

# Recent problems of turbulence sensors

Matthias Mauder, Spoleto, Jan. 18<sup>th</sup> 2004



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2nd QA/QC Workshop for Eddy Covariance Measurements  
Spoleto, Italy  
Jan. 18 -19, 2004



# Outline

- Cross wind correction of sonic temperature
- Timing error of LiCor 7500
- Iteration of corrections
- $u^*$ -correction and rotation



# Cross wind correction of sonic temperature

## Cross wind correction after

- Liu et al. 2001: New equations for sonic anemometer temperature variance and buoyancy heat flux with an omnidirectional sonic anemometer, BLM 100

$$\sigma_{T_c}^2 = \sigma_{T_s}^2 - 1.02\overline{Tq'T'} - 0.51^2\overline{q'^2\bar{T}^2}$$

$$- \frac{4\bar{T}^2}{(c^2)^2} (\overline{u'^2\bar{u}^2} A^2 + \overline{v'^2\bar{v}^2} B^2 + 2\overline{u'v'\bar{u}\bar{v}} AB)$$

$$+ \frac{4\bar{T}}{c^2} (\overline{u'T'\bar{u}} A + \overline{v'T'\bar{v}} B)$$

$$+ \frac{2.04\bar{T}^2}{c^2} (\overline{u'q'\bar{u}} A + \overline{v'q'\bar{v}} B)$$

Factors	CSAT3	USA-1	Solent R3, R3A, HS	Solent R2
A	7/8	3/4	$1 - 1/2 \cdot \cos^2 \varphi$	1/2
B	7/8	3/4	$1 - 1/2 \cdot \cos^2 \varphi$	1

$$(\overline{w'T'_c}) = \overline{w'T'_s} - 0.51\overline{w'q'\bar{T}} + \frac{2\bar{T}}{c^2} (\overline{w'u'\bar{u}} A + \overline{w'v'\bar{v}} B).$$



# Cross wind correction of sonic temperature

## Cross wind correction after Liu et al. 2001

**must be applied for:**

**Gill Solent R2, METEK USA-1 if covariance calculated from high frequency raw data or use of “zTcov”**

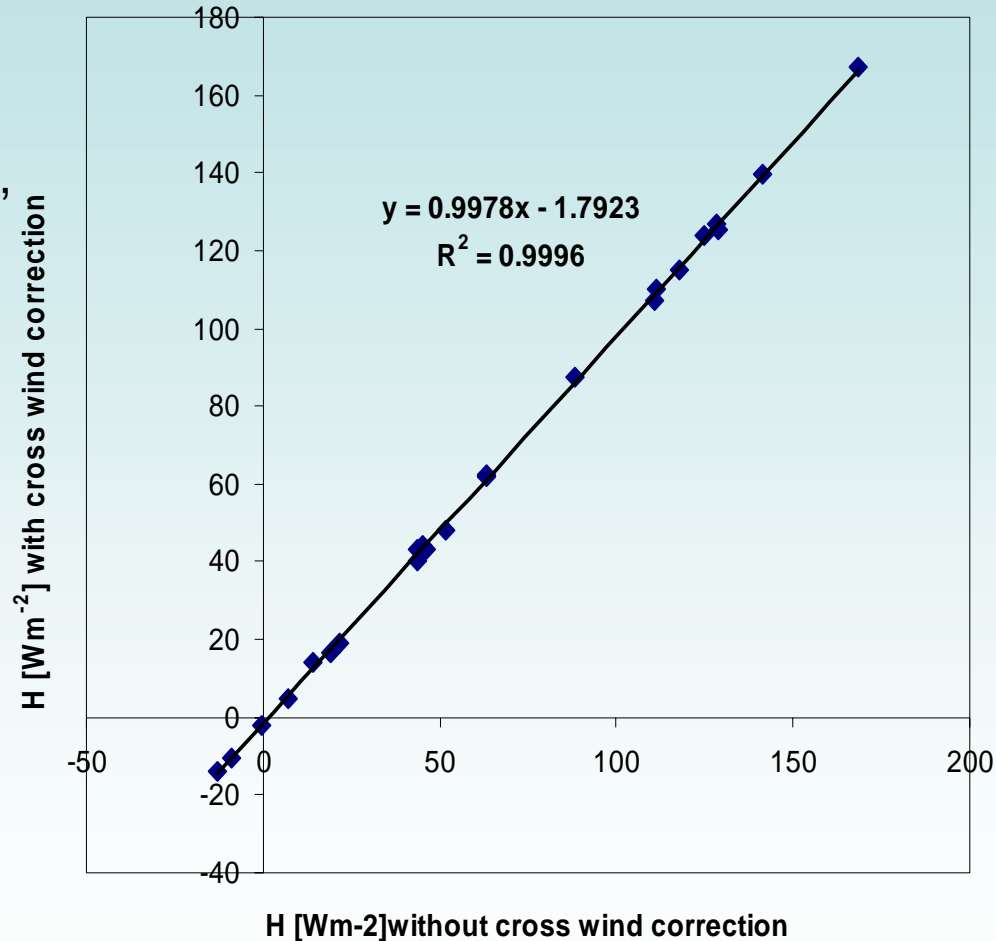
**is already included (redundant):**

**Campbell CSAT3, Gill Solent HS and R3, Young 81000, and METEK USA-1 if use of flux “hf”**



# Cross wind correction of sonic temperature

LITFASS-2003,  
26.05.2003



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# Timing error of LiCor 7500

July 2003: Li-Cor Inc. informs customers about timing error of Li-7500 CO<sub>2</sub>/H<sub>2</sub>O Gas Analyzer.

Software Release	Delay Time (ms)	Delay Step (ms)	Delay Step Increment	Total Delay (ms)
Published	230	6.579	11	302
Actual DAC (2.0.4)	138 - 197 (mean 167 ± 30)	4.5	11	188 - 247 (mean 217 ± 30)
Actual RS-232, SDM (2.0.4)	88 - 147 (mean 117 ± 30)	4.5	11	138 - 197 (mean 167 ± 30)



# Timing error of LiCor 7500

Example: LITFASS-2003 near Lindenberg/Germany 29.05.2003  
measuring height = 2.39 m, canopy: corn, sampling 20Hz

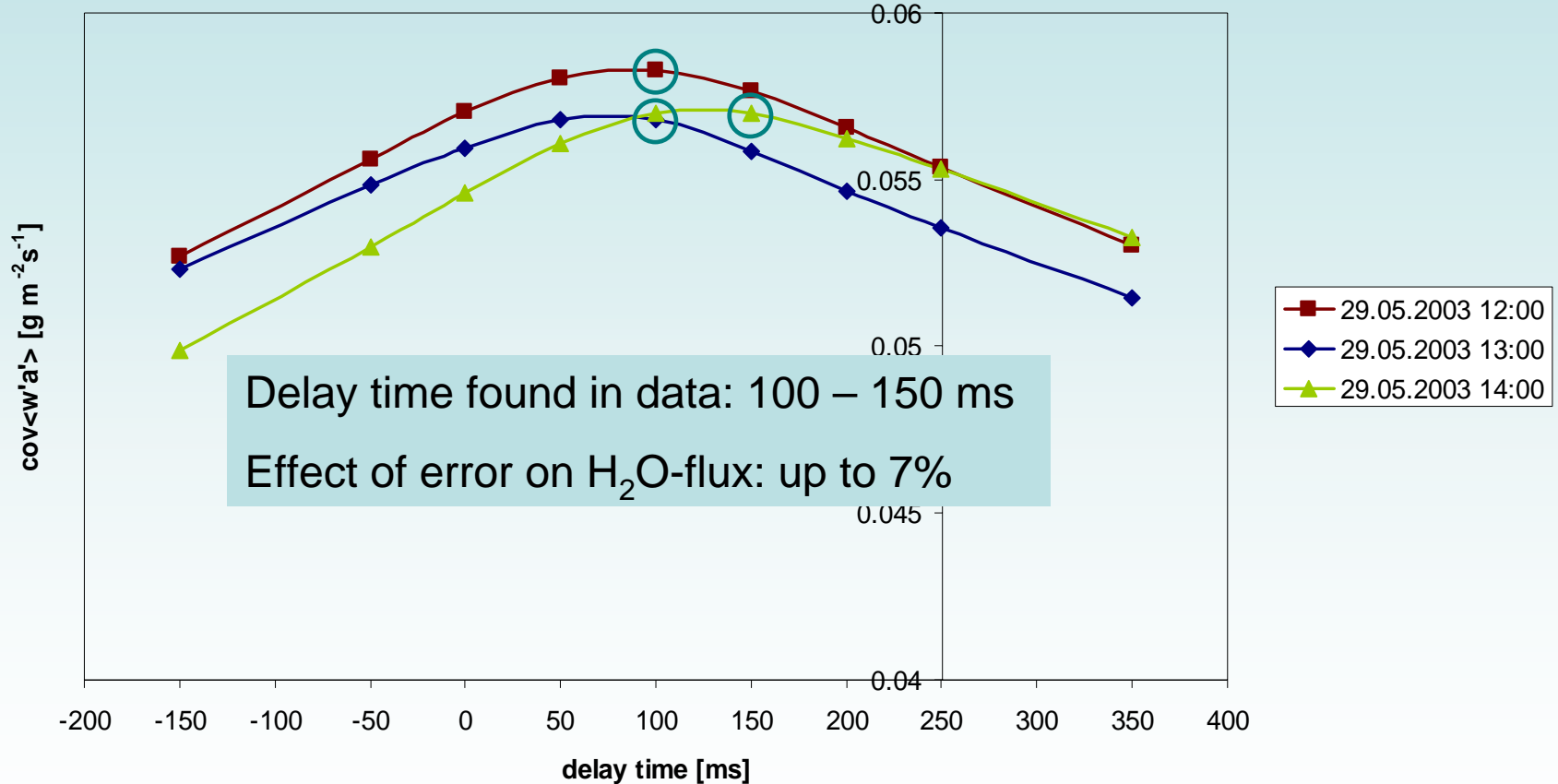
Our settings:

Software Release	Delay Time (ms)	Delay Step (ms)	Delay Step Increment	Total Delay (ms)
Published	230	6.579	3	250
Actual DAC (2.0.4)	138-197	4.5	3	152-211



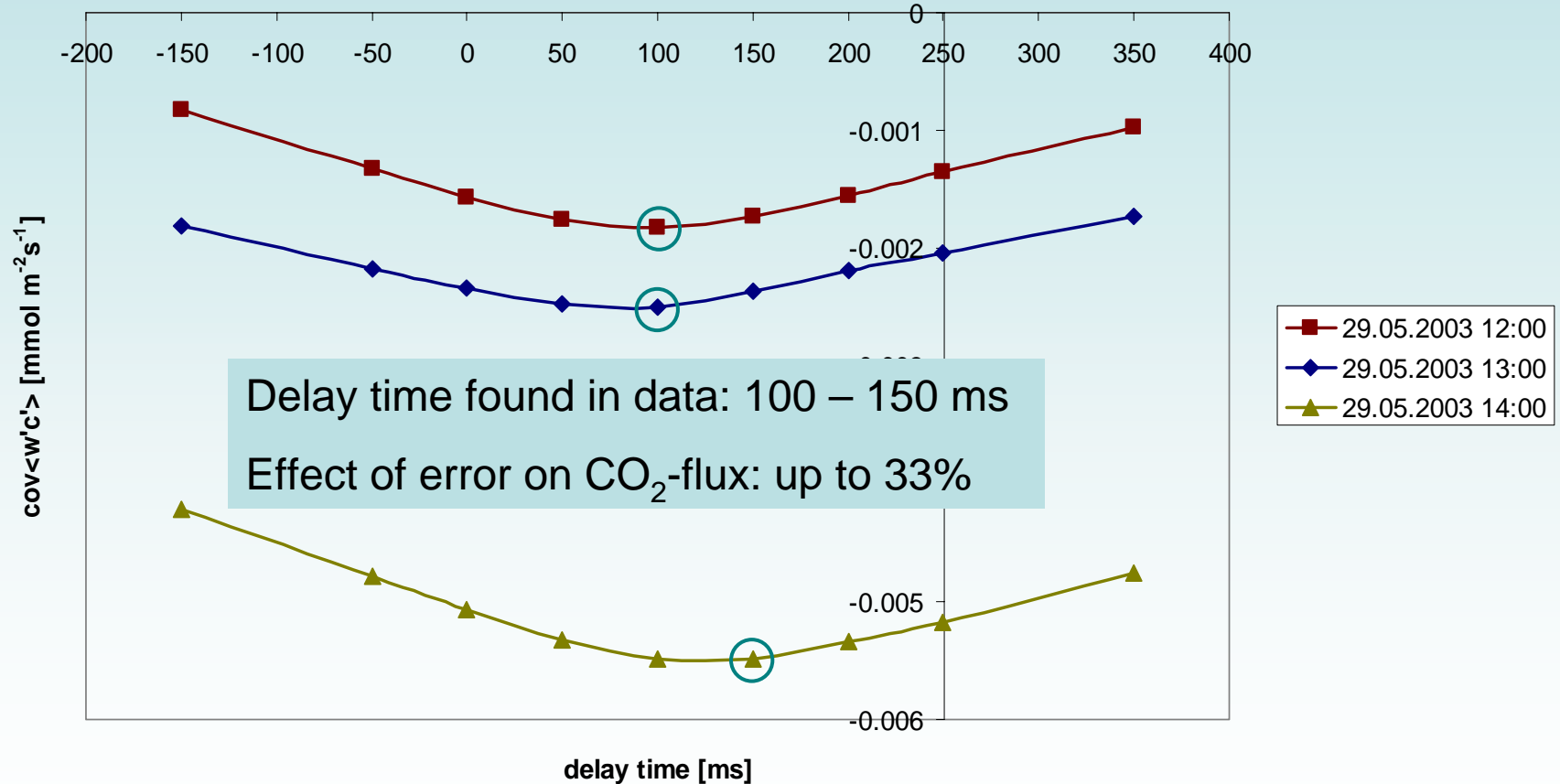
# Timing error of LiCor 7500

Example: LITFASS-2003 near Lindenberg/Germany 29.05.2003  
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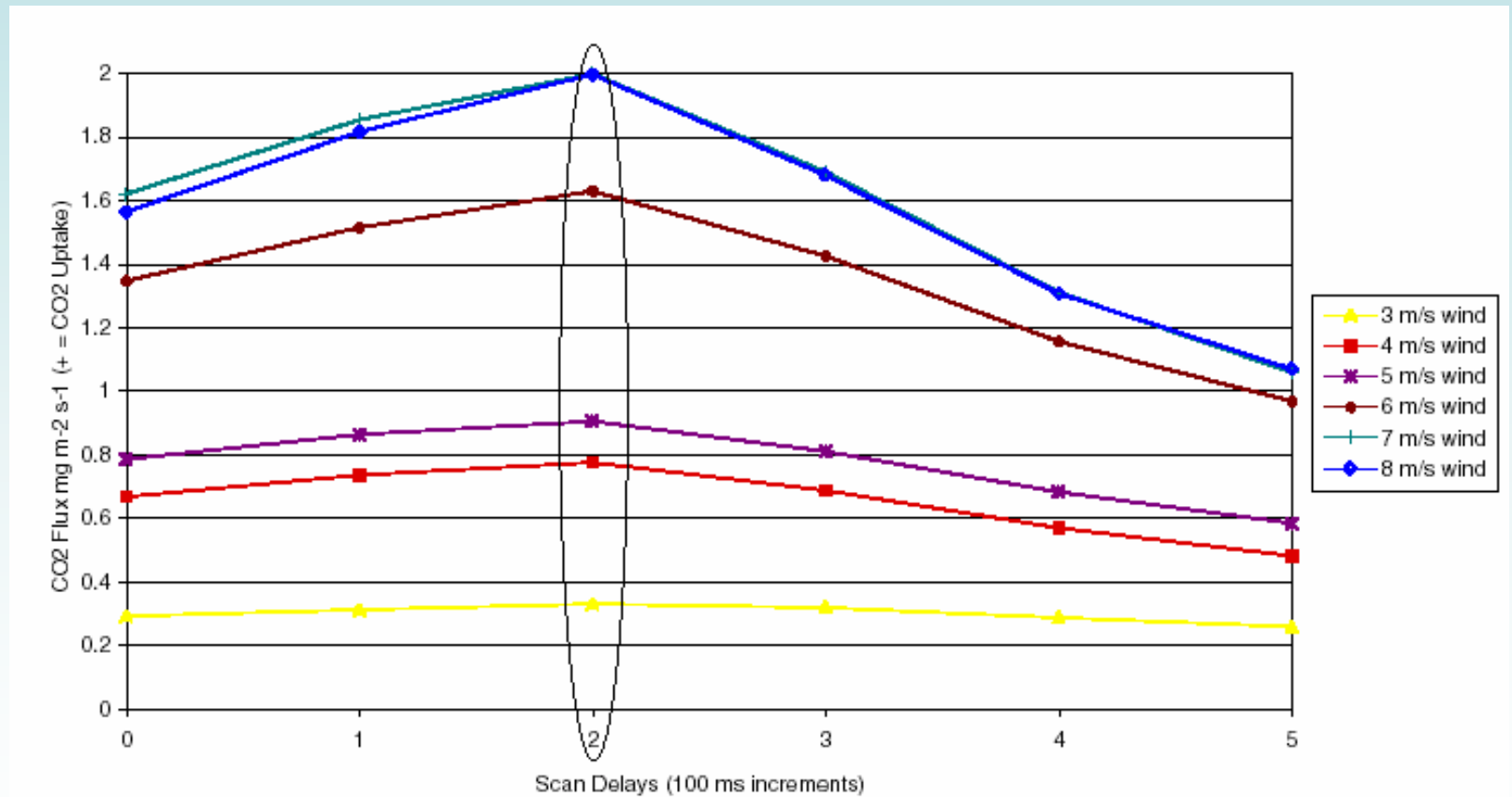
# Timing error of LiCor 7500

Example: LITFASS-2003 near Lindenberg/Germany 29.05.2003  
measuring height = 2.39 m, canopy: corn, sampling 20Hz



# Timing error of LiCor 7500

Error increases with wind speed.



# Timing error of LiCor 7500

Timing problem fixed with embedded software version 3.0.0

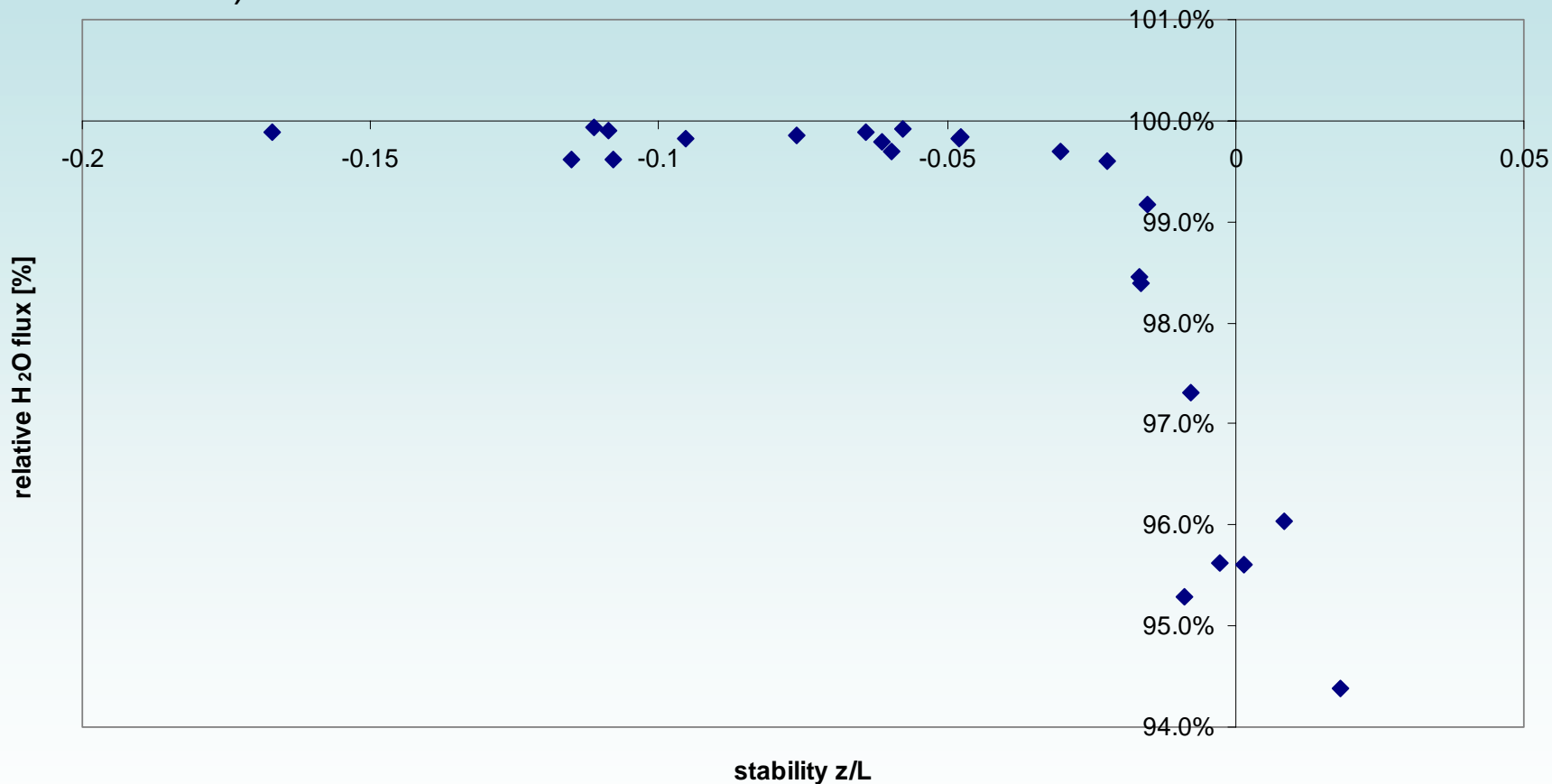
Software Release	Delay Time (ms)	Delay Step (ms)	Delay Step Increment	Total Delay (ms)
DAC (3.0.0)	240	6.5	9	299
SDM, RS-232 (3.0.0)	186	6.5	17	297

**Alternative: automatic determination of delay by cross correlation analysis**



# Correction for spatial separation

Effect of correction for longitudinal separation of sensors (LITFASS-2003, 26.05.2003)



# Iteration of corrections

High frequency data [10 – 20Hz]

Calculation of averages, variances and covariances for 30min intervals excluding physically not possible values and spikes

- coordinate rotation after Planar Fit method (*Wilczak et al. 2001*)
- correction of oxygen cross sensitivity for Krypton hygrometers (*Tanner 1993*)
- correction of spectral loss due to path length averaging, spatial separation of sensors and frequency dynamic effect of signals (*Moore 1986*)
- conversion of sonic temperature fluctuations into fluctuations of actual temperature for calculation of the sensible heat flux (*Schotanus et al., 1983, Liu et al. 2001*)
- correction for density fluctuations to determine fluxes of scalar quantities H<sub>2</sub>O und CO<sub>2</sub> (*Webb et al. 1980, Liebethal and Foken 2003*)

Iteration of the corrections until error < 0,01%

Post-field quality control (*Foken et al. 2003*)

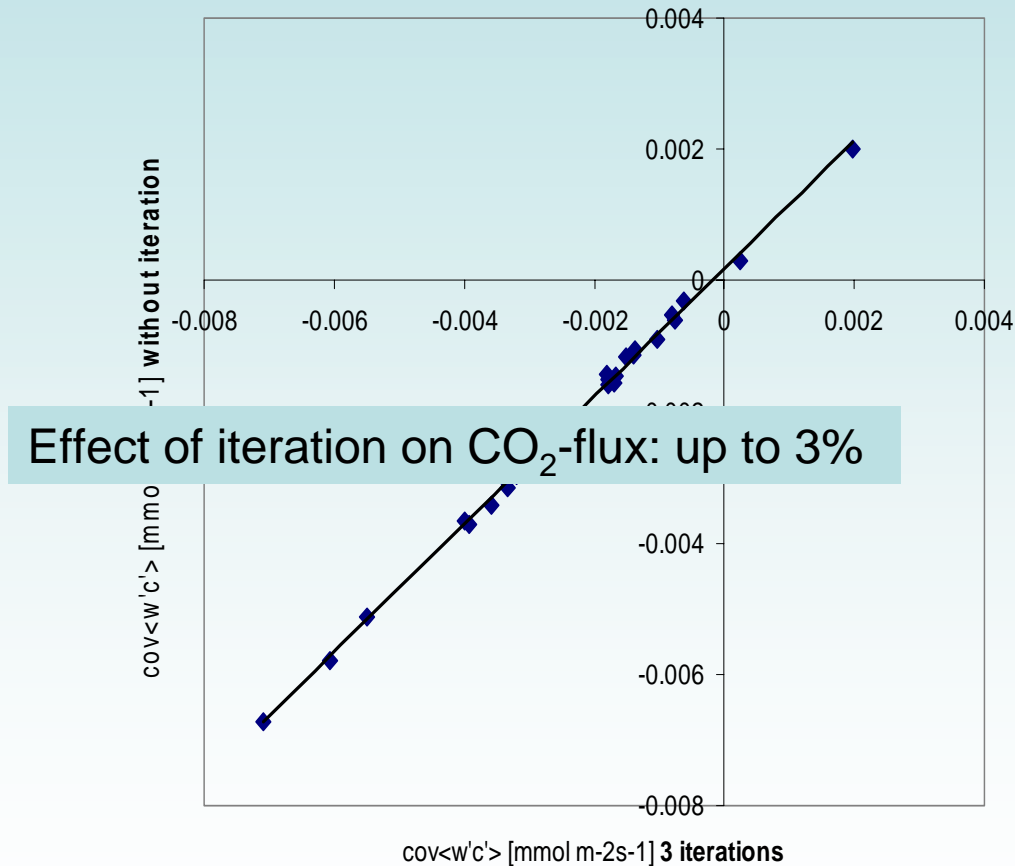
- Test for steady state conditions (*Foken und Wichura 1996*)
- Test for integral turbulence characteristics (*Foken und Wichura 1996*)

Corrected and quality assured results of turbulent fluxes

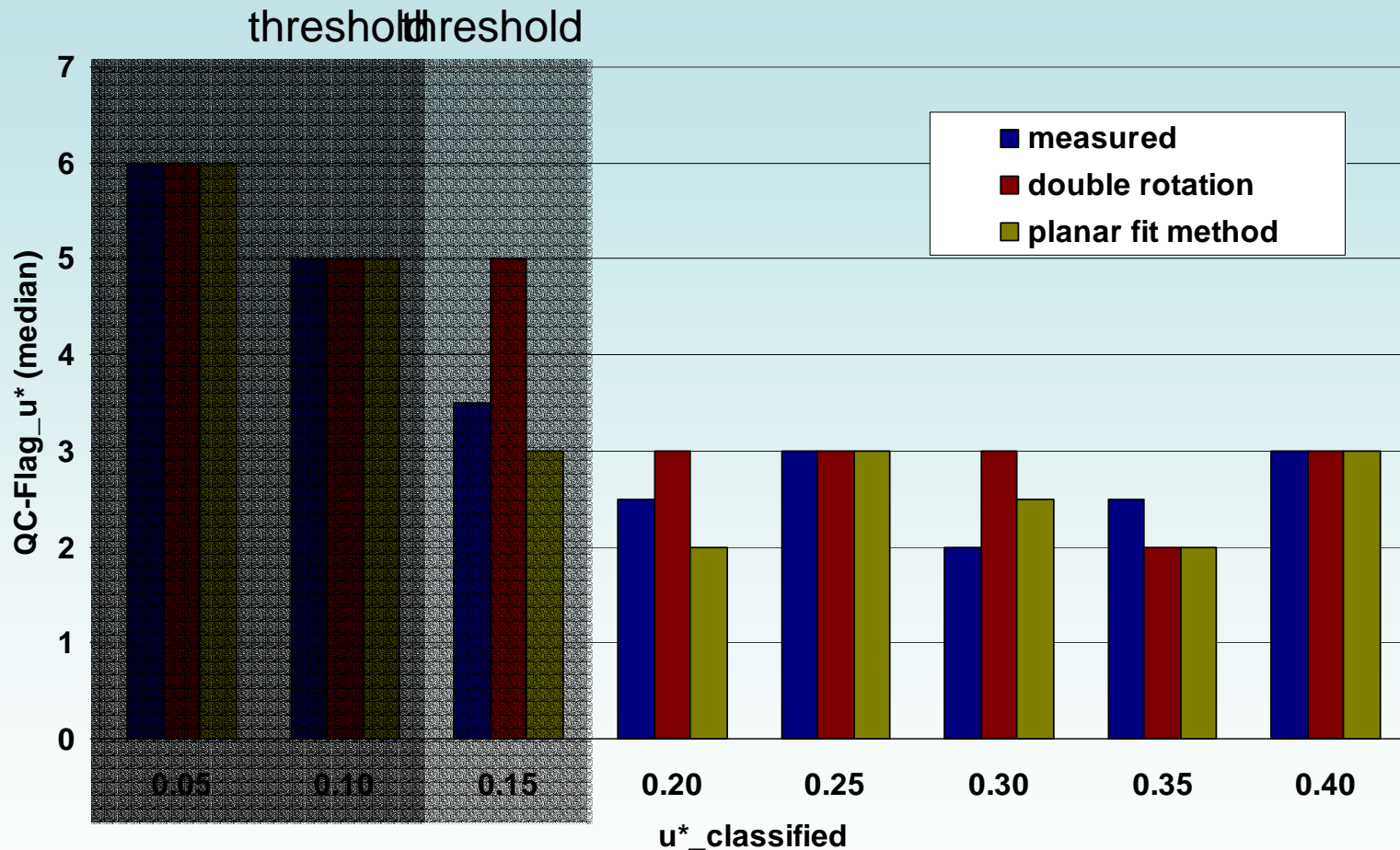


# Iteration of corrections

Example: LITFASS-2003 near Lindenberg/Germany 29.05.2003  
measuring height = 2.39 m, canopy: corn, sampling 20Hz



# $u^*$ -correction and rotations



Data from CSAT3 (UBT) during the EBEX-2000 intercomparison period



# Conclusion

**There are a lot of issues in the Eddy Covariance method which you have to be aware of!**

- Cross wind correction of sonic temperature
- Timing error of LiCor 7500
- Iteration of corrections
- $u^*$ -correction and rotation
- ...more

