INVESTIGATING THE EVOLUTION/IMPACT OF RAINFALL BIAS ERRORS THROUGH VERSION 7 AND BEYOND

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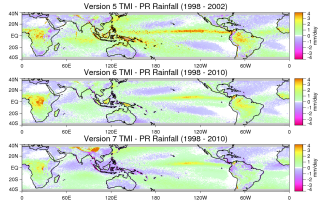
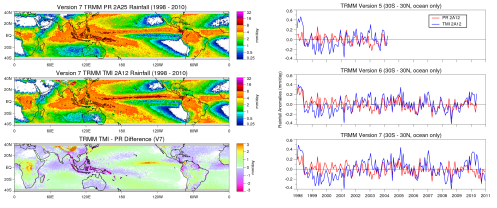
INTRODUCTION



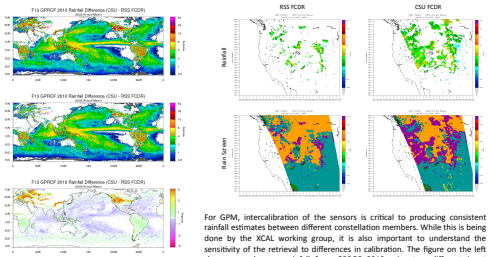
The figure on the left shows regional differences in mean rainfall between versions 5 ,6, and 7 of the TRMM TMI (2A12) and PR (2A25) retrieval algorithms based on the 3G68 datasets. The mean bias has been removed to emphasize regional differences. There are clear large-scale patterns with higher estimates by the TMI over the east Pacific and lower estimates over the North Atlantic, for example. While the amplitude of these differences was reduced significantly going from v5 to v6, the differences in regional biases over ocean shows little change with v7. The land biases, however, change significantly with v7 likely due to the calibration of the v7 land estimates to PR. The mean rainfall maps for v7 are shown in the figure on the right.

The figure on the far right shows a comparison of the monthly mean rainfall over oceans from the latest 3 versions of the TMI and PR estimates. The response to the 1997/98 ENSO changes significantly in the PR estimates. While version 5 shows no response to ENSO in the PR estimates, the response increases significantly in version 6, but then decreases again in version 7. Although a number of changes were made to the 2A25 algorithm between versions, it is interesting to note that the non-uniform beam filling correction was eliminated in version 6, but added back in version 7.



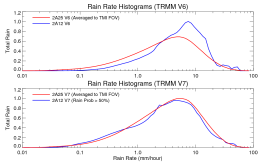
RAINFALL BIASES

Impact of Calibration on SSM/I Retrievals (CSU vs. RSS FCDR)

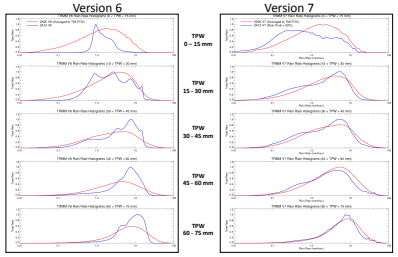


For GPM, intercalibration of the sensors is critical to producing consistent rainfall estimates between different constellation members. While this is being done by the XCAL working group, it is also important to understand the sensitivity of the retrieval to differences in calibration. The figure on the left shows annual mean rainfall from GPROF 2010 using two different input brightness temperature datasets from SSM/I F13. These two Fundamental Climate Data Record (FCDR) datasets are the Remote Sensing Systems (RSS) v6 data and the CSU B3 FCDR. Differences of up to a few kelvin lead to rainfall biases with opposite signs over land and ocean. Differences between the calibration of the 22 GHz channel, however, have the most noticeable impact around snow covered or frozen ground as the retrieval using this channel to screen these surfaces. As the figure above shows, this screen is very sensitive to small changes in the 22 GHz Tb.

Rain Rate Histograms (V6 vs. V7)

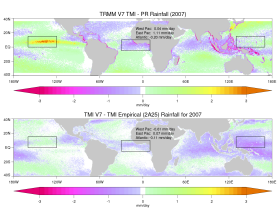


A comparison of rain rate histograms from TMI and PR for both version 6 and version 7 is shown in the left. The PR estimates have been collocated and averaged over the TMI field-of-view to account for differences in the spatial resolution of the sensors. There is a substantial improvement in the agreement in v7 across a wide range of rainfall rates. Although the v7 TMI estimates with a rainfall probability of less than 50% have been eliminated, there is a large increase in the amount of light rain from TMI. The agreement for moderate to heavy rain is also improved as the v7 algorithm incorporates PR observations into the database, which makes the apriori database better reflect reality. Unfortunately, however, the retrievals are no longer completely independent.

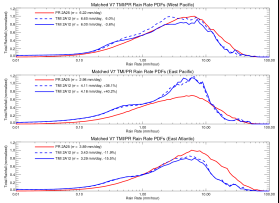


The histograms on the right are similar to the one shown above, but these are stratified by TPW. While the agreement between the v7 retrievals is better over the entire range of TPW, significant differences still remain particularly for low TPW. With the exception of the highest TPW range, there is a dip in the TMI histograms around 1 mm/hour that is not present in the PR distributions.

POTENTIAL SOURCES OF BIAS ERRORS

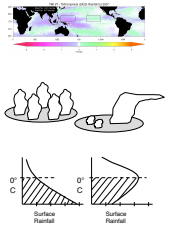


As discussed in the introduction and shown in the top left panel, significant regional differences remain between the v7 TMI and PR mean rainfall over oceans. While the v7 apriori database is created using the 2A25 rainfall estimates over matched TMI/PR pixels, the drop size distribution (DSD) of the hydrometeors is adjusted from the 2A25 values to better match the observed Tbs. In addition, light rain below the PR detection threshold is added to some pixels to account for differences between the observed and simulated Tbs. These adjustments are made in a bulk statistical sense for each SST and TPW bin in the database. The lower left panel shows the impact of these adjustments. In this case GPROF was run using both the v7 database as well as the empirical database, which simply uses the unmodified 2A25 rain rates. The adjustments to the v7 database decrease the amount of rain in the West Pacific from the original 2A25 values and increase the rainfall in the East Pacific. This points to a possible difference in the mean DSD for light to moderate raining pixels in these two regions. Confirming this hypothesis, however, will likely have to wait for the launch of the DPR on GPM.



The figure on the right shows rain rate histograms for the three selected regions indicated by the boxes in the above figure. The agreement is quite good in the West Pacific, although the adjustments in the database decrease the rain from the empirical 2A25 values by about 10%. In the East Pacific, however, the differences between PR and TMI are stark, and the adjustments to the 2A25 values have almost no impact. The opposite is true in the East Atlantic, where the TMI is significantly below the PR and once again the adjustments to the empirical values are minimal. These large biases in the East Pacific and the Atlantic and the lack of change between the empirical and v7 database runs suggests that other factors besides DSD are also a factor. Since the apriori database is stratified by SST and TPW, the differences between these regimes does not appear to be correlated with these parameters either.

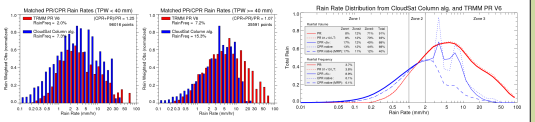
To account for differences between regimes, GPROF subselects profiles from the apriori database based on SST and TPW. This not only speeds up the retrieval, but makes sure that say mid latitude profiles from say a frontal system don't get averaged into the result for pixels in the deep tropics with similar Tbs. Since the Bayesian approach utilized by GPROF averages a large number of profiles from the database that have similar Tbs, profiles from very different rain systems can get averaged together. The SST and TPW stratification was designed to minimize this issue, but clearly using these two variables has not eliminated the regional biases. Several potential sources for these biases are discussed below. It is clear, however, that more work needs to be done to understand differences between rainfall regimes and how they may impact the radiometer retrievals. This will likely be an even bigger issue over land and may also impact other sensors differently due to changes in the frequencies, channel complements, and view angles.



- Microphysics (i.e. DSD)
  - Differences between V7 and the empirical database results suggest this is a factor, but it may only account for a portion of the differences.
  - GPM DPR should provide information to identify and hopefully resolve this issue
- Inhomogeneity in FOV
  - FOV sizes: ~15km for TMI and ~5km for PR
  - Were the changes to the NUBF correction in 2A25 from V5 to V6 to V7 a significant part of the change in the ENSO response?
  - This could be very significant for TMI and other radiometers due to the large footprint size.
- Vertical profile
  - Minor issue for PR/DPR due to surface clutter and extrapolation to the surface
  - Potentially significant for TMI since Tbs respond to changes in the column integrated water/ice, not the surface precipitation.
  - It is likely that changes in the vertical profile and inhomogeneity are related

LIGHT RAIN CONTRIBUTION (PR VS CLOUDSAT)

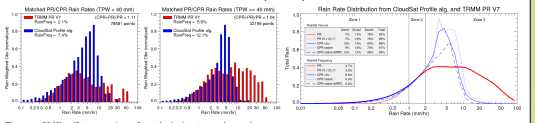
CloudSat Column Retrieval (Haynes et al. 2009) and PR 2A25 V6



A comparison of matched rain rates from the CloudSat column retrieval (v1.06) vs. the version 6 TRMM PR estimates. The results are split for regimes with TPW < 40 mm (left side figure) and regimes with TPW > 40 mm (right side figure). For higher TPW regions the agreement in the 1-3 mm/hour range is quite good, but this is not the case for the low TPW areas.

A comparison of unmatched rain rate histograms from CloudSat (v1.06) and TRMM PR (V6). To account for the different sampling between the sensors, the histograms are normalized by adjusting the total rainfall between 1 and 2 mm/hour to be equivalent. Estimates of the light rain missed by PR (< 1 mm/hour) and heavy rain missed by CloudSat(> 2 mm/hour) are then computed.

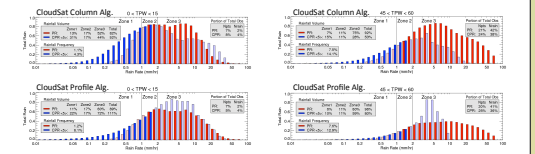
CloudSat Profile Retrieval (Lebsock) and PR 2A25 V7



The same PR/CloudSat comparison of matched rain rates as shown above, but with the latest CloudSat profile retrieval and PR V7 estimates. With the profile retrieval there is much better agreement below 2-3 mm/hour, particularly for the low TPW regions.

The same as the above figure but with the latest CloudSat profile retrieval and PR V7 estimates. The agreement in the 1-2 mm/hour zone is much better and the estimate of amount of rain "missed" by the PR has decreased significantly to ~5%.

Light Rain Contribution as a Function of TPW



Comparison of CloudSat and PR rain rate histograms are shown on the left for very dry regions with TPW < 15 mm and on the right for moist regions with 45 < TPW < 60 mm. The CloudSat column algorithm and PR V6 comparisons are shown in the top row, and the CloudSat profile algorithm and V7 comparisons are shown in the bottom row. While the overall agreement is much better better the latest retrieval algorithms, the contribution of light rain is still substantial over regions with low TPW.

SUMMARY

- The version 7 TMI 2A12 retrieval shows significant improvements in the detection and retrieval of light rain as well as a mean rain rate distribution that agrees much better with PR.
- Significant regional biases remain between the v7 TMI and PR retrievals, however, with the TMI producing substantially more rainfall in the tropical East Pacific and less in the East Atlantic.
- Clearly the SST and TPW stratification of the apriori database is not sufficient to capture regime-dependent differences in rain systems. Given the limited information available from the 9 channel TMI (only 7 channels for SSM/I), it is likely that other sources of information will need to be incorporated.
- It also appears that regime-dependent differences in the bulk DSD properties over ocean continue to be a factor for the PR, one which has a simple solution of waiting for the launch of GPM and the DPR.
- There are significant changes in the response of the PR estimates to ENSO with algorithm version. This remains a significant concern, however, that may be due to DSD variability, but the impact of the NUBF correction should also be explored further.
- The latest results from CloudSat suggest that light rain below the PR detection threshold remains an issue particularly over low TPW regimes, but the amount is less than originally thought (~5% globally).
- Intercalibration between sensors will be very important for GPM, but understanding and minimizing the sensitivity of the retrieval algorithms is equally important, particularly with regard to if tests or empirical thresholds.

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