EDDY COVARIANCE FLUX MEASUREMENTS AT ALQUEVA RESERVOIR

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ALqueva hydro-meteorological EXperiment

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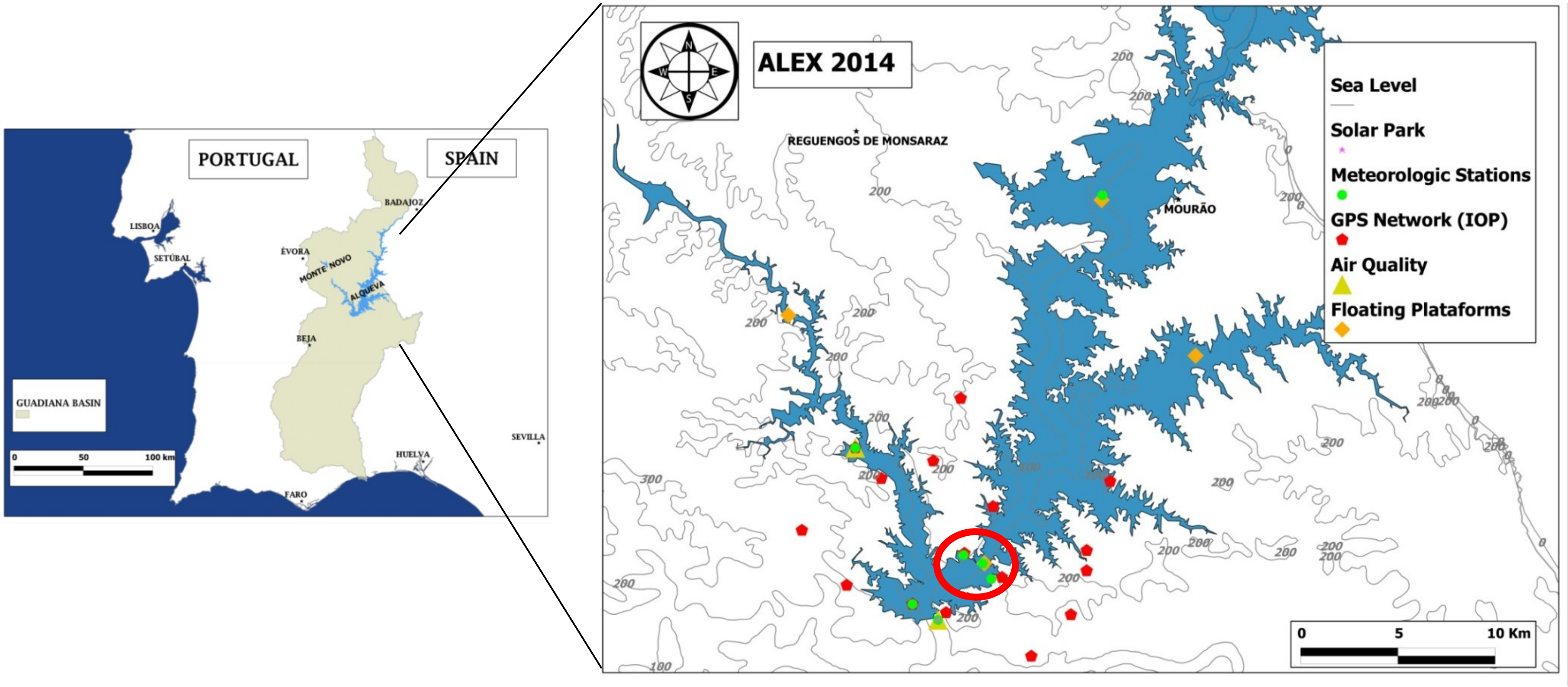
Alqueva reservoir



Surface area of 250 km^2
Gates were closed in 2002

Contents

Results presented here are focused in measurements over a floating platform:

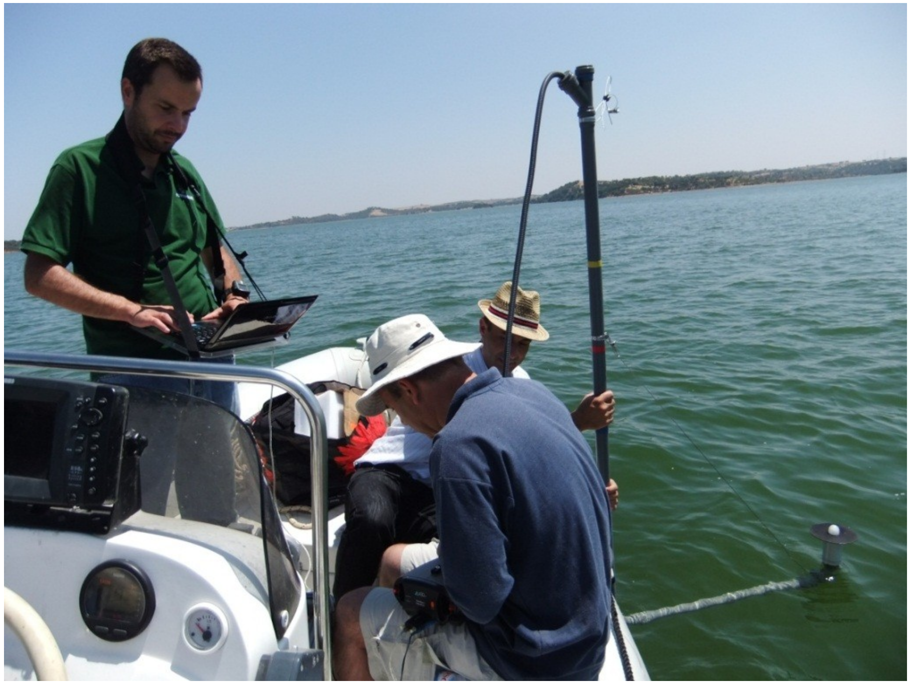
CONTINUOUSLY

- Water temperature at several levels
- Atmospheric turbulent fluxes
- Short and long wave radiation (up and downwelling)

MONTHLY

- Water surface spectral reflectance
- Inwater spectral irradiance
- Water quality

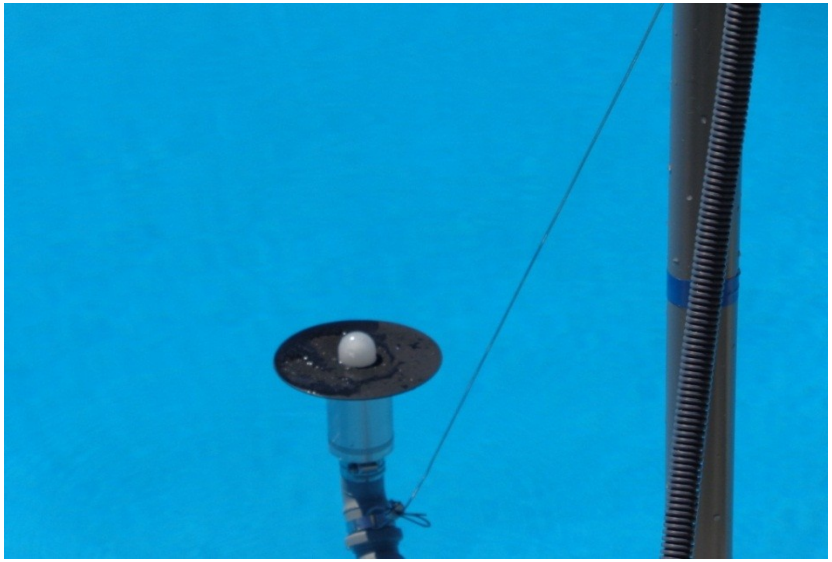
Underwater irradiance system



FieldSpec UV/VNIR da ASD coupled to an optical cable and a cosine receptor

- Wavelengths between 325 – 1075 nm
- Spectral resolution of 3 nm
- 180º of FOV
- Maximum depth of 3 m

Tests in a pool before ALEX2014



This is the reservoir !

Underwater irradiance profiles

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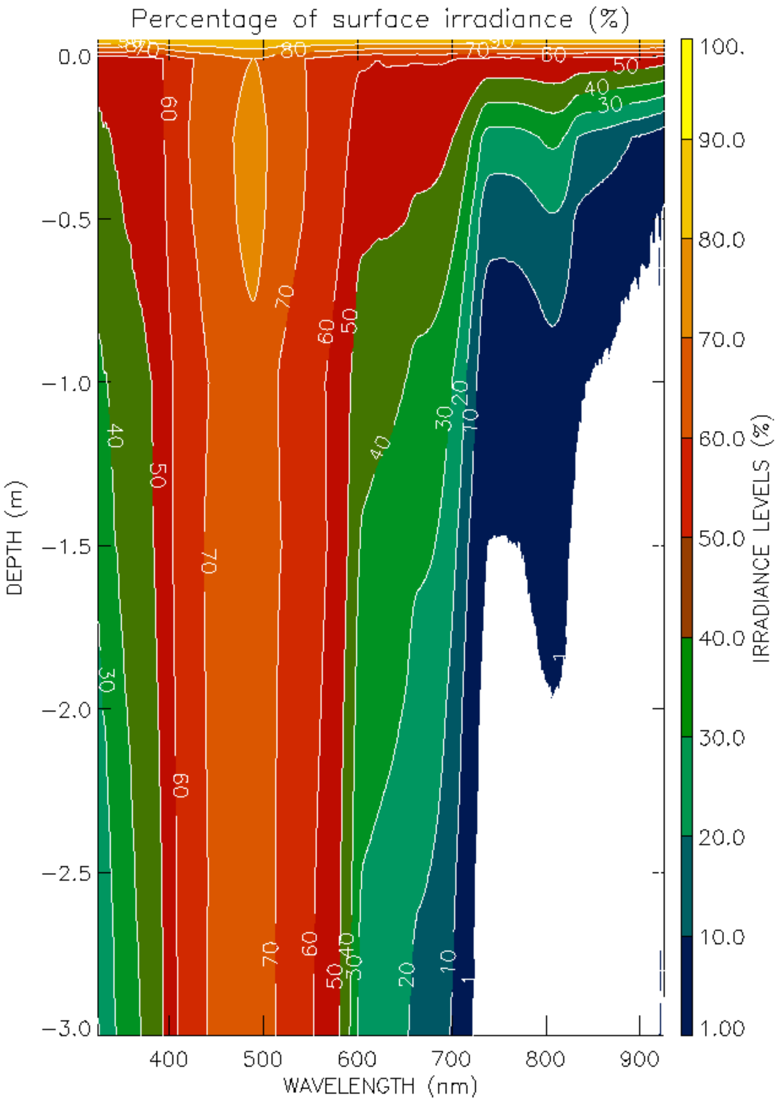
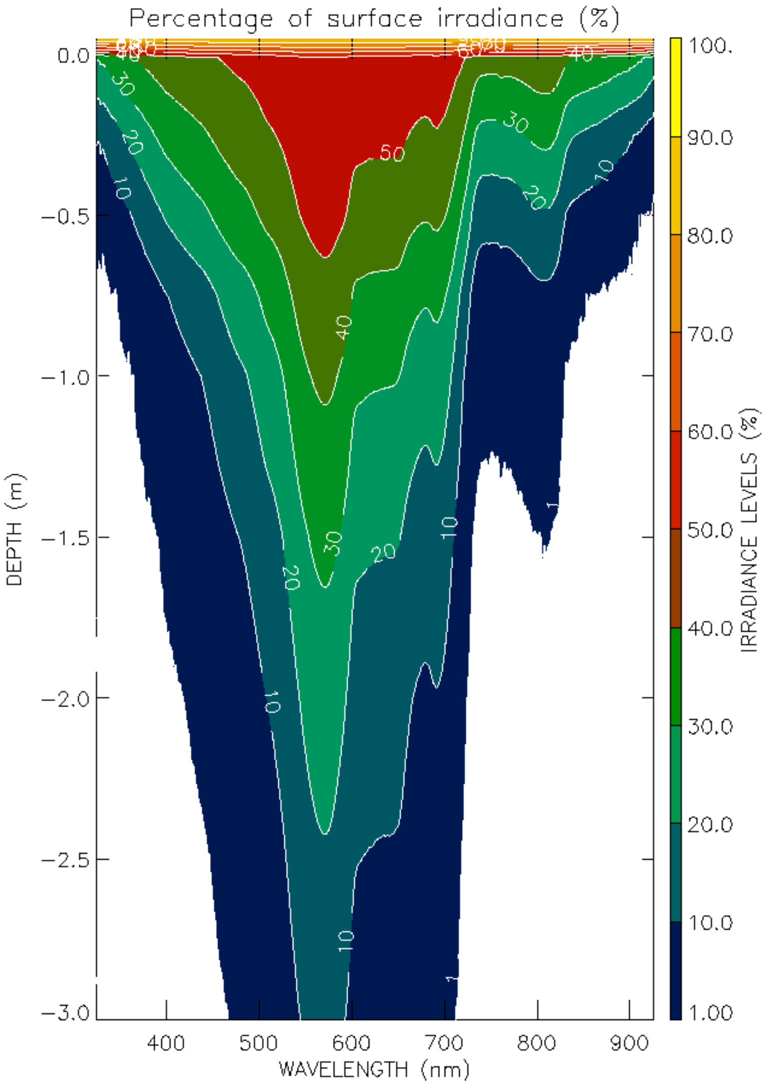
Pool – Very clean water



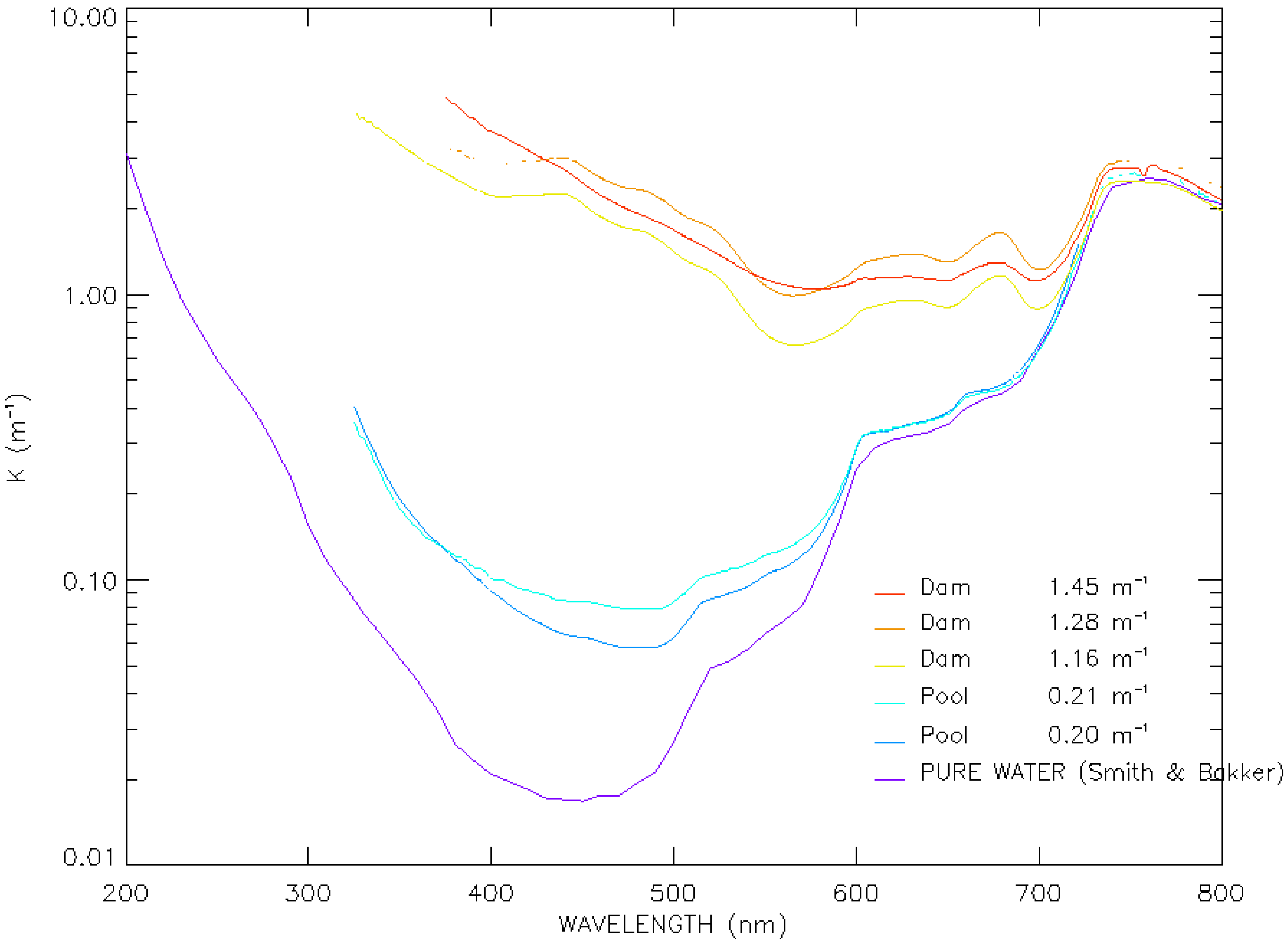
Alqueva reservoir – Turbid Water



Attenuation Coefficient and PAR values

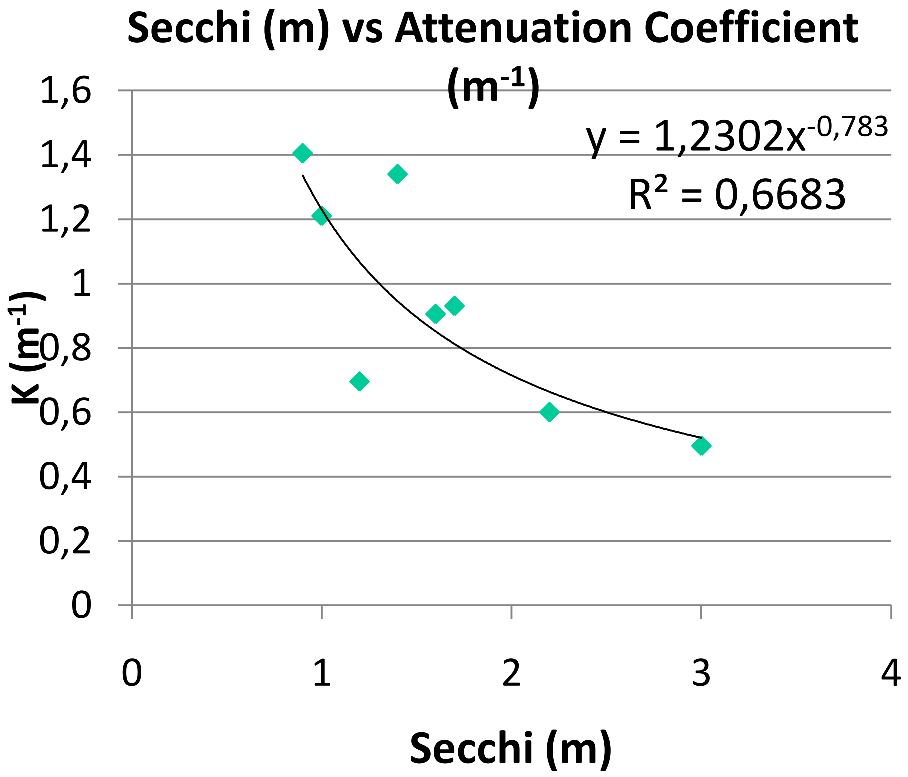
$$E(z,\theta,\phi,\lambda) = E(0,\theta,\phi,\lambda)\exp\left\{-\int_{0}^{z} K(z',\theta,\phi,\lambda)\,dz'\right\}$$

Preisendorfer, 1958



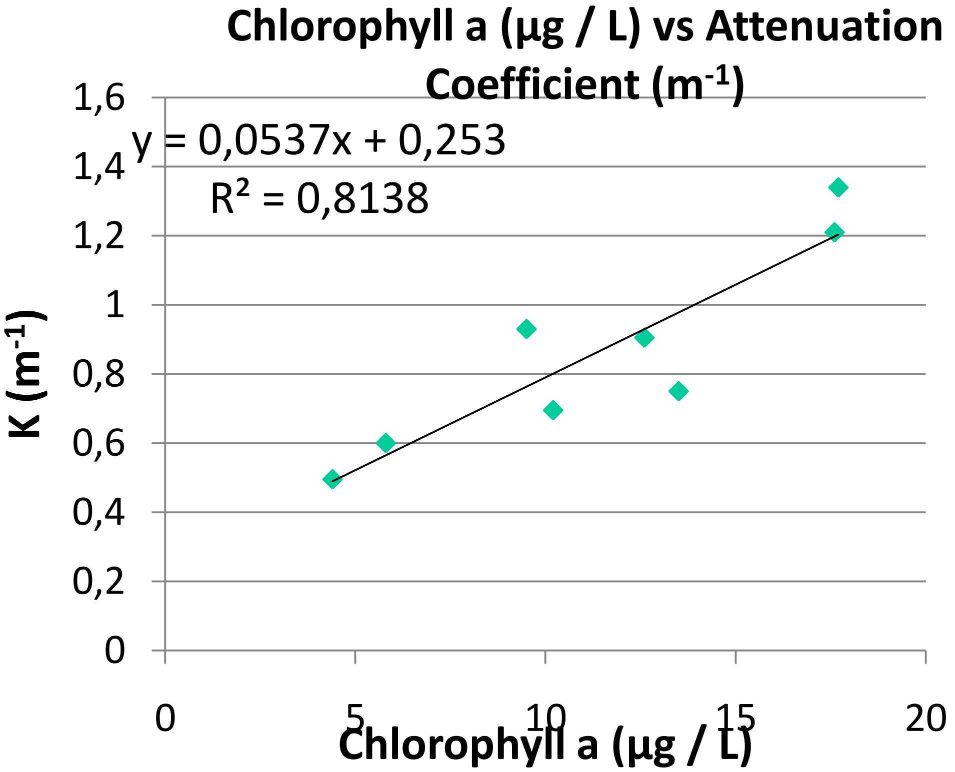
For pure and pool water the minimum of attenuation is between 400-500 nm and with increasing turbidity (in dams) this minimum shifts to 500 to 600 nm. PAR values (400-700 nm) increase with turbidity (not shown here).

Attenuation Coefficient vs Secchi depth and Chlorophyll a



Secchi (m) vs Attenuation Coefficient (m^{-1})

Power relation between Attenuation Coefficient and Secchi Depth

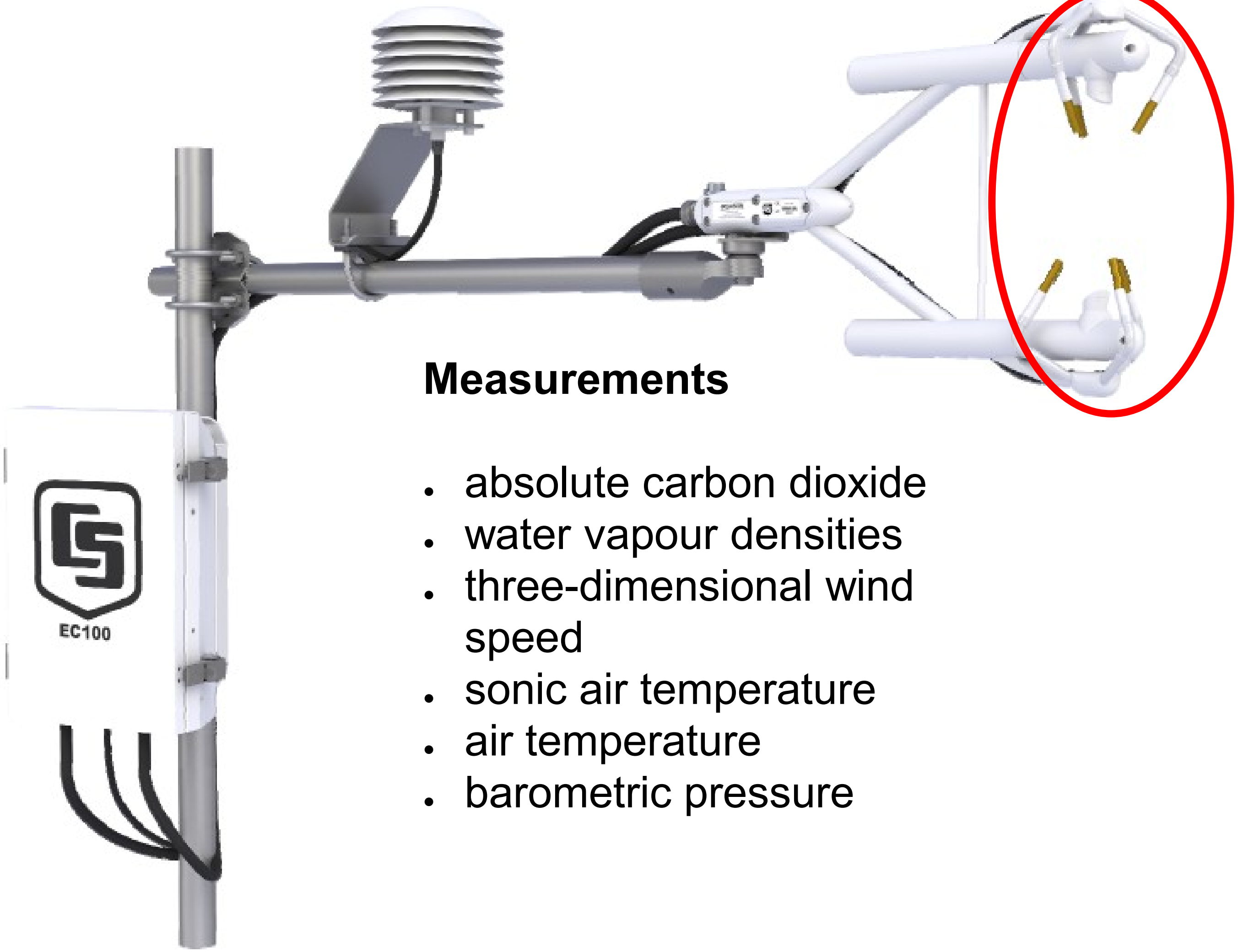


Chlorophyll a (µg / L) vs Attenuation Coefficient (m^{-1})

Linear relation between Attenuation Coefficient and Chlorophyll a

Eddy covariance system - IRGASON

Integrated CO_2/H_2O Open-Path Gas Analyzer and 3D Sonic Anemometer



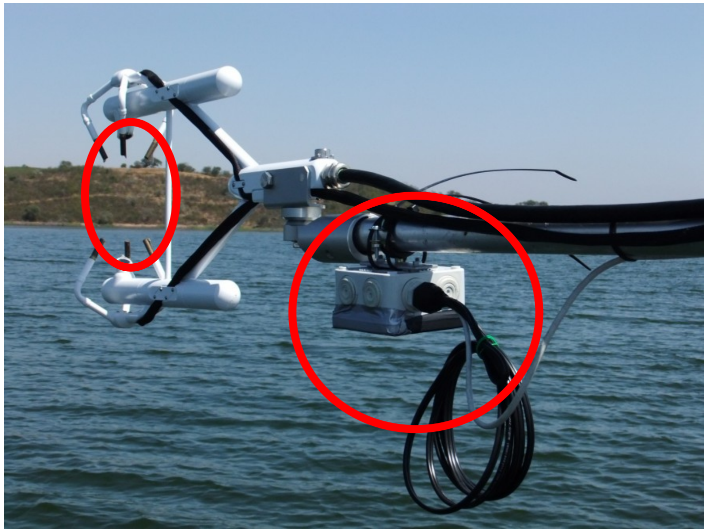
Measurements

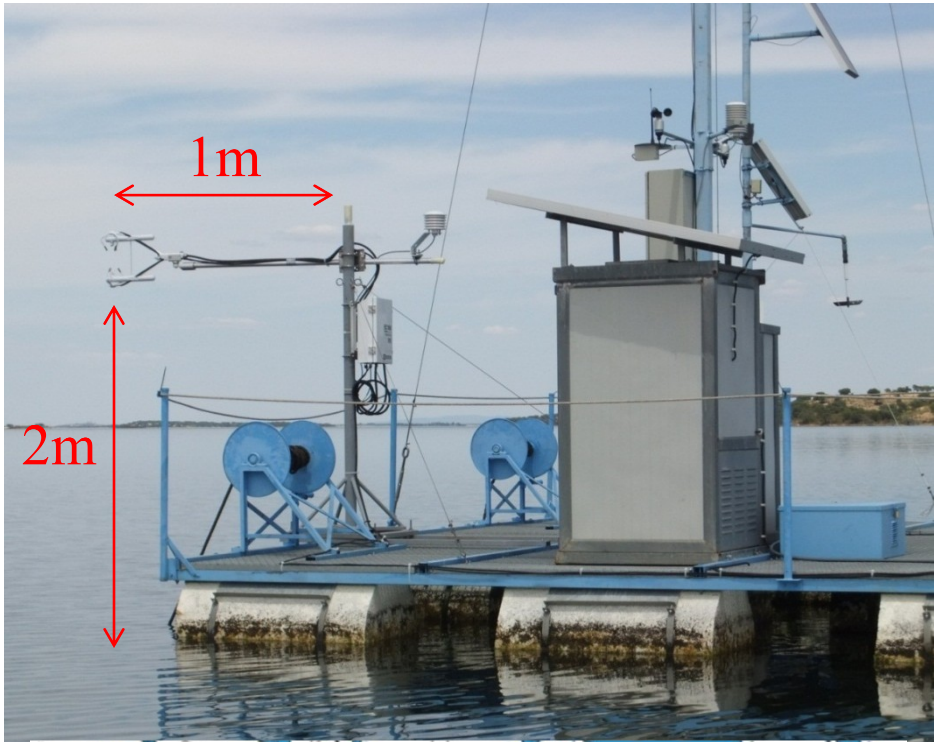
- absolute carbon dioxide
- water vapour densities
- three-dimensional wind speed
- sonic air temperature
- air temperature
- barometric pressure

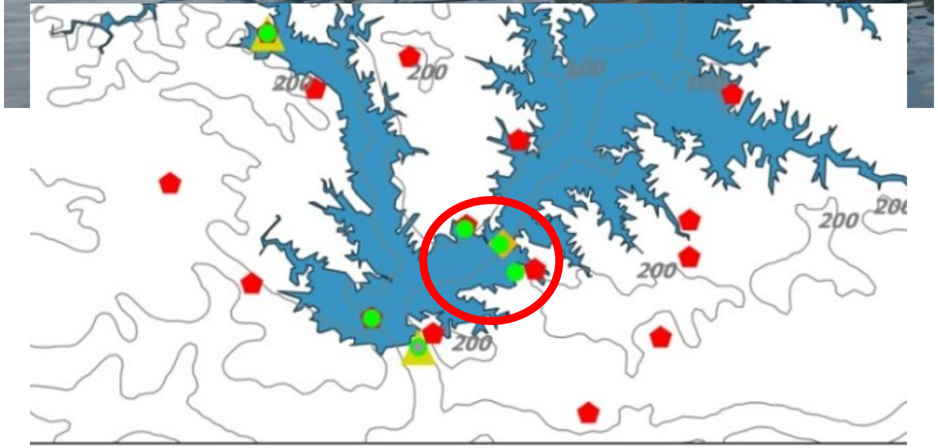
Eddy covariance In Alqueva platform

System: IRGASON
Frequency: 20 Hz
height: 2 m
Flux averages: 30 min
Orientation: Northwest (prevailing winds)

Built-in accelerometer in Waspmote board – Libelium to compute the vertical velocity of the arm





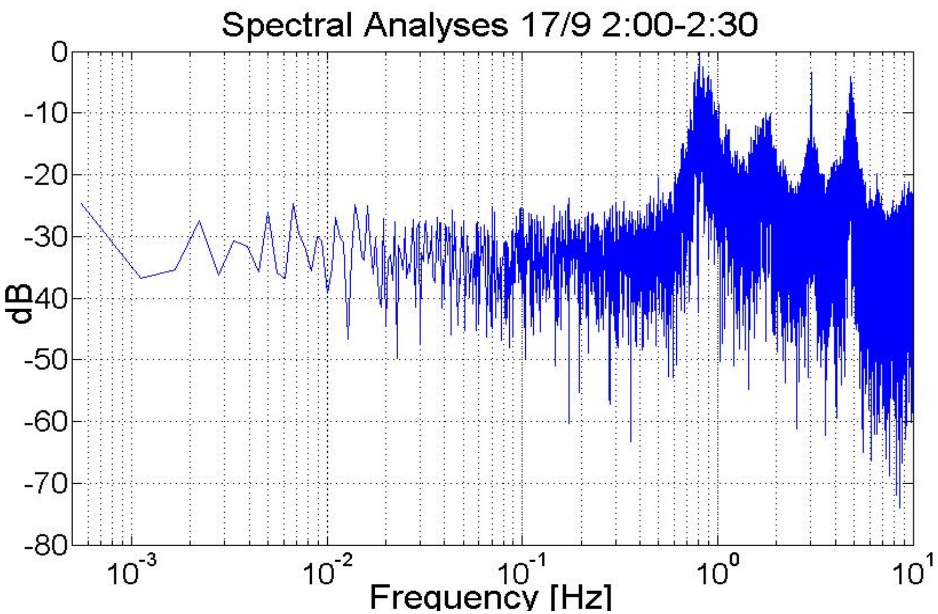


Platform Oscillation

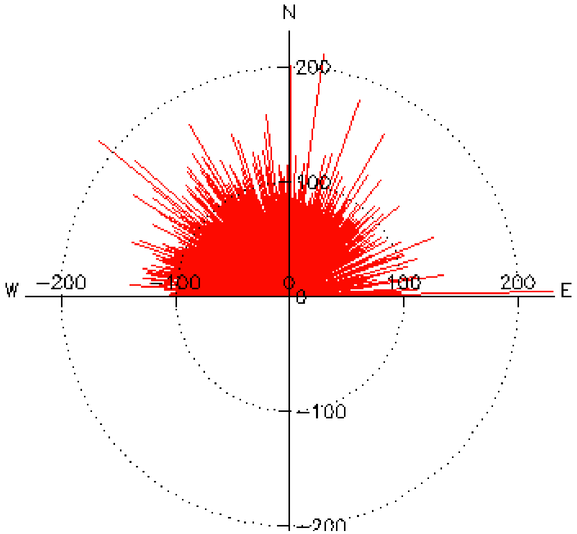
- The vertical velocity of the arm was of the order of 10^{-3} or 10^{-2} ms^{-1} (one order less than the vertical wind).
- A spectral analysis showed that the dominant frequencies of the platform are normally around 1, 2, 3 and 5 Hz, as shown in the example of the figure.
- A comparison between the fluxes with and without the correction for the platform motion is shown in the table below for normalized bias, mean absolute error and root mean square error. Differences are negligible.

June to September statistics

	tau	H	LE	CO_2
nbias	3.32×10^{-3}	2.63×10^{-3}	-2.54×10^{-3}	2.01×10^{-3}
nmae	1.19×10^{-2}	9.45×10^{-3}	7.52×10^{-3}	4.17×10^{-3}
nrmse	2.38×10^{-2}	1.82×10^{-2}	1.87×10^{-2}	1.09×10^{-2}


Spectral Analyses 17/9 2:00-2:30

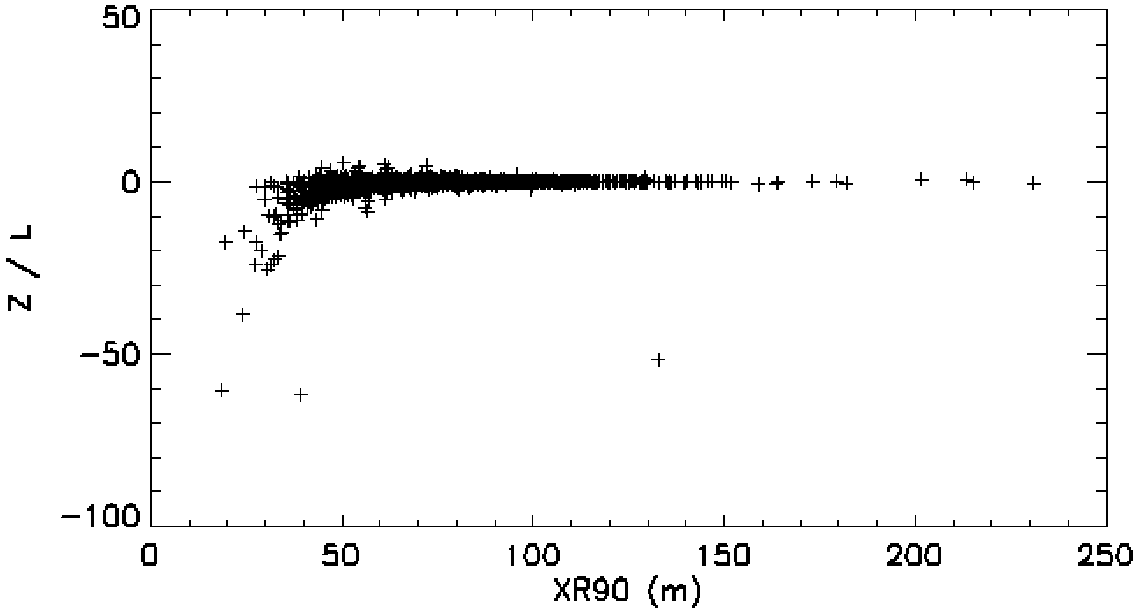
Footprint and Stability



Kljun et al. 2004

35% excluded by wind direction flag

Average XR90 : 72.6 m
Average Xmax : 36.2 m
Average Z / L : -0.47



CO_2 over reservoir (June to September)

At night – CO_2 plants respiration

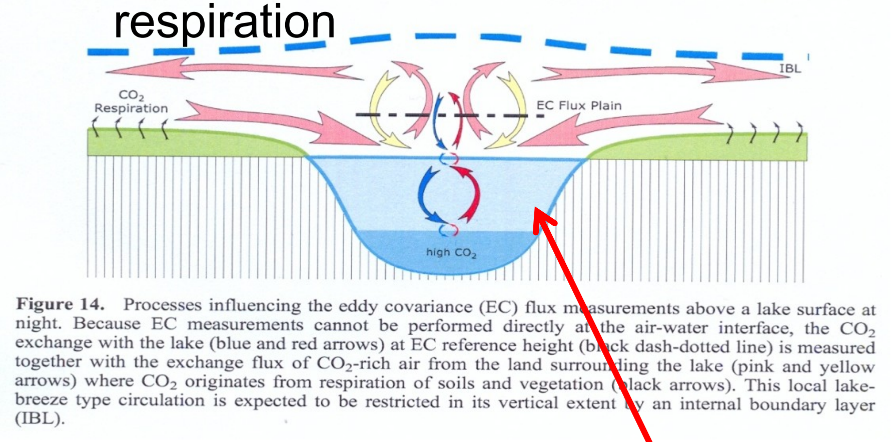
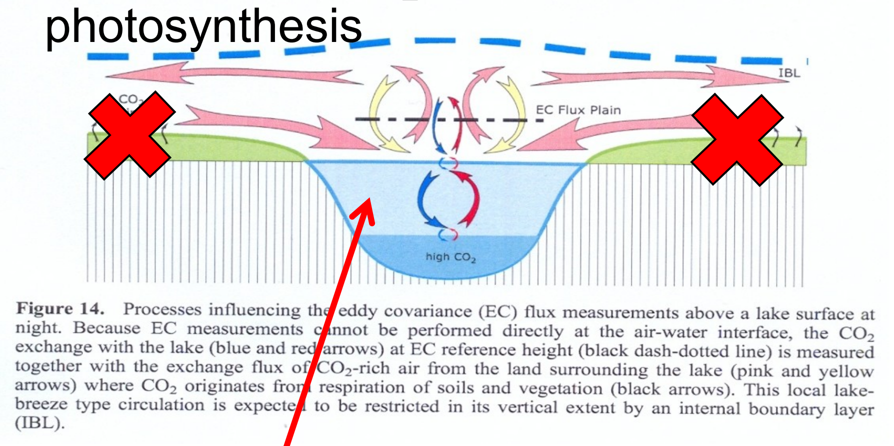


Figure 14. Processes influencing the eddy covariance (EC) flux measurements above a lake surface at night. Because EC measurements cannot be performed directly at the air-water interface, the CO_2 exchange with the lake (blue and red arrows) at EC reference height (black dash-dotted line) is measured together with the exchange flux of CO_2-rich air from the land surrounding the lake (pink and yellow arrows) where CO_2 originates from respiration of soils and vegetation (black arrows). This local lake-breeze type circulation is expected to be restricted in its vertical extent by an internal boundary layer (IBL).

Reprinted from Eugster et al. (2003)

During day – CO_2 plants photosynthesis



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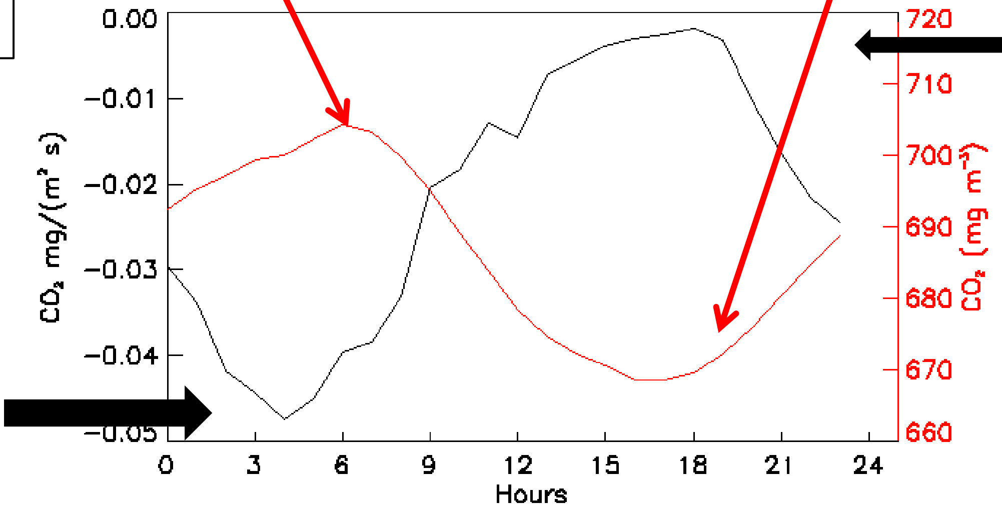
In black flux

Greater uptake by the reservoir during night – high negative flux



Lower uptake by the reservoir during day – weaker flux, still negative

In red concentration

CO_2 Fluxes & Instability (5 days in July -IOP)

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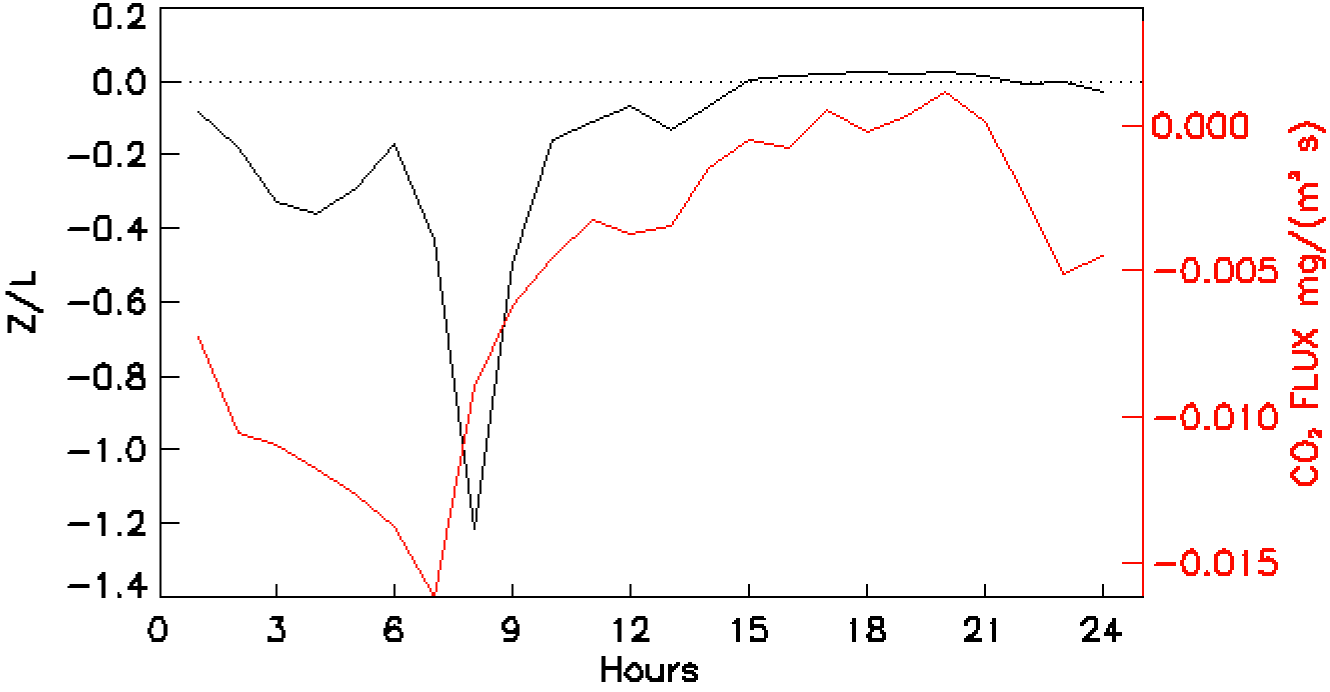
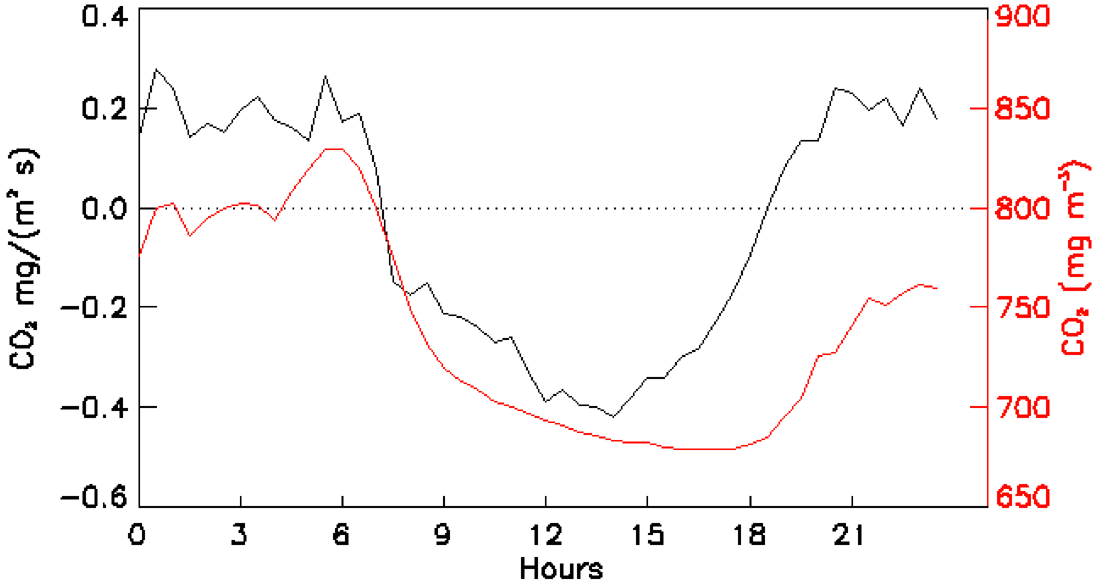


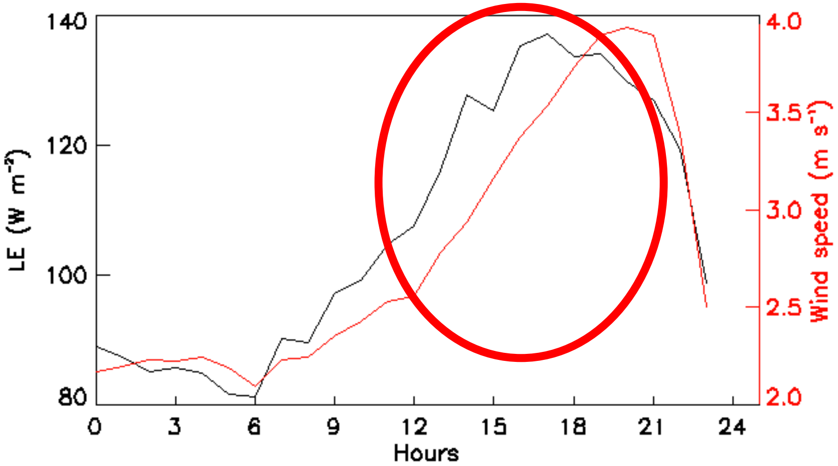
Greater uptake occurs under instability (Z / L) < -0.1
Atention, this is only for 5 days in July (IOP)!

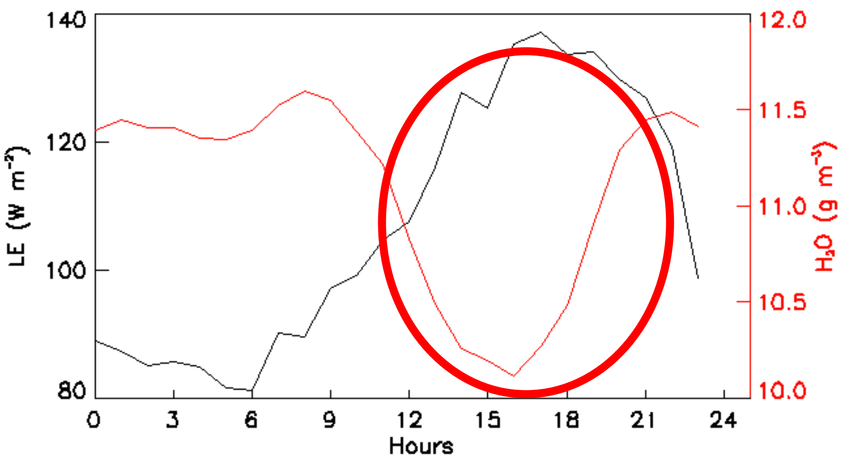
CO_2 over grass (April)

During Spring the system was mounted inland performing tests. The local was covered with grass. The results show positive flux during night and negative during daytime. The flux is well correlated with the concentration.

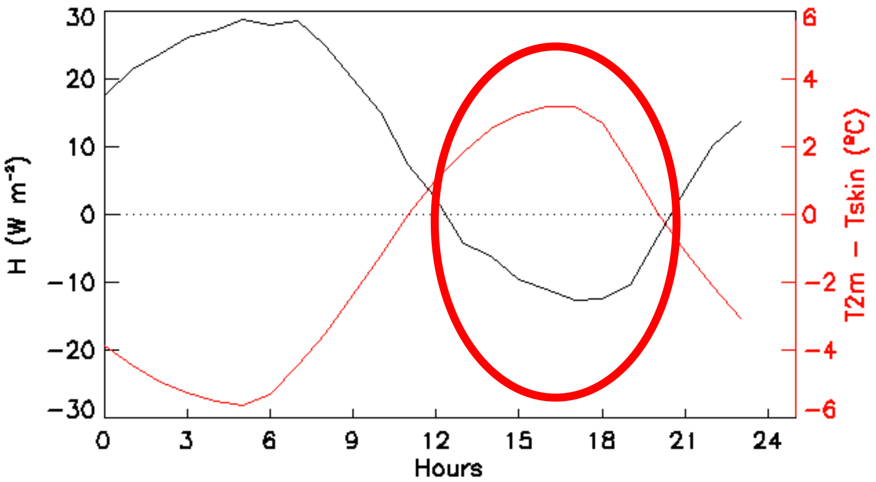


Heat fluxes (June to September)

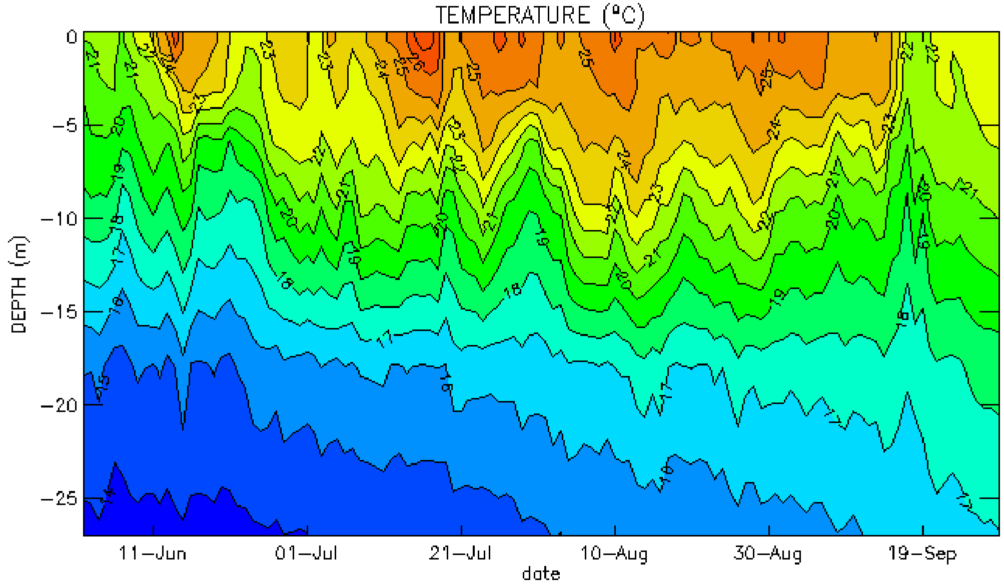




During the afternoon, between 12 and 21 hours, the air temperature is hotter then reservoir surface and lake breeze is developed allowing the subsidence of upper dry air leading to an increase of latent heat and forcing a negative sensible heat flux.

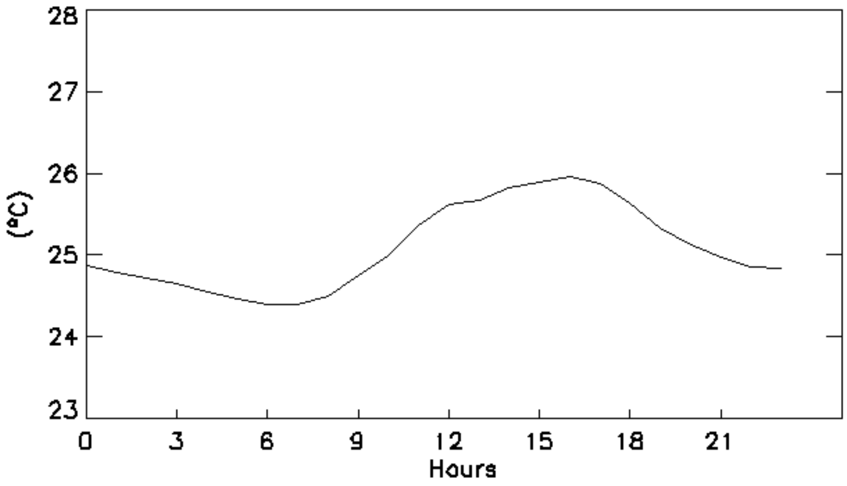


Water temperature(June to September)



Continuous measurements up to 27 meters depth during the 4 months

It shows the thermocline in the first meters and progressive increase of temperature in deeper layers (below 10 meters) during the study period.



This is the average skin temperature diurnal cycle for July.

Surface Energy Balance (June to September)

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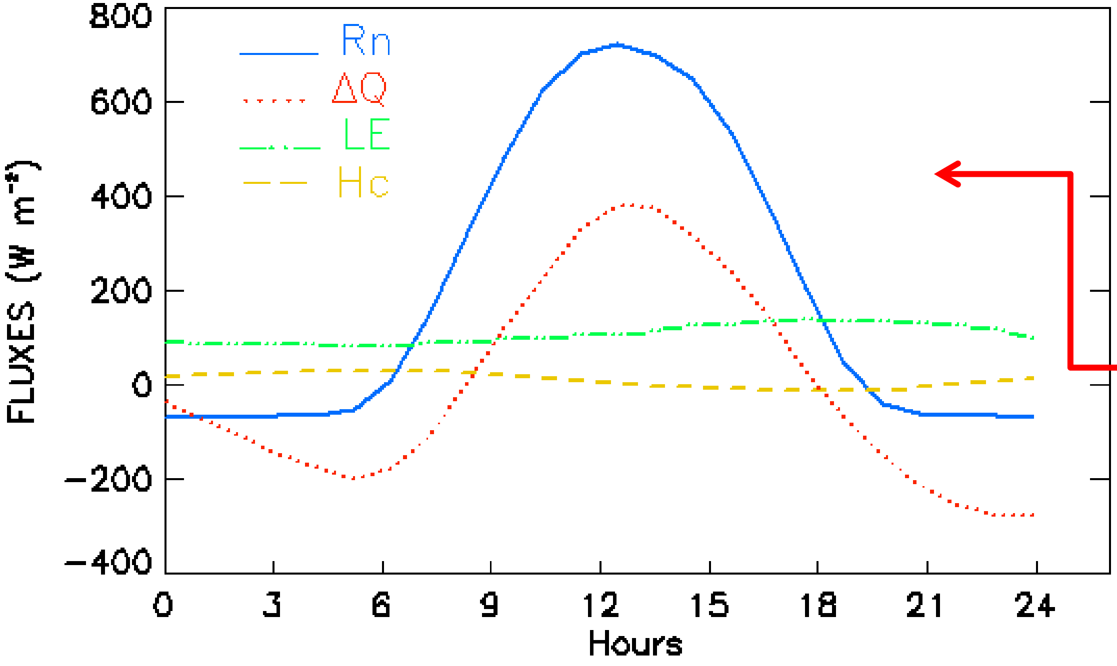
$$\Delta \quad = \qquad \sum_{i=} \quad \Delta$$

Rn – Net Radiation

ΔQ – Water column Heat

LE – Latent Heat

Hc – Sensible Heat



ΔQ depth (m)	RES (Wm^{-2})	RES STDEV (W m^{-2})
4	84.44	76.73
58	0.47	572.68

$$RES \approx \quad - \Delta \quad - \quad -$$

Available energy in terms of absolute residual (Wm^{-2})

Summary

- The newest underwater irradiance allows the calculation of solar attenuation of the water column and thus euphotic depth determination.

- The results from the built-in accelerometer installed in the platform show no need to correct the fluxes measurements for the raft oscillations.

- Results from carbon dioxide flux show the reservoir as a sink of carbon especially during night and morning, when the concentration of carbon dioxide and instability is higher in the adjacent atmosphere.

- The energy balance was estimated for the surface of the reservoir. Heat storage calculations (ΔQ) plays an important role and further calculations need to be done for better accuracy. Nevertheless, the reservoir is accumulating energy in this summer months.

Future work

- We are motivated to extend the 4 months experiment to one year in Alqueva reservoir and parallel, but seasonal, flux measurements in a smaller and eutrophic reservoir nearby.

Acknowledgments

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