Final Progress Report Grant 80NSSC19K0674 "Improved detection and quantification of precipitation by the TRMM/GPM combined algorithm"

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1 Project description

Ground clutter is signal in the radar observations caused by the ground. It may cause uncertainties in the radar precipitation estimates by obscuring precipitation signal. Ground clutter induced uncertainties tend to be large for shallow or low freezing-level precipitation systems in the off-nadir regions of the radar swath. This is because such systems are characterized by large variations in the precipitation intensity with range, and simple schemes to estimate the surface precipitation from observations not affected by ground clutter are usually not adequate. In this project, we developed a methodology to mitigate the negative impact of ground clutter on the detection and quantification of surface precipitation from both TRMM and GPM radar observations. The methodology is based on the fact that ground clutter is a function of the radar incidence angle, i.e. it is a minimum at nadir and drastically increases with the viewing angle. From an instantaneous and climatological perspective, it is necessary to accurately estimate precipitation at all radar viewing angles. We, therefore, developed a methodology to mitigate ground clutter issues using a comprehensive database of GPM near-nadir radar observations, minimally contaminated by ground clutter, matched with coincident GMI observations. For a given off-nadir radar reflectivity profile, the database is used to identify records characterized by similar surface conditions and precipitation type to reconstruct the information obscured by the ground clutter in the off-nadir profile.

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Shown in the left panel of Figure 2 is a cross-section through an observed reflectivity field at Ku-band (left panel). As apparent in the figure, the reflectivity field is increasingly contaminated by ground clutter (which results in much stronger echo than that usually associated with precipitation) with increasing viewing angle. In the absence of more complete information, one may assume that the precipitation rate is constant with height, and set the precipitation rate at the surface equal to that at the lowest clutter-free bin. However, this assumption is generally not valid and tends to lead to significant biases in the surface precipitation estimates. The left sub-panel of the right panel of Figure 2 shows the average stratiform precipitation profiles over oceans stratified by the freezing level bin. As apparent in the figure, the precipitation rate increases with range bin. A representation of the average stratiform precipitation profiles as a function of the range relative to the freezing level bin and normalized by the freezing level rate is also shown in the right panel of Figure 2. This representation removes most of the variability apparent in the absolute range bin representation and makes the different freezing level bins almost indistinguishable. Given the well-defined and robust variation of the precipitation rate with range, a simple, but effective, method to mitigate the biases in the surface precipitation estimates may be formulated by simply scaling the normalized precipitation rate profile to match the precipitation rate at the lowest clutter-free bin and use the resulting profile to fill-in the values

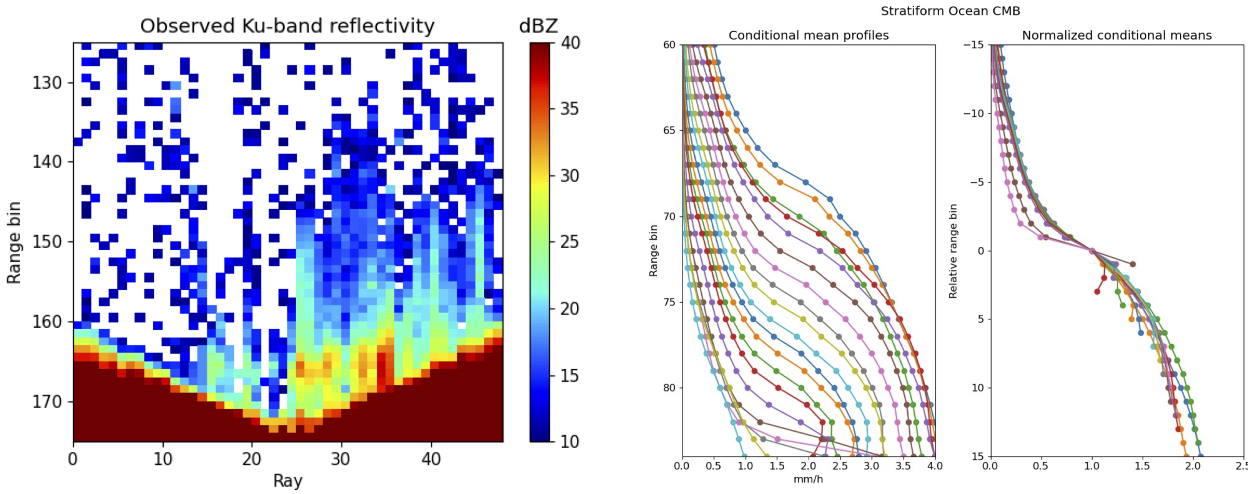


Figure 1: Cross-section through observed reflectivity field at Ku-band (left panel) and average stratiform precipitation profiles over oceans (right panel).

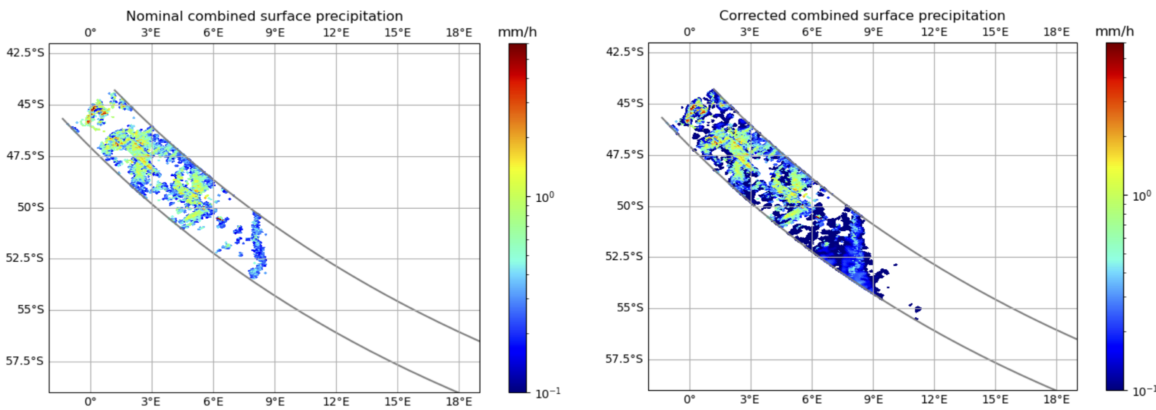
at longer ranges. Mathematically, this may be expressed as

$$PrecipRate(Z < ZCF) = PrecipRate(ZCF)NCM(Z)/NCM(ZCF) \tag{1}$$

where Z is the height, ZCF is the height of the lowest clutter-free bin, and $NCM(Z)$ is the normalized conditional precipitation profile.

Equation 1 is applied conditionally on the surface and precipitation type with different normalized average precipitation profiles being used for different surface conditions and precipitation types. Its global implementation and application to the GPM Ku-band radar observations resulted in:

- More precipitation at the surface over oceans. The impact is more pronounced at higher latitudes because the freezing level is lower and the precipitation rate increases with range is more pronounced above the freezing level.
- Less precipitation at the surface over land in the tropics and sub-tropics. This is because the precipitation rate tends to decrease with range below the freezing level due to evaporative processes. This is also the case at mid-latitudes in the summer.
- More precipitation at the surface over land in the mid-latitudes in the winter. This is because the precipitation rate tends to increase with range due to the fact that the lowest-clutter free bin is usually above the freezing level and there are no significant evaporative process to reduce the precipitation rate.
- The DPR does not miss all the light precipitation associated with a given point in the Tb-space.
- An empirical algorithm may be derived from collocated Tbs and DPR retrievals.
- The empirical algorithm is to be applied only when the DPR does not detect precipitation. When estimates are greater than 0, a decision is required.



Nominal combined surface precipitation
Corrected combined surface precipitation
mm/h

Figure 2: