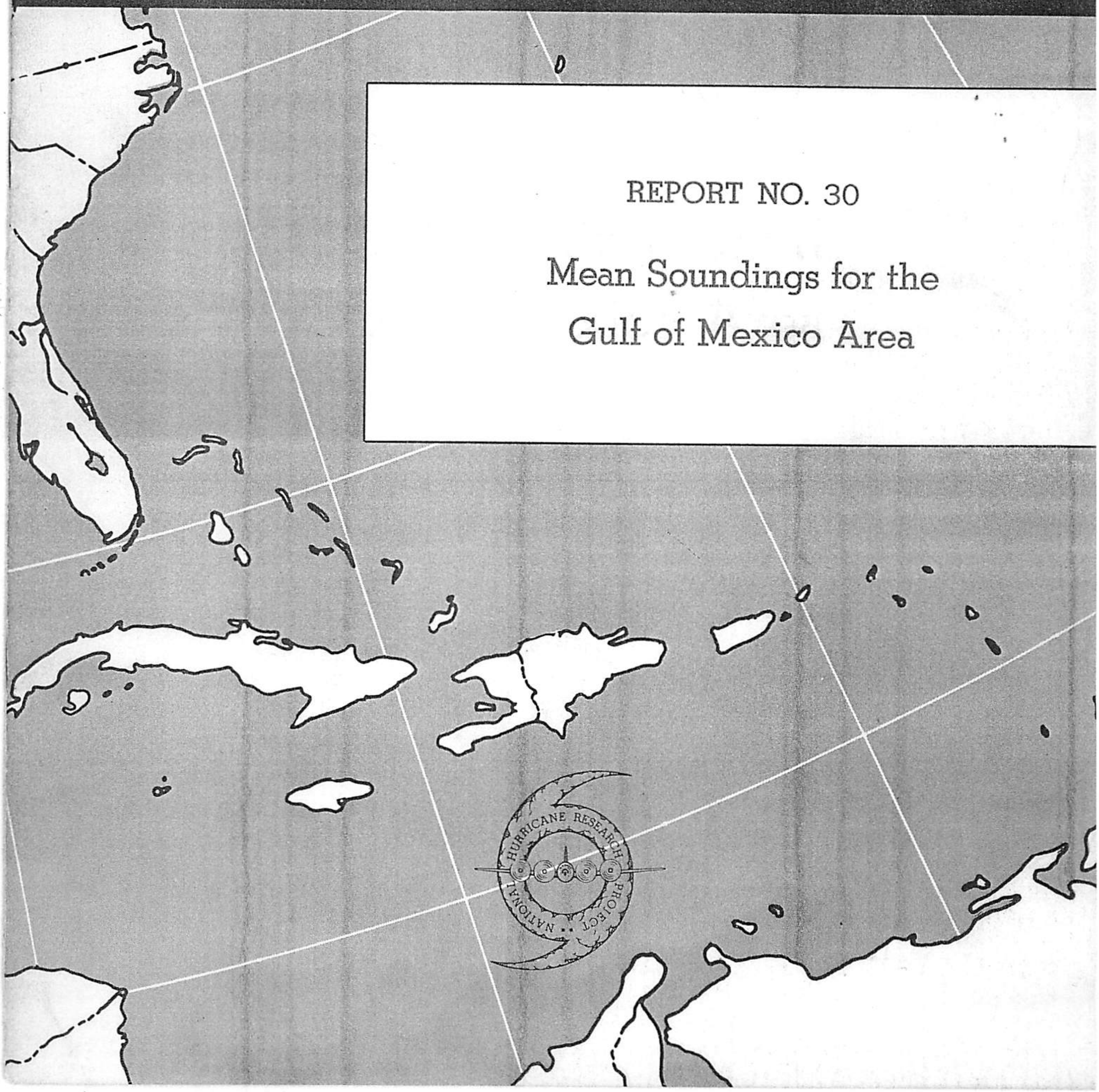
NATIONAL HURRICANE RESEARCH PROJECT

REPORT NO. 30

Mean Soundings for the Gulf of Mexico Area



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NATIONAL HURRICANE RESEARCH PROJECT

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Mean Soundings for the Gulf of Mexico Area

by
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NATIONAL HURRICANE RESEARCH PROJECT REPORTS

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MEAN SOUNDINGS FOR THE GULF OF MEXICO AREA

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ABSTRACT

Mean aerological data for the Gulf of Mexico area have been prepared from 10-year records for three stations. Mean monthly height, temperature, and relative humidity data are tabulated for constant pressure surfaces. More detailed information, including density, potential temperature, and specific humidity, is shown for the mean "hurricane season" sounding. The mean data are compared with those previously presented for the West Indies area and some of the interesting climatological features are discussed.

1. INTRODUCTION

Recently, mean sounding data have been presented for the West Indies area based on 10-year records for Miami, Fla.; San Juan, P. R.; and Swan Island [1]. At about the same time, mean aerological data were being prepared for individual U. S. Weather Bureau and cooperative stations for the same 10-year period, 1946-1955 [2]. Since the availability of these mean data for the individual stations greatly simplifies the preparation of mean soundings for geographical areas, it was decided to prepare, for comparative purposes, mean soundings for the Gulf of Mexico area by combining the published means for Brownsville, Tex.; Burrwood-New Orleans[2], La.; and Havana, Cuba. This new set of data for a slightly different geographical area (fig. 1) should be useful as a check on the representativeness of the mean West Indies data [1] and also provide information on seasonal variations of temperature, pressure, and humidity over the northern Gulf of Mexico.

2. PROCESSING OF DATA

In preparing the mean sounding data for the Gulf of Mexico area, the information was processed in a somewhat different manner than that employed in computing the mean West Indies sounding. Detailed information on the length of record and the techniques employed in reducing bias in the monthly means at the upper levels at the individual stations is given in [2]. In contrast to the mean West Indies soundings, the pressure-height data for the Gulf soundings were not computed from the mean temperature and humidity data; the height data for the standard pressure surfaces were obtained by simply averaging the reported heights at the individual levels. Checks made in [1] suggest that only very minor inconsistencies are introduced by treating the

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[1]This report was prepared with the support of the U. S. Weather Bureau.

[2]Data taken at New Orleans for the period Jan. 1947-July 1950 and at Burrwood for Jan.-Dec. 1946 and Aug. 1950-Dec. 1955 were combined in preparing the mean data [2]. This combined record will be referred to as Burrwood in the subsequent discussion.

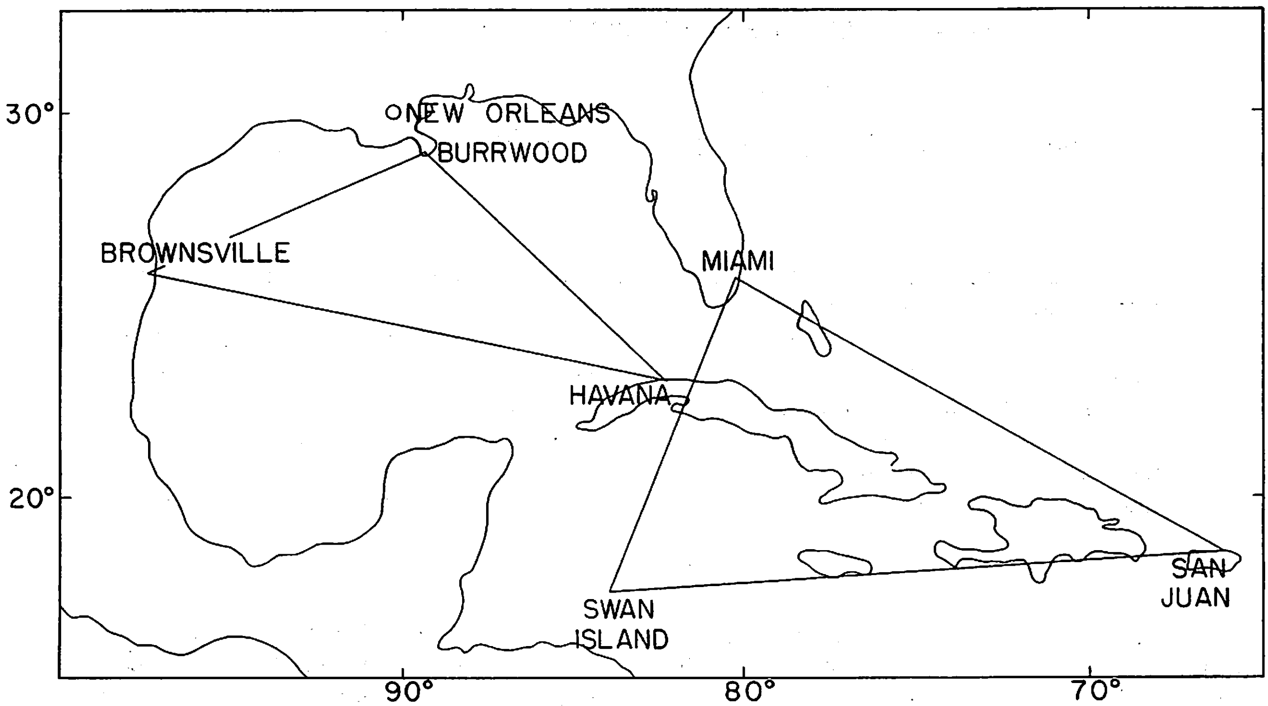

Figure 1. - Location map for stations used in the preparation of mean soundings for the Gulf of Mexico and West Indies areas.

data in this way. To the extent possible, mean data are shown for all standard levels up to 30 mb. as in [1] although relatively few observations reached this level in the earlier years. The mean surface pressures were reduced to mean sea level pressures simply by considering the mean elevation of the three stations and the mean temperature in the layer near the surface.

The mean values are based entirely on the 0300 GMT observations in both sets of data so that radiation errors, noted in radiosonde records in the past [3], need not be considered. The observations were scheduled at local times varying from approximately 10:30 p.m. at San Juan to about 8:30 p.m. at Brownsville. Since relatively small mean diurnal differences can be expected over a 2-hour period [3] and since any effect of this type introduced by the San Juan and Brownsville data would tend to be reduced by the data from the other stations, which are all within 10° longitude of each other, it is felt that diurnal differences can safely be neglected in comparing the Gulf and West Indies soundings.

3. THE MEAN AEROLOGICAL DATA

The monthly and annual temperature, height, and relative humidity data for the standard pressure surfaces for the Gulf of Mexico area, obtained by averaging the data for the three stations (fig. 1), are shown in tables 1-3. Seasonal changes at the individual stations especially Burrwood and Brownsville, are quite large and the mean monthly data for the winter months can hardly be considered as representative of conditions in the whole of the triangle shown in figure 1. In the summer months, thermal conditions at the three stations are very similar and month-to-month changes are small. The

Table 1. - Mean temperature (°C.) at standard pressure surfaces for Gulf of Mexico area. All values above the dashed line are negative.

Pressure	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
30	56.0	57.3	56.5		53.1		51.5	52.7	52.5	54.0	54.3	55.6	54.3
40	60.6	60.7	60.3	57.2	55.7	58.7	55.7	56.2	56.5	57.3	58.5	59.6	58.1
50	65.5	64.4	65.2	62.1	59.3	59.1	58.8	59.0	59.3	60.4	61.9	63.5	61.5
60	69.5	68.9	69.7	66.5	63.4	62.6	61.9	61.9	62.5	63.4	65.5	67.1	65.2
80	74.0	73.0	73.3	73.0	70.2	69.1	67.1	67.5	68.3	69.9	71.7	72.2	70.8
100	72.9	71.8	72.0	69.9	71.1	72.7	70.2	71.0	73.1	73.8	72.8	71.7	71.9
125	68.0	67.3	67.3	66.4	68.4	71.1	70.3	70.5	72.0	71.2	71.1	69.7	69.4
150	63.4	62.7	63.3	63.5	65.3	66.5	66.7	66.2	66.6	66.3	66.2	64.9	65.1
175	59.9	58.9	59.7	60.7	60.9	60.9	61.2	60.4	60.4	60.4	61.4	61.4	60.5
200	56.3	55.8	56.3	56.9	56.0	54.9	55.1	54.2	53.9	54.7	56.1	57.0	55.6
250	47.6	48.2	47.8	47.3	45.6	43.4	43.2	42.6	42.2	43.9	45.7	47.2	45.4
300	38.5	39.2	38.4	37.8	36.1	33.6	33.2	32.6	32.7	34.4	36.4	37.8	35.9
350	30.3	30.9	29.9	29.5	27.8	25.2	24.8	24.3	24.1	26.3	28.2	29.6	27.6
400	23.0	23.6	22.5	22.3	20.6	18.1	17.7	17.3	17.2	19.2	21.0	22.3	20.4
450	16.5	17.3	16.1	15.9	14.3	12.0	11.8	11.4	11.3	13.0	14.8	16.0	14.2
500	10.8	11.7	10.4	10.3	8.8	6.9	6.8	6.4	6.3	7.7	9.4	10.5	8.8
550	5.9	6.8	5.4	5.3	4.0	2.3	2.4	2.0	1.9	3.1	4.6	5.7	4.1
600	1.6	2.5	1.0	0.8	0.4	1.7	1.5	2.1	2.0	0.9	0.4	1.4	0.1
650	2.2	1.5	3.2	3.4	4.6	5.6	5.4	5.8	5.7	4.6	3.3	2.4	4.0
700	5.6	5.1	6.8	7.0	8.3	9.1	9.0	9.4	9.1	8.0	6.7	5.6	7.5
750	8.3	7.9	9.7	10.1	11.6	12.4	12.4	12.7	12.2	10.9	9.4	8.4	10.5
800	10.4	10.0	11.8	12.7	14.4	15.4	15.6	15.8	15.1	13.3	11.6	10.6	13.1
850	11.9	11.6	13.8	15.0	17.1	18.3	18.6	18.5	17.9	15.7	13.4	12.2	15.3
900	13.6	13.5	15.5	17.2	19.7	20.9	21.4	21.7	20.7	18.3	15.3	14.0	17.8
950	15.3	15.5	17.3	19.2	20.6	23.3	23.8	24.2	23.4	21.0	17.6	16.0	19.8
1000	17.1	17.5	19.3	21.4	24.0	25.8	26.2	26.6	25.8	23.5	19.9	17.9	22.1
Sfc.	16.7	17.2	19.1	21.6	24.1	26.0	26.5	26.8	25.8	23.1	19.4	17.3	22.0

Table 2. - Mean heights of standard pressure surfaces (meters) for Gulf of Mexico area. Sea level pressure (SLP) is given in millibars.

Pressure	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
30	23753	23738	23739		23903		24106	24085	24071	23927	23814	23773	23891
40	21936	21905	21928	22000	22074	22179	22250	22264	22219	22106	21983	21957	22067
50	20527	20515	20554	20610	20668	20771	20843	20860	20818	20706	20592	20553	20668
60	19427	19419	19453	19497	19555	19642	19707	19723	19678	19577	19477	19440	19550
80	17744	17730	17760	17787	17829	17903	17954	17966	17929	17839	17761	17728	17828
100	16448	16426	16450	16471	16509	16583	16618	16636	16609	16538	16457	16441	16516
125	15116	15096	15127	15136	15187	15272	15295	15314	15305	15225	15145	15115	15194
150	14005	13982	14017	14023	14081	14186	14201	14220	14211	14140	14055	14007	14094
175	13050	13020	13058	13072	13137	13270	13256	13273	13264	13193	13111	13061	13147
200	12211	12177	12214	12236	12297	12395	12417	12430	12422	12351	12272	12224	12304
250	10768	10734	10770	10792	10845	10932	10953	10962	10950	10887	10821	10779	10849
300	9540	9511	9542	9560	9605	9679	9698	9704	9690	9638	9582	9548	9608
350	8463	8436	8463	8479	8517	8578	8595	8600	8585	8543	8496	8468	8519
400	7500	7475	7498	7512	7544	7595	7603	7614	7598	7563	7524	7502	7544
450	6631	6609	6628	6642	6668	6711	6727	6728	6713	6684	6650	6632	6669
500	5822	5803	5818	5831	5852	5888	5903	5903	5886	5863	5835	5821	5852
550	5084	5068	5078	5090	5108	5140	5155	5155	5137	5116	5093	5082	5109
600	4396	4381	4389	4400	4414	4441	4456	4453	4437	4420	4401	4393	4415
650	3757	3745	3748	3759	3771	3795	3809	3806	3791	3777	3761	3755	3773
700	3151	3141	3140	3150	3159	3180	3196	3191	3175	3163	3151	3148	3162
750	2589	2581	2576	2585	2591	2609	2623	2617	2604	2597	2587	2587	2596
800	2048	2040	2032	2040	2042	2060	2075	2069	2055	2049	2043	2045	2050
850	1541	1534	1523	1529	1527	1543	1556	1550	1537	1536	1534	1538	1537
900	1061	1055	1039	1042	1036	1049	1063	1055	1044	1048	1051	1057	1050
950	608	601	583	582	573	584	594	587	579	585	594	603	589
1000	167	159	138	134	119	127	138	130	122	134	146	160	140
SLP.	1020	1019	1016	1015	1014	1014	1015	1015	1014	1015	1017	1019	1016

Table 3. - Mean humidity (percent) at standard pressure surfaces for Gulf of Mexico area.

Pressure	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
400	30	33	32	33	34	35	42	41	40	33	31	32	35
450	28	31	30	32	32	36	43	42	41	32	29	30	34
500	26	30	30	32	34	38	46	43	43	33	29	30	35
550	26	30	30	32	35	40	49	47	46	34	30	29	36
600	27	32	31	33	37	42	51	49	50	38	32	31	38
650	30	33	31	34	38	43	53	51	52	40	34	32	39
700	33	35	32	36	40	46	54	53	55	43	37	36	42
750	38	38	37	41	45	49	56	56	59	47	42	41	46
800	48	47	44	47	52	56	59	60	63	55	49	49	52
850	58	57	53	54	58	61	64	63	68	62	57	57	59
900	67	66	63	62	64	67	68	68	71	68	66	66	66
950	74	73	71	73	73	75	76	76	76	73	72	74	74
1000	78	77	80	79	81	81	81	80	81	77	75	77	79
Sfc.	84	82	83	82	84	84	83	83	84	83	82	83	83

mean soundings are, therefore, much more representative of normal conditions which would be expected over much of the Gulf of Mexico during this season. The major portion of the subsequent discussion will deal with summer conditions; however, some use will be made of the data for the other months in comparing seasonal variations over the Gulf of Mexico with those indicated for the West Indies area in [1].

The data for the months July-September have been combined into a mean "hurricane season" sounding (table 4). The data are presented in the same form as the mean "hurricane season" sounding for the West Indies area [1] and deviations from the West Indies sounding are shown for all quantities. The "hurricane season" sounding for the West Indies area used data for the months July-October but October was omitted in preparing the comparable sounding for the Gulf of Mexico area since the intrusion of westerlies at Brownsville and Burrwood is quite evident in the mean temperature data for October. This seasonal change in the circulation patterns is undoubtedly associated with the observed decrease in the frequency of tropical cyclogenesis between September and October [4], a tendency which is more marked in the Gulf of Mexico area than in the West Indies area.

There is little doubt that the "hurricane season" sounding offers a good approximation to normal summer conditions over the northern Gulf of Mexico. The deviations of the station means from the values given in table 4 were nearly all less than 1°C. at lower and middle tropospheric levels and less than 2°C. at all levels. Relative humidity values show more consistent deviations, with Brownsville running 4-5 percent less than the mean at some levels and Havana showing values greater than the means by a similar amount. The stations

Table 4. - Mean Gulf of Mexico "hurricane season" sounding data for isobaric surfaces. Mean values of height (H), temperature (T), density (ρ), potential temperature (θ), equivalent potential temperature (θ_E), relative humidity (f), and specific humidity (q) are tabulated. Deviations (Δ) of mean Gulf of Mexico sounding data from mean West Indies sounding data are given for all of the above quantities.

P (mb)	H (ft)	H (m)	ΔH (m)	T (°C)	ΔT (°C)	ρ (kg/m^3)	Δρ (kg/m^3)	θ (°A)	Δθ (°A)	θ_E (°A)	$\Delta\theta_E$ (°A)	f (%)	Δf (%)	q (g/kg)	Δq (g/kg)
30	79005	24087	116	-52.2	1.8	0.047	-.001	604	7						
40	72965	22246	107	-56.1	1.2	0.064	-.001	531	7						
50	68355	20840	97	-59.0	1.6	0.080	-.002	507	7						
60	64625	19703	83	-62.1	1.8	0.099	-.001	474	6						
80	58875	17950	63	-67.6	2.2	0.136	-.001	425	7						
100	54515	16621	53	-71.4	2.1	0.173	-.001	391	5						
125	50200	15305	45	-70.9	1.3	0.215	-.002	368	4						
150	46610	14211	34	-66.5	1.1	0.253	-.001	356	2						
175	43505	13264	26	-60.7	0.8	0.287	-.001	351	3						
200	40745	12423	27	-54.4	0.8	0.319	-.001	347	2						
250	35930	10955	20	-42.7	0.6	0.378	-.001	344	2						
300	31805	9697	15	-32.8	0.4	0.435	+.001	340	2						
350	28185	8593	12	-24.4	0.4	0.488	-.002	336	1						
400	24945	7605	10	-17.4	0.3	0.545	0	333	1	336		41		1.0	
450	22055	6723	20	-11.5	0.4	0.599	0	329	1	334	1	42	0	1.5	0.1
500	19345	5898	10	- 6.5	0.4	0.652	-.001	325	1	332	0	44	-1	2.1	0
550	16890	5149	11	- 2.1	0.4	0.706	-.001	322	1	331	-1	47	0	2.8	0.1
600	14595	4449	7	1.9	0.5	0.758	-.002	318	0	330	1	50	0	3.7	0.1
650	12470	3802	10	5.6	0.5	0.809	-.002	315	0	329	0	52	-2	4.6	0
700	10455	3187	5	9.2	0.6	0.861	-.001	313	1	330	0	54	-3	5.7	-0.1
750	8575	2615	6	12.4	0.6	0.911	-.002	310	1	331	0	57	-4	7.0	-0.1
800	6775	2066	3	15.5	0.9	0.964	0	308	1	333	0	61	-7	8.5	0.1
850	5075	1548	1	18.3	1.0	1.010	-.003	305	1	336	-1	65	-9	10.3	-0.7
900	3455	1054	0	21.3	1.1	1.057	-.005	303	1	340	0	69	-10	12.6	-0.8
950	1925	587	4	23.8	0.8	1.104	-.004	301	1	345	1	76	-5	15.2	-0.1
1000	425	130	-2	26.2	0.2	1.151	-.001	299	0	349	0	81	0	17.7	0.1
1015	0	0		26.4	0.1	1.161	-.001	298	0	349	0	83	-1	18.3	0.1

Table 5. - Deviation of mean Gulf of Mexico temperature data (°C.) from mean West Indies temperature data at selected pressure surfaces for individual months.

	July	August	September
50	+1.2	+1.2	+1.5
100	+1.1	+1.3	+0.8
150	+1.0	+1.0	+1.1
200	+0.8	+0.8	+1.0
250	+0.8	+0.6	+0.6
300	+0.7	+0.5	0
400	+0.5	+0.3	+0.1
500	+0.6	+0.4	+0.4
600	+0.7	+0.6	+0.3
700	+0.7	+0.6	+0.2
800	+1.1	+0.9	+0.2
900	+1.5	+1.2	+0.2
1000	+0.1	+0.2	-0.4

used in preparing the mean Gulf of Mexico soundings are not distributed so that the data can be considered truly representative of the portions of the Gulf of Mexico where tropical cyclogenesis is most frequent [4]. Data from the Mexican stations at Merida and Veracruz, combined with Burrwood and Brownsville, would probably have led to more representative soundings for the primary hurricane-formation area of the Gulf of Mexico. However, data for Merida and Veracruz - probably because of the shorter length of the records at these stations - were not included in the tabulations of mean aerological data [2].

The deviations shown in table 4 reveal that differences in the two "hurricane season" soundings are small throughout most of the troposphere. At levels up to 500 mb., the temperature and moisture differences are small enough so that the stability is almost identical over the two areas as revealed by the very small and unorganized differences between the equivalent potential temperature values for the two soundings[3]. However, the observed differences indicate that conditions over the Gulf are consistently warmer and drier than in the West Indies area. Deviations of this type in the troposphere are consistent with the fact that easterly flow increases with height over this area in association with the upper tropospheric anticyclone located over the southern United States during the summer months [5]. Stratospheric easterlies exist over the whole subtropical area in summer with maximum speeds above the 30-mb. level. The largest temperature differences shown in table 4 appear in the lower stratosphere where the mean easterlies increase most rapidly with height.

The fact that October data are included in the "hurricane season" sounding for the West Indies but not in the similar sounding for the Gulf area has a negligible effect on the features discussed above. This is evident from the fact that the temperature anomalies for the individual months, shown for selected levels in table 5, are very similar to those shown in table 4. The September deviations are smaller than those of the other months and the vertical distribution is such that the stability over the Gulf, in comparison with

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[3] The deviations of equivalent potential temperatures given in table 4 are based on corrected values of the equivalent potential temperatures for the West Indies sounding which will appear in a Corrigendum in the Journal of Meteorology.

the West Indies conditions, is slightly greater during this month. However, considered over deep layers differences are less than 1°C.

The fact that differences between the two mean "hurricane season" soundings are small and of such a form as to be consistent with the large-scale climatological features of the area, suggests that the mean "hurricane season" sounding presented in [1], although based on data from only three stations, is probably a close approximation to mean conditions over an extensive area in the West Indies-Gulf of Mexico region. Comparison of the mean soundings for individual summer months for the two areas would reveal differences only slightly greater than shown for the "hurricane season" soundings in table 4. This fact, together with the information that synoptic variations are usually small in these areas in the summer months, suggests that these mean soundings may prove much more useful than similar soundings for other areas where the seasonal and geographical gradients, as well as synoptic variability, are much greater. Disturbances - in the form of tropical cyclones which affect most, or all, of the troposphere, and upper-level cyclones which affect the middle and upper troposphere - do occur in the Gulf of Mexico area during the summer months [5]. In the vicinity of these disturbances marked departures from mean conditions can be expected.

4. CLIMATOLOGICAL FEATURES

The mean West Indies data [1] showed that throughout most of the troposphere the warmest mean monthly temperatures are found in September and the coldest values in February. An almost complete reversal was noted in the 200- to 150-mb. layer with the maximum values in February and the minimum values in June-July. In the stratosphere, temperatures were warmest in June-July and coldest in January-February. The temperature data for the Gulf of Mexico area (table 1) show similar variations except that at levels up to 600 mb. maximum values are observed in August (rather than September) and the reversal in the upper troposphere is first evident at 175 mb. rather than at the 200-mb. level. Also, the transition back to the "normal" seasonal pattern in the stratosphere occurs at a higher level, perhaps reflecting greater mean tropopause heights, with the 100-mb. level lying in the zone of small and somewhat irregular seasonal changes (table 1). The differences in the lower troposphere are consistent with the fact that Burrwood and Brownsville are affected by continental influences to a larger degree than the stations used in preparing the mean West Indies soundings. Cold air outbreaks which are common at these stations during the winter months make the major contribution to the greater range of the mean monthly temperature at lower levels in comparison with those observed in the West Indies data (fig. 2). The magnitude of the range over the Gulf area is greater at all levels in the troposphere; however, the major features of the curves for the two areas are remarkably similar. Minimum values of the range are found in the vicinity of 700-600 mb. and 200 mb. and maximum values near the surface and 350 mb. In the stratosphere, the curves continue to be very similar with the largest range shown in the West Indies data. The major features shown by this curve have been brought out in other studies [3].

The mean West Indies data showed a marked departure from the normal seasonal trend in early summer with cooling being shown from June to July at tropospheric levels above 700 mb. A similar break in the normal seasonal temperature change is evident in the Gulf data (table 1) but it is weaker and cooling

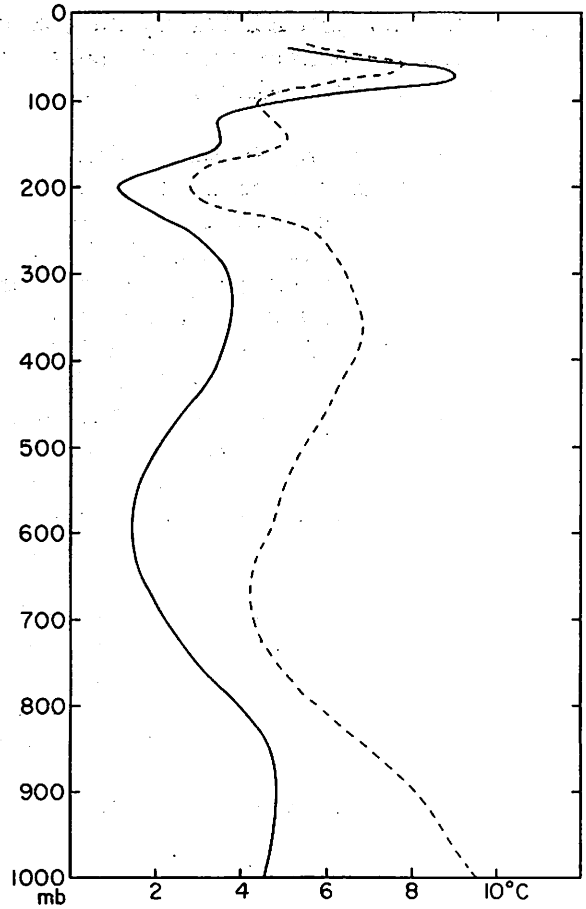

Figure 2. - The annual range of the mean monthly temperature for the Gulf of Mexico area (dashed) and the West Indies area (solid).

is found only in the 700- to 500-mb. layer.

The mean relative humidity data for the Gulf area were consistently lower than the mean West Indies values. The maximum deviations were generally in the 900- to 850-mb. layer where, during all months except September, the Gulf values were at least 10 percent less than the West Indies values. During July and August, this relatively dry layer still persisted but at higher levels the Gulf values were as great as or greater than those for the West Indies area. The low humidities in the 900-800-mb. layer in the summer months, together with the fact that temperature deviations reach a maximum in this vicinity (tables 4, 5) suggest that subsidence is a more prominent feature in this layer over the Gulf of Mexico than over the West Indies area.

It has been pointed out that there are systematic differences between the mean West Indies and Gulf soundings throughout the year, although differences are rather small during the summer months. These two sets of soundings have been studied in relation to the frequency of hurricane formation by computing the Palmén instability index for each area. This index, which Palmén used in his study of climatological aspects of hurricane formation [6], is defined as the difference between the mean 300-mb. temperature and the temperature of a parcel lifted pseudoadiabatically to this level from the earth's surface. Positive values of the index were considered as a necessary, but not sufficient, condition for hurricane formation.

The Palmén index has been computed for each month of the year using the mean surface and 300-mb. data for the West Indies and Gulf of Mexico areas (fig. 3). The September values in both areas are somewhat lower than those shown by Palmén which attained values of over 9°C. in the Gulf of Mexico area. Similarly, Palmén showed slightly positive values in the West Indies area in February while figure 3 shows negative values throughout the winter months. This difference can be accounted for by the fact that Palmén used sea surface temperatures and assumed the surface relative humidity to be 85 percent throughout the whole area considered. He used mean 300-mb. data for September and February from Swan Island. Actually the air temperature is generally slightly lower than the water temperature and this difference is accentuated in the present case since the mean West Indies and Gulf soundings are based on data taken

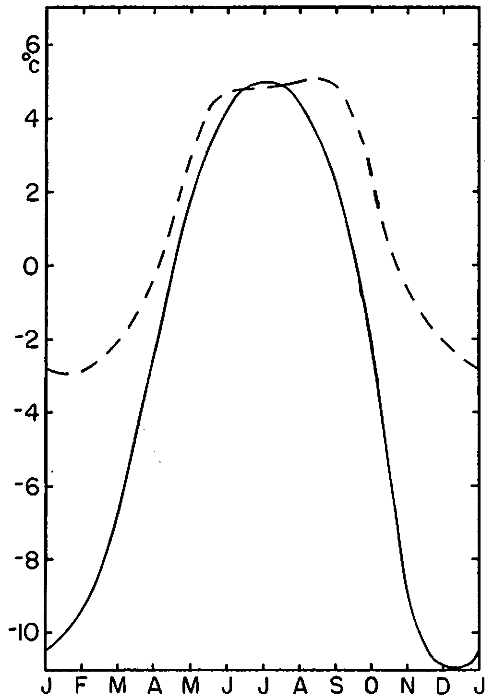

Figure 3. - Seasonal course of the Palmén instability index for the Gulf of Mexico area (solid) and West Indies area (dashed).

only at 0300 GMT. In addition, relative humidity values are less than 85 percent in some months, especially in winter.

The curves of the Palmén index (fig. 3) show a marked seasonal trend which is of the same type in the two areas and which agrees in a qualitative sense with the observed frequency of hurricane formation. Hurricanes are rare during the months which show negative values of the index and a maximum frequency is reached during the months which show positive values. However, the index rises sharply during the spring months and reaches high values in June and July when hurricanes are rare. The index for the Gulf area has already started to fall quite rapidly by September when the maximum of hurricane formation is reached. It is of interest that there are relatively large differences in the value of the index between the two areas in October and November when hurricane formation is still frequent in the West Indies-Caribbean region and much less frequent in the Gulf of Mexico area [4].

Hurricanes form with some regularity in the Gulf of Mexico in October and in the West Indies region in November although the mean instability index is slightly negative in these areas during these months. However, the hurricane formation periods may well coincide with abnormal periods when the index is positive. Of course, not all features of the seasonal distribution of hurricanes should be expected to fit in with the mean seasonal curves of the simple instability index. The importance of other factors is clearly suggested by the fact that higher values of the index are shown in June-July than in September, although there is a large increase in the frequency of hurricanes between June and September in both areas.

REFERENCES

1. C. L. Jordan, "Mean Soundings for the West Indies Area," Journal of Meteorology, vol. 15, No. 1, Feb. 1958, pp. 91-97.
2. B. Ratner, "Upper Air Climatology of the United States. Part I.," U. S. Weather Bureau Technical Paper No. 32, Washington, D. C., 1957.
3. H. Riehl, Tropical Meteorology. McGraw-Hill Book Co. Inc., New York, 1954, 392. pp.
4. J. A. Colón, "A Study of Hurricane Tracks for Forecasting Purposes," Monthly Weather Review, vol. 81, No. 3, Mar. 1953, pp. 53-66.
5. G. Dean, The 250 mb. Seasonal Wind Circulation over the Caribbean during 1956-57. (Unpublished.)
6. E. Palmén, "On the Formation and Structure of Tropical Hurricanes," Geophysica, vol. 3, 1948, pp. 26-38.