Geophysical Research Abstracts, Vol. 9, 10037, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-10037

A new methodology for estimating CO_2 advective fluxes in complex topography: the mass – consistent approach

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A key problem in using the eddy correlation (EC) technique for estimating the carbon budget of terrestrial ecosystems is the potential bias caused by advective fluxes of CO_2. Advective fluxes are often not considered because are difficult to identify and to quantify, especially in complex mountainous terrain with highly variable wind patterns and drainage flows. We propose a methodology to estimate these fluxes based on a full 3D experimental approach implemented at the topographically complex alpine forest site of Renon (1736 m a.s.l., canopy height 32 m). The measurements at Renon were carried out during 2005 in the framework of the CarboEurope-IP activity 1.2, co-ordinated by Marc Aubinet, on advective fluxes; they were consisted of vertical profiles of wind, air temperature and CO_2 concentration measured at five masts in order to get the full 3D resolution of airflows and concentration fields in the study area.

We applied an 3D-Eulerian approach for calculating the mass balance of a scalar (e.g. CO_2) in a control volume containing the forest ecosystem. This approach is based on wind vector modelling inside the grid cells within the control volume. The wind field is modelled using the WINDS code developed at the Department of Physics of the University of Genoa (Italy). It is a diagnostic mass-consistent model to reconstruct the 3D wind field in complex terrain using available wind data.

Overall CO_2 advective fluxes were calculated on the basis of interpolated 3D wind fields, 3D air densities and CO_2 concentration fields, using the equation that describes

the scalar flow crossing a closed surface. Fluxes calculated with this approach were validated with measured soil CO_2 fluxes and turbulent fluxes above the canopy.

Applying this 3D-Eulerian mass consistent approach and correcting EC-fluxes by advective fluxes, we were able to show that calculated night-time fluxes got closer to the fluxes observed with independent methods. The accuracy of this method for calculating advective fluxes depends on the spatial representativeness of the measuring set-up. In addition, the approach presented here needs to be tested for longer time periods and for different forest ecosystems.

The majority of forests is growing in complex terrain. Our approach may help to better understand limitations of the EC method, to develop tools for correcting EC measurements with regard to advection and storage, and to achieve more reliable and more representative carbon balances of forests.