GLOBAL IMPACT OF CLIMATE CHANGES AT SPITZBERGEN

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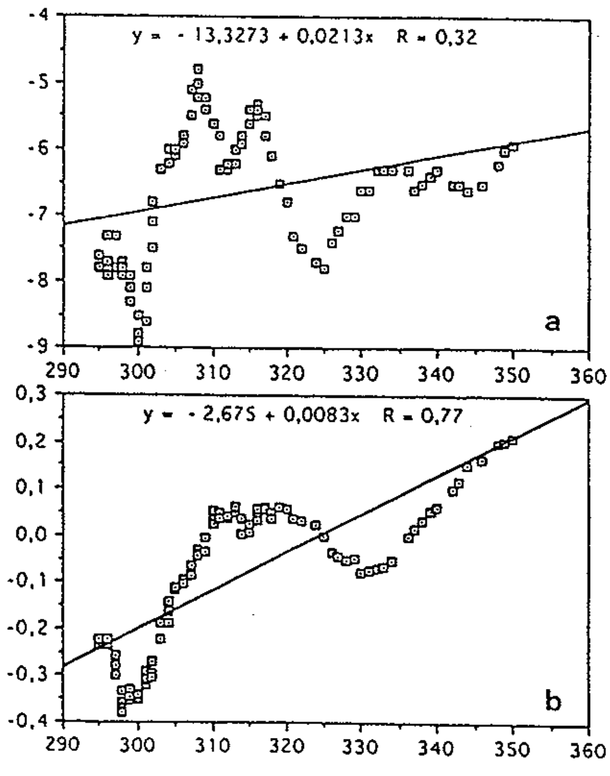
abstract

Many scientists have been of the opinion that there is a relationship between the increase in greenhouse gases and the general rise in global temperature during the past century or so. This has, however, proved difficult to confirm since this temperature rise has been quite irregular, in particular in the northern hemisphere. This paper attempts to explain the irregular global variations as a consequence of past climate changes at Spitzbergen (Svalbard airport). It is shown that the climate variations in that area exceed the temperature variations of the globe by an order of magnitude. These great variations are generally followed by temperature changes in the northern hemisphere with a lag of about 5 years and a considerably reduced amplitude. They also spread to the southern hemisphere with somewhat greater lag and a still less amplitude. Together with the increasing CO2 content of the atmosphere, this phenomenon makes it possible to explain 90% or more of the global climatic variations during the past century, both in the northern and southern hemispheres. Besides confirming the effect of the greenhouse gases and explaining the deviations from the greenhouse impact, the climatic variations in the area of Spitzbergen, moreover, seem to have a prognostic value for the whole globe, extending to several years. It is likely that the phenomenon is related to the thermal and saline anomalies of the ocean and sea ice in that area and to their circulation around the northern North Atlantic. Since Iceland is situated where this phenomenon is quite active it is possible to forecast the duration of Icelandic sea ice and temperatures for the succeeding year and even the mean conditions for the succeeding 5 years. This can be of considerable economic value for Icelandic agriculture and fisheries.

1. Climate oscillations

The hypothesis of the greenhouse effect on the temperature during the last 100 years can be tested crudely by means of the three graphs in Fig. 1, showing the relation between the CO2 and the temperature records from Spitzbergen (Birkeland et al. 1940), the northern hemisphere and the southern hemisphere. The temperature is based on the ten year running averages, while the CO2 values correspond to the centre of each ten year mean. Right at Spitzbergen the correlation is insignificant, 0.32, the irregular variations being far greater than the changes that can be assumed to be due to the CO2 record. The average rise in temperature corresponds to about 7.5 degrees with doubling of the CO2. Due to the great variability this average rise is of course very unreliable, even if it is in good agreement with the results of general circulation models in high northern latitudes. In the northern hemisphere the correlation is much better, 0.77, even if there are considerable deviations from a linear correlation with the greenhouse effect. However, the mean warming corresponds to about 3 degrees with a doubling of the CO2, which is in good agreement with the results of general circulation models. In the southern hemisphere, on the other hand, the correlation with the variation in CO2 is more significant, 0.94. There the warming corresponds to 3.7 degrees with a doubling of the present CO2 level.



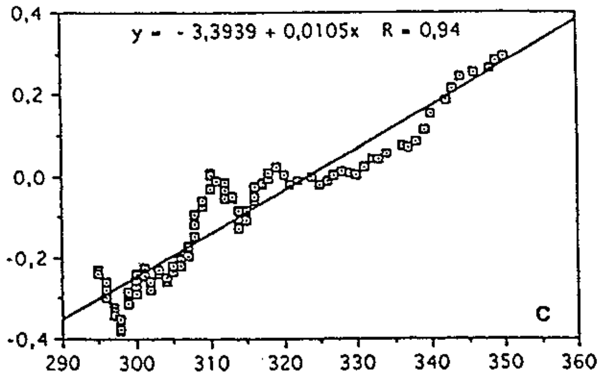


Figure 1. *Scatter diagrams and regressions of running 10 year mean temperatures as a function of CO2, 1893-1992. a) Spitzbergen, b) the northern hemisphere and c) the southern hemisphere. Temperatures in b) and c) are shown as anomalies relative to the mean values from 1950-1979.*

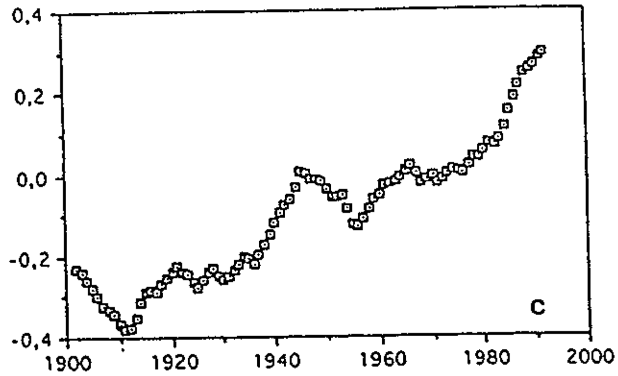
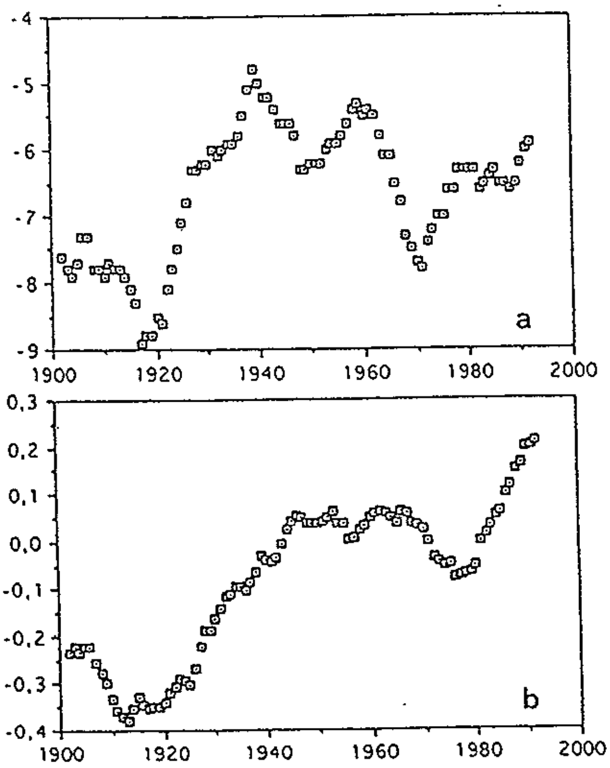


Figure 2. *The running ten year mean temperature as a function of time, 1893-1992. a) Spitzbergen, b) the northern hemisphere and c) the southern hemisphere.*

If we plot the temperature as a function of time, Fig. 2, we can see that there is a certain resemblance between the variations in all three cases. These variations are by far the greatest at Spitzbergen and smallest in the southern hemisphere. A closer examination reveals that the variations at Spitzbergen precede the global changes. This fact will now be examined in more detail.



2. Time lag between the climate at Spitzbergen and the global climate.

Fig. 3 shows the correlation coefficients between the ten year mean temperature at Spitzbergen and the ten year mean temperature of the northern and the southern hemispheres as a function of the assumed time difference between the oscillations for Spitzbergen and global oscillations, ranging between +20 years and -10 years. The plus sign denotes that the climate changes at Spitzbergen precede those of the northern hemisphere.

Let us first consider the northern hemisphere. The optimum correlation of 0.78 is obtained for a lag of 5-6 years behind Spitzbergen, while for minus 5-6 years it is little more than 0.5. It is remarkable that in order to obtain the temperature of the northern hemisphere the past temperature at Spitzbergen is more useful than the contemporary temperature.

We can now write a regression equation for the 10 year Spitzbergen temperature and the temperature of the northern hemisphere 5 years later (Fig. 4). As an additional parameter we use the CO2 level:

$$\dot{NH} = 0.11\ SP + 0.0053\ CO - 1.0 \quad R = 0.95 \qquad (1)$$

where NH is the estimated northern hemisphere temperature, SP is the corresponding temperature at Spitzbergen 5 years earlier, and CO is the current CO2 in ppm.

This indicates that the irregular climate variations in the northern hemisphere are about 11% of the corresponding variations at Spitzbergen, differing by an order of magnitude.

Considering the southern hemisphere (Fig. 3) we find that the probable lag behind Spitzbergen is even greater there, seemingly 7-8 years. Assuming the lag to be 7 years and taking the CO2 into account we find:

$$SH = 0.046\ SP + 0.00843\ CO - 2.47 \quad R = 0.97 \qquad (2)$$

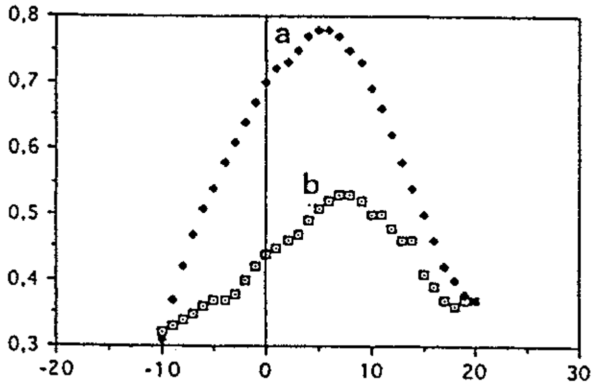


Figure 3. *Correlation coefficient between the running 10 year mean temperatures at Spitzbergen and the corresponding temperatures of a) the northern hemisphere and b) the southern hemisphere. Computed as functions of the time lag in global temperatures following Spitzbergen temperatures, in years.*

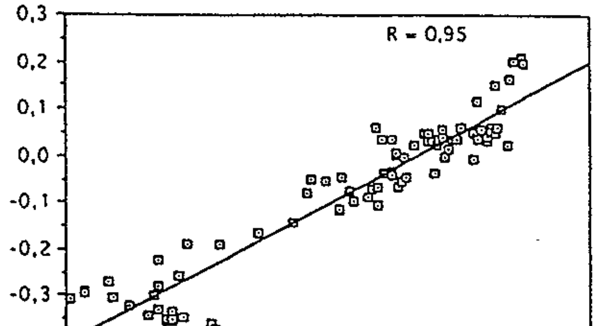


Figure 4. *Regression between estimated and actual 10 year running mean temperatures of the northern hemisphere. The estimates are computed from the 10 year running mean temperatures at Spitzbergen 5 years earlier and the current CO2 levels, according to Eq. 1.*

The multiple regression equation (Fig. 5) indicates that the irregular oscillations in the southern hemisphere are 5% of those at Spitzbergen, and the correlation is almost complete.

The above correlations depicted in Fig. 4 and Fig. 5 between the estimated and actual temperatures of the northern and southern hemispheres are rather remarkable. They indicate that in the northern hemisphere about 90% of the climatic variability is explained by the two parameters: past Spitzbergen temperature and the current CO2, while in the southern hemisphere about 94% is explained. This brings us closer to the conclusion that the greenhouse effect can already be distinguished in the global climate.

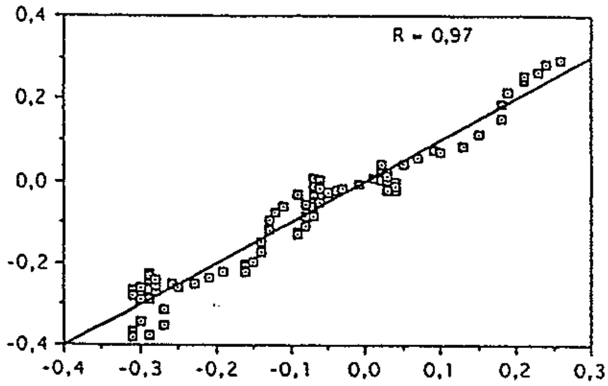


Figure 5. *Regression between estimated and actual 10 year running mean temperatures of the southern hemisphere. The estimates are computed from the 10 year running mean temperatures at Spitzbergen 7 years earlier and the current CO2 levels, according to Eq. 2.*

3. Some physical considerations

The reflections stated above are strongly indicative of important parameters governing the climate of the past 100 years. What remains is to look for any possible physical reasons for the relationship between the climate variations in the vicinity of Spitzbergen and for the globe as a whole.

It is well known that the oceans preserve their thermal and chemical characteristics remarkably well, not the least in the northern North Atlantic. In their classical work about the Norwegian Sea, B. Helland-Hansen and F. Nansen (1909) pointed out that temperature anomalies in the sea outside Sognefjord in spring were recognized near Lofoten a year later and two years later in the Barents Sea, having travelled about 2000 km. Bergthórsson (1969a) found that the air temperature at Jan Mayen in autumn can be used as a predictor of the sea ice conditions near Iceland in the following spring, 500 km further south, probably as a result of advection by the ocean currents. Bergthórsson (1972) furthermore showed that there is about 2-3 year lag between the 3-year mean temperatures on Spitzbergen and those in Stykkishólmur in western Iceland. It was concluded that the reason was the gradual advection of oceanographic conditions from the Spitzbergen area towards Iceland. Finally, in their paper on the "great salinity anomaly", Dickson et al. (1988) showed that a huge salinity anomaly north of Iceland in the year 1968 could be traced for about 14 years, flowing towards Greenland, Labrador and Newfoundland and from there to southern Norway and the Barents Sea and on to Spitzbergen and to the waters north of Iceland, with an average speed of about 3 cm per second, 1000 km a year, Fig. 6.

In this connection it is noticeable that in these waters there is a strong positive correlation between salinity and sea temperature. In the northern part of this great circulation the sea ice is also highly related to salinity and temperature. Low salinity in the uppermost layer makes the sea stably stratified. This prevents the surface water from sinking as a result of winter cooling, enabling sea ice to be formed. This again enhances low salinity, since the winter precipitation will be gathered on top of the ice. When it melts in the spring the salinity of the uppermost layer will be even less than before so that in the next ice season there can be still more favourable conditions for ice formation. This vicious cycle will cause heavy ice conditions to persist in the entire path of low salinity from the Barents Sea to Labrador, while it accordingly counteracts ice formation when salinity is high. This will lower the atmospheric temperature in the belt of heavy sea ice and raise it when this belt is characterized by anomalous open sea.

These observations indicate that the ocean area between Newfoundland and the Barents Sea can in some cases be a great source of positive or negative heat for the atmosphere. A temperature anomaly in the sea starting at Spitzbergen will constantly affect the temperature of the air passing this area and spread the heating or cooling cumulatively into the whole circulation of both hemispheres. This will be especially important on the first 5-6 year path along the border of the sea ice.

However, we have only discussed the global effects of the climatic variations at Spitzbergen and not the ultimate reasons. This would call for a special investigation.

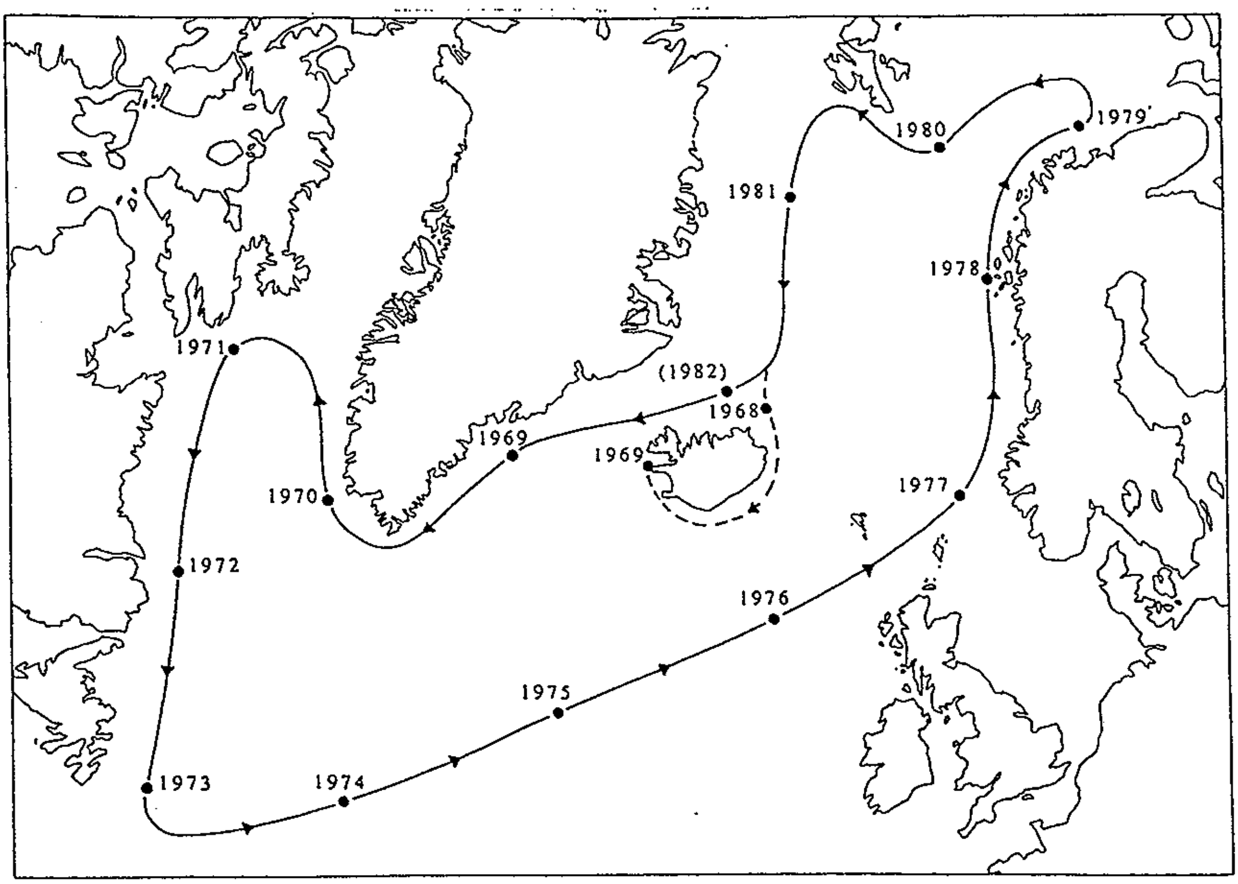


Figure 6. *Schematic presentation of the circulation of the great salinity anomaly, during the period 1968-1982.*

4. Seasonal and climatic forecasts in Iceland

The thermal conditions at Spitzbergen therefore have some prognostic value for the climate of the whole globe. However, for individual years these global forecasts are of little or no value. In Iceland, on the other hand, it is possible to carry out such short-range climatic predictions with some success.

Annual sea ice forecasts for the waters north of Iceland have been made since 1969, or for a quarter of a century. It turned out that the best predictor was the Jan Mayen temperature in August-January, measured as the average of the standard deviations d for each month. The relationship

$$\text{Ice period} = 12/(10^{d+1.6} + 1) \qquad (3)$$

is used to convert the temperature deviation into ice prevalence. Here the annual ice period is computed from the sum of the days when sea ice is sighted somewhere near the Icelandic coast, counted in months. For the years 1922-1988 this gives a correlation coefficent of 0.82 between the estimated and actual duration of annual sea ice.

Since 1987 the mean monthly deviation J from the mean Jan Mayen temperature in August-January has been used to forecast the mean temperature of the coming year in Stykkishólmur. An exponential smoothing is used, a weighted mean of the index of the past years, decreasing by 50% for each preceding year:

$$\text{Annual temperature} = 0.5\,J + 4.0 \qquad (4)$$

In 85% of all the years 1922-1993 the forecast states correctly whether the actual temperature was above or below the average of 1846-1980. This forecast has been successful since 1987 when it was first carried out (Bergthórsson, 987).

A forecast of the mean temperature of the ensuing 5 years in Stykkishólmur can be obtained from the past Spitzbergen temperature. As a predictor we can use a mean temperature obtained by exponential smoothing, where the weight of every year is 80% of the succeeding year. For the period 1896 to 1993 these forecasts give a correlation coefficient of 0.74, corresponding to a lag of approximately 2-3 years between Spitzbergen and Stykkishólmur, as would be expected from the velocity of the ocean currents.

These climatological forecasts are valuable for Icelandic industries. Hay and pasture production and animal husbandry are highly dependent on climatic variations (Bergthórsson 1988). There are also reasons to conclude that the fisheries in past centuries have been strongly related to the climate (Jónsson 1993, Bergthórsson 1969b) and recently Icelandic scientists have pointed out that conditions for marine life in the waters north of Iceland are related to the conditions in the Barents Sea 2-3 years earlier (Antonsson et al. 1994). That is in good agreement with the circulation of the great salinity anomaly.

It is the opinion of the present author that these climatic variations in the Spitzbergen area are even more consequential than the well-known El Nino phenomenon for the global climate.

Conclusions

The great climatic variations in the Spitzbergen area seem to have a widespread impact on the climate of the whole northern hemisphere and to a lesser degree also of the southern hemiphere, with a considerable time lag. This effect may even explain most of the deviations from the regular temperature change which would be expected from the ongoing increase of greenhouse gases. This is thought to be connected with the great anomalies of oceanographic characteristics observed in the vicinity of Spitzbergen and circulating in about a 14 year cycle around the northern North Atlantic. The sea ice in the northern part of this circulation seems to enhance the persistence of these anomalies. The time lag of approximately 5-7 years between this phenomenon in the Spitzbergen area and the globe as a whole gives it some predictive and economic importance. Iceland is situated where these anomalies are highly prominent, and in addition to the Spitzbergen data the annual variations at Jan Mayen are of great importance for Icelandic seasonal and climate predictions. This makes it possible, moreover, to forecast sea ice and temperature in Iceland for a whole year, and the mean temperature of the following 5 years.

Addendum on statistical climate forecasts.

It has been shown above that the two parameters, CO_2 and the Spitzbergen temperature, probably have some predictive value for the climate of both hemispheres.

A statistical forecasting method has been derived for this purpose. The following regression equation can be written.

$$Y = a + bX_1 + cX_2$$

where Y is the 7-year mean temperature forecast as the deviation from 1950-1979 for the northern (or southern) hemisphere. X_1 is the exponentially smoothed Spitzbergen temperature, with the annual damping of 0.75, and X_2 is the estimated average CO_2 for the following 7 years. a, b and c are coefficients which turn out to be;

N-hemisphere -1.37, 0.091 and 0.006
S-hemisphere -2.79, 0.042 and 0.0094.

The predictive equations give the following results based on data from 1893-1992:

	N-hemisphere	S-hemisphere
Correlation coefficient	0.94	0.96
Root-mean-square error	0.06 deg C	0.05 deg C

This forecasting method is entirely empirical. The high correlation indicates, however, that it may be something to take into account for the modellers of climatic variations.

It goes without saying that much further study is needed of the climatic characteristics of the northern North-Atlantic and the associated global climate.

References

Antonsson, _., Gudbergsson, G., Gudjónsson, S. 1994: Tengsl Barentshafs og Íslandsmida. Report, Institute of Freshwater Fisheries.

Bergthórsson, Páll, 1969a: Forecasting Drift Ice at Iceland by Means of Jan Mayen Temperature. *Jökull*, 19, 44-52.

Bergthórsson, Páll, 1969b: An Estimate of Drift Ice and Temperature in Iceland in 1000 years. *Jökull*, 19, 94-101.

Bergthórsson, Páll, 1972: Advection of Climate by Ocean Currents. *Sea Ice*. Proceedings of an International Conference in Reykjavík, 94-100.

Bergthórsson, Páll, 1987: Spár um árshita. *Aegir*, Reykjavík, 75-77.

Bergthórsson, Páll, 1988: The Effects of Climatic Variations on Agriculture in Iceland. In: M. Parry, T.R. Carter and N.T. Konijn: *The Impact of Climatic Variations on Agriculture*. Vol. 1. Assessments in Cool Temperate and Cold Regions, 389-444.

Dickson, R., Meincke, J., Malmberg, S.-A. and Lee, J., 1988: The "Great Salinity Anomaly" in the Northern North Atlantic 1968-1982. *Proc. Oceanog*. 20, 103-151.

Helland-Hansen, B. and Nansen, F.,1909: *The Norwegian Sea*. Report on Norwegian Fishing and Marine Investigations, 2, 2, Christiania (Oslo).

Hesselberg, T. H., and Birkeland, B.J., 1940: Sekulare Schwankungen des Klimas von Norwegen, Teil 1. *Geofysiske Publikasjoner*, Vol. XIV, No. 4. Oslo.

Jones, P.D., 1993: Personal communication.

Jónsson, Jón, 1993 (unpublished): Fisheries at Iceland 1600-1900. *Report, ICES 1993*, Symposium in Reykjavík on Cod and Climate Change.