Merging and Blending Disparate Satellite Data Types for Short-Term QPE

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INTRODUCTION AND BACKGROUND

One of the most important activities of the International Precipitation Working Group (IPWG, see Turk and Bauer, *BAMS*, May 2006) involves the research and development of multi-satellite precipitation algorithms and techniques, and their associated validation across varying spatial and temporal scales, seasons, and latitudes. Unlike single-sensor satellite retrievals of precipitation (i.e, individual overpasses), errors in multi-satellite precipitation analyses are inherently difficult to analyze owing to the intermittent and finite number of passive microwave (PMW) satellite overpasses and the means whereby the the precipitation evolution is accounted for in between satellite overpasses. Currently operational PMW data is obtained from five low Earth-orbiting satellite sensor types:

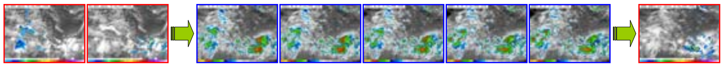
- The Defense Meteorological Satellite Program (DMSP) *Special Sensor Microwave Imagers* (SSMI) have been the workhorse for PMW imagery since 1987 and three (F-13, F-14, F-15) are still operational. In 2005 the follow-on SSMIS instrument was initiated on the F-16 platform, with four more SSMIS instruments to follow.
- The *Tropical Rainfall Measuring Mission* (TRMM) spacecraft was launched in late 1997 and is planned to operate through September 2009. Its low orbit (402 km) samples all local times, repeating every 23 days at the equator. TRMM has a Microwave Imager (TMI) and a companion Precipitation Radar (PR).
- The *Advanced Microwave Scanning Radiometer* for EOS (AMSR-E) was launched onboard the Aqua satellite in May 2002, into a local afternoon equatorial crossing orbit.
- The *WindSat* sensor onboard the Coriolis satellite, originally designed for ocean surface wind vector observations but sensitive to over-ocean precipitation, launched in 2003.
- The *Advanced Microwave Sounding Units* (AMSU), onboard the operational NOAA satellites since 1998, were originally designed for vertical temperature and moisture retrievals but have demonstrated sensitivity to ice-phase precipitation. The AMSU is currently the only across-track scanning instrument of these five sensors. NOAA-17 (local morning descent) and 18 (early afternoon ascent) are currently the operational satellites.

Even with these five sensors on multiple platforms, there exists gaps in overall revisit time, which the multi-satellite techniques aim to fill with additional datasets, such as sequential geostationary data, radar, and gauges. We refer to the multi-satellite techniques as High Resolution Precipitation Products (HRPP). A summary and examples from various HRPP techniques is provided below.

PMW REVISIT INTERVAL

HRPP TRANSPORT TECHNIQUES: Generate precipitation features in between PMW revisits via cloud tracking techniques. Sequential geostationary data is used purely as a transport mechanism.

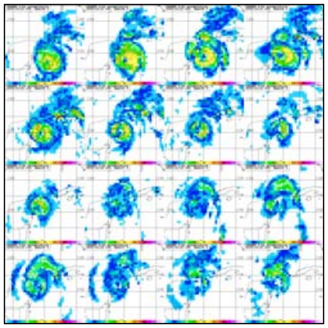
PMW PASS 1 **PMW PASS 2**



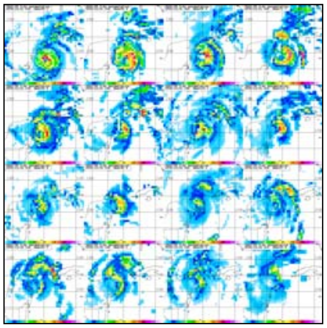
Collection of PMW overpasses within previous 6 hours

HRPP ADJUSTMENT TECHNIQUES: Calibrate precipitation rates in between PMW revisits via T_B-R relations derived from previous PMW overpasses. Sequential geostationary data is calibrated into equivalent rainrates and used to "fill-in" long revisits.

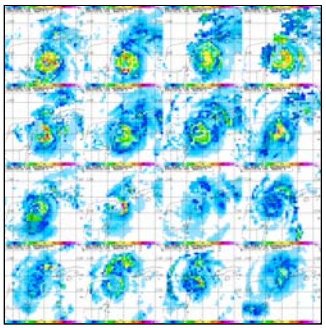
HRPP 1: CMORPH



HRPP 2: 3B42 V6



HRPP 3: NRL-Blend



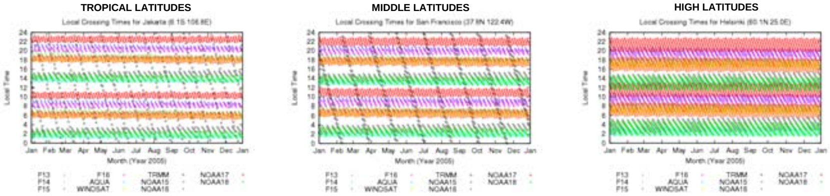
HRPP COMPARISONS: One of the most potent hurricanes in 2005, Hurricane Wilma was at category 4 intensity when it slowly crossed the coast of the Yucatan peninsula, producing intense rainfall during a 42-hour period from 00 UTC on 21 October to 18 UTC on 22 October. An image sequence of 3-hourly accumulations from three HRPP techniques is shown (16 frames), beginning at 00 UTC on 21 October 2005 (upper left) and ending at 21 UTC on 22 October 2005 (lower right). These are CMORPH (Ref. 2), GSFC 3B42-Version 6 (Ref. 1), and the NRL-Blend (Ref. 3). As evidenced in the TRMM imagery, all HRPP's display the nearly stationary eye position in the rainfall structure between 12 UTC on 21 October and 00 UTC on 22 October, after which the eyewall rainfall began to break apart. This sequence shows the differences between various HRPP techniques, in terms of accurate positioning, rain/no-rain screening, and quantification of amounts.

The Pilot Evaluation of High Resolution Precipitation Products (PEHRPP) is an expanded validation activity of the IPWG. The principal goal of PEHRPP is to characterize as clearly as possible the errors in various high resolution precipitation products (HRPP) on many spatial and temporal scales, over varying surfaces and climatic regimes ***(Invited Presentation by Dr. Philip Arkin, 900-930 AM in Session 1 of this workshop)***

REVISIT SEQUENCE OF PASSIVE MICROWAVE BASED SATELLITES

The figures below summarize the local time of observation for an entire year (2005) for three locations, the tropics (Jakarta), mid-latitudes (San Francisco) and the high latitudes (Helsinki), where each color denotes a different PMW satellite platform. Since the satellites do not make an exact integer number of orbits per day, and different sensors have different swath widths, the observation times shift slightly from day to day. As latitude increases, swaths overlap on successive orbits and overall worst-case revisit decreases. Note the gaps near 5 AM and 4 PM local time.

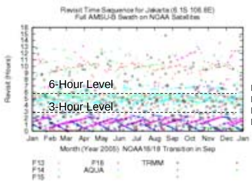
TROPICAL LATITUDES **MIDDLE LATITUDES** **HIGH LATITUDES**



IMPORTANCE OF NOAA SATELLITES IN REDUCING OVERALL REVISIT

Using the data from the Jakarta example above, the figures below summarize the year 2005 revisit time for the case where the four NOAA satellites were removed from the constellation. Note the importance of the wide swath AMSU-B (2100-km) sensors onboard NOAA-16/18 in greatly reducing revisit in tropical latitudes: Without the NOAA satellites, only 16% of the year is the revisit 3-hours or less, but 52% when the NOAA satellites are included.

TROPICAL LATITUDES WITHOUT NOAA SATELLITES

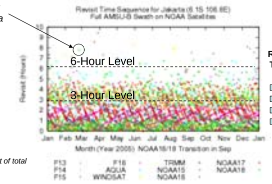


Percent of Year* That Revisit Is Less Than (Hours):
6 (57%)
5 (38%)
4 (21%)
3 (16%)

For example, a green colored point at Y=8 means that a NOAA-18 overflew at this time,and the previous satellite overpass had been 8 hours prior. Note how the longest revisits are often reset by NOAA-18 and Aqua.

**Percent of the entire year, not the percent of total number of points in the figure*

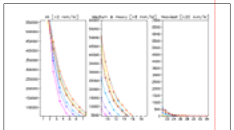
TROPICAL LATITUDES WITH NOAA SATELLITES



Percent of Year* That Revisit Is Less Than (Hours):
6 (97%)
5 (94%)
4 (81%)
3 (52%)

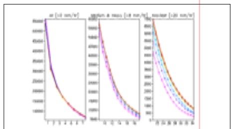
NORMALIZATION AND REFERENCING OF NOAA AMSU SATELLITE ESTIMATES

The AMSU-B precipitation estimates available from the NOAA satellites are based upon use of high-frequency sounding channels (89, 150, and three 183 GHz channels), whereby the rain is associated with clouds capped by a thick enough ice layer; the lack of emission channels inhibits the retrieval from over-ocean warm-based rain clouds. The AMSU instrument scans across-track, with a varying satellite zenith angle, which needs to be taken into account. Several approaches have been investigated which normalize the AMSU retrieved rainfall to a reference sensor such as the TMI, as a function of AMSU scan angle position. To improve light rain retrievals over ocean, the cloud liquid water retrieved from the AMSU-A instrument has also been examined as proxy for light precipitation.



Cumulative histograms of **AMSU-B** derived rain rates (mm/hr), latitude band 20S–20 N, land surfaces, 17 December 2004 – 12 January 2005

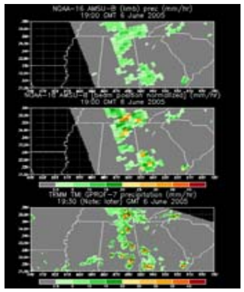
AMSU-B rainfall



Corresponding cumulative histograms of **TRMM TMI** derived 2A-12 rain rates (mm/hr) averaged to mapped AMSU-B beam position coverage

TRMM TMI rainfall

Purple: beam positions 80-85 (limb), Blue:74-79, Light Blue: 68-73 White: 62-67 Yellow:55-61 Orange: 49-54 Red: 43-49 (nadir).



Figures and techniques courtesy of Robert Joyce, NOAA/CPC/RSIS and Daniel Vila, NOAA/NESDIS

AMSU-B rainfall normalized TMI and AMSU-B beam position

REFERENCES

1. Huffman, G.J., R.F. Adler, E.F. Stocker, D.T. Bolvin, and E.J. Nelkin, 2003: Analysis of TRMM 3-Hourly Multi-Satellite Precipitation Estimates Computed in Both Real and Post-Real Time. *12th AMS Conf. on Sat. Meteor. and Ocean.*., 9-13 February, Long Beach, CA, CD-R.
2. Joyce, R. J., J. E. Janowiak, P. A. Arkin, and P. Xie, 2004: CMORPH: A method that produces global precipitation estimates from passive microwave and infrared data at high spatial and temporal resolution.. *J. Hydromet.*, **5**, 487-503.
3. Turk, F.J. and P. Bauer, 2006: The International Precipitation Working Group and Its Role in the *Improvement of Quantitative Precipitation Measurements.* Bull. Amer. Meteor. Soc., **87**, 643-647.

UPCOMING EVENT !!

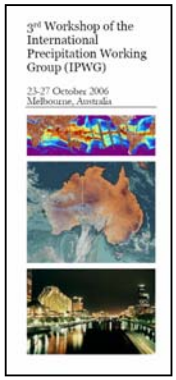
The Third Workshop of the International Precipitation Working Group

23-27 October 2006
Melbourne, Australia

Information brochure is available at the registration desk

For more information, see Beth Ebert or Joe Turk during this workshop, or look online for further information at:

http://www.isac.cnr.it/~ipwg/meetings/melbourne/melbourne2006.html



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http://www.isac.cnr.it/~ipwg http://essic.umd.edu/~msapiano/PEHRPP