VIRTUAL MOBILITY (VM) GRANT REPORT TEMPLATE

This report is submitted by the VM grantee to VNS Manager, who will coordinate the approval on behalf of the Action MC.

Action number: CA18235

VM grant title: Infrared-Microwave synergy to improve low liquid water path retrievals in fog

VM grant start and end date: 22/09/2021 **to** 15/10/2021

Grantee name: Donatello Gallucci

Description of the outcomes and achieved outputs (including any specific Action objective and deliverables, or publications resulting from the Virtual Mobility).

(max. 500 words)

The work conducted in this project aimed at investigating techniques to improve the retrieval of low liquid water path in fog condition, by exploiting the synergy of observations in the Microwave and Infrared regime. In order to accomplish this, we have first generated a dataset of Microwave and Infrared synthetic brightness temperatures with MonoRTM radiative transfer model, by using atmospheric profiles from the NWP model AROME. This dataset has then been used to develop a statistical regressive technique based on careful selection of the most relevant predictors in the MW and IR regime. We report below the three main outputs from the original proposal and outline the relative achievements.

1) A statistical regressive technique based on the synergy of Microwave (22 - 58 GHz) and Infrared (10.5 um) observations, for the retrieval of Liquid Water Path in fog condition from ground-based observations.

The multivariate statistical regression technique implemented in this project is based on the use of the following 14 predictors in the Microwave oxygen and water vapor band at [22.24, 23.04, 23.84, 25.44, 26.24, 27.84, 31.40, 51.26, 52.28, 53.86, 54.94, 56.66, 57.30, 58.00] GHz, together with the additional Infrared channel at 10.5 um. Both linear and quadratic (in the Infrared term only) regression have been applied, with training (70% dataset) and test (30% dataset) performed over both the whole regime (LWP < 2 mm) and/or lower values (LWP < 0.1 mm and LWP < 0.3 mm).

2) Improved retrieval of Low Liquid Water Path for a dataset of synthetic brightness temperatures obtained with radiative transfer models, using atmospheric profiles from the NWP model AROME.

We have first used a simulated dataset consisting of 8760 synthetic brightness temperatures (obtained with MonoRTM based on atmospheric profiles from the NWP AROME) to test the regressive approach. We find that the technique described above provides a better estimate of the LWP when the training is performed over very low values (LPW<0.1mm) rather than over the whole regime (LWP < 2mm). This is particularly the case when an additional predictor is used (a quadratic infrared term) which significantly improves the statistics of the estimate, namely the rms by 30% and the correlation by 8%.

3) Selected cases from the SOFOG3d campaign showing improvement of the retrieval of Low Liquid Water Path in fog condition.

Most part of this project has been dedicated to investigating the benefit of the above technique for selected real cases from SOFOG3D experimental campaign. We focused on two case studies at the site of Agen (2019/12/06 and 2020/01/06) featuring thick fog condition. The trained regressive coefficients have been applied, providing an accurate estimate of LWP as well as similar results to other robust approaches, such as the RPG neural network or Univ. of Cologne quadratic regression. In particular, the regressive technique has been proven to capture the fluctuations and trend of the LWP variation throughout the whole fog dynamics and for the entire duration of the fog event.

Description of the benefits to the COST Action Strategy (what and how).

(max. 500 words)

The outcomes of this project have contributed directly to the capacity building objectives, as well as to advancing the knowledge of Atmospheric Boundary Layer profiling and processes, especially in the presence of fog condition. Therefore, this is relevant for WG2 (advanced ABL profiling), especially for T2.2 (instrument synergy for the development of higher-level products). In fact, new products and algorithms have been developed and tested over both simulated and experimental data and are now applicable in several contexts; this might pave the way to important societal impacts, given the importance of fog forecast for ground- and air traffic, as well as solar energy plants.

Description of the virtual collaboration (including constructive reflection on activities undertaken, identified successful practices and lessons learned).

(max.500 words)

The research activity has been characterized by a continuous and productive collaboration between the partners involved in the project (CNR-IMAA, METEO-FRANCE, and University of Cologne) both via mail and virtual meetings. The first ones have been focused on the setup of the MonoRTM radiative transfer simulations and the tuning of parameters to define a common ground for the subsequent activities. Later, we discussed several ways we could define the regressive approach, analyzing the pros and cons of implementing a statistical regressive approach as compared to an NN-based technique or a physical approach. Finally, we have interacted frequently once the regressive coefficients from simulations have been applied to experimental cases, mainly trying to investigate scientific and technical reasons why some results were not as expected on a theoretical basis. To this end, we have devoted the final meetings to planning several tests (to be carried out on both sides) to match the parameter space between simulations and experiments, in order to figure out the source of discrepancy. These meetings and discussions have been enlightening to both define best practices as well as to figure out crucial scientific aspects to the relative importance of each predictor within the regressive approach.