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Improved algorithm for routine monitoring of cyanobacteria and eutrophication in inland and near-coastal waters

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ABSTRACT

This short communication describes several previously undocumented processing steps, pixel flagging procedures, and improvements made to the maximum peak height (MPH) algorithm, which is aimed at the operational detection of chlorophyll *a* (chl-*a*) and cyanobacteria blooms in inland and near-coastal waters. The improvements reduce false-positive cyanobacteria detection in oligotrophic waters; enable pixels in clear waters affected by environmental radiances (stray light) to be identified; and enhance detection of floating aquatic vegetation. Several case studies from around the globe are used to illustrate these improvements, and demonstrate new pixel flagging procedures and algorithm operation. The algorithm was validated using a large *in situ* dataset for chl-*a* from a wide range of inland water types. The MPH chl-*a* estimates were more stable than the fluorescence line height (FLH) and maximum chlorophyll index (MCI) values. The results demonstrate the potential for using the MPH algorithm, now released as a plug-in for the Basic ENVISAT A(ATSR) and MERIS (BEAM) processing toolbox, as a standard product for estimating chl-*a* (and trophic status) in inland and near-coastal waters using MERIS and the forthcoming Sentinel-3 Ocean and Land Colour Instrument.

1. Introduction

The maximum peak height or MPH algorithm (for details see Matthews, Bernard, & Robertson, 2012) was designed to give quantitative chlorophyll-*a* estimates in optically complex inland and near-coastal waters, as well as to detect cyanobacteria blooms and surface scum, and floating aquatic macrophytes. The algorithm uses the narrow red-edge MERIS bands positioned at 681, 709 and 753 nm and, using the 665 and 885 nm bands as a baseline, computes the position and height of the maximum peak at these wavelengths. The algorithm uses molecular scattering corrected bottom-of-Rayleigh reflectances (BRRs) or ρ_{BRR} and therefore avoids an error-prone aerosol correction over optically complex waters. BRR is the dimensionless reflectance above the aerosol and ground system corrected for gaseous absorption using climatological values for the gas content in the atmospheric column, and Rayleigh scattering which relies on barometric pressure (Santer, Carrere, Dubuisson, & Roger, 1999). This approach is used in favour of a full aerosol atmospheric correction because of the large uncertainties associated with water leaving reflectance products over turbid inland waters. The baseline subtraction technique effectively normalises for residual aerosol-induced effects given the relative spectral proximity of the red and near infra-red (NIR) bands. Cyanobacteria detection is performed using distinctive spectral features in the 620 nm and 681 nm bands, and a separate chl-*a* algorithm is used for these cyanobacteria-dominant waters. Floating matter identification is performed by the detection of a maximum peak position at 753 nm, which is then either classified as floating cyanobacteria (surface scum) or vegetation (macrophytes), depending on whether the spectral features of cyanobacteria are present. Designed for operational use, the MPH algorithm is intended to be broadly applicable to a wide variety of water types and trophic status encountered in inland and near-coastal waters.

The MPH has recently been extensively tested using the MERIS full resolution (FR) archived data from South African and global inland waters (e.g. Matthews, 2014, Odermatt and Brockmann, in preparation). This has highlighted the need for specific improvements, in particular surrounding the detection of cyanobacteria in clear, oligotrophic waters and the detection of dense floating aquatic macrophytes. The purpose of this paper is therefore firstly to provide details on these improvements since the first version of the MPH algorithm (Matthews et al., 2012).

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These improvements relate to the false-positive detection of cyanobacteria in oligotrophic-type waters, improved detection of dense aquatic macrophytes, as well as the introduction of a flagging procedure for pixels affected by the adjacency effect (stray light) or sun glint induced false classifications. Secondly, the detailed algorithm structure and processing scheme to be used for the MPH BEAM plug-in is presented. And finally, the paper shows initial validation of the MPH chl-*a* estimates using a selection of *in situ* chl-*a* datasets from lakes around the world.

2. The improved MPH algorithm

Fig. 1 shows a schematic of the algorithm processing procedure. ρ_{BRR} is calculated from the top-of-atmosphere (TOA) MERIS radiances using, for example, the Idepix plug-in processor available in BEAM 5. The ρ_{BRR} are computed for the red bands at 620, 664, 681, 709, 753 and 885 nm, which correspond to bands numbers 6 through 10 and 14. The first step involves the calculation of the various variables used in subsequent conditional steps. These include the identification of the reflectance peak magnitude and position for two different spectral ranges ($R_{max,0}$, $R_{max,1}$; $\lambda_{Rmax,0}$, $\lambda_{Rmax,1}$) used for the MPH calculation. $R_{max,0}$ is the maximum reflectance magnitude in bands 8 and 9, and $\lambda_{Rmax,0}$ is the corresponding peak position at 681 or 709 nm. Similarly, $R_{max,1}$ is the maximum reflectance magnitude in bands 8 through 10, and $\lambda_{Rmax,1}$ is the corresponding wavelength of the peak position. MPH_0 and MPH_1 are calculated from the corresponding $R_{max,0}$, and $R_{max,1}$. The rationale behind the two MPH variables is discussed in Section 4.

Other variables computed are the sun induced chlorophyll fluorescence (SICF) and the sun-induced phycocyanin absorption and fluorescence (SIPAF) peaks, as described in Matthews et al. (2012), and the

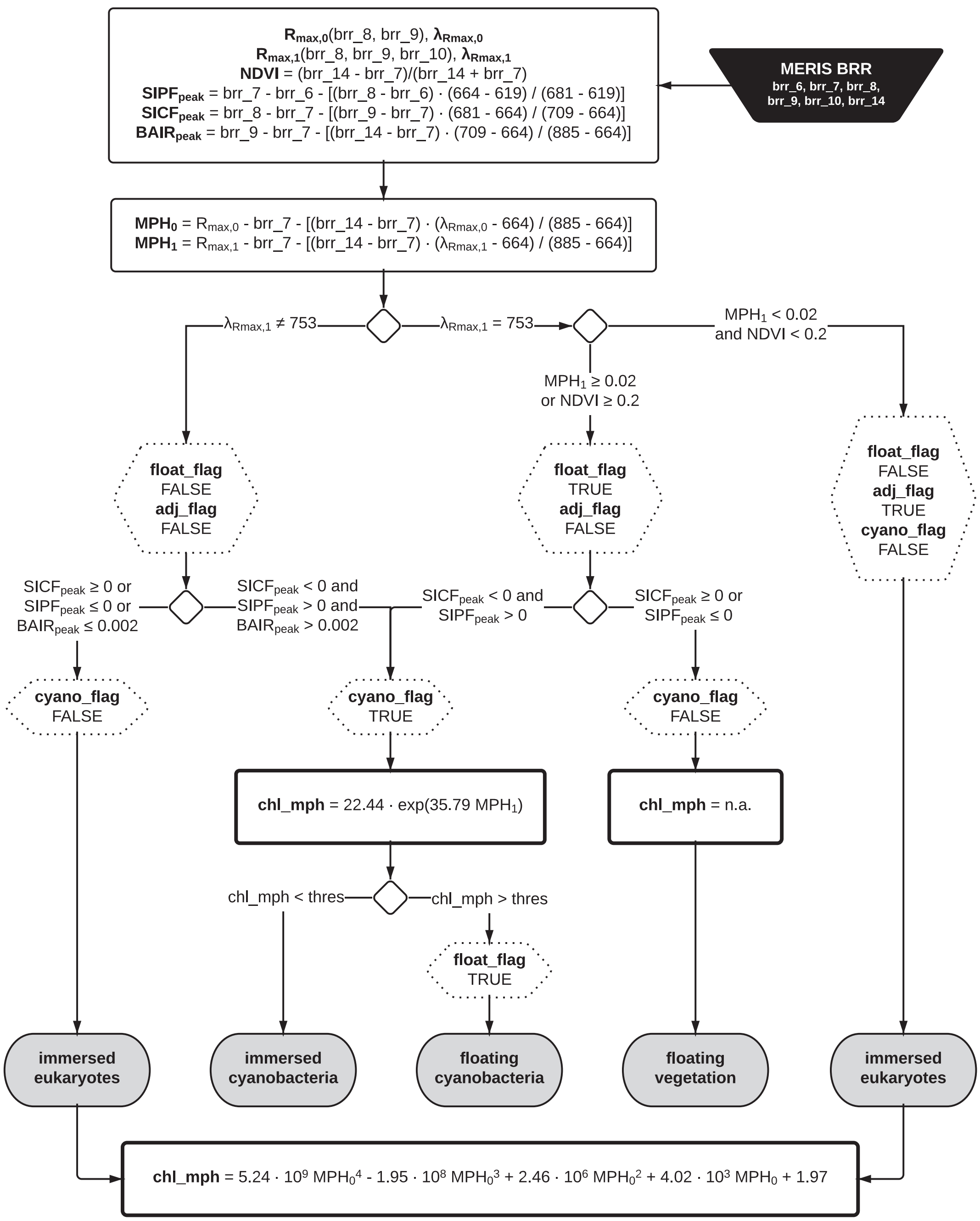

Fig. 1. Schematic diagram of the MPH algorithm processing procedure.