THE USE OF SATELLITE IMAGERY FOR ANALYZING SOME TYPES OF SYNOPTIC SCALE PRECIPITATION EVENTS

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ABSTRACT

There are various types of data available for measuring the areal accumulation of precipitation. Conventional data types include rain gauge measurements and radar estimates. However, satellite imagery may be used to supplement areal rainfall analysis. The Applications Group of the National Environmental Satellite Service (NESS) has developed a scheme for estimating convective rainfall using enhanced Infrared (EIR) and high resolution visible imagery as input. The potential of using satellite imagery for estimating heavy rain in convective systems is discussed in a NOAA/NESS Technical Memorandum 86 authored by Scofield/Oliver (1977a). Suggested changes to the rainfall estimation scheme are discussed by Scofield/Oliver (1977b). A simplified form of this precipitation estimation (decision tree) scheme was tested on a synoptic scale rainfall event that had deep embedded convective elements. These deep embedded convective systems are important in that they can produce substantial amounts of rainfall.

1. INTRODUCTION

October 9, 1976, was a day of much concern in the Buffalo, New York WSFO as heavy rain developed over southern portions of New York State. This rain followed two days of moderate rain that had thoroughly saturated the ground. The problems for the forecaster at the WSFO were twofold: (1) how much rain has fallen? and (2) how much longer will the significant rain continue? Rain gauge measurements, radar data, and satellite imagery are used to help solve these problems.

This paper concentrates on the time period between 1200 GMT to 1800 GMT, 9 October 1976. This was a period during which heavy rains fell in portions of New York State and Pennsylvania. Some generally lighter rain did occur in those same areas during the following six-hour period: 1800 GMT - 0000 GMT.

2. SYNOPTIC SITUATION

The 1200 GMT surface analysis (Figure 1) indicated that a deep surface low was located over central Virginia with a stationary front analyzed northward into New England. Continuous rain of varying intensities was observed from South Carolina northward into New England. The main feature in the 500 mb height/vorticity analysis (Figure 2) was a center of maximum vorticity located over northeast Tennessee with a maximum vorticity lobe extending northeastward into south central New York State. Over portions of West Virginia, Pennsylvania and New York State, the 500 mb contours and the maximum vorticity lobe were nearly perpendicular indicating the presence of strong positive vorticity advection. Moderate to heavy rain was observed near this vorticity lobe in Pennsylvania and New York State. The 300 mb height and isotach analysis in Figure 3 shows a 100-knot jet max analyzed from western North Carolina northward to extreme western New York State. Most of the heavy rain was occurring on the anticyclonic shear side of the 300 mb jet.

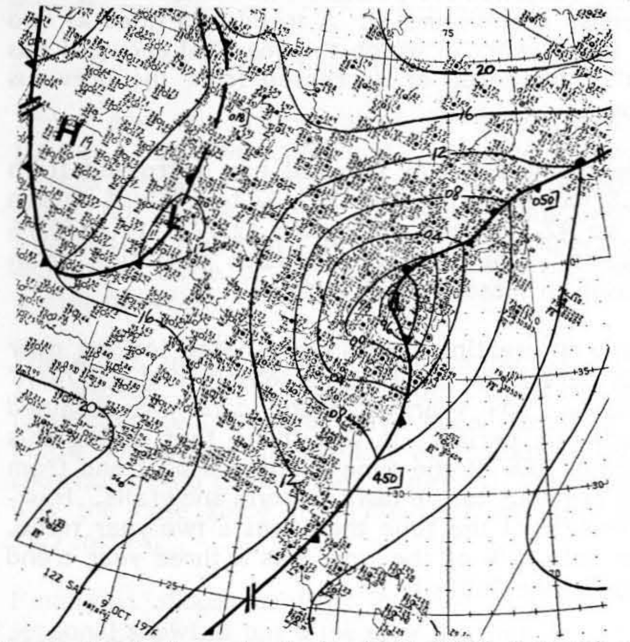

Figure 1. Surface Analysis, 1200 GMT, 9 October 1976.

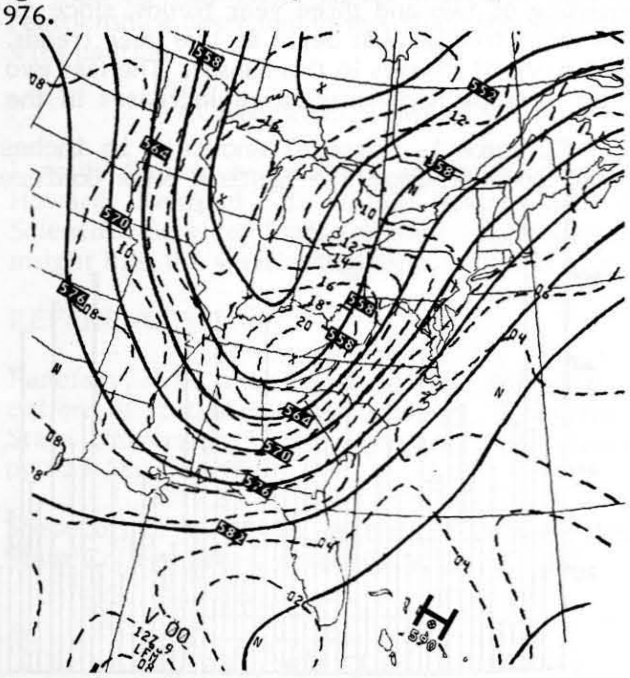

Figure 2. 500 mb Analysis and Vorticity Field, 1200 GMT, 9 October 1976.

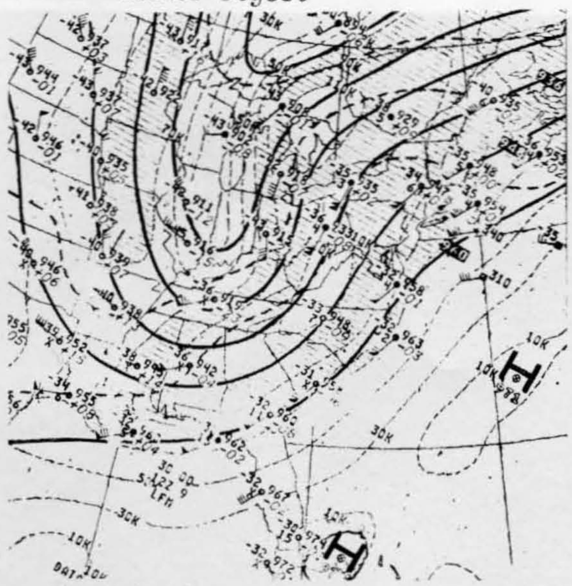

Figure 3. 300 mb Analysis 1200 GMT, 9 October 1976.

3. SATELLITE OBSERVATIONS

Satellite pictures for 1200 GMT, 1300 GMT, 1330 GMT, 1400 GMT and 1800 GMT are shown in Figures 4-8, respectively. These pictures show the sequence of events as they appear in the enhanced IR (Mb curve) imagery; Figure 6 is a 1-km visible view of the weather situation at 1330 GMT. The Mb enhancement curve contours the cold convective cloud tops to show their temperatures (or heights). The warm portion of the imagery is displayed using a nearly linear relationship between temperature and picture brightness up to the edge temperature of Cb anvils (about -32°C). Below this temperature, contours using various shades of gray show the temperature of the anvil ranging from medium gray (-32 to -41°C) at the warm end to white (below -80°C) at the cold end.

The 1200 GMT IR picture in Figure 4 shows a synoptic scale, comma-shaped disturbance over the middle Atlantic states. The comma's head near (C) has high cloud tops embedded in it as revealed by the black and repeat gray level enhancements. These high tops suggest that deep convective cloud elements are embedded in the comma head's synoptic scale cloud pattern. The back edge of the comma's tail (T) in Figure 4 corresponds closely to the position of the surface front. This comma tail is composed of thunderstorms that appear as individual oval and triangular shaped patterns with very cold (high) tops. In Figure 4, various enhanced cloud lines with embedded cold tops such as the one at L-L' appear to be connected to the comma head. These convective cloud lines are often associated with heavy precipitation, especially where they merge into the comma head at M. Houze and Hobbs, et al. (1976) have recognized that rainfall in extra-tropical cyclones tends to be concen-

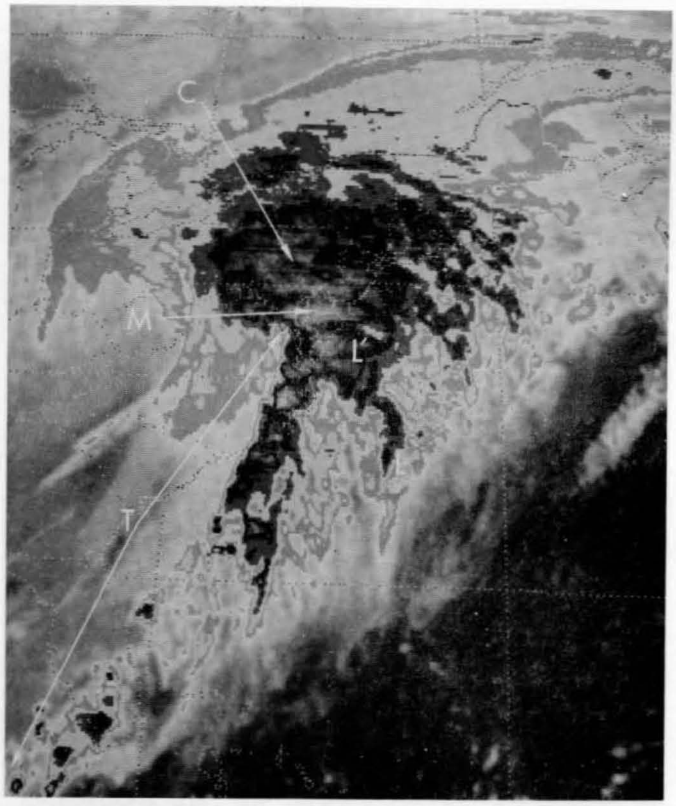

Figure 4. Enhanced IR Imagery (Mb Curve), 1200 GMT, 9 October 1976.

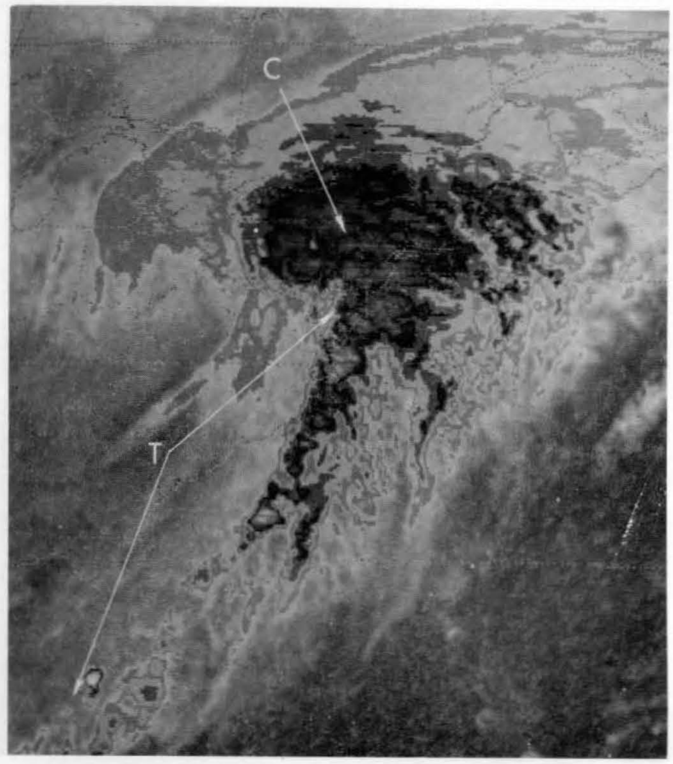

Figure 5. Enhanced IR Imagery (Mb Curve), 1300 GMT, 9 October 1976.

trated along convective lines or rain bands. Cloud bands embedded within the synoptic scale cyclone cloud canopy are often observed in the satellite pictures. The IR pictures at 1400 and 1800 GMT

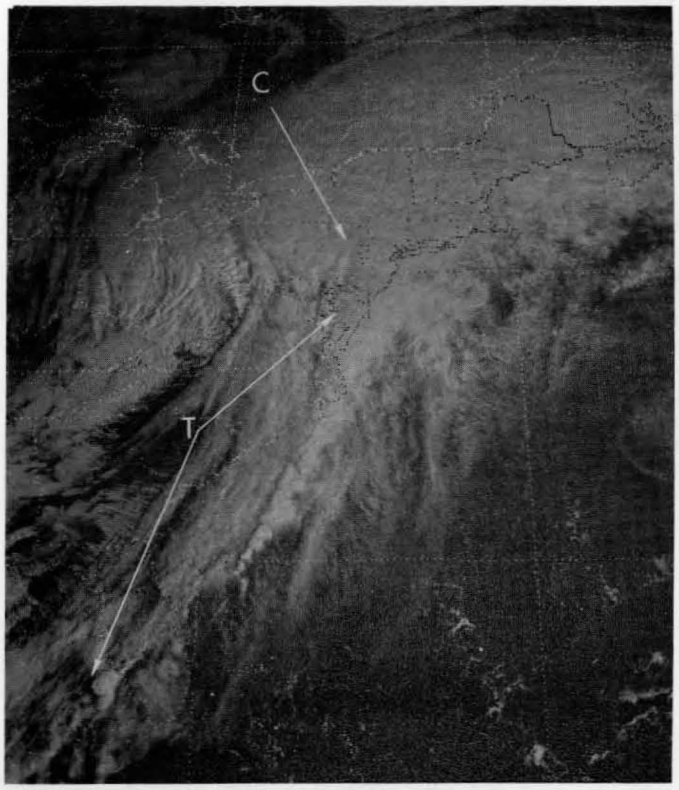

Figure 6. Two-Km Visible Imagery, 1330 GMT, 9 October 1976.

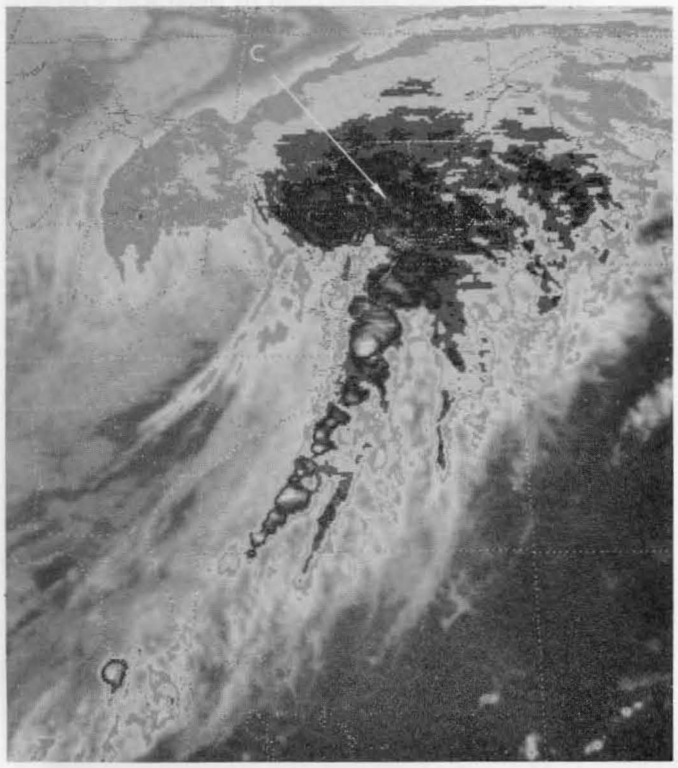

Figure 7. Enhanced IR Imagery (Mb Curve), 1400 GMT, 9 October 1976.

(Figures 7 and 8) show the comma shape disturbance moving northeast and the cloud top associated with the comma head (C) decreasing in height (becoming warmer); by 1800 GMT, the tops in the comma head at C are substantially lower

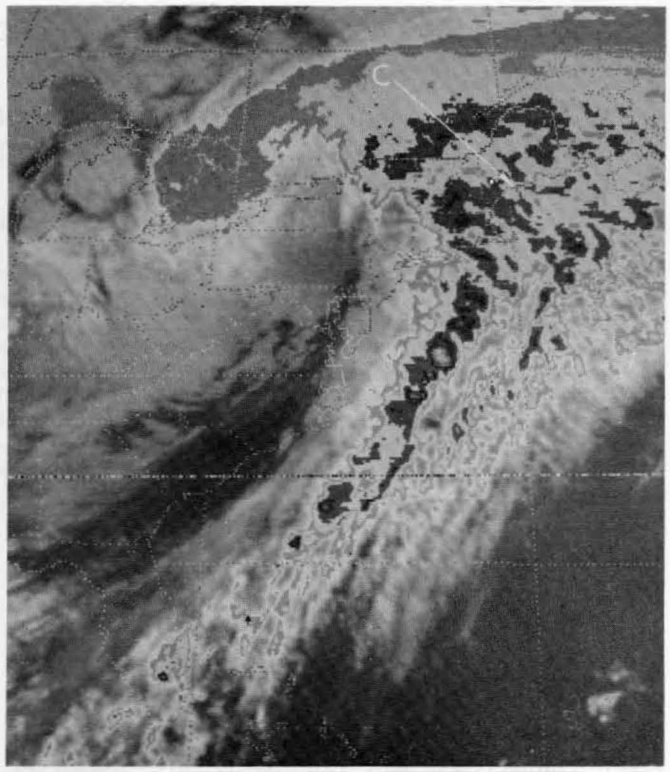

Figure 8. Enhanced IR Imagery (Mb Curve), 1800 GMT, 9 October 1976.

compared to the heights at 1200 GMT. These lower tops suggest that the embedded convection had decreased substantially in intensity resulting in overall lighter precipitation amounts.

The 2-km visible imagery at 1330 GMT, Figure 6, shows the comma shape disturbance -- the comma head at C and the comma tail at T. The comma head appears to be generally bright and smooth with some textured patches due to embedded convective elements. In addition, the comma tail is composed of bright, oval-shaped Cb elements.

4. THE FORECAST PROBLEM

Light intensity (VIP level 1) echoes were prevalent within the 125 nm radar range of Buffalo between 1200 GMT to 1800 GMT. A sample radar picture from Buffalo for 1350 GMT is presented in Figure 9.

The problem of how long the significant rainfall would continue over southern New York State could be partially solved by noting the past positions of the comma shape disturbance in the IR imagery as it moved northeast and then to extrapolate. By 1800 GMT, the IR picture in Figure 8 shows that the cold-enhanced clouds associated with the disturbance cover only a portion of northern New York State. It would be expected that the heavier precipitation has ended for the remainder of New York State except for local lake effects which could still produce signif-

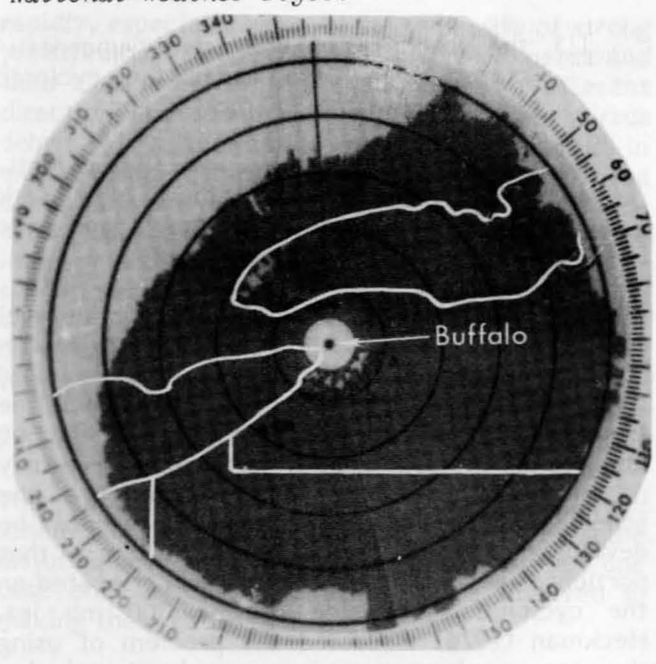

Figure 9. Radar Picture from Buffalo, 1350 GMT, 9 October 1976.

icant precipitation amounts in areas near Lake Ontario.

The problem of how much rain had fallen could be determined from radar and rain gauge measurements. The radar picture from Buffalo in Figure 9 showed a large continuous area of light rain (VIP 1 level of intensity). This large area of continuous rain changed little in intensity between 1200 and 1800 GMT but decreased in coverage after 1600 GMT. The echo pattern in Figure 9 suggested that rain was falling from stratiform cloudiness. Rainfall from stratiform clouds with an echo intensity of VIP 1 is less than 0.1 inches per hour. Rainfall continuing for six hours at this intensity would produce only light accumulations. However, if some of the rainfall was convective as suggested by the satellite imagery, rainfall from convective clouds with an intensity level of VIP 1 is 0.05 to 0.20 inches per hour. Rainfall continuing for six hours at this rate could accumulate up to 1.2 inches.

Six-hour observed rainfall amounts in Figure 10, ending at 1800 GMT, indicate accumulations in southern New York State from 0.82 to 1.70 inches of rain. If the rainfall was interpreted as falling from stratiform clouds, then the radar estimated accumulation would be much less than the observed. However, its convective counterpart would be much closer to reality.

5. THE ESTIMATION TECHNIQUE

Enhanced IR pictures shown in the previous figures indicate that high tops (dark gray to repeat gray levels) were present over portions of New York State, particularly the southern part

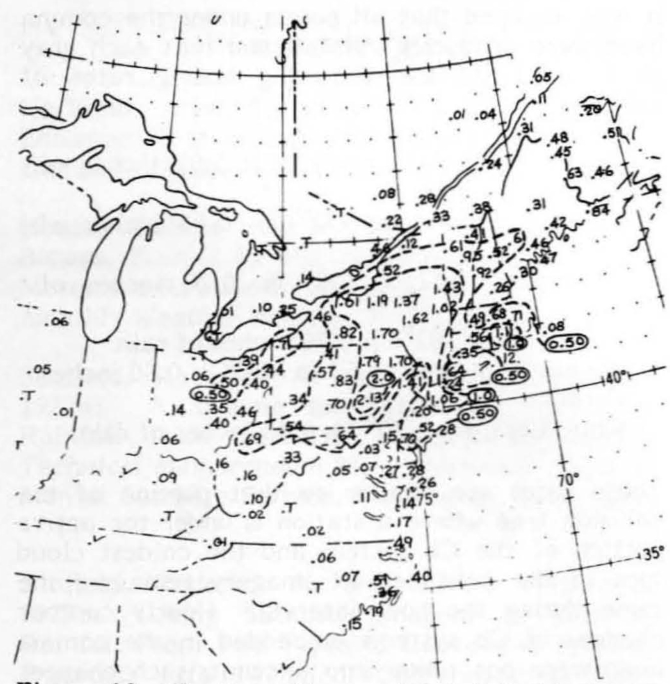

Figure 10. Six-Hour Observed Rainfall, 1200-1800 GMT, 9 October 1976.

during 1200-1400 GMT. Therefore, there were indications that the large scale rainfall associated with the comma head portion of the disturbance had deep convective elements embedded within it. Due to the presence of these deep convective elements, a simplified form of the Scofield/Oliver decision tree for estimating convective rainfall was used during the six-hour period (1200-1800 GMT) for analyzing rainfall within the comma head. Hourly estimates were made, using EIR pictures every hour; visible imagery was not employed. Visible imagery should be used in order to get the best results.

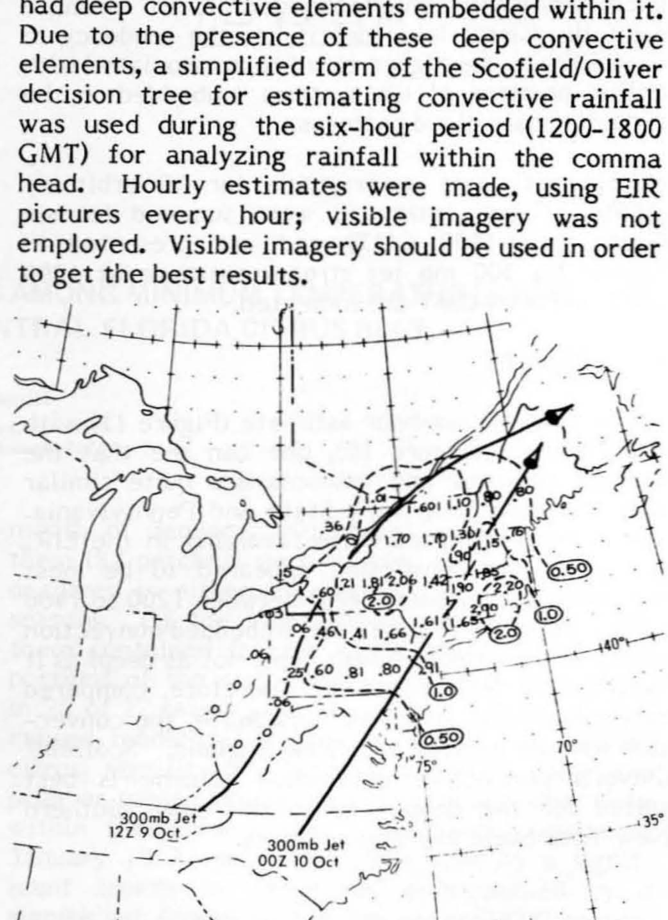

Figure 11. Six-Hour Rainfall Estimate from Satellite Imagery, 1200-1800 GMT, 9 October 1976.

It was assumed that all points under the comma head were producing rainfall and that each gray shade produced the following hourly rates of rainfall:

Medium gray (-32 to -41°C): 0.01 inches of rain
Light gray (-41 to -52°C): 0.05 inches of rain
Dark gray (-52 to -58°C): 0.20 inches of rain
Black (-58 to -62°C): 0.40 inches of rain
Repeat gray levels (-62 to -80°C): 0.60 inches of rain
White (less than -80°C): 0.80 inches of rain

These rates are similar to that portion of the decision tree where a station is under the active portion of the Cb system and the coldest cloud tops in the enhanced IR imagery remained the same during the hour interval. Hourly contour changes of Cb systems embedded in the comma head were not taken into account; such changes are usually important since they appear to be related to the intensity of the convection. Also, inactive cirrus debris associated with the jet stream and the downwind portion of Cb systems was not considered. Normally, caution must be exercised when using enhanced IR to estimate rainfall. Cirrus level debris has the tendency to contaminate the higher cloud tops associated with active portions of Cb systems embedded in the synoptic scale cloud patterns.

Hourly estimates were made for 40 arbitrary points. These estimates were summed for six hours (1200-1800 GMT) and are presented in Figure 11; 300 mb jet stream positions at 1200 GMT and 0000 GMT are indicated.

6. RESULTS

Comparing the six-hour estimate (Figure 11) with the observed (Figure 10), one can see that the rainfall patterns and amounts are quite similar over southern New York State and Pennsylvania. These areas compare quite favorably in the EIR, to where the convection appeared to be most prevalent and intense (deep) between 1200 to 1400 GMT. After 1400 GMT, the embedded convection appeared to weaken (lower tops, not as deep) as it moved over New England. Therefore, compared to Pennsylvania and New York State, the convection was not as deep over New England. Scofield/Oliver's convective estimation scheme is best suited for the deeper convection over southern New York State and Pennsylvania.

From the comparison of the six-hour rainfall estimate (Figure 11) and the observed (Figure 10), the following facts are noted:

(1) the precipitation was greatly underestimated over Ohio under the cyclonic shear side of the 300 mb jet, and

(2) the precipitation was greatly overestimated in extreme northern New York State northward into Canada and over portions of New England.

The reasons for (1) is that lower and middle level clouds on the cyclonic shear side of the jet can produce significant precipitation not accounted for in the convective scheme. Also, since the tropopause is lower on the cyclonic side of the 300 mb jet, all the gray shades of the mb curve may not show up. It appears that a variation of the scheme and of the enhancement curve must be developed for estimating precipitation in that portion of a synoptic scale disturbance located on the cyclonic shear side of the 300 mb jet. Heckman (1976) discussed the problem of using the same enhancement curve when analyzing thunderstorm tops for different tropopause heights.

The reason for (2) was discussed previously; here inactive cirrus debris from the jet stream and inactive Cb anvil material contaminated the higher cloud tops associated with significant rainfall. Inactive jet stream cirrus appeared to cover extreme northern New York State northward into Canada while inactive Cb anvil cirrus debris from convective activity over southern New York State and Pennsylvania appeared to overspread portions of New England.

The problem of separating out the inactive cirrus debris from the active cloud elements producing significant rainfall is partially solved by using techniques employed by the Scofield/Oliver decision tree for finding the active portion of a convective system. Clues for finding the active portion include locating the:

(1) coldest tops in the IR bounded by the tightest temperature gradients,

(2) bright and/or textured clouds in the visible,

(3) overshooting tops, and

(4) portion of the anvil which moves least.

Using clues such as the above for determining the active portions of convective elements embedded in a synoptic scale system may be quite painstaking, especially in an operational environment. Another way of separating out the cirrus debris is by animation. Jet stream cirrus and anvil cirrus debris normally move in the direction of the wind at cirrus level. This cirrus can move quite rapidly, especially when in the proximity of strong jet streams. Active portions of Cb elements and their associated rainfall often move at a different direction and speed as compared to the cirrus debris. As mentioned previously, rainfall in extratropical cyclones tends to be concentrated along convective cloud bands; these bands are often observed in the high resolution visible imagery and occasionally in the IR pictures. For synoptic scale systems without deep convection, a variation of the scheme and of the enhancement curve must be developed for estimating precipitation.

7. SUMMARY

This paper does not present a tested/finalized scheme for estimating rainfall from synoptic scale disturbances. Also, this paper represents only one case and various assumptions were involved in making these estimates.

However, this paper does suggest the possibility that by taking necessary precautions, such as filtering out cirrus debris associated with jet streams or thunderstorms and by locating cloud bands, that a synoptic scale rainfall estimation scheme with embedded deep convection could be developed to supplement radar observations and rain gauge measurements.

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ON THE INTER-SEASONAL RELATIONSHIPS AMONG MINIMUM TEMPERATURES AND DAMAGING FREEZES IN THE CENTRAL FLORIDA CITRUS BELT

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1. INTRODUCTION

A statistical summary of the Tampa, Florida and Orlando, Florida seasonal absolute minimum temperatures are presented for the winter seasons from 1884-1885 through 1976-1977. The occurrences of significant freezes in the Florida citrus belt are also included for this period. There were 34 seasons in which one or more freezes produced moderate or greater damage to citrus crops. The distribution of the seasonal minimum temperatures and of the freeze seasons throughout the time period, and to some extent of the periods within these seasons when freezes occurred, appear not to be randomly related. Of the 33 freeze seasons that occurred prior to last season (1976-1977) 22 contained significant freezes in the month of January. Of these 22 seasons, 18 of them (82 percent) were coupled with freezes that occurred in either the previous or the following seasons. Of the 4 seasons not so coupled, 2 of them contained freezes which occurred in other portions of the same season. Consequently then, in 20 of 22 seasons (91 percent) in which a freeze caused moderate or greater damage to Florida citrus, significant freezes occurred in either the prior or subsequent seasons or at some other time within the same season. The severe freeze of January 1977 was neither preceded by a significant freeze in 1976, nor accompanied by a significant freeze within the same (1977) season. The implications of this statistical set is that the chances for a significant freeze to occur in the Florida citrus belt during this coming season (1977-78) are considerably greater than a ran-