SOFOG3D – Task2

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Task 2

The objective is to improve retrievals of key fog parameters (temperature, humidity, fog water and microphysics, fog dynamics) based on the combination of the cloud radar and the microwave radiometer (MWR) measurements.

Sub-task 2.1: LWC and fog dynamics retrievals from radar and MWR

Sub-task 2.2: Closure analysis and retrievals assessment

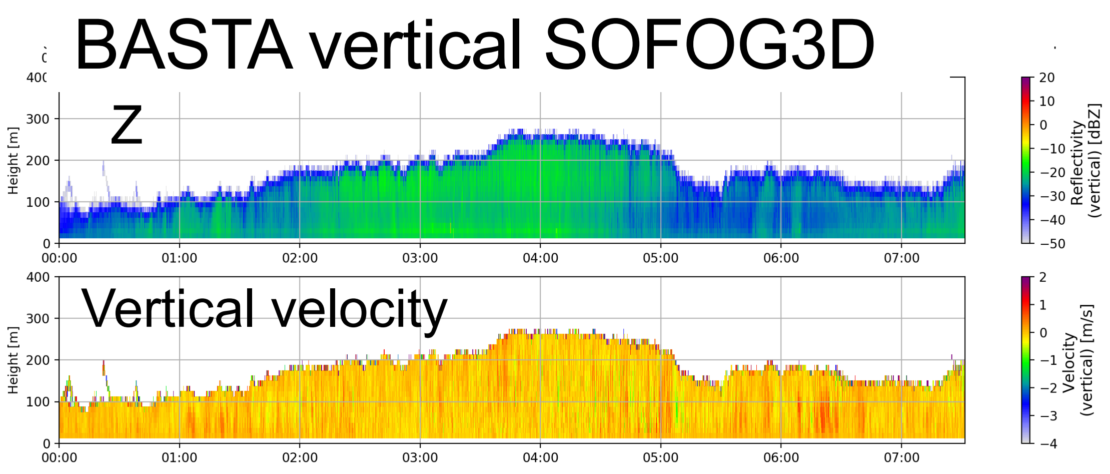
Sub-task 2.3: MWR profiles retrieval constrained by radar LWC

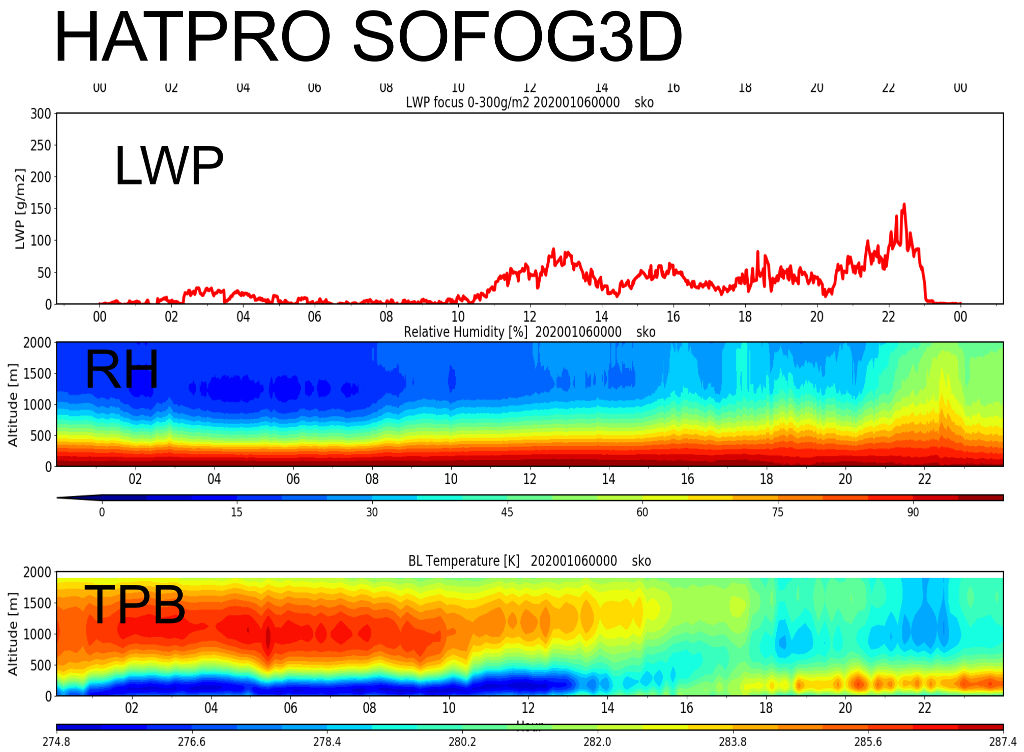
Deliverables:

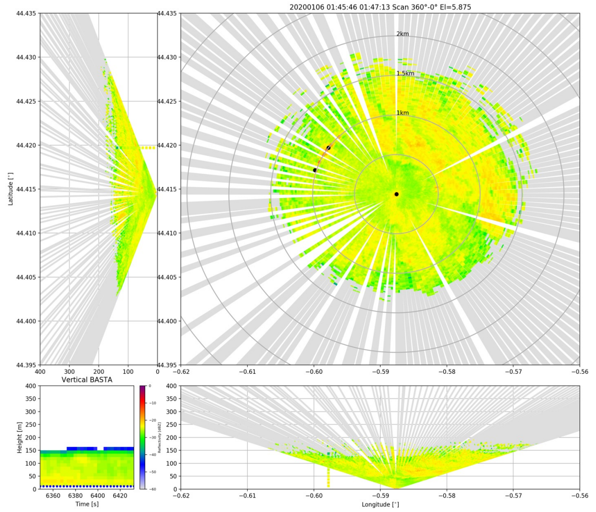
- D2.1.1: LWC profiles depending on different constraints from dedicated variational method ✓
- D2.1.2: Dynamics of the fog layer from velocity azimuth display technique ✓~
- D2.2.1: Evaluation of radar LWC retrieval vs in-situ measurements ✓
- D2.2.2: Improve radar forward model thanks to calibrated metallic targets ✗
- D2.3.1: Improved MWR temperature and humidity profiles retrieved with cloud radar LWC ✓
- D2.3.2: Feasibility study of cloud radar LWC assimilation within the MWR 1D-Var framework ✓

Sub-task 2.1: LWC and fog dynamics retrievals from radar and MWR

- **D2.1.1:** LWC profiles depending on different constraints from dedicated variational method ✓







Radar information
Vertical profile and 3D structure/dynamic

Radiometer information
LWP constraint

LWC profile and dynamic

LWC profile with better constraint and dynamic
Temperature & Humidity profiles :
Improved cloud base inversion and humidity retrievals

Temperature
Humidity & Profiles

Sub-task 2.1: LWC and fog dynamics retrievals from radar and MWR

- **D2.1.1:** LWC profiles depending on different constraints from dedicated variational method ✓

2 Retrievals based on variational approach

March 2022

PhD P. Vishwakarma (LATMOS)

1st approach (instrument oriented) :

- account for attenuation
- dedicated forward model (self adapted Z-LWC relationships)
- Z and MWR LWP included in the observation vector (radar stand-alone available)

February 2022

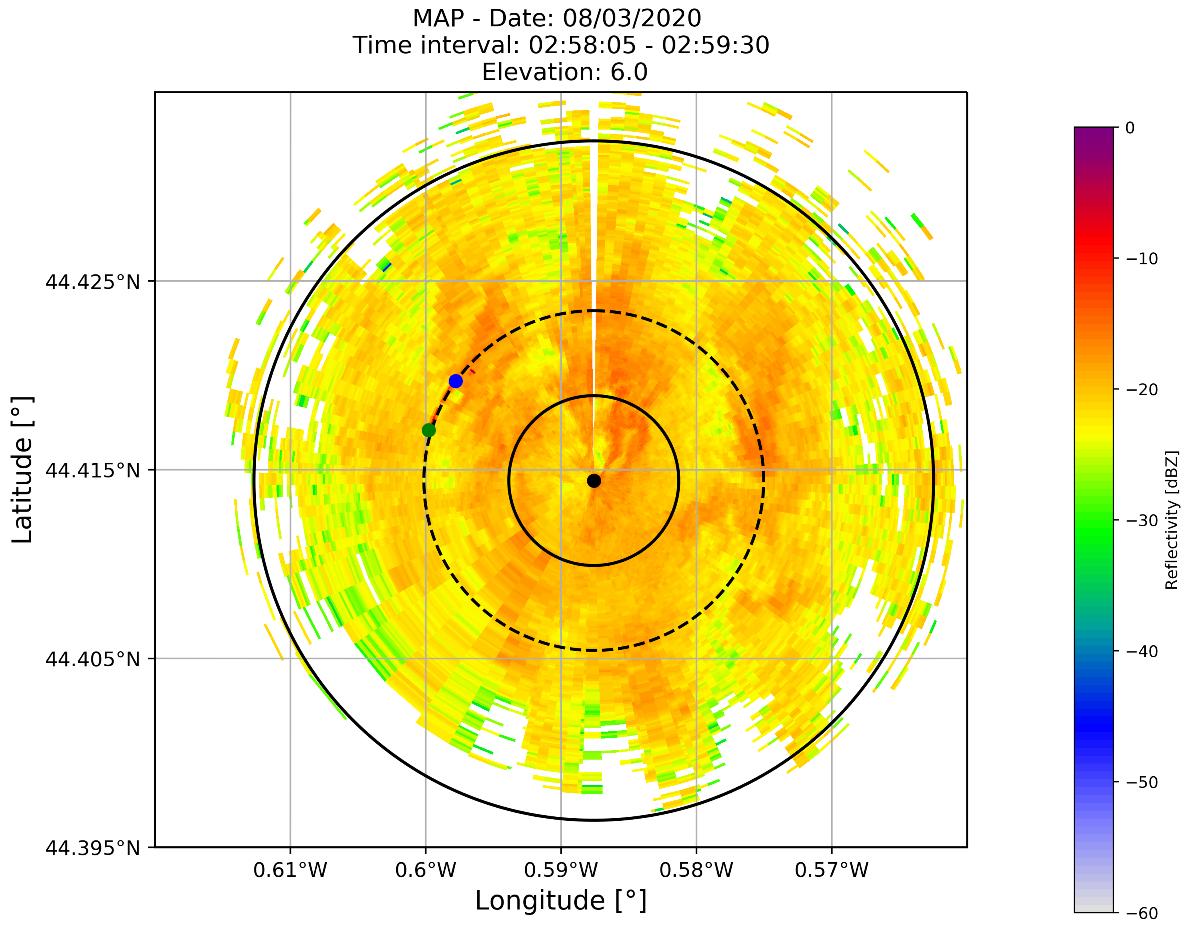
PhD A. Bell (CNRM)

2nd approach (assimilation oriented) :

- Z and MWR TB in the observation vector
- Constrained by a NWP model (currently the AROME model)
- Radar simulator and radiative transfer models used as forward models

Sub-task 2.1: LWC and fog dynamics retrievals from radar and MWR

- **D2.1.2:** Dynamics of the fog layer from velocity azimuth display technique ✔ ~



Data acquisition mode:

Scanning

Products:

MAP/PPI – Plan Position Indicator

The radar holds its elevation angle constant and varies its azimuth angle.

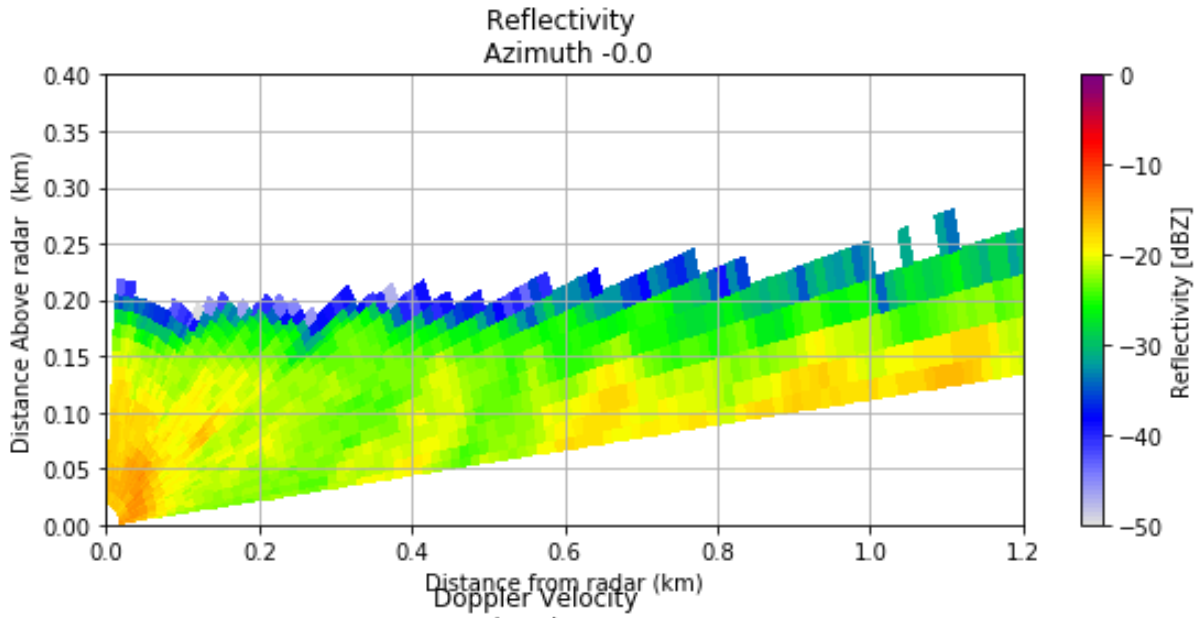
Example:

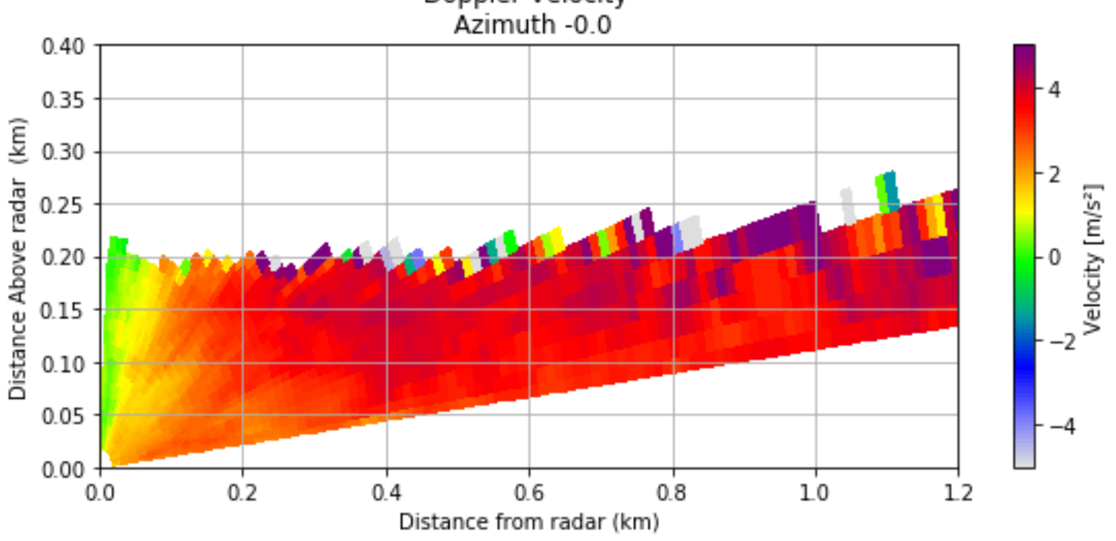
BASTA mini

LATMOS

08/03/2020

Super site





Data acquisition mode:

Scanning

Products:

RHI– Range Height Indicator

The radar holds its azimuth angle constant and varies its elevation angle.

Example:

BASTA mini

LATMOS

08/03/2020

Super site

Sub-task 2.2: Closure analysis and retrievals assessment

- D2.2.1: Evaluation of radar LWC retrieval vs in-situ measurements ✓
- D2.2.2: Improve radar forward model thanks to calibrated metallic targets ✗

Unfortunately, data quality of the target measurements are not good enough for making progress on this

Climatology of LWC and scaling factor using radar-MWR synergy

- **Objective:** To develop an algorithm for estimating LWC of fog ang warm clouds using 95 GHz cloud radar-microwave radiometer synergy

- **Methodology:**

Theoretical background → Climatology and algorithm → Sensitivity Analysis → Validation → Radar-only retrieval method

To estimate LWC we use the following power law relation:

$$Z = a \cdot LWC^b \longrightarrow \ln Z = \ln a + \mathrm{b} \cdot \ln LWC$$

Where $\ln a$ is the scaling factor

a and b vary with the cloud type and characteristics.

Reference	Z–LWC relation	ln a	Cloud type	Assumption
Atlas (1954)	$Z = 0.048 \cdot \mathrm{LWC}^{2.0}$	−3.0365	Clouds without drizzle	Empirical
Sauvageot and Omar (1987)	$Z = 0.03 \cdot \mathrm{LWC}^{1.31}$	−3.5065	Non-precipitating stratocumulus and cumulus	Empirical
Fox and Illingworth (1997)	$Z = 0.012 \cdot \mathrm{LWC}^{1.16}$	−4.4228	Non-precipitating marine stratocumulus	Empirical
Baedi et al. (2000)	$Z = 0.015 \cdot \mathrm{LWC}^{1.17}$	−4.1997	Stratocumulus clouds	Empirical
Wang and Geerts (2003)	$Z = 0.044 \cdot \mathrm{LWC}^{1.34}$	−3.1235	Non-precipitating marine stratus	Empirical
Krasnov and Russchenberg (2005)	$Z = 323.59 \cdot \mathrm{LWC}^{1.58}$	5.7794	Drizzle clouds	Empirical

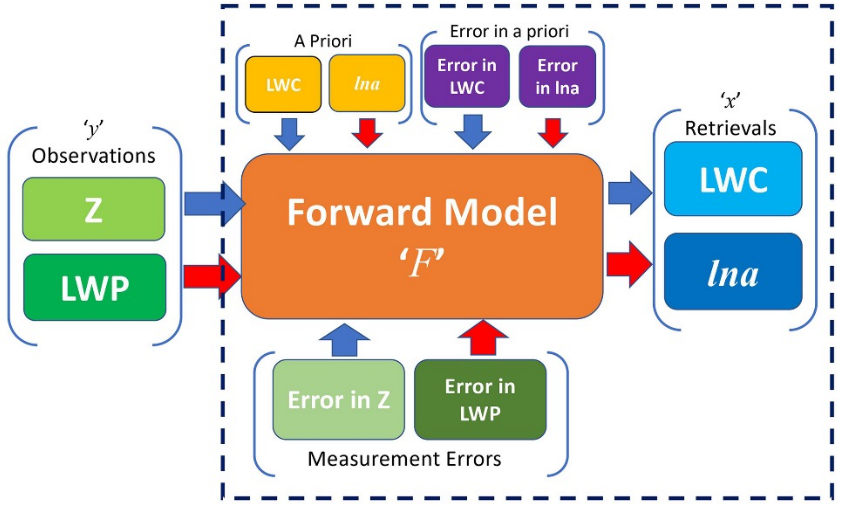
Can an algorithm based on radar-MWR synergy estimate the LWC for fog and warm clouds?

Article: Vishwakarma, P., Delanoë, J., Jorquera, S., Martinet, P., Burnet, F., Bell, A., and Dupont, J.-C.: Climatology of estimated liquid water content and scaling factor for warm clouds using radar–microwave radiometer synergy, Atmos. Meas. Tech., 16, 1211–1237, https://doi.org/10.5194/amt-16-1211-2023, 2023.

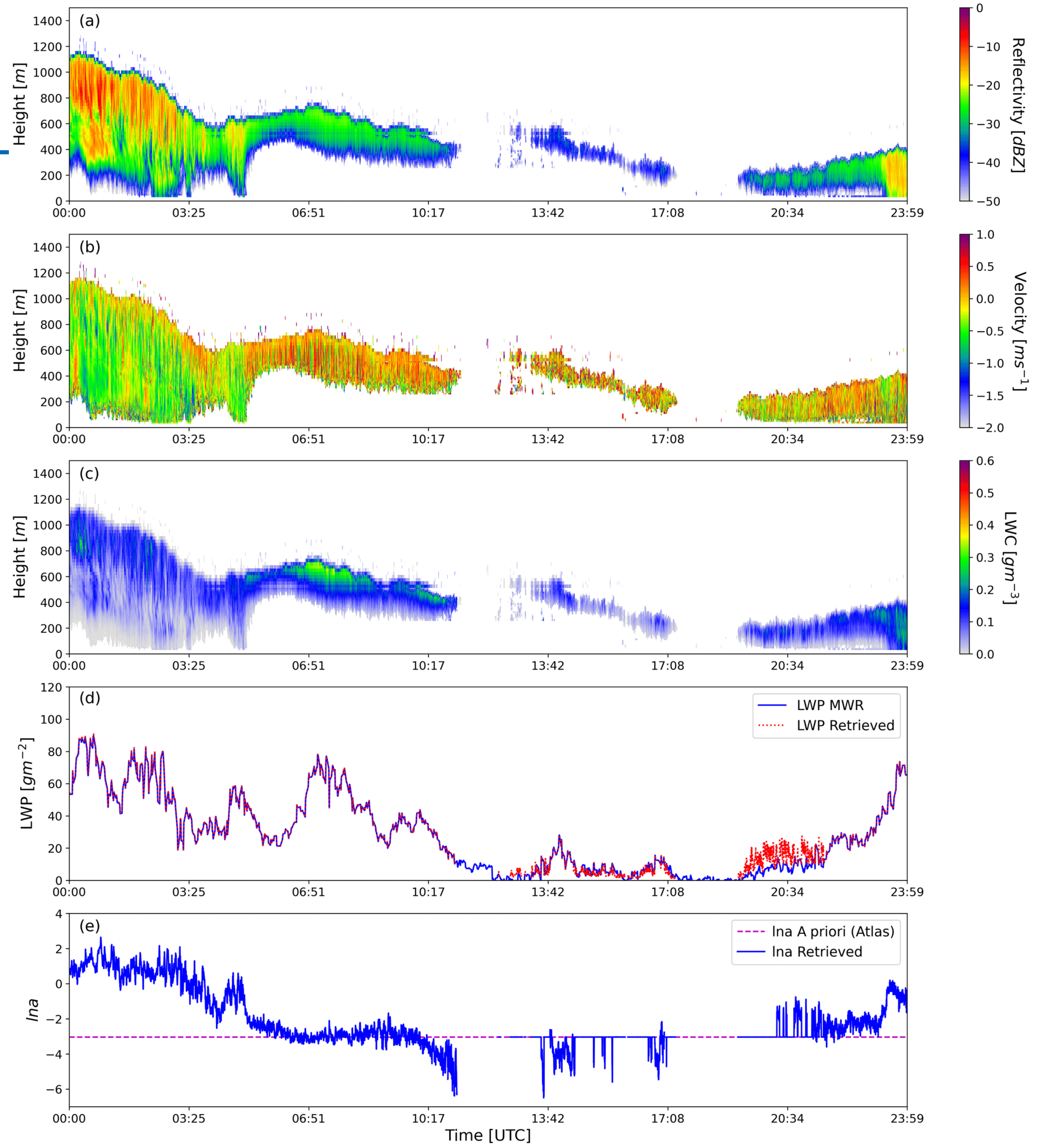
Climatology of LWC and scaling factor using radar-MWR synergy

Theoretical background → **Climatology and algorithm**

- The algorithm retrieves the LWC of clouds and fog using radar reflectivity and a climatology of the power law parameters.



- The algorithm enables the study of variations in the scaling factor when MWR observations are available (b is assumed constant).
- To build a climatology of the scaling factor can be used when MWR observations are not available
- **Implementation of the algorithm at SIRTA:**



Principal results:

✓ For liquid clouds: $\ln a = 0.186 \cdot Z_{max} + 1.829$

✓ For fog: $\ln a = 0.149 \cdot Z_{max} + 0.591$

Climatology of LWC and scaling factor using radar-MWR synergy

- To analyze uncertainties
  - Observations
  - Forward model
  - Priori information
  - Attenuation due to liquid droplets
  - LWP assimilation
  - Parameter b

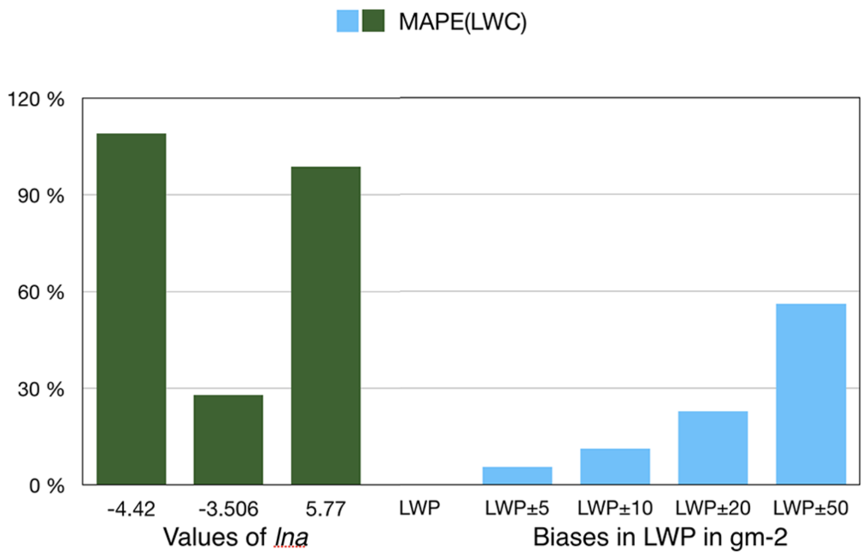


Fig: Errors in retrieved LWC when LWP is not assimilated (green bars), as compared to those when LWP is assimilated and affected by different values of biases (blue bars).

Principal result:

✓ The method is susceptible to LWP information

- SOFOG3D campaign allowed the comparison of the retrieves and measured LWC.
- Instruments involved: BASTA-mobile, MWR and CDP

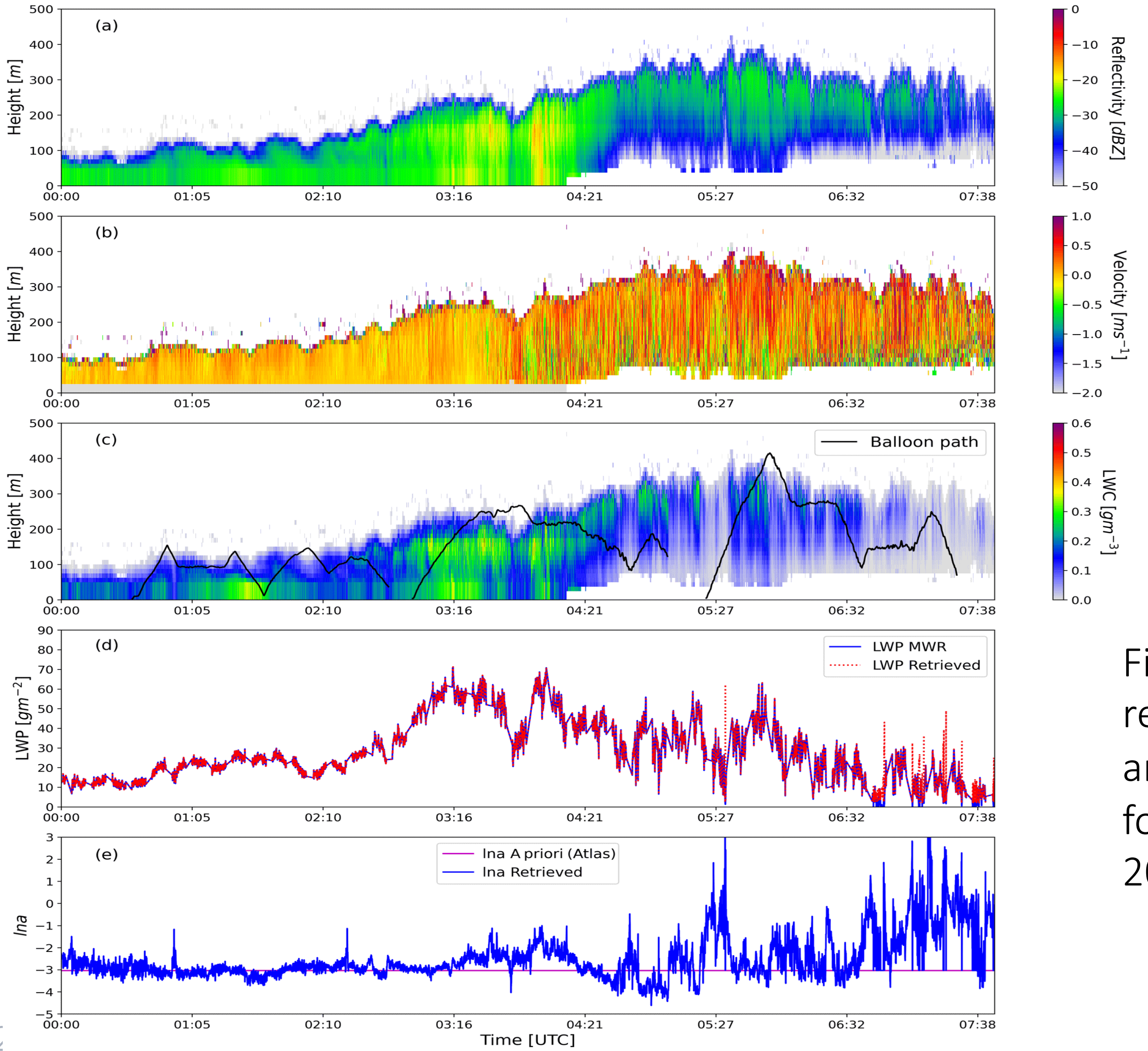


Figure: Radar reflectivity Z, (d) LWP, and (e) retrieved ln a for the 9 February 2020.

Climatology of LWC and scaling factor using radar-MWR synergy

Theoretical background | Climatology and algorithm | Sensitivity Analysis | **Validation** | Radar-only retrieval method

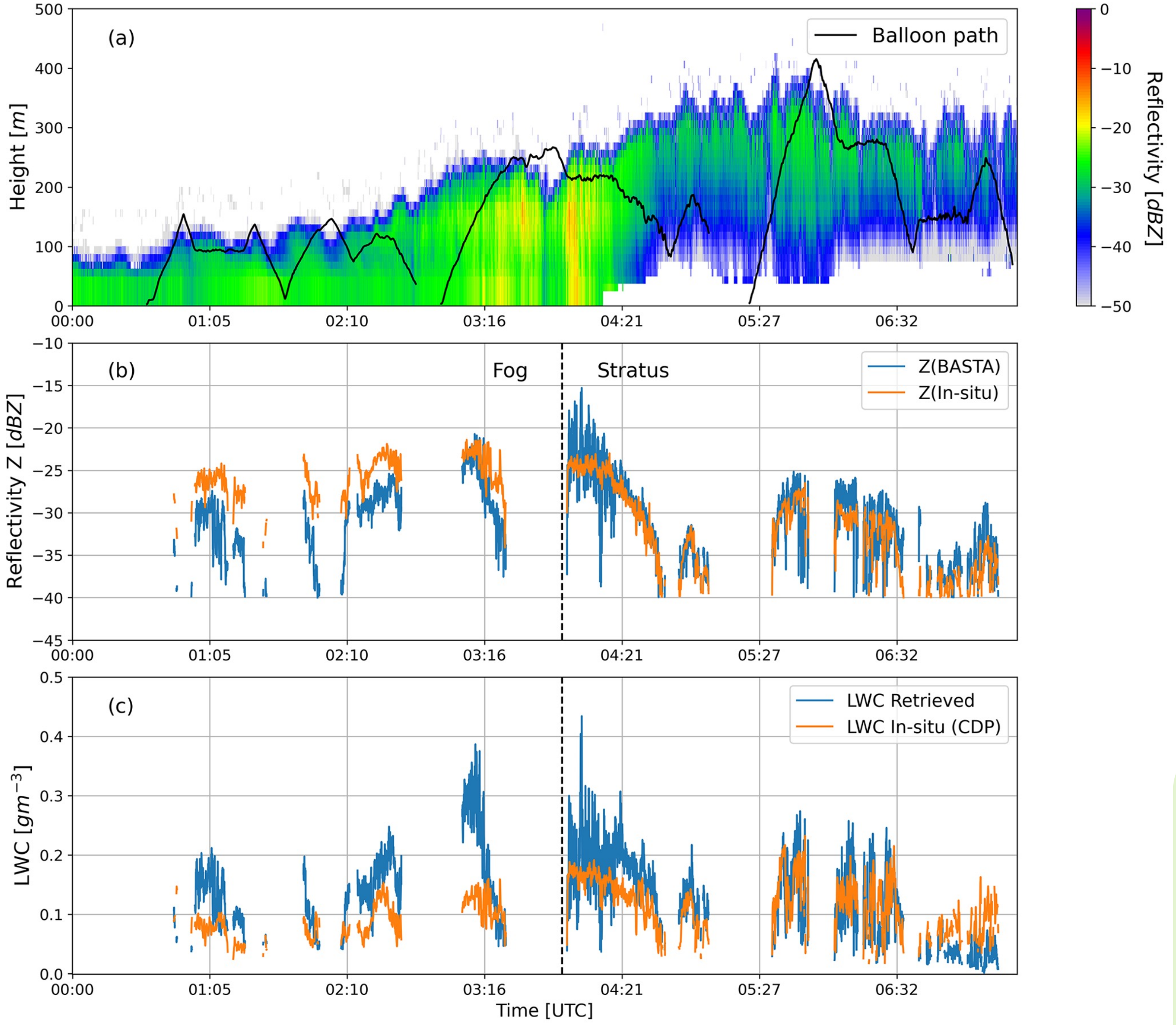


Figure: (a) Radar reflectivity and balloon path, (b) comparison of radar reflectivity with reflectivity calculated from CDP using DSD, (c) comparison of retrieved LWC with in situ LWC.

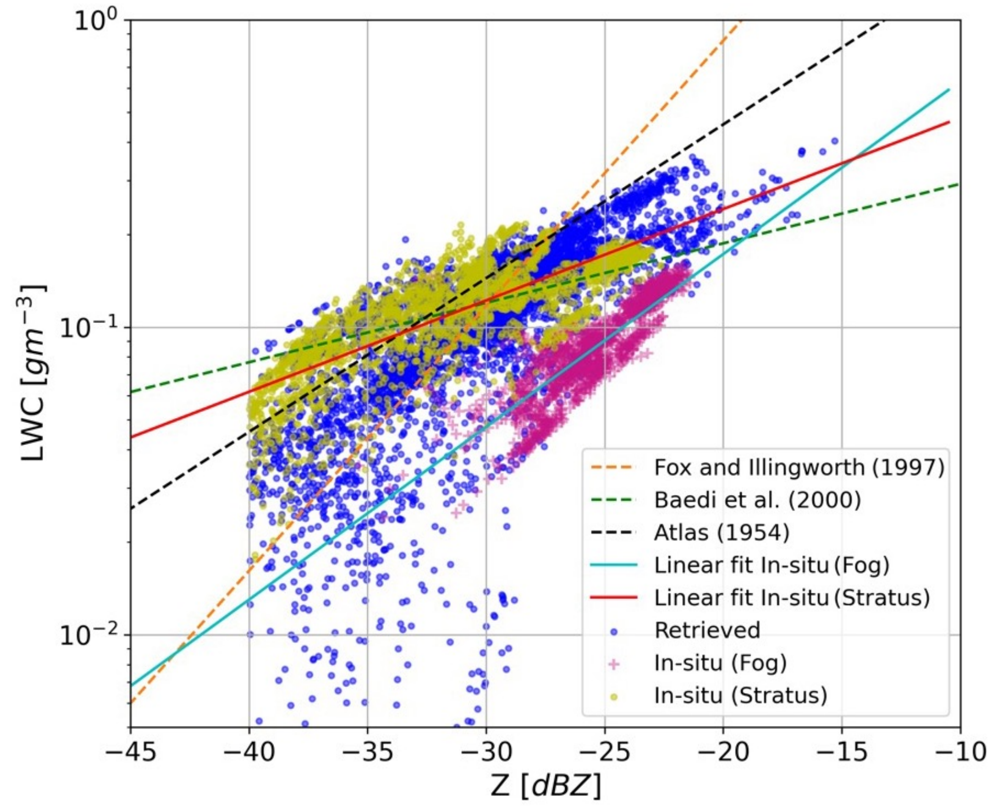


Fig: retrieved LWC and BASTA radar reflectivity relation

Principal results:

- ✓ The difference between simulated Z from CDP and radar measurements could be explained by the vertical and horizontal heterogeneity of the fog
- ✓ Cloud heterogeneity plays an important role

Communications

- Bell, A., Martinet, P., Caumont, O., Vié, B., Delanoë, J., Dupont, J.-C., and Borderies, M.: W-band radar observations for fog forecast improvement: an analysis of model and forward operator errors, Atmos. Meas. Tech., 14, 4929–4946, https://doi.org/10.5194/amt-14-4929-2021, 2021.
- Bell, A., Martinet, P., Caumont, O., Burnet, F., Delanoë, J., Jorquera, S., Seity, Y., and Unger, V.: An Optimal Estimation Algorithm for the Retrieval of Fog and Low Cloud Thermodynamic and Micro-physical Properties, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2022-30, in review, 2022.
- Vishwakarma, P., Delanoë, J., Jorquera, S., Martinet, P., Burnet, F., Bell, A., and Dupont, J.-C.: Climatology of estimated LWC and scaling factor for warm clouds using radar – microwave radiometer synergy, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2022-3, in review, 2022.

Theses:

- Bell, A., PhD thesis (2022)
- Vishwakarma, P., PhD thesis (2022)

Presentation:

- Martinet, P., Bell, A., Caumont, O., Vié, B., Burnet, F., and Delanoë, J.: Optimal estimation of thermodynamic and microphysical profiles within fog events from ground-based microwave radiometer and cloud radar synergy., EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-12410, https://doi.org/10.5194/egusphere-egu22-12410, 2022.