Monitorização da qualidade da água de barragens com redes neuronais artificiais
Dam water quality monitoring through artificial neural network modelling

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SUMMARY

The water quality control of dams is fundamental, since these constitute indispensable renewable water resources for a variety of purposes. A feasible low cost approach for monitoring water quality bio-optical quantities is to use satellite spectral measurements that allow to continuously and globally follow the evolution of the water surface spectral reflectance. The present approach takes advantage of the Medium Resolution Imaging Spectrometer (MERIS) measurements, onboard ENVISAT satellite, as well as of the in situ samples of chlorophyll-a, cyanobacteria and total suspended solids (TSS), regularly collected and analysed. The method is applied to Alqueva dam the largest artificial lake in Europe in terms of surface area (250 km2), located in the south of Portugal (Alentejo). It is based on the use of a neural network that, after trained with a proper set of data, is capable of predicting the concentrations of the bio-optical parameters from the atmospherically corrected satellite spectral radiance.

1. INTRODUCTION

The successful launch of ENVISAT in March 2002 has given a great opportunity to understand the optical changes of water surfaces, including inland waters such as lakes and dams, through the use of the Medium Resolution Imaging Spectrometer (MERIS). The potential of this instrument to describe variations of optically active substances has been examined in the Alqueva dam, located in the south of Portugal, where satellite spectral radiances are correlated with *in situ* measurements of several bio-optical water quantities. MERIS data has already been used to study the water quality of lakes (Bukata et al., 1995; Reinart and Pierson, 2004; Odermatt et al., 2007), including Alqueva artificial lake (Potes et al., 2007). Nevertheless, a new methodology is exploited here, based on a neural network approach, which better matches the need to compare the *in situ* measurements with the spectral satellite data.

An artificial neural network is a mathematical or computational model based on biological neural networks. In most cases it is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. In more practical terms, neural networks are non-linear statistical data modelling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data.

In the present work, the atmospherically corrected satellite measurements, representative of the water surface spectral reflectance, together with *in situ* measurements of chlorophyll-a, cyanobacteria and total suspended solids (TSS), are used to train the artificial neural network used, which allows subsequently for determining the variations of these limnological parameters for situation when no *in situ* data is available.

2. METHOD

MERIS spectral radiances measured at the top of the atmosphere are corrected for the atmospheric effects to obtain the surface spectral reflectance, which can in turn be related with the *in situ* measurements of limnology (Bukata et al., 1995).

For this purpose, the 6S radiative transfer model is used (Vermote et al., 1997). The necessary inputs provided to the code are: the solar and satellite geometry; the aerosol characterization in terms of concentration, size distribution and chemical composition, and the water vapour vertical column concentration, being the latter two obtained from the AERONET site located in the CGE observatory in Évora (see online at http://aeronet.gsfc.nasa.gov/); the ozone column concentration is obtained from MERIS level 1b data. The radiative transfer calculations allow for obtaining the corrected surface spectral reflectance, which are essential to study the surface water properties.

The parameters analysed in this study are chlorophyll-a, cyanobacteria and TSS, all obtained from *in situ* analysis (Serafim et al., 2006). All of these quantities are important indicators of the water quality, therefore their monitoring is of paramount importance.

The neural network employed is a backpropagation one (see online at http://www.qnetv2k.com/qnet2000doc.htm), which is an extremely effective learning tool that can be applied to a wide variety of problems. Backpropagation related paradigms require supervised training. This means they must be taught using a set of training data where known solutions are supplied. In this study, the neural network is trained using water surface reflectances at ten different wavelengths (Table 1), as well as the corresponding *in situ* measurements of the abovementioned bio-optical quantities (chlorophyll-a, cyanobacteria and TSS). Subsequently, the artificial neural network is employed to estimate the same bio-optical quantities for different situations, that is only the water surface spectral reflectance is provided. In this way, it is possible to estimate the water quality parameters whenever there are atmospherically corrected water surface reflectance values at the ten wavelengths (Table 1). This enables the enlargement of the spatial, as well as temporal coverage of the *in situ* measurements, which are routinely taken locally, once a month.

Tabela 1 **– Comprimentos de onda MERIS utilizados *(MERIS Wavelengths used)***

MERIS band number	Central wavelength (nm)	Band width (nm)
1	412,5	10
2	442,5	10
3	490	10
4	510	10
5	560	10
6	620	10
7	665	10
8	681,25	7,5
9	708,75	10
10	753,75	7,5

3. RESULTS

The maps in the next figures illustrate the results obtained for Alqueva Dam on 6 February 2006. Figure 1 refers to clorophyll-a concentration, Figure 2 to cyanobacteria percentage and Figure 3 to TSS concentration.

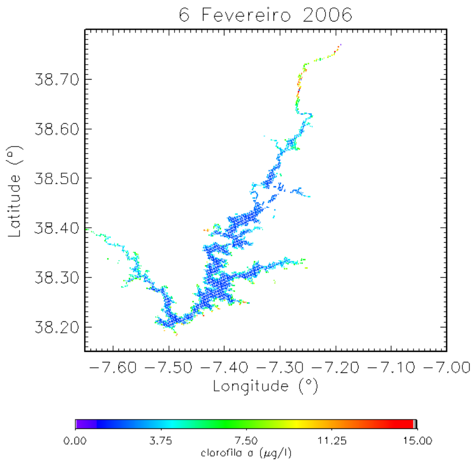

Figura 1 **- Concentração de clorofila-a obtida para 6 de Fevereiro de 2006, Barragem de Alqueva *(Chlorophyll- a concentration obtained for 6 February 2006, Alqueva Dam.)***

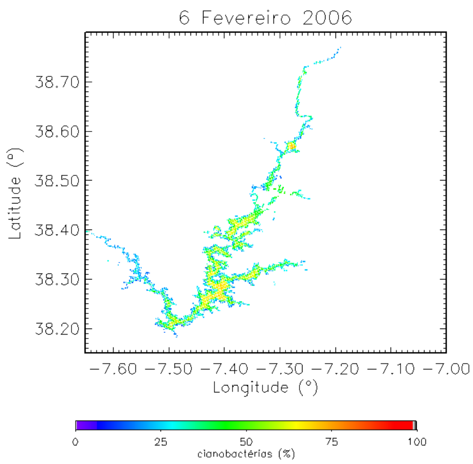

Figura 2 **- Percentagem de cianobactérias obtida para 6 de Fevereiro de 2006, Barragem de Alqueva *(Cyanobacteria percentage obtained for 6 February 2006, Alqueva Dam.)***

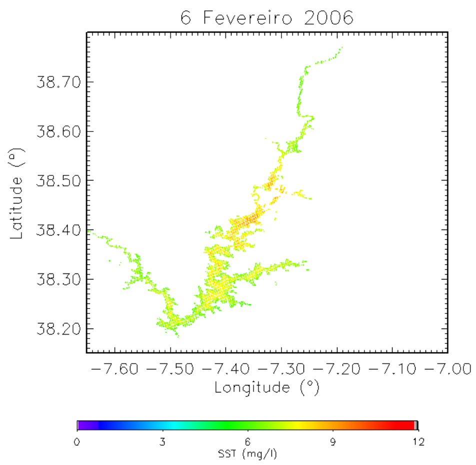

Figura 3 **- Concentração de sólidos suspensos totais (SST) obtida para 6 de Fevereiro de 2006, Barragem de Alqueva *(Total suspended solids (TSS) concentration obtained for 6 February 2006, Alqueva Dam.)***

4. CONCLUSION

The study enhances the great capabilities of MERIS sensor, associated with a powerful mathematical tool such as an artificial neural network, to monitor the quality of inland waters. The methodology allows to retrieve the chlorophyll-a and TSS concentrations, as well as the cyanobacteria percentages. Although results are preliminary, the comparisons with independent measurements give encouraging results.

Critical issues for the water quality parameter retrieval from satellite spectral measurements are the existence of measurements that allow for an accurate atmospheric correction. Further investigation is planned, including a campaign to directly measure the water surface reflectance, aiming at validating the method followed here.

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