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RE-CALIBRATING THE OPERATIONAL HYDRO-ESTIMATOR SATELLITE PRECIPITATION ALGORITHM

Robert J. Kuligowski*
NOAA/NESDIS/ORA, Camp Springs, MD

J. Clay Davenport
IMSG Corporation, Lanham, MD

Roderick A. Scofield
NOAA/NESDIS/ORA, Camp Springs, MD

1. BACKGROUND AND MOTIVATION

Routine operational production of satellite precipitation estimates at the National Environmental Satellite, Data, and Information Service (NESDIS) began in the late 1970's with the Interactive Flash Flood Analyzer (IFFA; Scofield 1987). The IFFA is a largely manual technique which uses information on cloud-top characteristics from infrared (IR) satellite imagery to derive spatial fields of instantaneous precipitation rate. In addition to the IR data, the IFFA also uses information from numerical weather model forecasts to adjust for subcloud evaporation of hydrometeors and for environments where very cold cloud tops are not favored but heavy rain can still fall from relatively warm clouds. The significant amount of manual labor required by the IFFA led to an automated version called the Auto-Estimator (A-E; Vicente et al. 1998) which made satellite precipitation estimates available every 30 minutes throughout the CONUS. Improvements to the A-E (Scofield 2001; Vicente et al. 2002) were followed by a new version called the Hydro-Estimator (H-E), which replaced the A-E as NESDIS' operational automated algorithm in the fall of 2002.

The H-E was developed to replace the A-E because the A-E tended to incorrectly assign nonzero rainfall rates to non-raining cirrus anvils due to their low temperature in IR imagery. Not only did this exaggerate the spatial extent of the heavy rainfall, but it also resulted in excessively high amounts of rainfall in multi-hourly totals. Efforts were made to fix this problem by using radar data to identify non-raining pixels, but this approach was not ideal since the primary strength of satellite-based estimates of precipitation is in providing data in regions where radar data are unavailable or inadequate. The H-E addresses this deficiency by considering not only the temperature of a pixel, but also its value relative to those of surrounding pixels in determining whether or not rainfall is occurring and in assigning a rainfall rate. Pixels that are colder than their surroundings are presumed to be associated with convective updrafts and thus with rainfall, while pixels that are as warm or warmer than the mean temperature of the surrounding clouds are assumed to no longer possess active updrafts and thus to not be producing rainfall.

Although the H-E represented a significant improvement over the A-E at discriminating raining from non-raining clouds without the aid of radar, users have expressed significant concerns with other aspects of the performance of the H-E. In particular, the H-E underestimates precipitation from clouds with relatively warm tops (temperatures greater than -58 °C, according to the operational definition used by the Satellite Analysis Branch (SAB) of NESDIS). These deficiencies are of special importance to SAB forecasters, who must produce manual IFFA estimates in those instance when the H-E does not accurately depict a heavy precipitation event, and thus lose valuable lead time in alerting field forecasters to potential flash flood situations.

This and other concerns are rooted at least in part in the calibration of the relationship between IR brightness temperature and rainfall rate that is used in the H-E. The original rain rate curve (shown in Vicente et al. 1998) was derived using only precipitation from convective cores, and only from a very limited sample of data from one particular region of the US. Furthermore, many of the adjustments that are made to the rainfall rates have not been systematically calibrated using observed data. Consequently, a systematic re-calibration of the H-E is needed to assure optimal accuracy of the product for operational use.

2. METHODOLOGY

2.1 Data Sets

To ensure a calibration that was applicable to a wider variety of precipitation regimes, data for the entire CONUS were archived for the period 23 August-1 October 2003. It was found that this time period did not contain a representative sample of cold-top mesoscale convective systems (MCS's), so two additional time periods (13-15 May and 24-26 May 2003) were also included. The data set consisted of the following fields:

- GOES-12 (East) channel 4 (10.7-μm) brightness temperatures (hereafter $T_{10.7}$);
- Eta model total column precipitable water (PW);
- Eta model layer-averaged relative humidity (RH; from σ=1.0 to σ=0.7);
- Convective equilibrium level (EL) temperature (computed from Eta model temperature and water vapor mixing ratio fields);
- Stage III 1-hour radar/rain gauge fields;
- 15-minute radar reflectivity fields.

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* *Corresponding author address*: Dr. Robert J. Kuligowski, E/RA2 RM 712 WWBG, 5200 Auth Rd., Camp Springs, MD 20746-4304; e-mail: Bob.Kuligowski@noaa.gov.

2.2 Radar Rain Rate Bias Adjustment

In Vicente et al. (1998), calibration was performed against radar reflectivity data that had been converted to rainfall rates using the standard Z-R relationship. However, numerous studies have shown the presence of various biases in radar reflectivity data, including range effects and bright band. In response, radar data over the CONUS are bias-adjusted using rain gauges in a method described by Fulton et al. (1998) to produce a 4-km bias-corrected field known as Stage III.

However, the Stage III fields are hourly totals, making them difficult to compare to individual GOES images. To enable a more appropriate match, 15-minute radar reflectivity fields were used to disaggregate the Stage III data from 1-hour to 15-minute resolution, under the assumption that there was at least some time-independence at short time scales of the factors contributing to radar bias.

2.3 Incremental Re-Calibration Strategy

The re-calibration is being performed on an incremental basis by starting with the H-E in its simplest form and then modifying the calibration as adjustments are added. The approximate steps are as follows:

1. Re-calibrate the rain/no rain separation. This is done by determining the probability of precipitation (PoP) as a function of both $T_{10.7}$ and the relationship of $T_{10.7}$ of the pixel of interest to the average value for the cloud pixels within a certain radius. This relationship is described by Z, which is simply the normalization parameter $Z=(T_{10.7}-\mu)/\sigma$, where μ is the mean value of $T_{10.7}$ and σ is its standard deviation within the specified radius. The optimal radius and value of Z are determined in the calibration.
2. Re-calibrate the unadjusted rainfall rate as a function of both $T_{10.7}$ and Z, using scatterplots of the data to determine the optimal functional form.
3. Re-calibrate the PW and RH corrections by plotting the errors in the rain rates from step (2) as a function of PW and RH separately to determine the optimal functional form for these corrections.
4. Re-calibrate the EL correction by plotting the errors in the rain rates from step (3) as a function of EL temperature to determine with optimal functional form for this correction.

3. RESULTS

Computer network issues at ORA have resulted in substantial delays in the work; consequently, the results of the calibration are not available as of the time when this preprint was submitted.

4. FUTURE WORK

In addition to the work mentioned here, a re-calibration of the orographic correction of H-E precipitation is required. The present version of the correction uses 850-hPa Eta model wind fields and digital terrain to compute the vertical component of wind resulting from the interaction between the atmospheric wind field and the terrain. This vertical wind component then forms the basis for enhancement (in updrafts) or reduction (in downdrafts) of precipitation rates. However, calibration of this parameter is made difficult by the lack of high-resolution (in both time *and* space) precipitation data in mountainous regions. The best approach is still under investigation, but it may utilize the PRISM data set described in Daly et al. (1994), even though this data set focuses on longer time periods than desired.

In addition, SAB forecasters have indicated that the H-E significantly underestimates rainfall rates during the early stages of convection. It is suspected that this is because at such times there may be strong updrafts and heavy precipitation, but the clouds have not yet had time to build to their full height. In response to this, efforts will be made to produce and calibrate an adjustment that accounts for changes in $T_{10.7}$ following the cloud motions.

5. REFERENCES

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