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Estimation of cyanobacteria biovolume in water reservoirs by MERIS sensor

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ABSTRACT

Planktonic cyanobacteria primarily develop in lentic water bodies, such as lakes and water reservoirs. In certain instances, toxin-producing cyanobacterial populations might dominate the phytoplankton community. Satellite remote sensing is a useful tool for large spatial scale monitoring of cyanobacteria, and the MERIS sensor from the Envisat satellite has taken worldwide images at a high frequency for over 10 years. This short time lapse image collection has provided an extensive record of images for the analysis of variation in the cyanobacterial communities in water reservoirs for management and scientific purposes. The objective of this work is to determine the relationship between measured cyanobacterial biomass as biovolume and the estimations derived from MERIS imagery. This study encompasses two independent studies relying on data from 23 water reservoirs. First, a long-term global limnological research study was conducted that provided a field data collection that included cyanobacterial biovolume, among other variables. Second, a survey was conducted that applied the processed images derived from the Envisat MERIS sensor. The chlorophyll-a (Chl *a*) content and phycocyanin concentration (PC) were estimated from the MERIS images. The PC estimated by remote sensing and total cyanobacterial biovolume measured from the field samples were found to be significantly correlated ($R^2 = 0.6219$; $p < 0.001$). No relevant differences were found among the taxonomical groups, which indicated that this tool provides accurate estimations irrespective of the cyanobacterial group. For validation, the algorithm derived from the entire dataset was applied to the MERIS image dataset of the Rosarito reservoir. An estimated cyanobacterial biovolume time series was performed and compared to the biovolume data collected in an extensive sampling schedule spanning 4 years. The results indicated a strong correlation ($R^2 = 0.72$; $p < 0.001$) between the measured and estimated data acquired on the same day.

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1. Introduction

Cyanobacteria are a phylum of photosynthetic prokaryotic organisms distributed worldwide (Whitton and Potts, 2002). In terms of human health risk assessment, cyanobacteria can pose a hazard when they produce cyanotoxins, a family of secondary metabolites that can affect different organs (liver, kidneys, skin, nervous system, etc.) (Chorus and Bartram, 1999). The harmful consequences of cyanobacterial toxins have been reported not only in laboratory bioassays but also in clinical and epidemiological studies that confirm the effects of toxic cyanobacteria on humans (Svircev et al., 2013). The production of certain cyanobacterial toxins is closely related to the amount of cyanobacterial biomass, especially when blooms appear (Spoerke and Rumack, 1985), which is why some organisations, such as the World Health Organization (WHO), have established criteria specifying the cyanobacteria abundance (cell number) and biovolume corresponding to different levels of threat to human health (Chorus and Bartram, 1999). A prompt response to dangerous blooms requires the accumulation of cyanobacterial biomass in water reservoirs to be continuously monitored. Numerous countries have developed regulations or guidelines to control cyanobacterial levels in water reservoirs, lakes, rivers and bathing zones by quantifying cyanobacterial biovolume, cell number, and chlorophyll-a concentration (Chl *a*) or cyanotoxin (i.e., microcystins) concentrations (Chorus, 2012).

Cyanobacterial development is greatly stimulated by eutrophication and nutrient excess in water (Vasconcelos, 2006). In limnological studies, the eutrophication level is assessed by quantifying the phytoplankton biomass (Willen, 1997) and Chl *a* (Hart, 1984). The Water Framework Directive (Directive 2000/60/EC[1]) and official regulations in many countries (Carvalho et al., 2013b) have specified that ecological status based on phytoplankton should be defined by measuring the biomass, composition and blooming events of the phytoplanktonic community. The Chl *a* concentration is a good parameter for evaluating the biomass of the entire phytoplanktonic community, but it does not provide information regarding the phytoplankton community composition, which must be assessed by biovolume estimations. Recent studies have shown that cyanobacterial biovolume can be used as a suitable metric for the assessment of the ecological status of lakes and reservoirs (Carvalho et al., 2013b).

Planktonic cyanobacteria develop mainly in lentic water bodies, including lakes and water reservoirs, and in some cases, the toxin-producing cyanobacterial population can dominate the phytoplankton, which might affect humans that consume the water or make use of it for recreational purposes or crop irrigation.

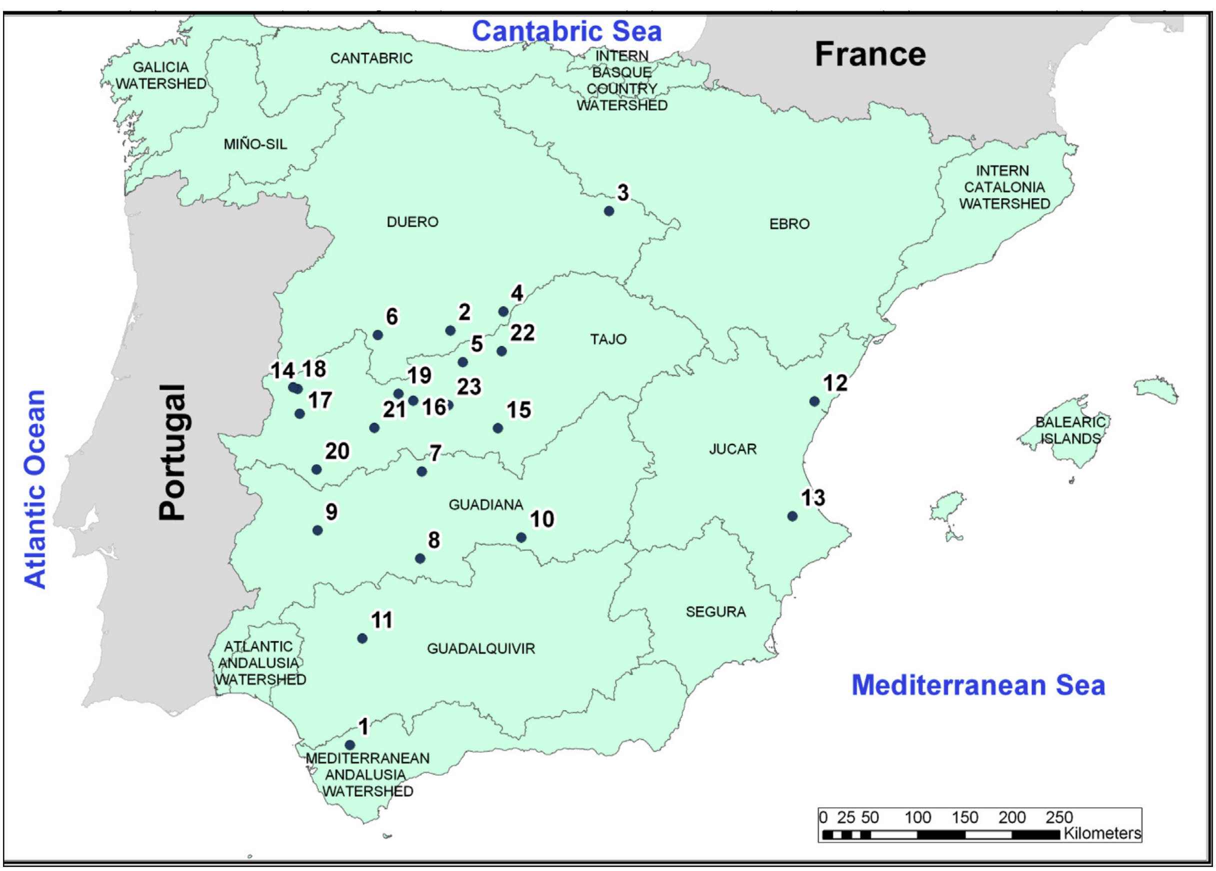

Fig. 1 – Map of the Spanish watersheds and water reservoirs that passed the inclusion criteria. (1) Arcos; (2) Castro de las Cogotas; (3) Cuerda del Pozo; (4) Pontón Alto; (5) El Burguillo; (6) Santa Teresa; (7) Cíjara; (8) La Colada; (9) Alange; (10) Vega del Jabalón; (11) Huesna; (12) Maria Cristina; (13) Bellus; (14) Borbollón; (15) Guajaraz; (16) Navalcán; (17) Portaje; (18) Rivera de Gata; (19) Rosarito; (20) Salor; (21) Valdecañas; (22) Valmayor; (23) Cazalegas.

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