# GLOBAL MONITORING OF PLANKTON BLOOMS USING MERIS MCI

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ABSTRACT The MERIS MCI (Maximum Chlorophyll Index), measuring the radiance peak at 709 nm in water-leaving radiance, indicates the presence of a high surface concentration of chlorophyll a against a scattering background. The index is high in "red tide" conditions (intense, visible, surface, plankton blooms), and is also raised when aquatic vegetation is present. A bloom search based on MCI has resulted in detection of a variety of events in Canadian, Antarctic and other waters round the world, as well as detection of extensive areas of pelagic vegetation (Sargassum spp.), previously unreported in the scientific literature. Since June 1 2006, global MCI composite images, at a spatial resolution of 5 km, are being produced daily from all MERIS (daylight) passes of Reduced Resolution (RR) data. The global composites significantly increase the area now being searched for events, though the reduced spatial resolution may cause smaller events to be missed. This paper describes the composites and gives examples of plankton bloom events that they have detected. It also shows how the composites show the effect of the South Atlantic Anomaly, where cosmic rays affect the MERIS instrument.

**KEY WORDS:** MERIS, Ocean colour, Phytoplankton, Algal blooms, Sargassum

## 1. INTRODUCTION

The MCI (Maximum Chlorophyll Index) shows the amplitude of a peak near 705 nm in the radiance spectrum of light reflected from the earth's surface, which several authors have associated with high levels of chlorophyll a in ocean, coastal and lake water targets, such as plankton blooms and floating or benthic plants (Gitelson et al, 1992, Yacobi et al., 1995, Gower et al. 1999, 2005). Among satellites for monitoring large ocean and coastal areas, the index is unique to MERIS, in that a band covering 705 nm (for MERIS this is centred at 709 nm) is not present on either MODIS or SeaWiFS. We have been able to demonstrate use of the MCI to detect plankton blooms (Gower et al., 2005), floating sargassum (Gower, Hu, Borstad and King, in press) and "superblooms" of Antarctic diatoms (Smetacek, 1992) associated with platelet ice (Gower and King, in preparation).

Global composites of this index provide a new tool for detection and monitoring of plankton blooms and other aquatic vegetation. Although the MCI will not detect all of the harmful algal blooms (HABs) that are causing increasing damage to aquaculture, tourism and coastal water quality, it is clear that it has a role in monitoring some of the surface, high-chlorophyll events, which are widely publicized as "red tides." Global composites will allow us and others to extend the search for plankton blooms to the limits imposed by MERIS data collection, sun-glint and global cloud cover.

**Figure 1.** Example of a MERIS daily global composite showing the MCI for 7 July 2006. Full coverage would consist of 14 day-time passes. A major bloom event in the Baltic (Fig 4) can be seen at top centre.

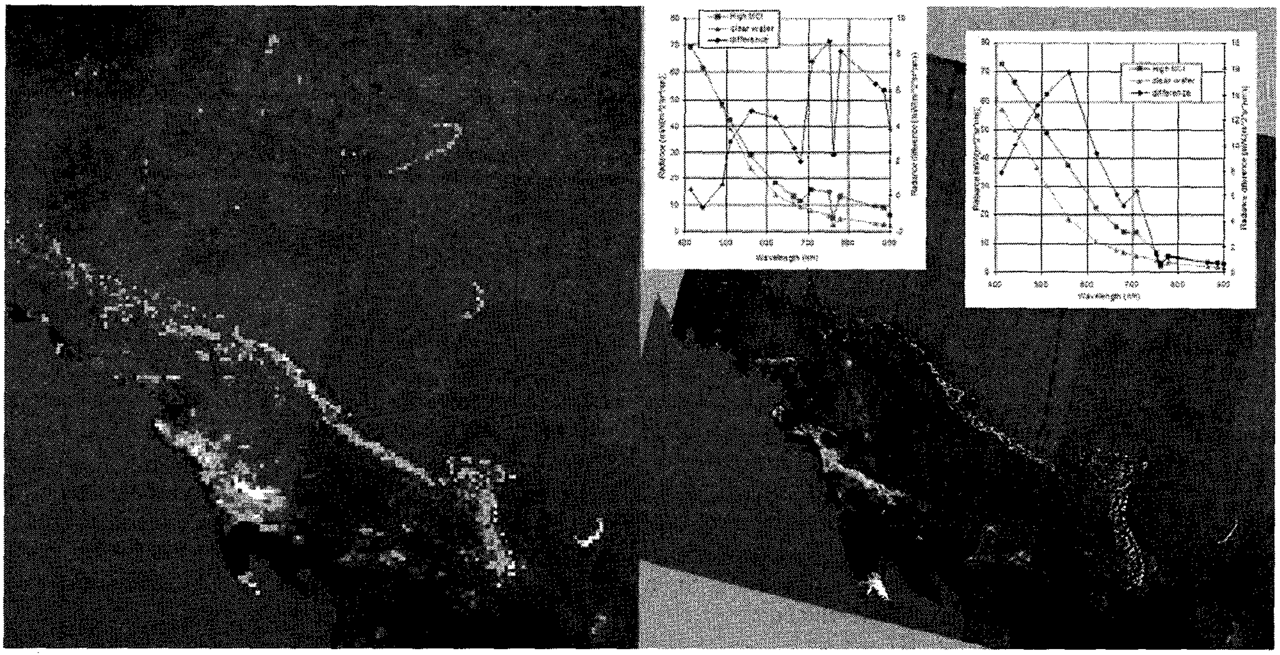

**Figure 2**. A bloom extending out of Repulse Bay, NE Australia, shown by the daily global MCI composite (left) for 21 August 2006, compared to higher resolution MERIS RR data (right), which includes spectra of level 1 (top-of-atmosphere) radiances from the bloom (left spectrum) and from an area of coral reef (right spectrum).

## 2. MERIS GLOBAL MCI COMPOSITE IMAGES

The global MCI composites have so far been developed by Pedro Goncalves as an example of the GRID computing capabilities at ESRIN, according to specifications provided by Jim Gower and Stephanie King at the Institute of Ocean Sciences (Fisheries and Oceans Canada) in Sidney BC, Canada. The specifications for the prototype composites were based on detection of MCI events in a number of locations round the world, including the coasts of Canada, the USA, India, Chile and Antarctica.

In Fig 1, an example of the present form of the composite, shows the 14 descending (daylight) passes which make up the MERIS coverage pattern for a single day. For this day, a missing pass causes a gap (white) on the right side of the composite, and a shorter gap occurs nearer the centre. Land, cloud and sunglint areas are masked to black. At this season, coverage is shifted to northern latitudes. There is adequate sunlight to collect data north of latitude 64N, where adjacent swaths overlap, while a cut-off at a minimum sun elevation prevents coverage over much of the Southern Ocean. Sunglint obscures the east side of the swaths between latitudes -10 and +50. MCI values are coded from dark blue (low), through light blue and yellow to red (high).

The MCI is computed as peak radiance at 709 nm above a linear baseline defined by radiances at 681 and 753 nm. Values are computed from level 1 data before atmospheric correction, since the events we are studying typically give radiances outside the range that can be handled by correction algorithms. The present prototype global composites have a nominal 5 km resolution, representing for each composite pixel, the maximum MCI value computed for any RR MERIS (1.2 km) pixel assigned to that composite pixel. The reduced spatial resolution compared to the 1.2 km of MERIS RR may result in smaller bloom events being missed, though the use of the maximum value for the composite will tend to preserve high values. (Figure 2).

Figure 2 compares the global composite data with MERIS RR data for a day and area when a bright surface bloom is detected in side Australia's Great Barrier Reef. Many details of the bloom and reef are preserved. The difference spectrum (bloom minus clear water) shows that a high percentage of water surface is covered with algae. The difference spectrum for the reef shows bright ocean bottom at blue and green wavelengths, with an MCI signal due to submerged vegetation on the reef. Fig 3 compares Fig 2 with earlier and later observations.

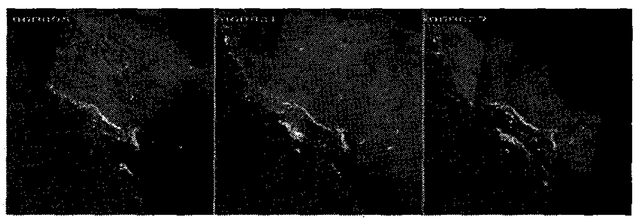

**Figure 3**. The bright bloom off Repulse Bay as shown by the daily global MCI composites for 5, 21 and 27 August 2006. The event started some time after Aug. 5, peaking near Aug. 21.

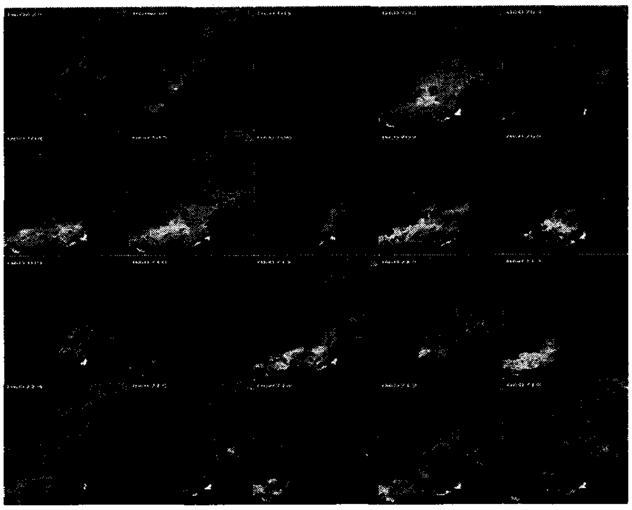

**Figure 4**. Segments of the daily global composites from 29 June (060629) to 18 July 2006 (060718) covering the southern Baltic

Figure 4 shows the Baltic Sea on a series of days when patches of high MCI were detected. The bright bloom (high MCI) event starts on about 30 June and continues intermittently to about 17 July. Sudden disappearances of the bloom after July 8 and 13 may correspond to surface winds mixing buoyant cyanobacteria cells down into the water column.

The Baltic blooms are confirmed by Swedish scientists to be intense surface blooms of cyanobacteria (E. Graneli, Kalmar University, pers. comm.) as observed in previous years. Blooms are at present being tracked using AVHRR satellite image data. These provide a single spectral band (band 1, 570 to 670 nm) for mapping the blooms, with a second band 2 (670 to 900 nm) that can be used to separate atmospheric effects, assuming band 2 water-leaving radiances are low. However, in many cases, this condition is not met. The additional spectral bands of MERIS can provide significant improvements in feature discrimination.


**Figure 5**. A bright bloom near the edge of the Chiang Jiang River plume as shown by the daily global MCI composites for 29 July and 1 and 4 August 2006.

Figure 5 shows patches of high MCI water off the coast of China in the area of the plume of the Chiang Jiang river. Although backscatter by silt in water will tend to increase MCI values, presence of high levels of chlorophyll are indications of plankton blooms in limited areas on the dates shown.

## 3. FALSE ALARMS FOR BLOOM DETECTION

There are a number of sources of false alarms which need to be taken into account in interpreting the composites. High MCI values in shallow water will often be due to benthic vegetation (Gower et al., 1999, 2005). Many examples are shown in Figs 2 and 3, associated with the Great Barrier Reef, and in Fig 5 near the coasts of China and Korea. Silty water will tend to increase MCI values by increasing backscattered radiances. However, the broad-band backscatter due to silt is easy to detect in the satellite data.

Events covering a small spatial area can also be due to cosmic ray hits on the single elements of the CCD detectors of MERIS. Figure 6 shows the global spatial distribution of single pixel events in MCI detected by MERIS. Events are located by examining 3 by 3 pixel areas of the global daily composites and accepting only areas where the eight edge pixels all have valid MCI (that is, excluding "no-data", cloud or land), where the standard deviation of the eight edge pixels is below a threshold S, and where the centre MCI value exceeds the average of the eight edge pixels by more than a threshold V. For Figure 6, S = 0.05 mW/($m^2$.sr.nm) and V = 0.3 mW/($m^2$.sr.nm). Because of the geometrical projection used for the composites, this algorithm will detect fewer events at higher latitudes, cutting off at about 60 degrees north and south latitude.

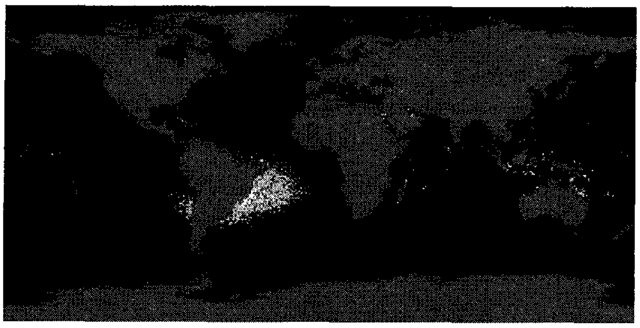

**Figure 6**. The global spatial distribution of single pixel events in MCI detected by MERIS, showing the higher concentrations in the South Atlantic Anomaly

Figure 6 was computed using all daily MCI composites for the month of July 2006. Colours from dark blue to green, yellow, red and white show increasing numbers of events in a given one-degree area. The large number of events over the South Atlantic off Brazil correspond to the position of the South Atlantic Anomaly in cosmic ray intensity at the altitude of Envisat. In other parts of the world, most events are due to vegetation on isolated coral reefs and other reefs. MCI values are computed only over cloud-free water, so that persistent cloud (for example, off Peru) blocks detection of events.

## 4. CONCLUSIONS

The MCI composites produced by GRID will make the search for plankton blooms and other aquatic vegetation using MCI, systematic and global. Wider distribution of the composites, once refinements are added, can involve a wider user base in detection and monitoring of blooms and in exploitation of MERIS data generally. Coverage is more frequent for events occurring at higher latitudes (such as the Baltic, Fig 4), due to convergence of Envisat's near-polar orbits. Nearer the equator, the gaps between passes widen (Fig 1) and coverage is also more limited by sunglint.

Although the MCI will not detect all of the harmful algal blooms (HABs) that are causing increasing damage to aquaculture, tourism and coastal water quality, it is clear that it has a role in monitoring some of the surface, high-chlorophyll events, occurring under clear-sky conditions.

## 5. ACKNOWLEDGEMENTS

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