PAPERS IN PHYSICAL OCEANOGRAPHY AND METEOROLOGY

PUBLISHED BY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

AND

WOODS HOLE OCEANOGRAPHIC INSTITUTION

VOL. XI, NO. 1

VERTICAL DISTRIBUTION OF TEMPERATURE AND HUMIDITY OVER THE CARIBBEAN SEA

BY

A. F. BUNKER B. HAURWITZ
J. S. MALKUS H. STOMMEL

CAMBRIDGE AND WOODS HOLE, MASSACHUSETTS

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Contribution No. 465 from the Woods Hole Oceanographic Institution

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CAMBRIDGE AND WOODS HOLE, MASSACHUSETTS

CONTENTS

I. INTRODUCTION

The observations presented and discussed in this paper were obtained as part of a research project conducted under contract NObs-2083 with the Bureau of Ships of the U. S. Navy by the Woods Hole Oceanographic Institution. The observations and their original reduction were carried out under the direction of Jeffries Wyman. The airplane soundings were undertaken by Kenneth McCasland and Alfred Woodcock. The sea surface temperature was measured on the surface ships by David F. Barnes and Roger Patterson. The necessary airplane (PBY-5A) and surface boats (PC's) were made available by the U. S. Navy.

All observations were made during the spring of 1946 at about 19.5°N latitude, 66°W longitude, north of San Juan, Puerto Rico, and at about 10°N latitude, 79.5°W longitude, north of Coco Solo, Panama. An extensive preliminary report on the results of the expedition with a limited circulation was prepared by Wyman and his collaborators during the summer of 1946.

The present paper deals with certain phases of the work in a more detailed fashion. Special attention is given to the temperature and humidity distributions in the vertical and to their interpretation in the light of meteorological principles. A discussion of atmospheric turbulence based on airplane measurements has already been published elsewhere (Langwell, 1948), and an application of the airplane soundings to the theory of cumulus clouds has been studied by Stommel (1947).

The second and third chapters of this publication deal with the description of observational techniques used by the expedition, with the methods of reduction and present the data on which the later discussion is based. It has been thought desirable to publish these data in extenso because they may be of interest to other meteorologists in view of the sparsity of upper-air observations in this region. The actual preparation of Chapters II and III is largely the work of Bunker and Stommel.

In order to show how the observations made off Puerto Rico fit into the general pattern of climatic and weather conditions in the Caribbean area Chapter IV presents a survey of the climate of this region and of the weather conditions during the time when the observations were taken. This Chapter was contributed by Joanne Malkus. It is pertinent to include in this general introduction the conclusion drawn in Chapter IV namely that the weather situations encountered represented, in general, a relatively undisturbed trade-wind regime of early spring.

The homogeneous layer of nearly dry-adiabatic lapse-rate of temperature and almost constant mixing ratio is one of the most characteristic phenomena in the lowest atmosphere of this region. It is also of utmost importance for the energy budget of the hydrosphere and the atmosphere. Therefore, a special discussion of this layer by Bunker is given in Chapter V.

Because of the nearly dry-adiabatic lapse-rate in the homogeneous layer most of the heat transfer between water and air in the trade-wind zone must be in the form of latent heat of vaporization, a conclusion whose thermodynamic implications were discussed thoroughly by Ficker (1936). For this reason the distribution of water vapor deserves special attention, and Chapter VI deals with this variable as a problem in turbulent mass exchange. The analysis presented in this chapter is due to Haurwitz and Stommel.

II. METHODS OF OBSERVATION AND REDUCTION OF DATA

1. Observational Techniques

Measurements of the dry- and wet-bulb temperature in the lowest 10,000 feet of the atmosphere over the Caribbean were made during the spring of 1946. Most of the observations were taken at 19° 30'N, 66°W, 50 miles North of San Juan, Puerto Rico, others were made at 10°N, 79° 30'W North of Coco Solo, Panama. The soundings, made from an airplane, were essentially of two types: vertical soundings extending from 25 feet above the sea surface up to 10,000 feet, and horizontal traverses of length of about 20 miles.

The vertical soundings were made in both clear and cloudy areas. Those in clear areas were usually obtained while the plane was in a continuous circling climb. The radius of the turn was about 10,000 feet, and the rate of climb about 100 feet/min. (see fig. 1). For vertical soundings in the clouds the descending part of the flight was

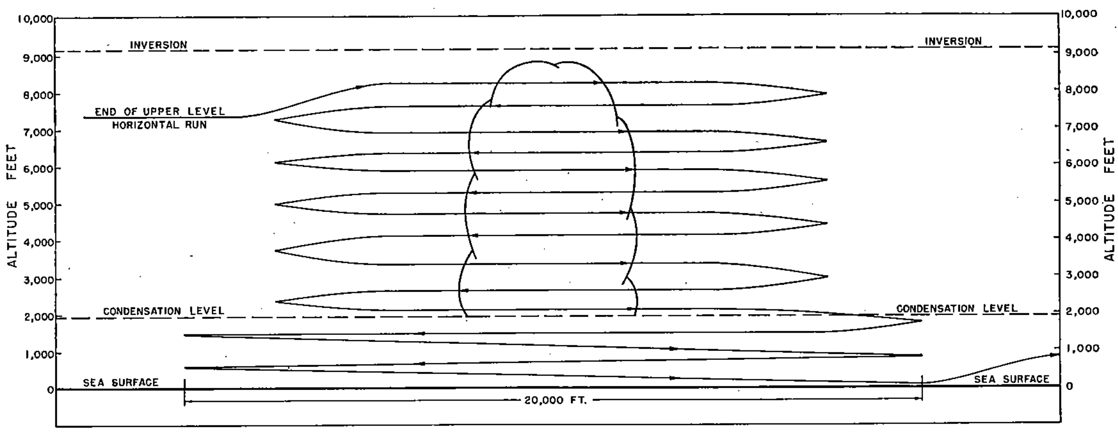

Fig. 1. Flight plan of airplane sounding. Horizontal and vertical dimensions drawn to same scale.

used as a rule. In passing through the cloud, the flight of the plane was levelled so that the altitude remained approximately constant. Each time the plane arrived at the 25 foot level the altimeters were checked and reset.

Horizontal traverses were flown at various elevations for a duration of 5 to 30 minutes with an air speed of about 100 knots. During these traverses every attempt was made to keep the altitude of the airplane constant, but variations in height did occur which occasionally exceeded 50 feet.

The main airborne instrument (fig. 2) was a recording psychrograph developed by the Radiation Laboratory of the Massachusetts Institute of Technology during the war (Katz, 1947). Two ceramic resistors, one moistened by a wicking, were mounted inside a radiation shield. The entire assembly was placed in the airstream at the forward part of the airplane fuselage. The resistors were connected intermittently to an electronic bridge and amplifier circuit whose output current was recorded on an Esterline-Angus recording milliameter.

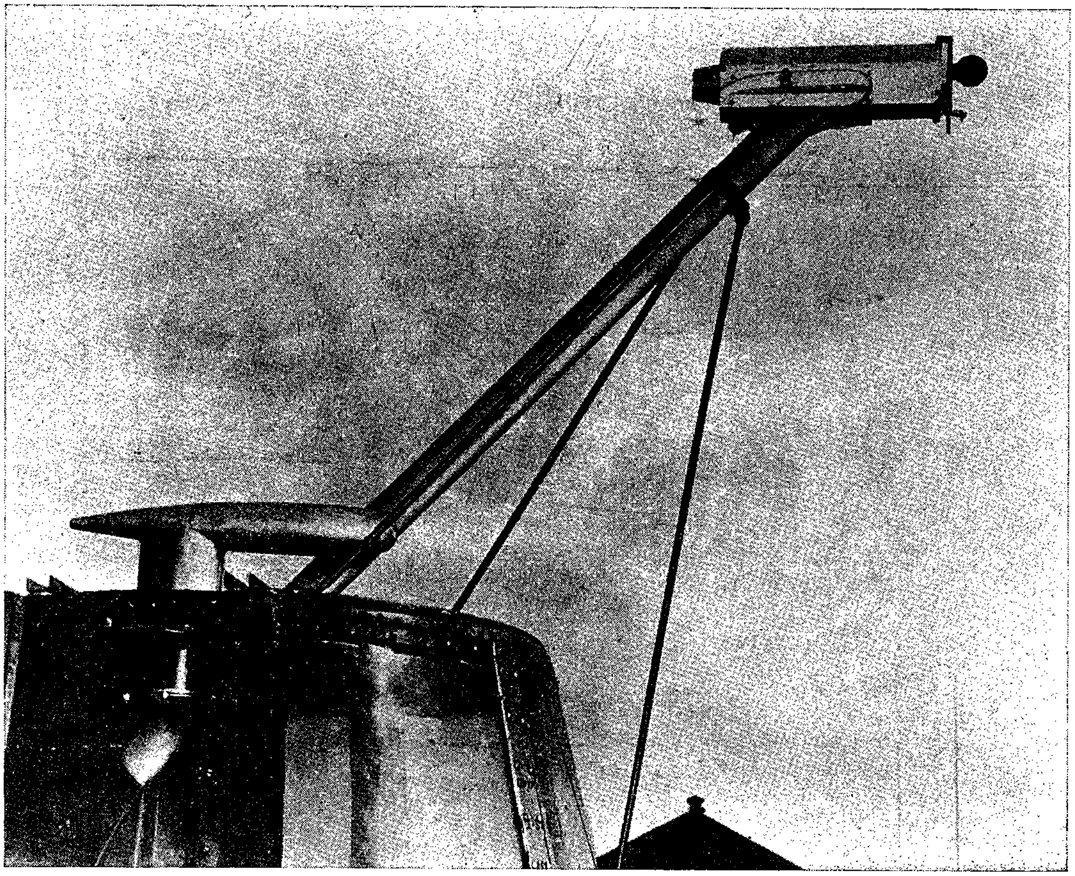

FIG. 2. Psychrograph housing mounted on airplane.

A series of high altitude photographs of the clouds was taken from 20,000 feet with a K-18 camera. A typical picture, showing both clear and cloudy areas, is reproduced in Fig. 3.

A specially designed water column accelerometer (Vine, 1945) was used to register the vertical accelerations imparted to the plane by the turbulence of the air and an angle-of-attack recorder registered the change in angle at which the wind strikes the plane. Records were made during the horizontal runs only. These observations of the turbulence have been discussed by Langwell (1948) and Malkus (1949).

At the surface, dry- and wet-bulb temperatures of the air and dip-bucket temperatures of the water were taken. The geographical positions of the airplane and surface craft were usually within 20 miles of one another.

2. Reduction of Data

a. Wet- and Dry-Bulb Temperatures — The psychrograph resistors were calibrated in a kerosene bath against a standard thermometer, and a calibration chart was prepared.

The calibration was repeated after the return of the expedition. The psychrograph elements showed a remarkable stability. Over a period of six months the element resistance increased only by the equivalent of 0.05°C.

Readings from the rolls of recorded data were entered in the calibration chart and temperatures for both the wet and dry resistor readings obtained. An adiabatic correction of these temperatures was necessary because of the heating of the air due to its motion past the resistors. The details of this effect are discussed by Katz (1947) and A. A. F. Weather Service Manual (1945). The empirical constants involved in this correction were determined by flying the airplane at widely different speeds.

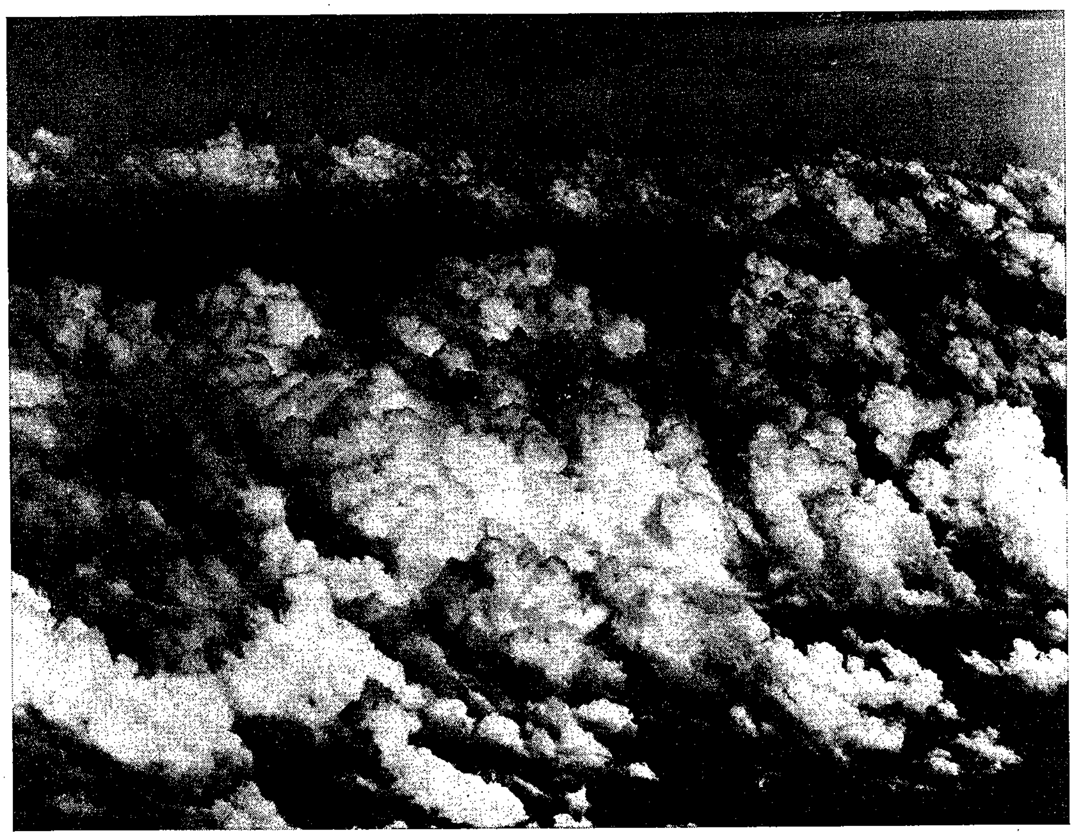

FIG. 3. Cloud photograph showing cloudy and clear areas north of San Juan.

The dry-bulb reading inside clouds was rejected because the resistor became covered with water droplets. Upon emerging from the cloud, the element required about 10 seconds for drying. Values taken during this drying period have been plotted on the horizontal runs although they give a fictitious drop of the dry-bulb temperature. For this reason, when traverses through clouds are studied, it is essential to use only the readings taken when the plane entered the clouds.

b. Altitudes — Indicated altitudes were read from the plane's altimeter which was built to read height according to the pressure-height relationship of the U. S. Standard Atmosphere, defined by a surface temperature of 15°C, a surface pressure of 1013.25 mb, and a lapse rate of −0.65°C per 100 meters. A correction to the indicated altitudes for actual surface temperature and lapse rate was applied to all altitude readings (Berry, Bollay and Beers, 1945, pp. 374–375) to give the true altitudes. For this correction a surface temperature of 26°C and a lapse rate of −0.9°C per 100 meters, the averages found from the observations, were used.

A surface pressure equal to 1015.9 mb, the mean for the month of April in the region of San Juan was used in these reductions. Pressures corresponding to the corrected or true altitudes are shown in Table 1.

TABLE I

Relation between pressure and height for the San Juan soundings

Altitude ft.	Altitude m	Pressure mb	Altitude ft.	Altitude m	Pressure mb
0	0	1015.9	3114	949	910.5
52	16	1014.1	3217	981	907.2
104	32	1012.2	3321	1012	903.8
208	63	1008.6	3425	1044	900.5
312	95	1004.9	3529	1076	897.2
416	127	1001.2	3632	1107	893.8
520	159	997.6	3736	1139	890.4
623	190	994.1	3840	1170	887.2
727	222	990.4	3943	1202	884.0
831	253	986.8	4047	1234	880.7
935	285	983.3	4151	1265	877.6
1039	317	979.7	4254	1297	874.2
1143	348	976.2	4358	1328	870.9
1246	380	972.6	4462	1360	867.7
1350	411	969.1	4566	1392	864.4
1454	443	965.6	4669	1423	861.2
1557	475	962.1	4773	1455	858.1
1661	506	958.6	4877	1487	854.8
1765	538	955.0	4981	1518	851.6
1869	570	951.6	5084	1550	848.5
1973	601	948.1	5188	1581	845.2
2077	633	944.6	5706	1739	829.6
2180	664	941.2	6223	1897	814.1
2284	696	937.7	6741	2055	798.9
2388	728	934.3	7258	2212	783.9
2492	760	930.8	7775	2370	769.2
2596	791	927.4	8292	2527	754.6
2699	823	924.0	8809	2685	740.3
2803	854	920.6	9325	2842	726.2
2907	886	917.3	9842	3000	712.3
3010	917	913.8	10358	3157	698.7

c. Mixing Ratios — In the preliminary report on the observations and results of the expedition the humidity was expressed in terms of the potential vapor pressure. The mixing ratio has been determined directly from this quantity. Since the mixing ratio determined in this manner is the result of rather devious calculations, check computations were made by means of the relation:

$$w = w_s - \Delta T\,(c_p + wc_{pv})/L \approx w_s - \Delta T/2.5.$$

Here w is the mixing ratio expressed in g/kg, w_s the saturation mixing ratio at the wet-bulb temperature, ΔT the wet bulb depression, c_p the specific heat of air at constant pressure, c_{pv} the specific heat of water vapor at constant pressure, and L the heat of vaporization of water. The quantity w_s was determined from Table 79 of the Smithsonian Meteorological Tables, fifth revised edition. No differences larger than 0.2 g/kg were found between the original and the check determinations.

3. Discussion of Errors

a. Temperature Measurements — In order to discuss the possible errors in the temperature measurements it is necessary to consider first the procedures by which the instrument was calibrated.

The thermistor element was inserted into a kerosene bath, the temperature of which could be regulated by dry-ice and heating elements. The temperature of the bath was measured by means of a standard thermometer graduated to tenths of degrees Centigrade; readings could be estimated to a probable error of ± 0.01°C. The thermistor element was not at the same position in the bath as the standard thermometer of course, but since the bath was well insulated and well stirred an error from this source may be regarded as negligible. At a number of different temperatures, determined as above, the resistance of the thermistor element was measured by means of a Leeds-Northrup Wheatstone Bridge whose probable error was ± 0.1%. A large master graph of temperature against resistance for each thermistor element was constructed by drawing a curve through the plotted points representing these measurements. The scale of this graph was such that the graphical errors were larger than the errors of measurement in the kerosene calibration bath. At first this seems like an unnecessary loss of precision, but it will be seen that there are greater sources of error than this introduced at later stages. Therefore the errors introduced by the standard thermometer and the Wheatstone Bridge are neglected, and the error in the temperature-resistance relationship is taken simply as that precision with which the graph was constructed and can be read. The probable error introduced in the temperature, as determined from the master graph, supposing that the true value of the resistance of the thermistor is known, is ± 0.02°C.

Besides the thermistor element, whose resistance varies with temperature, the psychrograph electronic circuit contains a number of precision resistors whose resistance change with temperature is very small. These precision resistors are provided for the purpose of making convenient a check of the resistance measuring circuit at any time.

The selector switch of the psychrograph is turned in succession to each of these precision resistors and the reading on the Esterline-Angus recording milliammeter is marked accordingly. This procedure makes it possible to convert the Esterline-Angus recorder readings directly into resistance. Because of the width of the pen trace the

Esterline-Angus record can be read to ± 0.1% of the full scale. A graph was constructed to give Esterline-Angus recorder reading as a function of resistance. The error accumulated in the preparation of this graph comes from the errors in the rated values of the precision resistors, the reading of the Esterline-Angus record, and the plotting of the graph, the latter corresponding to a temperature error of ± 0.01°C; the total probable error of resistance derived from these graphs supposing the Esterline-Angus reading to be true therefore corresponds to a temperature error of ± 0.1°C. From this graph and the first mentioned master graph a third graph was constructed with temperature as a function of Esterline-Angus recorder reading the accumulated error of both graphs now being added to the constructional error of the third. In addition the reading error of the recorder must be included again because it enters twice — once in the preparation of the recorder-reading vs. resistance graph and once in the actual temperature measurement. The accumulated error at this point corresponds to a probable error in temperature of ± 0.18°C.

Finally, the temperature as determined above must be corrected for the velocity of the thermistor element (airplane) relative to the air, as mentioned in the above section. The uncertainty in the determination of this so-called "dynamic correction" is such as to give a probable error of ± 0.05°C in the final result. The grand total probable error in the individual temperature measurement is therefore ± 0.23°C.

In any series of measurements, however, the errors due to calibration and preparation of graphs and in the dynamic corrections appear more as systematic errors so that the random probable error of temperatures in a series of measurements, say a single sounding or horizontal traverse, compared among themselves, is to be taken as ± 0.10°C (see also Katz, 1947).

b. Altitude Measurements — It is difficult to itemize the possible sources of error in the altitudes as given in the data. The aneroid altimeter which was used is graduated to read altitude intervals of 10 feet. However, during a continuous climb or descent there was a lag of 10 or 20 feet, which during a single sounding would appear as a systematic error rather than a random one. The zero setting was made by flying low over the sea surface and resetting the altimeters at an estimated altitude. The probable error of altitude is presumably about ± 25 feet in the vertical soundings.

During the horizontal traverses the pilots were instructed to maintain a level trajectory. In practice this could not be attained, but it was supposed that the indicated altitude could be held within a range of 50 feet. As a result this error must be included, so that the probable error of the altitude of any point on a horizontal traverse is ± 50 feet.

c. Sea-Surface Temperatures — The sea-surface temperature was taken by dipping a bucket into the sea and measuring the temperature of the contents. This procedure yields essentially the mean temperature of the top six inches of the sea water. The actual experimental errors are less than the rounding-off error. The sea-surface temperature measurements are given to a tenth of a degree.

d. Mixing Ratio — The estimate of the errors of the mixing ratio is based simply upon the errors of temperature and altitude previously given. The error is thus ± 0.1g/kg.

III. PRESENTATION OF DATA

The U. S. Weather Bureau Office at Hialeah, Florida, has prepared maps showing the probable trajectories[1] of the air at 5,000 feet arriving at Balboa, Panama and San Juan, Puerto Rico on the days when soundings were made in these areas. As a rough approximation these soundings may be regarded as representative of the air up to and including the inversion over a large area. The following quotation from a letter of the Weather Bureau is pertinent: "These maps represent a close approximation to actual trajectories, considering the paucity of available data over the adjacent ocean areas. Five thousand foot wind charts and 850 millibar pressure charts, consistent with available surface data, were used in computing the trajectories." The horizontal runs and maps of the trajectories are presented in Figures 4–55. Data of the vertical soundings are given in Tables 2–30. The times given are standard zonal times. Two vertical soundings for April 27, which are typical of many of the soundings, have been plotted and included in the set of figures presenting the other data for that day. Tables have been compiled to present the data obtained by vertical soundings. They give altitudes in feet, dry- and wet-bulb temperatures in degrees centigrade, and mixing ratio in grams per kilogram. Data concerning the time, place, and meteorological conditions are presented with each sounding and horizontal traverse. The meteorological observations taken on the surface vessel include cloud conditions, wind speed and direction, dry- and wet-bulb temperatures and sea temperatures. Heights of cloud bases and tops were measured by the airborne observers. Winds aloft were taken from either the San Juan pilot balloon reports or drift sight readings from the plane.

[1] The authors are indebted to Mr. P. H. Kutschenreuter of the Weather Bureau at Hialeah, Florida, for these trajectories.

TABLE 2

Coco Solo, 1 April 1946, 1135–1203 hrs.; 1/10 cumulus, base 1700 ft., top 2500 ft. Surface wind 050° 12 mph., T_d 26.3°C, T_w 23.4°C, W 16.9 g/kg. T_{sea} 26.9°C. Plane visible.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	26.3	23.1	16.6	1350	22.0	20.9	15.3
50	26.2	22.7	15.9	1400	21.7	20.5	15.5
105	25.9	22.4	15.5	1455	21.6	20.6	15.7
155	25.8	22.4	15.6	1505	21.8	20.6	15.6
210	25.6	22.7	16.2	1560	21.5	20.2	15.3
260	25.4	22.2	15.6	1610	21.4	20.1	15.1
310	25.1	22.4	16.1	1660	21.4	20.2	15.3
360	25.0	22.2	15.9	1710	21.3	20.2	15.3
415	25.0	22.1	15.7	1765	21.2	19.9	15.0
520	24.3	22.3	16.5	1870	20.9	19.7	15.0
570	24.1	22.1	16.2	1920	20.5	19.3	14.5
625	24.0	22.0	16.1	1975	20.6	18.9	13.9
675	23.9	21.9	16.1	2025	20.2	18.9	14.1
725	23.8	21.9	16.1	2080	20.6	18.6	14.2
780	23.7	21.3	15.3	2130	20.7	18.3	13.7
830	23.6	21.5	15.7	2180	20.6	17.5	12.1
885	23.5	21.3	15.4	2230	20.7	17.7	11.9
935	23.2	21.0	15.2	2285	20.7	16.8	11.2
990	23.1	21.2	15.5	2335	20.5	17.0	11.5
1040	23.0	21.2	15.6	2390	20.5	16.5	10.9
1090	22.8	21.2	15.8	2440	20.5	16.7	11.2
1145	22.7	21.3	16.1	2490	20.1	16.2	10.7
1195	22.6	21.3	16.3	2545	19.7	16.0	10.7
1245	22.4	21.4	16.6	2595	20.1	16.0	10.5
1300	22.3	21.0	16.0	2650	19.7	16.2	11.0

Table 3

Coco Solo, 2 April 1946, 1200–1216 hrs.; 2/10 cumulus base 2000 ft., tops 3000 ft. Surface wind 050° 10 mph., T_d 26.1°C, T_w 22.2°C, W 15.1 g/kg. T_{sea} 26.9°C. Plane visible.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	26.0	22.0	14.9
105	25.7	22.1	15.2
155	25.3	22.0	15.3
210	25.1	22.0	15.4
260	25.0	21.8	15.2
310	24.9	21.8	15.2
365	24.7	21.8	15.3
415	24.6	21.4	14.8
470	24.5	21.6	15.2
520	24.5	21.3	14.8
570	24.2	21.3	14.9
625	24.0	21.4	15.2
675	23.9	21.1	14.8
725	23.8	21.3	15.3
830	23.4	20.9	14.9
885	23.3	20.7	15.3
935	23.2	20.7	14.8
985	23.1	20.7	14.8
1040	22.8	20.7	15.0
1090	22.7	20.5	14.8
1145	22.5	20.1	14.4
1195	22.3	20.4	15.0
1245	22.3	20.6	15.3
1300	22.1	20.6	15.5
1350	21.9	20.4	15.3
1400	21.6	20.4	15.3
1455	21.6	20.3	15.3
1505	21.5	20.2	15.2
1555	21.4	19.9	14.8
1610	21.2	19.9	14.9
1660	21.0	19.8	14.8
1715	20.8	19.5	14.4
1765	20.6	19.7	15.0
1815	20.6	19.2	14.2
1870	20.5	18.7	13.7
1920	20.5	19.2	14.3
1975	20.2	19.2	14.5
2075	19.8	19.0	14.4
2130	19.6	18.3	13.6
2180	19.9	18.1	13.3
2230	19.7	18.4	13.6
2285	19.6	17.7	12.8
2335	19.4	17.9	13.2
2390	19.2	17.7	13.1
2440	19.2	17.3	12.7
2490	19.2	16.9	12.1
2545	19.2	16.9	12.2
2595	19.2	15.9	10.9
2650	19.4	15.9	10.8
2700	19.5	15.5	10.3
2750	19.1	15.7	10.7
2805	19.0	15.3	10.3
2855	19.0	15.1	10.0
2905	19.0	15.1	10.1
2960	18.8	14.9	9.8
3010	18.6	14.8	9.8
3115	18.5	15.4	10.7
3215	18.8	13.2	7.9
3270	18.8	13.2	7.9
3325	18.5	12.8	6.3
3375	18.5	12.7	7.5

TABLE 4

Coco Solo, 3 April 1946, 1104–1125 hrs.; Clear. Surface wind 030° 15 mph.; T_d 26.2°C, T_w 22.8°C, W 16.0 g/kg. T_{sea} 26.4°C. Plane visible.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.8	22.4	15.5	1820	21.1	19.1	13.8
105	25.7	22.0	15.2	1870	20.5	19.4	14.6
155	25.6	21.8	14.8	1920	20.5	18.4	13.2
210	25.2	21.7	14.9	1975	20.6	17.8	12.4
260	25.2	21.9	15.0	2025	20.4	18.2	13.0
310	24.9	21.8	15.2	2075	20.7	17.0	11.3
365	24.8	21.7	15.2	2180	20.5	17.3	11.8
415	24.6	21.4	14.9	2230	20.4	17.3	11.9
450	24.6	21.5	15.0	2285	19.9	17.5	12.4
520	24.4	21.7	15.4	2335	20.0	17.1	11.8
570	24.2	21.5	15.3	2390	20.4	16.5	10.9
625	24.0	21.3	15.1	2440	20.4	16.5	10.9
675	24.0	21.3	15.0	2490	20.4	16.4	11.1
725	23.8	21.1	15.0	2545	20.4	16.2	10.7
780	23.7	21.1	15.0	2595	20.4	16.1	10.6
830	23.5	21.1	15.2	2650	20.1	16.0	10.7
885	23.2	21.0	15.1	2700	20.2	16.2	10.9
935	23.2	20.8	14.9	2750	20.2	15.6	10.1
990	23.1	20.6	14.6	2805	20.1	15.3	9.8
1040	22.9	20.6	14.7	2855	19.9	15.1	9.6
1090	22.7	20.6	15.0	2910	20.4	14.6	8.8
1145	22.6	20.6	15.2	2960	20.2	15.0	9.4
1195	22.5	20.5	15.0	3010	20.2	14.8	9.1
1245	22.3	20.5	15.2	3060	20.0	15.0	9.6
1300	22.2	20.0	14.5	3115	20.2	14.7	9.0
1350	21.9	20.5	15.4	3530	19.5	—	—
1400	21.8	20.3	15.1	3630	19.3	—	—
1455	21.6	20.1	15.0	3735	18.9	—	—
1505	21.6	20.0	14.8	3840	19.0	—	—
1560	21.4	20.1	15.1	3945	18.7	—	—
1660	21.3	19.6	14.5	4045	18.4	—	—
1715	21.1	20.2	15.4	4150	18.4	—	—
1765	20.8	20.1	15.4	4670	17.7	—	—

TABLE 5

Coco Solo, 4 April 1946, 1139–1156 hrs.; 4–6/10 cumulus, base 1200 ft., tops 2300 ft. Sounding made in clouds. Surface wind 040° 16 mph., T_d 26.6°C, T_w 23.8°C, W 17.4 g/kg. T_{sea} 26.7°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	26.6	24.1	18.0	1610	22.2	21.5	16.8
50	26.5	23.5	17.0	1660	22.1	21.2	16.4
105	26.1	23.5	17.2	1715	22.1	21.0	16.2
155	26.0	23.5	17.3	1765	21.7	20.8	15.7
210	25.9	23.5	17.4	1815	22.0	20.5	15.5
260	25.8	23.1	17.2	1870	21.4	20.6	16.0
310	25.7	23.0	16.7	1920	21.4	20.5	15.8
365	25.5	23.0	16.8	1975	21.3	20.6	16.0
415	25.4	23.1	17.1	2025*	—	21.1	16.9
460	25.3	23.1	17.2	2075*	—	20.4	16.3
520	24.9	23.0	17.3	2180	19.9	19.8	15.6
570	24.9	23.0	17.3	2285	20.7	19.8	15.4
625	24.9	22.9	17.2	2330	20.6	19.8	15.4
675	24.7	22.7	17.0	2390	20.8	19.6	15.1
725	24.5	22.7	17.1	2440	20.8	19.4	14.8
780	24.3	22.8	17.3	2490	20.7	19.4	14.9
830	24.0	22.6	17.2	2545	20.5	19.3	14.9
885	24.0	22.6	17.0	2595	20.4	19.2	14.8
935	23.9	22.6	17.3	2650	20.5	18.9	14.3
985	23.8	22.3	16.9	2700	20.4	19.1	14.6
1040	23.6	22.1	16.7	2750	20.2	18.8	14.3
1090	23.5	22.1	16.9	2805	20.3	18.6	14.1
1145	23.3	22.2	17.0	3115	19.6	—	—
1245	23.1	22.1	17.3	3325	19.2	—	—
1300	23.1	21.9	17.0	3630	18.7	—	—
1350	22.6	21.9	17.1	4150	17.6	—	—
1400	22.6	21.9	17.1	4460	17.1	—	—
1455	22.4	21.9	17.3	4670	16.6	—	—
1505	22.4	21.4	17.2	4965	15.8	—	—
1555	22.2	21.5	16.7	5190	15.4	—	—

TABLE 6

San Juan, 10 April 1946, 1524–1540 hrs.; 1/10 cumulus base 2100 ft. Sounding made in clear. Surface wind 110° 18 mph.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	26.5	22.7	15.8	1510	22.0	20.6	15.5
50	26.5	22.5	15.4	1560	21.7	20.7	15.9
105	26.3	22.5	15.5	1610	21.7	20.4	15.5
155	26.1	22.2	15.0	1665	21.6	20.2	15.3
210	25.9	22.0	15.0	1715	21.3	20.2	15.4
260	25.5	22.0	15.2	1770	21.3	20.0	15.2
310	25.5	22.0	15.2	1820	20.9	19.9	15.6
365	25.4	21.9	15.2	1870	21.0	20.0	15.4
415	25.2	21.9	15.4	1925	20.7	19.9	15.4
470	24.9	21.9	15.4	1975	20.6	19.3	14.5
520	24.9	21.7	15.3	2030	20.5	19.2	14.3
570	24.7	21.6	15.2	2080	20.3	19.0	14.3
625	24.5	21.6	15.2	2130	20.3	18.9	14.1
675	24.4	21.7	15.5	2185	20.1	19.0	14.4
725	24.2	21.6	15.4	2235	19.9	19.0	14.6
780	24.2	21.3	15.0	2290	19.9	19.5	15.2
830	23.8	21.6	15.7	2340	19.8	19.0	14.7
935	23.5	21.3	15.5	2390	19.8	18.9	14.6
1040	23.3	21.0	14.8	2445	19.9	18.3	13.7
1090	23.1	21.0	15.2	2495	19.9	18.3	13.9
1145	23.1	20.8	15.0	2550	19.8	18.1	13.4
1195	22.9	20.7	15.0	2600	19.7	17.5	12.8
1250	22.6	20.7	15.1	2650	19.4	17.7	13.2
1300	22.6	20.7	15.0	2705	19.5	17.5	12.9
1350	22.4	20.6	15.2	2755	19.4	17.1	12.5
1405	22.3	20.7	15.4	2810	19.4	16.8	12.2
1455	22.3	20.6	15.3	2910	19.2	16.8	12.2

TABLE 7

San Juan, 12 April 1946, 1423–1450 hrs.; 2/10 cumulus base 2300 ft., top 5–7000 ft. Sounding made in clear. Surface wind 085° 18 mph., T_d 25.7°C, T_w 21.9°C, W 14.9 g/kg. T_{sea} 25.9°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	25.6	21.8	14.8
50	25.3	21.7	14.8
105	25.2	21.3	14.3
210	24.9	21.2	14.3
260	24.8	21.3	14.4
310	24.6	20.8	13.9
365	24.5	20.6	13.6
415	24.2	20.8	14.1
470	24.1	20.6	13.9
520	24.0	20.6	13.9
570	23.9	20.6	14.1
625	23.6	20.6	14.2
675	23.5	20.6	14.2
725	23.3	20.4	14.1
780	23.1	20.3	14.1
830	23.2	20.4	14.3
885	23.0	20.4	14.4
935	22.9	19.8	13.7
990	22.6	19.9	13.7
1040	22.4	19.8	13.9
1090	22.2	19.8	14.0
1145	22.0	19.6	13.7
1195	22.0	19.4	13.5
1250	21.8	19.4	13.7
1300	21.5	19.8	14.4
1350	21.4	19.6	14.2
1405	21.4	19.1	13.4
1455	21.2	19.0	13.4
1505	21.0	19.4	14.2
1560	20.7	19.2	14.1
1610	21.0	18.5	12.9
1665	20.7	18.9	13.5
1715	20.7	17.9	12.3
1770	20.6	18.1	12.5
1820	20.6	—	—
1870	20.3	18.5	13.4
1925	20.2	18.3	13.2
1975	20.2	17.8	12.5
2030	20.3	17.3	11.8
2080	20.2	17.2	11.8
2130	20.1	16.6	11.2
2185	19.8	17.3	12.2
2235	19.7	16.8	11.6
2290	19.5	16.8	11.8
2340	19.4	16.3	11.1
2390	19.7	16.2	10.9
2500	19.7	14.3	8.6
2550	19.7	14.1	8.3
2600	19.4	15.0	9.6
2650	19.3	14.1	8.6
2705	19.3	13.9	8.3
2755	19.1	14.0	8.6
2810	19.1	13.9	8.4
2860	19.0	13.7	8.3
2910	18.9	13.7	8.4
2965	18.7	13.9	8.8
3015	18.6	14.3	9.2
3070	18.4	14.2	9.3
3120	18.4	14.1	9.2
3225	18.4	—	—
3325	17.6	—	—
3430	17.8	—	—
3640	17.2	—	—
3745	17.0	—	—
4160	16.4	13.7	10.0
4265	16.2	—	—
4370	15.8	—	—
4460	15.7	—	—
4565	15.7	—	—
4670	15.3	—	—
5150	14.3	11.9	9.4
5250	14.3	11.8	9.3
5300	14.1	11.5	9.0
5350	13.6	11.5	9.3

TABLE 7 (*Continued*)

San Juan, 12 April 1946, 1423–1450 hrs.; 2/10 cumulus base 2300 ft., top 5–7000 ft. Sounding made in clear. Surface wind 085° 18 mph., T_d 25.7°C, T_w 21.9°C, W 14.9 g/kg. T_{sea} 25.9°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
5400	13.5	11.5	9.4	6120	12.5	10.0	8.3
5450	13.6	11.5	9.3	6175	12.2	9.9	8.7
5500	13.6	10.7	8.3	6225	12.5	9.1	7.3
5550	13.6	10.2	7.9	6275	12.4	8.2	6.5
5605	13.5	10.5	8.2	6330	12.3	8.2	6.1
5655	13.5	10.4	8.2	6450	12.1	7.8	6.3
5710	13.3	10.4	8.3	6500	12.1	7.9	6.4
5760	13.2	10.6	8.6	6550	12.0	7.9	6.5
5810	13.2	10.5	8.4	6605	12.1	7.2	5.8
5860	13.3	10.2	8.0	6650	12.0	7.3	5.8
5915	13.1	10.2	8.2	6700	11.8	7.3	6.0
5965	12.9	10.0	8.1	6750	11.7	6.9	5.6
6020	12.8	10.4	8.6	6855	11.8	6.1	4.8
6070	12.5	10.0	8.2				

TABLE 8

San Juan, 12 April 1946, 1505–1530 hrs.; Light rain from cumulonimbus base 1800 ft., top 7000 ft. Surface winds 085° 18 mph., T_d 25.6°C, T_w 21.7°C, W 14.7 g/kg. T_{sea} 25.9°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	25.6	22.0	15.0	2235*	—	18.5	14.4
50	25.2	21.9	15.0	2290*	—	18.7	14.0
105	25.2	21.7	14.8	2395	18.7	18.3	14.1
155	25.2	21.5	14.6	2445	18.6	18.3	14.2
210	24.8	21.7	15.0	2500	18.6	18.1	13.9
260	24.8	21.5	14.7	2600	18.6	17.9	13.8
310	24.6	21.4	14.7	2700	18.4	17.7	13.7
365	24.5	21.4	14.8	2755	18.5	17.5	13.3
415	24.3	21.4	15.0	2810	18.4	17.3	13.1
470	24.6	21.3	15.2	2860	18.1	17.2	13.1
520	24.1	21.0	14.5	2910	17.6	17.0	13.0
570	23.9	21.0	14.7	3015	17.2	16.6	12.8
625	23.7	21.0	14.7	3070	17.3	16.9	13.0
675	23.6	20.9	14.6	3120	17.4	17.0	13.3
725	23.5	20.9	14.8	3225*	—	16.7	13.5
780	23.3	20.6	14.4	3275	16.6	16.5	13.1
830	23.1	20.8	14.8	3330	16.7	16.4	13.0
885	22.7	20.8	15.0	3380	16.9	16.2	12.7
935	22.6	20.6	14.8	3430	16.5	15.9	12.4
990	22.5	20.6	15.0	3485	16.9	15.7	12.1
1040	22.5	20.4	14.6	3535	17.0	15.5	11.8
1090	22.2	20.4	14.8	3590	16.6	15.7	12.2
1145	22.2	20.2	14.5	3690	16.5	14.6	11.0
1195	22.0	20.3	14.8	3735	16.8	14.9	11.2
1250	21.8	20.3	15.0	3790	16.7	14.5	10.7
1300	21.5	20.2	15.0	3840	16.7	14.6	11.0
1350	21.4	20.0	14.8	3890	16.6	15.3	11.9
1405	21.3	19.9	14.8	3940	16.5	15.2	11.9
1455	21.0	20.0	15.2	3955*	—	15.6	12.9
1560	21.0	19.7	14.7	4050*	—	15.6	12.9
1610	20.8	19.7	14.8	4250	15.9	13.9	10.9
1665	20.7	19.6	14.8	4305	16.1	13.7	10.3
1715	20.6	19.3	14.4	4355	15.7	13.8	10.6
1770	20.5	19.2	14.3	4410	15.8	14.0	10.8
1820	20.4	19.5	14.8	4460	15.9	14.1	11.0
1870	20.4	19.2	14.4	4625	15.3	13.0	9.9
1925	20.0	19.2	14.6	4670	15.3	13.0	9.9
1975	19.9	19.0	14.4	4730	15.2	13.2	10.4
2080	19.8	18.9	14.3	4775	14.9	13.4	10.6
2185*	—	18.7	14.4	4880*	13.5	13.4	11.4

TABLE 9

San Juan, 12 April 1946, 1534–1550 hrs.; Sounding made in clear. Surface winds 085° 18 mph., T_d 25.6°C, T_w 21.7°C, W 14.7 g/kg. T_{sea} 25.9°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	25.7	22.3	15.5
90	25.7	22.1	15.1
140	25.4	22.1	15.2
190	25.3	21.8	15.0
245	25.1	21.8	15.0
295	25.0	21.6	14.9
350	24.9	21.6	14.8
400	24.7	21.2	14.4
450	24.4	21.2	14.6
505	24.3	21.6	15.3
555	24.2	21.4	15.2
610	24.1	21.2	14.8
660	23.9	21.2	15.0
710	23.8	20.9	14.6
815	23.5	20.8	14.6
870	23.2	20.9	14.9
920	23.1	20.6	14.6
970	23.0	20.6	14.7
1035	22.9	20.6	14.7
1075	22.8	20.5	14.6
1130	22.6	20.3	14.5
1180	22.4	20.1	14.4
1230	22.1	20.5	15.2
1285	22.1	20.1	14.6
1335	22.0	19.9	14.3
1385	21.8	19.9	14.4
1440	21.5	19.9	14.6
1490	21.4	19.7	14.4
1540	21.3	19.6	14.4
1600	21.2	19.3	14.0
1650	21.1	19.6	14.5
1700	21.0	19.4	14.3
1750	20.9	19.0	13.9
1800	20.9	18.7	13.5
1855	20.7	18.5	13.3
1910	20.7	18.5	13.2
1960	20.5	18.8	13.8
2060	20.1	18.5	13.3
2115	20.0	18.2	13.1
2165	19.8	18.4	13.2
2210	19.7	18.4	13.3
2270	19.7	18.2	13.2
2325	19.7	17.3	12.7
2375	19.6	17.3	12.7
2430	19.6	17.6	13.0
2480	19.3	17.7	13.1
2535	19.3	17.3	12.5
2585	19.3	16.4	11.5
2635	18.9	16.6	11.9
2690	18.9	17.2	12.6
2795	18.7	17.5	13.2
2845	18.7	17.1	12.8
2895	18.8	16.3	11.8
2950	18.7	16.8	12.3
3000	18.7	16.8	12.0
3055	18.4	16.3	11.9
3105	18.3	15.8	11.4
3155	18.3	15.8	11.4
3210	18.3	16.0	11.6
3260	18.2	15.5	11.1
3315	17.8	15.5	11.3
4150	16.3	13.8	10.3
4250	16.1	—	—
4670	15.4	13.0	10.0
4795	15.3	12.7	9.7

TABLE 10

San Juan, 13 April 1946, 1323–1345 hrs.; 1–3/10 cumulus base 2200 ft., top 2800 ft. Sounding made in clear. Surface wind 080° 12 mph., T_d 25.9°C, T_w 21.9°C, W 14.8 g/kg. T_{sea} 26.5°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	25.6	21.7	14.6	1815	20.6	18.3	13.1
50	25.5	21.6	14.6	1870	20.5	19.2	14.4
105	25.4	21.7	14.6	1920	20.4	18.5	13.6
155	25.2	21.4	14.3	1975	20.1	17.7	12.4
210	25.0	21.2	14.2	2025	20.2	18.7	13.9
260	24.9	21.3	14.3	2075	20.3	17.6	12.3
310	24.7	21.0	14.1	2130	20.2	17.7	12.4
365	24.5	21.0	14.3	2180	20.2	17.3	12.1
415	24.8	21.1	14.4	2230	20.1	17.3	12.1
470	24.4	21.1	14.5	2285	19.8	17.3	12.1
520	24.1	20.8	14.2	2335	19.8	16.6	11.4
570	24.1	20.5	13.9	2390	20.1	16.1	10.6
625	23.8	20.6	14.1	2440	19.9	15.8	10.4
675	23.7	20.6	14.1	2490	19.9	15.4	9.8
725	23.6	20.5	14.1	2545	19.8	15.4	9.8
780	23.5	20.6	14.4	2595	19.6	15.4	9.9
830	23.2	20.6	14.5	2650	19.3	16.3	11.4
885	23.1	20.6	14.6	2700	19.2	15.5	10.3
935	23.1	20.2	14.1	2805	19.2	14.9	9.6
985	22.8	20.1	14.0	2855	19.1	14.6	9.3
1040	22.6	20.2	14.3	2905	19.1	14.6	9.4
1090	22.5	20.0	14.3	3010	18.8	14.5	9.4
1145	22.3	20.1	14.3	3060	18.5	14.5	9.5
1195	22.2	20.2	14.5	3115	18.4	14.6	9.8
1245	22.0	20.0	14.5	3175	18.4	14.5	9.6
1300	21.9	19.9	14.3	3215	18.3	14.4	9.6
1350	21.7	20.0	14.6	4255	16.0	12.4	8.9
1455	21.4	20.2	14.9	4775	14.5	11.7	8.9
1505	21.3	20.0	14.9	5290	13.4	10.7	8.6
1555	21.2	19.5	14.3	5810	12.0	10.0	8.7
1610	21.2	19.2	13.9	6325	10.9	9.2	8.3
1660	21.2	18.5	13.0	6845	10.1	7.9	7.6
1715	21.1	18.1	12.5	7360	9.2	7.8	8.0
1765	20.7	18.1	12.7	7670	8.5	7.2	7.8

TABLE II

San Juan, 13 April 1946, 1414–1427 hrs.; 3/10 cumulus base 2100 ft., top 7000 ft. Sounding made in cloud. Surface wind 080° 12 mph., T_d 26.1°C, T_w 21.9°C, W 14.7 g/kg. T_{sea} 26.5°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	25.8	21.7	14.5
50	25.8	21.8	14.6
105	25.7	21.7	14.6
155	25.5	21.7	14.6
210	25.2	21.7	14.8
260	25.2	21.6	14.6
310	24.9	21.4	14.6
365	24.8	21.4	14.5
415	24.6	21.3	14.7
470	24.6	20.9	14.1
520	24.3	21.2	14.6
570	24.2	21.1	14.6
625	24.1	20.9	14.4
675	24.0	20.9	14.5
725	23.8	20.6	14.2
780	23.6	21.1	14.8
830	23.4	20.6	14.5
885	23.1	20.5	14.5
935	23.1	20.2	14.2
985	23.1	20.2	14.0
1040	22.9	20.2	14.2
1090	22.6	20.4	14.6
1145	22.5	20.4	14.8
1195	22.5	20.2	14.8
1245	22.3	20.2	14.6
1300	22.0	20.2	14.8
1350	22.0	20.0	14.6
1400	21.8	20.0	14.6
1455	21.7	19.7	14.2
1505	21.5	19.7	14.4
1555	21.4	19.8	14.6
1610	21.3	19.8	14.9
1660	21.1	19.6	14.5
1715	21.1	19.6	14.6
1765	20.8	19.4	14.5
1815	20.7	19.0	14.0
1870	20.7	19.2	14.4
1920	20.6	19.2	14.4
1975	20.4	19.2	14.6
2025	20.1	19.3	14.9
2075	20.1	19.0	14.2
2130	20.0	18.9	14.2
2180	19.9	19.1	14.5
2230	19.7	19.0	14.5
2285	19.4	18.7	14.2
2335	19.4	18.5	14.1
2390	19.1	18.4	14.1
2440	19.1	18.4	14.1
2490	19.0	18.1	14.6
2545	19.1	17.7	13.3
2595*	—	18.7	14.8
2650	18.1	17.3	13.1
2700	17.8	17.1	13.0
2750	18.3	17.6	13.6
2805	18.4	17.3	13.1
2855	18.8	17.3	13.0
2905	18.5	17.3	13.1
2960*	—	17.8	14.1
3010	17.6	16.9	13.0
3060	17.4	16.8	12.9
3115	17.6	16.4	12.5
3175	16.8	16.6	13.0

TABLE 12

San Juan, 13 April 1946, 1454–1511 hrs.; Sounding made in clear. Surface wind 080° 12 mph., T_d 26.1°C, T_w 21.9°C, W 14.7 g/kg. T_{sea} 26.5°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	25.7	21.9	14.9
75	25.7	21.9	14.8
130	25.6	21.7	14.6
180	25.5	21.4	14.4
235	25.3	21.2	14.1
285	25.2	21.4	14.5
350	25.0	21.2	14.2
390	24.8	21.4	14.8
440	24.5	20.9	14.2
495	24.4	21.3	14.8
545	24.4	21.2	14.6
600	24.1	21.1	14.6
650	24.1	20.9	14.5
700	23.8	20.8	14.5
755	23.7	20.9	14.7
805	23.6	20.6	14.4
855	23.5	20.6	14.4
910	23.2	20.6	14.5
960	23.2	20.6	14.6
1015	23.1	20.4	14.3
1065	23.0	20.4	14.5
1115	22.8	20.5	14.9
1170	22.6	20.2	14.6
1220	22.3	20.0	14.5
1270	22.4	19.9	14.3
1325	22.4	19.9	14.0
1375	22.1	19.4	13.8
1430	21.9	19.4	13.8
1470	21.7	19.4	13.9
1530	21.6	19.6	14.3
1575	21.4	19.6	14.5
1635	21.3	19.4	14.1
1685	21.3	19.0	13.6
1740	21.2	18.9	13.5
1790	21.0	19.0	13.8
1845	20.8	18.7	13.4
1895	20.7	19.2	14.2
1945	20.5	19.3	14.5
2000	20.6	18.8	13.7
2050	20.4	18.8	13.9
2105	20.4	18.8	13.9
2155	20.3	18.3	13.4
2205	20.1	18.1	13.1
2260	20.2	17.3	12.1
2310	19.8	18.1	13.3
2360	19.8	18.1	13.3
2415	19.5	17.3	12.3
2465	19.5	17.6	12.8
2520	19.4	16.8	12.0
2570	19.4	16.6	11.6
2620	19.2	16.6	11.7
2675	19.1	16.6	11.9
2725	19.0	16.5	11.7
2775	18.8	16.3	11.5
2830	18.7	15.8	11.0
2880	18.7	15.8	11.1
2935	18.4	16.0	11.4
2985	18.5	15.5	10.9
3035	18.3	15.6	11.1
3090	18.0	15.8	11.5
3140	17.9	15.0	10.6

TABLE 13

San Juan, 13 April 1946, 1533–1548 hrs.; Sounding made in clear. Surface wind 080° 12 mph., T_d 26.1°C, T_w 21.9°C, W 14.7 g/kg. T_{sea} 26.5°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	26.0	21.9	14.8	1505	21.8	19.8	14.5
50	25.7	21.7	14.5	1557	21.4	19.8	14.8
105	25.7	21.4	14.1	1610	21.4	19.4	14.1
155	25.6	21.2	13.9	1660	21.3	19.4	14.2
210	25.5	21.2	14.0	1715	21.3	18.5	12.9
260	25.2	20.9	13.8	1765	21.1	18.5	13.0
310	25.2	20.4	13.1	1870	21.0	18.4	12.8
360	24.9	21.3	14.5	1920	20.7	18.5	13.4
415	24.6	21.3	14.6	1975	20.6	18.1	12.9
470	24.5	21.1	14.5	2025	20.6	17.8	12.6
520	24.4	20.9	14.3	2075	20.5	17.7	12.2
570	24.1	20.6	14.0	2130	20.4	17.5	12.2
625	24.1	20.5	13.9	2180	20.5	17.2	11.9
675	24.1	20.6	14.0	2285	20.4	16.9	11.4
725	24.1	20.4	13.8	2335	20.5	16.4	10.9
780	23.6	20.3	13.6	2390	20.5	15.9	10.4
830	23.6	19.8	13.2	2440	20.6	15.1	9.2
885	23.3	20.5	14.3	2490	20.6	14.6	8.7
935	23.3	20.3	13.8	2545	20.3	15.1	9.4
985	23.1	20.5	14.5	2595	20.6	14.2	8.3
1040	23.0	20.3	14.3	2650	20.5	14.1	8.2
1090	22.9	19.7	13.7	2700	20.3	14.1	8.3
1145	22.8	19.8	13.9	2805	20.1	13.8	8.2
1195	22.6	19.8	14.0	2855	19.8	13.8	8.3
1245	22.6	19.5	13.7	2905	19.8	13.7	8.3
1300	22.3	19.4	13.6	2960	19.7	13.8	8.4
1350	22.1	19.4	13.7	3010	19.7	13.7	8.3
1400	21.9	19.4	13.8	3060	19.5	13.7	8.4
1455	22.0	19.0	13.2	3115	19.2	13.5	8.4

TABLE 14

San Juan, 14 April 1946, 0008–0035 hrs.; Sounding made in clear; 3/10 cumulus base 1900 ft. Surface wind 095° 13 mph., T_d 24.9°C, T_w 21.5°C, W 14.7 g/kg. T_{sea} 25.7°C. Plane visible.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
105	25.4	21.8	14.8	2440	19.1	16.1	10.9
155	25.2	21.9	15.2	2490	19.4	15.7	10.3
210	25.0	21.8	15.1	2650	19.2	15.5	10.2
260	24.9	21.5	14.8	2700	19.2	15.3	10.0
310	24.7	21.6	15.0	2750	19.1	15.3	10.3
365	24.5	21.3	14.7	2805	19.1	15.1	9.9
415	24.5	21.4	14.9	2905	19.1	15.1	10.0
520	24.1	21.0	14.5	3010	18.8	15.3	10.4
570	23.8	21.2	14.8	3115	18.7	14.7	9.7
625	23.7	20.6	14.2	3215	18.4	14.4	9.6
675	23.7	20.6	14.2	3325	18.0	14.1	9.6
725	23.6	20.6	14.2	3375	17.8	13.9	9.3
780	23.3	20.6	14.4	3530	17.8	13.6	9.0
830	23.3	20.6	14.4	3580	17.8	13.2	8.7
885	23.1	20.6	14.6	3735	17.5	12.9	8.5
935	23.0	20.6	14.7	3790	17.1	12.5	8.3
985	22.9	20.6	14.7	3945	16.8	12.5	8.4
1040	22.6	20.6	14.8	3995	17.0	12.7	8.6
1090	22.6	20.6	15.0	4150	16.9	13.1	9.3
1145	22.5	20.3	14.6	4205	16.6	12.7	8.9
1195	22.3	20.2	14.6	4360	16.5	12.5	8.8
1245	21.9	20.3	15.0	4410	16.4	12.2	8.5
1300	21.9	20.2	14.7	4565	15.8	12.4	9.0
1350	21.7	20.0	14.7	4620	15.6	12.0	8.8
1400	21.7	19.8	14.5	4775	15.5	12.1	8.8
1455	21.4	20.0	14.9	4825	15.2	12.2	9.2
1505	21.3	19.7	14.5	4965	15.0	11.8	8.8
1555	21.3	19.8	14.7	5015	14.7	11.8	9.0
1610	21.2	19.8	14.7	5190	14.5	11.5	8.9
1660	21.1	19.6	14.6	5240	14.1	11.1	8.6
1715	20.8	19.4	14.4	5395	13.9	11.0	8.7
1765	20.7	19.3	14.3	5445	13.8	10.3	8.0
1815	20.6	19.4	14.4	5600	13.8	9.7	7.3
1870	20.5	19.5	14.7	5655	13.5	8.7	6.6
1920	20.0	19.0	14.0	5810	13.4	8.2	6.1
1975	20.0	18.5	14.5	5860	13.1	8.1	6.2
2075	19.9	19.2	14.6	6015	12.7	7.9	6.2
2180	19.7	18.1	13.4	6070	12.4	7.8	5.8
2285	19.6	18.1	13.1	6225	12.3	7.3	5.8
2335	19.7	15.9	10.5	6325	12.0	7.0	5.6

TABLE 15

San Juan, 14 April 1946, 0615–0650 hrs.; 2/10 cumulus base 2100 ft. Sounding made in clear. Surface wind 090° 15 mph., T_d 25.2°C, T_w 21.3°C, W 14.2 g/kg. T_{sea} 25.7°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
25	25.5	21.7	14.7	1975	20.4	17.4	11.9
50	25.5	21.9	14.9	2025	20.4	17.2	11.8
105	25.4	21.7	14.7	2075	20.3	16.9	11.3
155	25.1	21.5	14.4	2130	20.0	18.1	13.1
210	25.0	21.4	14.5	2180	19.7	16.6	11.2
260	24.8	21.4	14.4	2230	19.8	16.9	11.7
310	24.7	21.4	14.7	2285	19.4	17.3	12.4
365	24.5	21.3	14.7	2335	19.1	17.3	12.5
415	24.3	21.0	14.3	2390	19.3	15.7	10.4
470	24.1	20.9	14.3	2490	19.3	15.9	10.6
520	24.1	20.6	13.9	2545	19.1	16.0	10.9
570	24.0	20.6	14.0	2650	18.9	16.1	11.2
625	23.7	20.4	13.9	2700	18.7	16.1	11.3
675	23.6	20.4	13.9	2750	18.7	16.1	11.3
725	23.5	20.3	13.9	2805	18.6	15.7	11.0
780	23.3	20.3	14.0	2905	18.3	16.0	11.4
830	23.1	20.3	14.1	2960	18.2	15.8	11.3
885	23.0	20.0	13.7	3010	18.3	15.3	10.7
935	23.0	19.9	13.7	3060	18.1	15.5	10.9
985	22.8	20.0	14.0	3115	18.0	15.4	11.1
1040	22.7	20.0	13.9	3215	17.7	14.9	10.4
1090	22.4	19.8	13.9	3320	17.5	15.1	10.9
1145	22.3	19.9	14.1	3425	17.3	14.9	10.8
1195	22.2	20.0	14.4	3530	17.1	14.4	10.2
1245	22.0	19.9	14.2	3630	17.0	14.9	11.1
1300	21.8	19.7	14.1	3735	16.6	14.9	11.3
1350	21.8	19.0	13.2	4150	15.9	13.6	10.1
1400	21.8	19.2	13.4	4670	15.0	13.2	10.5
1455	21.5	19.4	14.0	5190	13.9	12.3	10.2
1505	21.5	19.5	14.2	5705	12.7	10.7	9.0
1555	21.2	19.4	14.2	5810	12.5	10.8	9.1
1610	21.1	19.4	14.2	5910	12.4	10.8	9.3
1660	21.1	19.4	14.3	6015	12.2	10.6	9.2
1715	21.1	19.0	13.7	6120	12.0	10.3	8.9
1765	20.9	19.4	14.3	6225	11.7	10.2	8.5
1815	20.5	18.7	13.5	6325	11.6	9.5	8.3
1870	20.6	18.5	13.3	6430	11.4	9.1	7.9

TABLE 15 (*Continued*)

San Juan, 14 April 1946, 0615–0650 hrs.; 2/10 cumulus base 2100 ft. Sounding made in clear. Surface wind 090° 15 mph., T_d 25.2°C, T_w 21.3°C, W 14.2 g/kg. T_{sea} 25.7°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
6535	11.2	9.3	8.3	8290	9.2	2.6	3.2
6635	10.6	8.8	8.0	8395	9.3	2.2	3.0
6740	10.4	8.8	8.3	8500	8.6	2.5	3.6
6845	10.3	8.8	8.3	8600	8.8	2.9	3.9
6945	10.0	8.6	8.3	8705	8.9	3.4	4.3
7050	9.8	8.6	8.3	8810	8.9	2.7	3.6
7155	9.9	8.8	8.5	8910	9.1	2.6	3.4
7260	9.5	8.4	8.2	9015	9.2	1.2	2.3
7360	9.3	8.0	7.9	9120	8.6	1.3	2.7
7465	9.1	8.2	8.3	9220	8.8	1.0	2.4
7570	8.9	8.0	8.3	9325	8.7	0.9	2.3
7670	9.0	7.5	7.7	9430	8.2	2.3	4.0
7775	8.1	7.5	8.1	9535	8.2	0.7	2.4
7880	8.6	7.3	7.9	9635	8.2	−0.1	1.8
7980	8.9	6.5	6.8	9740	8.1	−0.4	1.5
8095	8.5	6.4	7.0	9840	7.7	−0.6	1.5
8190	8.6	4.5	5.3	9940	7.5	−0.8	1.5

TABLE 16

San Juan, 14 April 1946, 0720–0749 hrs.; 2/10 cumulus base 1900 ft. Sounding made near a cloud. Surface wind 090° 15 mph., T_d 25.2°C, T_w 21.4°C, W 14.3 g/kg. T_{sea} 25.7°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
35	25.7	22.0	15.0
50	25.6	21.7	14.6
105	25.4	21.7	14.7
155	25.2	22.0	15.4
210	25.1	21.9	15.3
260	25.0	21.7	15.0
310	25.0	21.7	15.0
365	24.8	21.4	14.8
415	24.5	21.2	14.6
470	24.4	21.0	14.4
520	24.2	21.2	14.6
570	24.0	21.2	14.8
625	24.0	20.9	14.6
675	23.8	20.6	14.2
725	23.7	21.0	14.8
780	23.6	21.2	15.1
830	23.5	20.8	14.7
935	23.2	20.8	14.8
985	23.0	20.4	14.3
1040	22.9	20.4	14.4
1090	22.7	20.5	14.7
1145	22.6	20.4	14.8
1195	22.5	19.9	14.3
1245	22.3	20.4	14.7
1300	22.3	20.1	14.5
1350	21.9	20.3	14.9
1400	21.9	20.2	14.8
1455	21.7	19.9	14.6
1505	21.6	19.1	13.6
1555	21.2	19.8	14.6
1610	21.2	20.1	15.2
1660	21.2	20.1	15.2
1715	21.0	19.4	14.3
1765	20.7	19.2	14.2
1815	20.7	18.9	13.9
1870	20.5	19.4	14.6
1920	20.5	18.5	13.4
1975	20.5	18.4	13.3
2025	20.3	18.0	12.9
2075	20.0	18.0	13.0
2130	20.0	17.8	12.7
2180	19.9	17.5	12.5
2230	19.8	17.5	12.5
2285	19.2	18.4	13.9
2335	19.5	18.0	13.4
2390	19.4	17.9	13.4
2440	19.2	17.5	12.8
2490	19.1	17.2	12.5
2545	19.1	17.0	12.1
2595	18.9	17.1	12.4
2650	18.7	16.9	12.3
2700	18.7	16.6	11.9
2750	18.6	16.4	11.8
2805	18.5	16.2	11.4
2855	18.5	16.0	11.3
2905	18.6	15.7	10.9
3010	18.3	15.5	10.8
3115	18.1	15.3	10.6
4150	16.1	12.5	8.7
5190	14.0	12.1	9.1
6225	11.7	9.2	8.1
7260	9.7	7.6	7.4
7775	8.5	7.1	6.8
8290	8.2	3.6	4.7
8500	8.7	1.3	2.8
8810	7.6	3.2	4.6
9120	8.1	0.4	2.2

TABLE 17

San Juan, 22 April 1946, 1854–1913 hrs.; 4–6/10 cumulus base 1750 ft. Sounding made in clear. Surface wind 030° 10 mph., T_d 25.0°C, T_w 21.8°C, W 14.3 g/kg. T_{sea} 25.6°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.6	22.3	15.5	1610	20.9	20.2	15.3
105	25.2	22.3	15.7	1665	20.7	19.6	14.6
155	25.1	22.5	16.1	1715	20.6	19.5	14.5
210	25.1	21.9	15.2	1770	20.6	19.0	13.8
260	24.9	21.8	15.1	1870	20.5	18.5	13.3
310	24.6	21.8	15.3	1925	20.2	18.8	13.8
365	24.4	21.8	15.5	1975	20.2	18.5	13.5
415	24.1	21.7	15.4	2080	19.9	18.1	13.2
470	24.1	21.6	15.4	2185	19.8	17.9	13.0
520	24.1	21.4	15.1	2235	19.7	17.8	13.0
570	23.9	21.4	15.3	2290	19.8	17.4	12.4
625	23.7	21.3	15.3	2340	20.0	17.3	12.4
675	23.6	21.2	15.0	2390	19.9	17.2	12.1
725	23.3	20.9	14.8	2445	19.6	17.2	12.2
780	23.1	20.9	15.0	2495	19.6	17.0	12.0
830	23.0	21.0	15.1	2550	19.2	17.3	12.6
885	23.0	20.9	15.0	2600	19.0	17.2	12.6
935	22.8	20.8	15.0	2650	19.0	16.9	12.0
990	22.5	20.8	15.2	2705	19.0	16.9	12.0
1040	22.4	20.4	14.6	2755	19.0	16.5	11.7
1090	22.2	20.6	15.1	2810	18.9	16.5	11.8
1145	22.1	20.9	15.6	2860	18.8	16.5	11.8
1195	21.9	20.8	15.5	2910	18.6	16.4	11.8
1250	21.8	20.2	14.7	3015	18.4	16.2	11.6
1300	21.7	20.4	15.1	3120	18.2	16.1	11.8
1350	21.5	20.3	15.0	4160	15.6	14.6	11.0
1455	21.3	20.4	15.3	5200	13.6	12.2	9.9
1510	21.2	20.2	15.1	6240	12.7	8.5	6.7
1560	20.9	20.5	15.7	6345	13.3	6.6	4.6

TABLE 18

San Juan, 23 April 1946, 0713–0732 hrs.; 1–3/10 cumulus base 1000 ft., tops 1600 ft. in clear areas, 7–9/10 cumulonimbus base 800 ft., tops over 6000 ft. in cloudy areas. Sounding made in clear. Surface wind 040° 14 mph., T_d 24.4°C, T_w 21.8°C, W 15.3 g/kg. T_{sea} 25.6°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	24.1	21.9	15.7	1815	20.0	19.0	14.1
120	23.6	21.6	15.4	1870	20.0	19.0	14.2
210	23.4	21.6	15.5	1975	19.8	19.0	14.4
260	23.2	21.6	15.5	2080	19.6	19.0	14.5
310	23.1	21.7	15.9	2130	19.3	18.8	14.4
365	23.1	21.9	16.3	2180	19.1	18.6	14.3
415	23.2	21.9	16.3	2285	19.0	18.1	13.8
470	23.1	21.7	16.0	2335	18.8	18.1	13.7
520	23.1	21.6	15.8	2390	18.7	18.1	13.9
570	23.1	21.2	15.2	2440	18.7	17.9	13.6
625	23.0	21.6	15.9	2490	18.7	17.7	13.3
675	22.7	21.2	15.5	2545	18.5	17.7	13.5
725	22.4	21.3	15.7	2595	18.6	17.4	13.0
780	22.2	21.2	15.7	2650	18.4	17.4	13.1
830	22.2	21.2	15.8	2700	18.4	17.3	13.0
885	21.9	21.2	16.0	2750	18.3	17.3	13.1
935	21.9	21.4	16.5	2805	18.2	16.1	11.5
1040	21.7	20.5	15.2	2855	18.1	16.1	11.7
1145	21.6	20.3	15.1	2905	18.1	16.1	11.9
1195	21.2	20.3	15.3	3010	17.9	16.7	12.7
1245	21.1	20.3	15.4	3115	17.5	16.7	12.9
1295	21.0	20.3	15.4	3215	17.2	16.4	12.9
1350	21.0	20.3	15.5	3325	17.1	16.4	12.8
1455	20.6	19.8	15.0	3735	16.6	15.7	12.3
1505	20.6	19.8	15.0	4150	15.4	15.0	12.1
1555	20.6	19.8	15.1	4720	14.6	14.2	11.7
1660	20.2	19.4	14.8	5190	14.0	13.6	11.2
1715	20.1	19.3	14.6	5705	12.9	12.3	10.3
1765	20.1	19.2	14.6	6245	12.4	11.5	10.1

TABLE 19

San Juan, 23 April 1946, 1307–1338 hrs.; 7–9/10 cumulus and cumulonimbus base 1700 ft. Sounding made in clouds. Surface wind 050° 18 mph., T_d 25.6°C, T_w 22.3°C, W 15.5 g/kg, T_{sea} 25.7°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
105	25.5	21.7	16.1	2025	20.4	19.3	14.6
155	25.2	22.6	16.1	2075	20.3	18.8	13.8
210	24.9	22.2	15.7	2130	19.9	19.7	15.6
260	24.8	22.2	15.8	2180*	—	19.3	15.2
310	24.4	22.1	15.9	2230*	—	19.3	15.3
365	24.3	22.1	16.0	2285	19.8	18.9	14.5
415	24.3	22.1	16.0	2335	19.5	18.8	14.5
470	24.3	21.9	15.7	2390*	—	18.8	14.9
520	24.1	21.8	15.7	2440*	—	19.0	15.2
570	24.0	21.7	15.5	2490*	—	18.8	14.9
625	24.0	21.0	14.6	2545*	—	18.2	14.3
675	23.5	21.7	15.7	2700	18.8	17.7	13.3
725	23.5	21.9	16.2	2805*	—	17.9	13.8
780	23.2	21.7	15.9	2855*	—	17.9	13.8
830	23.0	21.7	16.1	2905	17.8	17.5	13.5
885	23.0	21.7	16.2	3010*	—	17.2	13.7
935	22.7	21.4	16.0	3060*	—	17.1	13.5
985	22.7	21.3	15.9	3115*	—	17.1	13.7
1040	22.6	21.2	15.7	3215*	—	17.0	13.5
1090	22.5	21.2	15.8	3215*	—	17.2	13.7
1145	22.5	20.9	15.5	3320	17.3	16.5	12.7
1195	22.2	20.8	15.5	3345	17.6	16.8	13.1
1245	22.1	20.6	15.2	3375	17.5	16.3	12.5
1300	22.0	20.6	15.3	3840	16.2	15.5	12.3
1350	21.8	20.8	15.7	3840*	—	16.5	13.7
1400	21.7	20.6	15.5	4305	15.7	14.1	11.0
1455	21.5	20.6	15.6	4315*	—	16.2	13.2
1505	21.4	20.0	14.8	4825	14.4	13.1	10.5
1560	21.3	20.6	15.6	4825*	—	14.7	12.4
1610	21.1	20.5	15.6	5445	13.2	12.2	10.2
1660	21.1	20.4	15.5	5445*	—	15.1	12.9
1765	20.8	20.2	15.4	5600*	—	13.6	11.8
1815	20.7	20.2	15.5	5810	12.5	12.0	10.2
1870	20.6	20.3	15.9	6380	12.2	11.4	10.2
1920	20.5	20.2	15.7	6410*	—	13.1	11.8
1975	20.4	19.6	15.0				

TABLE 20

San Juan, 23 April 1946, 1353–1417 hrs.; Sounding made in clear. Surface wind 050° 18 mph., T_d 25.6°C, T_w 22.0°C, W 15.0 g/kg, T_{sea} 25.7°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.6	22.1	15.2	2075	19.8	19.3	15.0
105	25.5	22.1	15.3	2180	19.7	18.5	13.9
155	25.2	21.7	14.8	2285	19.6	18.5	14.1
210	25.1	21.9	15.3	2390	19.1	18.1	13.7
260	25.0	21.4	14.5	2700	19.1	16.6	11.8
310	24.8	21.7	15.0	2805	18.9	16.6	12.0
365	24.6	21.7	15.2	2905	18.7	16.5	12.0
415	24.6	21.7	15.2	3010	18.4	16.3	11.9
470	24.3	21.4	15.1	3115	18.2	16.1	11.9
520	24.2	21.4	15.1	3630	17.0	15.1	11.1
570	24.0	21.2	14.9	4150	16.0	14.3	11.0
625	23.9	21.2	15.0	4660	14.8	13.9	11.2
675	23.9	20.9	14.6	5190	13.9	13.2	11.1
725	23.5	20.6	14.4	5810	13.2	11.8	9.9
780	23.5	20.8	14.6	6245	12.2	11.3	10.0
830	23.2	21.1	15.2	6795	11.4	10.3	9.3
885	23.1	20.9	15.1	7245	10.6	9.4	8.9
935	23.0	20.6	14.7	7805	9.6	7.8	8.1
1040	22.9	20.5	14.6	8175	9.5	7.3	7.6
1145	22.5	20.4	14.6	8290	9.5	7.2	7.6
1245	22.2	20.5	15.1	8390	9.6	6.9	7.3
1350	21.9	20.4	15.1	8495	9.2	7.0	7.6
1455	21.4	20.3	15.2	8605	9.0	7.2	7.9
1555	21.3	19.8	14.7	8705	8.9	6.9	7.6
1660	21.0	19.8	14.9	8810	8.9	7.2	7.9
1765	20.8	19.8	15.1	9325	8.7	2.9	4.3
1870	20.5	19.2	14.4	9630	8.2	1.3	3.0
1975	20.4	18.5	13.5	10360	6.9		

TABLE 21

San Juan, 25 April 1946, 1616–1643 hrs.; Cumulus base 1950 ft., tops 5300 ft. Sounding made in cloud. Surface wind 090° 15 mph.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.9	22.3	15.4
105	25.9	21.6	14.3
155	25.9	21.7	14.5
210	25.6	21.2	13.9
260	25.5	21.6	14.6
310	25.6	21.4	14.4
365	25.1	21.2	14.3
470	24.7	21.6	15.0
520	24.4	21.6	15.2
570	24.5	21.6	15.2
675	24.1	21.4	15.2
780	24.0	21.2	15.0
830	23.9	21.4	15.4
885	23.9	20.5	14.1
935	23.8	20.5	14.6
985	23.5	20.5	14.2
1090	23.1	21.0	15.4
1195	22.7	20.6	14.9
1300	22.5	20.3	14.8
1350	22.5	20.2	14.6
1400	22.1	20.2	14.8
1455	22.1	19.9	14.4
1505	22.0	20.1	14.7
1555	21.9	19.8	14.5
1610	21.7	19.5	14.1
1660	21.6	19.5	14.2
1715	21.2	19.8	14.6
1765	21.0	19.8	15.4
1815	21.0	19.6	14.6
1870	20.9	19.3	14.3
1920	20.6	19.5	14.6
2025	20.4	18.7	13.7
2130	20.1	19.5	15.0
2160	19.5	19.0	14.7
2210*	—	19.3	14.9
2335	19.1	18.5	14.2
2335*	—	19.0	15.0
2440*	—	19.1	15.1
2540	18.8	17.1	12.5
2650	18.4	17.3	13.0
2700	18.1	16.6	12.3
2750	17.0	16.5	12.6
2865*	—	18.2	14.4
2960	18.0	16.0	11.7
3010	18.0	16.4	12.1
3060	17.5	16.1	12.0
3175	16.7	16.3	12.7
3270	16.7	15.1	11.4
3325	16.7	15.3	11.5
3375	17.0	15.3	11.4
3890*	—	15.6	12.7
4305*	—	12.3	10.8
4305	15.7	11.3	7.6
4825*	—	13.1	11.2
4825	15.8	9.0	5.7

TABLE 22

San Juan, 25 April 1946, 1646–1710 hrs.; Sounding in clear. Surface wind 090° 15 mph.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.9	22.2	15.2
105	25.2	22.1	15.3
155	25.4	22.1	15.4
210	25.1	22.1	15.5
260	25.0	21.9	15.4
310	24.8	21.9	15.5
365	24.7	21.8	15.3
415	24.5	21.4	14.9
470	24.4	21.4	15.0
520	24.1	21.6	15.3
570	24.0	21.4	15.2
625	23.9	21.3	15.2
675	23.8	21.2	15.0
725	23.5	20.9	14.8
780	23.5	20.9	14.8
830	23.4	20.8	14.8
885	23.2	20.9	14.9
935	23.1	21.0	15.2
985	23.0	20.5	14.5
1040	22.9	20.5	14.5
1090	22.6	20.6	14.9
1145	22.6	20.6	15.0
1195	22.5	20.5	15.0
1245	22.2	20.3	14.9
1300	22.0	20.1	14.7
1350	22.0	20.1	14.7
1455	21.7	20.1	14.8
1505	21.7	19.9	14.5
1555	21.4	19.9	14.7
1610	21.3	19.9	14.8
1660	21.3	19.4	14.2
1715	21.1	19.6	14.5
1765	20.8	19.6	14.6
1815	20.7	19.2	14.2
1870	20.7	19.2	14.2
1920	20.7	19.0	14.0
1975	20.4	18.9	14.0
2025	20.2	18.7	13.8
2075	20.1	19.1	14.4
2130	19.7	19.4	15.0
2180	19.9	18.1	13.2
2230	19.9	17.8	12.8
2285	19.9	17.7	12.7
2335	19.8	17.5	12.5
2390	19.6	17.4	12.5
2440	19.5	17.4	12.6
2490	19.5	17.1	12.2
2545	19.1	17.0	12.2
2600	19.0	17.3	12.8
2650	19.0	17.0	12.3
2700	18.9	16.8	12.2
2750	18.8	16.4	11.8
2805	18.7	16.3	11.8
2905	18.6	16.1	11.5
3010	18.4	15.4	10.8
3115	18.4	15.4	10.9
3660	16.8	14.6	10.9
4150	15.9	12.8	9.3
4720	15.7	8.5	5.1
5190	14.8	8.0	5.2
5685	13.3	6.8	4.8
6245	12.0	5.4	4.2
6795	11.4	2.6	2.4
7380	10.3	1.6	1.8
7830	9.6	3.1	3.6
8290	9.2	2.1	3.0
8810	9.8	1.3	2.6
8910	9.5	1.0	2.5
9015	9.3	0.8	2.1
9120	9.4	0.7	1.7
9220	9.7	0.1	1.4
9325	9.4	− 0.1	1.5
9430	9.1	− 0.5	1.3

TABLE 23

San Juan, 26 April 1946, 1319–1355 hrs.; 2/10 cumulus base 2200 ft. Sounding made in cloud. Surface wind 130° 15 mph.; T_d 25.8°C, T_w 21.7°C, W 14.5 g/kg, T_{sea} 25.8°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	26.1	21.7	14.2	1895	21.3	19.3	14.0
85	26.1	21.8	14.5	2000	21.1	18.9	13.5
135	26.1	21.3	13.9	2055	20.8	18.9	13.5
185	25.8	21.1	13.6	2110	20.6	19.2	14.2
240	25.7	21.3	14.1	2215	20.2	18.9	14.0
290	25.5	21.3	14.2	2315	20.1	18.5	13.5
345	25.5	21.1	13.7	2365	19.9	18.5	13.6
395	25.3	21.1	14.0	2420	19.7	18.8	14.2
445	25.1	21.0	13.9	2520	19.5	18.2	13.4
500	25.1	21.2	13.6	2625	19.5	17.8	13.3
550	24.7	21.2	14.3	2680	19.5	17.2	13.0
605	24.7	21.2	14.4	2760*	—	18.8	14.0
655	24.7	20.9	14.1	2770	19.3	17.1	13.0
705	24.7	20.6	13.6	3040*	—	18.0	13.9
760	24.4	20.6	13.8	3060	18.5	15.5	11.0
810	24.2	20.6	14.0	3350*	—	17.8	14.3
865	23.9	20.5	14.0	3370	17.7	16.3	12.5
915	23.9	20.5	14.1	3660*	—	16.9	13.6
965	23.8	20.5	14.1	3715	16.5	13.3	9.3
1020	23.5	20.5	14.1	3715	17.1	12.0	7.4
1065	23.4	20.4	14.2	4335	15.6	12.5	9.2
1115	23.4	20.3	14.1	4370*	—	16.5	13.5
1170	23.2	20.2	13.9	4370	15.6	12.8	9.5
1220	23.2	20.2	13.9	4855*	—	14.1	12.1
1270	22.9	20.2	14.0	4875	14.4	11.9	9.1
1320	22.9	19.9	13.8	4875	14.4	10.7	7.8
1370	22.6	19.7	13.6	5375*	—	13.0	11.4
1425	22.6	19.6	13.6	5375	13.6	9.8	7.3
1490	22.4	19.8	13.8	5945*	—	12.4	11.1
1590	22.1	19.5	13.8	5945	11.9	9.5	8.1
1690	21.9	19.3	13.8	6355*	—	11.2	10.5
1795	21.6	19.2	13.7	6440	11.6	5.4	4.3

TABLE 24

San Juan, 26 April 1946, 1416–1456 hrs.; 2/10 cumulus base 2200 ft., tops 3500 ft. Sounding made in clear. Surface wind 130°, 15 mph., T_d 25.8°C, T_w 21.7°C, W 14.5 g/kg, T_{sea} 25.8°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.9	21.9	14.8	1975	20.5	19.0	13.9
105	25.7	21.7	14.5	2075	20.4	19.2	14.3
155	25.7	21.3	14.2	2180	20.2	18.3	13.9
210	25.4	21.2	13.9	2285	19.9	18.5	13.6
260	25.1	21.4	14.6	2390	19.7	17.7	12.7
310	25.1	21.3	14.5	2490	19.5	17.8	13.0
370	25.0	21.4	14.7	2595	19.1	17.3	12.5
415	24.8	21.2	14.3	2700	19.1	16.1	11.1
470	24.7	20.8	13.9	2805	18.7	14.9	9.8
520	24.6	20.6	13.7	2905	18.3	15.0	10.0
570	24.5	20.5	13.6	3010	18.3	14.7	9.7
625	24.2	20.5	13.7	3115	18.0	15.3	10.9
675	24.1	20.6	14.0	3630	17.5	12.2	7.6
725	24.0	20.6	14.0	4130	16.3	11.6	7.7
780	23.8	20.6	14.1	4670	15.1	10.3	7.0
830	23.5	20.6	14.4	5165	14.0	9.9	7.3
885	23.3	20.5	14.3	5705	12.5	8.6	6.6
935	23.1	20.5	14.3	6190	12.0	8.0	6.6
985	23.1	20.3	14.2	6690	10.6	8.3	7.5
1040	23.0	20.1	13.9	6740	10.9	8.4	7.6
1090	23.0	20.1	14.1	7260	10.3	8.9	8.6
1145	22.7	19.8	13.7	7775	10.2	4.4	4.3
1195	22.6	19.8	13.8	7880	10.5	1.6	1.8
1245	22.4	19.8	13.8	7980	10.7	1.5	1.9
1300	22.3	19.8	13.8	8095	10.7	3.4	3.5
1350	22.2	19.8	13.9	8190	10.8	3.6	3.8
1400	22.1	19.6	13.7	8290	10.9	2.7	3.0
1455	22.1	19.4	13.6	8395	10.8	1.3	1.8
1555	21.5	19.8	14.5	8500	10.7	1.4	2.0
1610	21.5	19.7	14.4	8600	10.4	1.3	2.0
1660	21.4	19.4	14.1	8705	10.3	1.0	2.0
1715	21.3	19.4	14.1	8810	10.7	−0.1	0.8
1765	21.1	19.1	14.0	8910	10.3	0.2	1.3
1815	21.1	19.0	13.5	9015	10.1	0.4	1.6
1870	20.7	19.0	13.6				

TABLE 25

San Juan, 27 April 1946; 0923–0949 hrs; 2–3/10 cumulus base 2200 ft., top 8000 ft. Sounding made in cloud. Surface wind 120° 17 mph., T_d 25.3°C, T_w 21.2°C, W 14.0 g/kg, T_{sea} 25.4°C. Plane visible.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	26.0	22.1	15.0	2180	20.3	19.3	14.7
105	25.9	22.1	15.0	2285	19.9	19.5	15.2
155	25.6	22.0	15.1	2390	19.6	19.2	15.1
210	25.4	21.7	14.8	2440	19.5	18.5	14.1
310	25.2	21.5	14.7	2490*	—	18.5	14.3
415	24.9	21.8	15.3	2650	18.4	17.6	13.4
520	24.7	21.4	14.8	2700	18.2	17.0	12.6
625	24.5	21.4	15.0	2770*	—	19.0	15.0
725	24.2	21.2	14.8	2805	18.0	16.9	12.9
830	23.8	21.2	15.1	3010*	—	18.2	14.6
935	23.8	20.9	14.8	3060*	—	18.3	14.8
1040	23.5	20.6	14.5	3235	17.9	15.1	10.7
1145	23.3	20.5	14.5	3755	17.7	10.7	6.1
1245	22.9	20.4	14.7	3790*	15.8	14.1	10.6
1350	22.7	20.6	15.2	4255*	—	14.9	12.3
1455	22.5	20.5	15.1	4255	16.3	10.2	6.4
1560	22.2	20.5	15.3	4775	15.8	8.0	4.6
1660	21.0	20.3	15.2	4825*	12.4	11.9	10.0
1765	21.7	19.8	14.6	5790	12.1	8.0	6.5
1870	21.3	19.7	14.7	6325*	—	8.6	8.5
1975	21.0	19.6	14.8	6325	12.0	3.8	2.8
2075	20.8	19.3	14.5				

TABLE 26

San Juan, 27 April 1946, 1025–1049 hrs.; 2/10 cumulus, base 2600 ft., top 3500 ft. Sounding made in clear. Surface wind 120° 17 mph., T_d 25.3°C, T_w 21.2°C, W 14.0 g/kg, T_{sea} 25.4°C. Plane visible.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
60	25.9	21.2	13.7	2130	20.0	17.7	12.4
105	25.7	20.6	13.0	2180	19.9	17.5	12.5
155	25.6	20.9	13.6	2230	19.8	17.5	12.5
210	25.5	20.5	13.0	2285	19.7	17.0	11.9
260	25.3	20.3	12.9	2390	19.3	17.1	12.3
310	25.2	20.5	13.2	2490	19.1	16.3	11.3
365	24.9	20.3	13.1	2595	18.9	15.8	10.9
415	24.8	20.3	13.2	2700	18.8	15.0	9.9
470	24.6	20.3	13.3	2805	18.8	14.4	9.3
520	24.4	20.2	13.3	2905	18.7	13.6	8.5
570	24.2	19.8	13.0	3010	18.8	13.1	8.0
625	24.1	19.7	12.9	3115	18.8	12.8	7.5
675	24.0	19.7	12.9	3685	17.1	12.0	7.8
725	23.8	19.8	13.1	4150	16.5	11.3	7.5
780	23.7	19.8	13.3	4720	15.1	11.3	8.2
830	23.6	19.4	12.9	5190	14.0	11.8	9.4
885	23.4	19.4	12.9	5760	12.7	11.2	9.6
935	23.2	19.4	13.0	6225	11.9	10.9	9.7
985	23.1	19.4	13.1	6780	11.3	10.3	9.4
1040	23.1	19.4	13.2	7310	10.3	9.6	9.3
1090	22.8	19.2	13.0	7570	10.1	9.3	9.1
1145	22.7	19.0	12.8	7670	10.1	8.8	8.6
1195	22.5	19.1	13.1	7775	9.9	6.5	6.5
1245	22.4	19.2	13.3	7880	10.5	—	—
1350	22.0	19.0	13.2	7980	10.5	2.9	3.2
1400	21.9	18.7	12.8	8095	10.1	2.8	3.2
1455	21.6	18.7	12.9	8190	9.9	2.6	3.0
1505	21.6	18.8	13.0	8290	10.3	1.6	2.3
1555	21.4	18.8	13.2	8445	10.5	1.1	2.0
1610	21.4	18.4	12.9	8500	10.9	1.0	1.6
1660	21.3	18.5	12.9	8600	11.6	0.4	0.8
1715	21.2	18.7	13.4	8705	11.3	0.3	1.0
1765	20.9	18.5	13.2	8810	11.4	0.5	1.1
1815	20.7	18.1	12.8	8910	11.4	0.8	1.5
1870	20.6	18.2	13.0	9015	11.1	0.8	1.5
1920	20.6	17.6	12.3	9115	11.2	0.5	1.2
1975	20.5	17.8	12.6	9220	10.9	0.2	1.2
2025	20.2	18.4	13.6	9325	10.6	0.2	1.3
2075	20.0	18.1	12.9				

TABLE 27

San Juan, 27 April 1946, 1639–1712 hrs.; Cumulus clouds base 2000 ft., top 7000 ft. Sounding made in cloud. Surface wind 080° 15 mph., T_d 25.2°C, T_w 21.2°C, W 14.1 g/kg, T_{sea} 25.7°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.8	22.6	15.8	1975*	—	20.4	16.3
105	25.5	22.3	15.5	2280*	—	19.9	15.7
155	25.4	22.3	15.3	2280	20.4	18.0	12.3
210	25.2	22.1	15.4	2640*	—	19.0	15.2
260	25.1	21.7	14.7	2640	19.1	17.3	12.6
310	25.1	22.0	15.3	2700	18.3	16.7	12.3
415	24.7	21.2	14.3	2800*	—	19.3	15.5
520	24.5	22.1	15.9	3060*	—	18.4	14.9
625	24.3	21.9	15.9	3275	17.3	16.2	12.3
725	24.0	21.7	15.6	3740*	—	18.1	14.9
830	23.7	21.5	15.6	3740	17.0	15.4	11.6
935	23.5	20.1	13.7	4310*	—	16.7	13.8
1040	23.2	20.5	14.5	4260	15.4	14.0	10.9
1145	23.0	20.6	14.7	4775*	—	15.6	13.1
1250	22.9	21.2	15.7	4775	15.2	9.9	6.5
1350	22.5	20.9	15.5	5350*	—	14.7	11.3
1455	22.1	20.4	15.0	5360	14.0	9.9	7.5
1555	21.9	20.5	15.3	5820*	—	12.6	11.2
1660	21.6	19.8	14.6	5820	13.5	12.2	10.2
1765	21.2	19.3	14.0	6440*	—	11.2	10.4
1870	21.1	19.2	13.9	6490	12.2	9.8	8.4

TABLE 28

San Juan, 27 April 1946, 1728–1753 hrs.; Cumulus base 2300 ft., top 2700 ft. Sounding made in clear. Surface wind 080° 15 mph., T_d 25.2°C, T_w 21.7°C, W 14.8 g/kg, T_{sea} 25.7°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.8	21.9	14.8	1560	21.7	19.8	14.4
105	25.8	21.8	14.8	1660	21.4	19.9	14.6
155	25.6	21.7	14.6	1765	21.4	19.5	14.2
210	25.4	21.4	14.4	1870	21.1	19.5	14.3
260	25.4	21.3	14.3	1920	20.8	19.5	14.6
310	25.2	21.3	14.3	2080	20.6	19.0	14.0
365	24.9	21.2	14.3	2130	20.1	19.2	14.6
415	24.8	21.2	14.3	2285	20.0	18.7	14.0
470	24.5	21.1	14.4	2335	19.8	18.5	13.9
520	24.5	21.0	14.3	2490	19.6	18.4	13.9
570	24.3	21.0	14.3	2595	19.4	17.9	13.4
625	24.2	20.9	14.3	2700	19.6	16.2	10.9
675	24.2	20.7	14.1	2805	19.3	15.9	10.9
725	24.0	20.6	14.1	2910	19.3	15.5	10.4
780	23.8	20.6	14.1	3010	18.9	15.4	10.4
830	23.6	20.6	14.2	3110	18.7	14.1	9.1
885	23.5	20.6	14.3	3685	18.4	11.8	6.8
935	23.5	20.5	14.1	4100	17.5	10.9	6.4
985	23.3	20.5	14.3	4670	16.3	10.5	6.8
1040	23.1	20.3	14.1	5190	15.8	9.6	6.4
1145	22.8	20.3	14.4	5720	14.2	9.3	6.8
1250	22.7	20.2	14.1	6180	13.8	8.9	6.8
1350	22.4	20.3	14.5	6800	12.3	8.8	7.6
1455	22.1	20.1	14.6				

TABLE 29

San Juan, 28 April 1946, 0635–0705 hrs.; 2/10 cumulus base 2000 ft., top 8000 ft. Sounding made in cloud. Surface wind 140° 15 mph., T_d 25.1°C, T_w 21.7°C, W 14.8 g/kg, T_{sea} 25.5°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.8	22.2	15.3	1975	20.3	19.7	14.9
105	24.5	21.6	14.6	2075*	—	20.2	16.0
210	25.1	21.9	15.2	2180	19.8	19.3	14.9
310	24.8	21.4	14.7	2230*	—	19.9	15.9
415	24.5	21.3	14.8	3060	17.6	17.3	13.6
520	24.3	21.2	14.7	3115*	—	19.0	15.4
625	23.7	21.3	14.8	3580*	—	17.2	13.9
725	23.7	21.4	15.4	3550	17.0	15.0	11.2
830	23.5	21.7	16.0	4150*	—	16.6	13.8
935	23.0	21.1	15.2	4150	15.8	14.9	11.9
1040	22.7	21.2	15.7	4565*	—	15.5	13.0
1145	22.2	20.9	15.5	4565	15.4	12.9	9.8
1245	22.3	20.6	15.4	4855	14.4	12.2	9.5
1350	22.0	20.3	15.0	5155*	—	14.0	12.2
1455	21.6	20.1	14.8	5705*	—	13.6	11.9
1555	21.4	19.8	14.6	5705	13.2	11.6	9.8
1660	21.3	20.5	15.7	6225*	—	13.5	12.0
1765	21.0	20.5	15.9	6225	12.3	10.5	9.1
1870	20.7	20.3	15.8				

TABLE 30

San Juan, 28 April 1946, 0725–0747 hrs.; 2/10 cumulus base 2000 ft., top 2500 ft. Sounding made in clear. Surface wind 140° 15 mph., T_d 25.1°C, T_w 21.7°C, W 14.8 g/kg, T_{sea} 25.5°C.

Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg	Altitude Feet	Temperature Dry Bulb °C	Temperature Wet Bulb °C	Mixing Ratio g/kg
50	25.8	22.1	15.1	2180	19.6	18.7	14.1
105	25.3	22.0	15.2	2285	19.6	17.7	12.8
155	25.3	22.0	15.2	2390	19.6	17.9	12.0
210	25.0	21.8	15.1	2490	19.4	16.4	11.4
260	25.0	21.8	15.0	2595	19.1	15.9	10.9
310	24.8	21.7	15.0	2700	18.8	16.6	11.5
365	24.6	21.7	15.1	2805	18.9	16.1	11.4
415	24.5	21.4	15.0	2905	18.7	15.7	11.0
470	24.4	21.3	14.8	3010	18.4	15.7	11.2
520	24.4	21.2	14.6	3115	18.1	16.1	11.9
570	24.2	21.2	14.7	3685	17.1	14.2	10.3
625	24.1	20.9	14.5	4150	16.4	13.6	10.2
725	23.6	20.9	14.7	4670	15.7	12.9	9.9
780	23.5	21.1	15.0	5165	14.5	12.0	9.4
830	23.4	20.6	14.5	5705	13.4	11.0	9.1
885	23.2	20.6	14.5	6215	11.9	9.9	8.6
935	23.1	20.6	14.7	6740	10.9	9.0	8.2
985	23.0	20.5	14.5	7155	11.3	—	—
1040	23.0	20.6	14.7	7260	11.3	—	—
1090	22.8	20.6	14.9	7360	11.5	—	—
1145	22.6	20.6	15.2	7465	11.5	—	—
1245	22.4	20.6	15.2	7570	11.3	—	—
1350	21.9	20.6	15.4	7670	11.1	—	—
1455	21.7	20.6	15.5	7775	11.1	—	—
1555	21.4	20.1	15.0	7880	11.2	—	—
1660	21.2	19.9	15.0	7980	11.7	—	—
1765	20.7	19.7	14.9	8095	12.1	—	—
1870	20.7	19.3	14.4	8190	12.1	—	—
1975	20.3	19.0	14.1	8290	12.1	—	—
2075	20.0	18.5	13.7	8500	11.8	—	—

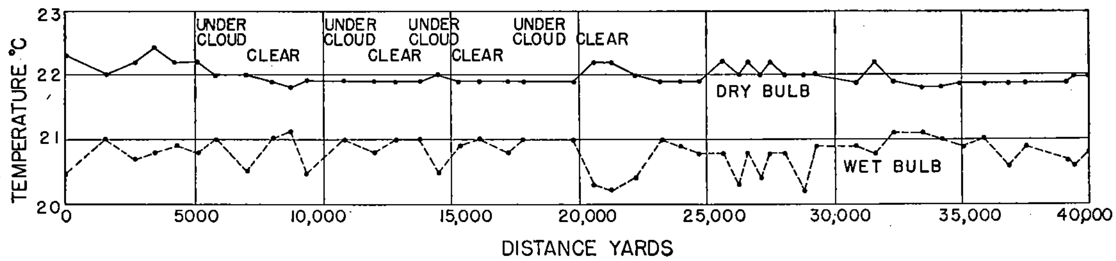

FIG. 4. Coco Solo, 1 April 1946, 1224–1235 hrs.; Altitude 1200 ft., Course 152°; 1/10 cumulus.

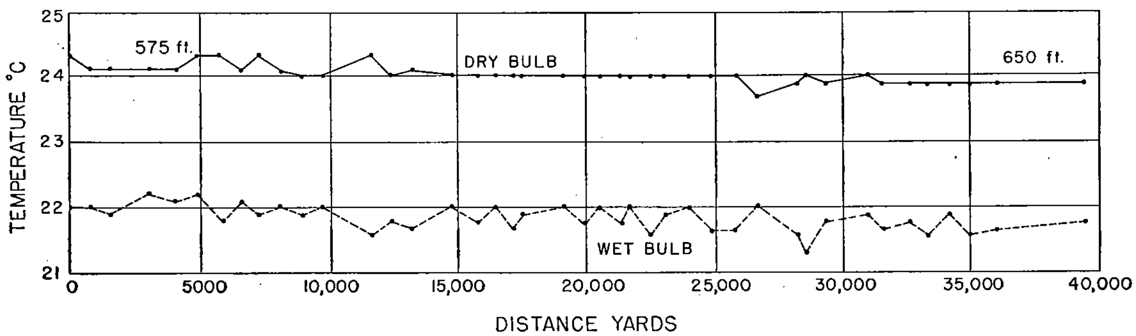

FIG. 5. Coco Solo, 1 April 1946, 1240–1252 hrs.; Altitude 575 ft., Course 342°; Clear.

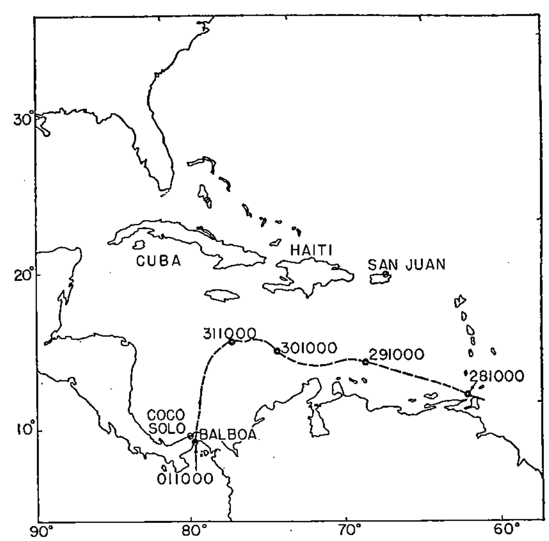

FIG. 6. Trajectory of air arriving at Coco Solo, 1 April 1946, 1000 hrs.

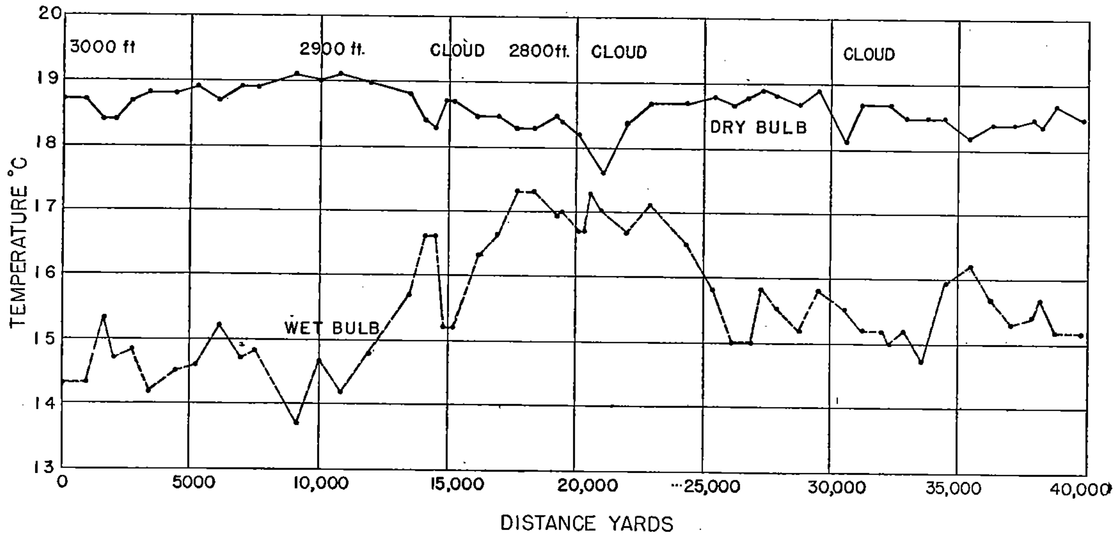

FIG. 7. Coco Solo, 2 April 1946, 1230–1242 hrs.; Altitude 2800–3000 ft., Course 010°; 2900 ft., wind 130° 9 mph.; 2/10 cumulus.

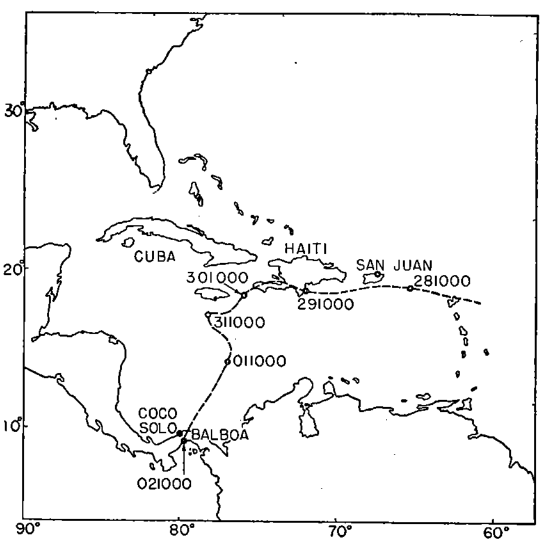

FIG. 8. Trajectory of air arriving at Coco Solo, 2 April 1946, 1000 hrs.

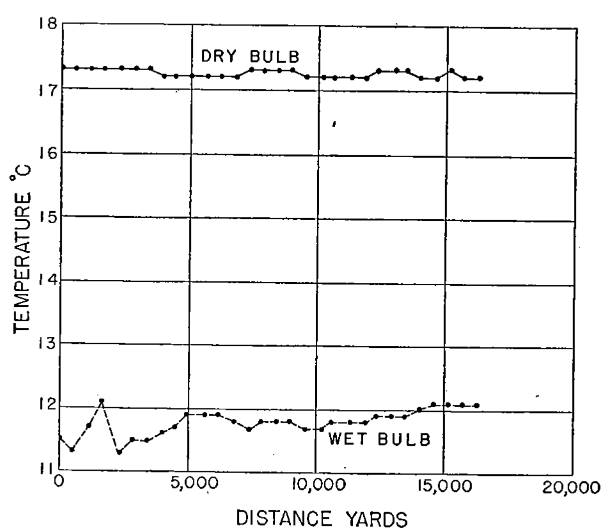

FIG. 9. Coco Solo, 3 April 1946, 1136–1141 hrs.; Altitude 4480 ft., Course 210°; Clear, Surface wind 030° 15 mph.

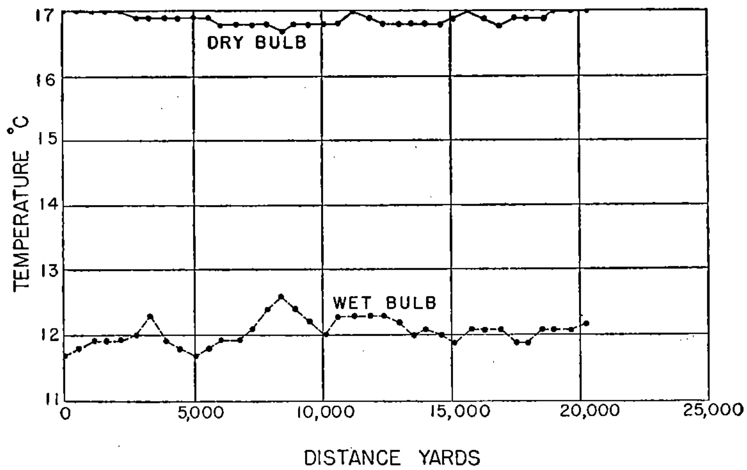

FIG. 10. Coco Solo, 3 April 1946, 1151–1157 hrs.; Altitude 4460 ft., Course 114°; Clear, Surface wind 030° 15 mph.

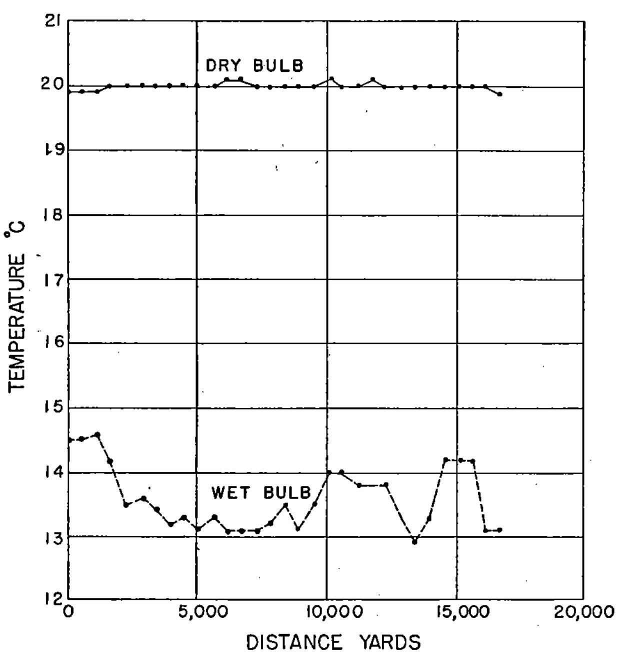

FIG. 11. Coco Solo, 3 April 1946, 1202–1207 hrs.; Altitude 3200 ft.; Course 290°; Clear, Surface winds 030° 15 mph.

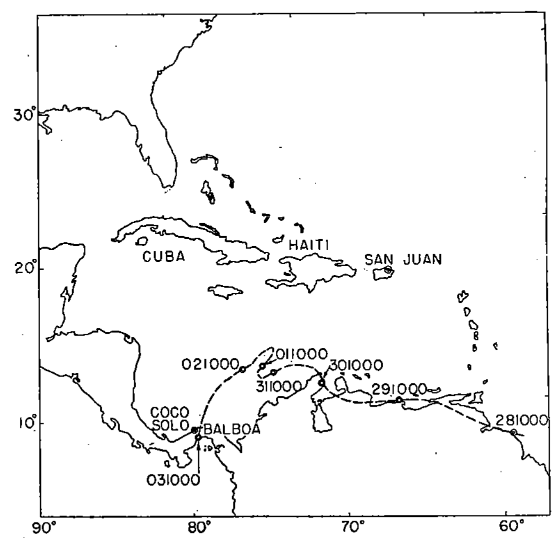

FIG. 12. Trajectory of air arriving at Coco Solo, 3 April 1946, 1000 hrs.

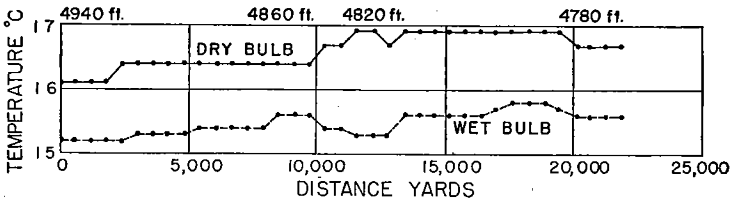

FIG. 13. Coco Solo, 4 April 1946, 1216–1223 hrs.; Altitude 4800–5000 ft., Course 093°; 6–8/10 cumulus; Surface wind 040° 16 mph.

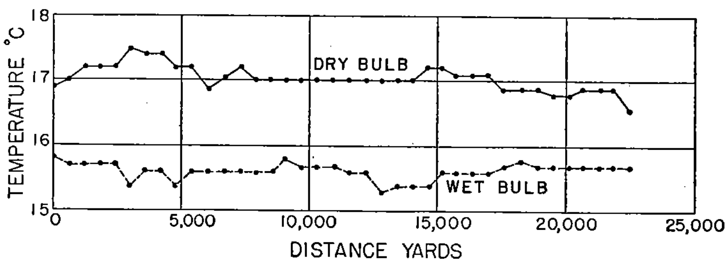

FIG. 14. Coco Solo, 4 April 1946, 1224–1231 hrs.; Altitude 4740 ft., Course 004°; 6–8/10 cumulus; Surface wind 040° 16 mph.

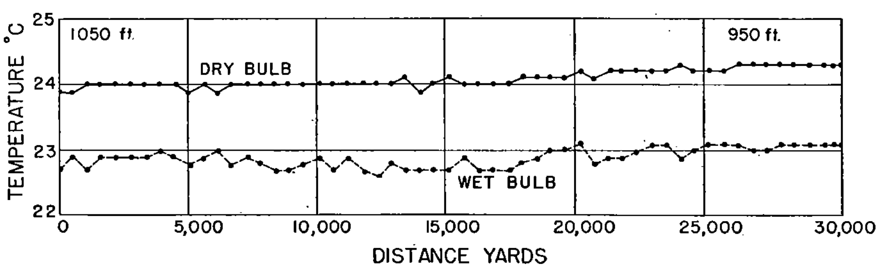

FIG. 15. Coco Solo, 4 April 1946, 1246–1251 hrs.; Altitude 1050 ft., Course 097°; 6–8/10 cumulus; Surface wind 040° 16 mph.

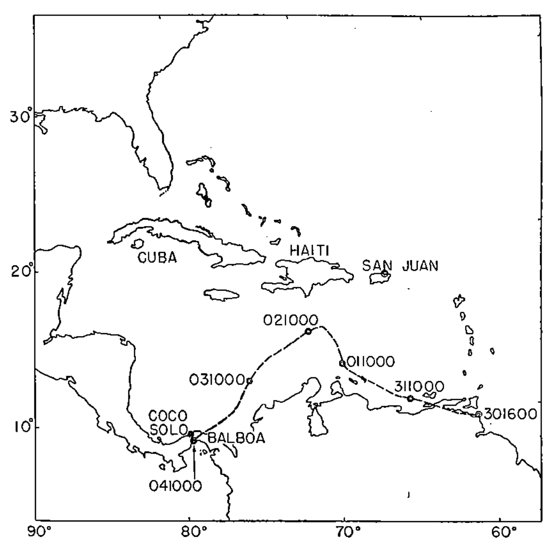

FIG. 16. Trajectory for air arriving at Coco Solo, 4 April 1946, 1000 hrs.

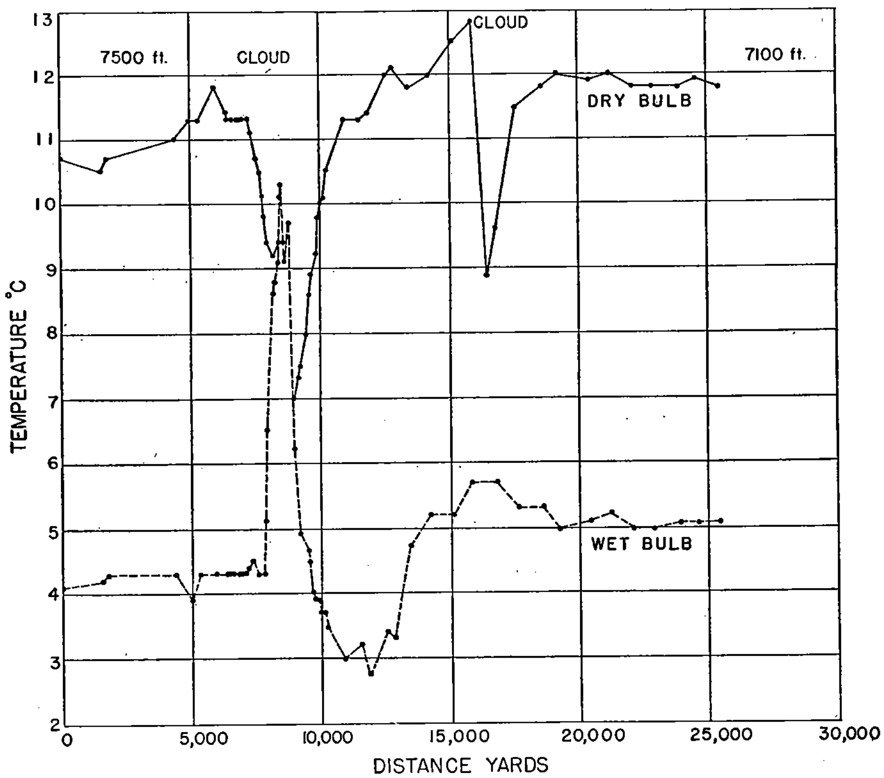

Fig. 17. San Juan, 10 April 1946, 1430–1438 hrs.; Altitude 7500 ft., Course 140°; 1/10 cumulus, 7000 ft. wind 100° 25 mph.

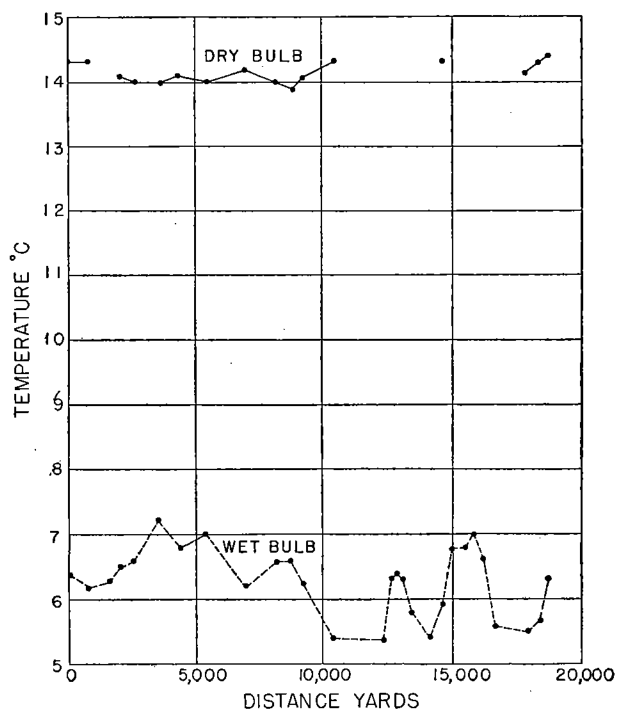

Fig. 18. San Juan, 10 April 1946, 1444–1450 hrs.; Altitude 5400 ft., Course 140°; 1/10 cumulus, 5000 ft. wind 110° 16 mph.

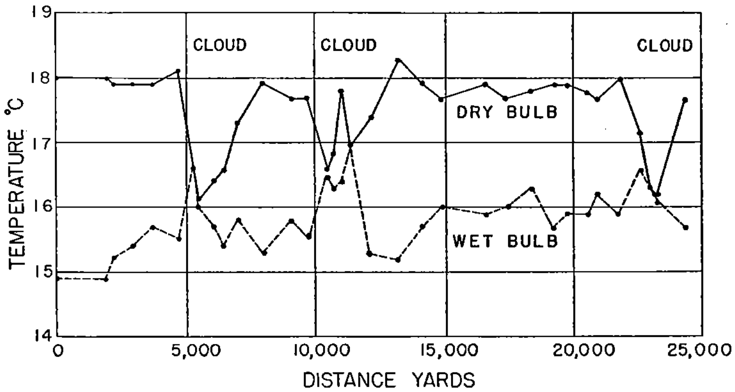

FIG. 19. San Juan, 10 April 1946, 1456–1502 hrs.; Altitude 3100 ft., Course 140°; 1/10 cumulus, 3000 ft. wind 110° 20 mph.

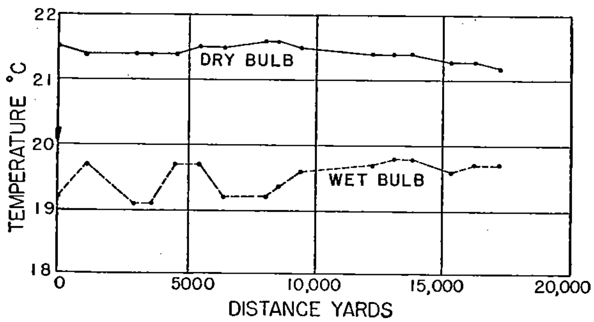

FIG. 20. San Juan, 10 April 1946, 1509–1514 hrs.; Altitude 1800 ft., Course 328°; 1/10 cumulus, 2000 ft. wind 090° 21 mph.

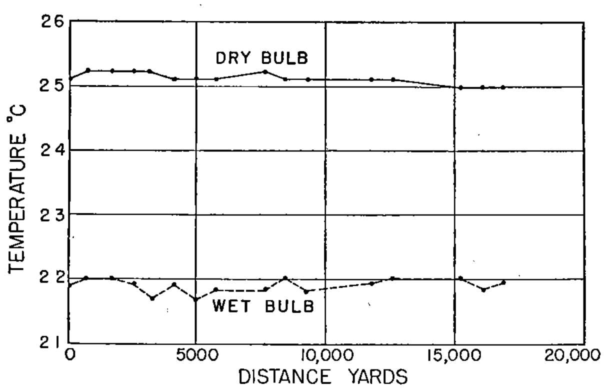

FIG. 21. San Juan, 10 April 1946, 1520–1525 hrs.; Altitude 170 ft., Course 328°; 1/10 cumulus, Surface wind 110° 18 mph.

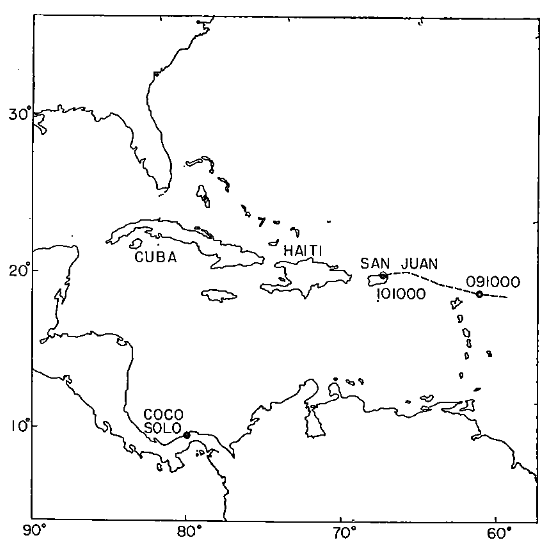

FIG. 22. Trajectory of air arriving at San Juan, 10 April 1946, 1000 hrs.

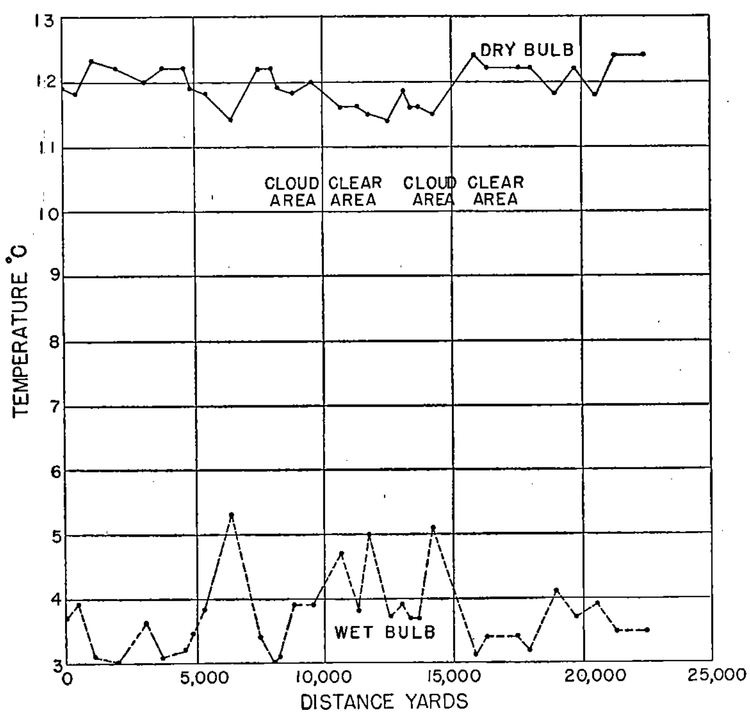

FIG. 23. San Juan, 12 April 1946, 1409–1416 hrs.; Altitude 6800 ft., Course 033°; 2/10 cumulus; 7000 ft. winds 120° 25 mph.

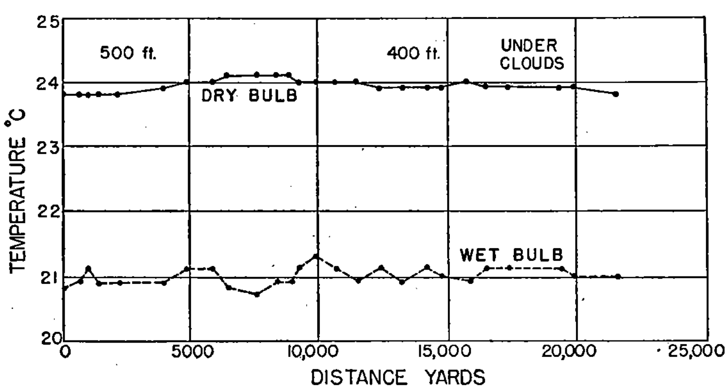

FIG. 24. San Juan, 12 April 1946, 1455–1501 hrs.; Altitude 500 ft., Course 100°; 2/10 cumulus, 1000 ft. winds 100° 16 mph.

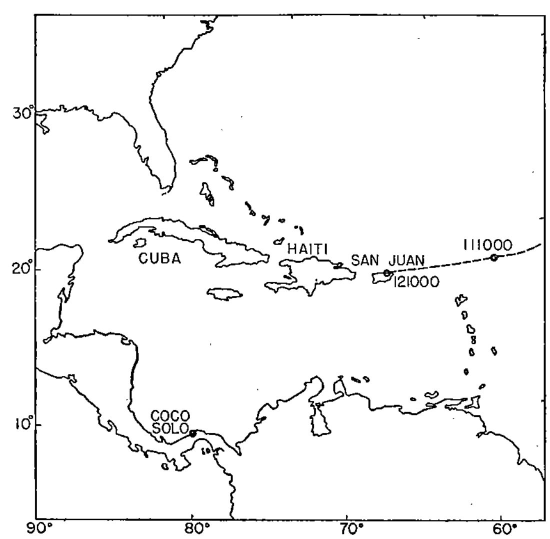

FIG. 25. Trajectory of air arriving at San Juan, 12 April 1946, 1000 hrs.

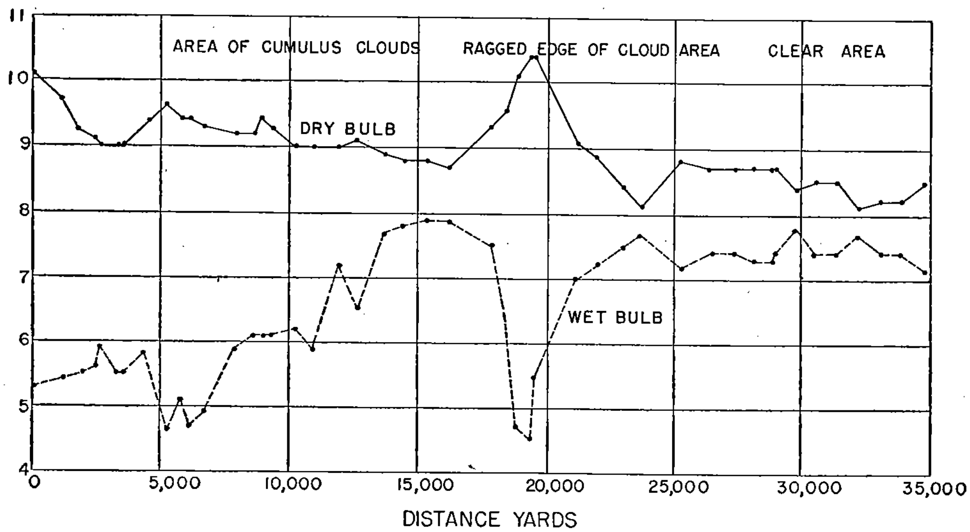

FIG. 26. San Juan, 13 April 1946, 1309–1318 hrs.; Altitude 7250 ft., Course 017°; 1–3/10 cumulus, tops not reaching flight level; 7000 ft. winds 120° 20 mph.

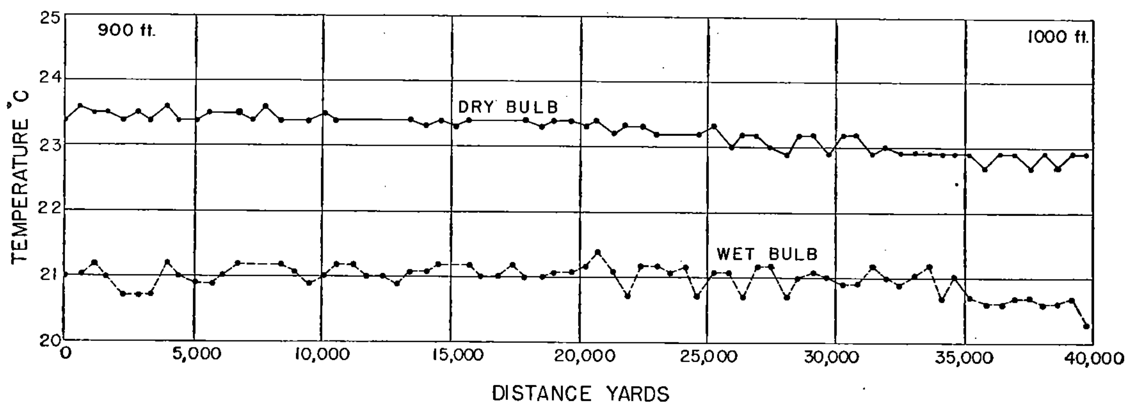

FIG. 27. San Juan, 13 April 1946, 2338–2350 hrs.; Altitude 950 ft., Course 011°; 2–4/10 cumulus base 2100 ft., 1000 ft. winds 080° 29 mph.

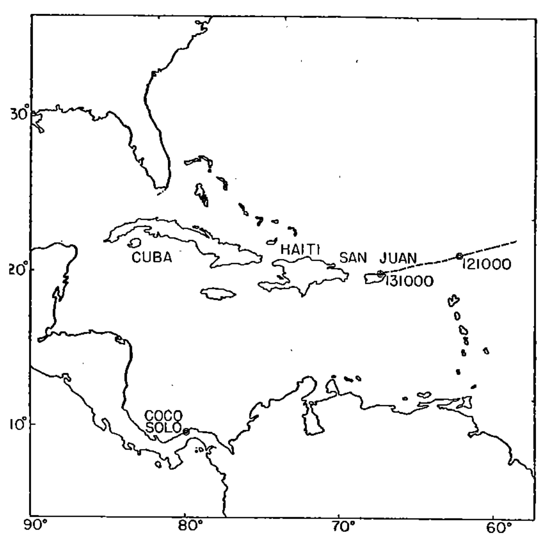

FIG. 28. Trajectory of air arriving at San Juan, 13 April 1946, 1000 hrs.

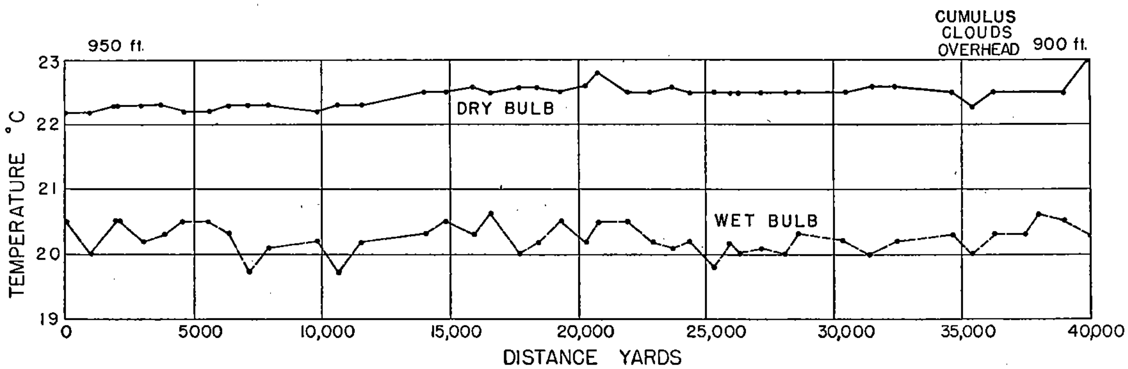

FIG. 29. San Juan, 14 April 1946, 0530–0541 hrs.; Altitude 950 ft., Course 010°; 2/10 cumulus, base 1900 ft.; 1000 ft. winds 090° 15 mph.

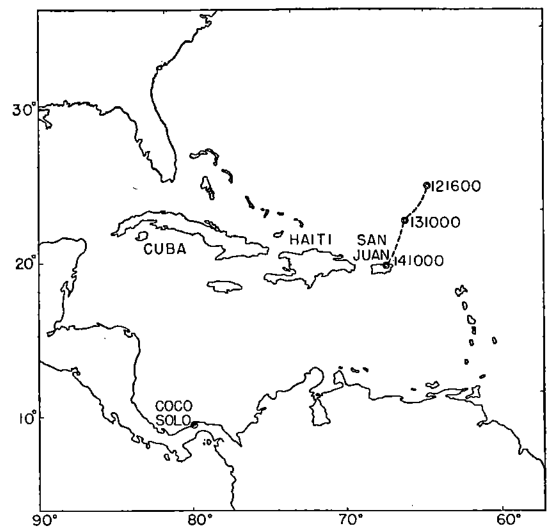

FIG. 30. Trajectory of air arriving at San Juan, 14 April 1946, 1000 hrs.

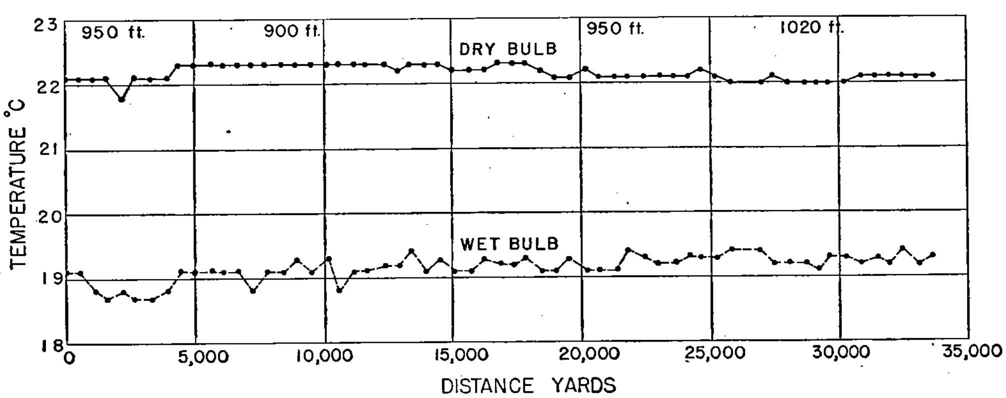

FIG. 31. San Juan, 17 April 1946, 1457–1507 hrs.; Altitude 900–1020 ft., Course 045°; 2/10 cumulus, 1000 ft. winds 090° 27 mph.

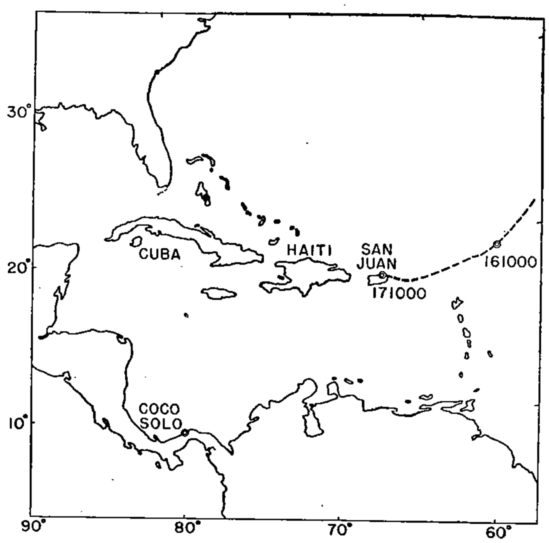

FIG. 32. Trajectory of air arriving at San Juan, 17 April 1946, 1000 hrs.

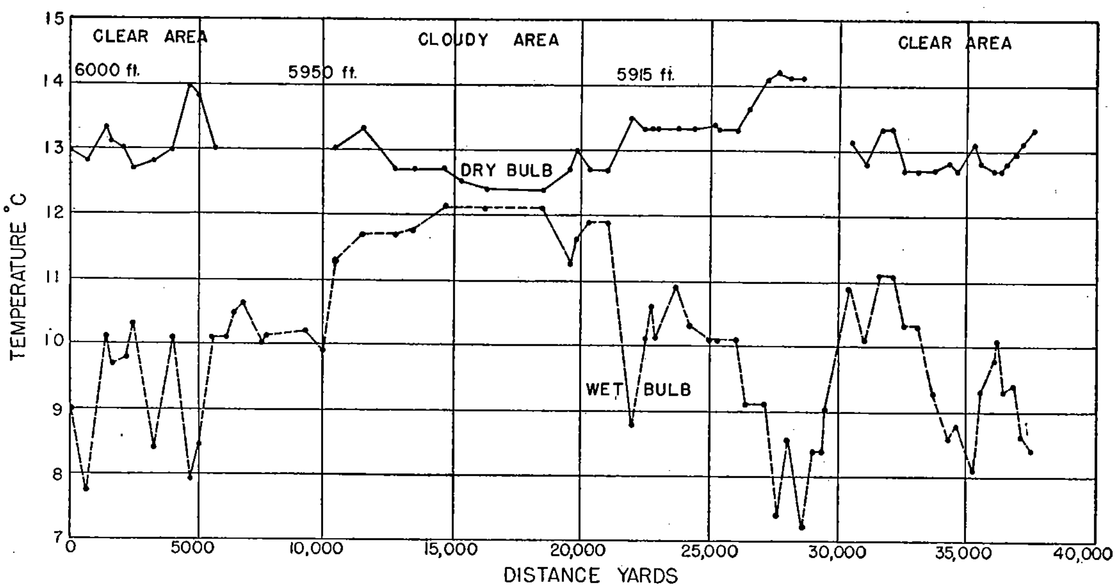

FIG. 33. San Juan, 22 April 1946, 1814–1825 hrs.; Altitude 6000 ft., Course 055°; 4–6/10 cumulus, 6000 ft. winds 040° 10 mph.

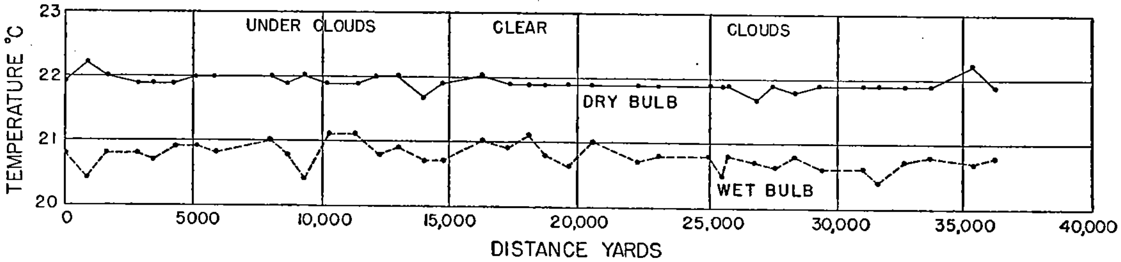

FIG. 34. San Juan, 22 April 1946, 1925–1936 hrs.; Altitude 1000 ft., Course 310°; 4–6/10 cumulus, 1000 ft. winds 030° 12 mph.

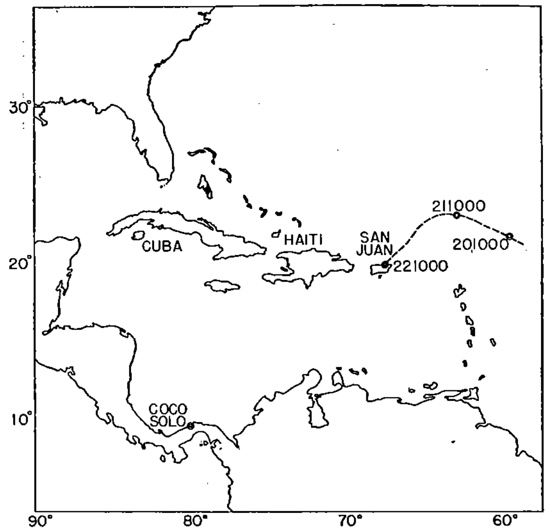

FIG. 35. Trajectory of air arriving at San Juan, 22 April 1946, 1000 hrs.

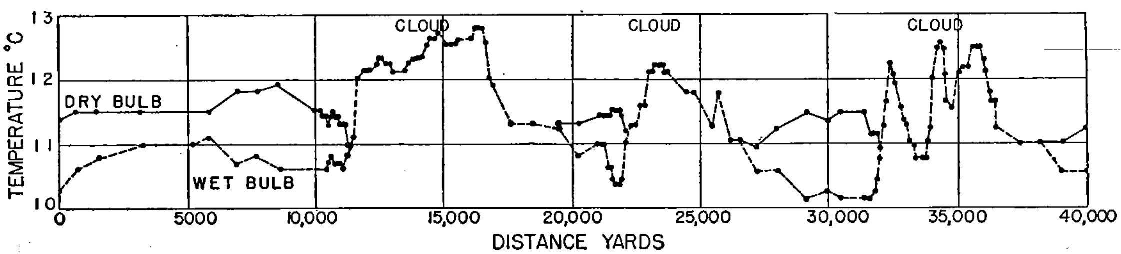

FIG. 36. San Juan, 23 April 1946, 0613–0625 hrs.; Altitude 6270 ft.; Course 055°; 7–9/10 cumulonimbus; 6000 ft. wind 050° 15 mph.

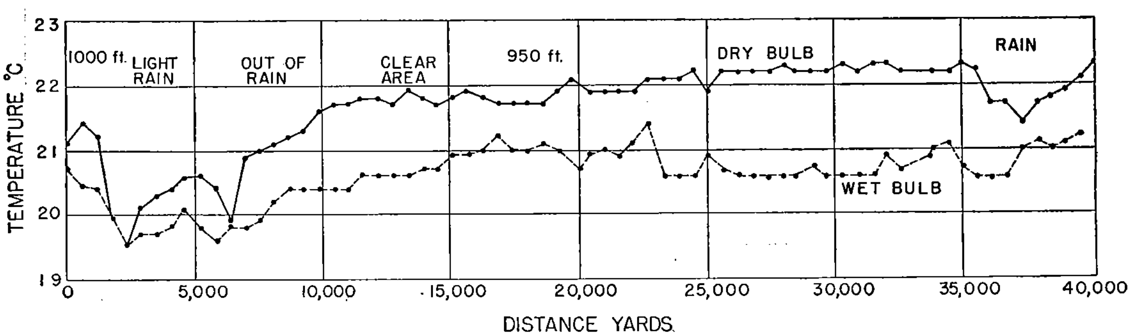

FIG. 37. San Juan, 23 April 1946, 0744–0756 hrs.; Altitude 1000 ft.; Course 18°; 7–9/10 cumulonimbus; 1000 ft. wind 040° 17 mph.

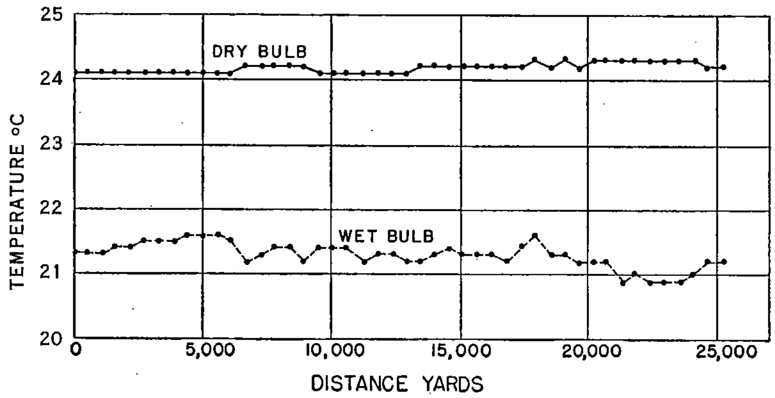

FIG. 38. San Juan, 23 April 1946, 1341–1348 hrs.; Altitude 500 ft., Course 105°; 1000 ft. wind 070° 13 mph.

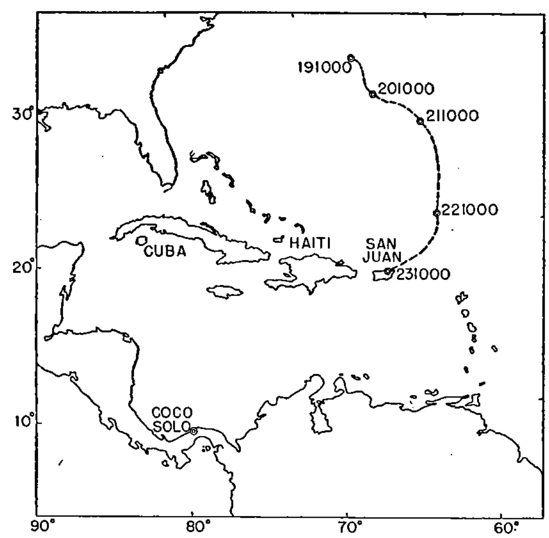

FIG. 39. Trajectory of air arriving at San Juan, 23 April 1946, 1000 hrs.

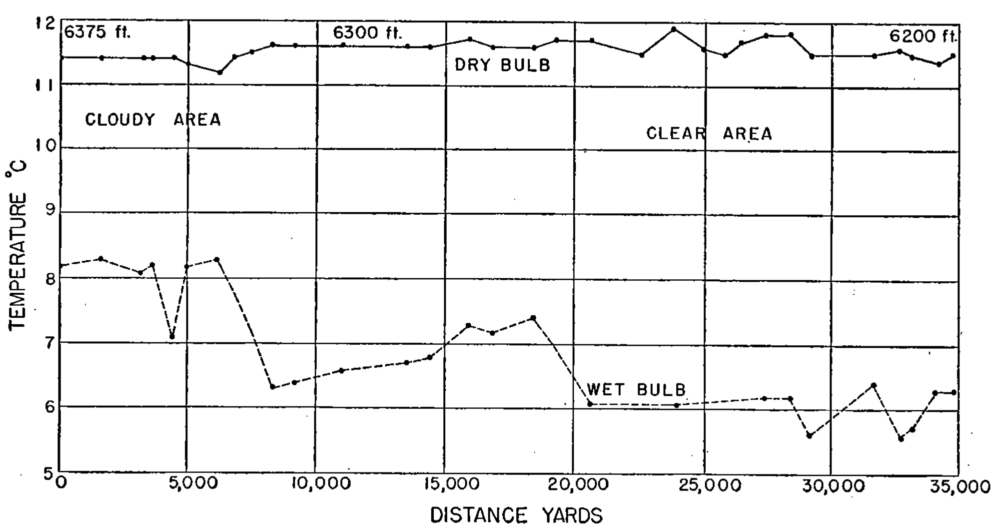

FIG. 40. San Juan, 25 April 1946, 1552–1602 hrs.; Altitude 6375 ft.; Course 050°; 6000 ft. wind 045° 20 mph.

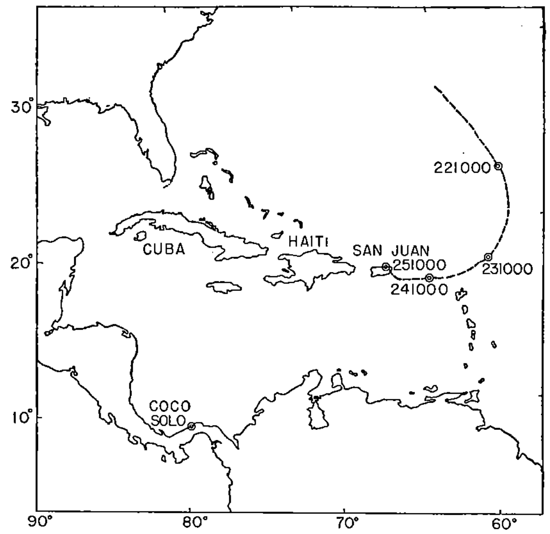

Fig. 41. Trajectory of air arriving at San Juan, 25 April 1946, 1000 hrs.

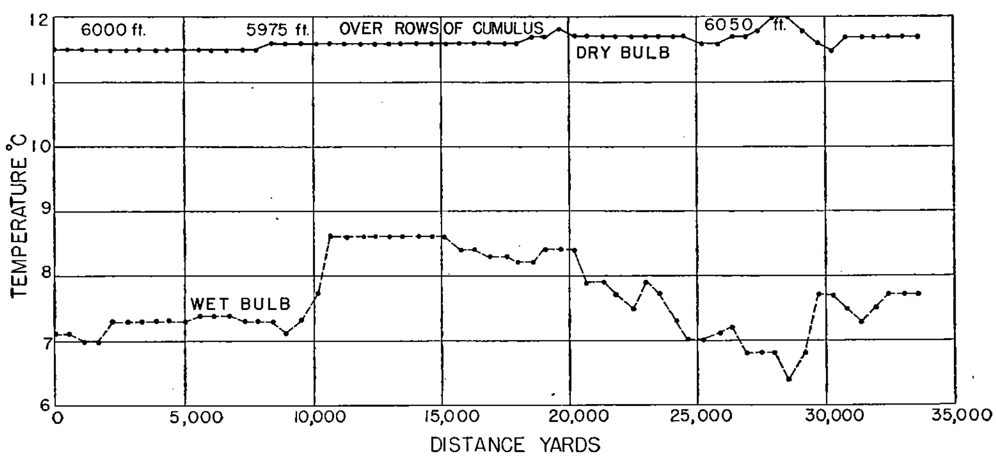

Fig. 42. San Juan, 26 April 1946, 1257–1308 hrs.; Altitude 6000 ft., Course 054°; 2/10 cumulus below flight level; 6000 ft. wind 130° 10 mph.

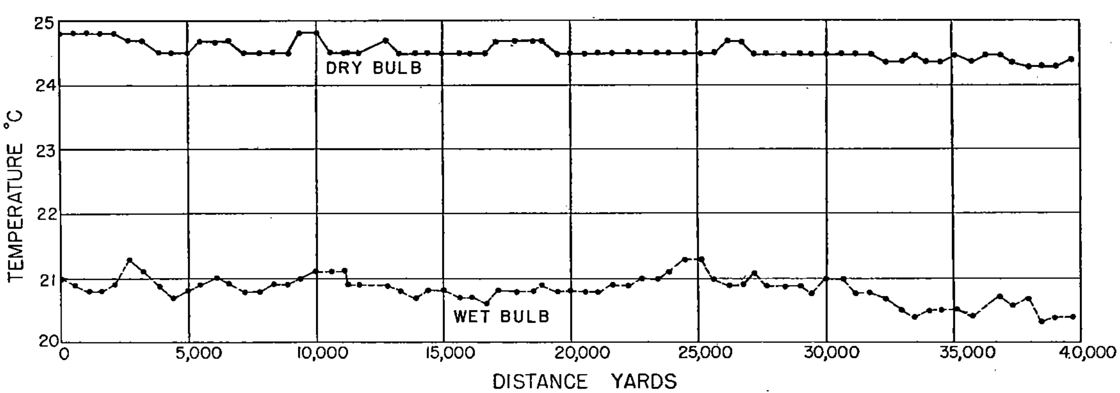

Fig. 43. San Juan, 26 April 1946, 1403–1415 hrs.; Altitude 500 ft.; Course 90°; 2/10 cumulus; 1000 ft. wind 100° 20 mph.

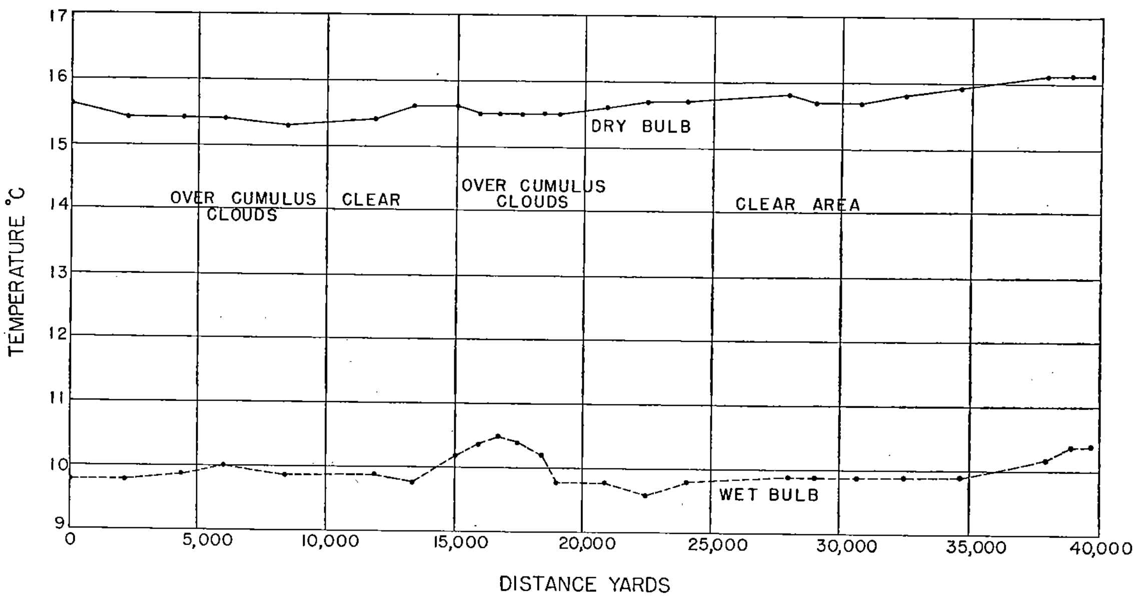

FIG. 44. San Juan, 26 April 1946, 1500–1512 hrs.; Altitude 4650 ft., Course 224°; 2/10 cumulus below flight level; 5000 ft. wind 120° 6 mph.

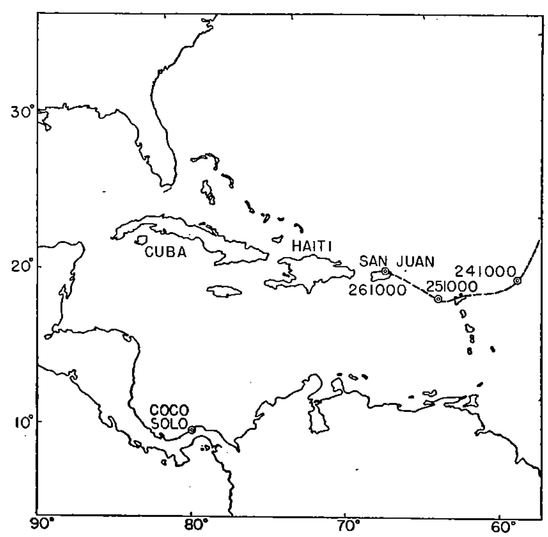

FIG. 45. Trajectory of air arriving at San Juan, 26 April 1946, 1000 hrs.

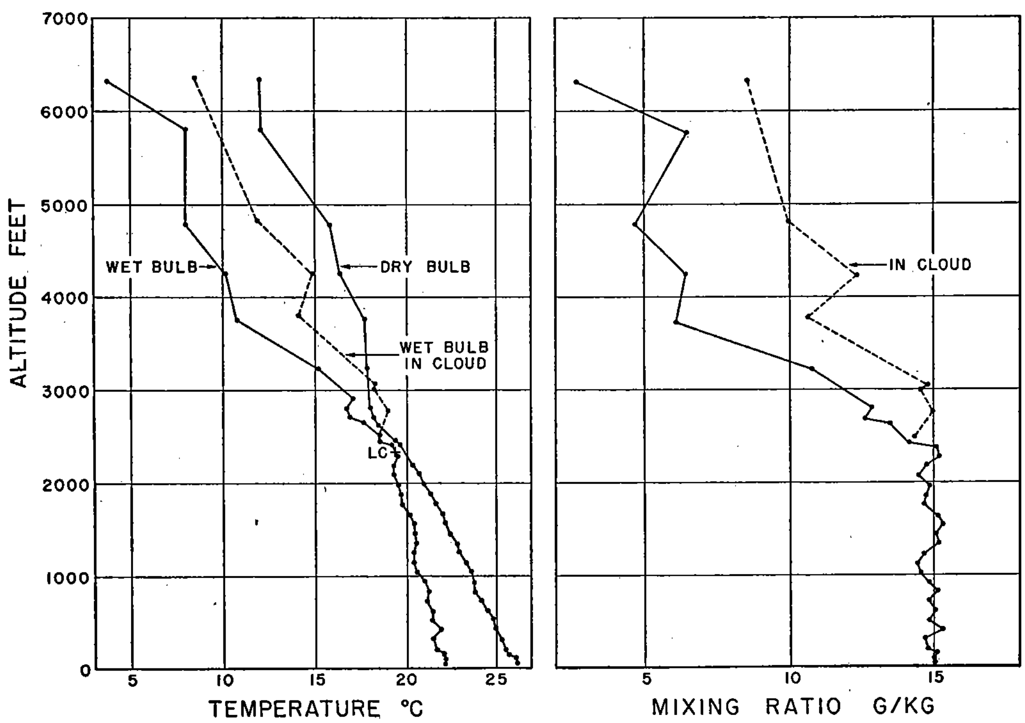

FIG. 46. San Juan, 27 April 1946, 0923–0949 hrs.; 2–3/10 cumulus base 2200 ft., top 8000 ft. Sounding made in cloud; Surface wind 120° 17 mph, T_d 25.3° C, T_W 21.2° C, w 14.0 g/kg, T_{sea} 25.4° C. Plane visible.

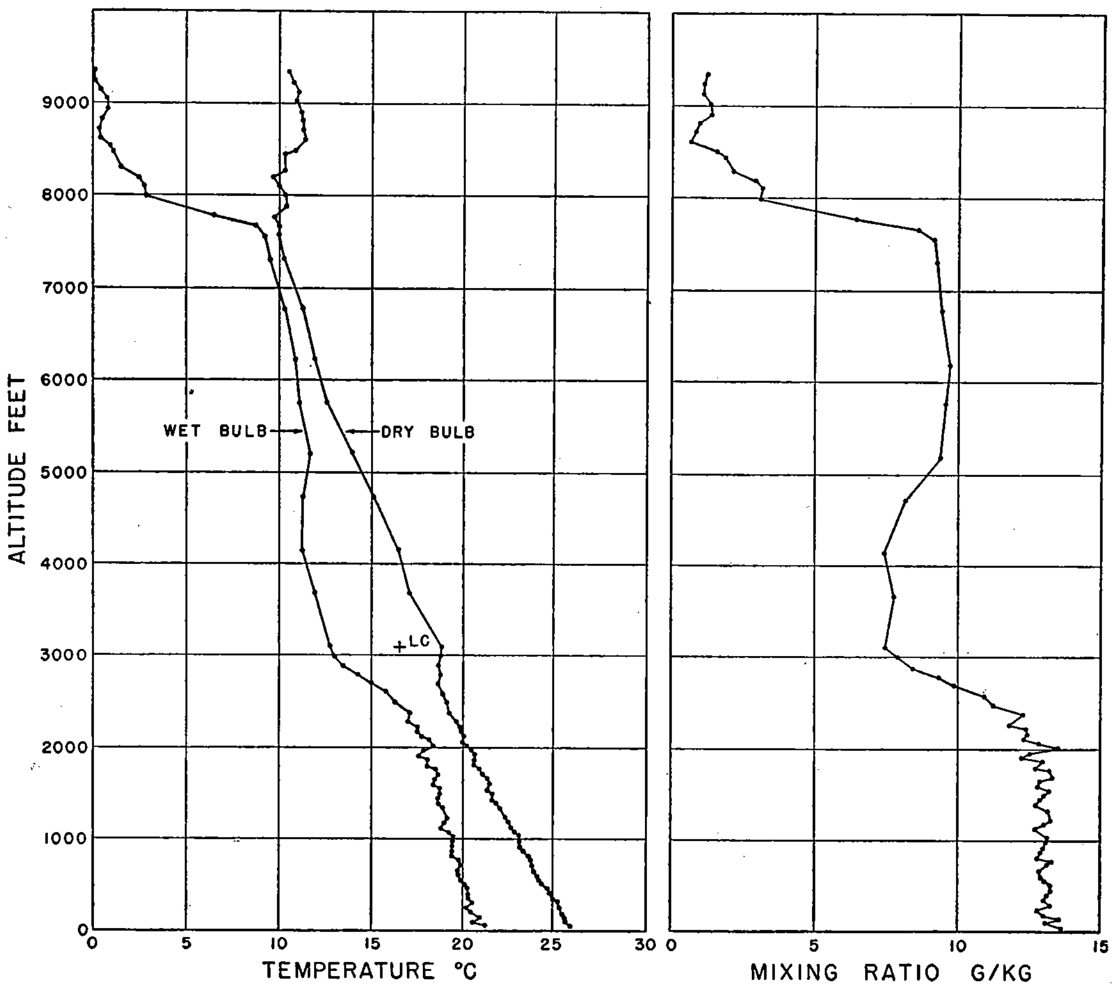

FIG. 47. San Juan, 27 April 1946, 1025–1049 hrs.; 2/10 cumulus, base 2600 ft. top 3500 ft., sounding made in clear; surface wind 120° 17 mph. T_d 25.3° C, T_w 21.2° C, w 14.0 g/kg, T_{sea} 25.4° C. Plane visible.

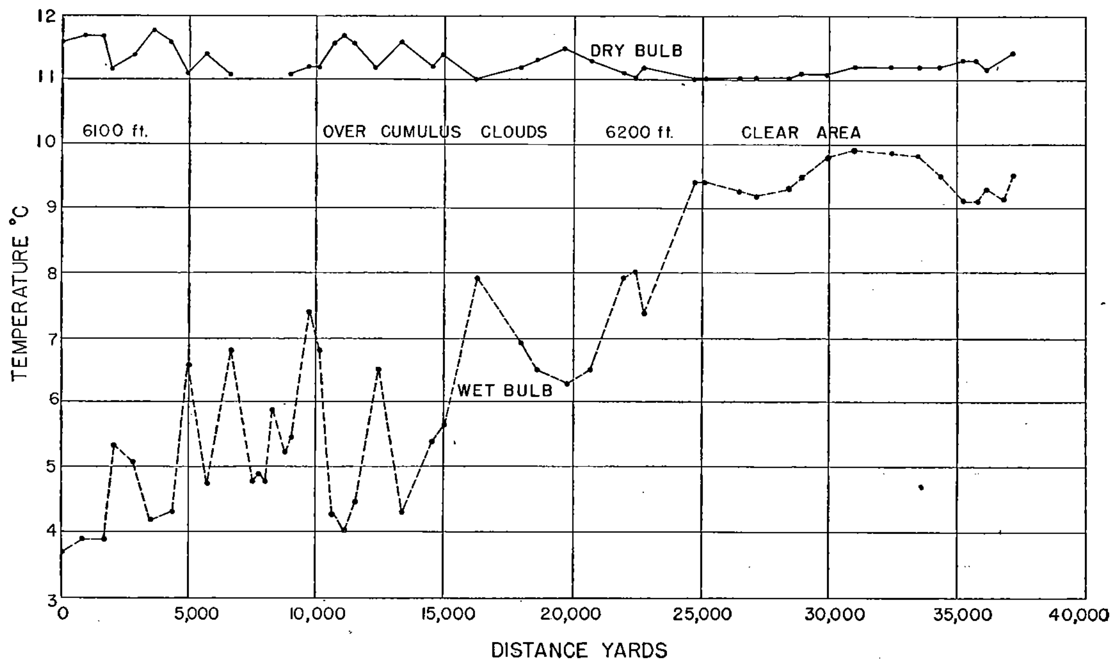

FIG. 48. San Juan, 27 April 1946, 0852–0903 hrs.; Altitude 6100 ft., Course 053°; 2/10 cumulus; 6000 ft. wind 120° 10 mph.

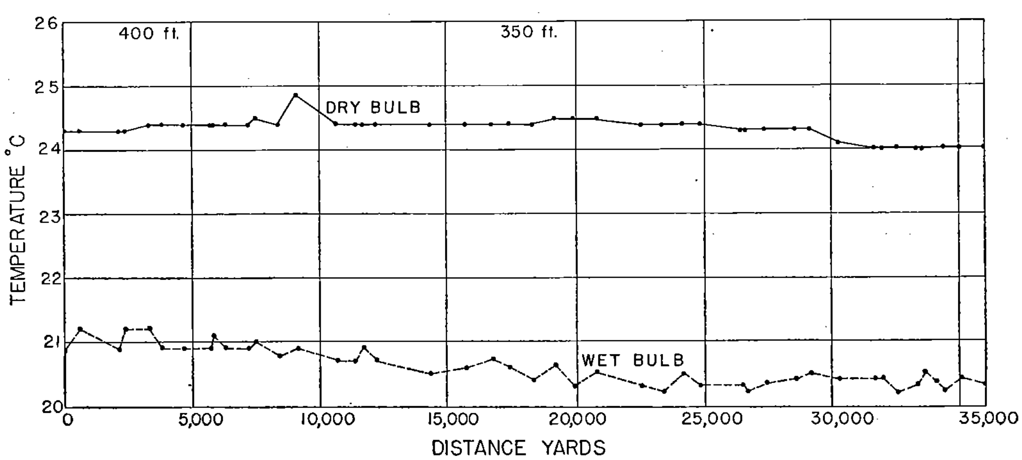

FIG. 49. San Juan, 27 April 1946, 0953–1003 hrs.; Altitude 400 ft., Course 083°; 2/10 cumulus; 1000 ft. wind 130° 6 mph.

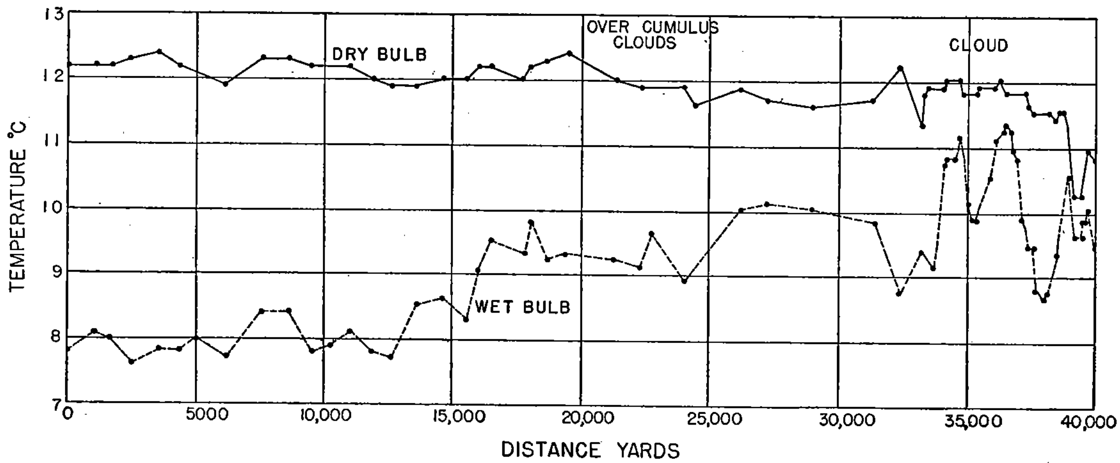

FIG. 50. San Juan, 27 April 1946, 1613–1625 hrs.., Altitude 6000 ft., Course 053°; 2/10 cumulus; 6000 ft. wind 140° 9 mph.

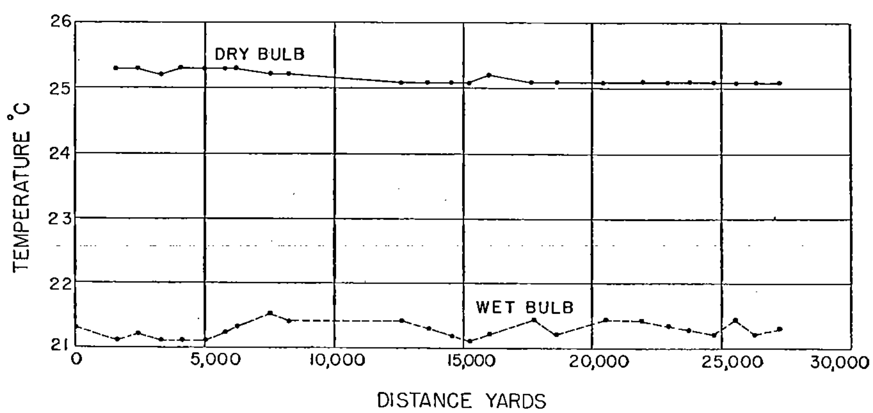

FIG. 51. San Juan, 27 April 1946, 1719–1727 hrs.; Altitude 220 ft., Course 230° 2/10 cumulus; Surface wind 080° 18 mph.

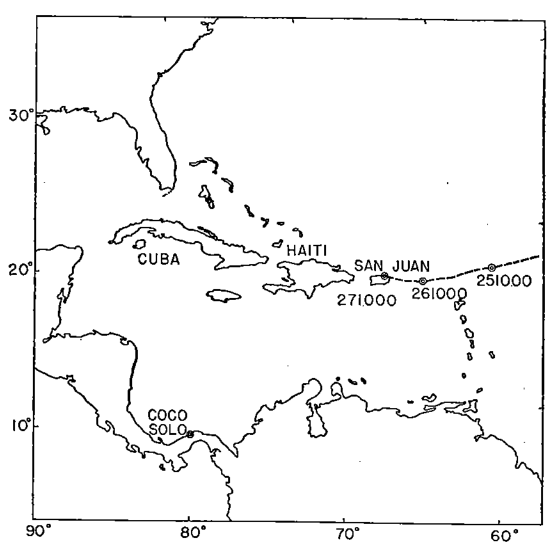

FIG. 52. Trajectory for air arriving at San Juan, 27 April 1946, 1000 hrs.

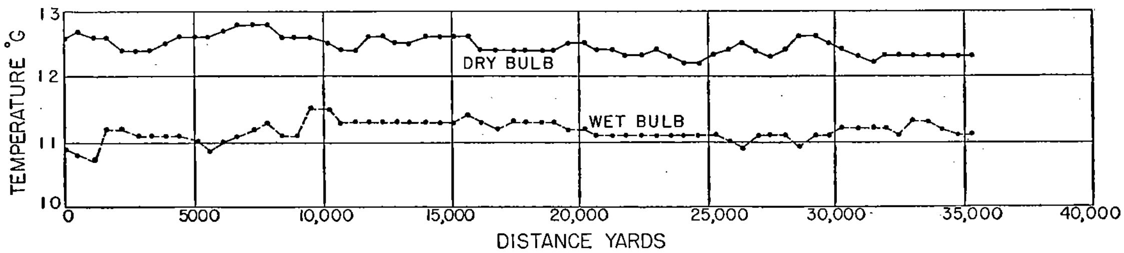

FIG. 53. San Juan, 28 April 1946, 0610–0621 hrs.; Altitude 6000 ft., Course 048°; Clear; 6000 ft. wind 070° 11 mph.

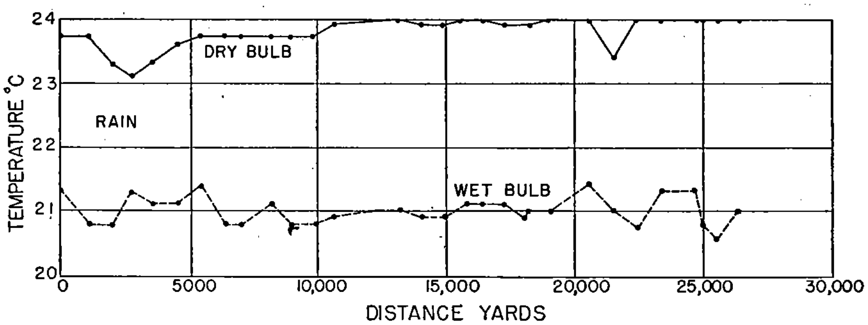

FIG. 54. San Juan, 28 April 1946, 0719–0726 hrs.; Altitude 500 ft., Course 238°; Rain from cumulonimbus; 1000 ft. wind 110° 13 mph.

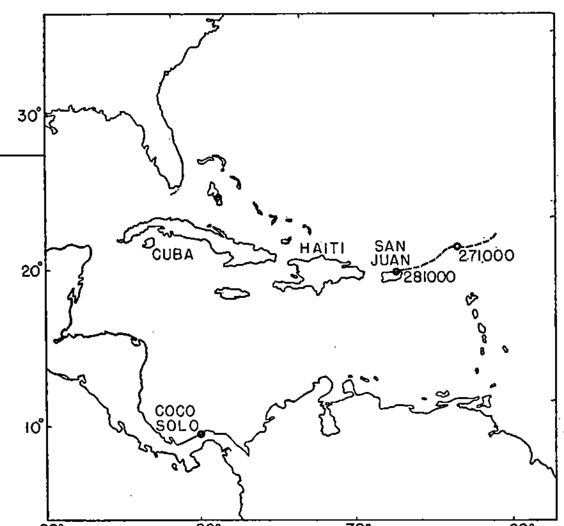

FIG. 55. Trajectory of air arriving at San Juan, 28 April 1946, 1000 hrs.

IV. CLIMATIC AND SYNOPTIC CONDITIONS OVER THE CARIBBEAN DURING THE APRIL 1946 EXPEDITION

1. Climatic Conditions

The most prominent feature of the surface synoptic maps in the subtropics are the large anticyclonic cells, three or four of which encircle the globe centered at about 30° north and south of the equator. Polewards of their centers are the variable middle-latitude westerlies, and equatorwards, the easterly trades, which cover 31% of the earth's oceanic area with a relatively stable surface wind regime.

The upper portions of the subtropical high cells are marked by subsidence, especially intense on their eastern sides, and gradually weakening toward the west. The "trade-wind" inversion so produced is one of the most important features of subtropical meteorology. In the case of the Azores-Bermuda high, the inversion is low and strong off the West African coast (base below 500 m; temperature difference greater than 5°C, according to von Ficker [1936,[1]]). The subsiding air above is dry, stable, and potentially warm. The air below, from contact with the sea, is moist, very unstable, and potentially cool. The discontinuity in east wind through the inversion is slight. As the two currents stream westward, one above the stable layer, the other below, continually acted upon by the ocean, increasing convection operates against decreasing subsidence to raise the boundary, until when the Caribbean is reached, the discontinuity is often no longer a true inversion but merely a relatively stable demarcation between air of about 70% relative humidity below, and air of about 20% relative humidity above. Its height has risen to an average of 1700 m to 2000 m.

Cumulus convection in the lower moist layer is the resulting weather pattern. Trade cumuli are found, day and night, in clusters several miles wide, alternating with broader clear areas, and occasionally bursting through the stable layer and mixing with the drier air above.

Weather disturbances in the Caribbean area are marked by changes in the thickness of the moist layer, resulting in an alteration of the regular trade cumulus convection. The associated divergence or convergence produces this modification by lowering or raising the stable layer, thus suppressing or greatly enhancing the cloudiness. The disturbances are divided into two categories: namely, those associated with deep easterlies, and those associated with the polar front. The prevailing type is determined by the depth of the easterly current. In summer, the subtropical high cell has its maximum poleward displacement and the minimum latitudinal shift in its axis with elevation. In this season, therefore, the easterly current over the Caribbean is extremely deep, reaching an average depth of 8–10 km. From time to time, wave-like perturbations move from east to west. These are the so-called "waves in the easterlies" described in detail by Riehl (1945) and others. In winter, on the other hand, the Bermuda high is found farthest equatorward, and due to a stronger latitudinal temperature gradient in the subtropics, its axis leans more strongly to the south with elevation. This means that in the Caribbean, west winds are superimposed on the easterly trades, often at as low an altitude as 3000 m. The polar front regularly invades the trade-wind region, bringing after it a modified cold high of middle latitudes. The synoptic systems are associated with the polar front, and their direction of steering is determined by the upper westerlies.

2. The Synoptic Situation

The expedition which gathered the data for this report visited the Caribbean during April 1946. Observations were made in the San Juan area (19.5° N latitude, 66° W longitude), with interruptions, from April 10 to April 28. Surface and time-section analysis clearly show that the weather regime during this period was still one characteristic of the winter season.[1] The base of the westerlies never rose above 8000 m during the entire 18 days and was more commonly found between 3600 and 4300 m. The upper westerlies were extremely intense, often reaching 80–90 mph just below the tropopause. The disturbances, with only one exception, moved in a general direction from northwest to southeast and were non-frontal in nature. Their sequence, which repeated itself several times during the period, was characterized by the approach of the polar front, preceded by an upper trough. The reflection of this high-level depression in the surface pressure and wind field constitutes the typical "polar trough" discussed by Riehl (1945). The polar trough is observed as a splitting of the surface anticyclone and a progressive, wave-like disturbance in the easterlies. It is accompanied by low-level convergence and pressure falls ahead, low-level divergence and pressure rises to the rear. The passage of a polar trough is usually followed by a later passage of a disturbance which once was the polar front itself, but can now be recognized only as an anticyclonic shear line, with strong northeasterly winds to the rear. The following polar anticyclone joins and strengthens the Bermuda high and the sequence, described by Bjerknes (1933), Riehl (1945) and others, is ready to repeat itself, with greater or smaller variations.

A typical surface weather map for the period is reproduced in Figure 56. It shows the characteristic features of a winter subtropical situation, except that the synoptic systems are weaker than those of mid-winter. A far better tool of analysis than the surface maps proved to be the time cross-section for San Juan, reproduced in Figure 57.

As far as the interpretation of data from the expedition is concerned, the most important feature of the time cross-section is the variation in height of the moist layer (the top of which is identical with the base of the stable layer remaining from the trade inversion). During the expedition, the moist layer varied in thickness between 1200 and 3600 m. Its top was most often near 2000 m. The observed weather varied accordingly, from only cumulus humilis during the times of a shallow moist layer, to cumulonimbus and showers during the period when the "inversion" was highest.

Most significant is the relation between the passing disturbances and the height reached by the cumulus clouds. The regions of convergence are clearly marked on the time-section by lifting of the convection lid, and those of divergence by lower cloud tops and diminished or suppressed cumulus activity. Their association with the wind and pressure field can be seen to correspond closely to the models of polar troughs and shear lines presented by Riehl (1945).

The most disturbed weather condition in which the expedition made observations occurred on 23 April. On this day, cumulonimbus clouds were observed by the plane (see legends on figures 36–38, tables 18–20), and showers were recorded at the San Juan

[1] According to Riehl (1945), this is not surprising, since the earliest waves in the deep easterlies commonly do not occur until the end of May.

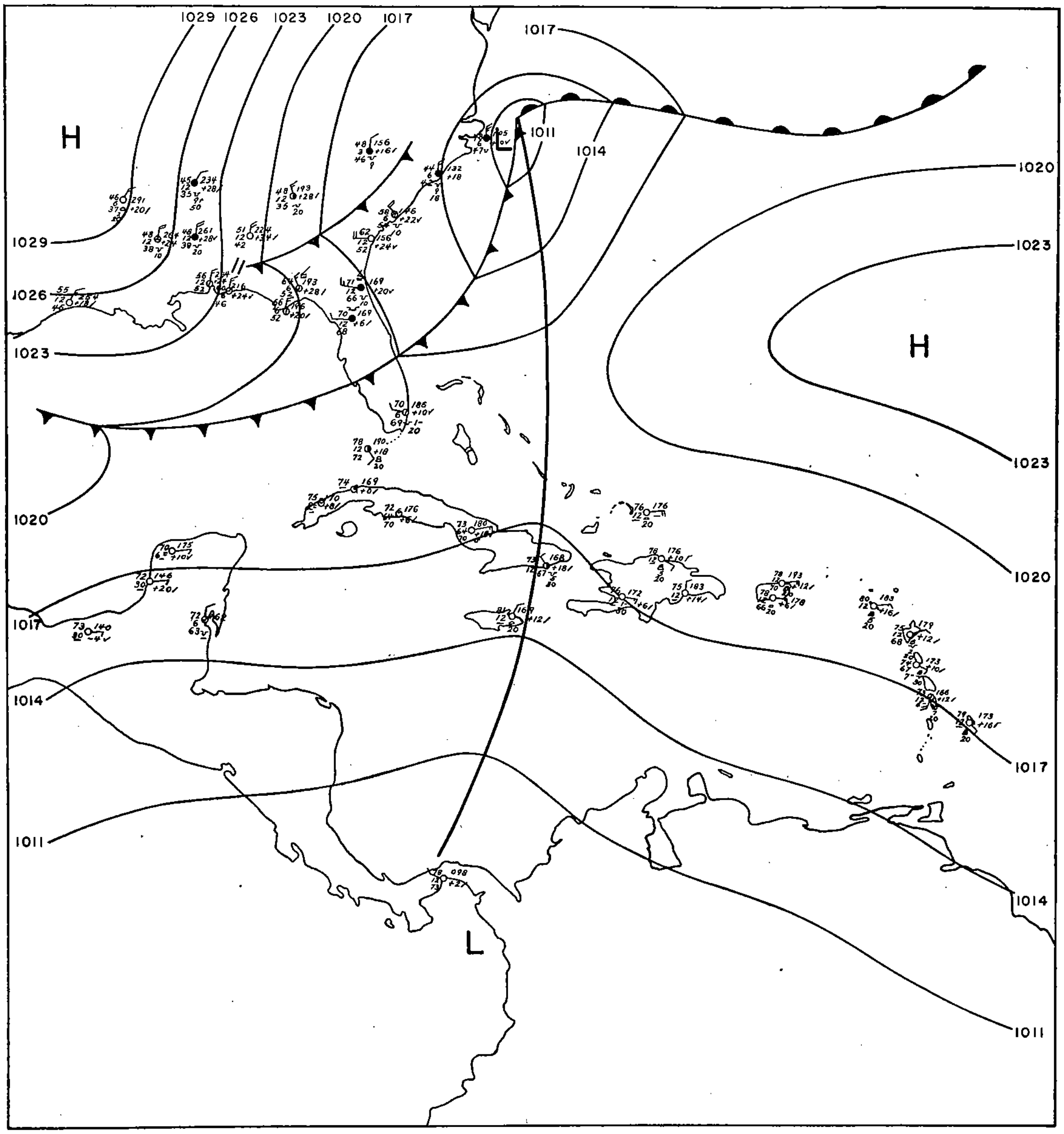

FIG. 56. Surface chart, April 12, 1946, 1230 z. The polar trough, indicated by the solid black line, is recognizable in low latitudes as an eastward-moving wave-like perturbation in the trades which passes San Juan on the early morning of April 14th (see Fig. 57). The polar front itself passes San Juan as an anticyclonic shear line on the morning of April 16th.

weather station. This active convection, accompanied by lifting of the moist layer to 2800 m, was caused by the approach of a westward-moving[1] convergence zone, resembling a summertime easterly wave in many respects, close to a weak eastward-moving

[1] This disturbance was the one exception to the general northwest steering characteristic of the period. Such "pseudo" easterly waves are regularly observed in the deeper easterlies to the rear of shear lines, and have been discussed fully by Riehl on pages 34–35, loc. cit.

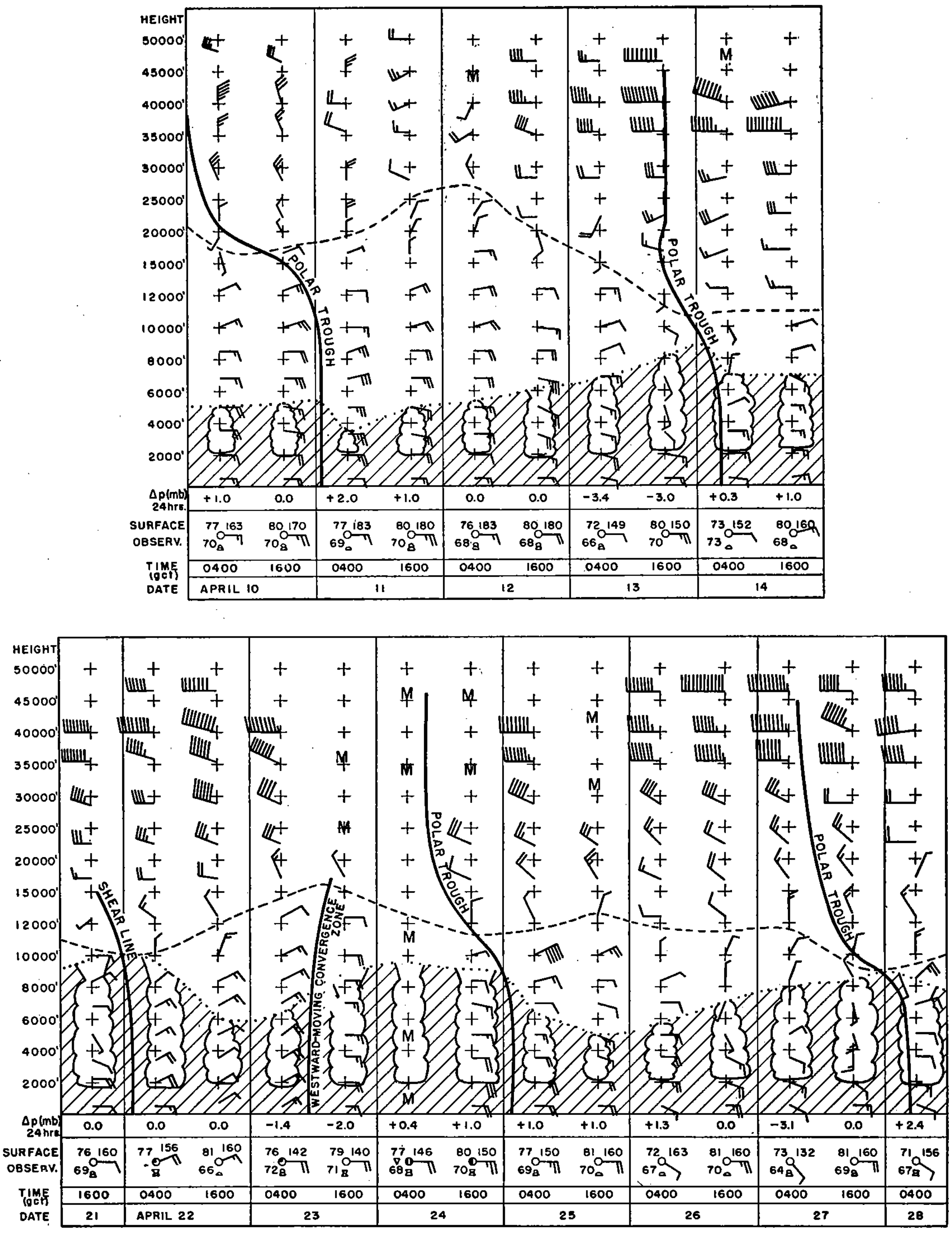

FIG. 57. Time cross-section for San Juan covering the days when observations were made by the expedition. The upper winds are RAWINS. A short barb indicates a speed of 5 mph, a long barb, 10 mph. Surface winds are in the Beaufort scale. The hatched region is the moist layer, the top of which is represented by a dotted line. The base of the westerlies is indicated by the dashed line.

polar trough. The time-section, together with the synoptic maps, indicates that the convergence zone passed San Juan moving westward between the morning and afternoon radiosonde flight of the 23rd, and joined the polar trough over Haiti. The whole system then moved back eastward over San Juan as a reinforced polar trough just before the morning radiosonde on the 25th. The accompanying weather, however, was only moderately bad on the 23rd. During the 24th no airplane flight was made.

On the days with more highly disturbed weather, among them the morning of the 16th when the strongest shear line passed (during the period omitted from the time-section), no observations were made. In general, it can be concluded that the expedition investigated a relatively undisturbed trade-wind regime of early spring, too late in the year for strong polar disturbances, and too early for the easterly waves and hurricanes associated with deep east winds.

V. CHARACTERISTICS OF THE HOMOGENEOUS LAYER AND OF ADJACENT LAYERS

1. Structure of the Lower Levels in the Trade Winds

The data presented in Chapter III have been used to study (1) temperature and mixing ratio lapse rates existing in the homogeneous layer, (2) fluctuations in the mixing ratio and accelerations imparted to the airplane, and (3) relations between the height of the layer and (a) wind speed and (b) the level of lifting condensation. From these studies certain facts have been found that clarify the picture of the basic physical processes operating in the trade region. Two pertinent conclusions reached are, (1) that the turbulent motions of the air in the homogeneous layer are not connected with the penetration of the convective currents of the clouds, but are produced by the flow of air over the rough water surface, and (2) that the height of the layer does not build up to the theoretical height expected for a given wind speed because its development is arrested by the low level of lifting condensation.

The processes of turbulent mixing of air, convection, condensation and evaporation of clouds, and subsidence of the air aloft are all operating simultaneously in this region, but one process is predominant over the others in a given height range. Thus in the lowest level turbulent mixing predominates, with the result that the homogeneous layer is formed and maintained as a permanent feature. At a higher level convection is the controlling process, producing the unending cycle of the formation and dissipation of the cumulus clouds, and transporting water vapor upwards from the lower levels. At a still higher level the subsiding effect of the Bermuda anticyclone is predominant and maintains the trade inversion against the mixing of the convection below its base. The resulting layered structure of the trade wind air over the Caribbean is shown in Figure 58, the sounding observed April 27, 1946, 1025 hrs. It shows the homogeneous layer, with its characteristic dry-adiabatic lapse rate and nearly constant mixing ratio, which are produced by the turbulent mixing of the air. Overlying the homogeneous layer is a thin stable layer. Its lapse rate is less than the dry-adiabatic, and there is a large decrease in the value of the mixing ratio through the layer. Above this is the layer in which the clouds build up and dissipate. It has a lapse rate less than the adiabatic and is topped by the main trade subsidence inversion.

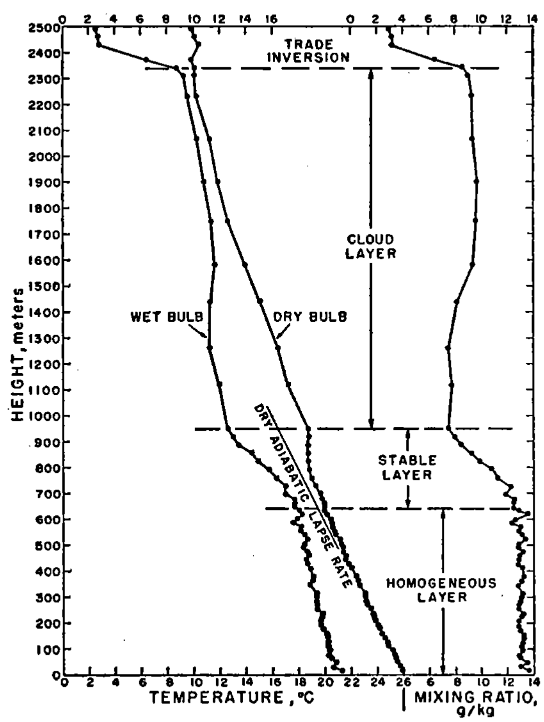

Fig. 58. Temperature sounding for 27 April 1946, showing the main features of the air up through the Trade inversion.

2. Description of and Predominating Processes Operating in the Homogeneous Layer.

a. Height — The data describing the conditions in the mixed layer have been compiled in Table 31. The height to which the layer extended on different days is tabulated in the third column. It was determined from inspection of the graphs of the soundings by noting the height at which the mixing ratio gradient changes from a small value (10^{-9}cm^{-1}) to a large one (10^{-7} cm^{-1}). With only a few exceptions, the dry-bulb lapse rate changed at this same height from the nearly dry-adiabatic lapse rate to a more

Table 31

Data for the Homogeneous and the Stable Layers

		Homogeneous Layer				Stable Layer	
Date	Time	Height Meters	Lapse Rate Dry-bulb °Cx10^{-5} cm^{-1}	Mean Deviation Mixing Ratio grams/kilogram	Lapse Rate Mixing Ratio x10^{-9} cm^{-1}	Potential Temperature Difference °C	Lapse Rate Mixing Ratio x10^{-8} cm^{-1}
April 1	1135	610	−8.9	0.31	−10	1.5	−10.2
April 2	1200	625	−8.9	0.23	− 7	2.5	−11.6
April 3	1104	550	−9.5	0.19	− 3	3.0	−13.8
April 4	1139*	490	−9.2	0.20	− 7	1.9	− 6.5
April 10	1524	640	−9.5	0.19	− 5	1.2	− 9.5
April 12	1423	460	−9.5	0.26	−10	1.9	−10.5
April 12	1505*	520	−9.2	0.14	+ 2	0.3	− 3.6
April 12	1534	460	−9.5	0.17	−14	2.0	− 5.9
April 13	1323	460	−9.5	0.20	+ 3	1.9	−12.1
April 13	1414*	670	−7.5	0.17	0	1.2	− 6.5
April 13	1454	610	−8.9	0.24	−13	1.2	− 8.8
April 13	1533	520	−8.9	0.34	− 1	2.4	−26.2
April 14	0008	640	−8.5	0.21	− 7	2.1	−31.8
April 14	0615	550	−9.2	0.28	−10	1.4	−12.1
April 14	0720*	580	−8.9	0.31	− 9	1.1	−14.7
April 22	1854	490	−9.5	0.24	− 6	1.8	−10.5
April 23	0713	300	−7.2	0.26	− 7	2.1	− 5.2
April 23	1307*	580	−8.5	0.25	−12	0.2	− 4.2
April 23	1353	640	−9.5	0.27	− 8	1.3	−13.1
April 25	1616*	640	−8.5	0.36	−12	0.2	− 7.2
April 25	1646	490	−9.5	0.16	−13	1.4	− 7.2
April 26	1319*	730	−8.9	0.22	− 6	0.5	−13.1
April 26	1416	640	−8.5	0.29	−10	0.6	−14.7
April 27	0923*	730	−8.2	0.22	+ 1	2.0	− 3.0
April 27	1025	640	−9.5	0.19	∸ 4	1.7	−21.3
April 27	1639*	520	−7.8	0.51	−15	0.4	−22.0
April 27	1728	700	−8.9	0.16	0	1.1	−11.5
April 28	0635	610	−8.9	0.35	+ 7	0.2	− 6.2
April 28	0725	550	−8.5	0.22	+ 3	1.4	−16.1

* Under Clouds

stable one. This upper boundary of the homogeneous layer is usually sharp and well defined, but in some cases the mixing ratio decreases slowly, and the height of the homogeneous layer can be determined only to within a hundred meters. The average height of the layer is 576 m for all cases, 607 m for cloudy areas, and 554 m for clear areas. The range of the heights is 300 m to 730 m.

b. Temperature Lapse Rate and Transport of Heat—The 4th column of Table 31 gives the lapse rates of the dry-bulb temperature in the homogeneous layer. They were determined by measuring the slope of the curve of dry-bulb temperatures plotted against height. This can be done with a probable error of $\pm 0.3 \times 10^{-5}$°C cm^{-1}. In two cases values of -9.9×10^{-5}°C cm^{-1}, were obtained. Since this is very close to the value of the dry-adiabatic lapse rate, the more accurate method of least squares was applied to determine the lapse rates of these soundings. The least-squares solutions gave values of $-9.5 \pm 0.03 \times 10^{-5}$°C cm^{-1} and $-9.7 \pm 0.03 \times 10^{-5}$°C cm^{-1}. Thus of the soundings made, none of the lapse rates equals or exceeds the dry-adiabatic lapse rate, in spite of the fact that the dip-bucket sea temperature ranged from 1.5°C warmer to 0.6°C cooler than the air at the lowest level of the airplane sounding. The fact that the lapse-rate of temperature in this layer is less than the dry-adiabatic would seem to indicate that the net flow of sensible heat is directed downward according to the derivations of Taylor (1915) and Schmidt (1921). However, recently Ertel (1942, 1943, 1944) and Priestley and Swinbank (1947) have pointed out that an upward flux of sensible heat may take place even with a less-than-adiabatic lapse rate because some of the air parcels starting from a given level during the mixing process will not be normal samples of the population at the level of origin. Naturally, parcels with a temperature higher than that of the environment will ascend thus causing a component of heat flux which is called "convective turbulence" by Priestley and Swinbank. It is not possible to estimate this quantity from our data and to decide whether the total flux of sensible heat is upwards or downwards. In any case there is a very considerable flux of latent heat upwards in the form of water vapor whose importance for the trade wind circulation has been demonstrated by von Ficker (1936, 2).

c. Mixing Ratio and an Estimated Value of the Coefficient of Turbulent Exchange—All soundings show the small mixing ratio gradients of the order of 10^{-9} cm^{-1} that are characteristic of the well mixed, turbulent layer. Most of the gradients are negative and lie between the values -15×10^{-9} cm^{-1} and $+7 \times 10^{-9}$ cm^{-1}. The average of the negative lapse rates, -9×10^{-9} cm^{-1} can be used to obtain a rough estimate of A, the coefficient of turbulent exchange, through use of the value for the mean annual evaporation, 4×10^{-6} g cm^{-2} sec^{-1}, of the region (Sverdrup, 1942, pp. 67–68). When these figures are substituted in the diffusion equation $E = -A\, dw/dz$, the value of A becomes 450 g cm^{-1} sec^{-1}, a somewhat high, but not impossible value.

Eight of the soundings showed zero or positive gradients ranging from 0 to 7×10^{-9} cm^{-1}. All mixing ratio gradients were obtained by considering the moisture distribution of the entire layer as a unit. When the layer is divided into upper and lower sections, it is found that the lower section usually shows a slight negative gradient while the upper part of these eight soundings shows a positive one. This suggests an accumulation of moister air at the top of the homogeneous layer. Because of the strong turbulent mixing in the layer it is difficult to understand how this state could be permanent. Such a body of moist air must either be mixed rapidly into the homogeneous layer or rise through the stable layer and develop into a cloud. The temporary nature of the positive gradient is indicated by the rapid changes in the soundings taken on April 12 in the same area. The 1505 hours sounding, taken under a cloud, shows a gradient of 2×10^{-9} cm while the 1423 hours and 1534 hours soundings show gradients of -10×10^{-9} cm^{-1} and -14×10^{-9} cm^{-1}.

Although the mixing ratio gradients are small, there are large deviations of the individual values from the mean for the homogeneous layer in each case. Some of this dispersion is caused by errors in the temperature measurement, the remainder comes from actual differences of water vapor content of the air. A mean deviation of 0.14 g/kg would result from a probable error of ± 0.1°C of the wet- and dry-bulb temperatures. The mean deviations observed are larger than could be caused by observational errors of the temperature. The variations represent real fluctuations of the amount of water vapor present, and are an indication of the balance existing in the layer between the turbulent mixing and the convection currents forcing dryer air into the layer. The average mean deviation is 0.27 g/kg for cloudy areas, and 0.23 g/kg for clear areas. These figures indicate that any large jets of dryer air from aloft forced by convection currents into the homogeneous layer are mixed rapidly by turbulence throughout the layer. This rapid mixing is consistent with the high value of the coefficient of turbulent exchange estimated from the mean annual evaporation.

d. Predominance of Turbulent Mixing over Convection in the Homogeneous Layer — Substantiating evidence that convection currents are not maintained far into the homogeneous layer is given by accelerometer records of the vertical motions of the plane as it flew under clouds and in clear areas. Table 32 gives the percentages of time that the accelerations of the plane were in the ranges 0.0 to 0.04g; 0.04g to 0.08g; and

TABLE 32

Accelerations Imparted to Airplane

		Clear			Under Clouds		
Date	Altitude m	0–0.04g	0.04–0.08g	0.08g	0–0.04g	0.04–0.08g	0.08g
April 14	300	81	17	2	85	15	0
April 23	300	84	13	3	90	10	0
April 14	150	81	17	2	76	22	2
April 13	135	78	19	3	73	23	4
April 26	150	82	16	2	77	20	3
Average		81.2	16.4	2.4	80.2	18.0	1.8

greater than 0.08g for both clear and cloudy conditions. The acceleration of gravity, g, is 980 cm sec^{-2}. The bottom row gives the averages for each range and cloud condition above the plane. The small difference shown in the turbulence in the homogeneous layer under the clouds and in clear areas indicates that convection in the cloud layer does not produce any recognizable increase of the turbulence in the layer below it.

In the cloud layer, bounded by the homogeneous layer and the trade inversion, the clouds are building up and dissipating constantly, producing areas of great turbulence in an otherwise smoothly flowing air. The accelerometer trace shows that the smooth air between clouds imparts accelerations of less than 0.04 g to the plane 99% of the time, while in and near clouds the accelerations reach 0.5 g. This great difference in turbulence is shown graphically in Figure 59 which presents actual traces of the accelerometer records at various heights inside the clouds, in the clear areas, and in the homogeneous

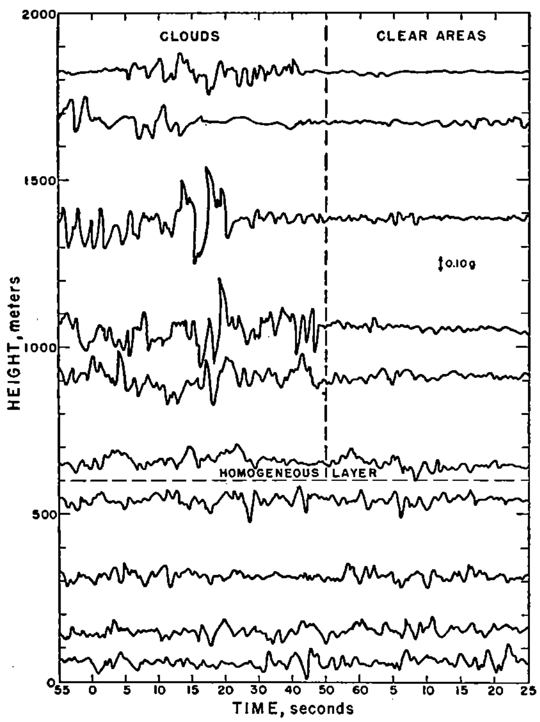

FIG. 59. Unreduced tracings of the accelerometer records. Zero acceleration line coincides with height at which the run was made. Double headed arrow indicates displacement equivalent to 0.10 g.

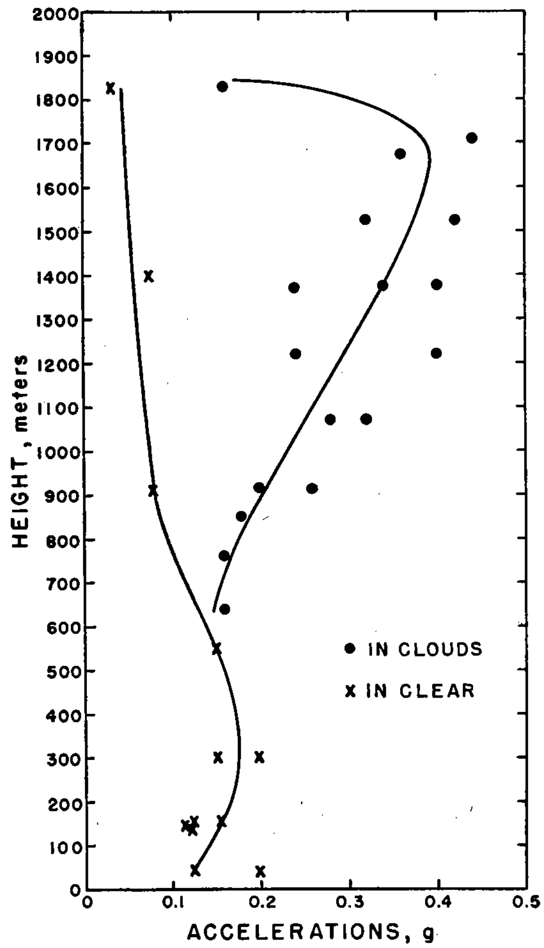

FIG. 60. Maximum accelerations observed at different heights in clear and in clouds.

layer. In Figure 60 values of maximum accelerations observed while flying through clouds and in clear areas have been plotted against height. Two distinct curves have been drawn through the points. The curve of the accelerations in the clear air reaches a maximum of 0.2 g at about 300 m, falls off to a value 0.125 g at the top of the homogeneous layer, and decreases slowly to a value of 0.025 g at 2000 m. If the coefficient of turbulent exchange is assumed to depend on the vertical velocities of eddies, then this curve may be considered to represent the variation of A with height. This assumption is subject to the limitation that the plane is selective in its response to eddies of various sizes. The occurrence of the maximum at 300 meters shows that the frictional force of the air flowing over the water surface is the source of the turbulent motion, rather than the penetration or development of convection in the homogeneous layer.

The curve showing accelerations in the clouds starts with a value of 0.15 at 700 m, increases to a value of 0.4 g at 1700 m and then suddenly drops as the cloud development is limited by the trade inversion. In extending the cloud curve downward it is seen that it intersects the curve of the maximum acceleration due to turbulence in the clear air at an elevation of about 600 m. The pronounced minimum at this level makes a sharp separation between the height range, 0–600 m, in which turbulent mixing is the predominating process of heat, water vapor, and momentum transfer, and the range, 600–2000 m, in which convection is the primary means of transfer. These curves may be taken as evidence that, below this level of 600 m buoyancy forces do not produce accelerations that can be recognized as convection currents.

From this evidence and the small difference in the mean deviation of the mixing ratio, under clouds and in the clear it is concluded that over the ocean the convection currents producing the clouds neither originate in nor extend an appreciable distance down into the homogeneous layer. Any masses of air forced down into the layer by the convection currents of the clouds above have their energy dissipated rapidly and the air is mixed by the turbulence which is greater in the homogeneous layer than in the cloud layer. The convective activity which eventually leads to cloud formation probably starts at the top of the homogeneous layer, rather than deep in the layer where the air is mixed more rapidly. With turbulence active in the layer, an accumulation of lighter air would be dissipated before buoyancy forces could give it an appreciable vertical acceleration.

3. Conditions in the Stable Layer Above the Homogeneous Layer

In the 7th and 8th columns of Table 31 data have been collected which describe the stability and moisture gradient of the air lying immediately above the homogeneous layer. The stability is described by the difference between the potential temperature at the base and at the top of the layer. The top of the stable layer is fixed in most cases by the beginning of an isothermal portion of the curve of the potential temperature as a function of the height. In some cases no maximum or isothermal layer can be found, and the determination of the height of the top and consequently the potential temperature difference, is less certain. The thickness of this stable layer varies from a hundred meters to three hundred meters. The difference between the potential temperature of the air at the top of the homogeneous layer and air at the top of the inversion or isothermal layer is found to range from 3.0°C to −0.2°C, a case of instability found in a cloud. The average temperature difference for clear areas is + 1.7°C, and for cloudy areas + 0.5°C. Soundings taken in the cloudy areas show that a stable layer may not exist when convective activity takes place.

The gradient of the mixing ratio in the stable layer has been determined graphically and is entered in the table. The average gradient for all soundings is $-11.8 \times 10^{-8}\ \mathrm{cm}^{-1}$.

4. Height Relations of the Homogeneous Layer

Data has been collected in Table 33 in order to study the relations of the height of the homogeneous layer to surface wind speed and the level of lifting condensation. The first three columns give date, time and place of the observations. The height in meters of the layer is entered in the fourth column. The level of lifting condensation,

Table 33

Date	Time	Place	Height m	LLC m	Wind Speed m/sec
April 1	1135	Coco Solo	610	590	—
April 2	1200	"	625	660	—
April 3	1104	"	550	610	—
April 4	1139	"	490	500	—
April 10	1524	San Juan	640	680	—
April 12	1423	"	460	730	9.3
April 12	1505	"	520	640	8.2
April 12	1534	"	460	640	8.2
April 13	1323	"	460	660	7.8
April 13	1414	"	670	660	7.8
April 13	1454	"	610	760	7.8
April 13	1533	"	520	820	7.8
April 14	0008	"	640	670	8.0
April 14	0615	"	550	660	8.2
April 14	0720	"	580	700	8.2
April 22	1854	"	490	570	9.8
April 23	0713	"	300	340	6.7
April 23	1307	"	580	550	10.8
April 23	1353	"	640	700	10.8
April 25	1616	"	640	700	—
April 25	1646	"	490	580	—
April 26	1319	"	730	860	9.8
April 26	1416	"	640	760	9.8
April 27	0923	"	730	690	10.8
April 27	1025	"	640	910	10.8
April 27	1639	"	520	550	10.3
April 27	1728	"	700	700	10.3
April 28	0635	"	610	600	9.8
April 28	0725	"	550	550	9.8

entered in the fifth column was found graphically from an adiabatic diagram. The sixth column gives the wind speed in meters per second. These observations were obtained from a hot-wire anemometer mounted eight meters above sea level on a surface vessel which cruised in the vicinity of the airplane sounding area.

a. Wind Speed-Height Relation — Rossby and Montgomery (1935, pp. 1–39) have shown that the height of the layer of frictional influence and thus the height of the gradient wind and the homogeneous layer is given by

$$H = \frac{246\, W_a}{\sin L \log[(z_a + z_o)/z_o]}$$

where H is the height of the layer in meters, W_a the wind speed in meters per second at anemometer level, L, the latitude, z_a, the height of the anemometer, and z_o is the roughness parameter. This equation is developed under the assumptions that the atmosphere is adiabatic and that the mixing length is a linear function of the height. From the observations taken at the Boston Airport they determined the equation $H = 136W_a$, corresponding to a value of $z_o = 3$ cm.

The heights of the homogeneous layer and wind speeds at San Juan are plotted in Figure 61. The scatter of the points is large and a mean curve, $H = 62W_a$, can be drawn only if the intercept of the line is taken as zero in accordance with theory. This slope of 62 for the relation represents a serious disagreement with the theoretical relation

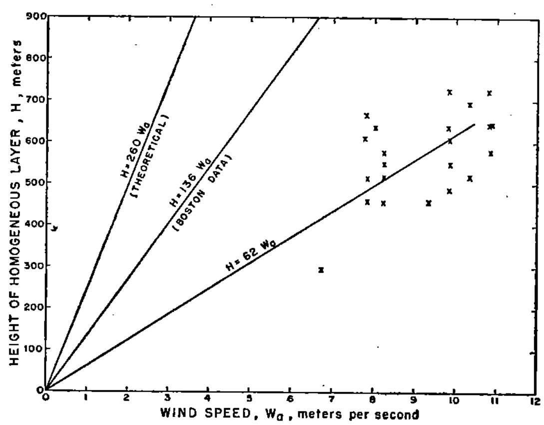

FIG. 61. Observed and theoretical relation between wind speed and height of the homogeneous layer.

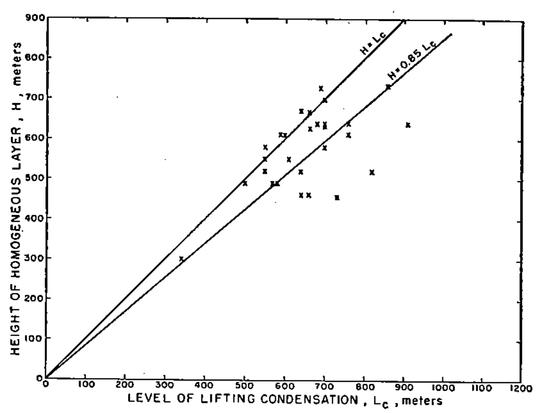

FIG. 62. Observed relation between the level of lifting condensation and the height of the homogeneous layer.

for H given in the preceding paragraph, for with the value of $z_o = 1$ cm, $z_a = 800$ cm, and $L = 19°$, the slope should have a value of 260. The slope can be forced into agreement only by assuming $z_o = 10^{-9}$ cm, which is too small to be considered reasonable.

b. The Level of Lifting Condensation — Height Relation — A relation between the level of lifting condensation and the height of the homogeneous layer is shown in Figure 62. The height of the layer is seen by inspection to be about 0.85 times the height of the condensation level. In a few cases layers have built up to or exceeded the level of condensation. These cases exceed it by a maximum of thirty meters which is within the limits of error of determination of the heights. Thus the condensation level appears as an upper limit to which the layer can build. When turbulent eddies lift parcels of air above this level, condensation takes place, forming clouds and producing the wet-adiabatic lapse rate. Further growth of the layer is damped by the increased stability, and the layer will cease to build much higher than the original level of lifting condensation. The theoretical height given by the formula of Rossby and Montgomery, $H = 260W_a$, will not be attained when it is greater than the level of condensation. This relation is based on the assumption of a linear function of mixing length with height, but this condition does not obtain when the condensation level is low. For this reason, the relation should not be used when the condensation level is low enough to modify the assumed height-mixing length relation. For the steady state over the ocean, the relation $H = 0.85\ L_c$ determines the height of the layer within 20–30% where L_c is the level of lifting condensation.

VI. TURBULENT MASS EXCHANGE AND THE VERTICAL DISTRIBUTION OF HUMIDITY OVER THE CARIBBEAN SEA

a. Humidity Distribution in the Homogeneous Layer — The airplane soundings made off San Juan, P. R., have shown the existence of a layer above the sea surface in which the specific humidity does not decrease with elevation, although irregular fluctuations around a constant value are found. This constant value is considerably smaller than the saturation specific humidity with respect to the sea surface temperature. Since this saturation specific humidity must be the actual value at the ocean surface a strong gradient exists in the lowest layer of the atmosphere. This layer is followed by the homogeneous layer which is found to exist at the lowest level of airplane observations, about 50 feet, although it may actually start at a lower level (Fig. 58). Above the homogeneous layer the specific humidity decreases rapidly through the stable layer and decreases slowly within the cloud layer. It is the purpose of this chapter to explain the observed humidity distribution.

The rapid increase of the specific humidity in the lowest layer is due to the small values of the diffusivity here, and the almost constant specific humidity in the remaining part of the homogeneous layer can also be explained by a reasonable distribution of the coefficient of eddy diffusivity. The assumed distribution of the latter is shown in Figure 63. Next to the sea surface, in the layer I the diffusivity is presumably entirely molecular, the effects of eddying motion being negligible. This layer has been introduced by Montgomery (1940) as the laminar layer where the coefficient of diffusivity $K_m = 0.24$ cm² sec⁻¹, the value of molecular diffusion of water vapor into air. Its height, denoted by h_1, may be of the order of 1 mm, according to Montgomery. In the next layer[1], II, the effects of turbulence become more and more important as indicated by the large lapse rates of temperature (Table 31). Hence the coefficient of diffusivity K^{II}, which is now *eddy* diffusivity, increases with height. It will be assumed that K^{II} is a linear function of elevation,

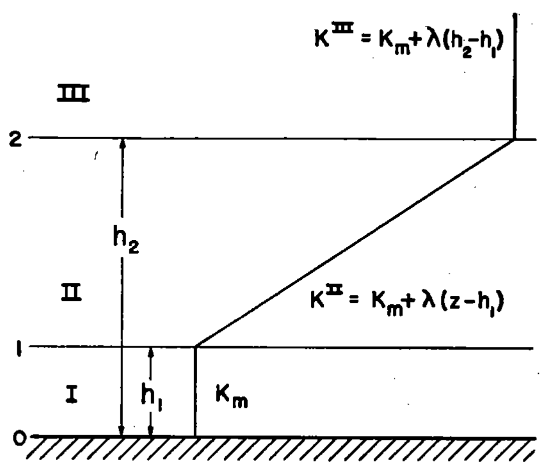

FIG. 63. Assumed distribution of the coefficient of eddy diffusivity.

$$K^{II} = K_m + \lambda(z - h_1) \quad (1)$$

because this assumption has been found compatible with many observational data. Moreover, it is evidently the simplest function to choose if the hypothesis of a constant coefficient of eddy diffusivity is abandoned. The layer II extends to h_2. In the next

[1] In the case of a hydrodynamically rough sea surface Montgomery (1940) interposes a "turbulent boundary layer" between I and II. This additional layer may be disregarded here since its presence or absence does not affect the main argument stated at the beginning of this paragraph.

higher layer, III, the coefficient of eddy diffusivity is assumed to be constant and equal to the value at h_2 in the layer II,

$$K^{III} = K_m + \lambda(h_2 - h_1). \qquad (2)$$

The humidity distribution may be regarded as being in the steady state, in the first place since the diurnal variations are small. Furthermore, the horizontal gradient of humidity, apart from local condensation phenomena must be very small or zero because the sea surface temperature in the Caribbean is very uniform over large areas. Finally, the vertical descent of air due to frictional outflow from the high pressure area is very small, and its effect will be neglected compared to that of eddy diffusivity. There may be an additional component of the vertical downward motion which compensates for the ascent in the cloudy areas. This component is important above the homogeneous layer, as will be shown later. But in the homogeneous layer it is very small because it must gradually decrease toward the sea surface.

Under steady conditions and in the absence of a horizontal gradient of q

$$\frac{d}{dz}(K\, dq/dz) = 0 \qquad (3)$$

where q is the specific humidity, z the height. Consequently

$$K\, dq/dz = -C \qquad (4)$$

The minus sign has here been introduced for convenience. The constant C represents the flux of water vapor.

For the laminar layer I one obtains from (4) that

$$q^I = q_0 - (C/K_m)\, z \qquad (5)$$

where the integration constant has been chosen so that q^I assumes the value q_0 at the sea surface. Integration of (4) for the layer II where K is given by (2) results in the following expression

$$q^{II} = q_0 - (C/K_m)\, h_1 - (C/\lambda) \ln (K^{II}/K_m). \qquad (6)$$

Here the integration constant has been determined so that q is continuous at $z = h_1$, the boundary between layers I and II. The constant C may be determined from the observed value q_2^{II} of the specific humidity at the level h_2. Then

$$C = \lambda \frac{q_0 - q_2^{II}}{(\lambda\, h_1/K_m) + \ln (K^{III}/K_m)} \qquad (7)$$

It is, of course, possible to determine C from humidity observations at other levels, but the foregoing choice simplifies the formulae. For the third layer

$$q^{III} = q_2^{II} - (C/K^{III})\, (z - h_2) \qquad (8)$$

where the integration constant has been selected so that q is continuous at the level h_2. It should be noted that not only q, but also dq/dz is continuous everywhere because of (4) and because of the continuity of K throughout the three layers.

The humidity distribution in the homogeneous layer was very similar on all days when observations were taken. Therefore the humidity distribution on one particular day, 27 April 1946 at 1025 AST will be considered as a numerical example. The temperature of the sea surface was 25.4°C. Hence, for the specific humidity of the air the value $q_o = 19.4 \times 10^{-3}$ must here be chosen which is the saturation value at this temperature. The small correction due to the salinity of sea water, about 2%, can be neglected. Since according to the airplane observations the temperature at 18.3 m was 25.9°C, 0.5°C higher than that of the sea surface the stratification of the lowest layer of the atmosphere was quite stable so that the assumption of a small value of the diffusivity is justified. For the second value of the specific humidity $q_2^{II} = 13 \times 10^{-3}$ at $h_2 = 400$ m has been selected. In the laminar layer $K_m = 0.24$ cm² sec⁻¹. The thickness of this layer is assumed to be 0.1 cm. It has further been assumed that the coefficient of eddy diffusivity K increases linearly through layer II until it reaches a value of 1.67×10^5 cm² sec⁻¹ at 400 m. This upper boundary for the layer II has been chosen quite arbitrarily. The Austausch coefficient is obtained by multiplying the coefficient of diffusivity by the air density, so that the Austausch coefficient at 400 m elevation would be 200 gm cm⁻¹ sec⁻¹. Above this elevation the eddy diffusivity remains constant. The constant value of A at 400 m assumed here is only half of the estimate given on page 70. However, the actual value of A is of little importance in the explanation of the humidity distribution throughout the homogeneous layer, the most influential factor being the rapid increase of A in the lowest layer as shown below.

The magnitude of the eddy diffusivity and the elevation up to which it increases are somewhat large, but they give better agreement with the observations than smaller values, as will be shown below. In view of the large lapse rate of temperature in the homogeneous layer these assumptions do not seem unreasonable.

The humidity distribution computed with the above numerical values is shown by the full curve in Figure 64. The observations and the assumed surface value of the specific humidity are indicated by crosses. The rapid decrease of the moisture content in the lowest layers and the almost negligible gradient of the specific humidity throughout the greater part of the homogeneous layer are well reproduced.

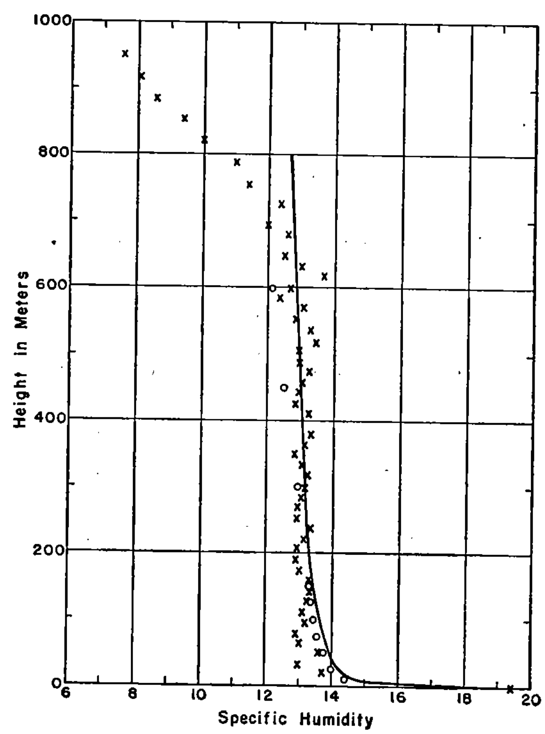

FIG. 64. Humidity distribution in the homogeneous layer on 27 April 1946, 1025 AST. Crosses indicate observations. The full curve is computed with a coefficient of eddy diffusivity increasing linearly to 1.67×10^5 cm² sec⁻¹ at 400 m; the circles are computed with a coefficient of eddy diffusivity increasing linearly to 0.83×10^5 cm² sec⁻¹ at 150 m.

In order to show how the theoretical distribution of the specific humidity is influenced by the choice of the values for the coefficient of eddy diffusivity the computation has been repeated under the assumption that the layer II reaches only to 150 m and that the coefficient of eddy diffusivity is here 0.83×10^5. The resulting humidity distribution is indicated by the circles in Figure 64. The differences from the other theoretical curve are slight, with the values in general being lower because of the smaller effect of turbulent eddies. In the upper part of the homogeneous layer the computed gradient of specific humidity is now somewhat larger because of the smaller value of K. Consequently, the agreement with the observed values is not quite as good as with the larger coefficient of eddy diffusivity.

At the time of the observation the wind velocity observed on the ship at a height of about 7 meters was 17 mph so that spray was presumably present in the lowest layers of the atmosphere. Evaporation from spray must increase the water vapor content of the air in the lowest layer so that the theoretical humidity distribution should here be modified. However since no observations are available so close to the sea surface these modifications will not be considered.

b. Humidity Distribution Above the Homogeneous Layer — Above the homogeneous layer the observed humidity distribution shows a pronounced decrease with elevation. This decrease continues in some cases throughout the stable layer and the whole cloud layer with approximately the same intensity, in other cases the lapse rate of the specific humidity may be very large in the stable layer and the lower part of the cloud layer and very much smaller in its upper part. This distribution of the specific humidity cannot be explained by the distribution of eddy diffusivity alone. It can however, be interpreted as a combined effect of vertical motion and eddy diffusivity. Since large-scale convection occurs evidently in the cloud layer, as indicated by the cumulus clouds, there must be, in the large clear areas, a slow subsidence of air which is the return flow of the air carried up in the clouds. For the sake of simplicity the height z may now be reckoned from the lower boundary of the stable layer. The vertical velocity w should vanish here and at the top, h, of the cloud layer. It is then convenient to assume that

$$w = -w_o \sin(\pi z/h) \tag{9}$$

where w_o is a positive constant. If K^{III} is assumed constant in the layer which is now being considered the diffusion equation is

$$w\, \delta q/\delta z = K^{III}\, \delta^2 q/\delta z^2 \tag{10}$$

From (9) and (10) it is found that

$$\delta q/\delta z = C \exp(w_o h/K^{III}\pi) \cos(\pi z/h) \quad \text{(C is a constant)} \tag{11}$$

A further integration cannot be made analytically, but the distribution of the vertical humidity gradient can readily be deduced from (11). Near the base of the cloud layer $\delta q/\delta z$ will be large because the cosine is positive and near unity. At the middle of the cloud layer $z = h/2$, and the cosine vanishes so that the exponential is much smaller. Finally, at the top of the cloud layer, $z = h$, the cosine becomes negative and equal to one so that the exponential is reduced still further. To give a numerical example the humidity distribution on 27 April during the afternoon, Figure 65, may be considered. The height h of the cloud layer at this time was 1800 meters. By selecting two points on the humidity curve C and w_o/K^{III} can be determined, the latter constant being found to be $.052 \times 10^{-3}$ cm^{-1}. With a density of 10^{-3} gm cm^{-3} and an Austausch coefficient of 100 gm cm^{-1} sec^{-1} the maximum vertical velocity $w_o = 5.2$ cm sec^{-1}. With these values $\delta q/\delta z$ is more than seven times larger at the base of the cloud layer than at the middle of the cloud layer while at the top of the cloud layer it is two hundredths of the value at the middle of the cloud layer. Those cases where the humidity lapse rate does not change appreciably through the cloud layer can be explained either by the assumption

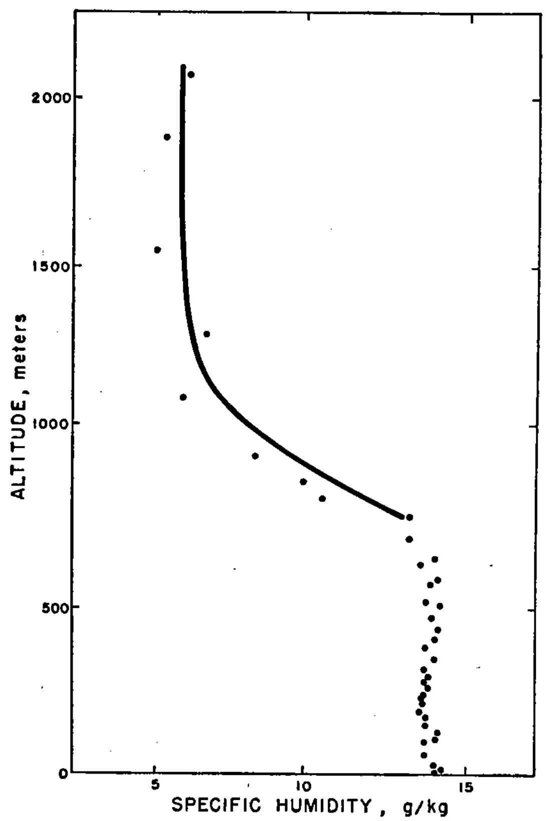

FIG. 65. Humidity distribution in the cloud layer on 27 April 1946, 1025 AST.

that the vertical velocity is very small or that it is nearly constant throughout the cloud layer. In either case the vertical variation of the humidity gradient throughout the cloud layer will be small.

The actual humidity distribution can, of course, be computed from (11) by numerical integration. As an example the specific humidity — height curve within the cloud layer for 27 April, based on the numerical values quoted above, is shown in Figure 65. The theoretical curve shows the essential features of the humidity distribution, viz. the slowly decreasing humidity in the cloud layer and the rapid decrease upwards through the stable layer.

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