# Driftwood as an indicator of relative changes in the influx of Arctic and Atlantic water into the coastal areas of Svalbard

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A total of 276 driftwood samples from Wijdefjorden on the northern coast of Spitsbergen were dendrochronologically analysed and compared with results from a similar study on driftwood from Isfjorden. The composition and origin of the driftwood from the two places differ. Whereas *Larix* is almost absent in the Isfjorden driftwood, it comprises 25% of the Wijdefjorden collection. The Isfjorden driftwood has its main origin in the White Sea region and the dates of the driftwood concentrate around the period from 1950 to 1979, with only a few dates from the period 1910 to 1950. The Wijdefjorden driftwood has two main origins: Siberia and the White Sea region. The dates of the White Sea components of the Wijdefjorden driftwood are concentrated mainly in the period 1910–1950. The dates of the Siberian (Yenisey) components of the Wijdefjorden driftwood are concentrated in the period 1950–1979. It can be argued that during the time period from ca. 1910 to 1950 the activity of a warm northerly flowing current along the western coast of Spitsbergen was stronger, transporting White Sea driftwood all the way to the Wijdefjorden area. However, after ca. 1950 the input of White Sea driftwood decreased, and the relative importance of the Siberian component increased. These results fit well with the climatic records from Svalbard, showing a warm regime during the first half of this century due to increased activity of the warm West Spitsbergen Current along the western coast of Spitsbergen. After ca. 1950, the influx of Atlantic Water became weaker, the climate became colder and the relative occurrences of Siberian driftwood transported by the Transpolar Current increased on the northern coast of the Svalbard archipelago.

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## Introduction

Svalbard is situated in a climatically sensitive area between the relatively warm Atlantic waters (a branch of the Norwegian Coastal Current) and the cold Arctic waters. The climatic variation in the Svalbard area depends mainly on the activity and properties of the Atlantic Water flowing into the Barents Sea and up along the western side of the archipelago (Loeng 1989).

Some boreal mollusc species, which are now extinct in Svalbard, are found in raised beach deposits, indicating changes in sea surface temperatures during the Holocene (e.g. Feyling-Hanssen 1955). Recent studies by Salvigsen et al. (1992) and Hjort et al. (1992) on the paleoclimatic implications of the changing mollusc fauna in Svalbard, indicate the absolute age for the Holocene marine climatic optimum on Svalbard to be from circa 9500 to 3500 radiocarbon years BP. During this time period, *Mytilus edulis* lived on Svalbard. Climatic variations in the Svalbard area during this century have been recorded in temperature and salinity sections crossing the water masses flowing into the Barents Sea. Temperature anomalies in a section from the Kola Peninsula along 33°30′E show that the longest period with a warm regime of inflowing Atlantic Water during this century was between 1930 and 1939, with a maximum in 1938. The years after 1945 were characterised by temperature fluctuations of 3–5 years duration (Midttun et al. 1981). Instrumental climatic records from Svalbard (Fig. 1) mirror the same changes, with a conspicuously warm period between 1920 and 1950 and a cooling trend with some fluctuations after that. Climatic records from stations in the Arctic and from other part of the Northern Hemisphere during this century show similar trends (Fig. 2) (Kelly et al. 1982).

Driftwood is present on many beaches in the Arctic, originating from the boreal forest regions of Russia, Alaska and Canada. Northward flowing rivers which drain the forest areas carry huge quantities of driftwood into the Arctic Ocean

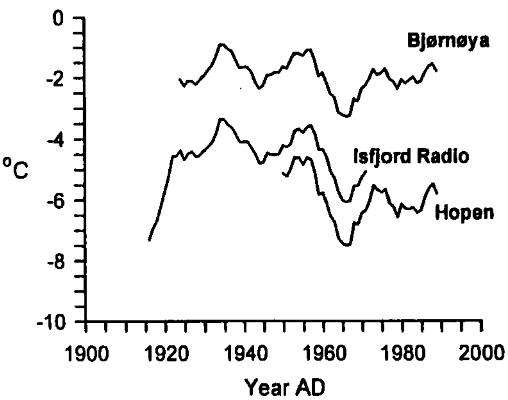


*Fig. 1.* Annual mean temperatures (°C) at Bjørnøya, Isfjord Radio and Hopen Svalbard, smoothed by five-year running averages. Data from DNMI.

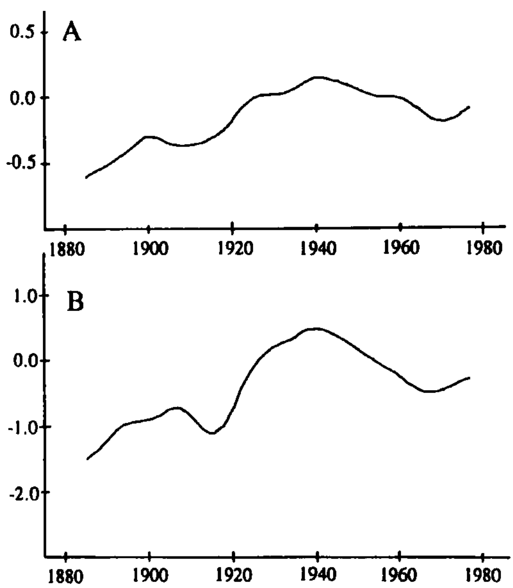


*Fig. 2.* Annual mean temperatures (°C) as departures from the reference period 1940–1960 averaged over (A) the Northern Hemisphere (0–85°N) and (B) the Arctic (65–85°N) (modified from Kelly et al. 1982).

(Fig. 3). The wood either derives from living forests, undercut by rivers, or from logs which have come loose during timber floating. The wood is caught in drifting ice, transported by ocean currents, and eventually deposited along the shores of the Arctic. (e.g. Kindle 1921; Eurola 1971; Häggblom 1982; Bartholin & Hjort 1987; Eggertsson 1992).

Most driftwood is caught in drifting ice and transported by ocean currents. Therefore it is important to have a clear view of the general characteristics of sea surface circulation in the Arctic Basin.

The main features are the Beaufort Sea gyre and the Transpolar Current. The Transpolar Current carries ice from the eastern part of the Siberian sea and the Bering Strait, across the North Pole area and down along the east coast of Greenland (Fig. 3). The average speed of the Transpolar Current is nearly constant over a distance of 2000–2500 km in the polar basin and has been estimated to be 2.8 cm/s (2.4 km/day). When it passes the narrowest part of the Fram Strait it is close to 9.5 cm/s (8.2 km/day) (Fig. 4) (Vinje 1982). From this, the transportation time for wood drifting from the Siberian coast to the Fram strait is estimated to be more than three years. Along the western coast, the Norwegian Coastal Current brings in relatively warm high-salinity water (Lunde 1963).

Agardh (1869) is considered as the pioneer of driftwood studies. He demonstrated that his material, 18 samples collected in Svalbard, was of Siberian origin. He also used the tree rings to deduce the climatic conditions under which the trees had grown. Agardh's methods were later taken up by Örtenblad (1881) and Ingvarson (1903, 1910). Häggblom (1982) estimated the amount and type of driftwood logs on raised beaches at different elevations above the present sea level on the island of Hopen, Svalbard (Fig. 5). He concluded that variations in the driftwood frequency probably reflected variations in sea ice conditions over time, and that the period between 9000 and 4200 BP was characterised by moderate sea-ice conditions due to long summers. Häggblom's idea was based on the fact that wood floating in open water has limited buoyancy and will sooner or later sink. Thus, much driftwood should indicate much drift ice.

Giddings (1941) was the first to apply the dendrochronological method to driftwood. He worked with dendrochronological studies in Alaska and noticed that the tree-ring record at timberline did not change rapidly from one locality to another. He assumed that cross-dating was applicable to dead logs. He realised the possibility of using the driftwood dates as an aid in mapping map currents in the Arctic region. Later Giddings (1943) detected that logs found on the Alaskan coast of the Beaufort Sea had a tree-ring pattern

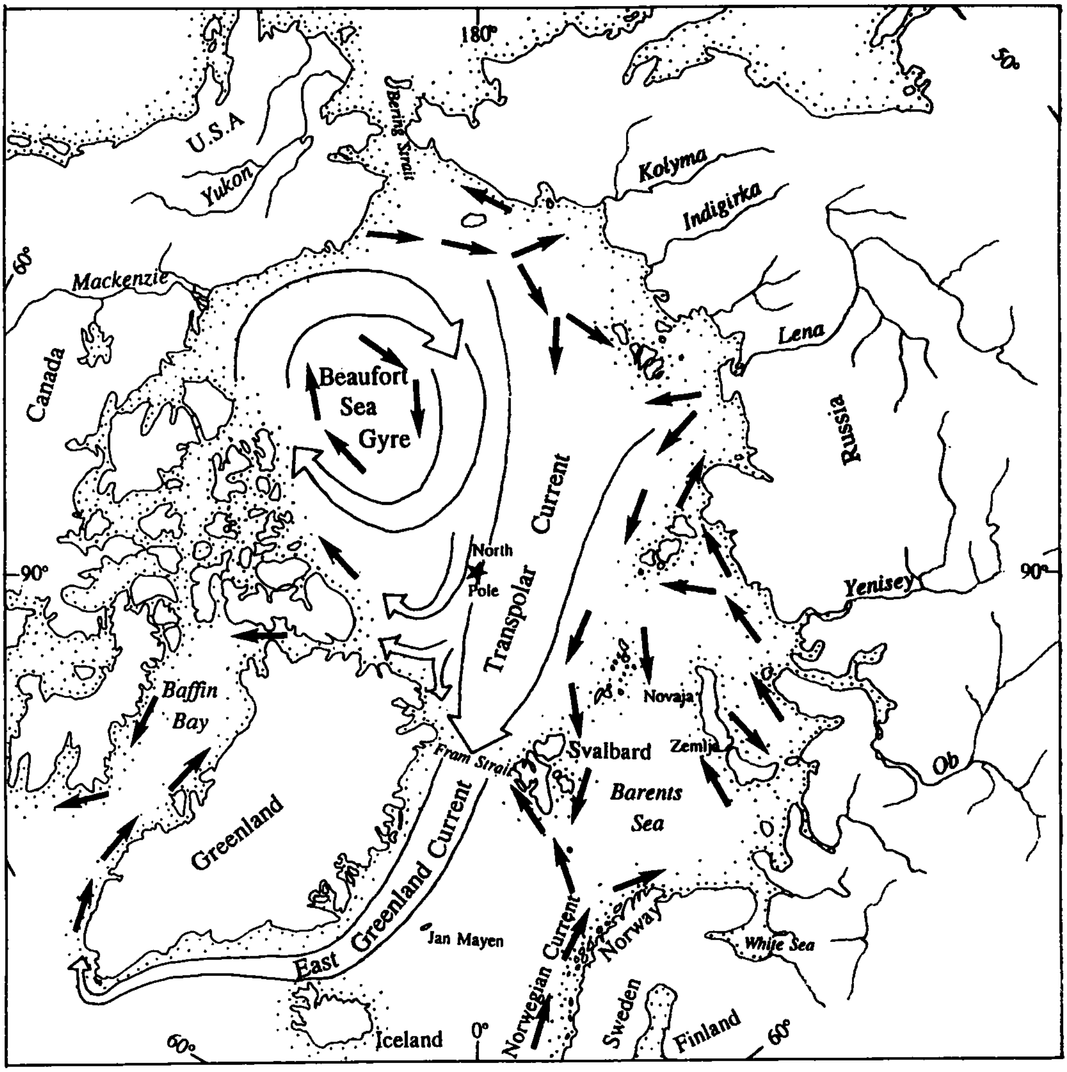


*Fig. 3.* Surface currents in the Arctic ocean (current pattern from Strubing 1968).

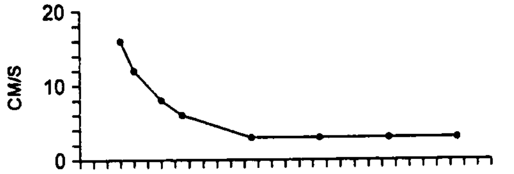


*Fig. 4.* Average drift speeds (cm/second) of ice observed in the Transpolar and East Greenland currents (from Vinje 1982).

restricted to the Yukon River region in Alaska. From this he was able to map the coastal sea currents (Giddings 1952).

Bartholin & Hjort (1987) analysed driftwood from Isfjorden on the western coast of Spitsbergen in Svalbard (Fig. 5). They were able to date most of the samples with the help of master chronologies from the White Sea region. Their work showed a potential for further tree-ring studies on Arctic driftwood and provided the impetus for this study.

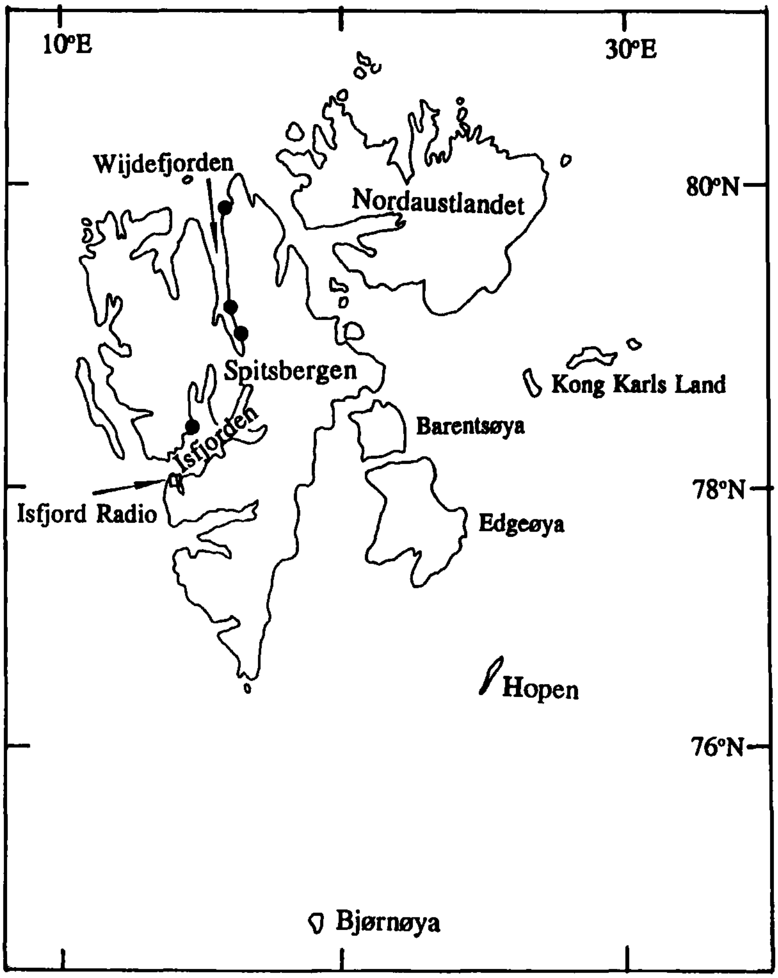


*Fig. 5.* The Svalbard area with sampling localities (black dots) and names referred to in the text.

In this paper the dendrochronological method is applied to identify the origin and age of driftwood deposited on the recent shores of Wijdefjorden in northern Svalbard (Fig. 5). The aim is to determine if changes in the relative influx of Arctic and Atlantic water masses around Svalbard during this century are reflected in the driftwood deposited on the shores.

## Material and methods

Fieldwork in Svalbard was carried out in July 1991. Driftwood was collected from three main localities on the eastern shore of Wijdefjorden on northern Spitsbergen (Fig. 5). Samples were cut with a chain saw, one sample from each log. Some logs still retained the root system, although the bulk of the wood was sawn timber from the forest industry in Russia. These logs had broken free during timber floating. No such industry is present in the drainage areas of northward flowing rivers in North America.

A total of 310 samples were collected, 276 of which were analysed. Their anatomical structures were analysed under a microscope in order to identify the tree species. Tree-ring widths were measured on an Aniol tree-ring measuring machine connected to a PC computer running the CATRAS software package (Aniol 1983). Two

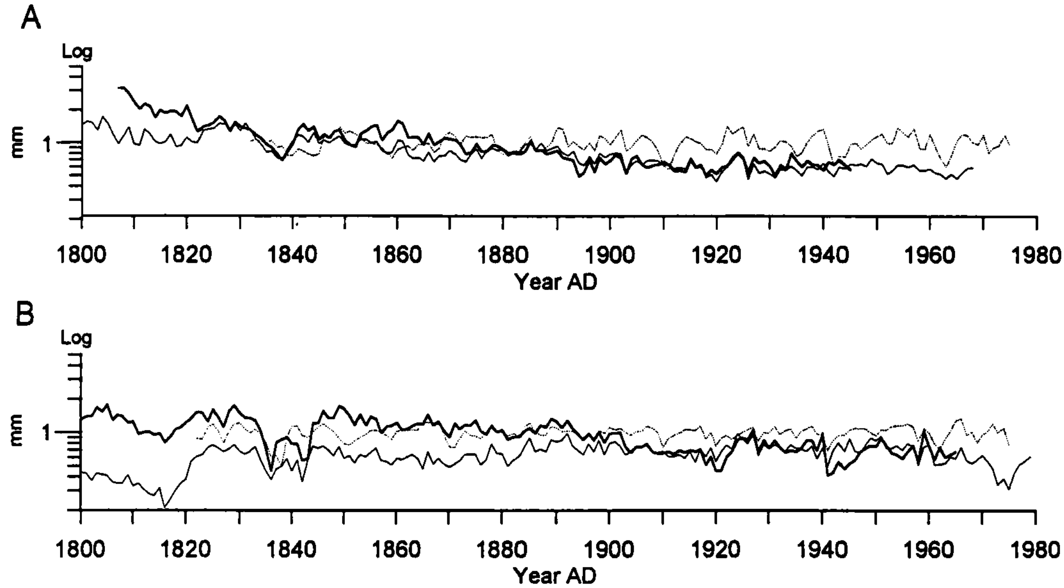


*Fig. 6.* Driftwood mean curves from Svalbard and master chronologies from the White Sea region. Thick line: mean curves from Wijdefjorden; thin line: mean curves from Isfjorden; dotted line: chronologies from the White Sea region. A. *Pinus*. B. *Picea*.

radii were measured and averaged on each driftwood sample, giving a single tree curve for each log. The tree-ring series were correlated with the help of t-values (Baillie & Pilcher 1973) and "percentages of agreement" values (Eckstein & Bauch 1969) and also by visual comparison. In cases where the driftwood logs had no bark, the dating reflects the age of the outermost ring observed.

Those tree ring series showing high correlation values were visually checked by comparing their graphical plots. The best fitted curves were used to build up mean curves. All mean curves presented in this paper were quality controlled by the COFECHA program (Holmes et al. 1986).

# Results

### *Driftwood from Isfjorden*

Before presenting the results from the present investigation it is important to summarise the results of Bartholin & Hjort's (1987) study on the origin of the Isfjorden driftwood. In 1984, 145 driftwood logs were sampled for dendrochronological analysis from the recent shore on the Bohemanflya Peninsula in Isfjorden (Fig. 5). Of the 88 *Pinus* samples collected, 62 could be correlated and 41 were used to construct a mean curve for that species (Fig. 6). Of 57 *Picea* samples analysed, 51 could be correlated and 25 were used to make a mean curve (Fig. 6). Absolute dates for the driftwood mean curves were obtained by using chronologies from the northwestern part of Russia. The best correlations for both the *Pinus* and *Picea* chronologies were obtained with tree-ring data from the Russian saw and paper mill industry in the White Sea region, centred around Arkhangelsk (Fig. 6; Fig. 7).

### *Driftwood from Wijdefjorden*

The distribution of different tree species of the driftwood within the Wijdefjorden and Isfjorden materials is shown in Table 1. The main difference is that *Larix* is almost absent in the Isfjorden material while it is a major component in the Wijdefjorden collection. From this it can be concluded that the origin of the driftwood differs in some way between the two localities.

If we examine the distribution of tree species in Russia (Table 2; Fig. 7), *Larix* is a minor component in the European part, but it is the major component of the forest areas in eastern Siberia. Therefore it is logical to conclude that

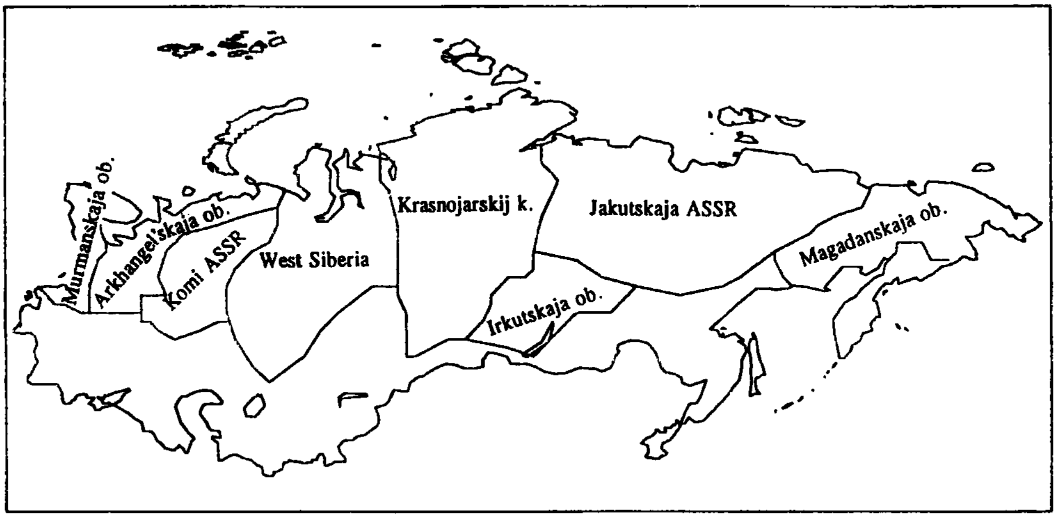


*Fig. 7.* Russia with regions according to Table 2.

*Table 1.* Frequency of the driftwood tree species in Isfjorden and Wijdefjorden.

| Tree species | Isfjorden [n] (%) | Wijdefjorden (total) [n] (%) | Wijdefjorden (except White sea driftwood) [n] (%) |
|---|---|---|---|
| *Picea* sp. | 56 (38.6) | 36 (13) | 19 (8.5) |
| *Pinus* sp. | 88 (60.7) | 167 (60.5) | 131 (58.7) |
| *Larix* sp. | 1 (0.7) | 69 (25) | 69 (31) |
| Broadleaf trees | – | 4 (1.5) | 4 (1.8) |
| Total | 145 | 276 | 223 |

*Table 2.* Distribution of tree species (in %) in Russia, from west to east. The regions are shown in Fig. 7 (from Kuusela 1990).

| Tree species | Murmanskaja ob. | Arkhangel'skaja ob. | Komi ASSR | West Siberia | Krasnojarskij k. | Irkutskaja ob. | Jakutskaja ASSR | Magadanskaja ob. |
|---|---|---|---|---|---|---|---|---|
| *Picea abies* | 44 | 71 | 58 | 10 | 11 | 6 | 1 | |
| *Pinus silvestris* | 45 | 23 | 28 | 36 | 14 | 36 | 11 | + |
| *Larix sibirica* | | 1 | 1 | 5 | 41 | 34 | 1 | |
| *Larix dahurica* | | | | | | | 87 | 36 |
| *Pinus cembra* | | | + | 18 | 15 | 13 | | 3 |
| *Betula* sp. | 11 | 4 | 10 | 24 | 9 | 7 | | |
| Others | | 1 | 3 | 7 | 10 | 4 | | 61 |

the Wijdefjorden material at least partly originates from Siberia.

Of the *Pinus* samples from Wijdefjorden, 42 could be correlated, and nine were used to construct a mean tree-ring curve for that species (Fig. 8). An attempt to date this mean curve by comparison with the *Pinus* driftwood mean curve from Isfjorden and master chronologies from the European part of Russia failed. However, a comparison with a *Pinus* master chronology from the middle reaches of the Yenisey river in Siberia (Fig. 3) (Eugene Vaganov, pers. comm. 1994)

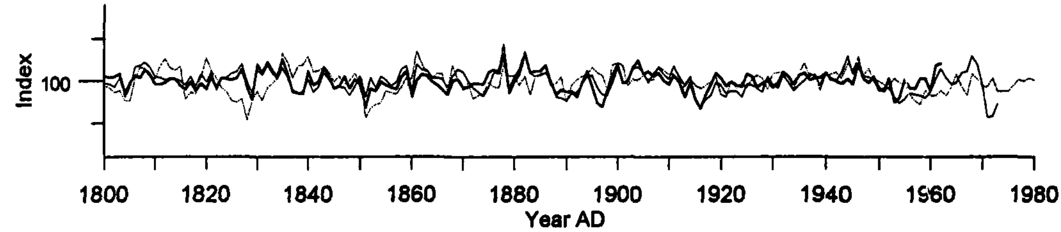


*Fig. 8.* *Pinus* driftwood mean curves from northern Iceland (thin line), Wijdefjorden, northern Svalbard (thick line) and a master chronology from the central reaches of the Yenisey River in Siberia (dotted line).

dated it, correlation values, t = 5.89; and percentage of agreement 61.1% (Fig. 8). It also correlates with a *Pinus* driftwood mean curve from northern Iceland (Eggertsson in press), with high correlation values, t = 16.4; and percentage of agreement 77.8% (Fig. 8). A considerable part of the *Pinus* samples from northern Svalbard therefore derive from central Siberia and have the same origin as the Icelandic *Pinus* samples. Another 36 of the *Pinus* samples remaining could be synchronised and seven of them were used to build a second mean curve for that species. Seventeen of the *Picea* samples could also be synchronised and seven of them were used to build mean curve for that species. These two chronologies could be dated with the *Pinus* and the *Picea* driftwood chronologies from Isfjorden. Fig. 6 shows the plots of the driftwood chronologies from Isfjorden (Bartholin & Hjort 1987) and the dated driftwood chronologies from Wijdefjorden, compared with master chronologies from the White Sea region, one for each species.

To summarise, 25% of the *Pinus* samples collected in the Wijdefjorden area originate in the drainage area of the Yenisey river and 21% arrive from the same place as the *Pinus* samples from Isfjorden; i.e. from the White Sea region. Of the 36 *Picea* samples collected, 17 derived from the White Sea region. The origin of the rest of the samples remains unclear, but it is most likely that the *Larix* samples have an origin in eastern Siberia, probably the drainage area of the Lena River (Fig. 3).

The distribution of the dates (the age of the outermost tree ring) of individual logs from Wijdefjorden, which originate from the White Sea region, is shown in Fig. 9. It can be seen that 73% of the dates are concentrated in the time period 1910 to 1950, and only 20% are younger. If this is compared with the results from Bartholin & Hjort (1987) (Fig. 10), where the dates are concentrated around the period from 1950 to 1979, it is evident that driftwood originating from the White Sea region is to a large extent "missing" after 1950 in the Wijdefjorden material. The driftwood in Isfjorden has only a few dates concentrated in the interval between 1910 and 1950. Possibly this is a result of the fact that the Isfjorden driftwood was easily accessible to trappers

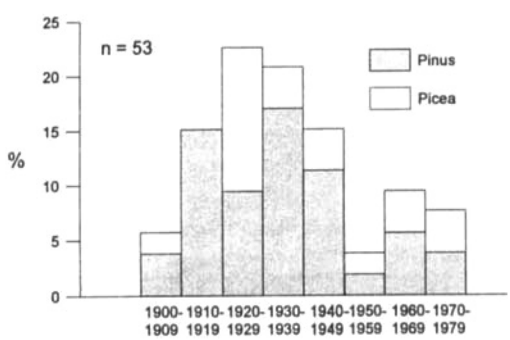


*Fig. 9.* Frequency distribution of White Sea driftwood samples of different end years (collected around Wijdefjorden in 1991).

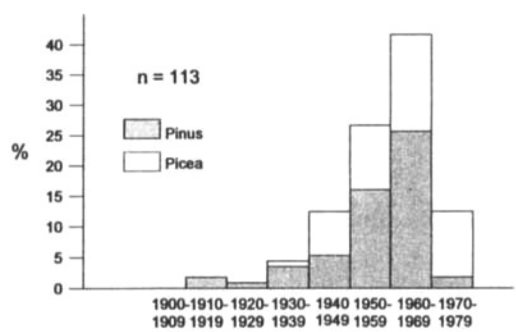


*Fig. 10.* Frequency distribution of White Sea driftwood samples of different end years (collected around Isfjorden in 1984, data from Bartholin & Hjort (1987)).

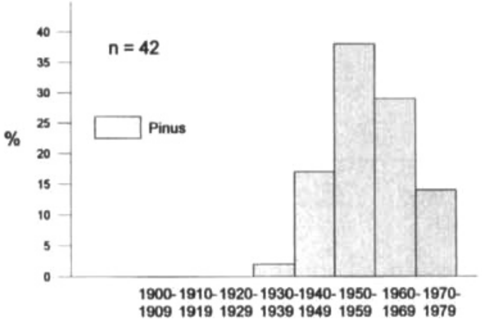


*Fig. 11.* Frequency distribution of Siberian (Yenisey) driftwood samples of different end years (collected around Wijdefjorden in 1991).

working in the area, roughly up to the Second World War, and that the relatively humid climate on the western coast of Spitsbergen is much less favourable for the preservation of driftwood than in the drier conditions to the north and east. The dates of the individual logs from Wijdefjorden which originate from Siberia (Yenisey) are concentrated in the period 1950–1979 (Fig. 11).

### *Further analysis of the Isfjorden driftwood*

Of the 145 samples collected in Isfjorden, 78% originate from the White Sea region (Bartholin & Hjort 1987). The rest, 26 *Pinus* and six *Picea* logs, were further analysed by the present author. None of the six *Picea* samples could be dated, but two of the *Pinus* samples were dated with the *Pinus* driftwood mean curve from the Wijdefjorden material that originates from the middle reaches of the Yenisey.

## Discussion

The influx of Arctic Water to the Barents Sea occurs along two main routes, between Svalbard and Frans Josef Land, and through the opening between Frans Josef Land and Novaja Zemlja (Dickson et al. 1970) (Fig. 12). The Isfjorden driftwood of Bartholin & Hjort (1987) contains only two logs fitting to the Siberian *Pinus* mean curve from Wijdefjorden, based on 42 logs. The Arctic Water flowing into the Barents Sea does not, therefore, seem to feed the West Spitsbergen

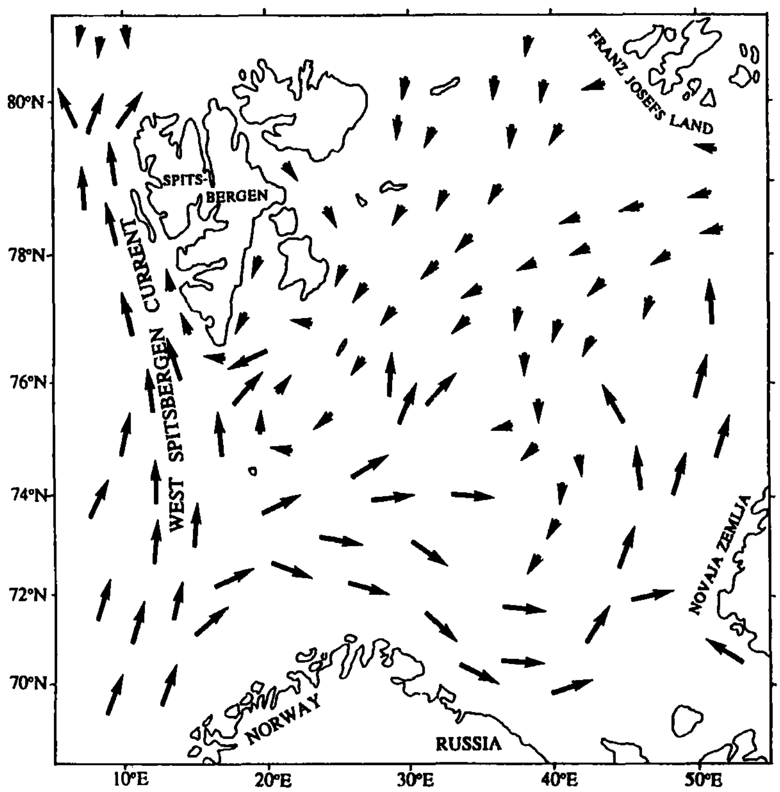


*Fig. 12.* Surface currents in the Barents Sea (modified from Loeng 1989). Long arrows = Atlantic Water; short arrows = Arctic Water.

Current (Fig. 12) with any significant amount of Siberian logs, at least not with respect to the coast from Isfjorden northwards. Thus it is reasonable to assume that the Siberian components in the driftwood collection from Wijdefjorden have been transported to that coast with a branch of the Transpolar Current (Fig. 3), flowing from the north.

During the period from circa 1910 to 1950, the activity of the warm West Spitsbergen Current was stronger, transporting White Sea driftwood all the way to the Wijdefjorden area. But after circa 1950 the input of White Sea driftwood decreased and the relative importance of the Siberian component increased. These results correspond well with the climatic records from Svalbard, showing a warm regime during the first half of this century which is attributed to increased activity of the warm West Spitsbergen Current. After circa 1950, the influx of Atlantic Water decreased, the climate became colder, and the relative occurrences of Siberian driftwood transported by the Transpolar Current increased along the northern coast of the archipelago. Fig. 13 illustrates the relative changes in the pattern of the ocean currents around Svalbard during this century.

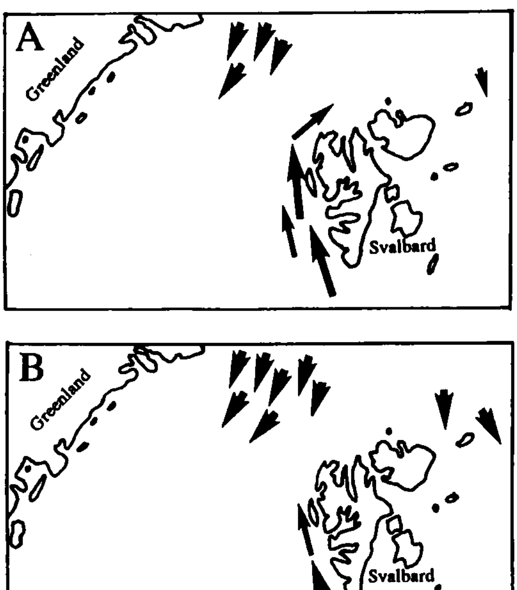


*Fig. 13.* Relative changes in the strength of the oceanic currents in the Svalbard area during this century. A. Before circa 1950, B. After circa 1950.

## Final Remarks

This paper illustrates the potential of applying the dendrochronological method of determining the origin and age of arctic driftwood, and at the same time mapping the relative strength and direction of surface sea currents. This application will, however, only be possible on a more regular basis when a dense network of master chronologies is available from throughout the circumpolar boreal forests. Such networks are now available for the European part of Russia (Bartholin & Hjort 1987), Alaska (Cropper & Fritts 1981), Canada (Eggertsson 1994) and partly for Siberia.

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