P4.4 THE COMBINATION OF A PASSIVE MICROWAVE BASED SATELLITE RAINFALL ESTIMATION ALGORITHM WITH AN IR BASED ALGORITHM

Robert Joyce[1)], John E. Janowiak[2)], and Phillip A. Arkin[3], Pingping Xie[2)]

1) RS Information System, Inc.
2) Climate Prediction Center/NCEP/NOAA
3) ESSIC, University of Maryland

1. INTRODUCTION

Recently, rainfall derived from low earth orbiting satellite passive microwave sensor (PMW) retrievals and geostationary satellite window channel InFrared (IR) data have been combined in a unique manner in order to develop the CPC morphing (CMORPH) technique (Joyce et al. 2004) in which the IR is used only as a means to spatially and temporally transport the rainfall features. Half-hourly analyses of CMORPH at a grid resolution of 8 km (at the equator) have been produced operationally since November 22, 2002. Validation of the CMORPH analyses indicate that the method is consistently better than blended IR-PMW rainfall estimation techniques that use IR-derived estimates of rainfall when PMW data are not available (Joyce et al. 2004). Furthermore, CMORPH estimates perform better than mere composites of PMW precipitation analyses and sometimes perform better than radar. This indicates that the propagation and morphing procedures has positive impacts compared to simply compositing all available PMW information.

There are several CMORPH related issues that CPC continues to investigate. The possibility of extending the CMORPH analyses back in time – perhaps back to the early to mid 1990's, is desirable. One of the limiting factors is the availability of sufficiently dense PMW coverage progressing backwards from current time. A shortcoming of the CMORPH method even with the present PMW sensor equipped satellite constellation (at the time of this writing) is that when precipitation forms and dissipates over a region between overpasses by PMW instrumentation it will not be detected. Other situations include when IR derived PMW rainfall propagation vectors used in CMORPH are not correct or when the morphing of both the forward/backward in time propagated PMW rainfall does not match the actual building and decaying processes of the actual rainfall complexes. A method is presented in which rainfall derived from a geostationary satellite IR-based PMW/IR combined sensor type algorithm called IR frequency (IRFREQ) is used to supplement the PMW-based CMORPH estimates for these situations to create the CMORPH and IR precipitation estimation (CMORPH-IR) algorithm.

2. DATA

Instantaneous passive microwave combined (MWCOMB) rainfall estimates from TRMM TMI, DMSP SSMI, and NOAA AMSU-B instruments are mapped to a half hourly, 8-km grid (Joyce et al. 2004) to be used as both input and validation (withheld versions only) of the CMORPH and IRFREQ algorithms. Operational half hourly, global (60N – 60S), 8 km (at the equator) NCEP/CPC CMORPH rainfall estimates (Joyce et. al, 2004) are used in daily validations. The operational version of CMORPH ingests all available MWCOMB analyses as input. A timestamp attached to each operational estimate determines the temporal distance of the rainfall information used from the nearest past/future PMW scan to develop the estimate, in half hourly increments from the half hourly period the PMW scan occurred.

For skill/error evaluation purposes, a parallel version of CMORPH is also produced in the same manner as the operational version, however, 25% of the half hourly MWCOMB input rainfall analyses are withheld (in a 4 day cyclical manner) from processing. The MWCOMB that is set aside is used later as validation of the withheld input CMORPH algorithm. Due to less instantaneous PMW rainfall used as input the half hourly timestamp attached to each withheld input CMORPH estimate is generally larger on average than timestamps from operational version estimates.

Half hourly, 8-km operational IR-based IRFREQ rainfall estimates are produced at CPC by frequency matching 8-km averaged geostationary satellite window channel IR brightness temperatures with 8-km (MWCOMB) starting with heaviest rain rates and coldest temperatures similar to the manner employed by Turk et al. (2003). A nine hour period, centered on current processing half hour is used to determine regional and surface dependent frequency matched statistics required for attaching a rainfall estimate to each cold IR temperature. In addition, for skill/error evaluation purposes, a parallel version of IRFREQ is produced basically in the same manner as the operational version, however, the exact same 25% of MWCOMB analyses set aside in producing the withheld input CMORPH are also set aside when developing the frequency statistics used for assigning rain rates. An extended (11-h to 12-h) period is used to determine the match-up statistics used in the withheld input IRFREQ in order to account for the amount of input MWCOMB set aside.

The withheld input versions of CMORPH and IRFREQ are kept at half hourly, however, averaged up to 0.25 degrees latitude and longitude for global validation against withheld MWCOMB rainfall. The operational CMORPH and IRFREQ versions (no input MWCOMB withheld) as well as the CMORPH-IR are averaged up to daily 0.25 degree latitude and longitude resolution for validation over the United States.

The daily CMORPH, IRFREQ, and CMORPH-IR estimates are validated using high-quality rain gauge data and radar data over the U.S. The United States rain gauge information that was used in this validation exercise is the Climate Prediction Center Realtime Daily Gauge Analysis (Higgins et al. 2000), which is composed of over 7000 stations. The "Stage II" hourly radar (Klazura and Imy, 1993) composites over the U.S. are also used as validation. For the validation results that follow, all data sets were gridded to a common 0.25 degree lat/lon daily grid.

3. METHODOLOGY

From the timestamp attached to each half hourly CMORPH estimate (both withheld and operational versions), a measure of skill and error as a function of temporal distance to nearest PMW pass can be determined if adequate validation is available. MWCOMB previously excluded as input is now used to determine the deterioration of the CMORPH rainfall estimation as a function of timestamp in the withheld input CMORPH version. There are several reasons for doing this. A global product, PMW-based CMORPH encompasses regions conducive of smoothly propagating stratiform rainfall complexes, seemingly relatively immune to infrequent PMW sampling, as well as dynamic convective regions often exhibiting little continuity in the development, decay, and propagation of rainfall complexes, cases obviously susceptible to sampling. On the other hand the frequent geostationary satellite IR sampling in IR-based IRFREQ yields relative algorithm strength for times far from PMW scan, especially in convective regions, however, a relatively poorer estimate at times when PMW sampling is already available and/or regions where cold cloud does not correlate well with rainfall. It would also lead to reason that both season and surface type would be a factor in algorithm type as well. Thus it would be impractical to use a local validation source in order to determine the relative strengths and weaknesses of IRFREQ with CMORPH algorithms.

Correlation of CMORPH (Fig. 1, top panel) against unused MWCOMB, determined as a function of temporal distance to nearest past or future PMW scan from which information is used to develop the CMORPH estimate, is shown for timestamp 2 (1 hour from PMW scan) for the 23 June – 26 July 2004 period. The number of pairs used in the correlations (Fig. 1, bottom panel) is determined by the number of occasions in which half hourly, 0.25 latitude/longitude CMORPH, IRFREQ, and withheld MWCOMB all exist, and at least one estimate in the group is 1 mm/hr or

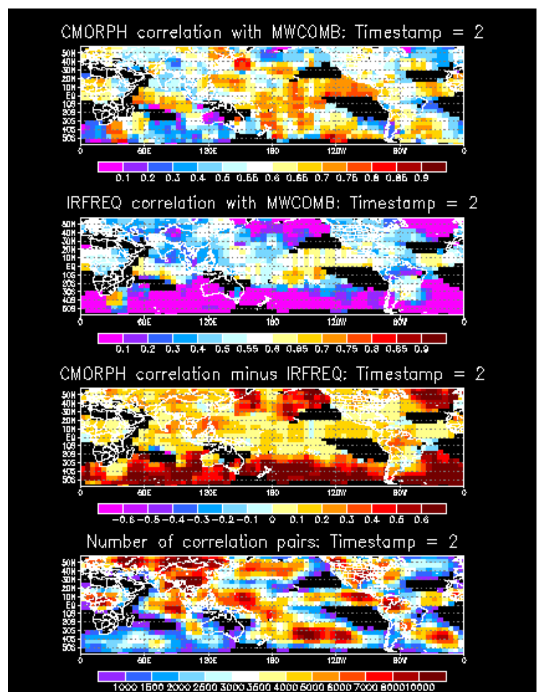

Fig. 1. Correlation of half hourly 0.25 degree latitude/longitude, withheld MWCOMB input CMORPH against withheld MWCOMB (top) 23 June – 26 July 2004. Nearest past/future PMW information used in CMORPH = 60 minutes away. Same, however, withheld MWCOMB input IRFREQ against withheld MWCOMB (2nd from top). CMORPH correlation minus IRFREQ (3rd from top). Number of pairs for both correlations (bottom).

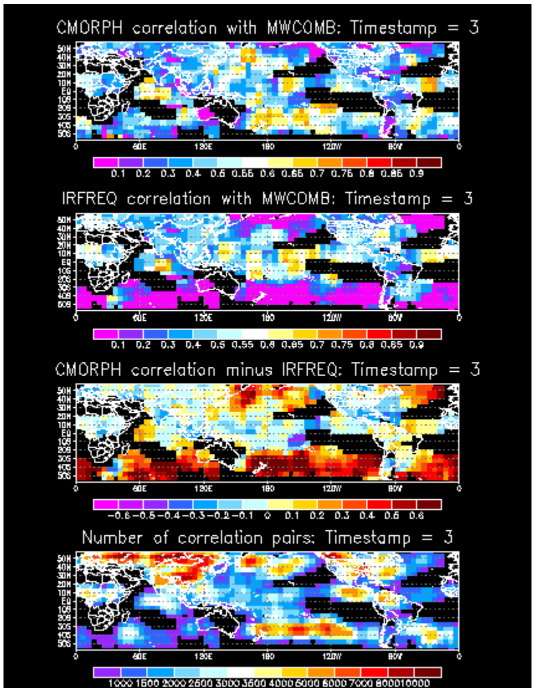

Figure 2. Correlation of half hourly 0.25 degree latitude/longitude, withheld MWCOMB input CMORPH against withheld MWCOMB (top). Nearest past/future PMW information used in CMORPH = 90 minutes away. Same, however withheld MWCOMB input IRFREQ against withheld MWCOMB (2nd from top). CMORPH correlation minus IRFREQ (3rd from top). Number of pairs for both correlations (bottom).

higher. Calculations are performed at 5 degree latitude/longitude intervals using overlapping 15 degree latitude/longitude regions, separated by surface type. As expected the highest values are over oceans where rainfall complexes exhibit a relatively more stable nature. Correlation of withheld input IRFREQ at timestamp 2 against the same withheld MWCOMB (Fig. 1, 2nd panel from top) reveals a quite different depiction in which the highest values are restricted to the Tropics. Also the land-sea contrast found in the CMORPH validation does not appear to exist. The validation correlation difference (Fig. 1, 3rd panel from top) reveals the CMORPH algorithm globally dominates the IRFREQ algorithm at one hour from PMW scan but much more so over ocean and mid-latitudes. Patterns remain the same, however correlations of withheld input CMORPH (Fig. 2, top panel) at timestamp 3 (nearest information used 1.5 hours from PMW pass) for the same period illustrates quite drop-off from the timestamp 2 validations. In a contrasting manner, correlations of withheld input IRFREQ at timestamp 3 (Fig. 2, 2nd from top panel) is roughly the same as the timestamp 2 IRFREQ correlations. Comparing the two algorithms at 1.5-h from PMW pass (Fig. 2, 3rd panel from top), CMORPH validation correlation only dominates IRFREQ over mid-latitude oceanic regions. The IRFREQ validates better than CMORPH in many Tropical and Northern Hemisphere land locations.

Since it appears that the relative validation skill of CMORPH compared with IRFREQ is highly dependent upon both time from PMW scan and earth location, the cumulative frequency of operational (all input MWCOMB ingested) CMORPH at each timestamp is investigated. The addition of TRMM TMI sampling is evident in elevating the percentage of CMORPH of timestamp 0 (Fig. 3, top panel) in the ~30–38 degrees latitude band (both hemispheres) to 20-25 percent. A timestamp 0 CMORPH estimate means that a PMW scan occurred over that region during the half hour period and the estimate is really the instantaneous PMW rainfall (MWCOMB) with no propagation. The cumulative CMORPH at timestamp 1 frequency (Fig. 3, middle panel) includes all the CMORPH that is ½ hour before and after an

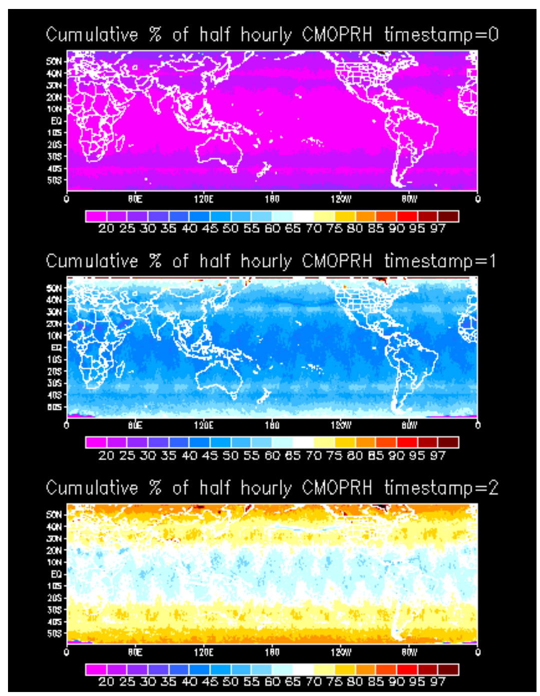

Figure 3. Cumulative percentage of operational CMORPH as a function of temporal distance from nearest PMW information used. Timestamp = 0 (top), Timestamp = 1 (middle), Timestamp = 2 (bottom).

instantaneous PMW CMORPH estimate. Even with TRMM TMI, the dearth of PMW sampling in the Tropics is evident when viewing the cumulative CMORPH frequency at timestamp 2 (Fig. 3, bottom panel), with many regions less than 65 percent, however, near or above 75 percent for most of the mid-latitudes. A quick measure to optimally combine the two algorithms in order to create CMORPH-IR, replaces CMORPH estimates with IRFREQ at timestamps when IRFREQ out-validates CMORPH. Corresponding with the relative algorithm validation difference plot for timestamp 3 (Fig. 2, 3rd panel from top), IRFREQ replaces CMORPH estimates in many regions of the world including most all of the United States for timestamps older than 2. The cumulative CMORPH frequency at time stamp 2 (Fig. 3, bottom panel) is mostly 70-75 percent over the United States, however, only 60-70 percent over the Tropics, yielding an approximation of what percentage of CMORPH-IR is CMORPH/IRFREQ for many of these

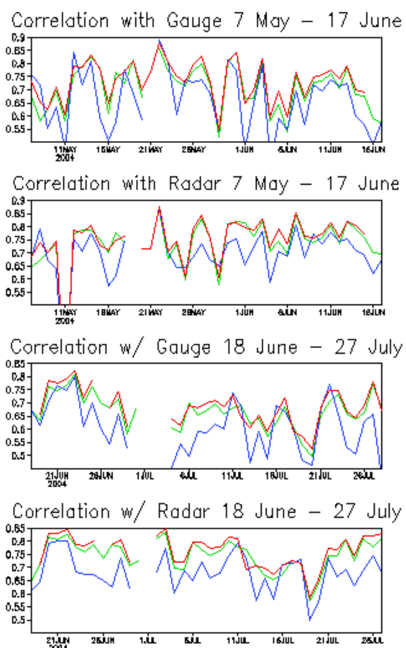

Figure 4. Correlation of daily 0.25 degree latitude/longitude CMORPH (green), IRFREQ (blue), CMORPH-IR (red) against gauge rainfall analyses over the United states (top) for the 7 May – 17 June 2004 period. Same, however using Stage II radar radar for validation (2nd from top). Same, however using gauge for validation over 18 June – 27 July 2004 period (3rd from top). Same, however, using Stage II radar rainfall for validation (bottom).

regions during the North Hemisphere early summer season. At each timestamp, spatial interpolation of withheld input CMORPH and IRFREQ validation correlation difference maps in poorly sampled regions is performed to determine the choice of either CMORPH or IRFREQ estimates within CMORPH-IR algorithm at the half hourly level.

4. VALIDATION

Correlation validation of daily 0.25 degree latitude/longitude operational (all input MWCOMB ingested) CMORPH, IRFREQ, and CMORPH-IR against United States gauge rainfall analyses is presented for the 7 May – 18 June (Fig. 4, top panel) and 19 June – 27 July 2004 periods (Fig. 4, 3rd from top panel). In a similar manner, Stage II radar rainfall is used for daily 0.25 degree latitude/longitude correlation validation for the same 7 May – 18 June (Fig. 4, 2nd from top panel) and 19 June – 27 July 2004 periods (Fig. 4, bottom panel). Generally CMORPH validates better than IRFREQ against both gauge and radar rainfall for the entire period. To a lesser degree, CMORPH-IR out-validates CMORPH throughout the period, also against both measures. It is interesting to note that IRFREQ validated relatively poorly compared to CMORPH on the few days CMORPH does as well or even slightly better than CMORPH-IR. However, from these validations, it is apparent that IRFREQ generally improves CMORPH during this late spring and early summer period over the United States. On a side note, the similarity of the performance of the gauge analyses and that of the radar as validation against all three satellite rainfall estimation algorithms gives confidence to the use of these two sources as validation tools. Overall, the radar does appear to correlate slightly higher with the satellite rainfall, however, not to a large degree.

5. SUMMARY

PMW-based CMORPH rainfall estimation out-validates IRFREQ against instantaneous PMW rainfall over most of the globe, especially over oceans and mid-latitudes, for all half hourly estimation periods that are within one hour (timestamp <=2) of a half hourly period containing a PMW scan. For increasing temporal distance from PMW scan, IRFREQ generally validates better than CMORPH, especially over Tropics and over land.

Even with TRMM TMI, PMW sampling in CMORPH is most sparse in the Tropics, with only 60-70 percent of CMORPH estimates derived with a timestamp of 2 or less, however, mostly more than 75 percent for mid-latitude locations including the United States.

Daily CMORPH-IR rainfall estimation generally out-validates CMORPH over the United States for late spring and early summer against gauge and radar analyses, especially when IR-based IRFREQ also validates well. For CMORPH-IR, there might be a better way to combine CMORPH and IRFREQ estimates at the half hourly 0.25 degree latitude/longitude resolution, for regions and timestamps when their relative validation correlations are similar.

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