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Monitoring and Predicting Tropical Cyclone Movement Using Geosynchronous Satellite Remote Sensing Techniques

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Monitoring and Predicting Tropical Cyclone Movement Using Geosynchronous Satellite Remote Sensing Techniques

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1. INTRODUCTION

This work was planned to investigate the potential usefulness of data collected by the VISSR Atmospheric Sounder (VAS) Satellite for studying and forecasting hurricanes. For the work originally proposed, the writer was to study tropical cyclone movement and to work closely with those at other institutions using the VAS to study other problems associated with hurricanes. This report therefore, concerns experiments designed to test the utility of VAS data in forecasting movement of tropical cyclones.

Considerable research in recent years has indicated that most of the movement of the hurricane can be explained by the mean winds in the troposphere averaged over a depth of about 800 mb in the area within 800 kilometers of the hurricane center. This has been strongly suggested by research of Miller (1958), George and Gray (1976) and Gray (1977). Research results have also shown that there is a high correlation between the winds in the middle levels (700 mb and 500 mb) of the atmosphere around the hurricane and the movement of the storm center; for example, Miller and Moore (1960) and George and Gray (1976). Chan and Gray (1982) investigated the relationship between movements of tropical cyclones and the winds averaged over a ring of 555 to 777 km radius around the center of the storm in each of the regions: Western Pacific, Western Atlantic and Australian. They stratified their data according to whether the tropical cyclone was moving fast or slow, was intense or weak, in high or low latitudes, etc. They came to the conclusion that there was a high correlation between the 12-hour movement (centered on observation time) of the storm and the winds at either 500 mb or 700 mb. There was a slightly better correlation with the direction of motion of the storm and the direction of the mean 500 mb winds and slightly better correlation with the speeds at 700 mb. In particular, on the average, tropical cyclones in the Western Atlantic moved 10 to 20 degrees to the left of the mean mid-tropospheric winds at 666 km radius about the cyclone center and about 1 m/s faster.

Pike (1985) investigated whether for the Western Atlantic the tropical cyclone motion was better correlated with the pressure patterns (geostrophic winds) or with the temperatures averaged through deep layers. He concluded that while either parameter could be used advantageously in the hurricane motion forecasting, better results would be obtained by using the constant pressure data.

While constant pressure maps, thicknesses charts, temperature charts, and many others can be retrieved from the VAS satellite data, the research results referenced above suggested that the constant pressure maps in the middle troposphere would be the best tools for this research on movement forecasting.

The VAS satellite measures radiances in 12 spectral bands.

Chesters, et al (1981) provide the following description of the VAS: "The VAS instrument is an improved version of the VISSR device used operationally on the GOES satellites. It was designed to provide multi-spectral infrared sounding data and exploits the geosynchronous station to give frequent coverage of mesoscale weather developments. VAS has 12 calibrated thermal infrared channels between 4 and 15 microns, which are chosen to distinguish the effects of tropospheric temperature, moisture and cloud cover upon the upwelling radiances. The VAS channels cover the troposphere with roughly 5-km vertical and 15-km horizontal resolution, and they suffer the usual passive infrared limitations on determining the state of the lowest atmospheric layers without ancillary surface data . . . ." The Geosynchronous VAS was designed to watch the development of mesoscale weather systems, "typically surveying the United States with 12 spectral bands once per hour at 15-km (nadir view) resolution. Satellite soundings derived from such multispectral scenes will have 30 to 90 km effective resolution, since several pixels must be used to average radio- metric noise and deal with broken cloud cover in the net sounding field of view (SFOV)".

2. THE DATA

The VAS satellite was operated in the dwell mode (permits retrieval of vertical soundings) over latitudinal bands in which there were hurricanes or other tropical cyclones on a number of days in 1981 and 1982. The storms for which VAS data were collected that were available for this study are listed in Table 1 along with the direction the storm was moving and whether it was a hurricane (H), tropical storm (ts) or a depression (d). (See Fig. 26 and 27 for tracks of the storms.) Hurricanes Harvey and Irene are especially interesting for a "movement study" because they made definite changes in direction of forward movement during the periods that VAS was collecting data for the hurricane study (Lawrence and Pelissier, 1982).

Regression equations were developed by Stout and Steranka (Internal Paper of Code 612, Goddard Space Flight Center), using the VAS radiances and data from rawinsondes paired closely in time and space with the respective radiances. These regression equations were used to retrieve from the radiances, pressure-heights, temperature, and moisture parameters at a number of levels and for a number of layers. For the height at various standard pressure levels (GPL) the following correlations (r) and explained variances (R) were obtained.

GPL (mb)	1000	850	700	500	300	250	200	100
r	.723	.775	.735	.752	.710	.695	.684	.632
R	.52	.60	.54	.57	.50	.48	.47	.40

After considering these relatively favorable results for the 500 mb level and those of Chan and Gray (1982) about that level accounting for most of the hurricane movement, it was decided to investigate use of the retrieved 500 mb heights to forecast motion of the tropical cyclones. The results are reported in Section 3a.

Other parameters which can be used to forecast hurricane motion were tested and results are reported in Sections 3 b to 3e.

Evaluation of the VAS and recommendations for its use in hurricane motion prediction are in Sections 4 and 5.

Table 1. Days VAS Data Were Collected and Direction of Movement [Hurricane (H), tropical storm (ts), depression (d)]

SEPTEMBER 1981

Storm							
Emily	9/2						
	NNE						
	ts						
Harvey	9/12	13	14	15			
	WNW	NW	NNW	NNE			
	d	H	H	H			
Irene	9/23	24	25	26	27	28	29
	W	WNW	NW	NW	N	N	NE
	d	ts	H	H	H	H	H
Gert	9/11						
	NNE						
	H						

SEPTEMBER 1982

Storm						
Beryl	8/31	9/1	2	3	5	6
	WNW	WNW	WNW	W	W	W
	ts	ts	ts	ts	ts	ts
Chris	9/10	11				
	WNW-NNW	N				
	d-ts	ts				
Debbie	9/13	14	15	16		
	NW	N	NNE	NNE-N		
	d	ts	H	H		

Data derived from Lawrence and Pellisier (1982) and Clark (1983).

3. RESULTS

a. Use of the 500 mb Charts

The 500 mb charts of the retrieved data for these storms are presented in Fig. 1-17. The retrieved data are plotted on a grid with one degree intervals in latitude and two degree intervals in longitude. The data collected on the special "hurricane days" has wide expanse east-west, covering the entire longitudinal belt normally scanned by the satellite.

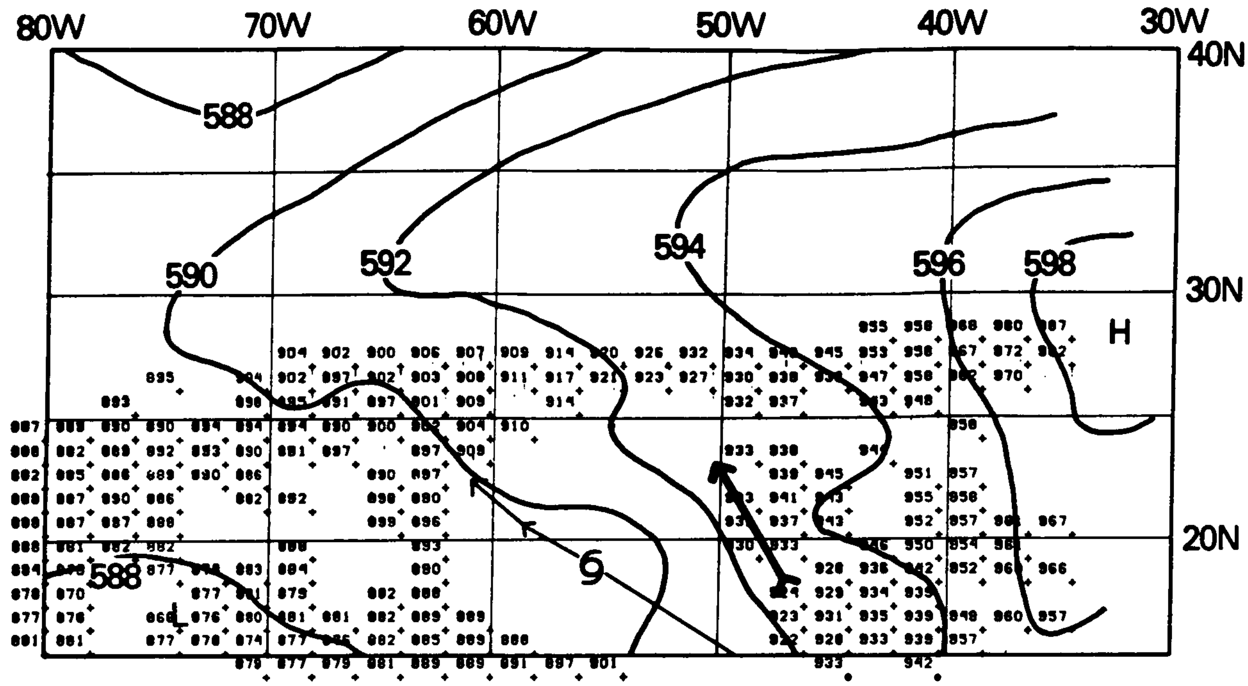

Fig. 1. Hurricane Harvey: 500 mb (12 September 1981, 1432 GMT). Heights at the grid points are in meters with the first figure omitted. They are values retrieved from the VAS data by regression equations (see text). The heavy arrow to the right of the storm center is the direction of motion of the storm center suggested by the analysis. The arrow upstream from the storm center is the movement of the center for the preceding 24 hours. The two arrows downstream from the center represent for the next 12 and 12 to 24 hours, respectively.

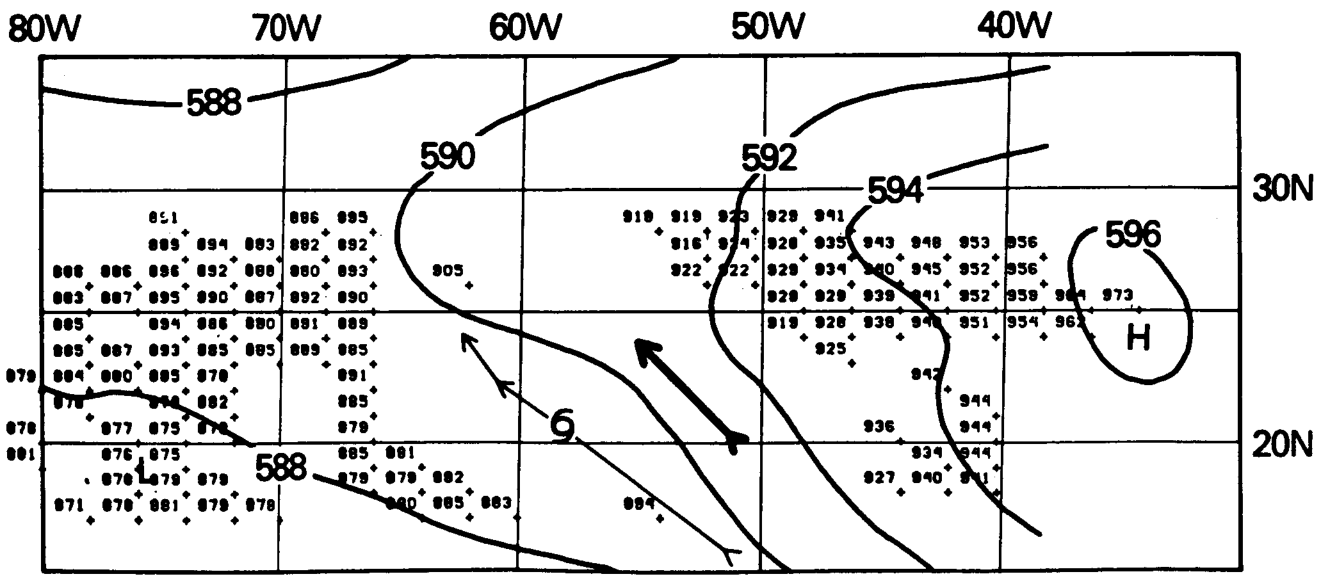

Fig. 2. Hurricane Harvey: 500 mb (13 September 1981, 0237 GMT). See Fig. 1 and the text for additional explanations.

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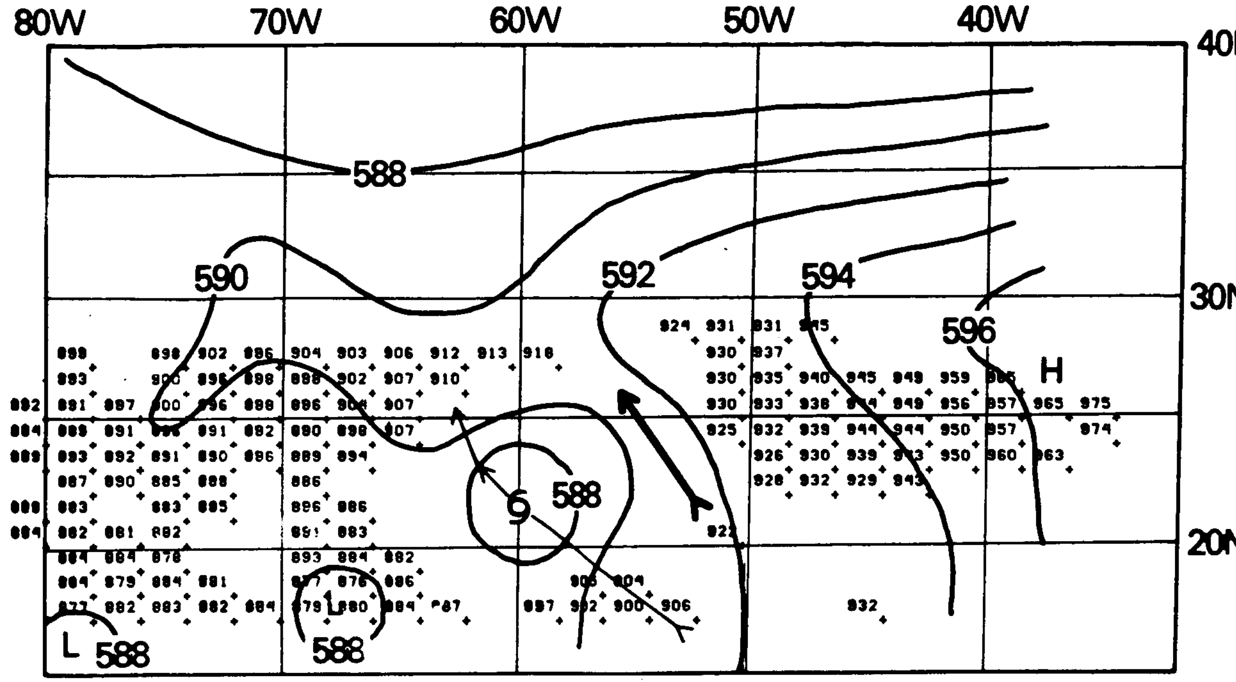

Fig. 3. Hurricane Harvey: 500 mb (13 September 1981, 0838 GMT). See Fig. 1 and the text for additional explanations.

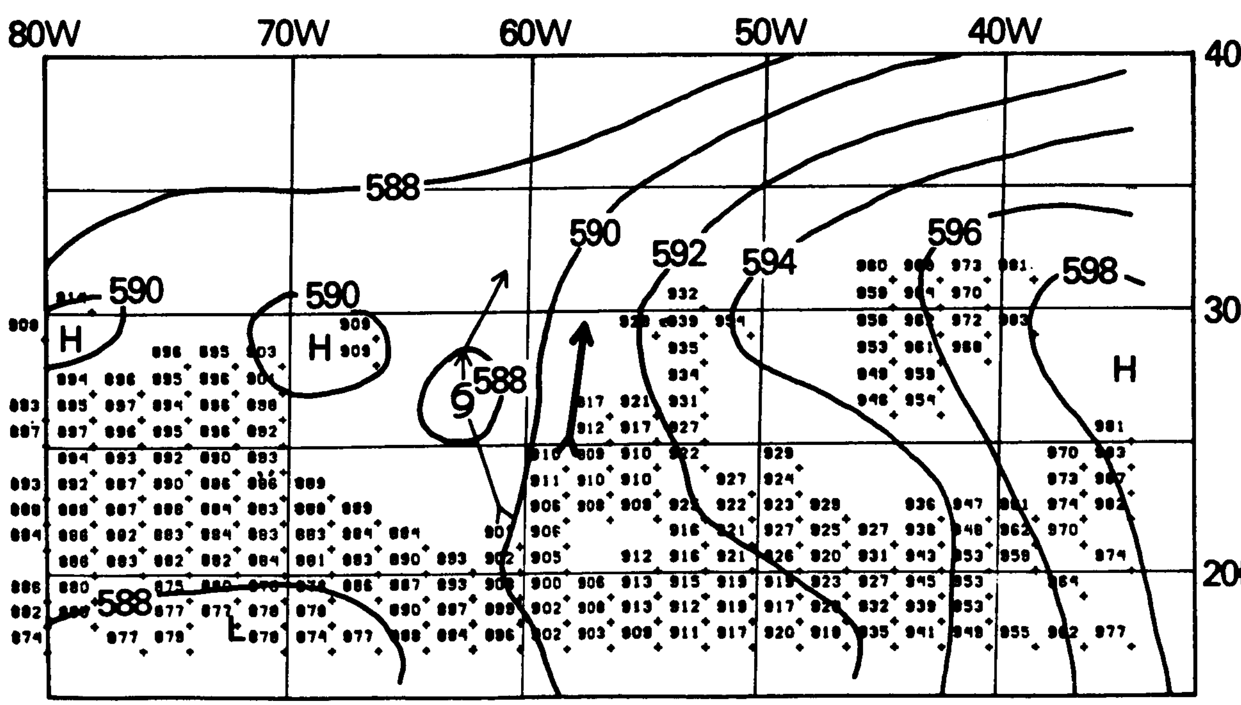

Fig. 4. Hurricane Harvey: 500 mb (14 September 1981, 1432 GMT). See Fig. 1 and the text for additional explanations.

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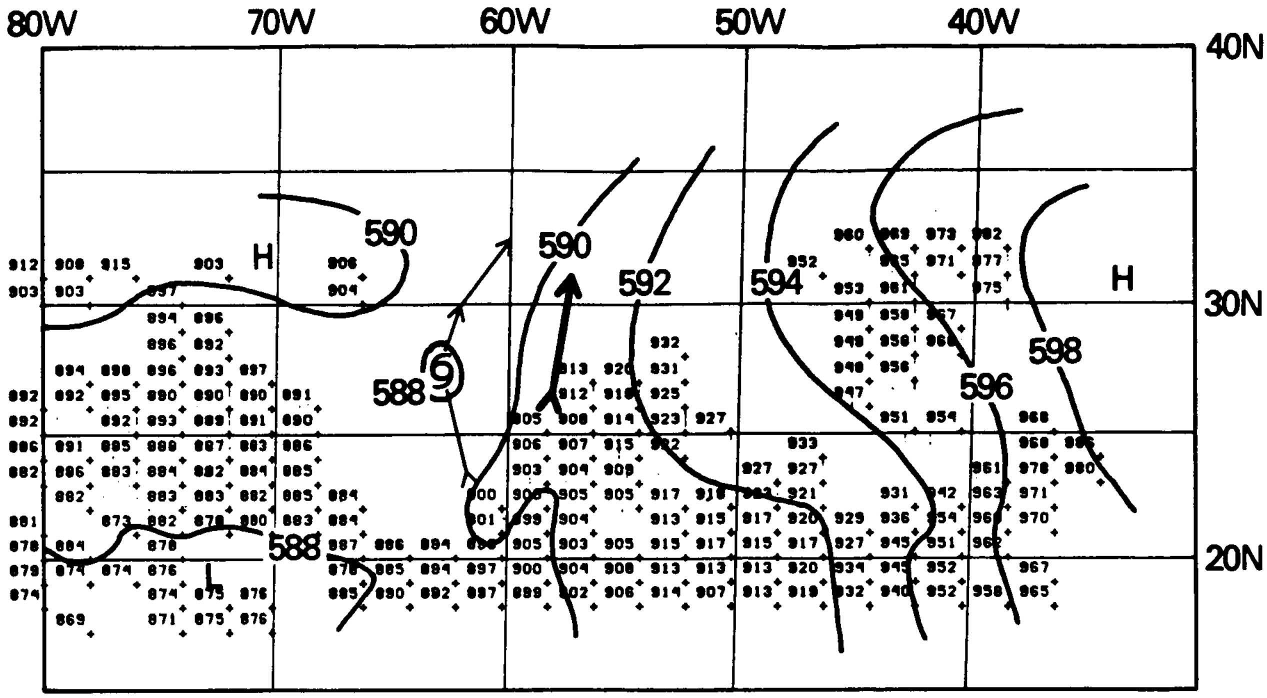

Fig. 5. Hurricane Harvey: 500 mb (14 September 1981, 2032 GMT). See Fig. 1 and the text for additional explanations.

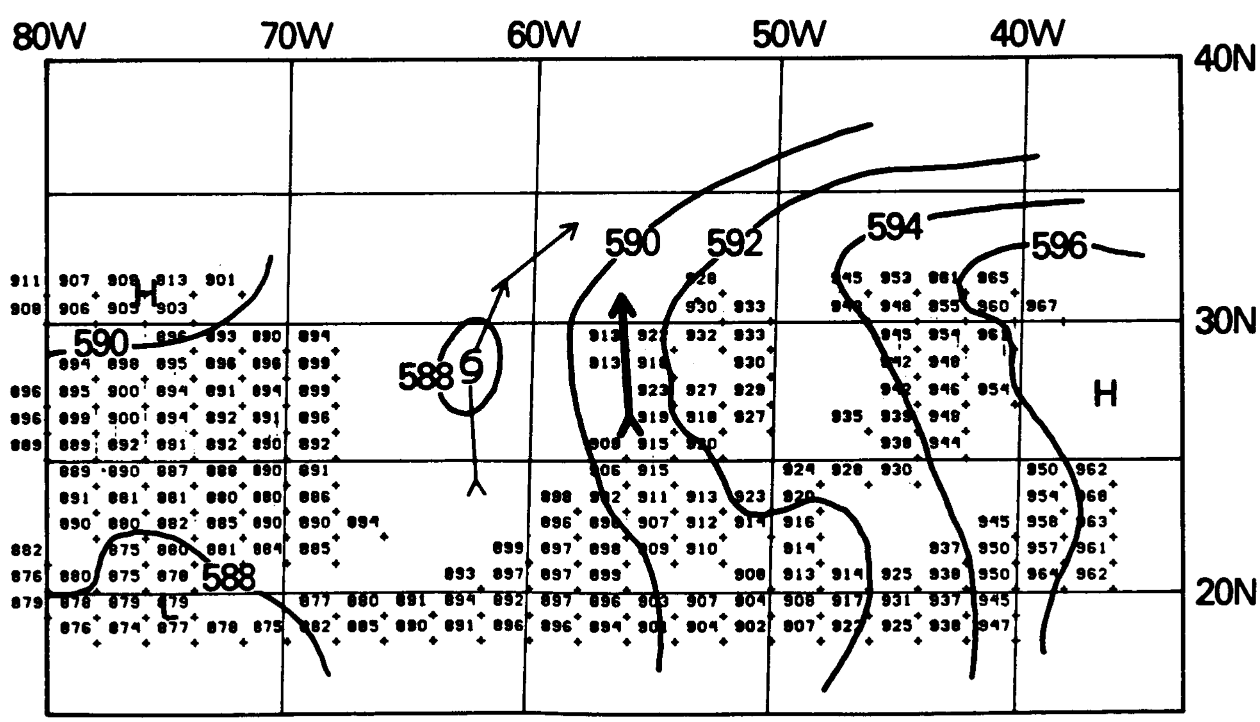

Fig. 6. Hurricane Harvey: 500 mb (15 September 1981, 0231 GMT). See Fig. 1 and the text for additional explanations.

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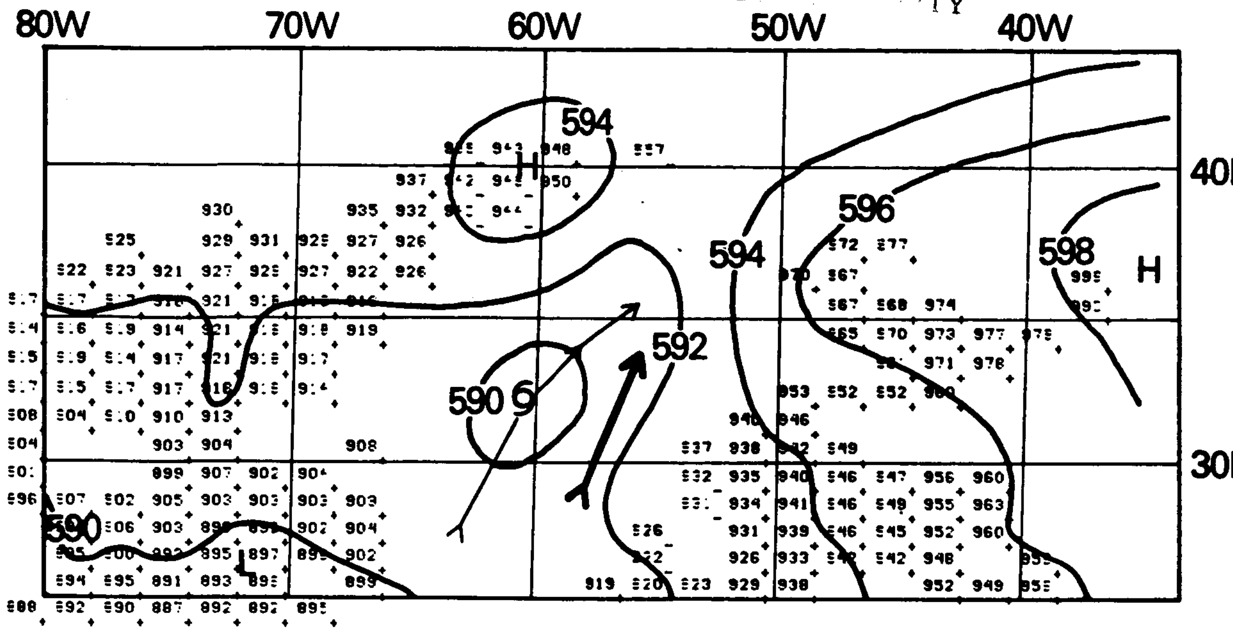

Fig. 7. Hurricane Harvey: 500 mb (15 September 1981, 1732 GMT). See Fig. 1 and the text for additional explanations.

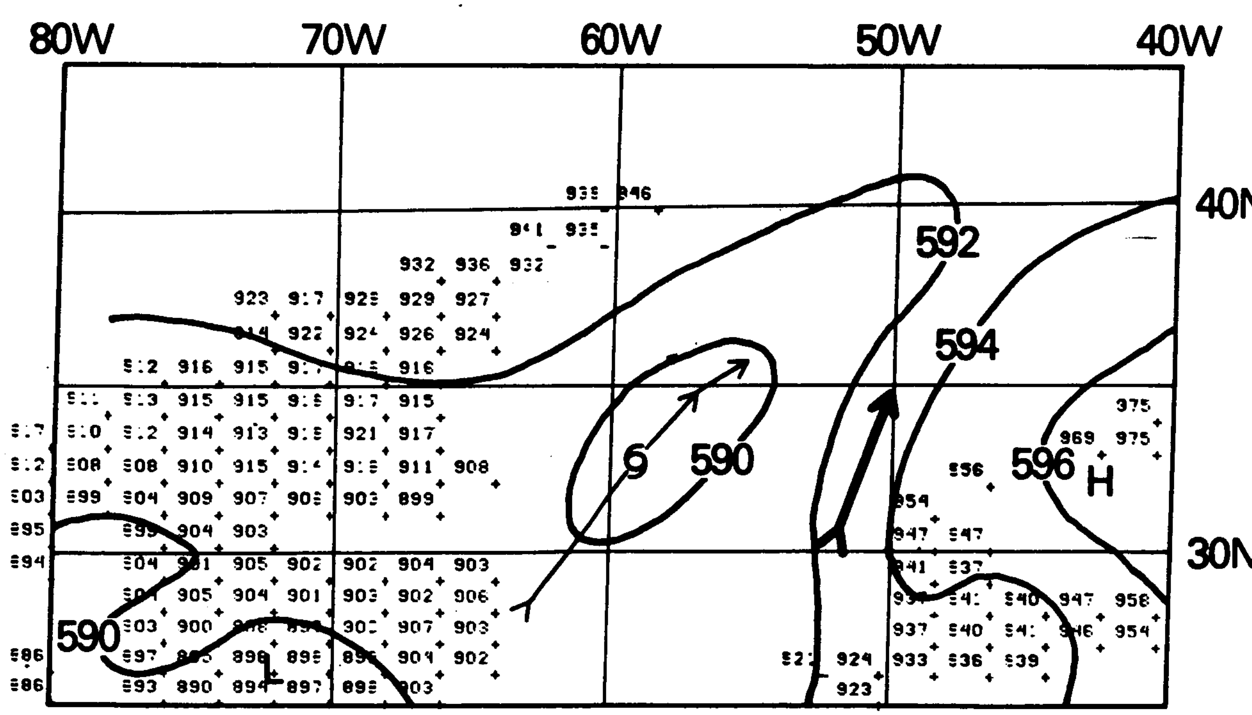

Fig. 8. Hurricane Harvey: 500 mb (15 September 1981, 2332 GMT). See Fig. 1 and the text for additional explanations.

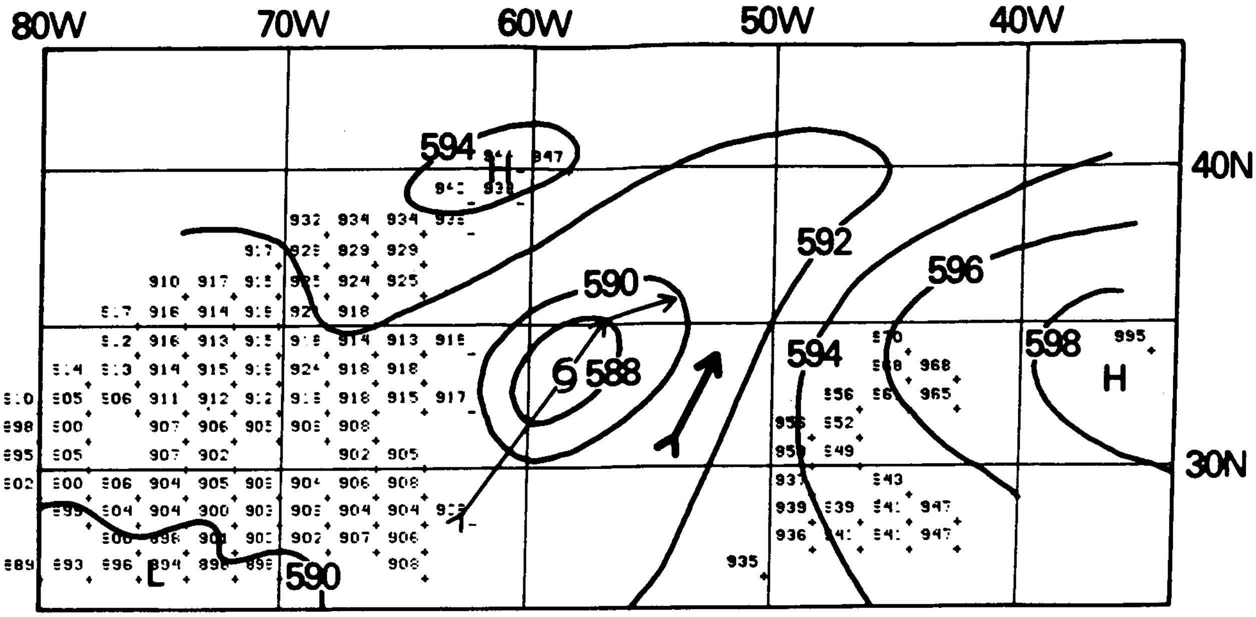

Fig. 9. Hurricane Harvey: 500 mb (16 September 1981, 0235 GMT). See Fig. 1 and the text for additional explanations.

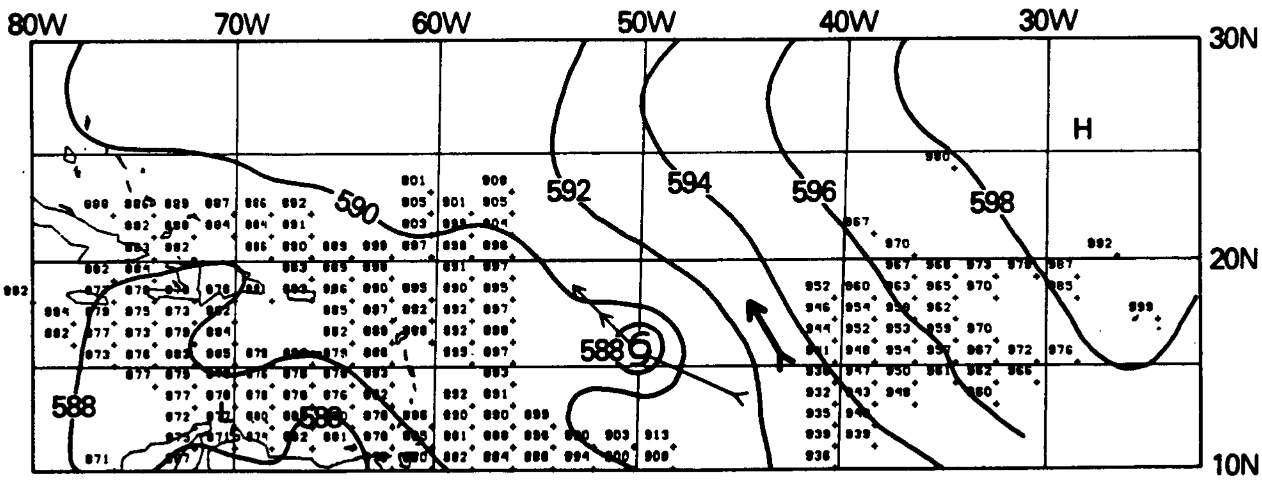

Fig. 10. Hurricane Irene: 500 mb (24 September 1981, 2333 GMT). See Fig. 1 and the text for additional explanations.

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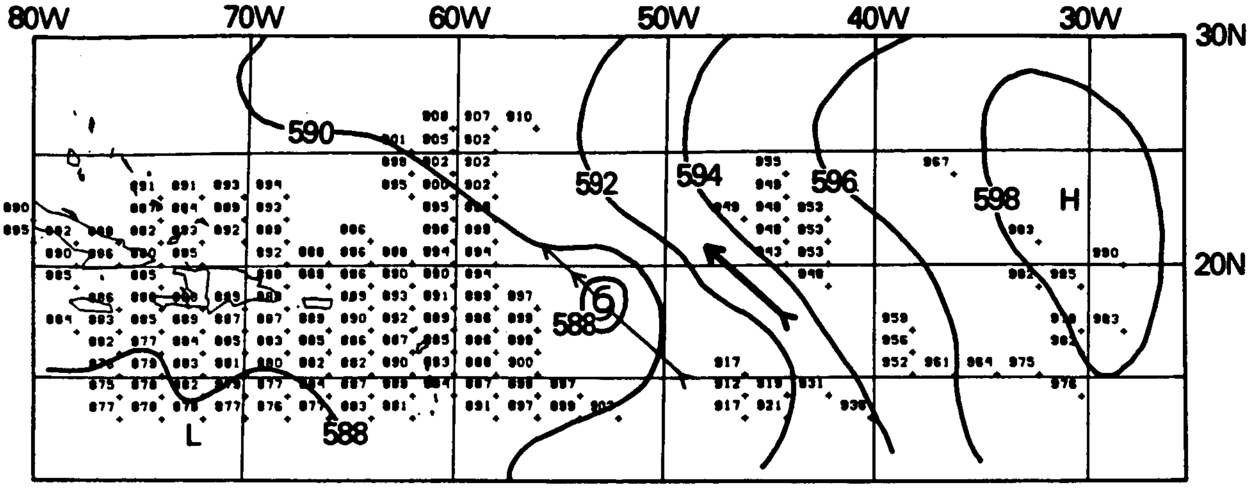

Fig. 11. Hurricane Irene: 500 mb (25 September 1981, 2032 GMT). See Fig. 1 and the text for additional explanations.

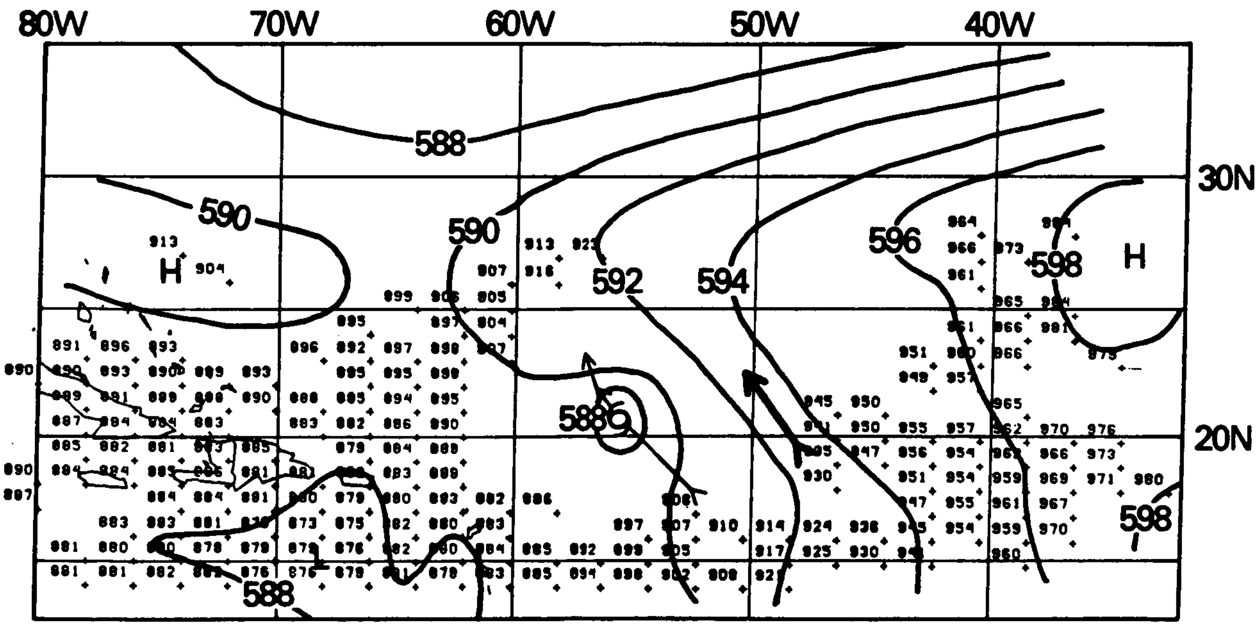

Fig. 12. Hurricane Irene: 500 mb (26 September 1981, 1431 GMT). See Fig. 1 and the text for additional explanations.

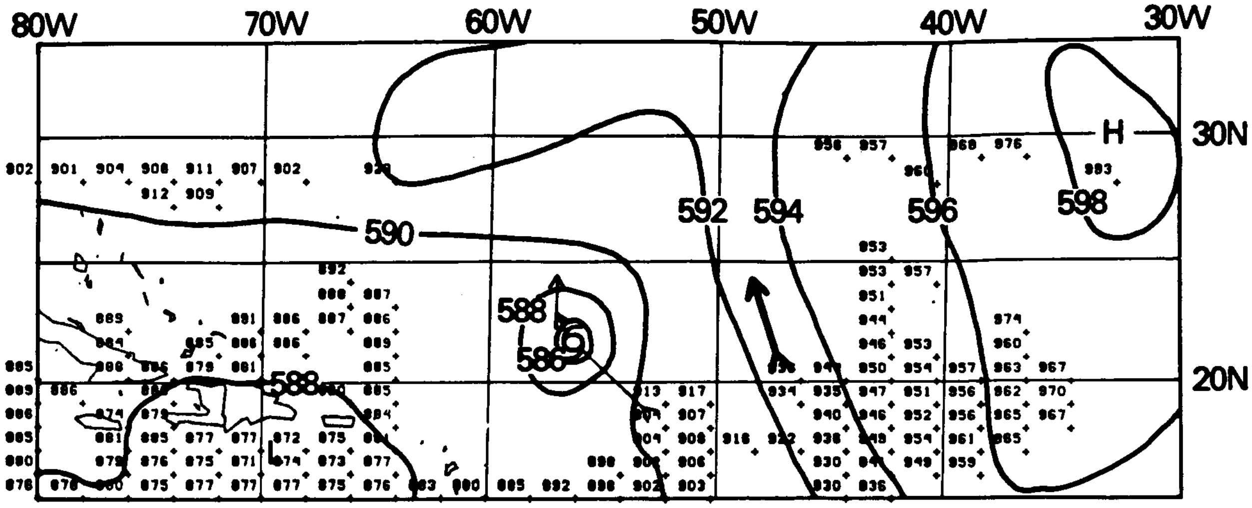

Fig. 13. Hurricane Irene: 500 mb (26 September 1981, 2331 GMT). See Fig. 1 and the text for additional explanations.

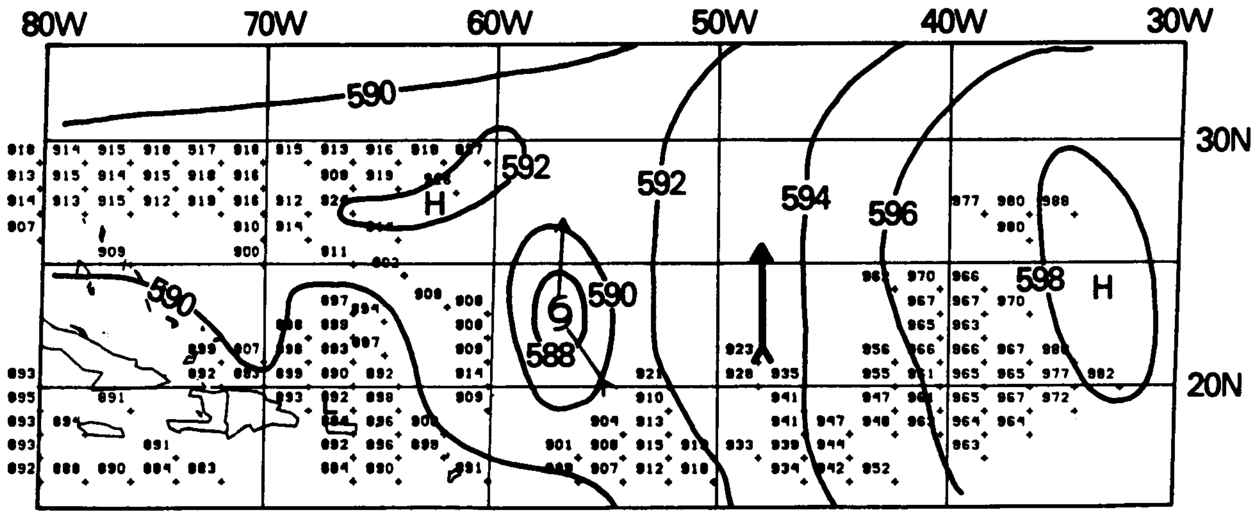

Fig. 14. Hurricane Irene: 500 mb (27 September 1981, 1133 GMT). See Fig. 1 and the text for additional explanations.

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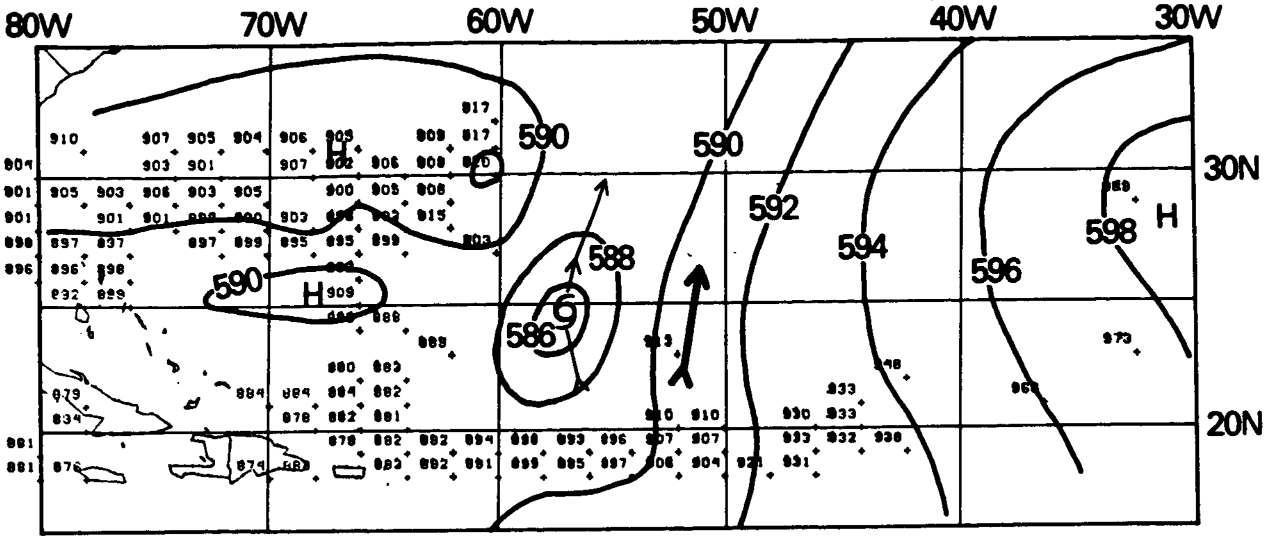

Fig. 15. Hurricane Irene: 500 mb (27 September 1981, 2331 GMT). See Fig. 1 and the text for additional explanations.

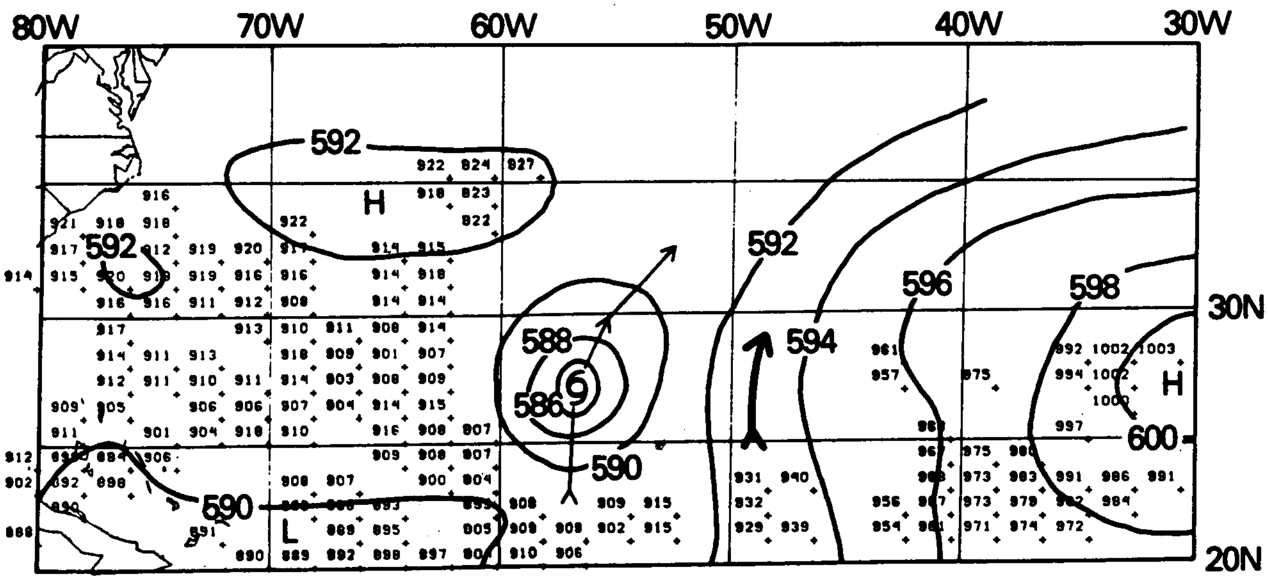

Fig. 16. Hurricane Irene: 500 mb (28 September 1981, 1137 GMT). See Fig. 1 and the text for additional explanations.

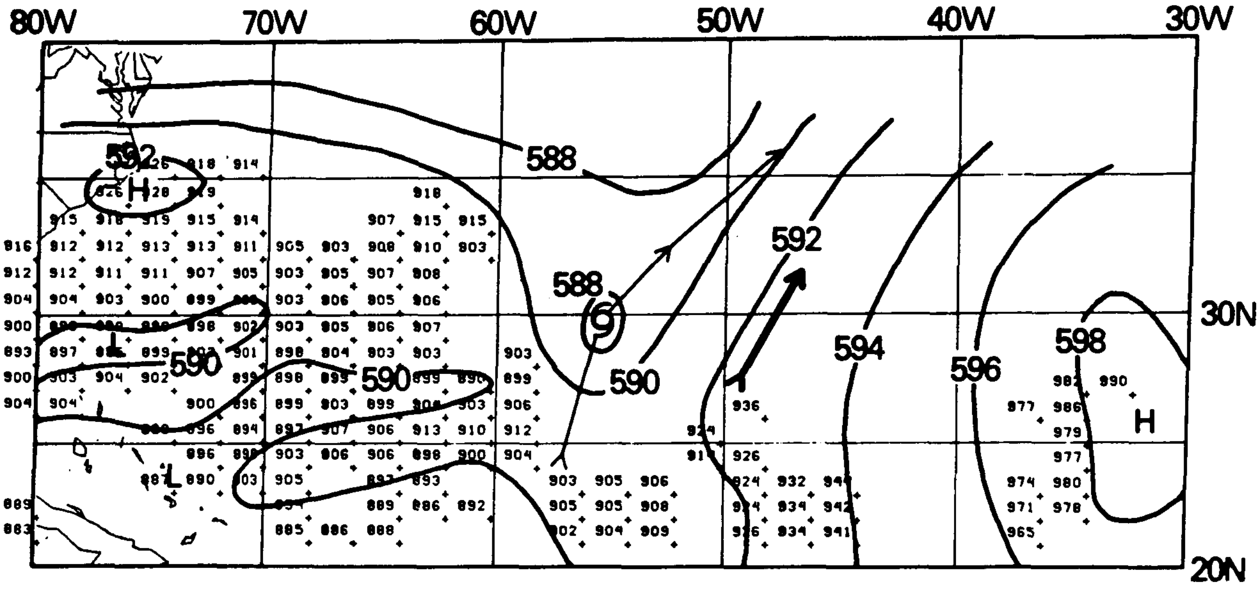

Fig. 17. Hurricane Irene: 500 mb (28 September 1981, 2331 GMT). See Fig. 1 and the text for additional explanations.

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However, to make possible more frequent coverage of the selected areas containing the tropical cyclones, the north-south coverage was relatively limited as is evident in the Figures. Data are plotted for all grid points in the area scanned by the satellite out for about 30° of longitude east and west of the storm center when satisfactory retrievals of the data could be obtained. Where data are not plotted in the belt scanned by the satellite for the respective times, it usually means there were too many clouds for satisfactory retrievals to be obtained. These cloudy areas are usually concentrated within a few hundred kilometers of the hurricane center, but sometimes extend for greater distances into one or more quadrants relative to the tropical cyclone center.

The isolines on the 500 mb charts (Fig. 1-17) were carefully drawn to agree with the retrieved heights. In general, only minor smoothing was permitted to eliminate some of the very small scale variations. The plotted numbers remain on the chart and the reader is invited to inspect how closely the lines fit the plotted values. When analyzing the charts in areas where there are no plotted values--especially in the latitude belts north of the plotted data--reference was made to the synoptic charts prepared by the National Weather Service at the National Meteorological Center (NMC). In these areas efforts were made to qualitatively fit the flow patterns delineated by the NMC charts rather than to reproduce exact isolines.

The heights reported at the rawinsonde stations (not plotted on the charts in Fig. 1-17) agree quite closely with the retrieved heights in the latitude belts south of about 25 degrees north latitude. At latitudes north of about 30 degrees there were some noticeable differences as will be discussed later.

On each chart to the east of the hurricane center is a heavy arrow representing the direction of motion the analyst thought was indicated by the 500 mb analysis for the tropical cyclone center. On each chart are also arrows indicating the movement of the storm center during the 24 hours before map time and 0-12 hours and 12-24 hours afterwards.

Qualitatively the storms did move in the general direction suggested by the analyzed height contours, i.e. with the approximate direction of the geostrophic wind. This was especially true when the storm center was at lower latitudes. For the charts where the center was north of about 27° latitude there was a tendency for the retrieved height values at latitudes north of the center to be too high. For example see Fig. 17. In the area near coastal North and South Carolina south of Cape Hatteras the retrieved heights were about 100 meters higher than the heights reported at the nearest rawinsonde stations. This magnitude of difference was not found on any of the charts for the rawinsonde stations in the Caribbean area. While the differences were larger on Fig. 17 than on many of the others, there was a tendency for the heights between 25 and 35 degrees latitude to be greater than the heights suggested by rawinsonde data at corresponding latitudes. This resulted in apparent anticyclones northwest of the tropical cyclone center on some of the charts which probably either did not exist or were much weaker in nature. Therefore, the analyzed charts for such situations did not show that the storm should be moving to the north or northeast as rapidly as it was moving. When the recurvature occurred farther south, however, the charts did suggest that the storm should be turning to a more north or northeasterly course than it had been following. See Figures 2 to 4 and 11 to 13.

The excessive heights at the more northerly latitudes will be discussed in Section 4, but in general are probably due to the training set of rawinsondes used in developing the regression equations prepared by Stout and Steranka being exclusively tropical soundings.

An effort to be more quantitative in the evaluation of the usefulness of the 500 mb flow was made by calculating the northward component of the geostrophic wind across the hurricane for each time the data were sufficient to support a reasonably objective calculation. Chan and Gray (1982) had compared winds averaged over a belt around the hurricane at distances of 555 to 777 km from the center with the speed of motion of the storm for a period from 6 hours earlier to 6 hours after the winds were measured. They found that the storm moved about 1 m s^{-1} faster than the mean winds. For our comparison we calculated the geostropic wind using a radius at 666 km from the storm center. The calculations were made only of the northward component of motion because there were too few cases where the east-west component could be calculated with the available data; that is, there were few cases where the height values 666 km both north and south of the center could be determined in an objective fashion from the retrieved values on the charts. The calculated speed of motion, the actual speed of motion for the next 24 hours, and the latitude of the storm for the beginning of the period are all reported in Table 2. Calculations were not made on a few of the charts in Fig. 1-17 because the plotted data did not adequately define the height at the necessary points east and west of the storm center in an objective fashion.

Table 2. Hurricane Movement and Northward Component of Geostrophic Wind.

(Using height values 666 km east and west of storm center)

Hurricane Harvey

Date Sept. 1981	Time G.M.T.	Lat of Storm Center	Calculated nwd-comp. of Geostrophic Wind $m\ s^{-1}$	Northward movement rate of Storm next 24 hours $m\ s^{-1}$
12	1432	19	5.3	4.5
13	0838	21	3.2	4.6
14	1432	27	1.8	5.8
14	2032	28	2.1	4.8
14	2334	28	2.0	6.4
15	0231	29	2.1	6.2
15	1732	32	1.3	4.2
	AVERAGE		2.5	5.2

Hurricane Irene

Date Sept. 1981	Time G.M.T.	Lat of Storm Center	Calculated nwd-comp. of Geostrophic Wind $m\ s^{-1}$	Northward movement rate of Storm next 24 hours $m\ s^{-1}$
24	2333	16	4.7	4.5
25	2032	18	4.8	3.1
26	1431	21	4.2	3.3
26	2331	22	3.2	3.7
27	1133	23	2.5	5.0
27	2331	25	2.4	6.6
	AVERAGE		3.6	4.4

The northward component of motion for Hurricane Irene averaged 0.8 m/s greater than the calculated geostrophic winds and for Hurricane Harvey averaged 2.7 m/s greater. The greater differences between the geostrophic winds and the movement occurred when the storm center was at or north of 27° latitutde. For cases where the center was south of 27°, the average difference between the geostrophic component and the north component of movement was 0.3 m/s. This compares quite favorably with the Chan and Gray results even though they used mean winds, (not geostrophic winds) and compared with the "instantaneous" storm movement rather than the movement for the next 24 hours.

The above results suggest that the constant pressure charts developed from the retrieved heights of constant pressure surfaces can furnish information that provides the basis for reasonable 24-hour forecasts of hurricane motion at least for the 2 storms studied. The data for the other storms listed in Table 1 were also studied. Unfortunately, either they did not change course during the period of the data or data were not available at critical times. To the extent that data were available, they did suggest the correct answers at least qualitatively.

b. Does VAS contribute data not already available?

The question still remains, "Are the VAS data contributing anything not available from other sources?" To answer this question, the 200 mb level was used. This level was chosen because since the jet aircraft largely replaced the propeller driven aircraft, more inflight winds have been reported at the 200-mb level than at the 500-mb level. Fig. 18 and 20 are 200-mb maps prepared in a fashion similar to the 500-mb maps described earlier. While one example each for Hurricanes Harvey and Irene are presented, they are representative and the conclusions to be drawn apply to

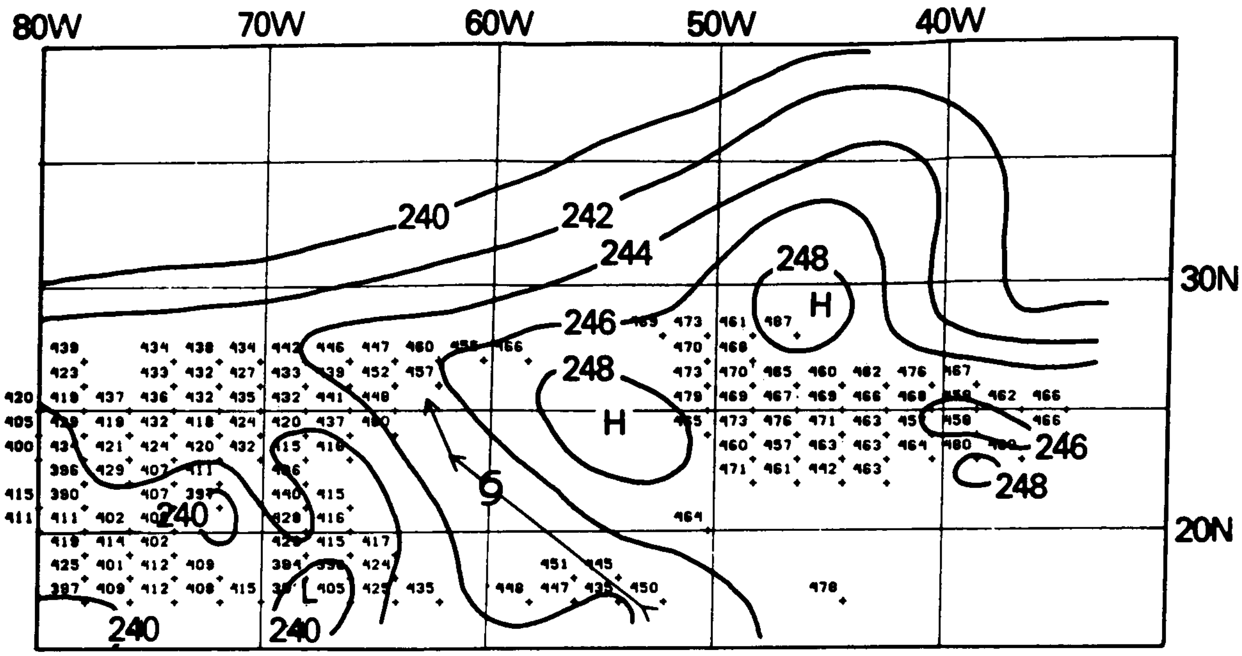

Fig. 18. Hurricane Harvey: 200 mb (13 September 1981, 0838 GMT). See Fig. 1 and the text for additional explanations.

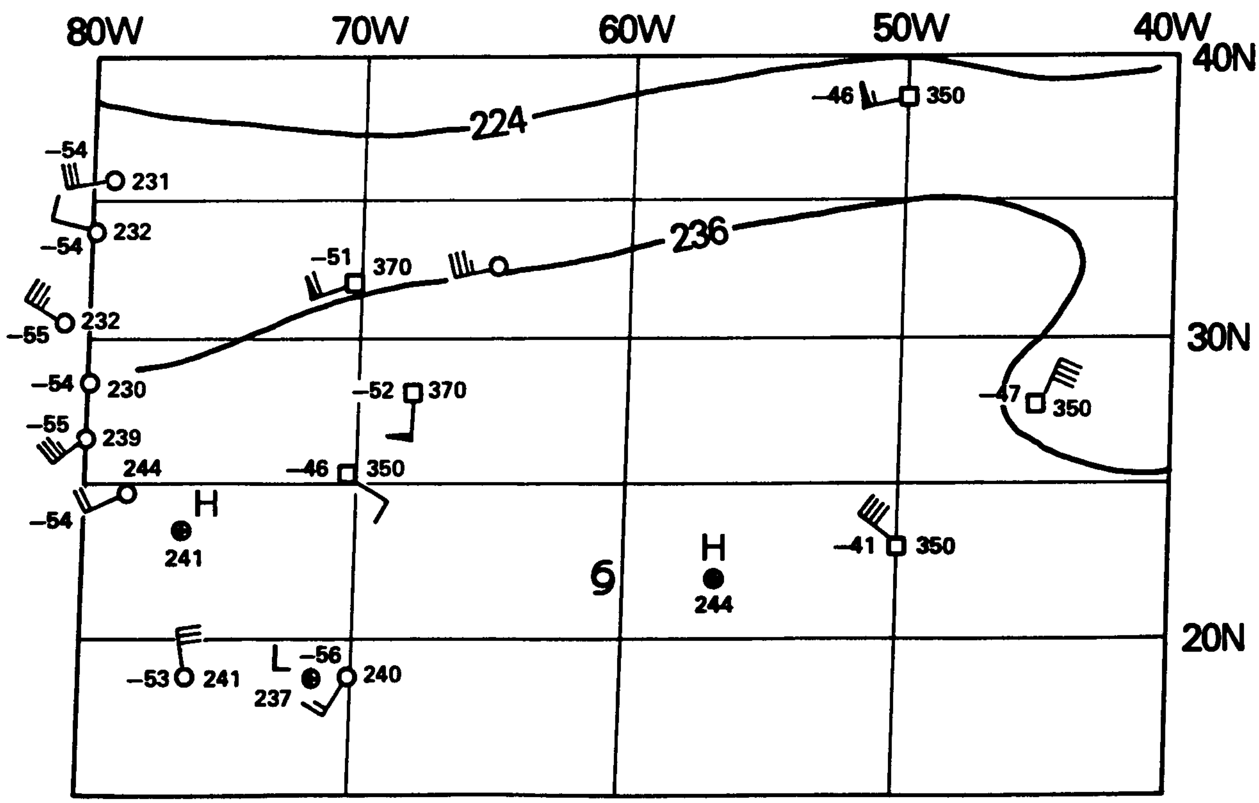

Fig. 19. NMC 200 mb Analysis (13 September 1981, 1200 GMT). Partial reproduction of 1200 GMT 13 September 1981 200 mb map prepared at the National Meteorological Center. The time is less than 3.5 hours different than the time of the map in Fig. 18.

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most of the other maps. Fig. 18 is the 200-mb map for Hurricane Harvey at 0838 GMT 13 September 1981. Fig. 19 is a reproduction of a portion of the 200-mb map prepared at the NMC for 1200 GMT 13 September 1981. All the height contours, all the high and low centers marked on the NMC map for the area shown are reproduced on Fig. 19. In addition, all the data that are on the NMC map are reproduced except for the satellite data (either from the VAS or one of the other weather satellites). Note the wealth of detail in Fig. 18 compared to Fig. 19 for the area of the VAS data, that is, between 17° and 28° North. Of course the hurricane forecasters had access to the satellite data and thus had more information than is reproduced in Fig. 19, but if they had been limited to the information in Fig. 19, it seems obvious that they would have welcomed the additional information contained in Fig. 18.

Fig. 20 and 21 provide similar illustrations for Hurricane Irene. Fig. 20 is the VAS map for 1431 GMT 26 September and Fig. 21 is the reproduction of a portion of the NMC 200 mb map for 1200 GMT 26 September 1981 similar to Fig. 19. Again the same conclusions apply. That is, for many areas of the world the VAS data can furnish pertinent urgently needed information that is not normally available to the weather analysts and forecasters except from some satellite.

Fig. 22 and 23 are the 500 mb charts corresponding to Fig. 19 and 21. They again reproduce all the data and analyses of the NMC charts except for the satellite data. Compare Fig. 22 with Fig. 3 and Fig. 23 with Fig. 12. In these cases, the hurricane center is near the rawinsonde stations in the Caribbean and a hurricane reconnaissance aircraft provided some wind information, yet there is still much less detail on the NMC charts (with satellite data deleted) than on those prepared with the VAS data.

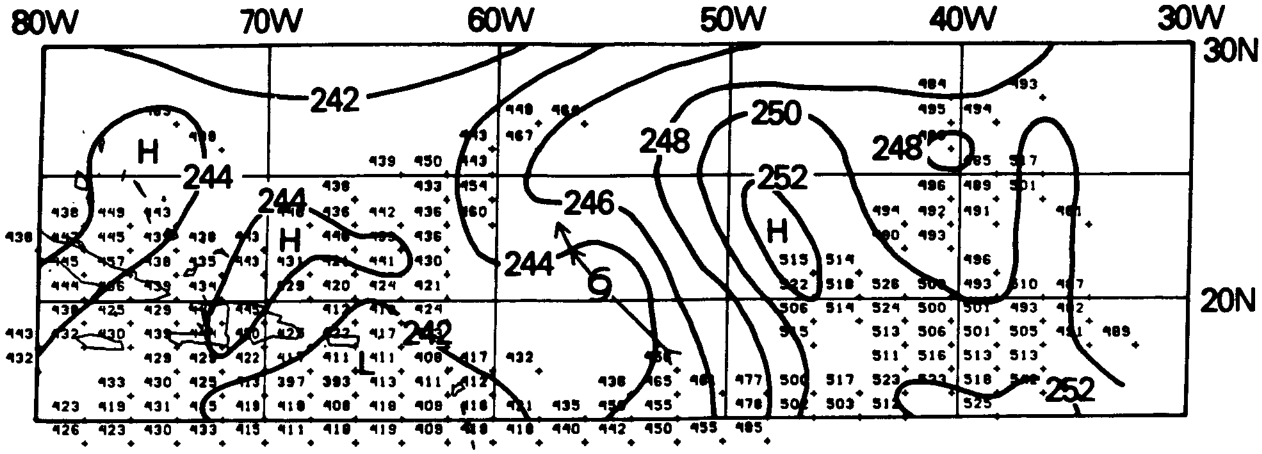

Fig. 20. Hurricane Irene: 200 mb (26 September 1981, 1431 GMT). See Fig. 1 and the text for additional explanations.

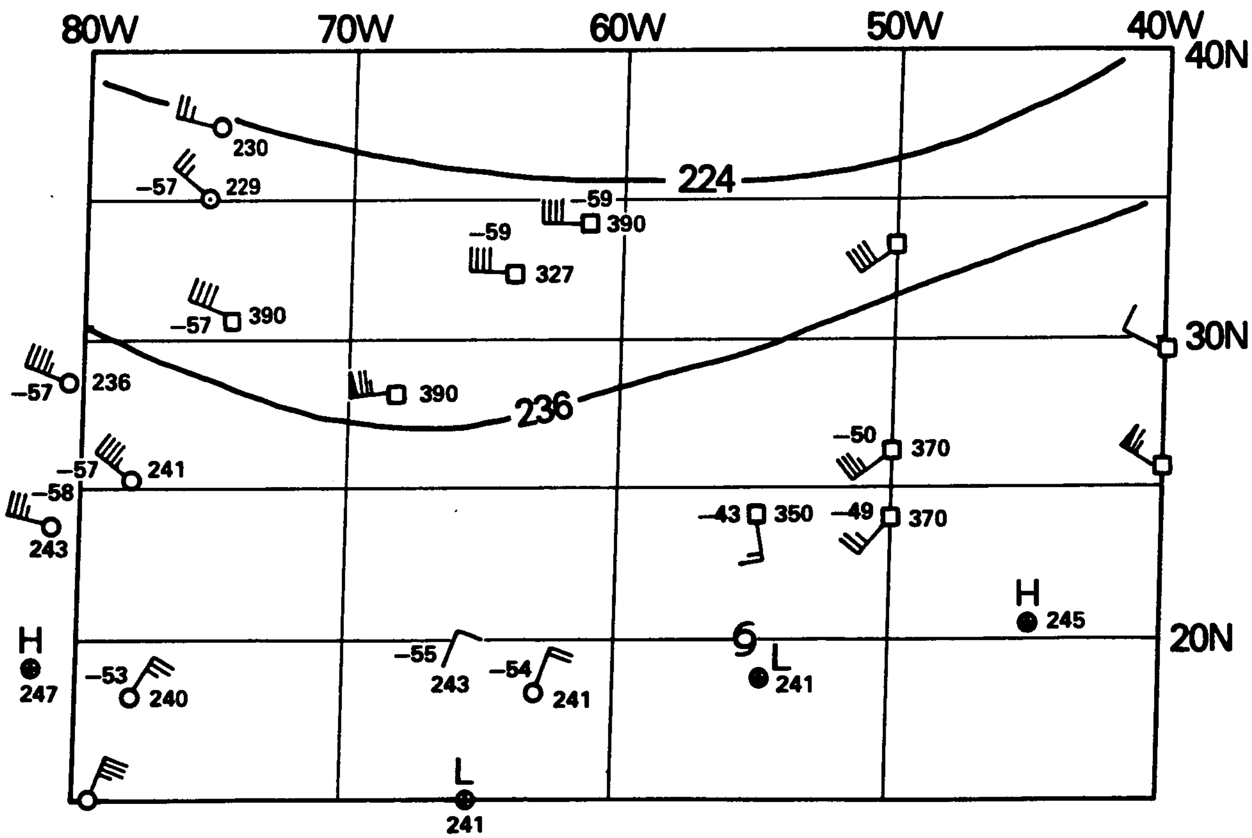

Fig. 21. NMC 200 mb Analysis (26 September 1981, 1200 GMT). Partial reproduction of 1200 GMT 26 September 1981 200 mb map prepared at the National Meteorological Center. The time is 2.5 hours earlier than the time of the map in Fig. 20.

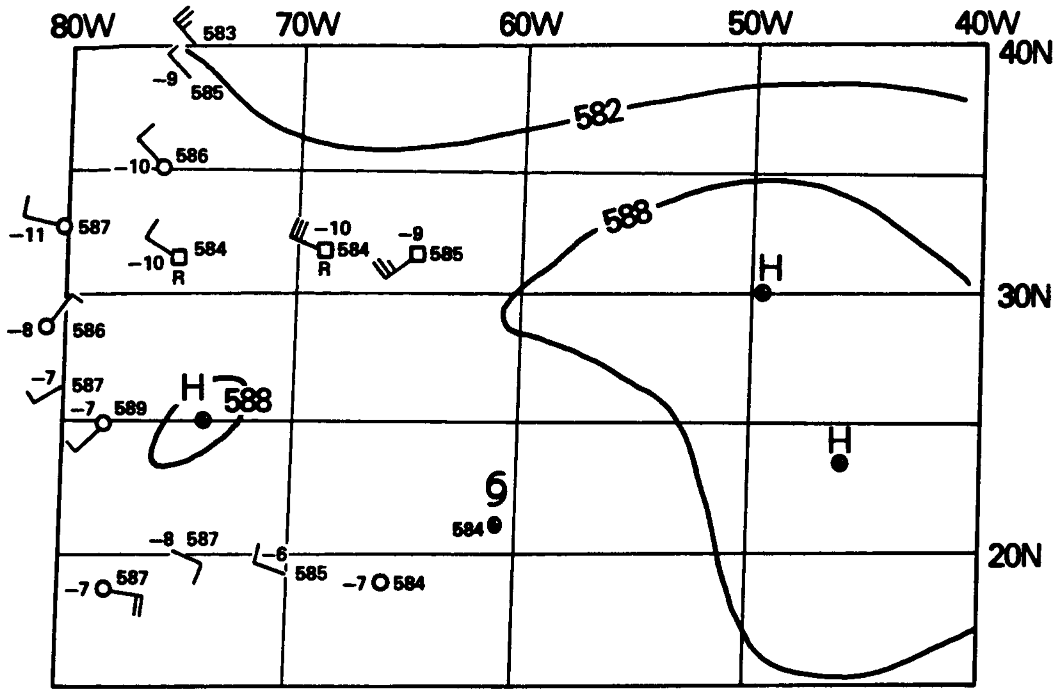

Fig. 22. NMC 500 mb Analysis (13 September 1981, 1200 GMT). Partial reproduction of 1200 GMT 13 September 1981 500 mb map prepared at the National Meteorological Center. The time is the same as that in Fig. 19 and within 3.5 hours of the time in Fig. 3.

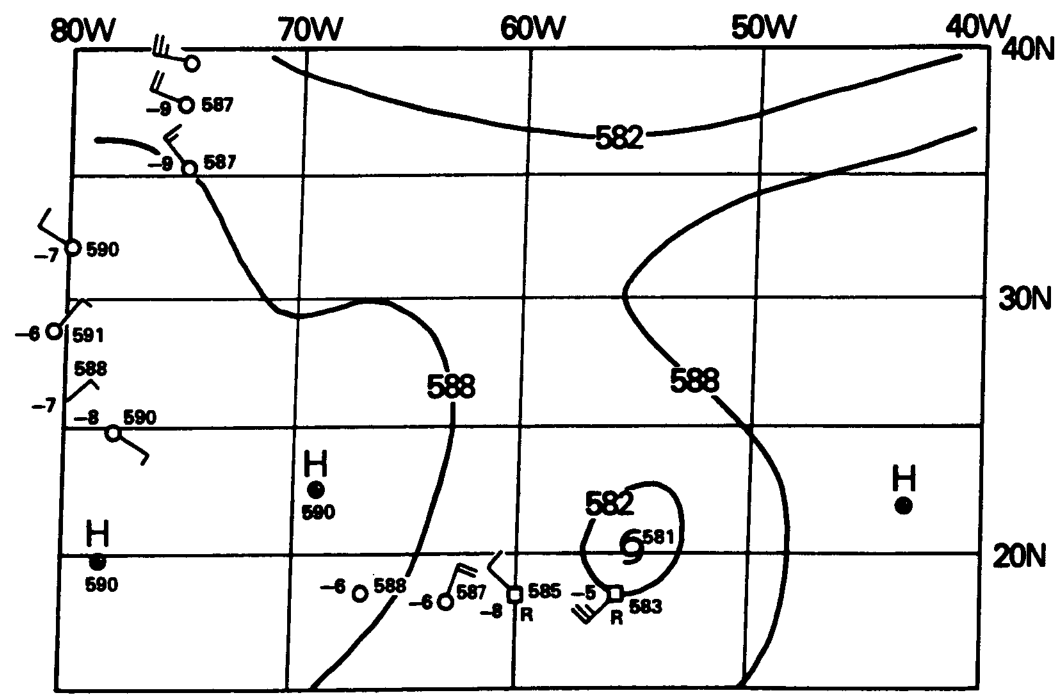

Fig. 23. NMC 500 mb Analysis (26 September 1981, 1200 GMT). Partial reproduction of 1200 GMT 26 September 1981 500 mb map prepared at the National Meteorological Center. The time is the same as that in Fig. 21 and is 2.5 hours earlier than the time of the map in Fig. 12.

c. Cloud Patterns

Various attempts have been made in the past to relate the cloud patterns observed by satellites to succeeding movement of the tropical cyclone. Fett and Brand (1974) developed a scheme for forecasting changes in direction of motion for typhoons in the Western North Pacific using visible and infrared data from the Department of Defense satellites. More recently, Dvorak (1984) developed and tested a forecast scheme using the moisture patterns measured by the GOES VAS-6.7 micron imagery taken at 6-hourly intervals to forecast changes in direction of motion of hurricanes in the Eastern and Central Pacific and the Western Atlantic. He used the data from the 1982 and 1983 hurricane seasons. We tested his forecast rules on the 1981 storms using data collected by VAS. Hurricane Irene had the patterns that called for recurvature at the time that the storm was recurving. Hurricane Harvey did not provide as positive verification. This could be due to lack of experi- ence of the writer in applying the rules, or that Harvey's changes in direction were much more gradual, and the criteria might not have been as easily recognized. Although the 1982 storms were used by Dvorak in his study, they were also examined by the writer. There were no cases of re- curvature involved; likewise the moisture patterns did not call for large changes in direction under the rules listed by Dvorak. Thus in general the study was supportive of Dvorak's hypothesis even though the number of cases were too few to provide strong verification.

The regression equations developed by Stout and Steranka were also used to retrieve values of total precipitable water. The charts for the 400-mb to 600-mb layer were used qualitatively in the sense Dvorak had used the 6.7 micron patterns. Again there was a positive correlation with the direction of movement, but the cases were too few to provide strong support.

d. Data in Mostly Cloudy Areas

The meaningful information one can obtain from VAS is limited when the pertinent areas are covered with clouds which is often true for some portions of the area around a hurricane. The argument is frequently advanced that by having VAS on a geosynchronous satellite one can obtain observations at frequent intervals, and that would permit collecting data at points which are obscured by clouds part of the time but are visible through breaks in the clouds at other times. To test this claim the data for Hurricane Emily were examined because the VAS radiances for 3-hourly intervals were collected from 1132 GMT 2 September 18 through 0232 GMT 3 September 1981. Fig. 24 is the 300 mb chart prepared for 1132 GMT 2 September in a fashion similar to Fig. 1-17. Note there are large areas to the East of the hurricane center with no data. The 300-mb charts at other times were inspected to see if having data at 3-hourly intervals would support a meaningful analysis for the Emily data. Fig. 25 shows a tabulation of the number of times out of a possible total of six there were data at each grid intersection. Lines are drawn for the 3 and 6 frequencies. The area enclosed by the six-frequency is also hatched. There are still areas of no data, but the area where data were available at least half of the time is much greater than the area of data in Fig. 24. In the case of Emily, the VAS satellite was programmed to scan only as far north as the 38th parallel, so absence of data farther north of there is not at issue in this case.

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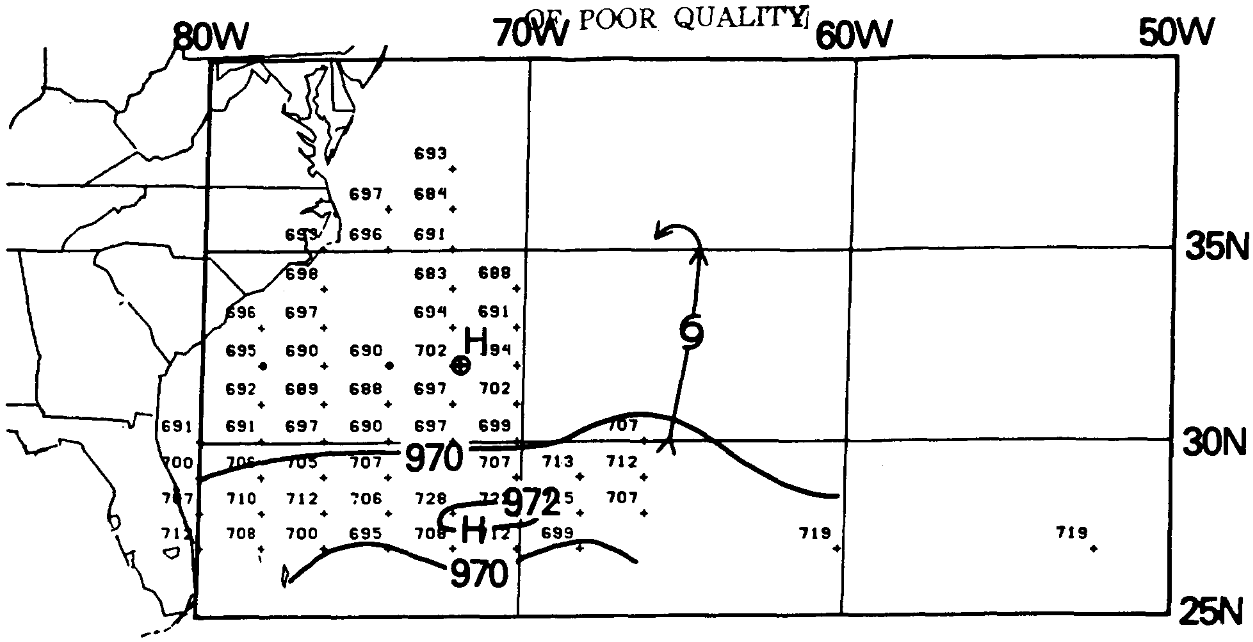

Fig. 24. Tropical Storm Emily: 300 mb (2 September 1981, 1132 GMT). See Fig. 1 and the text for additional explanations.

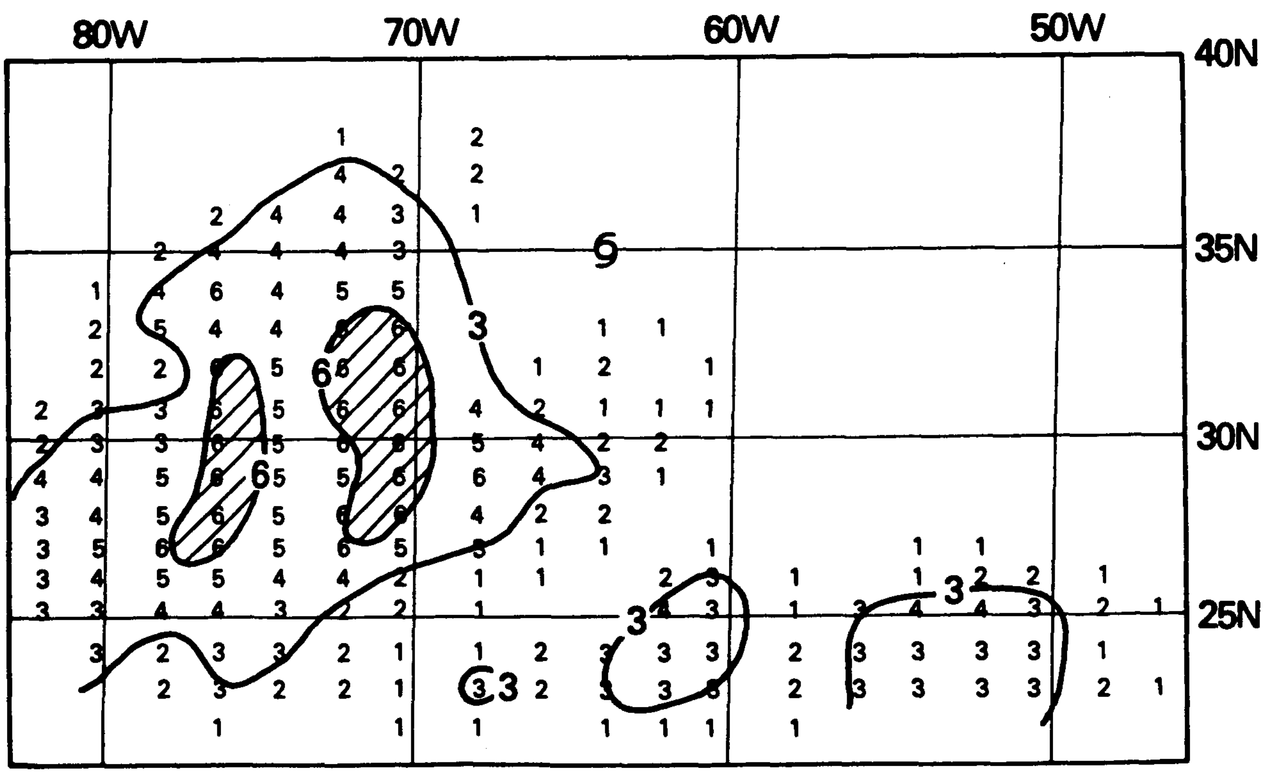

Fig. 25. Data Availability for Tropical Storm Emily (1981: 2 September, 1132 GMT-3 September, 0232 GMT). Frequency diagram of availability of retrieved data for Tropical Storm Emily for period 1132 GMT 2 September through 0232 GMT 3 September 1981. Hurricane symbol marks approximate location of the storm center during the period.

e. Winds

The winds that can be obtained by tracking clouds have long been known to be useful in forecasting. Rodgers and Gentry (1983) showed by having imagery at frequent intervals one could obtain more winds around a hurricane than by having data at 30-minute intervals. However, the VAS was not programmed to obtain imagery at frequent intervals so that technique was not available.

Gentry (1983) showed that the winds at 1000 to 2000 km northwest and north of the hurricane center could be used with considerable success to forecast recurvature of tropical cyclones. The clouds in the VAS cases were tracked when imagery were available in the appropriate areas. No data were found inconsistent with the earlier results. The necessary imagery was not available for many cases, but there is every reason to believe that this technique could be used in connection with the VAS observations when the VAS was programmed to collect the data in the appropriate areas.

A group at NOAA/NEDIS Application Laboratory at the University of Wisconsin has experimented with a technique to obtain winds by tracking patterns in the imagery from the water vapor channel (one of the VAS infrared channels). For example, see Stewart et al., (1985) and Stewart (1985). Preliminary results have been very interesting and opens another avenue by which the VAS may contribute to hurricane forecasting.

4. DISCUSSION OF RESULTS AND RECOMMENDATIONS

The results presented in Section 3 strongly suggest that the data retrieved from the VAS can be very useful in areas that are relatively void of other high quality data. This includes many of the regions of the world, especially over the tropical oceans—areas of great importance in forecasting for hurricanes. With the data presented for Hurricanes

Harvey and Irene, also analyzed for other storms but not presented, the VAS data support analyses of great detail and reasonable accuracy at least in the tropics south of 27° north latitude. At the more northerly latitudes the retrieved heights were too great and caused some errors in the analyses. This deficiency could be eliminated by use of another training set in developing the regression equations used in retrieving the heights. Because rawinsonde stations in the area studied were mostly from the tropics, the training set for developing the regression equations to retrieve the data was all from tropical stations. The results therefore were naturally much better for the tropical and sub-tropical latitudes than for the areas farther north. By using soundings from stations located farther north in a training set, one should be able to develop regression equations that would provide more accurate data for the more northerly latitudes.

Two other deficiencies showed in the data in figures 1 through 17. First, in many cases there were areas covered by clouds that prevented retrieving data in one or more quadrants of the hurricane. As shown in Section 3C having data at frequent intervals can help solve this problem. It would be desirable however to have a microwave sounder included in the next version of the VAS instrument. This would permit obtaining data in the cloudy areas even though they might not have as good resolution as data from the VAS instrument used in 1982 and 1983. The other problem is related to collecting data farther north of the storm than was done in some of the 1982 and 1983 cases. This is a simple matter of having the satellite programmed to scan over a broader latitudinal band.

5. CONCLUSIONS

An instrument such as the VAS can furnish data that are very useful in hurricane forecasting by supplying information in many areas where quality data are not otherwise readily obtainable. The north-south components of the geostrophic winds agreed with the succeeding 24-hour north-south component of the movement of the hurricane within 0.3 ms^{-1} on the average for cases in Hurricanes Harvey and Irene when the center was south of 27 degrees north latitude. The usefulness of the VAS can be greatly improved by using a microwave sounder with it.

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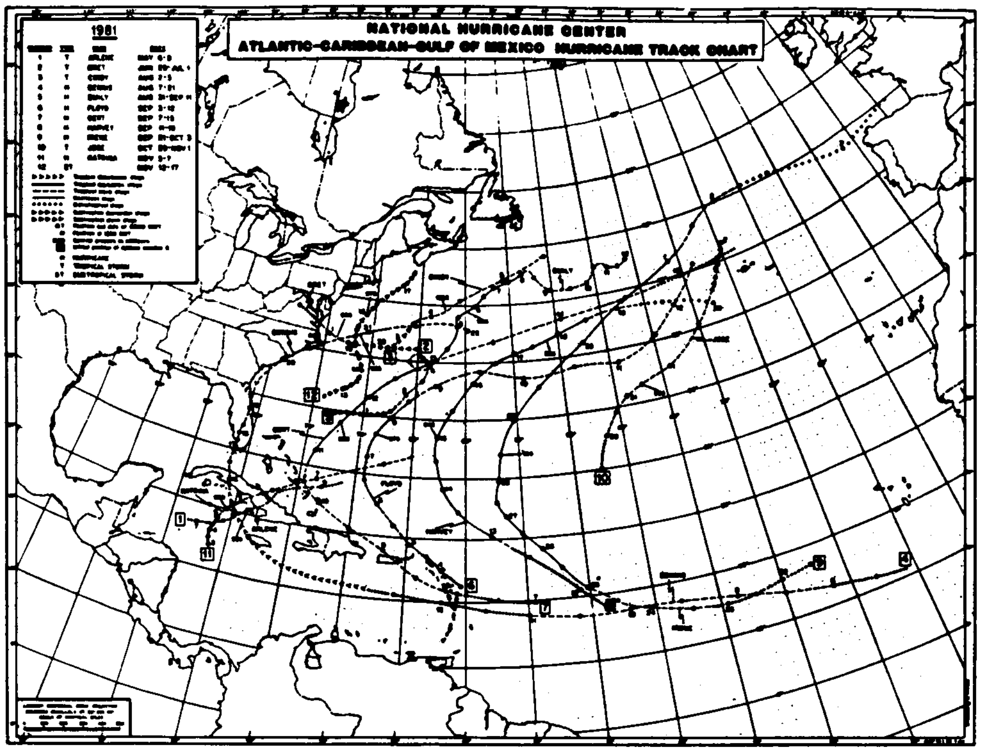

Fig. 26. Tropical Cyclone Tracks: 1981. Reproduced from Lawrence and Pelissier (1982).

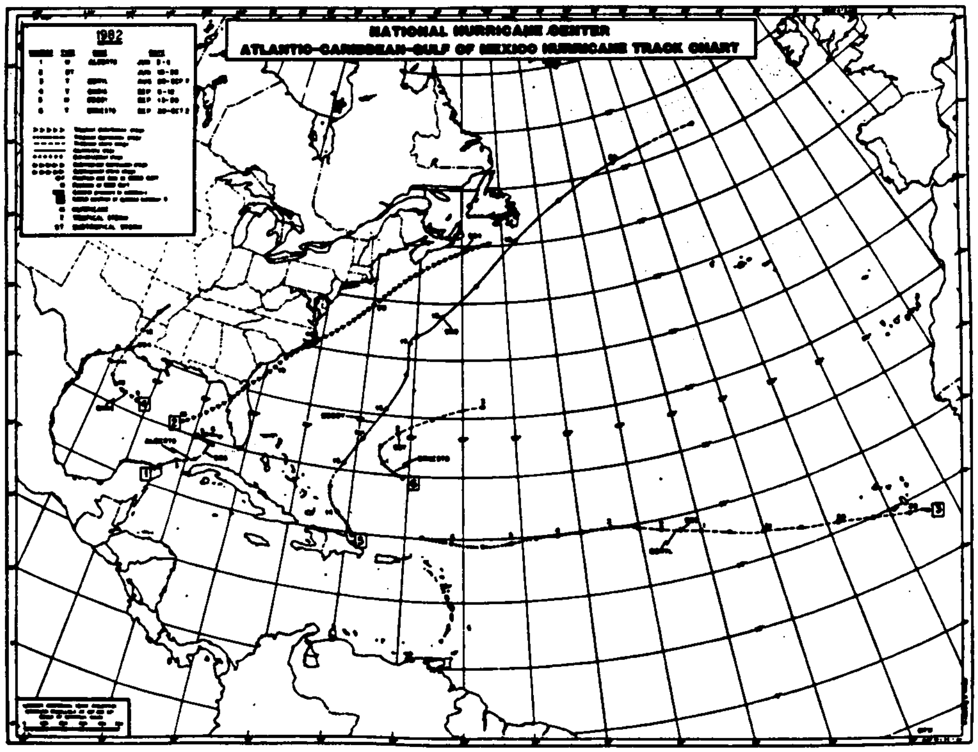

Fig. 27. Tropical Cyclone Tracks: 1982. Reproduced from Clark (1983).

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15. Supplementary Notes

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16. Abstract

Data collected on special "hurricane days" by the VAS instrument flown on a satellite in 1981 and 1982 were studied for their usefulness in forecasting motion of hurricanes. The retrieved constant pressure heights for the 500-mb surface provided the basis for reasonable forecasts of 24-hour hurricane motion. The conclusions are illustrated with examples from Hurricane Harvey (1981) and Hurricane Irene (1981). Recommendations are made for future use of the VAS type instruments for tropical cyclone forecasting.

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