Sea Surface Temperature in the Baltic Sea 2018

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Key message

The year 2018 was the warmest year since 1990 in satellite derived sea surface temperature (SST) as in air temperature. The SST was 1.19 K above the long-term average followed by 2014. May to August mainly contributed to the average by their positive anomalies of up to +4 - +5 K. The late winter led to negative anomalies in March and April. The winter of 2017/2018 was comparatively warm in the cold sum of air temperature but also in SST. March was the coldest month and the coldest day was in the first week. The warming occurred particularly in May and continued in June due to high solar radiation and low wind conditions. The conditions led to special development of phytoplankton. The monthly mean SST in May to August determined the upper limit of the variation range since 1990 in the western and central Baltic. The warmest day was around 1 August with up to 27°C in far parts of the central Baltic. In autumn, strong upwelling of cold water occurred along the Swedish coast due to abnormal westerly winds reflecting in the monthly anomalies.

Results and assessment

Cold and heat sums of air temperature of Warnemünde (Naumann et al. 2019) deliver information about the severity of winter and the course of the summer. The winter 2017/18 was with a cold sum of 67.7 K d below the long-term average (100.8 K d), which means the 34th warmest winter since 1948. In contrast to other years February and March contributed with 33.3 K d and 32.2 K d mainly to this value (long-term averages 30.4 K d and 8.1 K d). March was the 5th coldest March since 1948. The heat sum of the summer 2018 was 394.5 K d, more than 2.5 times as high as the long-term average (153.5 K d) and the warmest summer since 1948. All months from May to October exceeded the long-term averages of each month. 2018 was the warmest year since 1881 (Naumann et al. 2019).

Anomalies of monthly mean SST for the entire Baltic Sea in Fig. 1 referring to the long-term averages (1990-2018) are the basis for the discussion of overall thermal development in 2018. The seasonal development of monthly mean temperatures in the central areas of the Arkona, Gotland and Bothnian Seas are presented in Fig. 2 in comparison to the long-term monthly averages (1990-2018). For the detailed temperature development daily and weekly mean SSTs were implemented.
Mild January and February with SSTs slight above the long-term averages are characterised by positive anomalies less than +1 - +2 K. In March and April, cold weather prevented the normal warming in spring that the monthly means were in the range of the long term averages or below. The anomalies reached partly values to – 2 K. May, June, July, and August are characterized by positive anomalies with up to 5 K. May 2018 was the warmest since 1990 (second 2016), June was together with June 2002 the warmest except in the Bothnian Bay. July was the warmest followed by 2014 and

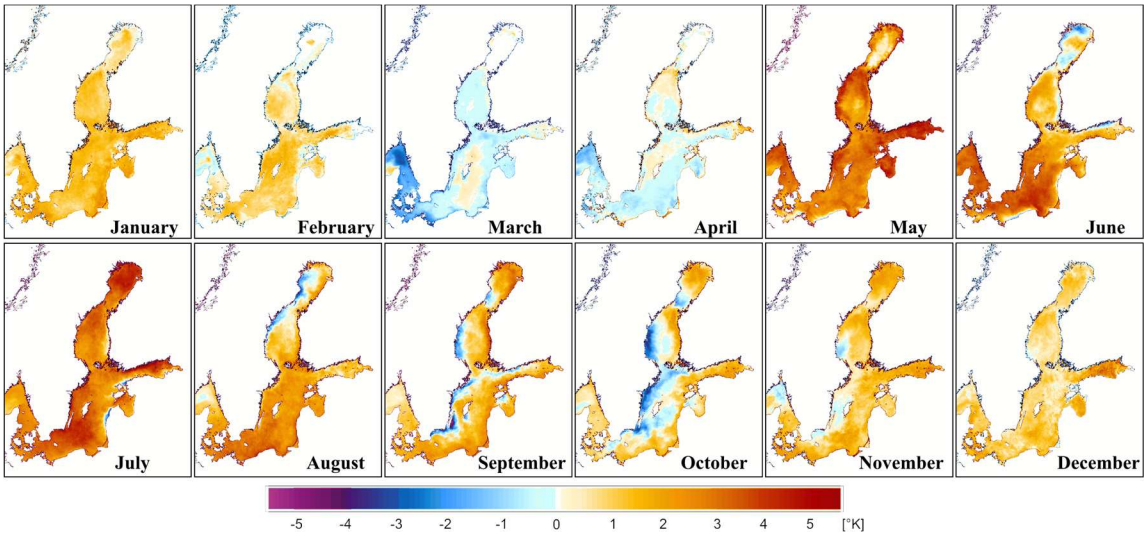

Figure 1: SST- Anomalies of the monthly mean temperature of the Baltic Sea in 2018 referring to the long-term means (1990-2018)

August belonged to the warmest in the central Baltic. In September and October, unusual long lasting westerly to north-westerly winds induced upwelling along the Swedish coasts visible in the anomalies. In November and December, positive anomalies between 0 and +2 K determine most areas.

The annual temperature cycles in the central parts of the Arkona Sea (AS), Gotland Sea (GS) and Bothnian Sea (BoS) in Fig. 2 show that March was the coldest month in all regions. January and February were warmer than in average. In March and April, the central parts were in the range or below the long-term averages due to the later winter. A strong warming took place in May and June with positive anomalies of up to +4 K. The warming was more pronounced in the western and central than in the northern Baltic Sea. The highest temperatures of the year occurred in the northern Baltic in July, in the central in August and in the western Baltic the averages of July and August were rather similar. In July, the anomalies were up to +4 K in all regions but in August only in the western and central Baltic. In October, the central stations were between the areas of positive and negative anomalies means in the range of the long-term averages. In September, November and December, the central stations are characterised by slight positive anomalies.

The year 2018 started with temperature between 3 and 7 °C in the western and central Baltic Sea which remained in the first decade of January before the typical cooling began. The cooling

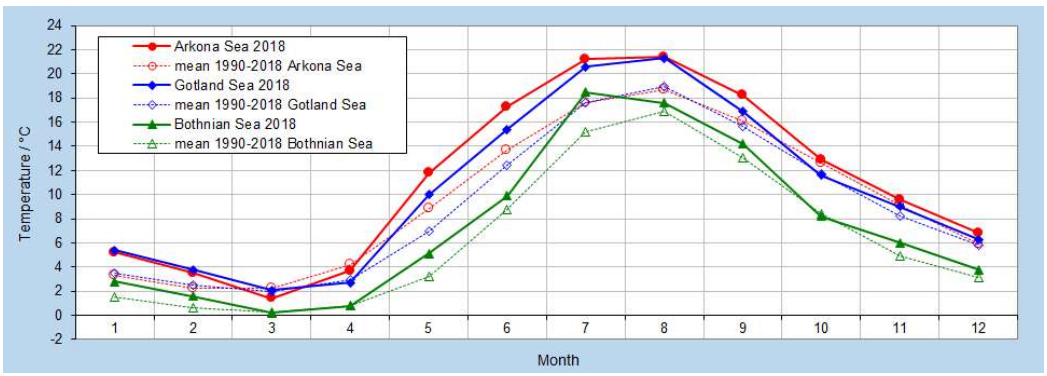

Figure 2: Seasonal cycle of SST in the central Arkona-, Gotland- and Bothnian Sea in 2018 in comparison to the mean values (1990-2018)

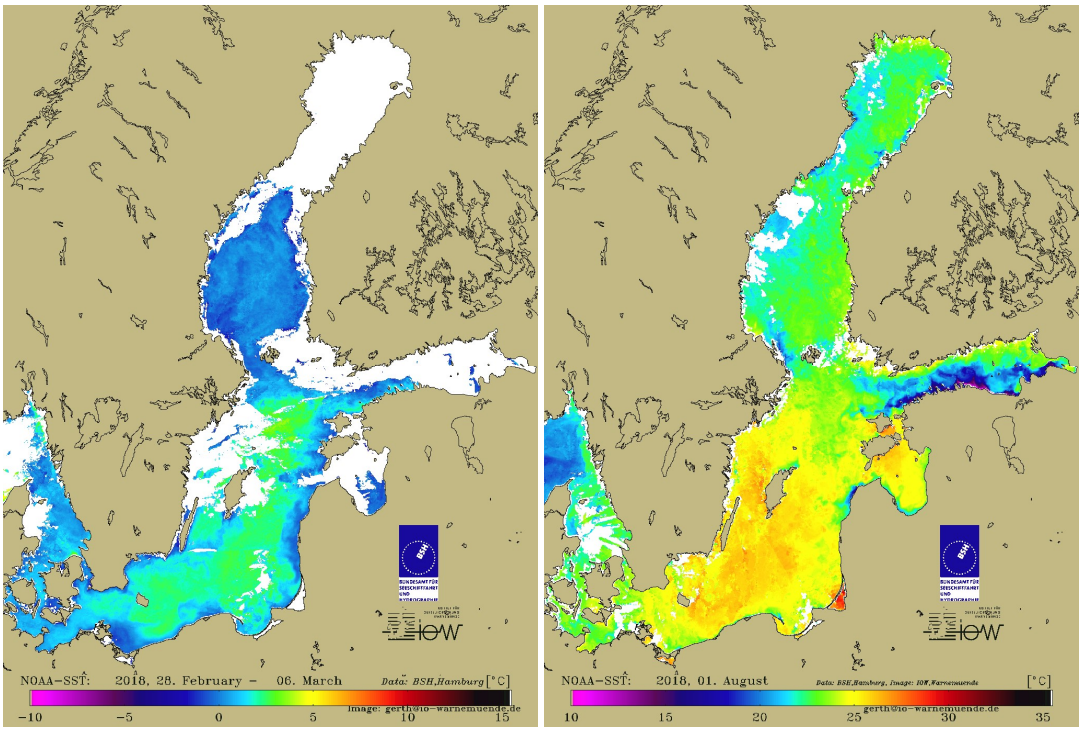

Figure 3: The first week of March included the coldest day and the 1 August was the warmest day of year 2018.

continued in February but was not so pronounced as usual that the first week of March became the coldest week of the year (Fig. 3, left image). SSTs varied between around 0 °C in the shallow Pomeranian Bight and in the northern Baltic, and 1-2.5 °C in the western and central Baltic Sea. This period matched with the maximum ice coverage (Naumann et al. 2019, Fig. 19, right image) on 5 March (Schwegmann, Holfort 2017). Because of the cold weather until end of March, the SSTs differ only slightly from the coldest week that March became the coldest month in all regions. The monthly mean SST along the transect through the entire Baltic in March was mainly in the range or below the long-term average except in the western Baltic. Particularly in the shallow westernmost parts, negative anomalies reached values of up to -1.5 K. The SST along the transect is presented in relation to long-term average (1990-2018), previous year, and the variation range in Fig. 4.

Mid-April, warm air masses from the Atlantic Ocean reached the Baltic region initiating a warming of surface water from the western part and particularly along the south coasts. SST reached the range of the long-term averages. The warming continued in May and particularly in the third decade a high pressure system established above the central Baltic with typical easterly winds which initiated upwelling along the East and South coasts of the Baltic Proper. Because of this typical situation in May, the upwelling patterns are not reflected in the anomalies of the monthly averages. Due to the high SST in the second half of May, the monthly mean temperature distribution along the transect through the central basins of the Baltic Sea in May 2018 determined the upper limit of the variation range from the Arkona Sea to the Bothnian Sea (Fig. 4). This means that May 2018 was the warmest May since 1990 in these regions. The conditions initiated a special phytoplankton development. This continued and led to temperatures of 18-20°C in the central Gotland Sea beginning of June inducing an early development of cyanobacteria. The June is characterised by changing conditions with warmer and colder phases in the Bothnian Sea and central Baltic, but on a high level leading to the positive anomalies of the monthly averages particularly from the western Baltic to the central Gotland Sea.

This situation remained until 5 July before a further strong warming occurred due to warm air masses from the Atlantic Ocean. Already on 12 July, the usual North - South gradient is balanced. In the following days the warming continued in the entire Baltic with only slight regional differences. On 19 July, the highest SST with up to approximately 25°C was determined in the Gulf of Bothnia. In the following days until the end of the month, the SST decreased slightly in the northern Baltic and increased particularly in the Baltic Proper. The highest SST was determined on 1 August with up to 27°C from the Bornholm Sea to the central eastern and western Gotland Sea, 22-25°C in the Gulf of Bothnia, 23-25°C in the western parts (Fig. 3). Only in the Gulf of Finland, the SST was reduced due to upwelling induced by easterly winds. This situation continued until 4 August before a stronger cooling took place particularly in the northern Baltic. On 10 August, the SST was still around 23°C in the Baltic proper but already less than 20°C in the northern parts partly due to upwelling along the Swedish coast. The cooling continued until the end of the month, but the temperatures were still rather high with values of about 18-20°C in the Baltic Proper and 15-17°C in the central Gulf of Bothnia. These high temperatures in July and August led to the strong positive anomalies of the monthly averages (Fig. 1). The SST averages of the months June, July, and August 2018 determined the maxima in the variation range since 1990 as seen in the temperature distribution along the transect through the central basins in Fig. 4 (Naumann et al. 2019).
The situation remained in the first decade of September before the temperature dropped by 3 K in the Baltic Proper during a strong wind event. Prevailing abnormal intense westerly winds induced upwelling along the entire Swedish coast until end of October, also reflected in the anomalies of the

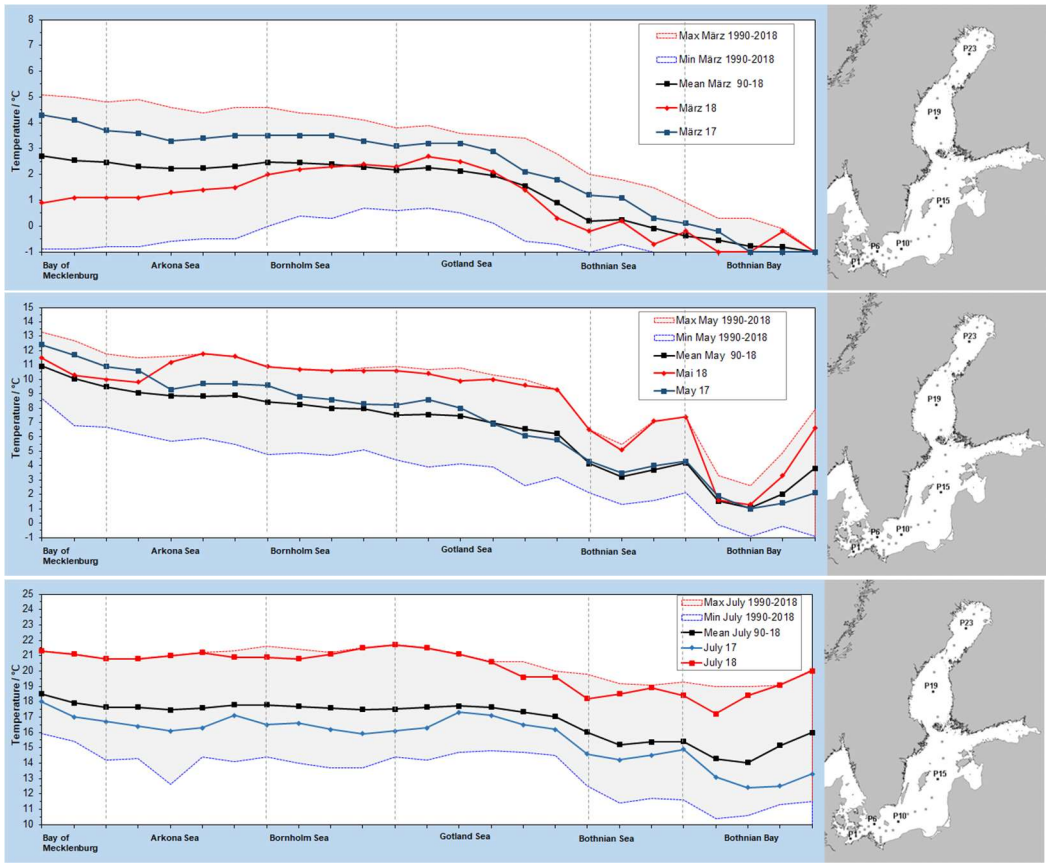

Figure 4: Temperature distribution along the transect through the central basins of the Baltic Sea in March, May, and July 2018 in comparison to the previous year, the long-term mean value of 1990-2018 and the variation range

monthly averages of September and October (Fig. 1). End of September, SSTs of 5-8°C were reached in the upwelling areas and up to 15-17°C in the eastern and southern Baltic. In October, the influence of upwelling areas increased and strong wind mixing end of the month reduced the SST ending in the range of the long-term average. The further cooling in November and December is lower than usual that December 2018 was warmer than the long-term averages.

Overall, 2018 was in the SST of the Baltic Sea as in the air temperature the warmest year of the last 29 years since 1990 (Fig. 5) closely followed by 2014 and the years 2015 and 2016. The annual temperature average throughout the Baltic Sea was 2018 with 1.19 K and 2014 with 1.14 K higher than the long-term average. The months May to August particularly contributed by their high positive anomalies.

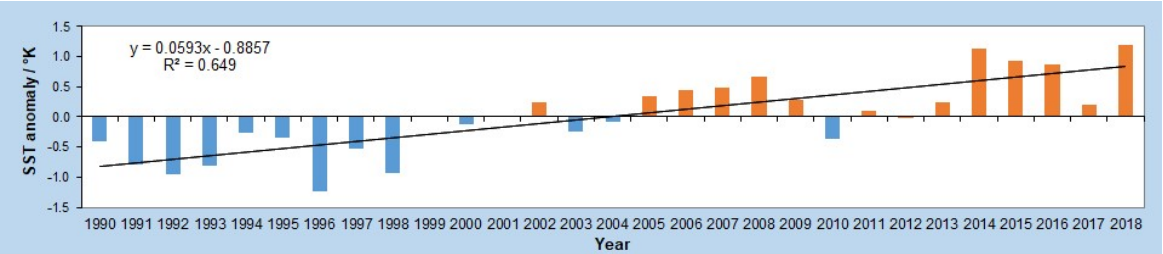

Figure 5: Anomalies of the annual mean sea surface temperature of the entire Baltic Sea during the last 29 years (1990-2018)

The contributions of different regions are summarized in table 1, which includes the annual mean SSTs of the entire Baltic Sea of the last years, the warmest years 2018 and 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 entire observation period since 1990, 2018 was together with 2014 the warmest year in the entire Baltic Sea, but it varies in the different regions. 2014 was warmest in the western and norther Baltic and 2018 in the large Gotland Sea. 2014 and 2015 were the warmest years in the Bothnian Sea.

Table 1: Annual mean SSTs of the entire Baltic Sea of the last years including the warmest years 2014 and 2018 and the coldest year 1996 as well as the average 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
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
2016	8.7	10.8	±	6.3	10.8	±	6.2	9.9	±	5.9	7.1	±	5.9
2017	8.0	9.8	±	5.4	9.8	±	5.3	9.3	±	5.6	6.8	±	5.7
2018	9.0	10.8	±	7.0	10.6	±	6.9	10.1	±	6.6	7.1	±	6.2

The time series of SST of the entire Baltic in Figure 5 reflects the strong warming in the Baltic region with a linear trend of 0.59 °C / decade referring to the period 1990-2018. The linear trend was

calculated for each point of the Baltic and summarized in the map in Figure 6. The highest temperature increase occurred in the northern Baltic, in the Gulf of Bothnia and in the Gulf of Finland, with linear SST- trends of up to 0.7 – 0.9 °C / decade in larger areas. The lowest trend was determined for the Skagerrak and the Bornholm Sea.

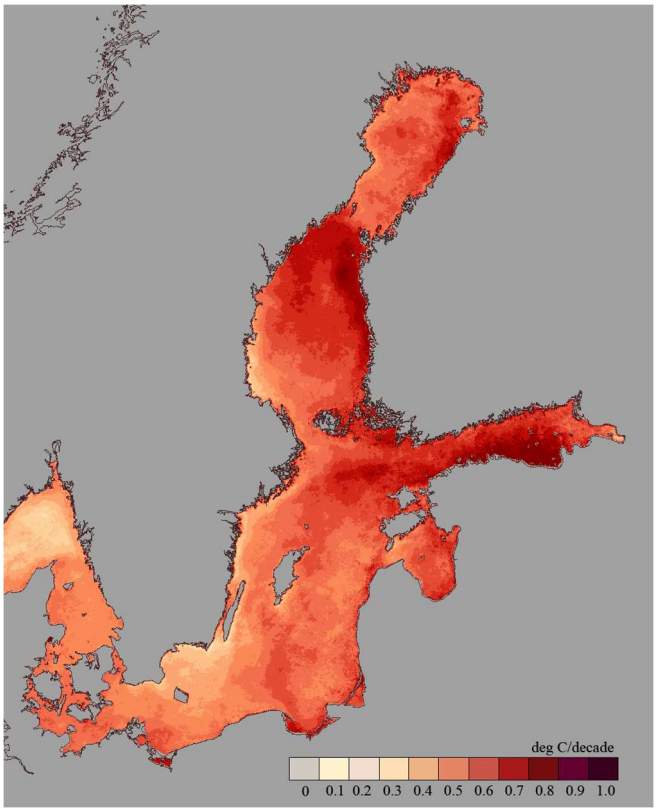

Figure 6: Map of linear trends of sea surface temperature in the entire Baltic Sea for period 1990-2018 (in deg C / decade)

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Data and Metadata
This HELCOM Baltic Sea Environmental fact sheet is based on satellite derived Sea Surface Temperature (SST) data 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 Naumann et al. 2017, 2018, 2019 and in HELCOM Environment Fact Sheets (Siegel & Gerth, 2017). 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.