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CLIMATOLOGICAL MAPS AND STATISTICS TO ASSIST IN THE ECONOMIC DEVELOPMENT OF ICELAND

Prepared for the Government of Iceland

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appointed under the
United Nations Programme of Technical Assistance

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This report is not an official document of the United Nations, but a paper especially prepared by an expert of the World Meteorological Organization appointed under the United Nations Technical Assistance Programme as his final report to the Government of Iceland.

FOREWORD

In accordance with a request from the Government of Iceland concerning technical assistance, Mr. Naftali Rosenan, expert of the World Meteorological Organization, was appointed under the United Nations Programme of Technical Assistance to advise on climatological maps and statistics to assist in the economic development of Iceland.

The duration of Mr. Rosenan's assignment was from 15 October 1959 to 14 December 1959.

His final report to the Government follows.

CONTENTS

ANNEXES

* See end of report

INTRODUCTION

1. The terms of reference of my mission to Iceland will be found in annex V to this report. The main question is whether climatic data available, after having been scrutinized by an earlier mission, could be used in the preparation of climatic maps and statistics, which would serve the Icelandic community and scientists at large. If not, what measures could be undertaken in order to improve the basic material so that maps and statistics could be prepared according to internationally accepted standards at an early date.

2. Iceland is situated at a strategic point of the North Atlantic Ocean, where warm air masses from the middle latitudes clash with cold ones pushing forth from the Arctic Ocean and the icy wastes of Greenland. The changing masses of warm and cold air are further influenced by the temperature of the currents of the Atlantic Ocean surrounding the island whose heat content depends upon the distance the water has travelled from the main branch of the Gulf Stream. In this environment the island of Iceland is set, and her surface forms, plant cover and hydrological features bear witness of its position at the border of the temperate climate of the middle latitudes and the cold climate of the Arctic wastes.

3. Further proof of the character of the island as part of the frontier fringe of the settled area of the world is given by its name and its history, which is a current account of the struggle of the inhabitants against the inclemency of the climate. The border position of Iceland also led to an early recognition here of the occurrence of climatic fluctuations, exemplified by the advance and retreat of forests, by the varying chance of growing corn, and, on the other hand, by the advance and retreat of the glaciers. Thus the economy of Iceland depends much more than that of countries in the heart of the temperate zone upon her climate. An improvement of her climate, though this may be slight, will enlarge considerably the area which is agriculturally usable and will increase the possibilities for agricultural activities. Past experiences of climatic deteriorations and the diversion of a part of the farming population into fisheries during the last century has resulted into the fact that today only the best agricultural areas within easy reach from the coast are being used. An ampler use of the agricultural potential of the country will necessitate, as a first step, the knowledge of the climatic characteristics of the new areas to be developed, of the temperature and precipitation regime normally to be expected, of the degree of risk caused by wind conditions, frequency of frosts and the occurrence of extended dry or wet spells during the growing season. These data needed for agricultural development were the main concern of my mission to Iceland.

4. But not the agriculturists alone will need climatic information before planning new activities. The same is true for many other civic activities towards the economic development of the country. The planners of harnessing new power in hydroelectrical plants will not be satisfied with the knowledge of discharge in the rivers; they will have to take account of the whole water balance of the catchment areas utilized, a task which cannot be achieved without

a thorough knowledge of its precipitation and temperature regimes (the latter influencing water losses by evaporation and evapo-transpiration). The acquaintance with wind conditions, furthermore, is important for planning of hydroelectric and other structures, which are subject to wind and water pressure in this windy island. The list of those in need of climatic information for planning and operation can easily be extended; industrial plants requiring climatizing installation; fisheries needing information on winds, weather, state of sea, sea temperature, etc.; communications, interested in snow cover, winds, precipitation (overland traffic, shipping, aviation); health services, making use of specific climatic properties for therapeutic purposes; these are only some few indications of the wide range of prospective users of climatic information for the benefit of the development of the natural economy of Iceland.

5. My mission was the consequence of two prior missions, that of Dr. A. Ångström in 1956, 1/ which had as its task the survey of the climatological and instruments section of the Icelandic Meteorological Service (IMS) and adequate recommendations towards the increase of their efficiency; and that of Mr. E. Hovmöller in 1957, 2/ which aimed at giving detailed advice towards an increased activity of the climatology section of IMS, especially by utilizing to a wider extent the data available in the archives of the Service. My mission, thus, may be regarded as a test to the recommendations of the prior missions by means of the practical case of trying to develop maps and statistics on important climatic items. The recommendations following this test may have, therefore, the special weight of the experience won by practical application.

6. My stay in Iceland lasted from 20 October to 14 December 1959. Most of this time was spent in the climate section of IMS in Reykjavik, but occasional visits were made to local scientists and institutions, in order to obtain information and views on special items of the maps developed. Some trips were undertaken to various parts of the country (see annex IV). On 27 November a lecture was given to agricultural and forestry authorities and interests on "Agricultural Meteorology" and the manyfold ways in which meteorology would help to develop agriculture and forestry, specially under the climatic conditions of Iceland.

7. On 7 December 1959, Mr. Emil Jonsson, the Cabinet Minister responsible for IMS received Mrs. T. Gudmundsson, the director of IMS, and the writer. The task of the mission was explained to him. The economic value of developing climatology in Iceland was particularly stressed by way of some practical examples. His assistance in the efforts to strengthen the staff of the Service for the benefit of climatology was promised.

1/ Anders Ångström, Report on Meteorological Requirements of Iceland, United Nations document TAA/ICE/1/Rev.1.

2/ Ernest Hovmöller, Climatological information on Iceland, United Nations document TAO/ICE/4.

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Acknowledgements

8. My work was carried out in continuous contact with Mrs. T. Gudmundsson, the director of IMS, and in day-by-day collaboration with Mrs. Adda Bara Sigfusdottir, the head of the climate section of the Service. Mr. Flosi Sigurdsson, head of the instruments' section, contributed much towards clearing up points of uncertainty.

9. Dr. S. Thorarinsson, Iceland's well-known geographer and geologist, and Mr. S. Rist, hydrologist of the State Electricity Authority, gave important advice, especially about the distribution of precipitation; Mr. Hilmar Sigurdsson, of Flugfelag Islands, the airline company servicing inland connexions in Iceland, was very helpful in granting a free-of-charge ticket for a flight Reykjavik-Akureyri-Egilsstadir and return. To all these my sincere thanks are extended.

I. PRECIPITATION MAPS

10. The first work which I undertook was to investigate whether the precipitation data available from meteorological stations together with certain indirect methods which are likely to shed light on the distribution of precipitation over Iceland are sufficient for the construction of precipitation maps in accordance with specifications like those given for climatic atlases for land areas. 3/

11. Dr. E. Hovmöller, who visited IMS in autumn 1957, gave, in annex VIII of his report 4/ a list of sixty-one stations for which he had computed the average annual precipitation for the period 1931-1955. This period was chosen as it covered the observation period of a great number of stations, and as it could easily be used as a basis for the computation of climatological standard normals for the period 1931-1960. These stations were selected from the records as being suitable for the computation of normals, from the point of view of homogeneity and length of record. Five years of record was the lower limit. Owing to the general character of the network of stations 5/ none of these stations is at an elevation of more than 450 m. and more distant from the coast than 50 km. It has to be borne in mind that the introduction of wind shields started in 1949 only. Today almost all gauges have wind shields.

12. This list of data for annual average precipitation formed the starting point for my endeavour to construct a precipitation map of Iceland. It was clear from the onset that with so restricted a material only a map of annual precipitation could be aimed at at the beginning. If we consider that ten years of homogeneous records are required as a minimum for the computation for monthly averages of precipitation, the number of stations available is reduced further to forty-nine.

13. For the preparation of the map it was imperative to learn about the laws underlying the distribution of precipitation from all kinds of additional sources, direct and indirect, which could lead to a spatial arrangement of precipitation values, which could be considered as the best guess. These sources were the following:

(1) Precipitation records, of short duration, not used by Hovmöller;

(2) Results of measurements by means of cumulative rain gauges;

(3) Consideration of the increase of precipitation with altitude, under various conditions of exposure towards the prevailing weather types;

(4) Comparison of hydrometric data for certain catchments with the corresponding precipitation data;

3/ World Meteorological Organization, Ninth Session of the Executive Committee abridged Report with Resolutions (Geneva 1958) WMO-No. 67. RC.14, pp.134-147.

4/ See footnote 2.

5/ See footnote 1.

(5) Scrutiny of the results of studies of the glaciers of Iceland, and specifically of Vatnasjökull, with the aim of deriving precipitation data therefrom;

(6) Using the knowledge of local scientists about the relative properties of certain areas.

14. Some remarks may be added to explain these items further:

(1) In the course of the history of meteorological observations in Iceland, a number of stations were operated for periods shorter than five years at places which were not occupied again by stations; furthermore, some stations were established recently, but had not yet reached the age of five years, when Hovmöller computed the average values; all these data were reduced to the period of reference (1931-1955) by means of neighbouring stations, and bracketed when derived from periods shorter than five years.

(2) In a similar way annual precipitation amounts from cumulative rain gauges, which were erected in an area of hydrological study or near to a base for glacier research, were reduced to the uniform period of comparison. Both ways of addition of information resulted in another forty values of annual precipitation. But those which were derived from shorter periods of observation could only be used with some reserve in the preparation of the map. A table deposited with IMS shows the names of the stations, periods of record, stations used for reduction, and annual precipitation amounts for the period of reference.

(3) By inspecting the data some rules were derived for the distribution of precipitation with height, with distance from the sea, and with exposure to the directions from which precipitation uses to come. These rules had to be reinforced by data from other countries where elevation and distance from the sea play a decisive role in the distribution of precipitation, as e.g. in inland areas of Norway and Israel. A "normal" rate of increase with elevation was assumed (50 mm. of precipitation for every 100 m. of rise in elevation), in contradiction to much higher rates of increase of precipitation with elevation at such coastal ranges which lie normal to the directions of rain-bearing winds. Such rates were won from short-period records of station pairs situated on such ranges and on their base to the windward of them (300-450 mm. increase of precipitation for every 100 m. of rise). The fact that for narrow ridges the line of maximum precipitation is displaced somewhat to the lee-side of the crest of the ridge was observed and applied when appropriate.

(4) A certain proof of the correctness of these rules of distribution of precipitation was given by the comparison of hydrometric and pluviometric data. A collection of hydrographical data was found in a publication by the Hydrological Survey of the State Electricity Authority of Iceland, 6/

6/ State Electricity Authority, Hydrological Survey, Icelandic Fresh Waters, part 1, by Sigurjón Rist (Reykjavík, 1956) in Icelandic and English.

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in which for a considerable number of catchments, inter alia, mean run-off data were given for periods varying from four to twenty-six years. In addition a "drainage map" shows isolines for mean annual area run-off. Tests were made for a number of larger catchments, covering altogether about one quarter of the island, by comparing mean annual precipitation over the catchment with the mean run-off from it. In doing so extrapolation of precipitation amounts followed the rules mentioned under sub-paragraph (3) above. When comparing the integrated total precipitation of a catchment with its run-off, it had to be considered, (a) that surface run-off from areas with a certain kind of cover of volcanic material was small or non-existent owing to subterranean drainage through highly permeable rock, (b) that run-off from glaciers might not reflect correctly the precipitation on glaciers owing to the present state of lack of equilibrium in the balance of the glaciers, marked by the continuous retreat of the glacier tongues, (c) that evapotranspiration and evaporation from the catchment is thought to be small as compared with the possible errors involved in both the climatological as well as the hydrological assessments. Using these precautions the following deviations were found from data published by the Hydrological Survey: 7/

		Km^2	Per cent
1.	Pjórsá	7,200	0
2.	Skjálfandafljót	3,420	1
3.	Lagarfljót	2,800	3
4.	Jökulsá á Fjöllum	7,380	10
5.	Ölfusá	5,760	14

Considering the uncertainties involved in both approaches these results may be regarded as satisfactory.

(5) As the area covered by glaciers is more than one tenth of the total area of Iceland and without any permanent precipitation stations, 8/ and as the glaciers are considered as areas of very high precipitation, it was important to collect all data which could lead to an assessment of the distribution of precipitation on the glaciers. Measurements of annual snow accumulation, carried out by Ahlmann, Thorarinsson and Rist, 9/ especially on Vatnajökull were valuable for estimating the amount and distribution of precipitation on glaciers, and their change from year to year.

7/ See footnote 6.

8/ See footnote 1.

9/ (a) Jökull, ársrit Jöklarannsóknafélags Íslands (Yearbook of the Iceland Glaciological Society), Nos. 1 to 8 (Reykjavik, 1951 to 1958) passim.
(b) Vatnajökull, Scientific Results of the Swedish-Icelandic Investigations 1936-37-38; chapters III, V and VI, by H. Wison Ahlmann and Sigurdur Thórarinsson, Geografiske Annaler, Stockholm; Vol. XIX, 1937, pp. 176-211, Vol. XX, 1938, pp. 171-239, Vol. XXI, 1939, pp. 39-66.

(6) Local scientists who have travelled widely across their country were able to add considerably to clear up certain points of uncertainty about the relative rainfall in or dryness of certain areas from which no data were available. Their advice was mainly based upon character of weather, streams and vegetation.

15. The draft of the map of average annual precipitation amounts for the period 1931-1955 was made upon sheet 2086, Iceland, of the International Civil Aviation Organization (ICAO) World Aeronautical Chart, 1:1,000,000, compiled and printed by the Geodetic Institute, Copenhagen, and published by the Civil Aviation Administration, Reykjavík, in 1957. The map has layer tints of 300 metres vertical intervals, up to 900 m., and contour lines of the same interval higher up. Elevations of mountain peaks are given profusely. This map was thought to be suited as well in scale as in lay-out for the preparation of the precipitation chart, as the layer tints and peak heights gave a good lead for assessing local elevations and their influence on extrapolated precipitation values, and as in this scale it is still possible to show some local features without being forced into too much detail. Isohyets were drawn for every 400 mm from 4,000 mm down to 800 mm, and in addition the 600 mm isohyet was plotted. This is not in full agreement with specifications for maps for climatic atlases for land areas of the World Meteorological Organization (WMO), as these would have required isolines for every 100 mm interval from 400 mm to 800 mm, for every 200 mm interval to 1600 mm, and for every 400 mm interval up to 3,200 mm. But considering the scarcity of information and the exploratory character which the map has by necessity, it was thought unwise to show too many lines which would have given the impression of an assuredness which does not exist. The degree of confidence which may be given to the isolines is expressed by the way the lines are drawn. Full lines represent areas, in which data, based upon measurements of precipitation, are sufficient for a firm drawing of the lines, whereas whenever information was insufficient or indirect, broken lines were used.

16. Considering the draft map as a whole, it has to be marked as a reconnaissance map rather than a map which can be judged by standard procedures. In spite of the fact that all direct and indirect information which was available has been used for the preparation of the map, there is so little data available for the interior and for elevated areas that only few parts of the island can be regarded as represented by a standard which is usual in most of the European countries. Furthermore, it must be borne in mind that topography and glaciation of Iceland would even render the job of drawing a precipitation map difficult, if there were a coverage of data like that customary in other countries in Europe. Nevertheless, it is imperative for the best of those activities in Iceland which are interested in information about precipitation data (electric power authorities, agriculture, engineering, etc.) to base precipitation maps to be drawn in future on firmer ground.

17. In order to achieve this the following actions are advocated:

(1) Precipitation in Iceland falls partly as snow, and this in many cases when strong winds blow. There is a considerable uncertainty in this country about the percentage of the catch of the snow by the precipitation gauges in use (which, of course, should be 100). Loss of catch will be reflected by a decrease in the amount of precipitation which forms the base for the computation of the data used for the construction of the

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map. As a first step in order to assure the reliability of the present instrumentation (standard "Hellmann" 200 sq. cm-gauge with simplified Nypher shield, with the onfice at 150 cm. above the ground or higher, as maximum snow depth requires), it is advocated that at a suitable station, preferably in the north of the country, where snowstorms are frequent and less interfered with by sudden changes to rain, comparisons should be carried out for at least two years between the gauge used locally and the "Interim International Reference Precipitation Gauge". 10/ At the same location and time comparative observations should be made in order to prove the effectiveness of the wind shield used locally and the "snow cross". Observations of snow depth and density should be done as well.

(2) Establishing manned precipitation stations would add to our knowledge of the distribution of precipitation in such settled areas where our information is scanty, as e.g. some areas in the north-west and north of the country. Endeavours should be made to establish a small number of stations at strategic points, and grant the observer a small compensation for his efforts. The number of stations added thus to the existing network need not exceed ten.

(3) Considering the satisfactory results which have so far been achieved in Iceland with cumulative precipitation gauges, this means of exploring annual total precipitation should be used to a much wider extent. As these gauges ("totalizators") are cheap in their upkeep, as they are being visited only once in a year, the main financial burden is the production and the erection. These totalizators are especially fit for exploring the precipitation distribution in the interior parts of the island, wherefrom information is urgently needed, firstly in order to assist in planning the important and short communications which would combine the different parts of the country as directly as possible, and secondly by exploring agricultural possibilities in areas which are possibly less affected by severe weather conditions than the coastal districts. The erection of totalizators at characteristic points along the tracks crossing the island from south to north is advisable; not more than ten instruments are thought necessary at this stage. Operation should continue for five years at least. Valuable assistance can be gained by collaboration with the State Electricity Authority which maintains a number of measuring stations in the interior of the country.

(4) As much uncertainty exists with regard to the increase of precipitation with height, it is thought advisable to investigate the change of precipitation with elevation and exposure in certain hilly areas, where some economical interest (pasture land, water resources) is involved. This is especially important in such areas close to the sea where rise in elevation means catch of more precipitation from the rain-bearing winds. A set of ten totalizators should be available for these investigations which as a rule should not be carried out for more than two to three years, when the set could be shifted to another item of research. The line of totalizators to be erected in each case should reach from lowland to lowland across the mountain to be investigated.

10/ Op cit. footnote 3, pp. 51-52, 127-128.

18. By the means advocated in the previous paragraph it should be possible to draw up after five years of implementation of these measures a precipitation map, which would be much superior to the draft made now. It may furthermore be stressed that the present draft map is for the period 1931-1955. As soon as the normals for the standard period 1931-1960 have been computed for at least some thirty stations, an adjustment can be made to make the draft map applicable to the standard period.

19. In addition to the map for average annual precipitation, maps of average monthly precipitation for a standard period should be aimed at at an early stage. However, Hovmöller's computations have shown that forty-nine stations only yield monthly normals for the period 1931-1955. Owing to the greater variation of the amounts of precipitation of a certain month from year to year, a much longer period of homogeneous and reliable records is needed as the base for the computation of long-period averages. Ten years may be regarded as the lower limit of the period of records required. As to the number of stations which, hitherto, have produced homogeneous and reliable data for ten years and more is rather small, the construction of maps of average seasonal precipitation could be an intermediate step, which would fill in a gap and give valuable information on the annual run of the distribution of precipitation over Iceland. As the writer's stay in Iceland was too short, in order to try these maps, it is advocated that these maps should be drawn up, as soon as the 1931-1960 normals of monthly data are available. A seven to eight years' period of record is thought sufficient for the computation of seasonal averages. In accordance with the special character of the Icelandic climate it might be advisable to divide the year into the following seasons: January-March, April-June, July-September, October-December, which would unite the months of low rainfall (May, June), which would be thrown to different seasons if the "classical" division into seasons, used also by the hydrologists, were applied.

20. A further item requiring cartographic presentation is the number of precipitation days for characteristic months. In order to avoid bias caused by the quality of the observer, days with a precipitation of 1 mm or more should be chosen as a basis of evaluation. This would also be preferable as a lower limit as, for outdoor agricultural activities like hay-making, very small precipitation amounts would not be important. As the number of precipitation days is a relatively conservative parameter, relatively short periods of record, say five years, could be used, in order to reduce them by means of those of a reference station to the standard period chosen. Here maps of such months with the highest economic importance should have preference, as those of May to September.

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II. TEMPERATURE MAPS

21. Both precipitation as well as temperature maps of Iceland were tried before on an exploratory basis with only very few station data at hand and by using widely the general laws of extrapolation; 11/ these maps were mainly intended to give a very generalized picture of the distribution of these climatic elements over Iceland. In line with the task put before me, the intention was to try to produce maps which could be used for reading off spot data, or evaluating means for certain districts, for planning in any economic sphere which is likely to need such data. Therefore it was imperative to go into as much detail as the scale of the map would permit, without exaggerating in the drawing of detail which is not based on relatively sound principles of interpolation. This consideration necessarily leads to a different style of drawing precipitation maps on one hand and temperature maps on the other. As we are on much firmer ground when investigating the distribution of temperature with elevation than when dealing with the change of precipitation amounts with height, it follows that isotherms can be drawn with much more confidence on the base of maps showing topography, when only certain lapse rates are known, than isohyets for which only very vague rules of their spacing with elevation exist. This also leads to the fact that only in a few exceptional cases was it felt necessary to show isotherms by dashes, indicating a low degree of confidence in the run of the isotherm in question, whereas the dashes line was rather the rule in the precipitation map.

22. As the time at my disposal for developing temperature maps was restricted, it had to be decided upon which of the possible maps would be of the highest immediate benefit, without involving too much computational work for producing the basic data. It was clear that among temperature maps which have high preference 12/ only those of mean daily temperature could be considered, as those of mean daily maximum temperature would have involved a considerable amount of re-computation. 13/ Among maps of mean daily temperature, those of highest value would be those for the hottest and the coldest month, whereas the map of mean daily temperature for the year was not regarded as fulfilling any practical purpose at this stage. It was therefore decided that I should try to construct maps for the mean daily temperature of the extreme months.

23. Only few computed values for mean daily temperatures of January and July, which are the coldest and the hottest months in Iceland respectively, for a period of any length were available in the files of IMS, except those for the period 1901-1930, which were only available for a small number of stations. In order to have data available for a relatively large number of stations, it was thought necessary, at this experimental stage of map development, to adopt a recent ten years' interval

11/ (a) J. Eythórsson: On the Present Position of the Glaciers in Iceland; some preliminary studies and investigations in the summer 1930; Vísindafélag Íslendinga X, Reykjavík 1931.
(b) Vincent H. Malmström: A Regional Geography of Iceland; National Academy of Sciences - National Research Council, Publication 584, Division of Earth Sciences, Foreign Field Research Programme, Report No. 1, Washington, D.C., 1958, pp. 42-84.

12/ See footnote 3.

13/ See footnote 2.

as the period of reduction, and thus the period 1946-1955 was chosen. For this period averages of mean daily temperature for January and July was available from 48 stations. Data from 47 more stations which were available only for part of this period or for time intervals outside the period used as a standard could easily be reduced to this period by means of neighbouring stations. Furthermore, two other questions could better be solved by the use of the recent period of ten years: (a) different formulae of computation of daily mean temperature were used at the various stations, in order to take account of the local temperature régime and the number and times of observations available; for the period of reference of the maps the formulae were almost uniform at most of the stations and the deviations of the means as derived by these formulae from the true mean were computed by Hovmöller; 14/ in the case of a longer period much digging into the archives would have been necessary; (b) during the period of reference the type of temperature screen used in Iceland was changed at most stations from a small wall screen to a double-walled screen of Norwegian pattern with the thermometer bulbs exposed at 2 metres above ground 15/. As the influence of this change of exposure of the thermometers on the measurements is known only to a small extent 16/, it was thought advisable not to apply any corrections but to consider the period as uniformly "mixed" at all stations. In reducing the data from the 47 additional stations to the period of reference, the deviations of the formulae used were taken into account as far as possible as well as for the data of the stations to be reduced as for the stations by means of which the reductions were carried out. Where some uncertainty existed, data were taken as if representing the true mean, and bracketing was used for marking them as of lower reliability. Five years of records was taken as a lower limit; in a few cases when important information from areas not otherwise represented was involved, shorter periods of records were used for reduction. A list showing names, co-ordinates, periods of record used for reduction, and the mean daily temperatures for January and July for the period 1946-1955 from 95 stations is deposited with IMS.

24. Statistics of the stations operated on a routine basis by IMS show that the elevation of 52 per cent of the stations procuring mean temperature data range from sea level to 25 metres, 21 per cent are between 26 and 50 metres, 10 per cent each between 51 and 100, and 101 to 150 metres, and the remaining 7 per cent are higher than 150, the highest station having an elevation of 450 metres, which may roughly coincide with the mean height of Iceland. This distribution shows clearly the main handicap when assessing mean temperatures for most of the area of Iceland. In order to find out the temperatures which are likely to prevail at higher elevations, a survey was undertaken of temperature observations carried out in the mountains by scientific expeditions on a temporary basis. This lead to the compilation of data from four temporary stations 17/ which ranged in their elevation from 680 to 1155 metres; only one of these made observations during the winter-half of the year as

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14/ See footnote 2.
15/ See footnote 1.
16/ See footnote 2.
17/ (a) Année Polaire Internationale 1932-1933, Participation Suisse. Th. Zingg: Die Polarstation Snaefallsjökull 1932/33; Station Centrale Suisse de Météorologie, Zurich 1941; pp. 1-69.
(b) P. Bout, J. Corbel, M. Derran, L. Garavel, et Ch.P. Péguy: Géomorphologie et Glaciologie en Islande Centrale; Norois, Revue Géographique de l'Ouest et des Pays de l'Atlantique Nord, 2e année, No. 8, Poitiers, 1955; pp. 497-502, and additional mimeographed tables.
(c) F.G. Hannell and R.H.A. Stewart: Meteorological Observations in Central Iceland; Meteorological Magazine, Vol. 81, pp. 257-263, London 1952.
(d) See footnote 9.

well. 18/ Some more data were available from journeys undertaken during summer on Vatnajökull, the largest glacier of Iceland from elevations between 1,080 and 2,000 metres. 19/ All these data were compared with simultaneous observations at neighbouring lowland stations; thus certain insight was won into the vertical gradients of temperature prevailing in winter and summer in Iceland, in glaciated and non-glaciated areas. Some reference was also made to the mean temperatures in the free atmosphere above Keflavík at altitudes corresponding to a pressure level of 850 millibars (1,200-1,450 metres) for January and July. 20/

25. The data thus received were assembled in diagrams showing mean temperature for January and July, separately, as against altitude and distance from the sea. A fair fit was reached when a uniform rate of temperature change with height was assumed for January and July, and for non-glaciated areas, of -0.6°C/100 m. This gradient was confirmed in general by observations during summer 1959 at five stations in the birch forest area of Hallormsstaðir in Eastern Iceland. The stations followed a line upslope from 56 m. to 325 m. rising from the valley bottom south-eastwards. 21/ For the distance from the sea, the following temperature gradients were found: -1.5°C/100 Km for January, and +2.5°C/100 Km. for July. For glaciated areas that little evidence which was available seemed to indicate that there exists a relatively steep temperature gradient on the slopes of glaciers, which decreases considerably when the vast expanses of the glacier domes are reached, and might even turn, in summer conditions, into a negative gradient, owing to the trend for the formation of a subsidence inversion over the cold glacier surface. For winter conditions, the data from the only mountain station which was once kept in operation during winter, and the upper air information could serve as a very poor indication only.

26. Unfortunately there were no indirect methods available which could have shed a light on the distribution of temperature over Iceland. There is no map showing distribution of vegetational types or plant societies which might have given an indication about areas favoured equally by their climatic conditions. Similarly, maps of the height of the firn-line of the glaciers (the line along which accumulation and ablation are equal) which exist, 22/ indicate that the height of this line at a certain place is the product of the influence of summer temperatures, and precipitation around the year, which, both being uncertain, cannot provide new information. Personal observations received from scientist coincide more or less with the data available for the lowland areas.

27. The data available for the temperature maps were inserted on the same type of base map as that used for the precipitation map, 23/ as the scale was thought to be adequate and the presence of contour lines and layer tints was even more important for the construction of the temperature maps. In spite of the specification given for the intervals of isotherms of maps of mean daily temperature in annex 2 to resolution 30 (EC-IX) (Specifications of requirements for national, sub-regional and regional climatic atlases for land areas), 24/ which requests intervals of 5 or

18/ See footnote 17 (a).
19/ See footnote 7.
20/ U.S. Department of Commerce, Weather Bureau: Monthly Climatic Data for the World, sponsored by the World Meteorological Organization, vols. 8 to 12, Asheville, N.C., 1955-1959 (for upper air data of Keflavík).
21/ Verbal Communication by Mr. Páll Bergthórsson of the Icelandic Meteorological Service.
22/ See footnotes 11 (a) and 9 (b).
23/ See chapter I, paragraph 15.
24/ See footnote 3.

2.5°C, it was thought advisable to have the maps drawn by means of isolines with intervals of 2°C, with 0°C as the basic isotherm of the January map, and 10°C as that of the July map. As some evidence was available for the temperature gradients applied, it was thought possible to refrain from the use of broken lines for the isotherms extrapolated in this way. The information on temperature on the glacier surfaces and slopes, however, was thought to be so scanty that broken lines had to characterize the temperatures assumed for these areas.

28. The two maps thus received (see annexes II and III) may be grouped somewhat higher in the degree of confidence to be allotted to them than the precipitation map. They range in their degree of reliability equal to some temperature maps of similar scale for mountainous terrain of countries which have adequate information for lowland stations but which lack mountain stations. The lack of information from lowland areas was especially felt for the interior of the plain of south-western Iceland, and for certain areas in the north of the country. Furthermore, it has to be remembered that the map was based upon the period 1946-1955; after the end of 1960, it will be the task of IMS to compute normals of mean daily temperature for the months and for the year on the base of the period 1931-1960. When this job is completed, the values so won will serve as a base for the construction of the final maps of temperature. The draft maps presented here may serve then as a guide for the drawing of the final maps. It is not expected that the normals for the thirty years' period will deviate from the short-period averages used now in different ways in various areas and at various elevations. Therefore, the isotherms shown on the present drafts will shift on the new maps in one direction or the other, but their general run will remain similar, unless new facts are added which, of course, can change the general picture in certain areas. Therefore, it is thought that the draft maps presented here can give guidance for the lay-out of the maps of the normal period 1931-1960.

29. The observational material used for the maps has shown that sometimes periods of observation of very short duration have proved to be very valuable for completing the mosaic of data in a certain area. As the time available until the end of the international standard period 1931-1960 is very short, and as the need to fill certain gaps is urgent, the following recommendations are made:

(a) to erect at points of major interest for the better coverage of the map climatological stations at settled places as far inland as possible or at such areas nearer the coast which are yet sparsely represented by meteorological stations. These stations may coincide with the precipitation stations advocated in chapter 1, para. 17. 25/ But the number of climatological stations may be slightly smaller than that of the precipitation stations.

(b) to investigate the feasibility of the erection of temporary stations, consisting of a thermometer screen, a set of maximum and minimum

25/ See footnote 3.

/...

thermometers and a thermograph of as long a period of continuous recording as possible (one month or more). These stations are intended to be erected along the tracks which cross the interior of the island or possibly at places which are visited more or less regularly by the hydrologists of the State Electricity Authority. The screens may remain in place during the winter, but the instruments should be removed during the last visit in the autumn. It is thought that the evaluation of the thermograph tracks of even a small number of such stations for the months May to September may add very important information about the temperature régime of the interior of Iceland, especially of the lower elevations (200-600 m.), which may be of very high practical importance for the economy of Iceland. It is thought that six such stations, which may be transferred to other places after two years of records from their first sites, would be an adequate maximum figure.

(c) IMS to collect all information which can be traced of meteorological observations carried out by mountaineering parties, foreign and local, and scrutinize them as to their reliability. A request should be made to the relevant scientific bodies asking them that copies of all meteorological observations carried out by parties should be deposited with IMS. Furthermore, all parties should contact the Service prior to their departure into the mountains, in order to ensure that the observations are made as uniformly as possible.

30. The programme of maps to be constructed once the normal values for the period 1931-1960 are available is given by the specifications mentioned earlier. 26/ The writer feels that the following maps deserve a higher priority than others, owing to certain characteristics of the Icelandic climate:

(a) Mean daily temperature for the months of May, June, July, August and September;

(b) Mean daily maximum temperature for the same months;

(c) Mean daily range of temperature for the same months;

(d) Mean monthly number of days with maximum or minimum temperature exceeding certain limits:

(1) Maximum temperature less than 0°C

(2) Minimum " " " 0°C

(3) " " " " 5°C for the same months.

31. Probably the agriculturists may need these maps and others - as, for example a map showing the mean monthly number of days with maximum temperatures

26/ See footnote 3, paragraphs 2.3.1. and 2.3.6.

of more than 15°C - as a first requirement; but hydrological interests may need maps which cover months of the rest of the year; the same may be true for the electricity authorities which might be interested in such parameters as degree days for heating requirements. Thus, it may be advisable to leave the programme of climatic maps as open as possible, with the provision that those maps which belong to the "first group" of the specifications mentioned above should have a high preference owing to their character as an international requirement.

III. CLIMATOLOGICAL STATISTICS

32. The second part of the directives 27/ requests the statistical analysis of certain weather phenomena which are important for the national economy owing to their detrimental influence. This analysis should cover stations situated in various districts of the country, in order to show the geographical variation in the occurrence of these phenomena. Shortness of time precluded a thorough analysis of the major phenomena which are important in this respect: winds, cold and rain. But for each item a statistical treatment was carried out which showed characteristic differences which are largely due to geographic influences, and it is hoped that on the basis of these tables IMS will be able to continue in the direction of a thorough recognition of the geographical variation of climatic factors favourable or detrimental to the national economy, and first of all, to agriculture.

33. The first item analysed was wind. Hovmöller 28/ had already computed frequencies of wind directions and frequencies of wind force for a number of stations in the various areas of Iceland. Furthermore, frequencies of storms (Beaufort number 9 and more) are being published currently in "Veðráttan", the IMS monthly and annual weather report and frequency tables of wind directions for the period 1931-1950 for twelve stations were published there in 1954. 29/ Therefore, I regarded it as my task to show what additional information can be won, if winds are analysed for frequencies of direction and of force simultaneously. Two stations were chosen as examples, one situated at the sea coast in the west (Arnarstapi) and one well-sheltered in the interior in the east. The three summer months (June-August) and the three winter months (December to February) were united in one table each; thus four tables were received, which covered the period 1955 to 1957 (three years). It could be shown that, both in summer as in winter, the wind régime was not uniform at either of the stations. At Arnarstapi, in the far west, in winter light winds and strong winds were mainly from north-east or north, whereas moderate winds were more frequent from a westerly direction; in summer, conditions were more uniform with the frequency divided almost equally between northerly and south-westerly to westerly winds in almost all ranges of wind force. At Hallormsstaður, in a sheltered valley near the east coast, both in winter as in summer the wind régime was quite different for light winds and for strong winds. In winter light winds were from the west in most cases, moderate winds were mostly from north-east, and strong winds were mainly from the south. In summer north-east prevailed as the direction of the light winds, whereas moderate and strong winds were from south or south-west. It was not thought necessary to go into the explanation of these shifts of direction with changes of wind force. It was, however, thought important to point out the

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27/ See Annex V.

28/ See footnotete 2.

3/ "Veðráttan", monthly and annual summaries of the Icelandic Meteorological Service, 1924 to date.

existence of such changes, especially in connexion with the considerable importance of wind breaks and shelter belts in Iceland. The planning of these should be made after thorough consultation of the "wind spectrum" of a certain place. As shown by the analysis of the two stations, there exist very marked local winds which, for a detailed application of climatology to agricultural planning might be verified by topoclimatological or even micro-climatological observations in the field for which wind breaks are to be planned.

34. The second investigation went into the question of the incidence of frost during the growing season (May to September). Frost statistics are regularly published for most stations in Iceland by "Veorattan" both for the number of days with frost and for the date of the last and the first frost. Frost for the climatological analysis in "Veorattan" is the occurrence of a temperature of 0°C and below in the meteorological screen at two metres above the ground. I felt that my task in this connexion was the evaluation of the length of the periods which were free from any frost at the ground near a station during a number of years for geographically different stations, and to make a statement about the average length to be expected. The stations chosen were Reykhólar, near the sea in a plain in the west, Hallormsstadur in a sheltered valley in the east, and Sámsstadir in a very wide valley adjacent to the wide plain which forms the main farming district in the south-west. The period was the nine years from 1949 to 1957. As comparisons for a period of some length between minimum temperature in the meteorological screen and at the ground exist only for Reykjavík, the mean difference for cases of monthly minimum temperatures in the screen was evaluated for a three years' period and the months May to September, with the result of 3.3°C. Thus, it was assumed that at a normally exposed station during the summer months ground frost may occur when the minimum thermometer in the meteorological screen shows 3°C or less. The occurrence of a screen minimum temperature of 3°C or less was therefore taken as a limit for a frost-free period. A second evaluation was, however, undertaken simultaneously which allowed in the frost-free period the occurrence of one to three nights with screen minimum temperatures between 2.1 and 3.0°C, assuming that the minimum temperature of 0°C at the ground may occasionally be of very short duration and therefore may not be able to do considerable harm to sensitive crops, or the difference between screen and ground minimum temperature might occasionally be less than 3°C. Another minimum condition for both evaluations was the duration of a frost-free period of sixty days, as below this limit no crop would be able to develop fully. During the nine years' period of evaluation Reykhólar had six years with a frost-free period of at least sixty days with the more rigorous conditions, or eight years with the later ones; Hallormsstadur had one year only according to the first definition, and four years according to the second; Sámstadir in the mild south-west had seven good years according to the stricter definition, and according to the more lenient one each of the nine years had a frost-free period of sixty days or more. The relative absence of frost was also brought out by the mean length of the frost-free period at the three stations which gave 84, 66 and 97 days for the first condition, and 74, 70 and 102 for the second one. This analysis shows quite well the climatic favour enjoyed by the stations in the west and south-west of the island, as against the station in the east. But this analysis even more than that for wind in the previous paragraph, requests detailed topoclimatic analysis in order to be of practical use in agricultural planning. It is known that the station of Sámsstadir lies on a gentle slope. Its favourable figures may, therefore, not be representative for the wide plains in the neighbourhood. The same may be true for the two other stations. Therefore, it is imperative, in the opinion of the present writer, that climatic

data for the use of agricultural planning should be implemented by local climatic surveys as well as of the site of the reference stations as of the agricultural plot for which data are required. A further remark may be added here. Hallormsstaður, the sheltered valley station in the east, which shows such unfavourable results with respect to the frequency of frost-free periods, has mean daily maximum temperatures in the summer months which are markedly higher than those of the stations in the south-west and west. Similar conditions prevail at most inland stations in the north and north-east. This is an additional argument for the preference to be given to the drawing of the map of mean maximum temperature for the summer months. 30/ It is clear that the two climatic conditions: of frost-free periods of a minimum length and maximum temperatures, together with length of sunshine (and day-light) are the decisive climatic criteria for every agricultural planning in Iceland.

35. A third item for analysis in order to emphasize the regional differences was that of dry and wet spells during the growing season, May to September. Four stations were selected which represent quite well four agriculturally important areas of the country: Reykjavík for the south-west, Akureyri for the north, Hallormsstaður for the east, and Hólar í Hornafirði in the south-east. The period chosen was that of 1949 to 1958. A dry spell was defined as a period of three or more consecutive days with less than 1.0 mm. of precipitation during a single day. A wet spell, concurrently, was a period of three days and more when each day showed a precipitation of at least 1.0 mm. Dry and wet spells were thrown to that month in which occurred the maximum of their duration, or in case of equal length in two months, to that in which the spell started. As well frequency tables of the lengths of spell for the single months, and the whole season, as well mean values were computed. The tables, which are deposited with the Icelandic Meteorological Service, show quite marked differences in the frequency of dry as well as wet spells in the south-west and south-east as against that in the north and east, where dry spells are longer and more frequent, and wet spells shorter and less frequent. Putting figures on the most simple index, mean length of all spells per year shows for the dry spells 84 and 88 days for the south-west and the south-east as against 107 and 105 days for the north and the east, and for the wet spells 26 and 28 days for the south-west and the south-east, as against 14 and 13 days in the north and the east. But the main value of these tables is not in this generalization which only shows quite strikingly what is already locally known. Much benefit may be drawn from a more thorough analysis of the frequency changes in the occurrence of dry spells and wet spells from month to month, in the average, and also from year to year. Although some marked differences in the frequency figures from month to month were achieved from the ten years' period of analysis, it appears that ten years is too short a period of analysis for the emphasis of the characteristic changes from month to month at the different stations. Whereas 85 per cent of cases of wet spells last from three to five days, there are two modes of frequency of dry spells, one between three and four days, and a second one at about twelve to fourteen days, with 25 per cent of all cases exceeding ten days in length. It, therefore, appears that two types of dry spells should be differentiated, as also their role in agriculture is quite different. The short dry spell is beneficial, especially towards the end of the growing season, for the progress of haymaking, whereas the long dry spell - this time mainly up to the middle of the growing season - may cause drought conditions. For the ten years of

30/ See footnote 2, chapter 2, paragraph 10.

record there occurred eleven cases of dry spells of twenty days and longer at Akureyri; the corresponding figures were six for Hallormsstaður, five for Hólar, and two for Reykjavík. In order to make a correct assessment of the damage done to agriculture by these extended dry spells, climatological water balances should be drawn up by deducting from the water available in the ground at the beginning of the dry spell that spent by evaporation and evapotranspiration, in order to decide whether supplemental irrigation might be advisable under such conditions for valuable crops. The installation of two or three evaporation pans of the United States Weather Bureau Class A type may be advocated in this connexion; the south-west, the north and the east are the areas where evaporation observations would be of primary importance. A final remark refers to the basic condition of the frequency table (three days with precipitation of 1.0 mm. or more following each other) which was chosen at random after a conversation with leading agriculturists. It is clear that the basic argument should be related as well to rainfall intensity as to rain amounts, as a drizzle lasting one day has a different effect on soil moisture, hay drying, etc., as a short-lasting shower which produces the same amount of rain. It is therefore the opinion of the present writer that the one and only rainfall recorder in Iceland, stationed at Reykjavík, should be supplemented by at least two or three more instruments of this type, to be established at characteristic stations of the main regions not yet represented, in order to enable the Icelandic Meteorological Service to draw firmer conclusions about the role of rainfall in the growing season of Iceland. It goes without saying that there are many other important activities (road construction among them) for which the knowledge of the regional variations in rainfall intensity are highly desirable.

IV. FINAL REMARKS: RECOMMENDATIONS

36. These remarks are intended to form a summary of the observations made in connexion with the terms of reference of my mission. These are partly included in the previous chapters as far as they refer to the detailed items of the task carried out. But as I feel that my mission constitutes a certain stage in the technical assistance given to Iceland in order to develop her facilities in the field of climatology and meteorological equipment, I regard it my duty to co-ordinate the recommendations made in the previous chapters within the wider frame just mentioned, and to enumerate them here together with such requirements already proposed by my predecessors. The suggestions are arranged according to the following headings:

Meteorological instrumentation
Climatological activities
Personnel
Technical assistance
International collaboration.

37. The addition of new meteorological stations to those existing is a fundamental requirement for IMS in order to enable them to fulfil the elementary task of supplying information about the climate of the island in its various regions. This was already stressed in the report of Dr.Ångström. 31/ Furthermore, special equipment is necessary, in order to comply with requests which sooner or later will be put to the Service by agriculturists, horticulturists, engineers, hydrologists, etc., as, for example, to give information about rainfall intensity, rates of evaporation and evapotranspiration, micro-climatic data, etc. Therefore, the following increase in meteorological equipment is suggested.

(a) six meteorological stations, consisting each at least of meteorological screen, four thermometers, and shielded precipitation gauge; 32/

(b) six unmanned temperature stations (screen, maximum and minimum thermometers, thermograph with clockwork of long run); 33/

(c) four precipitation gauges for additional manned stations, in areas with few or no stations up to now; 34/

(d) twenty cumulative precipitation gauges, half of them for fixed stations in the interior, the other half for short period measurements across ridges; 35/

31/ See footnote 1, chapter 8.

32/ See para. 17 (2) and 23 (a).

33/ See para. 23 (b).

34/ See para. 17 (2).

35/ See para. 17 (3) and (4).

(e) one International Interim Precipitation Comparison Gauge; 36/

(f) three recording precipitation gauges, in addition to the only one yet erected in Iceland; 37/

(g) two or three evaporation gauges, of the United States Weather Bureau Class A type; 38/ these instruments are of especially high importance in order to assess the water need of crops during prolonged dry spells in summer; 39/

(h) equipment for micro-climatic observations of temperature in the field; for forest nurseries, frost incidence, effect of wind breaks, etc., by means of thermo-couples. 40/

38. In order to utilize more thoroughly by the climate section of the IMS observations made hitherto and to be made in future with the existing equipment and the equipment whose addition is suggested, it is important that certain changes will be made in the organization of this division. From the date of the employment of the first and only meteorologist in the division (1953) until now, the main task was to bring the publication of the routine issue "Veðráttan" (monthly and annual weather report) 41/ up to date. This important goal has almost been reached, by restricting the delay from five years to one year. But it was reached at the expense of all other activities, which a climate division as a rule has to fulfil, as, for example, issuing normal values, climatic maps, tables of the frequency of occurrence of hazardous elements (storms, heavy snow, frost, fog, intensive rainfall, etc.), climatic descriptions of Iceland and its coastal waters, and the supply of specific information to economic factors of the country (agriculture, fisheries, industry, hydrology, engineering, aviation, etc.). These tasks will come to the foreground in the future, inasmuch as the economic elements of the country will become aware of the need for this information. The following is suggested as means towards this goal:

(a) Automatization of the publication of routine and other data. "Veðráttan" has already, since 1949, made ample use of punched cards. A further step would be the publication of its tables directly from machine tabulation. For this purpose it is considered highly desirable that the head of the section would be given the opportunity of studying the practical application of this method abroad;

(b) The establishment, within the Service, of a small offset press, in order to be able to print "Veðráttan" in its new form at minimum cost; the press should be used for printing of all the additional climatic information which is going to be issued in future, and in addition, for printing all forms,

36/ See para. 17 (1).

37/ See chapter III, para. 29.

38/ See footnote 1, chapter 3, sections (d) and (e).

39/ See chapter III, paragraph 29.

40/ See chapter III, paragraphs 27 and 28.

41/ See footnote 30.

maps, charts (for self-recording instruments) needed in all divisions of the Service (with the only exception of such items which are too large for the press as, for example, large synoptic maps and radiation charts);

(c) The collection of all available meteorological data derived from sources other than meteorological stations, as scientific and mountaineering expeditions, 42/ other interested agencies (agriculture, hydrology), ships (cargo ships as well as fishing trawlers); furthermore, endeavours should be made to add to the archives of the Service data from foreign ships plying in the vicinity of Iceland; it is regarded as important in this connexion to create liaison with vessels stationed at and visiting Reykjavík harbour. The officer entrusted with this part-time task should have thorough meteorological education and understand the problems of maritime meteorology.

(d) The archives of the Service are spread already today all over its premises, and a concentration, perhaps in the adjacent building in which the instrument workshop is housed, is highly recommended; a climate section can only fulfil its task properly when its archives are well arranged and properly accessible; the upkeep of the archives could be done by one person together with that of the library of the Service. It is not anticipated that the person in charge of the library and the archives is drawn from the staff of the climate section.

39. In order to carry out the climatological activities mentioned in the previous paragraph, it is thought necessary to increase the staff of the climate section, at least by one meteorologist and one assistant, as already suggested by Dr. Angström; 43/ the allocation of their duties arises from Dr. Ångström's suggestions and what is suggested in the previous paragraph. Considering the tasks which are allotted to the climate section, two meteorologists and three assistants are a bare minimum. Information supplied to a branch of the Icelandic economy (agriculture, power stations) may add to the national balance a greater sum than that needed for the upkeep of the section for years. The increase in instrumentation and network proposed in para. 32 will certainly be connected with an increase of the staff of the instrument section as well.

40. (a) As mentioned earlier, 44/ it would be highly advisable if the chief of the climate section could make herself acquainted with methods of publishing climatic summaries directly from punched card tabulation. The best time for this study would be when the publication of "Veddráttan" is brought up to date, which may be expected at the end of 1960. Norway may be regarded as a suitable place of study. This could be combined with a study of the means and ways that maritime climatology could make use of marine meteorological observations and oceanographic data. In addition, new methods in climatology could be studied. The Icelandic Government may wish to include a WMO fellowship for this purpose in its request for the 1961/1962 technical assistance programme.

(b) In connexion with furthering agriculture in Iceland by supplying climatological and micro-climatic information, it would be of great benefit if the

42/ See chapter I, para. 14 (5) and chapter II, para. 23 (c).

43/ See footnotes 1, 11 (b), 17 (b) and (c).

44/ See paragraph 32 (a) above.

/...

services of an expert in agricultural meteorology could be obtained from WMO who is acquainted with the carrying out of micrometeorological measurements for a period of three months in summary 1962; his presence, of course, is only of use when the measuring equipment advocated above in para. 31 (h) is available.

(c) The main task of the expert was undertaken one year prior to the end of the international normal period which will give for the first time the opportunity in Iceland to assemble climatological standard normals for a relatively large number of stations for the period 1931-1960; as the problems connected with the computation of these normals are not simple (see, especially, chapter II, para. 17), it might be advisable to request the visit of an expert in climatology, in order to give assistance in the problems connected with the computation of the normals and the adjustment of the climatic maps. Two months is considered as an adequate period. This mission should take place at some time after the return of the head of the climate section from her fellowship in Norway (see sub-heading (a) above), viz., in 1963.

41. Finally, it was felt that the work of the climate section in IMS was being performed in isolation. Contacts with climatic sections of other meteorological services do not exist, and all foreign connexions are restricted to literature - which is not very ample in the field of routine climatology - and the contact with the three experts which have visited Iceland hitherto. It is highly advocated, therefore, that the head of the climate section become a member of the Commission for Climatology of WMO and participate in the work of the Commission. This would be of great assistance to the climatological work in Iceland, as it would form a means of communication in order to become acquainted with new procedures, to the benefit of the efficiency of the section.

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ANNEX I, II, and III

(see end of report)

ANNEX IV

TOURS OF VISIT

Tour I - 22 October

Participants: Mrs. T. Gudmundsson
N. Rosenan
Flosi Sigurdsson

Route: Reykjavík-Rjúpnahaeð-Hafnarfjördur-Reykjavík Airport-Reykjavík

Visit to Geophysical Station at Rjúpnahaeð (rain collected for chemical and radiological analysis, aurora photographs). Catch of high rainfall as compared with Reykjavík. Airport meteorological centre with main observing station: outfit.

Tour II - 24 to 25 October

Participants: N. Rosenan
Eysteinn Tryggvason
Thorsteinn Ársaelsson

Route: Reykjavík-Hveragerði-Hella-Vík í Mýrdal-Mýrdalssandur and return.

Visit to three meteorological stations en route; seeing the area of very high precipitation in the south, and inspecting natural setting for high differences of precipitation amounts (Vík-Loftsalir); glacier tongues and their outflow; passing through rich agricultural area in south-west.

Tour III - 7 to 11 November

Participant: N. Rosenan

Route: Reykjavík-Akureyri-Egilsstaðir-Akureyri-Reykjavík
(by plane - courtesy of Messrs. Flugfélag Íslands)

Intended to show contrast of the landscapes in the humid south-west and in the more arid north and north-east. Owing to delay in time of departure, flight Akureyri-Egilsstaðir-Akureyri took place only near and after dusk, but part of the "desert area" of Iceland could be seen. Detained by severe snow storm at Akureyri, since all connexions between Akureyri and the rest of the world were discontinued from 8 to 10 November. Studied problems of precipitation catch in shielded rain gauges during snow storm with winds up to 35 knots, and representativeness of measurements of snow depth.

Tour IV - 17 November

Participants: Adda Bára Sigfúsdóttir
N. Rosenan

Route: Reykjavík-Thingvellir-Sog-Ljósafoss-Hveragerði-Hveradalir-Reykjavík

Visit to area of high precipitation on permeable ground; inspecting new power plant at Sog and discussing climatic information useful in the construction and working phases of hydro-electric power stations seeing meteorological station at second power station; visit to hot houses at Hveragerði and seeing conditions under which bananas are grown; visit to Hveradalir, place of highest measured precipitation amount in Iceland by standard means (2,900 mm).

Tour V - 20 November

Participants: Adda Bára Sigfúsdóttir
N. Rosenan
Thorir Sigurðsson

Route: Reykjavík-Hafnarfjörður-Krísuvik and return.

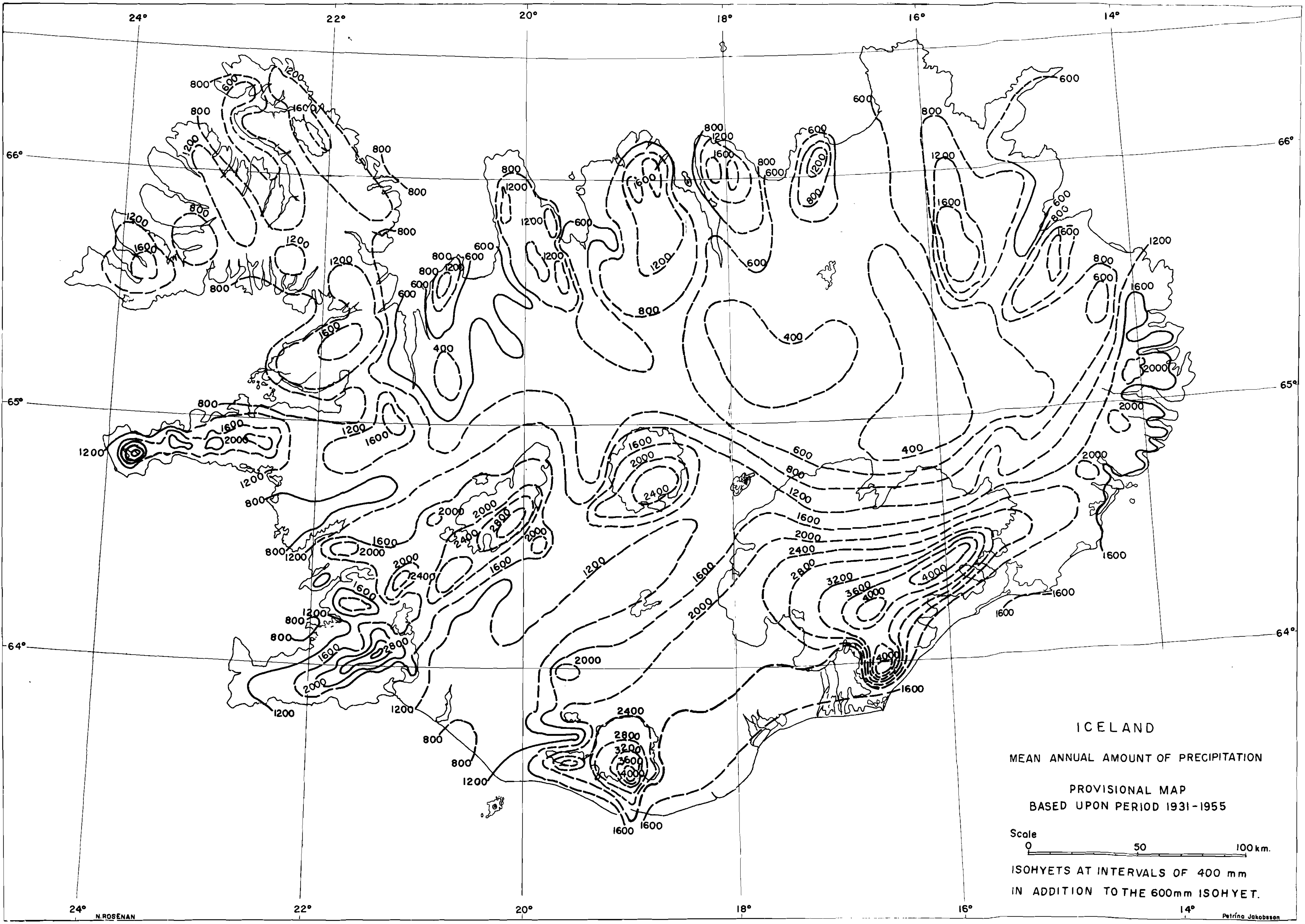
Visit to area of high precipitation without run-off owing to high porosity of lava areas; Solfataras of Krísuvík, and lake Kleifarvatn without outlet.

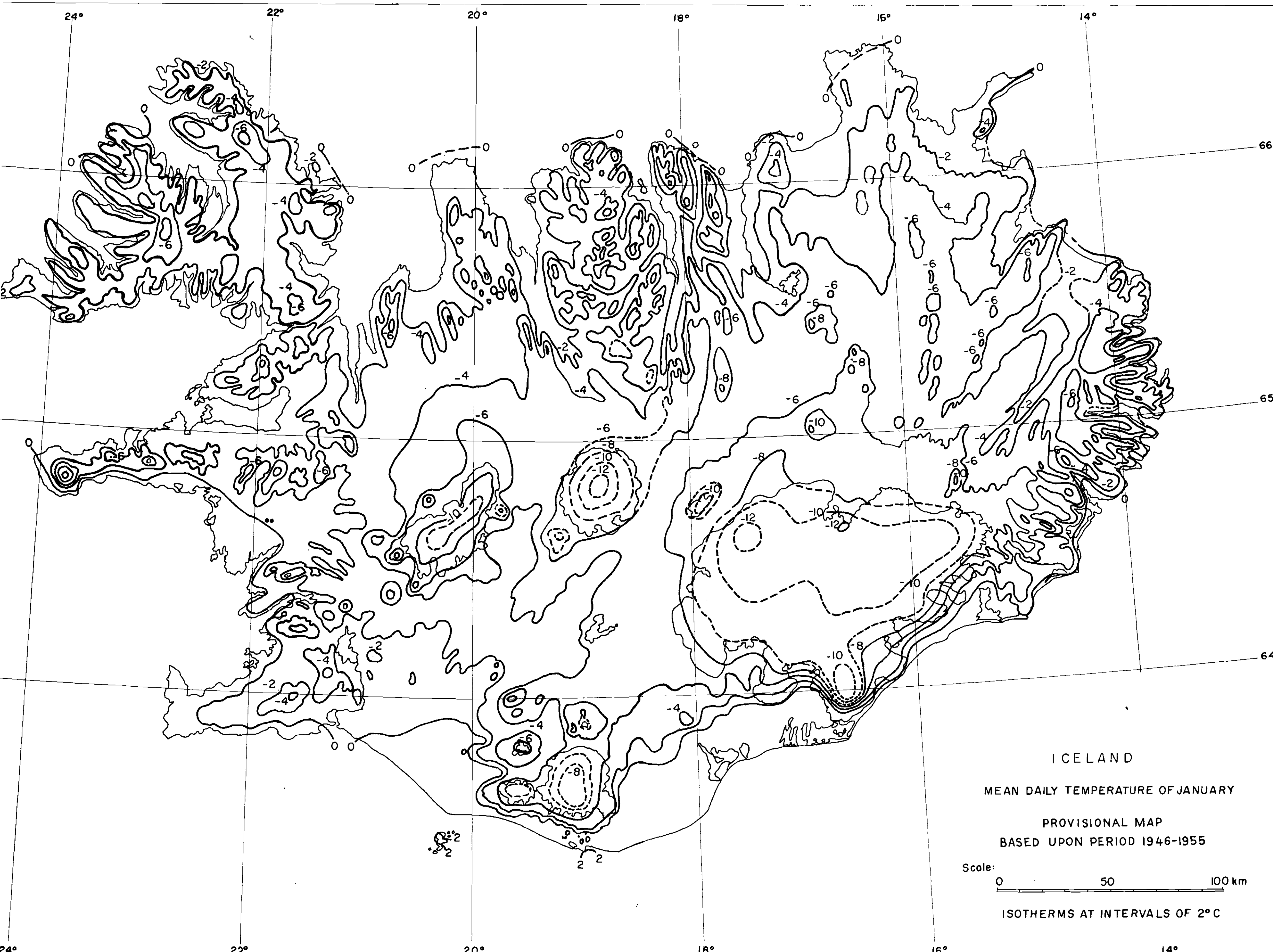
Annex V

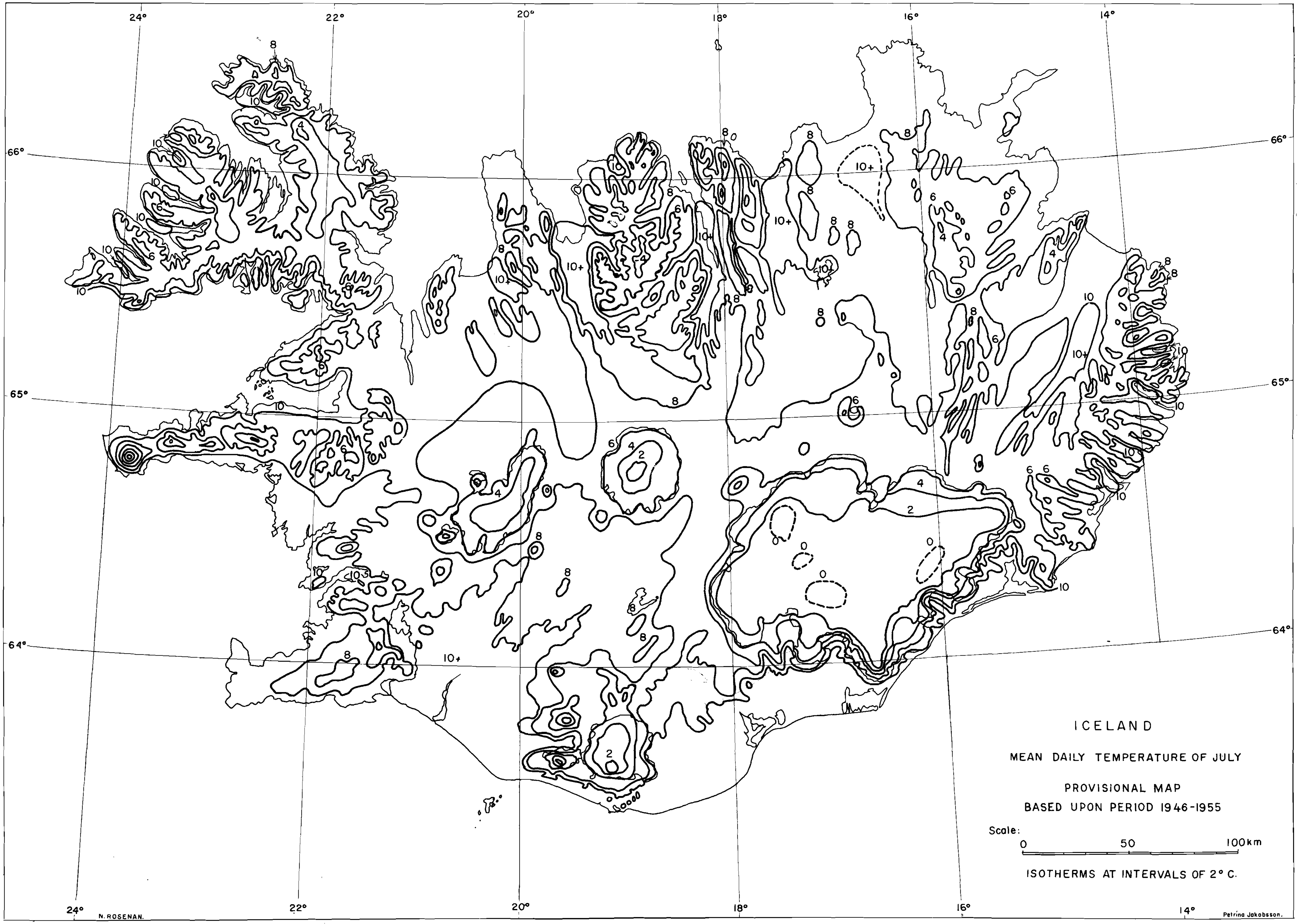
DIRECTIVES TO MR. ROSENAN RELATIVE TO WMO TECHNICAL ASSISTANCE MISSION TO ICELAND

(a) The network of climatological stations in Iceland is not sufficient to permit the construction, by ordinary methods, of climatological maps, such as maps of monthly normals of temperature or precipitation. It should be investigated whether indirect methods may permit the construction of such maps, and, if that is not the case, what requirements are necessary to ensure that the construction will be possible within a relatively few years.

(b) The occurrence of unfavourable weather conditions during the winter half-year, such as severe gales and excessive precipitation, and during the summer half-year, such as prolonged periods of cold, wet or dry weather, are a matter of considerable economic importance in Iceland. The frequencies of such phenomena show marked geographical variations which should be investigated. An effort should also be made to study the connexion between weather anomalies in Iceland and simultaneous anomalies of the general circulation.


ICELAND
MEAN ANNUAL AMOUNT OF PRECIPITATION
PROVISIONAL MAP
BASED UPON PERIOD 1931-1955
Scale
0 50 100 km.
ISOHYETS AT INTERVALS OF 400 mm
IN ADDITION TO THE 600mm ISOHYET.
N. ROSENAN
Petrína Jakobsson


ICELAND
MEAN DAILY TEMPERATURE OF JANUARY
PROVISIONAL MAP
BASED UPON PERIOD 1946-1955
Scale:
0
50
100 km
ISOTHERMS AT INTERVALS OF 2° C
24°
22°
20°
18°
16°
14°
66°
65°
64°
N.ROSENAN.


ICELAND
MEAN DAILY TEMPERATURE OF JULY
PROVISIONAL MAP
BASED UPON PERIOD 1946-1955
Scale:
0
50
100km
ISOTHERMS AT INTERVALS OF 2° C.
N. ROSENAN.
Petrina Jakobsson.
24°
22°
20°
18°
16°
14°
66°
65°
64°