Fluxes of energy and CO_2 over Alqueva reservoir, southeast of Portugal

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Summary

- Eddy Covariance Flux measurements
- Heat and CO_2 Fluxes from April to September 2017
- Two approaches for CO_2 flux from September to October 2017
- Final Remarks
- Acknowledgements

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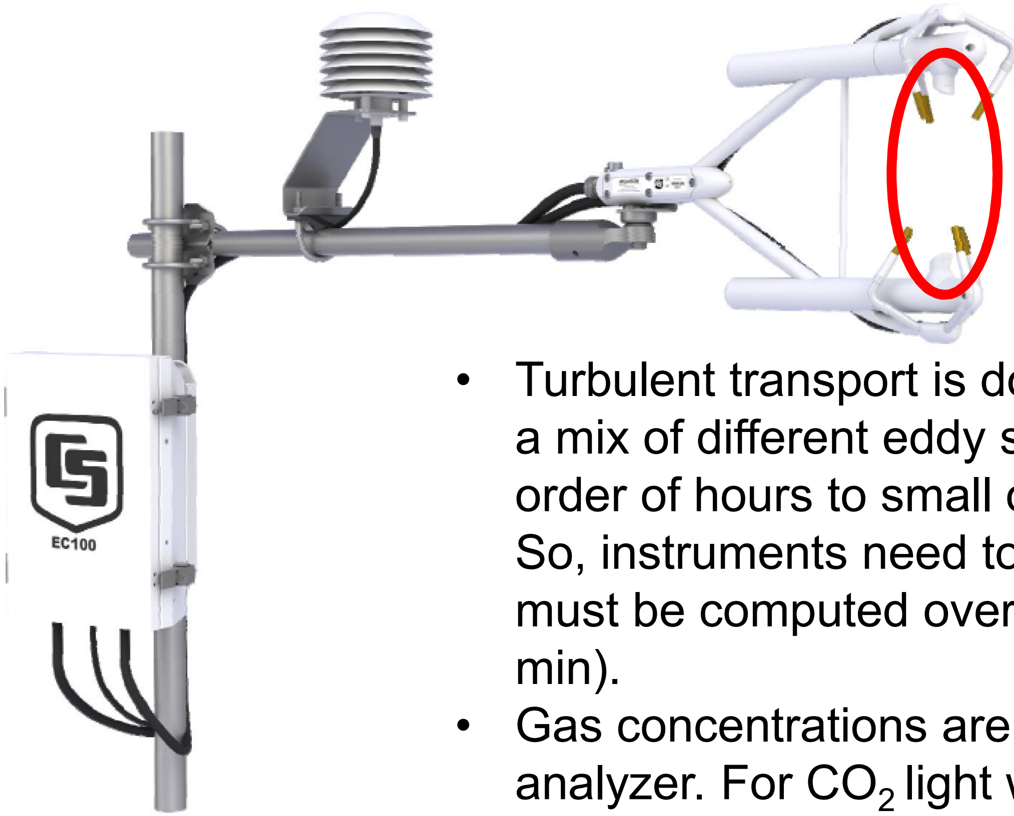
IRGASON

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



- Turbulent transport is done at different frequencies through a mix of different eddy sizes: from large movements of the order of hours to small ones on the order of 1/10 second. So, instruments need to be fast (10, 20 Hz). Covariances must be computed over a relatively long period (15, 30, 60 min).
- Gas concentrations are obtained mid-infrared absorption analyzer. For CO_2 light with 4.3 μm is selected as it corresponds to molecules asymmetric stretching vibrational band. For H_2O is used radiation at 2.7 μm, corresponding to waters symmetric stretching vibrational band.

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Resulting turbulent fluxes

Momentum Flux $\tau = -\rho_a \overline{\hat{u}'\hat{w}'}$

Sensible Heat Flux $H_c = \rho_a C_p \overline{\hat{w}'\hat{T_c}'}$

Latent Heat Flux

$$F_{LE} = \overline{\hat{w}'\widehat{\rho_w}'} + \left(\frac{M_a}{M_w}\frac{\overline{\rho_w}}{\rho_{a,dry}}\right)\overline{\hat{w}'\widehat{\rho_w}'} + \left(1 + \frac{M_a}{M_w}\frac{\overline{\rho_w}}{\rho_{a,dry}}\right)\frac{\overline{\rho_w}}{\overline{\overline{T_c}}}\overline{\hat{w}'\hat{T_c}'}$$

Carbon Dioxide Flux

$$F_C = \overline{\hat{w}'\widehat{\rho_c}'} + \left(\frac{M_a}{M_w}\frac{\overline{\rho_c}}{\rho_{a,dry}}\right)\overline{\hat{w}'\widehat{\rho_w}'} + \left(1 + \frac{M_a}{M_w}\frac{\overline{\rho_w}}{\rho_{a,dry}}\right)\frac{\overline{\rho_c}}{\overline{\overline{T}}}\overline{\hat{w}'\hat{T_c}'}$$

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The second term is for water vapor dilution and the third for thermal expansion (both correction of density fluctuations for water vapor – WPL corrections)

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Data treatment **before** flux computation

- Data series despiking
- Data series linear detrending
- Three dimensional coordinate rotations, which result in zero vertical wind
- Correction of density fluctuations for thermal expansion and water vapor dilution according Webb et al. (1980)
- Sonic temperature is corrected for water vapor according Kaimal and Gaynor (1991)

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Data treatment **after** flux computation

- Data filtering for wind direction
- Footprint analysis according Klunj et al. (2004)
- Correction for spectroscopic effects according Helbig et al. (2016)

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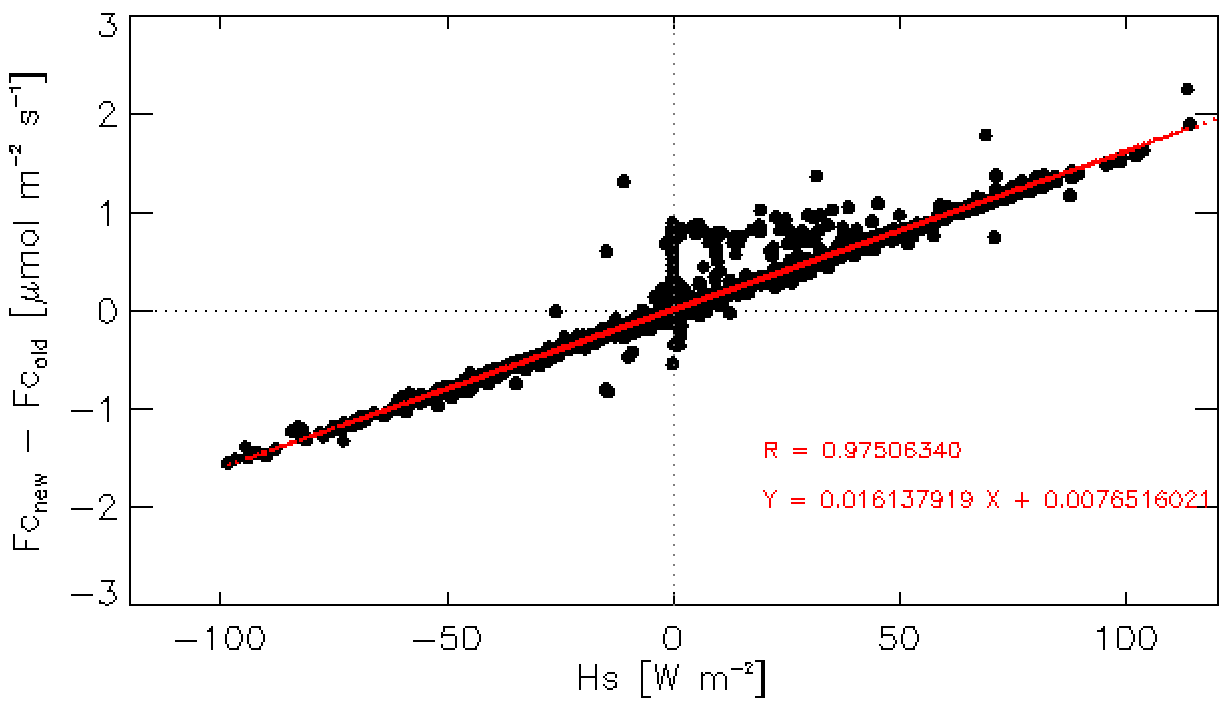
Spectroscopic correction

- IRGASON is measuring CO_2 absorption which is scaled with air temperature on a slow-response thermistor air temperature measurement. Helbig et at (2016) shown that kinematic temperature fluxes consistently determine the CO_2 fluxes errors.
- This year a new software version for IRGASON was released in order to correct this systematic bias with the use of fast-response air temperature derived from sonic anemometer measurements.



CO_2 flux difference between fast and slow response temperatures versus Sensible heat flux.

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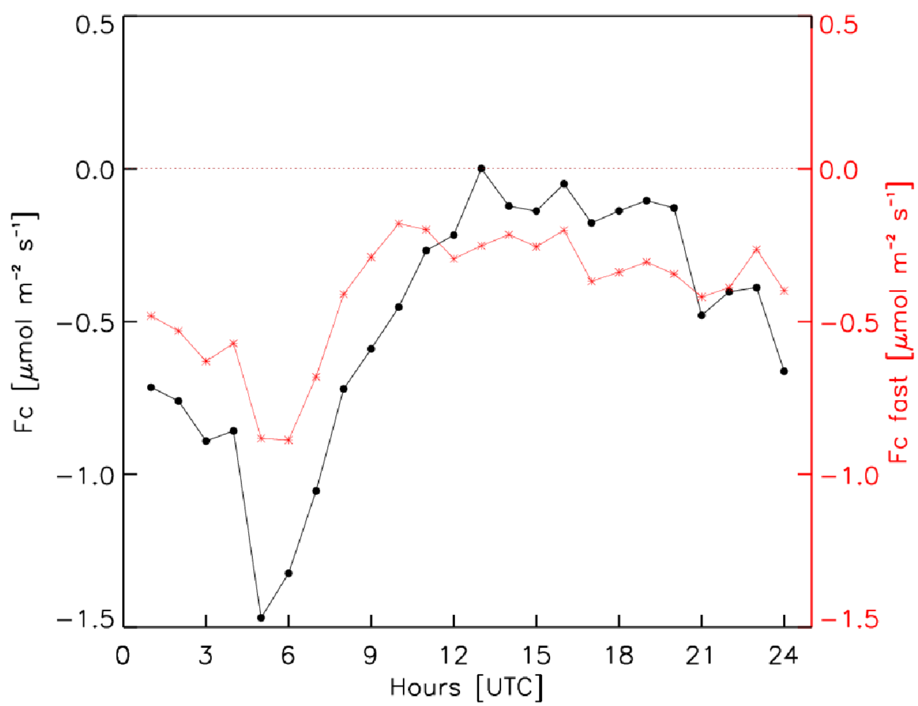
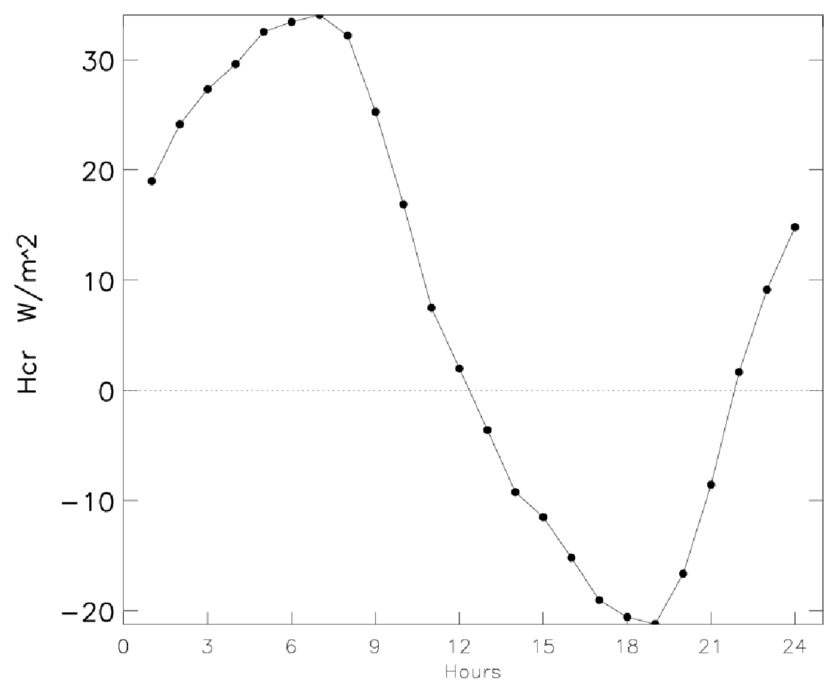
CO2 Flux with slow and fast-response temperature in 2017 Alqueva reservoir





The “fast” flux (in red) is attenuated related to “slow” flux. Positive sensible heat during night corresponds to less negative and the opposite.

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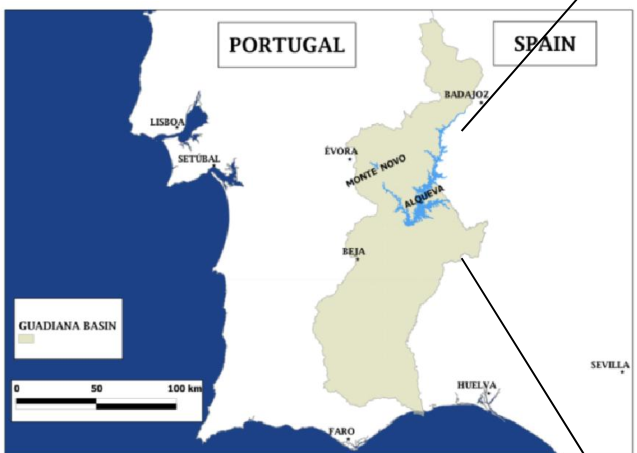
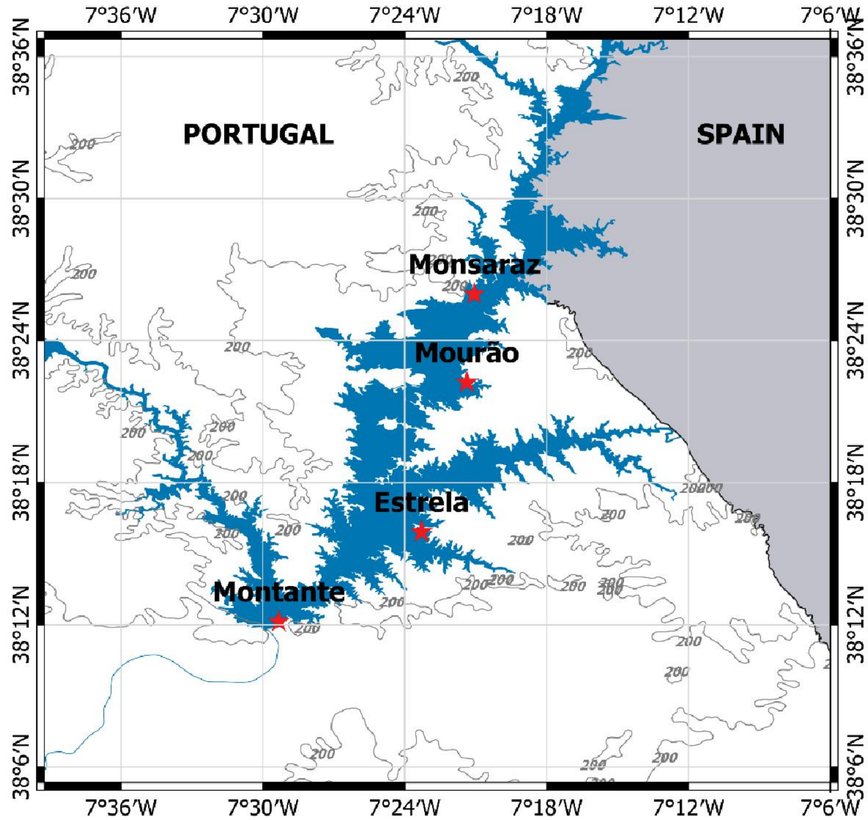
Alqueva reservoir





Alentejo Region:
Köppen classification: Csa
Annual precipitation: 571,8 mm
Number of days above 30ºC: 77.1

Surface area of 250 km^2
Age: since 2002

Presently is installed since April **2017** in the same platform as in **2014** in Alqueva reservoir. A new campaign of observation ALOP (Alentejo Observation and Prediction systems) intend to be one year long with multidisciplinary measurements all over the reservoir.

Eddy covariance in Alqueva reservoir

System: IRGASON (Campbell Sc.)
Frequency: 20 Hz
height: 2 m
Flux averages: 30 min
Orientation: North (prevailing winds from NW)

In this photo it is possible to see the IRGASON and below a pipe and inlet of a closed-path CO_2 analyzer (LICOR 7210) installed in June for a intercomparison study until the end of October? In collaboration with Helsinki University.

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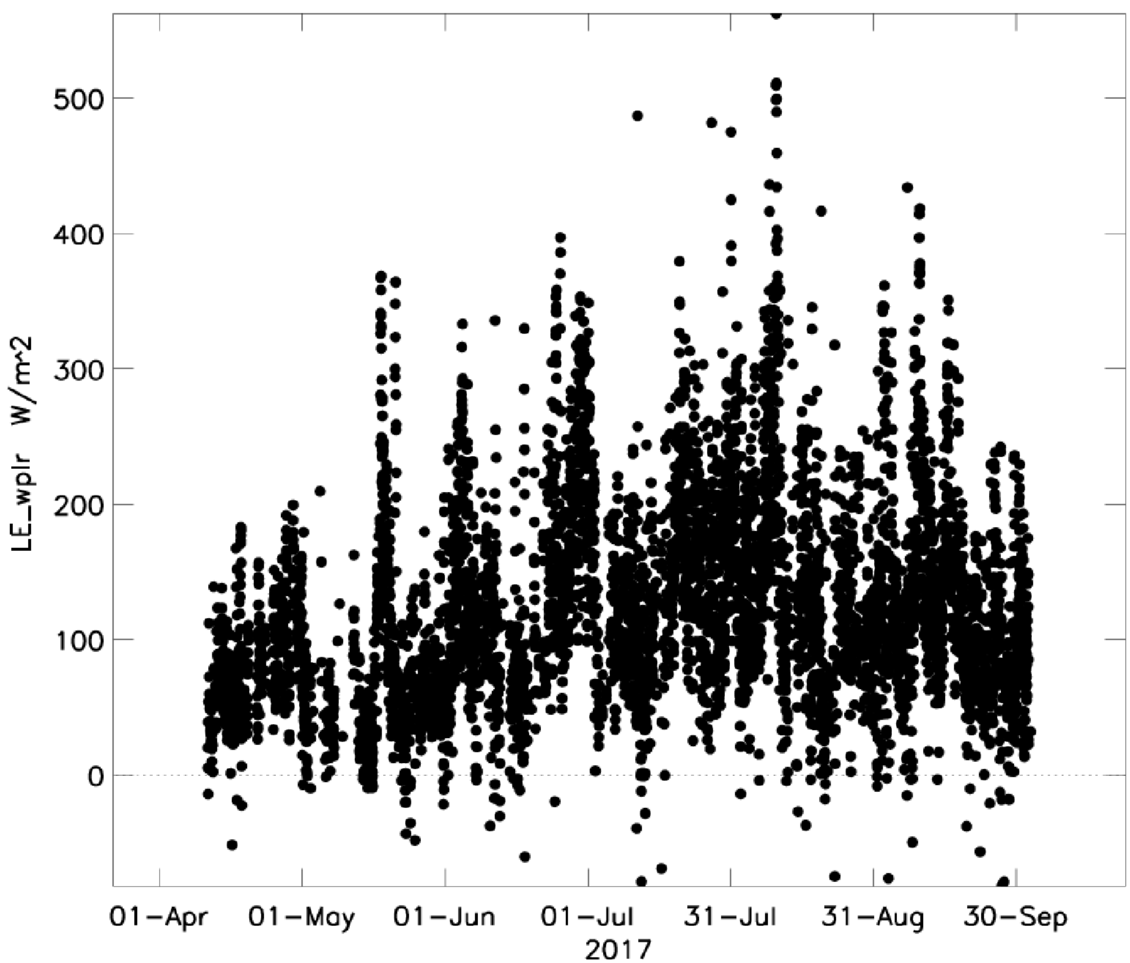
Latent heat flux (April to September 2017)



Average: 113,04 W m^{-2}
Maximum: 562,65 W m^{-2}
Minimum: -94,55 W m^{-2}

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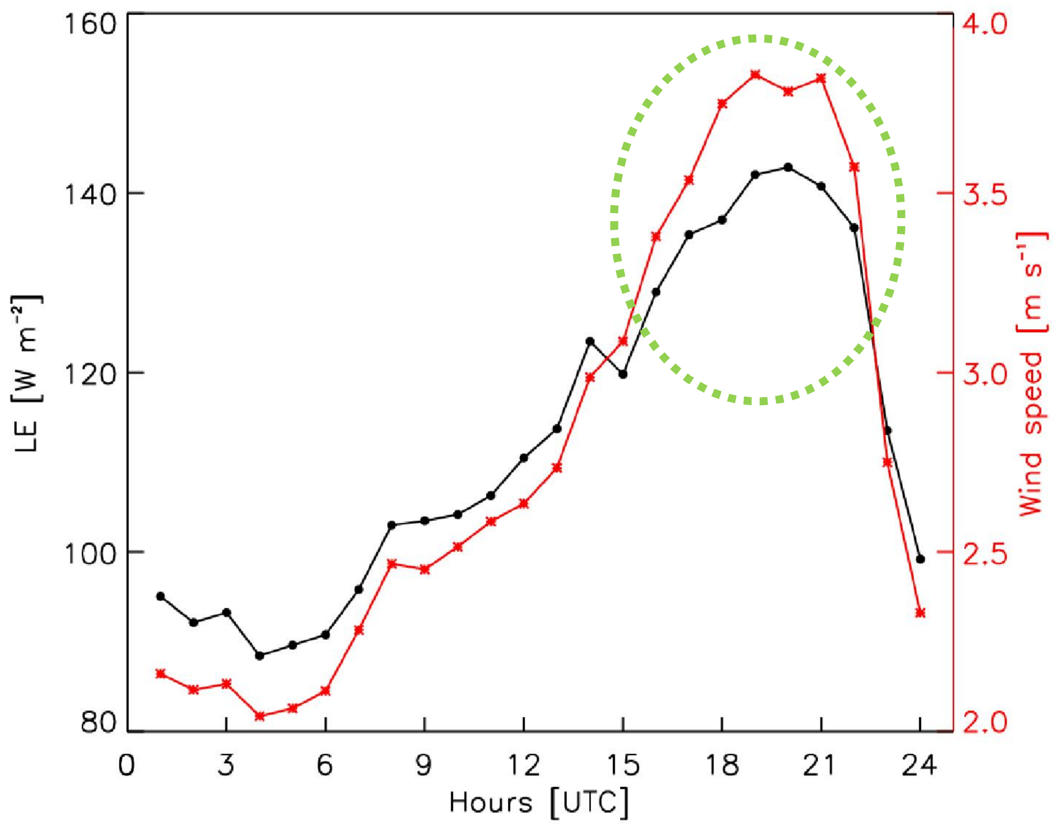
Latent heat flux (April to September 2017)



During the afternoon, an increase of wind speed (in red) due to the arrival of the sea breeze increases the latent heat.

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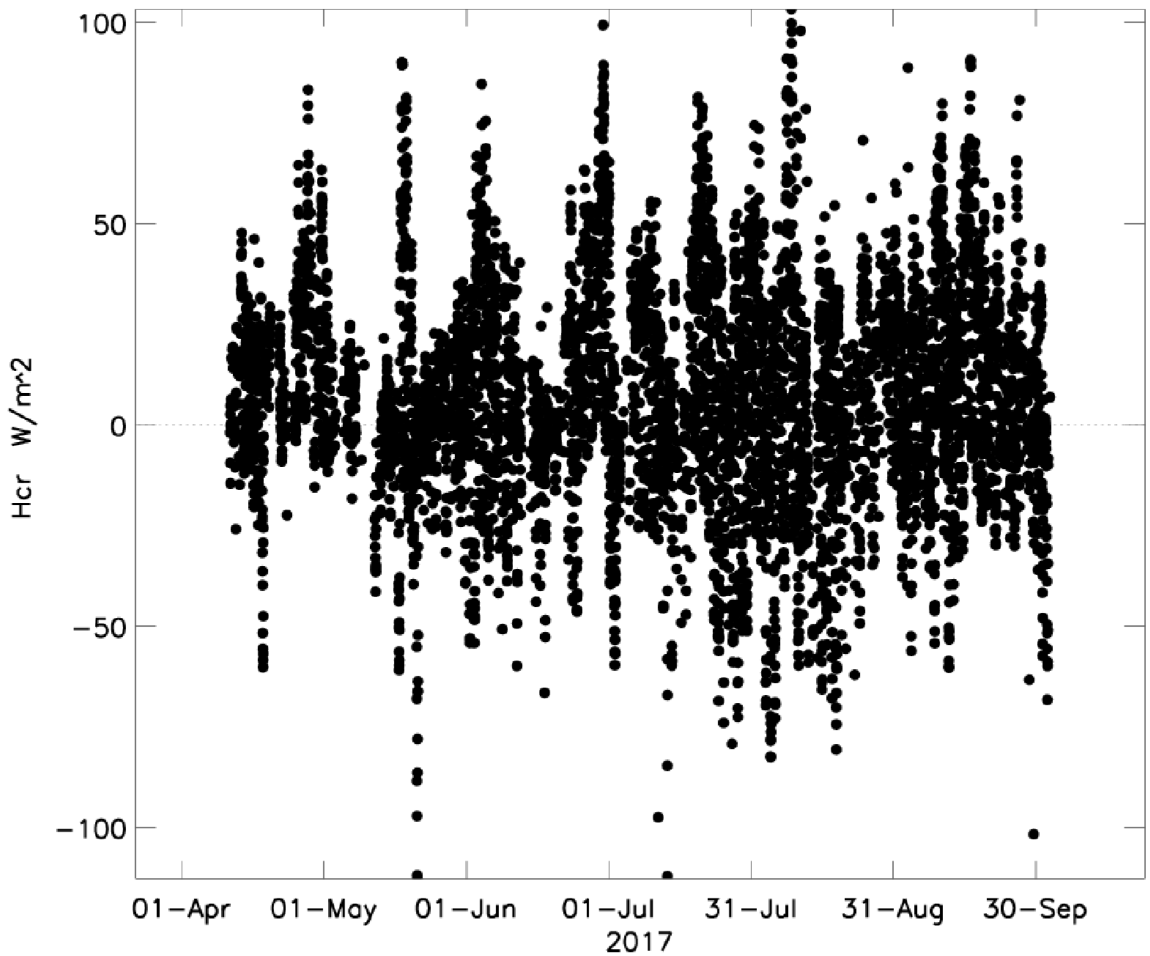
Sensible heat flux (April to September 2017)



Average: 6,08 W m^{-2}
Maximum: 103,31 W m^{-2}
Minimum: -112,65 W m^{-2}

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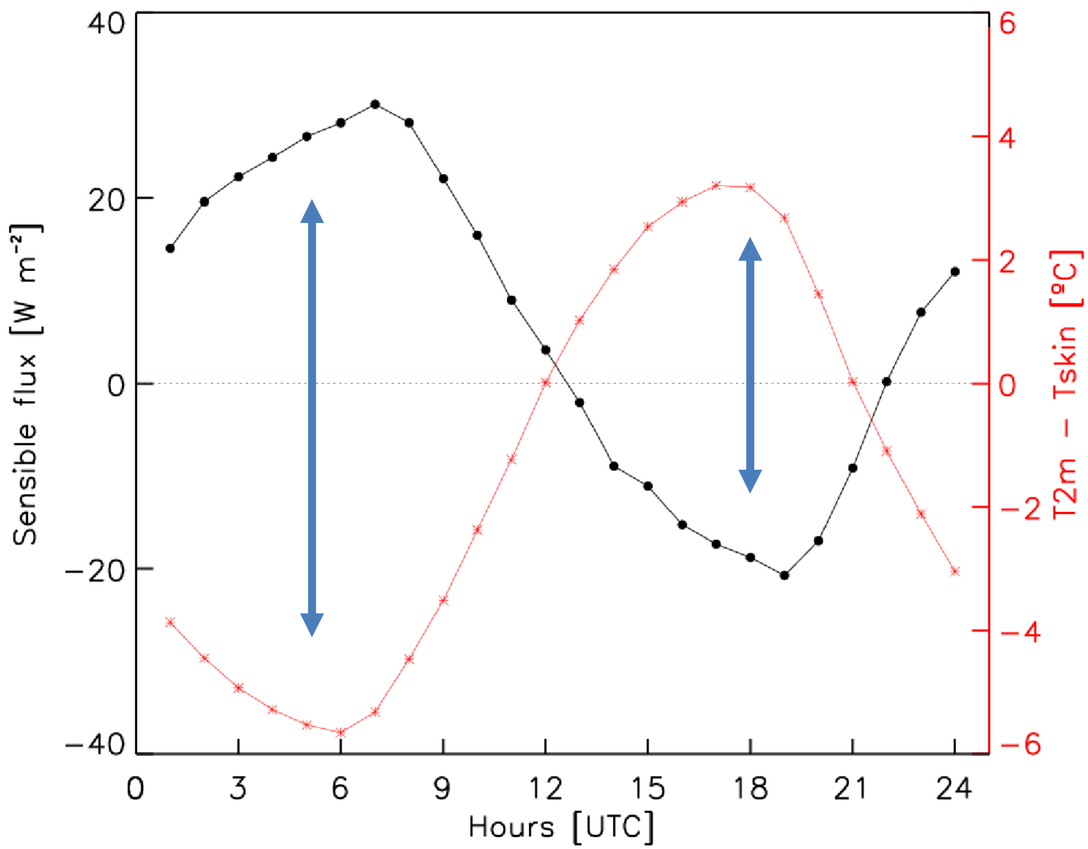
Sensible heat flux (April to September 2017)



During the afternoon, between 12 and 21 hours, the air temperature is hotter then reservoir surface (in red) and lake breeze can be developed locally (in cases of low wind speed) allowing the subsidence of upper dry air forcing a negative sensible heat flux.

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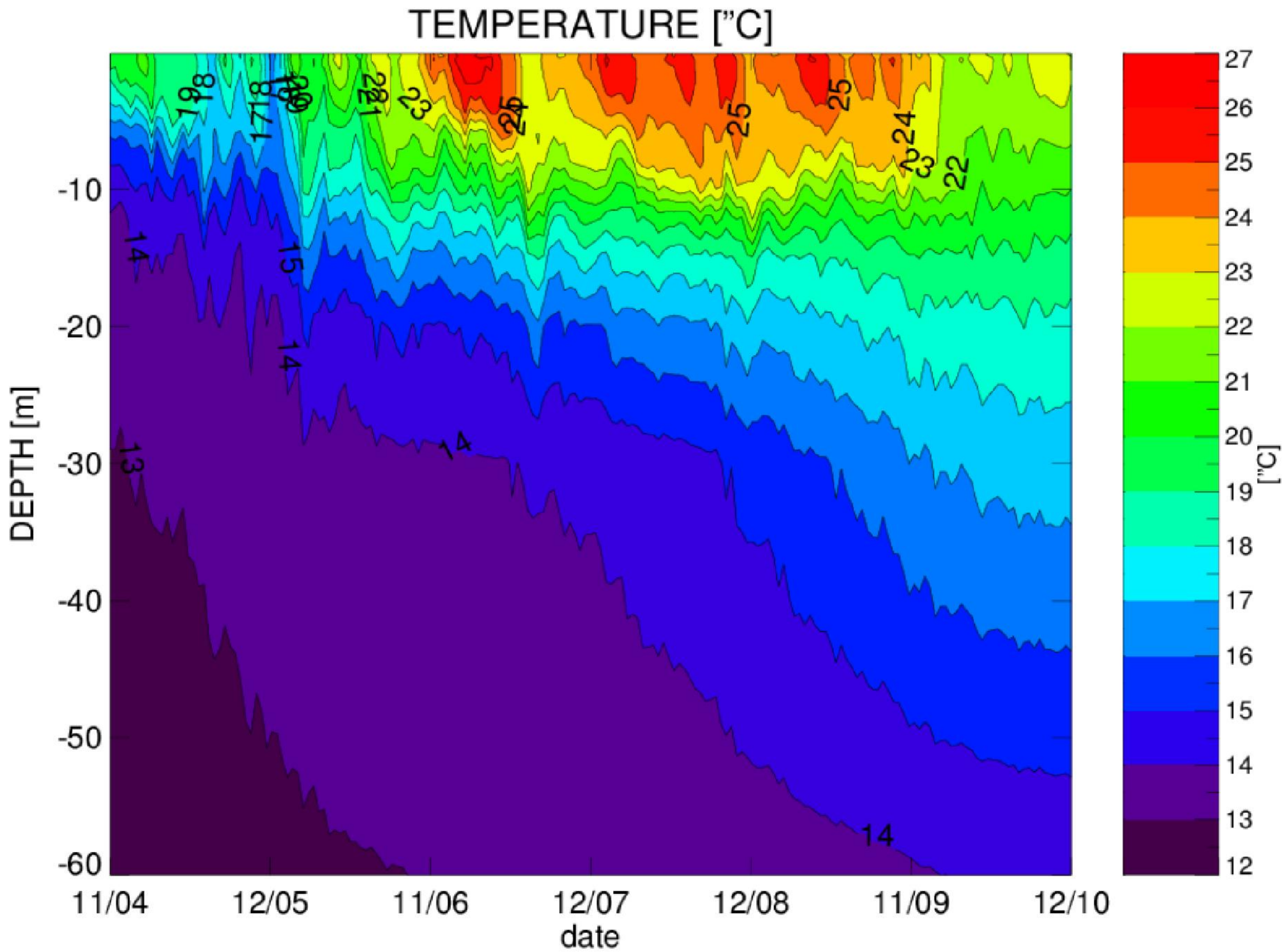
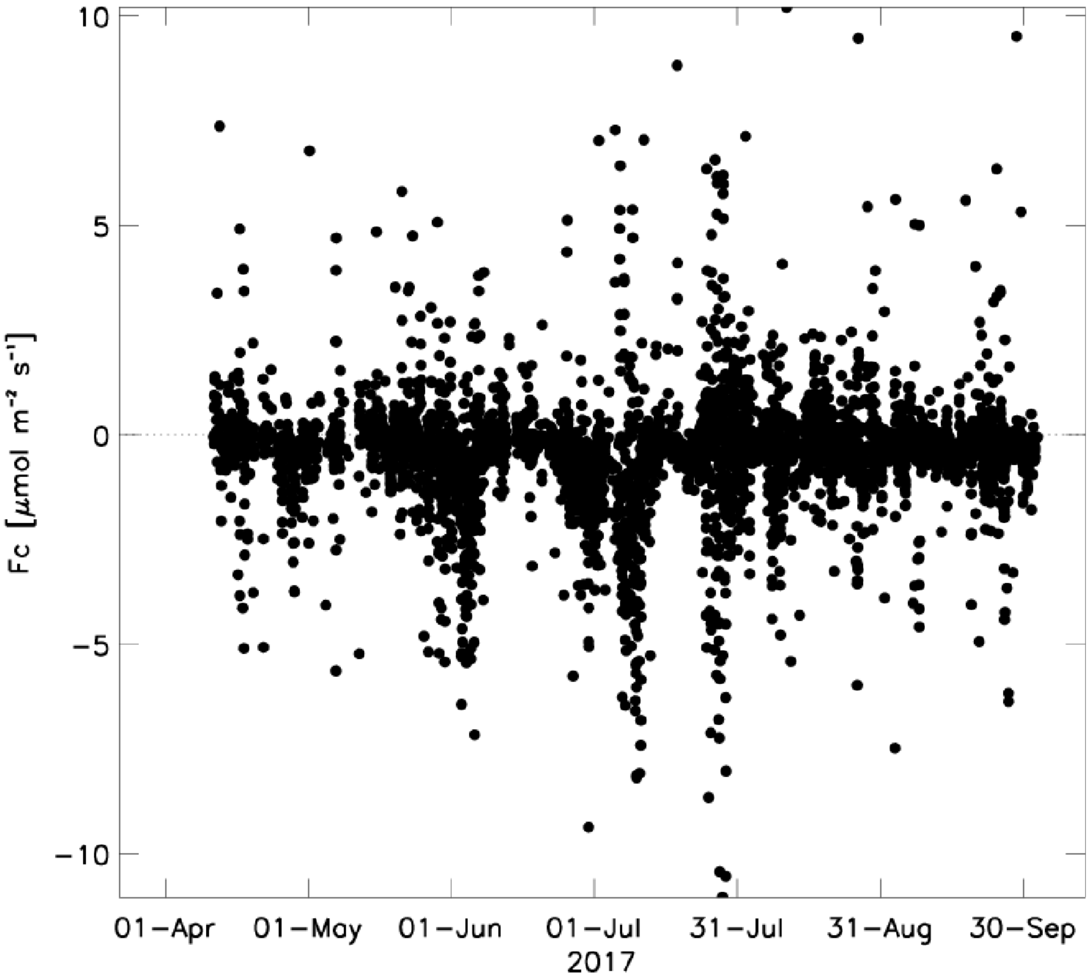
Water temperature (April to October 2017)



Measurements at 14 levels until 60 meters. The lake is well stratified showing a clear thermocline. In June, July and August very warm in the first layers (maximum of 27ºC) and progressive decrease of temperature in deeper layers (below 10 meters) during the study period.

CO_2 flux (April to September 2017)



Average: -0,415 μmol m^{-2} s^{-1}
Maximum: 11,036 μmol m^{-2} s^{-1}
Minimum: -10,206 μmol m^{-2} s^{-1}

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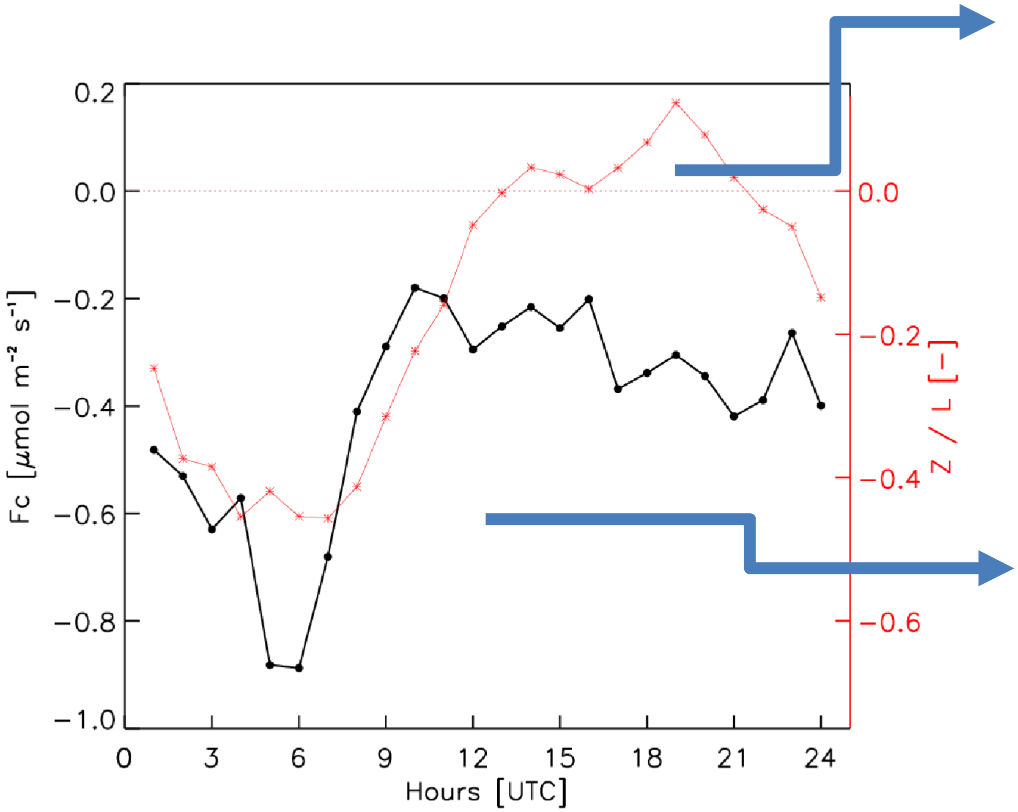
CO_2 Fluxes and Stability (April to September 2017)



Lower uptake occurs under stability (z / L) > -0.2

Greater uptake occurs under instability (z / L) < -0.2

$$L = \frac{\overline{T}_c u_*^3}{kg\overline{w'T_c'}}$$

Monin-Obukhov Length

- Results are consistent with a set of measurements from June to September 2014 in the same place, as shown in Potes et al. (2017).

CO_2 concentration inwater (Sept/Octb 2017)

$$Flux_{gas} = \alpha k(C_w - C_{eq})$$

α Chemical enhancement factor
K piston velocity (cm h^{-1})
C_w Concentration of dissolved gas in water
C_{eq} Concentration of dissolved gas at equilibrium with air concentration

System: Mini CO2 (PRO-OCEANUS)
Frequency: 5 seconds
Average: 1 and 30 min
Depth: 25 cm

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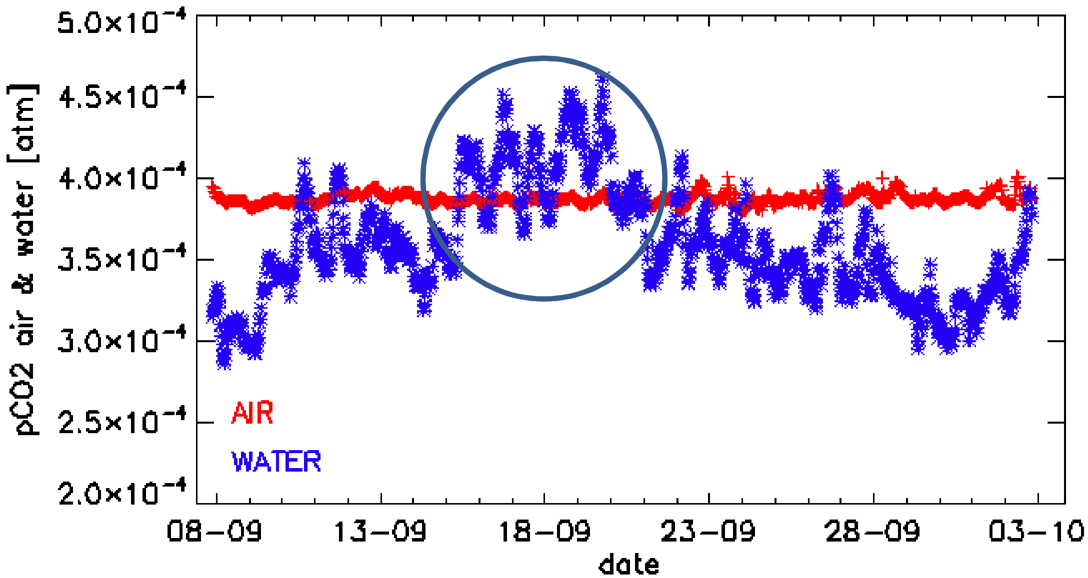
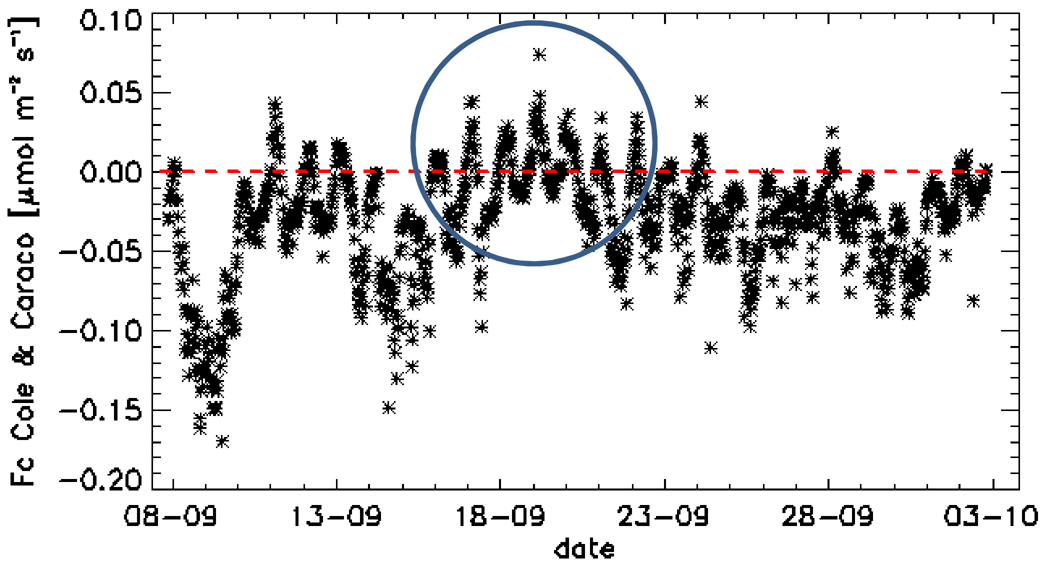
CO_2 partial pressure and flux (Sept/Octb 2017)





Mainly partial pressure in water is lower than air with a episode of 5 days with opposite behavior which results in positive fluxes.

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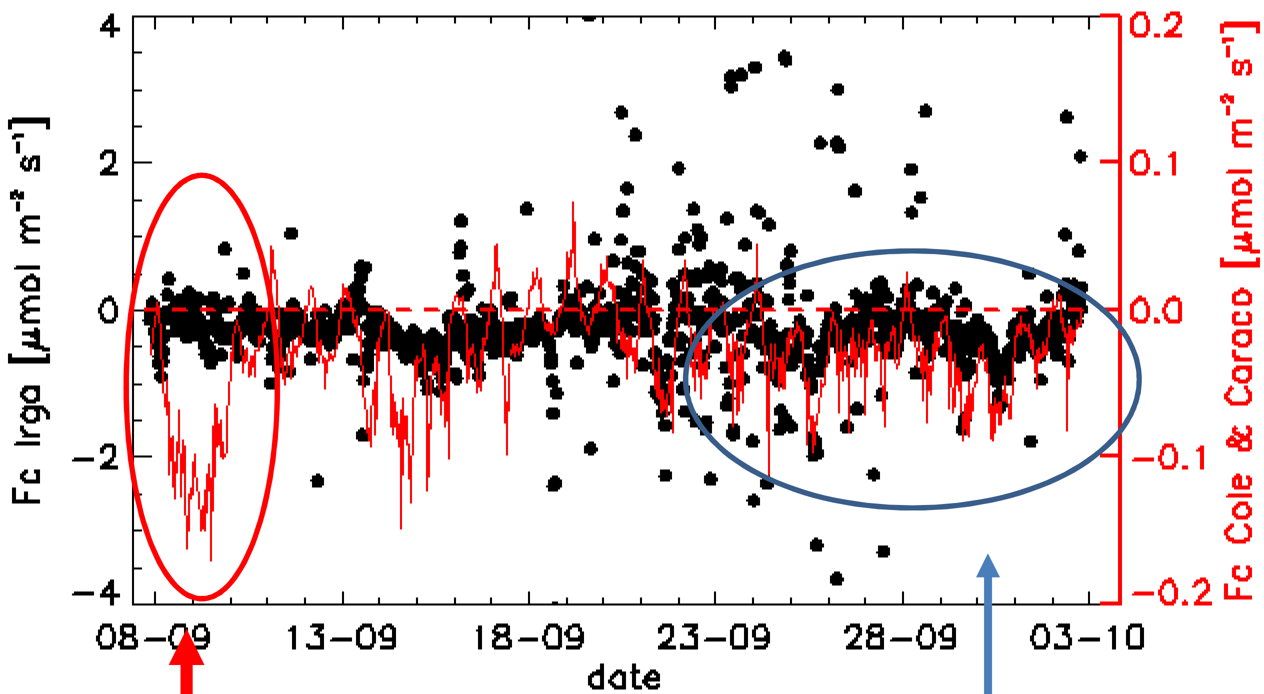
CO_2 Flux IRGASON and Cole and Caraco (Sept/Octb 2017)



Not good matching in the beginning

Better matching in the end. Anyway with ± one order of magnitude lower for Cole and Caraco!!

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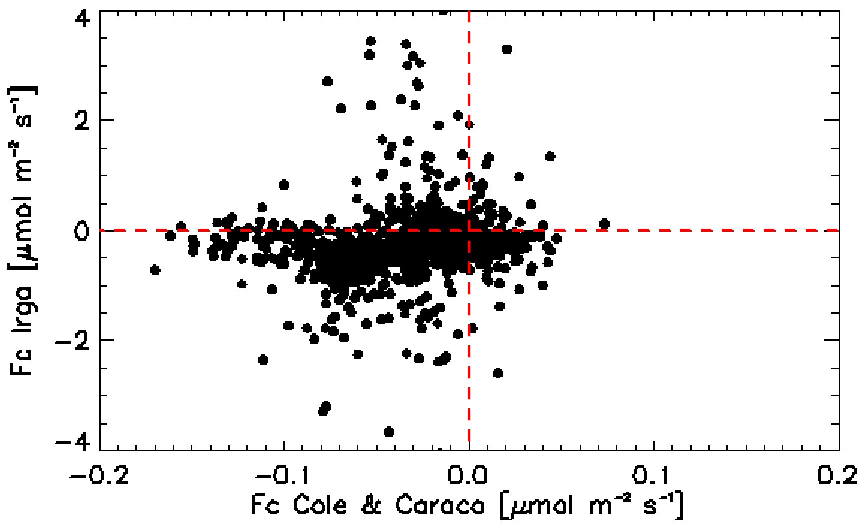
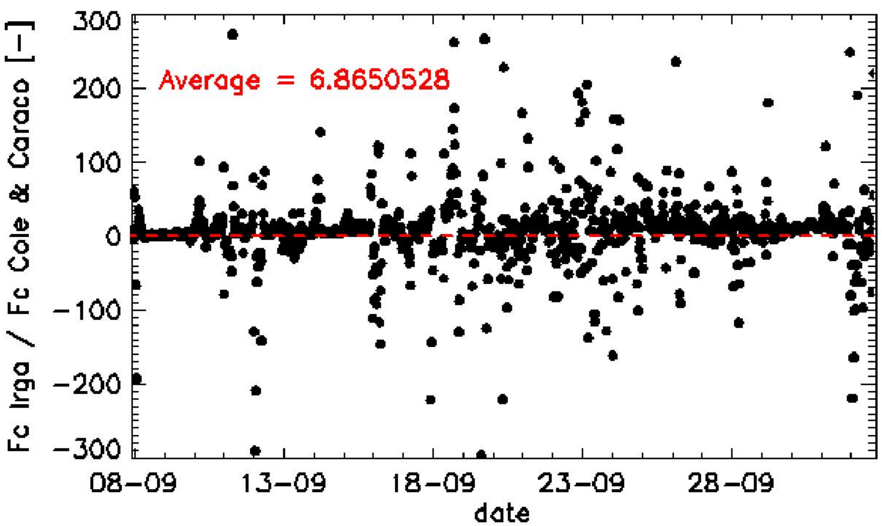
CO_2 Flux IRGASON and Cole and Caraco (Sept/Octb 2017)



R=0.13 !!
Poor correlation !!



The ratio between fluxes shows an average values of 6.86. Can we attribute this values to chemical enhancement factor (α) ? This parameter use to be 1 to acid waters but in Alqueva we have alkaline waters. pH in October, 3 was 8.82.

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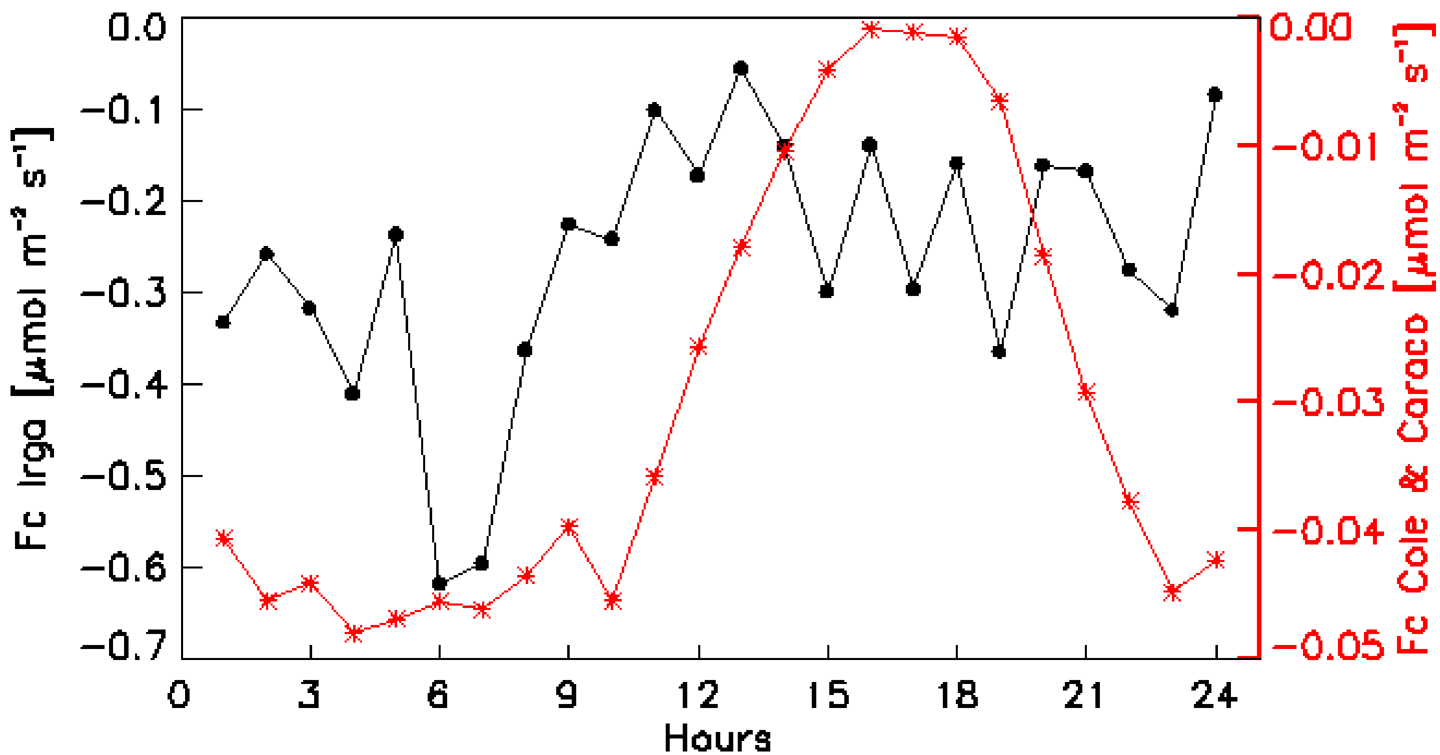
CO_2 Flux IRGASON and Cole and Caraco - daily cycle



Different scales in the Y axis.
In average both fluxes are more negative during nightime and less negative during daytime.

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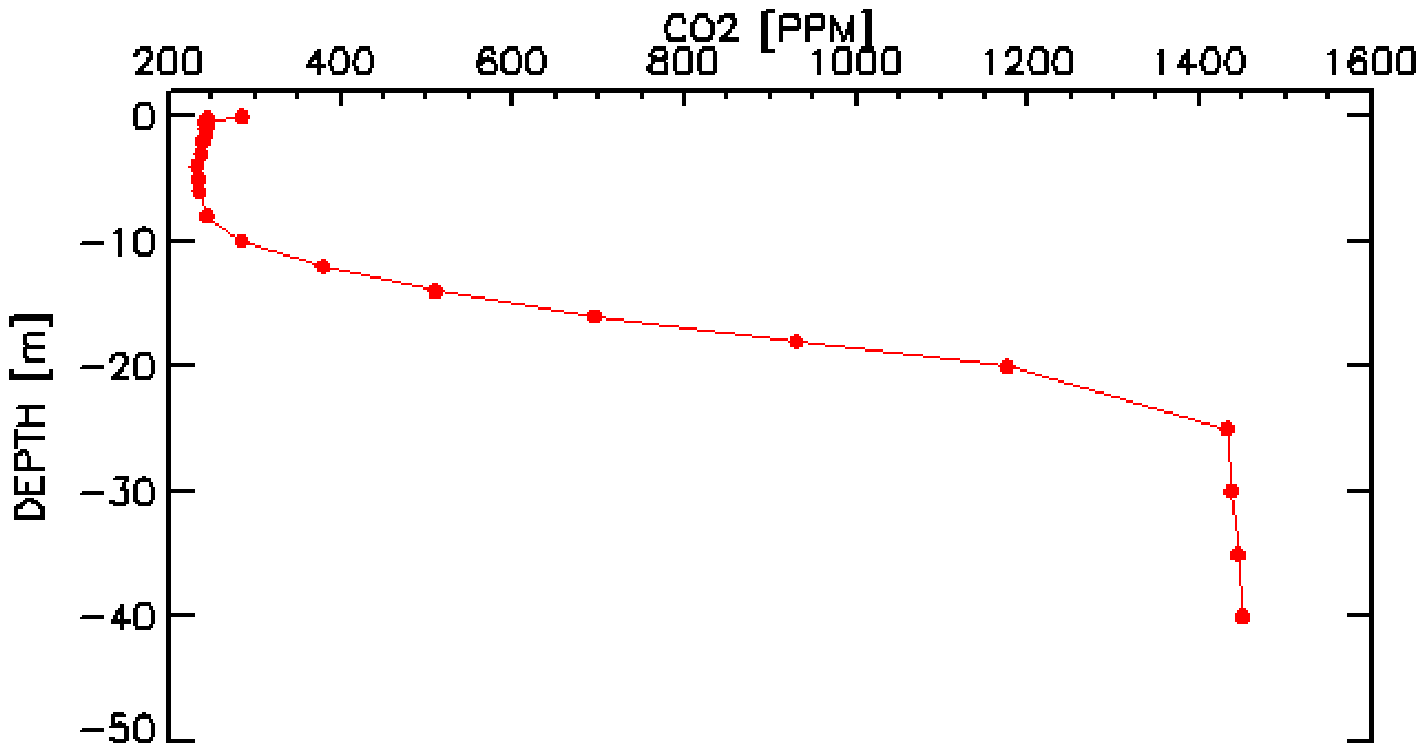
CO_2 concentration profile (03/10/2017 – 11:30 LT)



Profile of dissolved CO_2 concentration in PPM from the surface to 40 m depth. From 5 cm to 25 cm depth we record a decrease of around 40 PPM, then a constant layer until 8 meters with values around 240 PPM, between 8 and 25 meters an increase of around 1200 PPM remaining more or less constant until 40 meters depth with values of 1450 PPM.

Remarks

- Results are coincident from those obtained in 2014
- A new approach for CO_2 flux shows similar behavior but with different magnitude
- We will have results for one full year to obtain information about annual energy and CO2 budget next year.

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Acknowledgments

ALOP
Alentejo Observation and Prediction systems

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Thank you!

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