UPDATE ON THE TRMM MULTI-SATELLITE PRECIPITATION
ANALYSIS AND PROSPECTS FOR GLOBAL ANALYSIS

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Abstract

The structure of the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) algorithm is briefly summarized, together with some current issues that the authors plan to address. In particular, we outline a possible approach to constructing fully global precipitation estimates by developing a scaled cloud volume algorithm that works on satellite sounding retrievals at all latitudes, including polar regions.

DESIGN GOALS

Recognizing that satellites provide the only practical means of estimating precipitation over most parts of the globe, and that the available inventory of high-quality (passive microwave) precipitation-related satellite sensors has been increasing over the last decade, the authors have been developing the TMPA with several design goals: 1) We wish to use as much satellite-based precipitation data as possible. 2) At the same time, we recognize that, although absolute calibration is presently not possible, a stable intercalibration standard is essential. This supports another goal of 3) minimizing changes in the statistical character of the TMPA data record in the face of changes in the sensor inventory. 4) We wish to create a near-real-time product (TRMM product 3B42RT) that is consistent with a research-grade product (currently TRMM Version 6 product 3B42). 5) We wish to create a fine-scale product, consistent with reasonable spatial coverage by the microwave-based estimates, which testing showed to be true for 3-hourly, 0.25°x0.25° lat./long. gridding.

IMPLEMENTATION

The TMPA proceeds in four steps (Huffman et al. 2007). First, the passive microwave sensors are intercalibrated to a “TRMM best” product. The 3B42 research product uses the Haddad et al. (1997a,b) combined TRMM Microwave Imager (TMI) – Precipitation Radar (PR) estimates (TRMM product 2B31). This decision was based on validation against atoll gauge data during the development of Version 6. In contrast, the real-time product uses a real-time version of the Goddard Profiling (GPROF) algorithm (Kummerow et al. 1996) applied to TMI data (TRMM product 2A12RT) because there is currently no real-time 2B31. The intercalibration is carried out with histogram matching for large global regions that are specific to each data source. In the real-time system only, the combined microwave estimates are provided as product 3B40RT.

The second step in the TMPA is to calibrate infrared brightness temperatures (IR T\(_b\)) with the combined microwave estimates. This is done with histogram matching for overlapping 3°x3° squares for roughly 30 days of data to ensure stability. Such matching requires colder clouds to rain more, which is not necessarily true for instantaneous estimates, but yields correct averages for larger scales. There is a fall-back scheme that continues to provide (reduced quality) calibration coefficients in cases where the microwave estimates fail, mostly over snowy/frozen land and sea ice. In the real-time system only, the microwave-calibrated IR estimates are provided as product 3B41RT.

The third step in the TMPA is to combine the microwave and IR estimates. It is implemented as simply using the IR to fill gaps in the microwave for each 3-hour image. Many other combination schemes
distort the aggregate statistics of the precipitation estimates, but this approach admittedly preserves data boundaries. The combination is output in the real-time system as product 3B42RT.

The final step in the TMPA, which is only possible after real time, is to rescale the combination estimates with monthly gauge analyses. Currently, the Global Precipitation Climatology Centre (GPCC) monitoring product (Rudolf 1993) is used through March 2005; thereafter it is the Climate Monitoring and Analysis System (CAMS) product provided by the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC; Xie and Arkin 1996) due to operational timeliness of the latter. For each grid box, all of the combined estimates for the month are summed to create a monthly multi-satellite estimate. The monthly multi-satellite estimates and the gauge analysis are combined with an inverse random error variance weighting to create TRMM product 3B43, then all the individual 3-hourly combined microwave-IR fields are scaled to sum to the gridbox values of 3B43 and output as TRMM product 3B42. This gives the products the large-area bias of the wind-corrected gauge analysis, with minimal dependence on the gauge analysis where gauges are not present.

RESULTS

Global images of the different steps listed above show that different sensor types “see” different radiometric aspects of the same physical scene. In a mid-latitude frontal band, for example, the passive microwave responds to the hydrometeors along the front, while the IR picks up cold clouds ahead of the front. The inferred precipitation is in different geographical locations, even though they are internally consistent. To the extent that the passive microwave estimates have higher fidelity to instantaneous rain rates, we have designed the TMPA to minimize the use of IR estimates. Overall, the TMPA estimates at full resolution compare well with histograms of precipitation rates accumulated from surface radar data. However, scatter plots show very modest skill at full resolution; averaging is necessary to achieve reasonable correlation, as is true for the other high-resolution precipitation products now available.

FUTURE

A number of issues are now being addressed to improve the TMPA. First, additional sensors are being incorporated. The Defence Meteorological Satellite Program (DMSP) F15 Special Sensor/Microwave Imager (SSM/I) was rendered useless for precipitation estimates in August 2006 when the satellite’s RADCAL beacon was activated. Other groups are developing correction schemes that we will be implementing soon to restore the F15 SSM/I’s usefulness. The F16 and later DMSP carry the Special Sensor Microwave Imager and Sounder (SSMIS), which requires new retrieval software; it is forthcoming from the GPROF group. Finally, the recent Microwave Humidity Sounder (MHS) carried on NOAA18 and later and on the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) MetOp-A is being brought on-line. All of these are being included in the real-time system, while they cannot be included in 3B42/3B43 until the next general reprocessing in about 2009.

A second issue is that the difference in microwave calibrator and the availability of the gauge analysis causes systemic biases between the real-time and research versions of the TMPA. The real-time system is being upgraded to include a histogram-matching correction to the research version. The matching is being done with the same overlapping 3°x3° template as for the microwave intercalibration, and uses the previous two calendar months of data for stability.

Third, we discovered that incorporating the NOAA National Environmental Satellite Data and Information Service (NESDIS) operational estimates of precipitation based on the Advanced Microwave Sounding Unit B (AMSU-B; Zhao and Weng, 2002; Weng et al., 2003) caused a negative bias in TMPA estimates over ocean due to the algorithm’s lack of sensitivity to light precipitation. An algorithm change in August 2003 worsened the problem, while a second change in June 2007 seems to have substantially improved the problem. Although NESDIS has reprocessed the AMSU-B, these defects remain in the real-time archive, which is not being reprocessed, as well as in the 3B42/43 archive until the next reprocessing in about 2009.
The current real-time system generates results about nine hours after observation time due to the latency of various input data sets. Some users need a quicker release than this, so the new real-time system will eventually feature a second, earlier computation, accepting that it will contain less passive microwave input data. In our “best-effort” environment, the best plan seems to be an "early real-time" product at 4 hours after observation time, a "final real-time" at 9 hours, and the “research” version (currently Version 6) about 2 weeks after the end of the month.

HIGH LATITUDES

Satellite retrievals of precipitation are more challenging at high latitudes. This arises because the temperature and humidity profiles, surface temperature, and tropopause and melting levels differ from the tropical cases on which most retrievals were developed; because the precipitation is generally light; and because frozen and icy surface types prevent retrievals with window channels that respond to scattering. Note that validation is also challenging because precipitation gauges are sparser, gauge undercatch is more severe, and radar estimates are more difficult in the presence of snow and melting layers.

At this time the best solution appears to involve high-frequency microwave channels, chosen to give weighting functions that peak above the surface and consequently approximately slice the atmospheric signal away from difficult surface issues. However, some approximate alternatives already exist that can provide answers now. In addition, these approaches could fill inter-swath gaps in the high-frequency estimates when they appear, fill holes in them where they falter, and extend the record back to around 1979. One alternative is the Outgoing Longwave Radiation (OLR) Precipitation Index (OPI; Xie and Arkin 1998), which relates deviations in precipitation to deviations in OLR, both with respect to the local climatology. The alternative that we chose is the Susskind et al. (1997) calibrated cloud volume proxy developed for Television Infrared Observations Satellite (TIROS) Operational Vertical Sounder (TOVS) retrievals of temperature and moisture profiles. The authors first adapted the TOVS estimates for use in Version 2 of the Global Precipitation Climatology Project (GPCP) monthly estimates in response to the deficiencies in Version 1 – the high latitudes displayed either data voids or critically low estimates. The success of this work encouraged us to adapt the TOVS estimates for use at high latitudes in the GPCP One-Degree Daily (1DD) product. Validation over the Baltic Sea basin shows good skill in specifying the day-to-day events averaged over that region. Note that recently the TOVS scheme has been applied to Advanced Infrared Sounder (AIRS) data to enable a continued supply of high-latitude estimates in the GPCP Version 2 monthly and 1DD products after the cessation of TOVS observations.

When we turn to instantaneous swath data, it is clear that a better algorithm is needed, since the modifications to the TOVS data in both the monthly and daily GPCP were fairly substantial. Fortunately, the A-Train closely coordinates data from the AIRS, Advanced Microwave Scanning Radiometer for Earth Observations (AMSR-E), and CloudSat radar. AMSR-E provides swaths of state-of-the-art precipitation estimates, while CloudSat radar provides a two-dimensional “curtain” of cloud-sensitive radar data. Together, these provide a strong constraint on the content of the AIRS scaled cloud volume proxy estimates. We have already established that a simple recalibration of the AIRS estimates to AMSR-E estimates is not sufficient. This work is a funded National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) project. We will develop a new AIRS cloud volume proxy scheme, then develop a fully global merger of AMSR-E and AIRS swath data. One important issue will be how to gracefully transition from AMSR-E to AIRS at high latitudes and over snowy/frozen land. Thereafter, we hope to apply the new scheme to Advanced TOVS (ATOVS) and TOVS data to develop an improved long-term record at high latitudes. We recognize that these soundings tend to falter when it’s precipitating.

We also plan to explore using estimates from numerical simulations. To start, numerical model and reanalysis estimates should be included in comparisons with high-latitude surface data. It is likely that combinations of observation- and model-based estimates will provide the best answers.
REFERENCES


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