5A.7 Gauging Tropical Rainfall Potential With a Blended Satellite Technique

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1. INTRODUCTION

Tropical cyclones undergo most of their development over-water and outside the range of ground-based radar systems. While there have been various satellite-based methods developed to analyze storm intensity, information regarding a storm's rain accumulation and the changes temporally and spatially are important for monitoring flood-producing potential as the system approaches landfall. Fresh water flooding has become a major factor responsible for loss of life and damage as storms inundate low-lying coastal areas experiencing explosive population growth. In addition, recent improvements to several numerical weather prediction (NWP) models now permit the variational assimilation of satellite-derived precipitation observations. While low Earth-orbiting (LEO) satellites with passive microwave sensors (PMW) are capable of analyzing the rainfall associated with these storms, their observations take place at intermittently-spaced intervals depending upon the satellite overpass schedule, and do not capture the full evolution of the rainfall process. We describe a blended satellite technique developed at NRL-Monterey and demonstrate its validation and application to tropical cyclone precipitation nowcasting.

2. NRL BLENDED SATELLITE TECHNIQUE

The NRL blended technique is based upon an adaptive, ongoing analysis of an underlying collection of time and space-intersecting pixels from all operational geostationary-orbiting visible and infrared (VIS/IR) imagers and PMW imagers. Current PMW datasets used include the Advanced Microwave Scanning Radiometer (AMSR-E), the Tropical Rainfall Measuring Mission (TRMM) Microwave Radiometer (TMI) and the Ku-band Precipitation Radar (PR), the Sepcial Sensor Microwave Imager (SSMI) onboard DMSP (Defense Meteorological Satellite Program) F-13/14/15, and the National Oceanic and Atmospheric Administration (NOAA) Advanced Microwave Sounding Unit-B (AMSU-B), onboard NOAA-15/16/17. As new PMW datasets arrive, the PMW-derived rainrate pixels are paired with their time and space-coincident geostationary IR brightness temperatures (T_B) and visible reflectance data, using (currently) a 15-minute maximum allowed time offset. These data are used to dynamically update T_B-R lookup tables spaced every 2-degrees in latitude and longitude. The transfer of this information to the stream of steadily arriving geostationary data is then a relatively simple lookup table procedure, where an inverse-distance weighted average rainrate is computed from the nine nearest-neighbor lookup table-derived rain rates surrounding each IR pixel. 850 hPa wind vectors from the Navy Operational Global Atmospheric Prediction System (NOGAPS) forecast model are analyzed against a 2-minute resolution topographic database, and a correction is applied in regions of likely orographic effects on both the upslope and downslope. The previous 30-minute time history of the 11-µm IR brightness temperatures is analyzed for regions of active cloud top temperature growth or decay, and scaling factors are applied to intensify and lighten the overall rainrate. At 3-hourly time intervals, the instantaneous PMW and IR-derived estimates are backwards time-integrated, producing output products at typical intervals, e.g., 3, 6, 12, 24 hours, etc. Over the accumulations interval, PMW estimates are fully weighted, whereas the IR-based estimates are given a weight that depends upon their time proximity to a PMW observation, and the pixel latitude (PMW revisit is shorter at higher latitudes, so less IR information needs to be blended in). In essence, the IR-based rainfall estimates are only blended in where they are needed in space and time. Near the equator, the time-proximity threshold is longer than it is at higher latitudes, owing to the longer PMW revisit time.

3. VALIDATION AND EXAMPLES

An earlier study by Turk et. al. (2003) validated the NRL blended technique using the dense raingauge network operated by the Korean Meteorological Agency (KMA), which suggested that the blended technique is retaining a certain amount of information regarding the state of the accumulated rainfall even at a 3-hour time scale. While this is encouraging, in the analysis of these data no diurnal separation of the data was retained, so it is not possible to say whether the satellite technique is faithfully capturing the diurnal rainfall trends. This is an import consideration for monitoring tropical cyclones, as the rainfall strength often fluctuates between day and night due to solar heating, and the satellite technique should show good overall skill as well as demonstrating the capability to resolve short-term rainfall fluctuations.

We examine an additional data analysis, which was carried out over northern and southern Florida using data collected from five separate raingauge networks. The rainfall over Florida has a strong diurnal component with an afternoon maximum, modified regionally by the timing of the local seabreeze on the east and west coasts. Figure 1 shows the normalized rain rate diurnal cycles for each of the five networks, and the total overall normalized and actual rain rate cycles for the gauge and NRL blended-satellite estimates. Although the satellite technique is biased low relative to the gauge networks (Turk et. al, 2003), the normalized satellite-derived rain rate appears to track the evolution of the rain rate throughout the day, notably the afternoon maximum near 1500 local time.

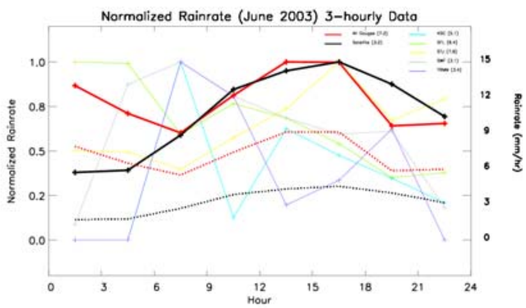

Figure 1. Normalized diurnal rainrate cycles (use left ordinate) over central-south Florida during June-2003 as measured by five raingauge networks and NRL operational blended rainfall algorithm. Raingauge networks consist of: (1) high density NASA/Kennedy Space Center Operations network (KSC - 20 gauges); (2) low density South Florida Water Management District network (SFL - 139 gauges); (3) low density St. Johns River Water Management District network (STJ - 69 gauges); (4) medium density Southwest Florida Water Management District network (SWF - 575 gauges); and (5) high density TRMM Ground Validation network (16 gauges). For normalized rainrate diurnal cycles, diagram shows 3-hourly network averages separately (thin solid colored lines), All-Gauge average (thick solid red line), and Satellite average (thick solid black line). Actual diurnal rainrate cycles (use right ordinate) for All-Gauge and Satellite averages are shown in red and black dash lines, respectively.

4. HURRICANE ISABELLE ACCUMULATIONS

Preliminary rainfall totals from the landfall of Hurricane Isabelle during September 2003 indicated maximums of 6 inches or more in some inland areas, as determined by radar and observed raingauge totals. An example of the evolution of Isabelle's precipitation is depicted in Figure 2., which depicts the 12-day accumulations (in inches) ending at 0045 UTC on 21 September 2003. After an initial phase of rainfall intensification in the eastern Atlantic, the storm greatly intensified in rain fallout during 15-17 September, with over 10 inches accumulated during this time. One caveat is that the precipitation totals offshore of North Carolina represent the sum of rain from the passage of Isabelle and that from an earlier storm during these 12 days. While the blended technique is not capable of picking up the fine scale structure of the over-land precipitation, it did highlight the main precipitation areas, and the maximum of near 6 inches was in accord with observed totals.

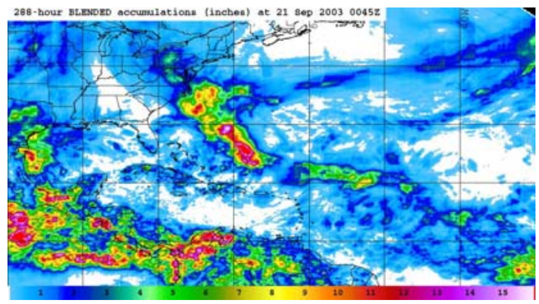

Figure 2. 288-hour (12-day) precipitation totals ending at 0045 UTC on 21 September 2003, as determined by the NRL blended satellite technique. The color scale units are inches. The hurricane rainfall strength greatly increased during 15-17 September, then decreased as it approached landfall (the rainfall accumulation off of the coast of North Carolina is a mixture of that resulting from Isabelle and that from an earlier storm). Landfall maximums are in the 6-inch range, in accord with observed reports.

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4. REFERENCES

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