MODELING ATMOSPHERIC CO_2 CONCENTRATION PROFILES AND FLUXES ABOVE SLOPING FORESTED TERRAIN

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ABSTRACT

CO_2 profiles were simulated in the atmospheric boundary layer above sloping terrain using a three dimensional transport model coupled with a vegetation sub-model. WMO/GAW concentration monitoring site and ecosystem flux measurement site were located inside the modeled region at the top of a hill and at boreal forest, respectively. According to model results, the concentration measurement at hill site was representative for continental background. However, concentration at few meters above active vegetation represented mainly local variation. Concentration difference between hill site and forest site was about 5 ppm during afternoon according to both model and measurements. The hill site was above boundary layer during night and inside boundary layer during daytime. The regional CO_2 signal dominated in both cases. The average flux to the whole model region was about 40 % of the local flux at the forest site.

INTRODUCTION

Concentration results from atmospheric CO_2 transport models are compared to measurements, which are often performed above sloping or mountainous terrain. Small scale transport models become especially useful in these conditions, because due to high resolution they can solve transport patterns better above complex terrain. Connecting the model boundaries to a regional or global transport model makes the system compatible in larger scale. In the current study performance of a local scale model is examined at the topographically complex Pallas region, where concentrations of CO_2 are measured at two separate sites located in different altitudes together with ecosystem flux measurements. The results will help in explaining the regional model results for the concentration measurement site and also in examining the possibilities for low altitude concentration monitoring.

MATERIALS AND METHODS

The Pallas region is characterized by arctic hills, mixed forest (Scots pine, Norway spruce, downy birch) and patches of wetlands and lakes. The main concentration measurement site for CO_2 is located at the treeless top of Sammaltunturi hill (67°58'N, 24°07'E, 565 m a.s.l.). The measurement is precision-calibrated according to WMO/GAW guidelines [see *Hatakka et al.*, 2003]. Concentrations are also monitored and fluxes measured by eddy covariance method above forested plateau (330 m a.s.l.), at about 5 km distance from Sammaltunturi.

A 3d model was built to describe the boundary layer above the sites. Site topography and land cover data from Finnish Land Survey were inserted to the model, and a tetrahedral grid was constructed. The resolution of the grid was 50 m and extents of the domain 10×10km. Exchange of CO_2 by forest was modeled using a 4-layer canopy model. Concentrations and surface CO_2, H_2O and heat fluxes were solved using commercial fluid dynamics simulation software FLUENT© utilizing finite element methodology. Inputs at the model boundary were obtained from ECWMF MARS database and inputs for CO_2 from regional transport model REMO [*Chevillard et al.*, 2002].

RESULTS

Simulations were performed over one clear summer day (July 22, 1998) with moderate wind conditions. Flow over hills changed profiles of environmental variables and height of boundary layer, however clear signs of heat exchange related phenomena, such as formation of mountain breeze, were not observed.

Diurnal profiles of CO_2 were significantly different at the hill site and at the forest site (Fig. 1). The original boundary input from a regional model with smaller vertical resolution is shown in the same figure, indicating that the profiles at the hill top follow the boundary forcing closely, while concentrations at forest site deviate at the lowest levels. During night the surface concentration at the forest site was about 2 ppm higher than at the hill top. Between 3 and 4 UTC respiration turned into assimilation, and the lowest level CO_2 concentration decreased close to the hill top values. During daytime the concentration at the forest site was about 5 ppm lower than at the hill site, reflecting the effects of the photosynthetical sink in the forest. Later during afternoon concentration at the forest site started to increase and between 16 and 18 UTC it increased to higher values than concentrations at the hill top. At night the mixing layer height was lower than 500 m a.s.l., well below the hill site. In the morning the mixing layer height started to increase and it passed the hill top level roughly between 6 and 9 UTC. The input from the boundary dominated the CO_2 signal at the hill top at all times of the day. Thus, the regional scale concentration signal can be observed at the hill top and most probably the signal can also be observed at the flux site, if the distance to the canopy is sufficient.

It is known from chamber experiments, that there exists a small sink of CO_2 at the hill top due to mosses, lichens and small sedges that grow in the rocky ground. This small flux, less than 2% from the assimilation rates measured at the forest site, did not have significant effect on the modeled CO_2 profile at the hill top. Forest CO_2 fluxes were simulated with the vegetation model and compared to eddy covariance measurements. Results were in good agreement at the forest site, suggesting that the simulations can be used to predict areal averages of fluxes. The average flux to the whole model domain was about 40% of the flux at forest site during active daylight hours, resulting from the fact that the flux site was constructed on a dense forest belonging to the highest flux class in the model.

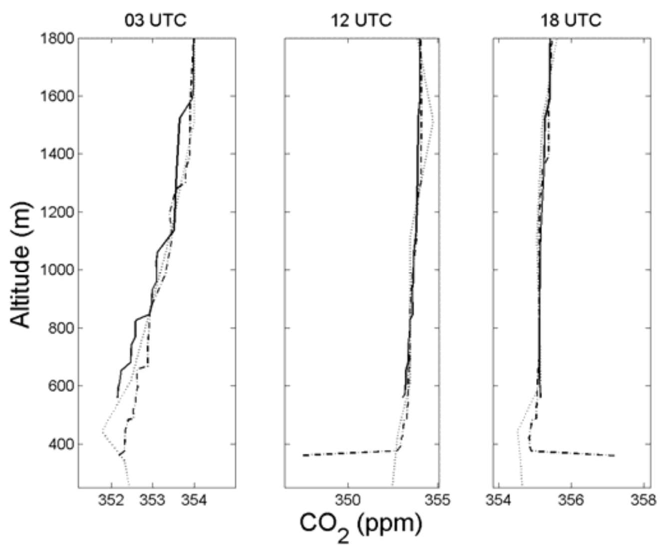

Fig. 1. Modeled profiles of CO_2 at hill site (solid line) and forest site (dashed line), and boundary input (dotted line).

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