# Veðurstofa Íslands
# Report

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# Regional Climate and Simple Circulation Parameters

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# Regional Climate and Simple Circulation Parameters.

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**Abstract.**

During the last 4 decades or so, there has been a considerable year to year variation in the circulation patterns over Iceland and the rest of Scandinavia. These notes describe this variation in some detail and explore the relationship between the circulation patterns and the climate of this area during this period. This is then put in the context of climatic change.

**Circulation parameters.**

There are some well known circulation parameters, the best known, without doubt, the circumpolar zonal index (discussed e.g. in Lamb, 1972 or Barry and Perry, 1975). In the following, the emphasis will be on similar parameters defined for small regions in a very simple way. The particular parameters were first used by Hovmøller (1979) as a part of a weather classification scheme for Iceland.

On the average Iceland is situated on the eastern fringe of a cold trough at 500hPa over E-Canada (fig.1, from Mysak et al., 1990). This trough maintains an average WSW-ly wind at this level over Iceland. A much weaker trough is situated over E-Europe. The flow over Scandinavia is on the average more zonal than over Iceland.

There are three conceivable modes of variations in this average field at any given location:

a) the strength of the field can change (gradient changes)
b) the direction of the flow can change
c) the height of the 500hPa level can change

In the following, references will be made to 500hPa and 1000hPa height values in the grid shown in fig.2.

The 500hPa height in p5 will be referred to as the height (H). The 1000/500hPa thickness in p5 will be referred to as the thickness ($\delta$).
The zonal component is defined from the heights (in gdm) at the points as follows:

$$A = (p7 + p8 + p9) - (p1 + p2 + p3)$$

The "unit" of A is thus gdm, but expressed as this sum of differences. In the following this rather arbitrary flow strength unit will be called H-units after E. Hovmöller, but he was the first to suggest the use of these parameters in his weather classification scheme for Iceland.

And the meridional component is defined similarly as:

$$B = (p3 + p6 + p9) - (p1 + p4 + p7)$$

A negative "B" thus indicates a northerly flow. From this it is also possible to define an overall strength and direction by simply transposing to polar coordinates.

At other pressure levels the zonal and meridional components are defined by the same procedure and the thickness gradient components easily computed. In the following capital letters refer to the 500hPa level (A=zonal, B=meridional, H=height), lower case letters to the 1000hPa level (a=zonal, b=meridional, h=height) and Greek letters to the thickness ($\alpha$=A-a (zonal), $\beta$=B-b (meridional), $\delta$=H-h (at p5)).

A similar grid is employed at two other locations. Over S-Norway, (p5 at 60°N,10°E) and over Finland (p5 at 65°N,30°E). The same notation is used, but with a F (for Finland) and N (for Norway) in parenthesis following the component letter (ex. A(N),

the zonal component at 500hPa over Norway, b(F): meridional component at 1000hPa over Finland.
In this way the fields are parameterized into a few simple components. This can be done on a daily, monthly or an annual basis.

All these parameters form a parameter space. The climate is mapped into this space.

**The relation of weather and parameter values since 1949.**

**Precipitation in S-Norway.**

Fig 3. shows 7-year running means of annual precipitation in Samnanger in W-Norway and 7-year running means of the zonal component of the westerlies over S-Norway, A(N). The units of A(N) are the Hovmöller units described above. As seen there is a fairly obvious relationship between the two. The precipitation at this station is very dependent on the strength of the zonal westerlies. This is also very evident if a simple linear relationship is calculated between the actual annual values of the two parameters. This dependency is in good agreement with the results of Han (1992).

But an impressive relationship, like in the case of the Samnanger precipitation, is rather an exception than the rule. The relationships are in most cases much more subtle. An example of this kind is e.g. the relationship between the circulation parameters and the precipitation in Nord-Odal in E-Norway (fig 4). Here we see that the estimate is a rather poor one. An explanation for this could be the yearly variation of the precipitation. During the summer one would expect the precipitation to be dominated by convectivity but this convectivity is more or less suppressed during the winter. The variance of the estimate is much, much lower than the actual variance. If we, however, look on the terms in the relationship (under the figure) one sees that an increased westerly flow (i.e. larger A(N)) tends to reduce the precipitation at this station (and/or vice versa increased easterly flow increases the precipitation), an increased southerly flow (larger B(N)) increases the precipitation and a fall in the 500hPa height also increases the precipitation. All of this is, as a matter of fact, as expected. Changes in the zonal and meridional flow influence manifestations of the orographic effects. The 500hPa changes reflect the convectivity in the area. This analysis would probably benefit from a focus on individual months rather than the annual values. This is not certain however.

The precipitation is more difficult to analyze than the temperature. This of course has to do with the different statistical properties of the two parameters. One day with very heavy precipitation can often have a considerable weight in a monthly total, whereas the same day can not offset monthly means of the temperature or the circulation parameters in the same way. A way to circumvent this problem is to use a weather type classification scheme based on the circulation parameters. This will be pursued in another monograph.

Similar relationships have been calculated for the precipitation in Sodankylä in Finland and deBilt in the Netherlands (with somewhat better results than for Nord-Odal, but not as impressive as for Samnanger) as well as for Stykkishólmur (W-Iceland) and Teigarhorn (E-Iceland).

**Temperature and thickness.**

In fig.5 one can see the temperature in Stykkishólmur (W-Iceland) versus the 500/1000hPa thickness 1949 - 1990. A relationship is apparent, and some features are worth pointing out. There are two points outside the main sequence to the lower right. One of the two is connected to heavy sea-ice at the coasts of Iceland. There is often an inversion in the lower layers associated with the sea ice, with low temperatures confined to the lowest 1-2km of the troposphere. A similar effect is seen at the top right. The year with the highest thickness (1987) is only the third highest in actual temperature. This is probably also due to the relative cooling effect of the sea around Iceland. It can possibly be inferred from this that the sea would supress a general tropospheric warming (due to an enhanced greenhouse effect) somewhat. The opposite can possibly be seen at the lower left. The coldest year (1979) is possibly relatively high in the main sequence because of a warming from the sea. A pronounced tropospheric cooling would thus be counteracted somewhat by a warming from the sea (as the case in a normal winter month) unless it was so large that sea ice would form.

It is interesting to compare this relationship in Stykkishólmur with a similar one for Sodankylä in Finland (not shown). What immediately catches the eye is that the interception of 0° and the thickness is much higher in Finland than in Stykkishólmur (about 533gdm compared to ca. 524 in Stykkishólmur). The value for Stykkishólmur is not far from the theoretical value for a neutral lower troposphere. During the winter there is not much room for a larger lapse rate than experienced at present in Stykkishólmur. In Sodankylä the winter climate is dominated by intense inversions at lower levels. Enhanced mixing would thus alone increase the winter temperature in Finland, but nothing much would happen in Iceland. During the summer months there is room for a larger lapse rate over Iceland, inversions are very common during the summer over the relatively cold sea. Similar relationships are evident in Iceland for individual months, admittedly rather weak in June and August, but strong for all other months. This can be used with some confidence to calculate 500hPa heights over Iceland month-by-month backwards to the last century. (This has been done, with some interesting results).

**Temperature estimated by the use of circulation parameters.**

In fig.6 one can see annual average temperatures in Stykkishólmur versus estimated ones. It is fairly obvious that the estimates are generally rather good (in spite of individual large errors). The temperature rises with higher values of the meridional (southerly flow), (B), it also rises with the 500hPa level, but falls slightly if the zonal component (A) increases in strength. The variance is suppressed. This suppression could in principle be counteracted by "inflating" the estimate. It is not done here, however. In Finland (fig 7) the temperature increases with an increase in the zonal component (A(F)), and increases sharply with the 500hPa height. It also incereases slightly with the meridional component (B(F), not shown here). Iceland is situated to the west of the Gulfstream and winds from the west often bring cold weather to the country. The westerly winds reaching Finland in winter are considerably warmer than the easterly.

The estimates are generally good for all months except June, July and August, (in August these estimates are more or less worthless, at least during this period of time). The September relationship can be seen in fig.8. The estimates very clearly discriminate between cold and warm months, but the variance is slightly suppressed.

It is of some interest to calculate the coldest and warmest estimates "possible" assuming that the three 500hPa parameters are independent (orthogonal) of each other. It is not, at the time being, certain if this assumption holds in the long run. If it holds, every combination of parameter values has a probability simply equal to the product of the three parameter probabilities. A complicating fact is that there are variations on the decadeal scale (and longer scales too) in the time series, so the mean values do not seem to converge and the standard deviation just tends to become larger as the time window gets longer. If one uses simply the lowest and the highest values of the parameters during the time period 1949 - 1990 as an input one gets 1.8°C and 5.7°C as the respectively highest and lowest annual averages in Stykkishólmur. This is lower and higher than temperatures experienced during this period, but the parameters have never taken these extreme values concurrently. A much more extreme case would be values of the parameters at 3 standard deviations from the mean, the three high values occurring concurrently and the low also concurrently, one gets extremes of -1.4° as the lowest, but 6.7 as the highest. This of course is very, very unlikely to happen all at once. In addition one has not used the moderating influence of the sea at all.

These estimate relationships can be used as an aid in the analysis of past climates, both in conjunction with the thickness/temperature relationship and without it. This is especially valuable when it is done in a fairly large area (like the NACD-region) so that the consistency of the information can be checked. (Of special interest in the past are e.g. blocking frequencies and the behavior of the Icelandic low).

**Extension by use of daily values of the circulation parameters.**

Monthly and annual means of the circulation filter out a great deal of information about the climatic system. The variance of the daily values of the circulation parameters is much larger than the monthly variance. The estimates of temperature inside this rather narrow range of parameter values are quite convincing, but there are of course great uncertainties about what happens outside the present range and in other epochs of time.

The different variance of daily and monthly values is illustrated in figs. 9 (montly means) and 10 (daily values). If one calculates temperature estimates for the daily values in November for this much greater range one gets very similar estimate coefficients. Fig 11 illustrates this point. The station in this case is Reykjavík. The estimate formula for the daily values is:

$$T(est) = -3.39 + 0.05*B + 0.15*(H-500) - 0.01*A$$

and for the monthly values (in Stykkishólmur):

$$T(est) = -3.24 + 0.07*B + 0.14*(H-500) - 0.01*A$$

This similarity greatly enhances the confidence in results of estimates outside the present monthly range. The main pit to watch for, when analyzing earlier epochs, is the influence of the sea (especially if there is sea ice or not) and the resulting variability of the lapse rates.

**The parameter climate of Iceland 1949 - 1991.**

This section will focus on the variability of the climate of Iceland during the period 1949 - 1991. In a bit wider context it is instructive to take a look at fig. 12 which illustrates the temperature variations in Stykkishólmur since the 1820s. The first 15 years of 1949 - 1991 is a warm period, albeit not as warm as the 1930s. There is a cold period starting in 1965. This cold period is not quite as cold as the cold period covering the 1860s towards 1920. There are a few years in the 1970s that are slightly warmer but a return to colder conditions in 1979. The last years have again been warmer.

Fig. 13 is a blow-up of the period 1949 - 1991, illustrated by the use of 12-month running means. One clearly sees the cold periods of 1965 to 1971, 1979 and 1981 - 1983. The warm years of 1987 and 1991 are not quite as warm as the warmest years before 1965.

The temperature should reflect changes in the meridional component (B) and the 500hPa height and it is instructive to look at these also (fig.14, B and fig.15 the height). In fig.16 one sees that the southerly flow is very weak during the cold period of 1965 - 1971. It is also weak during the later cold period, but not quite as weak. The 500hPa level is generally much lower during the later period than the earlier one. The sea level pressure is also higher during the earlier period (fig.16). The coldness of the first period can be attributed to an increase in northerly winds, but in the later period to the extension of the polar vortex towards the east. This extension was very much felt in Greenland around 1983.

There is a general decrease in the zonal thermal gradient in the area ($\alpha$(I),(fig.17)) and an increased variance after 1970. This can be attributed to either a relative warming in the north or a cooling in the south, or both.

**The "Great salinity anomaly" of the 1960s and later.**

As mentioned above the East Greenland sea ice returned to the coast of Iceland in 1965 after being more or less absent since the early 1940s. The extent of ice cover was again similar to what it was before the beginning of the warming in the 1920s. The ice was accompanied by cold water masses with a low salinity (Dickson et al., 1988). As seen above there was also a drop in temperature of the order of 1° or more in Stykkishólmur and more at the N and E coasts at the same time. Remarkably one could then follow this low salinity anomaly for more than a decade, first to Greenland, then to Newfoundland, and even east again to Ireland and the W coast of Norway, but eventually of a decreasing amplitude. The origin of this anomaly is somewhat controversial, but it seems to have started in 1962 or 1963 in the Spitzbergen area. During these years this area already expėrienced a temperature drop, similar to the one in 1965 in Iceland.

It is very probable that the "Great salinity anomaly" (to use the same name for the phenomenon as Dickson et al. do), the temperature drop and the weakening of the southerly meridional transport around Iceland are somehow connected. It is likely that this is also connected to the generally high pressure in the Iceland area during this period. This can be seen in figs.16 and 18. The month-by-month pressure is plotted in fig.18 without any filtering, most of the variance is due to the annual variation of pressure (high in spring, low around newyear). But one can also see three very abnormal months in the 1960s. These are: March 1962, January 1963 and February 1965. The question remains: Were these months so abnormal that they could have initiated the whole episode? This should be investigated more closely.

It is also very clear one looks at the two figures 16 and 18 that there is another abnormality towards the end of the series, namely the very low pressure of especially 1989 and 1990. If this will influence the oceanic circulation in these waters remains to be seen.

During earlier epochs there have been similar high (and low) pressure episodes in this area. It will be interesting to see if and how they are connected to the oceanic circulation.

The so- called North Atlantic oscillation (NAO) has received some attention lately, as well as a possible interdecadal arctic climate cycle. If these are exactly the same phenomena as the one informally described above or not is still not quite clear. (Rogers, 1984; van Loon and Rogers, 1978; Lamb, J.P and Peppler, 1987; Mysak et al., 1990). The importance of the northern oceans in the climate system is becoming more and more evident, not at least the role of the North Atlantic as a major deep water formation area (Manabe et. al., 1991; Manabe and Stouffer, 1988; Marotzke and Willebrand, 1991; Washington and Meehl, 1989; Mikolajewicz et al., 1990).

**Circulation parameters and climatic change.**

General circulation model experiments indicate that the climate will warm during the next decades (e.g. Manabe et al., 1991). There is some disagreement on how large this warming will be. The models are also lacking in regional detail. There is also some doubt on how well the models simulate the present climate (control runs) (e.g. Boer et al., 1992). It is possible to test model results against the parameter climate. The models should be able to simulate the observed means and variance of the circulation parameters. The results of equilibrium and transient runs of the models can also be used as an input to the simple linear regression temperature estimates above. It will be very interesting to see what changes in the parameters the models predict. One could indulge oneself in an informal speculation as the one below.

How would a general tropospheric warming of 3°C be felt in the Iceland area (the 3° is close to the zonal average warming of the lower troposphere at 65°N in as depicted in fig 16, p.801 in Manabe (1991)). This indicates approx. a 6gdm increase in the thickness. If one takes the thickness/temperature relationship from above at face value one could calculate the expected temperature in Stykkishólmur by use of the formula $T(est) = 0.4*(\delta - 523.5)$. At the present the average thickness is 532.5gdm and the corresponding temperature 3.6°C. A thickness rise of 6gdm would give a new average of 6.0°, a temperature rise of 2.4°C. Considering the great heat capacity of the ocean it is not unlikely that the slope of the linear curve will decrease rather than increase as a response to a warming aloft, so that possibly one should be using a lower factor than 0.4. An inversion over the ocean is probably more difficult to mix up than inversions over land due to the aforementioned heat capacity.

It is rather unlikely that a thickness change of 6gdm will be accompanied by a fall of pressure in the Iceland area, (but not impossible, a pressure fall in the Iceland area would, however, result in a stronger westerly flow in over Europe, with consequences for the climate in that area). It is more likely that this thickness change will be felt as a rise in the 500hPa level. Changes in the zonal and meridional flow are more open to question. If we use the B-H-A relationship, with unchanged A and B, but a 6gdm rise in H we get a new average temperature according to the relation $T(est) = f(B,H,A)$ of 4.7°C or a temperature rise of 1.1°C only. The interesting difference between the results from the two methods is open to question.

In Finland a positive change in the lapse rate is very possible under a general warming of 6gdm in the 500/1000hPa layer and there is more room during the winter for a larger warming than in Iceland (remember the very high thickness value at 0°). There is thus room for both a translation of the relation line towards higher temperatures as well as a change of slope, whereas in Iceland a translation of the relation line is very unlikely.

A direct calculation of T(est) from the B-H-A-relation would give a temperature rise of 1.9°C with no change in A(F) and B(F) (compared with the 1.1°C in Iceland). If A(F) gets larger as well as the heights changes, the temperature rise would be still greater.

**Acknowledgments:**

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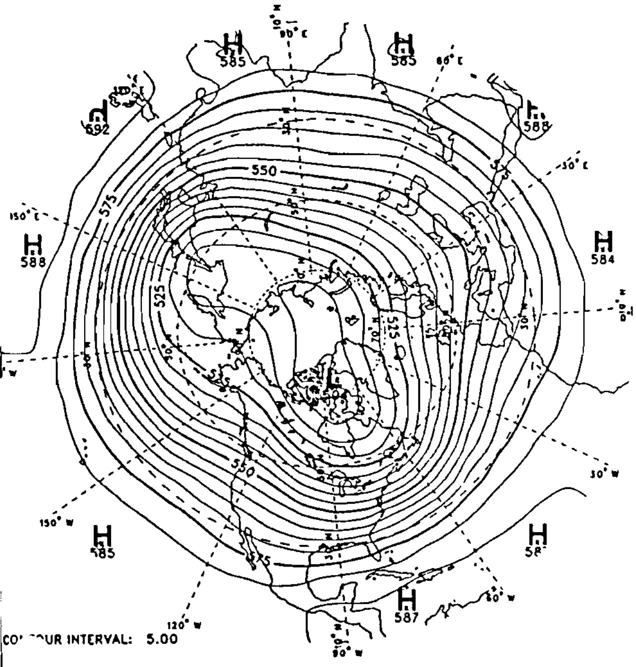
50 KPA
WINTER CLIMATOLOGY
1951–1980

1.

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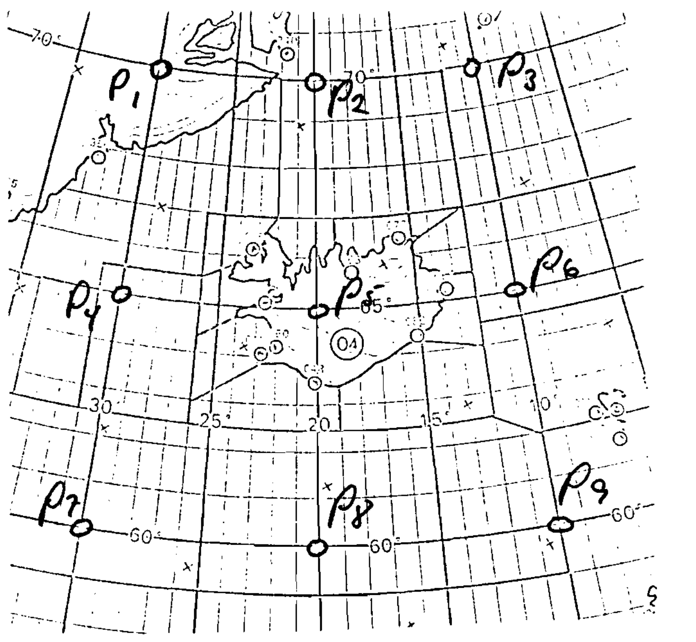
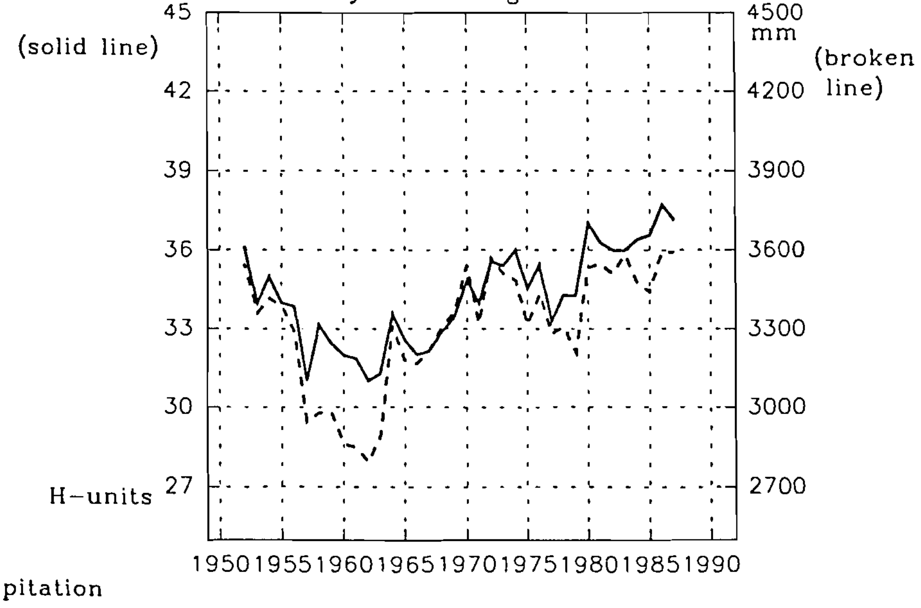


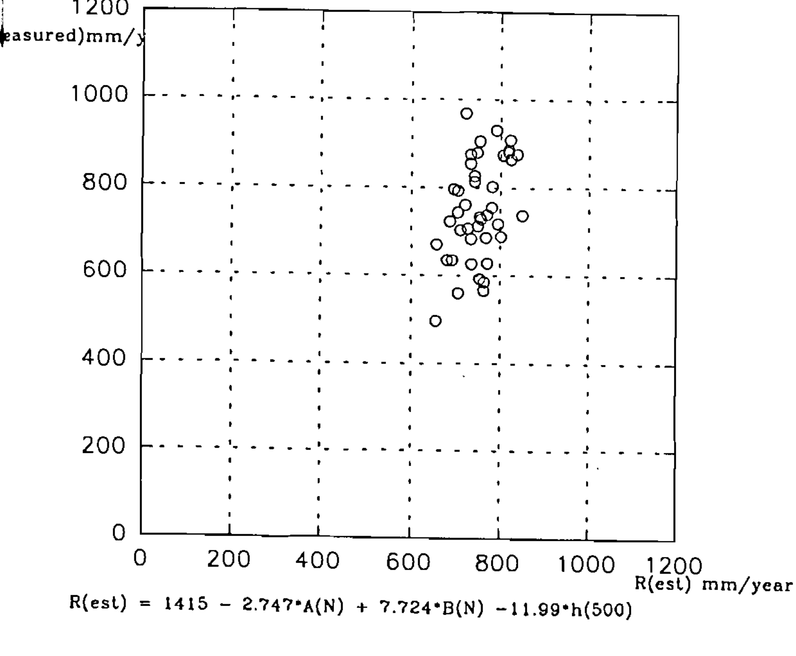

3

Precipitation in Samnanger vs. strength of zonal parameter at 500hPa over W-Norway 1949–1990
7-year running means



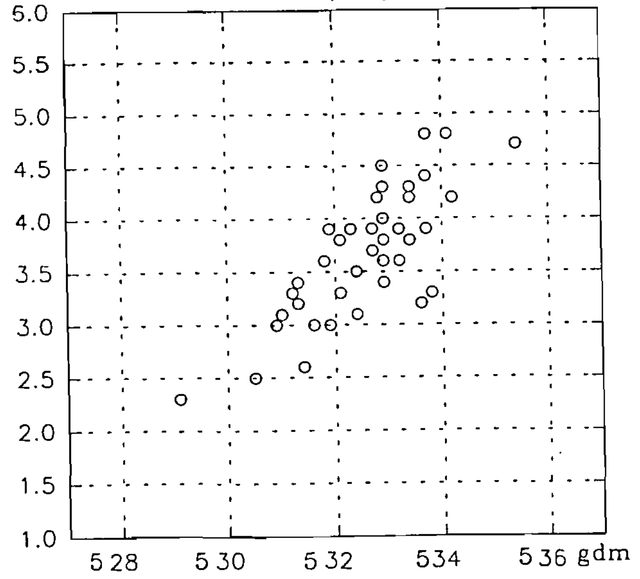

4

Nord-Odal (E-Norway)
Estimated v. measured precipitation
1949 – 1990

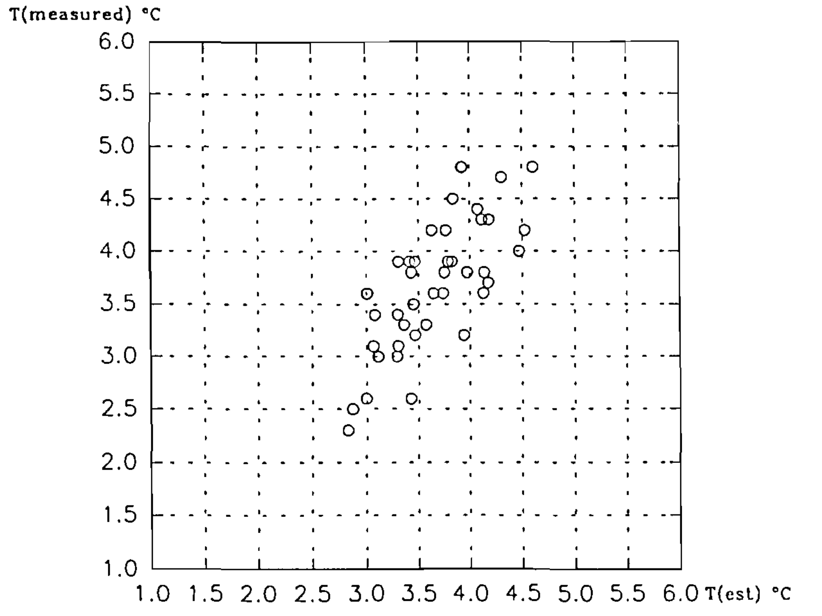



$R(est) = 1415 - 2.747 \cdot A(N) + 7.724 \cdot B(N) - 11.99 \cdot h(500)$

5. Annual average temperature in Stykkishólmur 1949–1990 v. thickness (500/1000hPa)

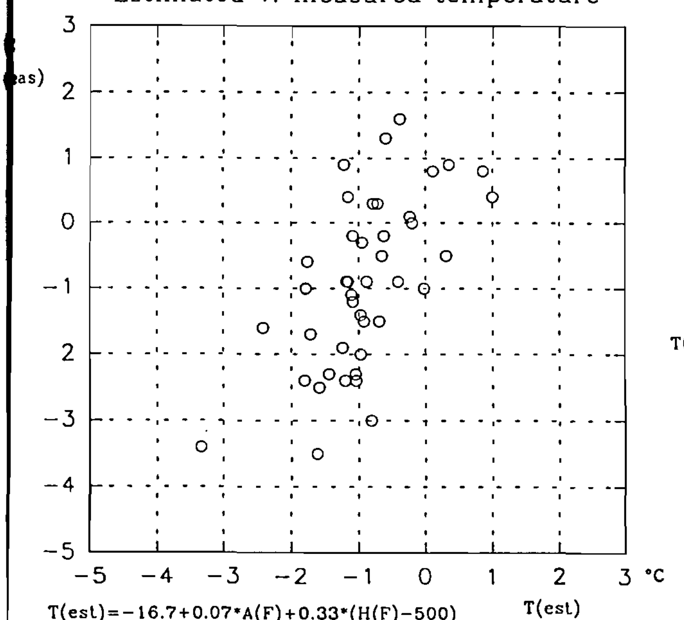



6. Stykkishólmur 1949–1990
Estimated temperatures v. measured temp.



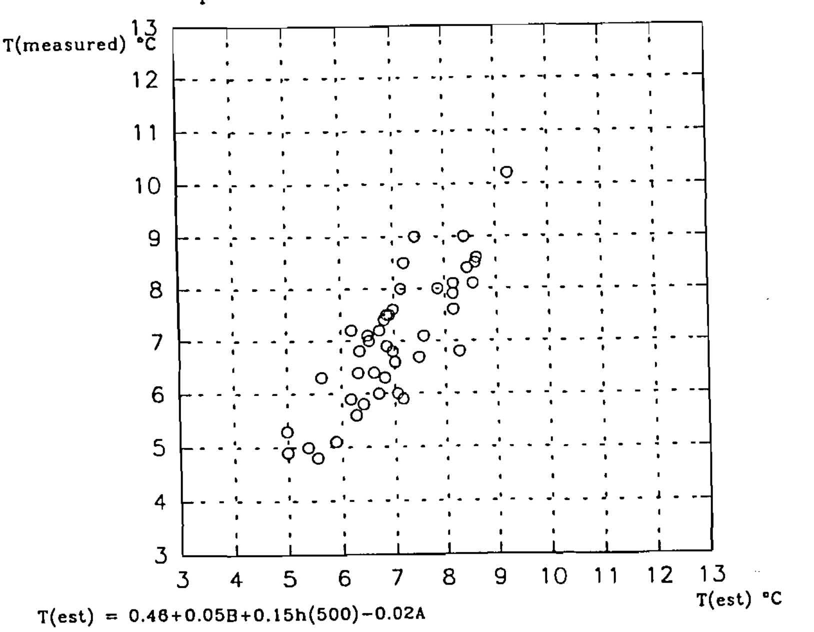

T(est) = −1.96 + 0.09*B + 0.15*h(500) − 0.03*A

7. Sodankylä 1949 –1990
Estimated v. measured temperature



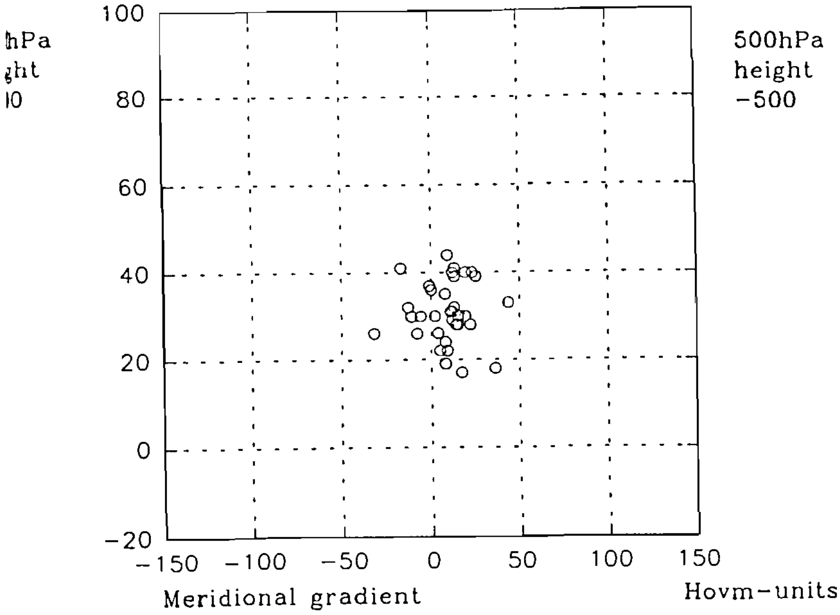

T(est)=−16.7+0.07*A(F)+0.33*(H(F)−500)

8. Stykkishólmur (W–Iceland)
Estimated v. measured temperature
September 1949 – 1991

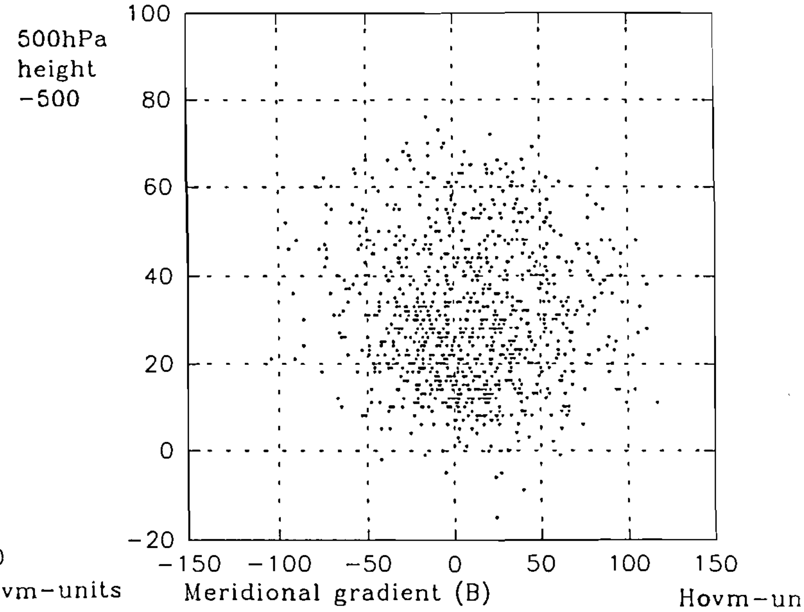



T(est) = 0.46+0.05B+0.15h(500)−0.02A

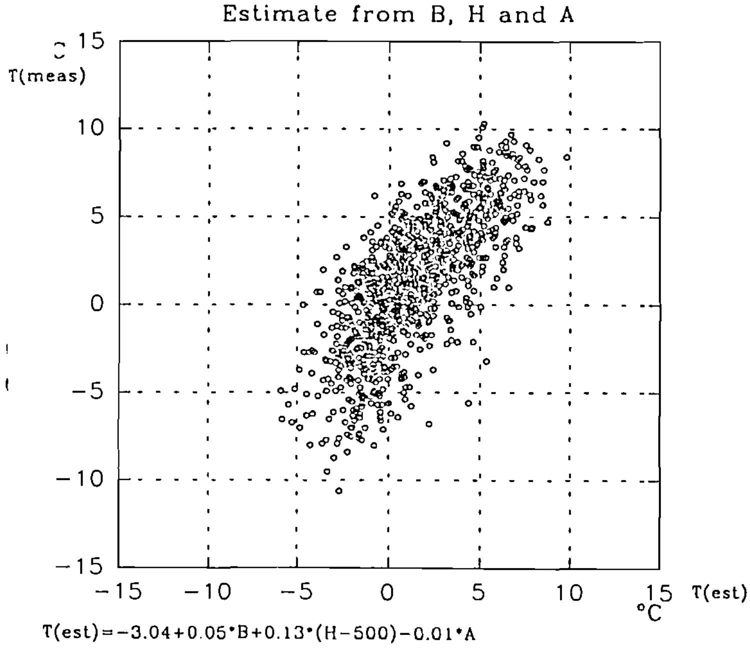
9. Monthly values of B and H over Iceland in November 1958 – 1991



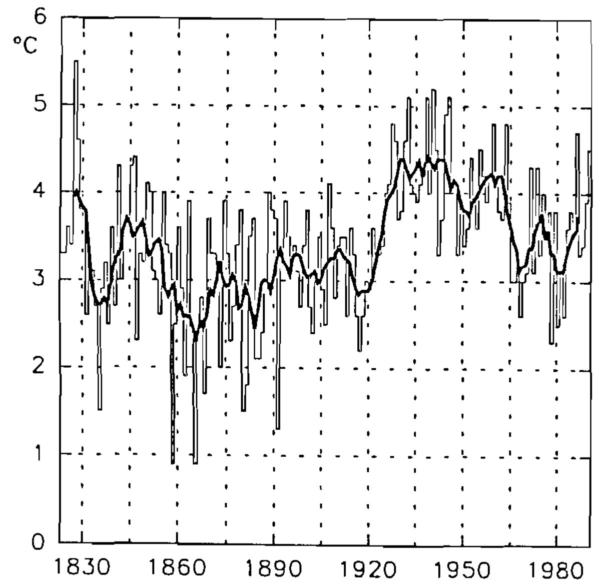

10 Daily values of B and H over Iceland in November 1958 – 1991



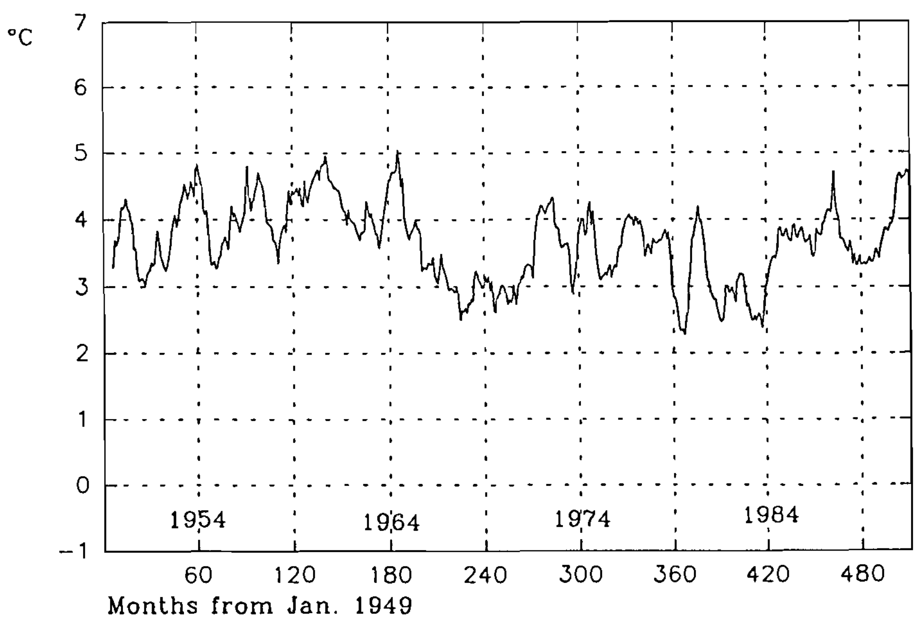

11. Estimated v. daily temperature in Reykjavík in Nov. 1958 – 1990
Estimate from B, H and A




12 Meòalhiti í Stykkishólmi 1823 – 1991
ásamt 7–ára keòjumeòaltali (breiòari lína)

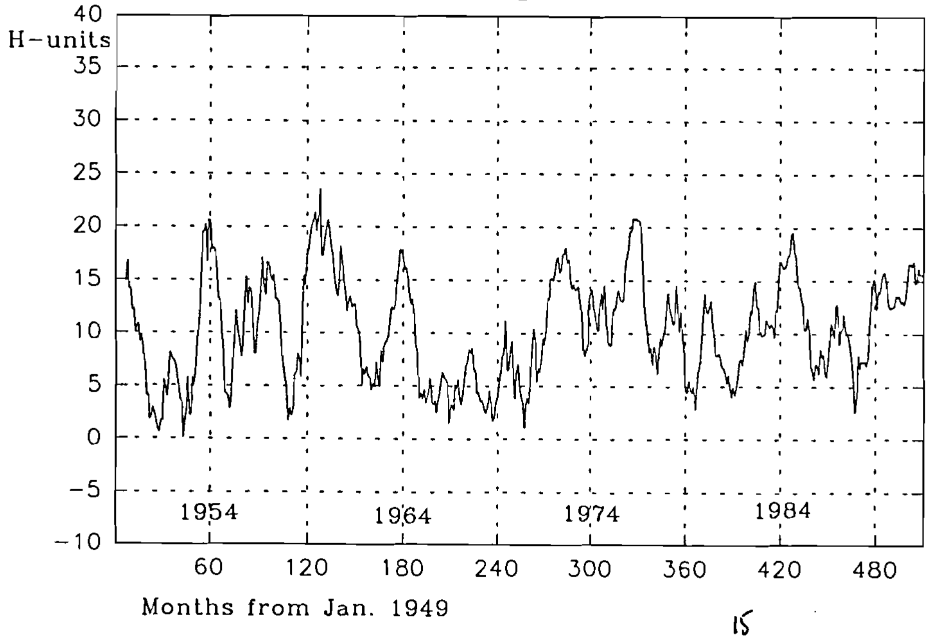



13. Temperature in Stykkishólmur (W-Iceland) 1949 – 1991
12–month running means



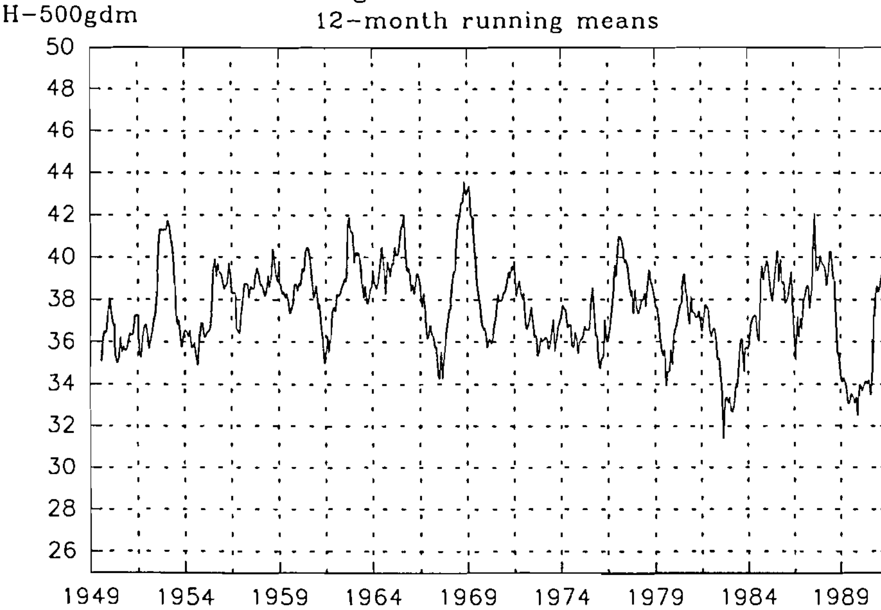
14

Meridional gradient at 500hPa over Iceland 1949 - 1991
12- month running means in H-units.



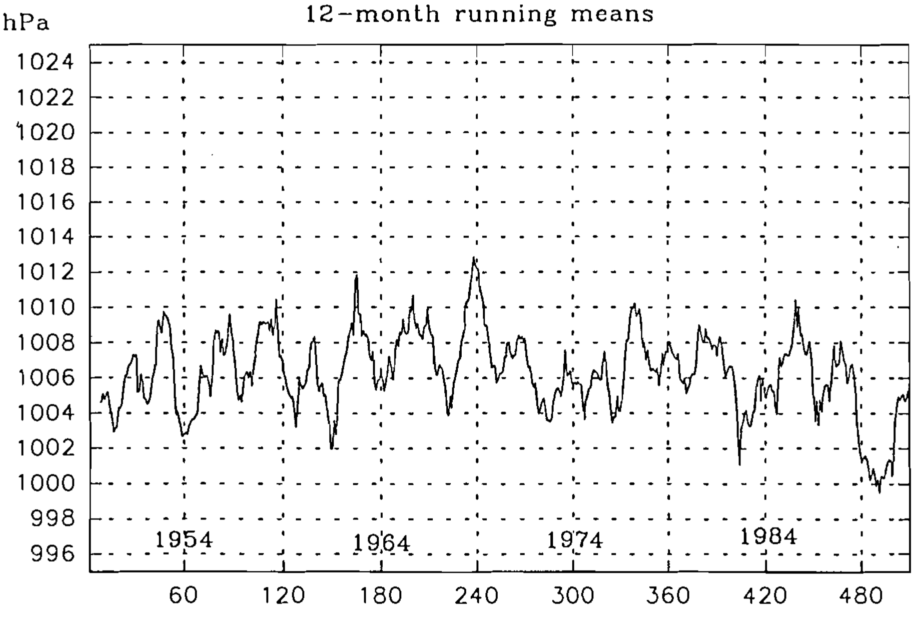

15

500hPa heights over Iceland 1949 - 1991
H-500gdm
12-month running means



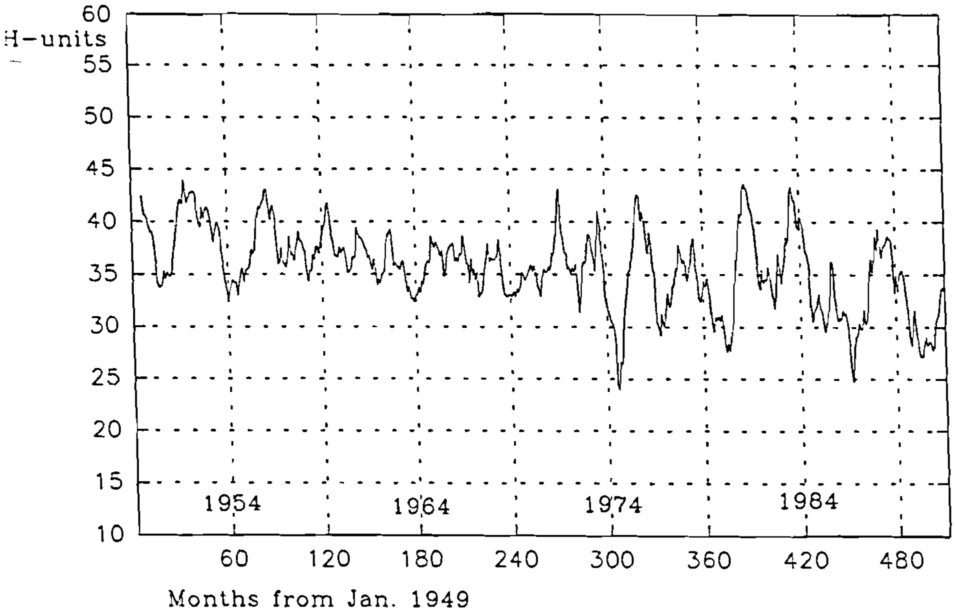

16

S.l. pressure in Stykkishólmur (W-Iceland) 1949 - 1991
12-month running means
hPa



17

Zonal thermal gradient (500/1000hPa) over Iceland 1949 - 1991
12-month running mean




18.

Month-by-month average s.l. pressure in Stykkishólmur (W-Iceland)
1949 - 1991