SOFOG3D – Task2

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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. Geostationary satellite data will be extracted to characterize the spatio-temporal evolution and patterns of each fog case.

**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

**Sub-task 2.4:** SEVIRI/MSG retrievals

**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 X
- **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 ✔
- **D2.4.1:** Time series of 2-D maps of cloud classes using a classification adapted for fog and low stratus evolution tracking (e.g. separating core fog, dissipation fog, formation fog pixels)
- **D2.4.2:** Time series of fog evolution indicators, such as distance to fog boundaries, cloud albedo and evolution of brightness temperature of the different cloud classes.
## Radar data processing information

<table>
<thead>
<tr>
<th>Tasks</th>
<th>State</th>
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<tbody>
<tr>
<td>Installation and operation of instruments at the Supersite</td>
<td>Complete</td>
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<tr>
<td>Radar catalogue for the 3 radars</td>
<td>Complete</td>
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<tr>
<td>Processing of the whole radar database in vertical position (L1)</td>
<td>Complete</td>
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<tr>
<td>Radar BASTA-CNRM processing</td>
<td>Complete</td>
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<tr>
<td>Production of quicklooks and netcdf files</td>
<td>Complete</td>
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<tr>
<td>Website BASTA: Quicklooks availability</td>
<td>Complete</td>
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<tr>
<td>Development of a method for analyzing scan data</td>
<td>Complete</td>
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<tr>
<td>Radar scanner treatment and Quicklooks</td>
<td>Complete</td>
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<tr>
<td>L2a (Agen and Super site) on FTP</td>
<td>Complete</td>
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<tr>
<td>Study: Radar coupling and fog detection</td>
<td>Complete</td>
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<tr>
<td>Study: Calibration transfer between radars</td>
<td>Complete</td>
</tr>
<tr>
<td>Study: Radar data and Radiometer data (Radiometer LWP co located with BASTA)</td>
<td>Complete</td>
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<tr>
<td>Balloon impact on the BASTA measurements</td>
<td>Complete</td>
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</tbody>
</table>
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 with better constraint and dynamic

**Temperature & Humidity profiles**: Improved cloud base inversion and humidity retrievals

Radar information
Vertical profile and 3D structure/dynamic

Radiometer information
LWP constraint

Temperature Humidity & Profiles

LWC profile and dynamic
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

**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)

**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
Radar- MWR synergy D2.1.1&D2.2.1

Vishwakarma 2022 and Vishwakarma et al. 2022

- Combine radar and MWR measurements to retrieve liquid clouds properties, including fog (no model inputs)
- Classical approaches use Z-LWC relationships (all quite different) – we never know which one to use

\[ Z = a \cdot LWC^b \]

Very sensitive to DSD

→ Additional information from an independent instrument can increase the accuracy of retrieved LWC.

**Radar and MWR Synergy**

**BASTA stand alone retrieval**

**Climatology of the power law parameter**

Adding LWP allows variability in one of the coefficient from power law

Ovtchinnikov and Kogan, 2000

We have therefore in a common framework (accounting for attenuation):
- Radar+MWR (lna and LWC)
- Radar only (LWC)
A sensitivity analysis to understand the behaviour of the algorithm

Structure of Sensitivity Analysis

AROME

NWP model for fog forecast with 1.3 km resolution
Bell et al. [2021]

→ LWC from a fog forecast at the nearest grid location of SIRTA are considered the truth

→ This true LWC is used to simulate Z and LWP (synthetic profile)

LWC (AROME)

Forward model for Z with attenuation

Z, LWP

Compare LWC

LWC Retrieval ALGORITHM

Retrieved LWC

Make the change in Sensitivity Parameters
A sensitivity analysis to understand the behaviour of the algorithm

Impact of LWP Assimilation

\[
MAPE = \frac{100}{n} \sum_{0}^{n} \frac{|LWC_{true} - LWC_{ret}|}{LWC_{true}}
\]

We test several things...

Without LWP assimilation

With LWP assimilation

Values of Ina

Biases in LWP in gm⁻²
Results using SOFOG3D data

09 February 2020 case at SOFOG-3D super-site

LWC Retrievals (SOFOG-3D) and comparison strategy

→ Reflectivity extrapolated
(assuming the fog properties are same between ground and first available gate)

BASTA radar(Z) + MWR(LWP)

LWC retrieval algorithm

Compare LWC with CDP (balloon)
Data from Burnet et al.

LWC and lna
Results using SOFOG3D data

Better agreement for stratus than fog

Z(in-situ) $\rightarrow$ 6\textsuperscript{th} moment of DSD from CDP

09 February 2020 case at SOFOG-3D super-site
What could be done next

• Compare retrievals for LWC
• How to use the scans for dynamic and 3D structure of fog?
• Dynamic and microphysics analysis


Theses:
• Bell, A., PhD thesis (2022)
• Vishwakarma, P., PhD thesis (2022)

Presentation: