delayed in ALLOBS forecasts, which globally lead to slightly colder temperatures until 12 UTC.

- After fog dissipation, the three forecasts are close each other.

- After 19 UTC, ALLOBS is closer to OBS and fog is not forecasted, contrary to REF and THIN.
Case study 1: a fog event at Charbonnières

**At 200m upon the ground**

Temperature time series comparison (20191225-20191226)
RMSE: G9XZ: 7.92  GEB0: 4.27  GEB2: 8.22

**Within the observed fog:**

- At 00 UTC, **ALLOBS** is slightly warmer than **THIN** and **REF**.

- Forecasts are close each other between 5 and 18 UTC.

- After 18 UTC, **REF** and **THIN** are cooling and lead to a fog formation. **ALLOBS** is closer to **OBS** (no fog forecasted).
Case study 1: a fog event at Charbonnières

At 500m upon the ground

Above the observed fog:

- At 00 UTC, **ALLOBS** is cooler (and closet to **OBS**) than **THIN**, being itself cooler than **REF**.

- Temperature forecasts improved in **ALLOBS** and **THIN** until 10 UTC. Afterwards, all forecast are close each other.
Case study 1: a fog event at Charbonnières

Interpolated BASTA observations upon the AROME vertical grid.
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Interpolated BASTA observations upon the AROME vertical grid.

REF
BASTA simulations G9XZ at CHARBONNIERE (20191225)

ALLOBS
BASTA simulations GE80 at CHARBONNIERE (20191225)

THIN
BASTA simulations GEB2 at CHARBONNIERE (20191225)
Case study 2: a non detection case at Agen

On the 13th of January, a fog event has been observed at Agen but not forecasted.
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On the 13th of January, a fog event has been observed at Agen but not forecasted.
Case study 2: a non detection case at Agen

At 50m upon the ground

Temperature time series comparison
(20200113-20200114)

- At 00 UTC, all the forecasts are close each other.

- After the first hours of forecast, ALLOBS and THIN start are cooler than REF and closer to OBS.

At the fog base:

- At 00 UTC, all the forecasts are close each other.

- After the first hours of forecast, ALLOBS and THIN start are cooler than REF and closer to OBS.
Case study 2: a non detection case at Agen

At 50m upon the ground

At the fog base:

- At 00 UTC, all the forecasts are close each other.

- After the first hours of forecast, ALLOBS and THIN start are cooler than REF and closer to OBS.

- Nevertheless, event if temperature forecasts are better, the air cooling was not sufficient to reach saturation (no fog forecasted in ALLOBS nor in THIN).
Conclusions and perspectives

- Temperature profiles retrieved from MWR observations can be assimilated.

- In comparison with non-assimilated MWR data, the assimilation of the retrieved temperature profiles improves the forecast up to 10 hours in average.

- However, a neutral statistical impact have been found on fog forecasts (with scores based on visibility).

- Consider a joint assimilation of temperature, humidity and LWP data retrieved from MWR.

- Tune the data assimilation experiments (diagnosed R matrix (and possibly a non-diagonal one), bias correction, ...).