Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2019-270-AC2, 2019

Biogeosciences Discussions
Open Access

Interactive comment on "A robust data cleaning procedure for eddy covariance flux measurements" *by* Domenico Vitale et al.

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Received and published: 8 November 2019

Referee general comment -*This study presents a novel scheme for quality control (QC) of eddy-covariance data, which is a very relevant topic for the readership of this journal. Especially, since more and more data become freely available and are being used in large-scale synthesis studies, a sound and robust data cleaning procedure is needed. This is certainly not the first attempt to provide such a method, and a number of common existing methods are cited, but this new method is somewhat innovative, since it separates the quality tests from data rejection criteria more rigorously than other methods. This allows for more flexibility in the selection of test algorithms, so that future developments can be integrated more easily.*

Authors' reply - Thank you for this kind reply and consideration. We appreciate that she/he caught the essence of the proposed approach. In the following, our replies to the referee comments.

Referee comment - *While I find the data actual QC algorithm logical and coherent, I find it very bold to assume that a random uncertainty estimate served as the only quality indicator eddy-covariance data, as e.g. stated in the conclusion.*

Authors' reply -We didn't state that this is the only quality indicator indeed. Rather, we state that, given an unbiased flux covariance estimate (as reported in ll. 676:677), a consistent estimate of the random uncertainty would provide an objective criterion for evaluating the quality of data. We will better clarify this concept in the revised version of the manuscript.

Referee comment - *More precisely, I have the following two concerns*:

1. *I agree, that systematic errors should either be avoided or corrected for. However, the uncertainty of a flux estimate may increase as a result of a flux corrections (because the estimate is partially modelled and not measured, particularly as a result of spectral corrections). How can this be included?*

   Authors' reply - Although an interesting topic, this work is not focused on the evaluation of flux correction methods neither on the evaluation of the error propagation. This paper aims at describing a flexible and robust data cleaning procedure for eddy covariance flux measurements. Of course, the uncertainty associated to flux estimates should take into account the contribution of all possible sources, including those related to flux correction procedures. However, the availability of "high-quality" datasets constitutes an essential prerequisite to increase the robustness and reduce the uncertainty of the results of flux correction procedures, for example those used for the estimation of spectral correction factors. In this perspective, the application of robust data cleaning procedures, as the one proposed in this work, can help to achieve consistent estimates of correction parameters and, consequently, less biased and uncertain flux estimates. We will add such considerations in the revised version of the manuscript.

2. *Moreover, the spatial representativeness of a flux estimate, cannot easily be accounted for in a random error estimate. What if there is a mixed land use within the flux footprint? This issue needs to be addressed in some way.*

   Authors' reply -We agree with the reviewer's concern, but this is mainly an issue related to quality assurance (QA) step, i.e. a problem of the site's characteristics with respect to the requirements of the eddy covariance method. This is out of the scope of the present manuscript and will be clarified in the revised version.

Referee comment - L98: *. . . because it would be extremely time consuming.*

Authors' reply -Thank you for this suggestion. It will be taken into consideration in the revised version of the manuscript.

Referee comment - L122: *I disagree that the random uncertainty is sufficient to characterize eddy-covariance data, for the above-mentioned reasons.*

Authors' reply -We tried to clarify above the point and where the concept applies in this case. The revised text will better explain the assumption underlying this statement and the limits of existing estimation methods (see also answer to reviewer 1 reported below).

Andrew Kowalski comment*: L82 This statement strikes is as excessively bold and over-simplified. For example, a random error that were to consistently reduce the covariance at a frequency of 0.01Hz (by introducing random noise at that frequency) would cause flux underestimation for the corresponding eddies. It could well be that these frequencies matter greatly for (convective) eddy transport during daytime, and far less so at night. The result would be an overestimation of NEE over the long term.*

Authors' reply to Andrew Kowalski comment. We agree with the reviewer statement that the presence of a specific source of error as the one reported in the example, could attenuate covariances and, consequently, introduce long-term biases.

We shall clarify that the distinction between random and systematic error affecting half-hourly flux estimates is based on the effects of the source of error on the quantity of interest and is thus not strictly linked to its features. In other words, the question to answer is: is the source of error responsible to introduce bias or to increase the uncertainty of the quantity of interest (e.g. covariance)?

With this definition, if the presence of some source of error is responsible for attenuating flux covariance estimates, then the source of error is systematic, even if the error component is a noise term having similar characteristic to random data. If, instead, the presence of some source of error is responsible for increasing the uncertainty associated with flux covariance estimates (i.e. standard deviation) then the source of error is classified as random.

We are aware that, in practice, it is difficult to distinguish between random and systematic errors because some source of error can have both a random and a systematic component, there are no reference values to evaluate the presence of bias, and there are not replicates to consistently quantificate the random uncertainty.

However, we consider the above-mentioned classification more suitable to characterize the multitude of errors affecting eddy-covariance time series. We will better clarify these concepts in the introductory section of the revised version of the manuscript.

Referee comment. L140: *I disagree with this statement. A bias can at least indirectly be determined using the energy balance closure.*

Authors' reply - We respectfully disagree with the reviewer for this point. Although important, the energy balance closure is still an open issue in the eddy covariance methodology, as the many attempts to explain and justify it didn't fully succeed so far. That's why we believe it can only be used to indirectly suggest the presence of some unknown source of systematic error affecting flux estimates, but not to determine it, at least at half-hourly scale (and in fact there is no consensus about the fluxes correction procedure on the basis of the energy balance closure). In the revised version of the manuscript we will add however some consideration about the use of

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Discussion paper

additional analyses as indicative about the presence of undetected/unknown sources of systematic error.

Referee comment. L461: *This might be a better reference for the Selhausen site: (Schmidt et al., 2012) because it is only one of several sites that are used as an example in Mauder et al. (2013), and the correct Site-ID is DE-RuS Schmidt, M., Reichenau, T. G., Fiener, P. and Schneider, K.: The carbon budget of a winter wheat field: An eddy covariance analysis of seasonal and inter-annual variability, Agric. For. Meteorol., 165, 114–126*

Authors' reply - Thanks for the suggestion, we will review the citations of all the sites and data and include specific references and acknowledgments.

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