Detection and use of Multiple Scattering and Non-Uniform Beam Filling in DPR data

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Multiple Scattering (MS) and Non-Uniform Beam Filling affect Global Precipitation Measuring mission Dual-Frequency Precipitation Radar (DPR) Ku and Ka band reflectivity measurements.

Certain recognizable features have been embedded in an automated approach to detect their occurrence, and perform retrievals that account for them to the extent that is possible.

The detection of such profiles is performed by a module called the 'Trigger' which performs a fast analysis of every profile based on relatively simple criteria in order to avoid unacceptable reduction in processing efficiency: the Trigger relies on all data from DPR (that is the Normal Scan, the Matched Scan, and the High-Sensitivity Scan) and produces an estimate of the probability of occurrence (and severity) of both phenomena.

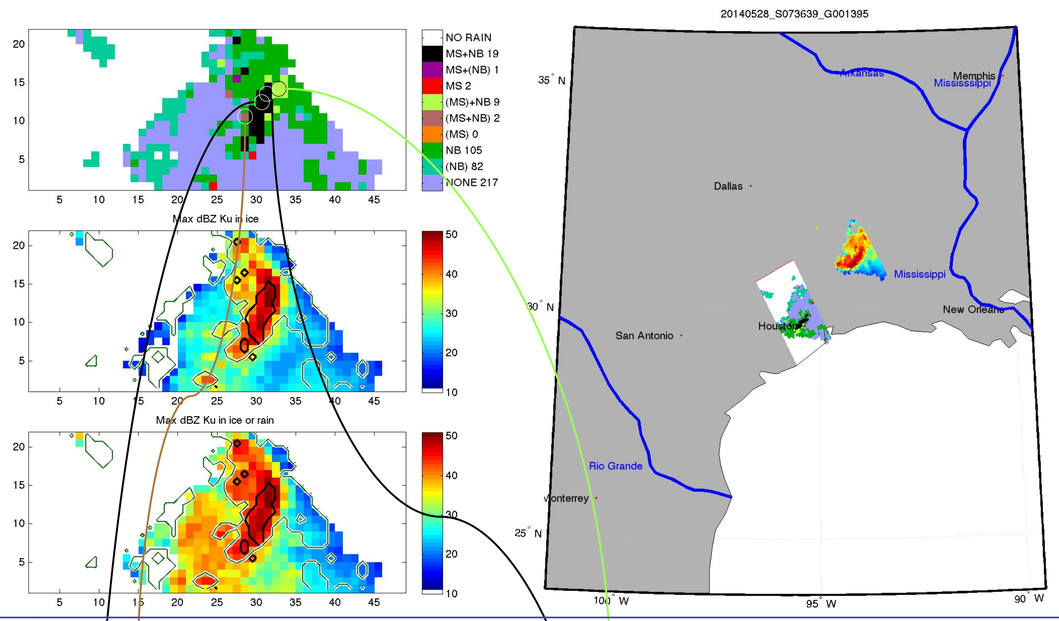
The retrieval of microphysical properties for profiles estimated to be affected by severe Multiple-Scattering is performed by flexible retrieval algorithm based on Optimal Estimation initialized with an ensemble of initial conditions compatible with the output of the Trigger. The retrieval module employs a forward operator which accounts for multiple scattering.

NO NUBF	POSSIBLE NUBF	CERTAIN NUBF
"NONE" Evidence of moderate or strong MS or NUBF is not detected. This does not imply that mild MS or NUBF are not present, or unlikely. They may very well still be present but they are not strong. A retrieval that doesn't account for NUBF or MS may produce errors with additional uncertainty, but not larger than all the standard sources of uncertainty.	**(NB)** Some features of the profile appear anomalous. Possible NUBF. No MS detected. These profiles are associated with a definitely negative check for MS, but either the HS or the PIA indicate that NUBF is possible. These profiles should be handled by a solver that is based on SS but accounts to some extent for NUBF (e.g., the new Solver by Seto). Two parameters are produced: the normalized std dev of Ka-PIA and the fraction of empty.	**NB** NUBF signatures detected. No MS detected. These profiles are associated with a definitely negative check for MS, but either the HS or the PIA indicate that NUBF is possible. These profiles should be handled by a solver that is based on SS but accounts to some extent for NUBF (e.g., the new Solver by Seto). Two parameters are produced: the normalized std dev of Ka-PIA and the fraction of empty.
(MS) Some features of the profile appear anomalous. Possible MS. No NUBF detected. These profiles may include MS effects, but poor quality of the relevant signals doesn't allow to be sure about it. Usually the most limiting factor is the Ka-sensitivity. These profiles should be handled by a solver that is based on SS and one based on MS to verify if solutions converge.	**(MS + NB)** Some features of the profile appear anomalous. No clear answer about NUBF and MS. This is the worst kind of diagnose. These profiles often exhibit features that are quite difficult to interpret even in a supervised manner. An ensemble of solvers should be used to at least characterize the overall uncertainty of the retrieved solutons.	**(MS) + NB** NUBF detected. MS possible. These profiles often exhibit features that are quite difficult to interpret even in a supervised manner. An ensemble of solvers should be used to at least characterize the overall uncertainty of the retrieved solutons.
MS MS detected. No NUBF detected. Using an SS based solver will cause grossly erroneous retrievals. MS-based solvers have been developed and are being validated.	**MS + (NB)** Signatures of MS are present. Possible NUBF. In this case the NUBF "may modulate" the MS tail. Using an SS based solver will cause grossly erroneous retrievals. Using an MS solver without NUBF will produce occasionally biased retrievals but with uncertainties not too dissimilar from the standard product.	**MS + NB** Signatures of MS and NUBF are present. In this case the NUBF "modulates" the MS tail. Using an SS based solver will cause grossly erroneous retrievals. Using an MS solver without NUBF will produce possibly biased retrievals but with uncertainties not too dissimilar from the standard product. No NUBF+MS solver has been developed to date. Correlation between surface precipitation and ice aloft must be established with ancillary datasets (e.g., Nexrad).

HOW DOES THE TRIGGER PRODUCT LOOK LIKE?

Each profile is associated to a probability of being affected by MS and/or NUBF. The probabilities are then grouped in 3 categories: Not detected, Possible and Certain.

The 3 x 3 matrix of possible profile categories is shown to the right, and an example of the map of classifications is shown below.



HOW OFTEN DOES EACH OF THESE CATEGORIES OCCUR?

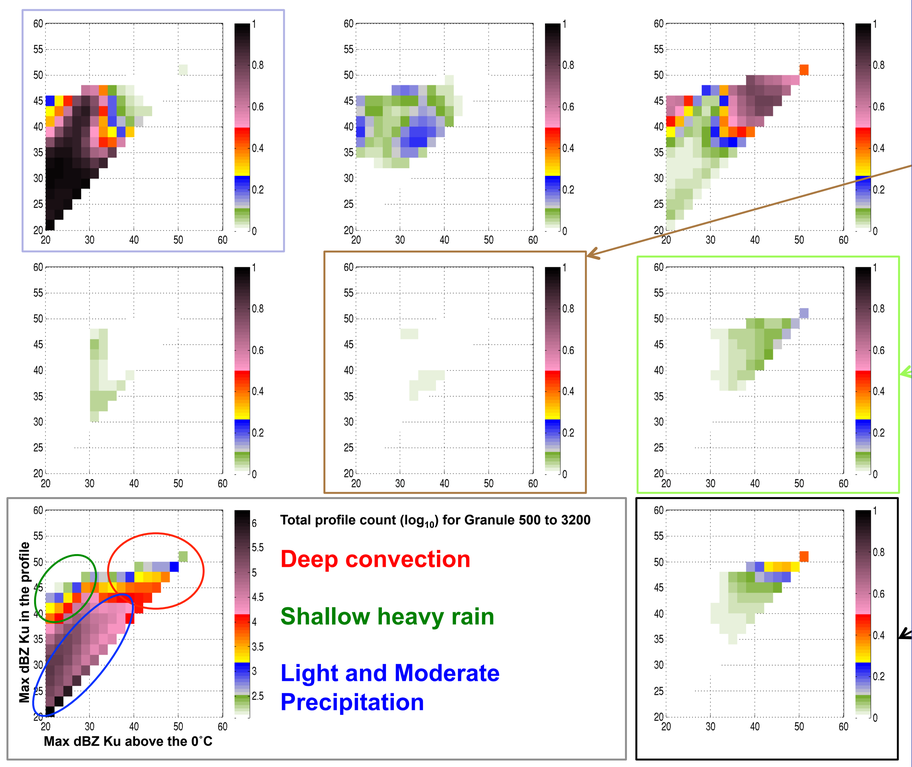
The probability of occurrence (conditional to a profile having been diagnosed as "rainy" by the DPR algorithm) of each of the categories shown above in the period April-October 2014 (V03B, Granules 500 to 3200) is shown on the left. The x axis shows the maximum measured dBZ Ku-band above the zero isotherm, the y axis is the maximum dBZ Ku-band over the entire clutter-free portion of the profile.

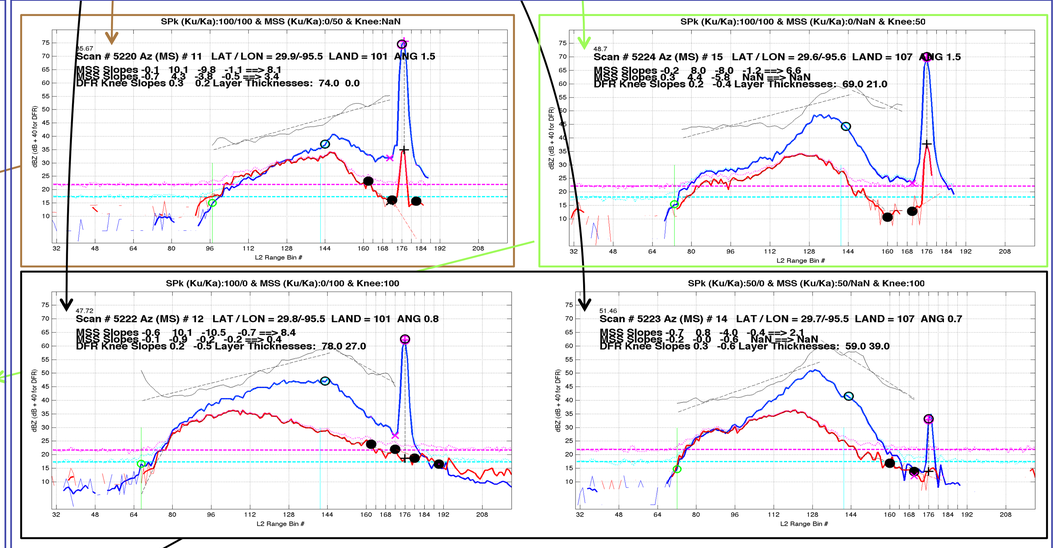
The 3 MS certain categories are aggegated into one in the lower left panel. The lower right panel shows the total number count of profiles and a rough partioning of the nature of profiles falling in a given region of the Z_{max} vs Z_{max} in ice axes.

Deep convective profiles are often associated to certain or possible MS, and they are almost always associated with NUBF.

Shallow heavy rain is often associated to NUBF and occasionally to MS.

Light an moderate precipitation rarely exhibit MS, but about one in ten (ROM) is affected by significant NUBF.





HOW DOES A PROFILE IN THE MS CATEGORIES LOOK LIKE ?

Examples for 3 of the categories are shown above.
Presence of the "DWR Knee" [1], or "MS tails" through the surface [2] are grounds for classification in the MS category.
Observed departure of the PIA ratio from expected range [3] or decorrelation of the 8 nearest Ka band neighbors [4] are ground for classification in the NUBF category.

WHY DO THIS?

1) The primary purpose of these algorithms is NOT to refine estimates of profiles that are affected by minor NUBF or MS effects. Rather, it is to detect with reasonable confidence which profiles would be grossly misinterpreted by standard solvers. Albeit rare in terms of probability of occurrence, these worst offenders are associated with extreme events and high precipitation rates, and therefore can affect global and zonal averages just as much as the more ubiquitous but less intense profiles.
2) The primary requirement of the Trigger algorithm is to be reliable in detecting, and fast (to avoid slowing down the processing chain excessively). Then, the sophisticated solvers that are less computationally efficient than the current operational ones can be 'Triggered' ONLY WHEN NEEDED (which is not often).

WHERE AND WHEN DO THEY APPEAR?

Global map (Apr 1 to Aug 13, 2014) of events where the Trigger detected MS.
The size of the circle is proportional to the number of profiles with severe MS, the size of the square is proportional to the number of profiles with moderate MS or moderate to severe NUBF.
Color fades from blue in April to red in August.
Below: histogram of relative occurrence of the 9 classes: black=total, red=land, blue=ocean.