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Evaluation of RAINSAT Products During the Canadian Atlantic Storms Program (CASP)

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ABSTRACT

RAINSAT, a technique first developed by McGill University, uses climatological radar and satellite data to assign probability of rain values to real-time satellite images. The newly developed RAINSAT Remote Display System (RRDS) was placed in operation in the CASP Forecast Centre for a one month period of the project. With RRDS, forecasters were able to access RAINSAT products; including remapped visible and infra-red imagery, smoothed probability of rain and forecast probability of rain charts.

Use of the RAINSAT products by the CASP forecasters was somewhat limited. Nonetheless, observations made by the forecasters serve as a basis for a number of recommendations. Two case studies appended to the report demonstrate a number of the characteristics of the RAINSAT technique.

1. BACKGROUND

RAINSAT was first developed in the late 1970's by the Stormy Weather Group at McGill University, with support from the Atmospheric Environment Service. RAINSAT was tested operationally during the summers of 1984 and 1985 at the Quebec Weather Centre (CMQ). Subsequently, a new display package was developed by the Satellite Applications Division of the AES. This new RAINSAT system (RRDS) was installed in the CASP Forecast Centre in early February, and was operational for the last month of the project.

2. RAINSAT TECHNIQUE

Essentially, RAINSAT uses a climatological matrix to assign probability of rain values to real-time satellite imagery. This matrix is developed through examination of a large dataset of cloud elements, collected over a period of several weeks within coverage of digital radar. The visible brightness value and infra-red temperature of each cloud element is compared with the radar signal. It then becomes obvious that bright (thick) cloud elements with cold tops are associated with precipitation more often than the dull (thin) variety with warm cloud top temperatures. One is then able to use the climatological matrix to assign probability of rain values to VIS-IR pairs. These same probabilities are used to generate RAINSAT maps in real time.

During the months of February and March 1985, digital data were obtained from C-band radar at the Halifax International Airport This data was used to develop a RAINSAT Climatological Matrix for use during CASP.

3. CASP RAINSAT PACKAGE

Satellite imagery received at the Satellite Data Lab in Downsview was processed by the RAINSAT computer (Eclipse S-130). The processed data were transmitted to the RAINSAT Remote Display System (RRDS) via a 1200 baud dedicated circuit. During daylight hours, four images were transmitted each half hour (three at night); with reception taking place between 20 and 30 minutes after the time of the original satellite photos. These images covered an area from about 38 to 50 N and 50 to 80 W. Furthermore, the products were all remapped to a Lambert-conic projection (see figures 3 and 4, Case Study I of the Appendix).

The RAINSAT products consisted of:

- Visible Satellite Image (16 brightness levels)

- Infra-red Image (16 temperature levels)

- Smoothed Probability of Rain Map (10 levels)

- Forecast Probability of Rain Map

The visible images were normalized diurnally to compensate for the effects of the changing the solar zenith angle. The Forecast Probability of Rain map was a three-hour forecast chart based on extrapolation between two consecutive probability maps. At night, no visible images were available, however, Probability of Rain maps based on an infra-red algorithm were transmitted.

It was also intended to transmit a set of correlation coefficients and velocity vectors. This set of data corresponded to the extrapolation technique used in the generation of Forecast products. In most cases, however, none of this data was received during CASP.

4. USE DURING CASP

Overall, RAINSAT was not used frequently by the CASP forecast staff. RAINSAT only became operational midway through the project and the CASP meteorologists had already developed their operational work habits, which included frequent use of the powerful McIDAS satellite workstation. Furthermore, most of the forecasters were reluctant to spend the time to become familiar with the RAINSAT system.

Two individuals did show more interest in the product, mainly because of previous experience with it. Several Colour Look-up Tables were created for the enhancement of RAINSAT products. These included enhancements to help better interpret visible and infra-red images, and to compare with equivalent McIDAS products (see Case Study I). In general, forecasters found it difficult to use satellite imagery that was restricted to 16 levels of information.

Precipitation onset times at Yarmouth and Sable Island were critical for CASP Logistics decisions, especially those concerned with aircraft operations and airsonde releases. Since both these locations were outside normal radar coverage, short-term precipitation forecasts were sometimes rather difficult. However, on several occasions, the use of RAINSAT Probability and Forecast Probability charts improved the timing of precipitation forecasts.

Some of the characteristics of RAINSAT products can be seen in the two case studies appended to this report. Case Study I compares RAINSAT probability of rain images with corresponding McIDAS products. Case Study II examines the behaviour of the forecast probability of rain product.

5. FORECASTERS' OBSERVATIONS/RECOMMENDATIONS

CASP Forecasters made a number of observations and comments on the RAINSAT products during its presence, and subsequently in a questionnaire. A number of recommendations can be based on their observations:

a. Remapping of satellite imagery to a conic (or preferably a polar-stereographic) projection makes satellite interpretation much easier. This was especially true during CASP with the GOES at 109 W.

b. Diurnal normalization of visible imagery is very useful operationally. This allows forecasters to apply techniques to relate precipitation or fog processes to cloud brightness.

c. The Probability of Rain charts seem to be controlled to a high degree by the visible information. In other words, it was cloud brightness that essentially determined the probability of rain values.

d. There appeared to be a diurnal trend in the normalized visible imagery, and hence in the probability of rain charts. This was especially true in the early morning (before 14Z) and late afternoon (after 19Z).

e. The threshold of rain/no rain seemed to be well related to a 40 percent probability value. The colour enhancement of probability charts was set up to reflect this relationship.

f. Snow and ice (bright), with cold temperatures "fooled" the RAINSAT algorithm. This was especially true between Cape Breton and Prince Edward Island, where high probability of rain values persisted when skies were cloudless.

g. Probability of Rain charts generated at night from only IR information were a source of confusion to most meteorologists. In wintertime, when many synoptic situations are stable involving arctic airmasses, infrared imagery is of limited use. Therefore, at night when the RAINSAT algorithm uses only the information from the infrared, no probability of rain maps should be generated.

h. The reduction of satellite information to only 16 levels makes the imagery difficult to use. Forecasters agreed that 64 grey or colour levels are essential for useful interpretation.

i. There did not seem to be any biases in RAINSAT as to the type of precipitation. However, leading edges (onset) of organized areas of precipitation seemed to be better described than rear edges.

j. For well organized precipitation patterns, the Forecast Probability of Rain chart appeared to extrapolate the area of precipitation well.

6. SUMMARY

The CASP Forecast Centre had the first opportunity to use the RRDS System operationally (Abraham (1986)). This was also the first test of RAINSAT products during the winter season.

The CASP forecast team, in general, did not have the opportunity to frequently use the RAINSAT products during the one month presence of the system. They did however, recognize the potential of RAINSAT, and made a number of valid observations. Overall, RAINSAT's usefulness was restricted to the approximately six hours of full daylight during the February-March period. At these times the RAINSAT concept seemed to work rather well. However, apart from this time interval in the middle of the day, the products were of little use.

7. REFERENCES

Abraham, J.D., 1986: Operational Experience with Graphical Display Stations During CASP. Atmospheric Environment Service, Atlantic Region Technical Note 86-002, Bedford, N.S.

Bellon, A., 1979: The Development of a System for Short Range Precipitation Forecasts using Combined Radar and Satellite Data. Final Report for Atmospheric Environment Service (DSS). Contract OSU 78-0056DSS file 01SU.KM 601-8-0253.

Cantin, A. and M. Roch, 1986: Operational Evaluation of the RAINSAT System. Presented at the First Workshop on Operational Meteorology, February 4-6, 1986, Winnipeg, Manitoba. Canadian Meteorological and Oceanographic Society.

APPENDIX

CASE STUDY I

This example is a warm frontal situation on 09 March 1986. Polar-stereographic visible photographs from McIDAS (Figures 1 & 2) have been enhanced such that the brightest clouds are shaded. McIDAS imagery is not normalized diurnally. In addition, the appropriate radar and surface weather reports are plotted on the image.

The corresponding RAINSAT Smoothed Probability of Rain charts are presented in Figures 3 & 4. The regions containing probability values of at least 40 percent have been outlined.

Several points can be made:

- Non-normalized imagery (McIDAS) shows a definite diurnal brightness change.
- McIDAS visible enhancement (grey-shading of the brightest clouds) does infer precipitation presence. This is consistent with summertime findings at CMQ (Cantin (1986).
- RAINSAT probability charts also show morning (and afternoon) diurnal variation.
- RAINSAT probability of rain threshold of 40 percent outlines fairly well the precipitation pattern fairly well.
- RAINSAT gets "fooled" by ice north of Cape Breton.

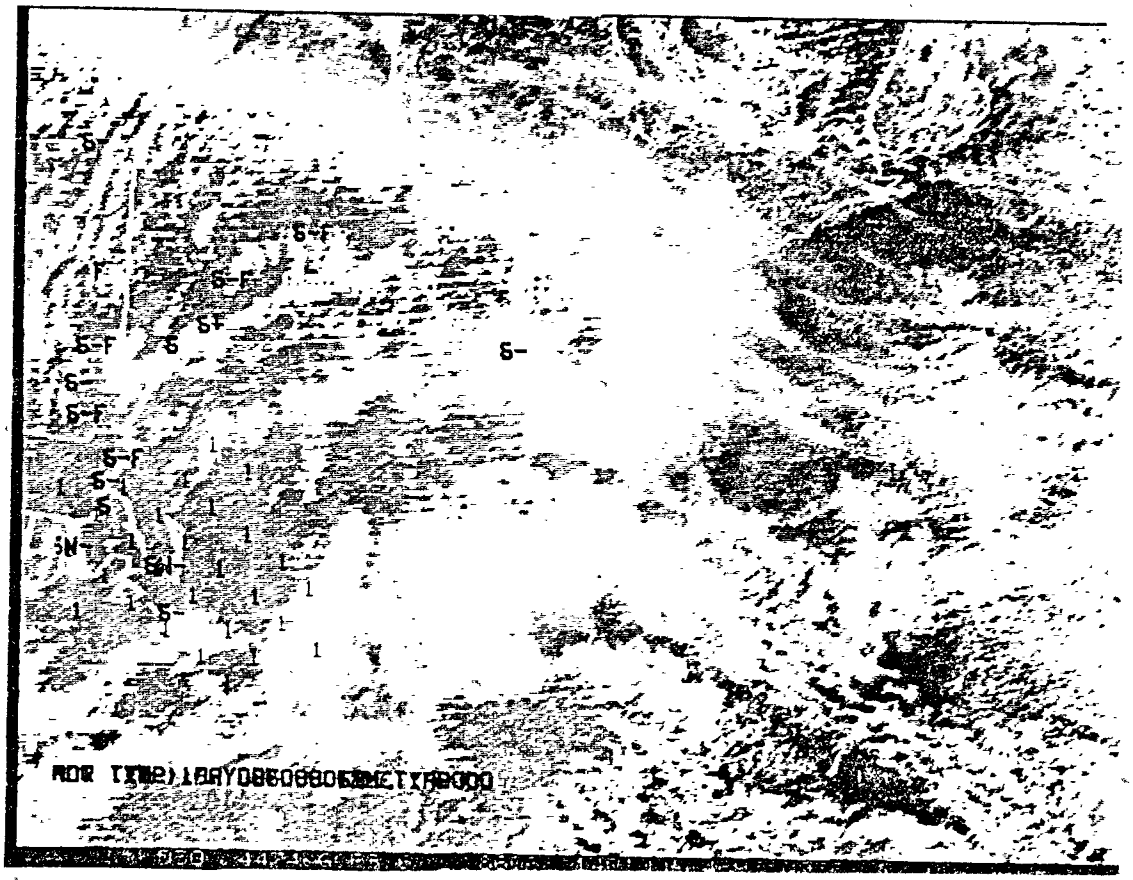

Figure 1.
McIDAS visible (enhanced) image; 09 March 86 1400 GMT
(weather and radar reports plotted)

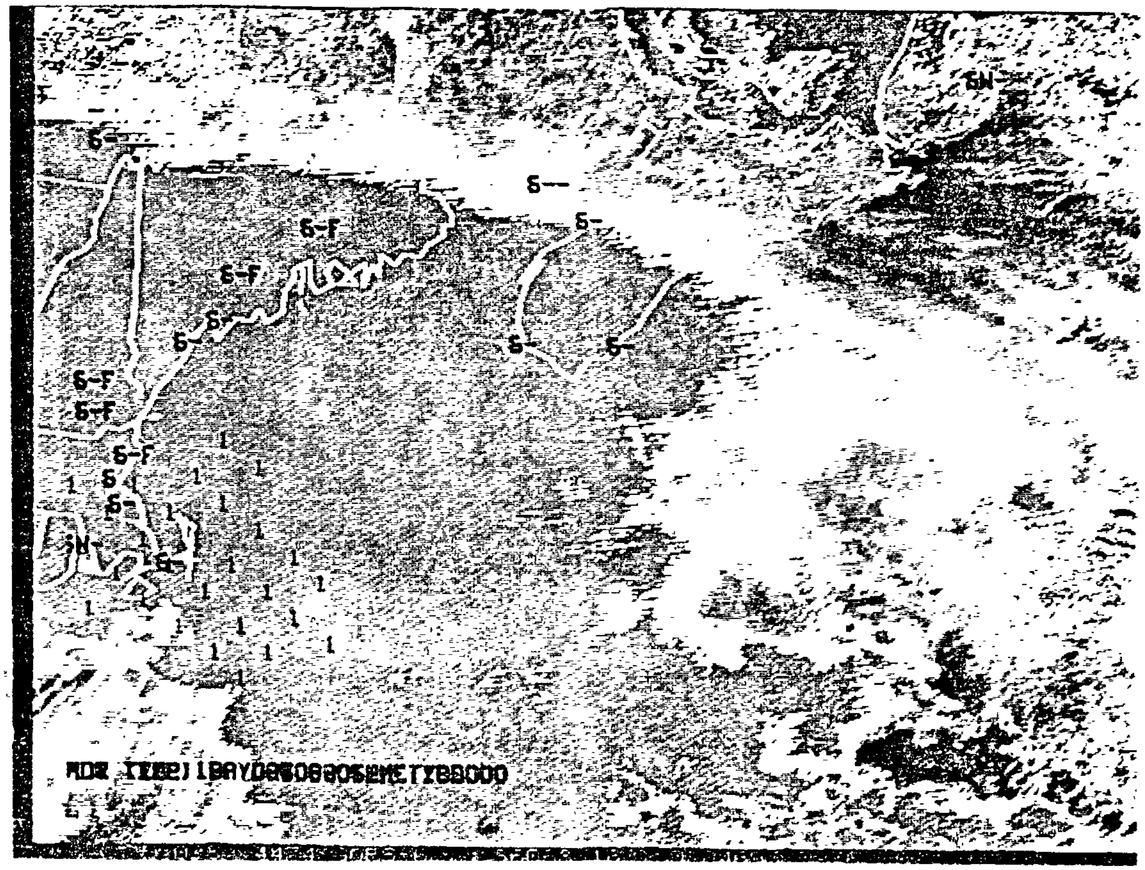

Figure 2.
McIDAS visible image; 09 March 86 1600 GMT

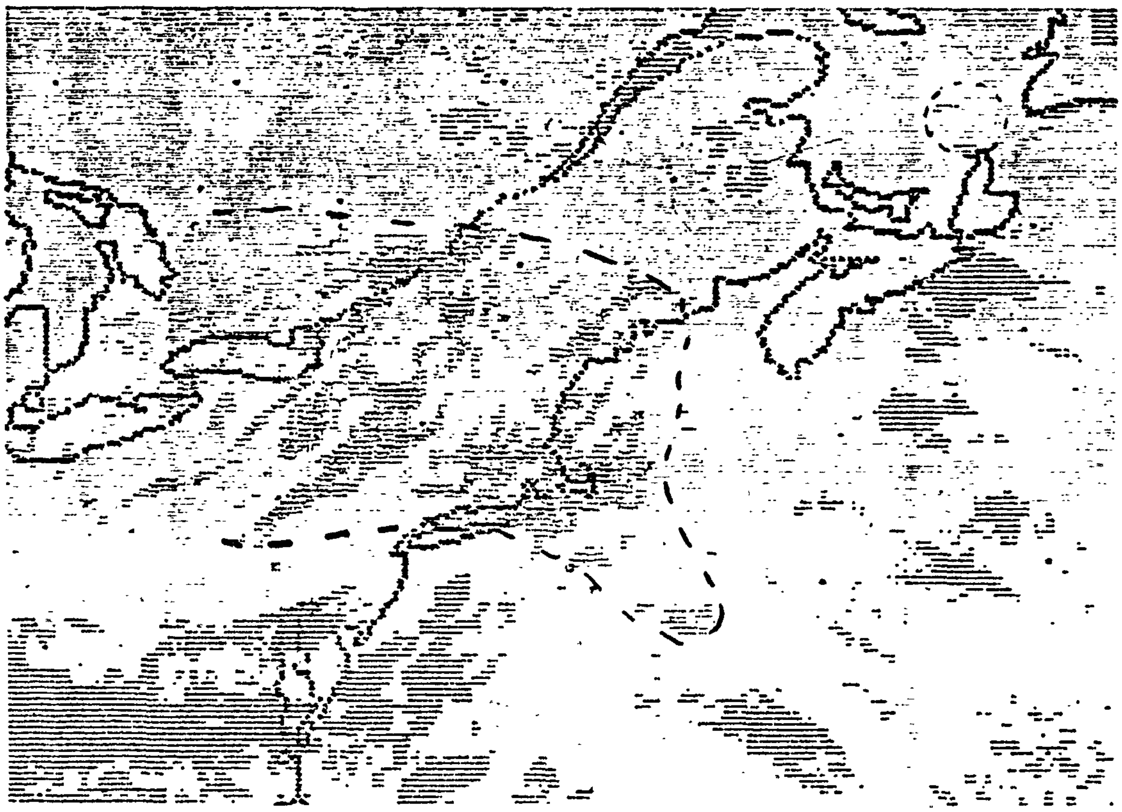

Figure 3.
RAINSAT probability of rain map; 09 March 86 1400 GMT
(dashes outline probabilities greater than 40%)

Figure 4.
RAINSAT probability of rain map; 09 March 86 1600 GMT

CASE STUDY II

The synoptic situation is depicted on the surface analysis (Figure 5) for 13 March 1986 at 1800Z as essentially a warm frontal situation. The RAINSAT Probability of Rain map for 1500Z (Figure 6) and the map for one-half hour earlier were used to generate the Forecast Probability of Rain chart for 1800Z (Figure 7). The actual RAINSAT Probability of Rain chart for 1800Z is included in Figure 8.

Examination of the figures reveals several things of interest:

- Comparison of the forecast chart with the actual Probability chart, shows that for this well organized precipitation pattern the short term extrapolation works rather well.

- Both the forecast and the actual Probability maps represent the actual area of precipitation well. This is especially true of the leading edge.

- By 1800Z, RAINSAT was again "fooled" by ice in the Gulf of St. Lawrence.

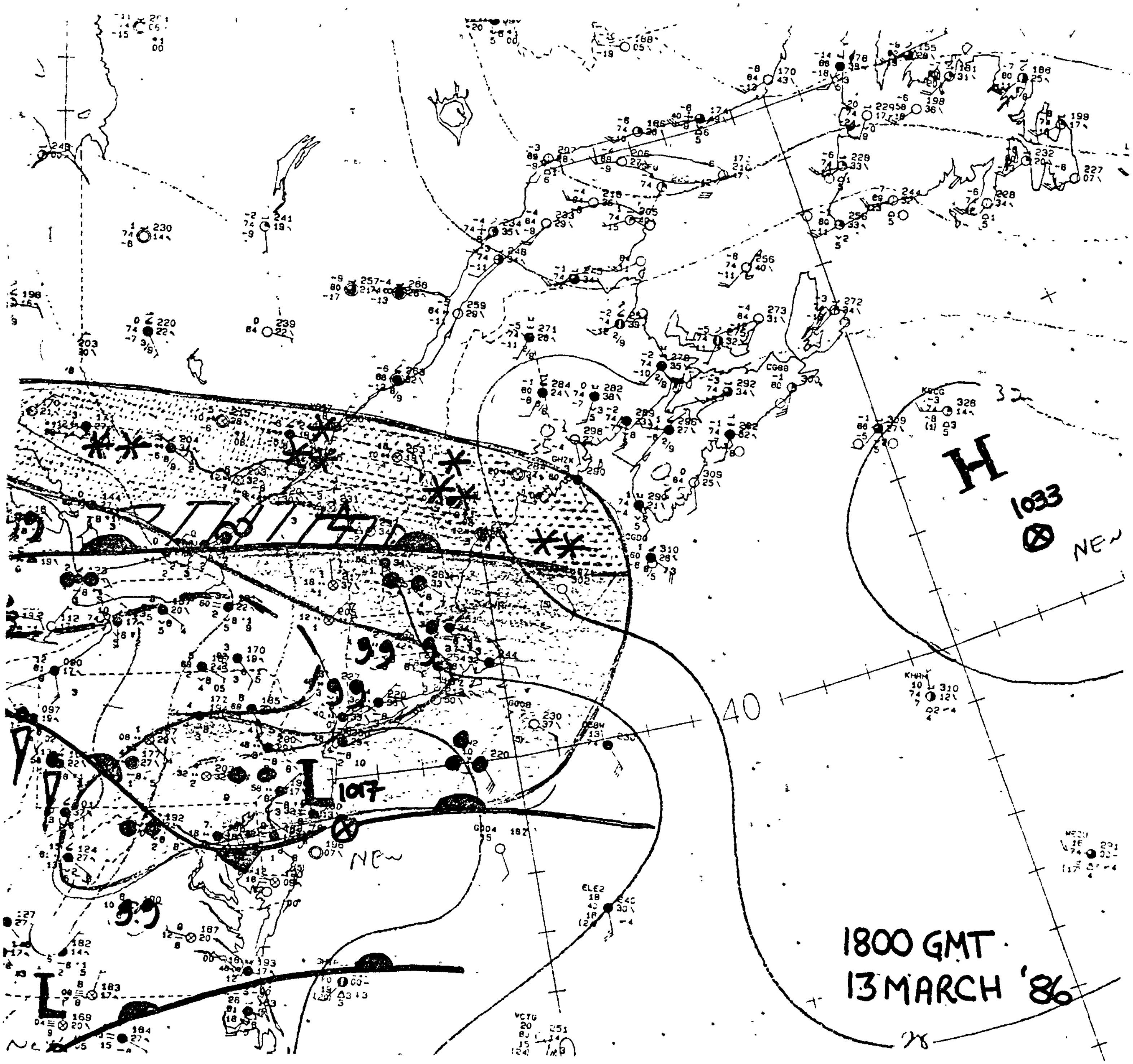

Figure 5.
Surface analysis; 13 March 86 1800 GMT

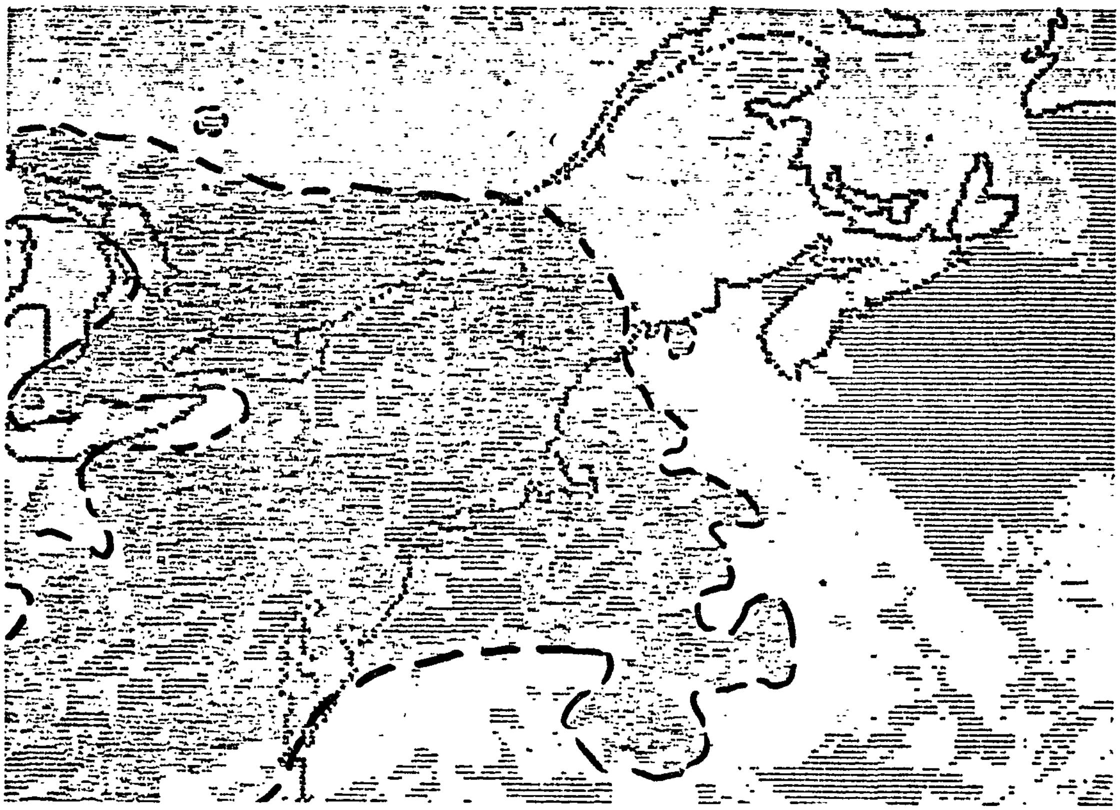

Figure 6.
RAINSAT probability of rain map; 13 March 86 1500 GMT

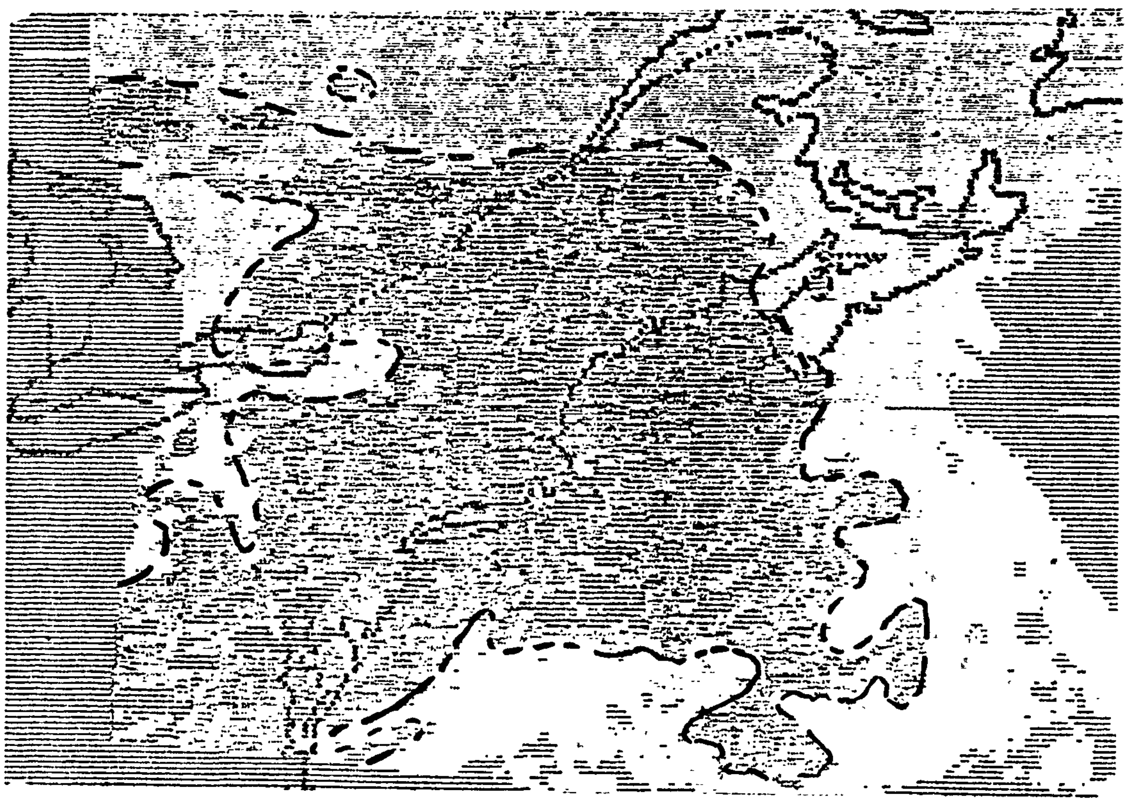

Figure 7.
RAINSAT 3 hour forecast probability of rain map
valid 18 March 86 1800 GMT (based on 1500 GMT data)

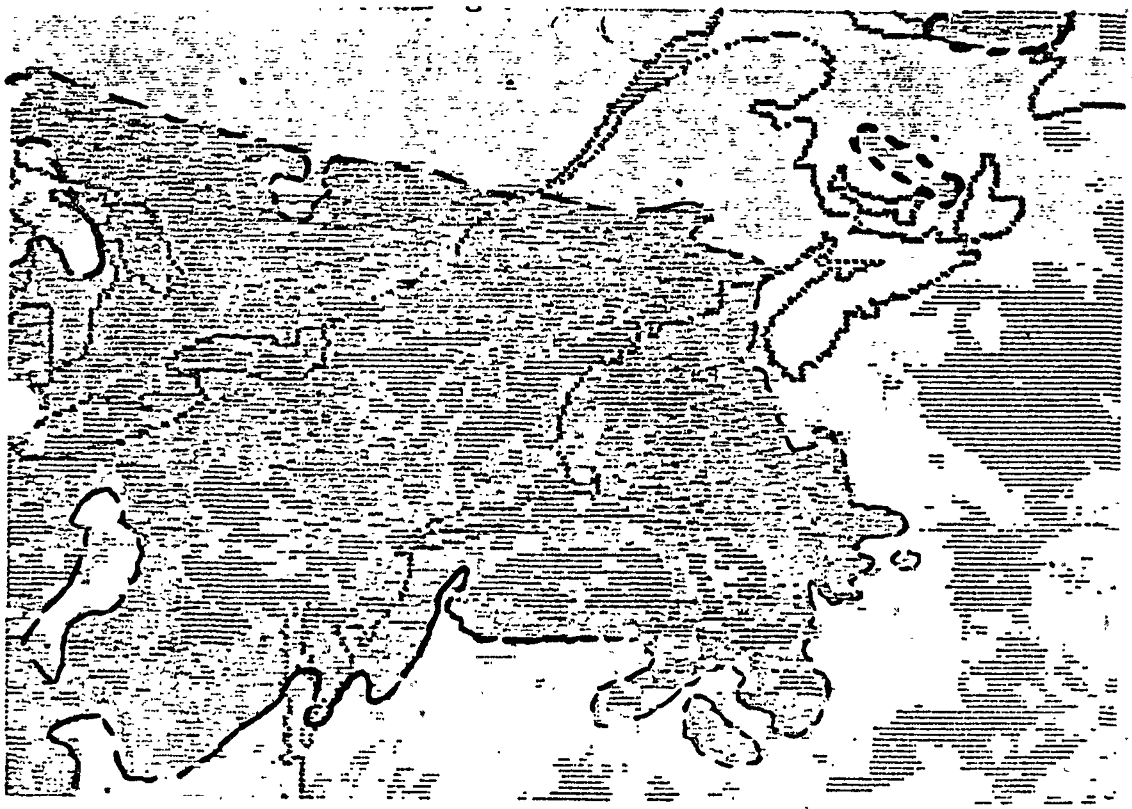

Figure 8.
RAINSAT probability of rain map; 13 March 86 1800 GMT