J1.9 UNCERTAINTY IN FINE-SCALE MPA PRECIPITATION ESTIMATES AND IMPLICATIONS FOR HYDROMETEOROLOGICAL ANALYSIS AND FORECASTING

George J. Huffman[*1,2], Robert F. Adler[1], David T. Bolvin[1,2], Eric J. Nelkin[1,2]

1: NASA/GSFC Laboratory for Atmospheres
2: Science Systems and Applications, Inc.

1. INTRODUCTION

There is a long-standing need for timely, accurate, fine-scale estimates of precipitation for a wide variety of applications around the globe, including characterizing local climatologies; providing input to water-resource, crop-forecast, and flash-flood analyses; and initializing numerical models. In response, the first generation of routine quasi-global precipitation estimates has been developed that are available at sub-daily intervals on sub-1° latitude/longitude grids, sometimes being computed within hours of the observation time. It remains for additional research to demonstrate the overall accuracy of such estimates and demonstrate their suitability for any particular application.

In this paper we consider the Multi-satellite Precipitation Analysis (MPA) system, which has been developed by the authors over the last three years to provide 0.25°x0.25° 3-hourly precipitation estimates for the global latitude belt 50°N-50°S.

2. THE MPA ALGORITHM

The MPA is under active development, so the following description is subject to modification as additional work is carried out and we learn more about the nature of the input datasets. Two implementations of the MPA are being developed in parallel, a real-time version (MPA-RT) that is run about six hours after observation time, and a research-oriented version (Version 6 3B-42) that is run after each calendar month of data is collected. The MPA-RT has been run quasi-operationally since February 2002 at the Tropical Rainfall Measuring Mission (TRMM) Science Data and Information System (TSDIS), located at NASA/Goddard Space Flight Center, Greenbelt, MD. The Version 6 3B-42 is slated to start routine computation at TSDIS when the general reprocessing for Version 6 begins (early 2004 at press time). Figure 1 displays a summary block diagram of the algorithm.

To the extend possible, we emphasize accessing the microwave data being collected by a variety of low-Earth-orbit (LEO) satellites, including the TRMM Microwave Imager (TMI) on TRMM, the Special Sensor Microwave/Sensor (SSM/I) on Defense Satellite Meteorology Program (DMSP), the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) on Aqua, and Advanced Microwave Sounding Unit (AMSU) on the National Oceanic and Atmospheric Administration (NOAA) satellite series. These data have a strong physical connection to the hydrometeors that result in surface precipitation, but each individual satellite provides a very sparse sampling of the time-space occurrence of precipitation. Even taken together, there are significant gaps in the current coverage by microwave estimates.

Referring to Fig. 1, the microwave data are all intercalibrated to a single standard using Probability Matching, then merged to a uniformly gridded set of 3-hourly High-Quality (HQ) estimates. The MPA-RT has taken the TMI as processed by the Goddard Profiling algorithm (GPROF; Kummerow et al. 1996) as the calibration standard, but the newest MPA-RT and Version 6 3B-42 use the TRMMM Precipitation Radar (PR).

We also employ the infrared (IR) data that are being collected by the international constellation of geosynchronous-Earth-orbit (GEO) satellites, as merged by the Climate Prediction Center (CPC) of the National Weather Service/NOAA into half-hourly 8x8-km-equivalent lat./long. grids. The IR brightness temperatures (T_b) are corrected for zenith-angle viewing effects and inter-satellite calibration. A related IR data set from CPC is used in the Version 6 3B-42 before the start of the 8x8-km merged data in early 2001.

Again referring to Fig. 1, histograms of time-space matched HQ rain rates and IR T_b's, each represented on the same 3-hourly 0.25° grid, are accumulated for a month, and then used to create calibration coefficients for IR precipitation rate that vary in space. By design, there is no rain when the T_b is greater than a threshold value that matches the frequency of precipitation in the IR to that of the microwave, and increasingly colder T_b's have increasingly large rain rates (hence the name Variable Rainrate, or VAR).

* *Corresponding author address*: George J. Huffman, NASA/GSFC Code 912, Greenbelt, MD, 20771; e-mail: huffman@agnes.gsfc.nasa.gov

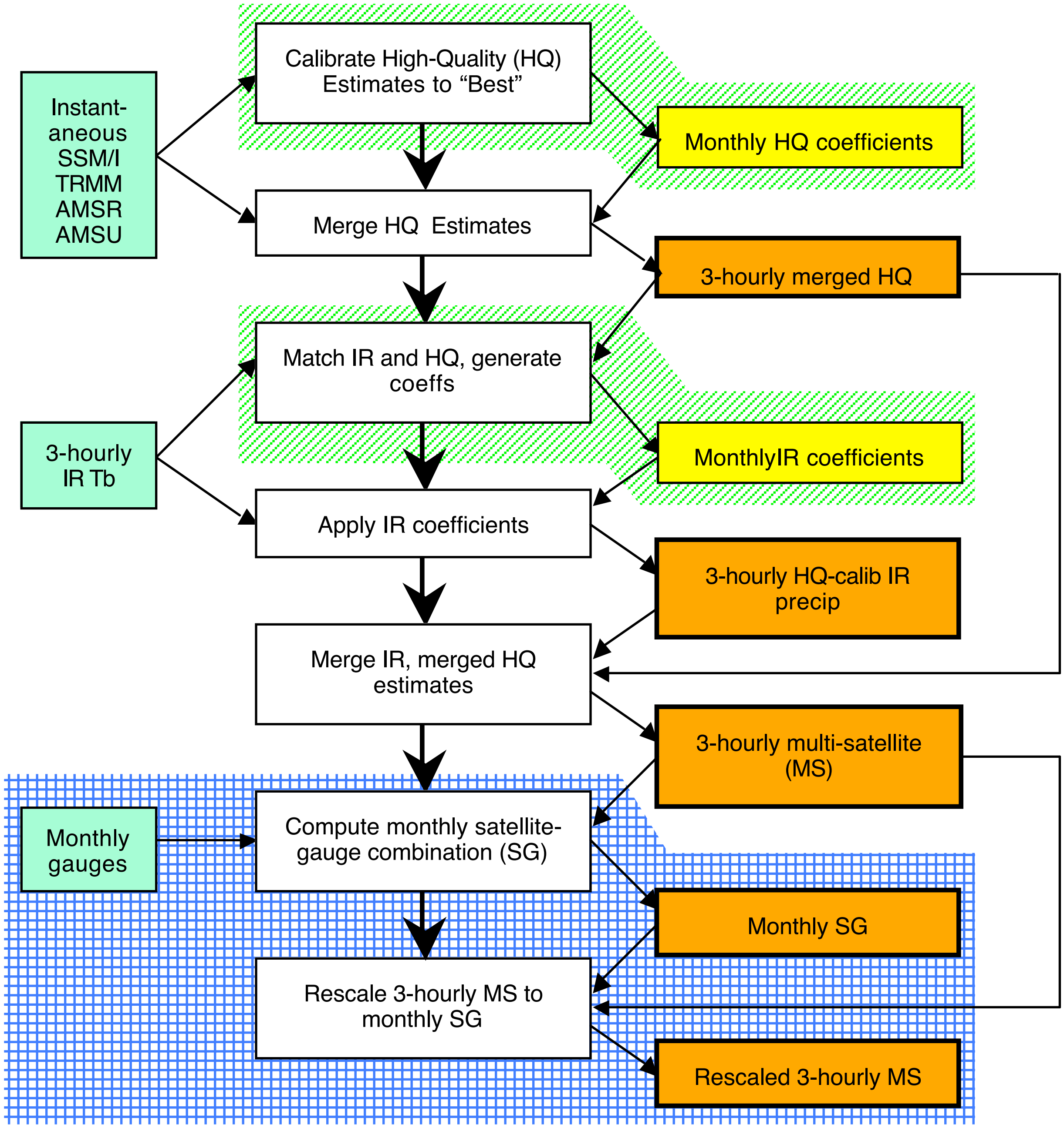

Figure 1 Block diagram for both the real-time and post-real-time 3-hourly algorithms, showing input data (left side), processing (center), output data (right side), data flow (thin arrows) and processing control (thick arrows). The items on the green shading run asynchronously for the real-time algorithm, and the items on the blue shading are only performed for the post-real-time algorithm. "Best" in the top center shaded box has been the GPROF-TMI for the real-time algorithm, but is now shifting to the TRMM PR precipitation estimate for both the real-time and post-real-time algorithms.

The calibration coefficients are then applied to the entire hourly IR data set.

The final output of the MPA is a simple priority merger of the HQ and IR precipitation fields in which the HQ value is taken if available, and the IR estimate is used otherwise. An additional processing step is implemented in the non-real-time version: Each calendar month of data is summed and combined with a monthly gauge analysis, forming the TSDIS 3B-43 product, and then the individual 3-hourly 3B-42 estimates are rescaled to sum to that monthly 3B-43 field.

3. PERSPECTIVES ON QUALITY

The RT-MPA has obvious potential for application to fine-scale hydrometeorological applications, but it is important to understand limitations imposed by uncertainties in the input data and algorithm. Figure 2 demonstrates that the histogram matching indeed causes the IR-based VAR estimate to correctly produce the right distribution of rain rates. On the other hand, there is no guarantee that the HQ and VAR will make estimates that are well-matched gridbox-by-gridbox, and Fig. 3 demonstrates that this is a substantial issue. This lack of quantitative agreement is somewhat puzzling at first because visual inspection of the HQ and VAR maps generally leaves the qualitative impression that the two are closely related.

It is a matter of on-going research to correctly characterize the performance of the various components of the MPA against each other, as well as against surface data. Several factors are clear:

1. The input to the HQ are accumulated over the ±90-min window centered on the nominal 3-hourly observation time. Individual rainstorms last only 30-60 minutes and can be advected across one or more 0.25°x0.25° grid boxes in that length of time. Likewise, the IR input is only taken to the nearest hour, so there can be additional time-of-observation mis-matches.
2. IR T_b's sense cloud-top temperature, and implicitly cloud height. Arkin and Meisner (1987) showed that such information is poorly correlated to precipitation at the fine scales. This is both because the development of cloud heights tends to lag precipitation, and because the morphologies of cloud tops and precipitation areas have some systematic differences.
3. There are a variety of algorithmic issues, particularly including performance in complex terrain and in winter-time that reduce the quality of estimates.

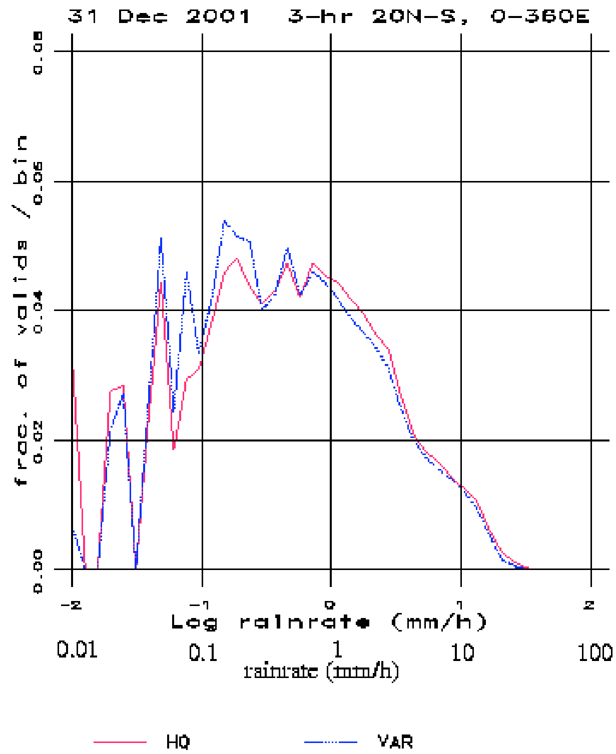

Figure 2 Example of histograms of rainrate (in mm/h) for the HQ (red) and VAR (blue) for the global latitude band 20°N-S for MPA-RT estimates valid 31 December 2001.

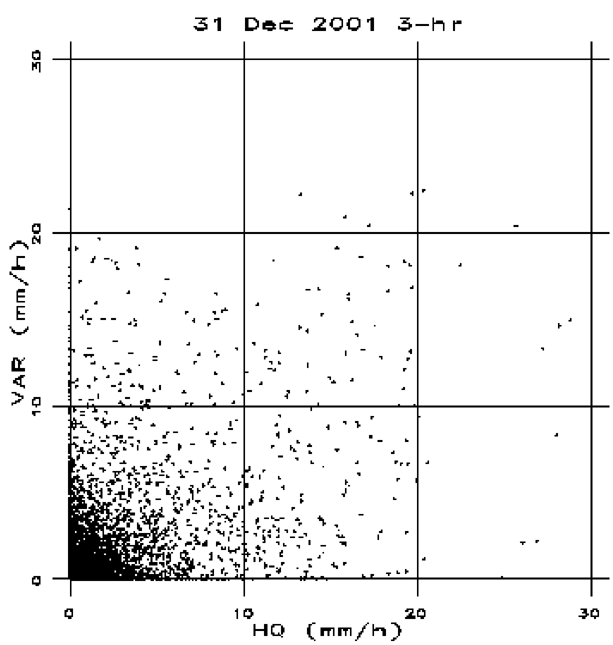

Figure 3 Scattergram of VAR versus HQ rainrates (in mm/h) corresponding to Fig. 2.

Experience shows that time- and/or space-averaging precipitation estimates increases the reliability of the data. For example, Arkin and Meisner (1987) showed that their simple IR-based algorithm was relatively well-correlated to surface-based radar analyses at scales larger than about 1 day and 2.5°x2.5°. However, such averaging is only effective at the random error that an estimate contains, not the bias. Accordingly, it is a matter of on-going research to determine the level of bias implicit in various fine-scale precipitation estimates.

One important initiative in this regard is the routine validation and intercomparison of various satellite-based estimates with gauges at the 0.25°x0.25°, daily scale that was begun for Australia by Dr. E. Ebert (BMRC), and followed for the continental U.S. by J. Janowiak (CPC) and for parts of Europe by Dr. C. Kidd (Univ. of Birmingham, U.K.). As one example, in the first six months of data the correlation coefficient between the MPA-RT and the CPC gauge data set for the continental U.S. has averaged around 0.6, with some days showing values as high as 0.8 or almost down to 0.4.

4. FUTURE DEVELOPMENT

We expect to continue cooperating with these continental fine-scale daily validations, which are evolving into a joint project of the International Precipitation Working Group and the Global Precipitation Climatology Project. It will be a substantial challenge to make use of the many statistics being planned for this project.

As part of introducing the Version 6 3B-42, we are starting to compute a gridbox-by-grixbox estimate of random error for each precipitation field. We believe that a great deal of work will be needed to adequately compute such estimates. In addition, there is a need for estimating the bias error. Finally, the study of precipitation in general needs a succinct statistical description of how fine-scale precipitation estimates perform over the range of scales up to global and monthly.

On the instrumentation side there is a concerted effort to provide complete 3-hourly microwave data. Most of this effort is focused on the National Aeronautics and Space Administration's proposed Global Precipitation Measurement (GPM) Mission. Besides simply increasing the frequency of coverage, it is planned to provide a TRMM-like "core" satellite to calibrate all the passive microwave estimates on an on-going basis. We expect to extend the MPA to fully global coverage using Television-Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS), Advanced Infrared Sounder (AIRS) data, and other sounder channels available from AMSU, among others.

5. DATA SET STATUS

The MPA-RT estimates are available from ftp://aeolus.nascom.nasa.gov or http://precip.gsfc.nasa.gov for February 2002 to the present, while the Version 6 3B-42 will be posted at the GSFC Distributed Active Archive Center (GDAAC; http://lake.nascom.nasa.gov/data/dataset/TRMM/index.html) as it is processed starting in early 2004, for January 1998 to the present.

6. REFERENCES

Arkin, P.A., and B.N. Meisner, 1987: The Relationship Between Large-Scale Convective Rainfall And Cold Cloud Over The Western Hemisphere During 1982-1984. *Mon. Wea. Rev.*, **115**, 51-74.

Kummerow, C., W.S. Olsen, and L. Giglio, 1996: A simplified scheme for obtaining precipitation and vertical hydrometeor profiles from passive microwave sensors. *IEEE Trans. Geosci. Remote Sens.*, **34**, 1213-1232