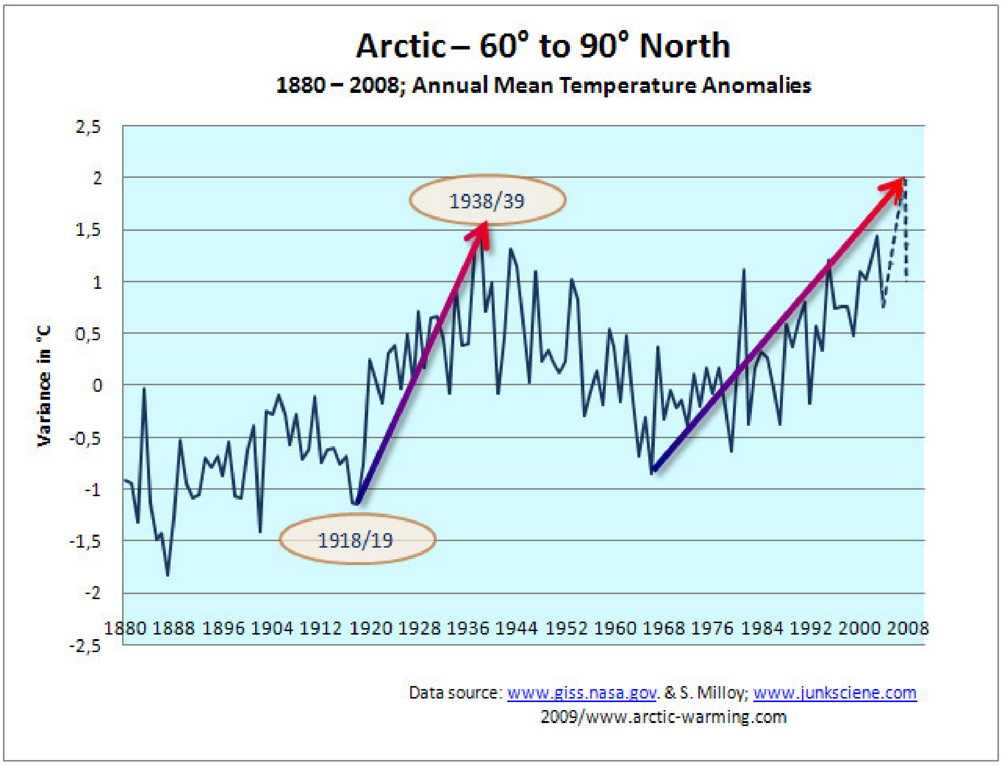
Chapter 4
Regional impact of the Spitsbergen warming

A. Introduction to When & Where

Being impressed by the big warming at Spitsbergen is one thing, another one, to make sense of it by putting the sudden temperature increase in winter 1918/19 in a perspective. How was the event recorded in other locations of the wider region? At what time could a commencement of the warming be observed, was it before Spitsbergen or after Spitsbergen; was it more pronounced or less pronounced, and how long did it last, two decades unit 1940 as in Spitsbergen or ended the warming up trend earlier? In so far this chapter can be called a fact finding mission. It aims at preparing the basis required to discuss matters of correlation and causation. After all, the heat that increased the temperatures in the Arctic region must have been generated either locally or somewhere else. If generated outside the Polar Circle, it should be possible to identify the generating source and the path of transport either through the atmosphere or the ocean system.



4. Spitsbergen temperature rocketing

When discussing "the nature of polar forcing" (Zakharov, 1997), the author stressed that the feature of climate change spatial structure in the 20th Century is most well pronounced in the northernmost part of the Atlantic and in the adjacent Arctic regions, which supports the idea that obviously, the atmosphere thermal regime is in some way connected with the ocean. To support this idea, as we will do in the next chapter, a broader picture on facts and information portraying the Spitsbergen event is required.

B. The regional feature with four sea water bodies

The availability of large water-bodies so high in the Northern Hemisphere are the ultimate "blueprint" for the Northern Hemisphere climate, which needs to be recognised in the first place. However such plain statement cannot explain the "climate revolution" in the region in the early 20th Century. Calling this initial event "Arctic Warming" might even be misleading, if the warming commenced primarily over the northern part of the North Atlantic, and even more precisely, in the Spitsbergen region. On the other hand all ocean space and seas within the Arctic Circle are relevant for the arctic weather and arctic climate, although on a very different scale due to size, depths, sea ice, freshwater, sun-less periods, and sea currents, to mention only few decisive factors. In order to detect the time and source of the sudden start of the Arctic Warming one must have a look at each of the specific sea areas in question. This needs to be kept in mind that the "explosion" of air temperatures at the Spitsbergen archipelago at 80º North during winter 1918/19, must have been generated by "something".

Although no option, including an internal atmospheric process, should be excluded, the most likely source is the sea area between the direction 135º (SE) and 270º (West) of Spitsbergen, which is usually sea ice-free throughout the year and belongs to the Barents Sea, the Norwegian Sea and the Greenland Sea. The source of the warming was presumably due to either internal processes within the water bodies, or influenced by more warm water coming from the Atlantic Gulf current, or both. The latter came with the Norwegian Current and West Spitsbergen Current, formed by water flowing from the Gulf Current after it had passed the Iceland - Faroe – Scotland line, enhanced by North Sea water, and continental run off rain and melt water. However, once the warm Atlantic water has passed the north of the Scottish Hebrides and Faroe, and travelling northwards, things tend to complicate.

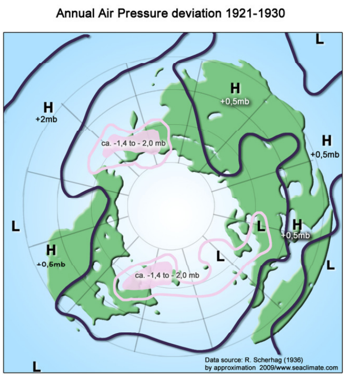
a) Arctic Ocean

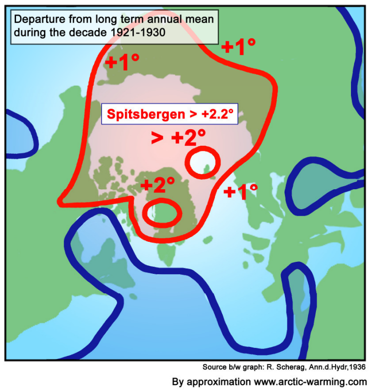
Due to the size of the Arctic Ocean, which is much larger than the Northern North Atlantic[28], and due to its considerable depths of more than 3000 metres, one would assume that its immediate impact on the weather should succeed by far the influence of the Northern North Atlantic. That is not the case. At least during the winter periods in the early 20th Century the Arctic Ocean was permanently covered by sea ice, which diminishes any heat release from the sea in the atmosphere to a small factor, thus making this huge water body "continental", characterized by cold and stable weather conditions, and clear skies. However the sea ice is not very thick, and not always unbroken, so that an interchange is not completely excluded. According to Aagaard (Aagaard, 1982) it seems possible that two-third of the oceanic flux should be accomplished by the Atlantic water of the West Spitsbergen Current.

The feature of the Arctic Ocean is very complex and only few aspects can be mentioned. Above the very cold and saline bottom water is a layer of "Atlantic Water", which occupies the depth range between ca. 150m and

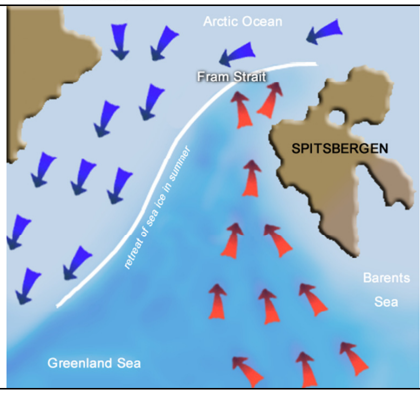
[28] Here meant as area between: Greenland, Iceland, Scotland, Norway, and Spitsbergen.

4. Spitsbergen temperature rocketing





Deviation from mean 1921-1930, air pressure (left), air temperature (right)



Source: www.arctic-heats-up.com; The Arctic Warming 1919 to 1939; by: Arnd Bernaerts

1936

Schokalsky, J. (1936)[1] ;

"Recent Russian researches in the Arctic Sea and the in mountains of Central Asia",

in: The Scottish Geographical Magazine, Vol. 52, No.2, March 1936, p. 73-84.

Extract from the paper:

____This work (of Russian scientists and institutions) was necessary in order to ascertain the temperature of the Atlantic branch of the Gulf Stream west of Spitsbergen, and to know what temperatures conditions may be expected along the Eurasian continental slope of the North Polar Ocean.

____During the memorable voyage of the FRAM (1893-1896), Nansen discovered that the upper layer of the Arctic Ocean from 200 to 500 metres in thickness was less saline than the deeper water, and that it had a temperature of –1,0° to –1,9° C, while the deeper layer, from 600 to 700 metres tick, was of oceanic salinity (over 35 per cent.), and had a temperature of +1,2°C.

----------- Five years later, S.O. Makazov, on the ice-breaker ERMAK, between Franz Josef Land and Novaya Zemlya, found that the zero temperature occurred at a depth of about 200 metres, and that below this the temperatures rose to +1,1°C. This confirmed Nansen's observations.

------------ In 1927 the ship ELDING, between Franz Josef Land and Novaya Zemlya, recorded temperatures of +0,6°C at 100 metres depth. Then, in 1928, the KRASSIN'S observation north of Spitsbergen in lat. 81°47'N revealed a new fact. At 70 metres the water was found to have oceanic salinity of over 35 per cent and a temperature of –4,6°C.

------------ Sverdrup's observations in the NAUTILUS in 1928 confirmed these facts for latitude 82°N. In 1929 the SEDOV and the PERSÉE, at almost the same place Makazov chose for his observation in 1901, found the zero isotherm to occur at the depth of 125 metres instead of 200 metres.
------------ Again, in 1931, the PERSÉE, in the same vicinity, found this thermobath at 75 metres, and the LOMOHOSOV, a little farther eat, found it from 25 to 40 metres, below which depth the temperature increased to +1,6°C. (cont.)

------------ And finally the PERSÉE in 1934 reaching 81°17'N, north of Spitsbergen, early in September, recorded an air temperature of 12°C and a sea temperature of +5,5°C down to 10 metres.

____The branch of the North Atlantic Current which enters it by way of the edge of the continental shelf around Spitsbergen has evidently been increased in volume, and has introduced a body of warm water so great, that the surface layer of cold water which was 200 metres tick in Nansen's time, has now been reduced to less than 100 metres in thickness.

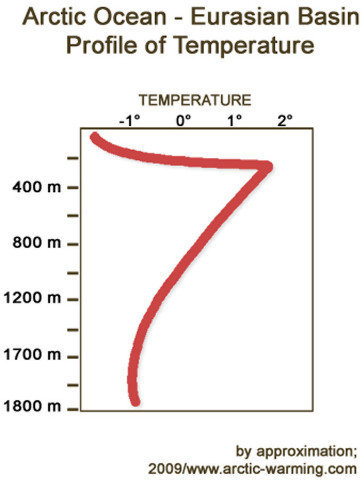
____These records, and others not cited here, together provide incontestable evidence of a progressive warming of the Arctic Ocean.

____For this purpose, it is necessary to know more about the thermal conditions of the branch of the Atlantic Current which passes round Spitsbergen.

NOTE: In 1953 H.W. Ahlmann provided the information: The thickness of the ice forming annually in the North Polar Sea has diminished from an average of 365 cm at the time of Nansen's Fram expedition of 1893- 96 to 218 cm during the drift of the Russian icebreaker Sedov in 1937-40. (Ahlmann, 1953).

[1] Professor Jules Schokalsky , President of the Geographical Society of the Soviet Union. A paper read before the Royal Scottish Geographical Society in Edinburgh on the 30th January 1935, on the occasion of the presentation to Prof. Schokalsky of the Society's Research Medal.

900m that is superseded by the "Arctic Surface Water" in the range from the sea surface to a depth of 150/200m and temperatures close to the freezing point (between –1.5° and –1.9°C). In this layer the salinity depends strongly on the degree of the sea ice processing, freezing or melting, ranging from about 28 to 33.5°/o. These conditions represent in the Arctic a relatively warm ocean surface water layer which has an influence on the regional air temperatures.



Despite the fact that the water body of Arctic Oceans is based on many complex features, and highly influenced by internal transformation, e.g. sea ice freezing and melting, and external influences, e.g. fresh water from rivers, there is not one aspect from which a sudden warming could have been generated. None of the seas in question can be excluded with such unequivocal certainty from the list of potential contributor for the early Arctic Warming as the Arctic Ocean.

This assertion is addressing only the sudden warming in the late 1910s. The huge water body in an extreme harsh environment will transfer any internal changes ultimately to the atmosphere, presumably with considerable time lags. One needs only to consider the water renewal time for the Arctic Bottom water, which is a couple of dozen years in the Amundsen- and Nansen-Basin but more than 500 years in the Canada- and Makarov-Basin. Due to the long internal processing most recent dramatic arctic warming and sea ice melting may have been caused by warm Atlantic water that arrived many decades ago. In order to find out, it would primarily require establishing what and why the Spitsbergen warming occurred in the first place, as it constitutes the early Arctic Warming from 1918 to 1940.

b) Greenland Sea

A significant climatic impact is due to the southward flowing East Greenland Current (EGC) which constitutes the major outflow route of Arctic water into the Atlantic. The pathway to the south of Greenland is due to the season covered with sea ice. The water temperature is below –1°C, and due to ice melting of low salinity of about 30-33 °/o. Some of it is diverted just north of Denmark Strait and northeast of Iceland into the East Iceland Current, which before reaching the latitude if Iceland towards the Norwegian Sea as part of the formation process of Arctic Bottom Water. The remainder pass the Denmark Strait, gets partly mixed[29] with the Irminger Current and in this combination flow around the southern tip of Greenland, Kapp Farvel, into the West Greenland Current[30]. Cold sea surface temperature of the EGC is associated with negative anomalies of surface air temperatures with an amplitude of 2° near Greenland declining to several tenth of a degree over north-western Europe (Delworth, 1997). In the west of Spitsbergen, the seawater has a temperature of 5°C and a salinity of 34.90 –35.00 mg.

[29] Transport estimates are 5 Sv (5 × 106 m3 s−1) for the East Greenland Current and 8–11 Sv (8–11 × 106 m3 s−1) for the Irminger Current. The combined flow continues around the southern tip of Greenland into the West Greenland Current.

[30] The Labrador Current originates from East Greenland Current, continues as West Greenland Current (NW), than as Baffin Island Current (SW), and subsequently the Labrador Current (SW), which transports cold Arctic and sub-polar water south along the Atlantic Canadian coast to the Grand Banks (Newfoundland) where it divides, the East branch joining the North Atlantic Current and the West branch flowing into the Gulf of St. Lawrence. The International Ice Patrol had first quantitatively studied the Labrador Current in 1937.

A significant part of the warm Atlantic Gulf water that has reached Spitsbergen "turns left" in the south-western direction, at the position of 75-77° North, and flows either as Greenland current down to Newfoundland and back in the Atlantic, or goes down into the huge Greenland Sea Basin with depths of 2,000 metres (max. ca. 3,500 m), or circles for some time at the sea surface water layer or in sub surface layers. At the surface the water forms a layer of 100 –200m, which reflects the depth of summer water heating. Within the annual cycle, these water body experience considerable deviation of temperature (4°C) and salinity (1.2 °/o).

Although the Greenland Sea represents a huge water body, the option for being a serious contributor to the extreme warming event in winter 1918/19 is remote. The West Greenland Current is colder and less salty than the Atlantic water of the Spitsbergen Current, and the current is to a considerable extent covered with sea ice during the winter season, but only partly in summer. Concerning this investigation the Greenland Sea matter gets "hot" if one looks at the EGC and whether the current had been getting more than usual portion of warm Atlantic water that made the temperatures exploding at Spitsbergen around winter 1918/19. Did the thus warmed up EGC current brought a warming to Greenland"s coast in the East and the West of the island? We will discuss this aspect later, while mentioning already now, that Greenland had experienced warmer sea water and warmer air during the time period in question, but later and only temporarily (Bjerkness, 1959).

c) Norwegian Sea

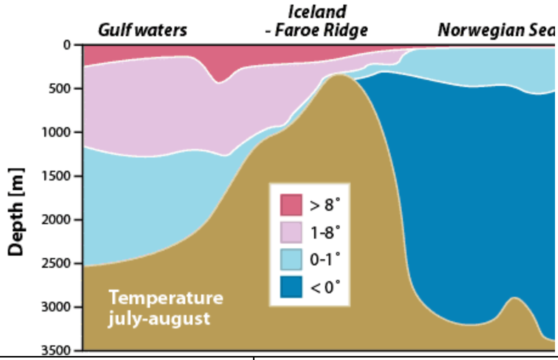
The Norwegian Sea Basin is up to ca. 3,000 metres deep, with a mean depth of 1740 m. The sea is separated from the Arctic Ocean by a ridge of about 600 metres under the sea surface. This allows huge water exchange from north to south and vice versa. A key role for the moderate temperature conditions in the region derives from huge warm water supply by a branch of the Atlantic Gulf currents which is "pushed down" to lower depths after passing by the Shetland Islands, Faroe Island and Iceland ridge, travelling North about 500 m below the sea surface. On the first stretch parallel the coast line of Norway, the warm Atlantic water is called Norwegian Current, which is to be kept separate from the Norwegian Coastal Current, but once it has reached the latitude of the North Cap the major part continues as West Spitsbergen Current (WSC) towards the Fram Strait in the West of Spitsbergen, and a small part goes eastwards in the Barents Sea. Due to its high northern location, size and volume, the Norwegian Sea has a lot of facets that are too complex for being presented in few words.

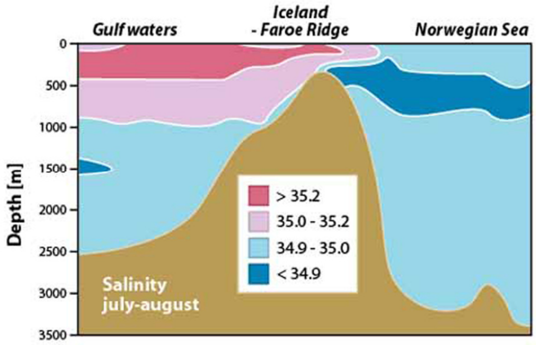
If for example the wind would not mix a low saline sea surface, due to rain fall, with saltier water from lower sea levels, the sea ice would presumably reach Iceland, Scotland and the North Sea at least every winter season. That would even happen when the most unique feature, the West Spitsbergen Current, would pass the Norwegian Sea as usually, but latest demonstrate its impact on the Arctic climatology as soon as the current has arrived in the West of Spitsbergen. This is of foremost interest, and any other details concerning the Norwegian Sea will be mentioned if deemed helpful.

As already mentioned, the WSC is the major source of heat and salt for the Arctic Ocean. The Current cools dramatically downstream, although the warmest water can be frequently observed 100-200m below the surface moves via the currents towards the basin of the Arctic Ocean. For the last distance over ca. 1000 km, Lofoten to Spitsbergen the travel time is about 5 weeks, which means the average speed is 0.30 to $0.35ms^{-1}$ Actually, due to the high salinity of the warm Atlantic water and the cooling process, the water becomes very dense and "falls" over a ridge (with a depth of 600 m below sea level) in the Arctic Basin. Before the Spitsbergen current reaches the ridge, at about 80° North, the water, has a depth of 20 metres, a salinity of about 35 per mile, and a temperature > 3° up to 7°C.

But also the basin of the Norwegian Sea is a reservoir for warm Gulf water, reaching depths of 800 metres. Status and dynamics of the Norwegian Sea is also strongly influenced by other factors, particularly wind, rain, melt water, and the low saline water form the North Sea. Any increase in temperature, or enlargement of the "warm water part", or "change of dynamics", would quickly be reflected in temperatures in Europe or elsewhere in the Northern Hemisphere.

Warm Atlantic water form the Gulf Current flow over the Iceland-Faroe Ridge in the Norwegian Sea





High saline Atlantic water enter the Norwegian Sea

d) Barents Sea

The Barents Sea is a shallow shelf sea with an average depth of 230m, and a maximum depth of below 500m. There are three main types of water mass; warm, salty Atlantic water (temperature >3°C), cold Arctic water, less salty (< 0°C), and warm coastal water, less salty than the Arctic water (>3°C).

Generally speaking, the warm Atlantic water "disappears" in the East of the North Cape. In the northern part polar water flows from Northeast to Southwest and partly joins the Spitsbergen Current in the south of Spitsbergen and Bear Island. The North Cape Current, and its subsequent currents, which supply the eastern part of the Barents Sea with Atlantic water, may have contributed to the warming in the long run, under the condition that a permanent inflow of warm Atlantic water is guaranteed. Actually the whole water body of the Barents Sea is replaced within a 3 – 4 year period. The Barents Sea itself is not able to sustain a longer warming period due to limited heat storage.

2005	Igor V. Polyakov et al. (2005); **“One more step toward a warmer Arctic”** Geophysical Research Letters, Vol. 32, L17605; Co-authors see: Reference list

The ABSTRACT notes that the study was motivated by a strong warming signal in2004 in the Eurasian Basin of the Arctic Ocean, claiming, that the source of this and earlier Arctic Ocean changes lies in interactions between polar and sub-polar basins. Evidence suggest such changes are abrupt, or pulse-like, taking the form of propagating anomalies that can be traced to higher-latitudes. For example, an anomaly found in 2004 in the eastern Eurasian Basin took _1.5 years to propagate from the Norwegian Sea to the Fram Strait region, and additional _4.5–5 years to reach the Laptev Sea slope.

The paper furthermore states:

- This evolution of water temperature is related to the atmospheric processes: (p: 2)
- The abrupt nature of these warming events is striking. The first temperature increase at the EEB slope of about 0.4_C in February 2004 happened in a single day, after which the AW layer equilibrated at a new warmer state for almost seven months, when another abrupt warming occurred. (p: 3)
- Through analysis of a vast collection of observational data it was shown that over the 20th century multi-decadal AW fluctuations are a dominant mode of variability (Figure 3). Associated with this variability, the AW temperature record shows two warmer periods in the 1930–40s and in recent decades, and two colder periods early in the 20th century and in the 1960–70s. (Concluding Remark)

Subsequently Igor A. Dmitrenko, Igor V. Polyakov , et al (2008) acknowledged: “recent Atlantic Water (AW) warming along the Siberian continental margin due to several AW (Atlantic Water) warm impulses that penetrated into the Arctic Ocean through Fram Strait in 1999–2000”. One year earlier The New York Times (2nd October 2007) – by Andrew C. Revkin - referred to Igor V. Polyakov, saying that he see a role in rising flows of warm water entering the Arctic Ocean through the Bering Strait between Alaska and Russia, and in deep currents running north from the Atlantic Ocean near Scandinavia.

Comment:

The stunning point is the statement that the “evolution of water temperature is related to the atmospheric process”, despite the various other mentioned aspects whereby the sea water records indicate to propagate anomalies. Do I.V. Polyakov and colleagues really think that the branch of the Gulf Current, the warm Atlantic Water on its way to Spitsbergen, is depended on atmospheric processes? Have they ever evaluated their conclusion in conjunction with the winter sea ice? At least concerning the early Arctic warming? What else than the warm Norwegian- and Spitsbergen Current could suddenly have initiated and sustained the sudden warming of the Arctic winter seasons. Climate is the continuation of the oceans by other means, namely heat & vapor. One of the best scientist in this field some time ago would presumably have advised to read the following from his book: “Oceanography for Meteorologists” published in 1942:

> *It might appear, therefore, as if the oceanic circulation and the distribution of temperature and salinity in the oceans are caused by the atmospheric processes, but such a conclusion would be erroneous, because the energy that maintains the atmospheric circulation is to a great extent supplied by the ocean. It will be shown that this energy supply is very localized, owing to the character of the ocean currents, and that therefore the circulation of the atmosphere, which depends upon where energy is supplied, must be influenced by the oceanic circulation. The reasoning leads to the conclusion that one cannot deal independently with the atmosphere or the oceans, but must deal with the complete system, atmosphere-oceans. This fact has been recognized in oceanography, where one gets nowhere by neglecting the relation to the atmosphere, but in meteorology it has not yet received sufficient attention. (p. 223) It is reasoned that the heat content of the ocean water is very great compared to that of the atmosphere, and that therefore any change in ocean current will for a long time influence the air temperature and the circulation. (p. 234)*
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> H.U. Sverdrup, 1942, “Oceanography for Meteorologists”, New York, 1942, Chapter X, p. 223

4. Spitsbergen temperature rocketing

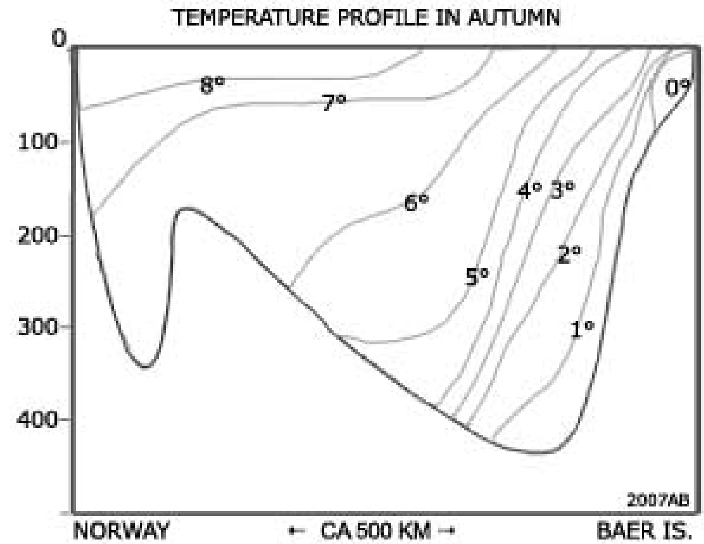
With regard to the Spitsbergen, it has already be mentioned that the air temperatures in North Norway have increased only modestly since 1920 (Manley; 1944). Neither Vardö (close to the North Cape), nor any Russian Station reported any exceptional winter temperature rise. On a 10-year mean basis (1911/20 and 1921/30), a significant increase of 6°C was observed at Franz-Joseph Land (Kirch, 1966), whereby the highest water temperatures in the top 200 m of the Barents Sea at 70-72°N; 33°E, north of the Kola Peninsula, shall have been reached during the period 1935-39 (Lamb, 1980). That all confirms a slow process but hardly any facts that the Barents Sea had significantly generated a temperature jump in its southern part (North Cape), or in the eastern part (Kola Peninsula).

The observed warming at Franz-Joseph-Land can also be hardly connected to the sea, which is partly supplied via the North Cape current and subsequent currents along the Kola Peninsula. In addition the Barents Sea between Spitsbergen (East) and Franz-Joseph-Land (West) is not very deep and is governed by very cold currents flowing southwest towards South Spitsbergen and the Bear Island. (See also next section).

According to Wagner (Wagner, 1940), the mean surface-water temperatures in the Barents Sea, the deviations from the means during the months July to September, was –0.7°C during 1912-1918, against + 1.1°C during the following years 1919-1928, as indicated in the table:

1914 = -0.3°C	1915 = + 0.7°C	1916 = -1.1°C	1917 = -1.5°C	1918 = -1.6°C
1919 = + 0.6°C	1920 = +2.2°C	1921 = +1.0°C	1922 = +1.9°C	1923= +1.0°C

Wagner's additional observations ascertain a "rise" of 2-3°C, at water depths of 100 and 200 m, during the last 30 years (1895 and 1927). However, a general observation of "over 30 years" is of little help in this case, presumably also his general assessment that the Barents Sea ice border retreated significantly since 1919, even though it is undisputed that the retreat occurred gradually over a two-decade period (Kirch, 1966).

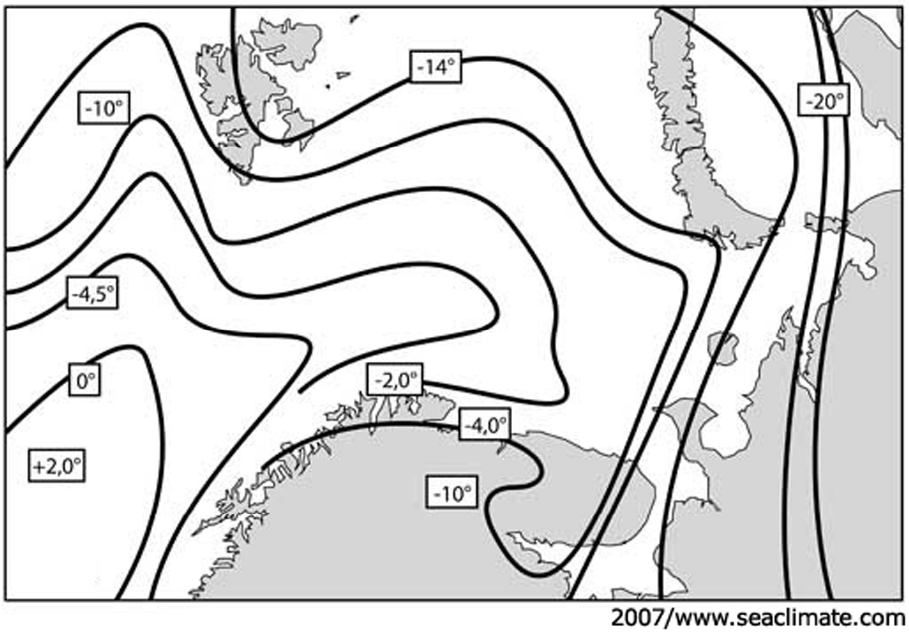


4. Spitsbergen temperature rocketing

There are no significant indications that the Barents Sea contributed significantly in the early stage of the Arctic warming. The presumably most relevant aspect is that no particular strong winter warming had been observed at the southern parts of the Barents Sea, albeit a trend change was observed since 1919. The question would remain, whether the trend change had been caused by higher temperatures in the North, or alone by the Barents Sea, or was due to changes over the European Continent, or had been a combination of all three factors. But this does not need to be answered here.

C. Summary

The brief overview on the possible potential of the most relevant sea areas for the early Arctic Warming could show that two, out of the discussed four areas, can be excluded with high certainty as serious contributor, namely the Arctic Ocean and the Greenland Sea, and with less certainty the Barents Sea. The highest potential by far has the northern part of the Norwegian Sea and the Spitsbergen Current. This preliminarily assessment shall be verified with further information in the next section.



Barents Sea - Ca. Mean January Temperature in °C