Spectral Extinction Coefficient measurements of inland waters

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Outline

- Past, Present and Future Work
- Background
- Inwater downwelling spectral radiance
- Spectral extinction coefficient calculations
- Summary

Past Work

- M. Potes, 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, Int. J. Remote Sens., 32:12, 3373-3388, 2011.

Remote sensing of water quality parameters in Portugal 3385

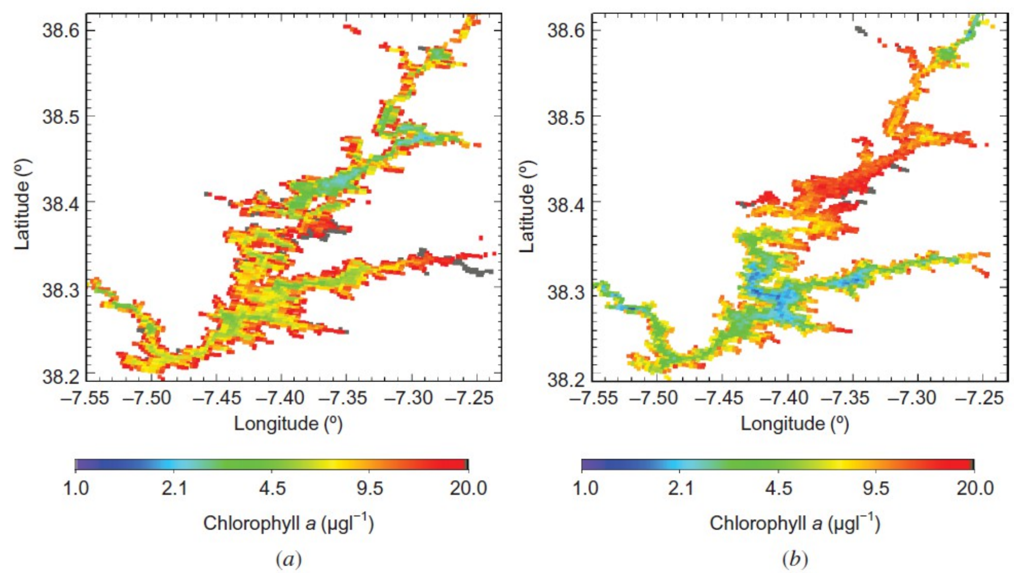


Figure 7. Chlorophyll *a* concentration maps over the whole Alqueva Reservoir surface for the year 2007: (*a*) 5 June; (*b*) 14 November.

The results of this work indicate that the methodology proposed allows the regular and inexpensive water quality monitoring, in terms of chlorophyll and cyanobacteria concentration.

Past Work

- **Potes, M., Costa, M. J., and Salgado, R.: Satellite remote sensing of water turbidity in Alqueva reservoir and implications on lake modelling, Hydrol. Earth Syst. Sci., 16, 1623-1633, doi:10.5194/hess-16-1623-2012, 2012**

1630 M. Potes et al.: Satellite remote sensing of water turbidity in Alqueva reservoir

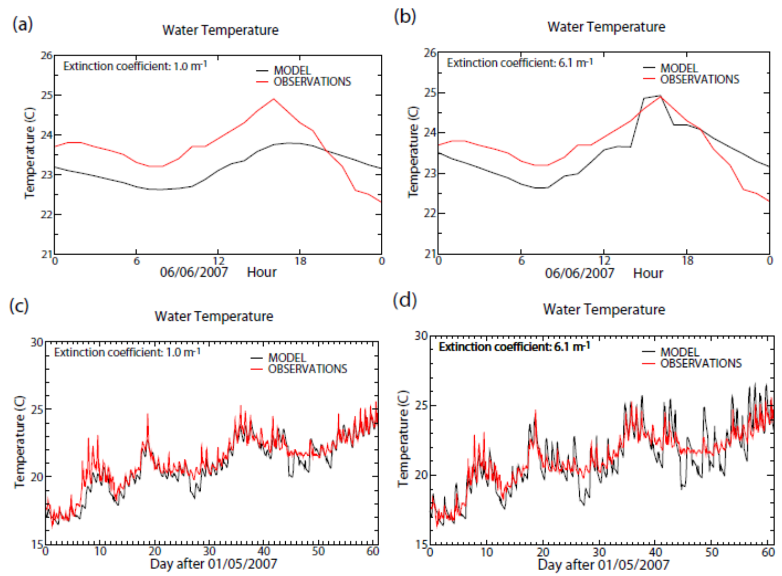


Fig. 6. Comparison between the lake water surface temperature observed and modeled with FLake for: **(a)** 6 June 2007 with an extinction coefficient of $1.0\,\mathrm{m}^{-1}$ (simulation Mo10); **(b)** 6 June 2007 with an extinction coefficient of $6.1\,\mathrm{m}^{-1}$ (simulation Mo61); **(c)** May and June 2007 with an extinction coefficient of $1.0\,\mathrm{m}^{-1}$ (simulation Mo10); **(d)** May and June 2007 with an extinction coefficient of $6.1\,\mathrm{m}^{-1}$ (simulation Mo61).

Results show that the FLake model is very sensitive to different extinction coefficient values and variations in turbidity can lead to significant changes in the lake surface temperature, which is a parameter that plays a central role in heat and moisture transfers between the lake and the atmosphere. Turbidity of water should be taken into account in lake schemes inside high resolution weather forecast models.

Following work of Lake10

Most Recent Work

- In-water spectral downwelling radiance measurements.
- Water spectral extinction coefficient calculations for the water column.

Future Work

- Developing an algorithm to retrieve the light extinction coefficient from satellite data with a future database in mind.

Background

In general, light intensity declines exponentially with depth, as described by Beer-Lambert Law:

$$I(\lambda, z) = I(\lambda, 0-) exp\{-K(\lambda) z\}$$

Where 0- indicates the immediate sub-surface depth, z is the depth and k is the rate of attenuation of downwelling radiation usually referred to as the extinction coefficient. Extinction is an apparent optical property and depends not only on the properties of the medium, but additionally on the geometric distribution of the illuminating light field.

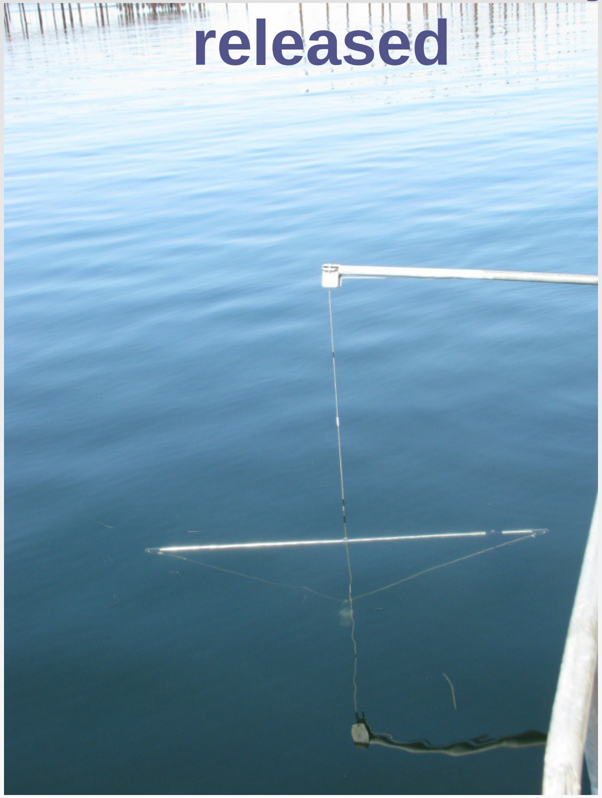
Spectroradiometer

A Portable spectroradiometer from ASD - FieldSpec UV/VNIR was used to measure downwelling radiance at several levels depth using an optical fiber.

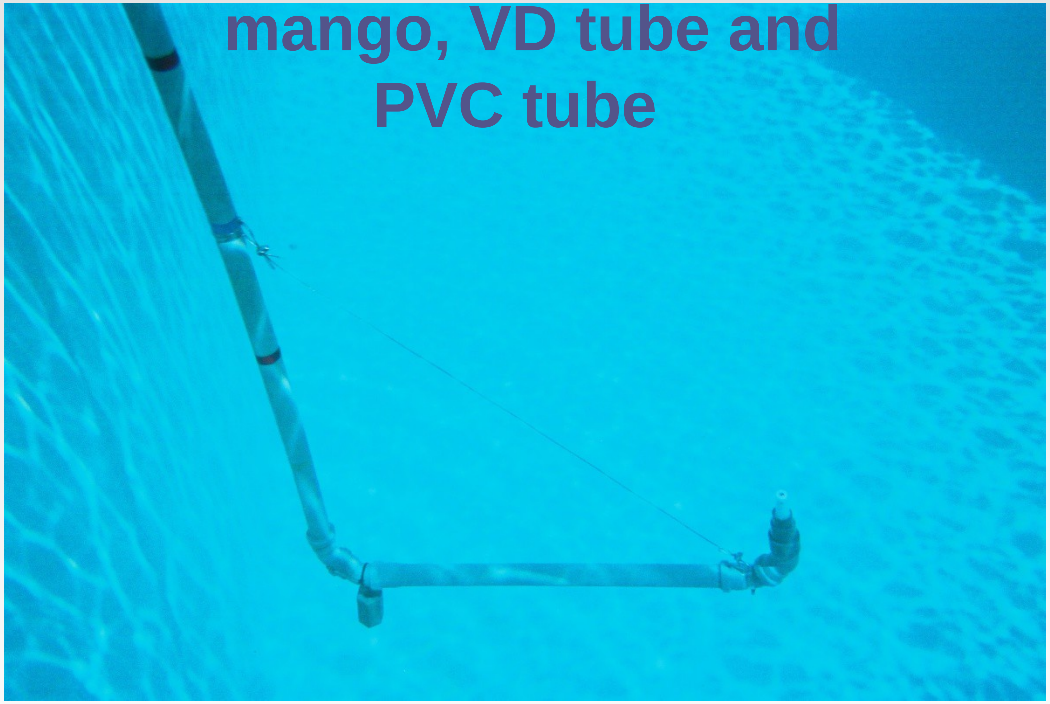
- **325 – 1075 nm range**
- **1 nm spectral resolution**
- **25 degrees of view angle**
- **17 ms to several minutes of integration time**

Devices

2011 (Thau Lagoon)
The fiber was freely released



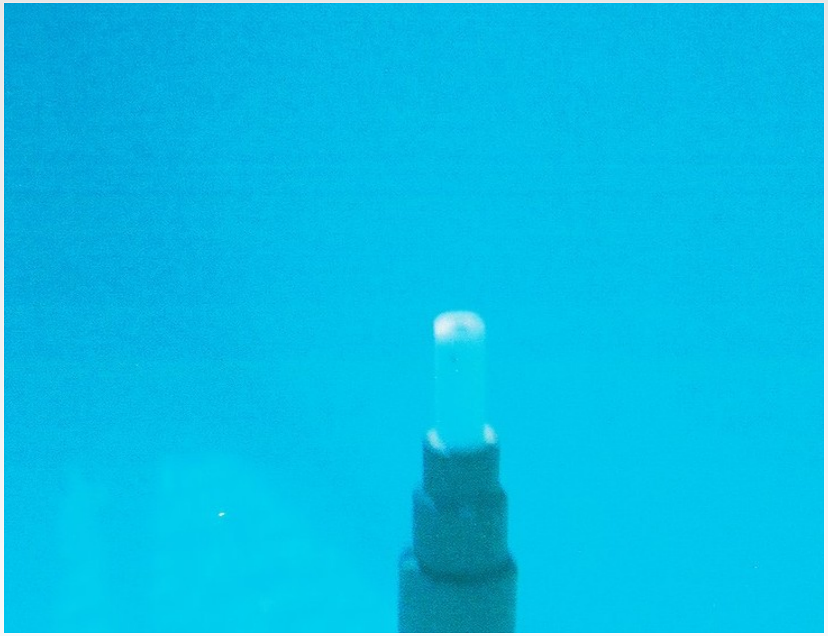
2012 (Evora pools)
The fiber is triply protected: fine mango, VD tube and PVC tube



In water environment

Evora municipal pools (02/07/2012)

Clean water



Alqueva Reservoir (31/08/2012)

Turbid water (14.95 FNU)

Influence of wind and waves on underwater downwelling radiance

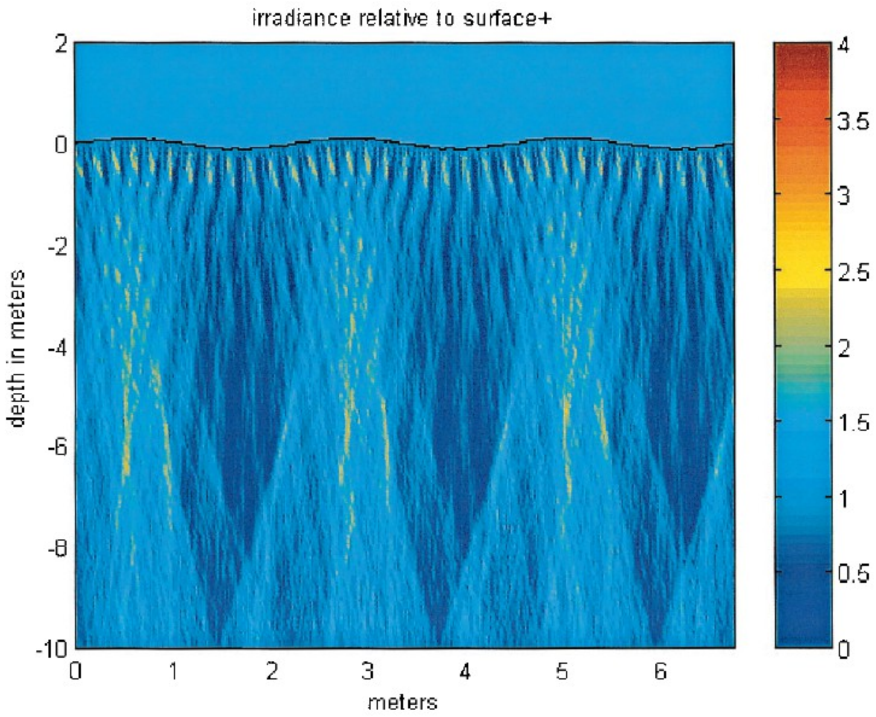
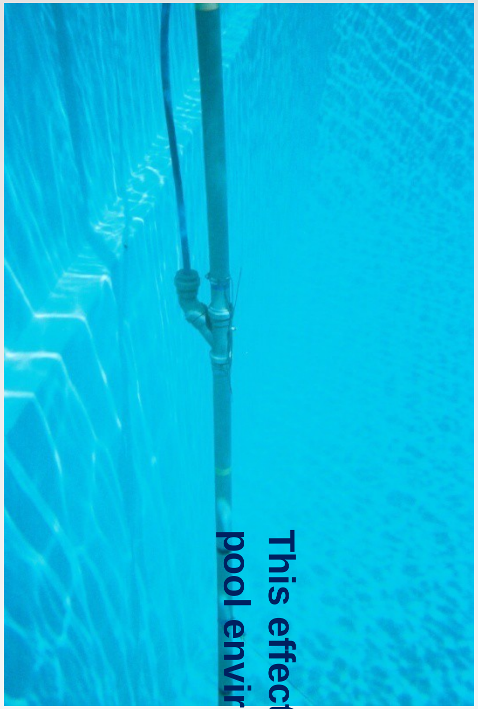


Fig. 6. Irradiance pattern beneath a superposition of sinusoidal waves with wavelengths of 2.25, 0.2, and 0.05 m and with amplitudes of 0.1, 0.01, and 0.002 m. Note that the addition of very small amplitude waves significantly alters the irradiance pattern.



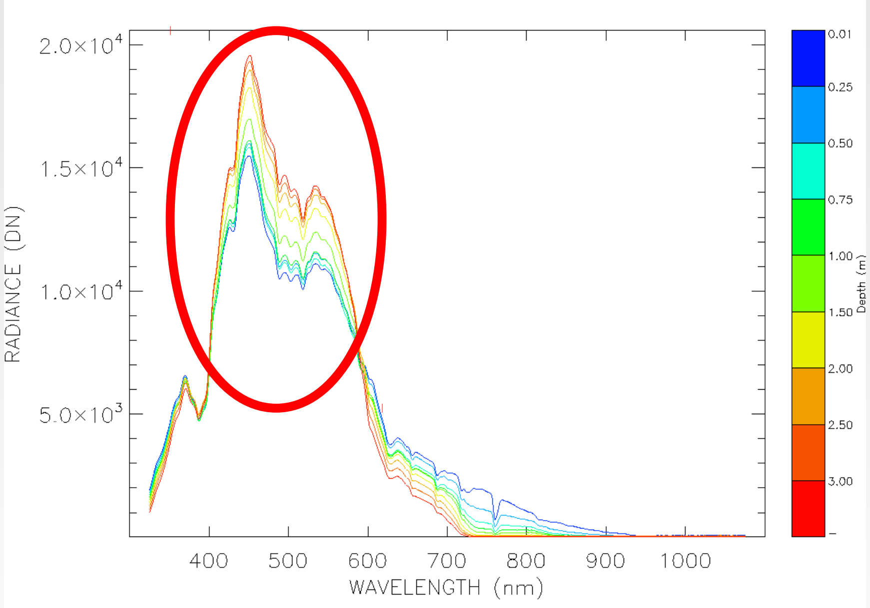
This effect is clearly visible
pool environment.

Zanefeld et al. (2001): Influence of surface waves on measured and modeled irradiance profiles. *Applied Optics* 40, 1442-1449.

Pools Tests – spectral downwelling radiance

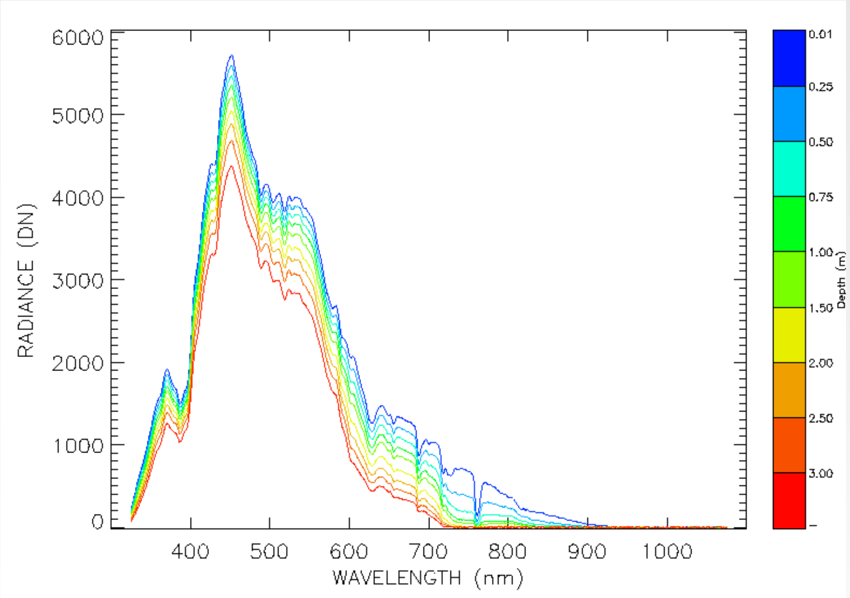
Sun zenith angle = 42.93º

Direct and diffuse component of downwelling irradiance

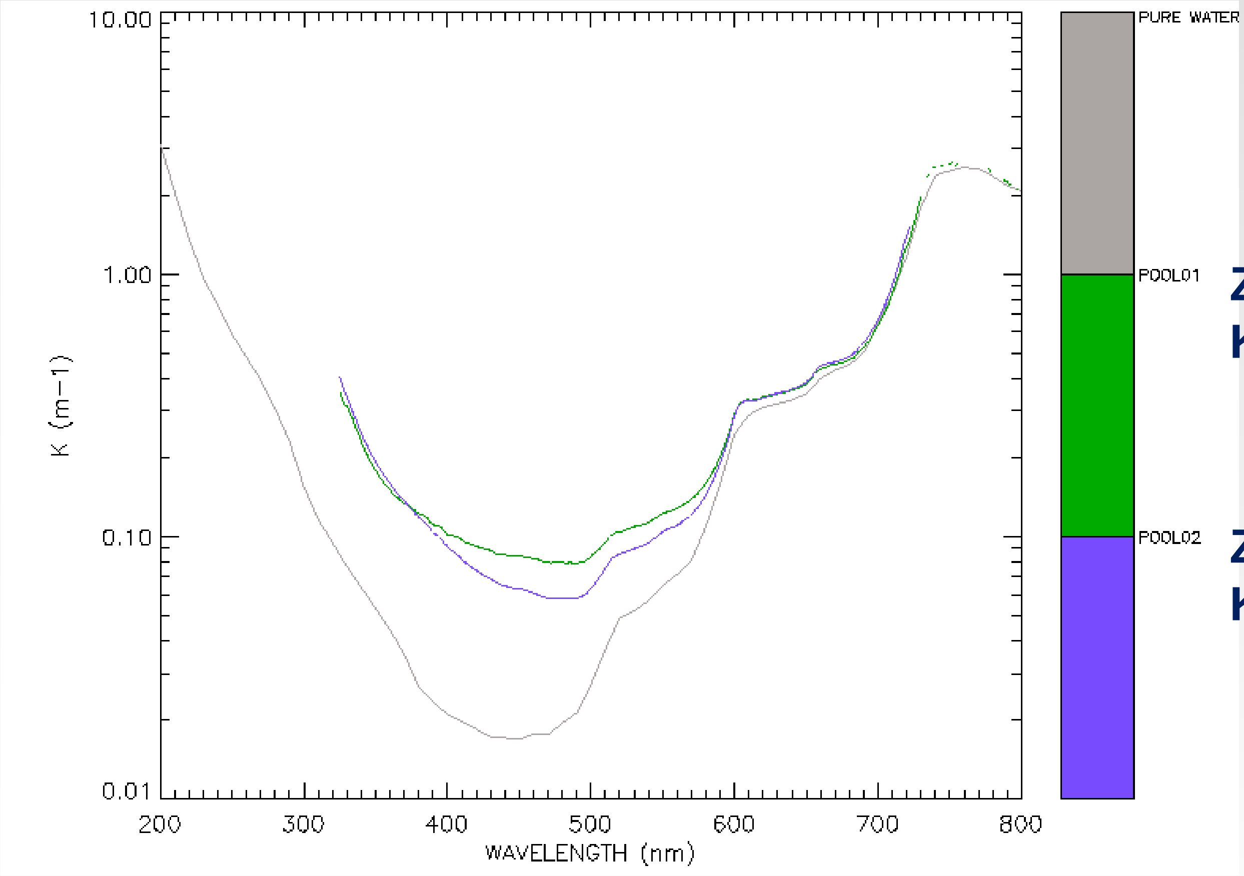


Sun zenith angle = 86.62º

Only diffuse component of downwelling irradiance



Diffuse extinction coefficient in the pool – comparison with pure water (Smith & Baker, 1981)

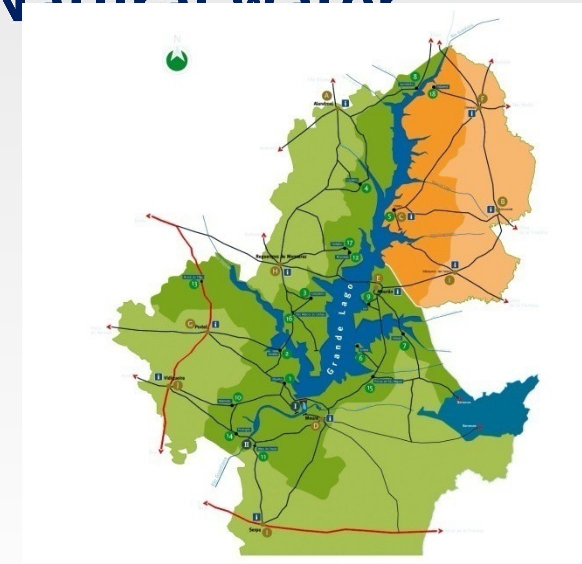


Zenith angle = 86.62º
K (PAR) = 0.21 m^{-1}

Zenith angle = 78.48º
K (PAR) = 0.20 m^{-1}

Alqueva Reservoir / Thau Lagoon

- Location: South-East Portugal
- Length: 83 km
- Surface: 250 Km²
- Maximum depth: 65 m
- Natural water

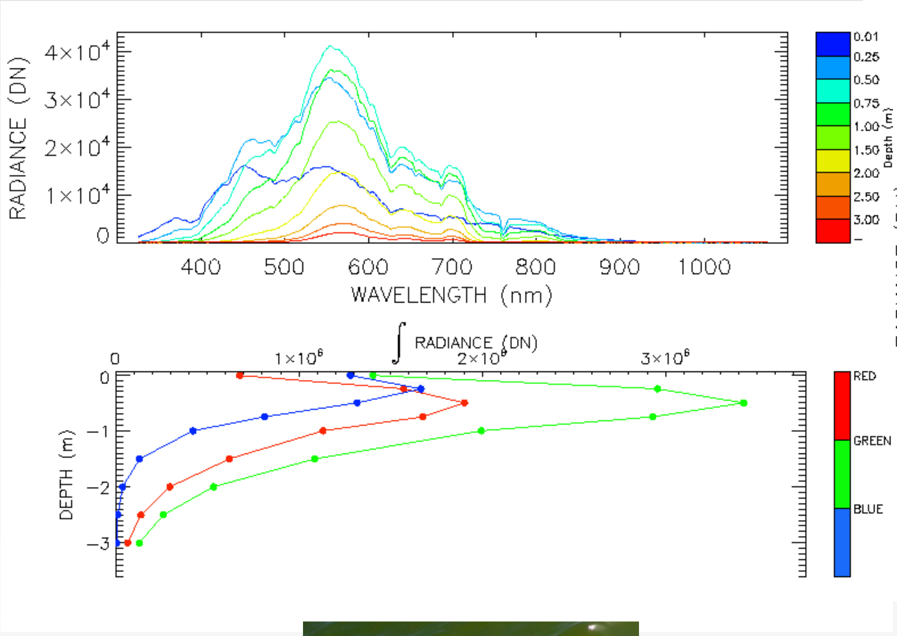


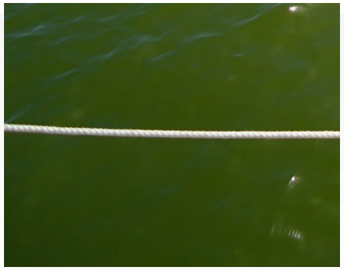
- Location: South-East France
- Length: 15 km
- Surface: 75 Km²
- Maximum depth: 8 m
- Salty water

Downwelling Radiance pattern over Alqueva and Thau

Alqueva

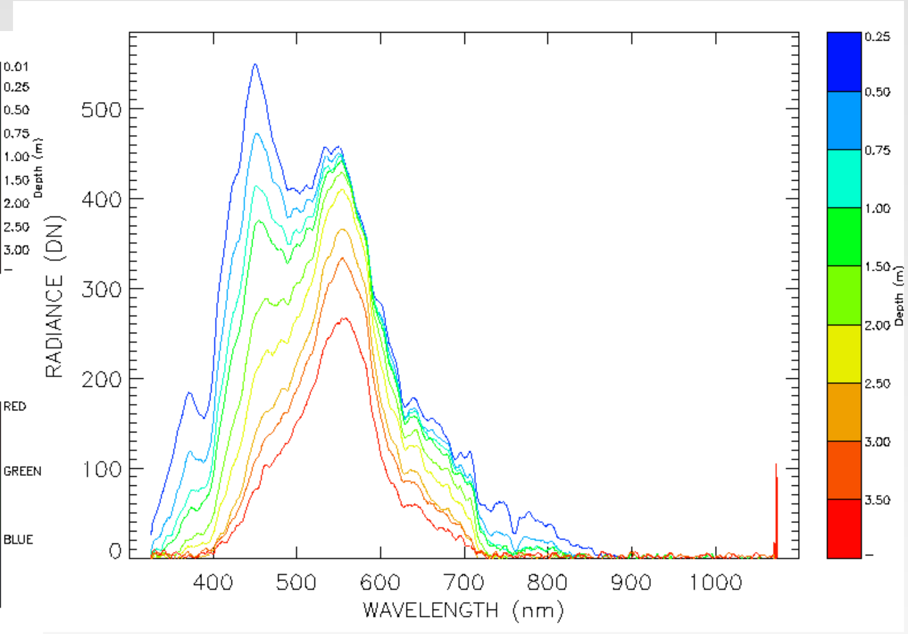
Sun zenith angle = 26.64º





Thau

Sun zenith angle = 52.44º



Significant irradiance enhancement

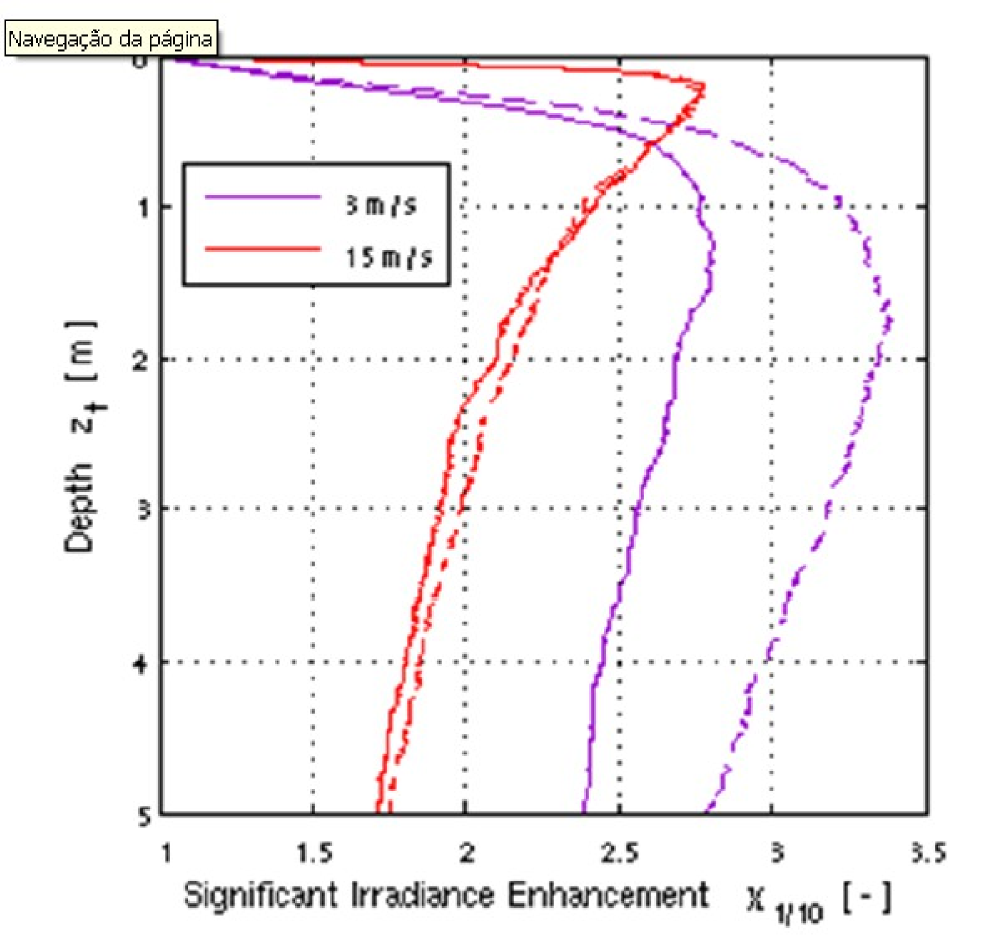


Fig. 7. Significant irradiance enhancement $\chi_{1/10}$ for two wind velocities with (dashed) and without (solid lines) long-wave modification of the applied wave spectra (Fig. 1).

With low wind speed 3 ms^{-1} , the irradiance peaks due to lensing effect of ultra-gravity waves appear strongest in the first 4 meters otherwise with strong wind speed 15 ms^{-1} the peak appears in the first centimeters.

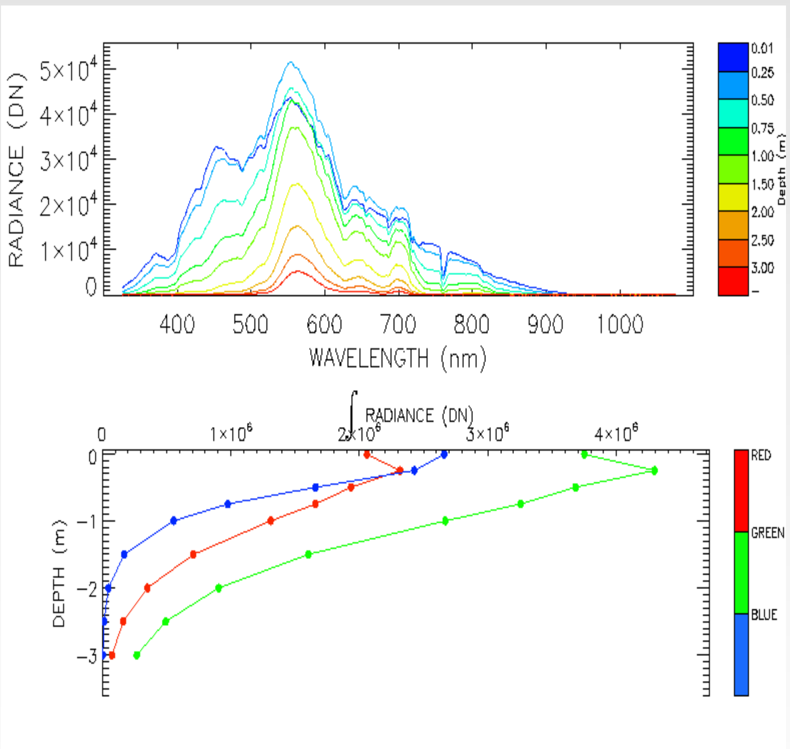
Hieronymi, M. and Macke, A.: On the influence of wind and waves on underwater irradiance fluctuations, Ocean Sci., 8, 455-471, doi:10.5194/os-8-455-2012, 2012.

Influence of wind speed

Alqueva Reservoir (31/08/2012)

Sun zenith angle – 37.85º

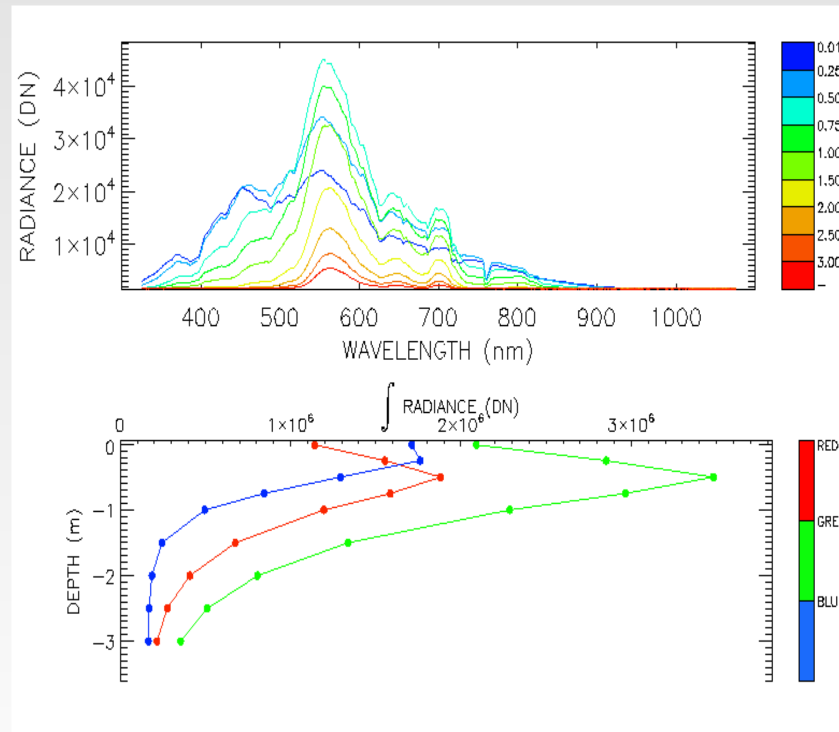
Wind speed – 8 m/s



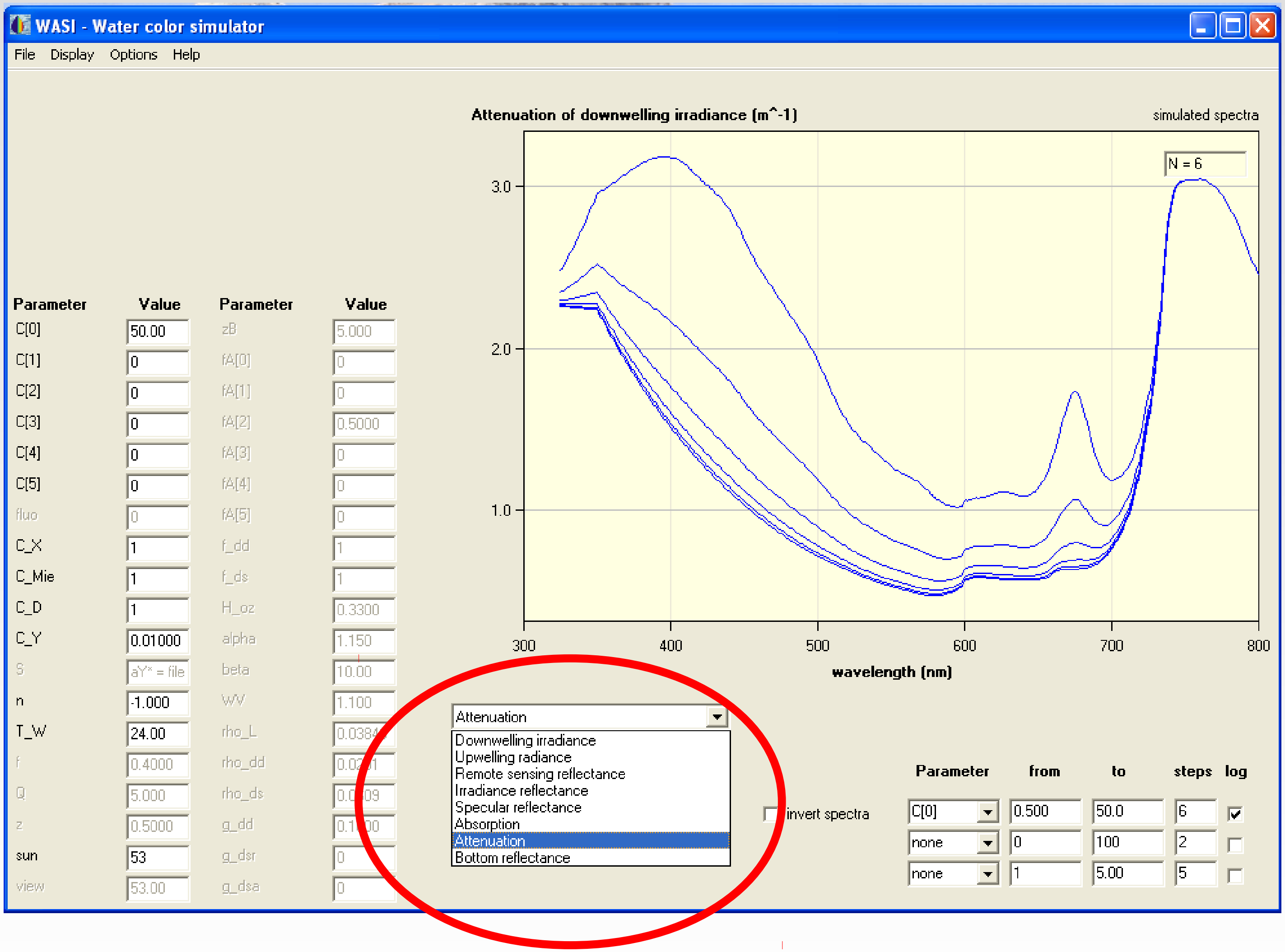
Alqueva Reservoir (06/09/2012)

Sun zenith angle – 41.49º

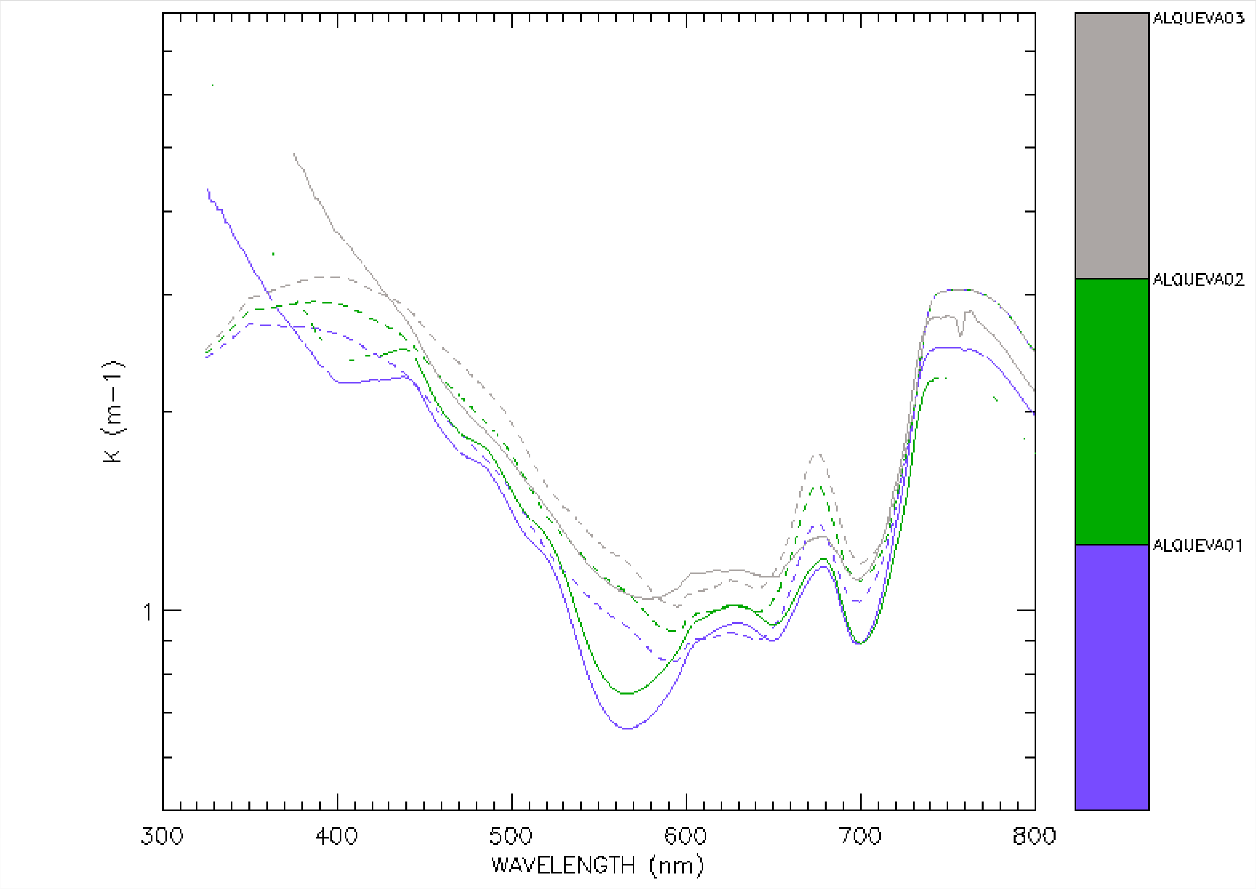
Wind speed – 3 m/s



Attenuation coefficient from WASI software (Peter Gege – ftp.dfd.dlr.de/pub/wasi)



Extinction Coefficient from Alqueva reservoir



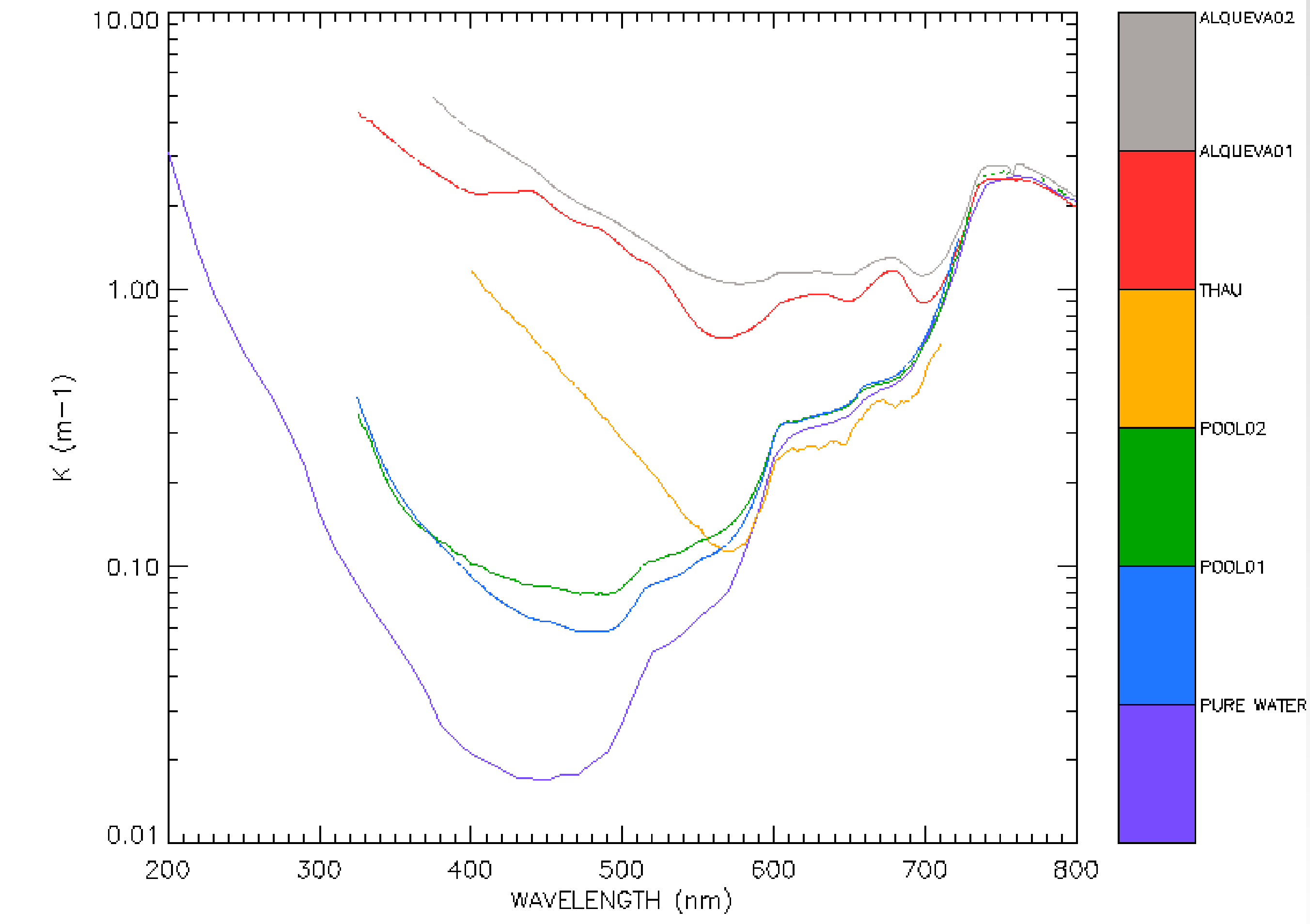
50 µg/l

41 µg/l

33 µg/l

Solid lines are mesurements from Alqueva reservoir and dashed lines are obtained with Wasi software.

Extinction Coefficient Summary



14.78 NTU
K (PAR) = 1.65m^{-1}

13.67 NTU
K (PAR) = 1.28 m^{-1}

0.50 NTU
K (PAR) = 0.37 m^{-1}

K (PAR) = 0.21 m^{-1}

K (PAR) = 0.20 m^{-1}

~0.01 NTU
K (PAR) = 0.16 m^{-1}

SUMMARY

- The newest device developed this year is robust enough to guaranty the best conditions of the optical fiber to ensure finest spectral downwelling radiance measurements.

- Wind speed and waves pattern enhance the underwater downwelling radiance (our case 25º of FOV), through the lensing effect, in the blue and green part of the spectrum in the presence of the direct component of the solar irradiance (lower zenith angles).

- For lower wind speeds this lensing effect is pronounced until 0.5m, where probably this effect is overcome the strong attenuation from the Alqueva water (in the pools this effect still verified till 3m depth). For stronger wind speed this effect is noticed up to 0.25m probably because the wave spectra have almost the same shape.

- The greatest Chlorophyll a and Turbidity the greatest extinction coefficient in the visible part of the spectrum.

ACKNOWLEDGEMENTS

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THANK YOU !