1. Research Objectives

Precipitating Clouds are critical components on the Earth’s hydrological cycle. Weather radars have been the main tool to study precipitation, however the use of microwave radiometers on board of satellites (TRMM and GPM) have shown the importance of having multi-sensor multi-frequency observations. This work focuses on observations by the microwave radiometer ADMIRARI [2, 6] and a weather radar. Rain Liquid Water Content (LWC) has been retrieved by independent methods.

The well known ZPHI method [4, 5] has been extended to radar RHI scans to obtain the rain’s attenuation. Similar to [3], attenuation is used to estimate LWC at radar’s spatial resolution. Retrievals of Cloud and Rain LWC is obtained from ADMIRARI’s observations [1]. To have a better insight on the microphysics of precipitating clouds, retrievals from both instruments are presented along with their uncertainties, attenuation effects and melting layer.

2.- Radiometer ADMIRARI and X-Band Polarimetric Radar (JuXPol)

ADMIRARI

- The University of Bonn’s ADvanced Microwave Radiometer for Rain Identification ADMIRARI is a triple-frequency (10.7, 21.0 and 36.5 GHz) dual-polarized (H & V) scanning passive microwave radiometer (MWR). Its polarization capabilities gives the ability to retrieve slant Liquid Water Path (LWP) and distinguish the cloud and rain components [1].
- Additionally to the MWR, ADMIRARI senses the atmosphere with co-located ancillary instruments, i.e. a 24.1 GHz micro rain radar and a 905 nm cloud lidar.
- Typical ADMIRARI data set comprise of Brightness Temperature (V & H); Polarization Difference (V - H) and the ancillary active instruments. Reflectivity at 24.1 GHz and backscattering factor at 962 nm [1, 2, 6].
- The JuXPol operational radar is a 9.3 GHz dual-pol and is one of the twin X-band systems in Bonn (BoXPol), Germany.
- The radar with its 1.03° beams-scanship performs RHI and volume scans for composite products together with its twin in Bonn.
- The RHI scans have 150 meters range resolution, and 0.2° elevation steps scanning from 0 to 30°

3.- The ZPHI method applied to radar RHI scans

The ZPHI method is used to correct the measured reflectivity Z, from attenuation in QPE, PPI scans at low elevation angles and thereby estimate rainfall [3]. The method couples the profiles of attenuated Z(x) and the differential phase ΔΦ(x). Assuming that attenuation A(τ) = a(τ)Z(x)[χ], where Z is the intrinsic reflectivity factor, then:

\[ A(τ) = a(τ)Z(x)[χ] = a(τ)[Z(x)[χ]exp(21a(τ)PLA) - 1] \]

\[ A(τ) = a(τ)Z(x)[χ] \]

with

\[ L(τ, ρ, ϑ) = 0.46 \int_{θ=0}^{θ_{top}} dθ a(τ)Z(x)[χ]dθ \]

and the Path Integrated Attenuation (PLA) is given as a function of ΔΦ as follow [3, 4, 3];

\[ PLA = a(τ)ΔΦ \]

The coefficients a(x) and ΔΦ are temperature dependent and normally are assumed to be constant along the path, which drives to the simplification of equations (independent of x). That assumption, however, is not valid for RHI scans since there is a evident change on temperature for high elevation angles. Once A(τ) is computed, similar as in [3] for rain rate, a power low relationship is applied to estimate rain liquid water content instead.

\[ \text{LWC}(r) = a(τ)[r] \]

All the coefficients are obtained from long-term DSD dataset for specific temperatures, subsequently polynomial relationships are used to map the atmospheric temperature profile to each radar range:

\[ Z(τ) = [0.19 - 0.527 + 0.01T]^2 \times 10^{-5} \], \quad 0 < T < 30°C
\]
\[ dτ = [0.05 - 0.37] \times 10^{-6} \]
\[ (dτ)^2 = 2.0410 - 0.020T + 0.0001T^2 \]
\[ (dτ)^2 = 3.0701 - 9.9045T \]

From top to bottom: MRR reflectivity, Cloud-lidar backscattering, radiometer Brightness Temperature, Polarization Difference. The red stars on the time axis indicate JuXPol scans.

4.- Results for Rain LWP and Rain Attenuation Coefficients

The ZPHI method is applied to the measurements to obtain the specific attenuation from the ZPHI method. The retrieved rain LWC is calculated by LWC(r) = \[ \frac{\text{LWC}(r)}{ρf} \]

The red cones indicate the radiometer’s field-of-view (FOV), i.e. the scenario that ADMIRARI measures.

5.- References


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On the multi-frequency signature of precipitation water content as observed by passive and active sensors

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