Geophysical Research Abstracts
Vol. 19, EGU2017-17970, 2017
EGU General Assembly 2017

A Strategy to Estimate the Systematic Uncertainty of Eddy Covariance Fluxes due to the Post-field Raw Data Processing

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Among several sources of uncertainty characterising the fluxes of atmospheric constituents to and from a given ecosystem calculated using the eddy covariance (EC) methodology, the systematic error due to the corrections applied in the post-field raw data processing is still relatively unknown. We performed an extensive analysis aiming at quantifying this portion of the uncertainty for the CO_2 exchange, and at defining a strategy of processing to be generically applied as to understand this uncertainty. We selected 11 years of raw EC data from 9 stations all over the Europe, corresponding to 4 different setups. Then we chose 2 or 3 possible valid options for each of the 8 most relevant corrections to be applied to the raw data, and produced as many outputs (1-year-long calculated hourly and half-hourly fluxes) as the combinations of all the different options (full-factorial design). Statistical analysis was used to quantify and characterise the uncertainty (n-way ANOVA) both on the (half-)hourly and the yearly cumulative fluxes. Factorial design of Experiment (DOE) was used to select a relatively small sub-group of combinations of processing options (fractional factorial design) to be applied to a given dataset in order to quantify the processing uncertainty, with a limited loss of information as compared to the full factorial. Our results show that: (i) the variability as expressed by the inter-quartile range (IQR) of the cumulate CO_2 flux is between 50 and 400 gC m-2 year-1. (ii) The importance of the single corrections (factors) in terms of variance explained is not constant among datasets, but a general trend is found such that the coordinate rotation (CR) and the trend removal (TR) have often a high weight on the overall uncertainty (i.e. between 10% and 50%), while the importance of the time-lag compensation (TL) is highly variable. (iii) 2x2 interactions between factors have some importance, mostly between the most relevant ones. (iv) The percentage error of the cumulate fluxes is correlated to its magnitude according to a power function. (v) The number of processing runs can be safely reduced to 32, and in most cases up to 16. Further reductions are possible, especially to roughly quantify the uncertainty, but tend to oversaturate the design, resulting in aliases between factors and interactions and making very difficult to understand their importance. Based on those results, we suggest that the systematic uncertainty of EC measurements from the post-field raw data processing can be estimated with one of the following methods (in order of increasing accuracy): (i) applying a power function to a single value of the yearly cumulate; (ii) from a combination of 4 different processing options: ‘2D rotations’ and ‘planar fit’ for CR and ‘block average’ and ‘linear detrending’ for TR. (iii) Performing a fractional factorial analysis of 32 (16) combinations of different processing options. The increase in operational power of computers allows, and will allow even more in the future, to run more parallel routines in acceptable time.