CO_2 TRANSPORT OVER COMPLEX TERRAIN

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ABSTRACT

The carbon dioxide transport at the Niwot Ridge AmeriFlux site was investigated in both gravity and streamline coordinates. For this forested site with a 6% slope, both nighttime drainage flow and daytime upslope flow played important roles in the CO_2 budget. Both the CO_2 respiration at night and the CO_2 uptake during the day are underestimated if the horizontal transport of CO_2 is not monitored; and the two components may not cancel out.

INTRODUCTION

Because the long-term CO_2 budget over terrestrial ecosystems relies on small differences between the CO_2 uptake by the ecosystem, and anthropogenic and natural CO_2 release, accurate measurements of CO_2 transport are crucial for climate-change studies. Currently there are hundreds of towers worldwide dedicated to monitoring the long-term CO_2 balance over various surface types by measuring time variations of vertical transport of CO_2 and CO_2 profiles at single towers. The significance of the horizontal CO_2 transport has only now begun to draw the attention of the biogeoscience community [*Sun et al.,*1998; *Aubinet et al.,* 2003; *Staebler and Fitzjarrald,* 2004; *Finnigan*, 2004].

OBSERVATIONS

The Niwot Ridge pilot experiment was conducted at the Niwot Ridge AmeriFlux forest site in the Rocky Mountains of Colorado during September 2002. Four 10-m towers were instrumented to supplement the two existing towers operated by the University of Colorado (CU) and the U.S. Geological Survey (USGS) [*Monson et al.,* 2002; *Turnipseed et al.,* 2002; *Anderson et al.,* 2005]. Three levels of wind and four levels of CO_2 were measured at three of the four supplemental towers. CO_2 concentration was measured by a centralized CO_2 analyzing system, Hydra, which consisted of two LiCor-7000 analyzers and 18 inlets with two calibration gases.

RESULTS AND DISCUSSIONS

The canopy flow was decoupled from the air above. At night the flow was stable everywhere but less stable within than above the canopy; while during the day, the air was mostly stable within the canopy layer, especially near the bottom of the canopy, and the layer above was unstable. The flow within the canopy was dominated by drainage and upslope flows while the air above was dominated by prevailing westerlies during the pilot experiment. In general the slope flow depends on the thermal gradient generated by the orography and large-scale flow. Under weak large-scale flow and summer conditions, both drainage flow and upslope flows can be strong and extended above the canopy layer. Protected by the overlying canopy, the drainage flow was responsible for transporting CO_2 at night while the stable layer above the canopy prevented upward CO_2 transport. The drainage flow was sensitive to the atmospheric stability and was normally confined below the maximum leaf-density level. Turbulent mixing due to wind gusts at night sometimes penetrated the canopy layer and eliminated creek-ward drainage flows, while the drainage flow associated with the large-scale slope survived the mixing. In the early morning, as the sun rose, the temperature increased fastest at the maximum leaf-density level, the air became unstable above it and remained stable below it. On average, there was a surge of CO_2 and water vapor for about two hours in the early morning, which was well correlated with the wind direction switch from downslope to upslope. The upslope flow transported the nighttime accumulation of moist and CO_2-enhanced air up the slope. The sharp reduction of the CO_2 concentration in the early morning was associated with photosynthesis, upslope flow, and flux venting above the upper canopy layer. The daytime stable boundary layer within the canopy prevented CO_2 venting and provided favorable conditions for CO_2 uptake, where the CO_2 concentration was relatively high from both local and remote respiration, and both direct and diffuse solar radiation were available for photosynthesis.

The magnitudes of advection and turbulent eddy fluxes are subject to the coordinates used. The commonly used streamline coordinates are sensitive to prevailing wind and the time period used for establishment of the coordinates. Fixed gravity coordinates as well as the streamline coordinates were used to investigate contributions of all the CO_2 transport terms in the CO_2 budget. Both horizontal and vertical advections of CO_2 were found to dominate the CO_2 budget especially under weak-wind night conditions, except during the daytime when the vertical turbulent transport of CO_2 was strong.

SUMMARY

Estimating of the net ecosystem exchange (NEE) is a challenging multi-disciplinary problem. Three-dimensional transport of CO_2 plays a crucial role in estimating NEE, which could be a small residual of all the transport terms in a fully dynamic system. Topography could induce not only the thermal gradient which drives upslope and downslope flows, but also the pressure gradient which accelerates/decelerates large-scale flows. The topography effect, maybe to a lesser degree, occurs even over a seemlingly locally flat terrain. In addition, surface heterogeneity also induces local circulations, which contributes to CO_2 transport. Missing one of the important transports in the CO_2 budget---its horizontal transport would underestimate not only the nighttime CO_2 respiration but also the daytime CO_2 uptake, resulting significant errors on long-term CO_2 observations.

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