HOW USEFUL ARE ATLANTIC SEA-SURFACE TEMPERATURE

TAKEN DURING WORLD WAR II.

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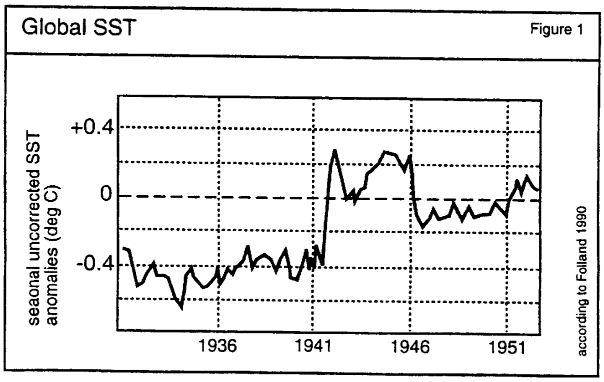
1. INTRODUCTION.

Historical records on sea surface temperature observations (SST) have become an interesting tool for determining the patterns of global climatic changes recently. However, their immediate use is not without shortcomings. This is particularly the case from September 1939 until May 1945 during World War II (WWII). Too obvious is an apparent "jump" during the early 1940s in the global data set (Figure 1). Does this suggest a multi-year climate event occurred in the ocean-atmosphere system over much of the globe in the late 1930s through mid-1940s" (Barnett 1984) or are the data sets distorted by five years of war at sea? The "jump" is particularly pronounced in marine air temperature data (MAT) set from 1942 to 1945 (Folland, et al. 1984; Jones et al. 1986). While the latter received the war-time related explanation that it was forbidden to expose any light at night forcing the measurements be taken well in-board (Folland et al.1984), **SST** deviation is regarded as result of joining sets of bucket SST with sets of engine inlet SST`s (Barentt 1984, Folland et al. 1995). But with the start of WWII much more happened. Immediately the war halted surface observations east of 35° West from ships of belligerent nations and from most neutral ships, and despite the appeals of the US Government for reports from sea, there are sometimes gaps of 1,500 miles between Bermuda and the Azores, with the result that it is impossible to make satisfactory Atlantic weather maps commented *The New York Times* (NYT,11 Feb. 1940). The low number of marine observations continued for the time being (Folland et al. 1986). This raises the question whether SST during the war are the reasonable reflection of natural changes or have been caused by substantial alteration in navigation patterns with little, if any, value for climatic research.



2. THE REASON TO INVESTIGATE WWII-SST.

Since SST data sets have been used for climate research, their time-varying biases have been scrutinized for applicable correction figures (Folland et al. 1995). Originally collected for compiling climatologic and oceanographic Pilot Charts and subsequently gaining prominence in weather forecasting, the present use of historical mean annual SST is based on a different observation quality. While the former use was confined to describing a status, any series of SST averages for climatic change should indicate dynamic processes (Bernaerts 1997). For this purpose, the heterogeneosity of historical marine data series is paramount and requires observations under comparable circumstances. Most observations were collected by merchant vessels since 1870 when systematic sampling commenced. Generally it is assumed to be done on fairly homogenous conditions except of evolving observational practices thus rectifying the application of staggered but uniform corrections for time periods (Barnett 1984, Folland et al. 1995)). But at least during WWII, seagoing was much different from common shipping. The circumstances and procedures for observations went far beyond evolution in observational practices and a mere abrupt transition from the use of uninsulated or partially insulated buckets to the use of engine inlets for measuring SST.

While the paper concentrates on the latter the underlying purpose is to arouse a more critical approach in investigating historical SST in particular in regard to any application of uniform correction figures from about 1870 to 1970. Shipping and navigation varied considerably during this time period. Size, type and routing of vessels changed. The collection of data served other purposes. Their reassessment for dynamic processes would at first glance require reassessing individual or groups of observations, e.g. sailing, steam or motor vessels. Shortcomings in this respect and applied corrections figures may look reasonable but are not necessarily of value for climate change research. As clarification and evidential reasoning in this respect for a time period for 100 years is too big a task presently, investigating the extreme significant WWII period may however provide enough indications for a more comprehensive review of SST. After all, a very significant warming of the northern hemisphere in the 1920's and 1930's was halted with the commencement of WWII. Central Europe and Scandinavia experienced the coldest winters for more than 100 years during 1939-1942 (Liljequist 1943) causing concern whether a period of extreme winters comparable to those from 1780-1859 had started (Rodewald 1948). While the cause of this sudden climatic "irritation" could be anthropogenic as a result of war at sea (Bernaerts 1996) the winters turned back to "normal" once the war at sea turned global in 1942. However, global average temperature remained low for three decades; more pronounced in the northern than in the southern hemisphere (Folland,Karl et al. 1990b). WWII data may have more to tell than mere odd looking statistics.

3. GENERAL OBSERVATION PRACTICE

Non-merchant vessel SST.

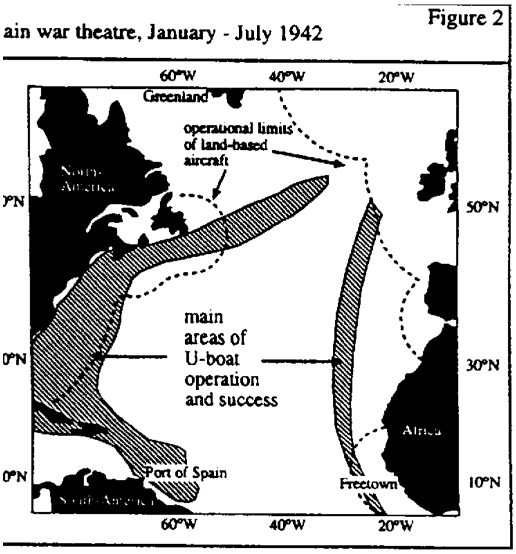
As of the beginning of WWII access to and handling of weather related information changed in many respects. Belligerent states regarded them as secrets. Merchant ships stopped supplying data fearing that German submarines might notice their positions. As it became impossible even for the US Weather Bureau to make satisfactory Atlantic weather maps, the United States assigned six Coast Guard cutters to two permanent floating weather stations on positions between Bermuda and the Azores in February 1940 (NYT 4 Feb.1940).

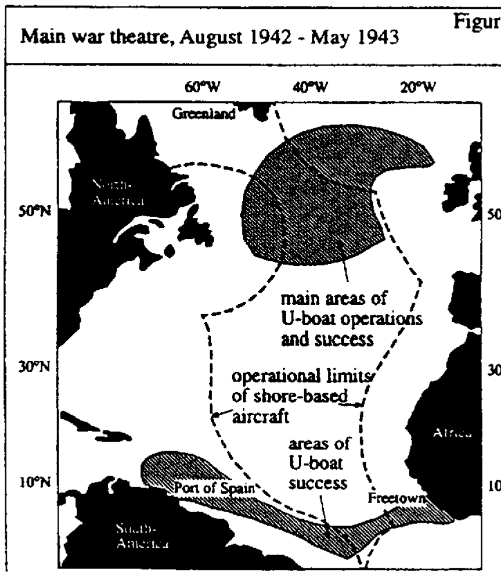
On the other hand, every nation at war made extreme efforts to gain the best possible data. Never before had such a quantity of methods and human resources been employed to collect marine data. Many ships and submarines were especially assigned for this purpose. German submarines (U-boats) took frequently positions in the Western Atlantic to serve as weather ships. The personnel of the US Airforce and US Navy weather services increased from 2500 in 1941 to 25,000 in 1945, with many hundreds of trained and well-equipped weather observers doing their service on board merchant and naval ships (Bates et al. 1986). Accordingly, it must be generally assumed that all possible care was taken to obtain the best possible and reliable measurements.

Nevertheless, this does not necessarily imply that the observations taken by non-merchant ships represent "sea surface" temperatures. Somehow observations from an aircraft carrier or a cutter are likely to turn out very differently. In particular water temperatures taken by submerged submarines may have very little in common with SST. But what should arouse even greater suspicion is the immense variety of all sorts of ships and personnel conducting measurements as well as the many substantial changes in navigational pattern during WWII. There is little reason to assume that SST were and could be collected on an qualitatively even level with pre-war conditions.

Cargo vessel's SST.
During WWII, shipping was largely confined to travel in convoys escorted by warships. Warfare by submarines had first become a main threat to overseas navigation in First World War. When merchant ship losses by U-boats had risen to an average of 500,000 gross tons per month during 1916, the British Admiralty introduced a convoy system in summer 1917 on all main supply routes and to the extent of possible U-boat attacks, roughly the range up to 15° West, Gibraltar and the Mediterranean Sea. The system immediately recommenced with the start of WWII and neutral shipping was soon anxious to join the system. Of 5,500 ships escorted until the end of 1939 (NYT 4 Jan.1940) only a dozen ships were lost to U-boats. During the same period they sank more than 110 vessels sailing independently. However, setting-up, running and protecting convoys developed gradually with no escorts west of Rockall Bank (15°West) at all until July 1940. The first North Atlantic convoy with a permanent escort left Halifax on 27 May 1941 with a route close to Iceland, as escort vessels couldn't sail the full distance to the UK and had to be replaced midway at that stage of war.
A typical North Atlantic convoy consisted of 40 merchant vessels (max. 70) forming a square, up to ten ships in a parallel line (each 650 Meters apart), each followed by four or more ships (each 650 Meters apart). Thus, the merchant vessels in order covered a sea area of about 10 square nautical miles (NM). This square was circled by a varying number of naval vessels between one to three NM off and around the convoyed ships (Costello et al.1977). At the early stage of the war the escorts often consisted of no more than three small naval vessels. The number continually increased throughout the war. During 1941/42, convoys were given an average protection of two destroyers, and five corvettes plus support vessels. Since 1942 North Atlantic convoys were often accompanied by more than 20 naval vessels including auxiliary aircraft carriers with 80 combat planes. Air cover by land-based crafts was restricted to a couple of 100 NM off the Eastern coasts at first but increased continuously (Figure 2 & 3) with 2200 aircraft searching and chasing submarines between July 1943 and May 1944 in the North Atlantic

sinking roughly as much U-boats as the U-boats were able to hit and sink cargo vessels. The U-boats lost the Battle of the Atlantic in summer 1943.





Operational Limits of land-based aircrafts;
Main operational areas of U-boats and success.
Source: Roskill, S.W.; The War at Sea 1939-45, HMSO/UK

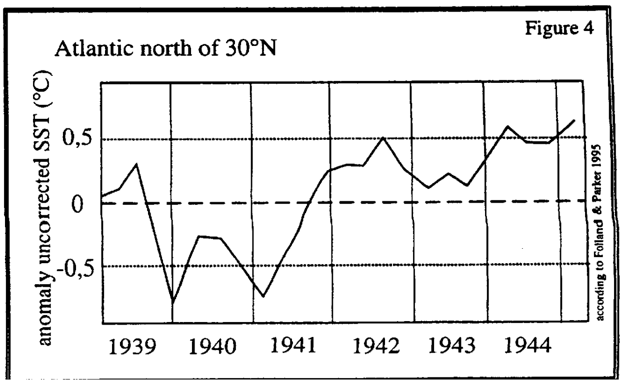
The protection of convoys against submarine attacks was based on the two principles that the escort was to detect, to hunt and to destroy enemy submarines and surface raiders, while the convoyed merchant vessels "zig-zagged", i.e. changing course in accordance with the leading ship to minimize hits by torpedoes. Any "zig" was executed by altering the course by 90 degrees to starboard or port and to speed to the keel water line of the previous ships- column (on the left or the right side before the "zig" was ordered) followed by the "zag" by altering the course by 90 degrees again back to the previous course once the keel water line of the former ships' column had been reached. Thus the vast majority of all convoyed ships always sailed through water already passed by a number of other ships only few minutes ago. This could be one or even nine ships. Any SST taken by one of these ships can not be regarded as being taken from the `sea surface` or compared to peace time SST. Actually, the water measured often might have become an undefinable `mix` from the surface down to 10 meter and more. In accordance with seasonal changes of temperatures in the upper surface layer (Lamb 1955), SST taken during the summer the temperature should tend to be colder and warmer during winter than the `true` figure. In addition, all ships permanently released hot cooling water and this may have affected all observations by ships behind, as it can not be excluded that seawater was taken at places with strong `mixed-up` water by bombs and depth charges or other military activities. Accordingly, not the means of measurement, type of bucket or engine water inlet is the principle question but the extent to which the seawater measured was different from an "unaffected" sea and whether any deficiency in this respect can be compensated by a corrective.

Impact by sailing schedule, routing, and observation.

At no time during WWII were observations taken on a consistent basis comparable to peacetime shipping. Sailing was bound to only a few points of destination on either side of the Atlantic and only in intervals. Ships were grouped into slow and fast convoys. Routing changed several times for various reasons. Only when the Allied naval escorts became fit for long distance (e.g. re-oiling at sea) and available in sufficient number (since 1943) did convoys sail along the great circle (shortest route). But when a convoy passed out of range of air cover, as it was still the case in 1943 (Figure 3), they could run into a several days battle with a dozen or more U-boats, which stretched over more than 1000 NM on route. In particular, the situation in the Northern North Atlantic was strung with hundreds if not thousands of significant aspects. E.g. a huge mine barrage of about 100.000 devices was laid between the Orkey Island and Iceland after the Germans invaded Norway (Hartmann 1979). Arctic convoying to Archangel/Murmansk started in August 1941 using routes very far to the north during summer time. Until May 1945 the number of east- and west-bound convoys total was 75, less than two per month on average but none from the end of June to September 1942.

After 57 months of war at sea the end result is impressive. The allies completed 300,000 Atlantic voyages during the war (Winton 1983) which means that more than 99% of all ships reached their destination. The allies and neutral losses by all war causes account for 5,411 merchant vessels with a total of 22 million gross tons; roughly half of it in the Atlantic theatre.

4. ATLANTIC-SST AND THE BATTLE OF THE ATLANTIC.

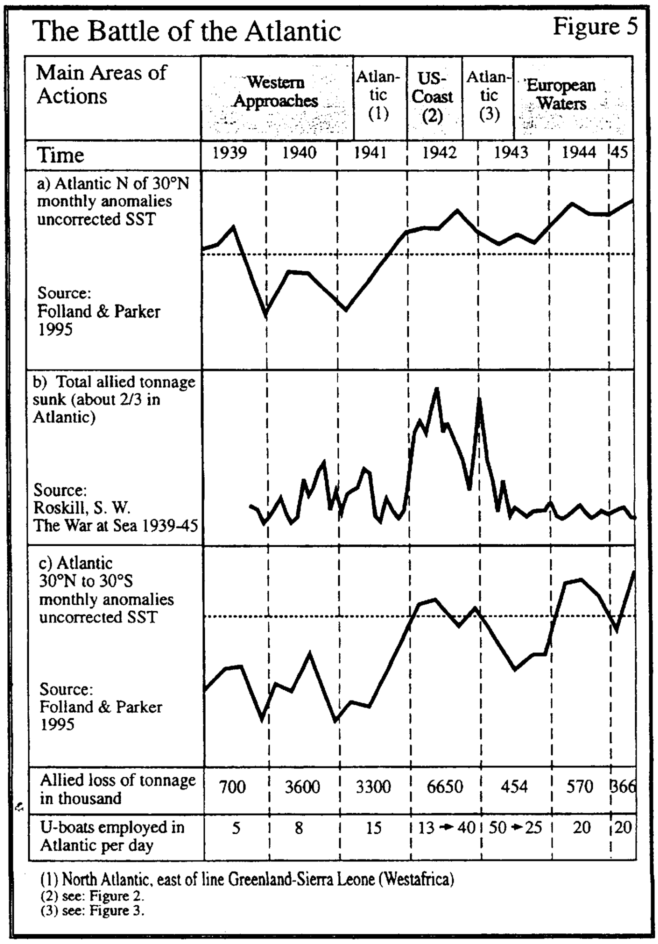


Method of Discussion.

Recently, Folland & Parker (1995) gave a detailed account of regional SST during WWII. The SST anomalies in the North Atlantic north of 30° N (Figure 4), or north of Gibraltar and Jacksonville/Florida have a similar feature as the global SST in Figure 1. The northern part of the Atlantic saw what is generally regarded as the Battle of the Atlantic.

Any detailed investigation on the relation between SST in one place and the war activities at the same time is out of question. But this war in the Atlantic developed circumstantial features which allow some generalizations. It is the aim to identify very significant patterns and to discuss these on a time related basis with the Atlantic SST anomalies

As the activities of U-Boats formed the major threat to ocean shipping, it is possible to summarize main areas of activities and the rate of success at a given time as shown in Figure 5. In addition the SST anomalies for the subtropical Atlantic 30°N to 30°S (Figure 5c) and some further data are given to provide a reasonably complete picture, as a considerable number of Axis submarine were active down to 10°N temporarily with considerable scores an route to West Africa (Sierra Leone) in 1941 and off South America (Northeast coast) 1942-1943 (Fig. 2 and 3). The Mediterranean war theatre required enormous supply from the United States, the United Kingdom and the southern hemisphere.



In full awareness of the fact that the method applied in accordance with Figure 5 is extreme in itself some additional remarks regarding navigation and warfare at a certain time of WWII should be made. They are selective and merely indicators of what should actually be taken into account for investigating the reliability of WWII SST in depth. Here, they shall be regarded as a mere hint for further considerations. After all, this paper attempts to question foremost the applicability of general correction figures. For this purpose realization of the variety of conditions of sampling and any uncritical processing into SST data sets is a precondition.

Northern Atlantic (Figure 5a).

a) 1939:

Pre-war SST observation were mainly provided by European ships. When WWII started on September 1, more than 80% of the world’s merchant fleet were coal burners. The German merchant fleet was swept from the Atlantic within weeks. Ships previously engaged in voluntary observations refused to transmit. Liner trade changed, ceased or sailed together with tramp ships in protected or unprotected convoys while very fast vessels continued to travel on their own, zig-zagging when danger was imminent. Consequently, it is difficult to assume that SST were sampled in accordance with former procedure and care, or to assume that log-book entries on SST can any longer be regarded

as taken by buckets until the ambush on Pearl Harbor in December 1941 (Folland et al. 1995), although under severe threat by U-boats and raiders. Arming some 3,000 merchantmen with 4.7-inch guns within twelve months (Slader 1995) was another twist on shipping pattern.
A sharp drop by 1.5 °C in late 1939 (Figure 4) is noticeable. During the same time the number of observations dropped either to about 10 to 20% of pre-war figures (Folland et al. 1990). This small number shall now be representative for an area effected in the East-Atlantic by war activities and in the West-Atlantic by 'nervousness'. Where ships recorded engine SST figures it would be necessary to regard them as too warm (Kent et.al. 1993) requiring a negative correction. But in 1939 most ships were still coal burners and little attention has been paid (Russeltvedt 1936) to evaluate the correctness of such data.

b) 1940:
Until March 1940 U-boat activities in the Atlantic concentrated on traffic near the Southwest coast of England/Ireland and around Scotland and ceased almost completely from April until June due to their participation in the German military seizure of Denmark and Norway. From there on, an average of nine submarines operated in the Northeast Atlantic attacking convoys at the surface during the night and with torpedoes. The temporarily higher SST in summer 1940 could be due to a relaxed attitude which quickly ceased toward the end of 1940 when submarines succeeded in sinking a monthly average of 200,000 gross tonnage (about 100 vessels) in the Atlantic per month.

c) 1941:
The northern and eastern Atlantic was no longer safe. Transatlantic convoys became more and more organized and protected. Since air coverage in the Western Approaches improved considerably in early 1941, U-boats attacked further into the Atlantic (45°W). When Iceland permitted the use of its harbors and airfields in July 1941, ship routing went much further north. U-boat attacks occurred to the South and East of Cape Farewell (Greenland) as a result. Russian convoys commenced August 1941. The ratio between ship and U-boat losses was 10:1.
The more the U-boats penetrated successfully into the Atlantic the more SST increased.

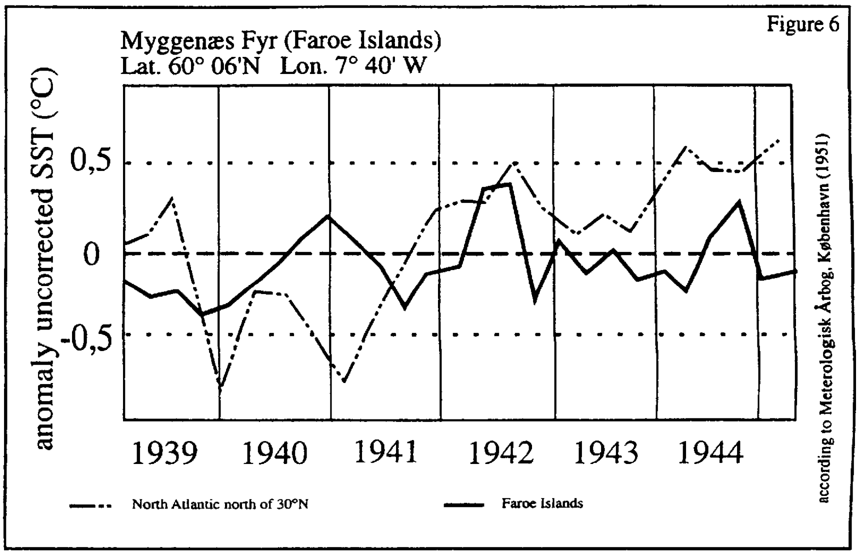
d) 1942:
The United States was drawn into the war; U-boats attacked shipping in the eastern Atlantic from St. Johns to Port of Spain until July. The "U-boats paradise in American waters" amounted to a loss of 2,5 Mio tonnage while a similar figure required repair (Figure 2). By then an efficient North-South convoy system had been established and the defense and detection of U-boats improved. The battle turned back to the center of the Atlantic in particular in those areas which still out of reach for attack air planes, called "the gap" were severe weather conditions prevailed in December 1942 until February 1943.
The SST peak coincides with the culmination of the highest sunken tonnage by submarines per month; 700.000 Gross Tonnage in June 1942 and the anomalies remained positive.

e) 1943:
The threat by the U-boats to shipping in the Atlantic reached its azimuth during winter 1942/43 (Nov.42 & March 43),(Figure 3). An average of almost 50 U-boats was permanently pursuing convoys mostly attacking as pack of five and more. On the other hand convoying was increasingly perfected, supported by surface radar and underwater detection. U-boats were forced to remain submerged and once detected subject to *creeping attacks*. Naval vessels hunted the boats with depth charges if necessary for hours. By May 1943 U-boats had lost the Battle of the Atlantic. During this month they

only sunk 34 vessels compared with a loss of 27 U-boats. From then on the Allied forces exercised superiority in the Atlantic able to run their convoys efficiently and with little or no `zig-zagging`.
The impact on SST is likely to be reflected in the new rise in SST in the remaining months of the third war year.

f) 1944/45:
The Transatlantic convoys were run with high precision and protection. Nevertheless, the appearance of U-boats was not fully banned but could be held at bay with several hundred -thousand depth charges and air bombs.
SST remained high until the end of the war. Once the abnormal circumstances ceased in 1945, the high level of SST data series decreased simultaneously (Figure 4).

Equatorial Atlantic (Figure 5c). From the total area of Figure 5c only one third, 10°N to 30°N can be generally regarded as involved in the Battle of the Atlantic. A major supply line from America to the Mediterranean Sea ran through this water. Many North/South and West/Eastbound convoys commenced in Port of Spain and Sierra Leone. What is noticeable is the simultaneous figuration in the graphs of Figure 5. In October 1942 the Allies' transferred 350 cargo vessels with the protection of 200 naval vessels across the Atlantic for the landing operation 'Torch' in North Africa. Late 1942 SST indicate a brief rise. A relation between employment of U-boats and the efficiency of protected sea transport could be responsible for the positive SST during early 1944. Many U-Boats operated from France until the Allies landed in Normandy. The last U-Boats left their Biscay bases by end of August 1944. But the threat to navigation was only banned when Germany capitulated in May 1945.



SST from Faroe Island by comparison. For comparison purposes, wartime SST anomalies at Myggenæs Fyr/Faroer are given in Figure 6 together with the data from Figure 4. At that time the occupation of Denmark and Norway (April to June 1940) took place and during winter 1940/41 data are incomplete.
As Myggenæs Fyr is well situated in the North Atlantic and within the Gulf currents system, it comes closest to ship observations. At least these coastal observations should indicate patterns comparable to those of general Atlantic SST. Actually, it is highly divergent.

5. CONCLUSION.

SST data series for WWII were taken under circumstances widely different to what one would generally regard as voluntary merchant ship observation (Bernaerts, 1997). These observations were anything but on a homogenous footing, making it difficult, if not impossible, to identify particular deficiencies and to define corrective figures. Too many and too different factors may have influenced SST at that time. In addition, comparison with a number of developments and ship protection procedures in WWII the time corresponding average of SST figures indicate the possibility of considerable inter-links with war-time events. In contrast to ships sailing in the keel water of four to ten ships could no longer take their samples from sea surface water (bucket) or unwhirled water (engine intake). The more efficient, protected and speedy the convoys became and the less they faced an immanent serious threat, as was the case until summer 1943) the higher was the turnout of SST. The assumed correlation between the sudden `jump` in SST at the end of 1941 with an abrupt switch from water buckets to engine inlet measurements may explain something but is not necessarily convincing. The low level of records during the first two war years may be due to "stress of crews" the later high level due to sufficient convoying and naval and air control in the Atlantic. After all, the data level in 1939 and 1946 was equal. What caused the "diversions" between these years is not yet answered. This actually prohibits the use of general correction figures presently. As long as there is not more clarification on SST taken during WWII any use of WWII SST data in climate change research may easily lead to wrong conclusions. Only with utmost caution should WWII marine data be used.

References

Bates C.C. and J.F. Fuller. 1986. American`s Weather Warriors, 1814-1985. USA:Texas A&M University Press, pp 52-57.

Barnett, T.P. 1984. Long-Term Trends in Surface Temperature over the Oceans. Mon.Weath. Rev. 112, 303-312.

Bernaerts, A. 1997. Reliability of Sea-Surface Temperature Data Taken During War Time
in the Pacific. In: Proceedings PACON 1997 Hongkong, (in print).

Bernaerts A. 1996. Climatic Change 1939-1945 - A Matter Of War At Sea ? Peace to the Ocean Bulletin, No 9/10, Moscow, 177-179.

Costello J. and T. Hughes 1977, The Battle of the Atlantic.
London.

Folland, C.K. and D.E. Paker. 1995. Correction of instrumental biases in historical sea surface temperature data. Q.J.R.Met.Soc. 121, 319-367.

Folland C.K. and D.E.Paker. 1990a. Observed Variations of Sea Surface Temperature. In: M.E. Schlesinger (ed.), Climate-Ocean Interation, Dordrecht, 21-52.

Folland C.K., T.K.Karl and K.Y.A. Vinnikov. 1990b. Observed Climate Variations and Change. In: Houghton J.T., G.J.Jenkins and J.J.Ephraums (eds.) Climate Changes, The IPCC Scientific Assessment, Cambridge, 194-238.

Folland, C.K., D.E.Paker & F.E.Kates. 1984. Worldwide marine temperature fluctuations 1856-1981. Nature 310, 670-673.

Hartmann G.K. 1979. Weapons That Wait,
Annapolis/Maryland, P. 241.
Jones P.D., T.M.L.Wigley & P.B.Wright. 1986. Global temperature variations between 1861
and 1984. Nature, 322, 430-434.
Lamb H.H. 1955. The Depth of the Wind-Produced Homogeneous Layer in the Oceans; Fishery Investigations XX, 3-11.
Liljequist G.H. 1943. The Severity of Winters at Stockholm 1757-1942, Geografiska Annaler
1-2, 81-104.
Rodewald M. 1948. Die barische Vorbereitung strenger und milder mitteleuropäischer Winter, Ann.d.Meteorolgie 1, 99-105.
Slader J. 1995. The Fourth Service - Merchantmen at War 1939-45,
Wimborne Minster/Dorset.
Winton J. 1983. Convoy - The Defence of Sea Trade 1890-1990, , London