The GPM GPROF V6 Database

GPM Constellation Status

Christian Kummerow
Dave Randel
Sarah Ringerud
Paula Brown
Ruanyu Zhang

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## The GPM Constellation

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Launch Date</th>
<th>Status</th>
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<tr>
<td>GMI</td>
<td>Feb 2014</td>
<td>Active</td>
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<tr>
<td>AMSR2</td>
<td>May 2012</td>
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<td>SSMI-F15</td>
<td>Dec 1999</td>
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<td>SSMIS-F17</td>
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<td>Jun 2009</td>
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<td>MHS/MetOp-B</td>
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<td>ATMS/NOAA-20</td>
<td>Date</td>
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Also MWRI, TEMPEST-D, and TROPICS & EUMETSAT in the future
The GPM radiometer algorithm

Step 1: Use GPM Satellite to derive set of “Observed” profiles that define an a-priori database of possible rain structures.

Step 2: Compare observed Tb to Database Tb. Select and average matching pairs.

Step 2:

\[ J_i = \exp \left\{ -\frac{1}{2} \left[ \mathbf{tb}^o - \mathbf{tb}(R_i) \right]^T \left( \mathbf{O} + \mathbf{S} \right)^{-1} \left[ \mathbf{tb}^o - \mathbf{tb}(R_i) \right] \right\} \]
Observations
The Bayesian Concept

A-priori information

F L A R M U D X

E M P D N V R P

V T W J E C T S
The Bayesian Concept

Observations

A-priori information

F L A R M U D X
E M P D N V R P
V T W J E C T S
GPROF 2014 Database Divisions

For Operational Algorithm:

*Do not mix different surface types*
*Do not mix different \( T_{2m} \) or TPW*
V5 Current Status

- Largely consistent across sensors
- Seamless transition between sfc types and regimes
- Mechanics are largely solved except for error covariance
- Matching climatology of a-priori
- Regional errors largely from lack of information content
Databases are constructed from GPM V4 “best estimate” of clear and precipitating profiles along the swath of DPR. These profiles are used for GMI and the constellation radiometers to create the “parametric algorithm”.

- In version 4 of DPR and CMB products, the “best estimate” of precipitation was a mix of DPR and CMB.
- Radiative transfer computation through the “best estimate” of hydrometeors did not always produce the “observed” Tb for GMI. Particularly true above 89 GHz (where sounders make most of their measurements).
- For light precipitation (snow over land and drizzle over oceans), the “best estimate was particularly deficient due to limited radar sensitivity.
- When no radar echoes are detected, neither DPR nor CMB retrieve anything.
Selecting the “best estimate”

DPR V4

Mean DPR NS Rainrate [mm/h] (50km, Jun 2014 - Jul 2016)

Mean Q3 Rainrate [mm/h] (50km, Jun 2014 - Jul 2016)

CMB V4

Mean CMB NS Rainrate [mm/h] (50km, Mar 2014 - Jul 2016)

Mean Q3 Rainrate [mm/h] (50km, Mar 2014 - Jul 2016)
If computed $\text{Tb}(19H)_{\text{GMI}} \neq \text{Observed Tb}(19H)_{\text{GMI}}$

Then bias $\Delta_{\text{Tb}} = \text{Tb}(19H)_{\text{Observed,GMI}} - \text{Tb}(19H)_{\text{Computed,GMI}}$

$\text{Tb}(18H)_{\text{database, sensorX}} = \text{Tb}(18H)_{\text{computed, sensorX}} + \Delta$

This is only true if $\Delta$ is small, and channels are similar. Frequencies are pretty close – view angles are more challenging, particularly for sounders.
Snow and Drizzle

✧ For snow covered surfaces, used direct matchups of every constellation satellite with MRMS to create 2 year empirical database over CONUS (T2m and TPW export the database globally)

✧ For oceanic drizzle, used GMI retrieval of CLW, with a threshold on CLW set to agree with CloudSat on the occurrence of precipitation. Excess Cloud Water was converted to Precipitation. Thresholds were defined by T2m and TPW also.
Ocean suite retrieval

\[ \Phi = (x - x_a)^T S_a^{-1} (x - x_a) + [y - f(x, b)]^T S_y^{-1} [y - f(x, b)] \]

How do we get a ‘full’ error covariance matrix?

Using months of ECMWF reanalysis data, CRTM, and two emissivity models (FASTEM6, RSS):

- **Full**
  - Run forward model on full reanalysis at GMI/AMSR2 frequencies

- **Simplified**
  - Run forward model on reanalysis at GMI/AMSR2 frequencies with retrieval’s simplified forward model [16 vs. 37 P levels, etc.]
  - For ‘Simplified’ add white noise to assumed parameters
  - Run ‘Full’ with two emissivity models—variance is proxy for uncertainty

\[ [\text{FM error}] + \text{[emissivity model error]} + \text{[Noise]} = S_y \]

Obs. Error = (Noise) + (Fwd model \( \varepsilon \)) + (Parameter \( \varepsilon \))

From Duncan and Kummerow (2016), Duncan et al. (in review)
Ocean suite retrieval

AMSР2
5/28/2016

Forward model is non-scattering—significant precipitation causes lack of convergence

No explicit RFI screening—retrieval does it by itself

Liquid Water Path [g/m²]

Columnar water vapor [mm]

Wind speed [m/s]

$\chi^2$ (quality of fit)
A-priori database

Combined DPR/GMI Profiles
OE GMI only profiles – non raining ocean only for now
Interpolation to 30 km
Will simplify and codify the a-priori database creation as much as possible. Philosophy is to take GPM Combined output whenever possible. Diverge only when necessary. Aim is to make database creation fully “prescriptive”

Working on retrieval improvements
- Improved error covariance formulation
- Convective/Stratiform separation
- Additional ancillary data
  - Improved Orographic precipitation improvement
  - High latitude drizzle
The Evolution of the CMB Product

V4

V5

V6

Mean Q3 Rainrate [mm/h] (50km, Mar 2014 - Jul 2016)

Mean Q3 Rainrate [mm/h] (50km, Mar 2014 - Jun 2017)

Mean Q3 Rainrate [mm/h] (50km, Apr 2014 - Jun 2017)
MiRS
Microwave Integrated Retrieval System

All-sky retrieval (NOAA)
18 GHz
No CLW over land in CSU sims
CSU RTrans over all including precipitation

183 +/-3 GHz
Surf precip
Sum(CLW) in 60 layers
Emissivity at 18GHz
V6 a-priori database

- DPR is now quite good over land where validation is available.
- Finalizing MIRS input. Will replace with community improvements over all or individual surface types.
- Snow over land continues to be an issue because *DPR has insufficient signal*. Continue to use sfc radars.
- Orographic precipitation continues to be a problem because *DPR has ground clutter issues and radiometers have little scattering signal*.
- High latitude oceanic drizzle continues to be a problem. Efforts underway to solve using GMI and a-priori DSD information from OceanRAIN. IPWG should strongly support that program.