Advancing multi-satellite precipitation retrievals

Chris Kidd

ESSIC-UMD/NASA-GSFC, Code 612.0, Greenbelt, United States (chris.kidd@nasa.gov)

1. Introduction

The Global Precipitation Measurement (GPM) mission Core Observatory, launched in February 2014, heralded a new era in the estimation global precipitation. The Core Observatory, with the GPM Microwave Imager (GMI) and Dual-frequency Precipitation Radar (DPR), acts as a reference for other satellite-based passive microwave sensors that form the GPM constellation. This mission builds upon the success of the Tropical Rainfall Measurement Mission (TRMM); both missions having active and passive microwave instrumentation.

A common precipitation retrieval scheme, the Goddard PROFiling scheme (GPROF) is utilized for the GPM Microwave Imager (GMI) on the GPM core observatory and for the sensors on the GPM international constellation satellites. GPROF is a physically-based Bayesian precipitation retrieval scheme built around databases populated with brightness temperatures linked to profiles of hydrometeors/rainrates; the brightness temperatures or profiles may be modelled or observed. The day-1 GPM version of the GPROF comprised pre-GPM populated databases generated from satellite/surface matched observations. The current version utilizes data from the GMI and DPR permitting the use of satellite-based reference data from which to construct the database.

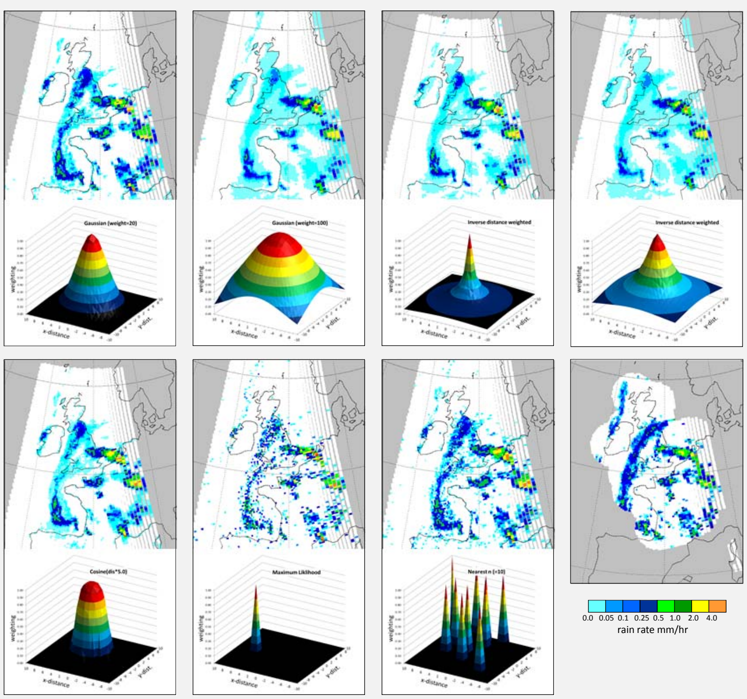
2. The GPROF precipitation retrieval scheme

In its purest form GPROF retrieves precipitation through the inverse modelling of observed brightness temperatures. Since this is a time-consuming process, to improve the computational efficiency, databases are used. GPROF2014 (version 1) used an observation-derived database based upon the TRMM PR (over ocean) and primarily surface radar over land; this has been replaced with a database based upon the GPM Dual-frequency Precipitation Radar, using model-derived brightness temperatures.

The creation, organisation and accessibility of these databases is key since they provide the transfer mechanism that allows the satellite observed brightness temperatures to be associated with suitable atmospheric profiles. Clearly, the information used to generate the databases is critical, although the selection of which information within these databases is just as important. Information available for the databases is split into a number of groups, thus *constraining* the information that is accessed when a retrieval is needed. There are currently 15 different databases based upon surface types; information within each database is then categorised by model-derived total column water vapour (tcwv) and 2 metre air temperature (T2m). A Bayesian scheme is used to generate the precipitation retrieval; all entries within the selected database/tcwv/T2m bin contributing to the final retrieval. However, (i) not all entries within a bin are necessarily appropriate and (ii) zero-rainfall is relatively rare since a contaminated rainfall entry within a nominal zero-intensity tcwv/T2m bin will always produce a non-zero rainrate.

A fundamental question is **"How simple (or complex) does a retrieval scheme have to be to properly represent the state of the precipitation at the surface and vertically though the atmosphere?"**

As an initial study a simple scheme was devised for the retrieval of surface precipitation. This was based upon a single database generated from DPR-MHS coincident matchups at a standard resolution of 15 km captured over an 18 month period providing a total of 9,334,786 entries. The retrieval scheme then interrogated this database using one of a number of simple schemes based upon the Euclidian distance between each profile and the database profile: no other information is used.



3. Case study, 2015-08-13, 21:16Z

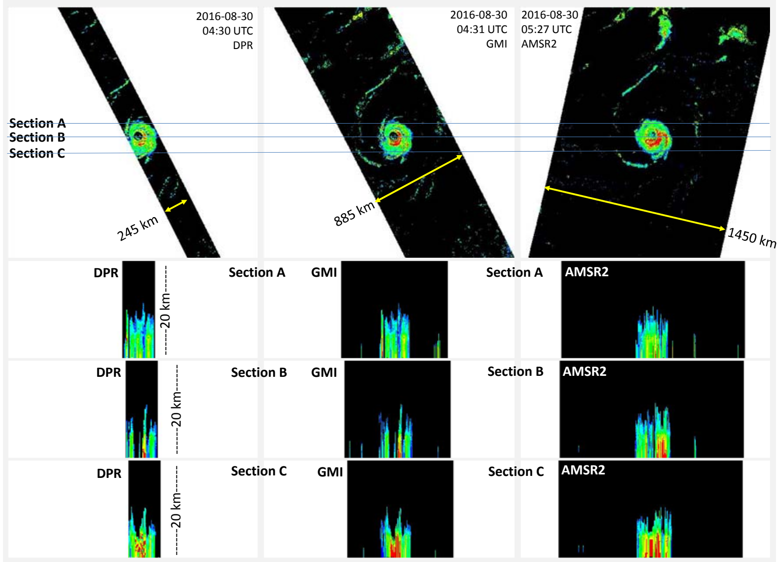
The figures above show precipitation estimates based upon a variety of database sampling regimes *(the 3D weighting functions are included for illustrative purpose; in practice these have the dimensions of n-channels).* The retrieval with the widest spread of contributing profiles results in a greater areal extent of precipitation and more generalised precipitation structure, while the retrieval with the most constrained number of contributing profiles results in a better representation of the precipitation field when compared with the surface radar. More importantly, constraining the retrieval also minimises the background surface effects. Selecting the correct range of profiles to consider is key in retrieval efficiency, the accuracy of the retrieved product, and the suppression of surface effects.

4. 3-Dimensional Precipitation Retrievals

The simple near-surface precipitation retrieval scheme was shown to work well with as few as about 6 closest profiles derived from the database of over 9 million. The next question is: ***can such a scheme successfully provide 3D precipitation retrievals from the passive microwave observations?***

A test case was established using data matchups between the GMI and DPR to generate a small database; the case study centres on Hurricane Gaston 30 August 2016 whilst it was located at 32°N 55°W. The database was populated with coincident GMI-DPR footprints at 5 km resolution (the resolution of the high-frequency GMI channels and that of the DPR) across the full 245 km of the DPR swath. Each entry comprised of the 13 GMI channels and the 176 levels of the DPR vertical profile together with location, (DPR) near surface precipitation, etc. This test database contained 29,768 entries (including non-raining profiles).

The retrieval, using a simple 'nearest Tb-space Euclidian distance match' was tested on two scenarios: first, to retrieve vertical profiles of precipitation from the GMI (at 04:31 UTC) across its full 885 km swath, and second; to retrieve vertical profiles of precipitation from the AMSR2 sensor (at 05:27 UTC) over a much wider 1450 km swath. This study therefore evaluates the ability of information gathered over a narrow-swath to be transferred to retrievals over a wider swath, together with the ability to transfer the information from one sensor (GMI) to another sensor (AMSR2). It should be noted that although the AMSR2 observations have a similar range of observational frequencies/channels and similar spatial resolutions, the number of channels available differ; the AMSR2 only having the lower (10-89GHz) channels. Processing time for these retrievals was trivial, taking just a few seconds.



The results of the two cases are shown above. The top left image shows near surface precipitation as observed by the DPR at 04:30 UTC; the top centre image shows the precipitation retrieval from the GMI overpass at 04:31 UTC; since this is virtually coincident with the DPR overpass the results are more-or-less identical to the DPR retrieval. The top right hand image shows the surface precipitation generated for the AMSR2 overpass at 05:27 UTC. The two overpasses show generally good agreement, with the main structure of the Hurricane visible in both.

Vertical cross-sections for each sensor are shown beneath these surface precipitation images; the cross-sections relate to the northern (A), centre (B) and southern (C) parts of the storm. Agreement between the GMI and DPR is very good, as expected since these form the basis of the database itself; agreement between the DPR (or GMI) and the AMSR2 retrieval is less good, although the broad structure of the precipitation system is still present.

The differences between these estimates can be attributed to a number of factors; first, the association of the information from the DPR to the GMI in the generation of the database and its subsequent retrieval by the GMI across the broader swath. Second, the retrieval of precipitation from the AMSR2 observations – with fewer channels and at a different time. At each stage there is a loss of *fidelity*; the critical issue is to ensure that this loss of fidelity is kept to a minimum.

5. Summary

This study reveals two key issues: (i) a relatively simple scheme can be used to estimate surface precipitation from passive microwave observations (in this case, cross-track observations), and; (ii) similarly, the retrieval of the 3D structure of precipitation can also be simply achieved. For (i) the retrieval scheme used just 63 lines of (Fortran) code (including all declarations, i/o etc) with no ancillary data sets (the basic GPROF code is nearly 3000 lines long, and requires model data, background surface types and snow/ice information). Similarly, the retrieval scheme for (ii) was under 100 lines of Fortran code with no auxiliary data sets.

6. References

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