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A PROVISIONAL CLIMATOLOGY OF LOW-LEVEL WINDS AS DERIVED FROM ATS-3 SATELLITE OBSERVATIONS

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INTRODUCTION

The motions of low clouds as observed in film loops constructed from photographs by the geostationary Applications Technology Satellite III (ATS-3) have been used to derive provisional seasonal climatologies of low level winds for data-void tropical regions of the Atlantic and Eastern Pacific Oceans. The preliminary results presented here are for winter, spring and a partial summer. Data were readily available only for the period December 1970 through July 1971--thus "summer" here comprises June and July. Extension of the study to include four complete seasons is planned.

The distinguishing feature of this paper is the operationally-oriented presentation of fields of a "Most Probable Wind" (MPW) instead of the more conventional mean or resultant winds which tend to be slower. The primary objective was to provide the analyst responsible for the NHC's ATOLL (Analysis of the Tropical Oceanic Lower Layer) chart with a quickly accessible climatology that would give him a MPW for those areas where recent observations are not available. It is expected that such a climatology will permit a better analysis when the ATOLL chart is automated.

PROCEDURE

Film loops constructed from series of ATS-3 pictures for this purpose must contain enough pictures for reasonable accuracy but not so many that selected cloud elements are not conserved through the period covered by the loop. Operational considerations of the NHC dictate that 5 pictures (covering about 106 minutes) be used in each of two loops prepared each day. The last picture on the first loop is used as the first picture on the second loop. The period covered by the two loops is almost always between 1200 and 1700 GMT.

The loops are projected on a work chart (Figure 1) where displacements of selected elements may be measured. Fujita (1) describes the curves on this chart and explains their use in correcting the apparent cloud displacement vectors. He has developed nomograms for this purpose and these have been converted to tabular form at the NHC, where a plastic tool has been designed to speed the correction procedure. For operational expediency no corrections are applied nearer the subsatellite point than 40% of the angular distance to the horizon. Further, direction of cloud motion is not corrected between 15N and 15S. Errors of measurement no greater than 10% in speed or 10 degrees in direction result from these omissions. No attempt is made to measure cloud displacements beyond 80% of the angular distance from subpoint to horizon

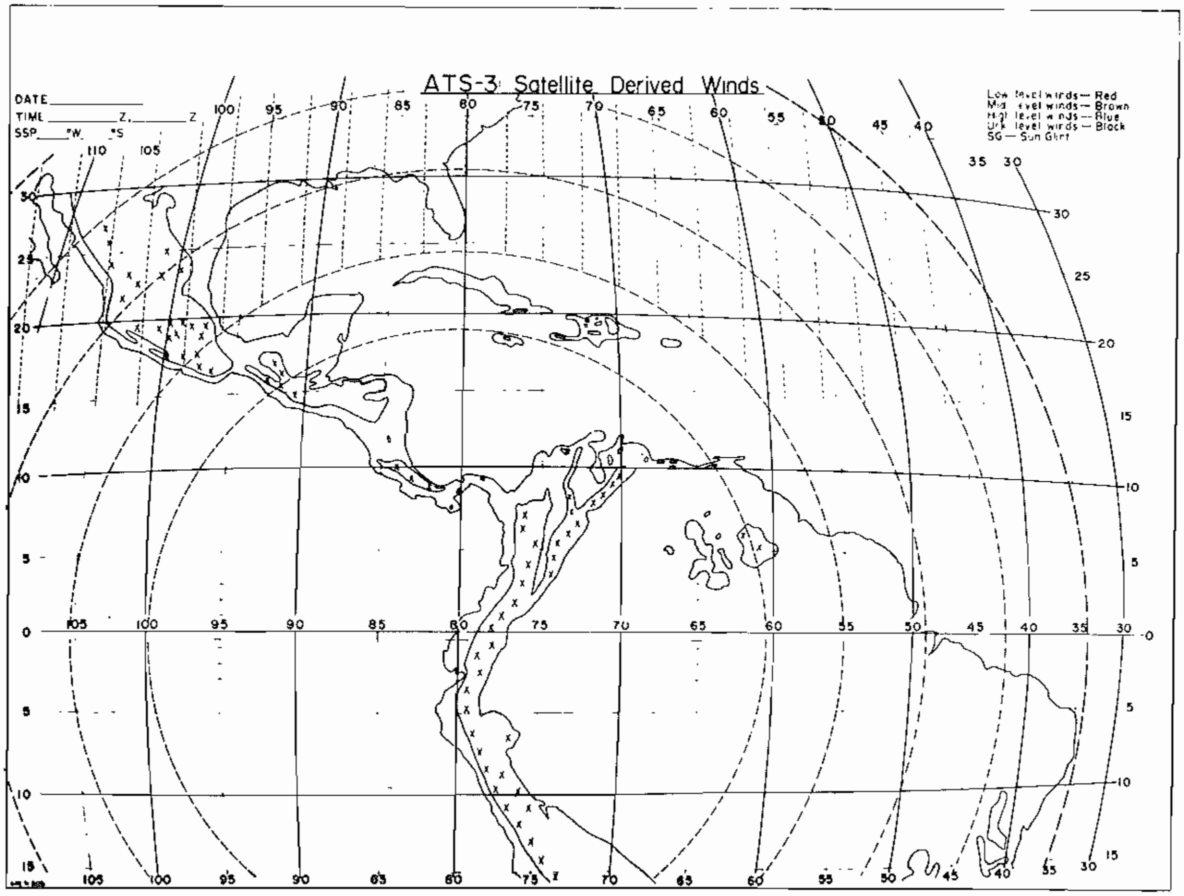

Fig. 1 SAS Winds Work Chart

because of the large corrections often required. An important feature of this chart is the terrain depiction. The solid thin lines enclose elevations of 3000 feet or greater while the crosses indicate elevations of at least 9000 feet. Terrain effects are reflected in the data.

As the loops are viewed, cloud elements are subjectively selected and their displacements marked. The displacement vectors are then converted to velocity and corrected as necessary. Results are punched on cards for later processing.

SOURCES OF ERROR

The data-base for this study consists of 12,441 determinations of low cloud velocities: 4812 for winter, 4075 for spring and 3554 for the two-month summer period--all subject to varying degrees of error.

A lucid treatment of the sources which contribute to the error of wind estimates made from geostationary-satellite pictures is given by Hubert and Whitney (4). It is beyond the scope of this paper to discuss the subject in detail, but a brief comment on some of the more significant error sources is in order.

Errors may occur through improper selection of cloud elements; in particular, the uncertainty of target cloud height is an error source. Comparisons at the NHC have indicated a better correspondence of low-level cloud motion and independently measured wind at the 2000-foot level than at 850mb. Other studies--Hubert and Whitney (4) and Serebreny, et al (6)--have shown good correspondence at 3000 feet.

Wherever possible small cumulus elements with sharp edges and conservative size and form are used. In the case of cumulus believed to have considerable vertical development measurements are made from the upshear side--this is the lower part of the cloud. Errors may also result from the influence of non-advective cloud motions. A special effort is made to avoid using developing or dissipating elements. Both these types of error are associated with the acutely subjective part of the total procedure and are reduced by experience.

Misregistration produces errors due to addition of the apparent motion of fixed points on the earth's surface and the real motion of cloud targets. These errors arise mainly from the use of a single grid for all pictures in the sequence. Picture-to-picture registration would minimize this effect but is is not feasible to use such a procedure in an operational environment. And again, as noted above, certain corrections to the apparent cloud displacements are not made near the subpoint. Errors from these sources are not severely "operator-sensitive"; they are considered acceptable by operational standards.

PROCESSING

The velocity data were processed by computer with results printed out by five-degree latitude-longitude squares for each season in two different ways. In one mode of presentation a table was derived showing the frequency distribution of directions and speeds for each square; ten-degree increments were used for direction, two-knot increments for speed. Figure 2 is an example of this format. The seasonal MPW for each square was determined from these tables according to the rules given in the Appendix.

A second mode of presentation shows the parameters of a family of probability ellipses for the set of vectors associated with each square having at least 18 observations. Figure 3A is an example of this format for the same square used for Figure 2. After the method employed by Neumann (5) a bivariate normal distribution of the u- and v-components of velocity was assumed. Figure 3B shows this distribution graphically--

FREQUENCY DISTRIBUTION OF SATELLITE DERIVED LOW LEVEL WINDS FOR 5-DEGREE SQUARE BOUNDED BY 15 AND 20N, 45 AND 50 W.
MONTHS INCLUDED IN SUMMARY ARE, DEC JAN FEB

WIND DIRECTION IN DEGREES

SPEED KTS	010	020	030	040	050	060	070	080	090	100	110	120	130	140	150	160	170	180
1- 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3- 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5- 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7- 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
11-12	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
13-14	0	0	0	0	0	1	1	0	3	3	0	0	0	0	0	0	0	0
15-16	0	0	0	0	0	1	0	4	5	3	1	0	0	0	0	0	0	0
17-18	0	0	0	0	0	1	1	2	5	3	0	0	0	0	0	0	0	0
19-20	0	0	0	0	0	0	1	6	6	5	0	0	0	0	0	0	0	0
21-22	0	0	0	0	1	1	3	4	7	2	2	1	0	0	0	0	0	0
23-24	0	0	0	0	0	0	1	1	2	3	1	0	0	0	0	0	0	0
25-26	0	0	0	0	0	0	1	0	3	5	4	0	0	0	0	0	0	0
27-28	0	0	0	0	0	0	1	1	2	2	0	0	0	0	0	0	0	0
29-30	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
31-32	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
33-34	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
35-36	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
37-38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41-42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43-44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45-46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47-48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49-50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53-54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55-56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57-58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59-60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61-62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63-64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65-66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67-68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69-70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71-72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73-74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75-76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77-78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81-82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83-84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85-86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91-92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93-94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95-96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
97-98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
99-100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	0	0	0	0	1	4	9	19	36	29	8	2	0	0	0	0	0	0

SPEED KTS	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	SUM
1- 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3- 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5- 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7- 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
11-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
13-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
15-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
17-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
19-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
21-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
23-24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
25-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
27-28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
29-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
31-32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
33-34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
35-36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
37-38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41-42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43-44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45-46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47-48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49-50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53-54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55-56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57-58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59-60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61-62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63-64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65-66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67-68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69-70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71-72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73-74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75-76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77-78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81-82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83-84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85-86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91-92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93-94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95-96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
97-98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
99-100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

TOTAL NUMBER OF OBS CALM IS 0. TOTAL NUMBER OF OBS IS 108

Fig 2. – Winds Frequency Distribution Table

PROBABILITY		SEMI-LENGTH MAJOR AND MINOR AXES			AREA(SQUNITS)	C1	C2	C3	C4	C5	C6
0.05	A#	1.65UNITS	B#	1.41UNITS	26283.	0.4077E 00	0.4641E 00	0.1271E 00	0.1633E 02	0.2514E 01	0.1635E 03
0.10	A#	2.37UNITS	B#	2.02UNITS	53997.	0.1985E 00	0.2260E 00	0.6187E-01	0.7949E 01	0.1224E 01	0.7961E 02
0.15	A#	2.94UNITS	B#	2.50UNITS	93275.	0.1287E 00	0.1465E 00	0.4011E-01	0.5154E 01	0.7933E 00	0.5161E 02
0.20	A#	3.45UNITS	B#	2.93UNITS	114339.	0.9371E-01	0.1067E 00	0.2921E-01	0.3753E 01	0.5778E 00	0.3759E 02
0.25	A#	3.91UNITS	B#	3.33UNITS	147409.	0.7268E-01	0.8275E-01	0.2266E-01	0.2911E 01	0.4482E 00	0.2916E 02
0.30	A#	4.36UNITS	B#	3.71UNITS	182761.	0.5862E-01	0.6675E-01	0.1828E-01	0.2348E 01	0.3615E 00	0.2352E 02
0.35	A#	4.79UNITS	B#	4.08UNITS	220734.	0.4854E-01	0.5526E-01	0.1513E-01	0.1944E 01	0.2993E 00	0.1947E 02
0.40	A#	5.21UNITS	B#	4.44UNITS	261748.	0.4093E-01	0.4660E-01	0.1276E-01	0.1640E 01	0.2524E 00	0.1642E 02
0.45	A#	5.64UNITS	B#	4.80UNITS	306334.	0.3498E-01	0.3982E-01	0.1090E-01	0.1401E 01	0.2157E 00	0.1403E 02
0.50	A#	6.07UNITS	B#	5.17UNITS	355171.	0.3017E-01	0.3435E-01	0.9404E-02	0.1208E 01	0.1860E 00	0.1210E 02
0.55	A#	6.52UNITS	B#	5.55UNITS	409158.	0.2619E-01	0.2981E-01	0.8163E-02	0.1049E 01	0.1615E 00	0.1050E 02
0.60	A#	6.98UNITS	B#	5.95UNITS	469510.	0.2282E-01	0.2598E-01	0.7114E-02	0.9141E 00	0.1407E 00	0.9154E 01
0.65	A#	7.47UNITS	B#	6.36UNITS	537932.	0.1992E-01	0.2268E-01	0.6209E-02	0.7978E 00	0.1228E 00	0.7989E 01
0.70	A#	8.00UNITS	B#	6.81UNITS	616919.	0.1737E-01	0.1977E-01	0.5414E-02	0.6957E 00	0.1071E 00	0.6966E 01
0.75	A#	8.59UNITS	B#	7.31UNITS	710342.	0.1508E-01	0.1717E-01	0.4702E-02	0.6042E 00	0.9330E-01	0.6050E 01
0.80	A#	9.25UNITS	B#	7.88UNITS	824681.	0.1299E-01	0.1479E-01	0.4050E-02	0.5204E 00	0.8011E-01	0.5211E 01
0.85	A#	10.05UNITS	B#	8.55UNITS	972091.	0.1102E-01	0.1255E-01	0.3436E-02	0.4415E 00	0.6796E-01	0.4421E 01
0.90	A#	11.07UNITS	B#	9.42UNITS	1179852.	0.9081E-02	0.1034E-01	0.2831E-02	0.3637E 00	0.5599E-01	0.3643E 01
0.95	A#	12.63UNITS	B#	10.75UNITS	1535023.	0.6980E-02	0.7947E-02	0.2176E-02	0.2796E 00	0.4304E-01	0.2800E 01
0.99	A#	15.65UNITS	B#	13.33UNITS	2359703.	0.4540E-02	0.5170E-02	0.1415E-02	0.1819E 00	0.2800E-01	0.1821E 01

STND DEVY	STND DEVX	CORR COEF	THETA#DEGS<	YMEAN	XMEAN	
4.63UNITS	4.94UNITS	-0.146	-33.02	0.03UNITS	-20.03UNITS	ELLIPSE IDENT IS DEC JAN FEB 15-20N, 45-50W

YDIR CENTROID# 0.035 XDIR CENTROID# -20.034 VARIANCE ALONG MAJOR AXIS# 26.6 VARIANCE ALONG MINOR AXIS# 19.3UNITS
STND DEV ALONG MAJOR AXIS # 5.1583 STND DEV ALONG MINOR AXIS # 4.3916 NUMBER OF CASES IS 108

EQUATION OF ELLIPSE IN X,Y COORDINATE SYSTEM IS GIVEN BY
C1*XSQ+C2*YSQ+C3*XY+C4*X+C5*Y+C6 = 1.0000

Fig 3A. – Probability Ellipse Printout.

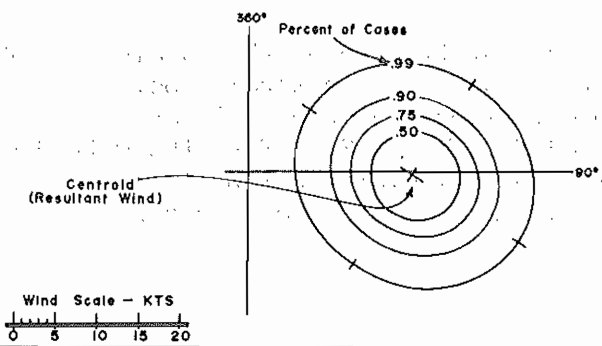

Fig 3B. Probability Ellipse

vectors are drawn with the head at the origin of coordinates. A vector from the centroid of the ellipses to the origin would represent the resultant wind since this point is the location of the means of all u- and v-components considered for the particular square. Details of the derivation of the ellipses may be found in Groenewoud, et al (2) or Hope and Neumann(3).

PRESENTATION OF RESULTS

Figures 4-6 exhibit fields of the MPW, except that the westernmost vectors shown in the A-figures for each latitude belt and in each ocean for winter and spring are resultant vectors. This irregularity is due to a programming error which rendered the frequency distribution tables for these squares unusable. The vectors are plotted with the proper directions; speeds are indicated in knots at the tails of the arrows. The number in the lower left of each square indicates the number of observations made in that square. This number is absent in Figure 4A for those squares south of latitude 10N where observations totaled less than 18, again due to a programming error. The minimum number of observations considered sufficient for determination of a MPW was 18. The derived vectors for squares 25-30N, 60-65W(winter) and 25-30N, 70-75W (spring) were discarded for reasons of irreconcilable incompatibility. Observations in the Pacific during winter are almost totally lacking because ATS-3 was kept well east, near 46W, during much of this period.

The B-figures show streamline and isotach analyses of the MPW which in general required only slight smoothing. Significant features are evident, e.g. the familiar isotach maximum in the Caribbean, etc.

CONCLUDING REMARKS

These results may be regarded as a provisional climatology of low-level, Most Probable Winds. This concept of a MPW leads to a useful analytical tool with direct operational application. While the analyst indeed may require information on the variability of winds, his pressing needs will usually be satisfied by the MPW. The probability ellipses provide more complete information. Charts of resultant winds, mean u- and v-components, standard deviations, etc. have also been prepared for easy reference--these can be provided on request.

The MPW as determined by the method given in the Appendix will normally have a speed faster than the resultant wind which is presented in most climatological studies. Also, a summary for a single season may not properly be considered a synthesis of events over a climatically significant period. There is further a probable bias toward cloud producing systems inherent in the data-base for this study. For these reasons the results are not directly comparable to other wind climatologies.

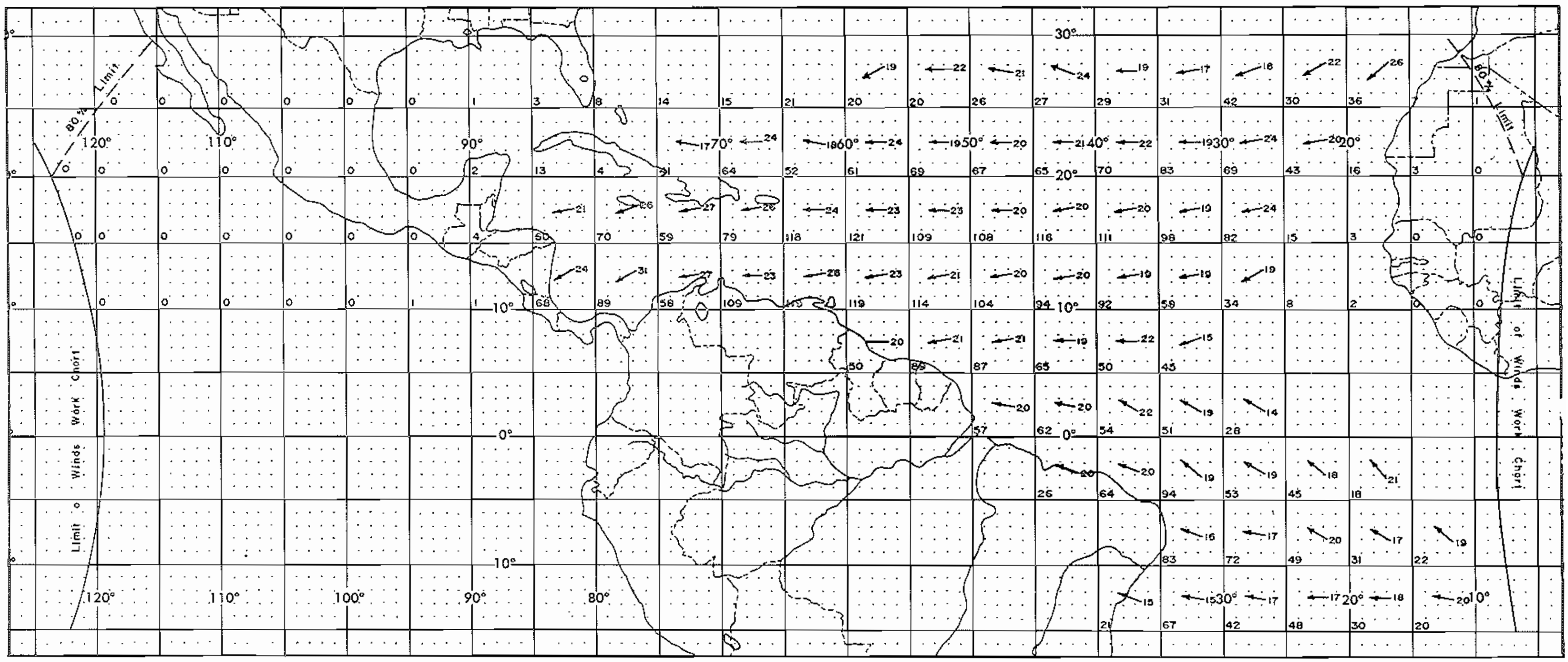

FIG. 4A WINTER WINDS: MOST PROBABLE WIND VECTORS

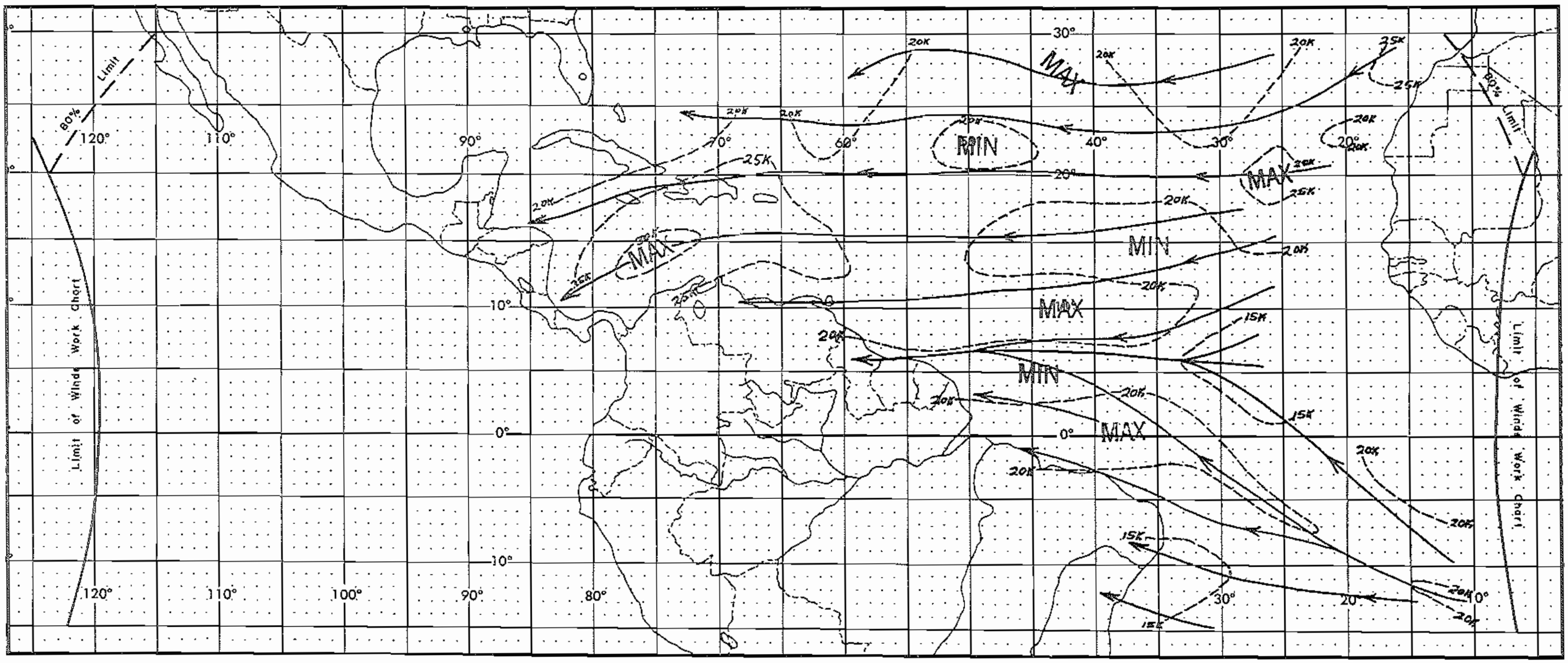

FIG. 4B WINTER SEASON ANALYSIS OF MOST PROBABLE WIND

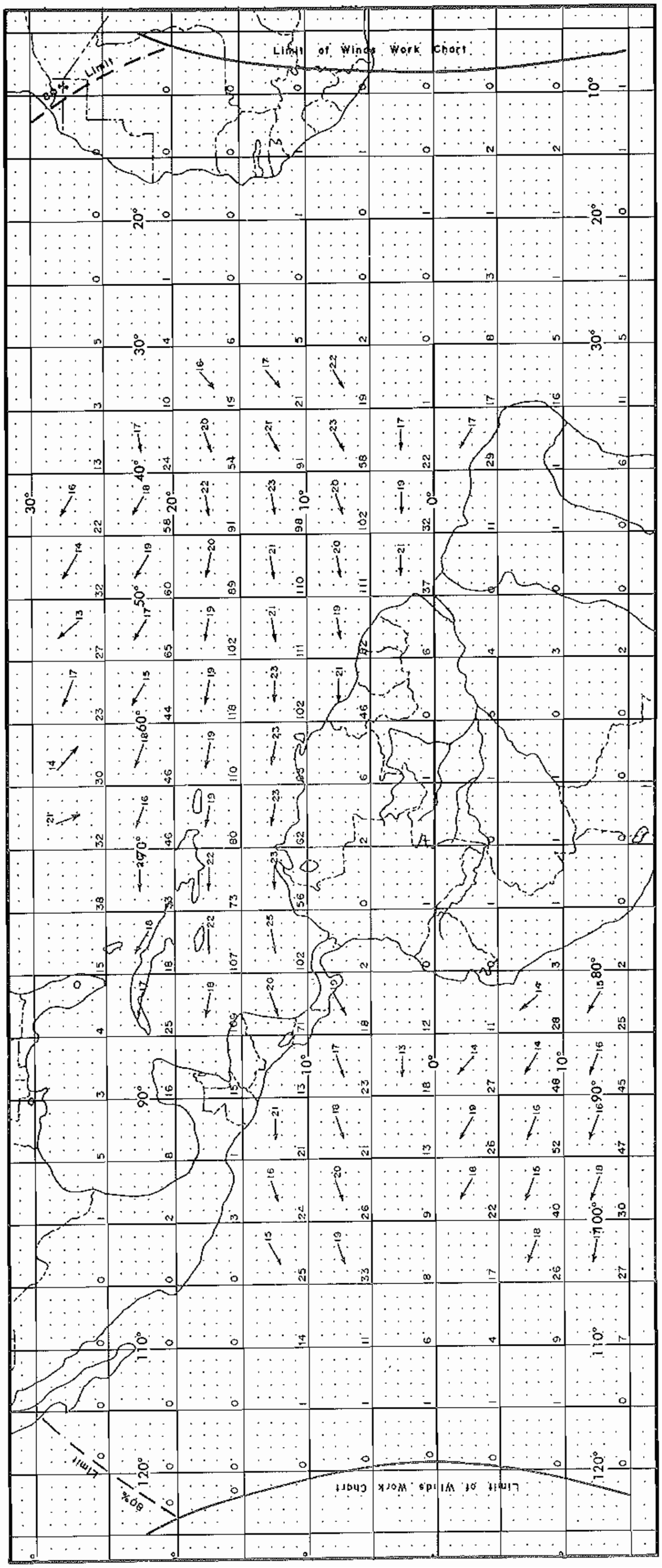

FIG. 5A SPRING WINDS: MOST PROBABLE WIND VECTORS

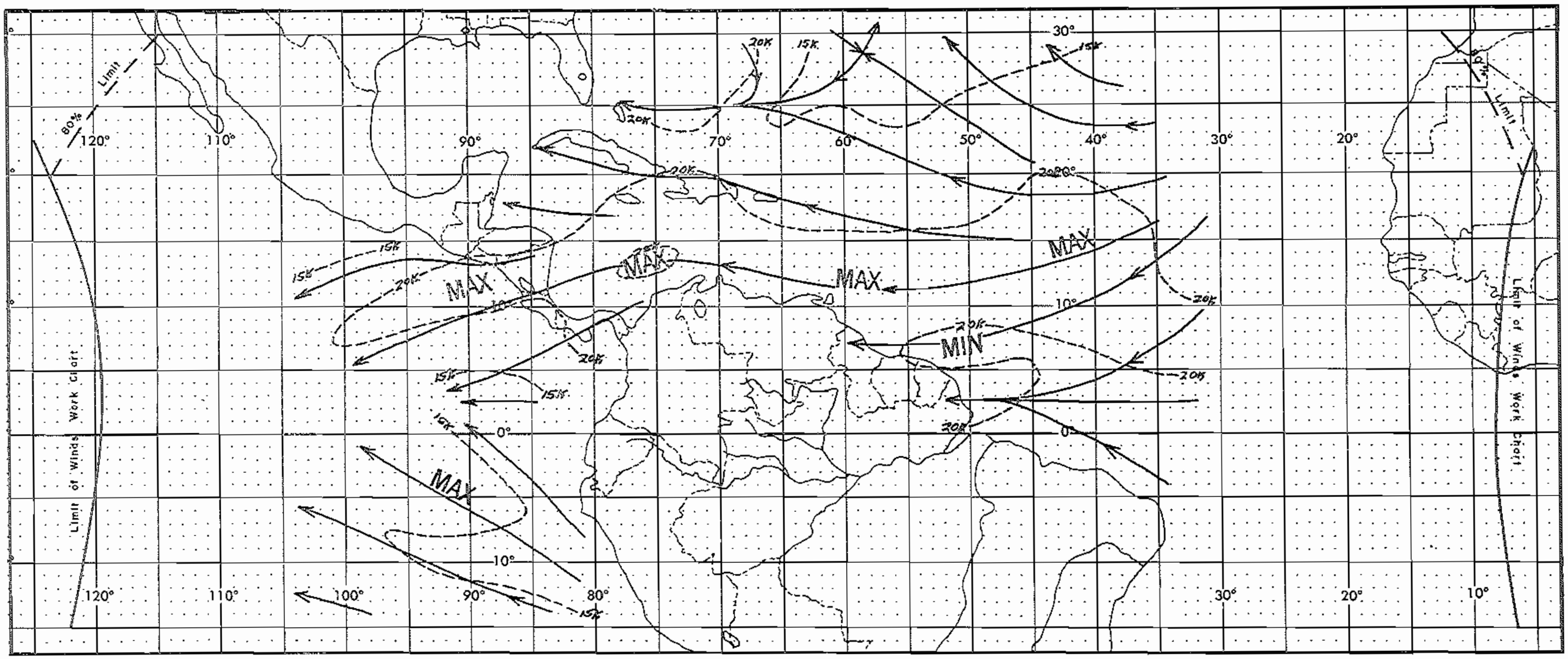

FIG. 5B SPRING SEASON ANALYSIS OF MOST PROBABLE WIND

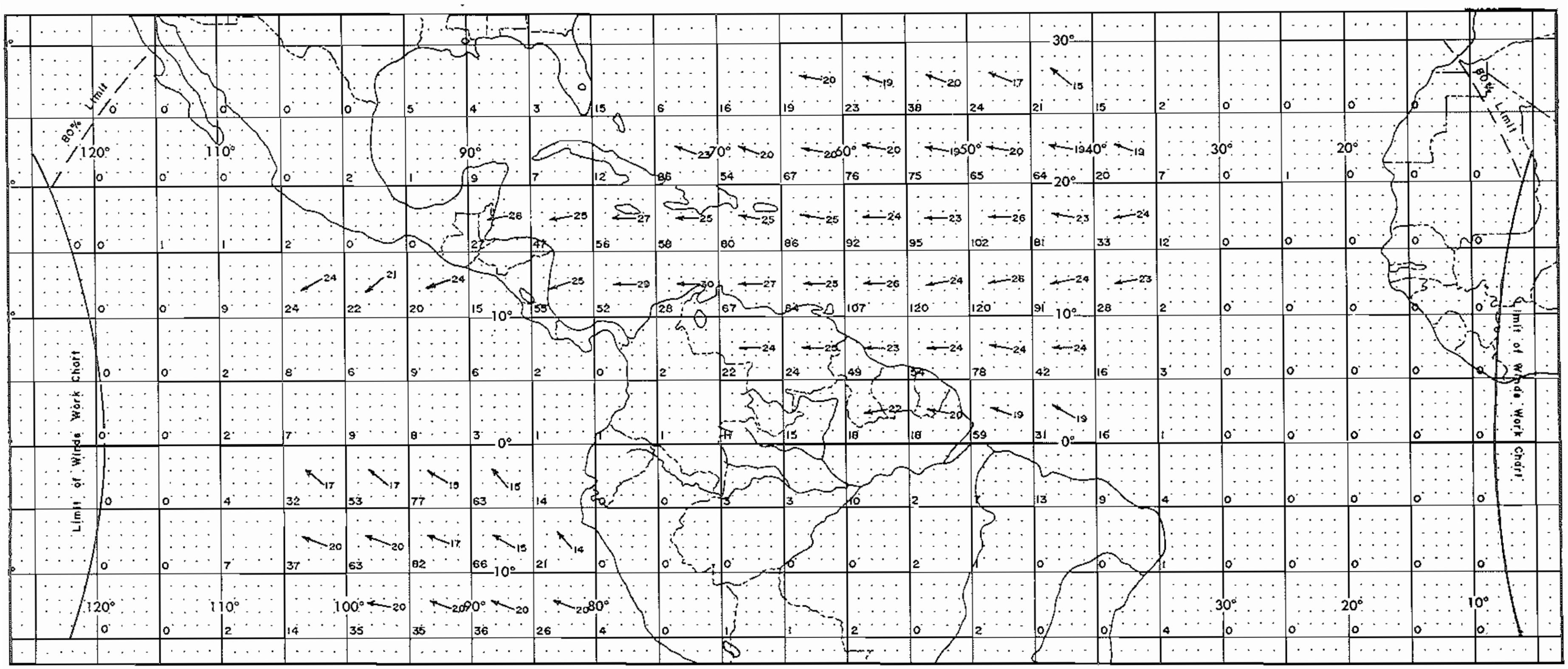

FIG. 6A SUMMER WINDS: MOST PROBABLE WIND VECTORS

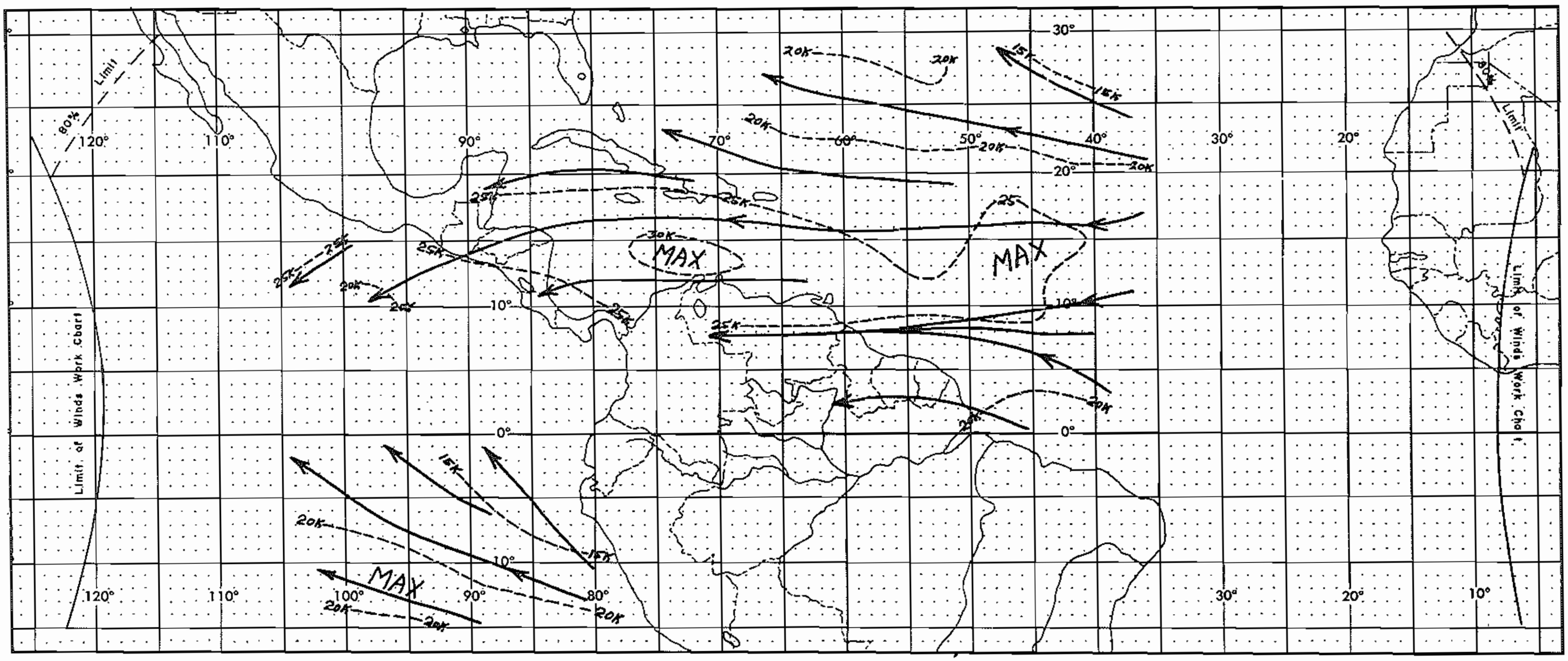

FIG. 6B SUMMER SEASON ANALYSIS OF MOST PROBABLE WIND

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APPENDIX

Method of determination of the Most Probable Wind (MPW) from frequency distribution tables (Example: Figure 2)

Direction of MPW

1. If a direction occurs with a frequency at least twice that of any other, take that as the MPW direction.

2. If (1) fails, locate the three adjacent columns with the largest sum total of occurrences and let the middle column represent the MPW direction; if two such groups have equal sum totals, use that group with the largest sum in the middle column.

3. If (2) fails use the mean u- and v-components from the probability ellipse printout to determine the resultant direction -- use this as the MPW direction.

Speed of MPW* (with direction determined)

4. If one speed within the range of the MPW direction -- where range refers to one column if (1) or (3) applies and to three columns if (2) applies, which is the usual case -- with a frequency at least twice that of any other, take that as the MPW speed.

5. If (4) fails, locate the three adjacent rows with the largest sum total of occurrences within the range of the MPW direction and take the middle row as the MPW speed; if two such groups have equal sum totals use that group with the largest sum in the middle row. If this procedure does not isolate a group of three rows include the next adjacent rows of higher and lower speeds for resolution.

6. If (5) fails and the groups overlap, take the overlapping row as the MPW speed. The possibility remaining (i.e., if the groups do not overlap) does not occur in the data.

EXAMPLE: Applying this set of rules to Figure 2, the MPW is found to be: 090°/20K.

* Two speeds, to whole knots, are associated with each row. The choice between them is made in each case according as the next lower or higher row has the greater number of occurrences.