J4.2 FROM SATELLITE QUANTITATIVE PRECIPITATION ESTIMATES (QPE) TO NOWCASTS FOR EXTREME PRECIPITATION EVENTS

Roderick A. Scofield* and Robert J. Kuligowski
Office of Research and Applications, NOAA/NESDIS, Camp Springs, MD

Clay Davenport
IM Systems Group, Kensington, MD

1. INTRODUCTION

The Satellite Analysis Branch (SAB) of the National Environmental Satellite, Data, and Information Service (NESDIS) provides satellite-derived Geostationary Operational Environmental Satellite (GOES) quantitative precipitation estimates (QPE's) for heavy rain or snow (including lake-effect snow) over the contiguous U.S. and Puerto Rico. SAB's efforts concentrate primarily on locations where there is a potential for or occurrence of flash floods or heavy precipitation. The estimates are sent via the Advanced Weather Interactive Processing System (AWIPS) as part of the satellite-derived precipitation message (SPENES). The SPENES message also contains manually produced guidance on satellite analysis, trends, and short range forecasts/nowcasts (Spayd and Scofield 1984). SAB's home page (http://www.ssd.noaa.gov) contains graphics products of these estimates. Heavy rainfall estimates from the Automatic Hydro-Estimator (H-E) have replaced many of the estimates computed interactively on the Interactive Flash Flood Analyzer (IFFA). An advantage of the H-E is its ability to vastly improve the spatial and temporal coverage of satellite precipitation estimates while improving timeliness. The H-E should be on AWIPS by the time of this conference.

A natural extension of the H-E is an H-E Nowcaster. Successful application of an H-E Nowcaster has the potential of increasing the lead time for some types of flash floods. However, this is not an easy task since one of the greatest challenges of an operational meteorologist is the short-term prediction of the direction and speed of movement of Mesoscale Convective Systems (MCS). Propagation is the controlling influence on the movement of MCS's. At this time, the mechanisms of storm propagation are minimally understood. Any 3-h nowcast algorithm must take into account propagation characteristics of MCS's.

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* *Corresponding author address*: Roderick A. Scofield, E/RA2, RM 601, WWBG, 5200 Auth Rd., Camp Springs, MD 20746-4304; e-mail: Roderick.Scofield@noaa.gov.

2. SATELLITE NOWCAST METHODOLOGIES

In the spirit of NCAR's (National Center for Atmospheric Research) radar-driven Auto-Nowcast system (Mueller et al. 2000), an initial attempt at developing a satellite-driven H-E Nowcaster is presented. A difference between the Auto and H-E Nowcaster is that the former predicts 0-3 h convective initiation while the H-E predicts 0-3 h movement/propagation of existing Meso-Beta Cores (MBC's) of heavy rainfall. MBC's are defined (Merritt and Fritsch 1984) as the coldest cloud-top clusters (as determined from the GOES 10.7-µm digital data) embedded within the MCS's; MBC's have spatial scales of 10-100 km and time scales of 1-10 h. As a note, satellite-derived MBC's may be relatively conservative features compared to the rapidly-changing rainfall cores detected in the radar, and thus may be easier to track and more reliably extrapolated in the 0-3 h time frame.

Satellite nowcast methodologies have taken two avenues of development. One approach considers synoptic scale wind fields and their influence on MBC propagation on the mesoscale. The other uses the 15-30 min movements of MBC's on the storm scale. Both are briefly illustrated in schematics (Figs. 1 and 2) and described below.

2.1 Synoptic-Mesoscale (Outside-In) Method

The first approach is a Synoptic-Mesoscale (Outside-In) methodology where the movement of a satellite-derived MBC is inferred from the mean cloud layer wind and propagation of the storm. To be more specific, Corfidi et al. (1996), Moore et al. (1993) and others have shown that MBC movement is equal to the mean wind plus the vector of the storm propagation. Diagnosing the proper mode of propagation is extremely important: forward propagation is associated with downshear development (new cells develop to the east of the parent MCS), while regeneration or back-building propagation involves upshear developments (new cells develop to the west of the parent MCS). As shown in Fig. 1, the movement of the MBC, given by ($\mathbf{V}_{MBC}$) is equal to the sum of the vectors of the mean cloud layer wind ($\mathbf{V}_M$) and the storm propagation vector ($-\mathbf{V}_{850}$). V_M is best calculated as $[\mathbf{V}_{850} + \mathbf{V}_{700} + \mathbf{V}_{500} + \mathbf{V}_{300}]/4$, while the propagation vector, ($-\mathbf{V}_{850}$) is the opposite of the low level jet (assumed to be at 850 hPa). In the case of forward propagating MCS, the propagation vector is less than the mean cloud layer wind, thus producing an easterly component in the movement of the MBC. For back building MCS, the propagation vector is greater than the mean cloud layer wind that in turn generates a westerly component for the MBC. The above critical wind data can be obtained from soundings, model analysis or short range forecast data, and satellite derived winds. As a cautionary note for back-building MCS, Meso-Gamma developing Towers (MGT) to the west of the parent MCS will control how far west the MCS will propagate. H-E rainfall estimates are computed for the MBC and as shown in Fig. 1 will be extrapolated in hourly increments either toward the east (for forward propagation) or toward the west (back building). Recently, Corfidi (2002) proposed to revise the calculation for forward propagating/downshear events. For these cases, the MBC movement is best represented by the sum of the $\mathbf{V}_{MBC}$ (as computed above) and the mean cloud layer wind ($\mathbf{V}_M$); thus the revised $\mathbf{V}_{MBC} = \mathbf{V}_{MBC}$ (original technique) + $\mathbf{V}_M$ (cold pool motion).

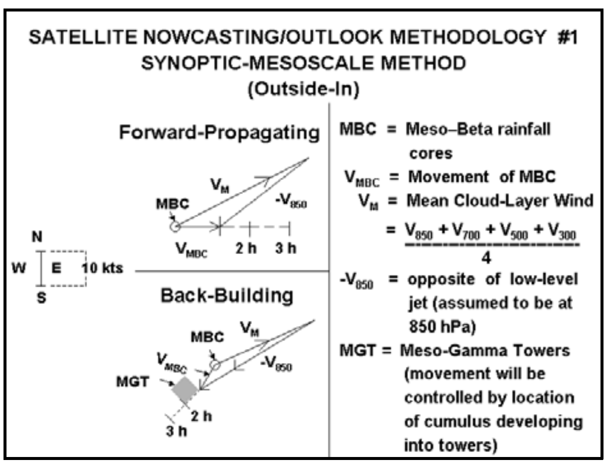

Figure 1. Schematic of the Synoptic-Mesoscale (Outside-In) method.

2.2 Storm-Mesoscale (Inside-Out) Method

The second approach is a Storm-Mesoscale (Inside-Out) methodology where the speed and direction of the MBC are calculated from two consecutive satellite images; preferably, the time between images should be 30 min or less. In the above calculation, a pattern correlation is used to determine cloud motions, from which a motion vector is assigned to every pixel in the image. The pattern correlation involves isolating the coldest 25% of the pixels within a 50 pixel radius; in most cases this region will contain the MBC. Each pixel that initially had rainfall (as computed by the H-E) is then advected along the motion vector for 3 h (as shown in Fig. 2), and rainfall is accumulated over the affected pixels. Note that at this time, the rain rates are assumed to be constant during the advection process.

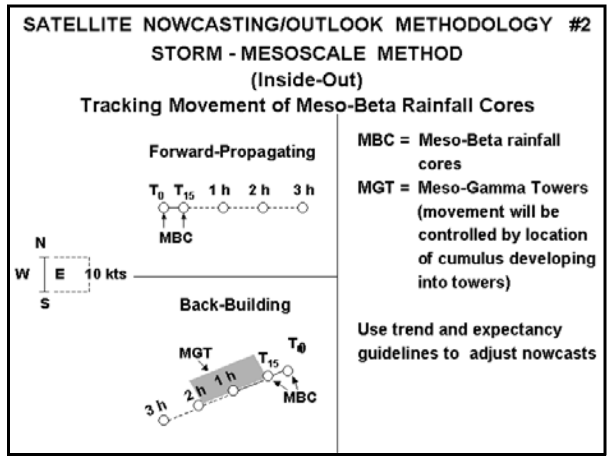

Figure 2. Schematic of the Storm-Mesoscale (Inside-Out) method.

A next step is to include regenerative convective systems (e.g. back building, quasi-stationary, forward-moving-meso beta systems--Corfidi et al. 1996, Chappell 1986, Shi and Scofield 1987, Juying and Scofield 1989) where the growth and movement of individual clusters must be considered in the computation process. Trend and expectancy guidelines (shown in Tables 1, 2 and 3--Spayd and Scofield 1984 and Scofield et al. 2000) will be used to anticipate the evolution of the convective systems for the next 3 h and to adjust the extrapolated rainfall. As with the Outside-In method, for back-building situations meso-gamma towers to the west of the parent MCS will control its westward propagation.

Examples of satellite QPE's and future nowcasts are on the NESDIS Flash Flood Home Page (http://orbit35i.nesdis.noaa.gov/arad/ht/ff).

3. SUMMARY AND CONCLUSIONS

The conceptual models presented in Figs. 1 and 2 are some what linear and straightforward, based on vector analysis and extrapolation. Eventually, trends of the MBC will be incorporated, which will further increase the lead time for some types of flash

Trend and Expectancy Guidelines

Adjust amounts UPWARD if:

- The trend of the last 3 half-hourly estimates is upward
- The speed of the coldest tops is decreasing or if the tops are becoming quasi-stationary or building upwind
- New convection is developing upwind of the coldest tops
- Cluster/line mergers or intersections with a low-level boundary are expected
- Warm, moist low-level inflow becomes increasingly perpendicular to the direction of movement of the coldest tops (increasing surface moisture convergence)
- Hourly surface data show increasing dewpoint or increasing instability in the low-level inflow

Table 1. Conditions for upward adjustments to the H-E Nowcaster rainfall forecasts.

Trend and Expectancy Guidelines

Adjust amounts DOWNWARD if:

- The trend of the last 3 half-hourly estimates is downward
- The speed of the coldest tops increasing
- The time of day is becoming unfavorable
- The system is moving into a different topographic region that is less moist and more stable
- The warm, moist, low-level inflow points in the same direction as, and becomes increasingly parallel to the direction of movement of the coldest tops
- Hourly surface data show decreasing dewpoint or increasing stability in the low-level inflow

Table 2. Conditions for downward adjustments to HE-Nowcaster rainfallforecasts.

Trend and Expectancy Guidelines

No adjustments if:

- The trend of the last 3 half-hourly estimates is nearly constant
- The speed of the coldest tops is nearly constant, but not quasi-stationary
- No mergers or intersections with boundaries are expected
- The time of day is still favorable
- The system remains in the same topographic region
- The direction of the warm, moist, low-level inflow maintains its orientation with the direction of movement of the coldest tops
- Hourly surface data show no change in dewpoint or stability of low-level inflow

Table 3. Conditions for no adjustments to H-E Nowcaster rainfall forecasts.

flood events. Also, an ability to diagnose and track MBC's should help address several issues concerning the H-E. These include an inability for the present H-E to quantify cell mergers and rain burst factors (extremely heavy bursts of rain in a short period of time), and to pinpoint the heavy cores of rainfall occurring in moderate to strong vertical wind shear environments.

Both methods will be tested, first within ORA and secondly with SAB. Additionally, selected Weather Service Offices (WSO's) will be involved in the test and evaluation before any implementation into operation. Hopefully, the strengths of both methodologies can be combined into a single algorithm before field testing at the WSO. Even though the methods presented are automatic and objective, they are still not very robust and need value-added, interactive adjustments using the intuition, experiences and non-linear resolving capabilities of field forecasters. For example, Scofield (1999) and Juying and Scofield (1989) have identified satellite, surface and upper air features associated with forward and backward propagating MCS's and regenerating MCS's; forecasters can use these features to adjust these automatic satellite nowcast methodologies.

Another step in the H-E Nowcast development will be to incorporate trend and expectancy guidelines as documented in Spayd and Scofield, (1984) and Scofield et al. (2000). Trends and guidelines will not only use the GOES infrared (IR) and visible (VIS) imagery and various Polar Orbiting Environmental Satellite (POES) microwave data but also utilize 6.7 μm GOES Water Vapor imagery, GOES derived products and Sounder data, SSM/I (Special Sensor Microwave Imager) data, the NOAA 15/16 AMSU (Advanced Microwave Sounding Unit), and TRMM (Tropical Rainfall Measuring Mission) data. Weather Service Radar-1988 Doppler (WSR-88D) data will assist in the diagnostics of storm evolution and be used as a boundary detector to help determine where MCS's will propagate. As the H-E Nowcaster evolves, VISIT (Virtual Institute for Satellite Integration Training) training will take place (as will be done soon with the H-E) to discuss strengths, weaknesses and applications with operational forecasters. One of the strengths of the H-E Nowcaster is to complement the WSR-88D, especially when the radar presents hard-to-interpret propagation patterns, or is unavailable due to maintenance or range issue. In the future, the H-E Nowcaster will evolve into a more general methodology to handle the 0-3 h nowcasting of convective initiation.

4. ACKNOWLEDGMENTS

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