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RELIABILITY OF SEA-SURFACE TEMPERATURE DATA TAKEN DURING WAR TIME IN THE PACIFIC.

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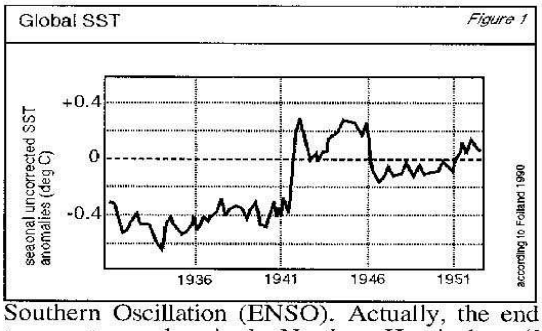
With particular regard to the Pacific Ocean, this paper discusses whether sea surface temperatures taken during World War II can be subject to corrections or should not be used at all. Calculation and use of correction figures require a uniform baseline, a comparable basis for observing ships in time and space. During the war a common factor was deeply affected. Although the war in the Pacific started two years later than the war in Europe in 1939, the Pacific region nevertheless saw 'political' changes and with them sea communication diverted from the pre-war shipping practice. The investigation of 'reliability' is based on the past and present handling of these data and the different circumstances during the war and uncorrected data anomalies for some Pacific regions in accordance with published graphs. The paper concludes that the World War II data series indicate a strong relation to war-related conditions and can generally not be corrected but require critical review in climate change and El Niño research.

THE RETURN OF SST BUT WITH CONSTRAINTS

With the onset of interest in "global warming", historical sea surface temperature observations (SST) gained new prominence two decades ago. They were sampled by merchant ships sailing the seas in international trade. The principle pattern of global shipping existed throughout this time with only a single exception. During World War II (WWII) shipping practices changed profoundly as did the SST data series indicating a big "jump" (Figure 1, from Folland and Paker 1990) attributed to a sudden but undocumented change in the methods used to collect sea water from unisolated to isolated buckets or engine cooling water intake, to make measurements of SST (Folland et al. 1984). Barnett (1984) was the first to observe this inconsistency and expressed the view that studies already undertaken may soon show ways of overcoming non-sensical or instrumental biases. Only the latter has received any attention, not the "jump". Thus restricting the investigation on the reliability of SST over a very brief period of time seems to be a small issue. This first impression does not hold if seen in the context of global climatic changes or temporary weather fluctuations as El Niño Southern Oscillation (ENSO). Actually, the end of the 1930s was a turning point in mean temperature values in the Northern Hemisphere (Jones et al. 1982). After rising for 20 years, global mean temperatures became significantly lower for three decades (Folland, Karl et al. 1990). Furthermore, this `turning point` moved along with fluctuations in the tropical Pacific. Some researchers assume that two El Niño's occurred during WWII, one from 1939-41 the second from 1942-44 (Bigg et al. 1992), while others proposed viewing the anomalies as one prolonged ENSO incident of a previously unknown state (Copper et al. 1989). As historical observations cannot be repeated, the ultimate proof of whether historical SST can be depended on is only available once the mechanisms of natural common changes are well understood. As it goes without saying that this is a long and painstaking process, even an initial review of a data series over a short time period is anything but a straight forward task.



THE SST DATA SERIES

Systematic ship observation started in 1854 (Folland and Parker 1990); data collection was established 75 years later with about 500,000 items of data per annum as of 1920 (Folland and Parker 1995). They served the purposes for which they were collected reasonably well, i.e. the improvement of pilot charts initiated by US Navy Admiral Matthew F. Maury at a conference in Brussels attended by the representatives of ten navies in 1835 and to assist

meteorological services through daily ship observation as discussed and implemented by the International Meteorological Congresses in Vienna in 1873 and in Rome in 1879 (Cannegieter 1963). As climate was regarded as static and defined as the "average weather over a substantial period of time" there was little left to complain 60 years later. The monthly average of the oceans was well documented in pilot charts and hundreds of ships reported daily their meteorological observations for improved weather forecasting. But in 1939 the situation suddenly changed. "The Weather Goes to War" reasoned a The New York Times (NYT) commentary by pointing out that the war's first effect was felt by the US Weather Bureau as ships of warring nations ceased to record weather conditions for fear of revealing their positions (NYT Oct/03/39). The annual number dropped to a fraction of pre-war figures during the war (Folland and Parker 1995). Although World War I saw an even bigger drop in annual numbers of SST than WWII (Folland and Parker 1995) the general situation was different. The war at sea remained, with the exception of some world-wide operating raiders, closely confined to European waters from August 1914 to November 1918. A temporary success of German submarines to sink a monthly average of more than 500,000 tons ship space started in late 1916 but was sufficiently 'counter attacked' by the introduction of a convoy system in summer 1917.

But the problems of the weather services at the commencement of the war in 1939 and the quality of marine observations during the subsequent years until 1945 would not give any reason for concern if SST did not serve a very different purpose recently. Even in the 1960s their use was still based on a static climate approach (Brown 1963) although the possibility of the influence of variable sea-surface temperature on atmospheric centers of action was already being considered (Namias 1963). With the start of discussions on "global warming" in the late 1970s there was renewed interest in historical SST. As the archives contained millions of SST observations from the world's oceans, it was felt that they are "virtually the only hope of getting a globally comprehensive view of long term surface temperature changes" (Barnett 1984). Observational studies became an essential component improving understanding of climatic mechanisms and SST was regarded as one of the most important climatic variables (Folland and Parker 1990). From now on SST were used to identify dynamic processes within the global natural commons and not only to record its actual status as it used to be.

But it soon became evident that the use of SST was not without limits with regard to instrumental bias as already mentioned. Pre-WWII SST values were too low relative to post-WWII (Figure 1). While Barnett (1984) considered a need for a positive correction in the order of 0.2 to 0.4 °C more recently it has been suggested to raise buckets based data series from 1900 to 1941 by about 0.4 °C (Bottomley et al. 1990) or to apply staggered figures over the period (Folland and Parker 1995). Also data from engine intake were found to require corrections as a recent special observation project for the North Atlantic showed that thermometers on ships in the North Atlantic trade produce biases of plus 0.3 °C (Kent et al. 1993). Whether these efforts can increase the understanding of dynamic processes in the natural commons is outside the subject of this paper, although one may wonder whether it is possible to summarize the many facets of shipping, seagoing and marine observations in one status. But without a 'uniform' picture at a given time, any instrumental correction figure applied in general, risk beeing speculative. In this respect no period is likely to be subject to greater uncertainty than WWII. This war at sea and its effect on shipping was so rich in events, alterations and constraints that it is difficult if not impossible to form a 'uniform' background picture for SST corrections.

THE GENERAL SITUATION 1939-1945

Actually, at the advent of WWII not every Pacific shore rested in peace. Japan had been sustaining its undeclared war on China since July 7, 1937, which caused ten million casualties by February 1940 (NYT Feb/11/40). Trade in and to the Far East was effected. On September 1st 1939 Germany invaded Poland forcing Great Britain and France to take up arms against Germany and its subsequent allies two days later. As the means of warfare regarding ships, submarines, airplanes, weapons and manufacturing of military goods had improved in many respects since the last war, this war immediately developed its own pattern. The world merchant fleet numbered 31,000 vessels with about 70,000,000 tons of which roughly one

third sailed under British and French flag. The convoy system was immediately re-introduced. On September 8, thirty British merchant ships which took refuge at Gibraltar resumed their voyage under escort of a squadron of destroyers (NYT Sep/09/39). Until July 1940 naval convoying in the North Atlantic was provided up to 15 % West, then extended to 17 % West and provided for the whole transatlantic route as of summer 1941. Convoying meant that up to 50 ships sailed in four to five columns, frequently altering course by 90 % simultaneously (zigzagging) while naval escort vessels formed a shield around them. Thus most of the vessels permanently sailed in the keel water of other vessels. Measurements taken no longer consisted necessarily of 'sea surface water'. But the threat by submarines and raiders was feared everywhere. Ships zigzagged the seas on their own as the British cruise liner "Andora Star" for ten days to cross the Atlantic (NYT Sep/13/39) or several ships joined and convoyed from ports in the South Atlantic (NYT Oct/06/39) northbound until they received naval and air protection in the Western approaches. The US liner "Manhattan" sailed from Bordeaux to the States escorted by two US Navy destroyers in mid September (NYT Sept/17/39). Britain announced that it would arm 2000 merchant ships with guns (NYT Oct/1/39). The German merchant fleet was swept from the oceans within weeks. All navies were on alert, patrolled the oceans and seas, bombed, battled, torpedoed and depth-charged the enemy, the Axis often neutral parties also, mined coastal waters, seized or delayed ships in search of counterband, escorted particularly threatened vessels in 'out-war' areas and prepared for the worst. And the worse did come, much worst than ever imagined. Although the Pacific was isolated from major war activities until December 7, 1941, its political, economic and trading patterns nevertheless changed on September 1, 1939 and with it the 'picture' of seagoing in the Pacific.

THE PACIFIC IN WWII

The sources of marine data series and data 'consciousness'.

Pre-war SST data were mainly provided by European ships (Barnett 1984) while Japanese data only began in 1933 (Folland and Parker 1995). They were substituted by US Navy logs and US Merchant Navy observations from the early 1940s but how they were taken, "no one knows for sure" (Barnett 1984). Towards the end of WWII the number of observations was twice as high as at the best previous sampling peak around 1935 (Wright 1986).

In 1939 'everyone' knew that a profound knowledge of meteorological conditions would play an important part in this war (NYT Sep/ 03/39). Sea surface temperatures had become an important weather forecasting tool. Only twelve months earlier the US Weather Bureau was shaken by misjudging the movements of a hurricane which devastated New England on September 21, 1938. Observation capabilities were immediately increased (NYT Sep/22/39). The first two Coast Guard cutters took mid-Atlantic station as 'weather ships' in early 1940 (NYT Feb/11/40). The Bureau's Monthly Weather Review notes since September 1939 frequently Coast Guard ships "on survey" near Aleutain and that it received regular information on weather conditions in the Pacific from a number of US and Japanese merchant ships until June 1941 after which the publication of the names of weather reporting vessels was deleted. Aware of the need for sufficient weather data the US Navy and Airforce started to train personnel in thousands and soon became the biggest weather service ever (Bates et al. 1986).

Politics, shipping and war in the Pacific 1939/41 and 1942/45

The Allies needed as much ship space as they could get to fuel their war efforts in Europe, their liner trade ceased. Japan's costly war in China and its pursuit of a "new order" for East Asia continued. Since June 1938 the United States had attempted to deter Japan's aggression through measures which would curb her economic and military power. The US-Japan trade treaty of 1933 expired in January 1940. As of June 1941 Japan was embargoed and only weeks later Japan assets in the US was put under US Government control. Still in 1939 the United States Navy strengthened its fleet at Manila, had plans to construct a naval air base on the Palmyra Island group midway between Hawaii and Samao (NYT Dec/13/39), sent 29 scouting vessels to Hawaii (NYT Oct/06/39) were the largest two dry docks east of Singapore went into construction (NYT Dec/22/39), subsequently barred Hawaii coal supplies for merchant vessels (NYT Jan/25/40) and required fortification of Pacific Islands, while the whole structure of the US shipping industry changed completely within months on

implementation of the US Neutrality Bill of November 1, 1939. Ships were laid-up, flagged-out or sold. The Allies bought and chartered ships whenever they could. On the other hand in 1937 a ship building program, the predecessor of the famous `Liberty` series, was introduced (NYT Jan/13/40). Two years later, when tankers of 19,000 tons could be built in four months, the US fleet had 1200 ocean-going vessels, 38% tankers (NYT Dec/14/41), and a program for 1200 more by 1943 but severe recruiting problems as well (NYT Dec/07/41). Actually, in 1943, US shipyards dilivered 1,896 ships totaling 20 Millions deadweight tons.
On December 7, 1941 a Pacific area image "Japan Rattles Sword - But Echo Is Pianissimo" (NYT Dec/07/41) ceased with the ambush on Pearl Harbor. The US Espionage Act of 1918 was invoked regarding information as to movements of transports (NYT Dec/09/41) and warnings on "loose talks" published (NYT Jan/23/42). Weather data became secrets. The weather maps had to go, and were accompanied by the comment "meteorologically we are living in the year 1800" (NYT Dec/16/41). The movement of all US merchant ships came under Navy reglementation (NYT Dec/14/41) and ship safety standards were eased (NYT Dec/18/41). As a convoy system could not be set up immediately ships were warned of raiders (NYT Dec/08/41) but Japan claimed to have seized 200 ships within the first war days (NYT Dec/10/41) while large scale sinking of ships commenced between the shores off San Francisco and Singapore. During the battle for the Philippines the first escorted resupply convoy of seven ships (which sailed from Honolulu on 29 November with reinforcements for the Philippines) arrived in Brisbane on 22. December 1941 and in January 1942 the United States began to rush garrisons to Pacific islands that would form staging and defence posts along the line of communication between Australia and Hawaii. Panama and the US West Coast. The main battle area remained West of the line Anchorage, Honolulu, New Hebrides and Darwin/Australia. Although Japanese naval forces remained concentrated in the Western Pacific navigating the Eastern parts of the Pacific was not free of considerable risks. Particularly during 1942 submarines, surface raiders and air planes posed constant dangers. Convoying was the order everywhere.

WWII REGIONAL SST SERIES

The material used is based on graphs of uncorrected SST anomalies as given by Wright (1986) for 1930 - 1960 for the North East, Central North-, North West, and Equatorial Pacific (Figure 2) and Folland and Parker (1995) for 1938 - 1948 for the North and Equatorial Pacific, but are only selective and simplified by the Figures given below. As the aim of the paper is restricted to discussing the reliability of WWII-SST in general the events mentioned should not be regarded as conclusive let alone proven. As each SST series is dealt with separately some repetition may occur.

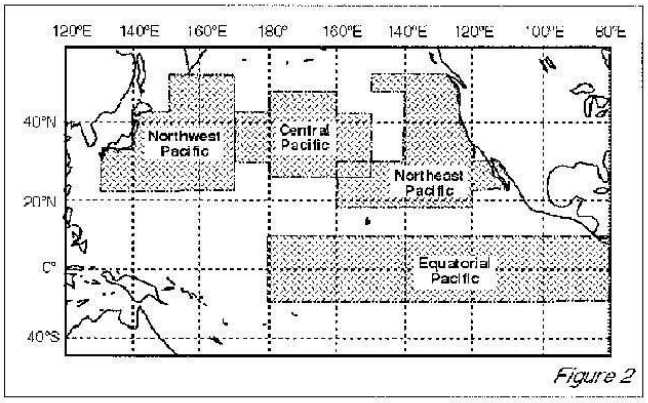
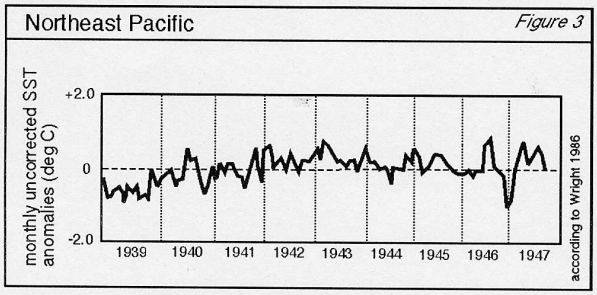


Figure 2

Northeast Pacific (NEPac)

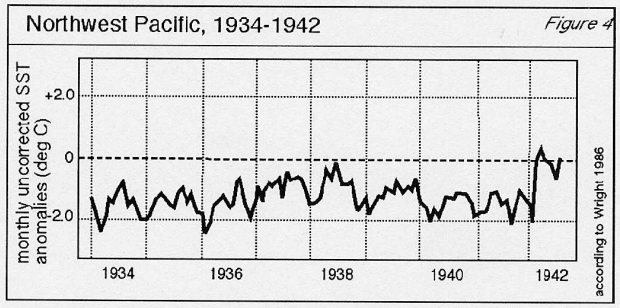
The generally unremarkable running of NEPac-SST from 1943 to 1954 (Figure 3) is the most interesting aspect of this series. If the "jump" (Fig.1) had been caused by a sudden change in measurement methods, it should be very pronounced in this region. As of late 1939 US naval and transport traffic increased permanently and the region had never been as 'congested' as from 1942 to late 1945. Yet, the only deviation between pre- and post war anomalies is a slight temperature increase during the Pacific war period which can be attributed to convoying or escorted sailing. Further indications: a) mid-1938 to late 1939, the temporary decrease could be subject to reduced and changes in liner traffic of commonly observing ships (British, Netherlands, Japan, see above); b) late 1939 to late 1941, the small increase may be due to greater US Naval presence, while the "summer peaks" in 1940 and 1941 (not identifiable in previous years) could be related to measurements by buckets (see: NWPac) e.g.

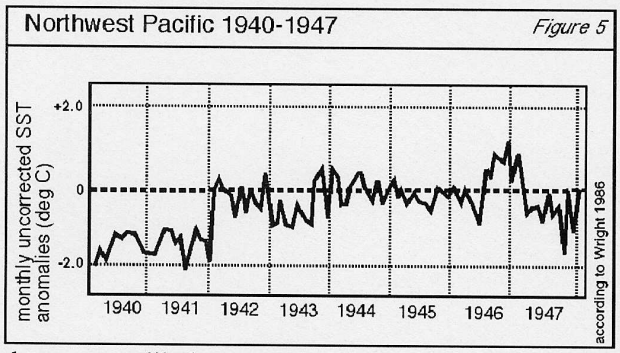


naval scouting vessels; c) late 1941 - early 1942, the brief 'zigzag' may stem from some immediate changes and increased activities along the US East coast after Pearl Harbor. Shipping was restricted to San Diego, San Francisco and Columbia River. The US tanker "Emidio" was torpedoed and sunk north of San Francisco on December 21; d) 1946 to 1947 could be related to still strong military transport but relaxed circumstances with pronounced "summer peaks" as in 1940/42.

Northwest Pacific (NWPac)

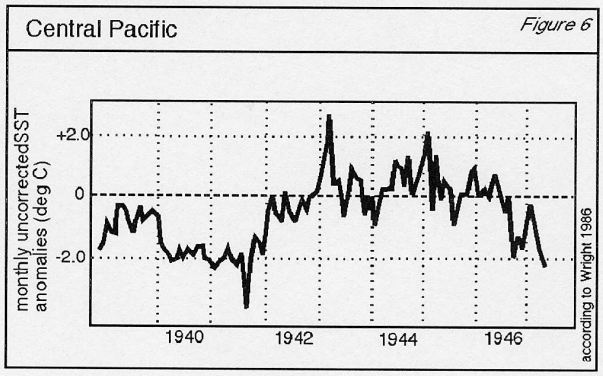
The NWPac series 1934 until 1941 (Figure 4) clearly indicates a seasonal sampling error (Wright 1986) by buckets during winter. The time it took between the withdrawal of the bucket from the sea and reading the thermometer influenced the initial temperature of the water for a number of reasons. This is well established (Folland and Parker 1995). However, the pronounced repetition of seasonal 'peaks' in the NWPac may be due to the data input by Japanese observations as of 1933, which ceased by December 1941, when the series "jumped". But the different SST values from 1942 to 1945 (Figure 5) can hardly be attributed to mere methodical changes. There was no Japanese transport in NWPac except for some convoys to the Aleutain and coastal waters off the Japanese coast. On the other hand Japan could hold enough military control over the NWPac during the war to prevent any type of surface naval traffic or a longer stay. Most of the time during the war in the NWPac only submarines could have provided SST frequently. If they took SST by buckets, the more unlikely case, the "jump" should have been much less pronounced, if they recorded engine inlet data it would be necessary to know how deep the boat had been at that time, 5, 10, 20 or more meters.





Central North Pacific (CNPac)

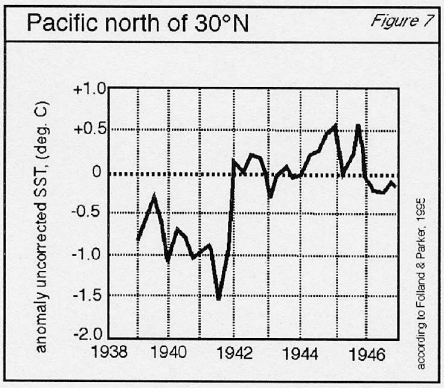
The data from CNPac (Figure 6) are particularly pronounced and could be explained as follows: a) late 1939 - late 1941, increased naval presence in the region; b) the deep 'crack' in summer 1941, in May 1941 a number of US and other ships sail to Vladivostok (Monthly Weather Report, May 1941), in June 1941 an embargo on Japan is declared; c) since January 1942 the introduction of convoying increases the data values during the war; d) the peaks in 1943, the US Aleutian compain on defense and recapture of islands started in full. US supply line partly runs through CNPac. Admiral Nimitz ordered the invasion of Attu on March 11, 1943. On March 26 the battle of the Komandsorski Islands took place. During the recapture of the Kiska Island in August an escort by



almost 100 naval vessels was employed to protect the troop transporters; e) 1944 to 1945, Japanese access to the Aleutain area by sea is confined to submarines, but as military activities continued under war conditions the war time series remained high until mid-1945 thereafter decreasing to the pre-war level.

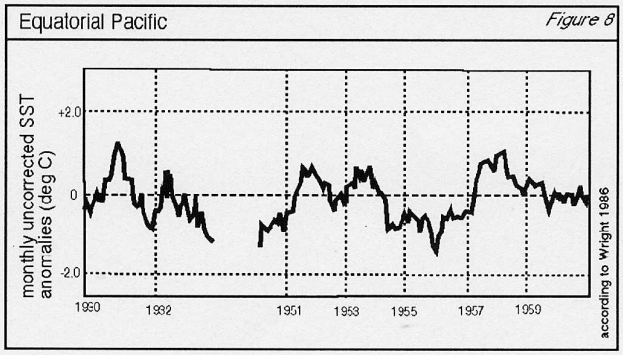
North Pacific north of 30 N (NPacN)

For the time series, NPacN (Figure 7) from 1939 to 1941 the remarks a)-c) for CNPac (Figure 6) apply accordingly. Due to the Lend-Lease Act passed by Congress in March 1941 supply convoys began to reach Vladivostok by May 1942, most by departing from Portland, Oregon. Despite the Soviet-Japanese non-aggression pact of April 1941 the Japanese Navy often harassed the convoys sinking at least 25 Soviet ships. The peaks in late 1945 and 1946 are of some surprise. As these peaks are not clearly supported by the material discussed here (Figures 3,5,6), the situation in the most northern part of the Pacific could be the reason, e.g. traffic to Russia, mine sweeping operations and the huge decommissioning of military bases and weather services in the Aleutian. The fact that the series peaks in winter could be an indication that observations north of CNPac are based on engine inlet water as the contrast between 'sea surface temperature' to deeper water would be most pronounced in sea areas off the Aleutian Islands.

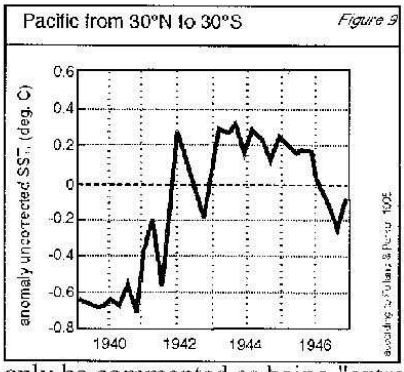


Equatorial Pacific (EquPac)

The advantage of elaborate SST in this region is the known rise of temperature subsequent to an El Niño event. The typical feature of SST of the established ENSO 1930, 1932, 1951,1953 and 1957 is given in Figure 8. EquPac-SST frequently peak within a year after the event. The picture is different for the ENSO during WWII as given by Wright (Figure 10) whether there was two, 1939-41 and 1942-1944, or only one prolonged event (see above), while the data series from Folland and Parker (Figure 9) seem to support the latter at first glance. But neither of these figures clearly supports the strong El Niño in 1939 and the subsequent running values may have been effected by the war situation.



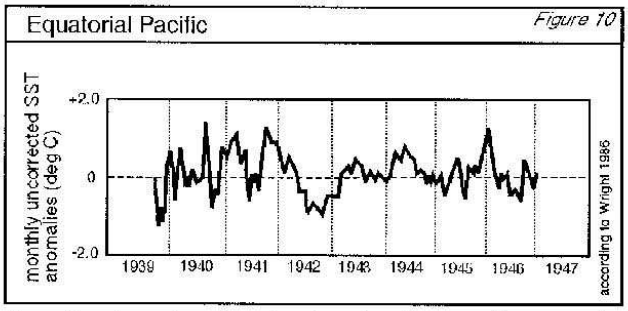
With regard to Figure 9 the coverage of more than half the Pacific from 30° N to 30° S must be questioned. From 1942 to 1945 the situation East and West of Hawaii/New Hebrides was different. In one half of the Pacific navigation was generally confined to military activities, while in the other half sea transport in convoys continued. The sudden increase in late 1941 may thus be mainly due e.g. to data from submarines (West) and convoying (East). The substantial data decrease after the war ended supports this view.



Of greater importance for a discussion are the data deviations in Figure 2 confined to the tropical sea from 10° N to 10° S and 80° W to 180° W. But as the pattern of navigation in this area from 1939 to 1945 varied extremely and information on transport was concealed as of December 1941 there is little room for a picture on conduct to any sufficient degree. The impact of the El Niño years, in particular the strong one in 1939, may nevertheless provide some indication as to the impact of WWII.

The data for late 1939 to Dec.1941 (Figure 10) do not indicate a typical ENSO event (Figure 8) in 1939, but a possible one in 1940 with a temporary 'cooling' during summer 1941. While the brief 'irritation' in late 1940 can only be commented as being "extraordinary", the drop in late 1939 can be due to the immediate 'confusion' when WWII started and the 'cooling' in 1941 could be subject to the embargo on Japan. On the other hand, the insignificant temperatures during 1940 may be due to the fact that European shipping in the Pacific was considerably reduced and often replaced by old (steamship) tonnage while the increase in early and late 1941 could be due to new freighters, greater data 'consciousness' and particularly by the growth of naval activities and transport of construction and war material. That the series 1939-1941 was effected by a mix of many circumstances can not be excluded. If so, a thesis of a continued ENSO from 1939-1941, instead of one in 1939, needs to be founded on additional or other sources than EquPac-SST.

The subsequent series from 1942-1945 (Figure 10) with a second prolonged ENSO 1942-1944 according to Grant et al. also arouses suspicion. The war and supply machinery got into full gear. Escorted convoys became the rule. The second US convoy arrived in Australia on February 1,1942. Routing changed as did the frequency of sailings. The drop of SST value over two degrees in 1942 could be due to SST taken by the engine inlet of big ships. If so, the very modest 'summer peaks' during 1943 and 1944 would require a positive correction. On the other hand, after the first twelve months of war, navigation in the East Pacific became more routine and might have caused a more frequent use of buckets.



The use of this tropical SST can not be easily applied for two separate ENSO events from 1939-1941 and 1942-1944 or as one prolonged event over the period of war. Figure 10 does not exclude it but as support it is a weak mean as well. The pre- and post war ENSO (Figure 8) are reflected too differently in the SST series as to dispel doubts. At least tropical data for ENSO research would need a closer review on an individual basis to be used as evidence or strong support. Whether the efforts would be worth the investment is difficult to say. After all, the first WWII winter 1939/40, with extreme weather conditions in the Northern Hemisphere, was accompanied by a significant shift from rising to lower global temperature values, lasting three decades. Thus any assumption or proof that the 1939 ENSO lasted until 1941 or even 1944, would need to account for the sudden shift in the Northern Hemisphere as well. The notion alone that the WWII ENSO(s) are a result of a previously unknown state (Copper et al) is too narrow a view, but if based on tropical WWII SST series more attention needs to be paid to the circumstances of navigation during the period.

CONCLUSION

A review of Pacific SST data series from 1939 to 1945 together with WWII seagoing conditions indicate detectable impacts. As one source for climatic changes and ENSO research the many facets of navigation during WWII require either a comprehensive review of the individual observations in question, or, if used as presently compiled, interpreted with extreme caution. WWII conduct at sea differed to greatly from other times.

The established difference between pre- and post war SST series is based on a comparable picture on seagoing operations and can be explained as a result of change in the methods of measurements but not the sudden "jump" by a sudden change in sample taking in late 1941. The immediate drop at the end of WWII (Fig.1) indicates the interplay of a different force but not a systematic one.

Historical SST are now evaluated and used to indicate climatic variations and dynamics. They can provide reliance as proved by pre- and post war ENSO signals in the tropical ocean (Figure 8) but in this respect corrections are not required. However, WWII produced a sea change of variations as well, defying attempts to draw a uniform background picture of observing ships sailing the seas. "Sea surface water" was not necessarily "sea surface water" (e.g. convoyed ships, submarines). As there are no sufficient means of establishing comparability between the data during WWII or between the war period and series during peace time, mere compiling and averaging of war-time marine observations cannot improve the reliability of the input. The average run of 'freak' data gives an average run of 'freak' results. Any use of SST series covering 1939 to 1945 requires due consideration of WWII conditions.

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