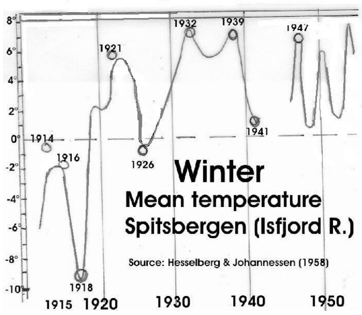
- D - Climatic Impacts of World War I

Introduction

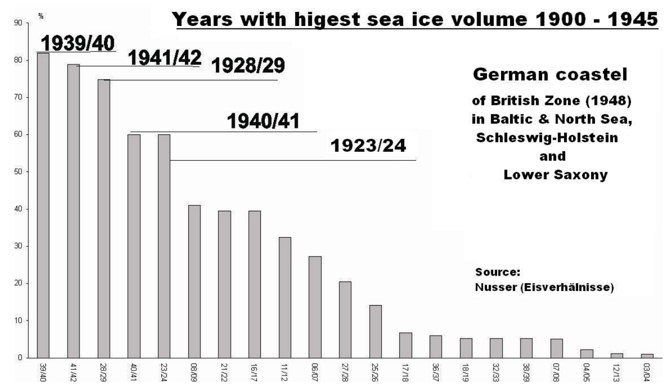
From a climatic point of view, World War I ended with a severe "bang" in late 1918. After four war years, a dramatic shift occurred in the northern part of the Norwegian Sea, at Spitsbergen, and lasted for two decades, until World War II started. Throughout the 20th century there had never been any climatic event as dramatic as this very pronounced one. At Spitsbergen, winter temperatures jumped up by 8°C in a few years. The Northern Hemisphere became suddenly much warmer. The terms "Greening of Greenland" and "Warming of Europe" became common expressions.



There is nothing clearer than the commencement of a "big warming" that occurred at exactly the same time with the end of WWI, in November 1918. This is not difficult to prove. What is more difficult to show is that naval war caused this event. On the other hand, it is easy to point out the fact that nothing else had happened at that time that could have caused such a dramatic climatic shift. There was no earthquake, no major volcanic eruption, no particularly intense sun spots, no unusual El Niño, and no meteorite fell from the sky. There had been only a devastating naval war, waged for four years at about 2000 kilometres further in the south, around the Isles of Great Britain. As the warming lasted for two decades, until the end of 1939, the warming was sustained and could have remained in place for so long only because of the interiors of the huge and deep Norwegian Sea, which permanently receives plenty of water masses that have passed the British Isles, either on its Atlantic side or coming from the North Sea.

While the chapter focuses on linking the naval war of WWI to the "big warming" since 1918, the following two sections will demonstrate that general weather conditions during WWI already showed similarities to WWII conditions as long as naval war did not went global since 1942.

During WWI, naval war never went global but was fought around Britain, actually starting seriously only in the autumn of 1916 when new naval weaponry became fully available and devastatingly effective, particularly sub-marines (U-boats), depth charges, and sea mines. During the war year 1917, the German U-boats alone sank 6,200,000 tons. The total loss during the war was of 12 million tons, with 5200 ships, plus about 650 naval vessels. Most merchant vessels had been fully loaded with cargoes of all kind, from grain, ore, coal, crude oil, to whatever war parties needed. All that stuff polluted the sea and was taken along with the Gulf Current or the Norwegian Current up to the North, passing Shetland Islands and going either to the Barents Sea or, most of them, to the Arctic Sea, after passing Spitsbergen at the latitude of 79° North.



Sinking ships was not all that happened at sea. The sea was churned and turned “up side down” in many ways. For establishing a link between naval war in Europe and the sudden ‘big warming’ at Spitsbergen more explanations are needed. Before giving more details in this respect, the reader should become aware that both European wars around the United Kingdom, during the last century, had similar weather impacts. After a weather comparison between WWI and WWII, the section will outline the naval forces unlashed during the last two war years, from the autumn of 1916 to 1918, before concentrating on the ‘big warming’ at Spitsbergen and its WWI causes. It is frankly admitted that this investigation cannot fully prove the latter claim, however there is no better explanation available, yet. Actually, little efforts have been made to investigate the causation of the event anyhow.

Weather Comparison WWI and WWII

Some important factors need to be mentioned first. The land war started immediately in 1914, the naval war commenced fully since the autumn of 1916. On land, there was already the famous icy winter battle in Masuria (north-eastern Poland), in February 1915, between the German Army and the Russian Tenth Army, which determined the German Field Marshall Hindenburg to wonder: "Have earthy beings really done this things or is all but a fable or a phantom?" (citation from NYT, the 7th of January 1942)

If rainmaking along the Maginot Line/Westwall, in autumn 1939, is the comparison element, then the devastating battle of Verdun is much more significant. The German attack on Verdun started on the 21st of February 1916, with one million troops; the battle became the longest of WWI and ended on the 18th of December 1916. French and German Army lost several hundred thousand men each. From a climatic perspective, it is to note that close battle field regions had been wetter than usually, e.g. Baden had 30% more precipitation, in the Black Forest rain level was even 50-80% higher than normal.

The battle of Verdun followed one of the top ranking cold winters during last century. The winter 1916/17 matched closely the record winter 1939/40. To keep in mind! The naval war started its devastating war phase only in the autumn of 1916. Submarines only went into action in 1915, sinking about 100,000 ship tonnages per month, which accelerated to about 300,000 tons per month in the second half of 1916. In addition, in 1916, a flotilla of more than 500 vessels was permanently navigating the seas around the British Isles, sweeping a daily average of 1.000 square miles. Together with the very increased use of sea mines, mine sweeping operations, and depth charges, the result was particularly significant on the weather all over Great Britain. The result can be read from weather records. In Britain, June 1916 was very cold and dull. Rain was persistent in the east and north, e.g. with about 150 hours of rain in Aberdeen and up to 200mm. The next extreme month was October 1916 which was wet and stormy, with record daily rainfall of 200mm. Up to this point, it was the highest daily rainfall ever recorded for the British Isles, and an extremely cold December 1916 followed.

With single events or statistical months, it is difficult to establish evidential circumstances. In addition, more factual data may provide the required proof. Great Britain surrounded by naval war may do it. For this purpose, we refer again to the time witness, A. J. Drummond from Kew Observatory at Richmond (London), who expressed his astonishment in 1943: "The present century has been marked by such a wide-spread tendency towards mild winters that the "old-fashioned winters", of which one has heard so much, seemed to have disappeared for ever. The sudden arrival at the end of 1939 of what was considered to be the beginning of a series of cold winters was therefore all the more surprising." He continued: "Since comparable records began in 1871, the only three successive winters as snowy as the recent ones (1939/40 to 1941/42) were those during the last war, namely 1915/16, 1916/17, 1917/18.[1]

Not to miss what naval war may have done on snow conditions in Great Britain, the comparable situation of the war years 1915-1918 shall be explained with the war winters 1939-1942, which were investigated by Lilian F. Lewis[2] who concluded that snow coverage in the British Isles during January and February over the three war winters 1940, 1941, and 1942 were unusual severe; the snow was considerable, and the number of days of snow-laying numerous and without precedent in the British Isles for at least 60 years. According to Drummond, during the first three WWII winters, snow fell on 23%, 48% and 23% of the days which was about 100% to 400% more snowfall than the average. The reasons for such a deviation are easy to explain: snow is likely to fall when humid air cools down. The more naval warfare has decreased sea water temperatures in the sea areas around Britain to below average level, the greater the chance of extensive snowfall due to lower air temperatures.

For the cooling down of the seas around Britain, it is also possible to find hard evidence. In 1935, J. K. Lumby published a seawater temperature series taken in the English Channel

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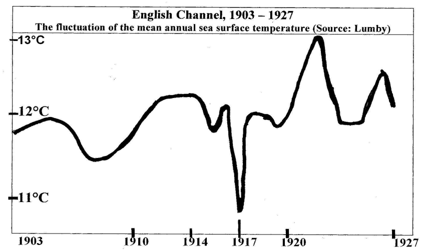
1 Drummond, A.J.; ‚Cold winters at Kew Observatory, 1783-1942'; Quarterly Journal of Royal Met. Soc., No. 69, 1943, pp 17-32, and: Drummond, A.J.; Discussion of the paper: ‚Cold winters at Kew Observatory, 1783-1942'; Quarterly Journal of Royal Met. Soc., 1943, p. 147ff.

2 Lewis, Lilian, F.; 'Snow-cover in the British Isles in January and February of the severe winters 1940, 1941 and 1942', in: Quarterly Journal of Royal Met. Soc., 1943, pp. 215-219.

from 1903 until 1927[3]. From 1901 until 1914, the temperature varied on a narrow band, from 11.5°C to 12.2°C. During the war years 1914-1917, the temperature dropped to its lowest point of the series, viz. to 10.9° C. By all means that should not come as a surprise when realising what actually happened during World War One for many times:

> "In September 1916, the U-boat flotilla from Zeebrugge alone sank nearly 50,000 tons of shipping in the Channel, without any hindrance from patrol vessels. It was soon clear that the existing methods of combating submarines were simply not working. For example, in one week of September 1916, three U-boats operated in the Channel between Beachy Head and Eddystone Light, an area patrolled by forty-nine destroyers (49), forty-eight torpedo boats (48), seven Q-ships (7), and 468 armed auxiliaries – some 572 anti-submarine vessels in all, not counting the aircraft. Shipping in the Channel was held up or diverted. The U-boats were hunted. They sank thirty ships, and were entirely unscathed themselves." [4]



Another investigation of the situation in the Irish Sea over the period 1900 – 1950 made by D.C. Giles in 1949 also shows a deep decline from 1914 to 1919[5]. Sea chilling is inevitable when naval warfare occurs during autumn and wintertime, when thousands of ships movements churn the sea day and

3 Lumby, J.K..; 'Seasonal changes of deep water temperatures'; Quarterly Journal Royal Meteorological Society, Vol.67, July 1941, pp.234-238.

4 Winton, John; 'Convoy – The defense of sea trade 1890-1990', London 1983.

5 Gilles, D.C.; 'The Temperature and Salinity of the Surface Waters of the Irish Sea for the Period 1935-46', in: Monthly Notices of the Royal Astronom. Society, Geophys. Suppl., Vol.5, Nr.9, London 1949, pp. 374-397.

night, when thousands of explosions under and above the sea surface turn sea levels up-side-down. Consequences are obvious: in autumn, the sea cools out quicker and colder air establishes subsequently, followed by more snow which leads to harsher wintertime, and so on. Sometimes, physical conclusions are very simple. The cooling down of Britain and the unusual temperature decline on the Isles, from 1915 until 1918, has its cause in naval warfare and in nothing else.

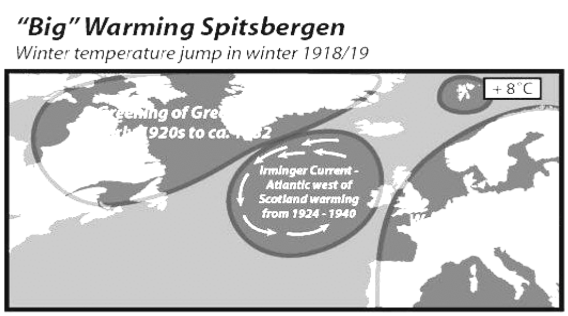
In conclusion, it can be said that weather anomalies in Britain during WWI and WWII have so many similarities that they can be taken as proof of the impact that war at sea had on weather conditions.

Spitsbergen 1918: warming jump by sea war south of it

The Jump

The most significant climatic event of World War One occurred at Spitsbergen, a remote archipelago between North Cape of Norway and the North Pole. There, winter temperatures suddenly exploded around the winter 1918/19, described by the eminent Norwegian scientist B.J. Birkeland in the year 1930 as being probably the greatest known statistical temperature deviation on earth[6].

The temperature jump which lasted until the war winter of 1939/40 has still not been scientifically explained. A sudden increase with plus 8°C in average winter temperature over a short period of time is an event which could have improved the understanding of the climate almost a century ago. Surprisingly, it might not be so difficult to find clues on causation as it looks in the first place. Timing,

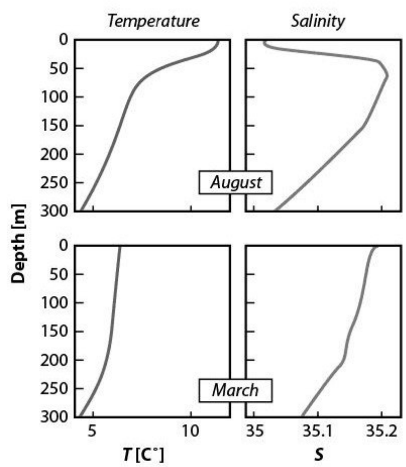


6 Birkeland, B.J.; ‘Temperaturvariationen auf Spitzbergen’, Meteorologische Zeitschrift, Juni 1930, p.234-236

duration and location may help us exclude or include options and possible causations.

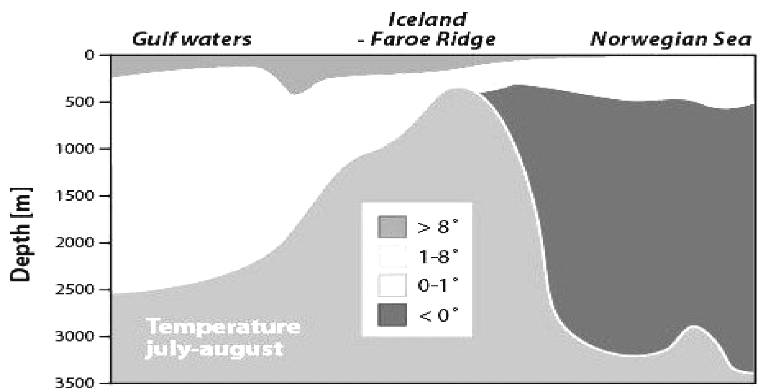
Concerning timing, there was no other force on sight before the winter 1918/19 than a devastating land and naval war in Europe, while nature ran its course without any significant earthquake, volcano eruption, meteorite falling down from the sky, or unusual sunspots.

Concerning duration, it needs to be noted that it was a sustained and lasting event, for two decades in Europe and for one decade in Greenland. From 1920 until about 1930, these events were so pronounced that the terms “Greening of Greenland” and “Warming of Europe” took birth. The sustainability is strong proof that warming was generated in the Northern North Atlantic, north of the Faeroe Island and south of the Arctic Sea.



Concerning the location, the sustained warming lasting two decades holds also the clue concerning the direction from which the warmth must have arrived. One can quickly exclude all sea areas around Spitsbergen, except for the Norwegian Sea. The Barents Sea, east of Spitsbergen, contains within its average depth of 300 metres too little water masses to sustain a warming over many years, if not constantly supplied with warm water coming from the Norwegian Sea. The Arctic Sea, north of Spitsbergen, is too cold and widely covered with sea ice to have played any role. The Greenland Sea can be also definitely excluded as a source of warming at Spitsbergen, as the Greenland Sea receives a huge bulk of inflowing water masses from the Norwegian Sea, via the Gulf Current, the Norwegian Atlantic Current and the Spitsbergen Current, and not vice versa.

Actually, the warming can only have been generated in the Norwegian Sea, which means that, during WWI, the southern border of the warming source is immediately connected to the northern border of the naval war area. In addition, on the way to the Norwegian Sea, the most significant warm water supply coming from the North Atlantic Gulf Current was passing Great Britain where a devastating naval war had been waged for four long years. Viewing the distance between Spitsbergen and Scotland of about 2000 kilometres under such a perspective, we observe that sea water which had passed Scotland needed only few months to reach Spitsbergen. The warming in the north and the war at sea in Europe can almost be regarded as neighbours. One can thigh both events even more closely together if one considers certain typical seawater behaviour as well. A brief overview shall be given in the next section.



Seawater physics in Norwegian Sea.

In the Norwegian Sea the seawater behaves physically as it behaves everywhere around the globe. Nevertheless, the warm water from the Gulf Current, the high latitude with cold winters, the passing of many forceful low pressure cyclones, and the massive Norwegian mountain ridge with plenty sweet water runoff, as well its size and depth produce a unique wealth and variation of physical appliances.

Fortunately, the basic rules are simple: salty and cold water is heavy and sinks, sweet water and warm water are light and “swim” over more heavy water. Therefore, cold freshwater can form a layer above warm water current. Cold freshwater may stay and flow below of warm saline rich water. And it is much more at stake because water is an excellent isolator. For example, 'swimming' rainwater of several centimetres thick can be as good as a refrigerator shielding stored food from outside temperatures. Without the mixing of rain and melted water near the Norwegian coast, the Norwegian Sea would be frozen over frequently each winter regardless how much warm Gulf water would pass through the Norwegian Sea.

Therefore, there is a long way from registering all principal physical rules to assessing the thousands of possible variations that occur. Usually, the Norwegian Sea surface water, which determines the weather and climate for the whole Northern Hemisphere, is particularly influenced by three natural events: the warm Gulf current, the freshwater from land and rains, and, last but not least, the wind. In addition, after the replacement of sailing ships with machine driven vessels, a lot of surface water mixing took place every day. Particularly during the two World Wars, large sea areas and water masses have been turned upside down.

The significant feature of the Gulf Current water that enters the Norwegian Sea is the high temperature and salinity. As soon as water has been cooled down, it sinks like fruit syrup in a glass with water. Due to high salinity, it is warmer than the water it replaces at lower level. The more water sinks, the more water will follow from the Atlantic, with subsequently more "warming potential" in the area than before. The more water is cooled down by mixing, the more forcefully this water masses will start sinking.

In comparison with salty water, freshwater is very light. Fresh, rain, river, and melt water has the strong tendency to float on brackish and salty water until it gets much colder than the saline water below, or otherwise an external force must occur and determine the mixing phenomenon.

Wind in any form is the most powerful means for sea surface water mixing. Actually, it is practically the only external source nature has at hand to do the mixing. In so far, one cannot emphasise the importance of this mixing means enough. On the other hand, the mixing range the wind reaches is extremely limited and goes hardly further than the 50-meter sea surface layer. All other seawater mixing occur according to internal processes, based on temperature, salinity, and density.

And what does naval war do? Naval war certainly does a lot of water mixing. Particularly during winter time, in any sea area north of the Biscay, it not only forces a rapid mixing between freshwater and more saline water, but also forces cooled down sea surface water to greater depth in exchange of warmer water, until the summer warmed water in shallow enclosed seas is exhausted and arctic air can easily take reign. This has already been explained in great detail in Chapter B. In the next section, we will focus on the sea situation between Britain and Spitsbergen during WWI, whereon the impact on the Norwegian Sea will be discussed to conclude the chapter about the warming of Europe between 1918 and 1939 by severe warming of Spitsbergen due to naval warfare.

Seas under naval stress

Naval warfare 1914-1916

When WWI started, in August 1914, the German Navy had 28 U-boats. Their capacity was limited. By February next year, they had lost 7 U-boats, but had only sunk 10 vessels with a total tonnage of 20,000. This figure accounted for only 10% of all British losses during the first six months of war. Mines sank double as much over the same period, of the about 40 millions ship tonnage available to the Allies. From August 1914 until December 1916, the U-boats sank 2,200,000 tons. This represented the total number of 1,500 Allies' vessels or about three vessels per day. On the other hand, the loss of U-boats also increased, mainly due to a newly developed depth charge with 300 pounds TNT or amatol (in 1915), which became available and fully operable since 1916.

Naval Warfare 1917-1918

The situation became dramatic for Britain in early 1917. U-boats sank more ships than shipyards could deliver. In April 1917, the annual rate of the previous years was reached, with almost 860,000 tons. In 1917, U-boats alone sank 6,200,000 tons. This amounted to more than 3,000 ships.

The total loss of the Allies' shipping was of ca. 12 million tons: about 5,500 merchant ships, 10 battle ships, 18 cruisers, 20 destroyers, and 9 submarines. The total loss in naval units of the Allies and the Axis was of 650 ships (including 205 U-boats) with a tonnage of 1,200,000 tons.

Depth Charges – What it meant to attack a U-boat?

The onslaught by U-boats reached the pinnacle with almost one million tons sunk per month, like in April 1917. Although the British Navy was able to prevent hundreds of attacks, real or suspected, the result was not encouraging. Only a mere 11 U-boats were sunk in four months. New protection measures such as convoying, patrols and a new most promising weapon, depth charges, etc. were regarded as necessary.

While U-boats hunted and torpedoed enemy merchant and naval vessels during the early days of WWI, the scenario changed after 1916. They became the hunted ones and were depth-charged. Thousands of naval vessels steamed the seas around Britain day and night. In May 1918, the experience of the U-boat U-72 may illustrate the situation at sea. In early May, some 75 depth-charges were dropped on the boat by anti-submarine vessels and from an airship. Later, a destroyer arrived and attacked U-72 with another 20 charges. This caused a leak in a fuel tank leaving a trail of oil at the sea surface. 24 hours later, U-72 was again depth-charged, more than 20 times, by two naval vessels. A British submarine sank U-72 a few days later.

Sea Mines

Main minefields in the North Sea were on Britain's East Coast, including the Strait of Dover, Helgoland Bight and the Northern Barrage. A rough figure for each of these areas is of 50,000 mines. The total number of mines in the North Sea was of 190,000 and the total number during the whole WWI was of 235,000 sea mines.

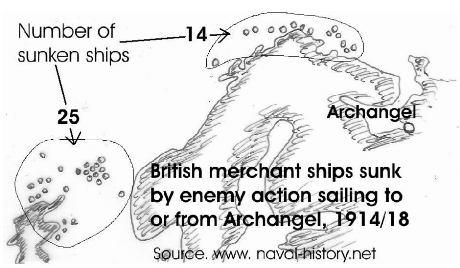
Minesweeping is an activity that stirs and shakes the sea on an unprecedented scale. The 'stir impact' on the seas could possibly be even many times higher than the mine laying and the impact of mines that 'hit a target' together. Between two sweepers in motion 'hung' a sweep wire, with a kite, to cut the mooring rope of the mines. Britain alone had more than 700 minesweepers in permanent operation and Germans also had a considerable number. Possibly 500 ships swept the North Sea day and night.

Operating in a sensible area – Around the Shetlands

Another example: U-boats were a problem for the British. For this reason, between the 15th and 25th June 1917, four flotilla leaders, with about 50 destroyers and seventeen submarines, were sent to an area stretching from NW of Stornoway, round to the north of the Shetlands and eastwards into the North Sea. The idea was to force the U-boats to the surface and to attack them. On sixty-one occasions, U-boats were sighted and attacked twelve times. In practice that must have meant that, in addition to the shelling operation of 75 naval vessels, many hundred depth charges had been dropped. No U-boat was sunk. This episode demonstrates that huge operations may have taken place in the sea, operations which did not go by without any impact on the sea area. However, these were not accounted for in relation to climate change.

Barents Sea and Baltic Sea

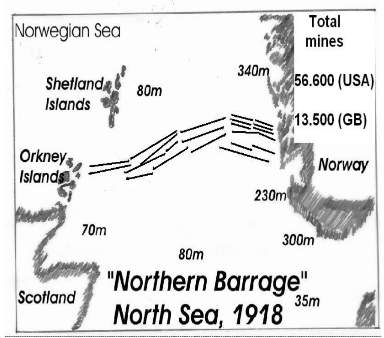
The matter is worth a detailed chapter but requires more pages. Although these seas were not the central stage of the operations, they saw immense naval activities and destruction. The intense encounters in the Barents Sea could have played an important role in the strong icing from the high North, in February 1915, and the harsh winter in North-Western Europe, 1916/17. Until early 1915, more than 450,000 tons of coal and 90,000 tons of weaponry had been shipped to the Russian port Archangel. Russian and German navies had laid thousand of sea mines and dozen of minesweepers were permanently in service. U-boats sank 25 ships, in late 1916, and 21 vessels from April until November 1917.



In the Eastern Baltic Sea, many dozen mine fields were laid with some ten thousand mines. Many naval activities took place every day over four years. British and Russian submarines operated successfully. The increasing sea icing during the war years, from 1914 until 1918, can be attributed to naval warfare in Baltic waters.

Northern Mine Barrage

U-boats had been a serious threat to the Allies since 1916. They regarded it paramount to prevent U-boats from leaving the North Sea and enter the Atlantic. To 'close' the northern outlet of the North Sea, a long barrage of about 150 sea miles (ca. 275 km), between the Orkney Islands and Norway, was required. Near the Norwegian coast, the water is 300 metres deep and near the coast of Orkney, of about 100 metres. Sea currents can reach 3-4 nautical miles/hour. That was a challenge and required the development of a new mine, the MK6. The charge consisted of 300 pounds of grade B trinitrotoluol (TNT). The mine itself was supposed to have a destructive radius of 100 feet (ca. 30m) against submarines. Calculations showed that approximately 100,000 mines should effectively prevent U-boats from passing the line. Actually, only about 70,000 mines were laid until October 1918. On the other hand, 20,000 mines were disposed during the laying of the 'Northern Barrage'.



Mines were available by March 1918. Shortly after the mine lay had commenced, mines began to explode. As a report for the USA Government noted, between 3 and 4% of 3,385 laid mines blew up prematurely. In the middle section "A", mines were supposed to be laid as it follows: 10 rows of mines at 80 feet submergence, 4 rows of mines at 160 feet submergence, and 4 rows of mines at 240 feet submergence. The laying of mines ceased when the armistice from November 1918 was in sight.

Mine sweeping started in the spring and ended in the autumn of 1919. From more than 73.000 mines

- about 15% exploded prematurely soon after laying;
- about 15% were disposed;
- from the remaining ca. 50,000 mines
    - more than 30,000 mines were already 'gone' in the spring of 1919, either drifted away or exploded during winter storms;

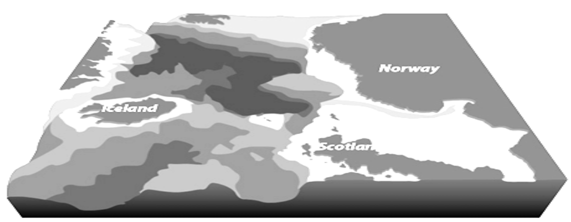
- 20,000 mines were swept in 1919.

Six months of sweeping operations comprised seven sweeping missions involving more than 70 vessels and 10 supply vessels.

Waiting for an answer to sever warming 1918-1939

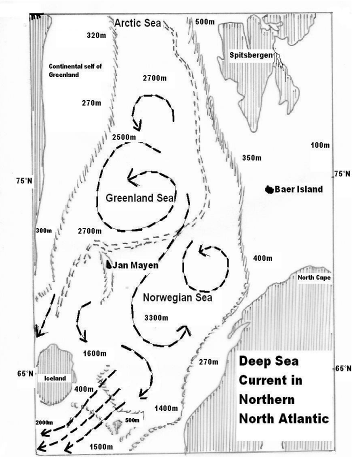
Let's face the facts. World War One was the most destructive global event for many years, since the volcanic Krakatoa, three decades ago. Much of the North Atlantic water bound for Arctic regions was part of the naval battleground for four war years before moving northwards towards Spitsbergen. Since 1918, the Arctic warmed twice as fast until 1938 as it had since 1980. From slightly above the Arctic Circle to the pole, the warmest years on record in the Arctic were the years of 1937 and 1938. War winter 1939/40 ended the Warming of Europe. The most convincing conclusion is: WWI must have played a significant role in the warming of the climate since 1918, but how?

We started the chapter on Spitsbergen warming in 1918 by pointing to the fact that two-decades sustained warming could only come from the Norwegian Sea and/or from the northern arm of the Atlantic Gulf current.



The Norwegian Sea basis is a three thousand meter deep hole. The heat reservoir is enormous, enough to keep the Northern Hemisphere ice-free during Nordic winters and to sustain regularly storms and winds. But not only the mass matters, what matters even more is a very delicate balance of water temperatures and salinity at numerous water depth. It may be hundreds or thousands which counts.

In addition, the warm water inflow from the south cannot be ignored. The inflow west of Scotland is the most significant and about 6-7° C warmer than water which travels north, crossing the Iceland-Faroe Ridge. The inflow to Norwegian Sea is roughly eight times the total outflow of all the world rivers or eight million tones per second, while the forwarded energy in terms of heat transport corresponds to an energy output of 100,000 major electricity power plants. In comparison to the 8x106 m3/sec warm water from the Gulf Current, the water transport in the Norwegian Coastal current at the southwest coast is of about 1 million cubic meter per second (1x106 m3/sec), increasing northwards with a speed between 30 and 100 cm/sec or 1 to 4 km per/h. The water needs merely 3 to 8 weeks to reach Spitsbergen. That is all big stuff and a nearby war at sea cannot necessarily compete with such dimensions, might quickly cross one's mind. But nature is not black and white and physics offers thousands of variations. In the same way as a very thin and undisturbed freshwater layer over huge sea areas during winter time would isolate almost completely the sea water body from the atmosphere, hundreds of other activities can change the structure of sea water layers. That must have happened in 1918, and it was a very severe phenomenon, indeed. Two decades of warming do not come from nowhere. Scientists who speak about climatic changes as a matter of expertise have to answer this question.



Giving reasonable explanation for the warming of Spitsbergen in 1918 might not be as difficult as it seems at the first glance. One explanation could be based on the fact that naval war around Britain and in the North Sea cooled the water down from September to March, thus affecting about up to 20% of all water that formed the Norwegian Currents, whereby the water from the North Sea had significant lower salinity as compared to the high saline water of the Atlantic. This colder water would go down faster than usually, forcing saltier water (from the inner Norwegian Basin) to the surface. Significant parts of the system were forced into higher motion, and, at the north of Spitsbergen, colder and saltier water flowed quicker into the Artic Basin, which, at its turn, allowed more water to flow into the Norwegian Sea via the Scotland, Faroe, and Iceland ridges. The “experiment” ended with a larger amount of warm water at north of Scotland, after the end of WWI.

There might be other more convincing explanation and we are always interested in any good reasoning. But what we find difficult to accept is that the severe and long-lasting warming of Spitsbergen, which took place almost one hundred years ago, has not been explained yet. After all, almost one century has passed since this sudden and severe warming started, lasting for two decades.