On the importance of a band at 709 nm

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Summary

- 709 band originally designed as FLH baseline, with 665 nm, to measure relative peak at 681 nm
- 709 nm band also defines the MCI index of MERIS to measure relative peak near 705 nm, with 665 or 681 and 754 baseline
- MCI is sensitive to intense surface blooms, blooms in muddy water and ice (709 peak) coastal vegetation, floating *Sargassum*, coral reefs, (“red-edge”)
- MCI is relatively insensitive to aerosols, haze, sun-glint
- Spectra exist that show variation almost entirely at 709 nm
MERIS FLH image (left) compared with Algal 1 standard chlorophyll product (centre) for 21 July 2005. Fluorescence factor is observed FLH/expected FLH (right).
MERIS FLH image (left) compared with FUB Algal 2 neural net chlorophyll product (centre) for 21 July 2005. Fluorescence factor is observed FLH/expected FLH (right)
Comparison of FLH with chlorophyll for an area off the west coast of Vancouver Island, Canada, on July 21, 2005. The solid line shows our standard model FLH=offset + 0.18C/(1+0.2C), where offset = -0.1 to represent the FLH value of “clear” water (C=0) in this case.
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Status of FLH?

- Seems to be a low priority product for NASA and US users generally
- Will not be present on follow-on VIIRS sensor (this explains the low priority?)
- Is preserved on Sentinel 3
- In the US, FLH applications have been identified for bloom detection as well as for chlorophyll
- How useful is 709 nm for FLH? MODIS does without, uses 748 nm
- We believe that FLH is a valuable product whose applications will become more apparent with time
Water reflectance model based on Morel et al., (1988), with fluorescence at 685 nm and red-tide peak at 705 nm
Model reflectance spectra for submerged vegetation showing MERIS band positions and high MCI with peak near 709 nm.
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*Noctiluca* bloom observed in Saanich Inlet on 25 June 2003. The radiance of the peak at 709 nm is 10 X the rms level of peaks in the spectrum computed without this band (and omitting 761, 900 nm).
CSA’s new data reception capability for MERIS FR at Gatineau and Prince Albert gives better and faster access to full resolution data in support of regional DFO programs and studies.

A new Ecosystem Research Initiative will focus modelling and observation effort on the Strait of Georgia in 2007 to 2010.

The MERIS FR image from Prince Albert on 11 August 2008 shows the pattern of chlorophyll fluorescence (centre) with bloom conditions off Comox (bottom left) and on the edges of the Fraser River plume (bottom right) detected by the MERIS MCI product.
The bloom detected by MERIS MCI in the Strait of Georgia off Comox on 11 August 2008, comparing the spatial resolution available through CSA’s new Canadian station capability, FR (300m), left, with the more commonly available RR (1200m), right.
Coastal Vegetation

- Eel grass and kelp (benthic vegetation in water) give strong MCI signals
- Signal is modulated by water level (tide) and season
- A Coop student (Sara Fissel) examined local (BC) areas of this vegetation
MERIS MCI images of kelp beds off Kyuquot Sound at different seasons and tide heights
Variation of MCI signal with season for Kyuquot kelp beds. Significant variation is added by tides.
MERIS bloom hunt:
2 June 2005
Western Gulf of Mexico
ESA’s G-POD initiative
(GRID – Processing On Demand)

• Intensive processing for higher level data products
• Global MCI proposal accepted by ESA. Product for 2002 to 2007 delivered by end 2007
• Our algorithm for G-POD computes MCI, keeping only pixels that are dark at 865 nm
• Global daily products give maximum MCI in 5000m pixel areas
• Global monthly products give maximum daily MCI for each month
Global MCI composite computed by G-POD for 11 August 2008. (Note data cut-off at southern polar latitudes in August, latitude dependence of background signal level related to sun angle, and data masked for glint on east side of swaths at low latitudes.)
The global, daily MCI time series can be used to map any area to show seasonal pattern of high MCI events by month. Here, Gulf of Carpenteria, Australia, showing blooms, peaking in September (across: Jan to Dec, down: 2002 to 2008)
Antarctic Superblooms

- Not previously detected from space
- First noted* West of Antarctic Peninsula (Ronne Entrance) by MERIS MCI, March 2006
- MERIS spectrum indicates chlorophyll absorption (on broken ice background)
- Phenomenon described by Smetacek et al (1992) from observations 1971 to 1989
- Found over much larger areas using images of Antarctica from MCI global composites
- Appear to be increasing in area and intensity, 2003-2008

Blooms in High-Scattering Waters

- Occur in many coastal areas near river plumes or areas of tidal re-suspension
- Blooms associated with stratification and nutrient inputs
- MCI detects these blooms because of absorption by chlorophyll a at 681 nm
- Bleaching refers to reduction of pigment absorption, which will reduce the MCI signal
Sediment plume of the Fraser River, BC on 18 April 2007.

Top: MERIS RR Level 1. Left: True colour image showing plume, clear water and cloud. Ferry track in red. Centre: FLH has high values in some of the plume and negative (black) in others. Right: MCI has high values in the plume. Cloud and land masked to black for FLH, MCI.

MERIS MCI from G-POD global composites shows extensive blooms in the Fraser plume in June 2002, April and May 2007
Coral Bleaching

- Identified as a critical problem, expected in global warming
- MCI detects coral by the combination of pigment and water absorption
- Bleaching refers to reduction of pigment absorption, which will reduce the MCI signal
Maldive coral reefs mapped by MCI
A segment of the MERIS time series, 4 months by 3 years

Fisheries and Oceans Canada
Pêches et Océans Canada
The MERIS global MCI product provides a quantitative measure of coral extent and perhaps of health, modulated by water level (tides).

Water absorption is 1.0 /m at 709 nm, reducing MCI by 10% for a 5 cm depth increase, or to half for 35 cm
The MERIS global MCI product provides a quantitative measure of coral extent and perhaps of health, modulated by water level (tides). The global average uses a mask covering 13,000 pixels (320,000 sq. km.)
Band at 709 nm

• Useful for FLH, land vegetation. Essential for surface blooms, *Sargassum*, coral reefs, blooms in ice
• Not present on SeaWiFS, MODIS, VIIRS
• Present on GLI, Hyperion, AVIRIS, S-GLI, Sentinel 3
• 710 band “never applied” on Japan’s GLI wide-swath ocean colour

MCI (Maximum Chlorophyll Index) by GLI data

Akihiko Tanaka and Hajime Fukushima

\[ MCI_{GLI} = L(710) - \left( \frac{L(749) - L(680)}{749 - 680} \right) (710 - 680) + L(680) \]

\(L(\lambda)\): radiance (L1B data) [W/(m²*sr*μm)]

\(L(680)\): band12
\(L(710)\): band14
\(L(749)\): band16
2003.07.16 Baltic Sea

noisy image because of the edge of the data
2003.09.22 Japan/East Sea
Conclusions

- The 709 band (MCI) is proving its usefulness beyond “FLH baseline”
- G-POD extends this to global coverage for bloom and other detection.
- Capability “unique to MERIS” gives ESA a technical lead over other wide swath missions.
- Data from Canadian ground stations improve local (FR) coverage for all areas of Canada.
- We need to ensure that the capabilities of MERIS are preserved (as a minimum) in future sensors.
- Major relative drawback of MERIS is low coverage (two satellites needed).
Cosmic Rays
South Atlantic Anomaly as observed with MERIS

Count of all single pixel MCI events in global composites for July 2006

Data provided by the European Space Agency