Technical University of Denmark

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Ibrom, Andreas

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Uncertainty of carbon dioxide flux estimates introduced by different high-pass filtering methods

A. Ibrom and the IMECC NA5 Team
Risø National Laboratory for Sustainable Energy, Technical University of Denmark (DTU), Roskilde, Denmark (anib@risoe.dtu.dk/+4546774160)

Accuracy and precision of eddy covariance flux measurements depend among other factors on the method of high-pass filtering (HPF). Even if the time series are not filtered by linear detrending or recursive filtering, measurements are high-pass filtered as a consequence of the limited sampling interval. This makes correction for HPF necessary. Although some recommendations exist, different methods are used by different groups and affect the flux estimates in a different way.

We investigated annual CO_2 flux data sets from 8 different European flux sites comprising a wide range of surface properties, climates and technical setups for the effects of linear detrending, recursive filtering and block averaging on systematic and random errors of the flux estimates. To correct for HPF effects, we used the spectral transfer function approach based on a common model spectra parameterisation.

Results showed comparably large absolute effects of HPF correction (Tab. 1), especially above rough surfaces (4 to 15% of the annual C uptake). Above smooth surfaces, like the cropland the grassland and the wetland sites, HPF effects were small. The higher the attenuation of the filter, i.e. linear detrending and recursive filtering with small time constants, the higher was the reduction of both the random error and the absolute flux signal. The HPF effects were the larger the higher measurement height and the smaller wind velocity which were two main effects leading to different accuracies at the different sites in this comparison.

Tab. 1 Effects of high-pass filtering correction on annual flux estimates and their standard deviation (g C m^{-2} yr^{-1}). Treatments: BA, block averaged, LD, linear detrended, RM, recursive filter with time constants (τ) equal to different fractions of sampling time (T_s)

surface type	BA	LD	RM τ=1/8 T_s	RM τ=1/4 T_s	RM τ=1/2 T_s
smooth (n=3)	-1(±0.2)	-1(±0.5)	-2(±0.8)	-1(±0.4)	-1(±0.2)
rough (n=5)	-8(±2.1)	-16(±4.0)	-27(±6.6)	-15(±3.6)	-7(±1.8)

However, like also found earlier, the systematic effect was largely reduced, but not fully compensated by the correction (Tab. 2). This effect introduced systematic bias to the flux estimates caused by the choice of the HPF filter method. Block averaging was used as a reference, but it is not clear how much the corrected flux after block averaging is biased by an incomplete correction. With one exception the residual differences were much smaller than not correcting the flux for HPF.

Tab. 2: Differences between high-pass filtering corrected annual flux estimates after linear detrending or recursive filtering compared to block averaging and their standard deviation.

surface type	BA	LD	RM τ=1/8 T_s	RM τ=1/4 T_s	RM τ=1/2 T_s
smooth (n=3)	reference	2(±1.3)	3(±1.0)	1(±0.4)	-1(±0.4)
rough (n=5)	reference	3(±0.6)	5(±1.4)	5(±0.6)	7(±1.5)

The investigation raises the question, if our understanding of turbulent fluxes is yet complete, i.e. whether lowfrequency flux contributions should be accounted for in plot scale flux studies or not and how these flux contributions can be determined and realistically represented by model spectra. The quantitative results indicate that this question is practically more relevant for forest studies than for cropland or grassland studies. With our presentation we aim at raising a discussion about the usefulness of the suggested spectral correction approach and want to raise awareness on accuracy and precision issues with regard to high pass filtering among users of the eddy covariance technique.

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