On the role of advection for the net exchange of CO_2 at a subalpine grassland in complex terrain

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- At most **FLUXNET** sites, the net ecosystem CO_2 exchange is evaluated by means of eddy covariance (EC) using a set of instruments on a single tower.
- **Assumptions**: flat, horizontally homogeneous terrain and stationary conditions.
- **Nighttime problem**: low turbulent mixing, stable stratification, advective fluxes.

  $\rightarrow$ Underestimation of nighttime net CO_2 exchange


Agricultural and Forest Meteorology

Direct advection measurements do not help to solve the night-time CO_2 closure problem: Evidence from three different forests

M. Aubinet, C. Feigenwinter, B. Heinesch, C. Bernhofer, E. Canepa, A. Lindroth, L. Montagnani, C. Rebmann, P. Sedlak, E. Van Gorsel

Boundary-Layer Meteorology (2005) 116: 63–94

COMPARING CO_2 STORAGE AND ADVECTION CONDITIONS AT NIGHT AT DIFFERENT CARBOEUROFLUX SITES

M. AUBINET, P. BERBIGIER, CH. BERNHOFER, A. CESCATTI, C. FEIGENWINTER, A. GRANIER, TH. GRÜNWALD, K. HAVRANKOVA, B. HEINESCH, B. LONGDOZ, B. MARCOLLA, L. MONTAGNANI and P. SEDLAK

Agricultural and Forest Meteorology 130 (2005) 193–206

Importance of advection in the atmospheric CO_2 exchanges of an alpine forest

Barbara Marcolla, Alessandro Cescatti, Leonardo Montagnani, Giovanni Manca, Günther Kerschbaumer, Stefano Minerbi

Biogeosciences Discussions

Contribution of advection to the carbon budget measured by eddy covariance at a steep mountain slope forest in Switzerland

S. Etzold, N. Buchmann, and W. Eugster

THE INFLUENCE OF ADVECTION ON THE SHORT TERM CO_2-BUDGET IN AND ABOVE A FOREST CANOPY

C. FEIGENWINTER, C. BERNHOFER and R. VOGT

AGRICULTURAL AND FOREST METEOROLOGY

A comment on the paper by Lee (1998): "On micrometeorological observations of surface-air exchange over tall vegetation"

John Finnigan

Agricultural and Forest Meteorology 148 (2008) 12–24

Comparison of horizontal and vertical advective CO_2 fluxes at three forest sites

Christian Feigenwinter, Christian Bernhofer, Uwe Eichelmann, Bernard Heinesch, Martin Hertel, Dalibor Janous, Olaf Kolle, Fredrik Lagergren, Anders Lindroth, Stefano Minerbi, Uta Moderow, Meelis Mölder, Leonardo Montagnani, Ronald Queck, Corinna Rebmann, Patrik Vestin, Michel Yernaux, Marcelo Zeri, Waldemar Ziegler, Marc Aubinet

Mass Balance Terms

$$NEE = F_c + F_s + F_{ha} + F_{va}$$

F_c=vertical turbulent flux, F_s=Storage term, F_{ha}=horizontal advection, F_{va}=vertical advection

- Eddy covariance measurements are challenging in non-ideal terrains, where **mountain ecosystems** are often naturally situated.
- No information exist on the role of advection at sites with **short canopies**


Alp Weissentein (Hiller et al 2008)


Renon (Marcolla et al 2005)

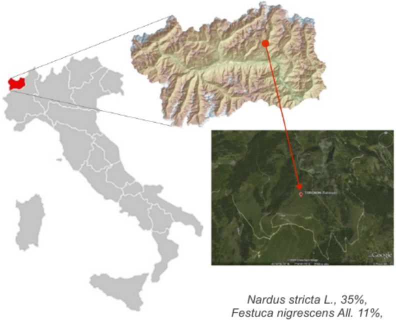

Lageren Forest (Etzold et al 2010)


Torgnon Larch Forest (Migliavacca et al 2008)


Kaserstattalm (Hammerle et al 2007)

Study site

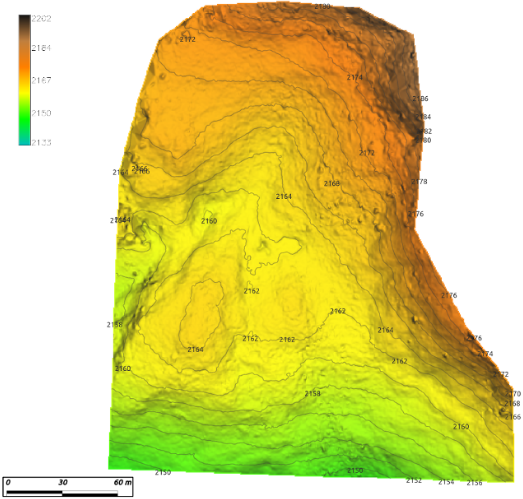
- Torgnon: Northwestern Italian Alps (Aosta Valley)
- Subalpine grassland (2160 m asl)
- EC measurements since 2008
- Maximum canopy height is 20 cm.
- Not located on a steep slope
- **heterogeneous microtopography**

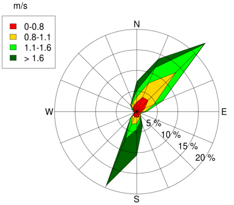


Nardus stricta L., 35%,
Festuca nigrescens All. 11%,
Arnica montana L. 8%,
Carex sempervirens Vill. 5%,
Trifolium alpinum L. 4%




Study site





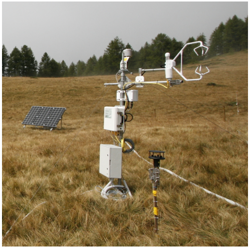
NE winds during nighttime
SSW winds during daytime

DEM 20 cm resolution
Isolines 2 m
Δ elevation $\sim$ 30 m

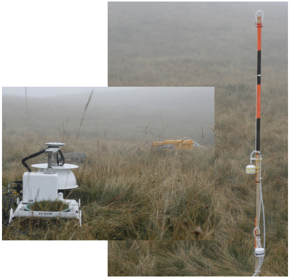
Methods

Four control volumes where sequentially investigated during the growing season 2012:

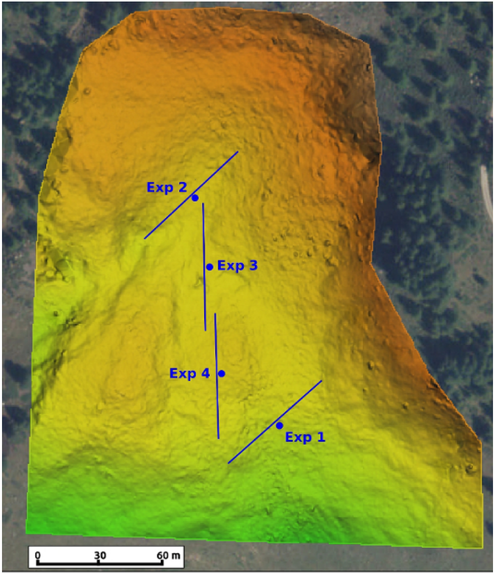
1. Eddy covariance:
- 3D sonic anemometer (CSAT3)
- Open-path IRGA (LI7500)
placed at **1.65 m agl**
- additional 2D anemometer
placed at **0.90 m agl**
- 10 Hz data processed according to commonly accepted procedures
- Planar-fit method (Wilczak et al, 2001)



2. Profiling system and Chambers:
- Two vertical CO_2 profiles
- Three measurement levels each (0.30, 0.80, 1.65 m agl)
- 30 meters uphill and downhill the EC tower along the different transects
- Three ecosystem respiration automated chambers (LI8100, LICOR)



Experimental scheme



Data processing: mass balance terms

Eddy flux

$$F_c = \overline{\rho_a}\ \overline{w'c'}$$

Storage term

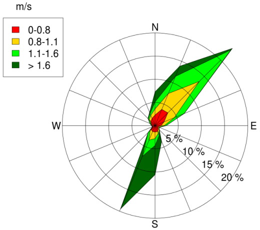
$$F_s = \int_0^{1.65} \frac{\partial \overline{c}}{\partial t} dz$$

Horizontal advection

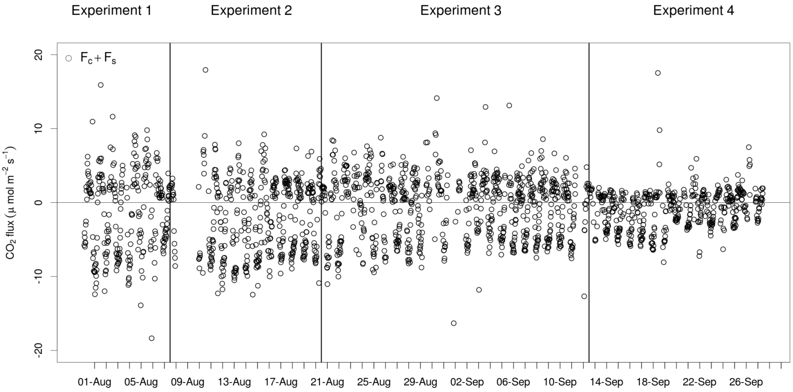
$$F_{ha} = \int_0^{1.65} \overline{u}(z) \frac{\partial \overline{c}(z)}{\partial x} dz$$

Vertical advection

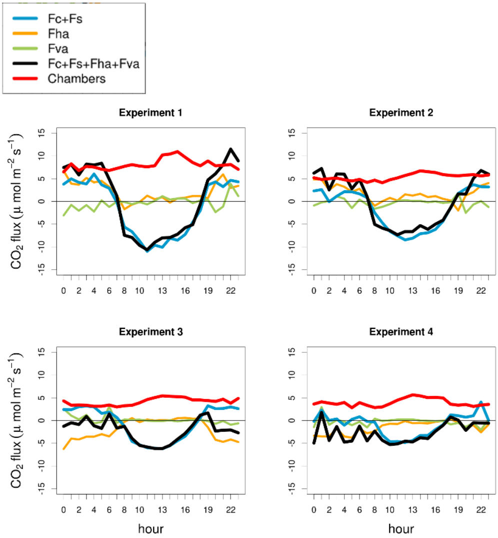
$$F_{va} = \overline{w}_{h1.65}(\overline{c}_{h1.65} - [\overline{c}])$$

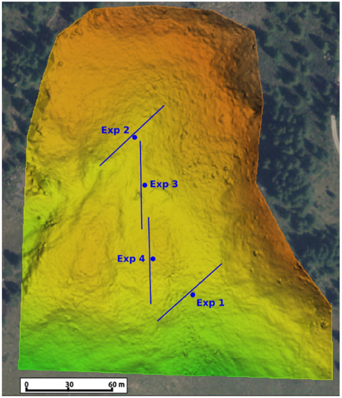


Results: Eddy fluxes

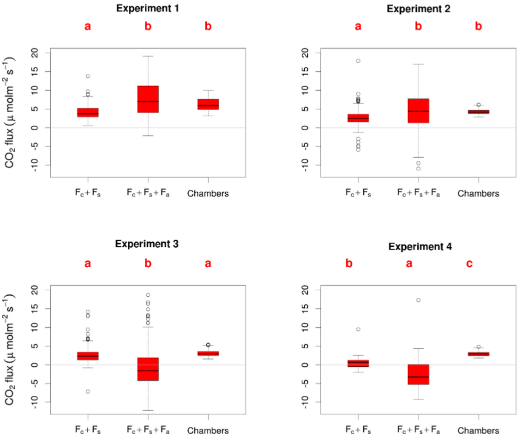


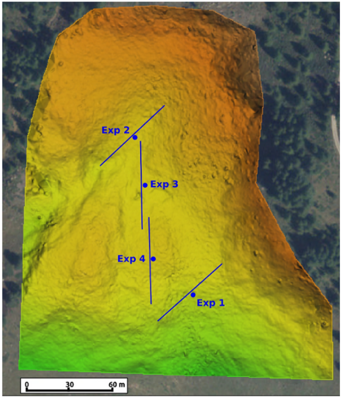
Results: mass balance terms - mean diurnal variation



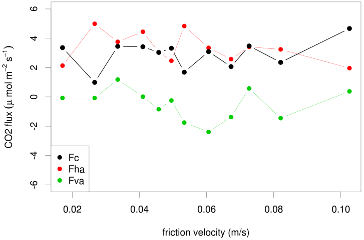


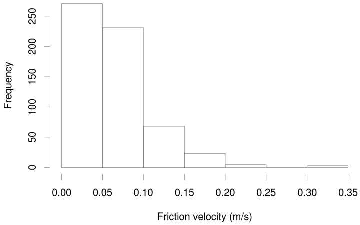
Results: mass balance terms - nighttime values





How to correct the nighttime problem?





It was not possible to identify an objective friction velocity threshold

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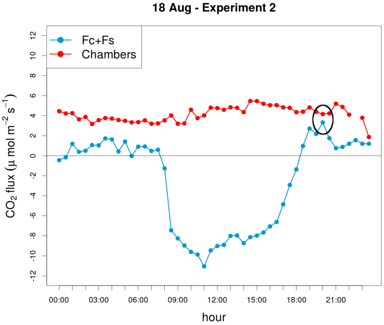
Alternative solutions

1. Using data when the maximum of F_c+F_s is observed in the **evening** to develop relationships between NEE and independent variables, such as soil temperature (Van Gorsel et al 2007)



2. To add a constant advective offset to F_c+F_s
3. It appears that there are places, even in this kind of complex topography, where F_c+F_s captures most of **the actual nighttime respiration** (e.g. control volume 3).

Conclusions

The main findings of this study are:

1. F_c+F_s considerably underestimates nighttime ecosystem respiration as measured by the automated ecosystem chambers.
2. Advection measurements indicate that horizontal, and to a lesser degree, vertical advection are important terms of the full mass balance during nighttime at the grassland site. During daytime advection appears to play a negligible role.
3. The NEE calculated by taking into account advection generally closely resembles nighttime ecosystem respiration as measured with chambers.
4. For two of the control volumes the order of magnitude of NEE computed with the mass balance approach ($F_c+F_s+F_{ha}+F_{va}$) was not compatible with biotic fluxes measured by respiration chambers (as previously described for other sites e.g. Aubinet et al 2010).
5. Ongoing work: testing the best correction approach
6. future 3D Experiments are planned to improve advection measurements.

THANKS FOR YOUR ATTENTION

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