

Cyanobacterial blooms in the Baltic Sea

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Key Message

This year's bloom in the Baltic Sea was characterized by large variations both in time and space. Early signs of a bloom were first observed in the Hanö Bight on the 21st June and during the following four weeks, with warm high summer weather and prevailing calm winds, surface accumulations of cyanobacteria were established in the southern parts of the Baltic Proper. The other half of July was cold and windy and observations of cyanobacteria were sparse. In August blooms could again be detected but now in the northern Baltic Proper and in the Bothnian Sea. This year's bloom was relatively harmless in comparison with previous years; the normalized bloom intensity and duration during 2009 were well below average (1997-2007), while the normalized extent of the bloom was normal.

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 and weather conditions during the summer are important factors regulating the intensity of cyanobacterial blooms in the Baltic Sea. During 2009 phosphate concentrations were normal in the Baltic Proper with the exception of slightly elevated concentrations in the Arkona Basin. (See SMHI, R/V Argos cruise reports 2009, www.smhi.se).

Weather conditions in the Baltic region during the summer 2009 showed large variations. Favorable weather conditions for cyanobacterial blooms prevailed during late June and the first half of July. From mid July the weather situation changed to unstable conditions which continued throughout August interrupted only by short periods of warm and calm weather.

To be able to compare blooms between different years, 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^2days . (Hansson, 2006 & Hansson & Håkansson, 2007).

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

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

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

Assessment

Less than a week after the first observations on summer solstice, 21st June, surface accumulations of cyanobacteria could be seen stretching from the Hanö Bight, along Öland and further north to the Archipelago of Stockholm. It was mainly the southern parts of the Baltic Proper that were affected by surface accumulations during the first two weeks in July. The blooms around Gotland and northward soon vanished, but further south the blooms increased and between 12th and 20th July surface accumulation could be seen covering vast parts of the Baltic Proper south of Gotland.

From mid July the weather situation changed to unstable conditions with lower temperature and more wind than usual for July. All visible surface accumulations were dispersed and almost no observations of blooms were made during a two week period until the 4th of August when blooms were detected in the eastern Bothnian Sea. Blooms also reappeared along the Swedish coast from Öland and further northeast towards the entrance to the Gulf of Finland. After a week the blooms started to decrease and no surface accumulation of cyanobacteria were detected in the offshore parts of the Baltic Sea after 25th August.

Scientists from SMHI onboard the R/V Argos noted heavy surface accumulation in the south Baltic Proper during the expedition 29th June to 4th July but only scattered accumulation during the next expedition between 27th July and 1st August. Samples from the first expedition showed large amounts of both *Aphanizomenon* spp. and *Nodularia spumigena*. During the second expedition *Anabaena* spp. were also present in the samples.

The strongest surface accumulation during 2009 could be found east of Öland and in the Kalmar Sound during mid July and in the eastern Bothnian Sea during a week in August. The Hanö Bight, the Archipelago of Blekinge and Stockholm were also affected by surface accumulations near the coast. Although, in comparison with previous years, the normalized bloom intensity (16433 km²days) and duration (2.2 days) during 2009 were well below average (1997-2007), while the normalized extent (7305 km²) of the bloom was normal. The maximal extent (~45 000 km²) was observed on the 17th July. Hence, the bloom during 2009 can be considered to be relatively harmless in comparison with previous years.

The cloud cover during late July and late August were frequent and the area covered with clouds were only below 50% during late June to mid July and during a short period early in August.

Number of days with cyanobacteria observations during 2009

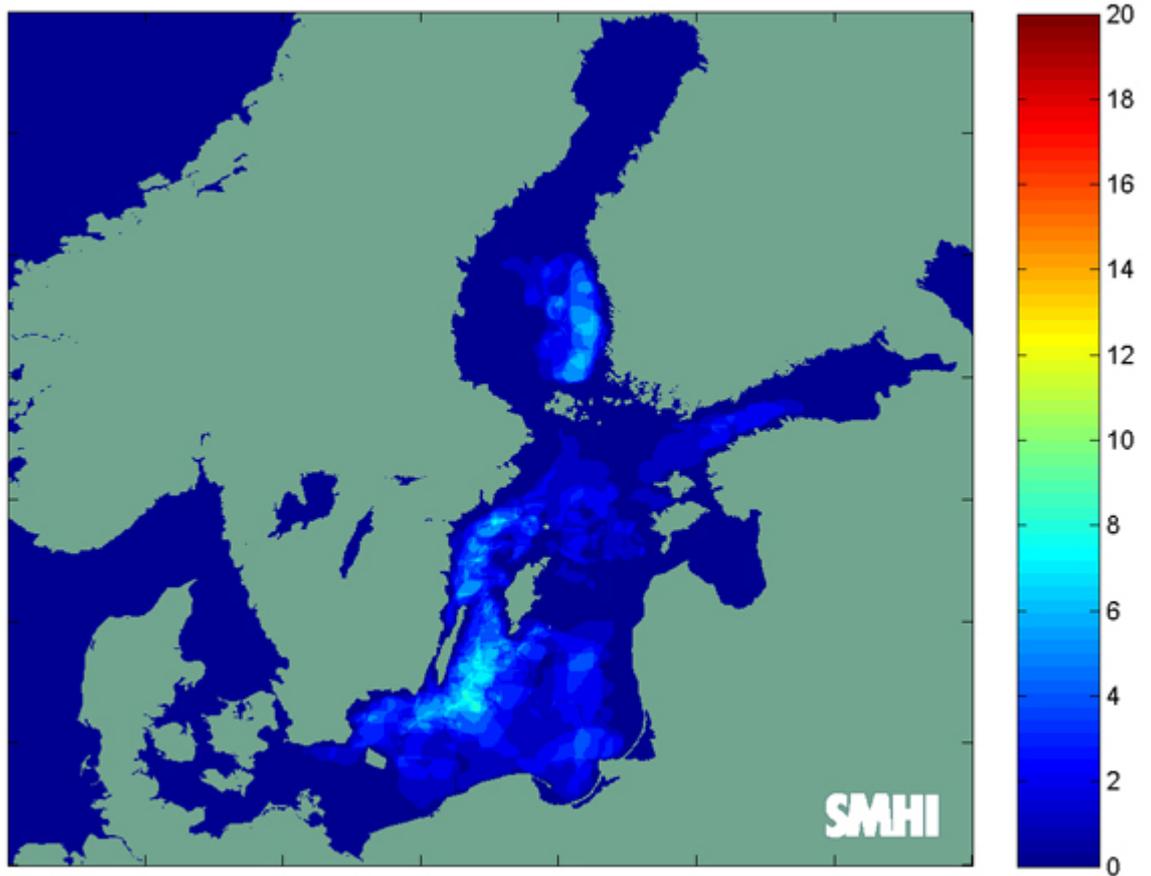


Figure 1. Number of days during 2009 with surface accumulations of cyanobacteria observed in each pixel based on NOAA-AVHRR satellite imagery.

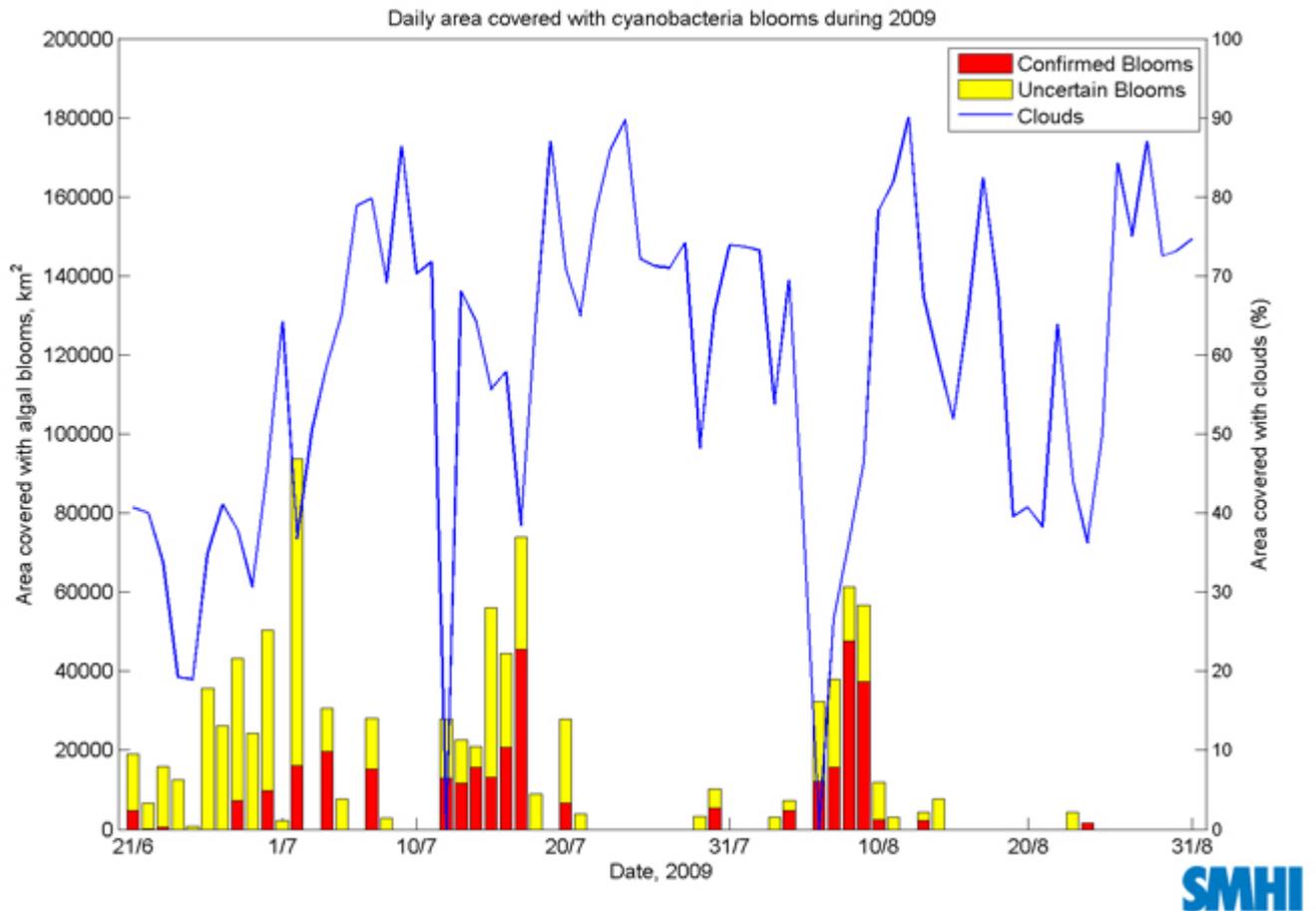


Figure 2. Daily extent of surface accumulations of cyanobacteria in the Baltic Sea during 2009, observed by NOAA-AVHRR satellite imagery. Red bars correspond to definite bloom observations and yellow bars indicate uncertain bloom observations. The blue line represents the integrated cloud cover (in percent of the total area) over the whole analyzed area.

Number of days with cyanobacteria observations during the period 1997-2009

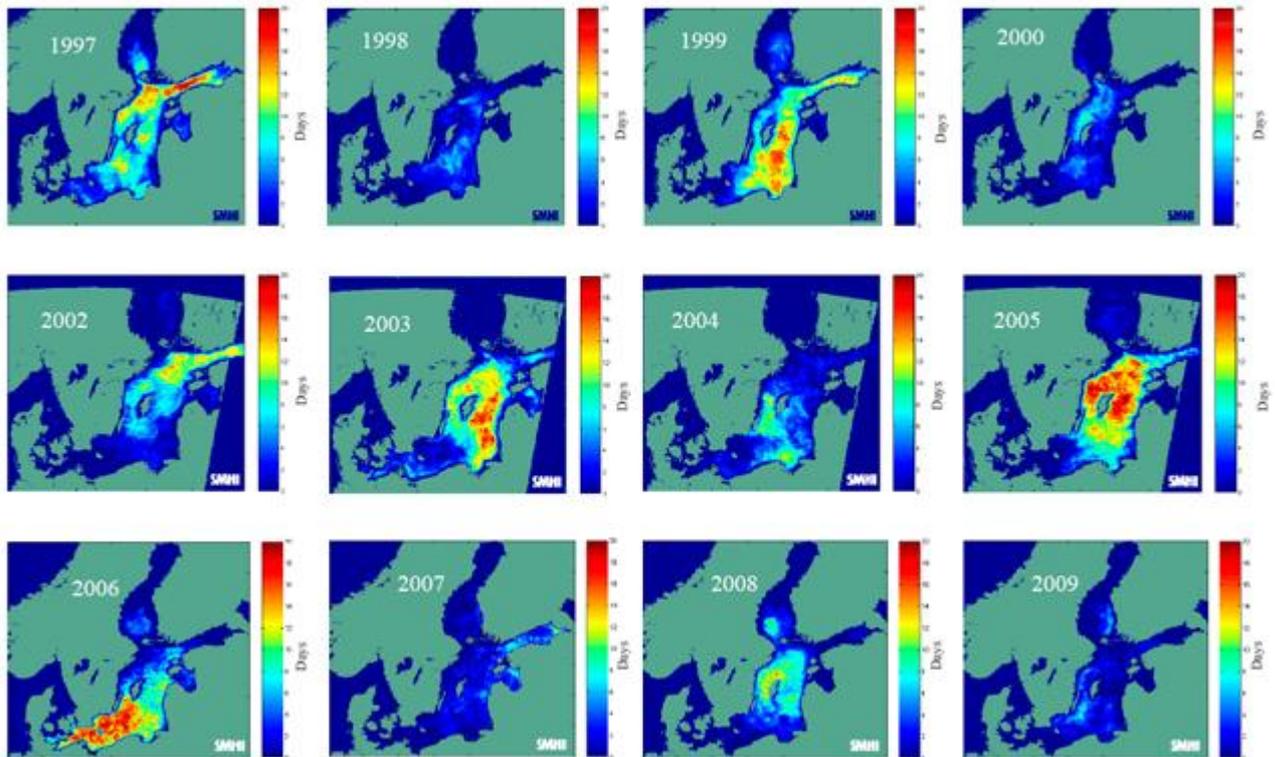


Figure 3. Summary of number of days with cyanobacterial observed in each pixel during the period 1997-2009, based on NOAA-AVHRR satellite imagery. Year 2001 is missing due to antenna malfunction at the receiving station.

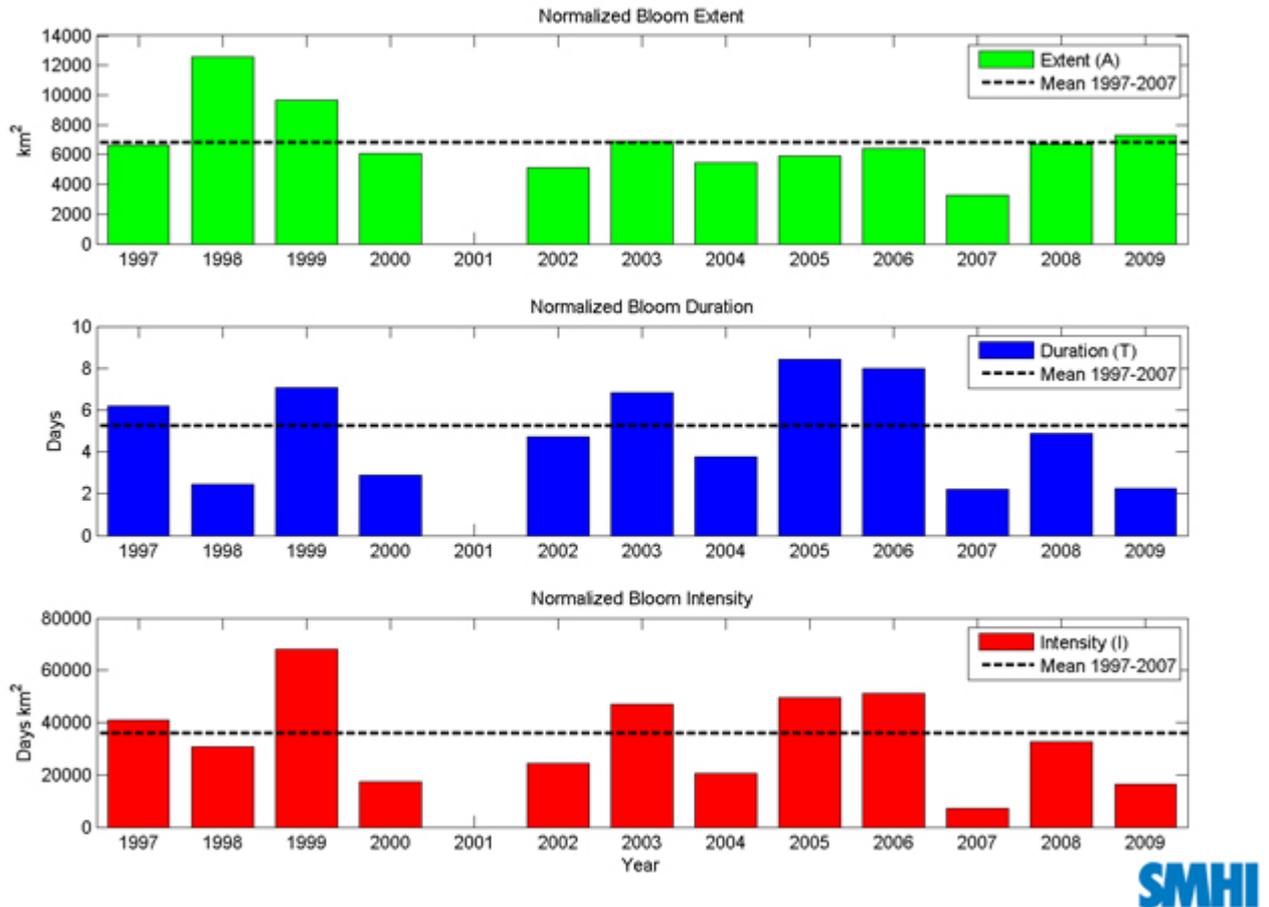


Figure 4. Presents a comparison of normalized extent, duration and intensity of cyanobacterial blooms between the period 1997-2009. The results are based on the yearly summaries. Note that presented data is normalized. See definition of normalized extent, duration and intensity above.

References

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SMHI, R/V Argos cruise reports & AlgAware, archive 2009.

<http://www.smhi.se/cmp/jsp/polopoly.jsp?d=7732&l=sv>

Data

The SMHI satellite receiving station in Norrköping collected the NOAA-AVHRR data.

Interpreted satellite images showing the extent of surface accumulations of bloom in the Baltic Sea is presented at the following website. The images are updated on a daily basis during summer.

http://www.smhi.se/weather/baws_ext/balt/BAWSstartDag_en.htm

Metadata

Technical information

- 1. Data source:** The AVHRR-data from NOAA-satellites was received with the antenna at SMHI headquarters, Norrköping. MERIS from ESA and MODIS from NASA.
- 2. Description of data:** The AVHRR-sensor measures radiation in 5 broad wavelength bands ranging from visible to thermal infrared.
- 3. Geographical coverage:** The satellite monitoring of cyanobacteria has many advantages compared to regular vessel based monitoring. The NOAA-AVHRR has a wide swath width (~2600km), hence the entire Baltic region are covered. An exception is near all land areas such as within archipelagos. These cannot be monitored due to the coarse pixel resolution (~1km). Since 2006 a new geographical coverage has been introduced covering the whole Baltic region.
- 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 Baltic Algal Watch System (BAWS) that performs daily interpretations of satellite imagery during the summer. AVHRR data have also been analyzed between 1997 and 2000 by SMHI in the EU-project HABES (Harmful Algal Blooms Expert System).
- 5. Methodology and frequency of data collection:** Satellite imagery is analyzed using both automatic cloud masks (O&SI-SAF) and manual interpretations. NOAA satellites have a repeat cycle of ~0.5 days and since there are several NOAA satellites mounted with the AVHRR sensor there can be ~12 overpasses per day. Between 0-6 overpasses are unsuitable for further analysis due to low viewing angles, sun glint, clouds or haze. The best viewing conditions are usually encountered during the morning.
- 6. Methodology of data manipulation:** Data were calibrated to albedo for visible and near infrared channels, and to brightness temperature for the thermal channels. Data were also geographically corrected to an equal area projection.

Quality information

1. Strength and weakness: Satellite data have high sampling frequency and allow a synoptic view.

However, monitoring is limited to open sea areas due to the coarse pixel size, and is also limited by cloud cover.

2. Reliability, accuracy, robustness, and uncertainty: The AVHRR satellite can only be used for monitoring of meso-scale, surface accumulations of cyanobacteria. Algae can be found further down the water column. These are impossible to detect with satellite imagery. Therefore satellite data must be complemented by shipborne measurements, for example by data from SMHI:s offshore sampling program or Alg@line. Uncertain bloom observations are always noted and reanalyzed when more satellite scenes are available.

Satellite data from the medium-resolution channels of MODIS (Moderate Resolution Imaging Spectroradiometer) flown on the TERRA and AQUA satellites and MERIS (MEdium Resolution Imaging Spectrometer Instrument) flown on ENVISAT were used when good imagery was available to re-analyse the algal maps derived from the NOAA-AVHRR data. Manual corrections were performed if needed.

3. Further work: Currently work, funded by the Swedish Space Board, is performed to establish a method to improve the detection of cyanobacterial blooms using a combination of three different satellite sensors; MERIS, MODIS and AVHRR. The aim is to have a new product operational to the blooming season 2010.

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