Evaluation of a 95 GHZ Radar Simulator for the retrieval of fog Microphysical Properties by cloud radar and Microwave radiometer synergy

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Retrieval of LWC from Radar Reflectivity

- LWC power relations of form: \( Z = a \cdot LWC^b \)
- Variational retrieval methods

**One-Dimensional Variational Retrieval (1D-VAR)**
- Advantage – information from other source(s) used to constrain retrieval

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

Radar Observation

AROME 1hr Forecast: T, P, Hu, LWC

Radar Simulator

Cost function \( J(x) \)

\[ \text{Minimisation} \]

New Profile: T, Hu, LWC, \( N, D \)

Russchenberg et al. 2004
Sensitivity of Forward Operator

- In the forward operator, main source of uncertainty comes from assuming size distribution
- Perturbation of ICE-3 gamma law parameters
- In fog, the number concentration of droplets can vary significantly
- N more significant to uncertainty than other parameters in distribution
- Uncertainty estimated to be 6dBz for LWC of 0.12 gm$^{-3}$
Radar Simulator was designed by Borderies et al.* which was adapted for ground based radar.

Forecasts from high-resolution NWP model AROME was used to initialise simulator.

AROME Forecast: $T$, $q_v$, $q_{lwc}$, $q_r$, $q_s$, $q_i$, $q_g$.

- Mie Scattering
- Ice-3 one-moment microphysical scheme
- Attenuation (Liebe, 1985)
- Back-scattering coefficients

Simulated Reflectivity $Z$
Selecting a Background Profile

- Often, a fog forecast can contain temporal or spatial errors
- The quality of a retrieval is linked to the quality of information contained in the background profile
- Correcting errors inside the background profile is likely to lead to improved retrievals
- Model profile selected from a 20 km x 20 km domain with a time window of ± 3 hours
- Radar Reflectivity simulated for all profiles
- Minimised weighted rmse ($Z_{dB\_Obs} - Z_{dB\_Simulation}$) – most resembling profile (MRP)

No Fog

Fog thickness
~140 m

Fog Thickness on 2018-11-04 at 2h20 UTC from AROME model

Fog Thickness Differences

Probability of Occurrence

0 0.05 0.1 0.15 0.2 0.25
0 -300 -200 -100 0 100 200 300

Thickness Difference (m)

Fog Formation Time Differences

Number of Occurrences

0 1 2 3 4 5
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6

Time Difference (Hours)
Quality of Background Profile

- Correction for time of fog formation/dissipation
- Better agreement in fog top height
- Statistics made for observation period winter 2018/2019 at Sirta (near Paris)
- Standard deviation (STD) and bias were compared for methods of closest grid point/time and MRP method
- Substantial improvement in both STD and bias