Challenges and opportunities of quantifying advection at a mountain forest in the Alps

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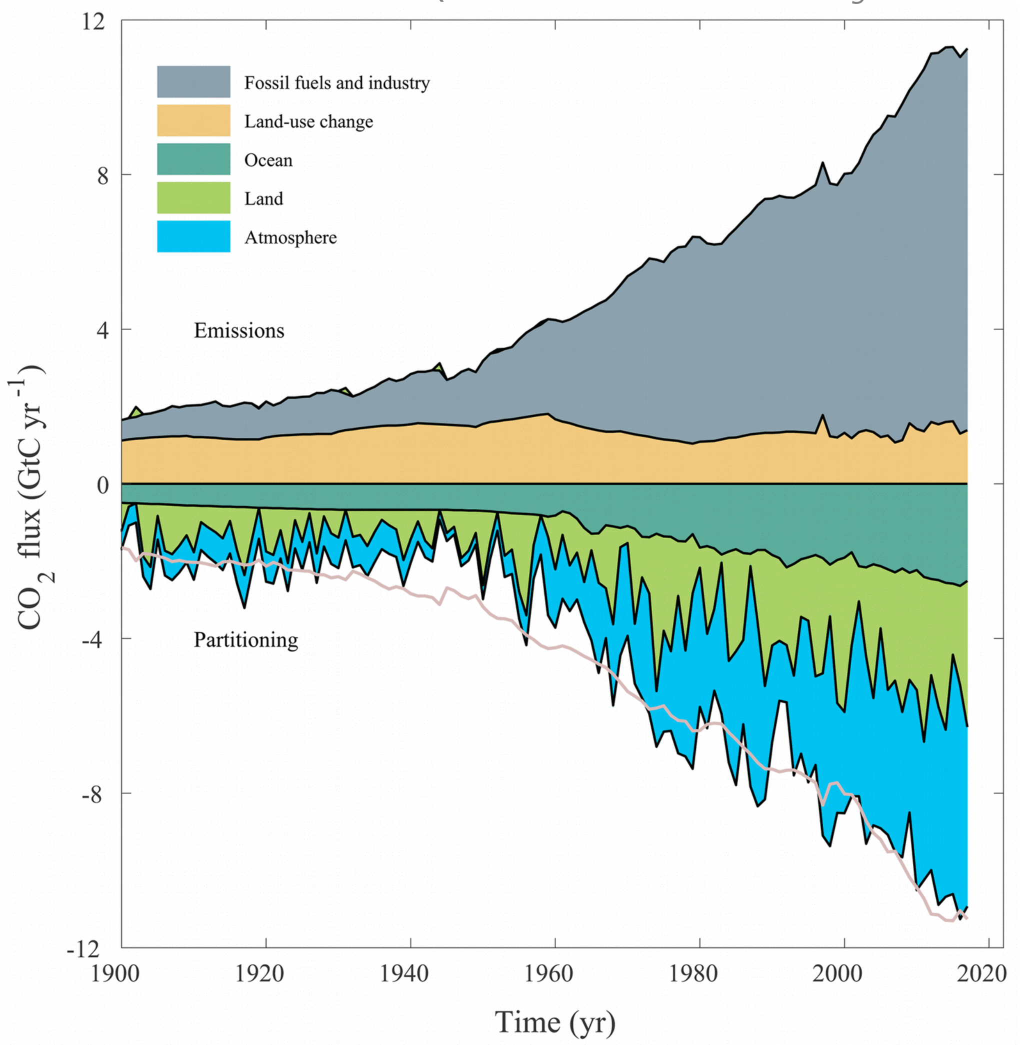
1. Background

- Efforts towards the understanding of the physiological processes regulating mountain forests are crucial to determine **local and global carbon sinks**

- However, the unaccounted presence of **advective CO2 fluxes** at eddy covariance sites, has the potential to bias the daily and longer-term CO2 flux towards **unrealistic net uptake**, a bias that urgently needs to be accounted for, in order to reduce uncertainties related to role of **mountain forests in the global carbon cycle**.

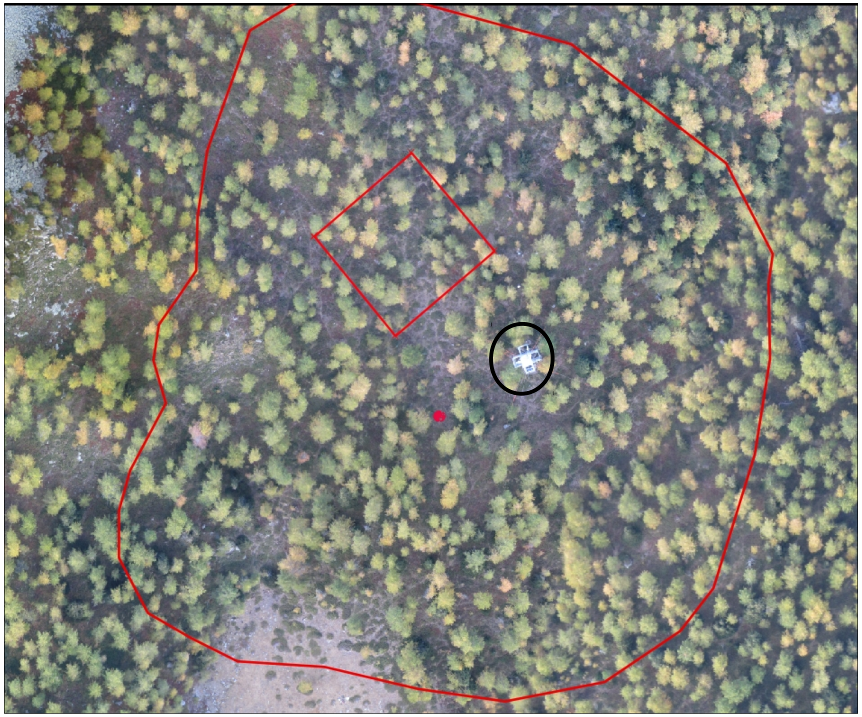
Le Quéré et al.: Global Carbon Budget 2018

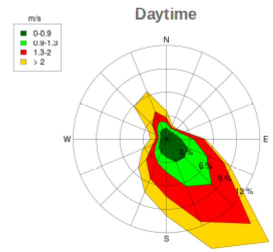


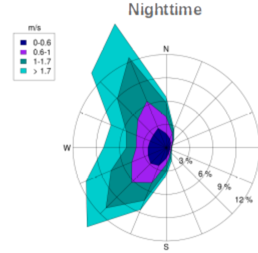
2. Challenges of measuring advection

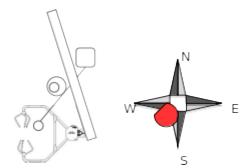
- Instrumental set-up (complex and expensive)
- Short-term studies
- Spatial scale
- CO_2 sink/source heterogeneity
- Winter season (snow covered surfaces?)
- Vertical advection (often highly erratic fluxes)
- Different results depending on ecosystem (flat or complex terrain, tall or short canopies, open or dense canopies)
- Lack of a reference “true” flux

3. Instrumental set-up









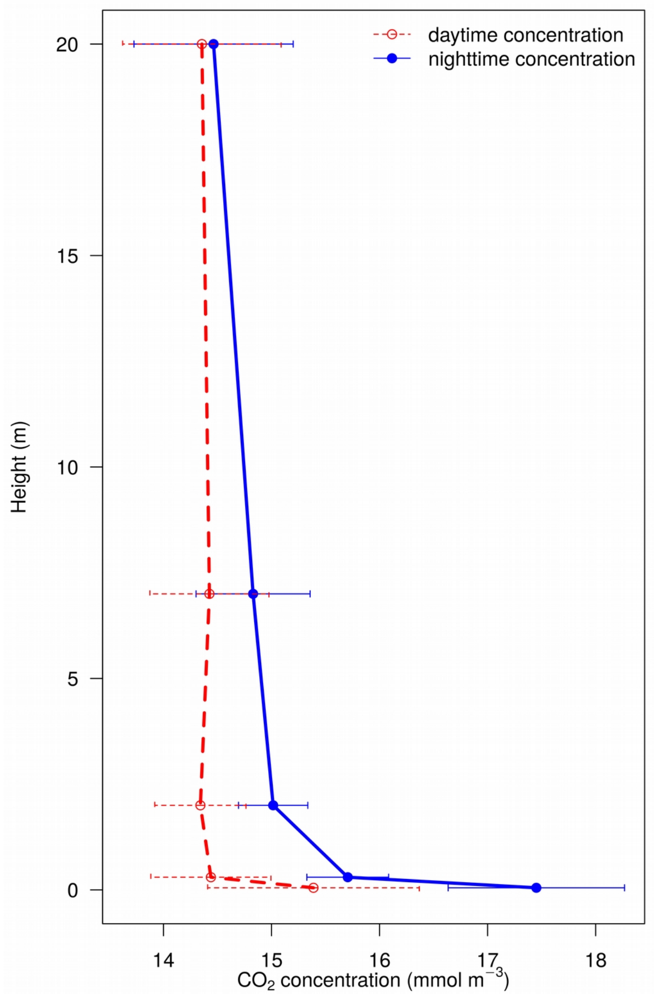
Advection set-up during the field campaign in 2018:

(Left) The black circle shows the **20m EC tower**, the red square the **40x40m advection volume,** the red dot is the location of the **subcanopy EC** system, the red contour represents the **flux footprint** (Xmax 85th percentile)
(Right) **Wind speed and direction** during daytime

(Left) **Multiplexer system** for measuring CO2 concentrations at 3 heights (0.05m, 0.3 m, 2m), **soil chambers** (Zhao 2017 AFM) and
(Right) **EC subcanopy system**

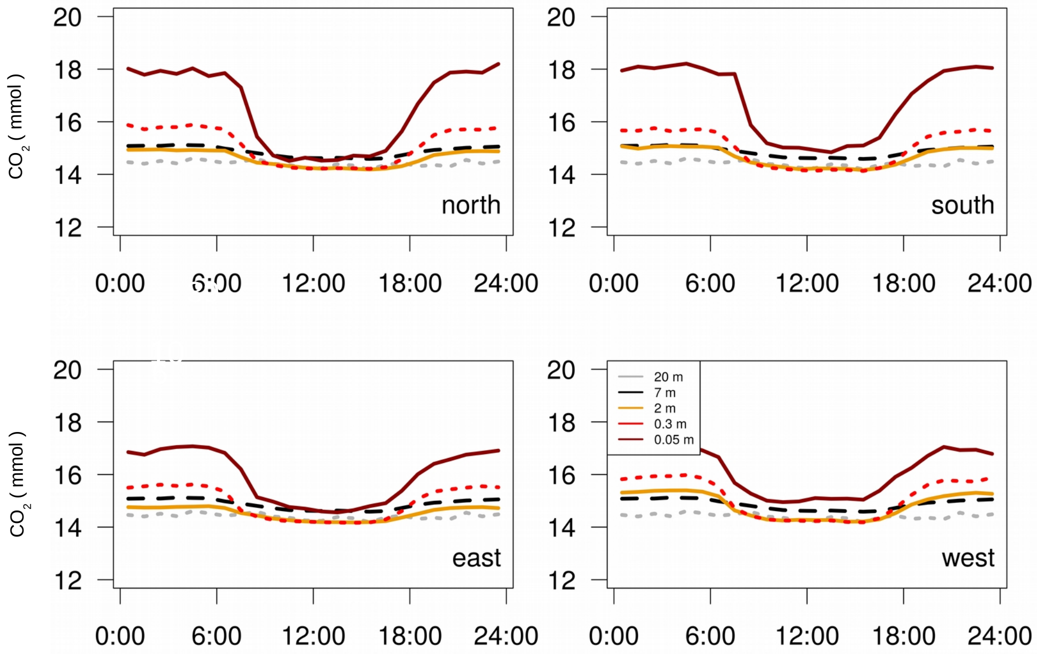
European larch forest (2160 m asl, Torgnon, Italy)

4. Results: Mean diurnal variations of CO_2 concentrations



- The mean CO2 gradients in advective conditions were shown to be limited to the **lowest part of the canopy and nighttime conditions**.

- Uncertainties related to the daytime CO2 gradients are likely due to **spatial variability in the CO2 sink/sources** within the experimental area



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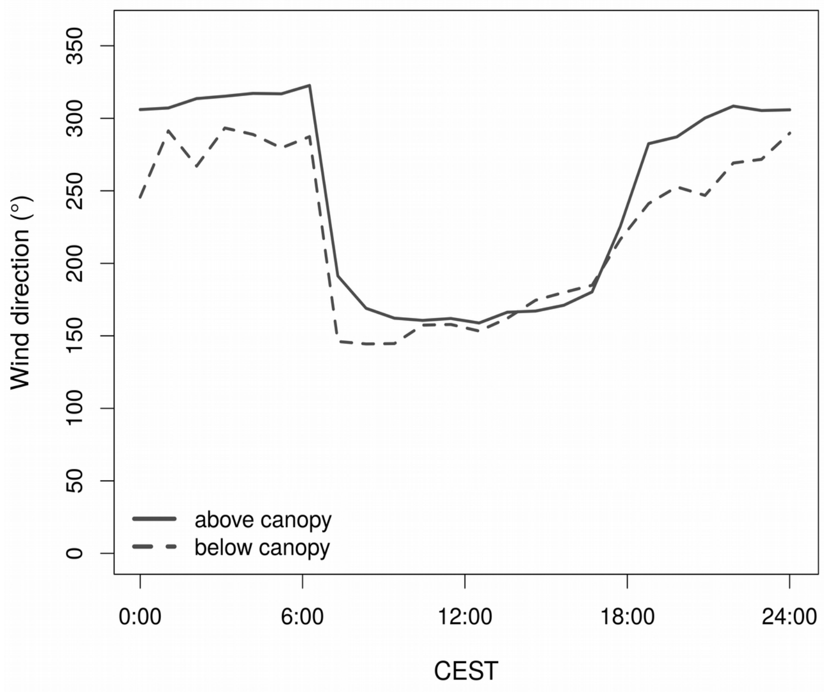
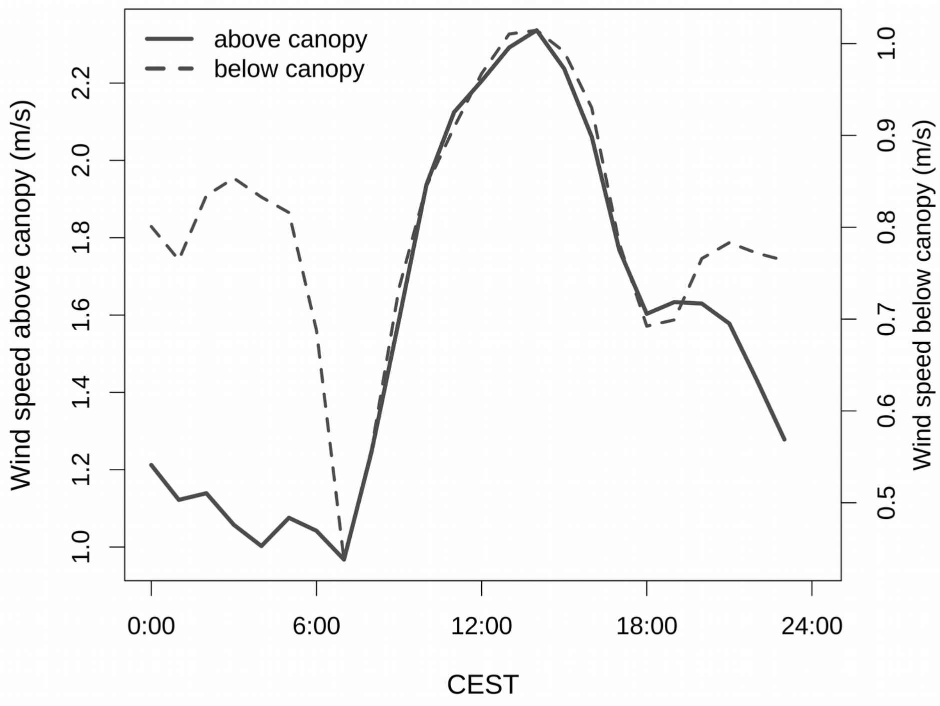
4. Results: Wind speed and direction





- Wind field was **strongly bi-directional** between daytime and nighttime, and directions were **coupled** between above and below canopy

- Wind speed above the canopy showed a strong daily variation compared to subcanopy

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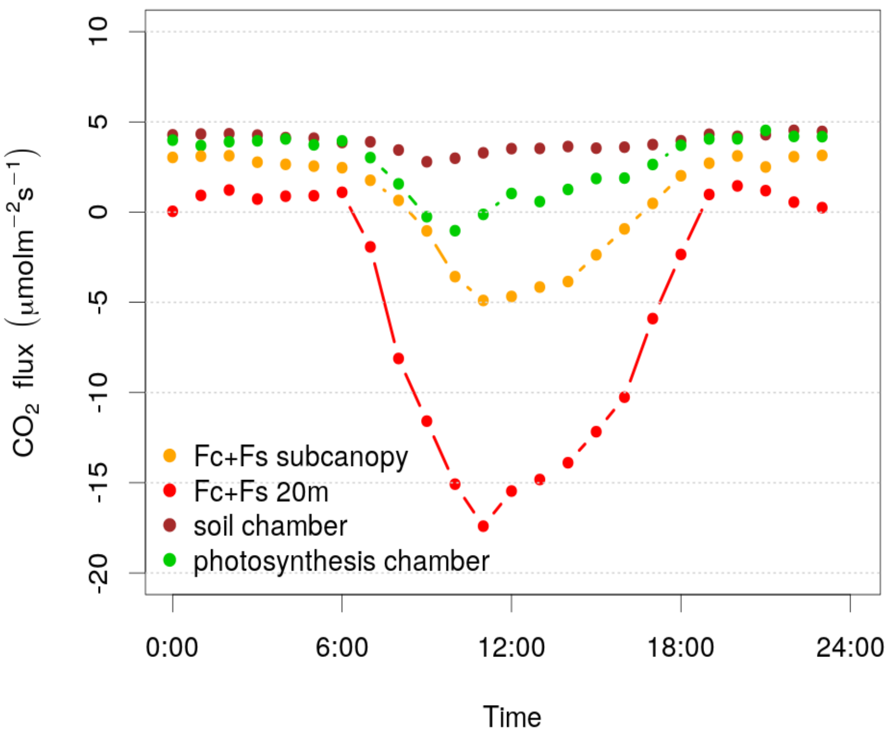
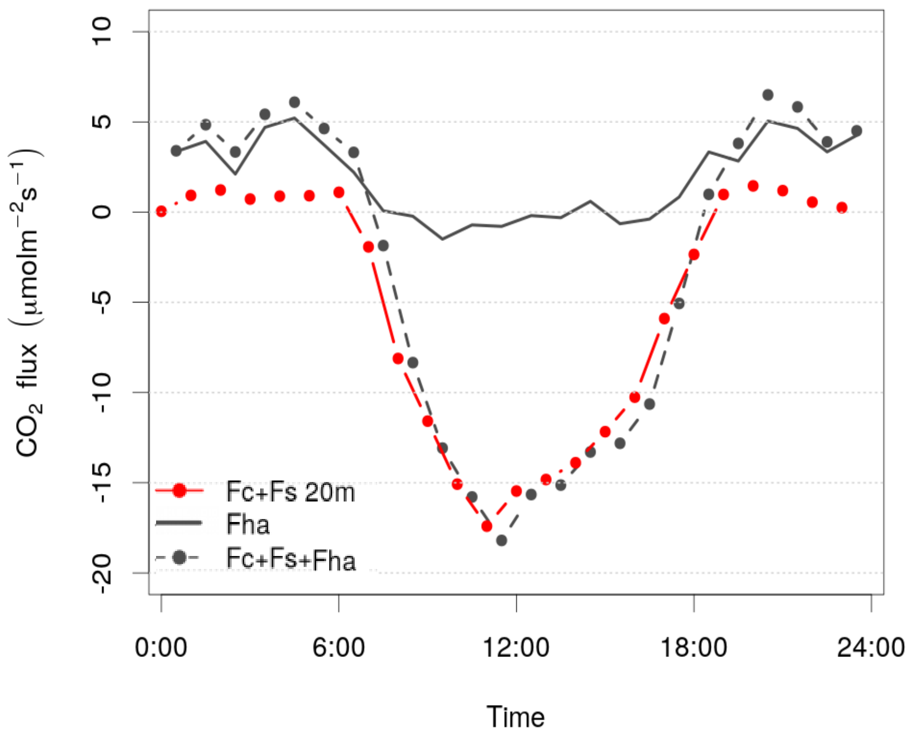
4. Results: Horizontal advection and subcanopy data





- **Nighttime** CO2 flux measured at a single point above the canopy is clearly **underestimated** with values close to zero
- Including the **horizontal advection** term in the CO2 mass balance equation allows to reach **nighttime** values of **NEE at 20m** close to those of respiration chambers and **subcanopy NEE**

NEE=Fc+Fs	***Eddy covariance Net Ecosystem Exchange at single point***
NEE=Fc+Fs+Fha+Fva	***Full CO2 mass balance***
Fc	***Mean vertical turbulent flux***
Fs	***Storage term***
Fha	***Horizontal advection term***
Fva	***Vertical advection term***

Summary and open questions

Eddy covariance measurements of NEE measured above the canopy should be representative of net photosynthesis of vegetation during daytime and of whole ecosystem respiration during nighttime. However, the nighttime NEE measured at a single point above the canopy is clearly underestimated.

- **Opportunities**: as previous studies showed (eg. Etzold et al 2010, Galvagno et al 2017), given the typical local **bi-directional wind system** in **mountains**, information on advective flows at these sites could be easier to detect compared to other terrains.

- Coupling measurements of **above and below canopy eddy covariance** in mountain forest sites seems essential for detecting the unaccounted CO2 flux and for improving carbon budget estimates in **long-term studies**.

- Further analysis will include also **vertical advection** into the mass balance equation, even if this term often results in unrealistic and highly erratic fluxes

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