S2. Spectral Analysis

Cutoff frequencies of EC systems can be evaluated using the ratio of the spectra of a scalar of interest to that of an assumed unattenuated temperature spectra ($f_{c,s}$). This involves computing ensemble-averaged spectra or cospectra using several hours of data with conditions that warrant scalar similarity (i.e., stationary, sunny conditions with positive sensible heat fluxes, moderate winds, and a high scalar flux (Aubinet et al., 2012)). Many studies using this empirical method select data from one ideal day meeting these conditions (Detto et al., 2011; Peltola et al., 2014; Rannik et al., 2015) to calculate $f_{c,s}$ as a metric for characterizing EC systems. Unfortunately, the low $N_2O$ fluxes observed in this study prevented an accurate analysis of the frequency response of the optimized TDLAS-TE system via spectral ratios.

One day of the study period had adequate conditions for spectral analysis (8 June 2015), i.e., consecutive 30 min periods with stationary signals, moderate winds (2 $m\cdot s^{-1} < U < 4$ $m\cdot s^{-1}$), strong fluxes, $|F_{N2O}| > 400$ ng $m^{-2}\cdot s^{-1}$), and positive sensible heat fluxes ($H > 25$ $Wm^{-2}$). At that time both $N_2O$ analyzers were operating using the older-style sampling systems with nominal flows and pressures (58 and 59 mb for TDLAS-LN and TDLAS-TE, respectively). Ensemble variance spectra and cospectra of the $N_2O$ signals were calculated using data from 13:00 to 17:00 on 8 June 2015. Cospectral analysis for the EC155 used data from a period with strong $CO_2$ signals ($|F_{CO2}| > 500$ μg $m^2s^{-1}$, 12:00 to 16:00 on 19 Aug 2015).

Spectral cutoff frequencies were calculated by fitting the cospectral ratios of the concentration signals and sonic temperature ($T_s$) to a first-order transfer function ($T$):

$$T = \frac{1}{\sqrt{1+\left(\frac{f}{f_{c,s}}\right)^2}} \qquad [S1]$$

Results of the spectral analyses are displayed in Fig. S1. Spectra from each $N_2O$ analyzer (Fig. S1a) were similar up to ~1 Hz where the TDLAS-TE noise became observable. Fig. S1b shows very good agreement between the $N_2O$ cospectra as measured by each analyzer. Cospectral ratios of both analyzers were similar (Fig. S1c) and demonstrated that both analyzers captured the majority of the $N_2O$ flux when using the older-style sampling system. $CO_2$ spectral analysis results for the EC155 are shown in Figs. S1 d, e, and f.  Cutoff frequencies calculated by fitting equation S2.1 to the ratio of $Co(f)_{wN2O}$ to $Co(f)_{wT}$ gave $f_{c,s}$ = 2.5 Hz for the TDLAS-TE, $f_{c,s}$ = 2.7 Hz for the TDLAS-LN, and 3.05 Hz for the EC155. These results are not directly comparable to the in situ frequency response test because the cospectral analysis includes other losses, such as sensor separation and synchronization.

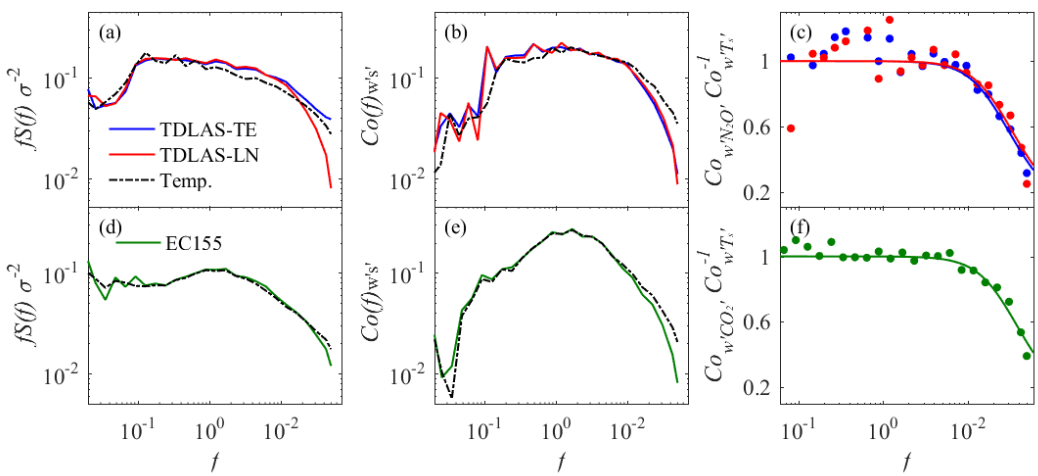


Figure S1.  Results of the spectral analysis. Normalized variance spectra (Fig. S1a) and normalized cospectra (Fig. S1b), and cospectral ratios of $N_2O$ (Fig. S1c) measured by the TDLAS-TE and TDLAS-LN for the period with strong $F_{N2O}$ (13:00 to 17:00 local time on 8 June 2015, $zL^{-1}$ = -0.045, $u$ = 3.55 $ms^{-1}$).  Figures d-f: Normalized variance spectra (Fig. S1c), normalized cospectra (Fig. S1d), and cospectral ratios of $CO_2$ (Fig. S1c) measured by the EC155 during a period of strong $CO_2$ flux (12:00 to 16:00 local time on 19 Aug 2015).

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