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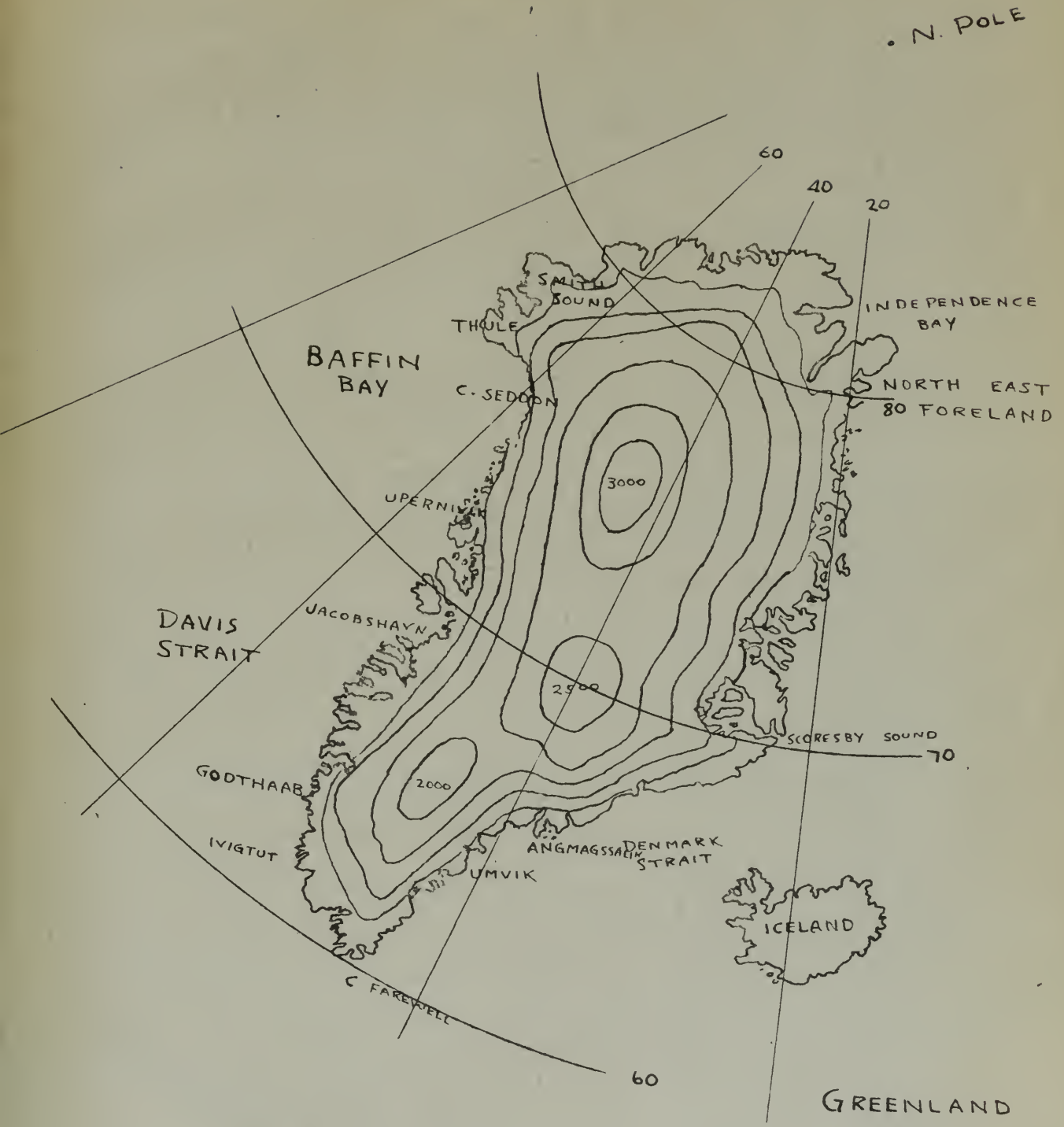

GREENLAND WITH CONTOURS OF SURFACE (METERS)

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Greenland, the largest island of the globe with its 850,000 square miles, has the shape of all the continents, broad in the northern region and tapering to smaller width in the more southern part. It extends from 85° north to 60° north latitude, and in breadth from 20° west to 60° west longitude. The interior is a great mass of perpetual snow and ice with marginal discharges along the whole coast. Nowhere in the interior is there a place where bed rock appears above the surface of the ice. About 40 miles from the southeastern edge, however, rise the high mountains of "Schweizer Land" and about 20 miles from the northeastern coast those of Queen Louise Land. As is obvious from the accompanying sketch the ice mass rises to elevations of 3,000 and 2,500 meters at high points of the interior. On the west coast there exists a chain of mountains not reached by the ice cap, but cut up by long branching fiords through which the drainage is accomplished. The ice free margins of Greenland, which vary in width from 5 to 100 miles, are generally mountainous, reaching from 5,000 to 8,000 feet on the east shore and from 5,000 to 6,000 feet on the west shore and dwindling into deep fiords and extensive bay regions.

Although Greenland contains the largest mass of land ice on the northern hemisphere, the ice area is not quite large enough to dominate the atmospheric circulation as was earlier supposed. The icelandic low pressure area, with its center between southeast Greenland and western Iceland, extends as a crescent being separated by an area of relatively high

pressure over Greenland. The prevailing winds, therefore, tend to blow outward from theisland of ice on either side, giving east or south-east winds in the west and west or north-west winds in the east. Barometric depressions sometimes cross the southern portion of the island from west to east, and these storms cause variable winds in the southern portions except along the coast where the surface wind directions are of course largely determined by the fiords. Generally speaking the winds blow radially out from the island. The general circulation may be considered as being determined by the rather shallow anti-cyclone existing over Greenland bounded on the north by the Arctic anticyclone, and to the south, east, and west by relatively lower pressure, and occasionally affected in the southern extremes by cyclones moving into the permanent Icelandic low where they are regenerated before progressing on eastward toward the European Continent.

From these aspects it is evident that two general climatological areas of different characteristics exist--the inland climate over the isoblink and the climate of the narrow ribbon of uncovered land on the coasts. Although the former dominates the area as a whole; as much data and information concerning coastal weather and its forecasting as is possible within the scope of this report will be given.

Much of the information here presented on inland winds will be the results of concepts formed from the reading of words by Professor Hobbs, Professor of Geology and Director

of the Greenland Expeditions of the University of Michigan. On the Greenland Expedition of the University of Michigan of 1926 - 1927 regular daily piball and other observations were made at Mount Evans on the slope of the ice cap for a period of two years. The results of the expedition lead to the conclusion that an anticyclone dominated the area. The interior of the ice-cap is probably the coldest region in the northern hemisphere. Explorers over the Greenland ice cap in summer have found temperatures far below 0° F., leading to the conclusion that this area is intensely cold in both winter and summer. Because of the vastness of the ice-cap, a dense cold stratum of air exists over the region; and because the dome everywhere has an outward slope, the cooled air slides down and radially outward to replace the warmer air of the coastal belt. This movement starts from a region of comparative calms at the summit and accelerates on its trajectory. This air cannot continue to move outward from a center in all directions unless air flows into the central area to replace it, and, coming as it must from above, this air must in turn be replaced by that of inwardly blowing currents at some higher level. This is of course the elementary definition of an anticyclone, or quoting Hobbs, "The Greenland ice cap is the northern wind pole of the earth which is technically described as the Greenland glacial anticyclone." It is interesting to note in this connection a quotation taken from the Bulletin of the American Meteorological society in a review of the "Scientific results of

the German Greenland Expedition, Alfred Wegener, 1929 and 30/31" as presented by V. Conrad. "The main result of the expedition as regardsmeteorology can be summarized as follows: 'A stationary permanent high pressure region (Hobbs' 'glacial anticyclone') does not exist over Greenland. The down-slope winds do not play any decisive role in the developement of cyclones and anticyclones of temperate latitudes because the thickness of the layer of slope winds is too small, only 400 to 1,000 m. at most'."
The effects of the down slope winds will be discussed below. It is regretted that more extensive information concerning the German expedition is not at hand, interpreted, for consideration here.

The precipitation of inland Greenland has been a subject of much discussion in past years. It is evident that some precipitation does accumulate on the cap because of the fact that the cap is not diminishing despite constant sliding into the fiords to form ice bergs and the slight melting in summer. Hobbs maintained that practically no cyclonic precipitation occurs at the intenior, but that the snow occuring there is due to surface cooling of air with consequent condensation. There is a great amount of radiation at the snow surface resulting in very low temperatures at the surface. Air constantly descending in the anticyclone reaches the surface, is cooled, and gives up its moisture as fine, sand-like, snow particles or as hoar frost. This he claims is a continuous frocess. This seems to be discounted by

most authorities as the sole cause of precipitation, although observations of later date show that there is some condensation of this sort. It is rarely observed that snow falls from the air having been sublimated without any cloud formation. Simpson offers a different theory. Precipitation is formed by the forced ascent in blizzards of air currents which advance over the more slowly moving or stationery surface layers in front of them. Though air is warmed and dried on descent in an anticyclone, on reaching the surface it loses so much heat by contact with the snow that the additional ascent of one or two kilometers would suffice to bring the temperature to the dew point. Such ascents easily occur in blizzards and condenses thick snow. Blizzards have been observed on the cap. At this point it might be pointed out that a blizzard is defined as a very strong wind of gale force with gusts that may go to 100 miles per hour which results from a steepening of the barometric gradient, but is not a cyclone of the ordinary type. It is probable that the precipitation is due partially to cyclonic activity along the coasts as well as the two types mentioned above.

In the ice-free marginal belts clouds, fog, and precipitation are greater. In summer the temperature rises noticeably immediately in front of theice border. In spring and summer the interior of the fiords are somewhat warmer than the outer coast, and in winter the reverse is true. Differences greater than five degrees have been noticed here. The foehn winds play an important part in coastal weather

and are probably the predominating feature of the coastal circulation. Although the ice cap is extremely cold, the winds blowing down these slopes are warmed adiabatically and reach the coast as warm winds. These winds produce astonishing results. When it has been blowing for some time it becomes very dry and sometimes causes snow to vanish by sublimation. These winds, very local in nature, have been known to raise the temperatures 30° to 40° f. in a very few hours. Eighty per cent of the west coast windblows from east to south-east, and 70% on the east side blow from north to north-west. Cyclonic activity affects the coasts of the south, east, and west. Paths of a few cyclones are shown on an accompanying diagram. These original paths were plotted by Fr. J. Georgi in connection with a paper, "Greenland as a Switch for Cyclones." It is evident that these storms, which are presented as characteristic, do not invade Greenland but are "switched" along the coasts. The polar anticyclone i responsible for this shyness. In precipitation the tapering end south of latitude 66° stands out rather sharply. There alone is precipitation high being somewhat of the order of 1,200 millimeters. In the north very arid conditions exist.

Not a great amount of specific information concerning local conditions at different regions is available, but the various expeditions of the past few years have been investigated, and the ovservations, impressions and conclusions for the more signigicat stations set up by these partys will be condensed here. The west coast will be considered first.

The expedition to northwest Greenland and the Canadian

Artic in 1937 headed by J.M. Woodie gathered some valuable information from their pilot balloon observations. The atmosphere here was generally fine for observing piballs with exceptions for lower phenomen such as fog and stratus. These observations, taken along the east side of Baffin Bay from Godhaven to Smith Sound, showed remarkable stillness of the air, expecially in the stratosphere. Strong winds when prevelent were from six to 12 kilometers near the top of the tropopause, but no velocities greater than 70 kilometers per hour were observed. The temperature in the tropopause fell to -51° C. at 11.25 kilometers and then rose to -41° C. in less than one kilometer, after which it rose gradually to -27° C. at 19.5 kilometers. In general the weather was calm in winter and summer and stormy at the equinoxes as would be expected when there was the greatest contrast of air masses during the transition periods. The Michigan - Pan American Airways Greenland Expedition establishes a station at about 74° 19 ' north on the west coast. A resume of the period will be given with respect to meteorological aspects. September and October were characterized by clear weather, decreasing temperature, and practically no north winds. The temperature continued to fall till February 15, but with a slight increase in pressure and precipitation. In February during a foehn storm the temperature rose from -32° F. to 47° F. in 48 hours, the pressure fell to 28 inches; and the storm of 100 miles per hour maximum wind brought three feet of wnow. From then till June clear, cold conditions prevailed. In late

May the snow cover disappeared. The three summer months of June, July, and August were characterized by fog and heavy precipitation. During the year not more than fifteen storms of wind velocity greater than 50 miled per hour existed. Forty-eight per cent of the total 18.4 inches of precipitation fell in July and August. The extreme temperatures recorded were 62° F. in July and -36° F. in March. South to south-east winds persisted to 2,500 meters and then shifted to the western quadrant. This wind variation with height is a characteristic of the west coast. A nearby island station showed that ice cap winds prevailed only a short distance seaward, thence coastwise winds prevailed. The predominant cloud type was alt-stratus.

The Wagner expedition on the east coast in the vicinity of Kangerdugssuak region found that the terrain necesitated north-east or south-west winds. As is characteristic of the fiords, gustiness existed. Winter winds were predominately north or north-east, but there were a few instances of true foehn winds with a low himidity, falling barometer, and strong fiord winds on rare occasions when cyclones passed through central Greenland. Maximum temperature of 62° F. was reached in the summer when the winds varied from north to south. At times along the coast sea mists existed which extended to within about 200 feet of the ground, leaving good visibilities at the surface. It was very rare that the visibility at the surface dropped to less than 200 yards unless there was precipitation.

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The British Arctic Air Route Expedition under Watson made some interesting notes on the weather in the vicinity of Angmagssalik. They observed that there was fog 45 days during the year, most of which occured in summer with from seven to nine days of fog in each month from May to August. This fog penetrated the fiords and manifested itself in small patches. Low visibilities were associated with precipitation. During the summer light south-east winds prevailed, and in winter north- winds. Fifty-eight per cent, of the observations in winter reported calm, and 47 per cent in the summer. There were 42 days on which gales blew, most of which were typical northern foehns with a temperature rise. The northern gales brought little clouds; the remainder, clouds and precipitation. These gales it was noted were local in nature. The maximum temperature recorded was 63° F., and the minimum -3° F. East coast flying weather was summarized by this expedition as follows: Summer weather was almost always warm, clear, little wind and general excellent flying conditions. Fog was rare except for about 10 days when theice was breaking up; small isolated patches were present at other times. During the winter there were many foehn gales which reached a force of 12. These gales, local in nature, were not preceeded by a fall of pressure of signigicance. However they were audible and visible whirling the snow for two to three hours before their arrival. These gales did not extend to high elevations, and it was supposed they would not hinder high flying if no landings were necessary. Two lakes located at 66° 21' north 35° west

and at Angnagssolik were recommended as bases for sea planes. These lakes, it was anticipated, would be open all time but about two weeks in the transition seasons when ice was forming and breaking, and were far enough apart to be used as alternate havens in case a local foehn gale was in progress at oneof the bases.

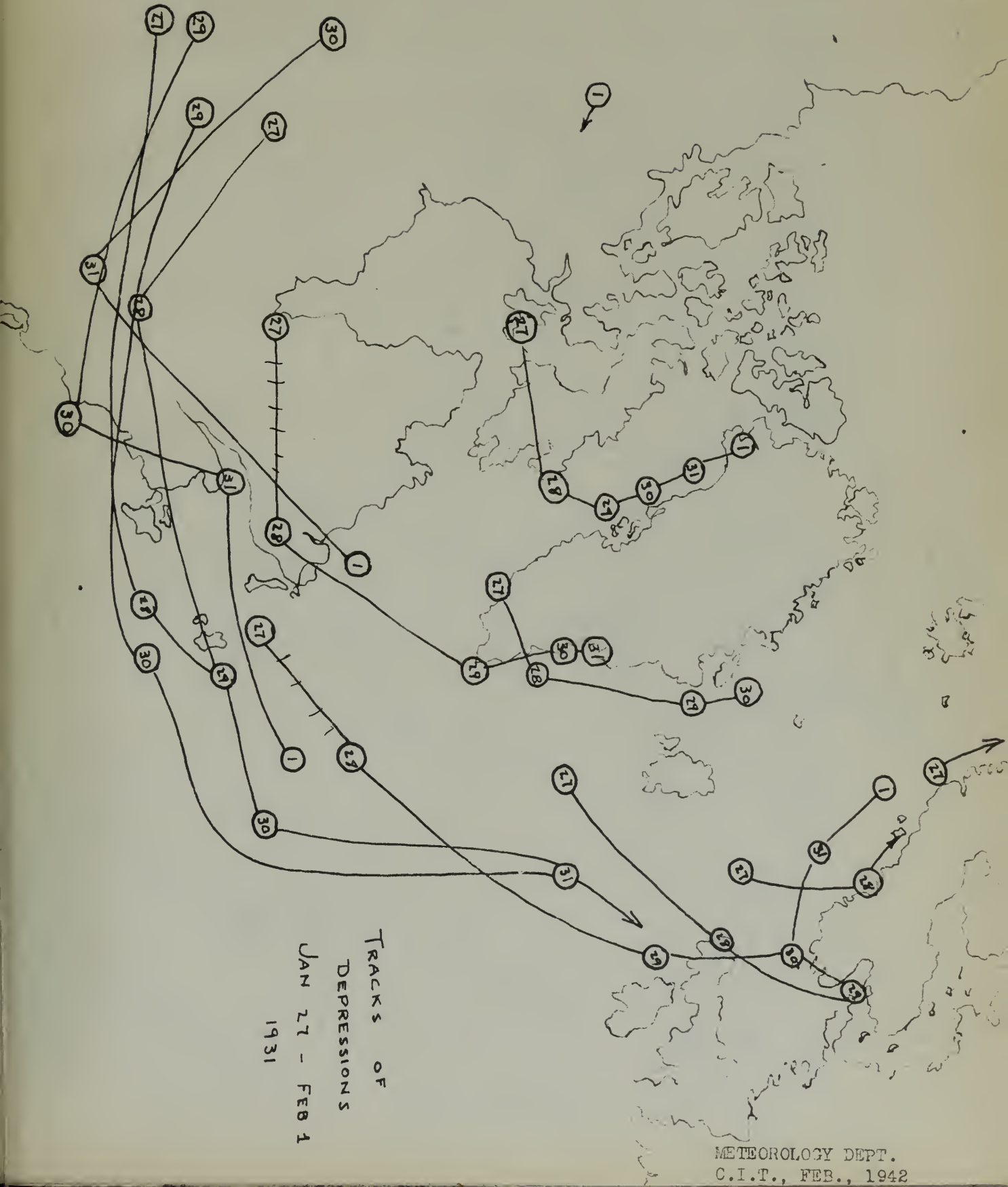
Ice cap observations were made in connection with this expedition. At their station which probaby was representative the visibility varied greatly due chiefly to blowing snow in connection with blizzards. It was found that the visibility was one and one-third miles or greater 67 per cent of the time in September and only one per cent in January. From November to February the visibility was less than one-half mile 44 per cent of the time. Blowing snow, which accounted for 26 per cent of the above 44 per cent, was close to the ground, the visibility at higher elevations being unrestricted. Fog was very rare. It was reported at nine per cent of the September observations and three per cent of the December observations. North winds prevailed from September to March with forces of four to seven. Gales were rare. The extreme recordings from the thermometer were 29° in September and -59° in January. There was an average difference of 44° between temperatures at the ice cap and at Angmagssalik on the coast. Since the extreme temperatures were due to the extensive radiation, they varied with cloud cover considerablly. High clouds predominated with north winds, and middle and some lower types with southerly winds.

The greatest barometric change was 24 millibars in 24 hours. The flying weather was summarized as being very good in summer, but not so good in winter because of the winds and precipitation. It was interesting to note that an inversion existed at all times over the ice cap. This could be used to advantage on flights both for the comfort of the plane occupants and better functioning of the engines.

Forecasting has not been in practice in Greenland enough to formulate criteria for weather prediction upon a regional basis. Doubtlessly problems exist there which are unique, and these problems will have to be analyzed individually when forecasting is put into practice in this region. The winds, when not under the influence of the fiords or other local donditions, may be assumed to follow the pattern of anticyclonic circulation. The accompanying sketch from Hobbs seems to correlate favorably with observations of other expeditions. Proposed plans of flight might well be subject to consideration of the idealized trajectories indicated to assure the maximum benifit of tail winds. Precipitation has been covered as thoroughly as possible above. A few gener l points on fog and favorable conditions for its existance in arctic regions are considered in order here. An excellent, more detailed discussion of the subject of arctic fog, its behavior, and theoretical consideration is to be found in Petterson's Weather Analysis and Forecasting. Practically all the fog of this region can be attributed to the passage of warmer air over cold surgaces and may be typed

as advective fogs, drifting in occasionally over the marginal, ice free belt of Greenland, but usually very shallow. When they invade the ice fields they gradually dissipate unless the advection of moist air from the open sea is sufficiently intense to overcome the effect of condensation on the melting snow. Fogs have been observed most frequently over the snow when the temperature is about freezing and to be characteristicly of dissipating nature when the temperature varies far from this point in either direction. In general the local nature of fogs, their patchy, and shallow characteristics do not warrent a major, general discussion. Long range forecasting suffers greatly from lack of data concerning the pressure pattern in the polar regions since any attempt at long range forecasting must be based upon the distribution of atmospheric depressions and wedges. Attempts at long range forecasting will continue to suffer until stations are established and continuous records are made available for a consideration of pressure distribution and the corresponding local phenomena characteristic of each pressure pattern.

The accompanying charts which are selfexplanatory, are presented to give a more prudent scope of the climatological and meteorological aspects of Greenland weather.



TRACKS OF DEPRESSIONS
JAN 27 - FEB 1
1931

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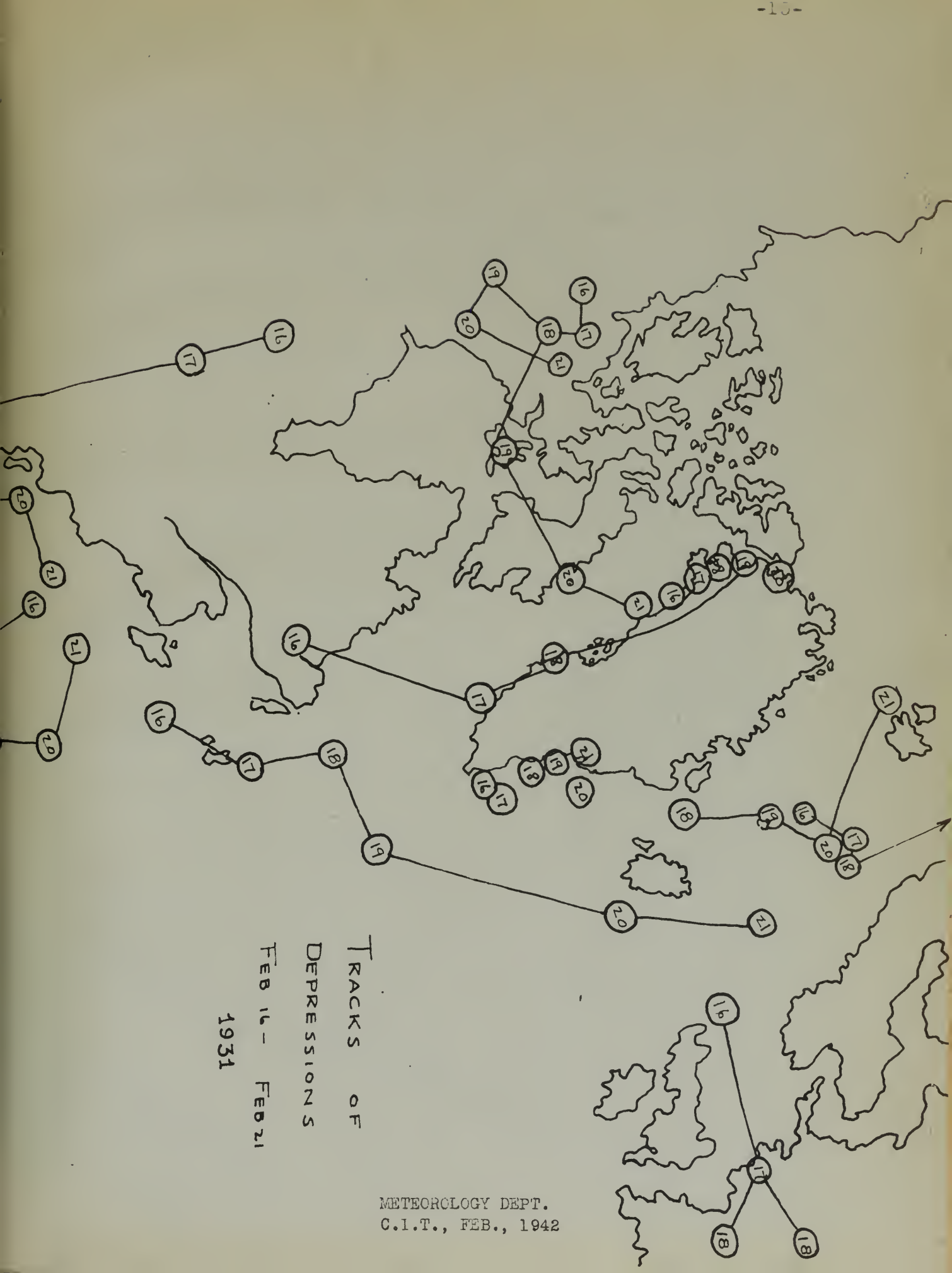

Tracks of Depressions
Feb 16 - Feb 21
1931

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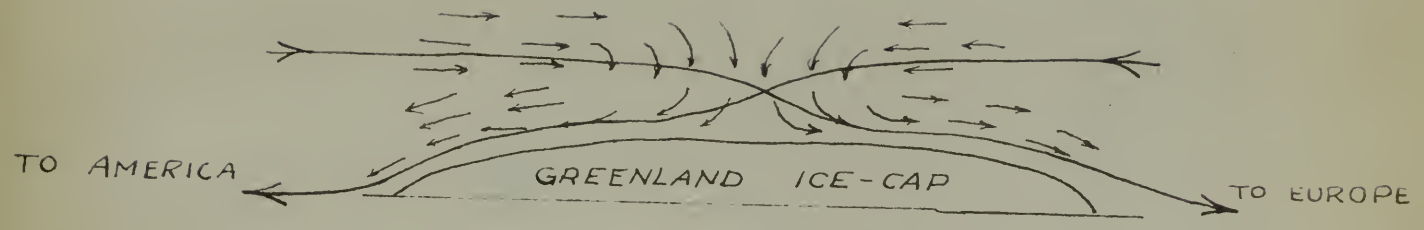

THEORETICAL CIRCULATION

AND

ADVANTAGEOUS FLIGHT WINDS

	N. Lat.	W. Long.	Average Temperature (C.) Feb.	July	Year
Ivigtut	61°12'	48°11'	- 7.5°	9.7°	0.5°
Jakobshavn	69°13'	50°55'	-19.0°	7.7°	- 5.7°
Upernivik	72°47'	55°53'	-22.8°	5.0°	- 8.7°
N. W. Greenland	82°0'	63°45'	-37.5°	3.2°	-18.8°
Danmarks Havn	76°46'	18°30'	-27.4°°	4.4°	-12.6°°
Angmagssalik	65°37'	37°16'	-10.8°	6.2°	- 2.2°

	Absolute Extremes (C.) Max.	Min.	Precipitation (mm.)	Frost Days
Ivigtut	23.4°	-28.9°	1170	208
Jakobshavn	19.4°	-42.0°	215	256
Ubernivik	17.8°	-40.4°	235	290
N.W. Greenland	10.5°	-52.1°	100	295
Danmarks Havn	17.1°	-40.9°	145	
Angmagssalik			930	

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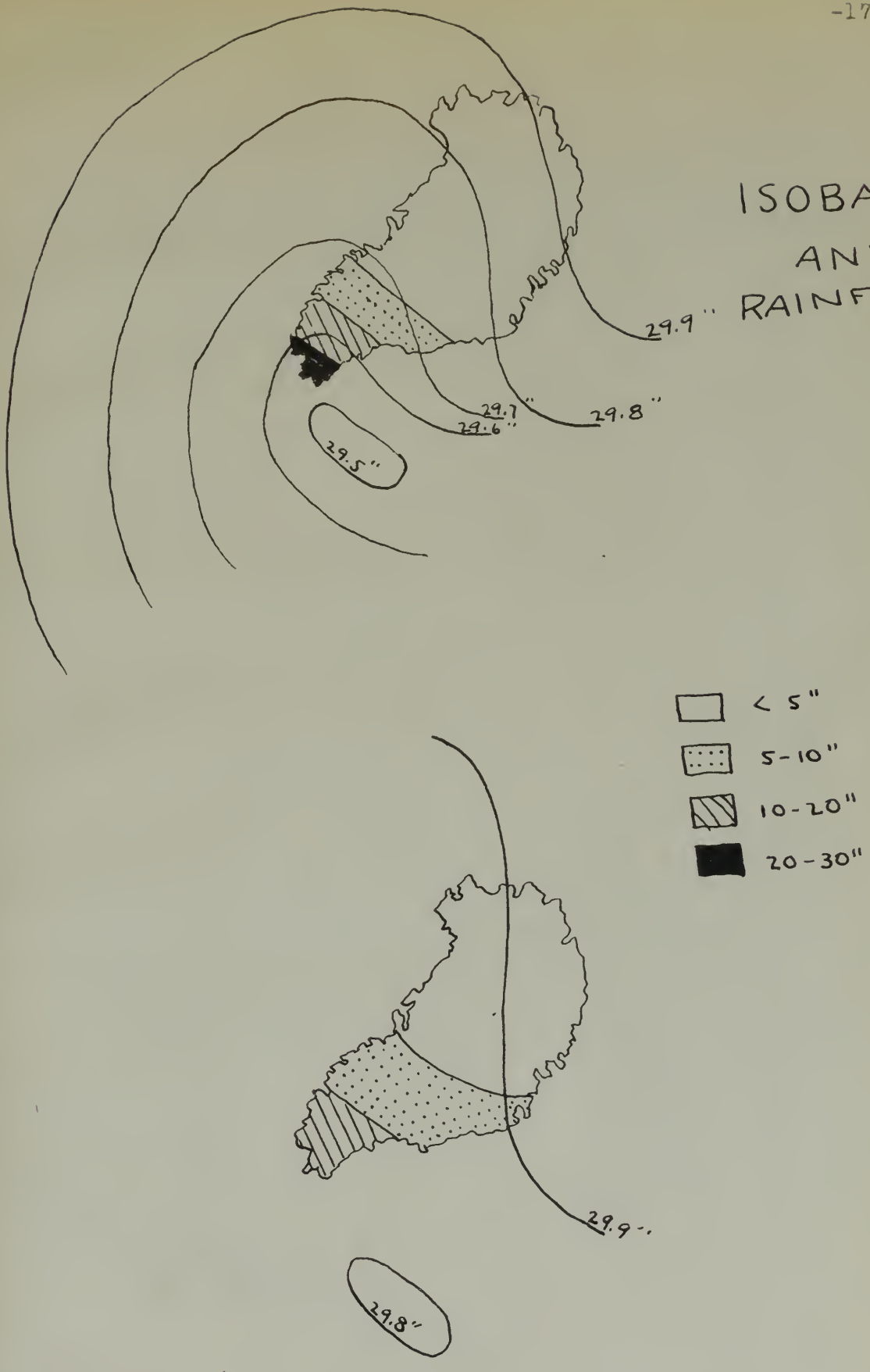
ISOBARS AND RAINFALL



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NORMAL SURFACE TEMPERATURES

January

July

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