# CARBON MONOXIDE FLUXES OVER A MANAGED MOUNTAIN MEADOW

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## BACKGROUND

**Carbon monoxide** (CO) is a toxic trace gas with an atmospheric lifetime of 1-3 months and an average atmospheric concentration of 100 ppb. CO mole fractions exhibit a pronounced seasonal cycle with lows in summer and highs in winter. Carbon monoxide has an **indirect global warming potential** by increasing the lifetime of methane ($CH_4$), as the main sink of CO is the reaction with the hydroxyl (OH) radical, which in turn is also the main sink for $CH_4$. Regarding the warming potential, it is estimated that 100 kg CO are equivalent to an emission of 5 kg $CH_4$. In addition, carbon monoxide interferes with the building and destruction of **ozone**. Emission into and uptake from the atmosphere of CO are thus relevant for global climate and regional air quality. Sources and sinks of CO on a global scale are still highly uncertain, mainly due to general scarcity of empirical data and the lack of ecosystem-scale CO exchange measurements, i.e. CO flux data that encompass all sources and sinks within an ecosystem.

## METHODS

Here we report on the $CH_4$, $N_2O$ and CO exchange measured between March and October 2013 at a temperate mountain grassland managed as a hay meadow near the village Neustift in the Stubai Valley, Austria, by means of the eddy covariance method. The three wind components, the speed of sound and the $CO_2$ mole densities were acquired at a time resolution of 20 Hz and used to calculate true eddy covariance $CO_2$ fluxes.

$CH_4$, $N_2O$ and CO mixing ratios were recorded at 1-5 Hz by a quantum cascade laser absorption spectrometer (**QCL-AS**), resulting in a disjunct time series when compared to the 20 Hz wind data. Fluxes of both compounds were then calculated using the virtual disjunct eddy covariance method (**vDEC**). Mixing ratios of $CH_4$ and $N_2O$ were then corrected for the cross-talk effect of water as described in earlier studies.
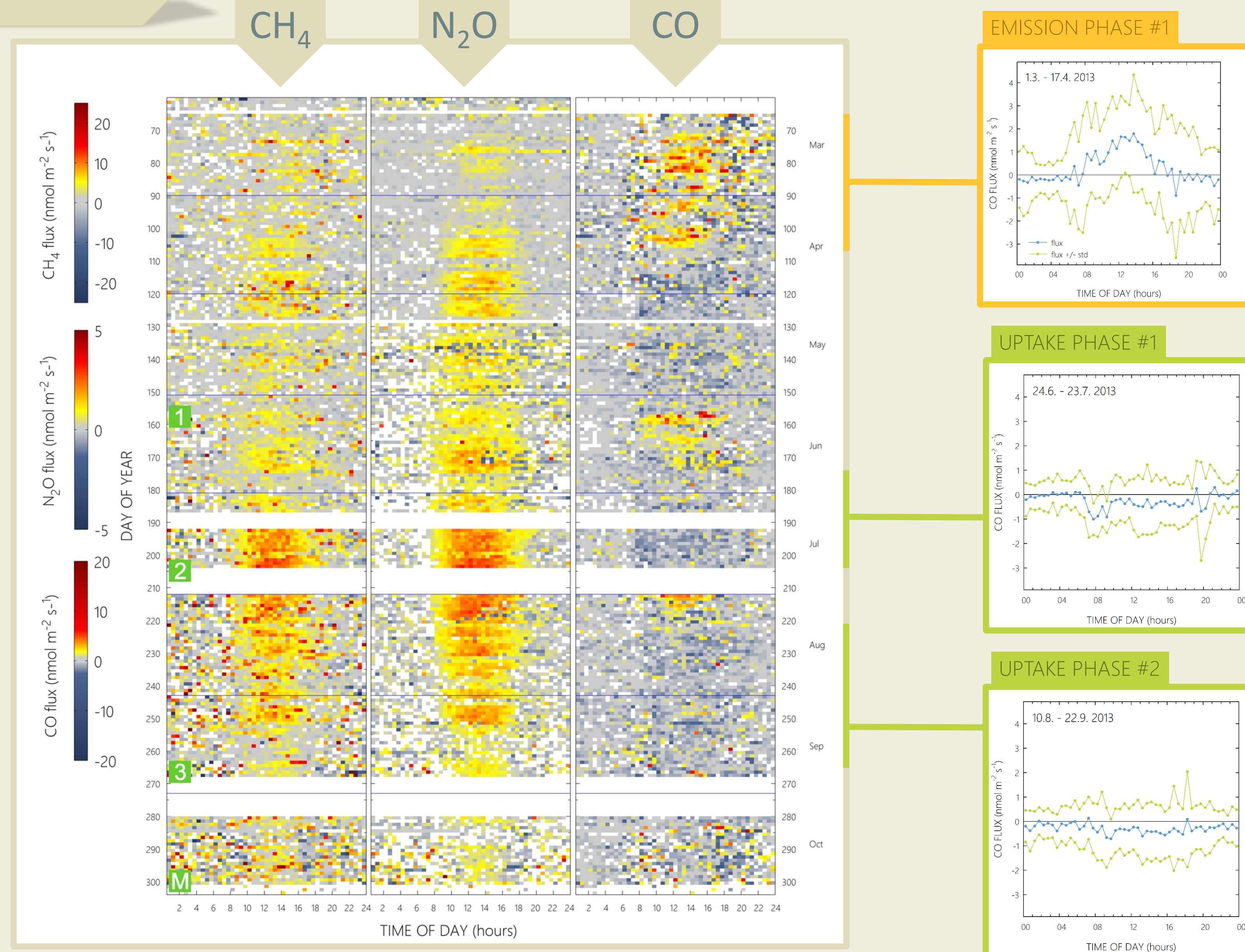
## FLUXES



**FIGURE 1.** LEFT: Half-hourly fluxes of $CH_4$, $N_2O$ and CO between 1 March and 31 October 2013. Numbers 1,2,3 denote dates where the meadow was cut, M shows the date of manure spreading. RIGHT: Average diurnal cycles of CO exchange during selected time periods. The meadow was permanently snow-covered until approx. 19 March.

The study site near Neustift, Austria.

## RESULTS

### FLUX DYNAMICS
Between March and October 2013, the meadow was a **weak sink for CO** and a source of $CH_4$ and $N_2O$ (Fig.1 and 2). We observed clear CO emissions in March when the meadow alternated between being snow-free and snow-covered.

Similar to cumulative NEE exchange at the site, the meadow became a net sink for CO some weeks after snowmelt and until the 1st cut. The cutting event turned the meadow into a CO source for about one week before it again became a net sink. This behavior recurred after the 2nd cut (Fig. 2).

### DRIVERS?
Our chosen set of ancillary data explained 45 % of observed CO fluxes when all data were pooled, and up to 75 % on shorter time scales (Table 1). Generally, CO was transported to the meadow when CO2 deposition occurred at low or intermediate soil water content (Fig. 3).

### GLOBAL WARMING POTENTIAL
Due to the low fluxes associated with CO exchange at the study site, it is unlikely that it is a significant factor regarding the GWP of the meadow.
First analyses showed that the meadow was a strong sink for $CO_2$ in 2013, with a cumulative uptake of -400 g $CO_2$ m$^{-2}$ (corresponds to 109 g $CO_2$-C m$^{-2}$) between January and December.

Between March and October 2013, this uptake was offset by 26 % due to $CH_4$ and $N_2O$ emissions, resulting in a preliminary GHG-total of -294 g $CO_2$ m$^{-2}$. However, $CH_4$ and $N_2O$ are also emitted during the cold winter months, data of which were not available for this analysis. Assuming a similar GHG flux behavior during the winter months like in 2011 at the same site, we would expect $CH_4$ and $N_2O$ to offset NEE by 40 % over the whole year.

Cumulative carbon exchange associated with $CH_4$ and CO fluxes between March and October were only 0.39 and -0.02 g C m$^{-2}$, i.e. not significant for the carbon balance of the meadow.

## REGRESSION ANALYSIS

Table 1

| | multiple $r^2$ | important regressors | partial correlation | p |
|---|---|---|---|---|
| EMISSION PHASE #1 | 0.30 (n.s.) | $T_{air}$ | -0.29 | n.s. |
| | | LE | 0.26 | n.s. |
| | | SHF | 0.19 | n.s. |
| UPTAKE PHASE #1 | 0.75 * | PAR | -0.62 | * |
| | | H | 0.65 | * |
| | | LE | 0.52 | n.s. |
| | | NEE | -0.45 | n.s. |
| UPTAKE PHASE #2 | 0.46 * | RHA | 0.45 | * |
| | | SHF | 0.40 | * |
| | | $T_{air}$ | -0.37 | * |
| ALL DATA n = xxx days | 0.45 * | xxx | xxx | xxx |
| | | xxx | xxx | xxx |
| | | xxx | xxx | xxx |

**TABLE 1.** Results of a **multiple linear regression** analysis using daily average values, with CO flux as the dependent variable and CO volume mixing ratio, relative air humidity (RHA), air ($T_{air}$) and soil temperature, photosynthetically active radiation (PAR), soil water sontent, soil heat flux (SHF), net ecocsystem exchange (NEE), and fluxes of latent (LE) and sensible (H) heat as independent parameters.
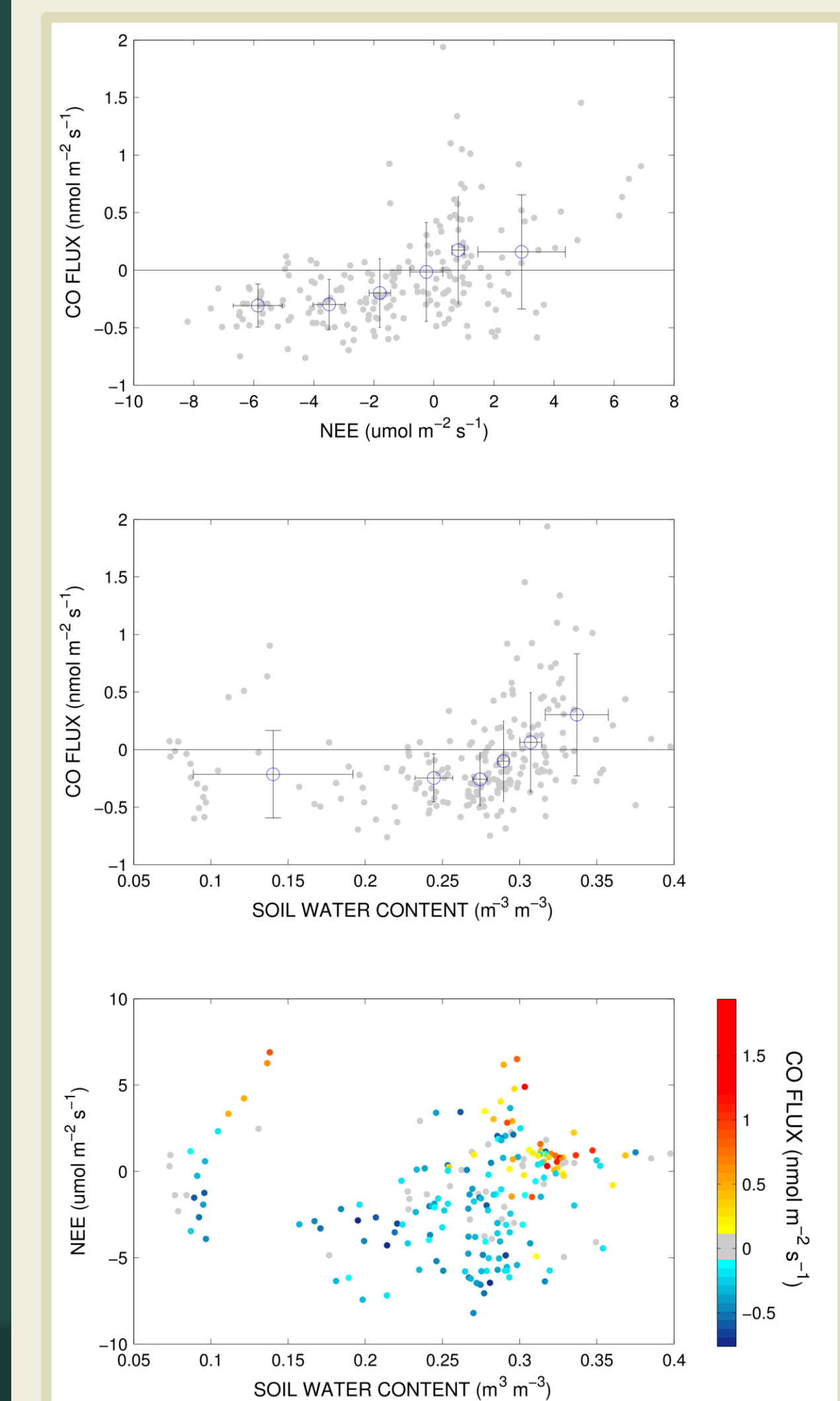
## DRIVERS?



**FIGURE 3.** CO daily average exchange (grey dots) versus NEE (upper panel) and soil water content (middle panel). Blue circles are bin averages (35 days per bin), error bars represent the standard deviation within each bin. In the lower panel, cooler colors indicate uptake of CO by the meadow, warmer colors emission. Manage-ment events were excluded from the analysis.
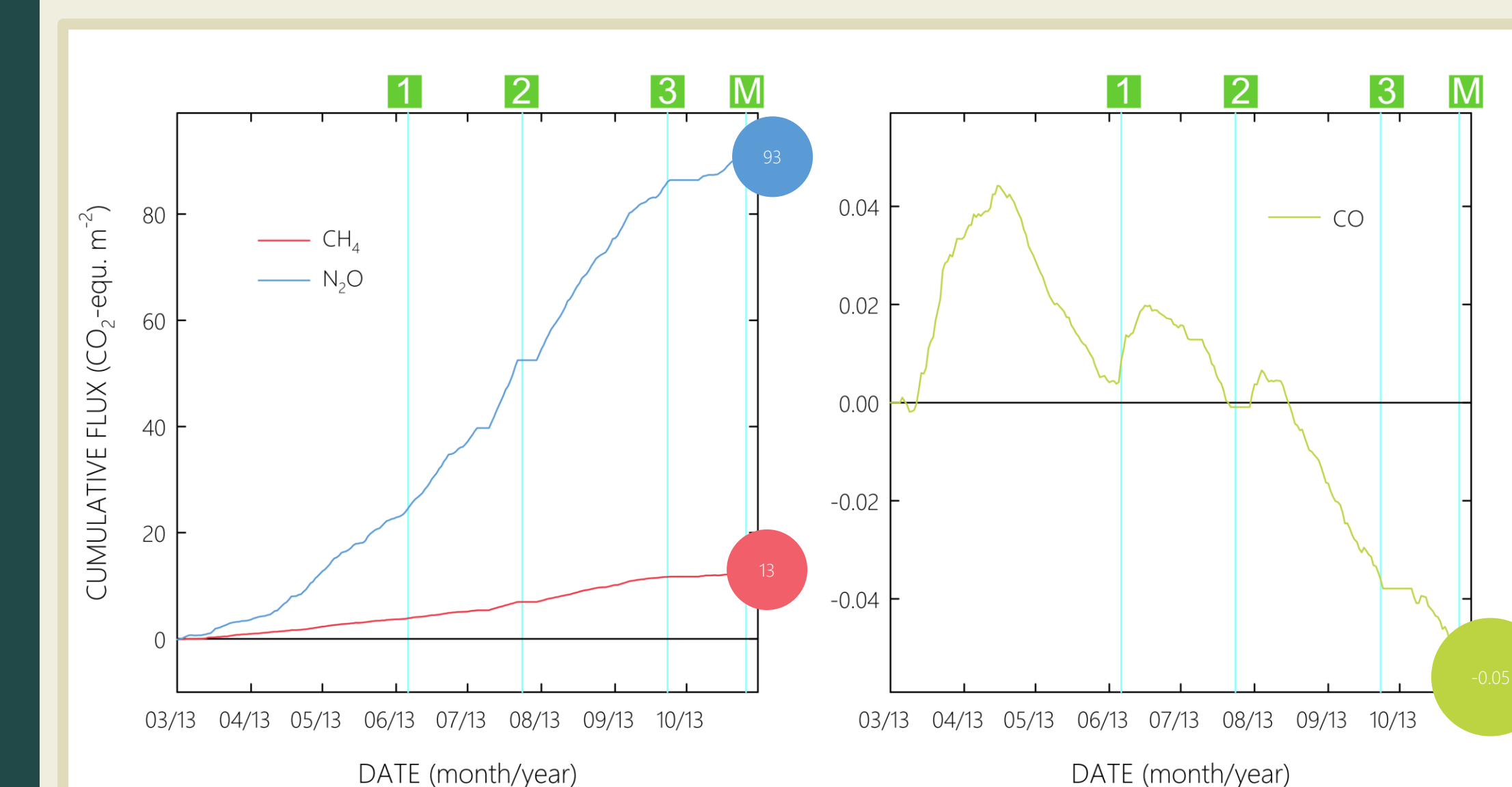
## CUMULATIVE



**FIGURE 2.** Cumulative GHG fluxes in 2013 expressed as $CO_2$-equivalents. Vertical lines show management dates, numbers 1, 2 and 3 in green squares indicate the 1st, 2nd and 3rd cutting of the meadow, respectively, while M denotes manure spreading.

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