Development of Sea Surface Temperature (SST) in the Baltic Sea 2013

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Key message

The year 2013 was characterized by a long winter from January to May with monthly mean SSTs below the long-term average in the western and much of the central Baltic Sea. The maximum negative anomalies occurred with up to -1.5 K and -2.5 K in April and March. On average March was with 0-1 °C, unusually, the coldest month of the year. The coldest day was 25 March with maximum SST of 1 °C and maximum ice cover in the northern Baltic Sea, which was already reached on 28 January in the western Baltic Sea. In May persistent southeasterly winds transported the coastal discharge of the southern Baltic Sea (Oder, Vistula, and Courland Lagoon) into the central basin. The water surface temperature temporarily greatly increased there (e.g. MARNET station Arkona Sea). The monthly mean SSTs of June-November were in the western Baltic Sea in the range of long-term average values or slightly above. In contrast, the months June and September reached in the central and particularly in the northern Baltic Sea positive anomalies of up to 4K. The warmest month was August with 16-20 °C and the warmest day the 5 August with 20 to 22.5 °C in the western and central Baltic, and 15-17 °C in the northern parts.

Overall, 2013 was despite the long winter the sixth warmest year since 1990 with about 8 °C in the annual mean SST of the entire Baltic Sea, about 0.34 K above the long term average (7.66 °C). In particular, the months June and September contributed to this high anomaly. The western Baltic Sea was in the range of the long-term average.

Results and assessment

The annual cycle of air temperature gives an idea about the thermal development of the year expressed in the following by the cold and heat sums of the weather station Warnemünde. The cold sum of the winter 2012/2013 was with 109.5 K d slightly above the long term average (K d means 104.5). December with 33.2 K d (K d 22.7), January with 37.3 K d (K d 39.1), and March with 28.4 K d (K d 8.6) contributed particularly to this cold sum. March had reached three times the long-term average, and the relatively warm February with 10.6 K d (31.9 K d) only one-third of the long-term average. The heat sum of summer 2013 in Warnemünde was with 230.4 K d well above the long term average (150 K d). All months from May to September were above the long term average values. July with 97.3 K d (K d 56.4) and August with 82.6 K d (K d 52.2) contributed particularly to the heat sum.

The general development of SST is discussed on the basis of the monthly averages. The anomalies of the monthly mean SST of 2013 are presented in Fig. 1. Seasonal course in the monthly mean temperatures in the central regions of the Arkona-, Gotland- and Bothnia Seas are compared in Fig. 2 to the long-term

averages (1990-2010). After the comparatively normal December 2012, the entire Baltic Sea cooled down in January and February 2013 to slightly negative anomalies. The cooling continued in March in the entire Baltic, which corresponds in the northern and central Baltic Sea to the ordinary course. In the western and southern Baltic Sea at least in March usually a warming starts from the west, that these areas are characterized by negative anomalies. Thus, March was the coldest month in the entire Baltic Sea. In April a slightly warming occurred in the western Baltic, in the Gotland Sea and in the Gulf of Bothnia the temperatures remained the same. This increased the value of negative anomalies and extended the area to the central Baltic. The monthly mean SSTs were in the western Baltic 2 K below the long term average values.

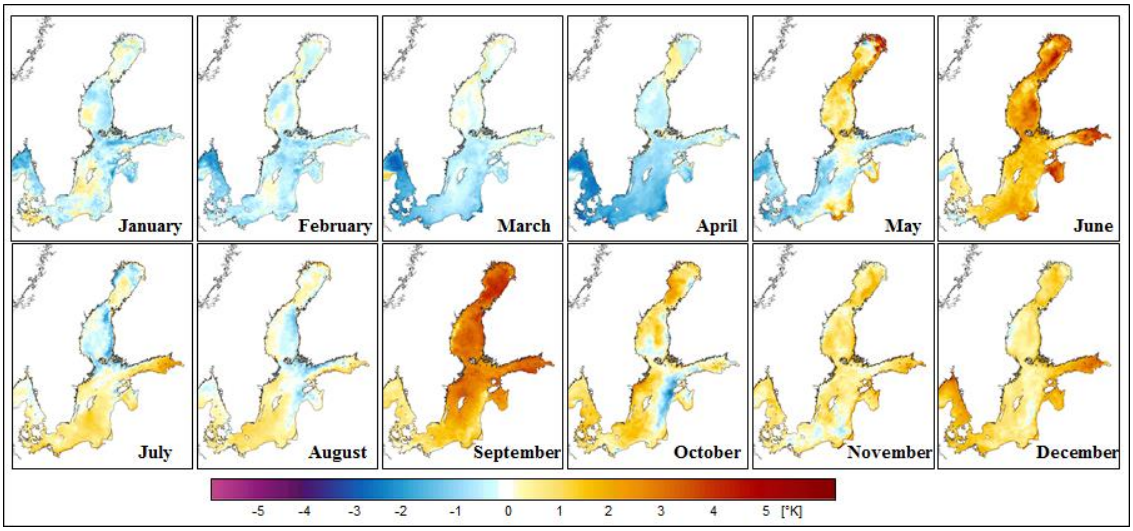

Figure 1. SST- Anomalies of the monthly averages of the Baltic in 2013 referring to the long-term means 1990 – 2010.

In the Gulf of Bothnia, the temperatures from January to April were in the range of long-term averages. The monthly mean SST of March (top) and April (bottom) along the section through the central basins of the Baltic Sea from the Mecklenburg Bight to the Bothnian Bay are shown in Fig. 3. March was the coldest month of the year and April had the highest negative anomalies. The temperatures of 2013 are compared to the previous year, to the long-term average 1990-2010 and the range of variation. In March, the monthly mean temperatures were in the western part of Mecklenburg Bight and Arkona at 1 °C and below, which meant -1.5 or -1 K below the long-term average. Eastwards the SSTs increased to values around 2 °C in the Bothnian Sea and Gotland Sea, and approached the long-term averages. In April, the SST increased less than normal to 3 °C in the MB and 2 °C from the Arkona Sea to the central Gotland Sea, which meant negative anomalies -1 to -2 K. In the Gulf of Bothnia, the SSTs were in the range of the long-term averages. In April the mean SST reached the minimum of the variation range. In May, a warming of 3.5-4.5 °C further meant negative anomalies from the western Baltic Sea over the western Gotland Sea to the Gulf of Finland. The southern, eastern and northern Baltic Sea was characterized by positive anomalies of +2 K and in the northernmost part of +4 K. In June, the SST of the

entire Baltic increased strongly and reached the long-term averages. The highest positive anomalies of up to +3 K were determined for the Gulf of Bothnia. This meant an increase in temperature from May to June of 6.5 °C in the western Baltic Sea and in the Gotland Sea, and of 7.5 °C in the Gulf of Bothnia.

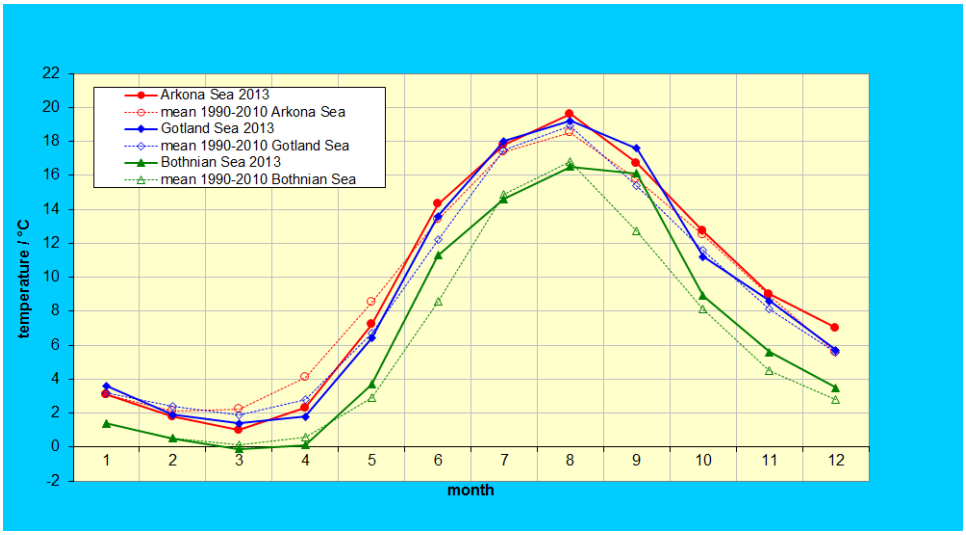

Figure 2. Seasonal course of sea surface temperature (NOAA-SST) in the central Arkona-, Gotland- and Bothnian Sea in 2013 in comparison to the mean values of the period 1990-2010.

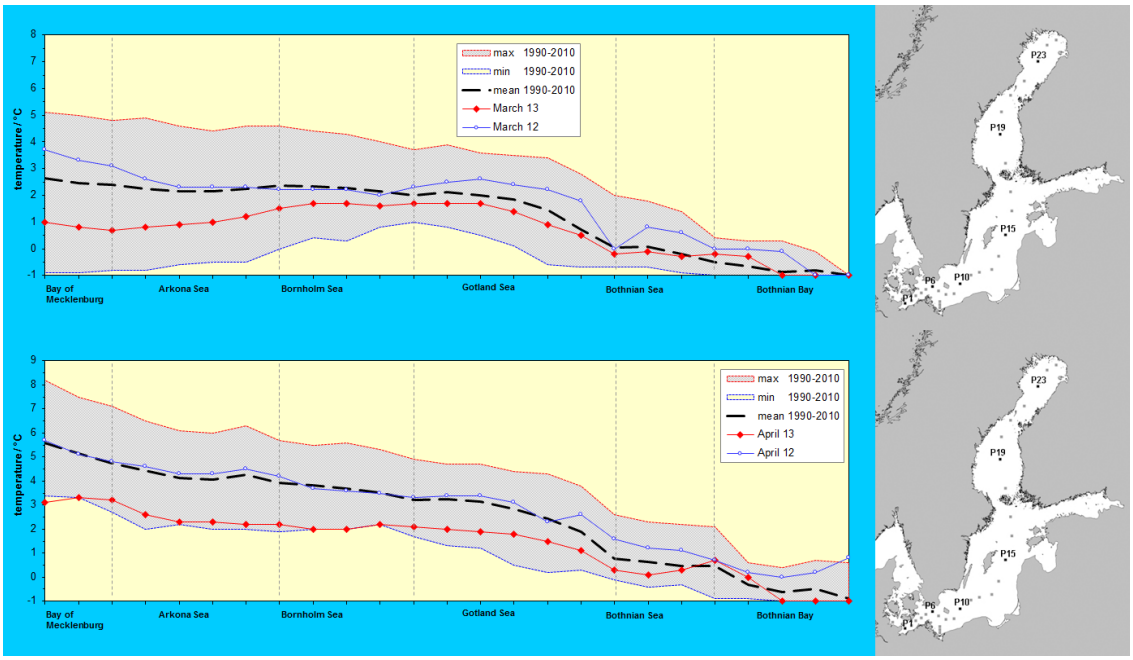

Figure 3. SST distribution along the transect through the central basins of the Baltic Sea for the coldest month March (upper panel) and April 2013 (lower panel) both in comparison to the previous year, to the long-term mean value of 1990-2010, and to the variation range.

In July and August, the temperatures were in the range of the long-term averages. Thereby August was with about 16 °C in the Gulf of Bothnia and up to 19-20 °C in the Arkona Sea and Gotland Sea the warmest month of the year. The monthly mean SSTs along the transect through the central basins of the Baltic for the warmest month August are presented in Fig. 4 (upper panel) in comparison to the averages of the previous year, the long-term averages and variation range. The SSTs from the Arkona Sea to the southern Gotland were with 19-20 °C approximately 1 K above and to the west and north in the long-term average values. From September to November the SSTs were in the western Baltic Sea in the range of long-term averages or alternately slightly above. In the other regions positive anomalies of up to +4 K were recorded in September.

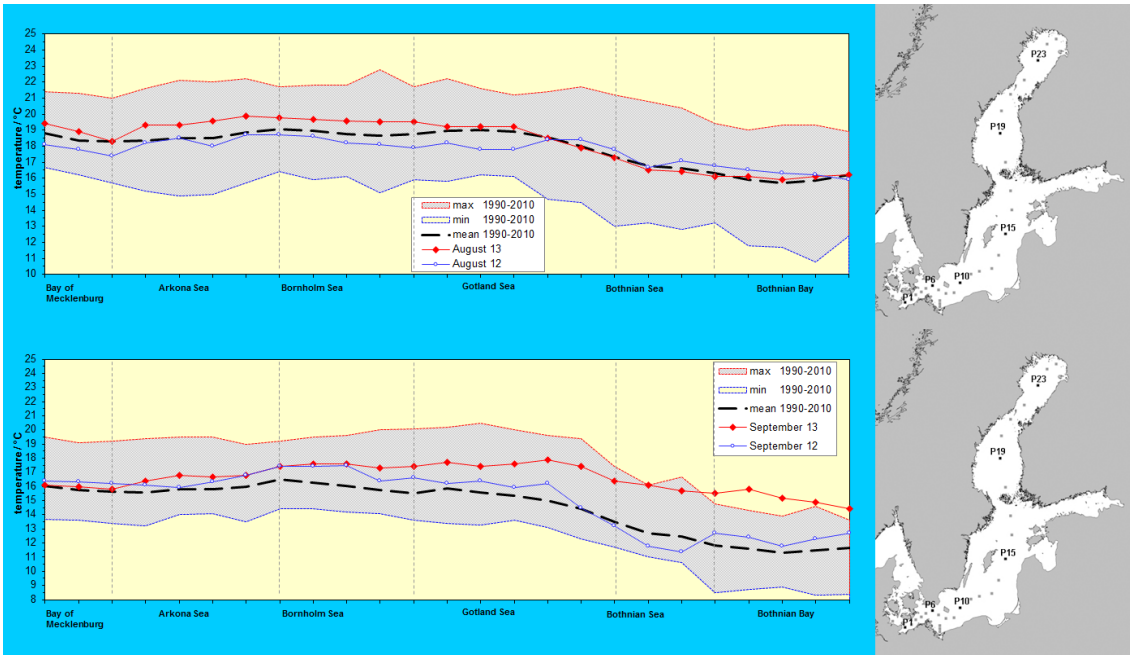

Figure 4. SST distribution along the transect through the central basins of the Baltic Sea in August and September 2013 in comparison to the previous year, the long-term mean value of 1990-2010, and the variation range.

Thus, the Baltic Sea was relatively warm with 16-18 °C and a very homogeneous distribution. In the northern Baltic Sea, it was on average warmer in September than in July. The SST transect through the Baltic in Fig. 4 (lower panel) showed very clearly the rarely occurring homogeneous distribution with temperatures between 15 and 18 °C and the increase in the anomalies from 0 K in the Mecklenburg Bight to +4 K in the Bothnian Bay.

In October and November, the SSTs were in most areas in the range of long-term average values. In December, the Belt Sea and the Gulf of Finland with anomalies of up to +2 K were relatively warm.

The following detailed description of the thermal development of the Baltic Sea in 2013 summarizes the most important phases in the course of the year. After normal December 2012, the SST was beginning of January between 2 and 4 °C in the western Baltic Sea, to 5 °C in the eastern Gotland and 0-2 °C in the Gulf of Bothnia. The cold snap in January has ensured that the formation of ice began in the inner coastal waters and also in the Pomeranian Bight. In the western Baltic Sea, the maximum ice coverage of the winter was reached already on 28 January. In the open western Baltic Sea, temperatures were at this time 1-2 °C, in the Gotland Sea 3 °C and in the Bothnian Sea more than 1.5 °C. A further ice development in the western Baltic Sea was prevented (SCHMELZER et al., 2013) by wind-induced mixing in the entire winter period. The SST stagnated until mid-February, before a cooling phase began from the west and from the north that the highest temperatures of about 2.5 °C remained in the southern Gotland. A further cooling after 10 March ensured that the March became the coldest month. The 25 March was the coldest day with maximum SST of 1 °C in the western and northern Baltic Sea, and 2 °C in the Baltic Proper, and also the day of the maximum ice cover (Nausch et al. 2014). The cold period lasted until the beginning of April. On 3 April, a first warming phase started from the west and intensified from 12 April. The heating continued until the end of the month and reached values of 4-7 °C in the western Baltic Sea, 3-4 °C throughout the Gotland Sea, and maximum 2 °C in the Gulf of Bothnia. Until 11 May, temperatures increased in the western Baltic Sea to around 8-10 °C and in the Pomeranian Bight to 10-12 °C. Thereafter, the MARNET station "Arkona Sea" measured a marked increase in temperature (Nausch et al. 2014, Fig. 13). The warm water from the Oder River was transported into the central Arkona Sea. The maximum extension was reached on May 20 (Fig. 5), showing the warm water having in the Pomeranian Bay 15 °C and in the Arkona Sea about 12-13 °C, which was in agreement with measurements at the MARNET station (Nausch et al. 2014, Fig. 13). This situation is similar throughout the southern Baltic Sea (Oder, Vistula, and Courland Lagoon). Due to the strong coastal runoff and southeasterly winds the river water was transported into the central basins and increased the SST here. A following wind mixing destroyed the stratification and reduced the temperature to 10-11 °C before end of May a slight

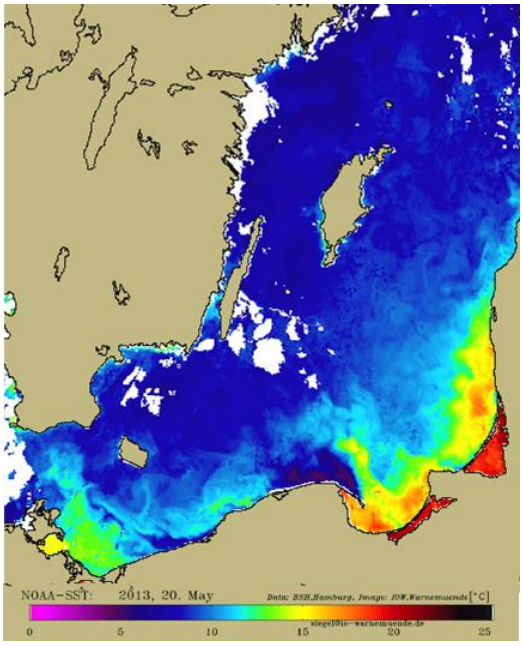

Figure 5. Temperature distribution in the southern Baltic Sea on 20 May 2013 showing the influence of coastal discharge in the central

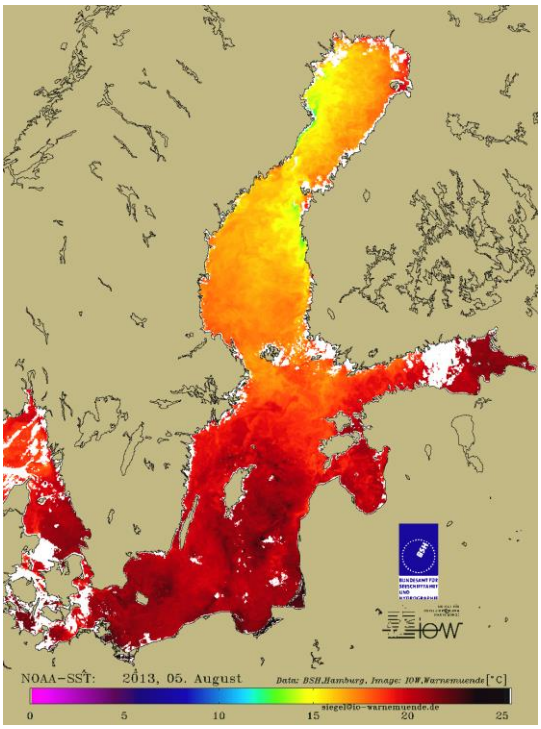

Figure 6. Temperature distribution in the Baltic Sea on the warmest day of the year (5 August 2012).

warming started. This was particularly evident for the northern coast of the Bothnian Bay with SSTs of 15-16 °C also traceable in the monthly means and anomalies. During a low-wind phase from 5 June, the heating expanded rapidly eastward and affected the central Baltic Sea, and particularly the Gulf of Finland and the Gulf of Riga. In these two regions, the SST has already been increased to 16-19 °C. On 8 June, in the western Baltic temperatures of 14-17 °C were recorded, in the Gotland 12-14 °C, and in the northern Baltic Sea 7-11 °C. This situation maintained in the central areas until about 17 June before from 18 June a new heating phase began. Wind events with heavy cloud cover and wind speeds of 13-16 ms^{-1} on 26 June and 30 June initiated mixing and temperatures of 13-17 °C throughout the Baltic Sea at the end of the month. From 3 July, three strong warming phases took place interrupted by low pressure systems with wind-induced mixing that prevented a continuous warming. End of July, 16-18 °C remained in the Gotland Sea, 20-23 °C in the Mecklenburg and Pomeranian Bights, and 11-16 °C in the Gulf of Bothnia excluded from the warming in July. High pressure influence with low wind increased the temperatures to 20-22.5 °C throughout the western and central Baltic Sea and made the 5 August to the warmest day of the year (Fig. 6). The northern Baltic Sea has also warmed up to 15-17 °C. Low pressure systems after 5 August brought only a slight temperature decrease, but the wind period from 9 August to 14 August mixed surface water and the SST decreased significantly to 17-19 °C on 15 August. After stagnation until 22 August the SST decreased by strong upwelling along the German coast. Although the southern Baltic Sea was quite chilled, the 15-17 °C were still present in the Gulf of Bothnia. Low pressure influence from 30 August and wind events on 1 and 2 September provided a mixing and temperatures of 16-18 °C in the Baltic Proper and 13-16 °C in the northern Baltic Sea remaining until about 14 September. Following low pressure systems with wind mixing reduced the SST until the end of the month to 13-15 °C in the western and southern Baltic, and to 8-13 °C in the northern and northeastern parts. For the strong cooling in October wind-induced mixing and especially upwelling along the German and Polish, as well as along the coasts of the Baltic countries and in the Gulf of Bothnia were responsible. End of the month the SSTs were 10-12 °C in the southern Baltic Sea and 5-10 °C in the northern parts. The SST decreased continuously and showed at 15 November 5-10 °C, the beginning of December 6-8 °C and in the north 0-5 °C, at 15 December 3-5 °C and 0-3 °C in the Gulf of Bothnia, which was maintained until the end of the year.

Overall, 2013 was despite the long winter the sixth warmest year since 1990 with an annual average of 8.1 °C, 0.4 K above the long term average (7.7 °C). This was mainly due to the high temperature anomalies in June and in September in the northern Baltic. The SST of the western Baltic Sea was in the

range of the long-term average. In Table 1 the annual means of the entire Baltic Sea of the last 4 years are presented including the warmest year 2008 and the coldest 1996. These are compared to the annual means of single points representing the central parts of Arkona, Bornholm, Gotland and Bothnian Seas and to the long-term averages of the period 1990-2013. The positive anomaly of the annual mean SST of the entire Baltic is dominated in 2013 by the Gotland Sea and the Gulf of Bothnia.

Table 1. Annual mean SSTs of the entire Baltic Sea of the last 4 years including the warmest year 2008 and the coldest year 1996 as well as the means of single points representing the central parts of Arkona, Bornholm, Gotland and Bothnian Seas and their standard deviation as well as the long-term averages (1990-2013).

year	Baltic	Arkona Sea	Bornholm Sea	Gotland Sea	Bothnian Sea
1996	6.6	8.0 ± 6.6	8.0 ± 5.9	7.6 ± 6.3	5.8 ± 6.4
2008	8.5	10.3 ± 5.6	10.3 ± 5.5	9.8 ± 5.6	7.3 ± 5.3
2010	7.5	8.5 ± 6.9	8.7 ± 6.6	8.9 ± 6.8	5.8 ± 6.3
2011	7.9	8.6 ± 6.3	8.8 ± 6.4	8.9 ± 6.8	6.6 ± 6.6
2012	7.8	9.0 ± 5.8	9.2 ± 6.2	9.1 ± 5.6	6.4 ± 5.5
2013	**8.1**	**9.4 ± 6.7**	**9.6 ± 6.8**	**9.1 ± 6.7**	**6.8 ± 6.4**
mean 90-13	7.7	9.3	9.4	8.9	6.2

After the warmest year 2008 stagnation occurred, but only the SST of 2010 was below the long-term average. Within the last years, the inter-annual SST variations of the entire Baltic are dominated by the Bothnian Sea showing quite good similarities. The highest standard deviation was derived for the Arkona Sea due to the cold winter and warm summer in 2010. The time series of the Sea Surface Temperature of the Baltic for the period 1990-2013 delivered a positive trend of 0.51 °C/decade (Fig. 7).

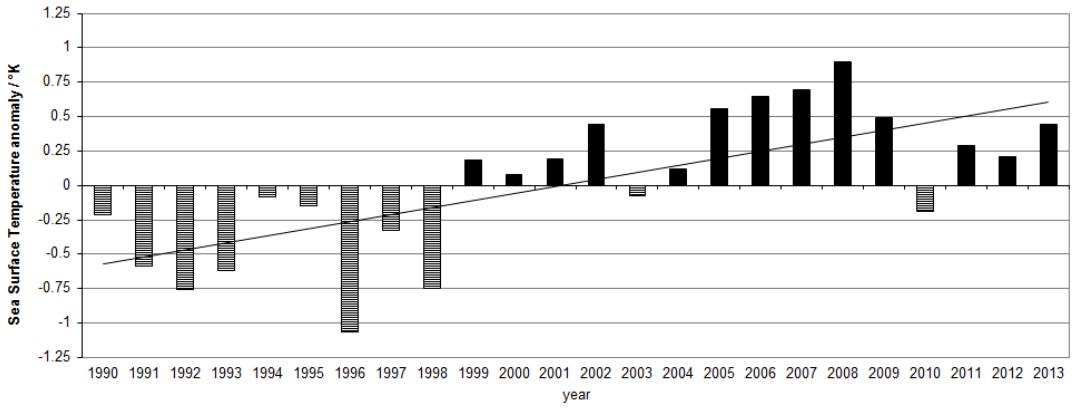

Figure 7. Trend of SST- Anomalies of the annual averages of the Baltic referring to the long-term means 1990 – 2012.

Data and metadata

This HELCOM Baltic Sea Environmental fact sheet for is based on satellite derived Sea Surface Temperature (SST) and heat and cold sum of air temperature measured in Warnemünde.

Sea Surface Temperature (SST) of the Baltic Sea derived from data of the Advanced Very High Resolution Radiometer (AVHRR) of the National Oceanic and Atmospheric Administration (NOAA) weather satellites NOAA 17 und 19 and from the European Weather satellite MetOp-2 was provided by the German Federal Maritime and Hydrographic Agency Hamburg (BSH) since 1990. The data evaluation procedure is described by Siegel et al. (2008). Daily mean values used for detailed description of the temperature development are calculated from up to seven overpasses covering the entire Baltic Sea. Monthly averages calculated from the daily means in each point are implemented for general statements. Yearly average of the entire Baltic are determined from the monthly averages and used for the assessment of the year in relation to the long-term mean values. Systematic studies on seasonal and inter-annual variations in SST are published by Siegel et al. (2006, 2008). SST was implemented in the yearly assessment of the Baltic Sea since 1996 provided by the Baltic Sea Research Institute Warnemünde (Matthäus et al. 1997). This environmental fact sheet is based on the results of the German assessment of the state of the Baltic Sea of 2013 (Nausch et al. 2014).

The air temperature data of Warnemünde provided by the German Weather Service was used to calculate the heat and cold sum which permits to evaluate the intensity of summer and winter.

References

Matthäus, W., D. Nehring, H.-U. Lass, G. Nausch, K. Nagel, H. Siegel, (1997). Hydrographisch-chemische Zustandseinschätzung der Ostsee 1996, Meereswissenschaftliche Berichte, Institut für Ostseeforschung Warnemünde, 24, 1-49.

Nausch, G., R. Feistel, L. Umlauf, V. Mohrholz , K. Nagel, H. Siegel, (2014): Hydrographisch-chemische Zustandseinschätzung der Ostsee 2013 . Marine Science Report, Baltic Sea Research Institute Warnemünde, 93, 1- 104.

Siegel, H., and Gerth, M., 2012. Development of Sea Surface Temperature in the Baltic Sea in 2011. HELCOM Indicator Report, http://www.helcom.fi/environment2/ifs/ifs2008/en_GB/sst/

Siegel, H., M. Gerth, G. Tschersich (2006): Sea Surface Temperature development of the Baltic Sea in the period 1990-2004, Oceanologia, 48 (S) 119-131.

Siegel, H., M. Gerth, G. Tschersich, (2008). Satellite-derived Sea Surface Temperature for the period 1990-2005. In: State and Evolution of the Baltic Sea, 1952–2005, A Detailed 50-Year Survey of Meteorology and Climate, Physics, Chemistry, Biology, and Marine Environment. Ed. By R. Feistel, G. Nausch, N. Wasmund, Wiley 2008, 241-265.

Acknowledgement

The authors thank Mrs. G. Tschersich and the BSH Hamburg for providing the NOAA AVHRR data.

For reference purposes, please cite this Baltic Sea environment fact sheet as follows:

[Author's name(s)], [Year]. [Baltic Sea environment fact sheet title]. HELCOM Baltic Sea Environment Fact Sheets. Online. [Date Viewed], http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/.

Last updated 3.11.2014