Evidence of oblate hydrometeors in TMI observations

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Introduction

The impact of hydrometeor shape on microwave radiation in the atmosphere is well known in radiative transfer theory. Validation attempts for radiative transfer models by means of ground based observations give promising conformance regarding the effects of oblate hydrometeors (Czekala et al. 2001).
Identifying the impact of hydrometeors (and their shape) on the satellite observed signals is more difficult, but possible in certain situations. By using TRMM level-1 data we show that the polarization difference (PD) will have a dynamic range in the order of 20 K at 85 GHz due to effects of precipitation particle shape. Positive PD of up to +12 K is associated with straiform precipitation, negative PD down to −12 K can occur over isolated convective storm cells.

Data Processing

In order to focus on specific precipitation events we use the data from the TRMM satellite. Due to its low orbit altitude TRMM is offering high resolution microwave observation (TMI) together with visible/infrared (VIRS), precipitation radar (PR), and lightning observations (LIS).
The high-resolution pixel-level products have different scan patterns and resolutions. In order to use the data for comparisons and statistical analysis, we match the high-resolution VIS/IR data and the low-resolution TMI data on the intermediate resolution of the radar grid.

Data used for the matched product:

- 1B01 Level-1 VIRS (Visible/IR data)
- 1B11 Level-1 TMI (Microwave Imager)
- 1C21 Level-1 Radar reflectivity profile
- 2A12, 2A23, 2A25, 2B31 Level-2 (analyzed products at pixel level)
- LIS lightning rates, lightning activity
- NCEP surface temperature
- analysis of melting layer, homgeneity

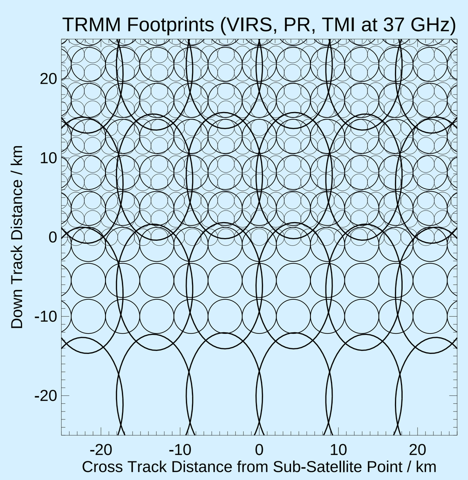

Figure 1: Scan pattern of the three main TRMM instruments in the center of the sub-satellite track.

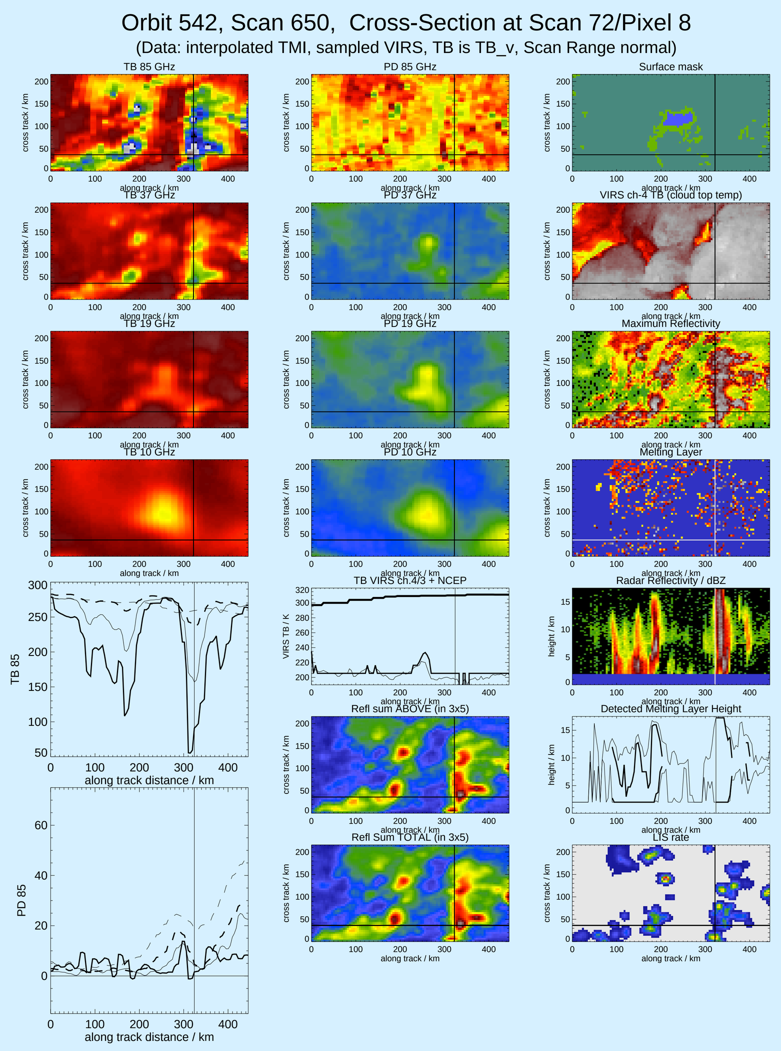

Figure 2: Sample of the most important variables (level-1) in matched product. Cross-track and along-track coordinates are chosen for browsing the orbit.

Stratiform Precipitation

From the precipitation radar we can analyse the existence and strength of the melting layer. This kind of classification with a different instrument than the TMI allows for an independent analysis of the TMI data since we do not need to characterize the stratiform or convective nature from the TMI data itself.
Important feature: In the presence of a melting layer the polarization difference at 85 GHz (PD_{85}) is always positive and larger then than PD_{37}. Only oblate particles can explain the observed magnitudes of PD_{85}.

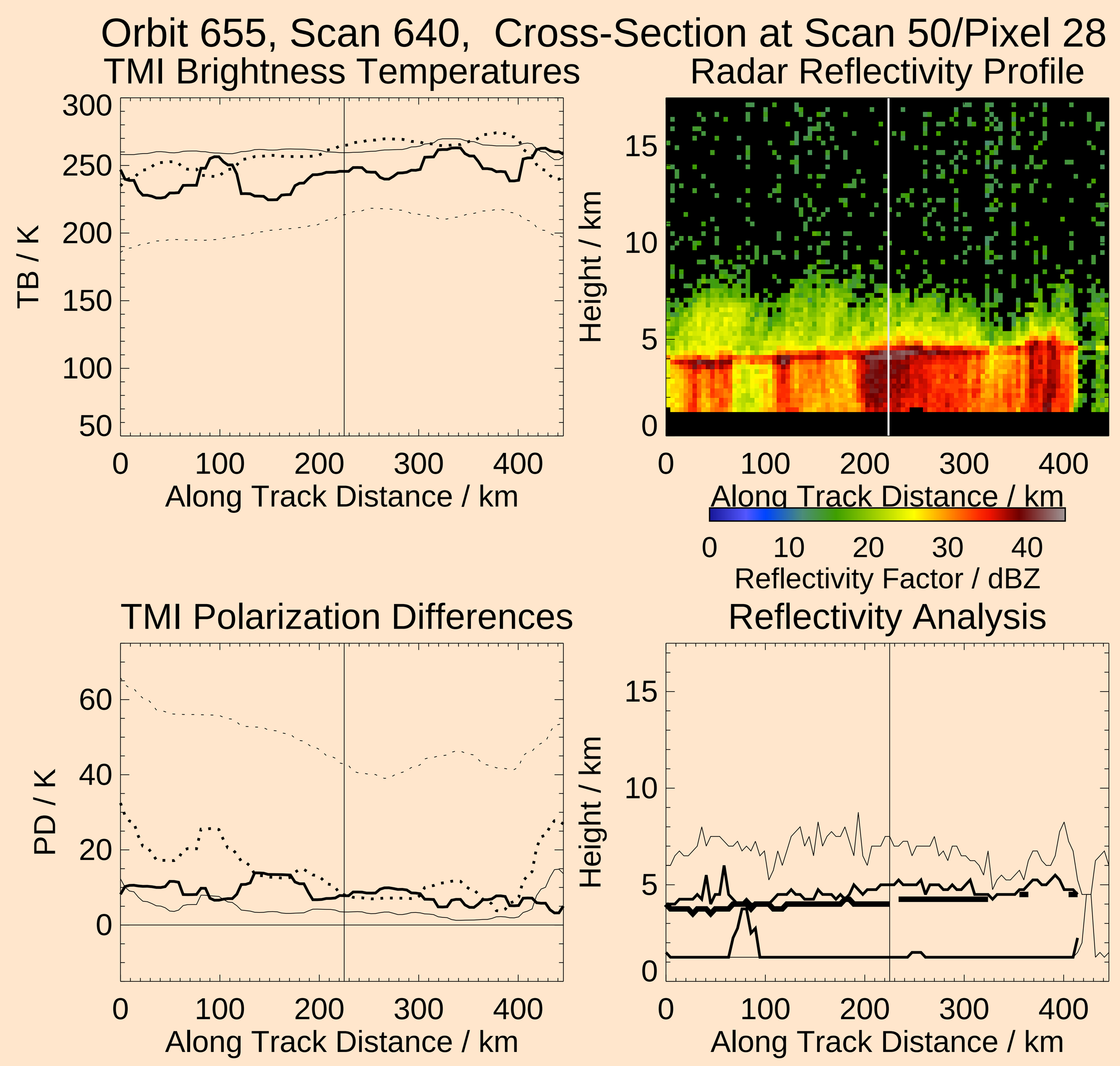

Figure 3: Stratiform precipitation over ocean. The X-axis gives the along track distance. Brightness temperature (TB), polarization difference (PD), radar reflectivity, and melting layer analysis are shown (thick line: melting layer, medium line: 25 dBZ contour, thin line: 18 dBZ contour). TB and PD are given for 85 GHz (thick solid), 37 GHz (thin solid), 19 GHz (thick dashed), and 10 GHz (thin dashed).
At 85 GHz surface polarization is blocked, so the observed PD is caused by the hydrometeors itself.

Convective storms

Isolated precipitation towers of convective rain storms sometimes show a very interesting signature in the microwave signature at 85 GHz: negative polarization differences occur (Prabhakara et al. 2001). Radiative transfer calculations suggest prolate ice particles as a reason for this signal (Czekala 1998).

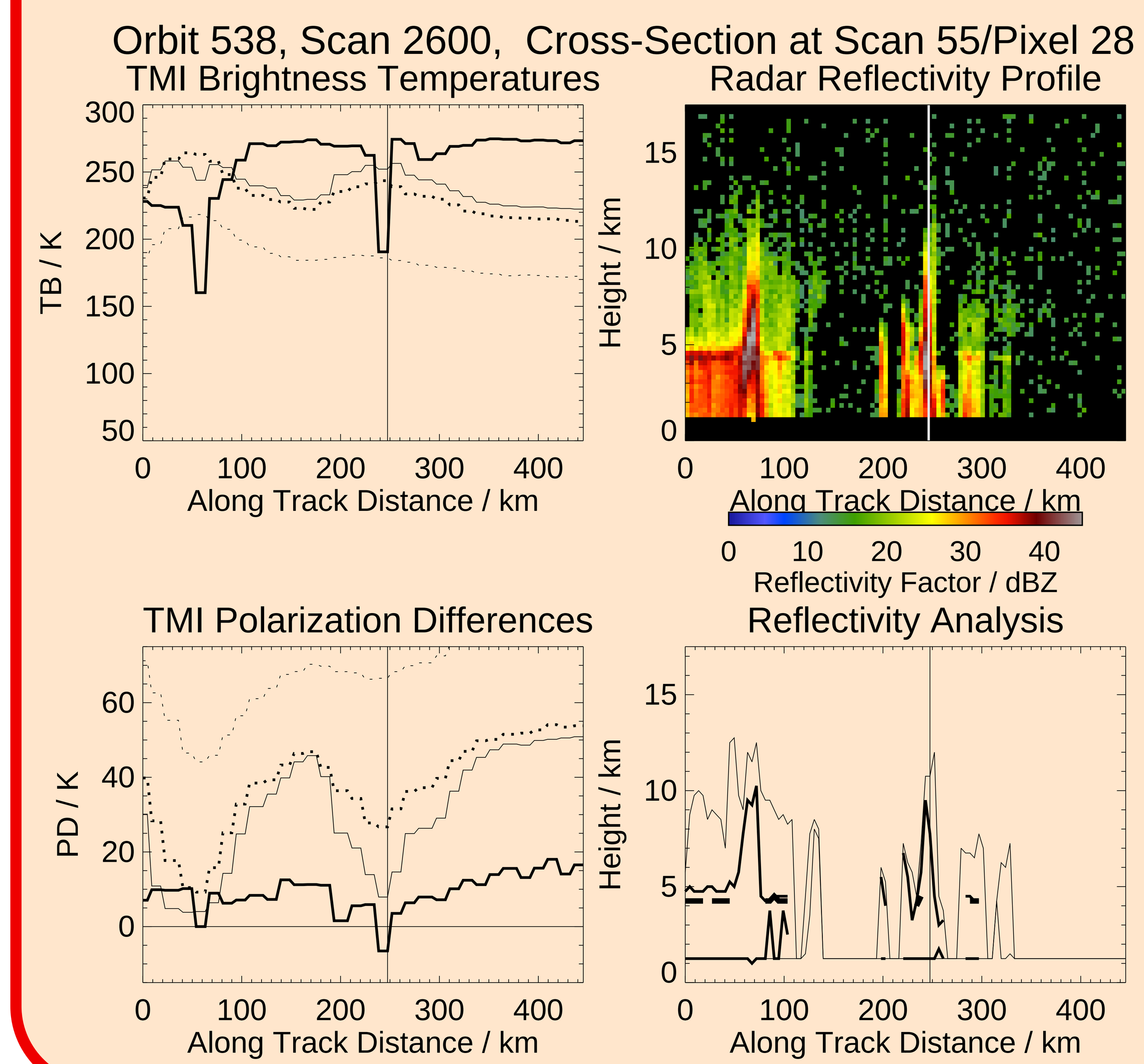

Figure 4: Convective precipitation over ocean. Isolated storms (less or equal to one pixel at 85 GHz) exhibit −5 to sometimes −12 K PD. This feature sometimes is associated with strong lightning activity, but not always. The most severe brightness temperature depressions do not show the strongest negative PD signature (see Fig. 2). Other microphysical effects (electric fields) might be involved. Over land this signature of less than −5 K occurs approximately 6 to 7 times more often than over ocean.

Statistical Analysis

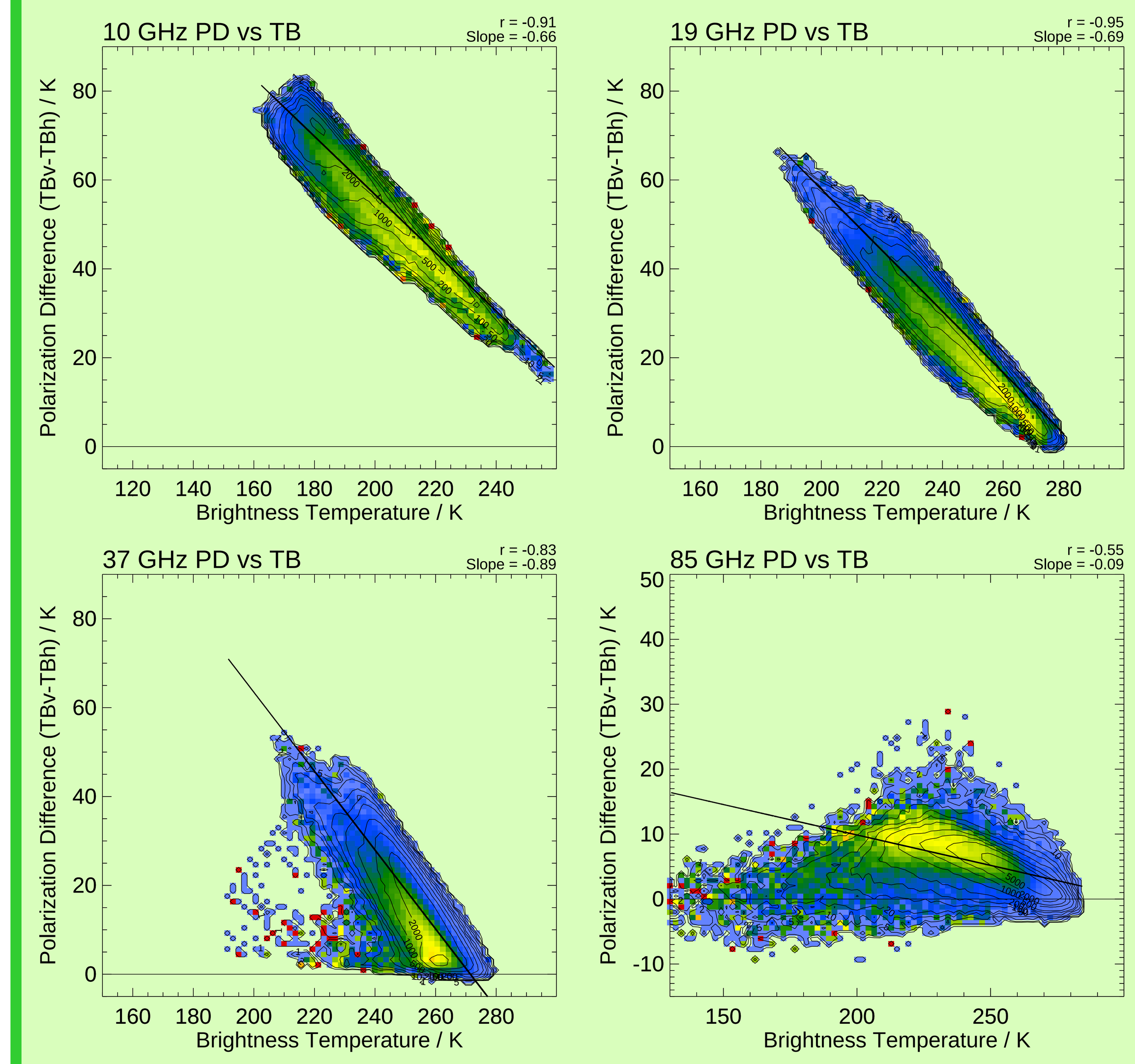

Figure 5: PD-TB scatter diagrams for data examples from January 1998. Contourlines with logarithmic spacing indicate the point density within the scatterplot, the color gives the percentage of points with an analysed melting layer (present if clear bright band structure of 25 dBZ or more exists, with restrictions to horizontal homegeneity).
At 85 GHz the stratiform precipitation exhibits a clear trend to positive PD with increasing optical thickness (e.g. decreasing TB).

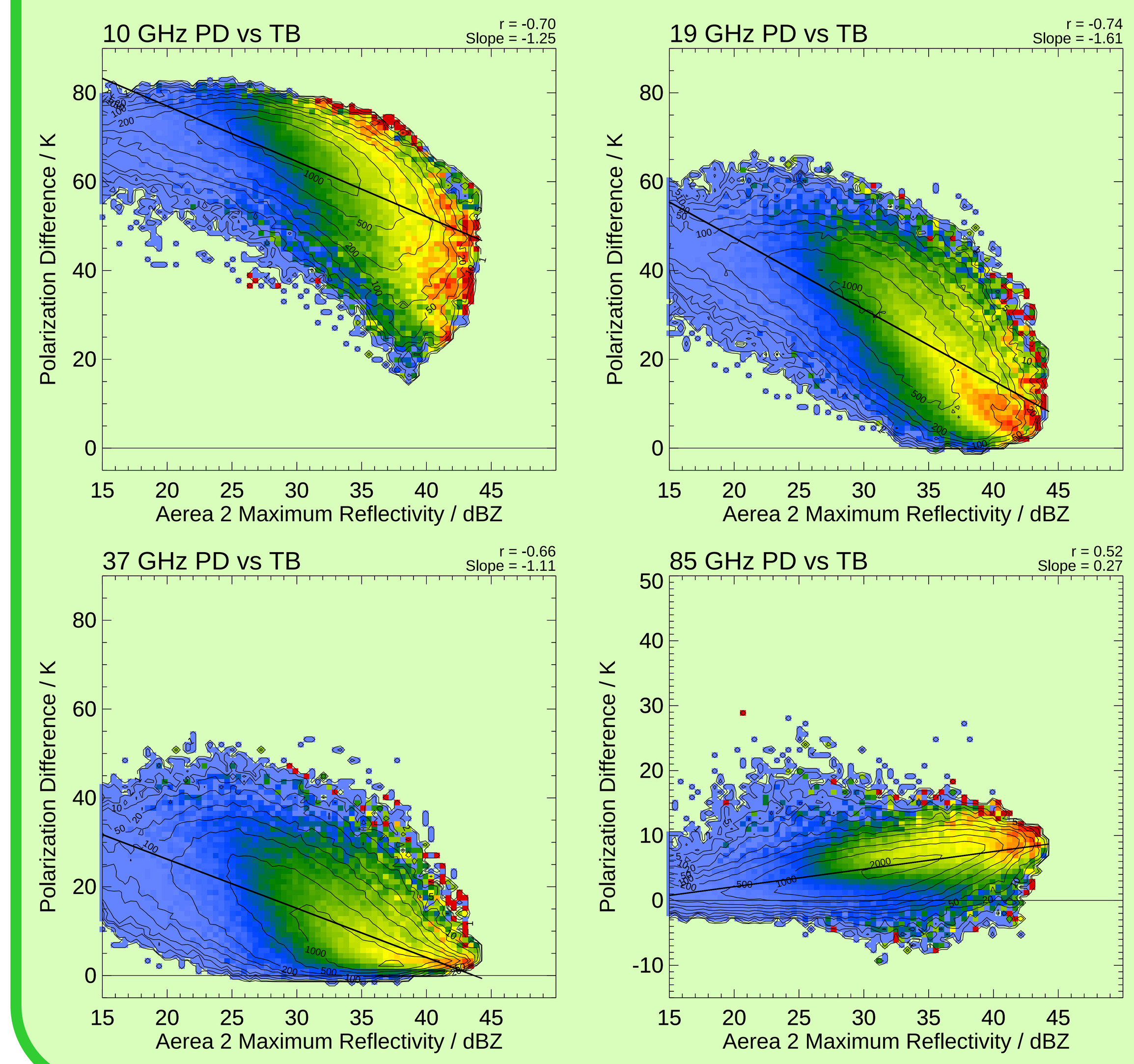

Figure 6: PD-Z scatter diagrams for data examples from January 1998. Point density and relative ocurrence of melting layer/bright band is indicated by contour lines and color scheme, respectively. The reflectivity shown is an area average of 3 by 3 radar pixels with the maximum reflectivity in each profile used for the averaging.
With increasing rain rate and increasing reflectivity the PD is also increasing at 85 GHz. This clearly indicates a hydrometeor effect rather than a surface effect.

References

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