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CLIMATOLOGICAL INFORMATION ON ICELAND

Prepared for the Government of Iceland

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appointed under the
United Nations Programme of Technical Assistance

UNITED NATIONS
Commissioner for Technical Assistance
Department of Economic and Social Affairs

Ernest Hovmöller er fæddur í Danmörku 1912. Hann lauk magisterprófi í veðurfræði við Hafnarháskóla árið 1937 og starfaði síðan á dönsku veðurstofunni fram til ársins 1946. Þá flutti hann til Svíþjóðar, tók þar fil. lic. próf í fræðigrein sinni og gerðist deildarstjóri veðurfarsdeildar sænsku veðurstofunnar árið 1955. Hovmöller hefur mikið unnið að veðurfræðirannsóknum og ýmsar greinar hafa birzt eftir hann í vísindaritum. Hann dvaldi hér á landi, sem tæknilegur ráðunautur Veðurstofu Íslands röska þrjá mánuði árið 1957.

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FOREWORD

In accordance with a request from the Government of Iceland concerning technical assistance, the Technical Assistance Administration (now the Bureau of Technical Assistance Operations) appointed Mr. Ernest Hovmöller, expert of the World Meteorological Organization, to advise on certain climatological matters in Iceland.

The duration of Mr. Hovmöller's assignment was from 15 September to 31 December 1957.

His final report to the Government follows.

I. INTRODUCTION

In accordance with a request from the Government of Iceland Dr. Anders Ångström was appointed by the Technical Assistance Administration as a WMO expert to advise on Climatology and Agricultural Meteorology. The duration of Dr. Ångström's assignment was from 30 July to 9 September 1956.

In his final report to the Government of Iceland (8), Dr. Ångström proposed further expert aid to be given to Iceland within the field of meteorology. Thus, he proposed that a climatological expert should be sent to Iceland for a period of about three months.

Dr. Ångström's proposal in this respect was approved by the WMO, and when a formal request had been made by the Government of Iceland, I was appointed to the aforementioned task.

My terms of reference arose from Dr. Ångström's statements regarding the requirements of increased activity within the field of climatology in Iceland. Dr. Ångström stressed the need for more observations and a wider utilization of the material available for both meteorological and practical purposes.

During my appointment, from 15 September to 31 December 1957, I have endeavoured to work along the lines indicated above. According to my terms of reference, I have limited myself to problems related to the climatology of Iceland and the activity of the climatological section of the Meteorological Service of Iceland (Veðurstofan).

This implies that I have occupied myself with observations made at synoptic stations to the extent in which they are used, or could be used, for climatological purposes, whereas I have left aside the purely synoptic viewpoints. Questions regarding the instrumental equipment of climatological stations have not been entirely disregarded, but as Dr. Ångström's report contains a proposal that an expert on instruments and methods of observation should be sent to Iceland, all details regarding instruments and all final decisions in this respect were left to be taken up between Veðurstofan and this expert.

It seems right to point out at this place that my task was facilitated and my efforts supported in every possible way by the staff of Veðurstofan. I was told that not only advice but also criticism would be welcome, and I soon felt that this was perfectly true.

It may also be mentioned that the need for technical assistance to the meteorological service in Iceland is due to the lack of funds available in that country and to the resulting undermanning of certain sections. The scientific training and practical ability of all staff members with whom I had any regular contact were at a high level. This latter fact gives the best possible assurance that any financial means, domestic or foreign, which could be made available to further the study and the application of climatology in Iceland, would be used judiciously, to the benefit of the economy of the country.

Lectures

On 28 October, I was invited by the Icelandic Society for Natural Science to give a lecture on the development of climatology, in particular as regards its practical applications.

At the request of the staff of Veðurstofan, I gave a series of lectures on statistical methods in climatology.

Travel

During the winter half-year, communications in Iceland are not favourable for an extensive program of visits to meteorological stations, some of which are situated in rather inaccessible localities. My program of travel was therefore limited. However, the staff of Veðurstofan took pains to arrange some visits which from my point of view were both interesting and valuable. Thus, in September I visited Sámsstaðir (of interest mainly because of its location in an agricultural district) and Þingvellir, and in October the aerological station in Keflavík. In December the Icelandic air transport company Flúgfélag Íslands kindly offered me a free return trip to Akureyri, which made it possible for me to visit the weather station in Akureyri and an experimental forest station, Vaglaskógur, where it is planned to establish a new climatological station.

II. RECOMMENDATIONS AND SUGGESTIONS

For easy reference, the recommendations and suggestions contained in the present report are repeated below, with the exclusion of a few suggestions of purely technical nature.

1. It is recommended that the standard normal temperatures used for Icelandic stations be revised **(page 9)**.

2. I recommend a revised procedure for the computation of current monthly mean temperatures **(page 9)**.

3. I recommend that observations should be made at 20 h Icelandic time at all stations where this is posssible **(page 9)**.

4. The daily maximum and minimum temperatures used for climatological purposes should be 24-hour extremes **(page 9)**. I recommend that when the mean maximum and minimum temperatures are computed for the standard period 1931-1960, they should be based, in principle, on the revised definition.

5. I recommend that the observations made at a number of Icelandic stations be included in the annual supplement of "Veðráttan" **(page 10)**.

6. I recommend that the publication in extenso of observations made at a small number (four to six) of the stations in Iceland, which was discontinued in 1924, be resumed when the data for 1961 are available **(pages 10 and 15)**.

7. It is recommended to arrange for special meteorological observations to be made at forestry experimental stations **(page 15)**.

8. Contact should be maintained between Veðurstofan and the Icelandic authorities and scientists in the fields of agriculture and forestry, with a view to ensuring a closer collaboration regarding the utilization of climatological data **(page 15)**.

9. I recommend that as detailed meteorological observations as possible should be made on trawlers and other ships fishing in the sea around Iceland **(page 15).**

10. I endorse Dr. Ångström's recommendation that at least one room be added to the space available for the Section for Climatology **(page 17).**

11. I endorse Dr. Ångström's recommendation to solve the housing problem of Ve urstofan by reserving a special building for this purpose. Such a solution would greatly facilitate the contact between the Weather Section and the Section for Climatology, to the mutual benefit of these sections **(page 17).**

12. Regarding Dr. Ångström's proposal to extend the network of meteorological stations in Iceland, I consider that the implementation in full of this proposal should be given high priority **(page 18).** Special attention should be given to the possibility of obtaining observations from uninhabited areas **(pages 18 and 93).**

13. I endorse Dr. Ångström's proposal regarding an increase of the staff of the Climatological Section. Several of the recommendations contained in this list can not be fully implemented as long as the staff is quantitatively insufficient **(page 18).**

14. I endorse Dr. Ångström's recommendation that scholarships should be sought for professional training under the Expanded Programme of the United Nations Technical Assistance, and recommend in particular that an Icelandic climatologist be given an opportunity to study climatology, including climatological statistics, in two or more foreign countries **(page 18).**

15. Further statistical studies of wind conditions in Iceland are suggested. Special attention should be given to questions of practical importance, as specified on **page 63.**

16. I suggest a thorough analysis of representative humidity data obtained from observations in Iceland **(page 90).**

17. It is suggested that the study of monthly mean values of precipitation in Iceland be continued, taking into account all available data **(page 103).**

18. I suggest further studies of daily amounts of precipitation along the lines described in Annex IX.

III. CLIMATOLOGICAL OBSERVATIONS IN ICELAND

A. HISTORY

The first comprehensive weather observations in Iceland were made more than 100 years ago in Stykkishólmur, on private initiative but in a way which has made it possible to use this material together with observations carried out later at official stations. The first network of climatological stations in Iceland was established in 1874 by the Danish Meteorological Institute.

Naturally, the number of stations was at first very small, but the observations made at these stations were fairly complete, and the results were published in meteorological year-books in much the same way as is still used in most countries. The number of stations increased considerably during the following years, but the observations made at some of these stations were in some cases rather incomplete. The publication of the material was continued in nearly the same way until 1923, but from then on only monthly values, including some frequencies, have been published. This reduction, which was considered necessary for economical reasons, is regrettable from several points of view.

The network of stations, however, has improved rather continuously: in particular the number of stations making weather observations is now much larger than 20 years ago. As for the number of stations at present, reference is made to the report of Dr. Ångström (8).

However, as pointed out by Dr. Ångström, the network of climatological stations in Iceland is still insufficient for many purposes. It has not been possible, for instance, to construct reasonably reliable climatological maps of the whole country, nor to answer several questions of practical significance, in particular problems of interest to agriculturists and civil engineers. Dr. Ångström's proposals regarding an improvement of the network, and the possibilities of publishing a larger part of the observations as well as more complete statistical tables, are discussed in a later section of the present report.

B. ROUTINE USE MADE OF CLIMATOLOGICAL OBSERVATIONS IN ICELAND

The monthly publication called 'Vedráttan' (11) differs somewhat, though not very much, from similar publications in most countries. It contains a summary stating the weather experienced during the month, the departures from normal conditions, and an account of damage caused by severe weather. The main part of the publication, however, is a table, giving (for all existing stations) monthly mean values and extremes of temperature, precipitation data for the month, wind frequencies, the frequencies of cloudy and clear days, data regarding snow cover, etc. Smaller tables contain information regarding sunshine and the diurnal variation of temperature. The preparation of the observation material for this publication is accomplished to a large extent by means of data-processing machines. The observations from all synoptic stations are transferred to punch-cards; all summations, the frequency tables for the wind, and in fact most of the numerical values used for or given in 'Veðráttan' are produced by means of these punch-cards. Iceland was one of the first countries in Europe to introduce this technique and is still using it, by proportion, more extensively than most other countries. The initiative taken by the Director of Veðurstofan, Mrs. Guðmundsson, in 1950 to introduce punch-cards for climatological purposes, has proved very profitable, and if any change should be proposed regarding the use of punch-cards in Iceland, it should be an extension rather than a reduction.

An annual supplement to 'Veðráttan' contains information similar to that given in the monthly publications, but in this case regarding the year as a whole. Besides it contains some additional information regarding e.g. radiation, atmospheric ozone, stations and instruments.

The contents of 'Veðráttan' were discussed at some length during my stay. In my opinion most of the information which is given in the tables or the text without belonging to the normal contents of publications of this kind, is valuable for purposes more or less specific to Icelandic conditions and therefore should be given in future also. However, I made some proposals regarding the definition and computation of the temperature data given in the tables. As described in Annex I, the way in which monthly mean temperatures are computed, is different for different stations and in some cases not quite satisfactory. As a result of my investigation regarding this problem I recommend:

(a) that the normal temperatures computed for Icelandic stations for the period 1901 - 1930 should be revised in order to give more correct values of the actual 24-hour monthly mean temperatures;

(b) that the current computation of monthly mean values should be revised, as stated in the last section of Annex I;

(c) that an observation should be made at 20 h at all stations where this is possible.

A revised definition is proposed regarding the monthly means of daily minimum temperature, as discussed in Annex II.

I further propose that the present monthly table showing the monthly amount of sunshine at different hours of the day at stations for which such information is available, should be replaced by a table showing the number of hours of sunshine day by day at the same stations. Regarding the table showing the monthly mean temperature at different hours of the day at a few stations, I propose an increase of the number of stations, but a reduction of the number of hours from 12 to 8.

As for the contents of the yearly supplement, I pointed out that this supplement gives a good opportunity of publishing summaries of the type regularly published in meteorological year-books by most countries. It seems advisable to publish tables of this kind for a number of stations in Iceland, although there may be good reasons for modifying the contents of the tables with regard to local requirements. Tables of this kind should include some information regarding temperature frequencies.

It is further recommended that the observations from four to six Icelandic stations, including one or two stations in the interior, be published annually in extenso.

Tables of this kind are published in the meteorological year-books of most European countries, including all countries in Scandinavia. They are of lasting value both for scientific and for practical purposes. It is suggested that the publication of these tables should begin when the observations for 1961 are available. It is possible to prepare extenso tables mechanically from punch-cards of the type already in use in Iceland; this method is advantageous from an economical point of view.

It may be mentioned that similar tables, containing observational data for selected Icelandic stations, were published regularly from 1874 to 1923 (4, 9).

C. PROBLEMS CONCERNING 'NORMAL VALUES', FREQUENCY STATISTICS, ETC.

Some preliminary climatological mean values for Icelandic stations were published as much as 60 years ago (5). Most of these values were based on 10-20 years of observation only.

When the International Meteorological Organization had recommended that the first three decades of the present century should be regarded as a standard period for which climatological 'normals' should be computed, as far as possible, in all countries, the computation of mean values for this period was taken up also in Iceland. Normal values of air pressure, temperature and precipitation for the standard period were published in various annual supplements to 'Veðráttan' during the 1940'es. However, in several cases the computation had to be based on insufficient data, many stations having only short series of observation. Some problems associated with the application of this set of normals or with the preparation of a new set of normals for the following standard period, 1931-1960, are discussed in Annexes VI and VIII.

A few statistical tables published in 'Veðráttan' contain climatological information based on observations made after 1930. However, due to lack of personnel, very little statistical evaluation of Icelandic meteorological data has been possible. I soon found it desirable to carry out as much work of this kind as possible during my stay, and to make up plans for further statistical tables, graphs and maps to be constructed as soon as circumstances may permit.

The more important and extensive projects completed or initiated during my appointment are described in some of the Annexes. Thus, Annex III deals with a study of the frequency distribution of departures of daily mean temperatures in Reykjavík from the corresponding 'normal' values; Annex IV takes up problems regarding wind statistics; Annex V discusses the 'Secular trends' appearing in monthly temperature and precipitation data from the present century; and Annex IX gives some preliminary results of frequency studies regarding amounts of daily precipitation. Finally, Annex VII gives the outline of a study regarding humidity conditions in Iceland which was initiated a short time before I left Reykjavík.

The Annexes just mentioned contain some remarks concerning the relative importance of the many problems of Icelandic climatology which it has not yet been possible to treat as exhaustively as might be wished from a scientific or practical point of view.

In this connexion it should be mentioned that the plans regarding the preparation of a World Climatological Atlas have rendered increased actuality to the need for a complete evaluation and discussion of the Icelandic climatological material, primarily by statistical methods but with much emphasis laid on geographical viewpoints. Broadly speaking, the available material does not at present permit a satisfactory mapping of climatological mean values, extremes or frequencies in Iceland. The most obvious requirement in order to make such a mapping possible is an increased amount of information, but it is not likely that there will be time to wait e.g. for the establishment of new stations, as far as the first edition of the planned Atlas is concerned. The only possibilities then seem to be to make as extensive and audacious use of the present material as is possible and scientifically sound - trusting that modern statistics has made it possible to derive important results even from a material with serious deficiencies - and to use theoretical considerations in an effort to obtain a fair idea of the climatic conditions over areas where no observations are available. It is much to be hoped, however, that the most urgent requirements of the climatological service of Iceland, as described in Dr. Ångström's report (8) and discussed in a following section of the present report, may be fulfilled as soon as possible. A complete realisation of the proposals made by Dr. Ångström before the beginning of the next standard period, i.e. before 1 January 1961, would give good reasons to hope for a new era of Icelandic climatology.

D. PROBLEMS ASSOCIATED WITH THE USE OF CLIMATOLOGICAL DATA FOR PRACTICAL PURPOSES

Perhaps the most characteristic feature of the development in climatology in recent years is the rapidly increasing use that is made of the observations for practical purposes. This development has led to a general and diversified application of statistical methods, and in some cases it has exerted influence backwards even to the program of observations, as for instance regarding agricultural meteorology.

It could not be expected that this development should have been equally explosive in Iceland as in more densely populated countries with a more complex economical structure. It may be said that in Iceland the development has only just started. But certainly the practical implications of climate are here of sufficient importance to warrant, in years to come, an increasing public understanding of the problems of applied climatology, and it may be hoped, in spite of the deficiencies of the available material, that Icelandic climatology will soon be able to expand by proving its practical value in a variety of different fields.

The attitude of climatologists towards the increased importance, absolutely and relatively, of applied climatology differs, naturally enough. It is, no doubt, in each individual case influenced by personal inclination as well as by a personal belief in, or disbelief in, the possibilities of climatology to meet the many and widely different new requirements. There will often be a feeling that the capacity of a climatological section is insufficient to do all the work that is asked for, and an understanding that the expansion of a climatological section is not always a purely economical problem. In Reykjavík, for instance, the personnel of Veðurstofan is barely sufficient for the most necessary tasks, and there is little hope that the number of meteorologists will increase considerably during the next few years. Therefore it is entirely justified if the staff of Veðurstofan finds it premature to start a broad action for a widespread use of specialized climatological information. It is to be hoped that the claims of public and private enterprise regarding such specialized information, and the practical possibilities of Veðurstofan to meet these demands, will increase in about the same proportion during the next few years.

As follows from these general remarks, I saw it as my primary task regarding applied climatology in Iceland to orientate myself as to the need of climatological information for special purposes, the general understanding of this need, and the possibilities of Veðurstofan to give the right information to the right persons. This led to a practical program in continuation of the initiative taken by Dr. Ångström and consisting of a series of meetings at which these problems were discussed with the authorities within respective fields. A list of these meetings follows:

1. The need of climatological information on the part of the University Institute dealing with the problems of fishery was discussed at a meeting on 16 October. The usefulness of extenso tables of meteorological observations (see page 9 para.(a)) was particularly stressed on this occasion.

2. The importance of climatology in connexion with the generation and transfer of electricity was discussed on 4 November at a meeting at 'Raforkumálaskrifstofan' (The State Electricity Board). Here the main problems seemed to be related to the resources of water-power as dependent upon precipitation, and the interruptions caused in transfer of electricity by severe icing in connexion with gales.

3. The problems of reforestation and the need for climatological information for this purpose were discussed at a conference on 29 November. Preliminary plans were made up regarding special meteorological observations at the forestry experimental stations.

4. The problems of Icelandic agriculture as related to climate and climatology were discussed at a meeting on 5 December. It was agreed that concrete proposals should be worked out in order to ensure a closer collaboration between Veðurstofan and the authorities of agriculture and forestry as well as research organizations within these fields. The plans for further action along these lines were discussed shortly afterwards at another meeting where representatives for the organizations and institutions of the type mentioned above were present.

5. The collaboration between Veðurstofan and representatives for fishery was discussed at a meeting on 23 December. It was agreed that more detailed

meteorological information should be obtained e.g. from trawlers fishing in the sea around Iceland, with a view to utilizing this information statistically when the amount appears to be sufficient for doing so.

6. At a conference with a civil engineer of Reykjavík community (27 December), the practical need for more detailed climatological information regarding local conditions in Reykjavík was discussed. Among the items mentioned on this occasion were precipitation data for the drainage system, and data regarding temperature fluctuations during the winter half-year for planning the removal of snow from the streets to be made in an economical way.

IV. COMMENTS ON DR. ANGSTROM'S PROPOSALS REGARDING THE CLIMATOLOGICAL ACTIVITY OF 'VEDURSTOFAN'

In his report on meteorological requirements of Iceland (8), Dr. Ångström offers a number of proposals, several of which have regard to the Climatological Section of the Icelandic meteorological service. During my $3\frac{1}{2}$ months' stay in Iceland I had ample opportunity to consider the situation which forms the background of Dr. Ångström's proposals. I therefore wish to express my personal view regarding each individual point as far as the climatological activity of Veðurstofan is concerned.

Dr. Ångström points to the necessity of an immediate extension of the space which is at present at Veðurstofan's disposal. In a letter to the Government, Mrs. Guðmundsson has proposed that when this extension, now planned in detail, can take place, one room should be added to the present space of the Section for Climatology. This must be regarded as a minimum requirement, necessary in order to enable full use to be made of the working capacity of the personnel which now serves on that section. As Dr. Ångström points out, it is very desirable that a more permanent solution of the space problem be obtained, and this seems possible only if a special building is reserved for Veðurstofan, including the weather service now at Reykjavík airport. I would like to stress that this solution is highly desirable as far as the Section for Climatology is concerned. Both this Section and the Weather Section would profit considerably from the possibility of a closer contact. Besides, it must be expected, as pointed out in the present report, that the development of applied climatology during the next few years will necessitate an extension of the Section for Climatology beyond that which is absolutely necessary at the present moment.

In my opinion, Dr. Ångström's proposals regarding a minor extension of the network of meteorological stations touched upon a matter of special urgency. It should be noted with satisfaction that a part of the extension has taken place, and one might wish to regard this as an indication that all details of the proposal in question will be implemented within a short time.

Dr. Ångström also recommends that a special station should be established in the uninhabited interior of Iceland. The desirability, not to say the necessity, of such a station for the purposes of pure and applied climatology is obvious. However, the possibility of establishing an unmanned, automatic station in central Iceland ought to be investigated, and it is assumed that the whole problem will be taken under thorough consideration by the expert on meteorological instruments who is expected to go to Iceland during 1958.

Dr. Ångström's proposals regarding an extension of the staff of the Climatological Section should, as he points out, be regarded as a minimum requirement. An increase beyond that proposed by Dr. Ångström may become indispensable within a few years, mainly through the development of applied climatology in Iceland.

The last proposal made by Dr. Ångström is a recommendation that scholarships should be sought for professional training under the Expanded Programme of the United Nations Technical Assistance. It should be mentioned in this connexion that it would be of great value if an Icelandic climatologist could thus get an opportunity to study the recent development of climatology in two or more foreign countries, and perhaps attend at the same time a suitable University course in statistics.

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ANNEX I

METHODS FOR CALCULATING MONTHLY MEAN TEMPERATURES

Methods used from 1874 until now

Many different formulae have been used in Iceland for computing monthly mean temperatures. A main reason for this is that the hours of observation have varied considerably, both with time and between stations.

The two first formulae to be used were:

$$\text{(A)} \qquad t_m = \frac{1}{9}(2t_8 + 2t_{14} + 5t_{21})$$

$$\text{(B)} \qquad t_m = \frac{1}{4}(t_7 + t_{14} + 2t_{21})$$

In the Danish Meteorological Yearbook (4) for 1874 it is stated that "according to the results obtained by the Second German Polar Expedition on Sabine Island (Eastern Greenland) these formulae lead to a fairly correct 24-hours mean value of the temperature".

In the Yearbook (4) for 1884 a correction of -0.1 to -0.2 is introduced, to be applied to both of these formulae as far as the months May through August are concerned. This correction, which was said to be based on 12 years of observations at Stykkishólmur, was in use until 1919.

According to Yearbook (4) for 1913, formula (B)was then no longer in use, but besides (A) the following formula had been introduced:

$$\text{(C)} \qquad t_m = \frac{1}{7}(t_8 + t_{14} + 5t_{20}),$$

with a correction during the summer months as for (A).

When Iceland became an independent state, the publication of Icelandic meteorological observations was transferred from the Danish Meteorological Institute to a national authority later called "Veðurstofan". The publications for 1920 - 1923 (9) contain a number of different formulae, viz.

(A) as above

(D) $$t_m = \frac{1}{9} (4t_6 + 2t_{13} + 3t_{16})$$

(E) $$t_m = \frac{1}{6} (5t_8 + t_{16})$$

(F) $$t_m = \frac{1}{5} (2t_6 + t_8 + t_{13} + t_{16})$$

(G) $$t_m = \frac{1}{6} (5t_8 + t_{16})$$

The formulae D-G are said to be used at synoptic stations. At stations which were both synoptic and climatological, occasionally two different formulae were used and both results published. The use of a correction was abandoned with the beginning of 1920, although this is not specifically mentioned in any of the publications.

The basic source of information regarding climatic data for Iceland from 1924 is "Veðráttan"(11), a monthly publication with an annual supplement. The supplements contain a varying amount of information regarding stations, observation hours, instruments, etc., but little or nothing is said about the computation of monthly mean values until 1951, when a rather comprehensive list is given stating the manner in which mean values are computed for each individual station. The following table shows the methods used for the computation of monthly mean temperatures for 1955:

Table I.1. Methods for calculating the monthly mean temperatures at Icelandic stations.

Method	Number of stations
By means of thermograms (adequately checked through parallel readings of ordinary thermometers)	4
By taking the simple mean value of the temperatures measured at 8 synoptic hours	10
By using monthly means of 5-7 synoptic hours, supplemented by (graphically interpolated) approximate mean values for remaining synoptic hours	9
By means of a reduction method (see below)	9
By formula (A)	12
By formula (H) $t_m = \frac{1}{10}(5t_8 + t_{14} + t_{17} + 3t_{21})$	2
By formula (I) $t_m = \frac{1}{10}(5t_8 + t_{11} + t_{17} + 3t_{21})$	1
By formula (K) $t_m = \frac{1}{6}(5t_8 + t_{17})$	5
By formula (L) $t_m = \frac{1}{10}(4t_6 + 2t_8 + 2t_{11} + 2t_{17})$	1
By formula (M) $t_m = \frac{1}{6}(3t_8 + t_{17} + 2t_{21})$	1

The so-called reduction method implies in this case that the difference between the monthly mean temperatures at two adjacent stations (of which one is used as a reference station) is taken to be equal to the mean value of the corresponding differences at those hours (usually during day-time only) at which observations are made at both stations.

The rich variety of methods indicates, of course, that the problem is a difficult one from a practical point of view. The effort which has been taken to obtain, for each individual station, a value as correct as possible, has led to the result that values for different stations, and to some extent values for different years at an individual station, are not strictly comparable. Although there are other, equally important reasons which make comparisons in space and time somewhat uncertain - as e.g. differences and changes in the exposure of the thermometers - it was felt that the problem was sufficiently important to warrant a fairly comprehensive study. The plan of this study was

(a) to ascertain the characteristic features of the diurnal temperature variation at selected stations;

(b) to investigate the systematic and non-systematic errors involved in the more important methods of computation used at present;

(c) to propose, if possible, such a change in the present technique that the number of different methods could be reduced to a minimum, and such measures that systematic differences due to the use of different methods could be avoided.

Diurnal variation of temperature at different stations and different times of the year

Nine stations were selected for the investigation of the diurnal variation of temperature. At two of these, Reykjavík and Akureyri, temperature values read from a thermogram at two-hourly intervals were available in the form of monthly means. At the other stations, corresponding monthly means had been computed for eight synoptic hours (three-hourly intervals). Some of the stations (especially

Dalatangi and Vestmannaeyjar) represent extremely maritime conditions, the diurnal amplitude being very small, while two stations (Akureyri and Kirkjubaejarklaustur) are more continental than the majority of stations in Iceland.

The investigation was limited to the most recent five-year period available (1950 - 1954). Table I.2 gives the result for Reykjavík in a condensed form (odd months being omitted):

Table I.2. Difference between mean temperature at a given time of the day and 24-hour mean temperature. Reykjavík, average for five years (1950 - 1954).

Greenwich time	3	5	7	9	11	13	15	17	19	21	23	1
Icelandic time	2	4	6	8	10	12	14	16	18	20	22	24
February	-0.3	-0.4	-0.2	-0.1	0.0	0.4	0.9	0.7	0.1	-0.1	-0.2	-0.4
April	-1.2	-1.4	-1.4	-0.6	0.3	1.2	1.6	1.4	1.0	0.2	-0.5	-1.0
June	-2.0	-2.1	-1.3	-0.2	0.6	1.2	1.6	1.6	1.2	0.7	-0.2	-1.1
August	-1.6	-1.9	-1.6	-0.5	0.4	1.5	1.8	1.7	1.3	0.5	-0.4	-1.2
October	-0.5	-0.5	-0.5	-0.5	0.1	0.9	1.1	0.9	0.3	-0.3	-0.5	-0.6
December	-0.2	-0.1	-0.1	0.0	0.1	0.2	0.2	0.1	0.0	0.1	-0.0	-0.2

The geographical variation of the diurnal range of temperature is exemplified by table I.3, giving the mean values of the differences (as in table I.2) for the period May to September.

Table I.3. Difference between mean temperature at a given time of the day and 24-hour mean temperature. Average values for the months May to September (incl.), 1950 - 1954.

Greenwich time	3	6	9	12	15	18	21	24
Icelandic time	2	5	8	11	14	17	20	23
Reykjavík	-1.6	-1.7	-0.5	0.9	1.7	1.4	0.5	-0.8
Stykkishólmur	-1.4	-1.3	-0.4	0.7	1.5	1.4	0.4	-0.8
Bolungarvík/Galtarviti	-1.3	-1.2	-0.3	0.7	1.2	1.1	0.4	-0.7
Akureyri	-1.7	-1.6	-0.4	1.2	1.9	1.5	0.4	-0.9
Raufarhöfn	-1.1	-0.9	0.1	0.9	1.0	0.8	0.0	-0.7
Dalatangi	-0.6	-0.6	-0.0	0.6	0.7	0.4	-0.1	-0.3
Hólar í Hornafirði	-1.7	-1.3	0.1	1.3	1.6	1.1	0.1	-1.2
Kirkjubaejarklaustur	-1.9	-1.7	-0.2	1.6	2.1	1.5	-0.1	-1.3
Vestmannaeyjar	-0.9	-1.0	-0.5	0.4	1.0	0.9	0.4	-0.3

Discussion of the various methods used in Iceland for computing monthly mean temperatures

It may be taken as an axiom that the mean temperature of a day or a month is that which could be computed from a perfect thermogram. Thus, the monthly mean temperature should not be defined, for instance, as the average between monthly mean values of daily extreme temperatures. At stations for which no thermogram is available, other methods must be used. The relative merits of the various formulae can be judged by applying them in cases where the correct answer is known (i.e., for stations where a thermogram is available).

It is fairly obvious that the average of eight equidistant temperature observations per day will give a very close approximation to the real mean temperature according to the axiomatic definition. This assumption is fully confirmed by the values for Reykjavík and Akureyri in Table I.3, and by the corresponding values for individual months. Hence, mean temperatures obtained from eight equidistant temperature observations per day may be used for checking purposes, if no thermogram is available.

The thermogram method has been used for those Icelandic stations which are equipped with a thermograph; the number of such stations at present amounts to four. The registrations are usually reasonably good, and extreme care is taken to secure that the necessary corrections based on parallel readings of a thermometer are determined properly. There can be no doubt that the monthly mean values obtained by this rather laborious method are adequate for any practical purpose.

The method of using eight equidistant temperature observations per day is also perfectly satisfactory. The result may be off by a few tenths of a degree for an individual day but will certainly agree very closely with the true mean as far as monthly mean values are concerned. It might even be permissible to use observations at 6-hourly intervals when observations at intermediate hours are not available. However, at a great majority of the stations in Iceland there is a nocturnal interval of nine hours during which no temperature readings are made. In this case, the method of using graphical interpolation to obtain missing synoptic-hour mean temperatures is a possible, but presumably not a very good solution.

The "reduction method" described on page 19 does not seem to be a really sound method, as the underlying assumption, namely that the temperature differences between adjacent stations are approximately the same during the night as during the day, is false. This method should not be used except in cases where a special investigation has been made to ascertain the magnitude of the systematic error thus introduced.

Some of the formulae (A) to (M) appear to be more reasonable than others, but only an actual test can prove the merits of each individual expression. Such a test was performed regarding five of the formulae, including those three which are at present, or were until recently, used at a substantial number of stations, namely (A), (H), and (K). The test consisted of using the formulae in question to compute monthly mean temperatures for nine stations where the result was known either in the form of a monthly mean temperature computed from thermograms or as an average of temperatures observed at 3-hourly intervals. The test period was 1950 - 1954.

Table I.4. Provisional corrections to be applied to a monthly mean temperature computed by means of formula (A), page 17. The corrections given in the table are unsmoothed values based on observations during five years (1950 - 1954).

	J	F	M	A	M	J	J	A	S	O	N	D
Reykjavík	+0.0	-0.1	+0.0	-0.1	-0.3	-0.4	-0.3	-0.3	-0.1	+0.1	-0.0	-0.0
Stykkishólmur	0.0	-0.0	+0.0	-0.1	-0.2	-0.2	-0.2	-0.3	-0.0	0.0	-0.0	-0.0
Bolungarvík/Galtarviti	-0.0	-0.1	+0.0	-0.1	-0.3	-0.4	-0.3	-0.3	+0.0	0.0	+0.0	-0.0
Akureyri	-0.1	-0.1	-0.0	-0.1	-0.3	-0.4	-0.4	-0.2	-0.0	+0.0	+0.0	-0.0
Raufarhöfn	-0.0	-0.0	+0.0	+0.0	-0.2	-0.1	-0.2	-0.1	-0.0	-0.0	+0.0	-0.0
Dalatangi	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.0	+0.0	-0.0	0.0	-0.0
Hólar í Hornafirði	+0.0	-0.0	+0.0	-0.1	-0.3	-0.4	-0.4	-0.1	+0.0	-0.0	+0.0	-0.0
Kirkjubaejarklaustur	-0.1	-0.1	-0.0	-0.1	-0.2	-0.2	-0.3	-0.2	+0.1	+0.0	0.0	-0.1
Vestmannaeyjar	-0.0	+0.0	-0.1	-0.1	-0.2	-0.3	-0.2	-0.1	-0.0	-0.0	+0.0	-0.0

Table I.4 shows the result regarding formula (A) for these nine stations. The essential finding is quite clear: the formula which has been used to compute most of the monthly mean temperatures for Icelandic stations since 1947, gives results which are systematically too high during the period May to August. The corrections based on 12 years of observation at Stykkishólmur (see page 17) are, as might be expected, fairly satisfactory as far as the more maritime stations are concerned, but definitely too small in the case of more continental stations.

The result concerning the other formulae tested was somewhat similar. Some of these formulae worked better than (A) during the summer but not as well during spring and autumn. On the whole, it may be said that none of the formulae was much better, and none much worse, than (A). During the winter all formulae proved to be excellent - naturally enough since at that time of the year the amplitude of the periodic diurnal variation of temperature is almost negligible. Table I.5 shows, for Reykjavík, the result of the test regarding formulae (A), (H), and (K).

Table I.5. Results of check regarding formulae (A), (H), and (K).

Reykjavík, 1950 - 1954.

	J	F	M	A	M	J	J	A	S	O	N	D
Formula (A)	+0.0	-0.1	+0.0	-0.1	-0.3	-0.4	-0.3	-0.3	-0.1	+0.1	-0.0	-0.0
Formula (H)	+0.1	-0.0	+0.2	+0.0	-0.2	-0.3	-0.1	-0.1	+0.2	+0.2	+0.0	-0.0
Formula (K)	+0.1	+0.0	+0.5	+0.3	0.0	-0.1	+0.1	+0.2	+0.5	+0.3	+0.0	-0.0

The result quoted above should be checked by means of data from another 5-year period; if the check confirms the preliminary result, the Icelandic normal temperatures for the standard period ought to be adjusted. To do this adjustment in a strictly correct manner implies, of course, full knowledge regarding the methods used for each station and each year, including knowledge regarding the corrections during a part of the standard period in question. It also implies estimating the value of the actual correction at stations where no comparison with a 'better' mean value is possible; in fact, this is the situation in the great majority of cases. It seems probable, however, that by using the results of the test obtained for stations not too far away, and taking into account that the correction is, roughly, proportional to the periodic diurnal variation, one may without too much effort arrive at fairly reliable values of the correction in each individual case.

The unsystematic ('random') errors which are introduced for an individual month by using one of the formulae discussed above are, generally speaking, small if the formula implies giving equal weight to mean temperatures for a fairly large number of times during the day (e.g., for the eight synoptic hours), but they may be rather large if one or two individual hourly means are given particularly large weight, as in formula (A). However, as far as monthly mean temperatures are concerned (as distinct from daily mean temperatures), the systematic errors constitute a more serious problem than the random errors.

Investigations regarding alternative methods

After some preliminary tests, the possibility of using one of the following formulae for computing monthly mean temperatures was tried:

(N) $$t_m = \frac{1}{2} (t_8 + t_{20}) + k_1$$

and (O) $$t_m = \frac{1}{2} (t_x + t_n) + k_2$$

where t_x and t_n are the monthly means of daily maximum and daily minimum temperature, respectively, and k_1 and k_2 are corrections, to be determined once and for all for each station and month. The result was that formula (N) proved to be fairly satisfactory, while (O) was much inferior. This is probably caused, to some extent, by the peculiarities of the definitions of daily temperature extremes used in Iceland, see Annex II. Besides, in particular the minimum temperature is more often influenced by instrumental errors than the temperature readings made at fixed hours, which also speaks in favour of formula (N). An obvious objection against formulae of the type to which (N) belongs is, that if the temperature mean value during an individual month is the same for each hour of the day, the correction should be zero. However, this objection is not serious from a practical point of view. The periodic variation of temperature during the day is often nearly zero during November, December and January, but at that time of the day k_1, too, is practically zero. During all other months of the year the periodic daily variation of the temperature will always be larger than k_1.

As formula (N) seemed promising, much effort was taken to compute k_1 and then test the formula numerically. The material used for this computation consisted of monthly mean values for ten years at eight stations; for the test, 15 additional stations were utilized.

At the stations used for the computation of k_1, t_m had been determined previously by one of the most reliable methods (see pages 22 - 24), and as t_8 and t_{20} were known, k_1 could be found quite easily. The unsmoothed monthly mean values of k_1 at the eight stations for which it was computed are given in table I.6, while table I.7 shows the standard deviation of the individual values of k_1 for any particular month and station. The values of k_1 are given to the nearest $\frac{1^\circ}{20}$, and the standard deviations to the nearest $\frac{1^{\circ}}{100}$. Although this accuracy may seem exaggerated, it appears to be justified by the figures themselves.

<u>Table I.6.</u> Values of k_1 determined by means of observations for the years 1946 - 1955 (see text).

	J	F	M	A	M	J	J	A	S	O	N	D
Reykjavík	+0.05	+0.25	+0.45	+0.20	-0.15	-0.30	-0.10	-0.05	+0.35	+0.40	+0.15	+0.00
Stykkis-hólmur	+0.00	+0.15	+0.30	+0.20	-0.10	-0.15	-0.05	+0.10	+0.30	+0.20	+0.05	-0.00
Bolungarvík/ Galtarviti	+0.00	+0.10	+0.25	+0.20	-0.00	-0.10	-0.15	-0.10	+0.20	+0.15	+0.05	+0.05
Akureyri	+0.10	+0.20	+0.45	+0.30	-0.05	-0.15	-0.15	+0.20	+0.50	+0.45	+0.15	+0.05
Raufarhöfn	+0.05	+0.15	+0.30	+0.20	-0.05	-0.15	-0.10	+0.00	+0.20	+0.25	+0.05	-0.00
Dalatangi	+0.05	+0.10	+0.20	+0.15	+0.05	+0.05	+0.10	+0.10	+0.15	+0.15	+0.05	+0.05
Hólar í Hornafirði	0.00	+0.25	+0.35	+0.15	-0.15	-0.35	-0.25	-0.00	+0.30	+0.30	+0.10	+0.00
Vestmanna-eyjar	+0.05	+0.10	+0.20	+0.15	+0.00	-0.05	-0.00	+0.10	+0.25	+0.15	+0.10	+0.00

<u>Table I.7.</u> Standard deviation σ_{k_1} of k_1, determined by means of the formula $\sigma_{k_1} = \sqrt{\frac{\left[(k_1)_v - (k_1)_m\right]^2}{n-1}}$, where $(k_1)_v$ is the true value of the correction in an individual case and $(k_1)_m$ the ten-year average value of k_1 given in table I.6. - Annual means were computed from the monthly means.

	J	F	M	A	M	J	J	A	S	O	N	D	Mean value
Reykjavík	0.09	0.17	0.14	0.10	0.08	0.12	0.16	0.17	0.11	0.10	0.13	0.09	0.12
Stykkis-hólmur	0.07	0.09	0.11	0.08	0.13	0.12	0.11	0.09	0.12	0.06	0.07	0.06	0.09
Bolungarvík/ Galtarviti	0.05	0.12	0.13	0.08	0.09	0.12	0.11	0.17	0.12	0.11	0.07	0.10	0.11
Akureyri	0.14	0.13	0.10	0.11	0.07	0.09	0.13	0.10	0.10	0.13	0.14	0.15	0.12
Raufarhöfn	0.09	0.09	0.18	0.05	0.13	0.17	0.17	0.15	0.12	0.11	0.12	0.10	0.12
Dalatangi	0.07	0.06	0.07	0.06	0.07	0.07	0.11	0.10	0.09	0.08	0.04	0.05	0.07
Hólar í Hornafirði	0.08	0.10	0.07	0.11	0.10	0.14	0.11	0.07	0.10	0.10	0.06	0.10	0.10
Vestmanna-eyjar	0.06	0.07	0.08	0.06	0.07	0.10	0.07	0.09	0.11	0.07	0.09	0.10	0.08

The main result shown by table I.6 may be described as follows:

The values of k_1 are generally negative during May, June and July, and positive during all other months. The largest values, $0.4 - 0.5^{\circ}$, are found during March, September and October, at stations having a relatively large diurnal amplitude.

It might have been supposed that the value of k_1 for an individual month would be roughly proportional to the mean value of $(t_x - t_n)$. This was tested in a provisional manner; the result was, broadly speaking, negative. The reason is, probably, that the unperiodic fluctuations affect the values of t_x and t_n to a considerable extent.

The values of table I.6 were mapped (month by month), and though the number of stations was very small, it seemed possible to draw tentative isolines for the k_1-values.

Although the k_1-values determined (for an individual station and month) for individual years did not vary excessively, it seemed worth while to study more closely those values which deviated most markedly from the relevant station-and-month average. Between 30 and 40 values, out of a total of 960, were checked. In a few cases it could be shown that a minor error had affected the computation of the mean temperature, but generally the anomalous feature could be traced back to two or three cases of rapid temperature changes which had taken place during the month, on different days but approximately at the same hour. Although such cases must be expected to occur just as frequently in the future, it is safe to say that at the stations for which k_1 was computed, the error of a t_m - value based on formula (N) will only rarely exceed 0.2°.

At most of the purely climatological stations the evening observation is, or was until recently, made at 21 h instead of 20 h. Therefore, the temperature difference between these two hours was estimated for the stations entered on the maps, and a second series of maps was constructed showing the approximate value of k_3 as defined by the formula

$$\text{(P)} \qquad t_m = \frac{1}{2}(t_8 + t_{21}) + k_3.$$

The latter maps were used for the testing of formula (P) and, indirectly, formula (N), see ~~below~~.

No entirely satisfactory, objective method could be found to check the reliability of the formulae (N) and (P) (or, more specifically, the reliability of the k_1-values interpolated from the maps) when applied to other stations. However, through the following procedure it seemed possible to arrive at fairly definite conclusions:

At eleven stations where the monthly mean temperatures were originally computed by means of formula (A), new mean values for each month during a five-year period were computed by means of formula (P). The values of k_3 were read from maps. The monthly averages of the differences between the results of the two computation methods are given to the nearest $\frac{1}{20}$° in table I.8

Table I.8. Average difference between the mean temperature as computed by formula (P) and the mean temperature as computed by formula (A). If formula (P) is assumed to lead to correct values, the tabulated differences may be interpreted as corrections for values obtained by means of formula (A). Test period: 1950 - 1954. - Among the stations of the table below, Reykjahlíð and Hallormsstaður are located in the interior; Hamraendar, Skriðuland and Sámsstaðir, though not very far from the coast, also have a relatively continental climate.

	J	F	M	A	M	J	J	A	S	O	N	D
Arnarstapi	+.00	+.05	-.10	-.05	+.20	+.20	+.20	+.15	-.10	-.00	+.00	+.05
Hamraendar	+.05	+.20	-.20	+.05	+.40	+.50	+.35	+.25	+.05	-.10	+.10	+.05
Suðureyri	+.05	+.05	-.05	+.05	+.20	+.35	+.30	+.35	+.15	-.00	-.00	-.05
Skriðuland	-.00	+.00	+.05	+.15	+.30	+.45	+.45	+.20	+.15	+.10	-.00	-.05
Sandur í Aðaldal	-.05	-.00	-.10	-.05	-.05	+.05	+.05	-.10	-.15	-.05	-.10	-.00
Reykjahlíð	-.05	-.05	-.20	-.10	+.10	+.55	+.65	+.25	-.10	-.10	-.10	-.10
Hof í Vopnafirði	-.05	-.10	-.15	+.10	-.05	+.05	+.15	-.05	-.15	-.10	-.05	+.05
Hallorms-staður	+.05	.00	-.05	-.05	+.25	+.50	+.55	+.30	-.00	-.10	-.15	-.05
Teigarhorn	-.00	+.00	+.00	+.20	+.30	+.45	+.40	+.15	-.05	-.05	-.05	+.00
Vík í Mýrdal	-.05	-.15	+.00	-.10	+.10	+.15	+.15	+.05	-.00	-.00	-.05	-.10
Sámsstaðir	+.15	+.10	-.05	+.15	+.45	+.70	+.60	+.30	+.30	+.05	-.05	+.15

The values of table I.8 were compared with the corrections which could be expected to be valid for mean temperatures computed by formula (A), judging from the test described on page 23; i.e., the values of table I.8 were compared with the values of table I.4. The stations are different, because all stations of table I.4 were utilized for the determination of k_1 and k_3 and thus could not be used for checking purposes. Hence, only the general character of the annual and - more roughly - the geographical variation of the table values could be compared. The result, which stands out more clearly when shown graphically, was positive: in fact, the general agreement between the values of the two tables is excellent. This may be taken, for the time being, as a proof that no systematic errors of any significance are introduced when computing monthly mean temperature by using formula (N) or (P). The random errors may sometimes be as large as 0.3° and possibly, in exceptional cases, as large as 0.4°, but on the whole they will not be larger when using formula (N) or (P) than when other formulae are used.

Conclusions

(a) It is recommended that the "normal temperatures" computed for Icelandic stations for the period 1901 - 1930 should be revised in the light of the result of the above investigation concerning systematic errors of the formulae used.

(b) It is recommended that the current computation of monthly mean values should follow the lines described below:

In all cases where either a complete thermograph record or a set of temperature readings for eight synoptic hours is available, the monthly mean temperature should, as hitherto, be computed as the average of the mean temperatures for every second or every third hour.

If the largest "gap" between hours at which temperature readings are made does not exceed six hours, the available monthly mean values for fixed hours should, as hitherto, be supplemented by approximate mean values for the remaining synoptic hours determined by graphical interpolation.

If the largest "gap" exceeds six hours, the monthly mean temperature should be computed by means of formulae (N) or (P). For the sake of uniformity, formula (N) is preferred, and it is recommended that stations making observations at 21 h and not at 20 h should make a shift to 20 h, provided that no strong reasons speak against such a change. - At stations where formula (N) [or (P)] is used, much care should be taken to ensure that the mean temperatures of 08 h and 20 [21] h are as correct as possible. This should be done, as hitherto, by computing mean temperatures for all hours of observation.

(c) At a few stations no observation is made after 17 h. It is recommended that, as far as possible, an observation be made at 20 h at these stations.

ANNEX II.

PROBLEMS ASSOCIATED WITH THE DEFINITIONS OF DAILY MAXIMUM AND MINIMUM TEMPERATURES

Historical remarks

During a very long period, the daily maximum (minimum) temperature was defined, in Iceland as well as in other countries, as the highest (lowest) temperature which occurred during the "meteorological day", i.e. from the morning observation on one day to the morning observation on the following day.

However, according to the so-called Copenhagen code and all later codes for synoptic reports, the minimum temperature of the night is given in the morning report, and the maximum temperature of the day in the evening report. To obtain the values which had to be reported, the minimum thermometer had to be set in the evening and read in the morning, while the maximum thermometer must be set in the morning and read in the evening. The observers were instructed accordingly. The new instructions, which were necessary to meet the requirements of the weather services , gave rise to much confusion which has not yet been entirely overcome, except perhaps in some countries where it was decided to read and set both thermometers twice a day and derive the 24-hour extreme temperatures from these readings.

If it is agreed that daily extreme temperatures in climatological records should be 24-hour extremes, the question remains whether they should refer to the time between two consecutive morning observations, as they did originally, or to the time between two consecutive evening observations, which they do now in some countries. In view of the normal diurnal course of temperature, the former definition may seem preferable as far as the maximum temperature is concerned, and the latter for the minimum temperature; on the other hand, the division into 24-hour periods should be consistent.

In polar countries the amplitude of the periodic temperature variation is often small, at least during winter, while the unperiodic changes, which may go in either direction at any time of the day, are often very large, especially during the winter half-year. Under such circumstances it does not matter very much - at least as far as the computation of monthly means of extreme temperatures is concerned - whether successive days are separated at the morning or the evening observation. However, it often makes a large difference whether a period of 24 hours or only a shorter period is covered when an extreme thermometer is read. Even in the case of weather reports, it might seem unfavourable to lose all information regarding maximum temperatures occuring during the night, or minimum temperatures occurring during the day. From a climatologist's point of view, the situation is worse than that.

When the Copenhagen code was introduced in Iceland (1932), the extreme temperatures were reported from inland stations only; the Icelandic stations providing reports for inclusion in international weather broadcasts were all regarded as coastal stations, and no immediate change was made as far as the other stations were concerned. In 1937, however, a letter was sent to all stations, instructing the observers to give (in monthly returns as well as in daily weather reports) the maximum temperature of the day and the minimum temperature of the night. The observers were instructed to make notations of the day's minimum and the night's maximum also, if these were notably low or high, respectively; this instruction was presumably given in order to ensure a correct determination of the absolute extremes of the months. It is not surprising that this part of the instruction was followed rather poorly by some observers.

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Since that time, the monthly mean values of the daily extreme temperatures, as published in 'Veðráttan', have been computed from day maximum and night minimum temperatures, respectively.

A further letter was sent to all Icelandic observers in 1941, asking them to set and read both extreme thermometers twice a day, in the morning and in the evening. This was obviously a much more practical arrangement. However, the monthly mean values of the extremes were still computed in the manner introduced a few years earlier.

Instructions valid in Iceland at present for determination of daily extreme temperatures

Veðurstofan recently issued a revised instruction booklet for climatological stations (10). According to this instruction, both extreme thermometers should be set and read at 8 h and 21 h Icelandic time (9 h and 22 h GMT). Thus, at the climatological stations the maximum temperature read in the evening refers to the time 8 - 21 h, while the minimum temperature read in the morning refers to the time 21 - 8 h. A small number of observers do not yet follow the instruction on this point in a perfect manner. It is hoped, however, that conditions will soon improve in this respect, due to more frequent inspections.

At the stations making synoptic observations, the maximum and minimum thermometers are read and set at 8 h and 17 h.

It is recommended that the evening observation at climatological stations be made at 20 h rather than 21 h (page 37). This would mean that the length of the day interval and the night interval would become equal. From a climatological point of view, it would be desirable if the time for the reading and setting of extreme thermometers could be 08 h and 20 h at all stations, but from other points of view 17 h may be preferable to 20 h at synoptic stations.

The monthly mean values for daily maximum and minimum temperatures at Icelandic stations are computed from the day maximum and night minimum temperatures. As night maximum and day minimum temperatures are also observed, it would be possible, at the cost of some additional labour, to base the monthly mean values of the daily extremes on 24-hour extremes, which should be considered as the correct procedure. It will be shown in the following section that the difference is quite important.

Numerical differences between monthly means of extreme temperatures as defined in Iceland and the corresponding values computed from 24-hour extremes

In order to ascertain the importance of the discrepancy between the definition of extreme temperatures used in Iceland and the classical definition (using 24-hour intervals) still in force in most countries, a study was made of the numerical differences caused by this discrepancy. The study was based on observations at four stations during five years. From the monthly reports of these stations all cases were listed where the day minimum (and, hence, the 24-hour minimum) was lower than the preceding night minimum; the maximum temperatures were treated in a similar manner. An example is given in table II.1.

Table II.1. Corrections to daily extreme temperatures. Akureyri, February 1950. The values of the table show the differences (in ^{o}C) between 24-hour extremes and extremes for day or night only. If no value is entered, the difference is zero. In the case of the maximum temperature, the 24-hour value is obviously $\geqq$ the day value, hence, if we interprete Δ_x as a correction, $\Delta_x \geqq 0$; similarly, the correction $\Delta_n \leqq 0$.

Date	Δ_x	Δ_n
1	1.0	-1.5
2	0.3	-1.5
3		
4	1.8	-2.8
5	2.4	-0.4
6		
7		
8		
9	2.0	-1.0
10		
11	3.0	-2.1
12	2.5	-0.5
13		
14	0.3	-0.6
15		
16	1.3	
17	0.5	
18	2.0	-0.8
19		
20		
21	2.8	-7.0
22	1.0	
23	1.0	
24		
25		
26		
27		
28		
Σ	21.9	-18.2
Σ :28:	0.78	- 0.65

The mean corrections $(\Delta_x)_m$ and $(\Delta_n)_m$ as determined from tables of this kind were transferred to another series of tables, one for each station. The contents of these tables are exemplified by table II.2, showing the values for one month only.

Table II.2. Corrections to monthly mean maximum temperature $((\Delta_x)_m)$ and to monthly mean minimum temperature $((\Delta_n)_m)$, Akureyri, February 1950 - 1954. The values for the individual Februaries were obtained from tables like II.1.

February	$(\Delta_x)_m$	$(\Delta_n)_m$
1950	0.78	-0.65
1951	0.94	-0.62
1952	1.33	-0.42
1953	1.01	-0.58
1954	1.16	-0.58
Σ	5.22	-2.85
Σ :5	1.04	-0.57

A third set of tables was prepared, giving (a) the uncorrected monthly extreme temperatures; (b) the corrections; (c) the mean values of the total diurnal temperature amplitude (including the unperiodic part), as determined from uncorrected monthly means of the extremes; and (d) the corrections to this amplitude. Each of these tables contains values for twelve months at one station.

Table II.3 gives an example of the contents. The individual values of the corrections are given with one decimal only in this table, which mainly serves the purpose of demonstrating the magnitude of the correction as compared with the amplitude to be corrected.

Table II.3. Uncorrected monthly means of daily extreme temperatures and of total daily temperature amplitude, with appropriate corrections. Akureyri, February 1950 - 1954. - The mean values of Δ_x and Δ_n were obtained from table II.2 and used (before rounding off) to compute $(\Delta_x - \Delta_n)_m$.

		t'_x	Δ_x	t'_n	Δ_n	$t'_x-t'_n$	$\Delta_x - \Delta_n$
February	1950	0.2	0.8	-4.9	-0.6	5.1	1.4
	1951	2.3	0.9	-3.8	-0.6	6.1	1.6
	1952	1.5	1.3	-3.7	-0.4	5.2	1.8
	1953	2.6	1.0	-2.0	-0.6	4.6	1.6
	1954	1.5	1.2	-2.9	-0.6	4.4	1.7
Σ		8.1		-17.3		25.4	
$\Sigma:5$		1.62	1.04	-3.46	-.57	5.08	1.61

Finally, average values for the different stations were brought together in two tables (II.4 and II.5) which give the result of the present investigation in a condensed form. This result may be summarized as follows:

Table II.4. Five-year means (1950 - 1954) of corrections to monthly means of extreme temperatures. The last two lines give corresponding four-station averages. All values given in table II.4 are rounded off to the nearest $\frac{1^{\circ}}{20}$, but the four-station average values were computed from the original two-decimal figures.

	J	F	M	A	M	J	J	A	S	O	N	D
Corr. to t_x												
Reykjavík	.95	.80	.65	.50	.35	.45	.45	.35	.50	.55	.60	1.05
Stykkis-hólmur	.80	.70	.55	.40	.30	.35	.20	.25	.25	.45	.70	.80
Akureyri	1.50	1.05	.85	.65	.75	.45	.65	.60	.60	.75	1.05	1.35
Hólar í Hornafirði	1.05	.80	.50	.40	.35	.45	.40	.30	.25	.40	.75	1.15
Corr. to t_n												
Reykjavík	-.60	-.50	-.25	-.10	-.05	-.00	-.05	-.05	-.05	-.15	-.45	-.50
Stykkis-hólmur	-.50	-.40	-.20	-.15	-.05	-.05	-.05	-.05	-.10	-.30	-.40	-.45
Akureyri	-.85	-.55	-.30	-.10	-.05	-.05	-.05	-.05	-.10	-.20	-.55	-.70
Hólar í Hornafirði	-.35	-.40	-.20	-.10	-.05	-.00	-.05	-.05	-.05	-.15	-.30	-.55
Mean values for the stations given above:												
Corr. to t_x	1.05	.85	.65	.50	.45	.40	.45	.40	.40	.55	.80	1.10
Corr. to t_n	-.55	-.45	-.25	-.10	-.05	-.05	-.05	-.05	-.05	-.20	-.40	-.55

Table II.5. Lines denoted by 'a' : corrected values of monthly means of total diurnal temperature amplitude. Lines 'b': corresponding uncorrected values. Lines 'c': The proportion between the uncorrected values given in line 'b' and the appropriate corrected values given in line 'a'. The numbers of lines 'a' and 'b' were rounded off to the nearest $\frac{1^{\circ}}{20}$. The values given in line 'c', however, were computed from the original values before these were rounded off.

		J	F	M	A	M	J	J	A	S	O	N	D
Reykjavík 1950-1954	(a)	5.25	5.20	5.30	5.55	5.40	5.85	5.35	5.90	5.80	4.55	4.70	4.85
	(b)	3.70	3.95	4.35	4.95	5.10	5.40	4.85	5.50	5.25	3.85	3.60	3.35
	(c)	.71	.76	.83	.89	.94	.92	.91	.94	.90	.84	.77	.69
Stykkis-hólmur 1950-1954	(a)	4.15	4.10	4.50	5.00	5.20	5.75	5.10	6.30	4.40	3.85	3.85	4.10
	(b)	2.85	3.00	3.75	4.45	4.80	5.40	4.90	6.00	4.05	3.05	2.75	2.90
	(c)	.69	.74	.83	.89	.93	.94	.95	.95	.92	.80	.71	.70
Akureyri 1950-1954	(a)	7.05	6.70	6.75	6.80	7.65	6.80	6.50	6.45	6.35	6.05	6.20	7.25
	(b)	4.75	5.10	5.60	6.05	6.80	6.30	5.75	5.80	5.60	5.10	4.55	5.20
	(c)	.67	.76	.83	.89	.89	.93	.89	.90	.89	.84	.74	.72
Hólar í Hornafirði 1951-1955	(a)	5.00	5.60	5.35	6.95	6.05	6.25	6.10	5.70	5.35	4.80	4.85	5.50
	(b)	3.60	4.45	4.60	6.45	5.65	5.80	5.65	5.40	5.10	4.20	3.80	3.80
	(c)	.72	.79	.87	.93	.93	.93	.92	.94	.95	.88	.79	.69

1. The corrections applicable to the maximum temperatures are significant during the whole year; they are large, 0.8 - 1.5°, in December and January, but generally less than 0.5° from May to September. A comparison between the maritime station Stykkishólmur and the more continental station Akureyri indicates that the correction is relatively large in inland districts.

2. The corrections applicable to the given minimum temperatures are negligible from May to August but generally as large as 0.4 - 0.7^{o} from November to February. At that time of the year the largest values are found at the most continental station (Akureyri).

3. The relation between the monthly means of the uncorrected total diurnal amplitude and the corresponding amplitude after correction is approximately the same at all stations (table II.5), i.e. the correction applicable to the amplitude during a certain month at different stations is roughly proportional to the amplitude itself. In December and January, the uncorrected amplitude is only about 70% of the corrected amplitude; in other words, the correction amounts to about 40% of the uncorrected value. From April to September, the corresponding figures are 90 - 95% and 5-12%, respectively.

The seasonal differences occurring in the magnitude of the correction are easily explained. During summer, the days are nearly always warmer than the nights; sometimes, the maximum temperature of a certain day - preferably in the case of prolonged rain - fails to reach the level observed the evening before, but very rarely is the temperature at a morning observation or later during the day lower than the minimum temperature of the following night. During winter, the periodic diurnal amplitude, as shown in Annex I, is negligible or nearly so, whereas the unperiodic variations, caused mainly by frontal passages, changes in wind direction or wind force, and increasing or decreasing cloudiness, are often large.

The difference between coastal and continental stations mentioned above (page 42) also reflects a contrast regarding the frequency and magnitude of temperature changes which are out of phase with the normal daily march of temperature. In the interior, such changes are mostly connected with the formation or destruction of ground inversions; in coastal areas, they may occur when an outflow of continental air is followed abruptly by the advection of maritime (or maritimized continental) air, and may in such cases be very rapid or even instantaneous. The larger values for continental stations (table II.4) indicate that the greater frequency and magnitude of ground inversions in the interior over-compensates the existence of the special effect near the coasts. It may be mentioned that in the windy climate of Iceland the inflow of mild air above a cold bottom layer nearly always leads to the destruction of the inversion, although this process may take as much as 6 - 12 hours.

Although the results summarized above (pages 42-43) were based on a very scanty material, it seemed advisable to express, tentatively, the generalized result in a quantitative manner (table II.6). The numbers given in this table should be used with caution, and if possible they should be checked by further investigations.

Table II.6. Tentative corrections to those monthly mean maxima and monthly mean minima in "Veðráttan" which are based on day maximum and night minimum temperatures. The values can not be expected to be very nearly correct for one particular station and month but are supposed to give a fairly realistic picture of the average magnitude of the correction at coastal and non-coastal stations, and of the annual variation of this correction. Still larger values than those given in the table may be expected at the most continental stations of the country, as this category is not represented in the investigation.

		J	F	M	A	M	J	J	A	S	O	N	D
Coastal stations	t_x	+0.9	+0.7	+0.6	+0.4	+0.3	+0.3	+0.3	+0.3	+0.3	+0.4	+0.7	+0.9
	t_n	-0.5	-0.4	-0.2	-0.1	-0.1	0.0	0.0	0.0	-0.1	-0.2	-0.4	-0.5
Stations in the interior	t_x	+1.3	+1.0	+0.8	+0.6	+0.6	+0.6	+0.6	+0.6	+0.6	+0.7	+1.0	+1.3
	t_n	-0.8	-0.5	-0.3	-0.1	-0.1	0.0	0.0	-0.1	-0.1	-0.2	-0.5	-0.7

Conclusions

(a) It is recommended that the daily extreme temperatures at Icelandic stations be defined as extreme temperatures for 24 hours - in principle from 20 h to 20 h, Icelandic time. From a climatological point of view it would be preferable if these hours could be adhered to at synoptic stations, too; but naturally it must be considered at first whether this would be compatible with the requirements of the weather services.

(b) It is recommended that when average values for the standard period 1931 - 1960 of monthly means of daily extreme temperatures are computed, these values should be adjusted, as well as possible, to agree with the definitions given above.

ANNEX III

FREQUENCY DISTRIBUTION OF DEPARTURES OF DAILY MEAN TEMPERATURE FROM THE CORRESPONDING 'NORMAL' TEMPERATURE. REYKJAVÍK, 1946-1955

During several years, the departure of the 24-hour mean temperature from the accepted 'normal' temperature (from 1945, the mean temperature for 1901 - 1930 was used as a normal) has been computed regularly for a small number of Icelandic stations, i.a. Reykjavík and Akureyri.

The departure tables form a convenient basic material for an elementary discussion of the statistical parameters valid for the distribution of daily mean temperature in Reykjavík during ten years (1946-1955). In the said tables, the departures are given to the nearest whole degree; for departures numerically less than 0.5°, the sign (if any) is given. The lack of decimals is unimportant for the present study, as the class interval of 1° is not too broad. The few cases where the departure was given as 0.0 were distributed evenly between the classes +0 and -0.

From the basic frequency tables (one for each month, with one line for each year) a larger table was prepared, showing the class frequencies month by month for the ten-year period. The cumulative frequencies for each month were determined from this larger table. Finally, the values of the cumulative functions were expressed as percentages of the number of days available for each month, mainly to allow for the unequal length of the various months (table III.1).

Table III.1. Frequency (in %) of daily temperature departures from the 1901-1930 normals. The table values show the frequency of departures exceeding, in the positive or negative direction as stated, a given amount. Reykjavík, 1946-1955.

$\Delta t \geq$	J	F	M	A	M	J	J	A	S	O	N	D
8.5	0.3		0.6									0.3
7.5	3.2		1.3			0.3					2.3	2.3
6.5	5.5	1.1	2.3			0.3				1.6	5.3	3.2
5.5	9.0	5.3	7.2	0.7		1.0			0.3	5.8	8.0	6.8
4.5	17.7	9.6	15.5	5.7	2.3	1.7	0.6		2.0	11.0	16.3	13.9
3.5	27.1	17.7	26.1	10.7	9.4	3.0	1.3	1.3	8.3	20.3	24.7	21.6
2.5	36.5	25.5	32.6	19.3	19.0	6.7	3.9	5.5	15.3	30.0	30.7	31.2
1.5	48.7	37.6	41.3	28.7	33.2	16.0	9.0	18.7	27.3	41.0	41.7	42.6
0.5	60.0	46.8	51.6	38.7	50.6	35.7	25.5	43.2	43.0	51.6	51.3	51.6
+0.0	63.9	51.8	56.5	49.3	59.0	45.7	40.3	59.0	50.7	58.4	56.0	55.5

$\Delta t \leq$	J	F	M	A	M	J	J	A	S	O	N	D
-0.0	36.1	48.2	43.5	50.7	41.0	54.3	59.7	41.0	49.3	41.6	44.0	44.5
-0.5	32.3	46.1	39.0	46.0	34.8	41.7	48.7	27.1	40.0	37.1	39.0	38.4
-1.5	23.2	36.2	31.6	34.3	26.5	15.3	20.6	8.1	24.0	26.5	32.7	29.4
-2.5	17.1	24.8	22.3	23.7	15.8	5.7	5.8	1.3	10.3	14.8	21.7	22.6
-3.5	13.9	17.0	18.4	17.3	9.0	2.0	1.0	0.3	5.0	9.0	14.7	19.0
-4.5	11.0	10.3	12.9	11.3	4.8	1.0			3.0	6.8	7.0	14.2
-5.5	8.7	6.4	8.7	7.0	2.6	0.3			0.7	4.5	4.0	11.6
-6.5	6.8	4.3	3.2	4.0	1.3					1.9	3.0	7.7
-7.5	3.9	2.8	1.3	2.3						1.3	0.7	4.8
-8.5	2.3	0.4	0.6	1.7								3.2
-9.5	1.6	0.4		0.7								1.3
-10.5	1.0	0.4										

As table III.1 shows, the summation was made from both ends towards departure 0. This is slightly preferable if one wants to compare the frequency of positive departures exceeding a given amount with the frequency of negative departures numerically larger than the same amount.

The characteristic features of the frequency distribution were demonstrated by a number of diagrams, i.a. by entering the cumulative frequencies (summed from low towards high temperatures only) on "Probability Paper" (see (6), page 81), which makes the deviation from a normal frequency distribution appear very clearly.

The general character of the distributions does not deviate too much from analogous distributions in large parts of western Europe. The contrast between summer and winter is striking: in August, no departure numerically larger than 4° (strictly, beyong the class limit 4.5°) has occurred, while in any of the months December to March 10-18% of the days have been more than 4° too warm and 10-14% more than 4° too cold. The largest positive departure observed during this ten-year period was $+9^{\circ}$ (in January 1947, March 1948 and December 1946), and the largest negative departure -11° (January 1949 and 1955, and February 1950). It may be pointed out, however, that whereas the limit for positive departures in Reykjavík is not far beyond $+9^{\circ}$ (probably +10 or $+11^{\circ}$), the negative departures may occasionally be much larger than -11°; in Stykkishólmur, not very far from Reykjavík, the whole month of March 1881 had a mean departure of about -12°, while the departure on the coldest day of this month was approximately -22°.

Whereas no departure during April - May or July - September has exceeded $+6^{\circ}$ ($+6.5^{\circ}$), one day in June 1955 was 8° too warm. It may be assumed that positive departures of 7 or 8° may occur in exceptional cases in April and May, whereas the limit may be a little lower in July, August and September.

From the values of table III.1 the mean temperature departure for each month during the ten-year period was computed (table III.2). These mean values might of course have been found more easily, and perhaps with greater exactness, from the published monthly mean temperatures; however, for the further statistical treatment it was considered preferable to use mean departures determined from the frequency tables.

Table III.2. Monthly values of mean departure (ξ), standard deviation (σ), and skewness (γ_1) of the anomaly of daily mean temperatures. Reykjavík 1946 - 1955. ξ has been computed from the anomalies, not from monthly mean temperatures. As for the definition of γ_1 , see (3) page 55. Sheppard's correction was not applied. The ten-year mean departures (ξ) from the 1901 - 1930 normals were taken into account when the values of σ and γ_1 given in the table were computed.

	J	F	M	A	M	J	J	A	S	O	N	D
ξ	+0.86	-0.05	+0.41	-0.45	+0.20	-0.01	-0.36	+0.32	+0.10	+0.59	+0.59	+0.24
σ	4.10	3.52	3.82	3.24	2.60	1.78	1.53	1.40	2.27	3.25	3.66	4.08
γ_1	-0.60	-0.25	-0.29	-0.40	-0.45	+0.46	+0.39	-0.01	+0.13	-0.26	-0.04	-0.47

It is seen that the mean departures are positive during 8 months out of 12. During February and June, they are negative but negligible; only April and July show a significant negative departure. For a discussion of the general trend of temperature (the 'climatic variation' during the present century, see Annex V.

The standard deviation and the skewness parameter of the distributions are also given in table III.2. These parameters were adjusted by taking into account the actual mean values of this departure (ξ in table III.2). The correction proved to be negligible (always less than 0.1^{o}) as far as the standard deviations were concerned, whereas it - as might have been expected - was of great importance for the values of γ_1.

A statistical treatment of the temperature departures at Akureyri, following the same scheme as above, was started before I left Iceland. A main difference, as compared with Reykjavík, was the generally wider scattering of the values, in accordance with the more continental position of Akureyri.

ANNEX IV

WIND STATISTICS

General remarks

It is well known that the frequency of gales in the coastal areas of Iceland and over the surrounding part of the ocean - including all important fishing banks in this region - is very high; at some localities on or just outside the coast, e.g. at Vestmannaeyjar, it may be called exceptionally high. During the winter, even winds of hurricane force are not quite unusual. The importance of these facts to fishery and shipping is obvious. The relatively frequent sudden shifts of wind direction, often combined with a very rapid increase of wind velocity, as well as the fact that large sections of the coast afford no shelter at all, add to make shipping, and above all fishing, in the oceans surrounding Iceland hazardous, in particular during the winter months. Those who engage in these activities are, of course, keenly aware of the importance of a well-functioning system of weather forecasting. (It is interesting to note that no specific gale warnings are included in the ordinary forecasts issued by the Icelandic weather service, the reason being that gales are much too frequent!) They may not be equally aware of the potential value of climatological studies concerning gale frequencies or, more generally, wind conditions.

The mean wind velocity, as well as the frequency of gales, is remarkably high in most inland areas of Iceland, too. Not only is the pressure gradient often very steep; it is also important that there are no extended forests in Iceland. The orography favours a high mean wind velocity in some areas (however, many of these areas are uninhabited), while in many valleys there is a distinct predominance of winds blowing along the valley - such winds may occasionally attain the character of severe gales, in particular when blowing directly from the open sea into a valley. There are, on the other hand, some orographically sheltered valleys where calms are frequent and winds mostly light, but they are exceptions. Most of the interior is an entirely uninhabited, relatively flat highland (appr. 500-800 m above sea level), freely exposed to the fury of the winds. Winds of hurricane force must occur occasionally on some of the glaciers which cover more than 10% of the surface of Iceland.

The comparatively high frequency of strong winds in the interior of Iceland is a matter of far-reaching consequences; not so much so because of the occasional damage to buildings etc., but mainly because of the wind erosion, which is a major problem for land utilization in Iceland. The soil of Iceland is fertile in many places, but in large areas it consists of sand or sterile volcanic products. The fertile soil may, if the vegetation cover is missing or insufficient, be carried away by the wind - perhaps from a place where it had formed the living basis of a farmstead to a locality where it is of no use at all.

A statistical treatment of the wind observations could not answer more than a fraction of the problems associated with the economical importance of the wind climate of Iceland. Most of the meteorological stations are on the coast itself or on a coastal plain; nearly all of the stations in the interior are situated in valleys; naturally, the large uninhabited area in the interior is not represented at all. Still, it seems beyond doubt that a careful statistical study of the available material would be worth while. Contrary to what is customary in many other countries, wind observations are made regularly at practically all meteorological stations in Iceland. Some of the main stations have been equipped with anemometers, generally of a non-registering type, during the last few years, but most of the available material regarding wind velocity consists of estimates. This circumstance is somewhat unfavourable for the study of regional differences in wind conditions, but on the whole it does not reduce the value of the material very much.

Statistics of gales in Reykjavík 1946 - 1955

The wind observations made at the airport of Reykjavík seem to constitute a reasonably homogeneous material, well suited for a statistical study of the occurrence of gales ($\geq$ 7 Beaufort) during a ten-year period (1946-1955). An anemometer functioned at the airport during this period. The mere fact that it is possible to get a relatively complete picture of the frequency of gales from various directions, and at different times of the year, from a material covering ten years only, tells a good deal about the windy climate of the capital of Iceland.

Table IV.1. Frequency of strong winds (7-12 Beaufort) expressed as a percentage of the number of observations. The table is based on 8 observations per day. Reykjavík, 1946-1955.

Beaufort	J	F	M	A	M	J	J	A	S	O	N	D
12	0.04			0.04							0.08	0.04
$\geq$ 11	0.36	0.13	0.04	0.04	0.04					0.08	0.08	0.16
$\geq$ 10	0.93	0.36	0.44	0.46	0.12				0.12	0.56	0.54	0.69
$\geq$ 9	2.5	1.6	2.2	1.4	0.36		0.16	0.32	0.79	1.4	1.3	1.8
$\geq$ 8	7.3	5.5	6.8	5.6	2.1	0.42	0.85	0.97	2.9	4.2	4.8	5.6
$\geq$ 7	15.3	11.1	14.3	11.1	5.2	2.5	2.5	4.0	6.9	10.4	10.4	12.1

Table IV.1 shows the frequency of gales month by month, without regard to the wind direction. The frequencies are expressed in per cent of the total number of observations. It is seen that winds of gale force prevail at no less than 10-15% of all observations during January to April and October to December; only during June and July the percentage is as low as 2-3. 10 Beaufort ("whole gale") is reported at nearly 1% of all observations during January, and force 12 has been observed on four occasions (January 1952 and April, November and December 1953).

The contrast between the relatively quiet period May to September and the remainder of the year is illustrated by table IV.2, which also gives the all-year percentage of winds reaching or exceeding a certain step ($\geq$ 7) of the Beaufort scale.

Table IV.2. Frequency values (computed by means of the values of table IV.1) illustrating the large seasonal variation of the frequency of strong winds. Reykjavík, 1946 - 1955.

Beaufort	January to April and October to December	May, June, July, August, September	Year
12	0.03		0.02
$\geq$ 11	0.13	0.01	0.08
$\geq$ 10	0.57	0.05	0.35
$\geq$ 9	1.75	0.33	1.2
$\geq$ 8	5.7	1.45	3.9
$\geq$ 7	12.1	4.2	8.8

Table IV.3. Frequencies of strong winds from the various directions and irrespective of direction. The values of the table are given as percentages of the total amount of observations used for the computation, i.e., not as percentages of the number of cases with wind from one particular direction. Reykjavík, 1946-1955; eight observations per day.

Beaufort	N	NE	E	SE	S	SW	W	NW	All directions
12	0.00				0.01		0.01		0.02
≥ 11	0.02		0.00	0.01	0.01	0.01	0.02	0.00	0.08
≥ 10	0.07	0.02	0.02	0.03	0.08	0.05	0.07	0.01	0.35
≥ 9	0.23	0.10	0.09	0.19	0.19	0.17	0.16	0.02	1.2
≥ 8	0.85	0.30	0.36	0.78	0.61	0.49	0.46	0.08	3.9
≥ 7	1.97	0.76	1.13	1.63	1.43	0.92	0.77	0.17	8.8

In table IV.3 the distribution of gales between the eight principal directions of the compass is given. The table shows that northwesterly gales are infrequent. This may to some extent be due to local orographic conditions, but essentially it appears to reflect the fact that pressure gradients corresponding to a northwesterly gale are unusual in and near western Iceland. The frequency of gales from the other main directions is more uniform, although there is a clear indication of a double maximum, corresponding to the directions N and SE.

Statistics of wind directions at nine stations, 1931 - 1950

The monthly publication "Veðráttan" contains, for all stations in Iceland where wind observations are made, frequency numbers for each of the eight principal directions, as well as the frequency of calms and the mean wind force for each individual month. This material, for the twenty-year period 1931-1950, has recently been transferred to punch-cards. The further evaluation of the material was limited, for the time being, to nine stations with complete series of observations for this 20-year period. For each of these stations, tables like IV.4 were arranged to show the average wind frequencies during each month and for the year as a whole.

Table IV.4. Frequency of different wind directions and of calms for each month and for the year as a whole.

Reykjavík, 1931-1950.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
N	8	9	9	14	10	12	16	13	12	13	10	9	11
NE	10	11	10	12	9	7	5	6	7	7	9	10	9
E	28	24	28	21	17	11	10	13	17	23	26	28	20
SE	14	13	13	12	14	14	13	13	14	16	17	16	14
S	14	14	12	12	12	11	10	15	15	14	12	14	13
SW	11	11	11	10	10	11	9	11	12	10	9	8	10
W	4	6	5	6	10	13	11	9	7	5	4	3	7
NW	3	4	4	6	9	12	15	10	6	3	3	2	6
Calm	7	8	8	8	9	8	11	12	10	10	10	9	9

The frequency table for Reykjavík (IV.4) shows the predominance of easterly winds during the greater part of the year. In weak-gradient situations during the winter half-year, the easterly wind may have the character of an outflow of cold continental air, but most often the easterly wind, as well as winds from other directions, is a large-scale phenomenon associated with the large-scale pressure distribution.

As shown by table IV.4, the frequencies of some of the wind directions exhibit a marked annual variation. Thus, the easterly and northeasterly winds are much more frequent during the winter half-year than in summer, while the frequency of winds from north, northwest and west varies conversely.

Table IV.5. Monthly frequencies (in %) of wind directions showing a markedly different frequency in different months. For easier orientation, two or three wind directions have been combined wherever it seemed advantageous to do so.

		J	F	M	A	M	J	J	A	S	O	N	D
Reykja-	NE+E	38	35	38	33	26	18	15	19	24	30	35	38
vik	W+NW+N	15	19	18	26	29	37	42	32	25	21	17	14
Stykkis-	SE+S+SW	42	40	35	35	30	25	21	32	36	40	39	42
hólmur	W+NW+N	16	22	19	22	28	35	32	27	24	22	19	15
Akur-	SE+S	47	46	43	35	33	28	20	28	37	46	48	49
eyri	NW+N	16	18	19	28	39	48	54	41	31	22	18	16
Grims-	SE+S+SW	50	50	51	43	47	38	35	42	48	52	49	52
staðir	N	10	13	10	15	18	25	28	23	15	15	12	11
Raufar-	S+SW	30	30	26	21	13	8	7	9	16	22	26	29
höfn	E	15	13	12	12	21	21	22	20	17	10	10	13
	N+NW	14	15	17	19	15	21	23	23	20	18	17	14
Teigar-	NW+N+NE	42	50	43	45	28	24	20	23	31	42	45	42
horn	E	10	6	10	15	27	26	27	22	16	8	8	8
Fagur-	NW+N+NE	42	43	38	34	24	18	12	16	25	34	42	47
hólsmýri	E	19	17	25	31	38	36	42	34	31	26	22	22
Vest-	N+NE+E	39	39	39	38	30	24	22	25	30	38	38	39
manna-	W+NW	16	20	18	21	21	24	28	24	23	20	17	15
eyjar	SE	13	14	18	17	24	25	23	20	18	17	18	17
Sáms-	N+NE+E	49	51	45	42	24	19	16	21	32	44	50	48
staðir	SE+S+SW	36	33	35	36	54	55	56	53	43	35	32	34

Table IV.5 which gives an extract of the frequency tables for all nine stations, demonstrates that the same phenomenon can be observed at all stations. It is interesting to note, however, that the wind directions showing a maximum of frequency during the winter are markedly different from one station to another; thus, in Reykjavík these directions are E and NE, in northern Iceland SE to SW, along the coast from the easternmost to the southwesternmost point of the country mainly N and NE. It may be concluded that the annual variation of wind frequencies is not essentially due to seasonal variations of the large-scale pressure distribution. Rather, it may be considered as a phenomenon of the monsoon type, associated with such modifications of the general pressure distribution which are caused by Iceland itself. It is perhaps a little surprising that these regional effects appear as distinctly as they actually do.

The wind directions having their highest frequency during summer are, as might be expected, mainly winds blowing from the sea. Two stations, Raufarhöfn and Vestmannaeyjar, show a more complicated picture, as the frequencies of two opposite directions vary in a very similar manner. It seems possible that one of these directions represents some kind of local sea-breeze blowing mainly in the afternoons and evenings, while the other direction represents a "monsoon" on a larger scale.

Table IV.6. Mean wind force (Beaufort scale), 1931 - 1950.
The figures of the table have been computed directly (as if the Beaufort scale had been linear), without any conversion to genuine velocity units.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Reykjavík	3.7	3.6	3.4	3.3	2.9	3.0	2.7	2.7	3.1	3.2	3.2	3.5	3.2
Stykkishólmur	3.3	3.4	3.1	3.0	2.6	2.4	2.1	2.3	2.7	3.0	3.1	3.1	2.8
Akureyri	2.2	2.2	2.0	2.1	2.1	2.1	1.7	1.7	1.9	2.0	2.1	2.1	2.0
Grímsstaðir	3.5	3.4	3.1	3.2	2.9	2.6	2.4	2.5	2.6	2.6	2.8	3.2	2.9
Raufarhöfn	3.6	3.4	3.0	3.1	2.6	2.4	2.2	2.3	2.7	2.8	3.0	3.1	2.8
Teigarhorn	2.8	2.6	2.5	2.6	2.1	2.1	1.7	1.9	2.2	2.4	2.5	2.5	2.3
Fagurhólsmýri	3.1	3.1	3.0	3.1	3.0	2.7	2.4	2.5	2.5	2.5	2.6	2.7	2.8
Vestmannaeyjar	5.7	5.4	5.2	5.0	4.5	4.2	3.6	3.9	4.4	4.9	5.0	5.3	4.8
Sámsstaðir	2.4	2.3	2.0	2.0	1.9	1.8	1.6	1.8	1.9	2.0	2.0	2.0	2.0

Table IV.6 shows the mean wind force as based on the observations (mainly non-instrumental) at the same stations. Two reservations must be made. Firstly, as the Beaufort scale is not a linear scale of velocity - strictly speaking, it is not a velocity scale at all, but rather a (non-linear) scale of wind force -, it is not quite permissible to compute average values as if it were a linear scale. The practical importance of this objection is probably not very great, considering the weight of the second reservation: Each observer estimating the Beaufort scale - number applies his own 'private' scale, which can not be expected to agree exactly with the scale of any other observer. Although there is no reason to expect that the importance of the 'personal equation' in this respect is larger in Iceland than in other countries, caution is required when the mean wind force at different stations are compared. It seems reasonable to believe, however, that the annual variation of wind velocity, and accordingly geographical differences with respect to this annual variation, may be deduced with a fair degree of confidence from statistical tables like IV.6.

By far the largest mean wind velocity is found, throughout the year, at Vestmannaeyjar. Although the position of this station is somewhat peculiar - on the top of a small, rather steep mountain -, there is no doubt that the mean wind frequency is very high on and near the Vestman Islands. Among the nine stations of the table, the lowest mean velocity is shown by Akureyri, near the bottom of a rather narrow fiord with relatively high mountains on both sides.

As for the annual variation of wind velocity, most stations show a maximum in January and a minimum in July.

Further statistical studies of wind conditions in Iceland are recommended. Special attention should be given to questions of practical importance in connexion with the construction of tall buildings, airports and harbours, or with the possibility of making use of snow fences or shelter belts for the protection of roads and cultivated fields.

ANNEX V

'SECULAR TRENDS' OF TEMPERATURE AND PRECIPITATION IN ICELAND DURING THE PRESENT CENTURY

Introduction

The climate of Iceland is, during the winter half-year at least, much milder than might be expected in a country which on a map gives the impression of being suspended on the string of the Arctic circle. Nevertheless, the climate is unfavourable or even prohibitive to many crops important in temperate latitudes. Very little cereal is grown; the main vegetable product of the country is hay. The almost complete lack of forests is not assumed to be due primarily to climatic conditions, but there is no doubt that the climate is a serious obstacle to the programme of reforestation.

The main difficulties to agriculture and forestry appear to be associated with the climate of the summer half-year. Although the summer days are long, they are usually rather cool, and in most districts night frosts may occur in June and late August; in the upper parts of some valleys and in the highlands, frost may occur at any time of the year. The summer precipitation may be unfavourably large or unfavourably scanty; in most northern districts, severe droughts are not uncommon in spring and early summer. The winter climate in the north of Iceland is on the whole rather favourable to vegetation, but in most other districts the frequent shifts from cold to mild weather and vice versa may have bad effects.

A moderate rise of summer temperature, as compared with conditions during the last decades, would mean that cereals could be grown successfully in many districts, which might lead to a revolution of Icelandic agriculture and radically change the economical conditions of rural districts, perhaps even of the country as a whole. A deterioration of the climate would lead to many difficulties and accelerate the process of evacuation of many isolated districts which has - for other reasons - taken place during the present century.

Fishery, too, is depending to a considerable extent on the climatic conditions of the atmosphere and, more directly, on those of the hydrosphere. The polar ice has sometimes, mainly during spring and early summer, blocked the harbours of northern Iceland for a considerable length of time; however, this has not happened since 1918. But even if the polar ice does not advance as far as that, the position of the ice limit, geographically and in relation to the occurrence of fish, is a matter of far-reaching consequences. The positions, and perhaps the character, of hydrographic boundaries, primarily the first-order boundary between arctic and atlantic water masses, appear to be related, in a complex manner, to the abundance of sea plankton and hence to the 'population density' of fish. See, for instance, (1) and (2).

Under these circumstances the problem of climatic fluctuations - as reflected, i.a., by the temperature and precipitation data for meteorological stations - is a problem of great significance to Iceland. Even a careful statistical study of past events will not enable us to forecast the future development of climate, as long as we have no physical explanation of the changes observed until now; nevertheless, it seems worth while to attack the problem from a climatologist's starting point and analyze the situation with the tools of statistics.

Secular trends of temperature in Reykjavík and Teigarhorn, 1901 - 1950

The primary requirement when using a series of observations in order to study climatic trends is, obviously, that the series is homogeneous. A lack of homogeneity small enough to avoid detection by ordinary blunt checking methods may be serious enough to influence the result of a 'trend' study. Even a change observed to occur simultaneously at several stations need not be real; it could have been caused by altered instructions or by roughly synchronized changes in the exposure of instruments.

As shown in Annexes VI and IX, most series of temperature and precipitation in Iceland appear to be more or less lacking in homogeneity during the period 1931 - 1955. It seems probable that very few stations are virtually homogeneous during the longer period 1901 - 1950. The Reykjavík series probably does not belong to this minority group, but as its lack of homogeneity does not appear to be very serious, as far as temperature is concerned, it was selected as one of the series to be discussed. The homogeneity of the series of Teigarhorn appears to be rather more satisfactory, but it should be noted that the early history of this station is not adequately known.

A general idea of the temperature trend as it appears in the Reykjavík series is given by table V.1. The values for the year as a whole do not give the impression of a slow and regular trend, but rather indicates a relatively sudden temperature rise of about 1° near the middle of the 50-year period. The rise is particularly large during the winter half-year.

Table V.1. Mean temperatures for successive ten-year periods of the twentieth century and for the fifty-year period 1901-1950. Reykjavík. (The monthly values were computed with two decimals but are given in the table to one decimal only.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
1901-1910	-1.0	-1.0	0.2	2.4	6.2	9.8	11.4	10.3	8.4	4.2	1.4	-0.2	4.38
1911-1920	-0.7	-0.8	-0.2	1.9	6.6	9.8	11.6	11.0	7.8	4.9	1.1	-0.7	4.34
1921-1930	0.1	1.4	1.5	3.4	6.0	9.2	11.1	10.4	7.2	3.7	1.5	0.8	4.70
1931-1940	0.2	0.2	1.6	3.7	7.6	9.9	12.0	11.3	9.2	4.9	2.5	1.6	5.42
1941-1950	0.4	-0.1	1.6	2.9	6.8	9.8	11.5	11.1	8.3	5.1	2.5	1.1	5.13
1901-1950	-0.2	-0.1	1.0	2.9	6.6	9.7	11.5	10.8	8.2	4.6	1.8	0.5	4.79

The normal statistical approach to the problem whether the climate has changed during a certain period is to set up as a 'null hypothesis' that it has not changed, and test the probability of this hypothesis (3, page 50).

Taking the monthly mean temperature of January as an example, the null hypothesis might be that the twenty values from 1931 to 1950 are taken from a 'population' of monthly mean temperatures having an average value identical with the mean temperature of January 1901-1930.

Tables V.2 and V.3 show the result of a computation following this method, for Reykjavík and Teigarhorn respectively. Some details regarding the statistical parameters used in these and the following tables are given in the text above table V.2.

Table V.2. By computation of 'Student's t' (see, for instance, (3), page 65) the collectives of Reykjavík monthly mean temperatures for the period 1931-1950 were investigated with respect to their affinity or alienage to the collectives of monthly means for the period 1901-1930. The number P gives (for each particular month) the likelihood that a collective like the 1931 - 1950 monthly means could arise when picking by chance twenty individual values from a collective with the same mean value as the monthly means for 1901 - 1930. Thus, if P is very close to zero, it is practically certain that "something has happened" to the climate (or, of course, to the station). b is the temperature rise per year shown by that straight line which gives the best possible linear representation of the fifty individual monthly mean values. Thus, the value of b for January, +.032, means that the straight line in this case rises 1.6° during the half-century.

Mean temperature	J	F	M	A	M	J	J	A	S	O	N	D
1901-1930	-0.6	-0.2	0.5	2.6	6.3	9.6	11.3	10.6	7.8	4.3	1.4	0.0
1931-1950	0.3	0.0	1.6	3.3	7.2	9.9	11.7	11.2	8.8	5.0	2.5	1.4
Increase	+0.9	+0.2	+ 1.1	+0.7	+0.9	+0.3	+0.4	+0.6	+1.0	+0.7	+1.1	+1.4
"Student's t"	2.1	0.4	2.9	2.1	2.6	1.9	2.2	3.8	3.2	2.3	3.1	3.7
P (see above)	.05	≫ .1	.009	.05	.18	.08	.04	.002	.007	.04	.008	.003
b (see above)	+.032	+.027	+.043	+.026	+.020	+.001	+.007	+.018	+.009	+.019	+.028	+.023

Table V.3. Temperatures and statistical parameters regarding the 'secular trend' of temperature at Teigarhorn. See further text above table V.2.

Mean temperature	J	F	M	A	M	J	J	A	S	O	N	D
1901-1930	-0.5	-0.2	0.1	1.8	4.7	7.9	9.6	9.0	7.1	4.0	1.2	0.2
1931-1950	0.4	-0.4	1.0	2.5	6.0	8.7	10.2	10.2	8.0	4.7	2.3	1.0
Increase or decrease	+0.9	-0.2	+0.9	+0.7	+1.3	+0.8	+0.6	+1.2	+0.9	+0.7	+1.1	+0.8
"Student's t"	2.0	0.5	2.3	2.5	4.5	3.8	3.5	6.3	3.6	2.7	4.1	2.5
P (see text to table V.2)	.06	≫.1.	.03	.022	.0002	.0012	.002	< .0001	.002	.014	.0006	.022

The P-values of both tables are in several instances very low. Some of these values seem to be almost sufficiently low to prove that the climate has changed during this century; taking them together, and considering that the sign of the apparent change is positive in 23 cases out of 24, one might think that even the slightest doubt would be out of place. Still, it should be remembered that the homogeneity of the series is not sufficiently corroborated, and probably cannot be proved to full evidence.

The slope of the straight line which would give the best approximation to the 50 individual mean temperatures for each month was computed for Reykjavík, by means of Marvin's eminently time-saving method (see, for instance, (3), page 281)

Secular trends of precipitation in Reykjavík and Teigarhorn, 1901-1950

Table V.4. Average precipitation and statistical parameters regarding the "secular trend" of precipitation in Reykjavik. (See further text above table V.2.)

Average precipitation (mm)	J	F	M	A	M	J	J	A	S	O	N	D
1901-1930	103	87	75	61	51	50	51	52	91	90	96	98
1931-1950	93	58	68	48	41	40	49	77	80	94	82	84
Increase or decrease	-10	-29	-7	-13	-10	-10	-2	+25	-11	+4	-14	-14
"Student's t"	0.9	5.2	0.9	2.5	1.8	2.8	0.4	3.4	1.3	0.4	1.6	2.0
P (see text to table V.2)	≫.1	<.0001	≫.1	.022	.09	.011	≫.1	.003	>.1	≫.1	>.1	.06

Table V.5. Average precipitation and statistical parameters regarding the 'secular trend' of precipitation in Teigarhorn. (See further text above table V.2.)

Average precipi-tation (mm)	J	F	M	A	M	J	J	A	S	O	N	D
1901-1930	146	108	97	82	79	65	70	88	136	134	111	139
1931-1950	147	93	92	77	77	72	90	93	125	127	117	148
Increase or decrease	+1	-15	-5	-5	-2	+7	+20	+5	-11	-7	+6	+9
"Student's t"	0.01	1.3	0.43	0.38	0.17	0.62	1.25	0.37	0.68	0.56	0.38	0.54
P (see text to table V.2)	$\gg .1$	$> .1$	$\gg .1$	$\gg .1$	$\gg .1$	$\gg .1$	$> .1$	$\gg .1$	$\gg .1$	$\gg .1$	$\gg .1$	$\gg .1$

Tables V.4 and V.5 contain the result of a similar investigation regarding the trend of precipitation amounts at the same stations. In this case there is a marked difference between the results, as there is a rather strong evidence of the reality of a decrease in precipitation in Reykjavík in certain months (mainly February but also April and June) and, curiously enough, of an increase of the August precipitation at the same station, whereas the data for Teigarhorn are well compatible with the 'null hypothesis'. Although it is not entirely out of question that there could be a considerable difference between the secular trends of precipitation at these two stations, the most reasonable explanation seems to be that the precipitation series of Reykjavík is not homogeneous. In fact this station is known to have been moved on several occasions.

ANNEX VI

PROBLEMS CONNECTED WITH THE APPLICATION OF AN EXISTING SET OF 'NORMAL TEMPERATURES' FOR 1901-1930 AND THE PREPARATION OF A NEW SET OF CORRESPONDING NORMALS FOR 1931-1960

Introduction

'Normal temperatures' for the standard period 1901 - 1930 were published in 'Veðráttan' for 1944. The normal values for each month were given for 58 stations.

In view of the scarcity of climatological stations in Iceland - still more marked in earlier years - it is natural that much care was taken to utilize all available material. A complete series of temperature observations from 1901 - 1930 was available in a few cases only; more often, the 'normal' values had to be computed from short series, e.g. 10-15 years. For this purpose the 'reduction method' was used.

It is easy to imagine that normal temperatures computed in this way may need an adjustment. In the two following sections of the present Annex this problem is discussed from various points of view.

Although the number of stations making temperature observations has increased during later years, it is still insufficient to answer many questions of scientific and practical significance. It seems advisable, under these circumstances, to start the preparations for computing monthly normal temperatures now for the standard period 1931 - 1960. Some problems connected with this preparatory work are discussed in the three last sections of the present Annex.

Consistency checks of existing "normal temperatures"

The usual procedure when computing "normal temperatures" from short series by comparing them with series which are complete, or more nearly complete, is to consider the temperature of each calender month separately. It is not customary to try to adjust the resulting normal temperatures of the twelve months by making special assumptions.

It might, however, under certain conditions be desirable to obtain the best possible estimate of the normal temperature of each month, even if this implies some additional labour. In such cases it seems reasonable to make the following assumption:

Unless special physical arguments point to the adverse, the differences in monthly normal temperatures between adjacent and reasonably comparable stations should exhibit a smooth, not too complicated yearly variation, preferably in the form of a single, roughly sinusoidal wave.

Support for this assumption can be obtained from normal temperatures (based on complete series of observations) from stations on the continent of Europe. It might be possible, too, to find quite a number of exceptions, although, presumably, such exceptions would be due to an insufficient understanding of the physical conditions, as influenced by the character of soil and vegetation, the interaction of large-scale and local winds, etc. There seems to be good reasons to believe that the assumption holds true in Iceland, but the temperature observations made in Iceland do not offer equally good opportunities to test the assumption, because stations with complete series are few and mostly far-between; this fact is the very reason for trying to stretch the material as far as possible. However, one example shall be given. The "normal temperatures" for 1901 - 1930 at Teigarhorn and Papey, both on the east coast of Iceland, and the corresponding differences, are shown below:

	J	F	M	A	M	J	J	A	S	O	N	D
Teigarhorn	-0.5	-0.2	0.1	1.8	4.7	7.9	9.6	9.0	7.1	4.0	1.2	0.2
Papey	-0.3	-0.1	-0.3	1.0	3.2	6.0	7.6	7.6	6.4	3.8	1.3	0.3
(T) - (P)	-0.2	-0.1	0.4	0.8	1.5	1.9	2.0	1.4	0.7	0.2	-0.1	-0.1

In this case the assumption is confirmed, although it might be pointed out that the winter minimum of the difference is remarkably flat.

For the practical application of the assumption, the most obvious method would be to compare the data for an individual station, A, with the data for a small number of neighbouring stations, e.g. B, C, D, and E. The annual variations of the differences of monthly mean temperature, Δ_{B-A}, Δ_{C-A}, etc., would then, taken together, indicate whether the series of monthly mean temperatures of A could be considered as sufficiently smooth. If, for instance Δ_{B-A}, Δ_{C-A} and Δ_{D-A} vary in a smooth manner while Δ_{E-A} does not, this indicates firstly that the A-series does not need to be smoothed, and secondly, either that the E-series needs smoothing or that E, for some reason or other, is not a good reference station in this particular case.

The method may be modified by comparing, e.g., station A with an 'artificial reference station' which, symbolically, might be called $\frac{1}{4}(B+C+D+E)$. The disturbing effect of one bad reference station, for instance E, is small in this case, and the result - showing the average temperature difference, month by month, between A on one hand and the station group B+C+D+E on the other - is well suited for a further analysis.

A concrete example of this method is given in table VI.1.

Table VI.1. Method of checking temperature 'normals' by computing differences between the values to be checked and corresponding average values for reference stations. The smoothed differences were determined by careful graphical smoothing, and the 'correction' is simply the amount of smoothing applied to each unsmoothed monthly mean.

	J	F	M	A	M	J	J	A	S	O	N	D
Ljósafoss	-2.0	-1.6	-0.9	1.8	5.7	9.4	10.9	10.0	7.3	3.4	0.1	-0.9
Hvanneyri	-1.9	-1.4	-0.7	1.6	5.7	9.4	10.8	9.7	7.1	3.0	-0.3	-1.0
Síðumúli	-2.8	-2.4	-1.6	0.9	4.9	8.9	10.9	9.1	6.7	2.5	-0.8	-1.7
Stórinúpur	-1.5	-1.2	-0.8	1.4	5.5	9.4	11.2	9.8	6.9	3.3	0.1	-1.0
4-station average	-2.05	-1.65	-1.0	1.4	5.45	9.3	10.95	9.65	7.0	3.05	-0.2	-1.15
Þingvellir	-2.9	-2.4	-2.2	1.5	5.6	9.4	11.2	9.7	7.0	2.2	-1.1	-2.0
Difference	-0.85	-0.75	-1.2	+0.1	+0.15	+0.1	+0.25	+0.05	0.0	-0.85	-0.9	-0.85
" (smoothed)	-0.9	-0.75	-0.7	-0.1	+0.15	+0.25	+0.15	+0.05	-0.25	-0.6	-0.85	-0.95
Correction	-0.05	0	+0.5	-0.2	0	+0.15	-0.1	0	-0.25	+0.25	+0.05	-0.1

A minor weakness of the method just described is that it demands a decision in each individual case as to which stations should be used as reference stations. If the reference stations, perhaps by necessity, are very asymmetrically distributed around the station to be checked, the result may be biassed and false corrections introduced.

An alternative method which is based on the same principle but which, partly at least, avoids this difficulty, makes use of the idea that instead of studying the annual variation of temperature differences between various stations, **we may compare the details of the annual march of temperature at these stations**. Although the difference between the two methods is purely practical, it is not entirely insignificant.

The alternative method consists of two steps. The first step is to compute 'second-order differences' of the series of monthly mean temperatures, for each individual station, as exemplified by table VI.2. The next step is to plot the second-order differences on maps - one map for each month - and analyze these maps. This analysis serves to reveal 'normals' which are more or less in conflict with the normals of neighbouring stations. If, for instance, the second-order difference corresponding to March at a certain station is remarkably high, then either the temperature rise from March to April is particularly large, or the rise from February to March particularly small, or both; the simplest explanation would be that the March normal is too low and needs a positive correction.

Table VI.2. Method of checking temperature 'normals' by comparing the second-order differences. (For further explanation, see text.)

	Reykjavik t_m	Δ_1	Δ_2	Þingvellir t_m	Δ_1	Δ_2
D	0.0			-2.0		
		-0.6			-0.9	
J	-0.6		+1.0	-2.9		+1.4
		+0.4			+0.5	
F	-0.2		+0.3	-2.4		-0.3
		+0.7			+0.2	
M	0.5		+1.4	-2.2		+3.5
		+2.1			+3.7	
A	2.6		+1.6	1.5		+0.4
		+3.7			+4.1	
M	6.3		-0.4	5.6		-0.3
		+3.3			+3.8	
J	9.6		-1.6	9.4		-2.0
		+1.7			+1.8	
J	11.3		-2.4	11.2		-3.3
		-0.7			-1.5	
A	10.6		-2.1	9.7		-1.2
		-2.8			-2.7	
S	7.8		-0.7	7.0		-2.1
		-3.5			-4.8	
O	4.3		+0.6	2.2		+1.5
		-2.9			-3.3	
N	1.4		+1.5	-1.1		+2.4
		-1.4			-0.9	
Ð	0.0		+0.8	-2.0		0.0
		-0.6			-0.9	
J	-0.6			-2.9		

A certain disadvantage of the latter method is that the analysis of the maps is a rather subjective matter. It is difficult to be completely 'neutral' if one for some reason or other starts out with the suspicion that a particular station is unreliable.

Although both methods are based on the same hypothesis, they diverge sufficiently in their practical application to supplement each other to a certain extent. They are both subjective, but not quite in the same manner. It should not be forgotten, however, that even if the two methods lead to identical results, both indicating, e.g., that the given 'normal temperature' of a certain month at station A is too low, this low temperature may be a real phenomenon, which has known or unknown physical causes. To give an example of this, the low 'normal temperature' of March at Þingvellir (table VI.2) might possibly be explained by the fact that usually the relatively large lake Þingvallavatn is covered by ice during the greater part of this month: the presence of the ice may, during the process of melting at least, cause a sensible delay in the rise of the air temperature.

The two methods just described were applied to the entire material of 'normal temperatures' valid for 1901 - 1930 at Icelandic stations. The results were somewhat similar but by no means identical. Fortunately a third method, based on a different idea but of approximately equal efficiency, could be applied to the same material. This third method is described in the following section.

Adjustment of existing normals by utilizing recent observations

Already when the 'normals' for the period 1901 - 1930 were computed, some use was made of observations performed during the following ten years. As it is beyond doubt that the regional temperature differences, disregarding the possible effect of inhomogeneities, are more constant from year to year than the temperature itself, this procedure, although perhaps somewhat unusual, is perfectly sound.

Now, as more than 25 years have elapsed of the following 30-year period, it is possible to go a step further. For this purpose, as well as for purposes stated later, all available monthly mean temperatures for individual years from 1931 through 1950 were transferred to punch-cards, and five-year sums were computed by means of data-processing machines.

Table VI.3. 'Normal' temperature 1901 - 1930 and five-year mean temperatures for the period 1931 - 1955 for each month and for the year. Húsavík. (Example of tables used for computation of five-year departures from monthly (and yearly) 'normal' temperatures.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Húsavík													
1901-1930	-2.3	-1.9	-1.6	0.4	4.4	8.3	10.2	8.5	6.3	2.7	-0.2	-1.2	2.8
1931-1935	-0.3	-1.4	0.1	0.8	6.5	9.5	11.0	11.0	8.2	2.6	2.2	1.0	4.3
1936-1940	-1.6	-1.2	-1.2	2.3	6.7	9.5	9.8	10.7	8.1	4.6	0.5	-0.4	4.0
1941-1945	-2.3	-2.2	0.5	2.1	4.9	8.3	10.5	9.3	8.0	3.7	2.0	0.2	3.8
1946-1950	0.6	-1.2	-0.5	-0.2	5.5	8.3	10.9	10.6	7.3	4.4	0.1	-0.5	3.8
1951-1955	-1.5	-0.9	-0.9	1.2	5.7	9.0	10.7	10.1	7.0	3.6	1.3	-0.7	3.7

Table VI.4. Five-year mean departures (1951-1955) from 'normal' temperatures. Excerpted from a table containing values for 40 stations.

1951-1955	J	F	M	A	M	J	J	A	S	O	N	D	Year
Sámsstaðir	+0.6	-0.1	+0.4	+0.5	+0.9	+1.1	+0.6	+1.0	+1.2	+0.8	+1.6	+0.3	+0.7
Hæll	-0.4	-0.5	+0.1	+0.6	+1.1	+1.0	-0.1	+0.9	+0.5	0.0	+1.0	-0.6	+0.3
Ljósafoss	+0.5	+0.2	+0.7	+0.3	+1.1	+0.8	+0.3	+1.2	+1.0	+1.0	+1.9	+0.1	+0.8
Þingvellir	+0.2	-0.5	+0.7	-0.2	+0.7	+0.7	-0.5	+0.6	-0.3	+0.7	+1.9	+0.2	+0.4

If we compare the mean monthly temperatures at a particular station during individual years - or, to simplify the procedure, individual five-year periods (table VI.3) - with the 1901-1930 normals, we find a set of departures, as exemplified by table VI.4, which we may check by comparing them with similar departures from other stations. To make this comparison, the deviations for each particular month and five-year period were plotted on a map; hence, altogether 60 maps were plotted. To obtain material as complete as possible, a considerable number of values for missing months were interpolated by ordinary methods before the five-year mean values were computed. The maps were analyzed with the object of obtaining a generalized picture of the departure in each case, assuming that the gradient of this departure is not very steep and does not vary too erraticly. It was thought that the permissibility of this assumption could be judged reasonably well as the analysis of the map series proceeded.

The analysis of the maps from the four five-year periods covering the epoch from 1931 to 1950 gave considerable support for the assumption and, hence, for the method. Although the details of the analysis were rather uncertain in some cases, it seemed possible to read off from each map a 'smoothed' departure for each station, for comparison with the directly computed, unsmoothed departure. The differences between these departures were tabulated station by station, as shown by table VI.5. Each table value was determined as the smoothed departure, obtained through the analysis, minus the directly computed value taken from tables like VI.4. The values of the table may thus be interpreted as a set of 'corrections' which, when applied to the directly computed departures, would make these fit perfectly well into the assumed general distribution of departures shown by the analysis.

Table VI.5. Table of differences between five-year mean departures (as taken from tables like VI.4) and corresponding values 'smoothed geographically' (see text). Monthly differences $\geq$ +0.3 or $\leq$ -0.3 are underlined. The monthly differences of each five-year period are added to give an indication of 'false trends', as described in text.

Þingvellir	J	F	M	A	M	J	J	A	S	O	N	D	Σ
1936-1940	0.0	+0.1	0.0	+0.4	+0.3	-0.1	0.0	+0.2	+0.6	+0.2	-0.1	+0.1	+1.7
1941-1945	+0.2	0.0	-0.1	+0.2	+0.3	-0.1	+0.1	0.0	+0.7	+0.1	0.0	0.0	+1.4
1946-1950	-0.2	+0.3	+0.2	+0.5	+0.2	-0.1	+0.3	+0.1	+0.6	+0.3	0.0	+0.1	+2.3
1951-1955	+0.1	+0.3	-0.1	+0.4	+0.3	-0.1	+0.2	0.0	+0.7	0.0	-0.3	-0.2	+1.3

The use which can be made of tables like VI.5 is fairly obvious. If, for instance, the values for a certain station and month are consistently, and not negligibly, positive, we may conclude that the normal value for that particular month probably needs a positive correction. In this case we do not have to make a reservation regarding special physical conditions, as these would almost certainly act in a similar way during the normal period and later.

The analysis of the maps for the period 1951 - 1955 proved to be much more difficult. One reason may be the effect of minor, but accumulating changes in the immediate surroundings of the station, making the 1901 - 1930 normals progressively less appropriate. The mean reason, however, seems to be that at a large number of temperature stations - in fact, more than 50% of those stations for which a normal is available and which were still in operation - the wall-screen was substituted by a freely exposed, larger screen of Norwegian type at some time between July 1949 and September 1953; it is obvious that one may expect such a change to affect the departures for 1951 - 1955, and affect them differently at the different stations, if only for the reason that the changes did not all occur at the same time. Therefore, the departures for the period 1951 - 1955 had to be disregarded when trying to determine corrections to the normal temperatures. It seemed necessary, however, to study the effect of the change from a wall-screen to a Norwegian-type screen in some detail, as described in a later section of this annex.

Finally, the results of the three methods for adjusting normal temperatures were compared. If the three corrections were not too different and the absolute value of their average was not less than 0.2°, a correction of the normal temperature was recommended. A total of 696 monthly normals were checked, and a change was proposed in 34 cases. The proposed change was mostly 0.2 or 0.3°, but amounted to 0.4° in nine cases, to 0.5° in two cases and to 0.6° in one case.

Homogeneity checks

Tables like VI.5 were used for homogeneity checks and proved to be well suited for this purpose. As might be expected, most of the nonhomogeneities which were found (or suspected) belonged, if significant, to one out of two types: either the monthly mean temperatures during a certain period appeared to deviate in a rather similar manner, or there was a marked difference between the apparent average deviations during summer half-year and winter half-year. The simplest, though perhaps not the most probable, explanation in the first case would be an instrumental error, and the most obvious explanation in the latter case would be some change in the exposure.

The homogeneity checks were, for stations where normals for 1901 - 1930 were available, based on these normals and on five-year monthly means from 1931 to 1950. The material for 1951 - 1955 was not utilized for this study, for reasons given above.

Among 56 stations checked, there were 36 for which departures for three or four five-year periods were available. 15 of these stations were found to be homogeneous or very nearly so, while 21 appeared to be more or less nonhomogeneous. The amount of the five-year monthly departures assumed to be due to nonhomogeneity was mostly 0.2-0.4° but in a few cases 0.5-0.8°.

A document stating in brief the results of the homogeneity checks for each individual station was left for future use at Veðurstofan.

A special homogeneity problem: effect of a change from wall-screens to freely exposed screens at Icelandic stations

Until about 1949, nearly all temperature observations in Iceland were made on thermometers placed in small screens attached to the outer wall of a building, sometimes near a window. In several cases the wall on which the screen was fastened was exposed to direct sunshine in the early morning or the late evening during part of the year.

An important renovation was initiated in this respect in 1949. From then on the wall-screens have been replaced by freely exposed screens at the majority of the temperature stations. This is a definite improvement and should be appreciated as such in spite of two facts which may tend to reduce, to some extent, the favourable effects of the change: firstly, the wall-screens are probably not equally inferior to the freely-exposed screens here as they would have been in a less windy climate; secondly, it would have been advantageous from some points of view if the period of renovation had started a little earlier and had not been concentrated in a few years, as this concentration makes it difficult to determine the effect of the change at any individual station.

It may also be remarked that it would have been very fortunate if fairly long series of parallel readings of wall-screen temperatures and Norwegian-type screen temperatures had been available from a number of stations. Mainly for economical reasons, it has not been possible to secure such an arrangement. Therefore, it was necessary to use an indirect method for estimating the effect of the change of exposure. This indirect method gives less reliable results in each case than a series of accurate parallel readings could have done; in fact, it does not seem to permit definite conclusions as to the magnitude of the effect in an individual case, although it does allow a fair estimate of the normal magnitude of this effect under the conditions prevailing in Iceland.

The method in question was based on comparisons between station pairs; of each pair, one, referred to as the main station, experienced a change from wall-screen to freely exposed screen, while the other station, called the reference station, remained unchanged (as far as known, and certainly in this respect) during the period of comparison. The length of this period should be sufficient to cover all seasons both before and after the change, but if the comparison were extended over many years, there would be a considerable risk that irrelevant changes occuring at any of the stations might blur the results. As a compromise, periods of four years were used whenever possible: two years before the change was made, and two years after that time. The month during which **the change occurred was disregarded.**

Table VI.6. Differences in monthly mean temperature between Húsavík and Raufarhöfn the last two years before, and the first two years after, the wall-screen at Húsavík was substituted by a freely exposed screen. (Raufarhöfn had a screen of the latter type during the whole period.) Positive values indicate that the temperature of Húsavík was higher than that of Raufarhöfn. For further explanation, see text.

	J	F	M	A	M	J	J	A	S	O	N	D
I	+0.1	+0.9	+0.8	+0.5	+1.5	+2.4	+1.9	+1.8	+1.5	-0.2	-0.2	-0.5
	-0.6	-0.3	-0.7	+0.2	+3.0	+2.2	+2.0	+1.5	+1.6	+0.6	-0.7	+0.4
Σ I	-0.5	+0.6	+0.1	+0.7	+4.5	+4.6	+3.9	+3.3	+3.1	+0.4	-0.9	-0.1
II	+0.6	-0.4	+0.4	+2.0	+2.5	+2.1	+1.5	+1.8	+1.3	+0.6	+1.1	+0.3
	+0.9	+1.5	+0.9	+0.7	+2.3	+2.8	+1.7	+1.1	+0.4	+0.2	+0.2	+0.6
Σ II	+1.5	+1.1	+1.3	+2.7	+4.8	+4.9	+3.2	+2.9	+1.7	+0.8	+1.3	+0.9
$\frac{\Sigma \text{II} - \Sigma \text{I}}{2}$	+1.0	+0.25	+0.6	+1.0	+0.15	+0.15	+0.35	-0.2	-0.7	+0.2	+1.1	+0.5
" smoothed	+0.7	+0.6	+0.6	+0.6	+0.4	+0.1	-0.2	-0.3	-0.2	+0.2	+0.5	+0.7

The practical arrangement is shown by table VI.6. The numbers of the two upper lines give the differences of monthly mean temperature between the main station and the reference station (positive, when the main station was warmer) during a 24-month period directly preceding that month in which the change was made at the main station. The numbers of the next line of the table give the two-year sums of these differences for the respective months. The lines 4-6 refer correspondingly to the 24 months after the change. The numbers of the seventh line represent unsmoothed values of the 'effect' which may presumably be ascribed to the change of exposure at the main station. The last line gives the corresponding values after repeated smoothing (two or three times, as required) by means of the formula $b_1 = \frac{a+2b+c}{4}$.

The unsmoothed values generally showed large and irregular variations from month to month. This might have been expected as the effect of the change of exposure will be overlapped by real differences associated with the general pattern of temperature departures of each individual month, the real differences being of the same order of magnitude, at least, as the effect to be studied. The smoothed values usually, but with some notable exceptions, showed an annual variation roughly of the type which might be expected for physical reasons: after the change has been made, the summer temperatures appear to be slightly lower than before, or the winter temperatures slightly higher; sometimes both. The exceptions may be due to effects of the 'random' factors regulating the temperature distribution of individual months, or they may be caused by an unrevealed or disregarded nonhomogeneity of the reference series.

Considered as a whole, the smoothed values (or, for that matter, the unsmoothed values) for the different station pairs may be assumed to give a good estimate of the overall, typical effect of the change from a wall-screen to a Norwegian-type screen under the conditions usually experienced at Icelandic stations. Table VI.7 shows average values based on 37 comparisons. The number of 'main stations' used was 26; in eleven cases, two reference stations were used. The values of table VI.7 were computed by giving all 37 individual sets of values the same weight.

Table VI.7. Mean values of 37 single (smoothed) values, showing the 'typical' effect on monthly mean temperatures of an Icelandic station when a wall-screen is substituted by a freely exposed screen.

	J	F	M	A	M	J	J	A	S	O	N	D
Mean of 37 single (smoothed) values	+0.18	+0.18	+0.12	-0.02	-0.18	-0.27	-0.28	-0.17	-0.08	+0.01	+0.08	+0.13

The result as shown in table VI.7 confirms that the normal effect of a shift from wall-screens to freely exposed screens is found also in Iceland. It may perhaps also be said to confirm the above-mentioned assumption that this effect, when expressed in absolute measure, is smaller than that generally found in other countries. However, this does not imply that the effect could be neglected. There are good reasons for being meticulous when using and discussing temperature measurements made at Icelandic stations.

ANNEX VII

REMARKS ON HUMIDITY MEASUREMENTS IN ICELAND

When a network of climatological stations was established in Iceland by the Danish Meteorological Institute (1874), the main stations were equipped with wetbulb thermometers. For these stations, values of vapour pressure and relative humidity were published in the extenso-tables of the Meteorological Year-book (4); monthly mean values were also published. This continued until 1923, and in the course of these fifty years some ordinary climatological stations were also equipped with wet-bulb thermometers, although for such stations only monthly mean values were published. Little or no further use seems to have been made of this material. - The readings of wet-bulb thermometers have been continued without interruption; in 1957, such readings were made at 42 stations. In the case of synoptic stations, the readings are used for determination of relative humidity or dew-point as required by the weather code. However, no humidity data have been published in "Veðráttan" or elsewhere since 1924, and as no other regular use was made of the data, the computation of humidity values not required for specific purposes was suspended, during many years, for most stations. This may have had unfavourable effects regarding the quality of humidity observations, as these were no longer regularly checked. Inspections of the stations have, until now, been much too sporadic to secure reliable observations on this point, which is known to be a crucial point for the average observer.

The above statements might give the impression that humidity measurements in Iceland are considered to be of little value. However, this impression is not quite correct. The main reason for not making full use of the available material is that the computational work required for that purpose would take too much time. An additional reason is, admittedly, a general feeling that the quality of the available observations is not quite satisfactory.

In fact, the humidity of the air is not a negligible factor of the climate of Iceland, and the staff of Veðurstofan is well aware that it is not. Its main importance is found in relations to agriculture and, perhaps, forestry. The high humidity often experienced e.g. in late summer is unfavourable for hay production, and the low humidity sometimes associated with strong winds in late spring seems to be unfavourable to reforestation.

It seemed worth while, therefore, to consider whether a fuller knowledge of humidity conditions in Iceland could be gained without an excessive amount of computations. The possibilities in this respect were discussed during my stay at Veðurstofan, but the actual computations were not started until shortly before I left. Therefore, the following discussion is based on considerations more than on facts.

A minor problem of some practical significance was considered at first, namely whether it was permissible, in view of the weather conditions prevailing in Iceland, to compute monthly means of relative humidity from monthly means of dry- and wet-bulb thermometer readings. This was found to be the case, as might perhaps have been expected when considering the moderating influence on air-mass properties exerted by the surrounding ocean: the effect of different procedures on the resulting monthly mean of relative humidity appeared to be negligible, hardly ever exceeding 1%.

The next step was to set up tables showing the annual and diurnal variation of mean relative humidity at selected stations. The first few tables of this kind indicate that, in coastal areas at least, the annual variation of the relative humidity is small, May or June generally being the driest month. The periodic diurnal variation is, for natural reasons, negligible in winter and not very large in summer.

The frequency distribution of relative humidity at various times of the day and the year is probably of greater practical importance than the mean values. The variations from day to day are often considerable, although very low humidities (below 40%) are unusual except under special circumstances (föhn).

The analysis of humidity conditions in Iceland might continue along the lines indicated above, until a clear and reasonably complete picture has been arrived at regarding the regional and seasonal variations of relative humidity, including frequency distributions. A further development, probably equally important from a practical point of view, would consist in studying the frequencies of possible combinations of, e.g., temperature and humidity, or wind velocity and humidity. These studies should, of course, be limited to such observations which are found to be reasonably trustworthy.

The future problem of humidity measurements in Iceland is partly a problem of using the instrument best fit for the circumstances. The computational work will be reduced to a very considerable extent if it is found that the psychrometer method can be replaced by readings of first-class hygrometers.

ANNEX VIII

PRELIMINARY ANALYSIS OF PRECIPITATION DATA FROM ICELANDIC STATIONS DURING THE PERIOD 1931 - 1955

General remarks on precipitation measurements in Iceland after 1930

The number of Icelandic stations measuring precipitation at the beginning of 1931 was slightly above 25; near the end of 1957, it was 72. In the first case it was a little lower than the number of stations measuring temperature; in the second, a little higher.

The rain-gauges used during the entire period are of the Hellmann type. During the last ten years, a considerable number of the gauges have been equipped with a Nipher shield. The need for this measure is obvious, in view of the prevailing wind conditions in Iceland and the fact that a considerable part of the precipitation falls in the form of snow.

The question of homogeneity of the precipitation stations required a special study, summarized in the following section.

The number of precipitation stations in Iceland is at least one order of magnitude too small to permit a direct mapping of normal precipitation, or of actual precipitation during e.g. one particular month. The orography of the country is partly extremely rugged, as on the northwestern peninsula and near the east coast. The combined effect of orography and prevailing wind conditions on the amount of precipitation must be extremely complex in such regions, and there are indications that in other regions, too, the pattern of average precipitation is more complicated than one might expect, with remarkably steep gradients even where the differences in altitude are quite moderate.

None of the regular precipitation stations is situated above 500 m, although more than half of the area of Iceland is above that level. There are two possibilities for estimating the amount of precipitation of this part of the country: by theoretical reasoning, or by utilizing measurements of the flow of the rivers. The latter possibility meets with special difficulties in Iceland because of the large storing of water in inaccessible underground reservoirs. To compute the water balance includes estimating the evaporation; in other countries, this is often the main difficulty. No measurements of evaporation are known from Iceland apart from a few series made on glaciers. Although one might expect the evaporation to be low on account of the low summer temperature and the usually rather high humidity, the high frequency of strong winds acts in the opposite direction, to an extent which it is difficult to estimate.

A series of water-flow measurements has been made in a greater part of the rivers of Iceland during recent years, and the results have been analyzed by Sigurjón Rist (7). By means of these series, it should be possible to arrive at a preliminary estimate of the mean normal precipitation in many interior areas of Iceland, but the values thus obtained will usually be mean values for rather large areas. To obtain a more detailed picture it is necessary to make actual measurements of the precipitation. In some cases this may be possible by means of totalizers placed at strategic points. A small-scale experiment of this type has been carried on for some years in the precipitation area of lake Hvalvatn, but the results are too incomplete, and partly not sufficiently reliable, to allow definite conclusions as to the potentialities of this method.

It is difficult to formulate a definite program for future precipitation studies in Iceland. It goes without saying that an increase of the number of ordinary stations is very desirable but there will be no possibility of an increase sufficiently large to solve the whole problem. In particular, other methods, probably along the lines indicated above, must be used regarding the uninhabited part of the country.

Homogeneity checks: method and results

Even a superficial study of the annual amount of precipitation measured at different stations during the last decades indicates that some of the series are not homogeneous. Checks had to be made in order to determine the nature and degree of existing nonhomogeneities. The practical problem was rendered more difficult by the fact that a large part of the series were quite short. In particular, not a single complete series was available from the northeasternmost part of the country.

For the homogeneity check, only the yearly amounts of precipitation were utilized. These were tabulated station by station, and the cumulative amounts were written down for each year. In the case of a complete series, the last number thus indicated the total precipitation amount for the entire period. The cumulative series' for selected pairs of adjacent stations were then compared by means of 'double-mass' curves. It proved possible to ascertain, in most cases with a fair degree of confidence, whether a series was homogeneous, and if it appeared that this was not the case, the nonhomogeneity could be studied in detail. It may be noted that short series were sometimes useful when checking the homogeneity of station having longer series.

There are some important limitations to this method. As far as possible, the distance between stations compared with each other should not be large; if this precaution were disregarded, real differences in average precipitation during several years might, wrongly, be taken as indications **of a non-homogeneity.** It might be mentioned, too, that occasionally the analysis of the double-mass curves was a rather subjective matter; sometimes as many as six or seven curves had to be constructed before a definite conclusion could be arrived at for an individual station.

A total of 65 stations were checked for homogeneity. Of these, 23 having series of 10 years or more, and 7 having shorter series, were found to be homogeneous or nearly so, while all other series showed indications of a more or less serious non-homogeneity. In eight cases the degree of non-homogeneity was such that it would seem preferable to split up a series into two. In 10 cases the precipitation totals of one year or a few years appeared to be in error.

A detailed account of the homogeneity study was placed at the disposal of Veðurstofan.

Mean yearly precipitation: a brief discussion

A series of 'normal' monthly and yearly precipitation values for 1901 - 1930 for 17 Icelandic stations was published in 'Veðráttan 1942. The quantitative insufficiency of this material has been felt quite seriously. For this reason 25-year mean values of yearly precipitation (1931 - 1955) were computed for as many stations as possible. The result is shown by table VIII.1. In this table, two values have been given for stations showing clear-cut nonhomogeneities. The number of years covered by each series, or each partial series, is stated.

Table VIII.1. Preliminary values of mean yearly precipitation 1931-1955 and, for comparison, normal precipitation 1901-1930, if available. The number of years of observations is also given. When determining this number, years with incomplete or doubtful observations were in most cases included. Series showing a marked non-homogeneity are given as if belonging to two stations, labelled, e.g., Hamraendar I and Hamraendar II.

Station	Average precipitation 1901-1930	Average precipitation 1931-1955	Number of years of obs. 1931-1955
Reykjavík	904	799	25
Rafmagnsstöðin		885	21
Hvanneyri	896	1003	10
Rafm. Andakíl		1478	6
Síðumúli		709	21
Arnarstapi		1406	20
Hellissandur		897	21
Stykkishólmur	680	760	25
Hamraendar I		750	10
" II		504	8
Reykhólar		681	7
Lambavatn		965	17
Suðureyri	902	1076	25
Bolungarvík I		633	10
" II		910	9
Hesteyri		538	6
Horn		1130	8
Hornbjargsviti		1171	8

Station	Average precipitation 1901-1930	Average precipitation 1931-1955	Number of years of obs. 1931-1955
Kjörvogur		791	22
Graenhóll	562		
Hlaðhamar		509	15
Núpsdalstunga		393	7
Blönduós	418	479	24
Hraun á Skaga	614	660	7
Nautabú		420	10
Maelifell		552	10
Skriðuland		483	21
Hraun í Fljótum	614		
Siglunes		622	19
Akureyri	465	481	25
Grímsey I		307	12
" II		504	11
Sandur í Aðaldal		463	21
Húsavík	509	522	25
Reykjahlíð I		354	12
" II		537	6
Grímsstaðir I		329	12
" II		472	8
Raufarhöfn I		550	12
" II		859	8
Skoruvík		640	9
Skálar		343	8
Höfn í Bakkafirði	496	532	12
Hof í Vopnafirði		540	6
Fagridalur		831	24

Station	Average precipitation 1901-1930	1931-1955	Numbers of years of obs. 1931-1955
Möðrudalur		519	7
Gunnhildargerði		449	6
Hallormsstaður		696	15
Seyðisfjörður		1442	17
Dalatangi		1417	17
Vattarnes		1270	14
Teigarhorn	1256	1300	25
Djúpivogur		1226	12
Hólar í Hornafirði		1639	25
Fagurhólsmýri	1828	1652	25
Kirkjubaejarklaustur		1681	25
Vík í Mýrdal	2093	2273	25
Loftsalir		1455	16
Vestmannaeyjar (Stórhöfði)	1241	1389	25
Sámsstaðir	989	980	25
Eyrarbakki	1123	1337	25
Úlfljótsvatn		1780	5
Ljósafoss		1610	18
Þingvellir		1276	21
Grindavík		1197	24
Reykjanes		1039	18
Vífilsstaðir		1091	14

The most striking feature shown by the precipitation figures is perhaps the large local variations in several parts of the country. Even stations situated very close to each other and with no very obvious differences as to local orography may show differences of yearly precipitation amounting to 30% or more.

Another striking fact, well known from earlier tables of normal precipitation, is the large contrast between the northern and southern parts of the country. South of a line from Reykjavík to Eskifjörður, no station has a yearly precipitation average below 1000 mm, and one station, Vík í Mýrdal, near the southernmost point of Iceland and just south of Mýrdalsjökull, has a mean value well above 2000 mm. North of the line from Reykjavík to Eskifjörður, only a few coastal stations receive an amount of more than 1000 mm, and at most stations in the north-central part of the country the average is somewhat below 500 mm.

It has not been possible to go very far into the question of the reliability of precipitation values as reported by the stations. There are some indications that the precipitation during the winter may be considerably larger than the reported amount, above all in northern districts. The snow which then dominates in this part of the country, is often of low density and, even if the wind is only moderately strong, extremely difficult to measure in a reliable manner. At most stations near the eastern, southern, and western coasts a considerable amount of precipitation falls when the wind is very strong, and in such cases even the correct measurement of rain is difficult, in particular if the rain-gauge is unshielded.

In cases where a precipitation normal for the period 1901-1930 is available, these values are included, for comparison, in table VIII.1. It is seen that in most cases the values of the new set of normals are somewhat larger than those of the old series. To some extent this difference may be due to changes in the exposure of the gauges, or to the introduction of the Nipher shield (page 87).

Preliminary studies regarding the percentage of yearly rainfall normally occurring during an individual month

For a discussion of the typical distribution of precipitation during the year the following symbols are introduced:

Annual mean precipitation at station A: $(P_Y)_A$

Mean precipitation for January, February, ... at A: $(P_1)_A$, $(P_2)_A$ ...

Mean share of annual precipitation at A received during January, February, ... $(p_1)_A$, $(p_2)_A$ ...

where $$(p_1)_A = \frac{(P_1)_A}{(P_Y)_A}.$$

If a series of observations station B is incomplete, covering, for instance, ten years, we may compute $(P_1)_B$, ... by the quotient method, using A as a reference station:

$$(p_1)_B = \frac{(P_1)_B^*}{(P_1)_A^*} \cdot (P_1)_A ,$$

where the star indicates mean values for the ten years for which observed values are available at B.

Another possibility in such cases is to assume that

$$(p_1)_B - (p_1)_B^* = (p_1)_A - (p_1)_A^* ;$$

as $(p_1)_B^*$, $(p_1)_A$ and $(p_1)_A^*$ can be determined from observed data, $(p_1)_B$ may be calculated. Obviously,

$$\sum_{\nu=1}^{\nu=12} (p_\nu)_B = \sum_1^{12} (p_\nu)_B^* + \sum_1^{12} (p_\nu)_A - \sum_1^{12} (p_\nu)_A^* = 1+1-1=1$$

The two alternative methods usually lead to similar (though not identical) results, and the amount of labour is also comparable. As it was thought that five-year mean values of the figures showing the share of the annual precipitation reveiced in each month might be of some interest, the latter method was preferred. To reduce the computational work, only 5-, 10-, 15- and 20-year partial series were used, but missing monthly values for up to 18 successive months were interpolated in order to obtain as complete tables of five-year mean precipitation as possible. A slightly modified procedure was followed when only one or two five-year periods were missing in a series of observations.

The preliminary result of the investigation is summarized in table VIII.2. The share values for the individual stations were further used for the computation of absolute amounts of monthly mean precipitation, as described in the following section.

Table VIII.2. Approximate monthly shares of total precipitation. The table is based on preliminary computations from the precipitation data for 1931-1955 and is intended to give a first orientation only.

	Highest values, %	Area of highest values	Lowest values, %	Area of lowest values
J	11-12	(a) Reykjavík area (b) extreme SE Iceland	6-8	Most of northern Iceland
F	8-9	Western Iceland	4-5	Extreme NE Iceland
M	8-9	Western Iceland	4-5	Extreme NE Iceland
A	about 7	South coast	about 5	Extreme NE Iceland

	Highest values, %	Area of highest values	Lowest values, %	Area of lowest values (cont.)
M	about 6	(a) Westernmost localities (b) E part of south coast	4-5	Most of northern Iceland
J	about 7	Small areas in different parts of Iceland	4-5	(a) Reykjavík area, (b) extreme NW Iceland
J	10-12	Extreme NE Iceland	5-6	Breiðafjörður area
A	11-13	Extreme NE Iceland	about 7	Extreme NW Iceland
S	12-14	Coastal areas of northern Iceland	8-9	Reykjavík area
O	12-16	Local coastal areas in northern Iceland	10-11	Eastern part of south coast
N	10-11	Western Iceland	about 9	Central and eastern part of northern Iceland
D	about 11	Extreme SE Iceland	8-9	Small areas in western and northeastern Iceland

Absolute amounts of normal precipitation, month by month

Monthly mean values of precipitation for the period 1931 - 1955 were computed for a number of stations. In the case of incomplete series, the mean values were computed from the monthly shares discussed in the previous section, for instance:

$$(P_1)_B = (p_1)_B \cdot (p_Y)_B \ .$$

Table VIII.3 contains monthly average values of the precipitation 1931 - 1955 for 14 stations. The stations were selected for this purpose because they had complete or approximately complete series which were also homogeneous or nearly so.

Table VIII.3. Preliminary values of mean monthly precipitation 1931 - 1955 at selected stations having relatively long and reasonably homogeneous series.

	J	F	M	A	M	J	J	A	S	O	N	D
Reykjavík	92	63	65	49	39	39	51	71	73	92	80	82
Síðumúli	57	60	60	48	36	46	56	68	71	82	65	60
Stykkishólmur	86	68	69	45	37	37	38	54	78	85	83	81
Lambavatn	69	61	57	46	50	47	62	75	96	94	87	86
Suðureyri	110	99	84	62	40	42	46	67	130	154	123	121
Blönduós	34	33	37	29	20	32	46	51	59	58	39	41
Akureyri	42	40	44	32	21	22	35	40	50	58	43	53
Húsavík	31	26	26	25	19	36	50	57	69	87	48	48
Fagridalur	50	32	33	45	40	57	109	116	110	98	82	67
Teigarhorn	139	93	88	80	71	67	84	94	129	140	119	144
Hólar í Hornafirði	204	115	126	110	85	81	95	122	166	169	181	184
Kirkjubaejar-klaustur	150	109	130	105	102	127	125	166	177	184	169	169
Vík i Mýrdal	184	160	166	169	136	161	178	202	243	233	205	233
Vestmanna-eyjar	142	107	106	96	75	79	86	116	131	160	136	153

As indicated by the table and confirmed by corresponding values for supplementary stations, the largest precipitation amounts occurring at Icelandic stations are found throughout the year in the southernmost part of the country, and almost consistently at the station Vík í Mýrdal. At this station the driest month, May, receives on an average 136 mm, while the five last months of the year all have between 200 and 250 mm. On the other hand, most stations in western and northern Iceland have monthly precipitation values below 100 mm throughout the year, and receive less than 50 mm during April, May and June.

At some stations in northern Iceland only a few months, mainly September and October, receive more than 50 mm, while May, which is the driest month nearly everywhere, gets about 20 mm.

If we compare the provisional values of mean monthly precipitation as given in table VIII.3 with the normal values for 1901 - 1930 as published in 'Veðráttan', the differences are far from being uniform. There is a tendency that positive differences dominate at some stations, and negative at others. However, during the months August - October nearly all stations showed an increase of precipitation from period to period. This increase is very marked at Vík í Mýrdal, which exhibits for the period June through October a sum of 1117 mm for the period 1931 - 1955 as compared with 785 mm during the preceding 30 years. At this particular station, however, the increase of summer and autumn precipitation is partly compensated by a decrease during the three first months of the year, from an average of 616 to 510. A similar decrease is found at Vestmannaeyjar.

It is suggested that the study of monthly mean values of precipitation in Iceland be continued, taking into account all available data.

ANNEX IX

FREQUENCY STUDIES REGARDING DAILY AMOUNTS OF PRECIPITATION AT ICELANDIC STATIONS DURING SELECTED MONTHS

The material: quantity, quality, and possible applications

The Icelandic stations at which precipitation measurements are made, are instructed to give the amount to the nearest tenth of a mm, and to record precipitation of a non-measureable quantity as 0.0. Generally speaking, stations making observations for synoptic purposes follow these instructions well, but at some climatological stations the reporting of small or very small quantities - as in other countries - is not entirely satisfactory. Amounts of 1 mm or more, however, seem to be reported by almost all stations in a reliable manner. The reliability of the reported amounts of precipitation in the form of snow was discussed in Annex VIII.

The only statistics of days with precipitation published so far are a table in "Veðráttan" for 1941, giving a 10-year average of the total number of days with 0.1 mm or more for each month (1931-1940) at a relatively large number of stations, and a similar table of 20-year averages (1931-1950) in "Veðráttan" for 1949. A more complete treatment of available data, taking into account the amount of precipitation measured on each day, might be expected to give some valuable additional information.

The daily amount of precipitation is a matter of some practical importance in several connexions. In many areas, but mainly in regions near the eastern, southern and western coast, excessive rains may cause flooding and even landslides; on such occasions, roads and bridges are often seriously damaged.

During the summer, even small daily amounts of precipitation, if continuing during a prolonged period with little or no sunshine, constitute a serious menace to hay production. On the other hand, hay production also suffers from the droughts which are not uncommon in northern Iceland during spring and early summer. In winter, heavy precipitation in the form of snow and accompanied or followed by severe drifting frequently hinders traffic even on main roads; in fact, most of the roads connecting different parts of the country are usually closed for some weeks or even months during the winter half-year. Clearing a blocked road under winter conditions is sometimes economical, sometimes not, depending on the probability of renewed heavy snowfall within a short time.

Methods and preliminary results

As time did not permit a complete statistical treatment of the available material, the investigation to be dealt with in this annex was confined to a frequency study of daily precipitation amounts during odd-numbered months as reported during the ten-year period 1946-1955.

The first step to be taken was to prepare, for 37 stations having complete or almost complete observations, tables like IX.I. The variability of precipitation conditions during a certain month from year to year is illustrated by these tables, cf. for instance September 1952 and 1953 at Fagurhólsmýri.

Table IX.1. Basic table of the type used for frequency stüdies of precipitation days. The values contained in the table indicate the absolute number of days belonging to each class.

Fagurhólsmýri, September.

	No prec.	0.0	0.1-0.4	0.5-0.9	1.0-1.9	2.0-2.9	3.0-4.9	5.0-9.9	10.0-19.9	20.0-29.9	30.0-39.9	40.0 mm
1946	10	3	4	1	5	1	1	3	2	0	0	0
1947	8	3	3	0	3	1	3	4	3	2	0	0
1948	15	3	1	1	2	1	1	1	2	2	0	1
1949	5	0	2	6	1	5	1	2	1	6	0	1
1950	12	1	1	1	4	4	2	3	1	0	0	1
1951	8	1	1	1	2	1	1	3	5	4	1	2
1952	23	2	0	0	1	2	0	0	0	2	0	0
1953	7	1	0	2	3	1	1	2	6	3	1	3
1954	9	5	2	1	1	2	0	2	4	3	1	0
1955	9	1	3	2	1	1	2	1	4	4	2	0
Σ	106	20	17	15	23	19	12	21	28	26	5	8

Table IX.2. Example of Summary, part I, of frequency table for an individual station (Fagurholsmýri). The upper line for each month gives the absolute frequencies for ten Januaries, ..., ten Novembers (1946-1955) of a 24-hour precipitation within the indicated limits. The numbers of the lower line for each month show, as indicated by the symbol $\overleftarrow{\Sigma}$, the cumulative absolute frequencies when counting from the right. Thus, the total number of January days having at least 10.0 mm of precipitation was 96.

Fagur-hólsmýri		No prec.	0.0	0.1-0.4	0.5-0.9	1.0-1.9	2.0-2.9	3.0-4.9	5.0-9.9	10.0-19.9	20.0-29.9	30.0-39.9	40.0 mm
January		8	14	9	16	19	16	22	35	51	32	8	5
	$\overleftarrow{\Sigma}$	310	227	213	204	188	169	153	131	96	45	13	5
March		108	24	14	15	21	16	15	29	29	27	7	5
	$\overleftarrow{\Sigma}$	310	202	178	164	149	128	112	97	68	39	12	5
May		135	23	16	14	18	15	18	27	19	16	6	3
	$\overleftarrow{\Sigma}$	310	175	152	136	122	104	89	71	44	25	9	3
July		94	22	20	19	29	20	15	27	35	20	4	5
	$\overleftarrow{\Sigma}$	310	216	194	174	155	126	106	91	64	29	9	5
September		106	20	17	15	23	19	12	21	28	26	5	8
	$\overleftarrow{\Sigma}$	300	194	174	157	142	119	100	88	67	39	13	8
November		118	10	11	18	14	14	11	25	38	18	10	13
	$\overleftarrow{\Sigma}$	300	182	172	161	143	129	115	104	79	41	23	13
Total for odd months		644	113	87	97	124	100	93	164	200	139	40	39
	$\overleftarrow{\Sigma}$	1840	1196	1083	996	899	775	675	582	418	218	79	39

The next step was to prepare ten-year summaries, as exemplified by table IX.2. As this table shows, cumulative frequencies, expressing the number of cases during, e.g., ten Januaries, of a 24-hour precipitation equal to or larger than certain specified amounts, were also computed, as well as relative cumulative frequencies (table IX.3).

<u>Table IX.3.</u> Example of summary, part II, of frequency table for an individual station (Fagurhólsmýri). The values of the table give the frequency, in % of the total number of days during, e.g., ten Januaries (1946-1955), of days with at least 0.0, at least 0.1, ... mm of precipitation. Thus, 31% of all January days had at least 10.0 mm of precipitation.

Fagurhólsmýri	≧ 0.0	≧ 0.1	≧ 0.5	≧ 1.0	≧ 2.0	≧ 3.0	≧ 5.0	≧ 10.0	≧ 20.0	≧ 30.0	≧ 40.0 mm
January	73.2	68.7	75.8	60.6	54.5	49.4	42.3	31.0	14.5	4.2	1.6
March	65.2	57.4	52.9	48.1	41.3	36.1	31.3	21.9	12.6	3.9	1.6
May	56.1	49.0	43.9	39.4	33.6	28.7	22.9	14.2	8.1	2.9	1.0
July	69.7	62.6	56.1	50.0	40.6	34.2	29.4	20.6	9.4	2.9	1.6
September	64.7	58.0	52.3	47.3	39.7	33.3	29.3	22.3	13.0	4.3	2.7
November	60.7	57.3	53.7	47.7	43.0	38.3	34.7	26.3	13.7	7.7	4.3
Mean for odd months	65.0	58.9	54.1	48.9	42.1	36.7	31.6	22.7	11.8	4.3	2.1

Table IX.4. Excerpt from one of a number of tables giving relative frequencies (in % of number of days of observation) for odd months at 37 stations. For further discussion, see text.

≧ 5.0 mm	Jan.	March	May	July	Sept.	Nov.	Mean for odd months
Reykjavík	23.5	15.8	7.4	13.5	11.3	15.0	14.5
Síðumúli	14.2	11.3	4.8	15.8	11.3	10.7	11.4
Suðureyri	23.9	20.6	6.1	11.3	22.3	21.3	17.6
Kjörvogur	7.7	7.1	5.2	11.6	21.0	12.3	10.8
Blönduós	5.8	7.4	3.5	9.0	10.7	5.3	7.0
Akureyri	9.7	11.6	1.9	7.1	12.7	7.7	8.3
Raufarhöfn	11.3	9.0	6.1	12.9	21.3	11.0	11.9
Dalatangi	27.1	13.9	11.0	18.1	26.3	28.7	20.8
Hólar í Hornafirði	40.3	21.0	10.3	18.4	23.0	28.7	23.6
Fagurhólsmýri	42.3	31.3	22.9	29.4	29.3	34.7	31.6
Vestmannaeyjar	33.6	21.6	16.1	21.3	19.0	28.7	23.4
Haell	19.0	21.0	12.6	23.9	18.3	18.0	18.8

The numbers contained in the tables of the last-mentioned type were transferred to another set of tables, the arrangement of which is shown by table IX.4. Similar tables were prepared for all precipitation limits used in the basic tables, except 30.0 and 40.0 mm. These tables show important differences between different parts of the country, between different months, and between the character of the annual variation of precipitation frequencies in different areas. It must be pointed out, however, that the measurement of precipitation in the form of snow, as discussed in Annex VIII, is very difficult in most parts of Iceland: the possibilities, and perhaps the ambition, of the observers to provide reliable values for precipitation in winter seem to differ sufficiently to influence both the picture of the geographical distribution of precipitation during the winter half-year and the yearly variation of precipitation frequencies as given by the tables of this Annex.

Even with allowance for this, the seasonal and geographical variations are striking. Thus, table IX.4 shows that no less than 40% of all days in January have at least 5 mm of precipitation at some stations near the south coast, whereas in large parts of northern Iceland the corresponding proportion does not even amount to 10%. The average number of days with a precipitation exceeding 5 mm in May is at some stations less than half the average of such days during any other odd-numbered month. At the station of Kjörvogur the frequency given in table IX.4 for September is three times as large as that for March, whereas the September value of the frequency is lower than the March value at the stations in southwestern Iceland.

Table IX.5. Frequencies (odd months, 1946 - 1955) of a 24-hours precipitation amount equal to or larger than 0.1, 0.5, ... 40.0 mm, expressed in % of the frequency of an amount of 1.0 mm or more. In Fagurhólsmýri, for instance, 24% of the days having a precipitation amount not less than 1.0 mm, receive 20.0 mm or more.

	≥ 0.1	≥ 0.5	≥ 2.0	≥ 3.0	≥ 5.0	≥ 10.0	≥ 20.0	≥ 30.0	≥ 40.0 mm
Reykjavík	143	117	75	58	36	12	2.2	0.8	0.1
Síðumúli	138	119	74	57	33	10	1.9	0.6	0.3
Suðureyri	144	117	80	64	43	18	5.6	2.3	0.9
Kjörvogur	159	122	76	56	35	15	3.9	1.8	0.5
Blönduós	143	117	64	45	24	7.0	1.1	0.4	0
Akureyri	145	121	72	56	31	9.7	1.8	0.2	0.2
Raufarhöfn	142	117	74	55	35	13	2.4	1.1	0.3
Dalatangi	139	113	80	64	50	31	16	8.3	4.2
Hólar í Hornafirði	125	110	83	72	57	35	15	7.1	4.9
Fagurhólsmýri	120	111	86	75	65	46	24	8.8	4.3
Vestmannaeyjar	131	110	82	68	49	27	6.2	1.7	0.6
Haell	122	111	82	67	48	19	3.9	1.7	0.8

Table IX.5 shows the relative frequencies (in the form of values averaged over all odd-numbered months), computed by dividing all individual absolute frequencies by the corresponding absolute frequencies of days with 1.0 mm or more. This table, too, shows large regional contrasts; in Fagurhólsmýri, e.g., no less than 46% of the days which have at least 1 mm of precipitation receive 10 mm or more, while the corresponding figure is only 7% in Blönduós.

Some other tables and graphs were prepared from the material under discussion and placed at the disposal of Veðurstofan. One of the graphs may be mentioned briefly:

The figures given in the last line of tables like table IX.3 were entered on diagrams (logarithmic scale for the precipitation amount, linear scale for frequency). The graphs for the various stations showed interesting and in some cases puzzling differences which, however, to some extent may be due to the limited amount of observations used for this investigation.

The study of precipitation frequencies should, as soon as the circumstances permit, be enlarged so as to include even-numbered months and perhaps an additional ten-year period.

Maximum amounts of precipitation

As a supplement to the statistics of days with precipitation, a set of tables was prepared (by means of data-processing machines) showing the maximum amounts of 24-hours precipitation, station by station and month by month. For a restricted number of stations having a complete or nearly complete series of observations, the result is summarized in table IX.6. Some interesting features are shown by this table, e.g. : Although the precipitation at Vík í Mýrdal during all months except January is larger than that of Hólar, the maximum daily amount of Hólar exceeds that of Vík during all months except July, August and September - in some instances by 50 or even 100%. It is surprising to find that during May, which is nearly everywhere driest of all months, a 24-hour precipitation of 89 mm has occurred at Lambavatn, exceeding by a large amount the maximum experienced during any other month at that station.

Table IX.6. Maximum of daily precipitation (mm) for each month, 1931 - 1950. The absolute maximum for each station is underlined. Extracted from a larger table giving similar values for 50 stations, some of them with short series of observations only. (For most of the stations given below, the series was complete, but in a few cases 1-5 years were missing.)

	J	F	M	A	M	J	J	A	S	O	N	D
Reykjavík	36	19	57	21	18	30	25	33	32	37	44	55
Síðumúli	23	47	36	20	26	27	19	36	40	35	28	44
Stykkishólmur	68	44	50	35	23	53	20	27	46	55	69	46
Lambavatn	34	31	33	21	89	53	55	51	51	35	37	50
Suðureyri	60	53	59	59	36	35	30	71	64	75	54	65
Blönduós	13	19	17	18	19	22	20	24	30	30	24	18
Akureyri	17	21	27	16	24	19	27	52	92	30	27	25
Húsavík	37	28	22	20	22	28	33	54	46	55	59	37
Fagridalur	40	79	27	61	60	73	83	121	61	111	80	87
Teigarhorn	60	110	48	46	52	67	68	68	72	49	62	62
Hólar í Hornafirði	134	107	78	90	106	84	61	56	122	100	106	92
Kirkjubaejar-klaustur	56	56	76	47	50	69	80	68	93	74	87	60
Vík í Mýrdal	64	78	49	68	52	51	70	65	150	77	79	76
Vestmanna-eyjar	60	54	92	53	33	40	37	42	54	74	47	68
Haell	36	67	68	36	32	32	59	37	44	54	55	46

Table IX.7. Maximum of 24-hour precipitation derived from complete or incomplete series of observation during the period 1931 - 1950.

	mm	Month	& Year	Years of obs.		mm	Month	& Year	Years of obs.
Re javík	57	3	'31	20	Grímsstaðir	36	10	'48	15
Rafmagnsstöðin	54	11	'32	16	Raufarhöfn	69	7	'42	17
Hvanneyri	101	11	'41	10	Skálar	49	10	'41	9
Síðumúli	47	2	'40	16	Skoruvík	28	9	'46	8
Arnarstapi	91	7	'48	15	Höfn í Bakkafirði	45	8	'46	13
Hellissandur	66	2	'37	16	Fagridalur	121	8	'50	19
Stykkishólmar	69	11	'46	20	Hallormsstaður	61	1	'50	10
Hamraendar	53	10	'43	14	Dalatangi	112	10	'43	12
Lambavatn	89	5	'41	12	Vattarnes	72	2	'38	13
Kvígindisdalur	105	9	'49	20	Teigarhorn	110	2	'38	20
Suðureyri	75	10	'45	20	Djúpivogur	83	8	'46	7
Bolungarvík	45	9	'45	16	Hólar í Hornaf.	134	1	'46	20
Kjörvogur	66	3	'40	16	Fagurhólsmýri	125	11	'36	20
Hlaðhamar	36	3	'40	10	Kirkjubaejarkl.	93	9	'45	20
Núpsdalstunga	26	4	'43	12	Vík í Mýrdal	150	9	'33	20
Blönduós	30	9	'46	19	Loftsalir	64	11	'42	11
Nautabú	24	10	'48	5	Vestmannaeyjar	92	3	'31	20
Maelifell	43	7	'42	10	Sámsstaðir	76	9	'33	20
Skriðuland	107	9	'46	16	Haell	68	3	'41	15
Siglunes	61	7	'43	14	Eyrarbakki	58	9	'37	20
Akureyri	92	9	'46	20	Ljósafoss	99	3	'48	13
Grímsey	45	2	'43	15	Þingvellir	63	12	'38	16
Sandur í Aðaldal	63	8	'50	16	Grindavík	75	9	'45	20
Húsavík	59	11	'47	20	Reykjanes	47	12	'35	13
Reykjahlíð	48	9	'46	13	Vífilsstaðir	55	1	'46	9

Some supplementary information is contained in table IX.7. A daily amount of 50 mm or more is seen to have been measured at most stations during the period in question, and there are several examples of an amount exceeding 100 mm, the absolute extreme being 150 mm at Vík í Mýrdal. One may note the excessive amounts of precipitation at some stations in northern Iceland (Skriðuland, Akureyri) one day in September 1946.

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