The Marine Laboratory
Institute Of Marine Science
UNIVERSITY OF MIAMI

MESOSCALE STUDIES OF INSTABILITY PATTERNS AND WINDS IN THE TROPICS

Second Interim Technical Report
1 September 1962 - 31 December 1962

to

U. S. Army Electronics Research and Development Laboratory
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April 1963

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To extend knowledge of tropical mesometeorology for non-hurricane disturbances; to investigate the utilization of weather radar for filling tropical data voids; to develop short-range forecasting techniques for mesoscale systems in the tropics.

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PURPOSE

This research is directed toward mesoscale studies of instability patterns and winds in the tropics. Of primary concern are waves in the easterlies which affect southern Florida and adjacent waters.

The purpose of this research is:

1. to advance knowledge of tropical mesometeorology, particularly with respect to waves in the easterlies.
2. to investigate the utilization of weather radar for filling data voids in the tropics.
3. to develop short-range forecasting techniques for mesoscale systems in the tropics.

The research was initially divided into tasks as listed in the First Interim Technical Report [1]. Work is planned around these tasks for several case studies. Criteria for case selection were described in [1].

The first report covered wind studies and radar precipitation echo movement for the case of 1800Z, 8 August 1958. This report summarizes similar studies for the case of 1800Z, 26 August 1961, but with particular reference to the translational motion of certain specific echoes and cells. An analysis of the cloud cover as seen by Tiros satellite is included.

ABSTRACT

The synoptic situation and an analysis of the cloud cover as seen by Tiros III satellite is presented for a case study of 1800Z, 26 August 1961. Particular reference is made to the translational motion of precipitation echoes in the tropics, as determined by tracking selected small echoes and cells. Comparisons of these motions are made with winds aloft.

The space-smoothed translational motion of precipitation echoes in this case study most nearly represented the wind flow at 10,000 ft.

PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

Publications, lectures and reports

There were no publications, lectures or reports resulting from this research for the period 1 September - 31 December 1962.

Conferences

There were no conferences with regard to this research during the period 1 September - 31 December 1962

LIST OF DEFINITIONS APPLICABLE TO THIS REPORT

MESOMETEOROLOGY	- Mesometeorology is the study of meteorological systems which range in size from 2 to 500 miles, as suggested by Fujita [2].
MESOSCALE	- Mesoscale refers to the horizontal scale of mesometeorological systems.
INSTABILITY PATTERNS	- The rather broad array of convective patterns are called "instability patterns". In the tropics this refers to phenomena including waves in the easterlies, sea breeze fronts, hurricane spiral bands (excluded from this research), etc.
WAVES IN THE EASTERLIES	- Fairly sinusoidal oscillations in the low-level tropical easterly current are referred to as "waves in the easterlies". Some may extend to the upper troposphere. According to Riehl [3], they are accompanied by pressure waves and the troughs and ridges in the pressure field correspond to the troughs and ridges in the wind field. It is assumed that this is true for all scales of "waves in the easterlies".
EASTERLY WAVE	- The expression "easterly wave" is reserved for rather intense waves in the easterlies with extensive accompanying weather. Relatively large regions experience prolonged cloudiness with many areas receiving moderate to large amounts of rainfall. Tropical cyclones or hurricanes may spawn from these waves. Very few waves in the easterlies qualify as "easterly waves".
SCOPE OF STUDY	- The scope of this research is confined in general to the lower and middle portions of the tropical troposphere.
GEOGRAPHICAL AREA OF STUDY	- The primary area of study centers around southern Florida and adjacent waters. Analysis of the area between 15°N-31 $1/2^{\circ}$N and 68°W-91°W was considered as the minimum required for proper description of synoptic-scale systems in the primary area.
TYPE OF ECHO UNDER STUDY	- Primarily, precipitation echoes are studied in this research. If the word "echo" appears in the report without a modifier, "precipitation echo" is assumed.

ECHO CELLS - Echoes as observed by special projection equipment appear to be composed of one or more roughly circular geometric shapes. In some instances two neighboring and roughly circular echoes appear as one echo due to beam-width stretching. These individual circular shapes, whether as separate echoes or as part of one echo, are called "echo cells".

ECHO CORES - The most intense inner portion of a cell is called a core and can be shown on radar by use of iso-echo contouring.

RESOLUTION OF AIR MOTION - Linear horizontal motions of air can be thought of as being approximately composed of four types of pure motion: translational, vortical, divergent and deformative, [4]. Streamline maps represent complex combinations of these motions.

RESOLUTION OF ECHO MOTION - The linear horizontal motions of precipitation echoes can be thought of as being approximately composed of the type of pure motions as described for air, plus, additional motions resulting from growth and decay and other propagative processes.

TRANSLATIONAL MOTION OF ECHOES - The complex combination of the pure motions of echoes is termed "translational motion of echoes", for lack of a better notation.

1.0 INTRODUCTION

This report presents work completed during the period 1 September - 31 December 1962, for the 1800Z, 26 August 1961 case. Work which is only partially completed at this time will be included in the next report.

2.0 SYNOPTIC SITUATION

The synoptic situation at the surface and aloft for the case of 1800Z, 26 August 1961 was typical in many respects of a common summertime regime for the southern Florida area. Not so typical was the cloud cover as observed by Tiros satellite.

2.1 Surface Situation

Figure 1 represents a type of mesoscale analysis using 1-mb isobars and synoptic-scale data as discussed in [1]. Many troughs or waves in the easterlies were detected on this chart. Two such waves appeared in the primary area of interest. Operational charts did not indicate either of these waves due to general interest in synoptic-scale features.

The northern and southern portions of the wave, which appeared to be oriented somewhat with the Gulf Stream east of Florida and thence to northern Cuba, moved westward during the 12-hour period centered around 1800Z. It remained relatively stationary near a point some 70 miles southeast of Miami. This wave had trackable history aloft but as the trough aloft recurved toward middle latitudes, it appeared to be leaving the surface wave. It is felt that this phenomena may have had something to do with inducing the new trough at the surface from Lake Okeechobee to just west of Key West.

The trough in southern Florida from Lake Okeechobee to west of Key West had questionable association aloft. Either it was induced as mentioned

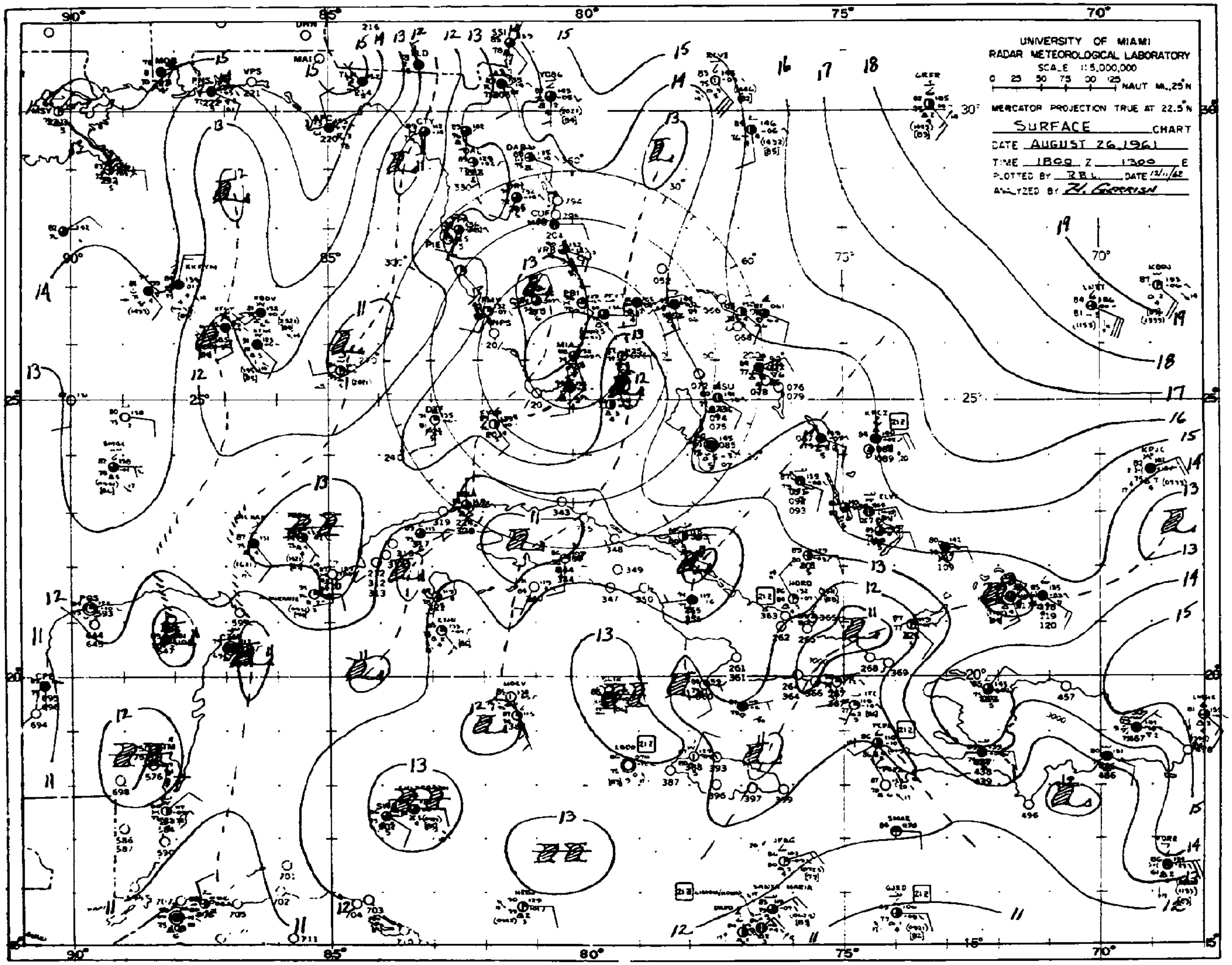


FIG.1- SURFACE WEATHER CHART 1800Z, 26 AUG. 1961

above or it may have been associated with a mesoscale wave aloft. (The authors feel that greater insight into these associations and mesoscale waves aloft may be achieved to some degree by use of weather radar. This is an objective of our research).

2.2 Situation Aloft

The region from southern Florida to the vicinity of Jamaica in the summer is regarded by tropical forecasters as a favored area for the southeasterly current aloft, which flows along the Leeward Islands, the Greater Antilles and Cuba, to recurve toward middle latitudes. When this flow takes on the anticyclonic curvature characteristics associated with the meridional transport of air, wave systems aloft which had trackable history often become difficult to analyze and sometimes become hopelessly lost. Later in the recurvature cycle they may reappear. The case of 1800Z, 26 August 1961 was one of these situations.

The area of recurvature shifted southward with height from the southern Florida area at 3000 ft to near 20^{o} north latitude at 20,000 ft. Due in part to the proximity of recurvature to southern Florida at levels below 10,000 ft, troughs at these levels were only faint, if distinguishable at all in this area. At 10,000 ft (see figure 2) some troughing was noted with an apparent vortex in the Bahamas. At 15,000 ft and 20,000 ft (see figure 3), troughing was evident over the Florida Straits including the Bahamas.

Isotach analysis of the upper-air charts indicated that areas of maximum wind speeds were oriented along the western and eastern coasts of Florida with bands of minimum wind speeds noted down the center of the Florida peninsula and over the Bahamas. This pattern appeared to shift slightly eastward with height.

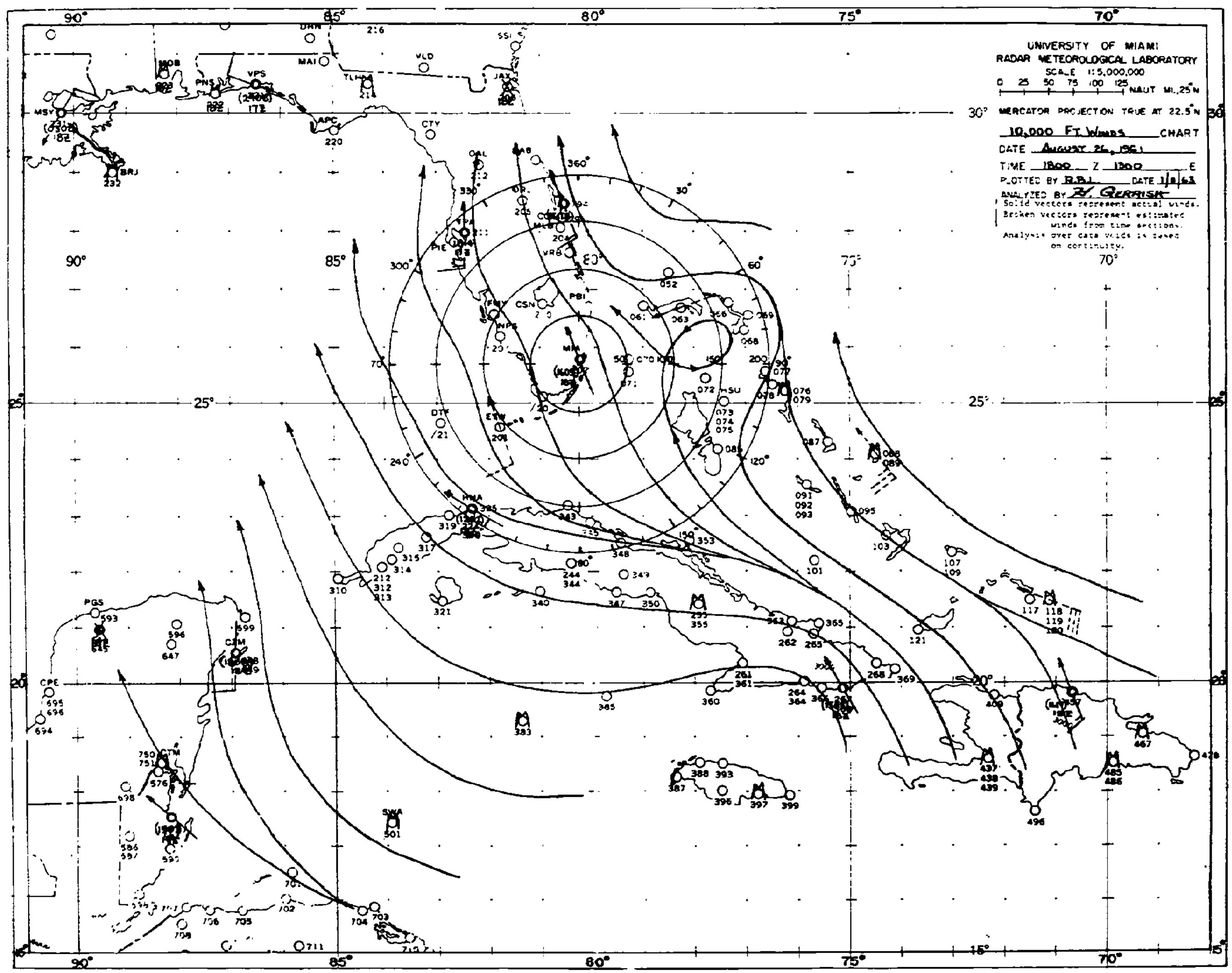


FIG. 2- 10,000-FT WINDS ALOFT CHART, 1800Z, 26 AUGUST 1961

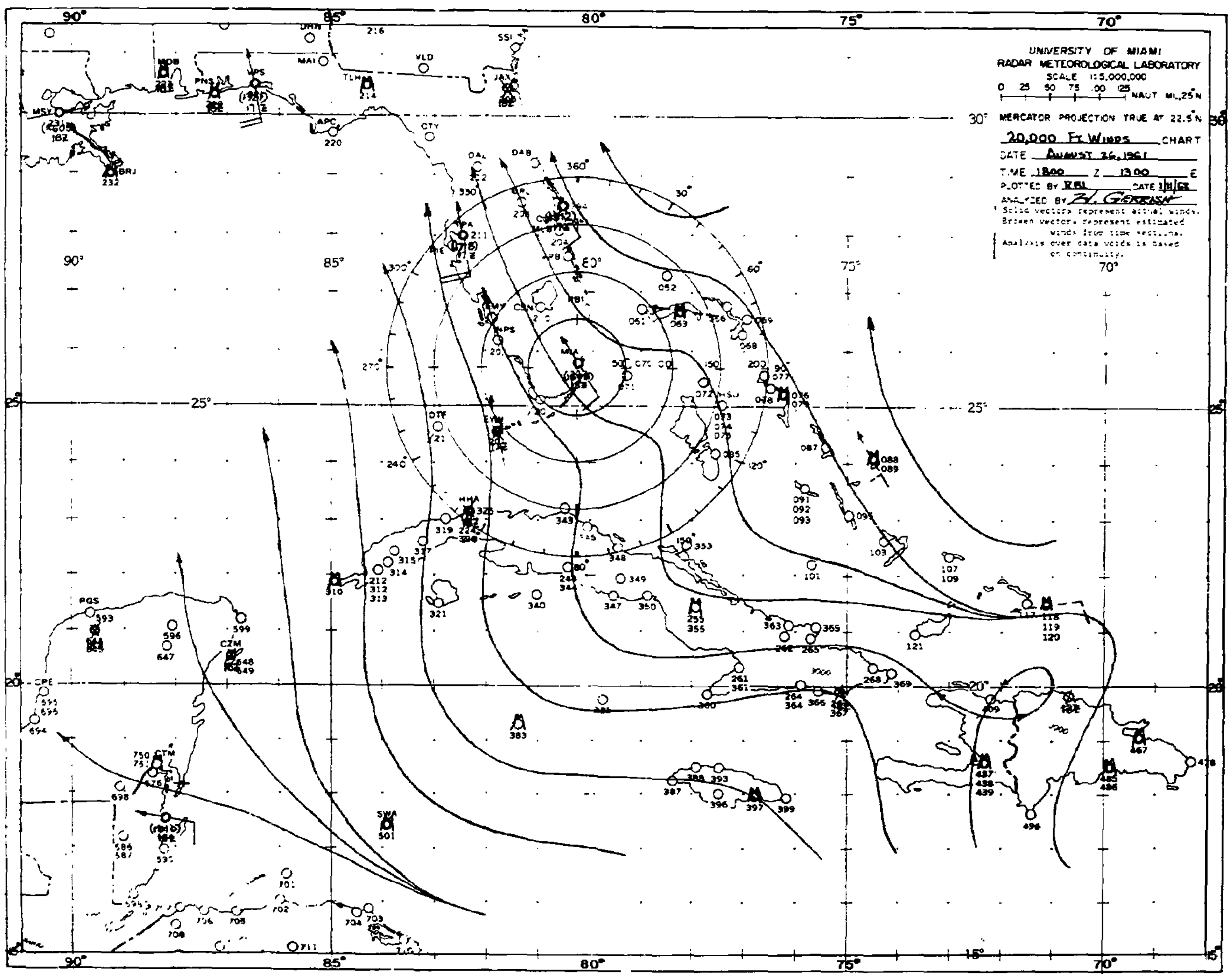


FIG. 3-20,000-FT WINDS ALOFT CHART, 1800Z, 26 AUGUST 1961

The isotach and streamline analyses over the primary area of concern suggested that shear and curvature combined to yield generalized anticyclonic vorticity at lower levels. At higher levels, cyclonic curvature due to troughing over the Florida Straits was probably compensated for to a large extent by anticyclonic shear. Weak areas of cyclonic vorticity probably resulted in this area and in certain areas where cyclonic shear occurred with little or no curvature. Elsewhere, general anticyclonic vorticity appeared to prevail.

2.3 Cloud Patterns and Weather

As mentioned earlier in the report, there was one aspect of this case which could not be classified as typical. This was with regards to the cloud pattern as observed by Tiros satellite. Figure 4 shows the cloud cover as observed by Tiros III satellite at 1724Z. No attempt was made to differentiate shades of grays due to the relative homogeneity of the clouds. The clouds over Florida and Cuba had a rather striking and unusual appearance in that they resembled the geographical shapes of these areas, displaced somewhat to the northwest. The apparent amalgamation of individual cumulus, towering cumulus, and cumulonimbus clouds was probably due to poor resolution of the wide angle camera lens as general overcast conditions were not indicated from the surface map except in northern Florida.

The shift of the clouds to the northwest over Florida was possible for several reasons. First, the general flow aloft up to at least 20,000 ft was from the southeast quadrant. Also, along the east coast the sea breeze regime probably carried the clouds inland by early afternoon. Along the west coast of Florida sea breeze effects would tend to establish clouds inland, but cirrus from cumulonimbus clouds would be carried offshore.

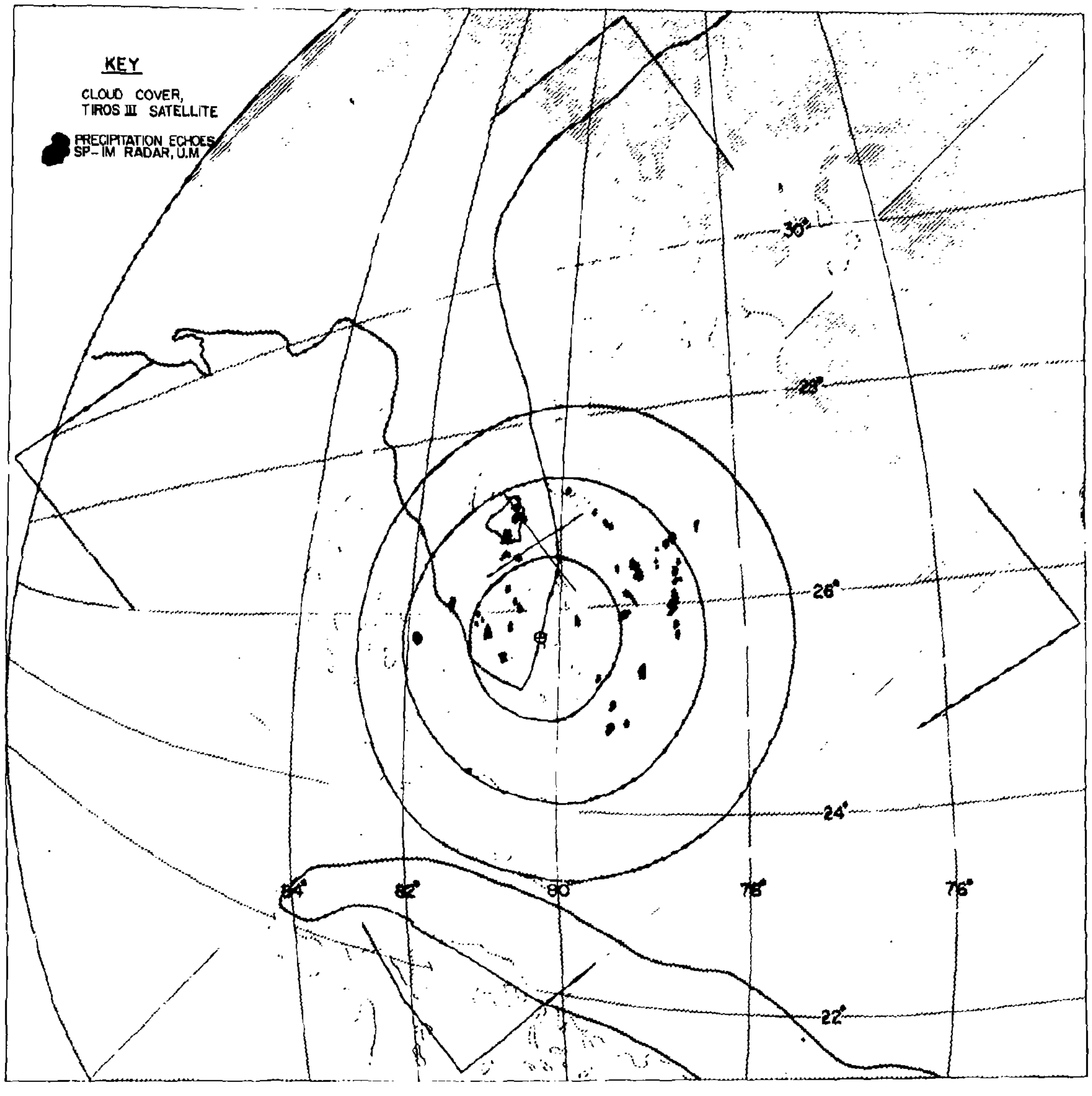


FIG. 4-CLOUD COVER AS SHOWN BY TIROS III SATELLITE, R/O NO. 650, 1724Z, 26 AUGUST 1961, AND PRECIPITATION ECHOES ON UNIV. MIAMI SP-IM RADAR.

Evidently the cirrus from cumulonimbus clouds near Lake Okeechobee did not spread sufficiently to close the cloud gap resulting from reduced thermal activity over the lake as a cloud void was observed downstream from the lake.

Synoptic and special Tiros observations indicated general swelling or towering cumulus clouds over southern Florida, whereas central and northern Florida in particular experienced towering cumulus and cumulonimbus clouds with numerous thundershowers. A funnel cloud was noted 12 mi east of Jacksonville about 1700Z.

Cloud patterns associated with the mesoscale waves in the primary area of interest could not be analyzed on the mesoscale except to some degree using the special Tiros observations. It was possible, however, to associate precipitation echoes with the waves. Radar precipitation echoes as observed on the University of Miami SP-1M radar (see figure 4) did appear to be oriented with the waves. Specific associations are being investigated in three dimensions and results will be presented in a later report.

Preliminary analysis of the rainfall pattern over southern Florida indicated that very little rain was caught by official rain gages, not only near 1800Z, but for the entire day. Thus, precipitation from the mesoscale wave in southern Florida in particular, occurred mainly between reporting stations.

The two mesoscale waves within range of the radars at the University of Miami at 1800Z were apparently relatively weak as the precipitation echoes were not numerous and RHI time-lapse radarscope photographs indicated that the higher echo tops ranged in general from 20,000 to 30,000 ft MSL. Although the echoes were not numerous they were relatively isolated and not congested in masses as much as in the previous case. This fact, plus the interesting synoptic situation, provided the impetus to choose this case for comparison of echo motions with winds aloft.

3.0 WINDS ALOFT AND ECHO MOTIONS

A significant stride forward in tropical meteorology could be made with knowledge of the relationship between precipitation echo motions and winds aloft. A knowledge of translational motions in particular is desired. Unfortunately, the relationship in the tropics is not known. Since motions of slow-moving echoes in the tropics are quite complex as opposed to fast-moving echoes, a large part of our current research is devoted to familiarization with these motions. In particular, our endeavor is directed toward isolating translational motions of echoes as much as possible.

3.1 Procedure Used

In order to compare translational echo motions with winds aloft, either echo motions must be compared directly with wind reports aloft or indirect methods must be used. The following comments suggest that the former is not practical on a routine basis and that the latter is preferred:

Time of Observations

Winds Aloft - Routinely, actual release times of pibals or rawinsonde balloons are not included with the transmitted reports. Instead, the release time to the nearest hour is transmitted. Balloon releases are also restricted to specified time intervals. For instance, in the case of a balloon run for 1800Z, releases are scheduled as close to 1730Z as possible with no releases except as specifically authorized permitted earlier than 1700Z or later than 1800Z. Delayed releases as late as 1900Z are permitted, however, for rawinsonde balloons. Rawinsonde observations are confined primarily to 0000Z and 1200Z, whereas pibal observations are made at 0000Z, 0600Z, 1200Z and 1800Z. Thus for reports labeled as 1800Z (primarily pibal reports), the balloons were scheduled to be released between 1730Z and 1800Z. At a time of rawinsonde observations, say 1200Z, those balloons could have been released between 1130Z and 1229Z to be labeled as 1200Z. Consequently, the time of a particular upper-wind observation is not known very accurately.

Echo Motions - With well documented radar film, the time of echo motions can be determined accurately.

Location of Observations

Winds Aloft - The lower 20-25,000 ft of the tropical atmosphere is of primary concern for our studies. In this layer a balloon is not likely to drift more than 5 mi from a given station unless winds persist at speeds of greater than 30 knots from the surface to 10,000 ft, or greater than 15 knots from the surface to 20,000 ft. This is based on the rule of thumb that the balloon rises at the rate of approximately 1000 ft per minute. Location of the balloon appears to be important only for higher levels of the layer or in certain instances at lower levels with wind speeds in excess of 30 knots.

Echo Motions - The movement of echoes can be positioned in space accurately.

Number of Observations

Winds Aloft - The following six stations, which observe and compute upper-wind data, are within a radius of 200 n. mi from the University of Miami: Havana, Tampa, Cape Canaveral, Key West, Grand Bahama and Miami. The first three are 160-200 n. mi from our radars. At this range, the SP-1M radar using the 5-microsecond pulse length would see only the tops of certain precipitating columns. Motion of the tops may be different from the lower and middle portions consequently, larger representations of the clouds are desired for this study. Miami airport is within the ground pattern of our radars. Therefore the number of observations available for direct comparisons would be two, Key West and Grand Bahama.

Echo Motions - For translational motion studies, the number of usable echoes is reduced considerably due to strict requirements for selection of suitable echoes. Also, the number is reduced with increasing time interval. For 10-min intervals, 1-2 dozen echoes may be suitable, depending on the situation.

Length of Observations

Winds Aloft - Upper-wind reports in the layer of interest are based on 2-min averages.

Echo Motions - Echo motions based on 10-, 15-, and 30-min averages are relatively common.

Scale of Data

Winds Aloft - Winds-aloft reports represent microscale observations as a result of the short length of individual observations.

Echo Motions - Due to the length of echo-motion observations, some microscale effects are removed from these motions. If scale of data is based on space only, possibly most microscale effects are removed and the resulting motions are due to high speed mesoscale wave phenomena. This will be mentioned briefly later in the report. This points out the need for considering both space and time, in scale considerations of echo motions.

<u>Scale of Map Analyses</u>

Winds Aloft - Streamline and isotach analyses of upper-wind maps represent synoptic-scale analyses.

Echo Motions - Due to frequency of data, streamline and isotach analyses of echo-motion maps probably represent mesoscale analyses.

<u>Where Observations Were Made</u>

Winds Aloft - Winds-aloft observations that are made outside of the convective clouds are preferred to those within because the effects of convection are less in the environment. Thus, rawinsonde-wind reports within precipitating convective clouds should be treated cautiously and possibly eliminated Exact comparisons of echo motions with winds aloft, however, cannot be made unless the balloon is within the echo portion of the cloud for the period of comparison.

Echo - Precipitation echoes as observed on PPI scopes are within precipitating clouds in general. These echoes may appear outside of clouds at times due to wind-driven precipitation or virga. (Beam-width stretching neglected).

<u>Representativeness of Data</u>

Both winds-aloft and echo-motion data are only representative for the period of observation. Beyond this period representativeness is questionable due to smaller-than-synoptic scale phenomena which are likely to be moving through the atmosphere.

Since it is not practical to make direct comparisons, the indirect method of comparing map analyses was used. Considering the foregoing discussion, it appears that scales of data must be made compatible and certain assumptions must be made in order to compare echo motions with upper-wind data. To make the scales compatible, mesoscale and small-scale features were filtered from the echo-motion maps as much as possible so that the resulting synoptic-scale maps could be compared with synoptic-scale upper-wind maps. Comparing synoptic scales also permits certain relaxations with regard to times of both echo and upper-wind reports as long as the reports are within 1/2-1 hr of each other. Working with this scale conveniently covers the necessary assumptions.

Filtering was accomplished by space smoothing data at certain grid points. The technique was to average data at surrounding grid points in order to determine the smoothed data for a particular grid point. Those surrounding grid points which were located at a uniform distance comparable to the grid size from the point in question, were used in the smoothings. The largest grid used had a north-south and east-west spacing between points of 100 n. mi. This would filter out systems with wavelengths less than 200 n. mi and retain larger systems. The SP-1M radar film taken at the University of Miami was used for this study. The pulse length of 5 microseconds permitted ranges of up to 200 n. mi to be studied; however, there were very few echoes beyond 100 n. mi. Initially the research was arbitrarily restricted to a range of 100-120 n. mi. Thus larger grids could not be used and therefore certain larger mesoscale waves were not filtered out. It is believed that enough mesoscale systems were filtered out so that general comparisons are valid. Due to the nature of the data on upper air maps, the grids were applied to these maps as well.

After both echo-motion and upper-wind maps were smoothed by various grids, comparisons were made at grid points.

3.2 Winds-Aloft Charts

Winds-aloft charts at 1200Z and 1800Z, 26 August 1961 and 0000Z, 27 August 1961 for the following levels and layers were plotted and analyzed using the principles of streamline and isotach analysis:

Levels	Layers
3000 ft	3000-10,000 ft
5000 ft	10,000-16,000 ft
10,000 ft	16,000-23,000 ft
15,000 ft	3000-23,000 ft
20,000 ft	

To assure consistency, winds for the layers (called mean-layer winds or MLW) were computed using a remodeled winds-aloft plotting board.

Analysis of the 1800Z wind maps, a time of pibal winds, was based to some extent on continuity between the 1200Z and 0000Z maps. These maps contained rawinsonde data which were somewhat superior to pibal data.

As a second check on continuity, time sections were plotted for Key West, Tampa, Cape Canaveral, Miami, Grand Bahama, San Salvador, Turks Island, and Havana. Data from Eleuthera were not available. Figure 5 shows the time section for Miami.

For the wind study, only upper-air winds and surface data were plotted on the time sections to avoid confusion. They were then analyzed using a qualified type of streamline and isotach analysis. "Qualified" refers to whether steady state is assumed and to the interpretations which can be made from the analysis. The following points should be remembered with regard to these time sections:

1. The streamlines do not show vertical motions as might be suggested at first glance. The data are plotted so that north is at the top of the page, south at the bottom, etc. Therefore, horizontal flow is plotted at various levels aloft and it should be interpreted that way.

2. Isotachs must be drawn independent of this type of streamline, rather than elongating maximum regions along the streamline, etc., as in standard analysis.

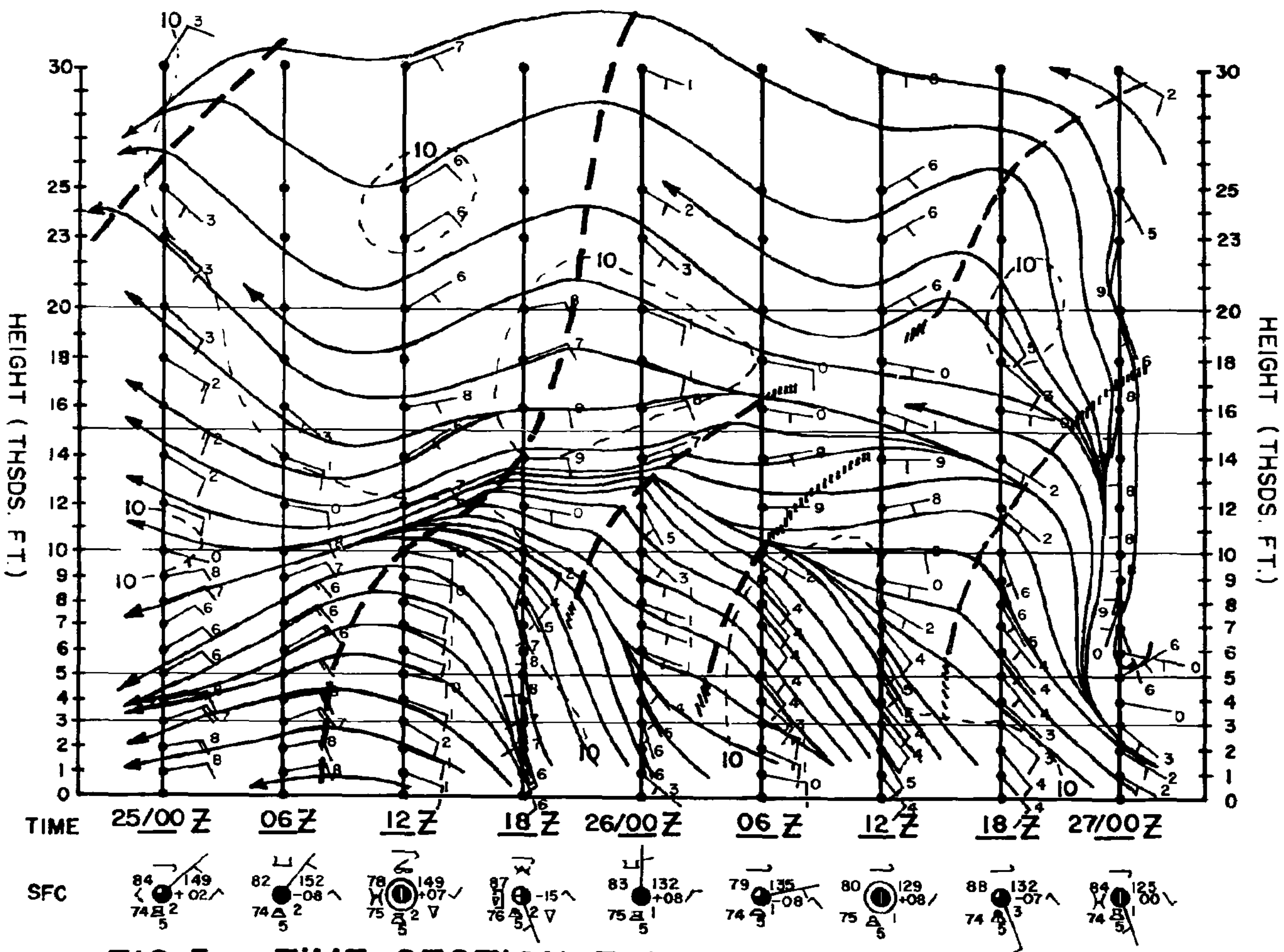


FIG. 5- TIME SECTION FOR MIAMI, FLA. 0000 Z, 25-27 AUGUST 1961

3. Regions which appear to suggest diffluence or confluence actually do not, but rather indicate rapid changes in direction only. No information on divergence or convergence can be deduced unless steady state is assumed and a space section drawn.

4. Trough lines can be found by small wind shifts. It is not necessary for the wind to shift through east in order to locate a trough.

Winds in regions of missing data were inferred in a number of instances based on the streamline and isotach analyses. These winds were then placed on upper-wind maps as dashed vectors. Knowledge of trough positions aloft as deduced from these time sections also aided the analysis to some extent.

This type of analysis provides an insight into the vertical associations of various troughs. Figure 5 suggests that the troughs do not extend throughout the entire 30,000 ft layer except in certain instances. In general the troughs appear to prefer the lower 10-12,000 ft layer and the layer above 16-18,000 ft. Although several time sections indicated troughs in the layer between the preferred layers, it was evident that associations became quite complex in this particular layer. Figure 5 indicates that the troughs at 1800Z, 26 August 1961, over Miami, Florida, are probably not related. The vertical structure of the surface trough located over southern Florida at 1800Z is not clear from Figure 5 even though a wind shift is noted at the surface over Miami near 1200Z and troughing is evident aloft. A mesoscale trough may be evident in the lower 5000 ft from analysis of data at shorter time intervals, or the surface trough may be induced by a trough aloft. Since steady state is not likely in this case, neither can be resolved from the figure.

3.3 Echo Tracking

As in the earlier case study, precipitation echoes and cells were tracked by projecting their film images for various times on to a tracing table and noting their displacements. This was accomplished by using the versatile Nemeth Radar Data Plotter. Time-lapse 35-mm radarscope film was enlarged to six times the actual repeater scope diameter for this purpose.

The procedure was to plot all echoes at 5-min intervals for the period of interest on one piece of which non-glare paper, using different colors to denote different times. This was done for each period as required for the echo-motion maps. Continuity checks were made on those echoes which were considered as being potentially suitable for translational motion studies, since it is this motion which is of interest for this study. This required viewing the film forwards and backwards many times to check the identification of the echoes at 40-sec intervals.

Various types of motions are represented by the tracking of echoes, echo cells, or echo cores. Propagating effects are inherent to varying degrees in all three methods. Until these effects are described quantitatively, it will not be possible to remove them from the complex motion of echoes. The authors feel that "cell tracking" of selected, small, rather isolated, mono- or duo-celled echoes is the best method available for approximating translational motion of slow-moving tropical echoes. Thus, small mono- or duo-celled echoes were considered as being potentially suitable for tracking. It was decided that echoes with three or more cells in general would not be suitable for this type of study due to difficulty in "cell tracking" and complex propagative effects. The process of "centroid tracking" of slow-moving echoes in general, can lead to gross errors due to propagative effects.

Potentially-suitable echoes which did have continuity for 5-min or longer, were screened further. First of all, those which were within 25 n. mi of our radars to the west, and within 30 n. mi to the east, were predominantly rejected as being unsuitable because of confusion with ground clutter to the west and with ships plying the waters of the Gulf Stream to the east. RHI data were used to assist identifications. Secondly, it was arbitrarily decided that cell motions of duo-celled echoes would be rejected if they differed from each other or if the centroids of the cells were closer together than 5 n. mi. This type of filtering possibly minimized propagative effects for those echoes. Deformative and divergent air motions may cause neighboring cells to move differently; however, since little is known about the magnitudes of these motions on the mesoscale or microscale, it is best to ignore them for small echo displacements. Therefore, if the cells of duo-celled echoes moved differently, this was thought of as being manifestations of propagative processess. If there are possible attractive forces between neighboring cells, it was felt that this would possibly occur with centroids of the cells within 5 n. mi of each other.

Those echoes that remained after successive screenings were studied in greater detail at higher image magnifications. The magnification of the projected images was increased to the point where film grain became extremely noticeable. Echo trajectories were determined at 5-min intervals and echo shape histories were drawn for 40-sec intervals. Careful procedure was required since slow-moving echoes of speeds less than 10 knots would be displaced less than 1 mi in 5 min. For this degree of accuracy, the non-linearities of the radar had to be considered explicitly rather than minimizing them. The projector was raised or lowered slightly as required for each frame in order that the distance between range circles in the segment under study would be the same during the trackable period. Focusing was not a critical factor when standardized. Film grain in the area of interest was used to determine whether the area was in or out of focus.

The trajectories showing translational motion of slow-moving echoes in the tropics are exceedingly difficult to determine. It is concluded after investigating trajectories based on 5-min echo positions that accuracy for intervals this short is near to, if not beyond, the capability of human observers. For this reason, 10-min intervals or longer are suggested. It should be mentioned that preliminary analysis of trajectories based on 10-min echo positions suggests non-random serrated or curvilinear patterns much like those based on 5-min positions except dampened. This could be physically explained as high speed waves moving through the lower tropical atmosphere possibly as a result of some of pressure-wind unbalance, if one considers the translational motions to be relatively accurate. This sort of phenomenon was suspected in [1], and a cursory attempt was made to describe it by appearance and speed. Although the appearance as portrayed in [1] was based in part on some data which may not have been as good approximations for translational motions as used in this study, it is suspected that with sufficient and accurate translational data, these waves would appear as mesoscale sinusoidal oscillations much like waves in the easterlies. Not enough observational evidence is available to adequately describe these waves at this writing.

Echo shape histories, although complicated by external FAA interference, did assist with cell tracking and provided an increased feeling for echo evolution. These shape histories were made using a high magnification of 125 times the 35-mm film size. Under this magnification, cell identification could be resolved with more certainty in many instances. Examples of shape histories will be presented in a later report.

After verifying the motions of the selected echoes utilizing high image magnifications, echo-motion maps for the various periods were analyzed.

3.4 Echo-Motion Maps

The 30-min period from 1730-1800Z, 26 August 1961, was used as the period for echo tracking in this case study. Lack of radarscope data after 1800Z dictated the choice of period. This period was broken up into 10-, 15-, and 30-min periods. Echo maps with vectors depicting translational motions were analyzed using the principles of streamline and isotach analysis.

Due to additional restrictions placed on choosing suitable vectors for this case study, as well as this being a situation with fewer echoes, not nearly as many vectors were used on each map as compared with the first case. Thus, the analysis resulted in a much more simplified pattern although more vectors would have been desired. Figure 6 represents one of these patterns. Again, as in the earlier case, sequent analyses led the authors to believe that fast-moving waves can be observed moving through slower ones. With more observational evidence, examples will be published in a later report.

3.5 Space Smoothing

The following grids were used to space smooth upper-wind and echo-motion maps:

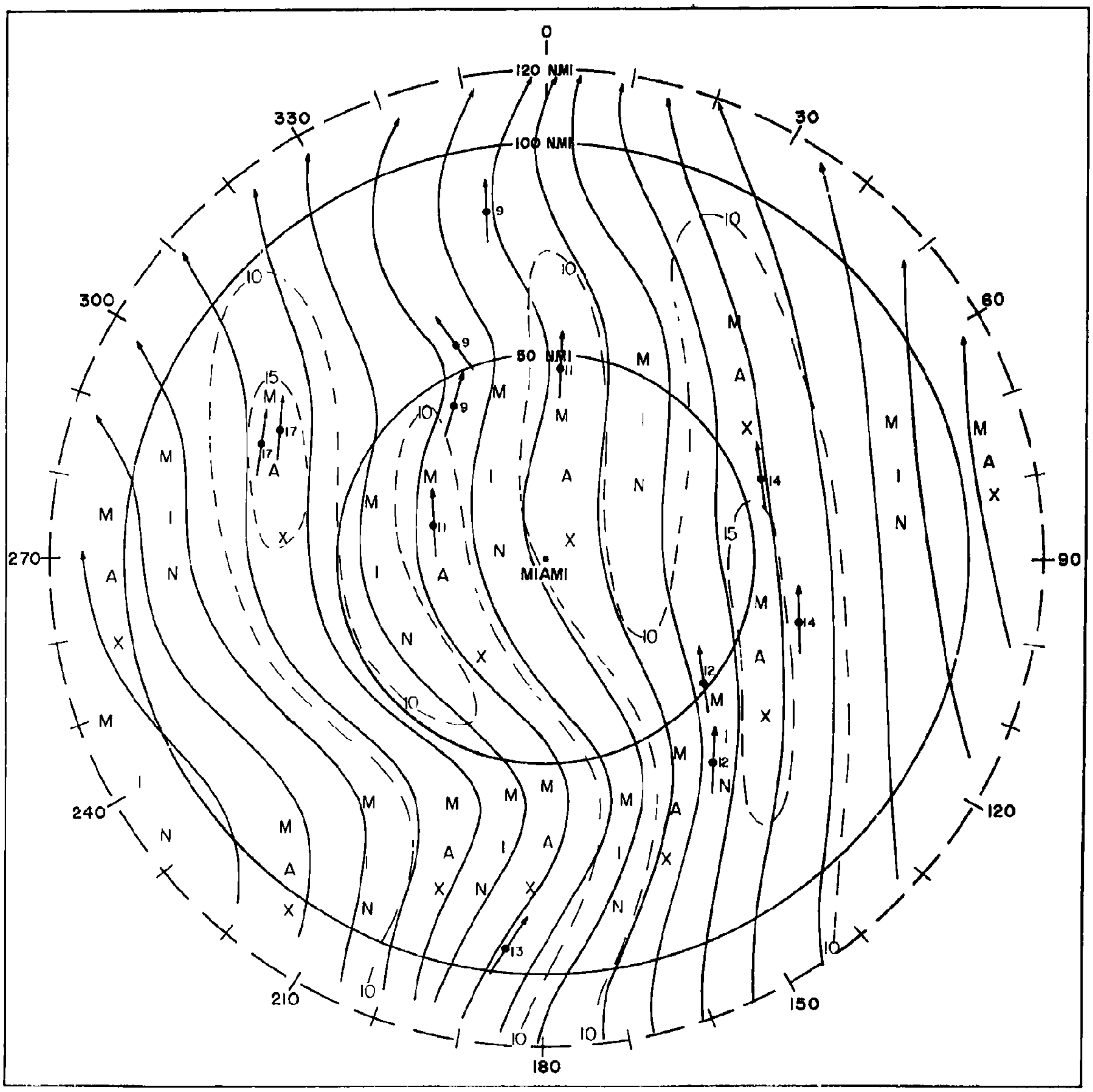
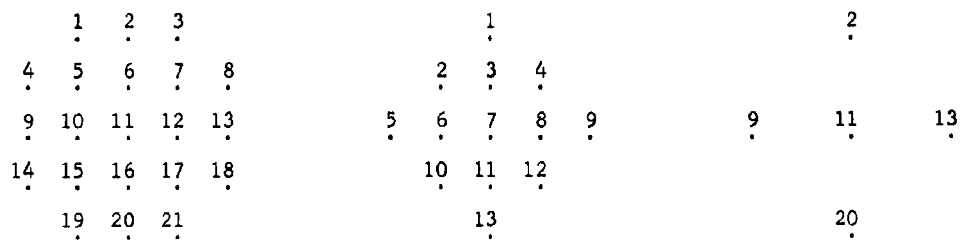


FIGURE 6— ECHO-CELL-MOTION MAP FOR THE PERIOD 1740-1750Z, 26 AUGUST 1961. STREAMLINES (SOLID), ISOTACHS (DASHED).



(point 11 is Miami) (point 7 is Miami) (point 11 is Miami)

<u>50-N. Mi Grid</u> <u>60-N. Mi Grid</u> <u>100-N. Mi Grid</u>

The grid size refers to the east-west and north-south distances between grid points. As mentioned earlier, smoothings were accomplished in such a way that on the 50-n. mi grid, the mean a point 6, (M_6), was found by averaging the data at points 2, 5, 7 and 11 rather than at points 1, 3, 10 and 12. An average mean can be determined for Miami by averaging M_6, M_{10}, M_{12}, and M_{16} on the 50-n. mi grid to get $\bar{M}_{11}$, and M_3, M_6, M_8, and M_{11}, on the 60-n. mi grid to get $\bar{M}_7$.

Data at points 1, 5, 9 and 13 on the 60-n. mi grid had to be inferred from extension of analysis beyond 100 n. mi. The 60-n. mi grid would have been dropped from this case study due to lack of echoes beyond 100 n. mi, however, it was decided to attempt to salvage data from it for over-all comparisons of various grids after several case studies are completed.

After space smoothing, upper winds and echo-cell motions were compared at grid points.

3.6 <u>Comparison of Echo-Cell Motions with Winds Aloft</u>

Figures 7-11 present diagrams showing echo-cell motions and winds aloft at grid points resulting from various space smoothings. The following key applies to the diagrams:

KEY

Symbol	Meaning
A	mean 3000-ft wind
B	mean 5000-ft wind
C	mean 10,000-ft wind
D	mean 15,000-ft wind
E	mean 20,000-ft wind
W	mean 3000-10,000-ft mean-layer wind
X	mean 10,000-16,000-ft mean-layer wind
Y	mean 16,000-23,000-ft mean-layer wind
Z	mean 3000-23,000-ft mean-layer wind
□	mean 10-min echo-cell motion
○	mean 15-min echo-cell motion
△	mean 30-min echo-cell motion

Comparisons based on Figures 7-11 appear in Table 1.

Table 1 suggests that on a synoptic-scale basis, the translational motion of echoes most nearly resembled the wind flow at 10,000 ft. The 3-23,000-ft MLW verified next best with the 5000-ft wind and the 3-10,000-ft MLW nearly tied as third best. The 20,000-ft wind verified surprisingly well in this case.

The 15-min echo-cell motion seemed to verify better than the 10- or 30-min echo-cell motions. The reason for this is not clear although it may have something to do with the amount of data and smoothing.

The over-all verifications were not as high as expected considering the ground rules and careful procedures that were used in this case. Possibly this is due to the subjectiveness which is a necessary evil of streamline and isotach analysis. Also, the boundary conditions affect smoothings at many of the grid points.

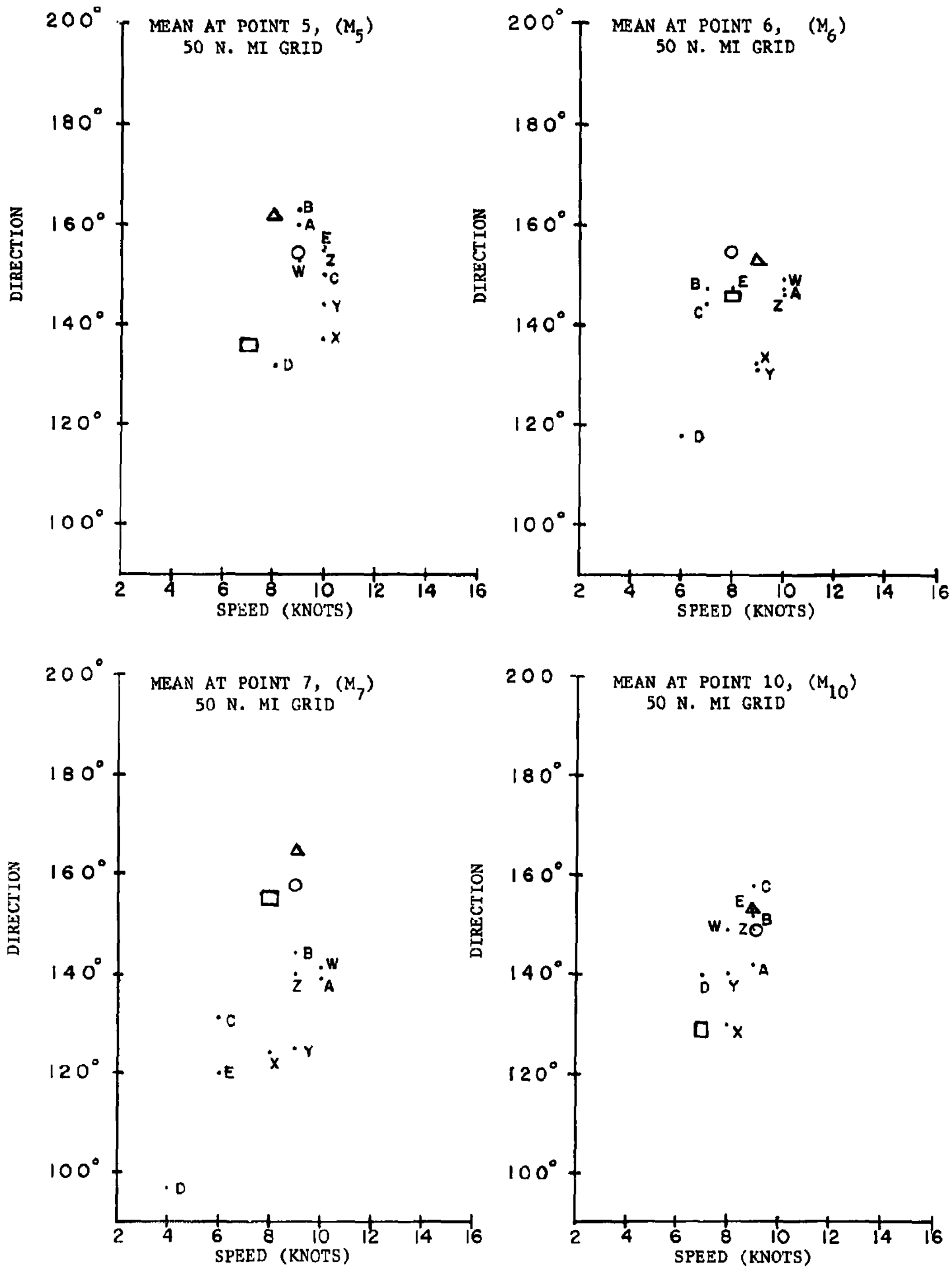


FIGURE 7 Mean Echo-Cell Motions and Mean Winds Aloft At Grid Points

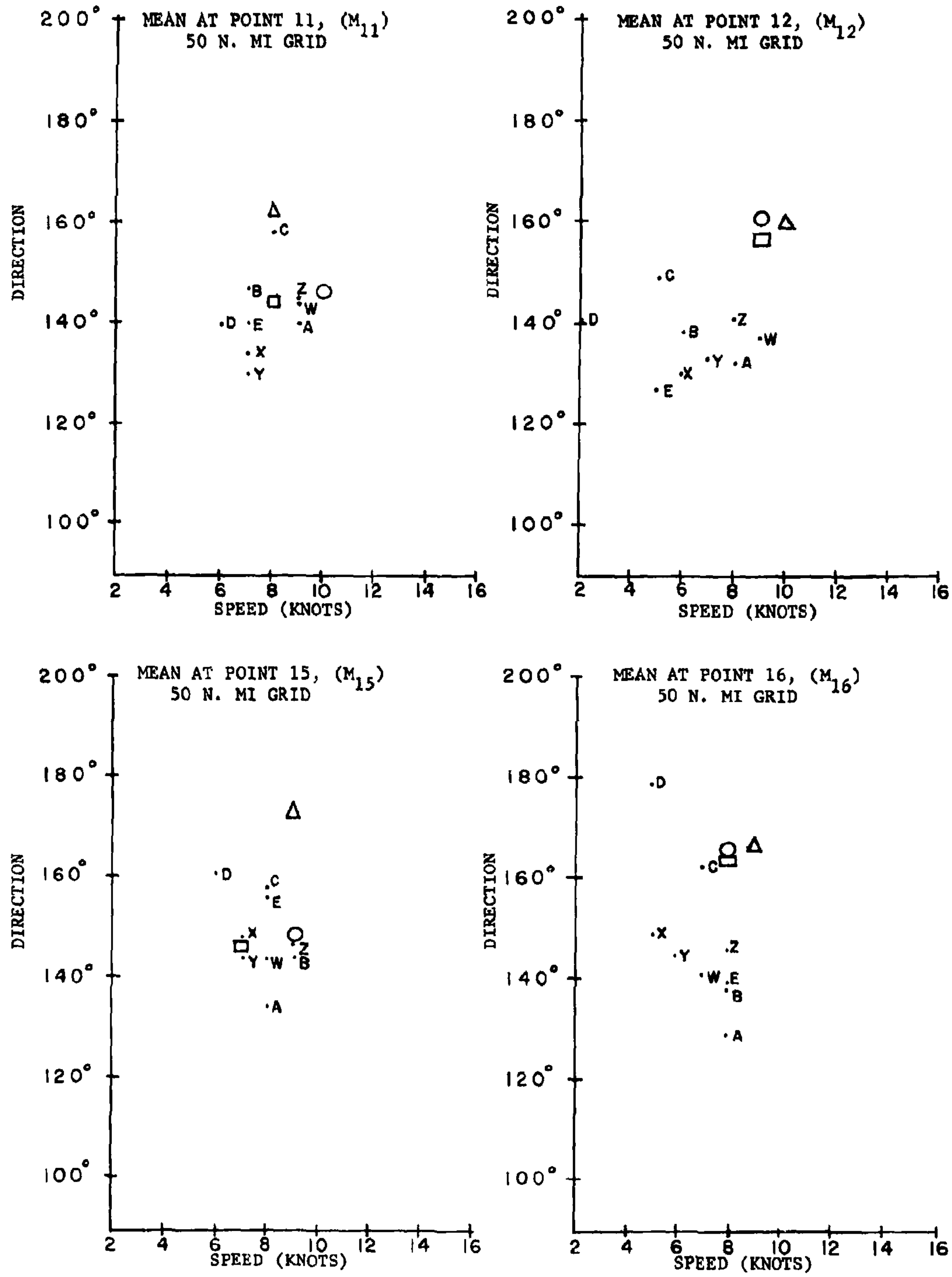


FIGURE 8 Mean Echo-Cell Motions and Mean Winds Aloft at Grid Points

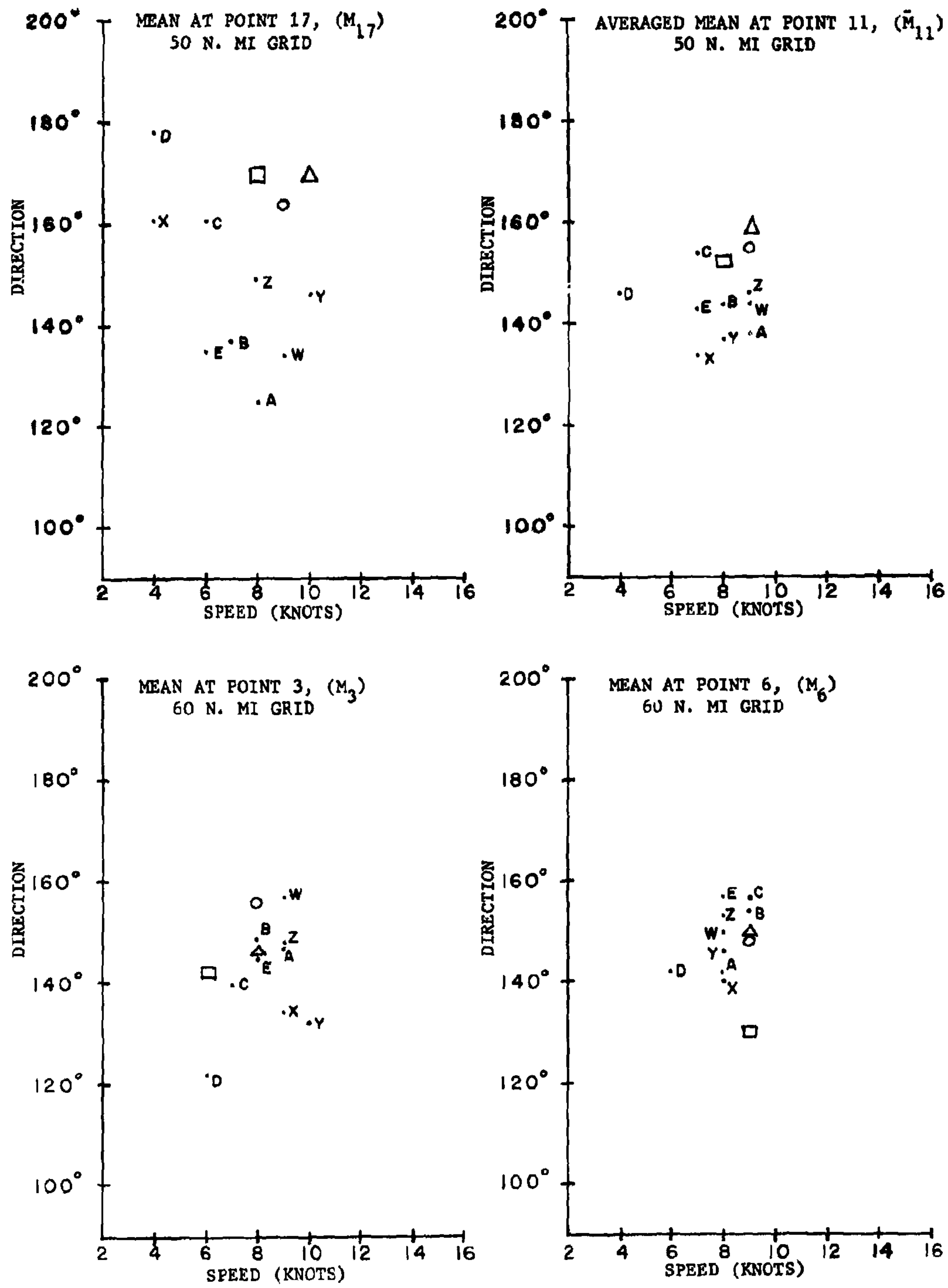


FIGURE 9 Mean Echo-Cell Motions and Mean Winds Aloft at Grid Points

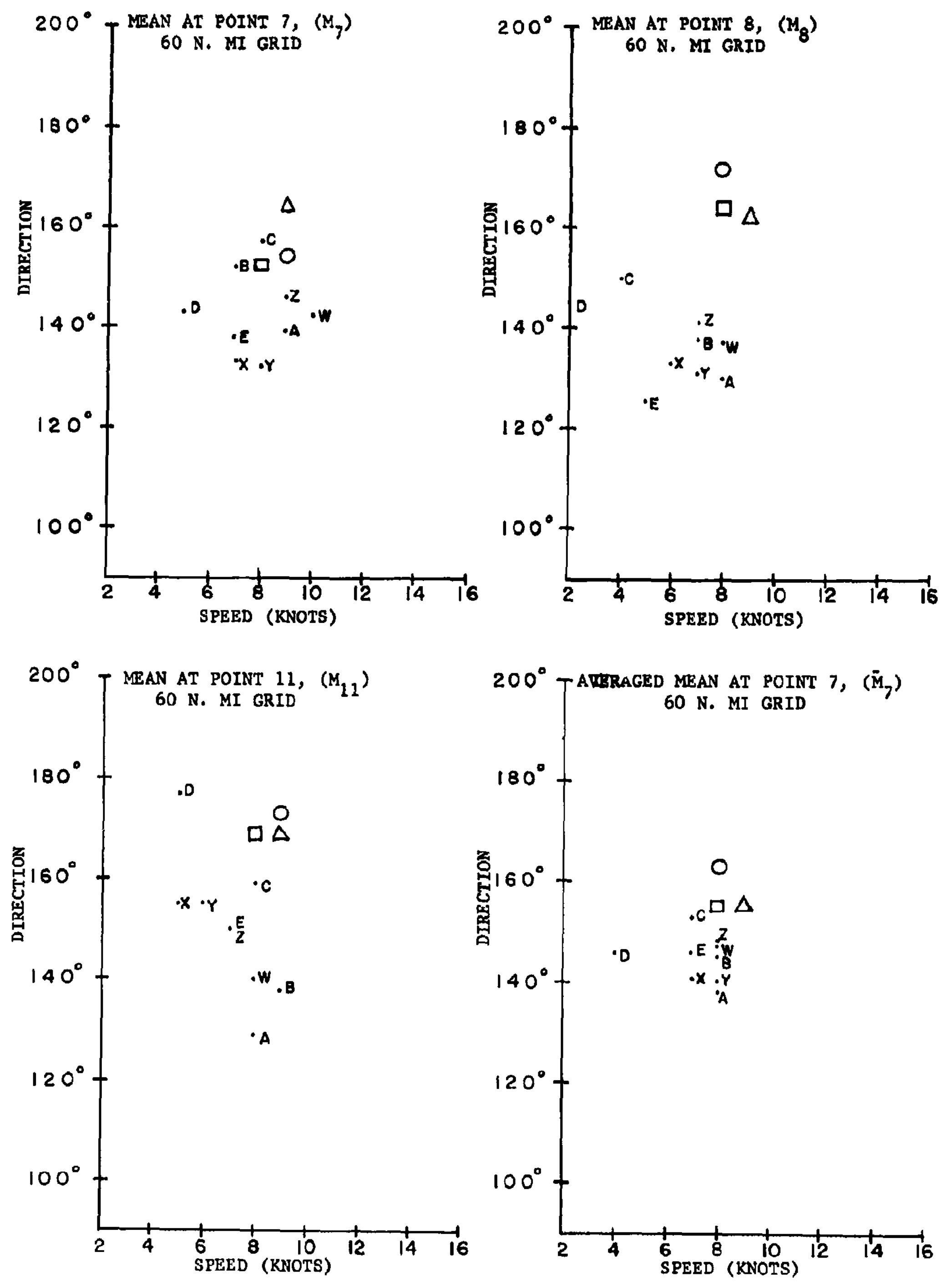


FIGURE 10 Mean Echo-Cell Motions and Mean Winds Aloft at Grid Points

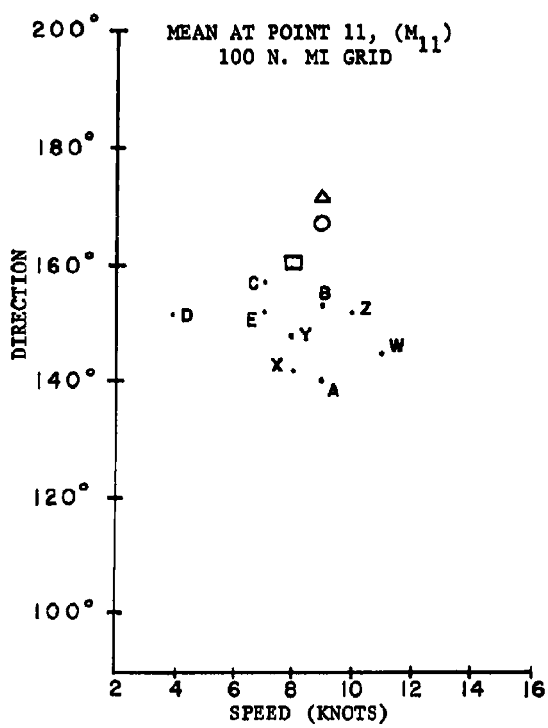


FIGURE 11 Mean Echo-Cell Motions and Mean Winds Aloft at a Grid Point

MEAN WINDS ALOFT		DEVIATIONS OF MEAN ECHO-CELL MOTIONS FROM MEAN WINDS ALOFT: ± 10° and ± 2 Knots					± 20° and ± 5 Knots				
		50-N. MI GRID		60-N. MI GRID		100-N. MI GRID	50-N. MI GRID		60-N. MI GRID		100-N. MI GRID
		M (9 pts)	M̄ (1 pt)	M (5 pts)	M̄ (1 pt)	M (1 pt)	M (9 pts)	M̄ (1 pt)	M (5 pts)	M̄ (1 pt)	M (1 pt)
MEAN	10*	2	0	0	0	0	5	1	3	1	1
3000-ft	15*	4	0	2	0	0	6	1	3	0	0
WIND	30*	2	0	1	0	0	3	0	2	1	0
MEAN	10*	3	1	2	1	1	5	1	2	1	1
5000-ft	15*	4	0	3	0	0	6	1	3	0	1
WIND	30*	3	0	1	1	0	4	1	3	1	1
MEAN	10*	3	1	3	1	1	7	1	4	1	1
10,000-ft	15*	4	1	3	0	0	8	1	4	1	1
WIND	30*	4	1	2	1	0	8	1	5	1	1
MEAN	10*	2	0	0	0	0	6	1	4	1	1
15,000-ft	15*	1	0	0	0	0	5	1	3	0	1
WIND	30*	0	0	0	0	0	3	1	2	1	1
MEAN	10*	3	1	1	1	1	4	1	3	1	1
20,000-ft	15*	4	0	1	0	0	5	1	3	0	1
WIND	30*	3	0	0	1	0	4	1	3	1	1
MEAN	10*	3	1	1	1	0	7	1	3	1	1
3-10,000-ft	15*	5	0	2	0	0	6	1	3	0	0
MLW	30*	3	0	1	1	0	4	1	2	1	1
MEAN	10*	3	0	1	0	0	7	1	4	1	1
10-16,000-ft	15*	1	0	2	0	0	6	0	2	0	0
MLW	30*	0	0	0	0	0	1	0	3	1	0
MEAN	10*	1	0	0	0	0	6	1	4	1	1
16-23,000-ft	15*	3	0	1	0	0	6	1	2	0	1
MLW	30*	0	0	0	0	0	2	0	3	1	0
MEAN	10*	3	1	1	1	1	8	1	3	1	1
3-23,000-ft	15*	5	1	3	0	0	9	1	3	0	1
MLW	30*	3	0	1	1	0	5	1	3	1	0

10* Indicator for 10-min mean echo-cell-motion verifications
15* Indicator for 15-min mean echo-cell-motion verifications
30* Indicator for 30-min mean echo-cell-motion verifications

TABLE 1. Grid Point Comparisons of Mean Echo-Cell Motions With Mean Winds Aloft. Number of instances the 10-, 15-, and 30-min mean echo-cell motions verified within the given deviation from the mean winds aloft at the grid points for which mean values (M) and averaged mean values (M̄) were determined.

Not enough RHI data were available within 10 n. mi of the grid points in this case in order to describe what effect echo heights might have on verifications of non-smoothed vectors. Smoothed vectors could not be used for this because the data used in the smoothings might involve echoes of varying heights.

3.7 Comparison of Results With Other Studies

In [1], it was concluded that echoes most nearly moved with the 5000-ft wind. Although some non-translational motions were used in that study, it is felt that the various grids would have eliminated many of the undesirable small-scale features. The results at 5000 ft were considered as reasonable due to shear in the tropics.

In the current case, the 10,000-ft wind verified best. Inspection of the diagrams in figures 7-11 reveals that the 5000-ft wind verified similarly to the 10,000-ft wind except at points 12, 16 and 17 on the 50-n. mi grid, and points 8 and 11 on the 160-n. mi grid. In particular at points 16 and 17, as well as at point 11, the verification was decidedly in favor of the 10,000-ft wind. Smoothings at these points were based on data from Miami as well as from points in the general area south and southeast from Miami to a range of about 100 n. mi. The flow at 5000 ft over this area was relatively undisturbed and from the southeast, whereas at 10,000 ft, the flow had begun turning to the right due to weak troughing. All of the echo charts indicated a trough with moderate amplitude in this area. This would account for the 5000-ft wind not verifying as well as the 10,000-ft wind. It is felt that upper-wind data from Eleuthera would have been the key for identification of possible troughing at 5000 ft. The existence of this troughing would have produced verifications which would have more nearly resembled those in [1]. This points out the critical nature of the analyses in this type of comparison technique. Unfortunately, other techniques suffer severe drawbacks and are therefore considered inferior to the present technique. It seems to the authors that pibals from Nassau would be justified operationally as well as for research purposes in situations such as this when Eleuthera does not take upper-wind observations for extended periods.

The level near 10,000 ft is thought to verify well in middle latitudes. Due to shear which is rather common in the tropics, it would appear that a level somewhat lower than 10,000 ft, say near 5000 ft or between 5000 ft and 10,000 ft, would verify best in these regions. This is substantiated reasonably well by [1] and the current case study.

3.8 Recommendations for Future Studies

Since one of the problems in this type of research is a lack of upper-wind data, the use of time sections for various stations is highly recommended as an aid for analysis of upper-wind charts.

Echo shape histories and trajectories based on 10-min echo positions are suggested to aid tracking of slow-moving echoes.

Investigations should be made of the variations in motions of echoes resulting from tracking echoes, cells, and cores. This is a sizeable task.

To better understand the evolution of precipitation echoes, time-lapse movie studies of clouds are suggested and planned for future situations with two radars recording PPI and RHI data concurrently for the same clouds.

4.0 CONCLUSIONS

1. Time sections can be used effectively as an aid for understanding vertical associations of troughs as well as providing a convenient tool for map analysis. Certain mesoscale waves can be observed on these sections.

2. Echo shape histories and trajectories as deduced under high film magnification assist with cell identification and provides another tool to aid cell tracking of slow-moving tropical echoes. An increased insight into echo evolution processess results from these histories and trajectories.

3. Echo trajectories based on 5-min echo positions are of questionable value for slow-moving tropical echoes. Trajectories based on 10-min positions are suggested.

4. High-speed waves are inferred to be moving through the lower tropical troposphere. Further description awaits additional observational evidence.

5. The translational motion of precipitation echoes, as depicted by "cell tracking", most nearly resembled the wind flow at 10,000 ft in this case study. If the existence of a trough over the Florida Straits at 5000 ft could be verified, the 5000-ft wind would have verified nearly as well.

6. Streamline analysis, in particular with regards to upper wind charts, is a critical portion of the over-all procedure used to compare echo motion with winds aloft.

5.0 PROGRAM FOR NEXT INTERVAL

Echo-motion studies and comparisons with winds aloft will be completed for two more cases. Other tasks as outlined in [1] will be accomplished as time permits for all four cases.

6.0 PERSONNEL

Percentage of time worked by Project Personnel during the period 1 September-31 December 1962 is listed below.

Homer W. Hiser	Project Supervisor	10%
Harold P. Gerrish	Principle Investigator	100%
David L. Adams	Part-time Student Asst.	50%
Dale R. Hayden	Part-time Student Asst.	50%
Rudy B. Lauterbach	Part-time Student Asst.	50%

7.0 ACKNOWLEDGEMENTS

The authors wish to acknowledge many helpful comments by H. V. Senn with regards to this research. Dr. W. H. Portig also contributed stimulating comments in a private communication. Lillian Rapp typed the manuscript.

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Radar Meteorological Section, The Institute of Marine Science, Univ. of Miami, Miami 49, Florida. MESOSCALE STUDIES OF INSTABILITY PATTERNS AND WINDS IN THE TROPICS - Gerrish, H.P. and H.W. Hiser.

2nd Interim Technical Report, 1 September 1962 - 31 December 1962, 32 pp. (Contract DA-36-039 SC-89111) DA Project 3A99-27-005. Unclassified Report.

The synoptic situation and an analysis of the cloud cover as seen by Tiros III satellite is presented for a case study of 1800Z, 26 August 1961. Particular reference is made to the translational motion of precipitation echoes in the tropics, as determined by tracking selected small echoes and cells. Comparisons of these motions are made with winds aloft.

The space-smoothed translational motion of precipitation echoes in this case study most nearly represented the wind flow at 10,000 ft.

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