Development of Sea Surface Temperature (SST) in the Baltic Sea 2015

Authors: Herbert Siegel and Monika Gerth,
Leibniz Institute for Baltic Sea Research Warnemünde (IOW)

Key message

The year 2015 was after 2014 the second warmest year since 1990, 0.9 K warmer than the long-term average (1990-2015) and 0.3 K colder than the warmest year 2014. All months contributed with their positive anomalies to the high annual average except the summer months June-August. SST anomalies of up to +2 K characterized nearly the entire Baltic from January – May, due to one of the mildest winter in air-temperature since 1948. January – March and October belonged each to the warmest months since 1990. In the Baltic Proper, March was the coldest month of the year and February in the Arkona and Bothnian Seas. February, 18-24, was the coldest week in the entire Baltic. The lack of typical atmospheric warming, particularly in June, led to negative anomalies in the monthly mean SST. A warming phase beginning of July followed by a long phase of deep pressure influence made 5 July to the warmest day in the western and central Baltic and caused negative anomalies for July. Due to the SST increase in August in the northern Baltic, 19 August became the warmest day of the year there. The anomalies became positive in the North and slightly negative in the South. As in long-term average, August was the warmest month of the year. From September to December, positive anomalies slightly increased so that November and December 2015 became the warmest months since 1990 each.

Results and assessment

The cold and heat sums of air temperature of Warnemünde (Nausch et al. 2016) give information about the severity of winter and course of summer. The winter 2014/15 was with a cold sum of 19.8 Kd one of the mildest since 1948. December and November 2014 contributed with about 78 % to this cold sum and February 2015 with only 22 %. The heat sum for summer 2015 (182.3 Kd) was approximately 50 Kd lower than 2014, but exceeded the long-term average (151.3 Kd). July and August exceeded only slightly the long-term means. November and December were very mild without any daily mean temperature below zero.

Anomalies of monthly mean SST of the Baltic Sea in Fig. 1 represent the overall thermal development in 2015. The seasonal development of monthly mean SST in the centre of the Arkona, Gotland and Bothnian Seas is compared to the long-term monthly means (1990-2015) in Fig. 2. Daily mean SST is the basis for the detailed discussion of the development. Positive anomalies of +1.5 to +2 K characterized the winter 2014/2015 from November to April and September to December 2015. January to March and November to December belonged each to the warmest months since 1990.

Beginning of January, the SST was in the open western Baltic and Gotland Sea around 5 °C. Arkona Sea cooled down to 3-4 °C mid-February and the Gotland Sea to around 3 °C beginning of March. In the

Arkona Sea and Bothnian Sea, the mean SST of February and March were rather similar and represented the annual minimum (Fig. 2).

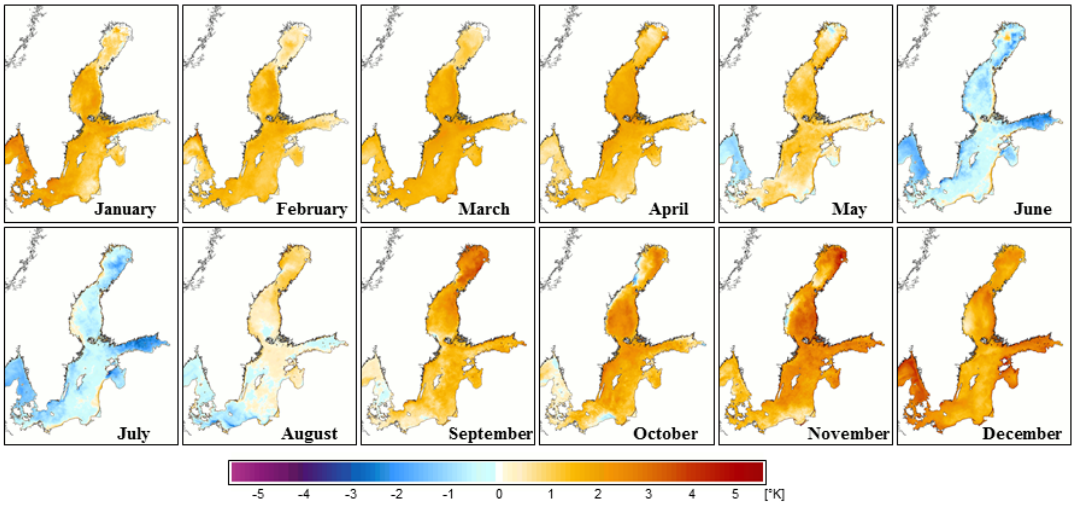

Figure 1. SST- Anomalies of the monthly averages of the Baltic in 2015 referring to the long-term means 1990 – 2015.

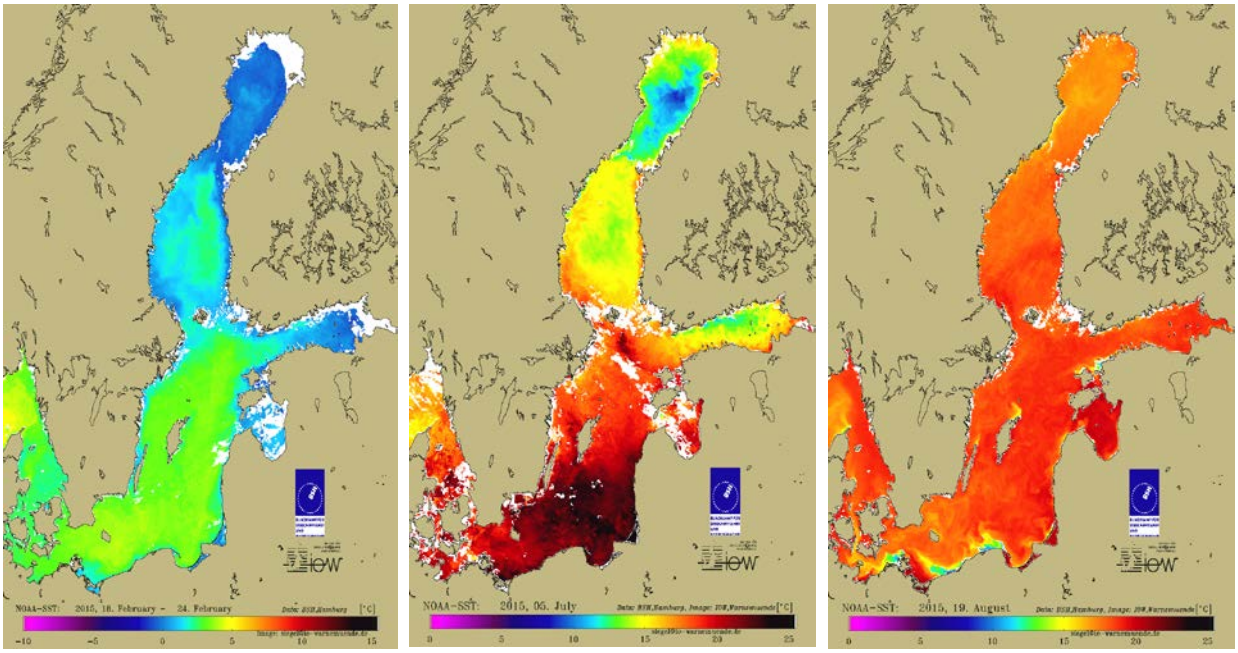

Figure 2. SST of the Baltic for 18 - 24 February, the coldest week (a), on 5 July, the warmest day of year 2015 in the southern Baltic Sea (b) and on 19 August, the warmest day in the northern Baltic (c) with rather homogeneous distribution and strong upwelling along the southern coast.

Only in the Gotland Sea, the March was slightly colder. Because of the strong changing cloud coverage, it was difficult to define the coldest day. The week, February 18-24, was selected as the coldest week in the entire Baltic with 2 - 4°C except the colder Bothnian Bay and inner Gulf of Finland

(Fig. 3a). The transect of mean SST in February in relation to long-term average (1990-2015), previous year, and variation range (Fig. 4a) reflect the impression from Fig. 1. SST is higher than the long-term averages, but in the variation range. March started with slight warming before after a stagnation a stronger heating occurred from 25 March reaching end of March 5 °C in the Western Baltic and about 4 °C in the Gotland Sea. After 10 April, a stronger warming occurred from the West and influenced the Gotland Sea and Bothnian Sea. End of April, SSTs of 8-9 °C in the Mecklenburg Bight, 7-8 °C in the Arkona Sea, 5-6°C in the Gotland Sea and about 3 °C in the Bothnian Sea were observed. This led to monthly anomalies of +1 to +2 K in the entire Baltic Sea. Further heating in May in the Arkona Sea was not as pronounced as normal. SST of the Arkona Sea approached the long-term averages. The Gotland Sea and Bothnian Sea show nearly the same anomalies as in the months before. End of May, the SSTs in the different basins were similar to the values end of April. In June and July, the anomalies are slightly negative with 0 to -1 K in the entire Baltic Sea except for the Gulf of Finland with -1 to -2 K (Fig. 1). The typical warming in June was much slower than in the long-term averages (Fig. 2).

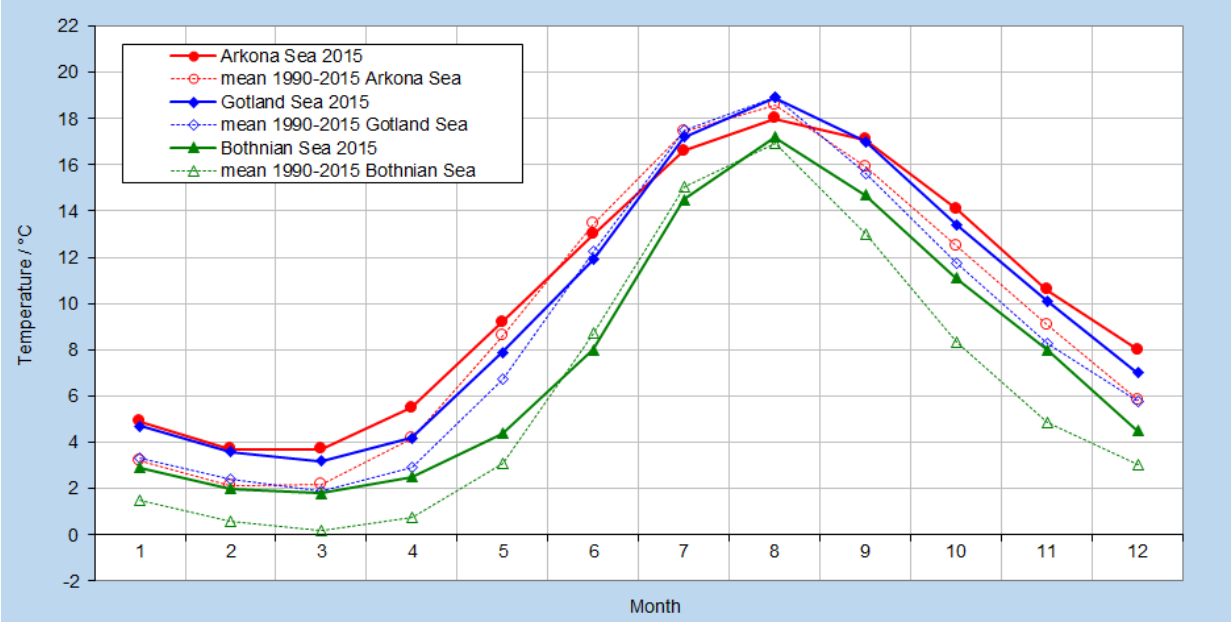

Figure 3. Seasonal course of sea surface temperature (NOAA-SST) in the central Arkona-, Gotland- and Bothnian Sea in 2014 in comparison to the mean values of the period 1990-2015.

After a stagnation in the first decade of June, a first warming occurred and a second started on 20 June and extended to northern parts. By the end of June, SST reached 15-18 °C in western Baltic, 15-16°C in Gotland Sea and about 12-13 °C in Bothnian Sea. This warming intensified from 1 to 5 July followed by changing meteorological conditions that 5 July reached SSTs of up to 20°C in the western Baltic and up to 22°C in the southern Gotland Sea and developed to the warmest day of the year there (Fig. 3b). The northern Baltic was excluded from this warming. The central parts of Bothnian Sea and Gulf of Finland had only 13-15°C and Bothnian Bay 10-13°C. Westerly winds of up to Beaufort 8 starting from 6 July mixed the surface water and reduced the SST to 15-17°C particularly in the southern and western Baltic.

In the following days, SST increased more in the northern parts that the entire Baltic had similar temperatures of 15-18°C end of the month. Low-pressure systems with changing wind and cloud coverage prevented further warming. This resulted in monthly mean SSTs of July just below the long-term average (1990-2015), presented in Fig. 4b with the previous year and the range of variation. Anomalies of up to -2 K occurred only in the Gulf of Finland due to the long lasting westerly wind and induced upwelling there (Fig. 1). In the first decade of August, SST increased in the entire Baltic Sea. After a short interruption, the high-pressure system "Isabel" (Nausch et al. 2016) determined the weather in the Baltic region from 15 August, particularly in the northern parts. The image on 19 August (Fig. 3c), shows a homogeneous SST distribution in the entire Baltic and 18°C represent the maximum of the year in the North. Easterly winds continued until 25 August, inducing upwelling at the southern coasts reducing SST with core temperatures of less than 10°C. Monthly mean SST of 17-19°C in the entire Baltic led to the slight negative anomalies in the southern and western and to positive in the northern Baltic (Fig. 1). As in the long-term average, the August was clearly the warmest month of the year 2015 (Fig. 3). After the 25 August, westerly winds induced upwelling in the northern Baltic, stopped the upwelling at the southern coasts and reduced slightly the SST throughout the Baltic. Beginning of September, SST decreased stronger until 8 September followed by a 10 days stagnation. Around 20 September, SST decreased by 1 K in all regions, which was stable until end of the month.

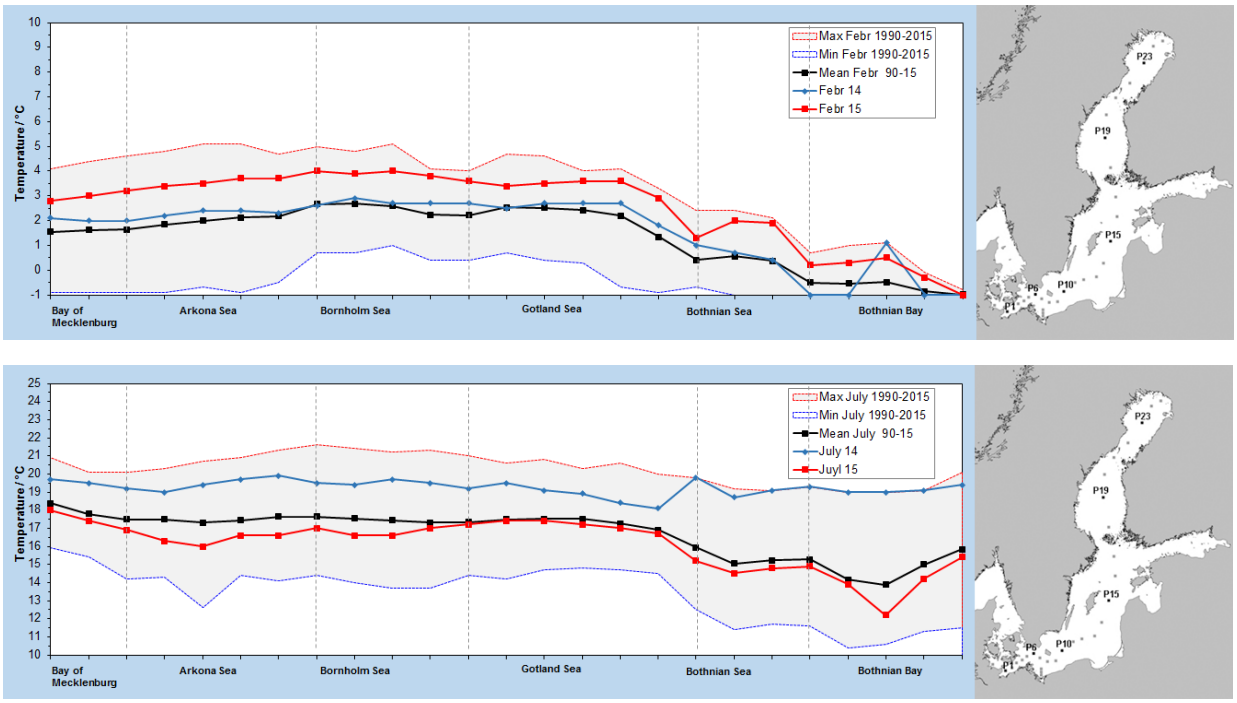

Figure 4. SST transect through the central basins of the Baltic Sea in February (a) and July 2015 (b) in comparison to the previous year, long-term mean values (1990-2015), and to the variation range.

Monthly mean values of 16-18°C in the central and western part represent the long-term average and 13-16°C in the Gulf of Bothnia correspond to anomalies of up to + 3 K (Fig. 1). In October, phases of westerly and easterly winds alternated, induced upwelling at western and southern coasts and reduced until end of the month the SST to 7 - 10°C in the northern and 9 -13°C in central and western parts. The

long lasting upwelling cells are only slightly visible in the anomalies (Fig. 1) with slight negative anomalies in the cores. Positive anomalies of up to +2 K occurred in the northern Baltic. October 2015 was the second warmest October since 1990. In November, SST did not decrease as expected from the long-term means. Strongest reduction took place around 20 November and at 28 November. End of November 4-6°C were observed in the Gulf of Bothnia and 6-9°C otherwise. This development causes monthly averages of 5-11°C and positive anomalies nearly in the entire Baltic smaller values in south (0 to +1 K) and +1 to +3 K in the north (Fig. 2). By that, 2015 was the warmest November since 1990. In December, three cooling phases in air temperature took place without strong influence on SST. End of December, SST reached values of 5-7°C in the central and western Baltic, Gulf of Bothnia 2-5°C and in the coastal areas of northern Bothnian Bay sea ice formed. December 2015 was the warmest December since 1990. The mild air-temperature (T_{air} > 0°C) in both months caused the high SST.

Overall, 2015 was the second warmest year since 1990 (Fig. 5). The annual SST average throughout the Baltic Sea was about 1 K higher than the long-term average, and only 0.2 K below the warmest year 2014. January to April and September to December contribute with 1.5 – 2 K above the long-term averages particularly to this high value. The temperature trend was 0.6 K per decade.

The contribution of different regions becomes visible in the summary in table 1, which includes the annual mean SSTs of the entire Baltic Sea of the last years, the warmest year 2014 and the coldest year 1996 as well as the means of single points representing the central Arkona, Bornholm, Gotland, and Bothnian Seas and the standard deviation. In the warmest year 2014, the southern and western Baltic had the highest contribution with mean values of 11-11.6°C compared to 10.3-10.4°C in 2015.

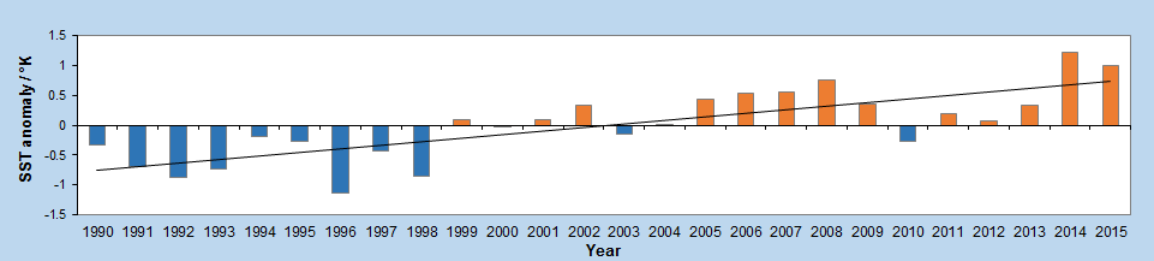

Figure 5. Anomalies of yearly SST- average of the entire Baltic Sea of the last 26 years (1990-2015).

The Gotland Sea was slightly warmer in 2015 than in 2014 and the Bothnian Sea was similar in both year. In 2015, the standard deviation were lower in all regions than in all other years because of the lack of real winter and summer temperatures in the relatively warm winter and rather cold summer.

Table 1. Annual mean SSTs of the entire Baltic Sea of the last 5 years including the warmest year 2014 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.

year	Baltic	Arkona Sea			Bornholm Sea			Gotland Sea			Bothnian Sea		
	mean	mean		stdv	mean		stdv	mean		stdv	mean		stdv
1996	6.6	8.0	±	6.6	8.0	±	5.9	7.6	±	6.3	5.8	±	6.4
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
2015	8.8	10.4	±	5.3	10.3	±	5.2	9.9	±	5.7	7.6	±	5.5

Data and metadata

This HELCOM Baltic Sea Environmental 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 of the Baltic Sea was derived from data of the Advanced Very High Resolution Radiometer (AVHRR) of weather satellites of the National Oceanic and Atmospheric Administration (NOAA) and from the European MetOp-2. The Federal Maritime and Hydrographic Agency (BSH) Hamburg provided up to eight daily satellite scenes since 1990. Evaluation methods and methodological investigations are discussed in Siegel et al. (2008). The annual assessment of the development of SST in the Baltic Sea is summarized in Nausch et al. 2016 and in HELCOM Environment Fact Sheets (Siegel & Gerth, 2015). Reflections on long-term development of SST since 1990 are presented in Siegel et al. (1999, 2006, 2008). 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.

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