Spatial and temporal variability of sea surface temperature in the Baltic Sea based on 32-years of satellite data

Malgorzata Stramska [a, b] Adam Wachuda [b]
[a]Institute of Oceanology of the Polish Academy of Sciences, Powstańców Warszawy 55, Sopot 81-712, Poland
[b] Department of Earth Sciences, Szczecin University, Mickiewicza 16, Szczecin 70-383, Poland

Sea surface temperature (SST) is a key parameter for constraining the exchange of energy and moisture between the ocean and the atmosphere and is classified as one of the Essential Climate Variables. Satellite SST datasets are based on measuring electromagnetic radiation that has left ocean surface and has been transmitted through the atmosphere. Satellite SST measurements are used in many applications as they provide a synoptic view of the dynamic thermal character of the ocean surface. Such data are valuable to agencies and institutions investigating climate variability, providing operational weather and ocean forecasting, for validation and forcing of ocean and atmospheric models, ecosystem studies, tourism and fisheries.

In this study we have examined the multiyear trends and variability of the Baltic Sea surface temperature (SST) using 32 - years of satellite data. Similar analyses of SST in the Baltic Sea published before have been based on significantly shorter time series (Bradtke et al. 2010, Karagali et al., 2012). Our results indicate that there is a statistically significant SST trend of increasing SST in most of the Baltic Sea. This trend shows different values depending on the exact geographical location and varies with the month of the year. Higher values of SST trend are generally present in the late summer months. The seasonal cycle of SST in the Baltic Sea is characterized by well-defined winter and summer seasons with relatively short transition periods of spring and fall. The analyzed data show significant interannual variability with extremely high sea surface water temperatures present in the central Baltic in some years.

Methods:

We have used the 32-year long data series (from 1982-2013) known as the NOAA Optimum Interpolation SST (OISST) Version 2 dataset (Reynolds et al. 2007).
These SST data were provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, through their Web site at http://www.esrl.noaa.gov/psd/. These are daily data with spatial resolution of approximately 0.25º x 0.25º.
In addition we have analyzed the meteorological data from the NOAA-CIRES Climate Diagnostic Center NCEP/NCAR (National Centers for Environmental Prediction and National Center for Atmospheric Research) Reanalysis 1 and the North Atlantic Oscillaition index Hurell data ().

Results:

32-year average

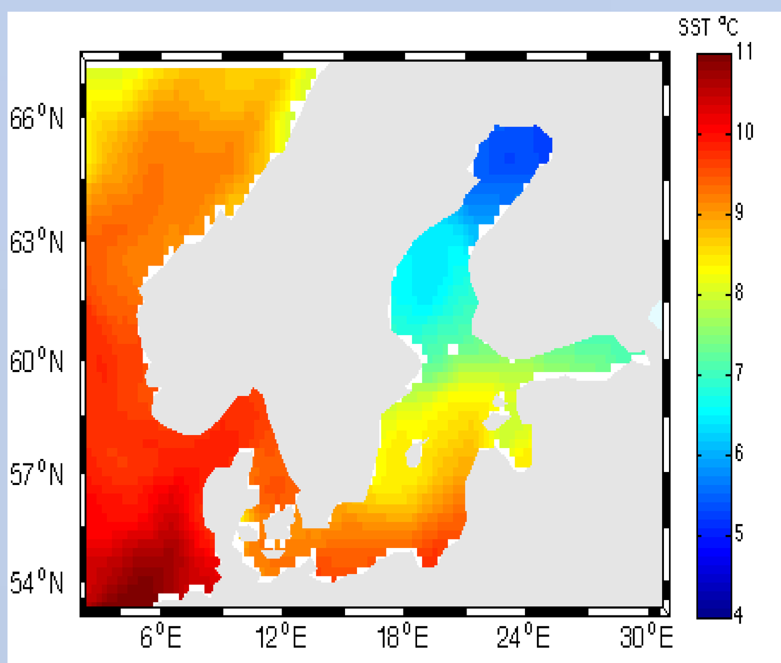


Figure 1. Map of the 32-year (1982-2013) average SST in the study region.

Note that the 32-year average SST is characterized by a significant gradient between the southern and the northern parts of the Baltic Sea, and that the SST in the North Sea near the entrance to the Baltic Sea is greater than the SST anywhere in the Baltic Sea.

32-year extreme daily SST

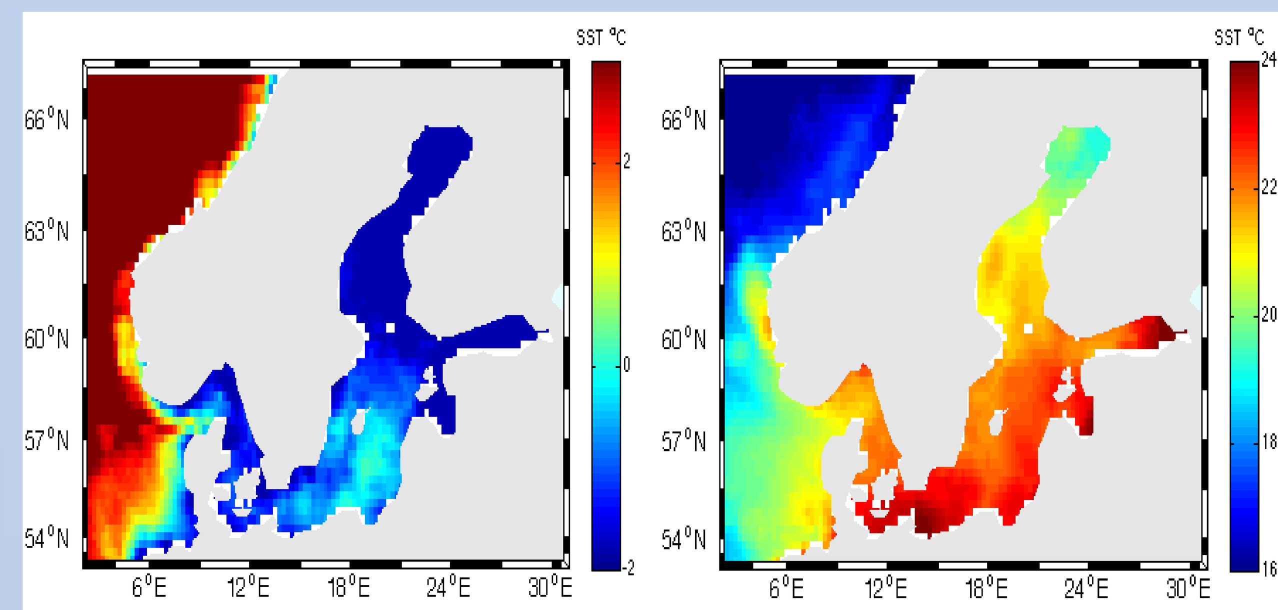
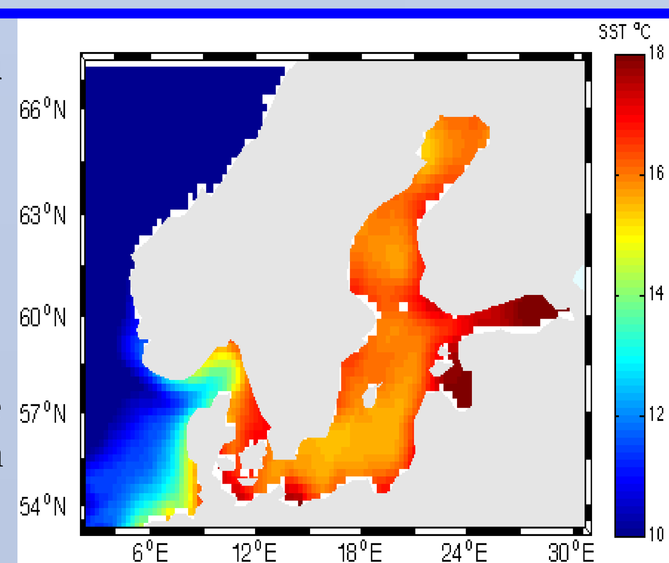


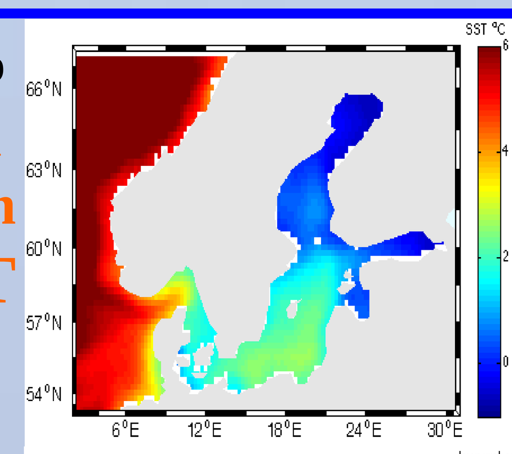
Figure 2. Extreme SST values: a) map of the minimum SST, b) map of the maximum SST, observed at each pixel in the time period between January 1, 1982 and December 31, 2013. Note that the color scale is different in plots a) and b).

32-year average annual cycle

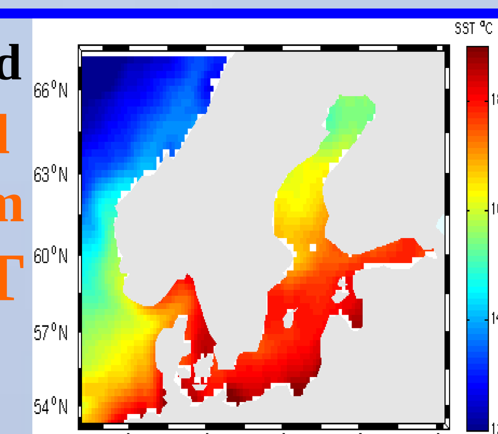
a



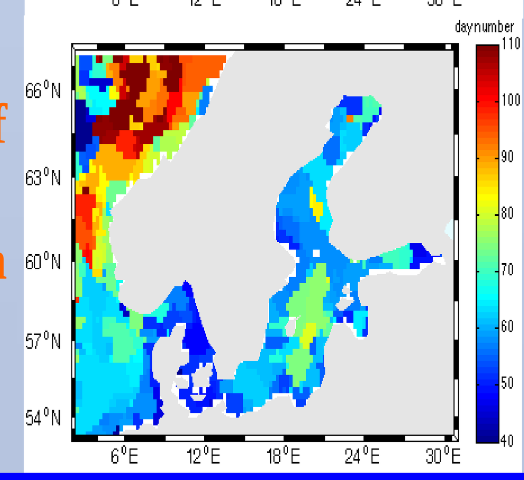
b annual minimum SST



d annual maximum SST



c date of annual minimum



e date of annual maximum

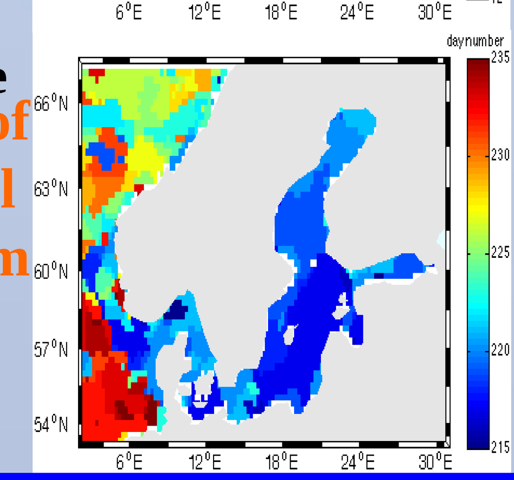


Figure 3. Summary of the 32-year averaged annual cycle of SST: a) amplitude, b) minimum SST, c) date of the annual minimum, d) maximum SST, e) date of the annual maximum as observed in the 32-year averaged annual cycle data.

Note that the amplitude of the SST annual cycle in the Baltic Sea is larger than in the North Sea, with significantly lower annual minimum SST and higher annual maximum SST in the Baltic Sea in comparison to the North Sea near the entrance to the Baltic Sea.

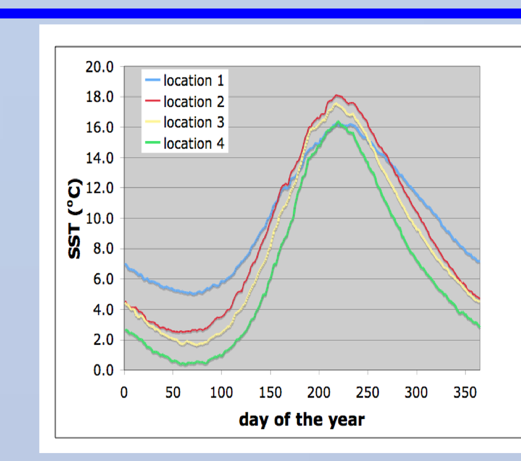


Figure 4. Comparison of the 32-year averaged annual cycle of SST at 4 study locations shown in Figure 5. The location 1 is characterized by smaller annual SST amplitude than other locations.

Conclusions:

1. The most prominent feature of the SST variability is the annual cycle with SST amplitude of about 16 ºC. On average, annual minimum temperature of about 3ºC in the southern Baltic and -2ºC in the northern Baltic is observed in February- March. Annual maximum temperature of about 19 ºC in the southern Baltic and 16 ºC in the northern Baltic is observed in August, but in some years SST can exceed 24 oC.

2. The 32-year SST data show statistically significant trend (p<0.05, 95% confidence level) of increasing SST values. Our analysis indicate that this trend is strongest in the summer months (July-September).

3. Interannual variability (illustrated as annual anomalies) seems to be coherent in different regions of the Baltic Sea and in the North Sea near the entrance to the Baltic Sea. This variability can be linked to the North Atlantic Oscillation index.

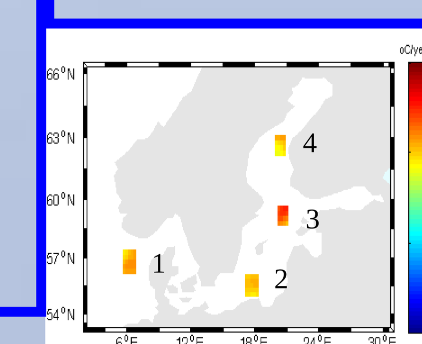


Figure 5. Location of the study sites.

32-year trend

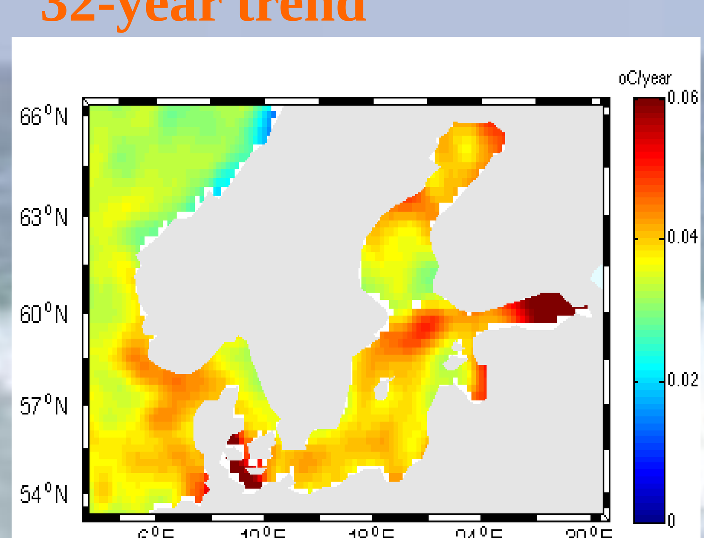
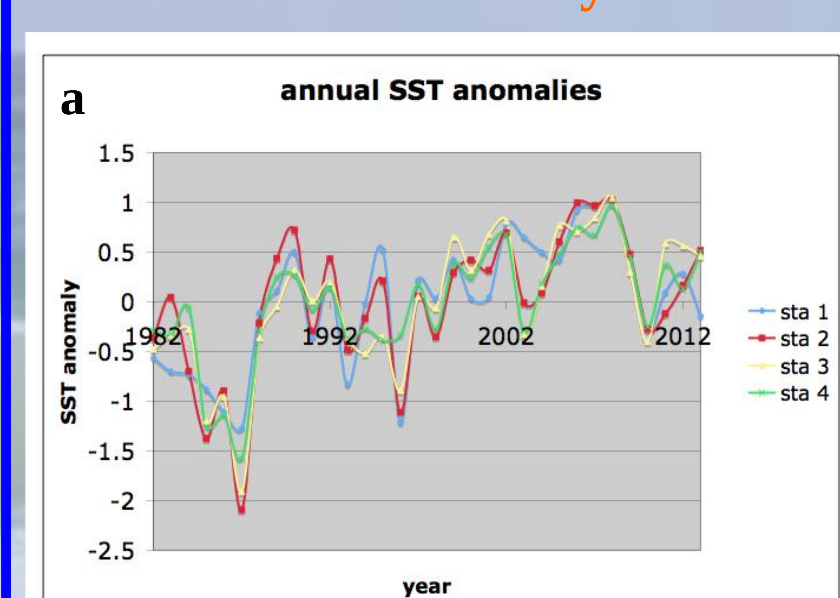
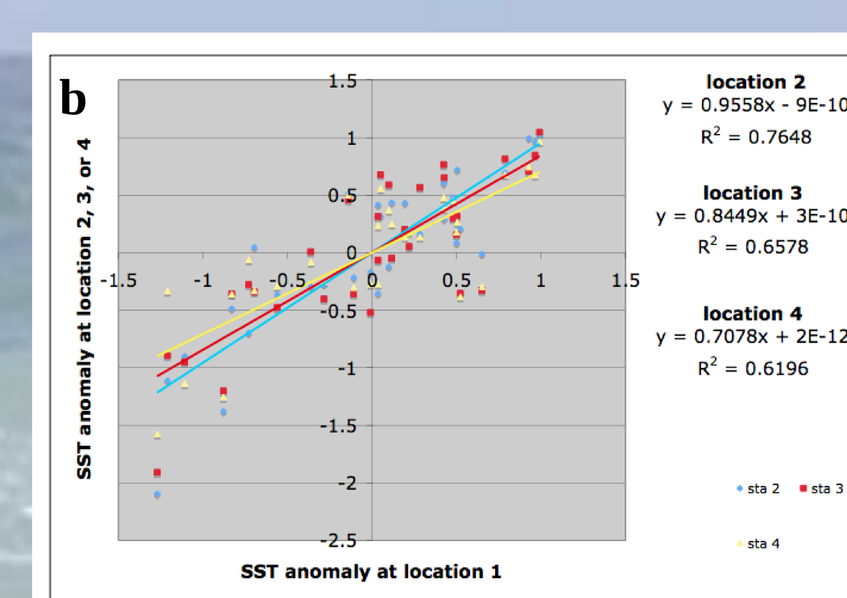


Figure 6. Trends in the SST records based on the time series from 1982-2013. Trends are statistically significant (p<0.05, 95% confidence level).

Figure 7. Trends in the monthly SST data averaged at the four study sites.

interannual variability





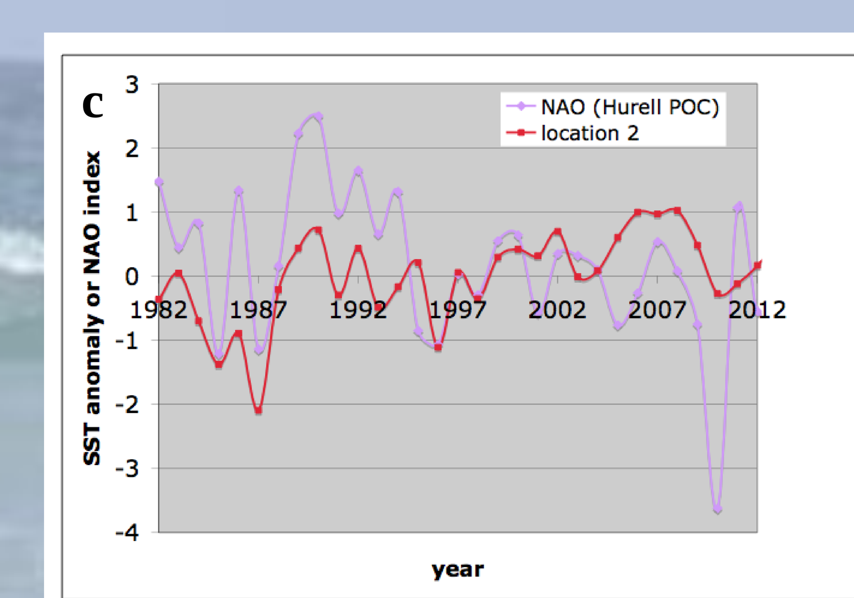


Figure 7. a) Annual SST anomalies at the four study sites. b) Correlation between SST anomalies at site 1 and other sites. c) Comparison of the PC based Hurrel North Atlantic Oscillation (NAO) index and SST anomalies at site 2. These Figures show that the interannual variability of SST in the Baltic Sea is coherent with SST variability in the North Sea near the Baltic entrance. The patterns in the interannual SST variability are similar to the patterns in the NAO index.

Acknowledgments. Financial support was provided by the SatBaltic project funded by the European Union through European Regional Development Fund, (contract No. POIG.01.01.02-22-011/09 entitled 'The Satellite Monitoring of the Baltic Sea Environment'). The National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) Reanalysis Project data were provided by NOAA-CIRES Climate Diagnostics Center.

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