DEFORMATION ZONES AND HEAVY PRECIPITATION

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ABSTRACT

During the Winter Season of 1982 - 1983 and the Spring of 1983, a number of deformation zone cloud systems were monitored in satellite imagery to determine the relationship between these systems and locations of heavy precipitation. Several examples are presented showing this relationship. Previous studies have shown that the heaviest precipitation often occurs along the southern edge of the tight IR temperature gradient. This paper documents that the heaviest precipitation area also includes the unenhanced portion of the IR imagery from about 1 degree latitude south or southeast of the tight IR temperature gradient to nearly the midpoint of the enhanced cloud area, and the unenhanced area up to 2^{o} Lat. south or southwest of the southern tip of the enhanced cloud band. Guidelines are also presented that may prove useful to forecasters when dealing with deformation zone cloud systems.

1. INTRODUCTION

Since the mid 70's when infrared satellite data became available at half hour intervals, it has been shown that these data could be used to determine areas of heavy precipitation (2). Weldon (3) defined a "deformation zone" as the elongated region along the stretching axis of a hyperbolic zone or col region of a wind field. He also discussed and illustrated (3, 4, 5, 6) numerous types of satellite observed cloud patterns associated with deformation zones. Weldon suggested that one of the most important of those cloud features was that associated with the "comma head" portion of a mature comma-shaped cloud system (Figure 1). The arrows represent the circulation at high levels, with the axis of maximum winds indicated by the heavy arrows. The "comma head" is defined as being located to the left of the axis of maximum winds, and is in an area of large positive vorticity advection.

He also pointed out that, as a comma cloud system evolves into a mature storm pattern, the comma head portion of the cloud system often becomes elongated parallel to the deformation zone, displaying a region of cold cloud tops separated from other parts of the storm. Therefore, with storm systems in the westerlies, the "head deformation zone" cloud feature can be considered as a separate cloud system and related to analyses and progs of the upper air wind field.

More recently a number of authors (7, 8, 9) have shown that the heaviest precipitation often occurs along the southern edge of the tight IR temperature gradient of deformation zone cloud systems as seen in IR satellite imagery. This is usually where the best combination of deep layered moisture and vertical motion is located.

Weber and Wilderotter (10) mentioned that deformation zone cloud systems usually form on the

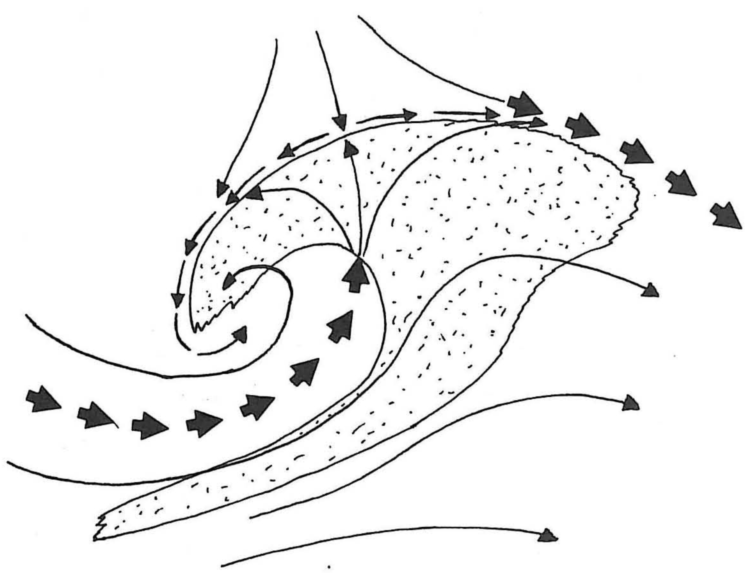

Figure 1. A mature comma - shaped cloud system (Weldon (3)).

north and west sides of developing synoptic-scale comma-shaped cloud systems. The developing deformation zone clouds imply cyclogenesis (closed Low forming) in the mid and/or upper levels. Deformation zones are associated with light winds within a mid and/or upper level col region (Figure 2). The converging air slows and undergoes difluence, turning cyclonically around the developing mid and/or upper Low. The shape of these clouds depends upon the synoptic pattern, the amount of convergence and the availability of moisture. Deformation zones often affect very deep layers of the atmosphere, and because of this, significant clouds and precipitation are associated with them.

Deformation zone cloud systems are particularly related to snowfall during the winter season as opposed to precipitation in general. This is especially so east of the Continental Divide and is due to the availability of low-level cold air in addition to precipitation in that part of the storm system. Even when the precipitation is not of large water content, significant snow can occur.

2. ANALYSIS

Satellite IR imagery at 0000 GMT 14 April 1983 (Figure 3, MB enhancement curve) showed a deformation zone cloud system extending from Wyoming and Colorado to extreme southwest Minnesota.

The 12-hour 500-mb height fall center had moved from the Texas panhandle northeast to the eastern Kansas - Oklahoma border (X's in Figure 3). The corresponding 500-mb closed Low has moved nearly parallel and to the left of the height fall center track from the souther Colorado - New Mexico border northeast to north central Kansas.

At 0000 GMT a surface Low was located near St. Louis and was moving north. One location reported moderate snow, and that was near the southeast Nebraska - Kansas border. 500-mb heights had fallen 110 meters in the last 12 hours. The distance between the surface Low and its upper level support was narrowing and a major snowstorm was developing.

When an upper level closed Low is stationary and not filling, the deformation field will remain strong and the associated deformation cloudiness will persist (10). However at 0000 GMT, the deformation cloudiness was decreasing with time and indicated that the upper Low was on the move, as the current and past positions showed.

Satellite imagery at 0800 GMT (Figure 4) showed the deformation cloud system redeveloping from western Iowa through northwest Wisconsin to the western tip of Lake Superior. The deformation zone clouds to the west (A to B in Figure 4) had almost completely dissipated.

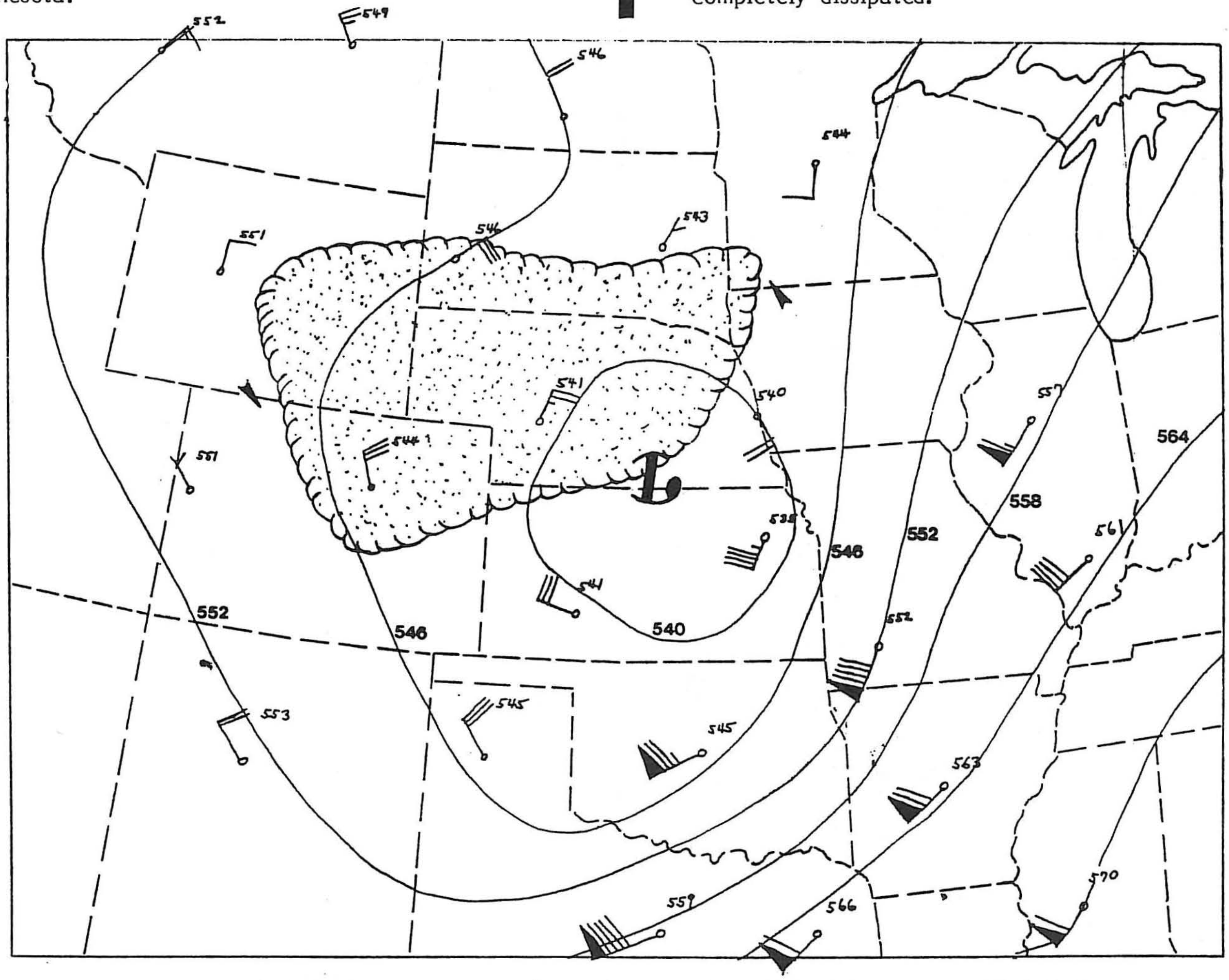

Figure 2. The 500-mb height analysis for 0000 GMT 14 April 1983.

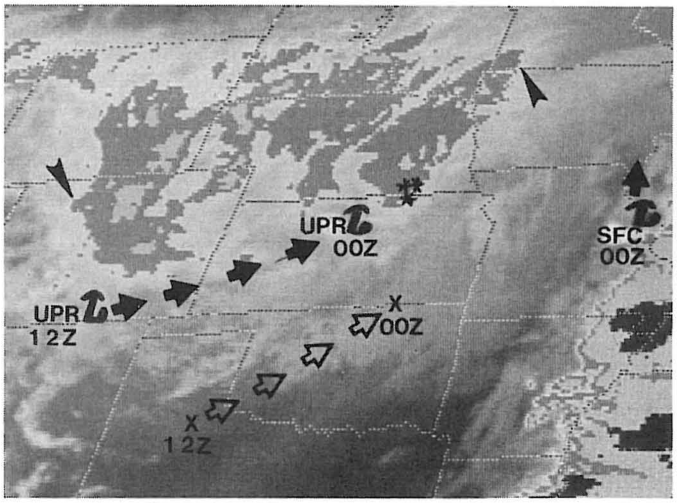

Figure 3. Satellite imagery at 0000 GMT 14 April 1983 with MB enhancement shows a deformation cloud system extending from Wyoming - Colorado to southwest Minnesota.

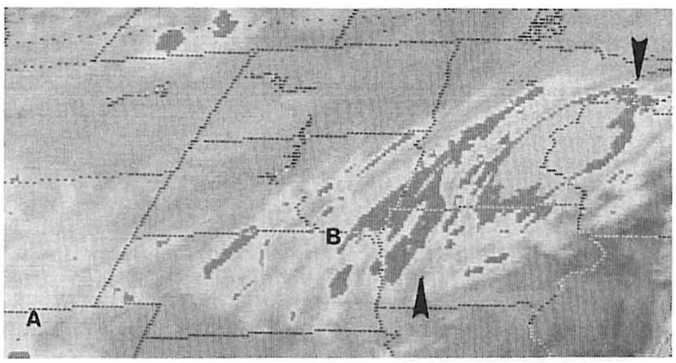

Figure 4. Satellite imagery at 0800 GMT 14 April 1983 with MB enhancement shows deformation zone cloud system redeveloping from western Iowa to the tip of Lake Superior.

At 1200 GMT (Figure 5) the deformation zone cloud system was well organized and extended from western Iowa to western Lake Superior. A band of moderate snow extended from near the midpoint of the enhanced clouds over north central Iowa through east central Minnesota. It most likely continued across northwest Wisconsin into the west portions of Lake Superior and upper Michigan. Part of the band had to be inferred due to lack of surface reporting stations.

The 12-hour 500-mb height fall had increased to 240 meters, with the center now near Moline, Illinois. The 500-mb Low had correspondingly moved to east central Iowa. The surface Low was now over west central Wisconsin. Light snow was falling to the northwest of the moderate snow band. The northern fringe of the enhanced clouds (A to B in Figure 5) was devoid of precipitation. Minneapolis received a total of 13.6 inches of snow from this mid April snowstorm.

Other deformation zone cloud systems were monitored for locations of heavy precipitation. Three other examples follow.

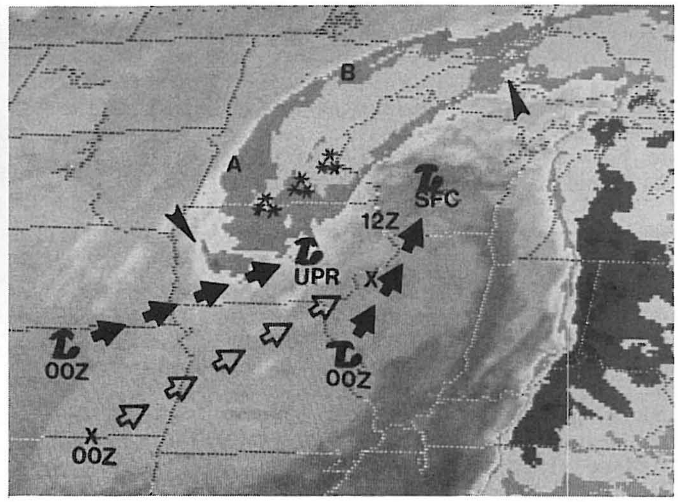

Figure 5. Satellite imagery at 1200 GMT 14 April 1983 with MB enhancement shows deformation zone cloud system well organized and extending from western Iowa to western Lake Superior.

Satellite imagery at 0500 GMT 28 December 1982 (Figure 6, CC enhancement curve) showed a deformation zone cloud system extending from southeast Nebraska to northern Lake Superior. A surface Low was located over southeast Iowa. A band of moderate snow extended from south central Nebraska and northeast Kansas across northwest Iowa to east central Minnesota. Moderate rain was falling over north central Iowa to the southeast of the band of moderate snow. Note that the moderate snow falling is south central Nebraska and the moderate rain in north central Iowa were both occurring in an unenhanced portion of the IR imagery.

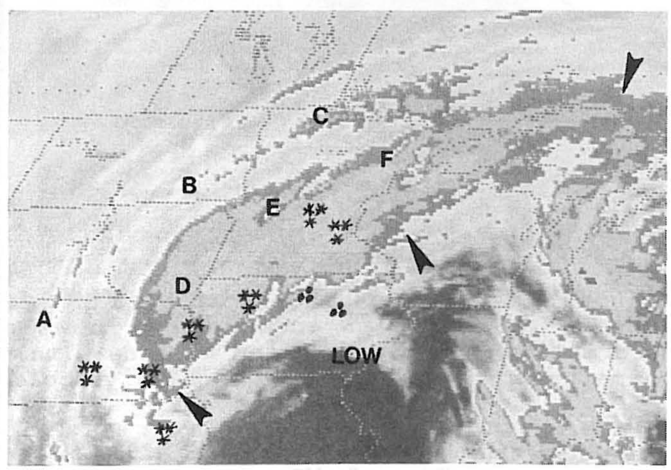

Figure 6. Satellite imagery at 0500 GMT 28 December 1982 with CC enhancement shows deformation zone cloud system extending from southeast Nebraska to northern Lake Superior.

The remains of the deformation zone cloud system that existed earlier to the west (it had redeveloped eastward to its location at 0500 GMT) can be seen as scattered colder cloud tops from north central

Nebraska to northern Minnesota (A to C in Figure 6). Because of this, light snow extended over a large area to the north of the band of moderate snow. In this instance this included the area under the north portion of the enhanced clouds of the newly developed deformation zone cloud system (D to F in Figure 6). Many times, however, this area is devoid of precipitation.

In another example, satellite imagery at 1800 GMT 20 January 1983 (Figure 7, MB enhancement curve) showed a deformation zone cloud system extending northeast from northern Louisiana and merging with a comma head over the central parts of Tennessee and Kentucky. A surge region (the dry intrusion of air into the comma cloud, indicating the jet stream punching into the system) can be seen from the Gulf of Mexico across Alabama and western Georgia. A surface Low was located just south of the Mississippi coast. A band of moderate rain was occurring across southwest, central and into east central Mississippi, from near the southern edge of enhanced clouds to about 2 degrees latitude (120 nautical miles) to the northwest. Light rain was falling to the northwest of this band. No precipitation was occurring farther to the northwest under the north portion of the enhanced clouds of the deformation zone (A to C in Figure 7).

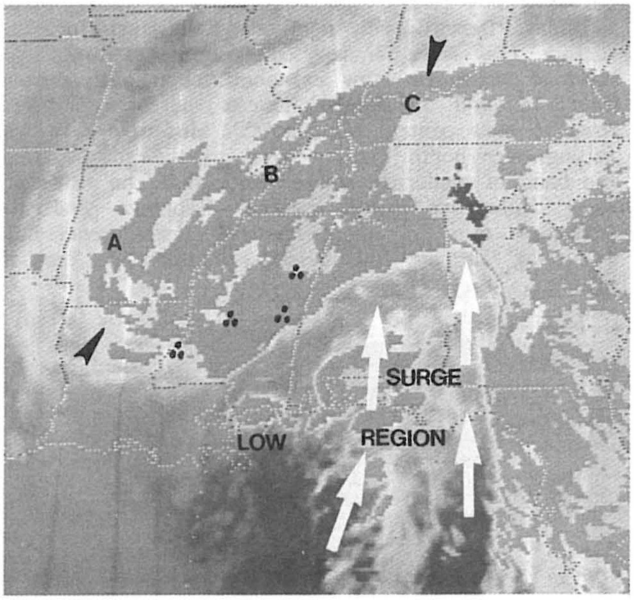

Figure 7. Satellite imagery at 1800 GMT 20 January 1983 with MB enhancement shows a deformation zone cloud system merging with a comma head. A surge region is also visible.

In the final example, satellite imagery at 1700 GMT 01 February 1983 (Figure 8, MB enhancement curve) showed a deformation zone cloud band extending from Nebraska and northern Kansas to eastern Iowa, where it merged with the vorticity comma head. A surface Low was along the Oklahoma - Arkansas border. A band of moderate snow extended from near the midpoint of the deformation clouds over south central Nebraska and the north central Kansas - Nebraska border, northeast along the tight IR temperature gradient to southern Iowa. Light snow was falling to the north of this band. No precipitation was occurring under the north portion of the enhanced clouds (A to C in Figure 8).

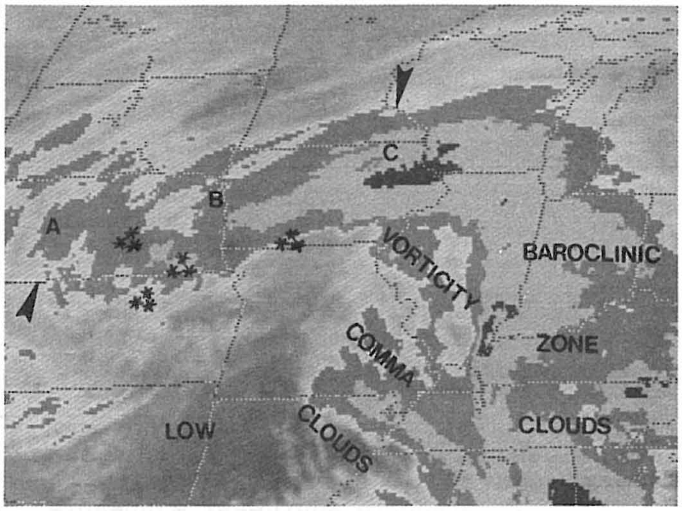

Figure 8. Satellite imagery at 1700 GMT 1 February 1983 with MB enhancement shows a deformation zone cloud band extending from Nebraska to eastern Iowa merging with the vorticity comma head.

The deformation zone continued moving north, causing visibilities to lower in moderate to heavy snow at stations located farther to the north in eastern Nebraska and central and northern Iowa. Snow became light and visibilities increased over south central Iowa after the southern edge of the enhanced clouds (first level medium gray in MB curve) passed to the north.

3. FORECAST GUIDELINES

1) If a surface low pressure system (or upper level cutoff Low with no attendant surface system) has a well formed deformation zone cloud system, the most likely location of moderate to heavy precipitation will be within an area from about 1° Lat. south or southeast of the tight IR temperature gradient in the unenhanced portion of the imagery, to nearly the midpoint of the enhanced cloud area, and in the unenhanced area up to 2° Lat. south or southwest of the southern tip of the enhanced cloud band (Figure 9).

2) If the deformation zone cloud system is rather fragmented unorganized), chances are it is either weak or is dissipating and may be reforming farther east. There will be no well-defined large area of moderate to heavy precipitation. Only spotty areas will exist at best.

3) In a well-formed deformation zone cloud system, do not expect moderate to heavy precipitation for the entire length of the cloud system. It appears that the moderate to heavy precipitation band will extend

northeast to a point generally north or north northeast of the surface Low, and to the northeast of the upper Low (Figure 9). The stage of development of the system is a factor here.

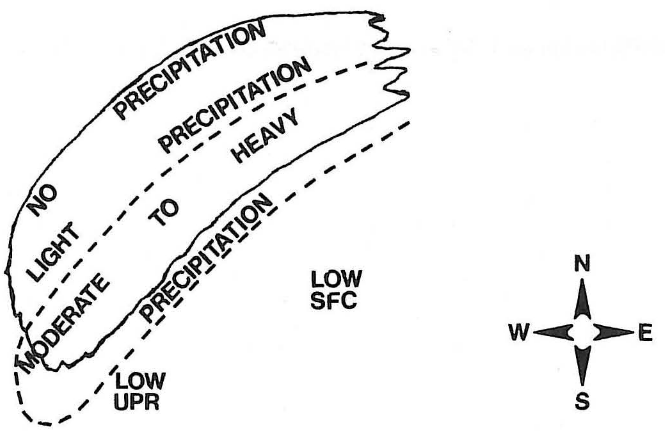

Figure 9. The location of precipitation areas often observed in a well formed deformation cloud system.

4) A band of light precipitation occurs to the north or northwest of the moderate to heavy precipitation band. Just how far north or northwest cannot be estimated, because the width of both the moderate to heavy precipitation band and the width of the deformation zone cloud system is determined by a number of factors, such as the intensity of the low-pressure system and the amount of available moisture, etc.

5) Frequently the area under the north or northwest part of the deformation zone cloud band is devoid of precipitation.

6) If the associated vorticity comma and the baroclinic zone cloud systems separate from the deformation zone cloud system, and the deformation zone cloud band elongates, upper level changes are occurring. The closed and vertically deep upper Low is lagging behind and is probably filling, and will most likely redevelop farther to the east nearer the baroclinic zone cloud system (10).

7) Since moderate to heavy precipitation occurs in the south or southeast part of the deformation zone cloud band and the north or northwest part of the band is frequencly devoid of precipitation, it follows that a tight Probability of Precipitation (POP) gradient must exist across the deformation zone cloud band. Therefore one must pay close attention to the movement of the edges of the band. For example, if your location is to the north of the band, a slight shift toward you would mean increasing POP's and may bring light precipitation into your area; a greater shift and heavy precipitation may occur. If your location is east of the band, a slight shift toward you would also mean increasing POP's and may bring unexpected heavy precipitation into your area.

4. DISCUSSION AND CONCLUSION

Satellite IR imagery using both the CC and MB curves were used in monitoring deformation zone cloud systems. First-level enhancement (medium gray) in both curves begins between temperatures of -30°C and -40°C with only a couple of degrees difference between the two. As a result, it does not seem to matter which curve is used in applying the imagery to deformation zones.

Deformation zone cloud systems and precipitation often behave differently than features found on the associated surface chart, such as the shape and movement of the surface Low center. In fact, precipitation (especially snow) can be occurring in the deformation zone region with no surface Low and little other indication on the surface chart, and with little correlation to PVA on the 500-mb charts.

It is therefore very important to monitor satellite IR imagery for the development and movement of deformation zone cloud systems. They are important heavy precipitation producers, and are most common during the fall, winter and spring months when low pressure systems are more strongly developed.

During the Winter Season of 1982 - 1983 and the Spring of 1983, forecasts from two offices were observed that might have been improved by using IR satellite imagery to monitor the movement of the edges of deformation zone cloud bands, and by reading the latest satellite information messages.

In the first instance, a winter storm warning was in effect for heavy snow for the "tonight" period. The southeast edge of a deformation zone cloud system was far to the west. Satellite IR imagery showed the edge not moving any closer. The late evening zone release continued the winer storm warning that was in the late afternoon zones. Using the satellite imagery, the forecaster should have been able to determine that the heavy sonw would not move any closer. The late evening zone release should have cancelled the winter storm warning over most if not all of the area. The band of heavy snow fell far to the west and northwest of the area.

In the second instance, an aviation forecaster issued several terminal forecasts at the 1440 GMT release time with either no mention of any precipitation for the entire forecast period (24 hours beginning at 1500 GMT) or just mentioned "CHC 2S-." A deformation zone cloud band pushed rapidly northward and within 5 to 6 hours two locations reported "W1 x 1/4SF." Higher POP's and the possibility of moderate to heavy rain (snow) should be mentioned in forecasts if a deformation zone cloud band is observed developing over or moving into the forecast area.

Finally, forecasters are reminded not to leave a winter storm watch or warning in forecasts if it is obvious, not only using conventional data (radar, surface observations, etc.) but satellite imagery as well, that a deformation zone cloud band and its associated moderate to heavy precipitation will not be moving into the forecast area.

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NOTES AND REFERENCES

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