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## TEMPERATURE AND PRECIPITATION SERIES AT NORWEGIAN ARCTIC METEOROLOGICAL STATIONS

PER ØYVIND NORDLI

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## TEMPERATURE AND PRECIPITATION SERIES AT NORWEGIAN ARCTIC METEOROLOGICAL STATIONS

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PER ØYVIND NORDLI

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This presentation of time series from the Norwegian Arctic stations includes data from Jan Mayen and Svalbard. Each time series is presented graphically for each of the four seasons as well as the whole year. Low pass Gaussian type filters are used to show climatic trends. In Svalbard the temperature reached a maximum value in the 1930's. During the last 15 years, however, there has been no trend in temperature. This contrasts with the recent increasing trend in mean temperature observed in northern hemisphere.

The report is the text of the authors presentation at NHK's seminar about Arctic hydrology 14.-17.9.1990

UNDERSKRIFT

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C O N T E N T S

# TEMPERATURE AND PRECIPITATION SERIES AT NORWEGIAN ARCTIC METEOROLOGICAL STATIONS.

## 1. INTRODUCTION.

Recent focus on the greenhouse effect has led to an increased interest in climatic time series especially those from Arctic regions where the predicted change in climate has been greatest. In this article time series from the Norwegian stations 9971 Bj╔rn╔ya, 9972 Hopen, 9984 Svalbard Airport and 9995 Jan Mayen will be presented.

I am indebted to Ester Steffensen, whose earlier publications form much of the basis of this presentation, and to Inger Hanssen-Bauer who provided me with the homogenized Svalbard Airport series. My own contribution consists of an analysis of the original historical reports from each station with the goal of locating breaks in homogeneity.

## 2. A BRIEF DESCRIPTION OF THE CLIMATE AT SVALBARD AND JAN MAYEN.

The polar regions import heat from southerly latitudes to compensate for the net heat loss from the top of the atmosphere. There are few barriers (like Greenland) to the interchange of air between the Arctic regions and the adjacent oceans and continents. The polar ocean is a region of relatively intense cyclonic activity. The cyclones move mainly from the North Atlantic Ocean, via Baffin Bay and the Norwegian and Barents Seas. Winter maps show, on the average, four to six cyclones per month over the Norwegian-Barents-Kara Seas (Orvig 1970).

Winter temperatures in Svalbard are remarkably high considering the high latitude. This can be attributed to the warm North Atlantic Current, a continuation of the Golf Stream. The energy interchange between sea and air helps to maintain a relatively warm atmosphere. Likewise the general circulation with a high frequency of southerly winds tends to favour high temperatures at Svalbard.

Advection of different air masses, particularly in winter, leads to fluctuations in Svalbard temperatures. Mild, humid and cloudy air from the Atlantic Ocean is often followed by a cold, dry Arctic air mass. In summer, fluctuations are small. Arctic air masses contain less clouds than Atlantic air masses, the result being that solar radiation more often destroys the surface inversion in the Arctic air masses.

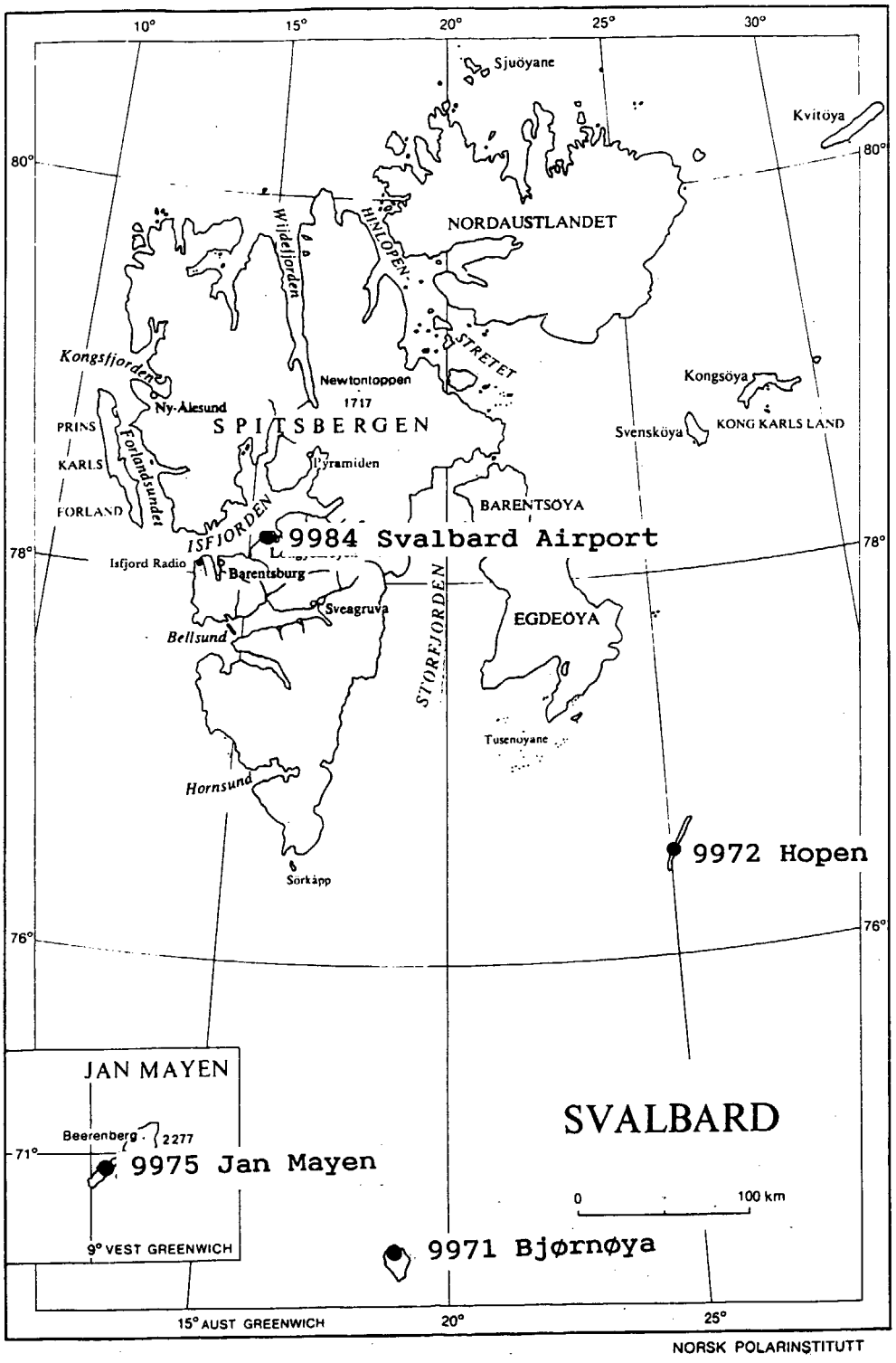



Fig. 1 Svalbard and Jan Mayen

The sea ice is limited mainly by the distribution of warm and cold sea currents, as well as local wind conditions. The sea ice extends farthest south in April, when the mean limit is situated near Jan Mayen and Bjørnøya. Of particular significance is the area of open sea which normally occurs west of Spitsbergen, even in April. The sea ice limit reaches a minimum in August, at which time it is normally absent from the sea near all Norwegian meteorological stations.

Wind. In winter, the mean pressure distribution causes prevailing easterly winds at Bjørnøya and Hopen. At Jan Mayen, the most frequent wind direction is from the north due to the high pressure centred over Greenland. At West Spitsbergen the wind may be catabatic, with the result that the steering effect of Adventfjorden often gives rise to winds from the south and southeast at Longyearbyen. The circulation in summer is weaker, and wind direction more variable.

Temperature. According to Köppen's climatic classification the Arctic stations have a tundra climate meaning that mean temperature in the warmest month lies above freezing and below 10 $^{0}$C. The mean annual temperatures are below freezing at all stations.

The lowest temperature observed at any Norwegian Arctic station is -46.3 $^{0}$C recorded in March 1988 at Svalbard Airport. However, all Norwegian Arctic stations are situated relatively near the fjords, and the temperature at Spitsbergen is thought to be lower at some valley floors in the interior of the island. The recorded minimum at Jan Mayen, the southernmost island, is -28.4 $^{0}$C and at Bjørnøya -31.6 $^{0}$C. North and east of Bjørnøya, towards the sea ice limit, a rapid increase in the horizontal temperature gradient occurs. The difference in winter temperature between Bjørnøya and Hopen is about 5 $^{0}$C, (Fig. 10a).

During April and May a pronounced temperature rise occurs, and July and August are the warmest months. The monthly means in July and August are 4-6 $^{0}$C at the stations except Hopen, where the temperature at this time averages about 1 $^{0}$C. Chapter 4 includes details on temperature in the different seasons.

Precipitation. The annual means of measured precipitation at stations in Svalbard, including Hopen and Bjørnøya, do not exceed 500 mm. The mean precipitation at Jan Mayen is about 700 mm. Measured precipitation is presumed to be lower than real values due to gauge catchment errors.

The number of measurement points at Svalbard are far to few to enable calculation of areal precipitation. However, the accumulation of snow during winter indicates that the greatest amount of precipitation occurs over glacier and mountain slopes freely exposed to winds in the south-east sector (Hisdal 1976). This agrees well with the prevailing wind direction under cyclonic activity.

## 3. A SHORT SURVEY OF THE HISTORY OF THE NORWEGIAN ARCTIC STATIONS AND A DISCUSSION OF THE HOMOGENEITY OF THE TIME SERIES.

### 3.1 The problem of homogeneity.

The aim here is to show the variation in Arctic climate and discover existing trends in the time series. The longest records of temperature and precipitation extend over 70 years. During this time some of the meteorological instruments have been either changed or relocated. Thus, before establishing a climatic time series it is essential to investigate whether or not such changes have had any influence on measurements. If changes in instrument type or location have had no influence on the measurements in a series, the series is said to be homogeneous. If the opposite is true, the series is said to be either inhomogeneous, or to contain a break. A break in a series is serious because it may mask the real variability or trend in the climate.

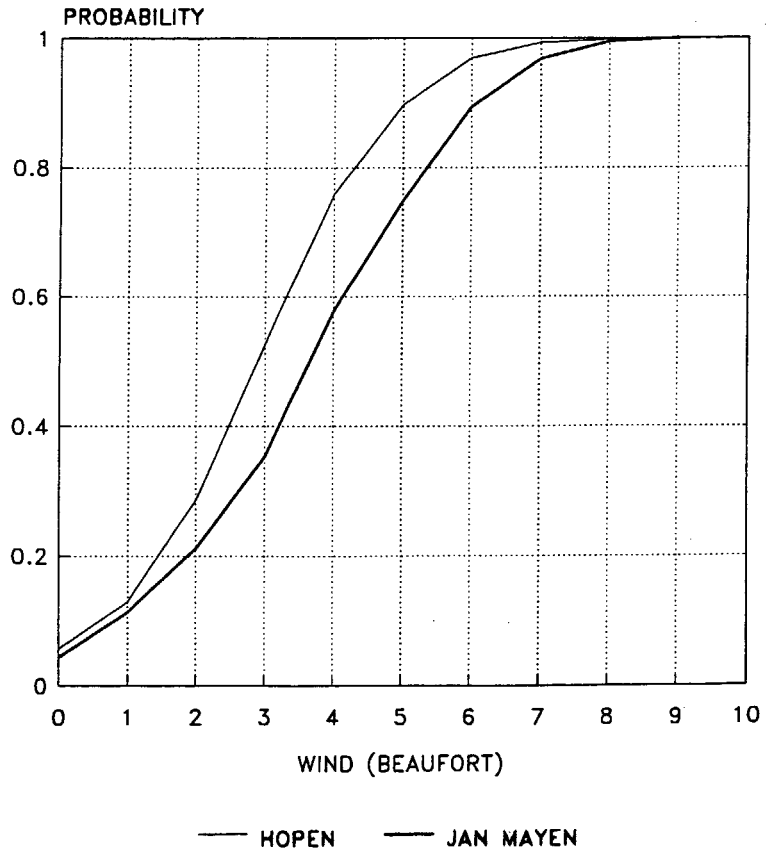
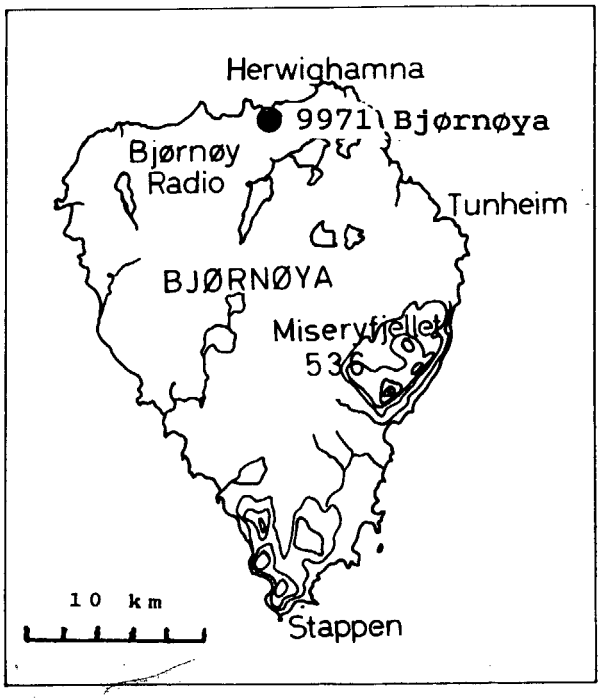



Fig. 2 The cumulative distribution of wind force under precipitation conditions at Hopen and Jan Mayen in the period (1956-1989).

In the Arctic, investigating the homogeneity of a time series is often very difficult due to the lack of neighbouring stations. One general problem involving temperature measurements is overheating of thermometers caused by short wave radiation during periods of calm. However, these periods are rare in the Arctic as thermometer screens are usually well ventilated by the wind.

On the other hand the frequent occurrence of strong wind with snow has made many of the precipitation time series in the Arctic unreliable. The capture efficiency of the gauges is sensitive to changes in both horizontal and vertical wind speed, which in turn again is strongly influenced by the local terrain. Therefore, any movement of the gauges, as well as changes in the local environment, may significantly influence measurements. The problem is illustrated in Fig. 2 which shows the distribution of the wind force during precipitation conditions at Hopen and Jan Mayen for the period 1956-89.

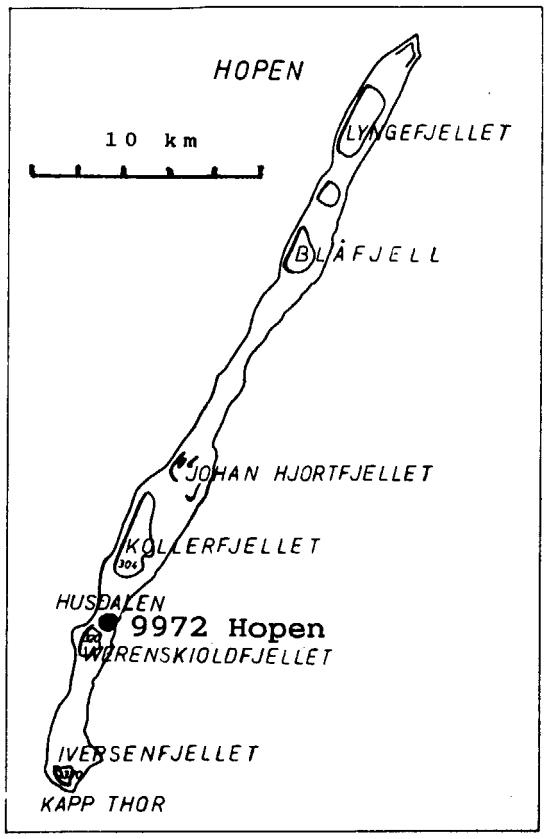
### 3.2 Bjørnøya.




Bjørnøya is situated halfway between the southern tip of Spitsbergen and the coast of Finnmark. The weather station was established at Tunheim in 1920 (Fig. 3) and moved 7.5 km to Herwigshamna in 1947. There were also minor movements of the instruments in 1929, 1945 and 1969. The station is thought to be homogeneous for temperature. The homogeneity of the precipitation measurements is questionable.

**Fig. 3 Bjørnøya**

3.3 Hopen.




The weather station was established by German soldiers in November 1944 and operated through July 1945 (Fig. 4). In October 1945 the station was reestablished at Hopen radio. Since then the temperature time series has been homogeneous.

In 1948 the gauge was equipped with a shield which seems to have increased the capture efficiency considerably. Since then there has been no significant change at the station.

Fig. 4 Hopen

3.4 Svalbard Airport.

The station is situated on Spitsbergen at the inner end of Adventfjorden, a branch of Isfjorden (Fig. 5).

Measurements began in August 1975 and are still being made. Other time series exist from Spitsbergen with more or less regular observations. In order to investigate the variation in temperature, as far back as possible, it was necessary to combine these time series into one series valid for Svalbard Airport. The following is a short description of the process involved.

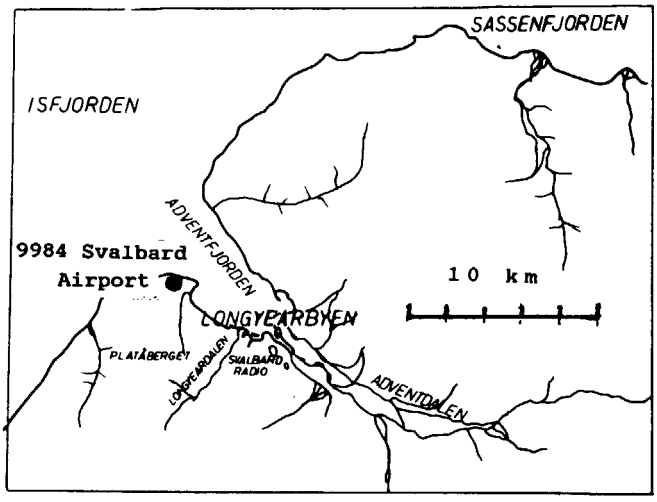



Fig. 5 Svalbard Airport

At Longyearbyen, about 4 km southeast of Svalbard Airport, observations were made from November 1916 to July 1977. Thus, for the period August 1975 to July 1977, the two stations Longyearbyen and Svalbard Airport were running simultaneously. For this period mean monthly temperatures from the two stations have been compared and a correction table worked out (Hanssen-Bauer, 1990). The correction is related to the month of the year and ranges from -1.4 $^{0}$C in April to 0.0 $^{0}$C in October.

The series from Longyearbyen has some missing data. To overcome the gaps measurements from two nearby stations have been utilized, i.e. Green Harbour for the period 1916 - 1930 and Isfjord Radio from 1934 - 1957. The extent of these corrections depend on the month and vary from -0.1 $^{0}$C in September to 1.6 $^{0}$C in June for Green Harbour, and from -2.9 $^{0}$C in February to 1.6 $^{0}$C in July for Isfjord Radio (Steffensen, 1969).

No data was collected at Svalbard from 1941-45 due to destruction of the stations during World War II. To compensate for this missing data a method of optimal regression analysis has been used (Steffensen, 1969). The predictors were mean sea level pressure differences taken from synoptic weather maps and temperature observations from Jan Mayen and the Soviet station at Bukhta Tikhaya (80$^{0}$21'N, 52$^{0}$48'E). The coefficients of multiple correlation ranged from about 0.7 during the summer months to 0.9 in winter. The standard deviations of the residuals were about 1 $^{0}$C for the mean monthly temperatures.

For the winter 1941/42 the series includes reduced German observations from Spitsbergen as these observations are thought to be better than the values found by regression analysis.

For the period 1912 - 1915 reduced data from Isfjord Radio have been added (Hanssen-Bauer, 1990) thus creating a time series beginning from 1912.

3.5 Jan Mayen.

The island is situated between Iceland and Spitsbergen at $70^0$,30' north latitude. The station was established in 1922 and destroyed during the war in September 1940, but reestablished already in May 1941 (Fig. 6).

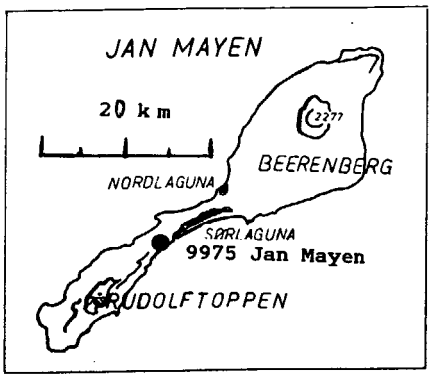



Fig. 6 Jan Mayen

The station was moved 1941 (three times), 1943, 1946, 1949, 1962 and 1969. The longest movement was in 1962; 11.3 km southeast. The station site has changed from the southeastern side to the northwestern side of the island, but always within an area near the middle of the island. Station altitude has ranged from 5 - 40 m above sea level.

From 1960 to April 1962 two stations were running simultaneously at different sides of the island. There is no bias in the temperature differences between them which suggests that the temperature time series for Jan Mayen is homogeneous, in spite of these movements (Steffensen 1969). The precipitation measurements are probably not homogeneous.

## 4. TIME SERIES OF TEMPERATURE AND PRECIPITATION.

### 4.1 Variation in the Svalbard Airport temperature series.

The Svalbard Airport temperature time series is plotted in Fig. 7. In order to show climatic trends, two low pass filters of the Gaussian type are used. Filter 1, with standard deviation three years, shows variation at a scale of about 10 years and filter 2, with standard deviation 9 years, shows variation at a scale of about 30 years.

Highest temperatures occurred in the 1930's and 1950's. A particularly cold period occurred in the first part of the series from 1912 to 1917. Four of these years are among the five coldest years of the entire series. The 1960's were also very cold. There has been a slight declining trend in temperature since the 1930's.

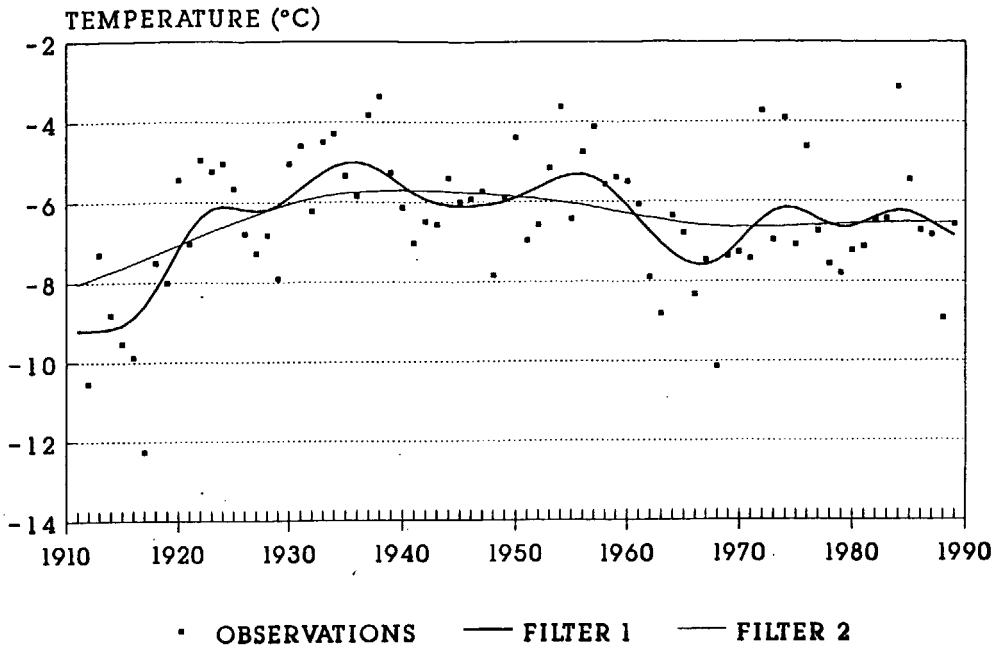



Fig. 7 Homogenized temperature time series for Svalbard Airport. Each point represents the mean annual temperature.

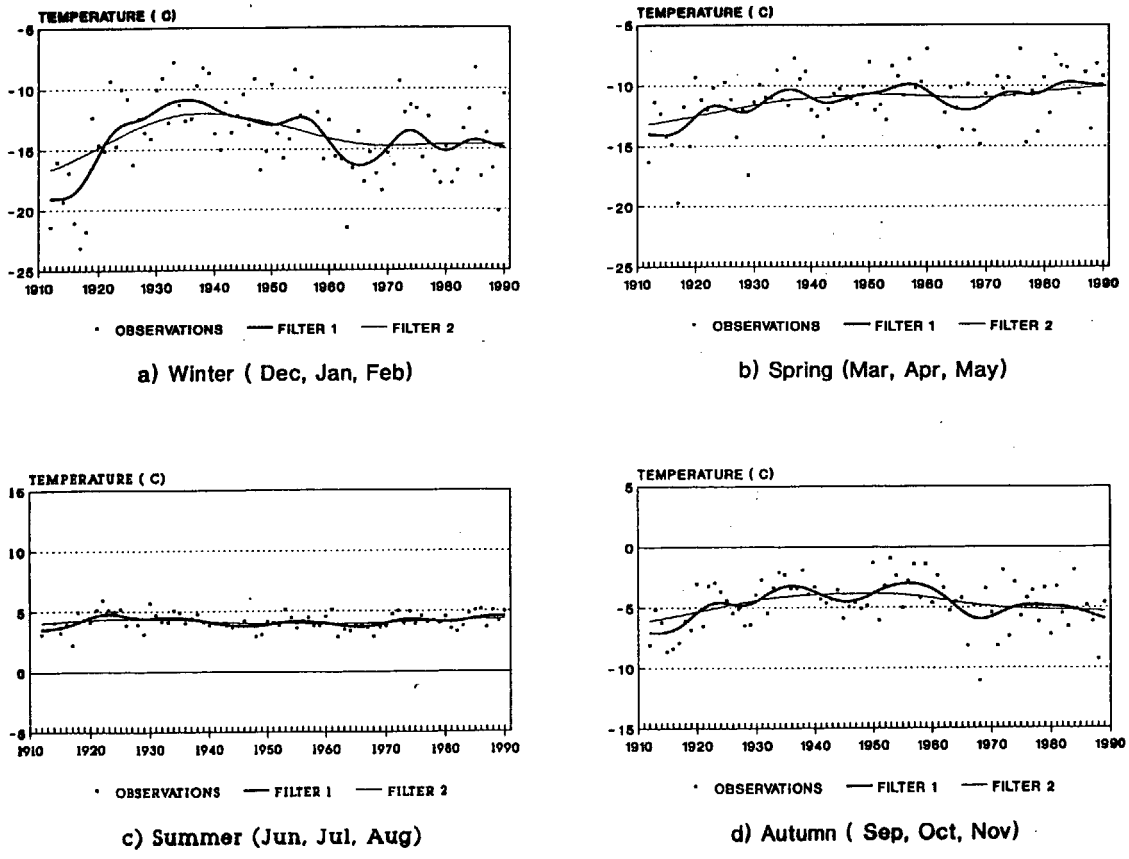



Fig. 8 Homogenized temperature time series by season for Svalbard Airport. Each point represents the seasonal mean temperature.

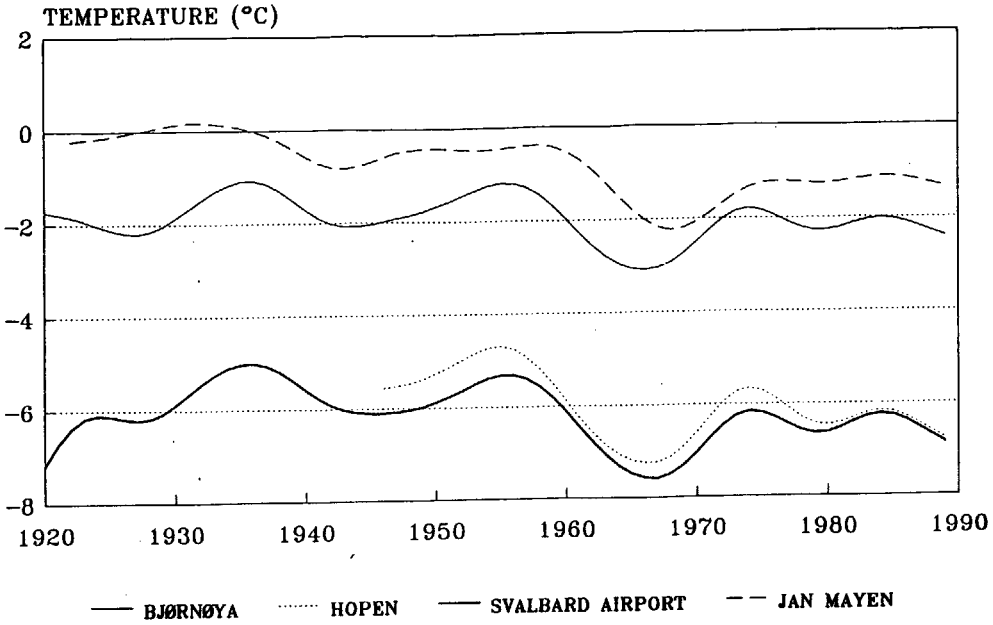
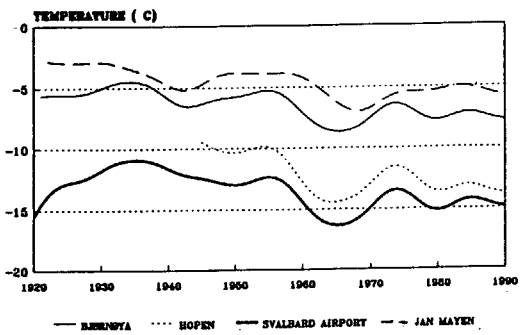
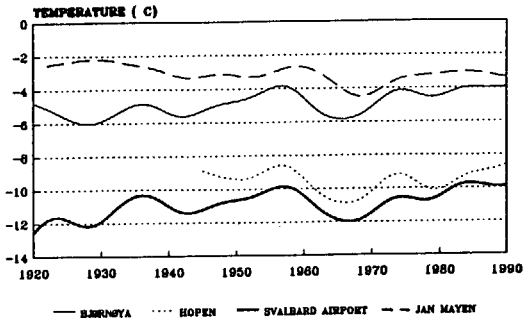


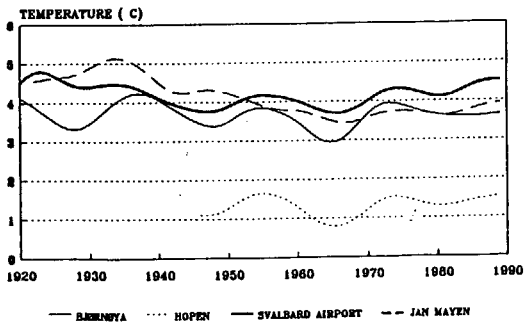

Fig. 9 Time series of mean annual temperature for the Norwegian Arctic stations.



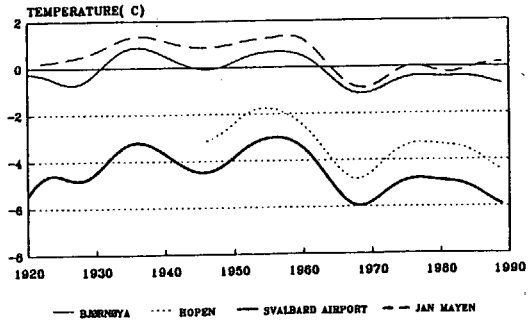

a) Winter (Dec, Jan, Feb)




b) Spring (May, Apr, May)




c) Summer (Jun, Jul, Aug)




d) Autumn (Oct, Nov, Dec)

Fig. 10 Time series of mean seasonal temperature for the Norwegian Arctic stations.

Fig. 8 shows the time series for each of the four seasons. Variation is greatest in winter and least in summer. There is a good correlation (r = 0.89 for filtered values) between the winter season and the whole year.

4.2 Variation in temperature on a time scale of 10 years, 1920 - 1990.

For ease of comparison between stations, each station's annual and seasonal variation and trend in temperature have been plotted in Fig. 9 and 10. The curves correlate well and show characteristics similar to those previously mentioned in section 4.1 concerning Svalbard Airport. None of the stations show an increasing trend during recent years, and the mild spells of the thirties and fifties, and the cold spell in the sixties, are easily recognizable.

The same warm and cold spells are also recognizable in the individual seasons, except summer which shows the least variation. An increasing trend may be seen during spring at all stations, with the exception of Jan Mayen.

The variation shown at Svalbard Airport and Hopen is greater than that shown at the two southernmost stations Bjørnøya and Jan Mayen. A possible explanation is that the latter two are surrounded by open sea for most of the year.

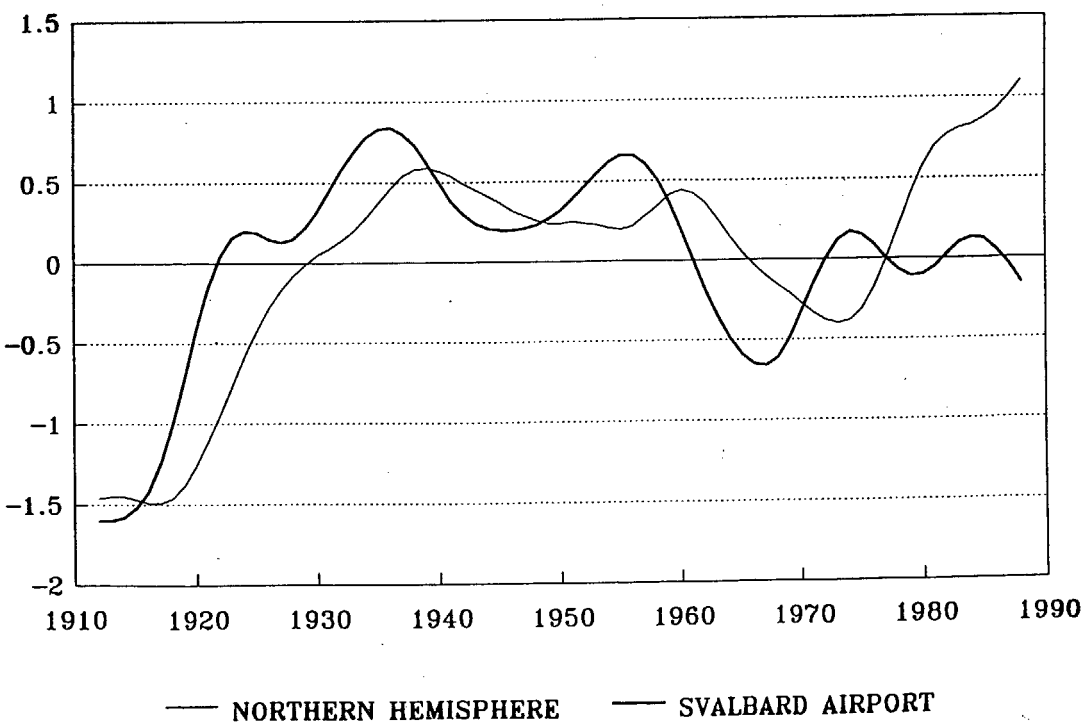



Fig. 11 **Normalized mean temperature for Svalbard Airport and the Northern hemisphere, filtered values.**

During the last decade global temperature has increased, perhaps due to an increasing greenhouse effect. In Fig. 11, mean temperature for the northern hemisphere is compared with the Svalbard Airport series. Both series are normalized with zero mean and unit standard deviation. Before about 1975 the two series show the same fluctuations, with a delay in the hemispheric mean, but in recent years there is no trend in the Svalbard data, in contrast to the increasing trend for the hemisphere.

4.3 Variation in the Hopen precipitation series.

At Hopen there has been no change in equipment or gauge location since 1948, and the staff there have been well trained. The station has been inspected by personnel from the Meteorological Institute almost every year. Therefore it seems likely that the station is homogeneous for the period in question (Fig. 12). Annual precipitation has varied from below 300 mm in 1956 to over 700 mm in 1983. Since the sixties, there has been an increasing trend in precipitation.

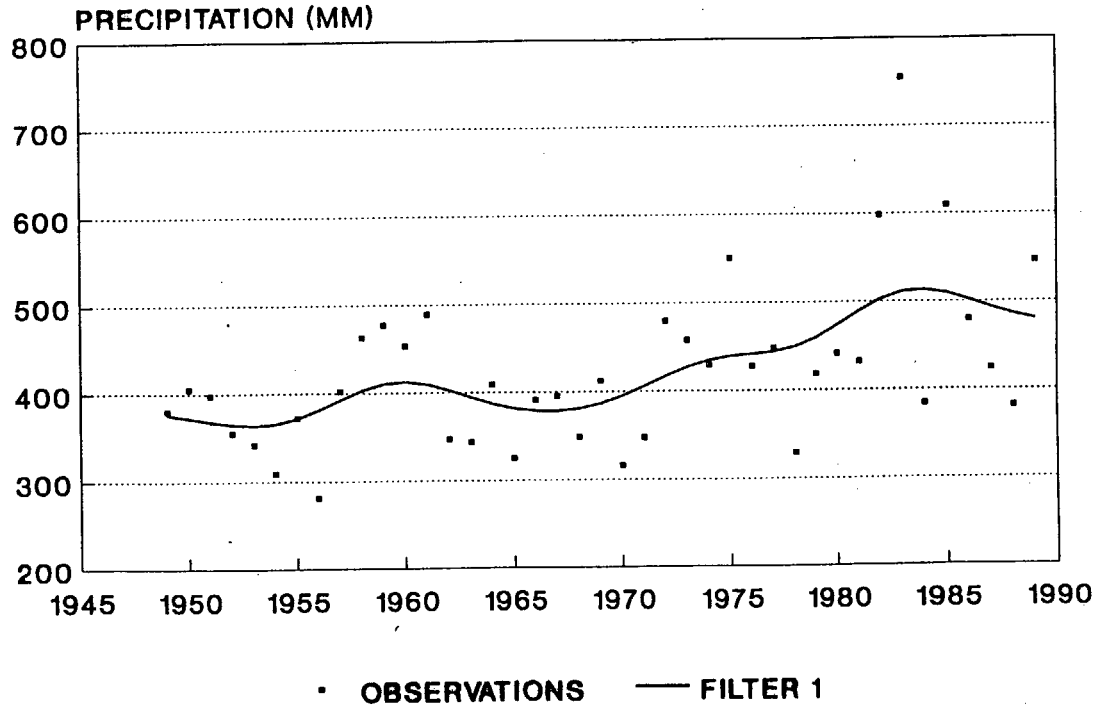
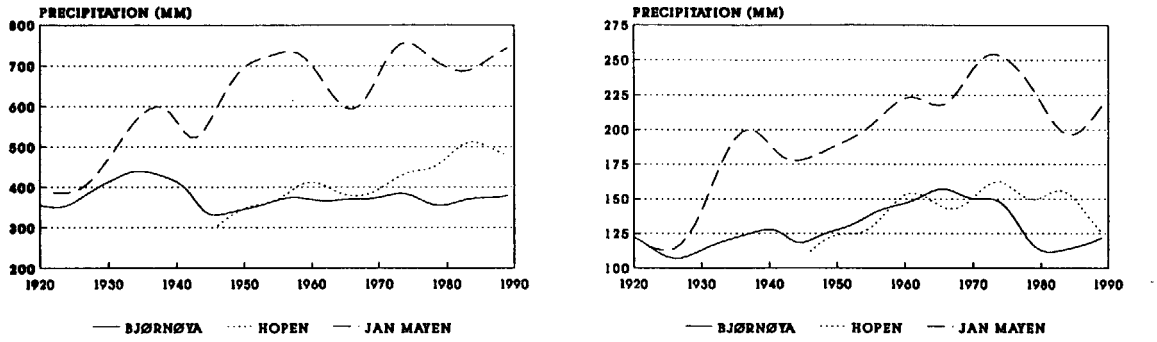



Fig. 12 Homogeneous time series of annual precipitation from Hopen.

4.4 Variation in precipitation on a time scale of 10 years, 1920 - 1990.

The three longest annual precipitation series from stations still in operation in the Norwegian Arctic are shown in Fig. 13a. No common trends are apparent, though real trends may have been masked by inhomogeneity in the series.

From June to September the temperature is usually above zero, and precipitation usually occurs in liquid form, which lessens the problem of homogeneity (Fig. 13b). All stations show an increased summer precipitation for the period from about 1950-70.




a) Annual precipitation

b) Summer precipitation (Jun - Sep)

Fig. 13 Time series of the annual precipitation and precipitation for June-September for three Norwegian Arctic stations.

## 5. CONCLUSIONS.

Graphic presentation of the temperature time series of the Norwegian Arctic stations for the period 1912 to 1990 show a very cold period from 1912 to 1917. The 1960's were also very cold. Mild decades were the 1930's and 1950's. The 1930's was the mildest decade during the period of observation. In the last 15 years there has been no trend in temperature, in contrast to the increasing trend in mean temperature of the northern hemisphere.

There are no common trends in the precipitation data from the different stations. However, a very serious problem in Arctic regions is catchment losses in the gauges, and the breaks in the series due to relocated sites. These effects may mask trends in the data. For liquid precipitation the problem is minor. Thus the series containing only summer data is more reliable. Summer precipitation seems to have increased in the period from about 1950-70.

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