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True eddy accumulation and eddy covariance methods and instruments intercomparison for fluxes of CO_2, CH_4 and H_2O above the Hainich Forest

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The eddy covariance (EC) method is state-of-the-art in directly measuring vegetation-atmosphere exchange of CO_2 and H_2O at ecosystem scale. However, the EC method is currently limited to a small number of atmospheric tracers by the lack of suitable fast-response analyzers or poor signal-to-noise ratios. High resource and power demands may further restrict the number of spatial sampling points.

True eddy accumulation (TEA) is an alternative method for direct and continuous flux observations. Key advantages are the applicability to a wider range of air constituents such as greenhouse gases, isotopes, volatile organic compounds and aerosols using slow-response analyzers. In contrast to relaxed eddy accumulation (REA), true eddy accumulation (Desjardins, 1977) has the advantage of being a direct method which does not require proxies. True Eddy Accumulation has the potential to overcome above mentioned limitations of eddy covariance but has hardly ever been successfully demonstrated in practice in the past.

This study presents flux measurements using an innovative approach to true eddy accumulation by directly, continuously and automatically measuring trace gas fluxes using a flow-through system. We merge high-frequency flux contributions from TEA with low-frequency covariances from the same sensors. We show flux measurements of CO_2, CH_4 and H_2O by TEA and EC above an old-growth forest at the ICOS flux tower site “Hainich” (DE-Hai).

We compare and evaluate the performance of the two direct turbulent flux measurement methods eddy covariance and true eddy accumulation using side-by-side trace gas flux observations.

We further compare performance of seven instrument complexes, i.e. combinations of sonic anemometers and trace gas analyzers. We compare gas analyzers types of open-path, enclosed-path and closed-path design. We further differentiate data from two gas analysis technologies: infrared gas analysis (IRGA) and laser spectrometry (open path and CRDS closed-path laser spectrometers).

We present results of CO_2 and H_2O fluxes from the following six instruments, i.e. combinations of sonic anemometers/gas analyzers (and methods): METEK-uSonic3/Picarro-G2301 (TEA), METEK-uSonic3/LI-7500 (EC), Gill-R3/LI-6262 (EC), Gill-R3/LI-7200 (EC), Gill-HS/LI-7200 (EC), Gill-R3/LGR-FGGA (EC).

Further, we present results of much more difficult to measure CH_4 fluxes from the following three instruments, i.e. combinations of sonic anemometers/gas analyzers (and methods): METEK-uSonic3/Picarro-G2301 (TEA), Gill-R3/LI-7700 (EC), Gill-R3/LGR-FGGA (EC).

We observed that CO_2, CH_4 and H_2O fluxes from the side-by-side measurements by true eddy accumulation and eddy covariance methods correlated well. Secondly, the difference between the TEA and EC methods using the same sonic anemometer but different gas analyzer was often smaller than the mismatch of the various side-by-side eddy covariance measurements using different sonic anemometers and gas analyzers.

Signal-to-noise ratios of CH_4 fluxes from the true eddy accumulation system system were superior to both eddy covariance sensors (open-path LI-7700 and closed-path CRDS LGR-FGGA sensors).

We conclude that our novel implementation of the true eddy accumulation method demonstrated high signal-to-noise ratios, applicability to slow-response gas analyzers, small power consumption and direct proxy-free ecosystem-scale trace gas flux measurements of CO_2, CH_4 and H_2O. The current results suggest that true eddy accumulation would be suitable and should be applied as the method-of-choice for direct flux measurements of a large number of atmospheric constituents beyond CO_2 and H_2O, including isotopes, aerosols, volatile organic compounds and other trace gases for which eddy covariance might not be a viable alternative. We will further develop true eddy accumulation as a novel approach using multiplexed systems for spatially distributed flux measurements.