Development of Sea Surface Temperature (SST) in the Baltic Sea 2014

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Key message

2014 was the warmest year since 1990 with about 2.3 K above the average of the period 1990-2014 and 0.5 K above the previously warmest year 2008. All months except February and June contributed and in particular, the months of July and August in the northern Baltic. The western Baltic was in all months +1 to +3 K above the long-term average.

After mild start of the year, a cold snap from around 20/01/2014 caused a strong cooling until early February. Nevertheless, the January- monthly average was +2 K higher than the mean values (1990-2014) and January 2014 was the second warmest after 2007 in the western Baltic Sea. February was in the range of the long-term mean values and was in the Arkona Sea and the Gulf of Bothnia, the coldest month of the year. The 4 February was the coldest day in the entire Baltic Sea. March developed as usual to the coldest month of the year in the central Baltic Sea. From March to May, anomalies of +1 to +3 K were recorded throughout the Baltic Sea and even from March to December in the western part. June was the only month with basin-wide negative anomalies of -1 to -2 K in the central and northern Baltic Sea. July was only in the Mecklenburg Bight the warmest month, otherwise August. The warmest day was 28 July with temperatures of 21-25 °C. The atypical uniform temperature distribution throughout the Baltic Sea in July and August led to high anomalies of up to + 5 °C in July in the northern Baltic Sea. The July 2014 was the warmest since 1990 in that area. The months of October and November were with anomalies of up to +3 K respectively warmest month in the western Baltic Sea in the last 25 years.

Results and assessment

The cold and heat sums of the air temperature of Warnemünde (Nausch et al. 2015) provide information about the severity of the winter and the course of the summer. With a cold sum of 66 K d in Warnemünde the winter belonged 2013/14 of the warmest winters since 1948. This cold sum completely accounted to the month of January, which was essential colder than the long-term January mean of 39.1 K d. The remaining winter months were +2 to +3.5 K to warm. The total heat sum of the year 2014 was in Warnemünde with 236.9 K d just above last year's levels (230.4 K d), but well above the long-term average (150 K d). The months of May and July to October were above long-term averages and July contributed in particular to the heat sum with 117.7 K d (56.4 K d).

The general development of SST is discussed on the basis of monthly averages. The monthly anomalies 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 and the variation range of the period 1990-2014. The detailed description of the temperature development is based on daily averages, which are not presented here.

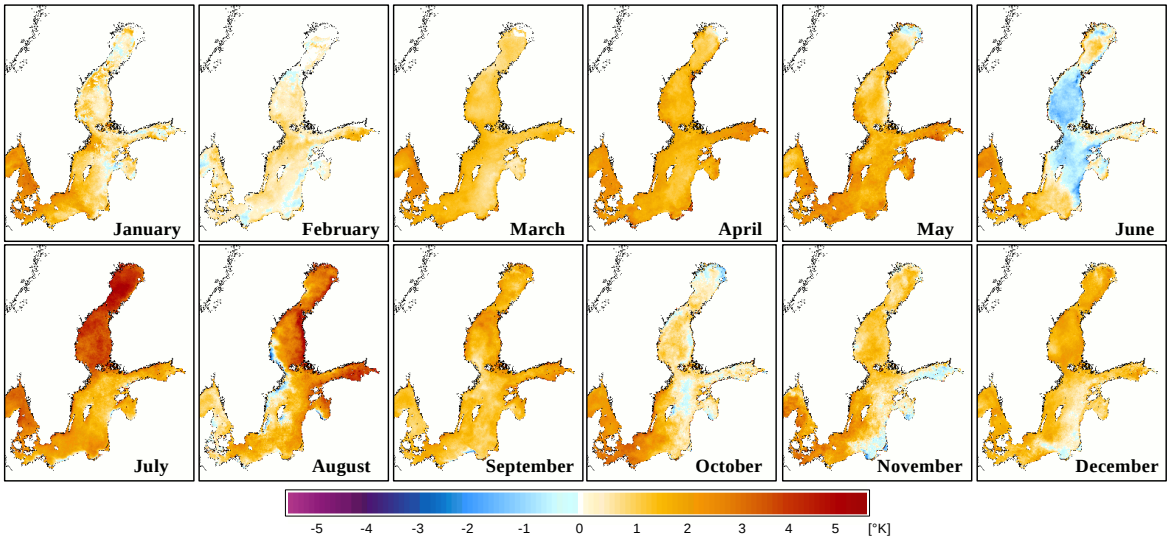

Figure 1. SST- Anomalies of the monthly averages of the Baltic in 2014 referring to the long-term means 1990 – 2014.

After relatively mild first half of January in the western Baltic Sea with SST of 5 °C, a cold snap from around 20/01/2014 (see cold sum of air temperature) caused a strong cooling until the beginning of February. The SST decreased to about -0.5 °C in the Pomeranian Bay (PB), 1-2 °C in the Mecklenburg Bight and 2-3 °C in the Arkona Sea on 4 February (Fig. 3). This was also the coldest day in the German coastal waters and in the entire Baltic Sea. Despite the cooling, the monthly mean anomalies of January show up to +2 K and January 2014 was after 2007 second warmest January of the last 25 years in the western Baltic Sea. The temperatures reached in early February remained to the end of the month. February was in the range of the long-term mean values and was in the Arkona Sea and the Bothnian Sea the coldest month of the year. The following days, a wind mixing caused a slight cooling in the Arkona Sea, the shallow areas warmed up slightly. From mid-February, a slight warming led to temperatures of 2-3 °C end of the month. March was characterized by a uniform increase with short periods of stagnation. End of the month, 4-5 °C were achieve throughout the western Baltic Sea, 3-5 °C in the central Baltic Sea to the Gotland Sea and 0.5-2 °C in the Gulf of Bothnia and in the Gulf of Finland.

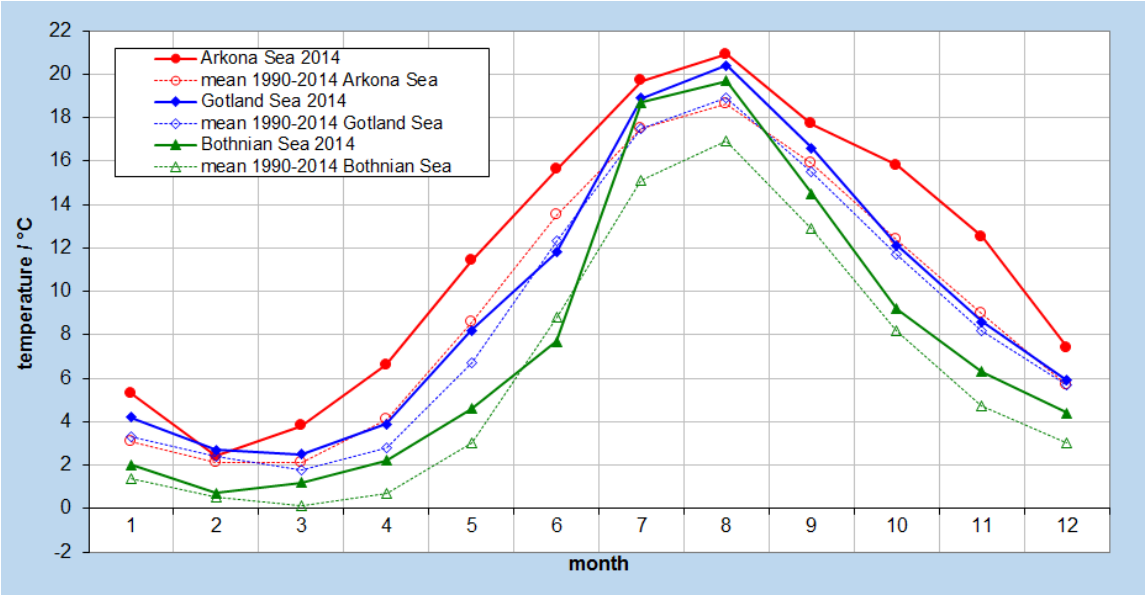

Figure 2. Seasonal course of sea surface temperature (NOAA-SST) in the central Arkona-, Gotland- and Bothnian Sea in 2014 in comparison to the mean values of the period 1990-2014.

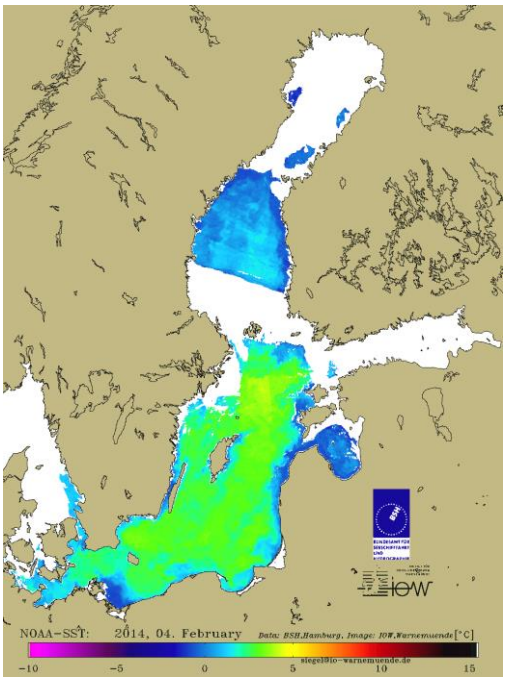

Figure 3. SST of the Baltic on 04 February, the coldest day of the year 2014.

From March to May, the entire Baltic was characterized by anomalies of +1 K to +3 K. As usual, March was the coldest month in the Gotland Sea. In the western Baltic, anomalies remained similar throughout the years and exceeded the +2 K in October and November only. The heating continued in April without strong wind mixing, which often caused drastic temperature changes in previous years. In the shallow areas of the Mecklenburg Bay (MB), the Pomeranian Bay (PB) and the Gdansk Bay (GB) values of 10 °C were partially achieved by the end of the month. In the central areas of the western Baltic Sea, SST was 7-8 °C and of the central Baltic 5-7 °C. In the northern Baltic Sea, the SST already reached 2-4 °C. This was significantly warmer than in the previous year at the same time. By mid-May, the western Baltic warmed slowly up to 9-12 °C and the northern Baltic Sea to 2-5 °C. A

rapid warming from 20 May led on 26 May to values of 14-17 °C in the western Baltic Sea, 12-15 °C in the Baltic Proper, 10-12 °C in the northern Gotland, and 5-8 °C in the Gulf of Bothnia. Thereafter, a wind-induced mixing caused the first serious cooling of the year by more than 1-2 °C. May was particularly warm with +2 to +3 K and after May 2008 the second warmest of the last 25 years. Large variations occurred in the anomalies in the northern Baltic Sea. In May and especially in June (Fig. 2), the typical north-south increase with up to 8 K was very pronounced. The temperature distribution along the section through the central basin of the Baltic Sea for the month of June 2014 shows that very impressive in Fig. 4, compared to the long-term average from 1990 to 2014, the year before and the variation range.

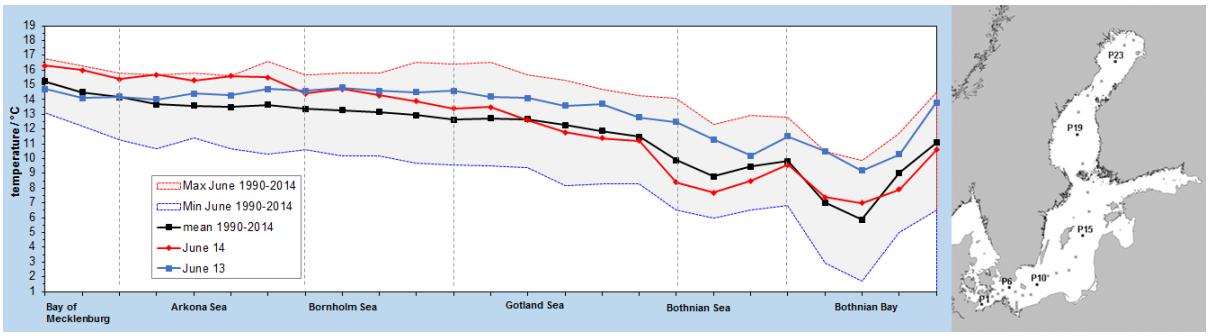

Figure 4. Distribution of monthly mean SST along the transect through the central basins of the Baltic Sea for June 2014 in comparison to the long-term mean value of 1990 – 2014, to the previous year, and to the variation range

June was highly variable, high-pressure phases, which ensured a warming were repeatedly interrupted by deep pressure systems with high cloud cover and wind. As a result, the water temperature only slightly increased in June. The monthly mean temperatures were relatively low and caused negative anomalies in the central and northern Baltic Sea. The monthly mean SST was in the Arkona Sea already at 16 °C (anomaly +2 K), in the Gotland Sea at 12 °C (-0.5 K), and in the Bothnian Bay at 7.5 °C (-1.5 K) only. The next massive warming took place in early July. On 06 July, SST increased to 17-20 °C in the western Baltic Sea, to 15-18 °C in the central Baltic Sea and 12-16 °C in the Gulf of Bothnia. In the next few days, the northern Baltic heated particularly strong, so that uniform temperatures of 16-20 °C prevailed on 9 July in the entire Baltic Sea. After a wind-induced mixing of 12-15 July, these temperatures were reached again on 16 July. Thereafter, the temperature strongly increased during a low wind phase. From of 22 July the northern Baltic Sea was warmer than the central and western parts. Easterly winds and upwelling along the German and Polish coast prevented a stronger warming in the southern and western Baltic Sea. From 25 July, the SST in the northern Baltic Sea was 23-25 °C. A reduction in the intensity of upwelling ensured that the 28 July developed with temperatures of 21-24 °C to the warmest day of the entire Baltic (Fig. 5). After that, easterly winds in the south and west winds in the north intensified upwelling in the southern Baltic Sea and in the Gulf of Bothnia. That reduced the SST to below 19 °C in the upwelling regions and 23 °C in large parts of the Baltic Proper.

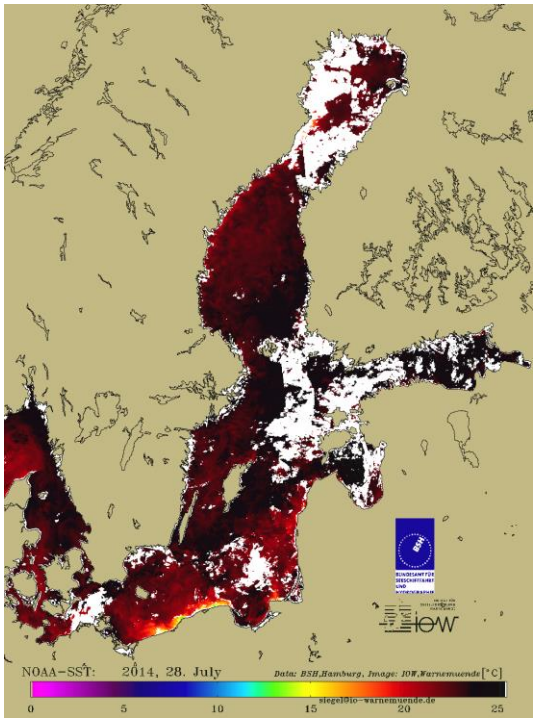

Figure 5. SST of the Baltic on 28 July, the warmest day of the year 2014.

In contrast to all other months, in July and August the North - South gradient did not exist, that the entire Baltic Sea had similar monthly mean temperatures of about 19-21 ° C. This is very nicely seen in the annual cycle of SST in the three central basins in Fig. 2. The monthly mean values are very close together. The temperature distribution along the section through the central basin is compared for the month of July 2014 in Fig. 6 to the long-term average 1990 - 2014, the previous year and the variation range. The figure clearly shows the small temperature differences along the section (red curve). In the north, in the Bothnia Bay and Bothnian Sea July average 2014 determined the upper limit of the variation range of the entire study period. As a result, extreme anomalies arose in the northern Baltic Sea with up to +5 K. The July 2014 was in the northern Baltic Sea by far the warmest of the last 25 years.

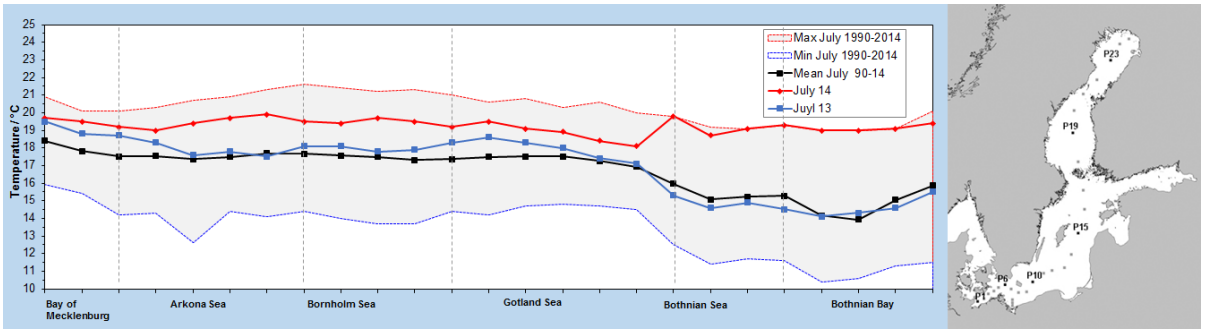

Figure 6. Temperature distribution along the transect through the central basins of the Baltic Sea in July 2014 in comparison to the previous year, to the long-term mean value of 1990 – 2014, and to the variation range of the investigation period.

The temperatures of the end of July continued until approximately 9 August before a first cooling began. Passage of low-pressure systems in the second half of August caused further cooling, so that the SST was reduced end of the month to 17-18 °C in the western and southern, and to 13-17 °C in the central and northern Baltic Sea. In the three selected areas, August became the warmest month of the year. He was also next to August 2002, the warmest in the observation period. The further course was characterized by positive anomalies in the monthly average. Only in the eastern Gotland, the monthly means were in the range of the long-term average values. The temperatures of the end of August persisted until about 10 September. Until 20 September, temperatures stagnated in the southern Baltic Sea at about 17 °C before low-pressure areas caused wind-induced mixing and a reduction of temperature. End of the month, SSTs of about 15-16 °C were observed in the southern and western Baltic Sea, 13 -15 °C in the central and 8-13 °C in the northern Baltic Sea. From 3 to 6 October it came to a brief warming in the western to 15-17 °C, which represented a difference of more than + 2 K compared to last year. Then the next cloudy phase began, in which the SST had steadily decreased until the end of the month to 12-14 °C in the western Baltic, 9-13 °C in the central and 3-8 °C in the northern Baltic Sea. The SST anomalies of October and November were in the western Baltic particularly pronounced (Fig. 1, 2), and the highest in the past 25 years. The monthly average SST in October along the section through the central basins of the entire Baltic shows this clearly (Fig. 7). The monthly average determined the maximum values of the variation range of the study period in the western Baltic Sea. The temperatures remained until about 11 November before low-pressure system with high cloud cover passed. By the end of the month, in particular the shallow areas of the western Baltic Sea and the Baltic Proper cooled to 7-8 °C. The Arkona and Bornholm Seas were still at 10 °C, whereas the lagoons and the northern Bothnian Bay had only 1-4 ° C. From 2 December, the SST decreased especially in the shallow parts of the western Baltic Sea. These temperatures of 5-7 °C lasted until about 20 December before the SST reduced in the entire Baltic Sea to 1 °C in the northern Baltic Sea, to 6 °C in the southern Baltic Sea by the end of the year.

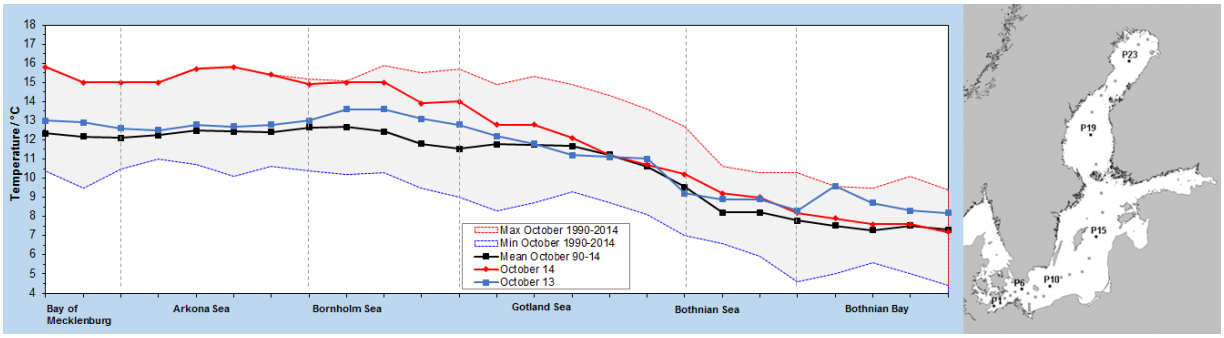

Figure 7. Temperature distribution along the transect through the central basins of the Baltic Sea October 2014 in comparison to the previous year, to the long-term mean value of 1990 – 2014, and to the variation range of the investigation period.

Overall, 2014 was the warmest year of the last 25 years with an annual average of 9.0 °C, 2.3 K above the long-term average (7.7 °C) and 0.5 K above the previously warmest year of 2008. In Table 1, the annual means of the entire Baltic Sea of the last 5 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 1990-2014. Fig. 8 shows the anomalies of the yearly mean SST of the entire Baltic for the last 25 years including the trend line.

In the western Baltic Sea, the anomaly of the monthly mean values was, except in February, above the long-term average values. In October and November, sometimes even +3 K were exceeded, which meant that both months developed to the respective warmest of the last 25 years. In the central and northern Baltic Sea in particular, the months of July and August contributed to the warmest year in the northern Baltic Sea. Atypical uniform temperature distributions throughout the Baltic Sea have led in July to anomalies of up to + 5 ° C in the northern Baltic Sea. The western Baltic Sea and the Gulf of Bothnia contributed most to the positive anomaly of the annual mean SST of the entire Baltic in 2014.

Table 1. Annual mean SSTs of the entire Baltic Sea of the last 5 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 the standard deviation. The long-term averages of the period 1990-2014 are presented in addition.

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
2014	**9.0**	**11.6 ± 6.4**	**11.0 ± 6.3**	**9.7 ± 6.3**	**7.6 ± 6.7**
mean 90-14	7.7	9.4 ± 0.7	9.4 ± 0.6	8.9 ± 0.5	6.3 ± 0.6

During the last 15 years, only the yearly averages of 2003 and 2010 have been below the long-term averages. After the previous warmest year 2008, stagnation occurred before 2014 became the warmest year. The time series of the Sea Surface Temperature of the Baltic for the period 1990-2014 delivered a positive trend of 0.57 °C/decade (Fig. 8).

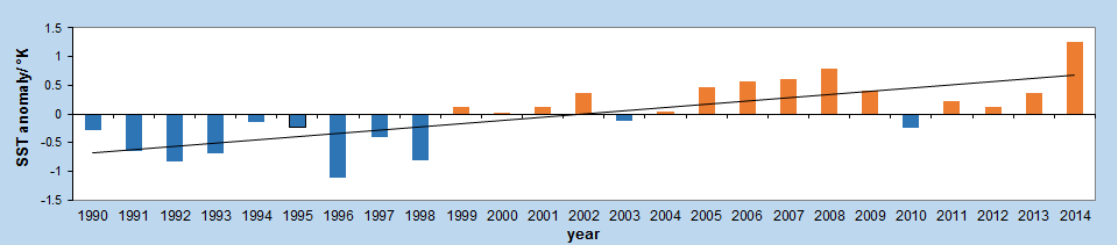

Figure 8. Anomalies of yearly average temperature of the entire Baltic Sea of the last 25 years (1990-2014).

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Data and Metadata

This HELCOM Baltic Sea Environment Fact Sheet 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 was 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. The data were 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.