2nd Workshop on Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling

Study of Water Quality using Satellite data

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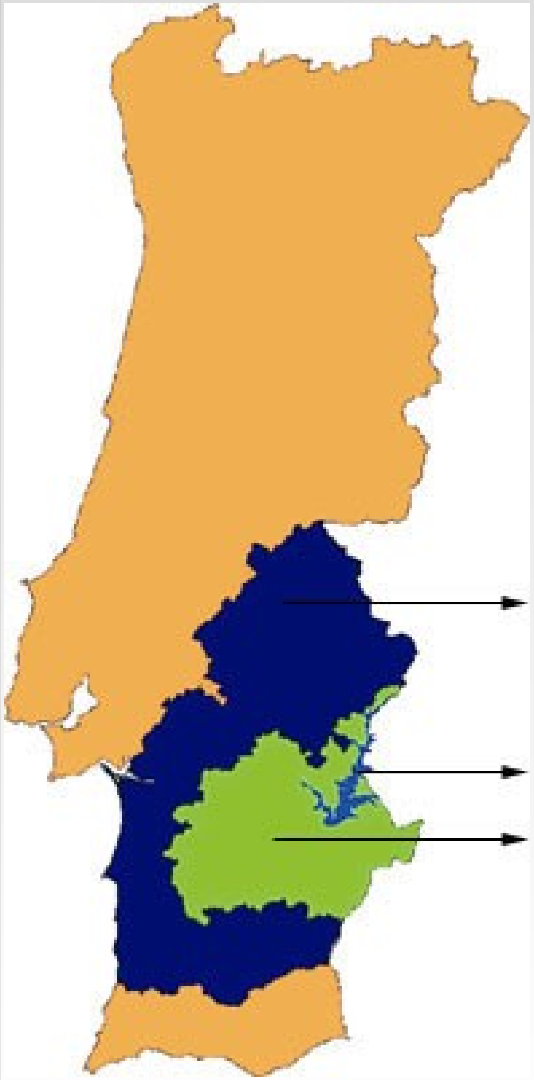
CGE

Norrköping, 17 September 2010

Reservoirs

- Constitute essential renewable water resource for domestic, agriculture, industry, energy, flood control, among other applications.
- Involve substantial changes to the system "river": residence time, temperature, stratification and often an increase in primary production.
- The seasonality of climate, particularly rainfall and solar radiation, resulting in seasonal changes in water quality.
- The variability and complexity of these changes are reflected in water quality, thus, detection of spatial and temporal changes in the state of the reservoir are very important for monitoring the water quality.

Alqueva Reservoir



Alentejo

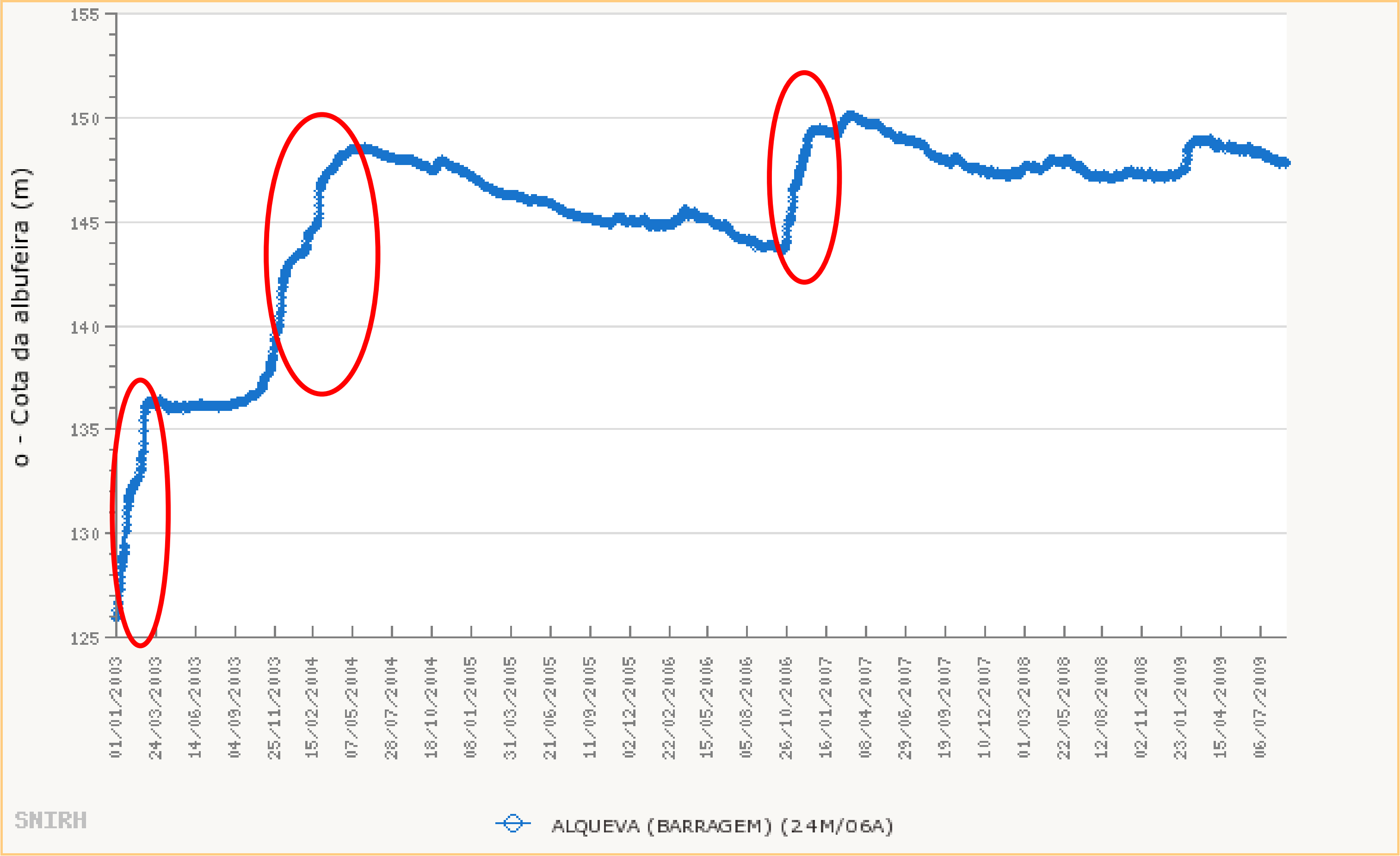
Alqueva reservoir

Influence area of Alqueva reservoir

SNIRH, INAG

- Location: Alentejo
- Length: 83 km
- Surface: 250 Km^2
- Maximum depth: 65 m
- Trophic state: eutrophic
- Gates closed in 2002

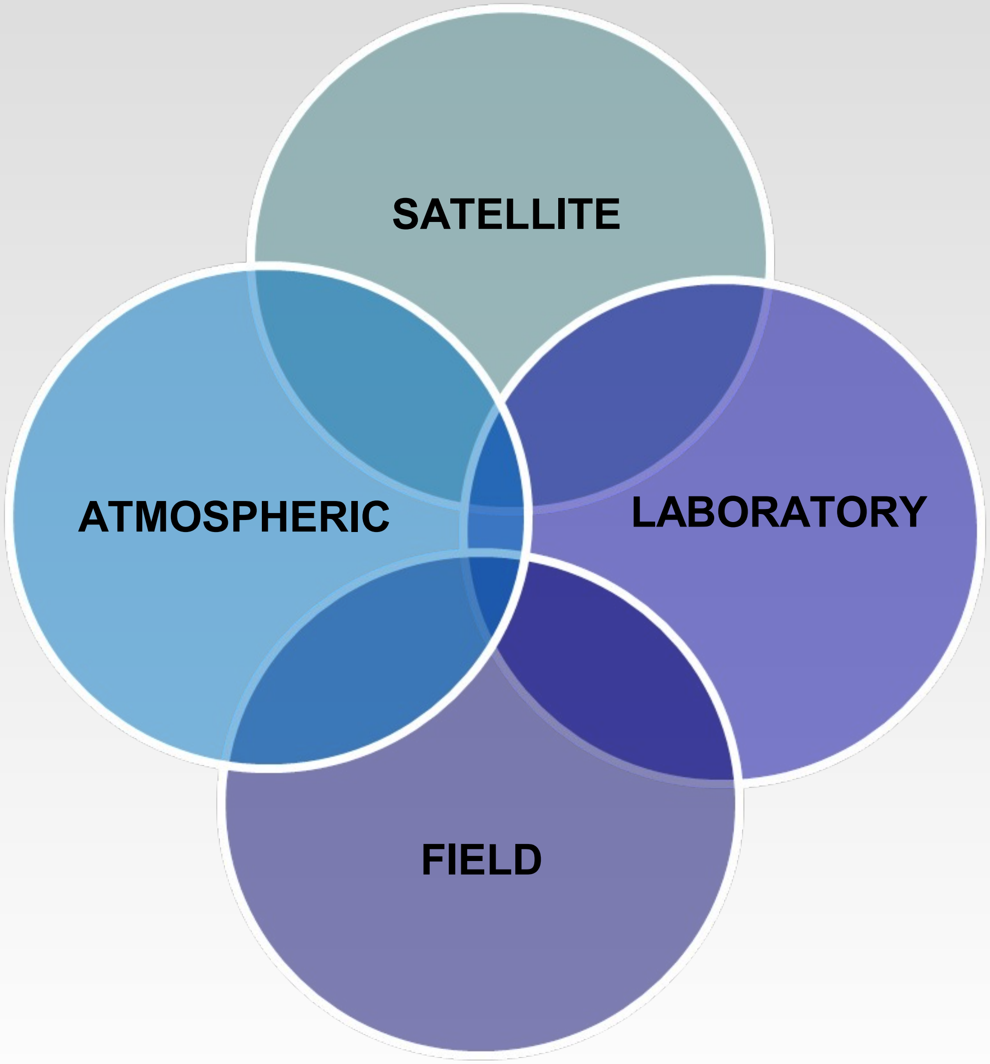
Evolution of Alqueva quota



Objective

- The goal of the present work is to explore reliable remote sensing methods for full spatial cover and continuous monitoring of key biological parameters which affect the water quality of inland water bodies such as Alqueva.

Data



Satellite Data

- **MERIS** (Medium Resolution Imaging Spectrometer) spectrometer aboard ENVISAT-1 satellite
- MERIS has 300 m full resolution in 15 spectral bands (0.4 to 1.05 μm)
- MERIS Level 1 products with TOA radiance
- Launched in 2002

Alqueva Reservoir

No.	Band centre (nm)	Band width (nm)	Application
1	412.5	10	Yellow substance and detrital pigments
2	442.5	10	**Chlorophyll absorption maximum**
3	490	10	Chlorophyll and **other pigments**
4	510	10	Suspended sediment, red tides
5	560	10	**Chlorophyll absorption minimum**
6	620	10	Suspended sediment
7	665	10	Chlorophyll absorption & fluo. reference
8	681.25	7.5	Chlorophyll fluorescence peak
9	708.75	10	Fluo. reference, atmosphere corrections
10	753.75	7.5	Vegetation, cloud
11	760.625	3.75	O_2 R- branch absorption band
12	778.75	15	Atmosphere corrections
13	865	20	Vegetation, water vapour reference
14	885	10	Atmosphere corrections
15	900	10	Water vapour, land

Atmospheric Data

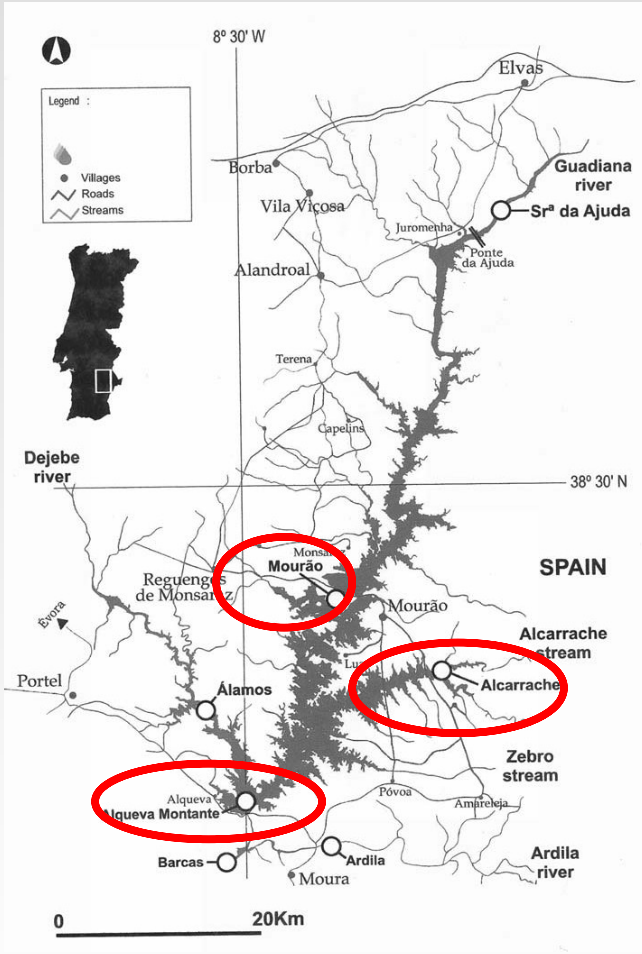
- Spectrophotometer CIMEL CE-318-2 is installed on Évora Geophysics Centre Observatory.
- Determine aerosol optical depth (AOD), aerosol size distributions, water vapor concentration in the column.
- Operating since June 2003.
- Data available at AERONET (AErosol RObotic NETwork): http://aeronet.gsfc.nasa.gov/

Laboratory Data

- Laboratory data were provided by **EDIA** (Empresa de Desenvolvimento e Infra-Estruturas de Alqueva) in collaboration , with Water Laboratory from Évora University, through the water quality monitoring program of Alqueva reservoir.

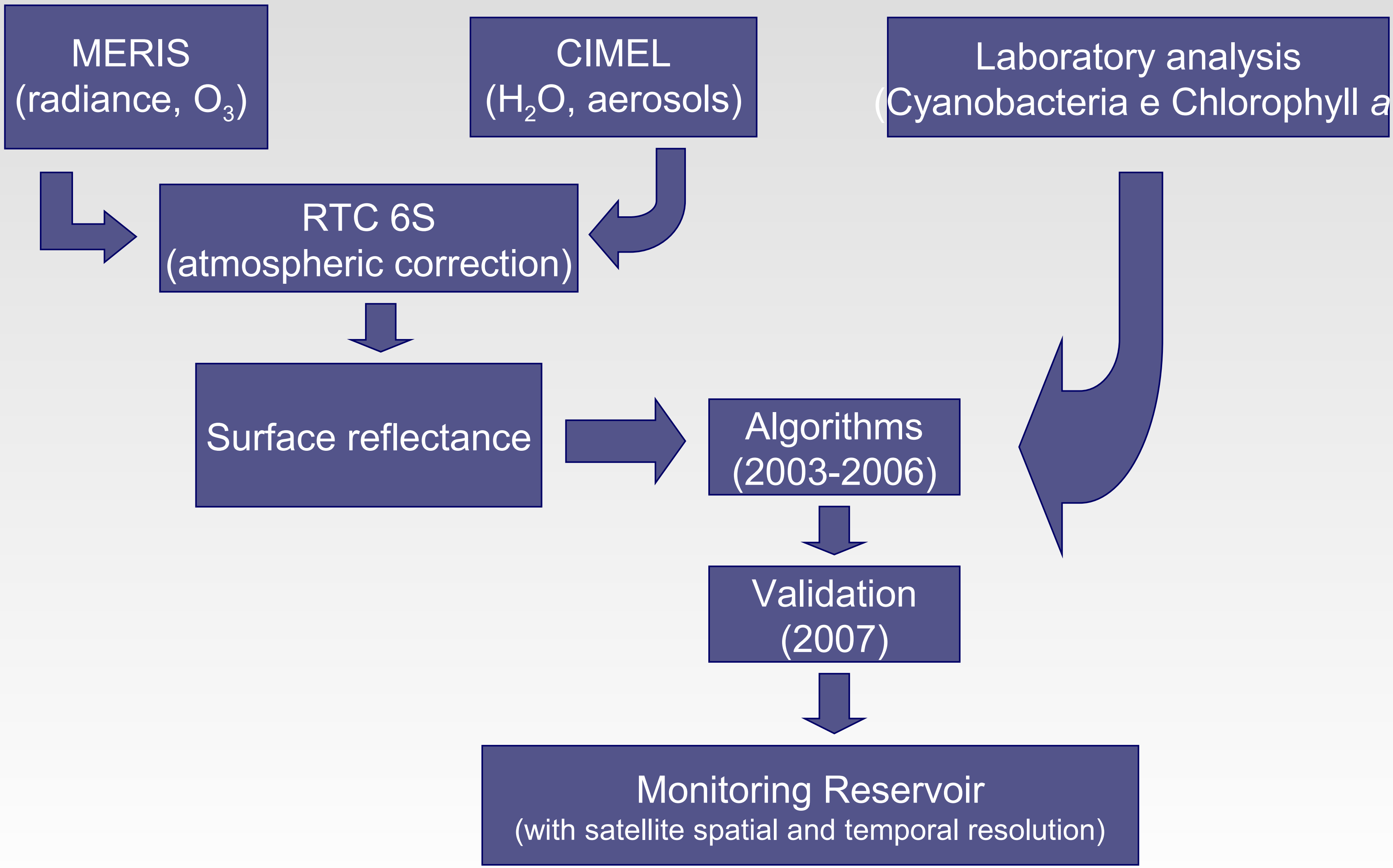
- Monitoring of cyanobacteria is very important since the formation of large density lead to blooms, resulting in toxins production – a serious risk to public health.

- Chlorophyll determination allows to estimate the phytoplankton concentration.



Serafim et al., 2006

Methodology

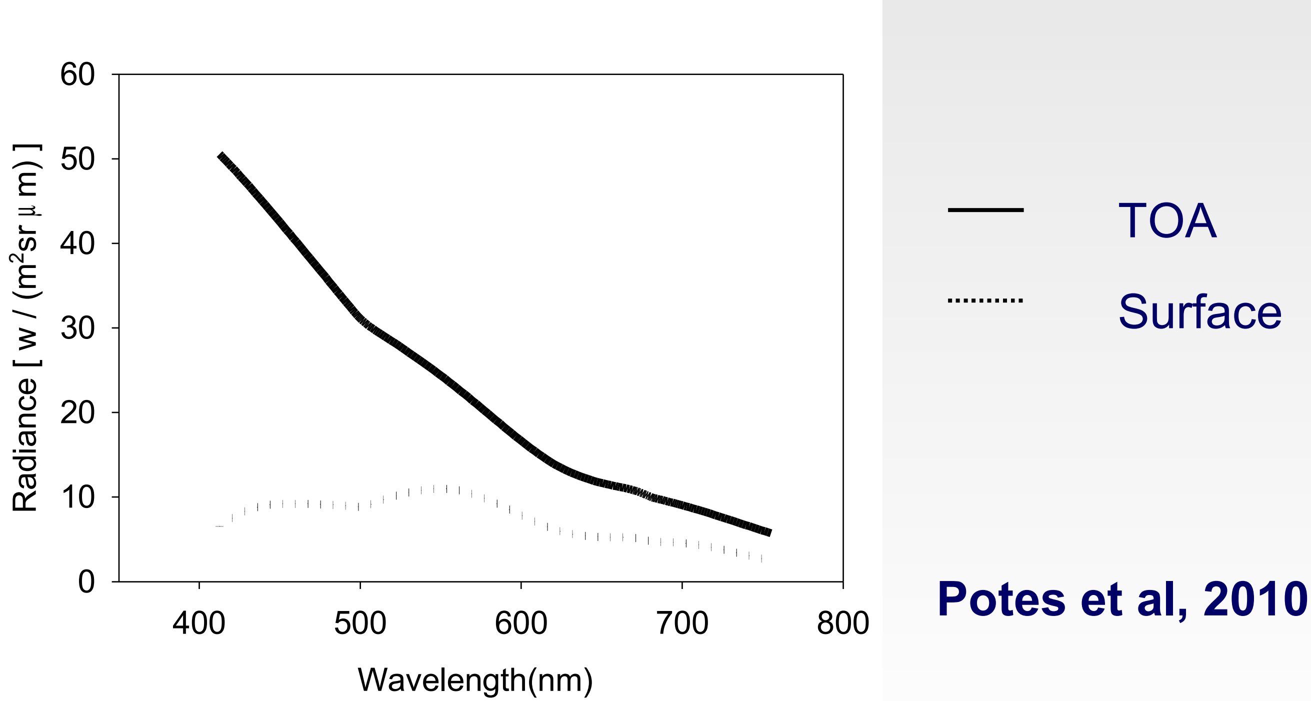


Atmospheric Correction (input 6S)

- Geometric condition (zenith and azimuth angles)
- Atmospheric condition (H_2O and O_3 concentration)
- Aerosol charaterization (AOT, size)
- Target characterization (height, ambient, radius)
- Band characterization (response function)
- TOA radiance

CTR 6S (some output parameters)

- Total transmittance of atmospheric gases
- Surface spectral radiance and reflectance corrected for atmospheric effects



Potes et al, 2010

Reflectance & pigment

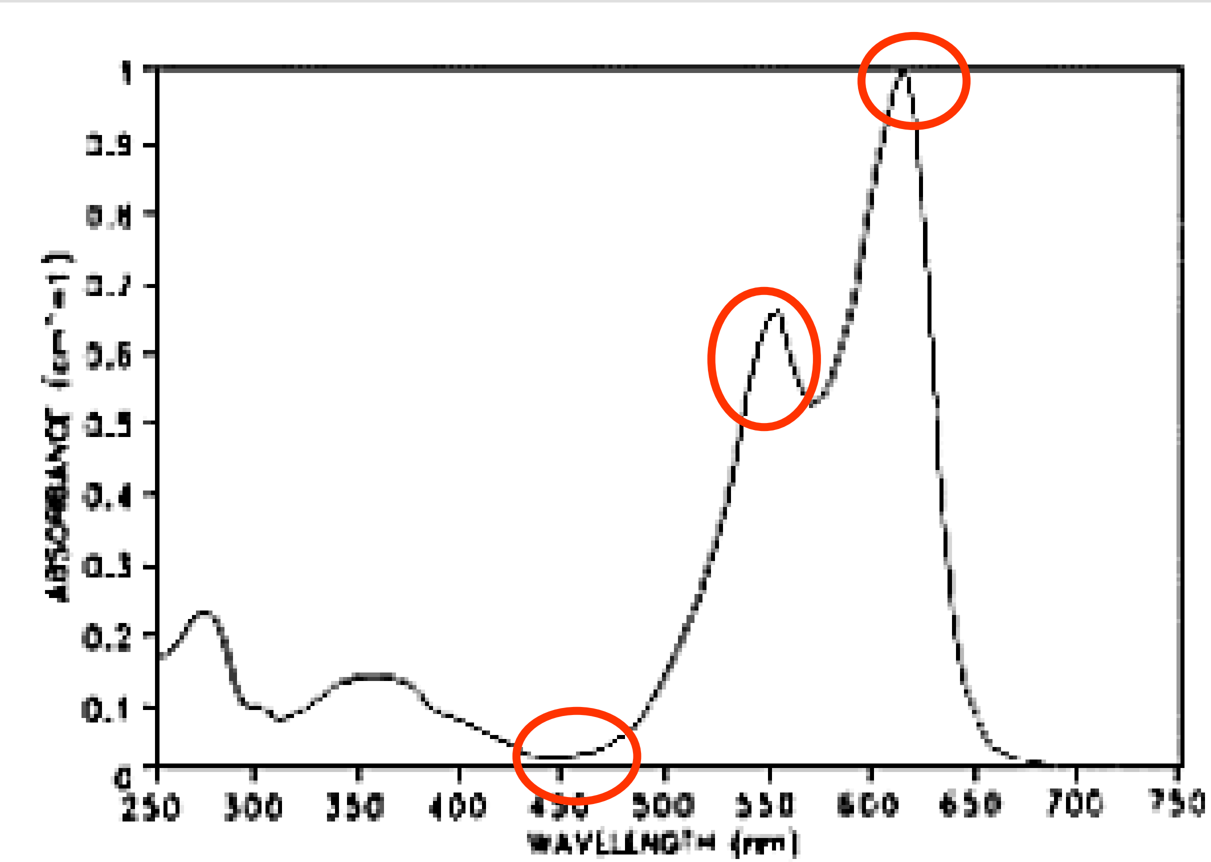
- The surface spectral reflectance was related to laboratory analysis, and how?

1 - Analysis of the absorption spectrum of pigments: phycocyanin (present in cyanobacteria) and chlorophyll a.

2 - Selection of MERIS spectral bands suitable for each pigment.

3 - Linking the surface reflectance of the closer pixel of sampling point to the chlorophyll concentration and cyanobacteria density.

Absorption spectrum (cyan)



R-Phycocyanin

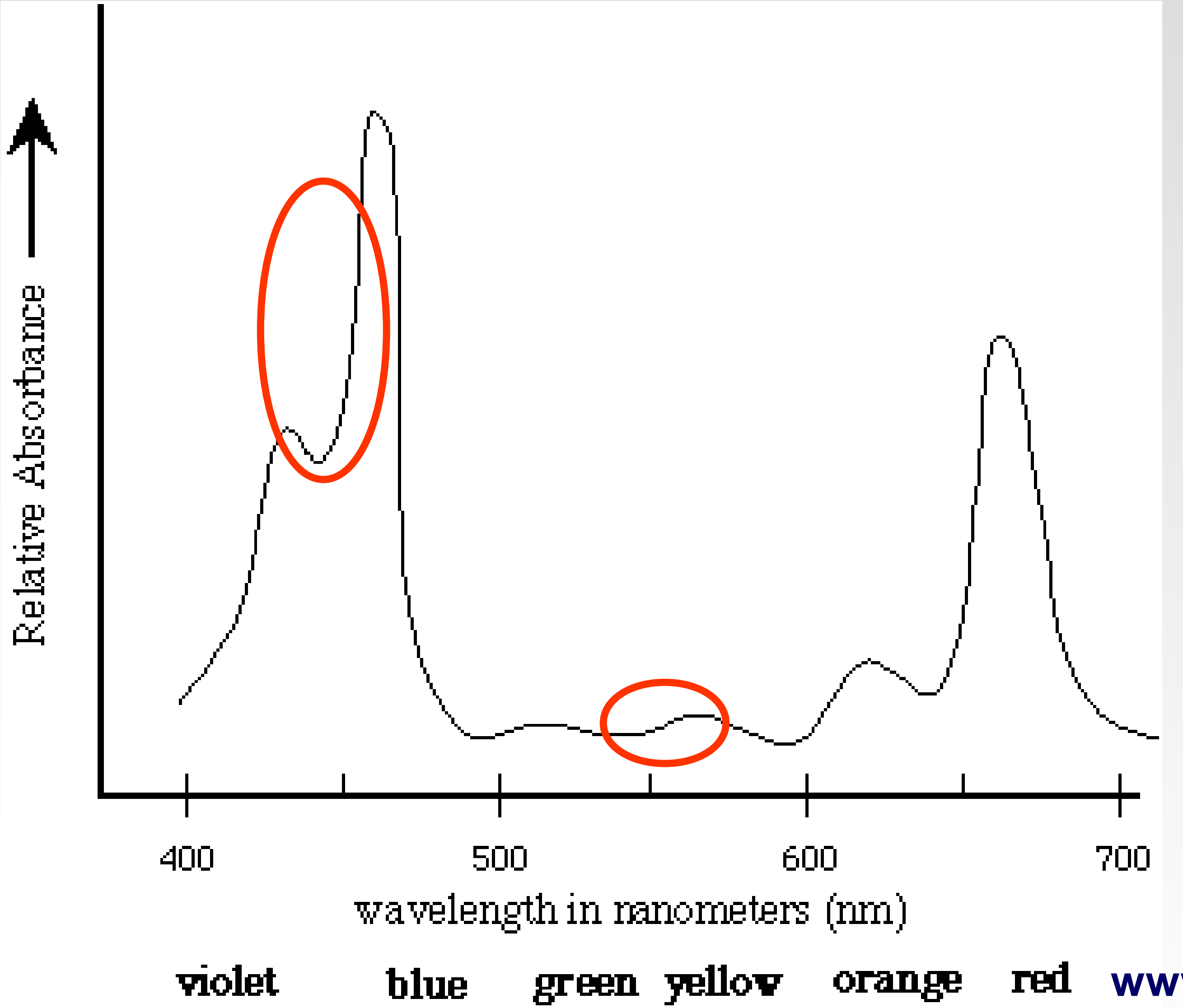
B3 → 490 nm

B5 → 560 nm

B6 → 620 nm

www.prozyme.com

Absorption spectrum (chl a)



B5 → 560 nm

B2 → 442.5 nm

www.bio.davidson.edu

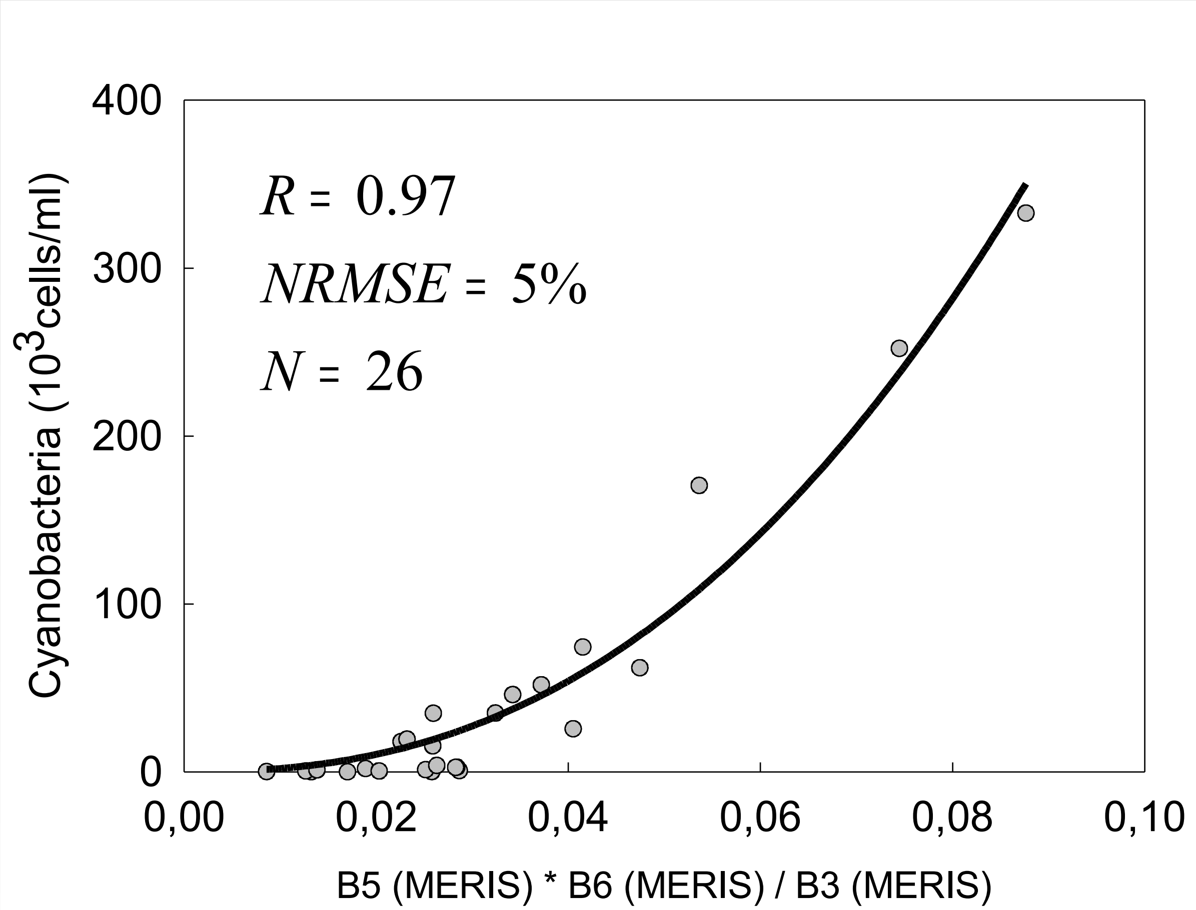
Empirical Algorithms

❑ The operational chlorophyll retrieval algorithms are generally empirical regressions based upon selected ratios of spectral radiances recorded by the satellite sensor. Expressed as a function of upwelling radiance L(λ), such single component retrieval algorithm assumes the form:

$$\{CHL\} = x\left[\frac{L(\lambda_1)}{L(\lambda_2)}\right]^y$$

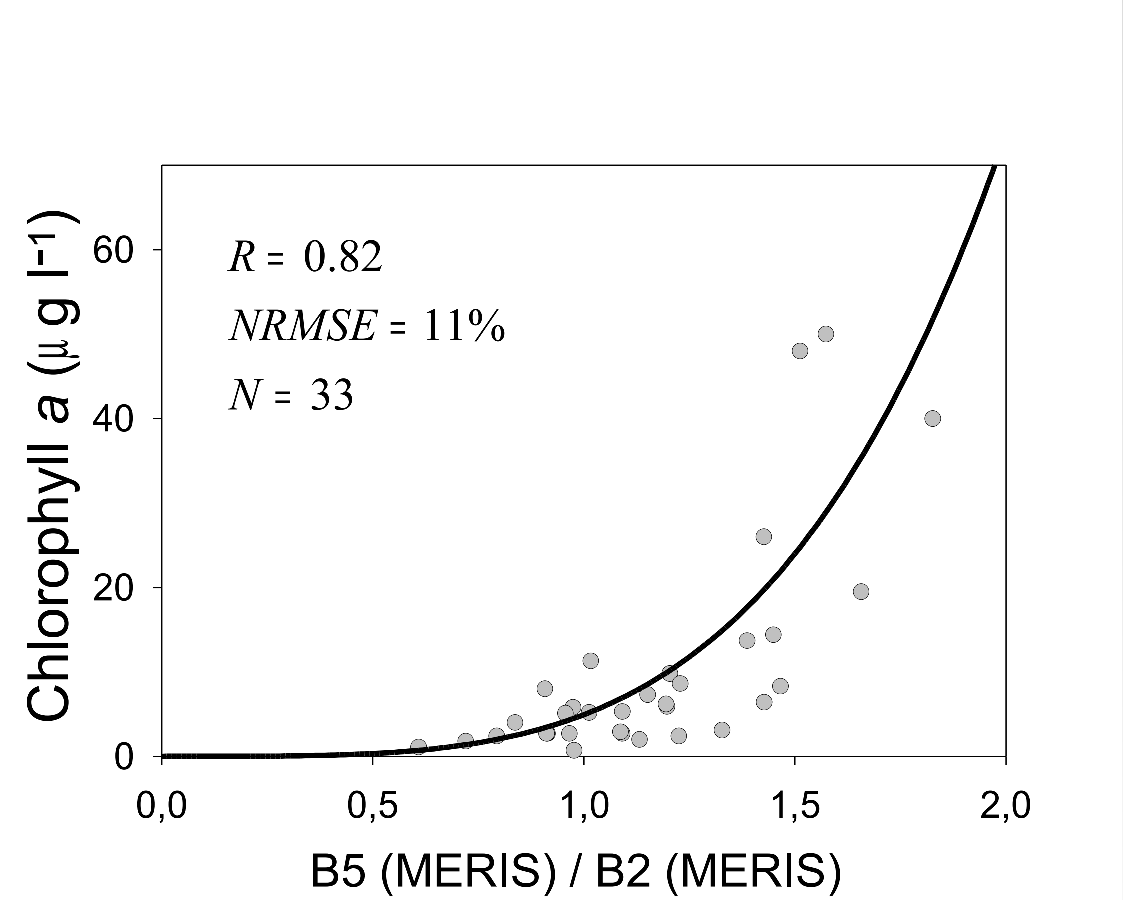
Bukata et al, 1995

Cyanobacteria algorithm



$$Cyanobacteria\left[10^{3}\, cells\ ml^{-1}\right] = 1.15 \times 10^{5} \times \left(\frac{B5 \times B6}{B3}\right)^{2.38}$$

Clhorophyll a Algorithm



$$Chlorophyll\ a\left[\mu g\ l^{-1}\right] = 4.23 \times \left(\frac{B5}{B2}\right)^{3.94}$$

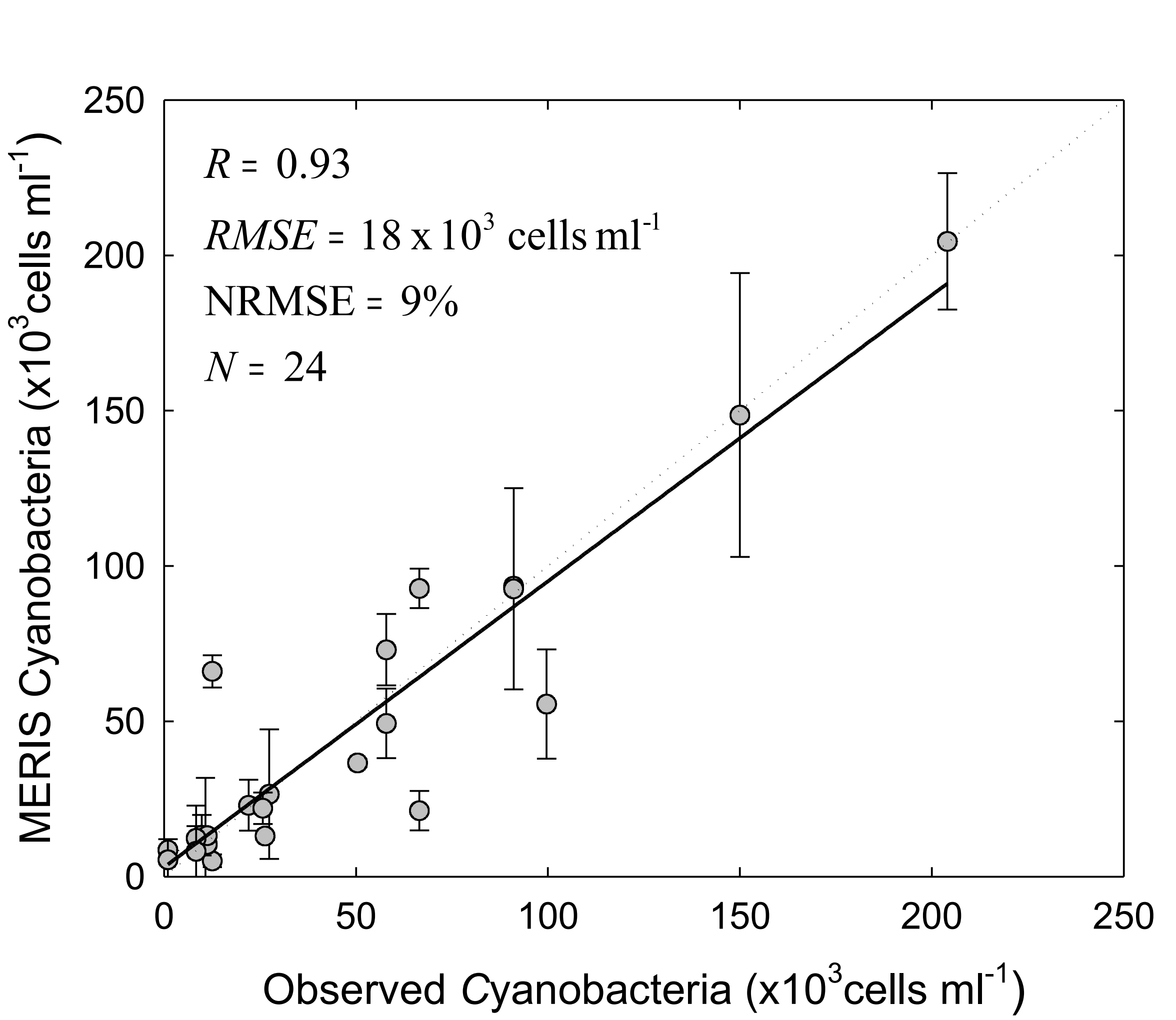
Validations of Algorithms

- The results obtained using the developed empirical algorithms were compared with limnological data collected in 2007.

- The mean concentration value corresponding to four selected pixels around the geographical location of the site under study, is computed and used for comparison with the limnological data.

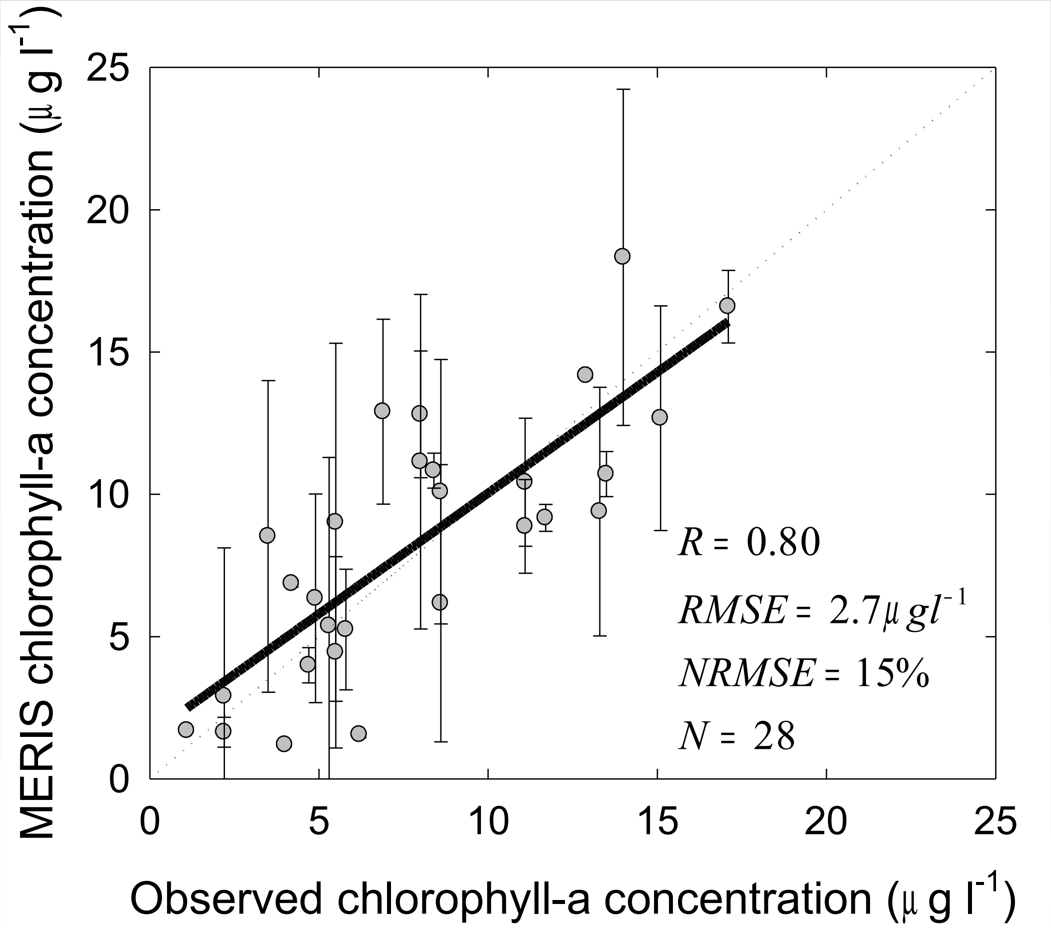
- The vertical error bars represent the standard deviations corresponding to the mean of the four selected pixels.

Cyanobacteria



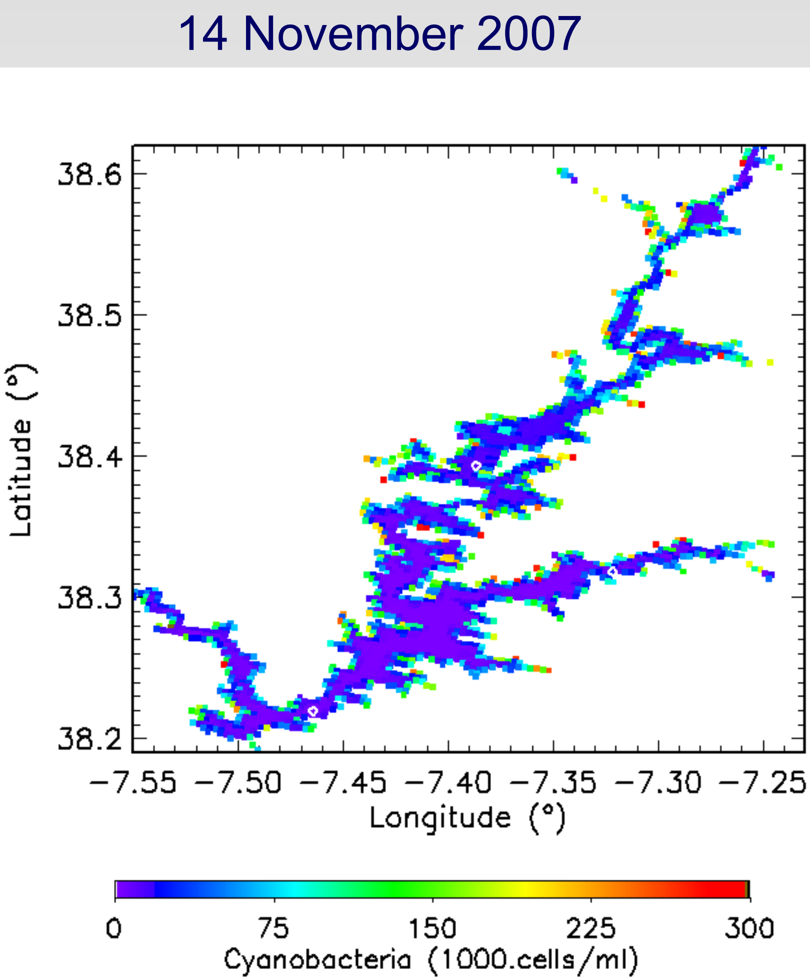
Potes et al, 2010

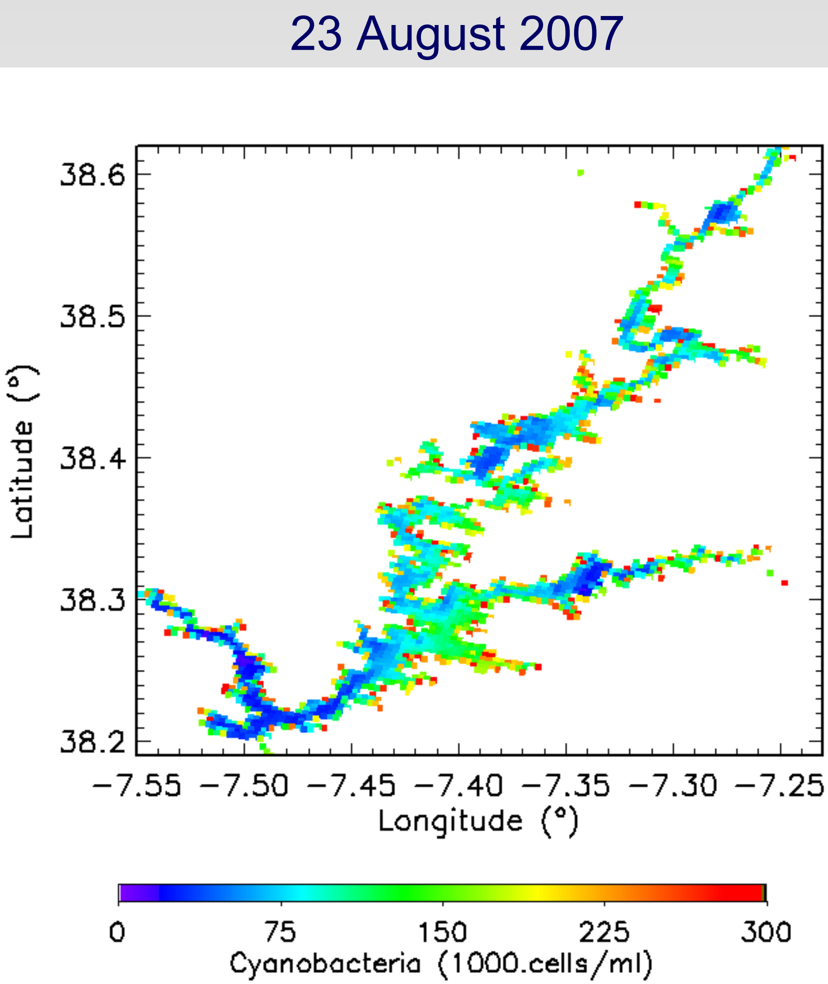
Chlorophyll



Potes et al, 2010

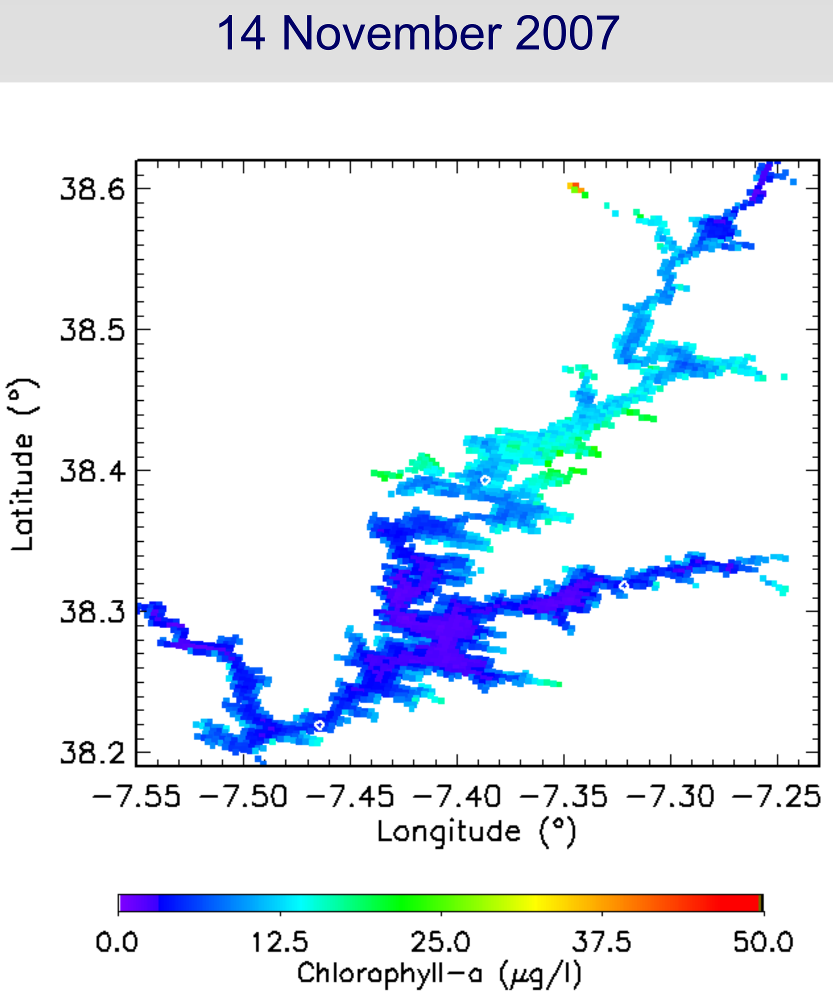
Cyanobacteria monitoring

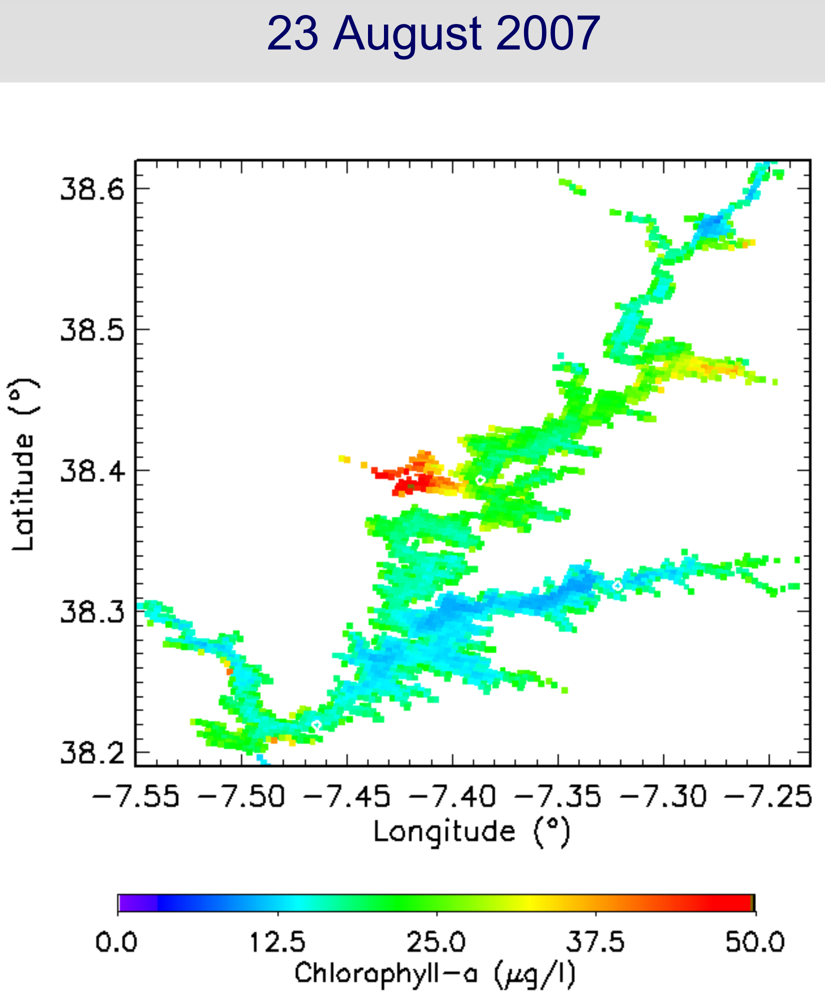




Potes et al, 2010

Chlorophyll *a* monitoring





Potes et al, 2010

Recent Work (field data)

- Recently a portable spectroradiometer was acquired – ASD FieldSpec UV/VNIR.

- Two field campaigns were conducted in order to obtain surface reflectance measurements, which are subsequently used to validate the satellite atmospherically corrected reflectance.

Spectroradiometer details

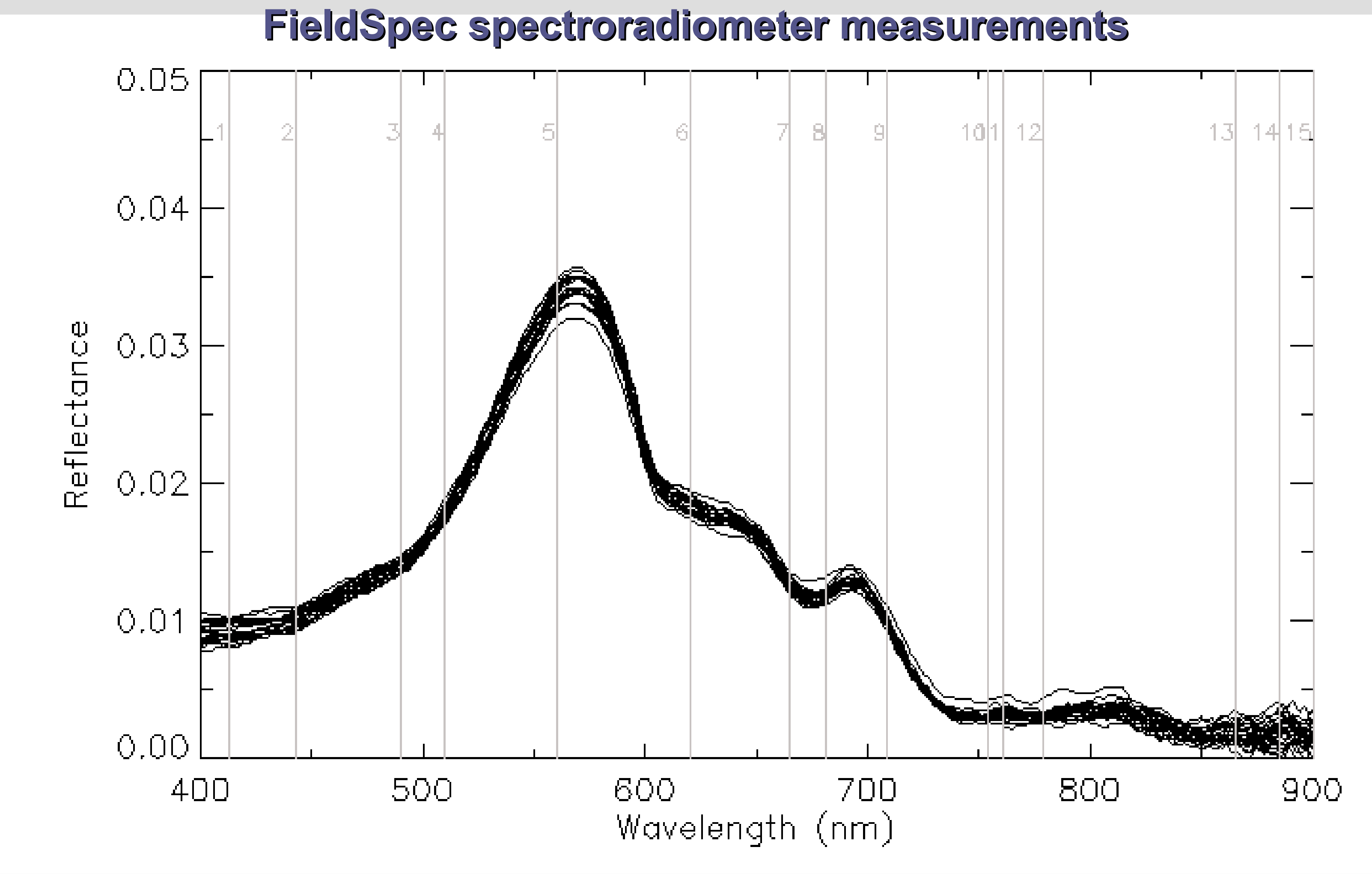
- 325 – 1075 nm range
- 1 to 3 nm spectral resolution (from VIS to NIR)
- 1 – 25 degrees of view angle
- 17 ms – several minutes of integration time
- Possible radiance, irradiance and reflectance measurements

First field campaign – 27 July 2010

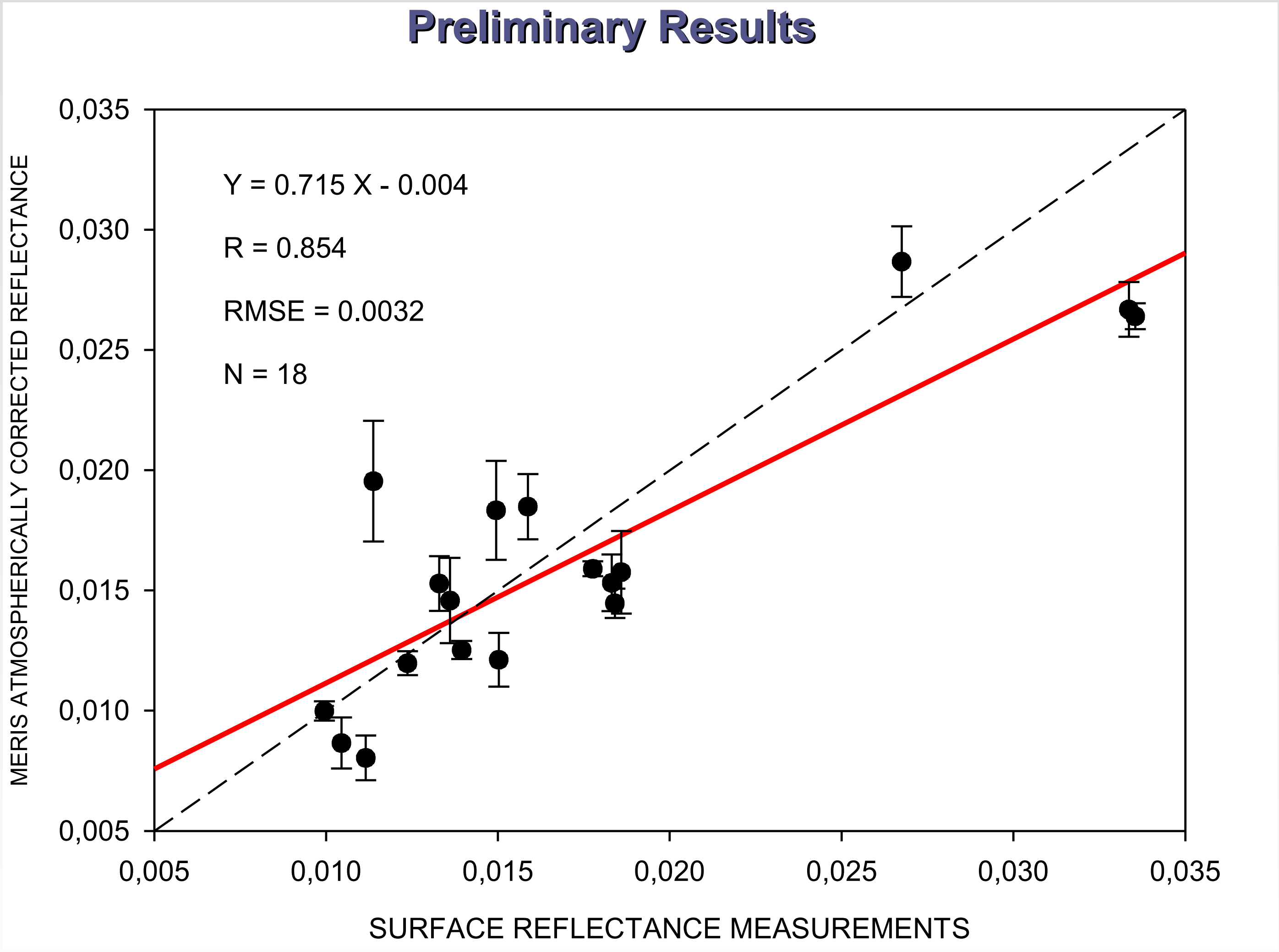
FieldSpec working

Water under analysis

Surface Spectral Reflectance



Atmospheric Correction Validation



CONCLUSIONS

- The good correlations obtained for both cyanobacteria (R = 0.97) and chlorophyll a (R = 0.84) demonstrate the broad capabilities of MERIS sensor to monitor the water quality of reservoirs.

- The developed methodology can be a valuable tool to be used in combination with laboratory measurements, enabling the monitoring of water quality on a regular and economical basis, contributing to the implementation of a alert system, useful to the authorities in case of outliers phytoplankton parameters.

- The good correlation (R=0.85) obtained by the recent field campaigns constitute promising results aiming at the validation of the atmospheric correction implemented.

Future Work

- **Carry on the recent field campaigns in Alqueva**
- **Extend field measurements to water turbidity**
- **Spectral extinction coefficient calculations *in situ* and remotely**

References

- BUKATA, R.P., JEROME, J.H., KONDRATYEV, K.YA., & POZDNYAKOV, D.V., 1995, *Optical Properties and Remote Sensing of Inland and Coastal Waters*, pp. 135-250 (CRS Press).

- POTES, M., M.J. COSTA, J.C.B. DA SILVA, A.M. SILVA & M. MORAIS, Remote sensing of water quality parameters over Alqueva reservoir in the south of Portugal. *International Journal of Remote Sensing.* Accept on 19/02/2010.

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