Development of Sea Surface Temperature in the Baltic Sea in 2006

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Key message

The sea surface temperature of the year 2006 was characterized by comparatively warm months, July, Octobers and Decembers and in the annual average 2006 was the warmest year of the period 1990-2006. The months February - May were comparatively cold. The March belonged almost in the entire Baltic Sea after 1996 to the coldest since 1990. The maximum ice coverage in the northern Baltic Sea was reached to 16 March. The Gulf of Bothnia and the Gulf of Finland were completely covered with ice. Similarly to 2001 and 2005, July was the warmest month in the course of the year in the southern and western Baltic Sea. In the central and southern Baltic Sea 2006 was the warmest July since 1990. The high temperatures in July initiated similar to 2005 an intensive cyanobacteria bloom. The maximum temperatures were reached in the central Baltic Sea on 8 July with values of 23-25°C. In the western Baltic Sea the maximum values of 23-25°C were observed between 20 and 30 July. In August, the monthly means were only slightly lower in the central Baltic Sea, but in the Gulf of Bothnia the monthly means reached the maximum values of the year. The October was by far the warmest since 1990. The high temperatures in autumn and December contributed to the high annual average 2006.

Background

Sea Surface Temperature (SST) derived from data of the Advanced Very High Resolution Radiometer (AVHRR) of the National Oceanic and Atmospheric Administration (NOAA) weather satellites were provided by the German Federal Maritime and Hydrographic Agency Hamburg (BSH). The BSH operates a SeaSpace HRPT (High Resolution Picture Transmission) receiving station and receives data from two NOAA satellites. The SST data evaluation procedure is described by Siegel et al. (1994, 2007b). 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). Systematic studies on seasonal and inter-annual variations in SST are published by Siegel et al. (1999) and Siegel et al. (2006). This fact sheet is based on the results included in the assessment of the year 2006 (Nausch et al. 2006). The assessment of SST for the year 2006 was performed on the basis of daily and monthly mean values derived from all cloud free pixels and overpasses of the satellites NOAA 17 and 18. The monthly means were used to investigate the seasonal development and inter-annual variations. The daily mean values were applied to retrieve particularities in the detailed thermal development. Based on the monthly mean values of the year 2006 and the long-term means of all months of the period 1990 - 2004 anomalies were calculated.

Results and assessment

The yearly development of water temperature was always compared to air temperature of Warnemünde (Nausch et al. 2007). The cold sum of air temperature of Warnemünde showed that the winter 2005/2006 was in the range of the long-term averages. That was mainly due to the months January and March. After the mild months November and December it cooled strongly down in January. The cooling sums reached

the 1.7-fold in January and in March even the 2.4-fold of the long-term average value (39.9 K, Jan.; 8.8 K, Mar.). The heat sum of the summer 2006 exceeded with 355.1 K the long-term average value (144.6 K) and represented by far the highest value of the last 60 years. That was also the case for the months July and September, and June was the third-warmest. The month August lay with 63.4 K over the average value (50.5 K).

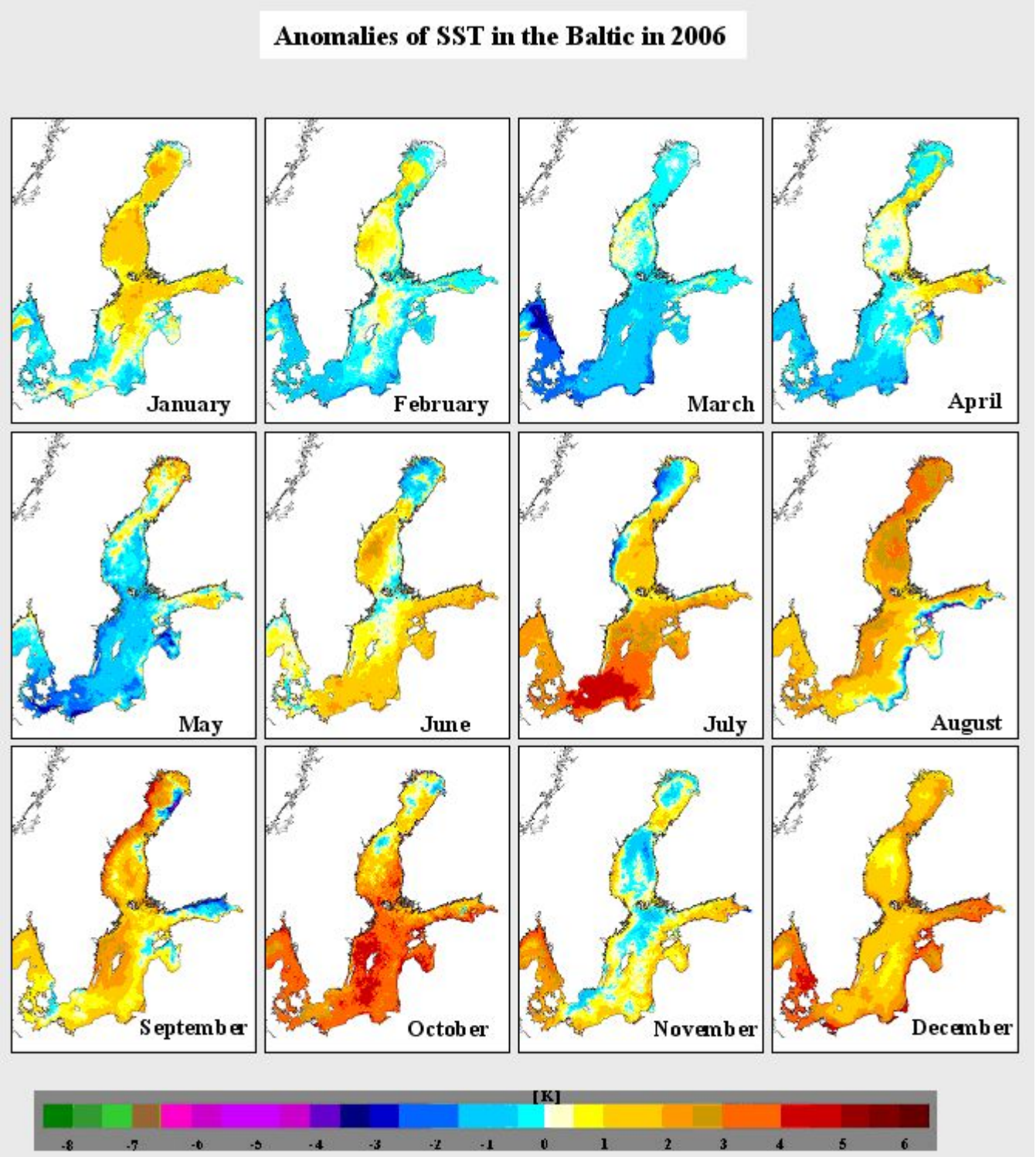

Figure 1. Anomalies of sea surface temperature (SST) in the Baltic Sea in the monthly mean values of the year 2006 referring to the mean values of the years 1990 - 2004.

These particularities in air temperature were reflected also in the sea surface temperature. Partly, they were still more pronounced and characterised by a temporal delay. The anomalies of the monthly mean SST of the year 2006 are represented in Fig. 1. After comparatively warm December the cold weather reduced the water temperature in January in the southern Baltic Sea under the long-term average which partly continued in February. The cold March increased the range of negative anomalies, which persisted in the subsequent months April and May. The highest negative anomalies with up to -2 K were observed in March in the western Baltic Sea and in May particularly in the upwelling areas along the Polish and German coast. In March the negative anomalies in the Skagerrak reached even up to -4 K. After June with slight positive anomalies of up to +1.5 K the July was particularly remarkable, as expected from air temperature. Extended parts of the Arkona Sea, Bornholm Sea and the southern Gotland Sea exhibit positive anomalies from +4 K to +5 K. The upwelling areas at the Polish coast and the western Baltic Sea are excluded. The negative anomalies in the Gulf of Bothnia and in the Gulf of Finland were also remarkable. That points at dominating high pressure situations, which had their centre within in the area of the central Gotland Sea with westerly winds at the northern and easterly winds at the southern side, which led to the respective upwelling. The negative anomalies in August along the coast of the Baltic States point at frequent easterly to north-easterly winds in the central Baltic Sea. Causes for the warm October were the high air temperatures end of September and a long lasting high pressure situation in October. The entire Baltic Proper is characterised by extreme positive anomalies of +4 K to +5 K. Also in December the anomalies are positive in the entire Baltic Sea.

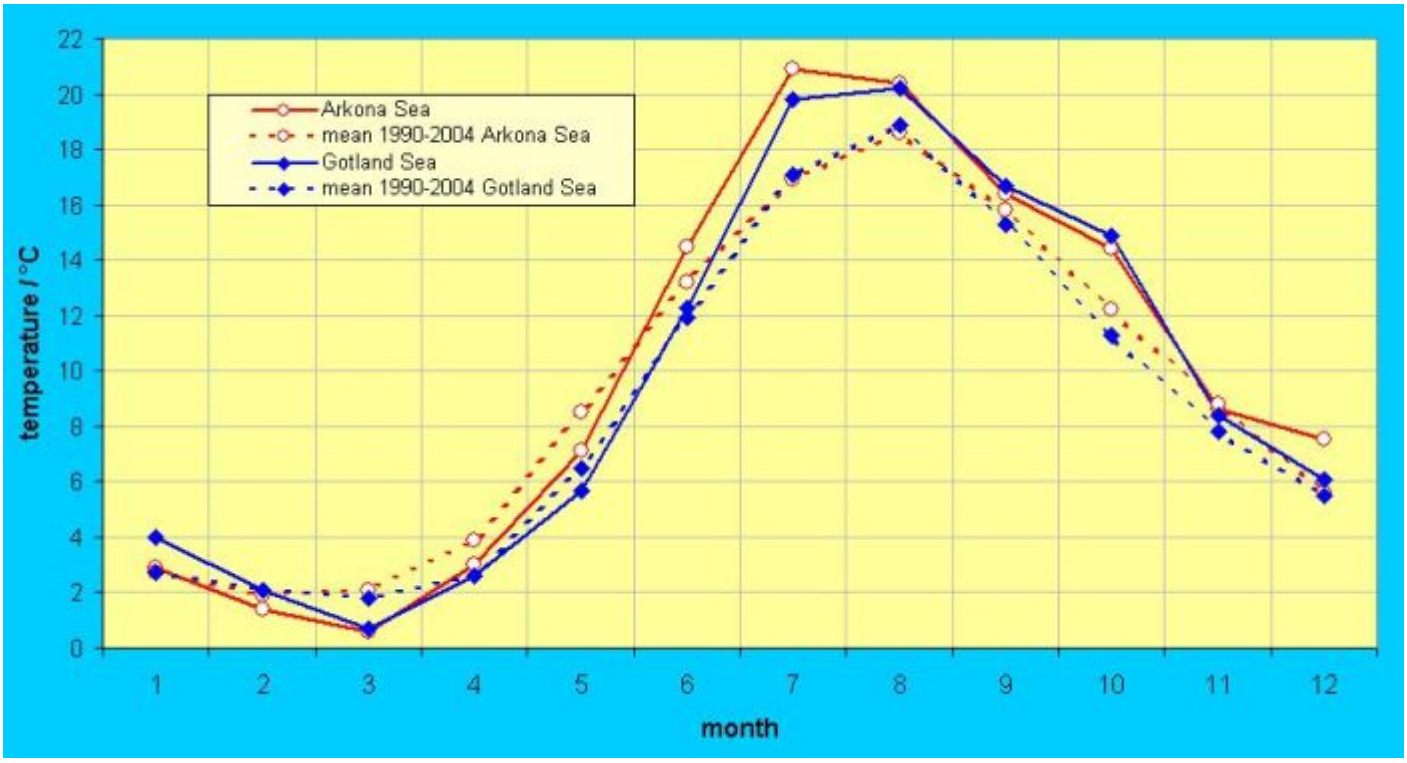

Figure 2. Seasonal course of sea surface temperature (NOAA-SST) in the central Arkona- and Gotland Sea in 2006 in comparison to the mean values 1990-2004.

The discussed particularities in the anomalies are reflected also very well in the seasonal course of the monthly average temperature in the central parts of the Arkona Sea and the eastern Gotland Sea (fig. 2). The month March was colder in both areas than in the long-term means, which continued in the Arkona

Sea also in April and May. The faster heating in June in the Arkonasee can be clearly seen, against what the eastern Gotland Sea was from April to June in the range of the long-term averages. In July and August, the monthly means in both areas lie clearly over the long-term average values.

The month July reached in the Arkona Sea (+4 K) with approximately 21°C the maximum temperature of the year. In the eastern Gotland Sea July (+3 K) is slightly colder than August. In both areas the August temperatures exceeded with +2 K clearly the long-term average values. The September is only slightly warmer in both areas than the means, but the differences became substantially clearer in October. In the Arkona Sea the monthly means lie with +2.5 K and in the eastern Gotland Sea with +4 K over the average values. After the adaptation in November, the December was only warmer in the Arkona Sea than the average value.

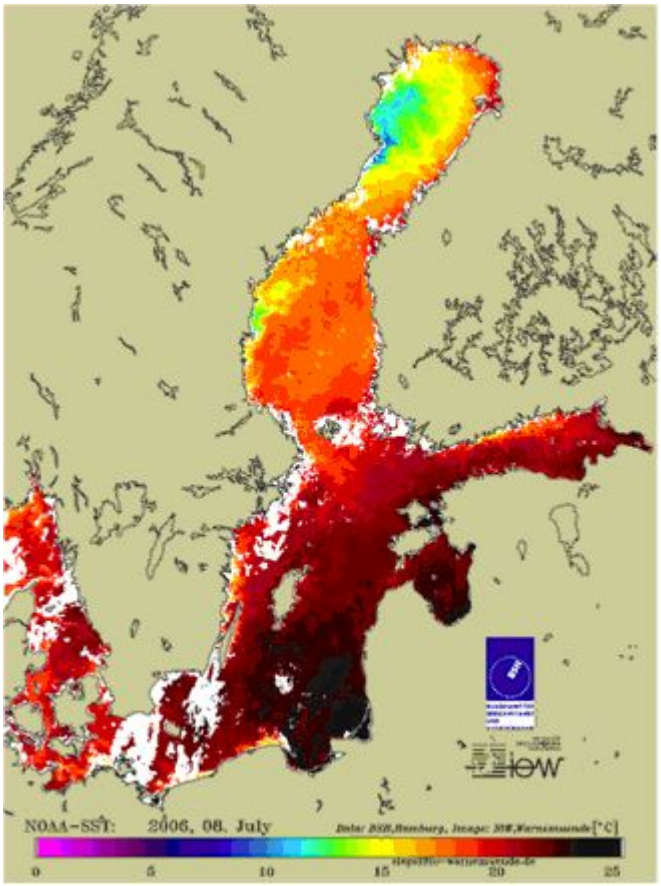

Figure 3. Maximum SST of the year 2006 on 8 July.

In the following, the thermal development of the year 2006 in the Baltic Sea will be described in detail. Beginning of January was characterized by temperatures around 3-5°C in most parts of the Baltic Sea. The cold weather period particularly between 15 and 25 January with the high cooling sums and air temperatures down to -8°C cooled the Baltic Sea down to 0-3°C at the end of January. The lower temperatures arose beside the northern Baltic Sea in particular in the western Baltic Sea and within the coastal ranges. This cooling continued in February in the central parts and reached after lower temperatures 1-2°C at the end of February. These low temperatures with 1°C in the western and northern Baltic Sea and 1-2°C in the central parts remained until approximately 25 March. The maximum ice coverage was reached in the northern Baltic Sea on 16 March. The after-winter heating up period inserted then from the western Baltic Sea starting from 20-25 March and covered at the end of March also the

central Baltic Sea. This development led to the fact that March 2006 belonged to the coldest since 1990 from the western Baltic Sea to the central Gotland Sea. In the Arkona Sea and Bornholm Sea only March 1996 was still colder and in the central Gotlandsee beside 1996 also March 2003. At the end of April temperatures between 2-5°C are reached in the central Baltic Sea and in the Belt Sea and in the coastal discharges up to 7°C. The Baltic Sea continued the warming up in May slowly, until it proceeded from 15 May until end of May faster in the western Baltic Sea (10-12°C) than in the central parts (7-8°C). In June the temperature rises rapidly, so that on 14 June at the south coasts temperature up to 18°C was observed. A wind event on 15 June mixed the water again and reduces the surface temperature. Temperatures between 15 and 18°C were reached again from 20 June in the central and western Baltic Sea, which increased to the end of June to 17-18°. In the following 8-10 days the temperature rose very strongly and achieved in the south part of the eastern Gotland Sea around 9 July maximum values of 23-24°C (fig. 3). In that phase in July the discussed high pressure situation influenced the Baltic. It is colder in the upwelling areas at the Polish coast and in the western Baltic Sea (east wind), and in addition, at the Swedish east coast (west wind). In the Arkonasee the temperatures were approximately 21°C, which is in a good agreement with measurements at the MARNET station "Arkonasee". After a wind event on 14 July the temperature in most parts of the Baltic Sea sank down on values of 19-20°C. North of Gotland Island the temperatures were below 18°C and in the western part of the Bothnian Sea below 15°C due to strong upwelling. Starting from 17 July then heating up began, which affects however only the western Baltic Sea to the Bornholm Sea. On 19 July the temperatures reached in the Arkona Sea values of 22°C and 23-24°C in the Pomeranian Bight. This situation continued until end of July. Fig. 4 shows how the thermal development affected the monthly means of July regionally. The highest temperatures (21°C) and anomalies (+4 K) were observed in the southern Baltic Sea, from the central Arkona

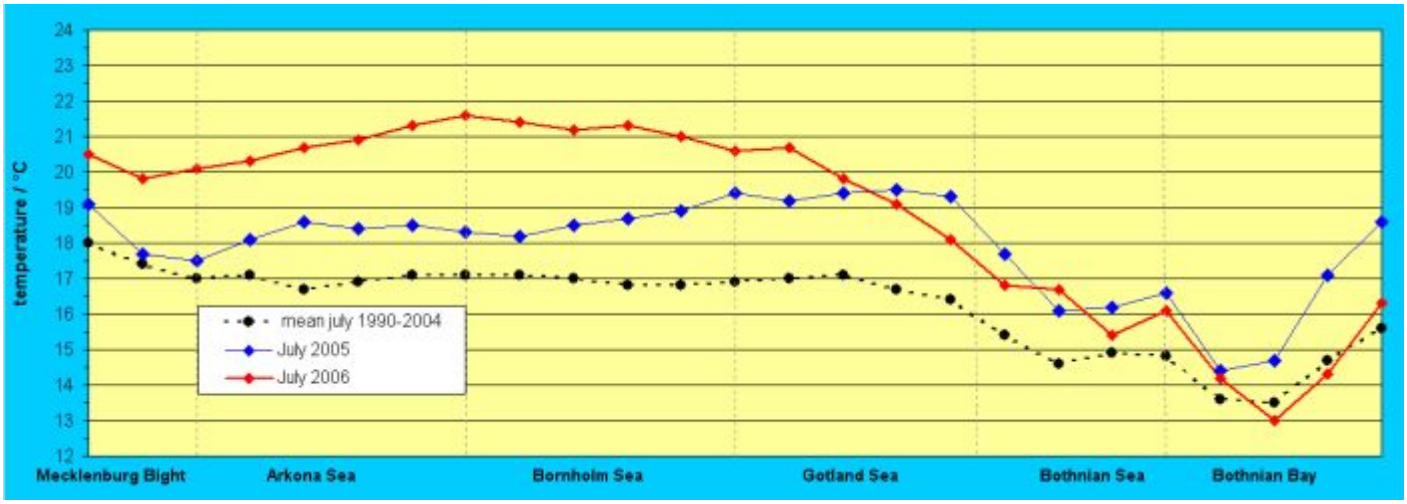

Figure 4. Temperature distribution along the transect through the central Baltic Sea in July 2006 in comparison to the mean value of 1990 – 2004 and to the previous year.

Sea over the Bornholm Sea to the southern Gotland Sea. In comparison to the year 2005 enormous inter-annual differences occurred in this region. The temperatures increase at the beginning of August also further north. The wind turned in the central and northern Baltic Sea on east. The upwelling areas at the entire Swedish east coast propagated offshore and on 10 August the temperatures was in the entire Baltic Sea including the Bothnian Sea approximately 20-21°C. The coastal areas off the Baltic countries were excluded due to upwelling processes. In the Arkona Sea a wind event on 5 August reduced the values accordingly. A wind event during the night 15-16 August provided a further slightly cooling. Starting from

20 August the upwelling decreased and the entire Baltic Sea is characterized end of August by temperatures of 18-20°. In the monthly average values were around 21°C in the western Baltic Sea and above 19°C in the entire Baltic Sea including Bothnian Sea and only in the Bothnian Bay the temperatures were between 18 and 19°C. In the central Bothnian Sea 2006 is with 19.7°C secondary warmest August after 2002 and the temperatures were more than 7 K above that of coldest August 1992. Wind velocities of up to 18m/s during the night from 4 to 5 September induced a further cooling on 15-17°C around 10 September in the central and western Baltic Sea. In the Bothnian Sea the cooling was substantially stronger in this phase and reached values of 10-15°C. Up to 6 October the temperature distribution remained similar. A wind event on 7 and 8 October cooled the Baltic Sea slightly down on 13-16°C. Because of a long continuing high pressure situation in the mid-October these temperatures were observed until 25 October in the central and western parts, but the Bothnian Sea cooled down on 7-10°C. The long phase of constantly high temperatures led to the fact that October in the Baltic Proper was the warmest of the investigation period (fig. 5).

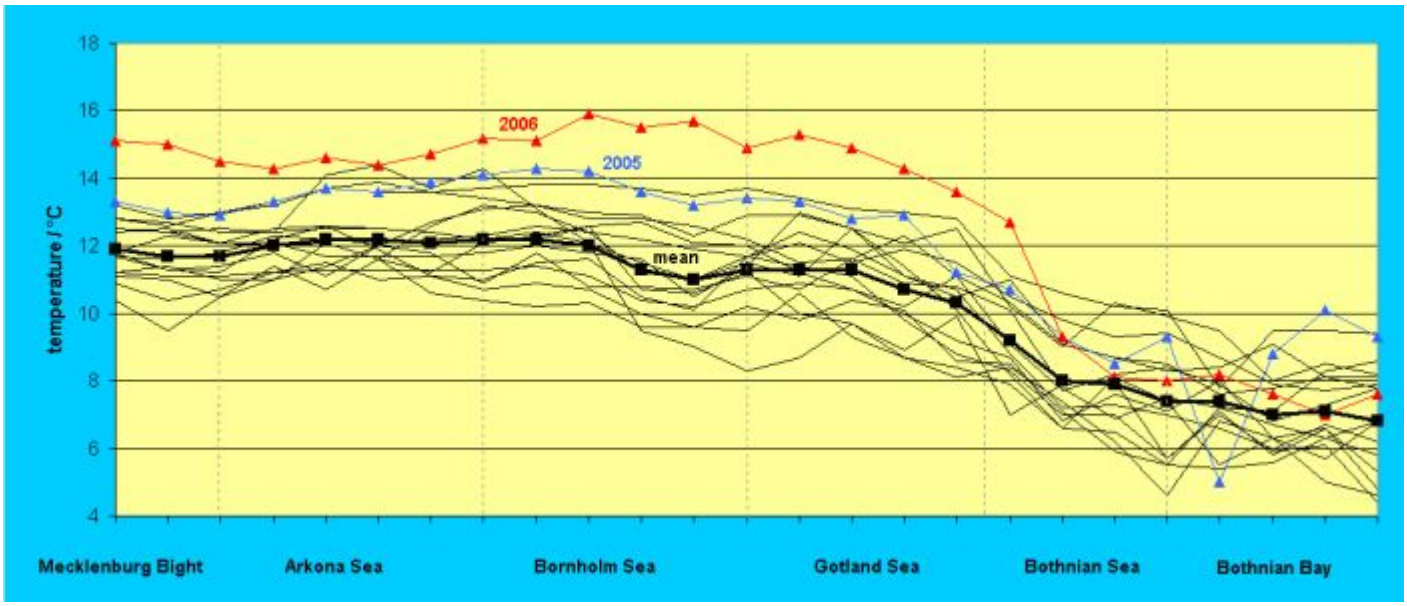

Figure 5. Temperature distribution along the transect through the central basins of the Baltic Sea in October 2006 in comparison to the mean value of 1990 – 2004 and to the other years.

Wind velocities of more than 20m/s on 27 October led in the southern part to temperatures of 10-13°C end of October. In November the cooling continued rapidly. At the end of November the temperatures were in the Baltic Proper around 7-8°C and in the Bothnian Sea already far below 5°C. In December the temperatures remained largely and were around 5-8°C in the central and western Baltic Sea and around 3-5°C in the Bothnian Sea.

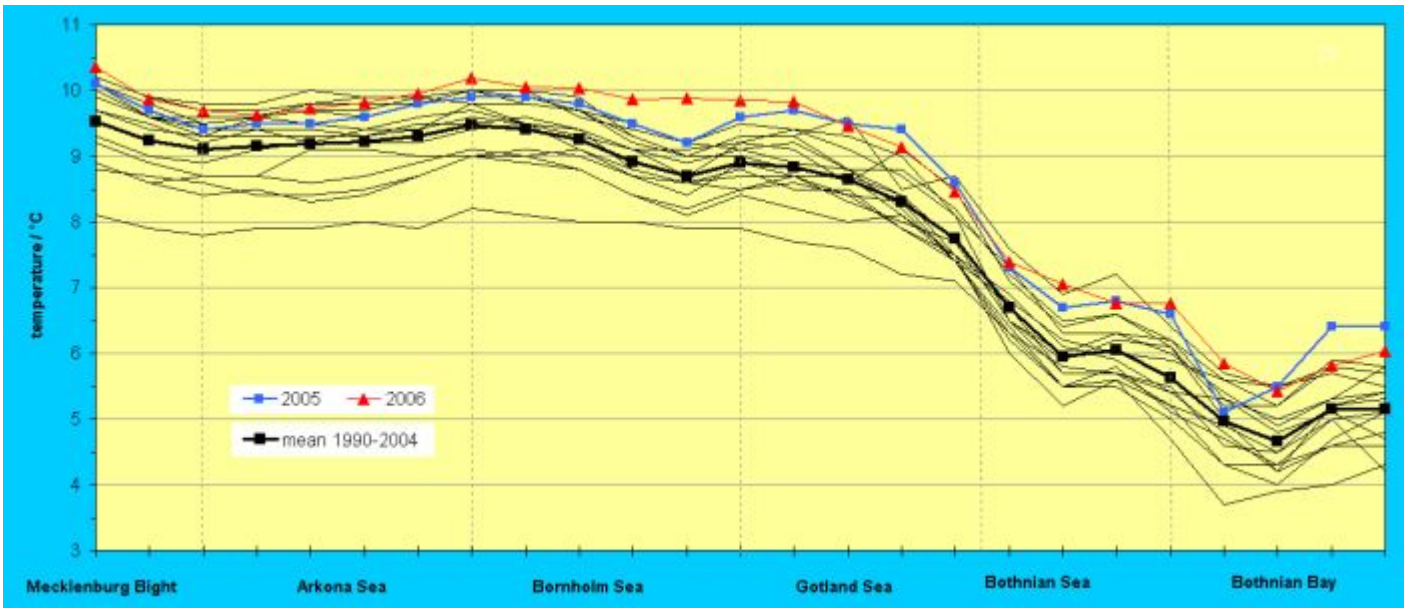

Figure 6. Yearly mean temperature along the transect through the central basins of the Baltic Sea in comparison to the different years and the mean value of the time period 1990 – 2004

The warm second half of the year 2006 contributed strongly to the annual average of SST that the year 2006 became with a mean value of the entire Baltic Sea of more than 8°C to the warmest of the period 1990 - 2006 in the Baltic Sea. (Siegel et al. 2007a) The diagram of the annual average temperature along the transect through the central parts of the Baltic Sea in Fig. 6 shows that it belonged to the warmest in all regions. This is also in a good agreement with the assessment of the temperature development of the northern hemisphere.

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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/.