Soil Respiration using Forced Diffusion: From the Tundra to the Savanna

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Abstract

Eddy Covariance (EC) systems have been widely used across the globe for more than 20 years, offering researchers invaluable measurements of parameters including Net Ecosystem Exchange (NEE) and Ecosystem Respiration (R_{eco}). Measurements of soil respiration (R_s) at the ground level are critical to properly assess and partition the individual components of respiration in order to better understand the processes that contribute to R_{eco}. While chamber systems have been used for many decades to study R_s, little work has been done on partitioning R_{eco} because commonly used chamber approaches do not offer adequate temporal frequency for comparison. The recently developed Forced Diffusion (FD) method allows for inexpensive and autonomous measurements of soil CO_2 flux and provides a scalable approach to matching the EC footprint compared to other chamber systems.

Here we present two studies where the FD technique is used in conjunction with EC measurements to help understand R_s and R_{eco}. The first study is from Zackenberg, Greenland where the FD method is employed in a permafrost area that has experienced strong warming during the last two decades. The FD chambers are deployed in a Cassiope heath plant community; a vegetation type that covers approximately 10% of the high and middle Arctic areas and is a dominant contributor to ecosystem fluxes. The second study is a 2-month monitoring campaign in a Californian oak savanna, where the FD chambers are deployed in the footprint of a long-running EC tower. This site is located in an area where summer drought typically reduces R_{eco} and R_s to near zero before increased rainfall in the autumn causes a gradual increase in R_{eco} and R_s that is abbreviated by short-lived respiration pulses after each rainfall event.

What is Forced Diffusion (FD)

Forced Diffusion (FD) is a novel method for continuous measurement of soil respiration (Risk *et al.*, 2011). The FD technique is functionally similar to dynamic steady-state chamber systems but uses a diffusive membrane, rather than a pump, to regulate the flow of gases (Figure 1). Measurement of soil respiration using this diffusive regulation approach offers several benefits created by the lack of external moving parts, including reduced power consumption and the ability to function in harsh environments, including under snow pack.

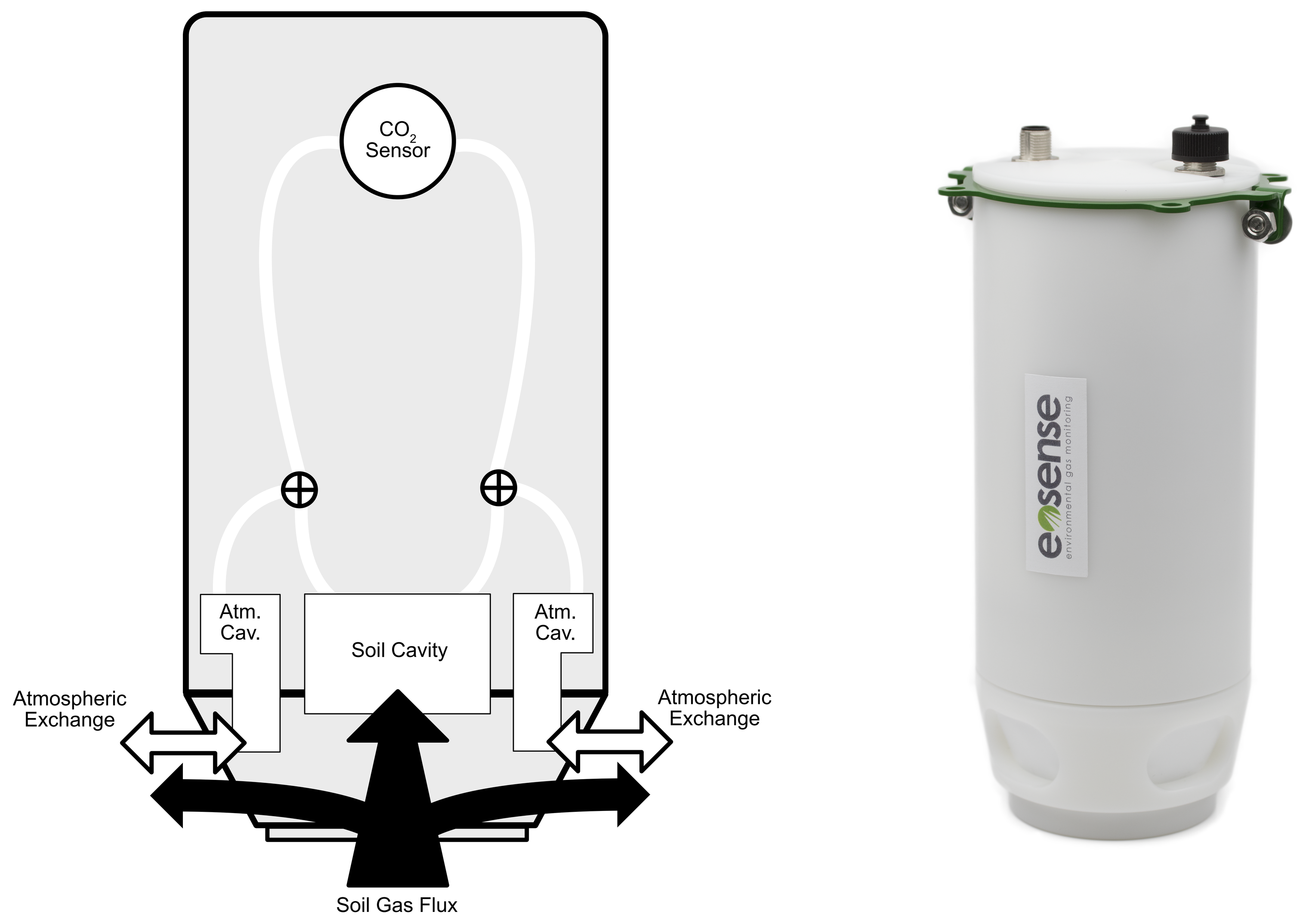

Figure 1: Left - View of the eosFD Chamber flow paths showing the exchange of atmospheric gases and soil flux with the chamber sampling cavities. Right - The current generation of eosFD chambers manufactured at Eosense.

Tundra Site & Results

The Zackenberg site (Figure 2) currently consists of an eddy covariance system supplemented with a wide array of meteorological measurements. The site has line power delivered from the research station supplemented with a battery pack charged by wind mill and solar panels. Starting in early July, 6 eosFD soil flux chambers were deployed on the site within the dominant footprint of the eddy covariance system. Each eosFD was supplied with its own independent battery power source so that they could be easily relocated within the footprint (Figure 2, left). Approximately every 2 weeks, the eosFD units were relocated within the eddy covariance footprint, as is presented in the table in Figure 2.

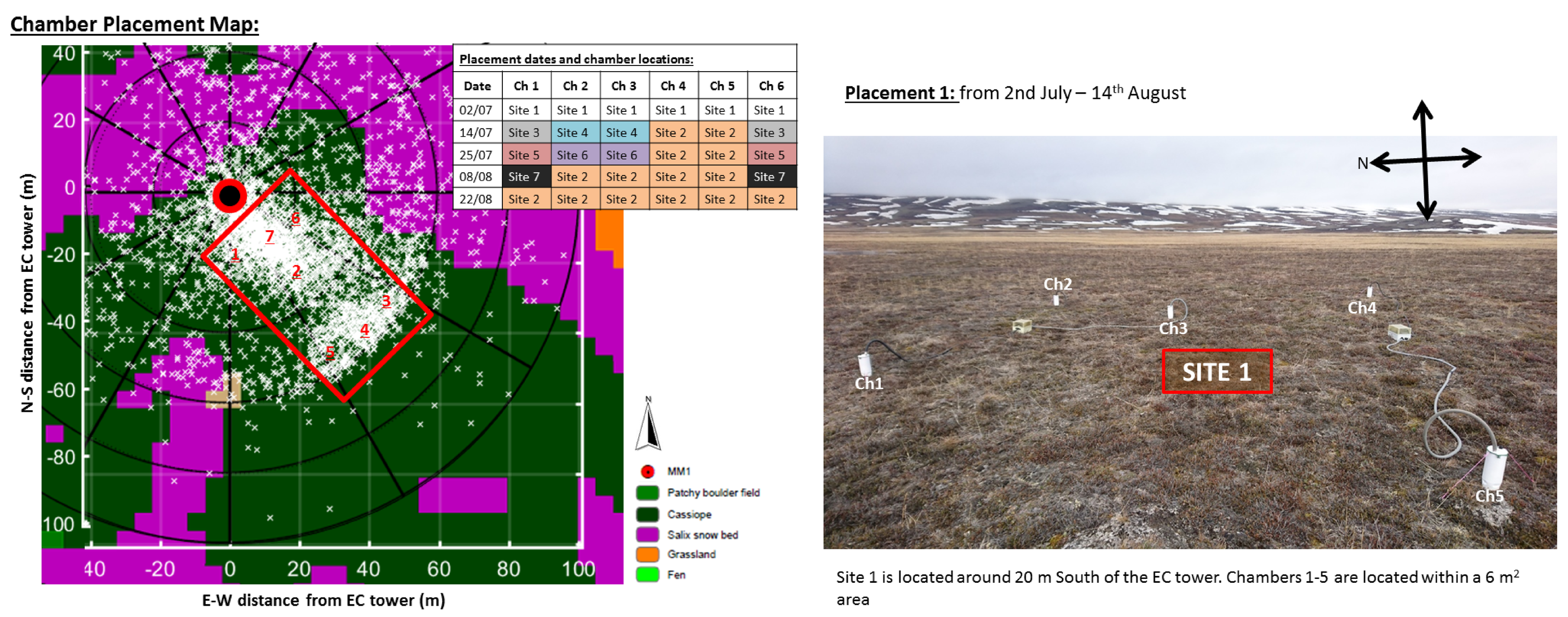

Figure 2: Left - Map of the area around the eddy covariance tower showing the plant types in the area and sites on which the eosFD chambers will be deployed (schedule top right). Right - Example placement of the chambers at Site 1.

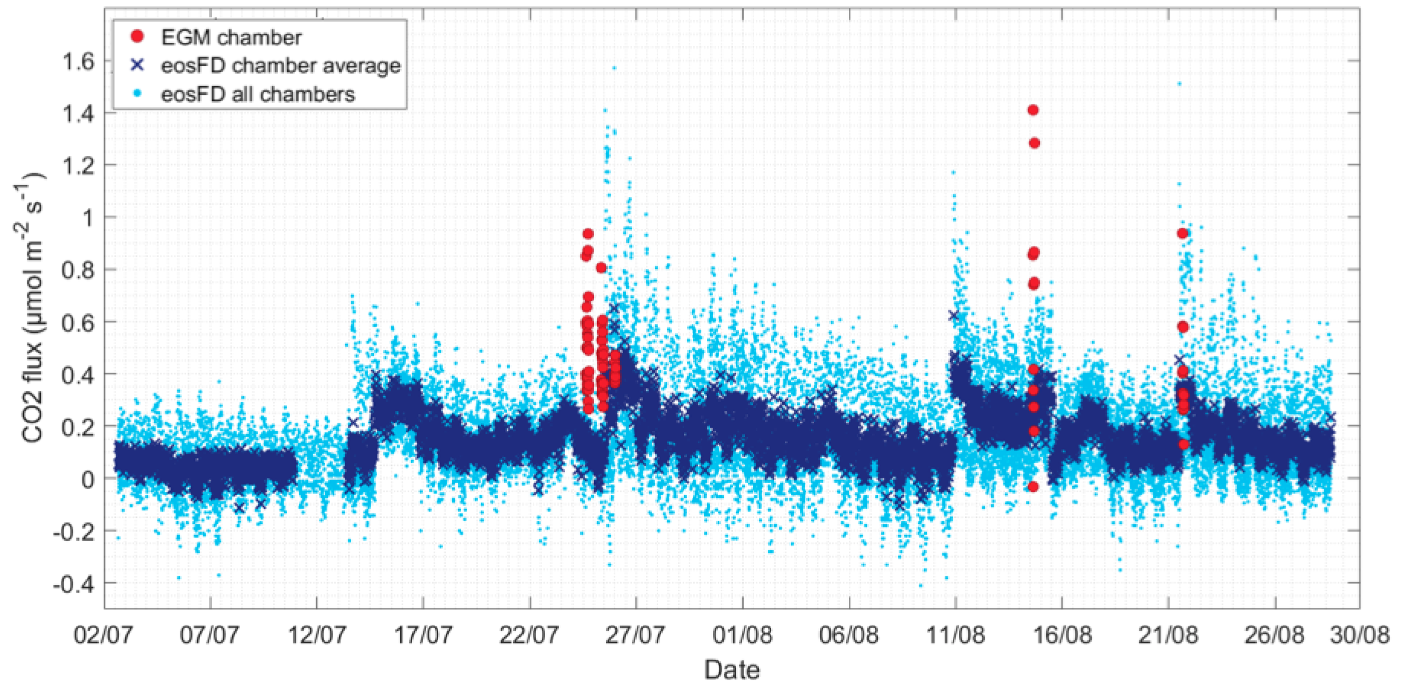

Figure 3: A comparison of chamber-based soil respiration measurements from inside the EC footprint. Shown are data from the eosFD chambers (blue markers) and manual PP Systems EGM-5 measurements (red markers).

Analysis of dark NEE using light response curves indicates that soil respiration as measured by the eosFD chambers is smaller than R_{eco} estimates. Over the period 11th - 20th July we estimate a dark NEE rate of 1.23 μmol CO_2 m^{-2} s^{-1}, whereas the mean flux measured by the chambers was only 0.17 $\pm$ 0.08 μmol CO_2 m^{-2} s^{-1}. Similarly, for the 21st July to 9th August we estimate a dark NEE of around 0.98 μmol CO_2 m^{-2} s^{-1}, whereas mean eosFD flux estimates were substantially lower (0.20 $\pm$ 0.10 μmol CO_2 m^{-2} s^{-1}). In fact, the chamber-measured soil respiration fluxes are between a factor of five and seven lower than the R_{eco} estimates. Although there is large disagreement between the two fluxes, it is important to remember that we are comparing two different fluxes - one at the microsite scale, and one at the ecosystem scale.

Savanna Site & Results

The Tonzi and Vaira savanna sites are both located in the Sierra Nevada foothills. Tonzi is characterized by an overstory of blue oak and grey pine with approximately 3 trees/ha with an understory of grasses and herbs. Vaira is a managed grassland site with no overstory species. The understory at both sites is dormant until the wet season begins, with growth typically starting in October and ending in early May. In late October, 2017, 4 of the 6 eosFD units used at the Zackenberg site were installed at the Tonzi and Vaira sites, powered by existing site infrastructure.

Figure 4: Photos for 2 of 4 eosFD units installed at the Tonzi and Vaira sites in late October, 2017. eosFD units were colocated with gradient measurements for future comparison.

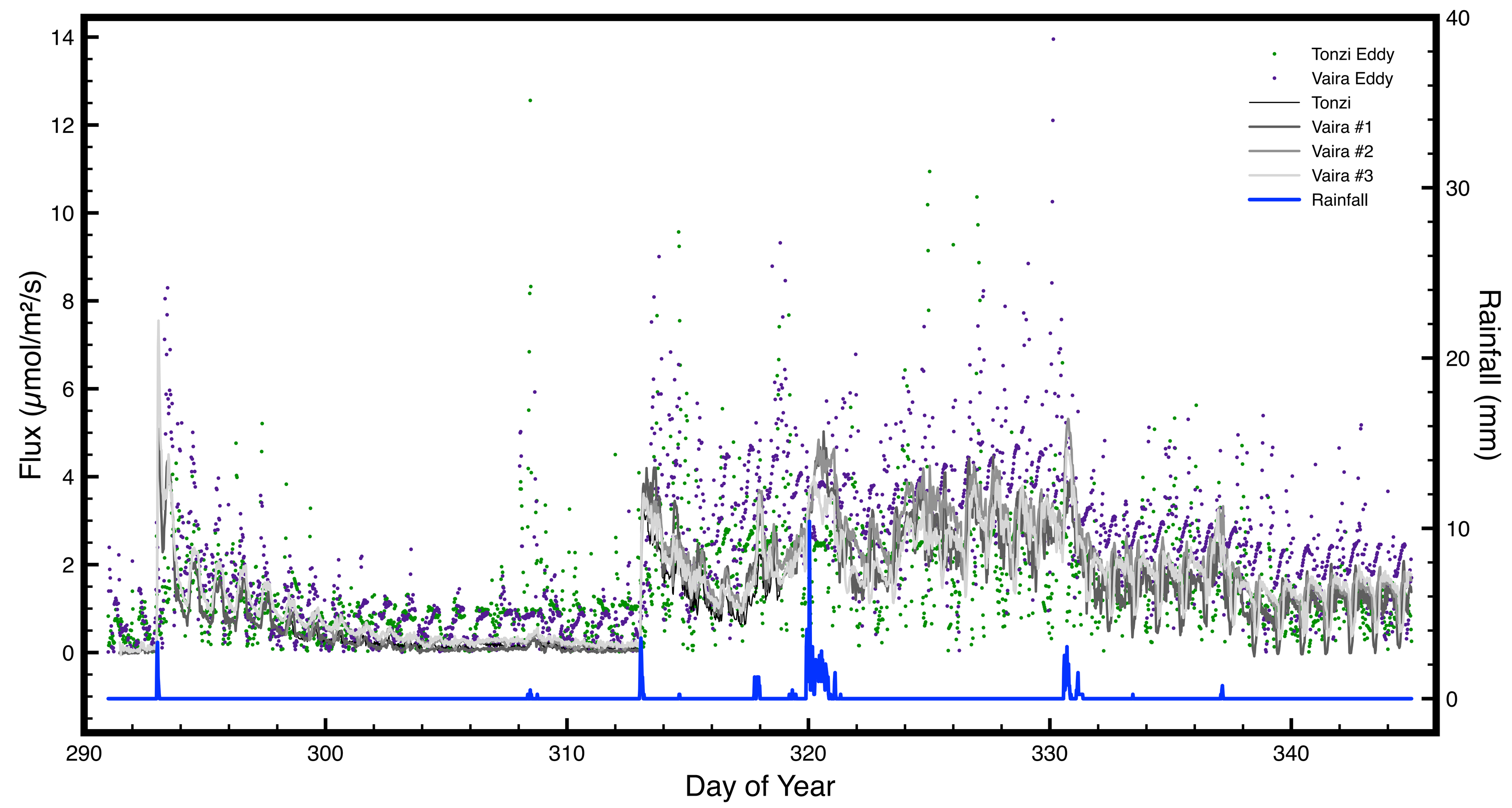

Figure 5: Time series data for the eosFD chambers and Eddy Covariance systems installed at Tonzi and Vaira. Both the chambers and EC systems show excellent correspondence throughout the dry season, with clear respiration pulses related to precipitation events. Ratios of R_s/R_{eco} at the site averaged 0.86 during the observation period.

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