Impact of the LICOR 7500 Lag Correction on Field Data sampled 2000-2003 at the University of Basel

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6.10.2003 / Rev. 7. 1. 2005

In July 2003 a timing error of the LICOR 7500 Open Path Analyzer was published by LICOR. The error affects the time delay (lag) between the measurement and DAC, SDM and the RS-232 output of the 7500. The new software version 3.0 will fix the problem. However, the already collected data from prior experiments must be corrected. This time delay error results in an underestimation of the flux, the range given by LICOR is 0 to 15%. In this note the effect is evaluated for different field experiments of the University of Basel (EBEX, BUBBLE and WATERUSE 2002 / 2002). During all experiments raw data from the DAC output were collected (see Tab. 1).

Tab. 1: Experiments with open path sensors 7500 involved (prior version 3.0):

Experiment Site Height Surface	Operation Period	7500 Serial No.	Output Delay	Sensor Separation	Analog Input at Sonic	Maximal theoretical input resolution	Range
BUBBLE Basel-Sperrstrasse Level F, 31.7m Urban	June 15 2002 - July 15 2002	75H- 0332	DAC 249.73 (3 Steps)	Horizontal: 0.40m[C] Vertical: 0.10[C] Azimuth: 165° Horizontal: 0.26m[D] Vertical: 0.10m[D]	14 bit 100Hz -5 to +5V (Gill HS)	H_2O: 0.31 mmol m^{-3} CO_2: 0.005 mmol m^{-3}	H_2O: 0-2500 mmol m^{-3} CO_2: 10-50 mmol m^{-3}
BUBBLE Basel-Sperrstrasse Level C, 14.7m Urban	June 25 2002 - July 13 2002	75H- 0254	DAC RS232 249.73 (3 Steps)	Horizontal: 0.24 Azimuth: 7°	11 bit 10 Hz 0 to +5V (Gill R2)	H_2O: 1.22[A] / 0.51[B] mmol m^{-3} CO_2: 0.01 mmol m^{-3}	H_2O: 0-2500 [A] / 200-1250 [B] mmol m^{-3} CO_2: 10-30 mmol m^{-3}
WATERUSE Rio Frio 20.64m Cork Oak Plantation	July 25, 2002 - August 8, 2002	?	DAC 249.73 (3 Steps)	Horizontal: 0.41m Azimuth: 135°	14 bit 100Hz -5 to +5V (Gill HS)	H_2O: 0.003 g m^{-3} CO_2: 0.0012 mmol m^{-3}	H_2O: 0-27 g m^{-3} CO_2: 10-20 mmol m^{-3}
WATERUSE Canosa di Puglia 12.15m Olive Trees	July 2, 2003 July 13, 2003	?	DAC 249.73 (3 Steps)	Horizontal: 0.43m Azimuth: 155°	14 bit 100Hz -5 to +5V (Gill HS)	H_2O: 0.18 mmol m-3 CO_2: 0.0012 mmol m^{-3}	H_2O: 0-1500 mmol m^{-3} CO_2: 10-20 mmol m^{-3}
EBEX Kettleman City B2 2.4m Cotton Field	August 1, 2000 August 18 2002	TU Dresden	DAC 249.73 (3 Steps)	Horizontal: 0.25m Azimuth: 120°	METEK USA-1	Various settings	Various settings

[A] Settings before June 26, 2002, 08:35, [B] Settings after June 26, 08:35.[C] before July 5 2002 09:30 [D] after July 5 2002, 10:15 all times CET

The electronic lag L_E between the measurement and the DAC output in versions prior to 3.0 was supposed to be 230 msec plus an increment of 6.579 msec that could be specified by the user. In all experiments 3 additional increments were set resulting in totally 249.73 msec (an offset of 5 records to the sonic at 20Hz). According to LICOR, a “corrected real electronic lag” cannot be given as a constant for all LICOR 7500 for software versions prior to 3.0. The base delay is estimated for the DAC to be within 138 and 197 msec with a mean of 168 ± 30 msec. The increments are 4.5 msec. They suggest that "customers who have collected raw time series data may be able correct for these various delays by doing a cross correlation of CO_2 flux vs. time delay".

This maximizing of the correlation in dependence of a lag was applied for all data during the experiments. A program was written to perform this automatically. The program returns the time lag of the maximal cross correlation within a frame of ±1000 msec. The cross correlation function C(L) is tested to show no other major local maximums nor minimums in the range ±1000 msec. A sample of an ideal C(L) is given in Fig. 1.

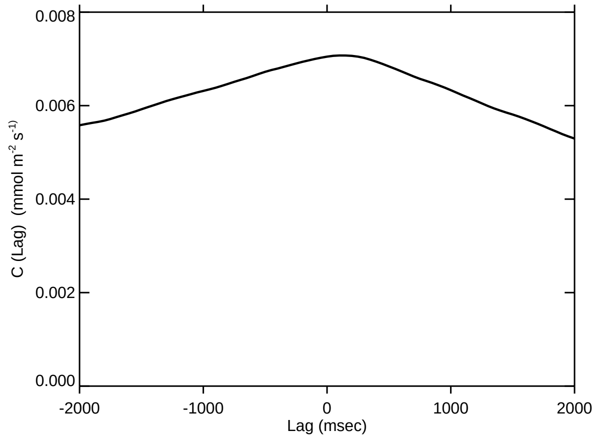

Fig. 1: Covariance in function of lag for a sample run at Basel-Sperrstrasse 31.5m during BUBBLE.

Based on this analysis, the following covariances are calculated and compared:

$\overline{w'c'}_{old}$	The covariance calculated for the (wrong) lag of **249.73 msec (**fix offset of 5 records at 20 Hz for all runs)
$\overline{w'c'}_{new}$	The covariance calculated for the new lag specified in the LICOR note on the error of 167 msec + 4.5 msec per increment resulting in a total of **170.5 msec (**fix offset of 3 records at 20 Hz for all runs).
$\overline{w'c'}_{indivlag}$	The covariance calculated for the lag with **maximal correlation** L_T (variable for each run).
$\overline{w'c'}_{meanlag}$	The covariance calculated for the **mean** value of the lag with **maximal correlation** taking into account the effects of wind direction, so that only the electronic lag L_E is taken into account (variable for each experiment).

The total lag L_T at maximal covariance shows a high depedence on wind direction (and also wind velocity), an effect of the sensor separation (Fig. 2). The influence of the sensor separation (i.e. the time needed for an air parcel to travel from the sonic to the LICOR 7500) is dominating over he effect of the electronic lag L_E, making it difficult to separate the electronic lag:

total lag (L_T) = electronic lag (L_E) + sensor separation effect (s/u_a)

s is the sensor separation (in m) and u_a the wind component in the axis sonic-LICOR (in m s^{-1})

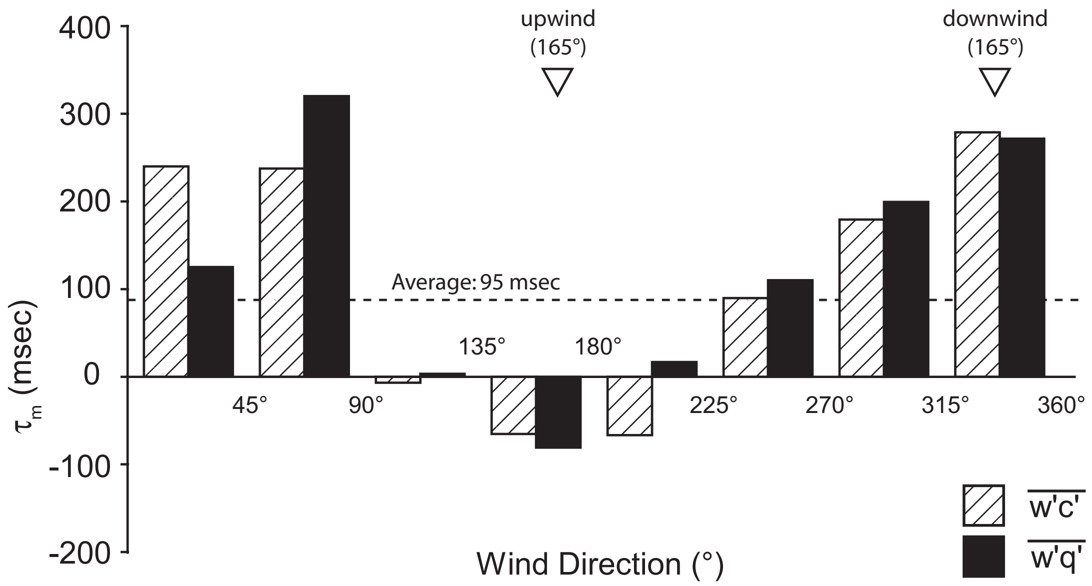

Fig. 1: Total lag L_T between *w'* and *c'* and *w'* and *q'* from the 7500 in dependence of wind direction at Basel-Sperrstrasse 31.7m (Period: June 15 to July 5, 2002).

To separate the electronic lag L_E (which is of interest) from the effects of the sensor separation, two methods were applied:

1. **Equalization Method:** Here, for each experiment, data are classified into the 8 wind direction classes according Fig. 2. An average lag was determined by averaging all 8 class averages. By this "equalized weighting" of all wind directions, the sensor separation effect will be counterbalanced by opposite wind direction classes. This method does not take into account the wind velocity.

2. **Regression-Method:** Since the sensor separation s and the position of instruments are known, the travelling time (s/u_a) for an air parcel between the sonic and the LICOR can be calculated easily from wind direction and wind velocity. By applying a linear regression between travelling time and total lag L_T the offset a_0 of the regression $L_T = a_1 (s/u_a) + a_0$ (i.e. for a travelling time of 0 sec) returns the electronic lag L_E. And a_1 should be around 1.

Tab. 2: Lag determined for all experiments with different methods.

Experiment Instrument / Height	Time Period	Recalculated Electronic Time Lag (msec)				Propsed Shift in Records
		CO_2 Equalization-Method	H_2O Equalization-Method	CO_2 Regression-Method	H_2O Regression-Method	
BUBBLE Basel-Sperrstrasse Level F 31.7m	June 15, 2002 - July 5, 2002, 08:00	97 msec	95 msec	95 msec	131 msec	**2** (100 msec)
	July 5, 2002, 10:00 - July 15, 2002	102 msec	97 msec	119 msec	110 msec	**2** (100 msec)
BUBBLE Basel-Sperrstrasse Level C 14.7m	June 25, 2002 - July 13, 2002	410 msec	234 msec	397 msec	212 msec	**7** (336 msec)
WATERUSE Canosa di Puglia Level T7 12.15m	July 25, 2002 - August 8, 2002	159 msec	154 msec	142 msec	147 msec	**3** (150 msec)
WATERUSE Rio Frio Tower Level T9 20.64m	July 2, 2003 - July 13, 2003	290 msec (1)	278 msec (1)	279 msec	232 msec	**5** (250 msec)
EBEX Kettleman City Tower B2 2.4m	August 5, 2000 - Ausgust 18, 2000	234 msec (1)	236 msec (1)	230 msec	230 msec	**5** (250 msec)

(1) not all wind direction classes are present for averaging.

Summary: The effects of correcting the raw data for the "7500 error" are fairly small for all experiments of the University of Basel (between 0 and 3% of the fluxes, see Tab. 3), effects of the roughness and the measurement heights. In general, the corrections are higher with instruments mounted closer roughness elements. In some cases (EBEX) the new fixed offset $\overline{w'c'}_{new}$ even lowers the flux (probably an effect of internal delays of the analog inputs of the METEK and the R2). It is suggested to use either the existing calculations or if recalculation is done, the values in the last row of Tab. 2 for the offset.

Tab. 3: Effects of the different lags on kinematic fluxes of CO_2 and H_2O (in %)

Experiment Instrument / Height	Time Period	$\frac{\overline{w'c'}_{new}}{\overline{w'c'}_{old}}$	$\frac{\overline{w'c'}_{indivlag}}{\overline{w'c'}_{old}}$	$\frac{\overline{w'c'}_{meanlag}}{\overline{w'c'}_{old}}$	$\frac{\overline{w'q'}_{new}}{\overline{w'q'}_{old}}$	$\frac{\overline{w'q'}_{indivlag}}{\overline{w'q'}_{old}}$	$\frac{\overline{w'q'}_{meanlag}}{\overline{w'q'}_{old}}$
BUBBLE Basel-Sperrstrasse Level F 31.7m	June 15, 2002 - July 5, 2002, 08:00	+0.36%	+0.89%	+0.36%	+0.29%	+0.79%	+0.20%
	July 5, 2002, 10:00 - July 15, 2002	+0.37%	+0.86%	+0.37%	+0.34%	+0.85%	+0.30%
BUBBLE Basel-Sperrstrasse Level C 14.7m	June 25, 2002 - July 13, 2002	-1.33%	+1.44%	+0.71%	-0.13%	+1.28%	-0.46%
WATERUSE Canosa di Puglia Level T7 12.15m	July 25, 2002 - August 8, 2002	+1.38%	+2.77%	+1.38%	+1.16%	+2.35%	+1.16%
WATERUSE Rio Frio Tower Level T9 20.64m	July 2, 2003 - July 13, 2003	-1.49%	+0.53%	+0.00%	-0.50%	+0.02%	+0.00%
EBEX Kettleman City B2 2.4m	August 5, 2000 - Ausgust 18, 2000	-2.09%	+0.29%	+0.00%	-1.72%	+0.30%	+0.00%

$|w'c'| > 0.002$ mmol m^2 s^{-1}, $|w'q'| > 0.01$ mmol m^2 s^{-1}