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Use of Millimeter and Sub-millimeter Wavelengths to Retrieve Cloud/Rain Information in Mediterranean Systems

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Context

Millimeter and sub-millimeter wave radiometry offers new perspectives for the characterization of clouds and rain at global scale. Recent theoretical studies on the atmospheric sounding capabilities of space borne millimeter and sub-millimeter wavelengths have shown that cloud contents, rain detection and quantification, as well as properties of ice particles, can be derived from brightness temperatures simultaneously measured at different frequencies above 100 GHz with multi-channel retrieval algorithms (Jimenez *et al.*, 2007; Defer *et al.*, 2008). Millimeter and sub-millimeter waves are also adequate for a radiometer deployment at a geostationary location due to the relative small antenna size compared to those required at usual radiometric wavelengths (< 100 GHz) to assure geostationary observations at a convective-cell-size spatial resolution. We present here the skills in terms of rain detection, rain quantification and cloud content retrieval for different millimeter wave combinations including GOMAS-like (Geostationary Observatory for Microwave Atmospheric Sounding; Bizarri *et al.* (2005) - designed to provide precipitation estimate with a high temporal sampling, for now-casting) mission and CIWSIR-like (Cloud Ice Water Sub-millimeter Imaging Radiometer; Buehler *et al.* (2005) - dedicated to the observation and characterization of ice clouds from a polar orbit, focusing on climate studies) mission.

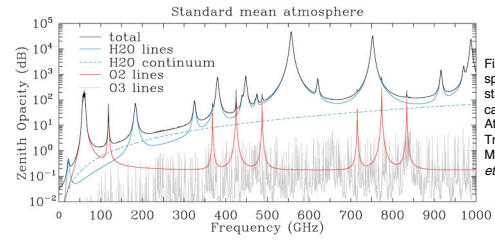


Fig-1. Atmospheric spectrum for a clear standard atmosphere calculated with the Atmospheric Transmission at Microwave code (Pardo *et al.*, 2001).

Cloud/Rain Retrieval with Millimeter Radiometry

Methodology

A data set of simulated brightness temperatures (BTs) at millimeter/sub-millimeter waves is created, using realistic atmospheric profiles derived from a cloud resolving model, and the statistical relationships between the BTs and the cloud/rain properties are examined.

- The atmospheric situations are modeled using the 3D non-hydrostatic mesoscale Meso-NH model designed with an explicit cloud scheme that calculates the evolution of the particle distributions of five microphysical species (cloud droplets, raindrops, ice crystals, snowflakes and graupels) (SIMGEO database; Chaboureau *et al.*, 2008).
- Radiative transfer calculations are performed with the Atmospheric Transmission at Microwaves model (ATM, Pardo *et al.*, 2001) for a large set of frequencies ranging from 23.8 to 875 GHz (Fig-2, Alger case in the SIMGEO database). It includes atmospheric gaseous absorption, scattering by hydrometeors, and surface emissivity to calculate the expected BTs corresponding to the atmospheric conditions simulated by Meso-NH (Meirol-Dautner *et al.*, 2007).
- To evaluate the cloud model outputs and the radiative transfer computations, realistic cloud/radiative simulations at AMSU, TMI and SSM/I frequencies are compared to real satellite observations (Meirol-Dautner *et al.*, 2007).
- Finally BTs of different frequency sets, integrated cloud parameters and hydrometeor profiles are used to build over sea and land separately (Defer *et al.*, 2008):
 - cloud/rain detection tool based on supervised classifications;
 - neural network (NN) cloud/rain retrieval schemes.
- Analysis of the skills of cloud/rain detection tool and NN cloud/rain retrieval schemes relative to the User requirement table from the EUMETSAT position paper (Rizzi *et al.*, 2006).

Rain Detection

- A frequency set like F07 (GOMAS-like mission; Fig-3) can satisfy the user requirements to the breakthrough level, in terms of rain detection for both NoW-Casting (NWC) and Numerical Weather Prediction (NWP) applications even without the O₂ 50 GHz band (F08).
- Adding (in F10) a frequency below 150 GHz to the frequency set proposed for the CIWSIR mission would also allow detection of precipitation with a suitable accuracy (Fig-3).

Cloud/Rain Content Retrieval

- Rain rate retrievals for frequency ranges containing frequencies below 100 GHz (i.e., F01, F02 and F07) present less dispersion (Fig-4).
- Over land and ocean, the r.m.s. errors for a mission such as GOMAS are below or close to 50% (breakthrough) for rain rates above 1 mm/h, which is similar to what can be obtained with AMSU-A or AMSU-AB frequency configurations for the present database (Fig-4).
- Suppressing the frequencies below 100 GHz from GOMAS (i.e., HF-GOMAS/F10) does not change the results significantly over land, contrary to what is observed over ocean especially below 1 mm/h (Fig-4).
- Except for very low rain content, rain profiling capability over sea exhibits r.m.s. error below 50% breakthrough threshold (Fig-5; over land, the results are slightly worse, especially at low altitude).
- Total (snow+graupel+ice) ice profiling can be performed with r.m.s. error below the 50% breakthrough threshold for medium to high ice content (Fig-5; note that the total ice profiling capability was investigated for only precipitating pixels).

From these theoretical calculations millimeter/sub-millimeter wave observations can be used to detect and quantify rain but also to retrieve vertically integrated hydrometeor quantities (e.g., ice, snow, graupel - not shown here) and hydrometeor profiles.

The next step requires the validation of instrumental concepts using millimeter/sub-millimeter technology on airborne platforms during well-documented measurement campaigns.

Two Actions Underway

ESA Study on an Airborne Demonstrator

Two teams lead separately by SULA (with LERMA) and ASTRUM are involved in the ESA "Study of a Sub-millimeter Wave Airborne Demonstrator for Observations of Precipitation and Ice Clouds" to determine the instrument specifications of an airborne demonstrator to prove the scientific mission concepts of CIWSIR and GOMAS.

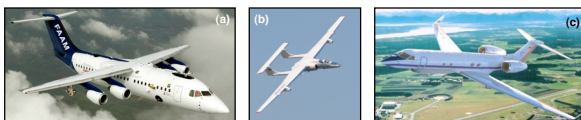


Fig-6. Three potential platforms envisaged in the ESA study (UK Met Office FAAM (a), Geophysica (b), HALO (c)).

ANR Proposal to Build a Millimeter Wave Technological Demonstrator

LERMA and LPN have submitted a proposal to ANR to build a **Multi-Beam Sub-Millimeter Wave Schottky Radiometer for the Study of the Atmosphere** at 183 GHz, 325 GHz, 340 GHz and 380 GHz.

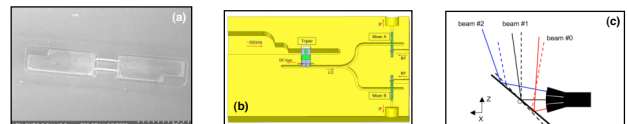


Fig-7. Some of the technical innovations envisaged for the millimeter wave demonstrator. (a) example of LPN Schottky diodes (b) : 3D model of a dual-beam 183 GHz integrated Schottky mixer / multiplier; (c) envisaged scan strategy with three beams.

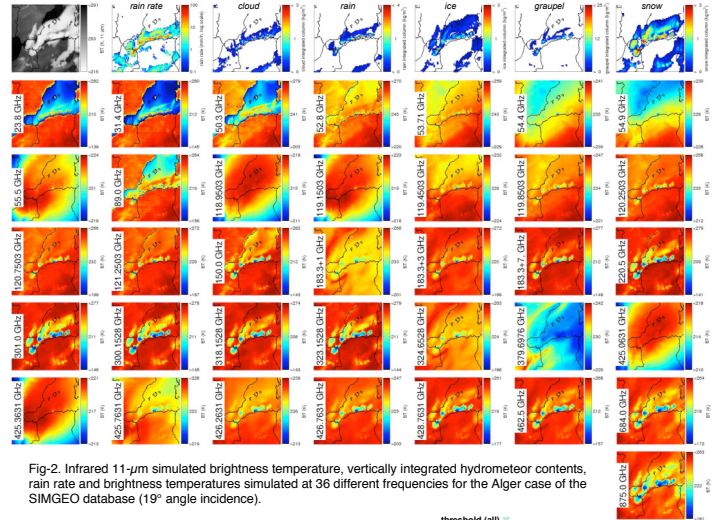


Fig-2. Infrared 11-µm simulated brightness temperature, vertically integrated hydrometeor contents, rain rate and brightness temperatures simulated at 36 different frequencies for the Alger case of the SIMGEO database (19° angle incidence).

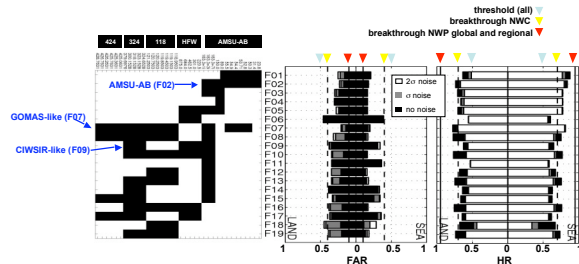


Fig-3. Performances of the rain classification for the 19 frequency sets defined in left panel (19° incidence angle). The breakthrough and threshold values defined in the EUMETSAT position paper (Rizzi *et al.*, 2006) for NWP (Numerical Weather Prediction) and NOW (NoW-Casting) are indicated with solid and dashed lines respectively.

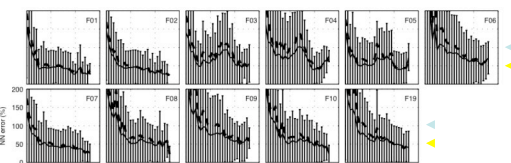


Fig-4. The mean absolute relative error (solid lines) +/- standard deviation (vertical segment) and the r.m.s. error (dashed line) computed per 0.1 bin for pixels over ocean at 19° incidence angle for different frequency sets.

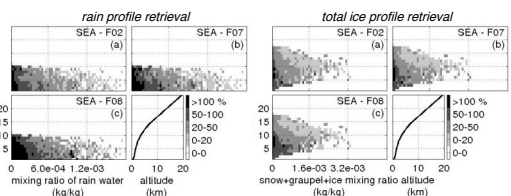


Fig-5. Retrieval of vertical profiles of rain and total ice profiles for three different frequency ranges (over sea, 19° incidence angle). The r.m.s. error is computed per bin of rain and per level. The grey scale follows the error thresholds defined by the EUMETSAT user requirements (Rizzi *et al.*, 2006).