Removing Negative Biases in Rain Estimates from the TRMM Precipitation Radar

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Introduction

Comparisons with ground-based rain gauge measurements or run-off simulations using the Precipitation Radar rain retrievals as input indicate that the Version 6 TRMM PR retrieval algorithm [2A25] may produce rainfall estimates that are biased towards lower rainfall rates, particularly over land. As work progresses on the Version 7 TRMM algorithms we have performed sensitivity studies and compared these against the Version 6 results. Most of the code modifications have been performed at NICT while monthly testing has been conducted at the NASA Precipitation Processing System. Below is a summary of results and future directions.

Modifications to the Version 6 2A25 Algorithm

To address these negative biases we have focused on three main areas:

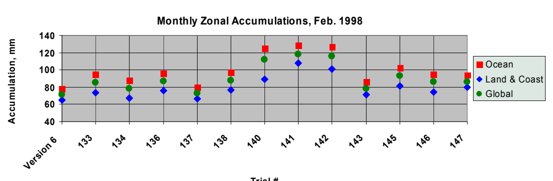
- Non-uniform beam filling correction (NUBFC)
- Specific attenuation profile above the freezing level.
- Initial assumptions for the drop size distribution (DSD).

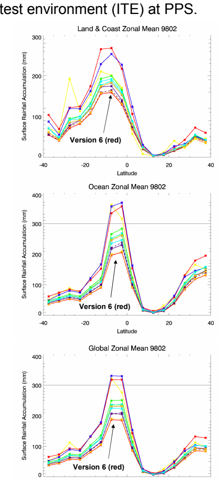
Changes have also been made to the method of determining the adjustment from initial DSD assumptions based on PIA constraints, computing corrected Z, and R from a probabilistic method to a maximum likelihood estimation (ML) method. How each of these changes impacts the final retrievals and if they address the issue of negative biases over land is discussed below.

Zonal Means

Means of estimated surface rain from area weighted 5 degree zonals from the TRMM monthly accumulation algorithm [3A25]. The 5 degree grids were partitioned into ocean and non-ocean areas using the monthly TMI-only accumulation algorithm [3A11] mask. Results are presented as accumulations and % differences relative to the Version 6 results. The month used was Feb. 1998 which is during the El Nino just after TRMM's launch. While this month is not the most representative it can be used to give an indication of relative differences. These tests were run in the integration and test environment (ITE) at PPS.

Feb. 1998	Accumulation in mm			%Diff (Trial - V6)/V6*100			
ITE #	Ocean	Land	Global	Ocean	Land	Global	Notes
Version 6	78.3	64.96	71.44	0.0	0.0	0.0	v6.67 (Version 6)
133	94.54	73.72	85.43	20.7	13.5	19.6	v6.91 NUBFC ON
134	87.34	67.3	78.62	11.5	3.6	10.1	v6.91 NUBFC OFF
136	96.13	76.32	87.13	22.8	17.5	22.0	v6.91 NUBFC ON, alpha = 0 for conv.
137	79.58	66.45	72.66	1.6	2.3	1.7	v6.67 alpha = 0, all types
138	96.98	76.66	87.83	23.9	18.0	22.9	v6.91 NUBFC ON alpha = 0, all types
140	125.34	89.38	111.49	60.1	37.6	56.1	v6.91 NUBFC ON (2) New coeffs.
141	128.54	107.68	117.97	64.2	65.8	65.1	v6.91 NUBFC ON alpha = 0 all types, epsilon0
143	86.18	71.3	78.61	10.1	9.8	10.0	v6.67 New stratiform DSD
145	102.42	81.38	92.84	30.8	25.3	30.0	v6.92 New DSD parameters (2)
146	94.81	74.12	85.72	21.1	14.1	20.0	v6.92 w/ V6 DSD parameters
147	94.05	80	86.28	20.1	23.2	20.8	v6.92 DSD params (2), stddev_epsilon restricted.





Impact of various changes

The impact of the many changes are summarized by the change in estimated surface rainfall accumulation. This by no means is an exhaustive test as many other retrieved values are also altered such as total PIA, convective and stratiform partitioning of rain accumulations, and corrected reflectivity. This is an attempt to gauge the impact of the changes in NUBFC, DSD assumptions and vertical model changes.

NUBFC

Increases due to the non-uniform beam filling correction alone are 9.5% over land, 8% over ocean and 8.6% globally. In ITE 140 the impact of using extreme coefficients in the NUBFC result in much larger increases, however, these can have a negative impact on R and Z profile shape and sometimes yield unrealistic final PIA estimates.

DSD Assumptions

Alternate initial DSD parameters including lower water content above the freezing level result in increases of 9.8% over land, 8% over ocean and 8.3% globally.

Ice Content Above Freezing Level

Vertical model assumptions have also been changed to have less liquid water above the freezing level than initially assumed. The extreme case where no attenuation is attributed to precipitation above the freezing level yields a 4% increase over land, a 2.6% increase over ocean and a 2.8% increase globally.

Background on 2A25

Like any other single frequency radar retrieval algorithm, the TRMM PR rain profile algorithm is dependent on some prior knowledge of Drop Size Distribution (DSD) information. The DSD information used by the Version 6 PR algorithm was constructed based on several independent DSD data sets in an attempt to capture global variability. The dependence on a fixed DSD is mitigated by the use of an adjustment technique using a reference measurement of the path integrated attenuation (Surface Reference Technique, [TRMM 2A21 algorithm]) to account for variations from the assumed DSD. Information on how the DSD changes as a function of an alpha adjustment parameter (epsilon) is prescribed in a series of Z-R relations at several nodes in the 2A25 vertical precipitation model. Just how strongly the a priori DSD is altered for any given ray is a function of the weighting of the SRT PIA. The weighting used in the Version 6 algorithm attempts to strike a balance between using available, reliable SRT PIA estimates and including adjustments that may imply unphysical DSDs.

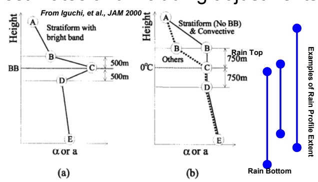


FIG. 4. Schematic presentation of the profiles of α and a. The initial values of a, b, and α are given at five points, A, B, C, D, and E. When a bright band is detected (a), C is chosen at the brightband (BB) center, B is two range bins above C, D is two range bins below C, A is the top of the echo, and E is the lowest valid range bin. If there is no bright band (b), C is chosen at the estimated freezing height, and B and D are 750 m above and below C, respectively. Here A and E are the same as before. Coefficients between these points are calculated by interpolation. Note that the profile for stratiform rain without a bright band is similar to that for convective rain, but their actual values are different.

"The coefficients at point E in Fig. 4 are calculated by interpolation or extrapolation of the coefficients at 0C and 20C."

In version 6 of the algorithm the "other" category is treated as "convective". The population of "other" rain was drastically reduced in Version 6 to ~ 2.5% of all rain profiles.

DSD and Vertical Model Assumptions

The actual rain profile can fall across nodes in various configurations depending on the storm top height and the lowest gate with rain. The final coefficients used in the reflectivity correction and rainfall rate determination are different for each PR ray.

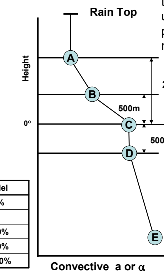
Fractional Water Content

Stratiform

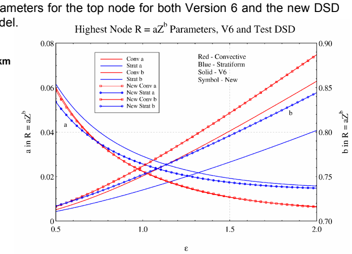
Node	Version 6	New Model
A	1.10%	Snow 0%
B	1.70%	1.70%
C	17%	17%
D	0deg.100%	0deg. 100%
E	20deg. 100%	20deg. 100%

Convective

Node	Version 6	New Model
A	1.10%	Snow 0%
B	0deg. 100%	1.10%
C	0deg. 100%	0deg. 100%
D	0deg. 100%	0deg. 100%
E	20deg. 100%	20deg. 100%

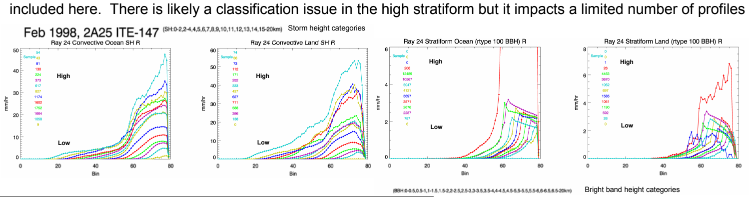


An alternate vertical model is being investigated where the DSD is fixed from the rain top down to the first node, extending the path length through the pure ice phase. In the convective example to the right, the parameters for liquid water in the new model are not used until the estimated melting layer. The graph below shows the parameters for the top node for both Version 6 and the new DSD model.

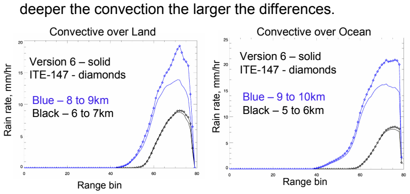


Profiles

Rainfall rate profiles from Feb. 1998 for the latest test algorithm. Profiles are separated by land, ocean, and rain type. Stratiform rain only includes rain type 100 (with bright band) and convective only includes the two most populated categories. Convective profiles are categorized by storm height while stratiform profiles are categorized by bright band height, the limits of each are shown next to the plots. Only nadir profiles are included here. There is likely a classification issue in the high stratiform but it impacts a limited number of profiles



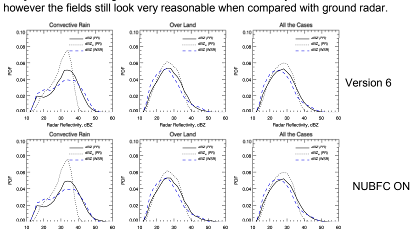
Comparisons of individual R profiles for Version 6 and the test case for convective profiles at two heights. The deeper the convection the larger the differences.



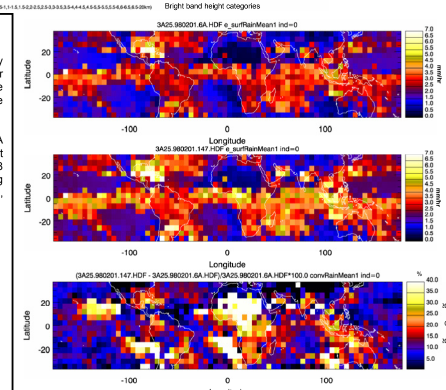
Comparisons with Ground Radar

The use of ground data for validating satellite retrievals of precipitation has traditionally been a post production activity. As the satellite algorithms mature there is a greater need for examination of localized biases prior to the distribution of products to the general community. To address this we have started to more closely incorporate available ground data into the satellite algorithm testing process.

The graphs below show comparisons of reflectivity from the Melbourne, FL. NOAA NEXRAD radar and the TRMM PR for both the standard Version 6 products and a test of the non-uniform beam filling correction. Coincident events with rain from 1998 through 02/2007, totaling 234 overpasses were used to in this comparison [Liang Liao]. There is a slight increase in corrected reflectivity with the NUBF correction, however the fields still look very reasonable when compared with ground radar.

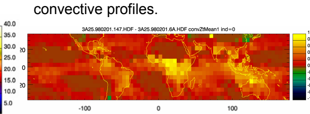


We see this as a model for future testing of the Global Precipitation Measurement (GPM) mission retrieval algorithms. GPM is already building a virtual network of ground validation data using NOAA NEXRAD radars with the intent of expanding this resource to sites around the globe.



Maps

Monthly maps illustrate the impact of algorithm changes. The conditional mean estimated surface rainfall rates are shown to the left for the Version 6 and latest test algorithm. Mean rain rates have increased over both ocean and land. Bottom left shows the percentage increase in conditional convective surface rainfall at 2km. Increases over sub-Sahara Africa are substantial while increases over the open ocean are considerably less. Below is the difference in corrected reflectivity for convective profiles.



Summary

Algorithm changes will continue to be assessed and once a stable set of parameters is decided upon a longer time series will be generated for further analysis. The NUBF correction will be assessed using additional ground radar data. The impact of non-spherical drops is also being investigated with a 3rd set of DSD parameterizations. This should have little impact on the light rain rates but reduce slightly the rain estimates for higher rain rates.

Authors acknowledge support and input from Steve Nesbitt, JAXA, NASA, Precipitation Measurement Missions Science Team, and NASA Precipitation Processing System