On the need for uncertainty assessment of long-term eddy-covariance measurements

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Introduction

Eddy-covariance measurements are performed at several hundred sites all over the world on a long-term basis. The increasing demand on standardised and comprehensive quality flagging and uncertainty quantification of these fluxes has led to this review of established quality assessment procedures and the development of a strategy, focusing on automatically applicable tests on high-frequency data, expanding existing tests on statistics, fluxes and corrections, plus quantification of errors which will be used within the Helmholtz-project TERENO.

Data sets

Site name	Operator	Ecosystem	Coordinates	Measurement height	Canopy height	Sensor combination	Data period
Fendt	KIT	grassland, pre-alpine valley	47°49'59"N, 11°03'40"E, 600 m a.s.l.	3.5 m a.g.l.	0.25 m	CSAT3/ LI-7500	25/07/2010–23/08/2010
Graswang	KIT	grassland, pre-alpine valley	47°34'15"N, 11°01'58"E, 865 m a.s.l.	3.5 m a.g.l.	0.25 m	CSAT3/ LI-7500	25/07/2010–23/08/2010
Lackenberg	KIT	wind throw, low mountain range	49°05'59"N 13°18'17"E 1308 m a.s.l.	9.0 m a.g.l.	2.0 m	CSAT3/ LI-7500	25/07/2010–23/08/2010
Selhausen	FZJ	agricultural land, sugar beet, flat	50°52'14"N, 6°26'58"E, 103 m a.s.l.	2.5 m a.g.l.	0.45 m	CSAT3/LI -7500	01/06/2011–30/06/2011
Wetzstein	MPI-BGC	spruce forest, low mountain range	50°27'13"N, 11°27'27"E, 785 m a.s.l.	30 m a.g.l.	20 m	Solent-R3/ LI-6262	15/07/2006–13/08/2006

Table 1

Tests on high-frequency data

- **usage of internal quality tests** and diagnostic flags (e.g. Campbell CSAT3, Li-Cor LI-7500).
- **spike test** based on Median Absolute Deviation (MAD) for outlier or spike detection
- screening of the high-frequency data for **instrumental plausibility**

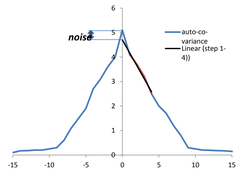
Tests on statistics

assumptions of the EC method (simplified flagging after FW96):

- **stationarity** of the covariances
- **ITC**: well-developed turbulence
- zero mean **vertical wind velocity**
- **Inter-dependence** of flux conversions and corrections on fluxes

Errors and uncertainty

- **instrumental noise**
  only present in first term of
  auto-covariance function → error propagation



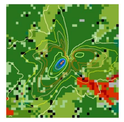
- **random error**
  ~ 1 / √ # **independent** observations, Finkelstein & Sims (2001):
  the statistical variance of a covariance is expressed as function of its **auto-covariances and cross-covariance**
  → **detrending** through high-pass filter **before**

- **systematic error**
  the total surface flux is not represented by the covariance in the presence of large eddies;
  indirect error definition via energy balance ratio:

$$\sigma_F^{sys} = F \cdot \left(\frac{1}{EBR} - 1 \right) \text{ for } R_g > 20 \text{ W m}^{-2}$$

$$\sigma_F^{sys} = n/a \qquad \text{for } R_g \leq 20 \text{ W m}^{-2}$$

- **source area – representativeness**
  application of footprint model (Kormann & Meixner, 2001) on each averaging interval



Results

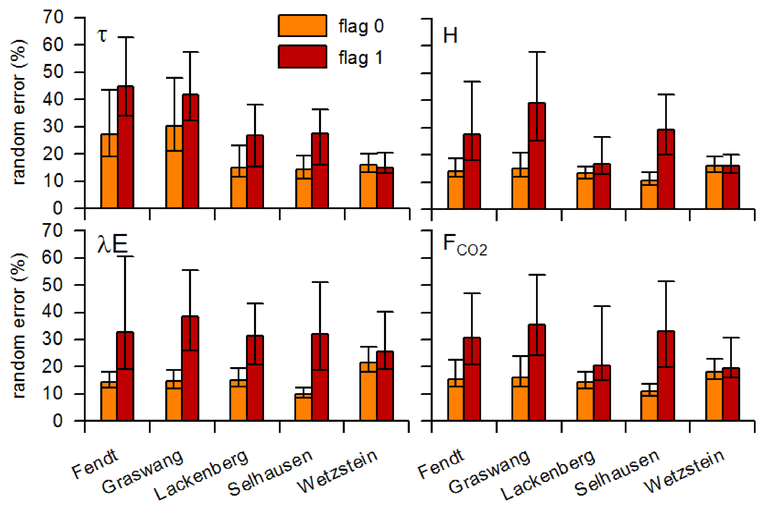


Figure 1: Relative random flux error (%) for the investigated fluxes (median, lower and upper quartiles) as a function of their quality flags (orange: highest quality= flag 0, red: medium quality=flag1).

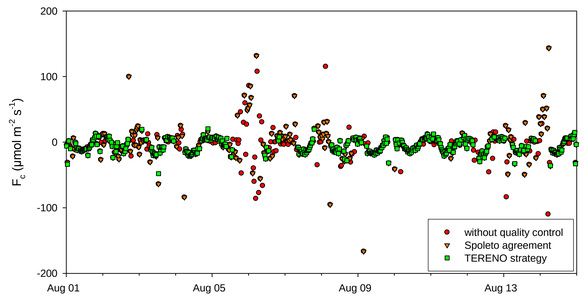


Figure 2: CO_2-fluxes for Graswang: without quality control (red circles), flagging according to FW96/Spoleto (orange triangles), filtering according to TERENO quality assessment scheme (green squares)

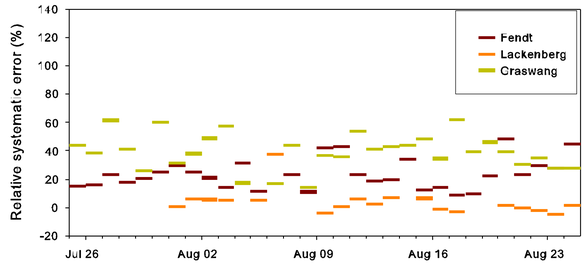


Figure 3: Relative systematic errors (%) for three test data sets determined from the energy balance ratio

	Fendt	Graswang	Lackenberg	Selhausen	Wetzstein
τ	1/1277	5/1348	0/1044	1/1383	2/1395
H	1/916	7/1121	21/882	9/1262	19/1153
λE	2/820	5/850	7/762	13/1127	18/1059
F_c	3/757	9/888	8/765	7/1113	2/1064

Table 2: Results of the MAD-based outlier test (Papale et al. 2006) after application of the proposed flagging scheme: (number of detected values by the Papale et al. (2006) procedure / number of available data with flag 0 and 1.
1440 data records were tested for each site.

Conclusions

- noise errors typically ≤1%
- random errors 20-30%
- highest data quality associated with smallest random errors
- systematic errors: existence known, but difficult to quantify

Combination of diagnostic flags, robust spike detection, interdependence of fluxes, and footprint analysis improved the quality assessment strategy compared to established ones.

Publication: Mauder, M., M. Cuntz, C. Drüe, A. Graf, C. Rebmann, H. P. Schmid, M. Schmidt, R. Steinbrecher. *A strategy for quality and uncertainty assessment of long-term eddy-covariance measurements.* AFM,Vol. 169, 2013, pp. 122-135.