Cyanobacterial blooms in the Baltic Sea in 2012

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Key Message

This summer, surface blooms of cyanobacteria were observed for six weeks in the Baltic Sea, from July 8 to August 20. More extensive blooms were present from July 25. The eastern side of the Bothnian Sea faced blooms for three weeks, starting in the end of July whereas the Gulf of Finland had very little blooms.

This year's bloom was lower than average in an initial comparison with previous years; however, the normalized bloom intensity, extent and duration should not yet be compared with the blooms between 1997 and 2009, as an improved detection method is used since 2010.

Due to the loss of the ENVISAT satellite in April, only MODIS data was used in 2012.

Results and Assessment

Relevance of the indicator for describing developments in the environment

Nitrogen fixation by cyanobacteria is a significant source of nitrogen to the Baltic Sea.

The amount of available phosphate in the surface water, water temperature and weather conditions during the summer are important factors regulating the intensity of cyanobacterial blooms in the Baltic Sea. During 2012 phosphate concentrations were high in the Baltic Proper, particularly in the southwest. (See SMHI, www.smhi.se/en/cruise-reports)

The weather in the Baltic region during the summer was unstable. Low pressure passages were common with frequent winds preventing the formation of surface blooms. However, subsurface blooms were commonly observed throughout the season.

Assessment

The Baltic Sea

The fickle weather this summer with few stable situations also affected the conduct of the cyanobacterial bloom. The lack of warm and calm periods allowed the wind to stir the uppermost layer of the sea, which prevented the formation of surface accumulations. The SMHI offshore sampling in the Baltic Sea on July 9-14 accordingly showed ample amounts of cyanobacteria, well mixed in the surface layer.

The cool and rainy start of the summer led to a sea surface temperature of only 14 °C by the end of June. Subsurface blooms of cyanobacteria were observed in the northern Baltic Proper on June 29, on the July 8 satellite data also showed some surface blooms in the Gdansk Bight. Continued unstable weather meant that more extensive surface accumulations were not observed in the Baltic Sea until the 25th of July. On July 27, satellite data indicated blooms in large parts of the Baltic Sea including the Gulf of Finland and the eastern side of the Bothnian Sea.

Increasing winds dispersed the surface blooms by the end of the month. The first days of August were calm, and surface accumulations now appeared in large parts of the Baltic Sea. A low pressure passed on the 6th and mixed the bloom into the surface layer. Surface blooms appeared once again, now mostly in the western Baltic Proper as well as on the eastern side of the Bothnian Sea. The blooms could be observed until the Baltic again became overcast on August 21. The last signs of a cyanobacterial bloom were seen in the Hanö Bight on the 27th of August.

In situ observations

During the SMHI expedition on July 9-14 with the Coast Guard vessel KBV001 Poseidon, the researchers observed scattered surface blooms in the Hanö Bight. Cyanobacteria, mainly of the species *Nodularia spumigena* and *Anabaena* sp. were blooming from the Hanö Bight northwards to the waters around Gotland. No blooms were found in the southern and southeastern Baltic Sea.

At the next expedition on August 22-27, the samples contained cyanobacteria mainly of the species *Aphanizomenon flos-aqua* but only in moderate quantities. As on the previous cruise, no extensive surface accumulations were observed. Instead, the bloom was well mixed in the water.

Normalized indexes

To be able to compare blooms between different years, the definitions of bloom normalized **duration (T), extent (A)** and**intensity (I)** have been developed. Based on the annual summaries (see example in Figure 1) where the area (a_i) is equal to the extent that is covered by surface accumulations of blooms during (i) number of days, the normalized duration and extent is given, with (i) ranging from 1 to the maximum number of days with bloom observations during the current year. The intensity is given in “extent days” or km^2 days. (Hansson, 2006 & Hansson & Håkansson, 2007)

$$\text{Duration, } T = \frac{\sum a_i * i}{\sum a_i} \quad [days]$$

$$\text{Area, } A = \frac{\sum a_i * i}{\sum i} \quad [km^2]$$

$$\text{Intensity, } \quad I = A * T \quad [km^2\ days]$$

Although no comparison with the years 1997-2009 should be made since the detection procedure has changed and the time series have not been corrected, the normalized bloom intensity was 10412 km^2days and duration 1.8 days, while the normalized extent was 5679 km^2. The maximum extent (~28 000 km^2) was observed on the 27th July. Overall the bloom in 2012 can be considered to be weak.

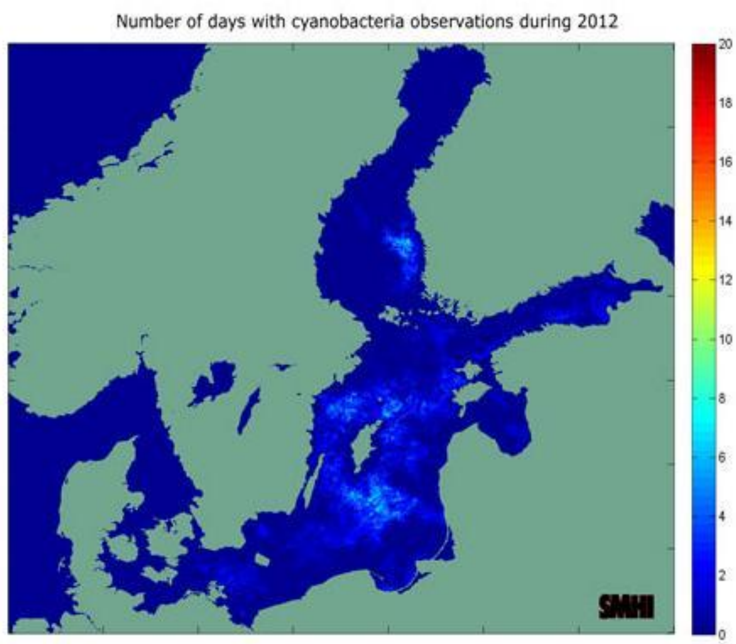

Figure 1. Number of days during 2012 with surface blooms of cyanobacteria observed in each pixel based on MODIS satellite data.

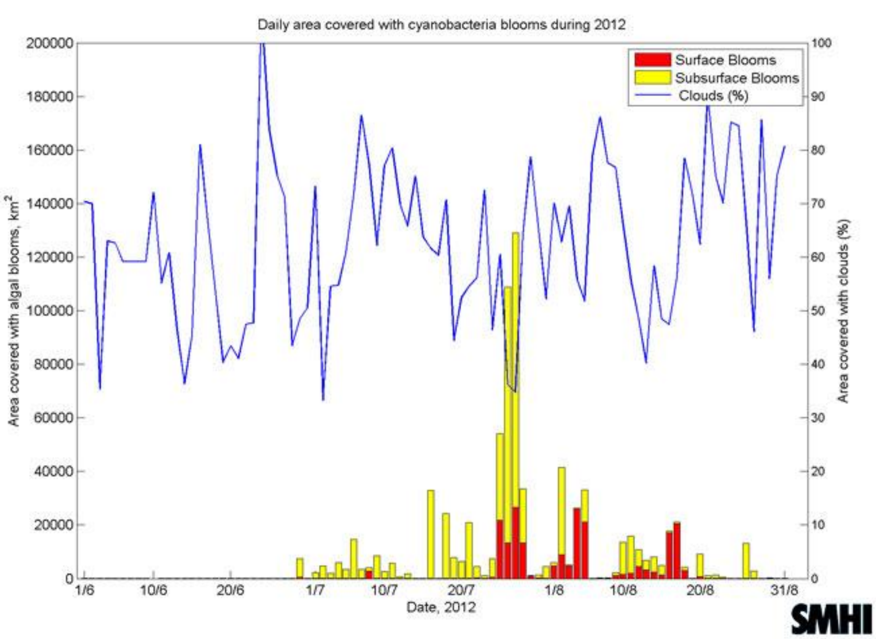

Figure 2. Daily extent of cyanobacteria blooms in the Baltic Sea during 2012, detected by MODIS satellite imagery. Red bars correspond to surface bloom and yellow bars indicate subsurface bloom. The blue line represents the integrated cloud cover (in percent of the total area) over the whole analysed area.

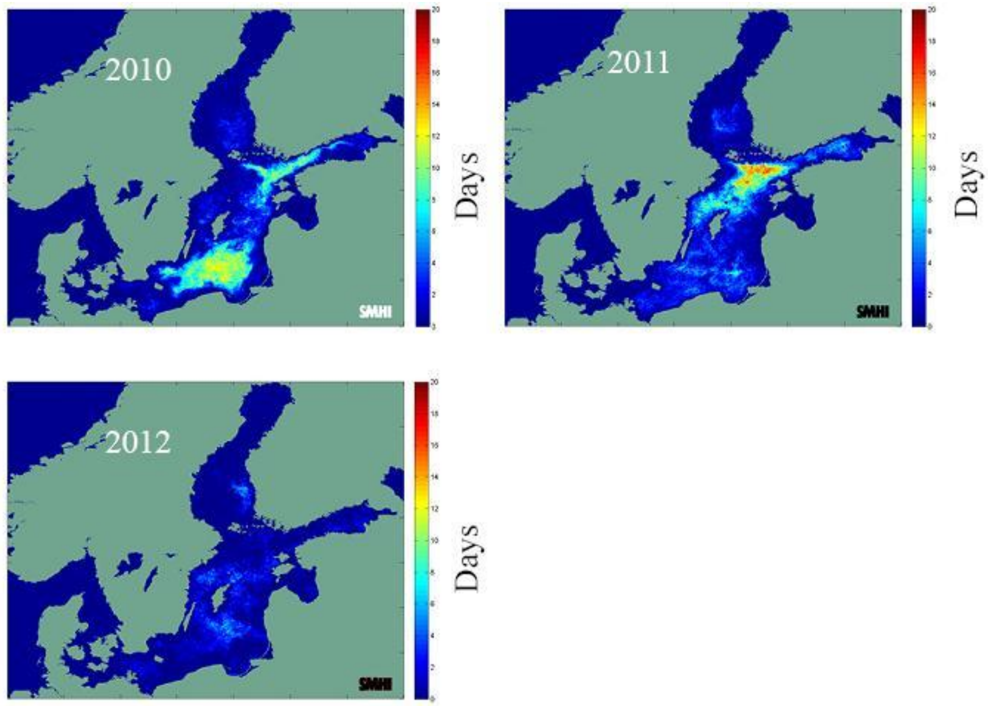

Figure 3. Summary of number of days with cyanobacterial blooms observed in each pixel during the period 2010-2012. Note that comparison between these results and results from the period 1997-2009 should not be made since the detection method is different.

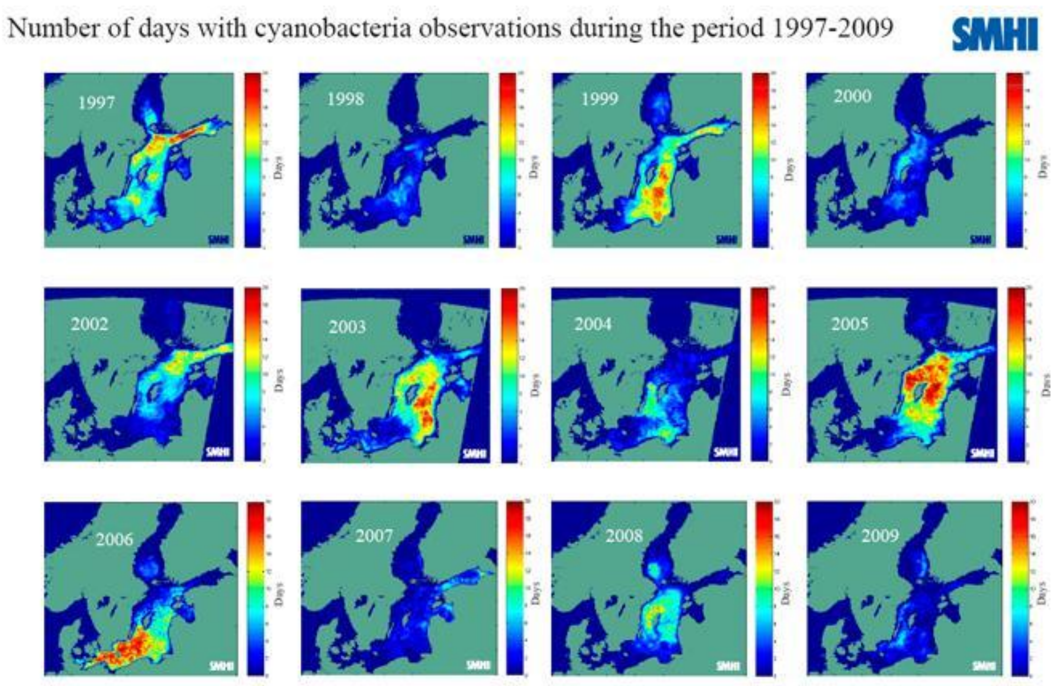

Figure 4. Summary of number of days with cyanobacterial observed in each pixel during the period 1997-2009, based on NOAA-AVHRR satellite imagery. Year 2001 is missing due to antenna malfunction at the receiving station. Note that comparison of the results from 2010-2012 with previous years is not possible since the detection method is different.

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Data

All MODIS L2 data covering the Baltic region that were available from the previous day area were automatically collected via FTP-boxes (Near Real-Time service at OceanColorWeb, NASA) to SMHI. Data from the previous day is convenient to use, since a new bloom map can be made available directly around 09:00 local time and the public and environmental managers can then get updated information about the algal situation early in the morning. It is also practical for the operator who does not need to wait for late arrival of satellite data which can delay the production of bloom maps. Analysed satellite images showing the extent of surface and subsurface bloom in the Baltic Sea is presented at the following website. The images are updated on a daily basis during June-August.

www.smhi.se/en/Weather/Sweden-weather/the-algae-situation-1.11631

Metadata

Technical information

1. Data source:

MODIS data is collected from the near real time service at OceanColorWeb at NASA.

2. Description of data:

Normalized water leaving radiance (nLw) from MODIS L2 data is used.

3. Geographical coverage:

The Baltic region; due to the longer revisit interval and the smaller swath width compared to AVHRR, daily coverage from MODIS of the entire Baltic region cannot be achieved.

4. Temporal coverage:

Data from the NOAA-AVHRR sensor have been available since the late 1970s. Karhu et al. (1994; 1997) has produced a compiled time series of satellite data for analysis of cyanobacterial blooms in the Baltic Sea from 1982 to 1994. In 2002, SMHI initiated the Baltic Algal Watch System (BAWS) that performs daily interpretations of satellite imagery during the summer. AVHRR data have also been analysed between 1997 and 2000 by SMHI in the EU-project HABES (Harmful Algal Blooms Expert System).

5. Methodology and frequency of data collection:

Data are collected automatically via ftp to SMHI. Scenes from the entire Baltic region are not always available on a daily basis since MODIS has a revisit interval of 1-2 days.

6. Methodology of data manipulation:

Methods to detect surface accumulations of cyanobacteria in the Baltic Sea has been develop for several satellite sensors: CZCS, AVHRR, SeaWIFS [Kahru 1997, Kahru 2007], and MODIS data. The detection scheme to classify blooms in MODIS data [Kahru, 2007] relies on a combination of threshold value masking of normalized water leaving radiance (nLw) in two bands; 551 and 670 nm. For the 551 nm band, where the radiation penetrates a few meters down in the water column, [Kahru, 2007] estimated a threshold of nLw(551) > 0.8 mWcm-2µm-1sr-1 by visual inspection of RGB composite images. The water signal in this channel is sometimes affected by shallow depths which gives a false high signal from the bottom. It is also sensitive to turbid waters such as river plumes or sediment rich coastlines, which has a strong signal. Because of water's strong absorption properties at 670 nm the radiation does not penetrate as deeply as band 551 nm. Hence, this gives a signal from the water surface that can be used to detect surface accumulations and also to filter out bottom reflections when combine with the 551 nm band. For the 670 nm the authors [Kahru, 2007] used the turbid water flag of MODIS which corresponds to a threshold of nLw(670) > 0.18498 mWcm-2µm-1sr-1. The method can be used to distinguish between blooms at the surface and blooms present just below the surface; subsurface blooms.

MODIS L2 data were collected from NASA's Ocean Color Web.

Two satellite data sets from one overpass are usually needed to cover the Baltic region. Depending on what data are available, the system can handle one or two data sets from each sensor. MODIS data is mapped to an equal area projection covering the Baltic Sea. Flags from the dataset is used to eliminate clouds or other conditions in which bloom detection is either not possible or likely to produce errors. Error pixels are marked as no data. The bloom maps present the occurrence of surface and subsurface blooms, clear water, clouds and areas with no data.

The operator quality controls the bloom map and writes a daily report, which is published on the web. A weekly composite, comprising of stacked images of the bloom observations during the last seven days is also published.

Quality information

1. Strength and weakness:

Satellite data have high sampling frequency and allow a synoptic view. Monitoring is limited to open sea areas due to shallow water effects and land contamination of pixel data, and are also limited by cloud cover. However, the new method enables monitoring closer to land than previously and it is now possible to detect blooms through scattered clouds, which is impossible when using AVHRR.

2. Reliability, accuracy, robustness, and uncertainty:

The new method has been tested on satellite data with well known blooms, such as 31^{st} of July 2008 and 11^{th} July 2005, with good results. The whole summer season of 2008 (1 June – 1 September) has also been tested to certify that results didn't drift throughout a season. The results and comparison with the previous method, which not yet have been published, show a good overall agreement between MERIS/MODIS and AVHRR. The detected area is slightly smaller with the new method since bloom patchiness is better represented. It is also evident from processing the bloom season 2008 that more blooms could be seen, since the cloud influence on the detection results was less with the new method.

3. Further work:

Up to now the main work has been to make the new combined MODIS and MERIS detection scheme operational. This work, funded by the National Swedish Space Board, is now finished but further work is needed to harmonize the time series from 1997 to 2009 with the new detection method. Future work will focus on the differences between MODIS and MERIS flags, since MODIS seems to be more restrictive than MERIS. The Maximum chlorophyll index (MCI) and Fluorescence Line Height (FLH) will also be evaluated to see if they are suitable contributing tools in the monitoring process.

Future work will also focus on availability of satellite data. MERIS has been lost and MODIS is operating beyond its technical lifetime so it is necessary to introduce other similar satellite data or include new missions into the service as soon as data are made available.

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/.