Version 7 algorithm for the TRMM Precipitation Radar

Toshio Iguchi (NICT), Robert Meneghini (NASA/GSFC), Jun Awaka (Tokai U.), Toshiaki Kozu (Shimane U.), John Kwiatkowski (George Mason U.),
Naofumi Yoshida (JAXA), Shinta Seto (U. of Tokyo), Ken'ichi Okamoto (Tottori U. of Environmental Studies)

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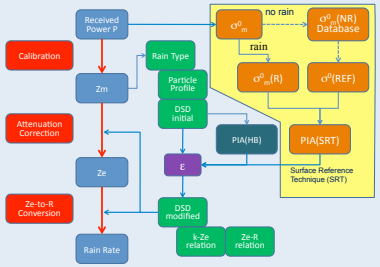
Major changes in V7

- Improved PIA estimates by SRT. (Backward reference, better hybrid reference, and new error evaluation)
- New rain type classification with increased convective rain type
  – many of shallow non-isolated rain cases are convective in V7.
- Adding 0.5 dB to PIA estimates over land from 2A21 to compensate the wetting effect
- Introduction of a new precipitation particle model
  - Introduction of non-spherical rain drop model
  - New DSD model for stratiform rain (Z=267$R^{1.38}$)
  - Changed the assumed vertical profile of specific attenuation k (α in k=αZ_e^{β}) -- 100% solid ice above -20 degree C
- Use of GANAL for 0 deg. C
- Changed the uncertainty of ζ (α and Z_m) in the Hitschfeld-Bordan attenuation correction method
- Expected value to maximum likelihood value in estimating α
- Echo bottom was raised by 1 range bin (250 m)
- Introduction of NUBF correction
- Correcting the smearing of BB in off-nadir beams

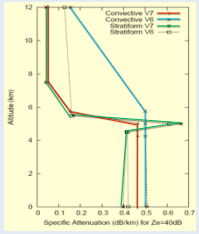
PR Algorithm Flow



Adjustable Parameters

- Calibration
- Particle model
  – DSD parameters
  – particle profile
    - BB model
    - snow model
- Measurement errors
- PIA errors
- Rain profile in surface clutter
- Inhomogeneity

k profiles for Z_e=40 dBZ

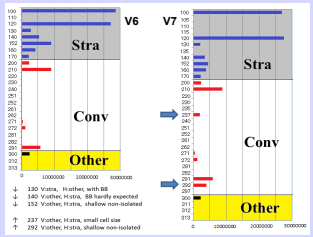


0 degree C height is assumed at 5 km
The lapse rate is assumed to be -6 degrees/km.

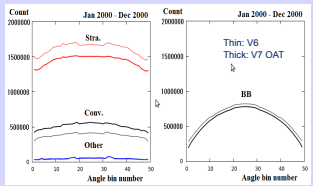
The assumed profile has been changed to the red line in V7 (ITE232). (100% ice above the -20 degree level.) It was the solid line before the change. (100% ice above the -15 degree level.)

Comparisons with V6

Rain Type Classification

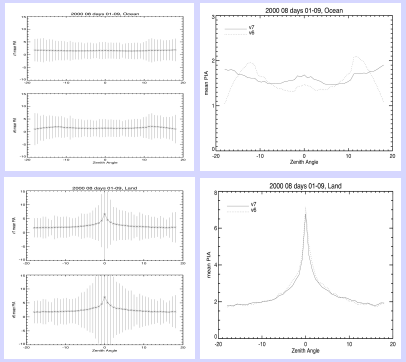


Jan 2000 – Dec 2000



Angle bin dependence of each rain-type count and that of BB count

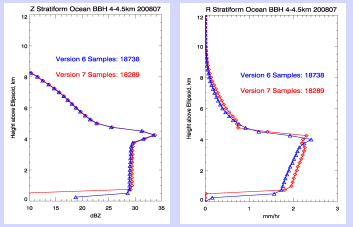
PIA from SRT



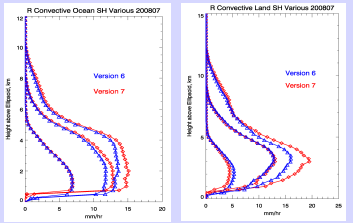
Over Ocean, v7 appears to have better behavior than v6 with respect incidence angle dependence: the difference is probably caused by error in the cross-track fitting used in v6 [Figs on left show mean and 2*std dev of PIA data; only mean values are shown on right-hand plot]

Over Land, v6 and v7 appear to be similar: note that mean is always higher near-nadir because of the higher variance of the NRCS; i.e., mean must be higher than the std deviation for the estimate to be reliable or marginally reliable (only reliable/marginally reliable data are shown in the plot)

Vertical Profiles

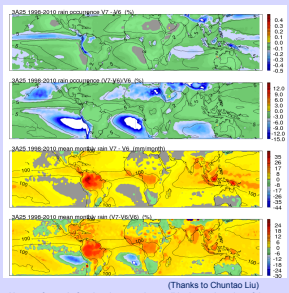


Peak R in BB is reduced in V7. V7 below BB is generally larger R.
Note the effect of raising the bottom bin.



Convective R, various storm heights.
Low SH, V6 comparable to V7, High SH, V7 larger.

3A25 Rain Estimates



(Thanks to Chuntao Liu)

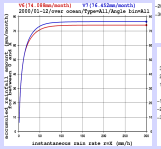
Near surface rain fraction decreased, possibly due to the raise of the range bin number.
Rain amount increased almost everywhere, except US, South Africa, South Australia, and the stratocumulus regions. The biggest increases are over Amazon.

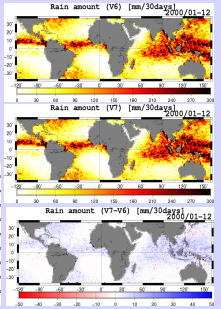
Rain Rate

Over ocean

Rain amount over ocean is larger in V7 than in V6, particularly in Tropics. Not only heavy but weak rain increases

Cumulative distribution function of instantaneous rain rates

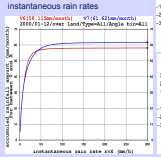


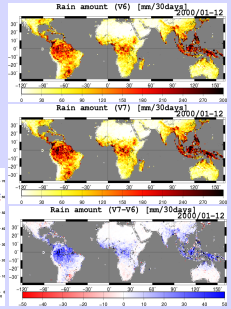


Over land

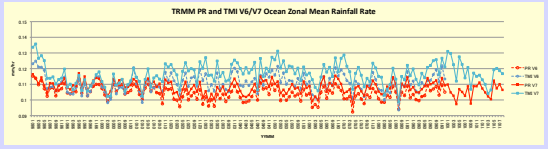
Rain amount over land is larger in V7 than in V6, particularly in Tropics. Contribution of heavy rain (> 50mm/h) increases in V7

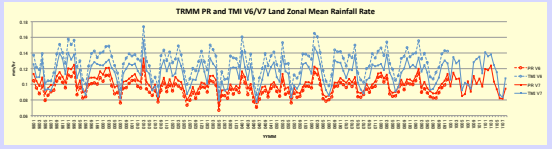
Cumulative distribution function of instantaneous rain rates





Rain Rate Time Series





(There are many other comparisons. E.g., orographic rain (Steve Nesbitt) and instantaneous comparisons with rain gauges (Eyal Amitai))

Summary

- V7 appears to be better than V6
  – V7 removed several problems in V6.
  – Introduction of better models and algorithm
    - More reliable PIA estimates by SRT
    - Better DSD model
    - ML estimation
    - etc.
  – Increased rain estimates at most places
    - better agreement with TMI and surface data

Remaining issues in the frame of V7

- Improvement in the correction of beam mismatch effect after the orbit change
  – A cause of underestimation in the latter half of the scan
  – We did not implement this correction in V7
- Remove exceptional errors that happen in extreme phenomena
- Improvement of the NUBF correction
- Improvement of SRT over land
- Improvement in smearing correction algorithm
- Improvement in the vertical profile model in surface clutter
- Improvement in the solid particle models and their vertical profile model

Possible improvement in a future version

- ε-statistics shows a clear difference between rain over ocean and rain over land.
  – The current algorithm assumes common PSD parameters over ocean and land for each storm type.
  – A positive bias of ε often found over ocean and a negative bias over land suggest that there are more small drops than the assumed PSD over ocean and the opposite over land for convective rain.
  – Possibility of defining regionally dependent PSD models from the knowledge we accumulated in the past.
- Orographic rain.
  – vertical structure of orographic rain may differ substantially from other types of rain.
  – Estimating surface rain from the rain echoes at altitude much higher than the surface involves a large error.
  – Poor performance of SRT in mountainous regions amplifies the issue.
- Non-uniformity of rain distribution within a footprint remains to be a very complex but important issue to be solved in the future.