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Spatiotemporal Variability of Chlorophyll-a Concentration in Lake Malawi using MERIS Data

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ABSTRACT

Lake Malawi is one of the most important lakes in Africa, due to its biodiversity and usefulness to the adjacent populations. However, some anthropogenic activities can threaten its water quality and ecosystem services. Lack of a systematic regular monitoring of chlorophyll-a (Chl-a) concentration, and understanding of its spatial and temporal variation are some of the drawbacks. In this study we propose the use of MERIS Level 1B data to monitor the lake's Chl-a concentration, and its spatial and temporal distribution. Using the NASA's standard OC4E_v6 algorithm for clear water, Chl-a concentration was retrieved, during the 2003-2011 period. The highest mean concentration (> 1 mg m^{-3}) for the entire lake was found in 2003. Since then the values dropped to a mean value below 1 mg m^{-3}. Nevertheless, the results showed a slight increase along the years although in small concentration. The Western and Southern part of the lake proved to be the most affected, having a mean Chl-a concentration around 5 mg m^{-3} , probably influenced by the anthropogenic activities in these areas, as the population pressure is high. The seasonal effects have also shown to have an influence in the Chl-a concentration, the highest concentrations were found in the first two seasons (November to April; May to August). It was also found that Chl-a concentration may differ depending on the location and season.

1. INTRODUCTION

Freshwater accounts for around 2.5% of total global water from which surface fresh water is about 1.2% and lakes 20.9% of the surface freshwater[1]. As the numbers above show, lake water is part of a very small percentage of fresh water available for direct use on earth. Lake Malawi is one of the most important lakes in Africa along with Tanganyika and Victoria. It is the source of fresh water, fishery products, and a variety of benefits to the bordering countries of the lake basin. It is located between (09^{o} 30' -14^{o} 40' S, 33^{o} 50' - 33^{o} 36' E, 472 m amsl) and also known as Niassa in Mozambique and Nyasa in Tanzania, but internationally and scientifically known as Lake Malawi. This lake is the 3rd largest lake in Africa after Victoria and Tanganyika and the 9th largest in the world[2]. Due to its location, Lake Malawi experiences three different seasonal variations in temperature, wind, and precipitation, here after from November to April Season one (S1), Season two (S2) May to August, and Season three (S3) from September to October. Chlorophyll-a (Chl-a) is tested in lakes to determine how much algae is in the lake, and algae is important in lakes because it adds oxygen to the water as a by-product of photosynthesis. On the other hand, if there is too much algae in a lake it can produce a foul odor which can be harmful to the people[3]. Therefore, understanding Chl-a concentration, its spatial and temporal variation in Lake Malawi is of paramount importance.

2. METHOD

We propose the use of MERIS Level 1B data downloaded from [4] to monitor Lake Malawi's Chl-a concentration, and its spatiotemporal distribution. The outputs from the atmospheric correction Neural Network (NN) of Case 2 Regional (C2R) processor, water-leaving reflectance were used as input for the calculation of Chl-a concentration. The C2R processor underwent a validation process for atmospherically corrected water-leaving reflectance[5]. Due to the known characteristics of Lake Malawi (clear water), NASA's standard MERIS OC4E_version_6 [6] was found to be the ideal model to retrieve Chl-a. This is a blue and green band ratio algorithm aimed at clear waters. The algorithm is expressed as follows:

$$\mathrm{Chla}_{\mathrm{OC4Ev6}} = 10^{(0.3255-2.7677b+2.4409b^2-1.1288b^3\ -0.4990b^4)}$$

where b is the $\log_{10}$ of the maximum band ratio of the three bands at the Rrs443, Rrs490, Rrs510 to Rrs560 and the coefficients were derived using version 2 of the NASA bio-Optical Marine Algorithm Data set (NOMAD) [6].

3. RESULTS

In this study, periods of peak of Chl-a were detected as well as their seasonal variability, which was complemented with the long-term change variation. Chl-a mean value-based maps were produced for yearly data.

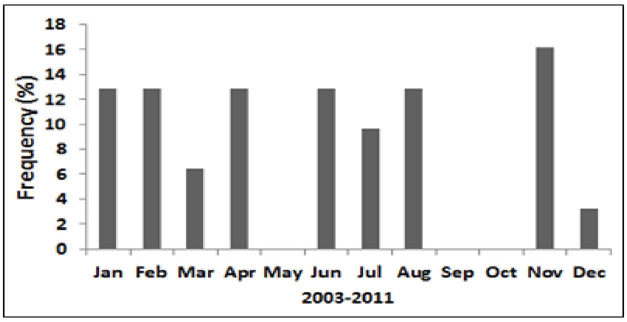

Fig 1. Monthly mean distribution of chla peaks for the period from 2003 to 2011.

As shown in Fig 1, no peaks were found in May, September, and October for the entire study period. However, March and December showed peak availability less than 10%. Contrary to previous months, November shows the highest peak frequency more than 14% followed by January, February, April, June, and August. These results go along with [7] regarding the peak found in April 2012 in their study and shows other peak seasons that were not detected by *in situ* measurements. The fraction of peak distribution throughout the months shows that S1 is the most active in terms photosynthesis in Lake Malawi. Fig 2 illustrates the Chl-a concentration range based on the annual mean value.

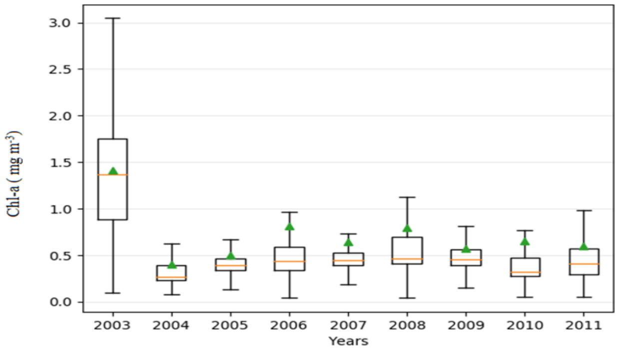

Fig 2. Temporal Variability of Chl-a.

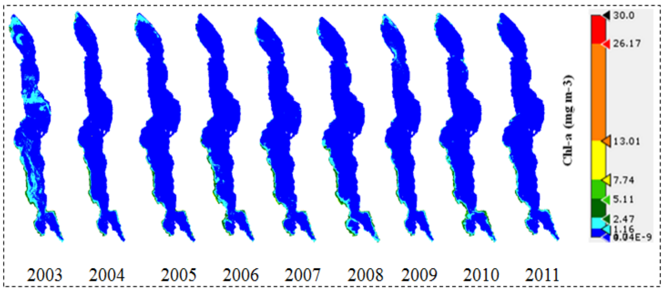

Fig 3. Spatial Variability of Chl-a

Figure 3, shows Chl-a spatial distribution during the 9 years of study. The first year of the study revealed to be the most spatially dynamic compared to other years. Generally, the mean Chl-a value in fig. 2 are (< 1 mg m^{-3}), represented by the green triangle.

4. DISCUSSION

After the abnormality in Chl-a spatial distribution in 2003, the yearly variation stabilized to a smooth but noticeable increase from 2004 to 2008 and an oscillation between 2009 and 2011. Throughout the 9 years of study, it was found that the highest values of Chl-a are found in the northern region of Lake Malawi, and in the central region with distinct attention to the West coast of the central and southern part of the lake. This is particularly true and goes along with formerly published papers [7,8] indicating the influence of anthropogenic activities. Chl-a detected in this corresponding area varies from 1.16 to 7.74 (mg m^{-3}).

5. CONCLUSION

During the 9 years of study using remote sensing data, S1 showed to be the most influential. The seasonal effects have also shown to have an influence in the Chl-a concentration, the highest concentrations were found in the first two seasons (November to April; May to August). It was also found that Chl-a concentration may differ depending on the location and season. Although 2003 presented high Chl-a values the rest of the years show low Chl-a concentration values, therefore the lake can still be considered as clear (oligotrophic). However, this trend tends to change, suggesting an increase in Chl-a concentration in the Lake.

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