Microphysical properties of ice particles as revealed by satellite microwave polarimetric measurements and radiative transfer modeling

A proposed cloud scattering polarization parameterization for un-polarized fast RT models

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1. Motivation

- Stratiform clouds have shown to produce highly polarized (TBV-TBH=TBVH) passive microwave observations at frequencies above 80 GHz (~10K at 166 GHz) due to the deposition and aggregation growth of snowflakes that are predominantly oblate and horizontally oriented. This contrasts with convective regions that show smaller polarization, as graupel and/or hail become randomly oriented. Polarized microwave observations could thus be used to classify observations as convective/stratiform.
- A number of questions arise when radiative transfer (RT) experiments are used to explore polarized microwave cloud signals: are polarized models robust? What do observations have to offer?
- Operational radiative transfer models do not account for polarized scattering. We propose here to derive an estimate of the polarization difference (TBVH) at 89 and 166 GHz to be applied to un-polarized calculations, based on the analysis of one year of GMI observations.

2. Methodology

- All 2015 TBV and TBVH observations at 37, 89 and 166 GHz are analyzed over both land and ocean surfaces, and parameterized using a Hermite cubic spline interpolation.
- A radiative transfer (RT) modeling framework is applied to a case study with coincident GMI observations: deep convection in Southeastern South America to physically support the statistical relationships parameterized. The Atmospheric Radiative Transfer Simulator (ARTS) DOIT scattering solver is coupled with the Goddard Profiling Algorithm (GPROF) hydrometeor mixing ratios, to model the sensitivity of polarized signals to ice particle microphysics parameters.

3. Overview of the observed cloud polarization characteristics GMI Level 1C global data analysis: Focus on the 36.5, 89 and 166 GHz polarized channels

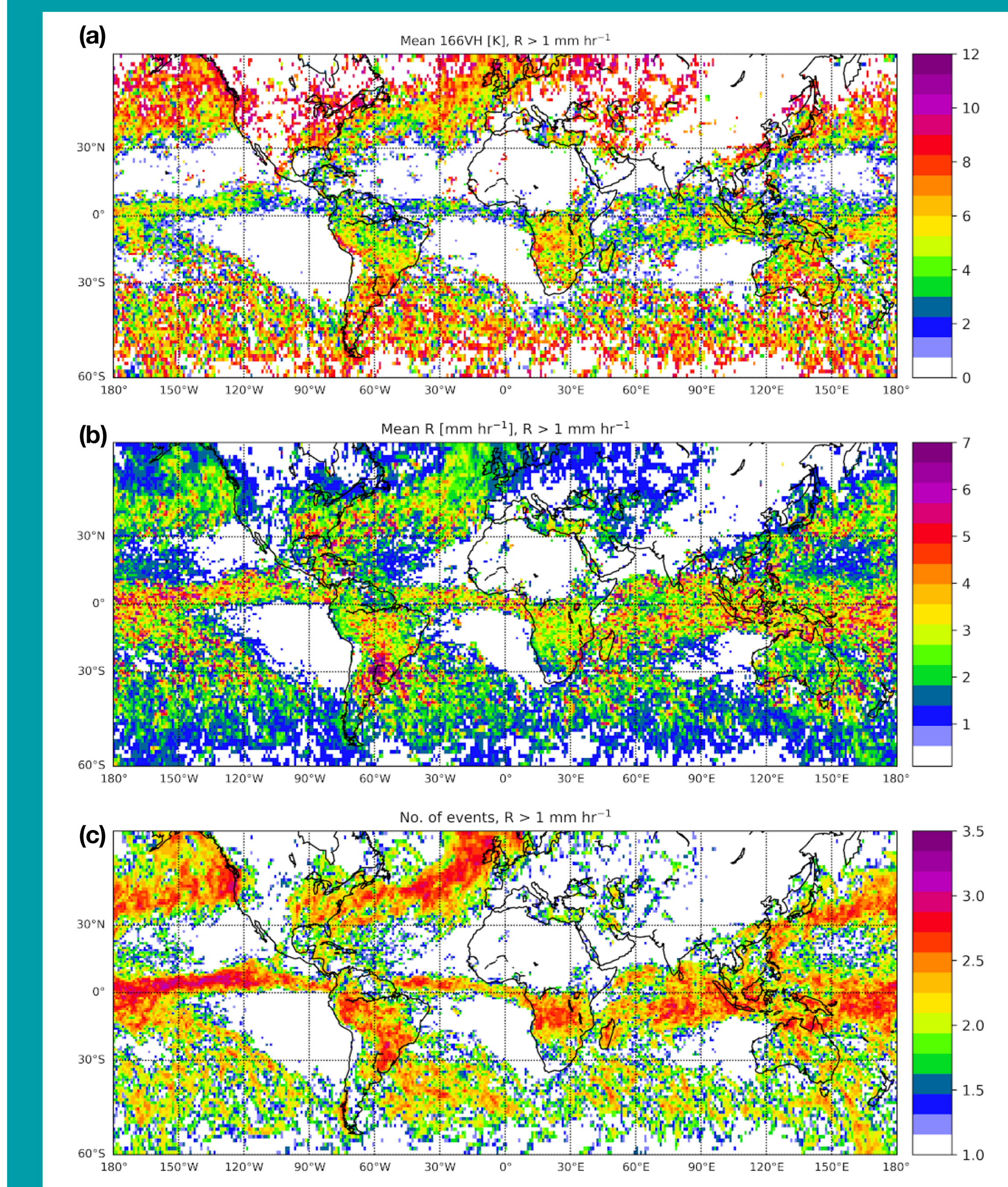


Figure 1. (a) Mean TBVH(166 GHz) values calculated from all 2015 GMI observations with R > 1 mm hr^{-1}. Additional information is provided in **(b)** regarding mean R and **(c)** the number of events taken into account statistically with R > 1 mm hr^{-1}. The rainfall data was taken from the rainfall 2A GPM product. Note that Southeastern South America has large polarization and rain-rates.

Data analysis reveals the existence of the previously documented 'bell-curve' type relation between the vertical brightness temperature (TBV) and difference between the vertical and horizontal polarization (TBVH), by i.e., Prigent et al. (2001), Galligani et al. (2013), Defer et al. (2014) and Gong et al. (2017).

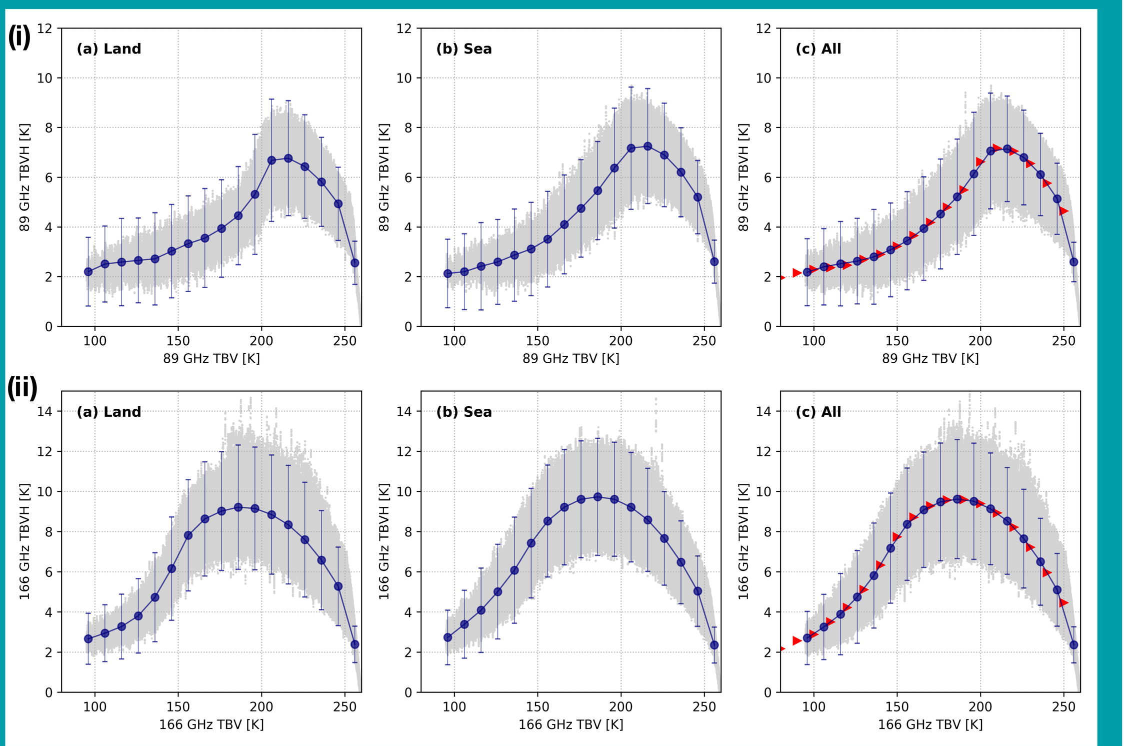
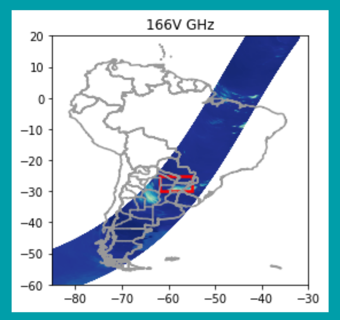


Figure 2. Scatter plot of the polarization difference (TBVH) versus the vertical polarization (TBV) at **(i)** 89 GHz and **(ii)** 166 GHz for (a) land, (b) sea and (c) both, in the Tropics and Mid-latitudes from the available 2015 GMI data. Only regions with R > 1 mm hr^{-1}are included (see **Figure 1**). Data have been smoothed with a moving average over a 20-sample width (grey dots). The mean values with standard deviation for each 10 K TBV bin are shown by the blue lines. The Hermite spline interpolation is shown with the red triangular markers.

4. Case study: an intense mesoscale convective system over north-eastern Argentina on 13 January 2018



Associated severe weather events such as intense precipitation (14.5 mm h^{-1}), hail and intense lightning activity (two deaths). GMI observations at 14 UTC show strong brightness temperature depressions associated with cloud scattering. The regions with low TBV (convection) show TBVH values close to 0 K, while regions with less pronounced TBV depressions (stratiform) show TBVH values ~7K at 89 GHz and 10K at 166 GHz.

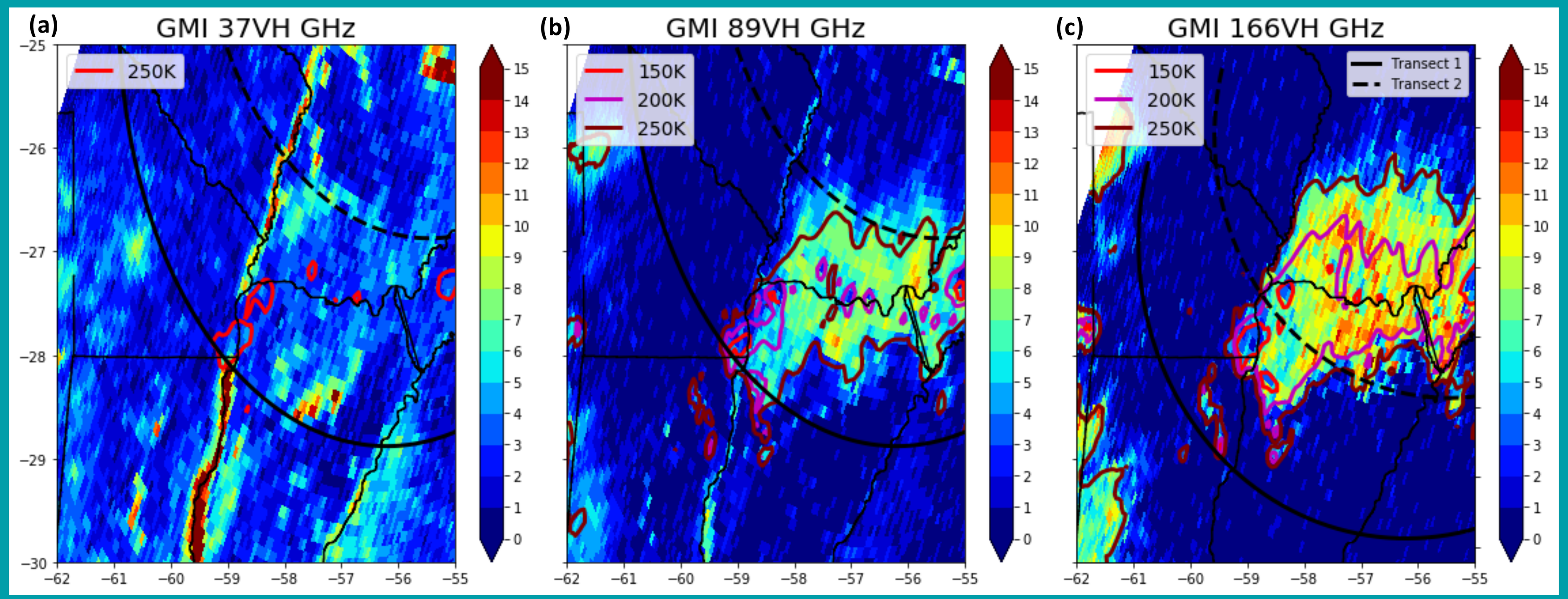


Figure 3. GMI observations on 13/01/2018 at 1420 UTC (1120AM LT) over north-eastern Argentina for TBVH at (a) 37 GHz, (b) 89 GHz and (c) 166 GHz. The red, magenta, and maroon lines correspond to TBV contours at the temperatures specified in the legend. Transect 1 and Transect 2 are presented in **Figure 6/7**.

The parameterization derived from the global satellite dataset agrees well with this specific summer mid-latitude case.

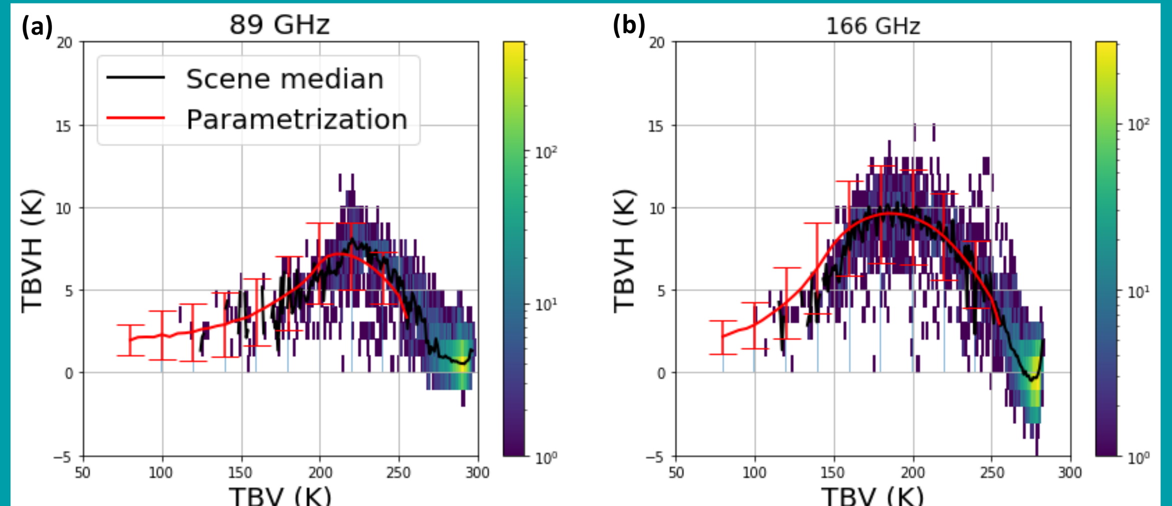


Figure 4. GMI TBVH versus TBV, for (a) 89 and (b) 166 GHz over land only. For each 1K by 1K box, the color indicates the normalized number of counts in each TBV-TBVH pair on a log scale. The red line and its error bars illustrate the proposed parameterization and its corresponding STD.

5. RT modelling to physically support statistical relationships parameterized

The single scattering properties were calculated using the T-matrix, for spheroids (both randomly oriented and horizontally aligned) and the DDA Liu (2006) sector habit with the equal mass size approach to ensure consistency (Galligani et al., 2017) with the WRF particle size distribution. Different oriented spheroids were tested and their microphysical properties include densities ranging from 0.1-0.3 g/cm^3 and aspect ratios of 1, 1.3 and 1.6.

A. Scatter plot of the TBV simulated vs. the median simulated TBVH over land for the case study in Figure 3:

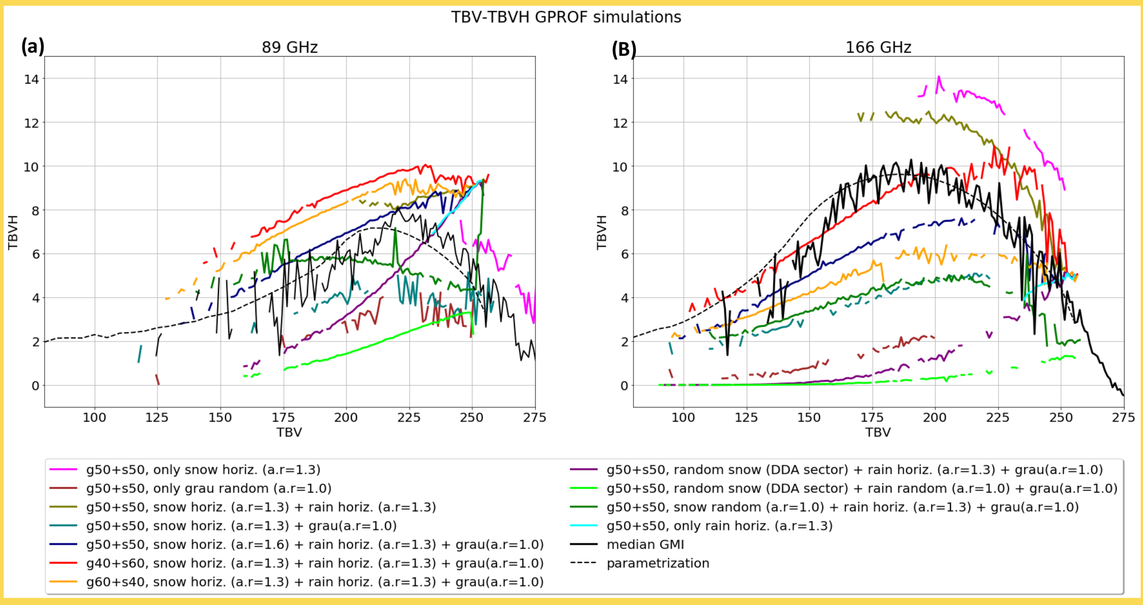


Figure 5. The color curves illustrate the median TBVH versus TBV at **(a)** 89 GHz and **(b)** 166 GHz as simulated by the radiative transfer framework implemented for the case study (land only). The simulated TBV and TBVH are binned in 1 K bins. The solid black curve illustrates the real GMI observations while the dotted black curve is the proposed Hermite parameterization as shown in **Figure 2**.

B. Applied parameterization to different transects: reconstructing TBVH from the simulated TBV

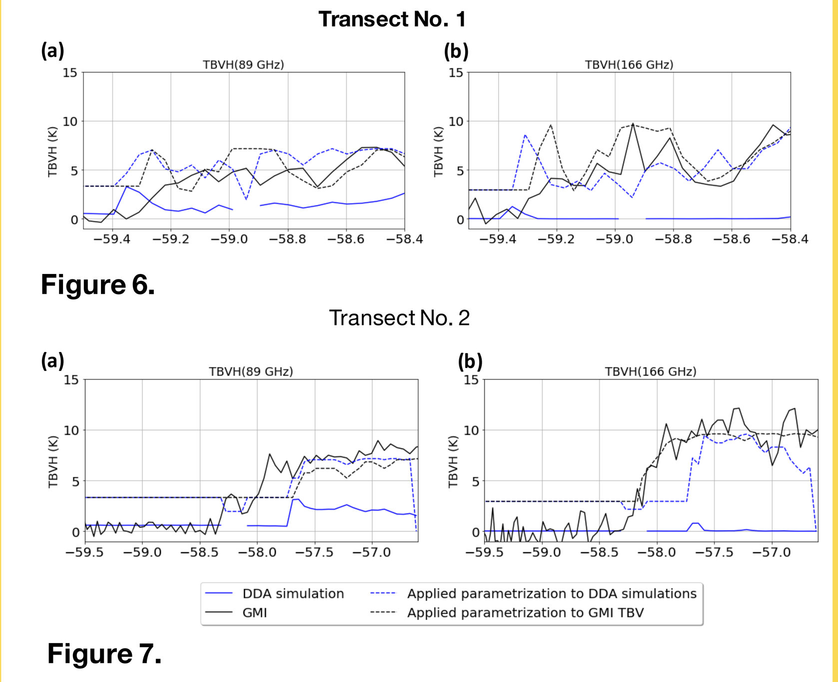


Figure 6, 7. Panels (6,7 a) show the observed and simulated (DDA simulation, light green curve in **Figure 5**) TBVH with solid black and solid blue curves respectively for two transects shown in **Figure 3**. The dashed blue and dashed black curves additionally show the reconstructed TBVH using the presented parameterization for the observed and simulated TBV.

6. Future work: Test the RT framework with the recently available ARTS Microwave Single Scattering Properties Database with oriented particles.

6. Bibliography

* Galligani, V. S., C. Prigent, E. Defer, C. Jimenez, and P. Eriksson (2013), The impact of the melting layer on the passive microwave cloud scattering signal observed from satellites: A study using TRMM microwave passive and active measurements, J. Geophys. Res. Atmos.
* Defer, E., Galligani, V. S., Prigent, C., and Jimenez, C. (2014), First observations of polarized scattering over ice clouds at close-to-millimeter wavelengths (157 GHz) with MADRAS on board the Megha-Tropiques mission, J. Geophys. Res. Atmos.
* Gong, J., and D. L. Wu, 2017: Microphysical properties of frozenparticles inferred from Global Precipitation Measurement (GPM) Microwave Imager (GMI) polarimetric measurements., Atmos. Chem. Phys.
* Galligani, V. S., Wang, D., Alvarez Imaz, M., Salio, P., and Prigent, C.: Analysis and evaluation of WRF microphysical schemes for deep moist convection over south-eastern South America (SESA) using microwave satellite observations and radiative transfer simulations, Atmos. Meas. Tech.

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