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The influence of vegetation and relief heterogeneity on turbulent exchange of CO_2 between land surface and the atmosphere

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The possible effect of spatial heterogeneity of vegetation cover and relief on horizontal and vertical turbulent exchange of CO_2 was described using a process-based two-dimensional (2D) turbulent exchange models (Mukhartova et al. 2015). As a key area for this modeling study the hilly territory situated at the boundary between broadleaf forest and steppe zones in European part of Russia (Tula region) was selected. The vegetation cover in the study region is represented by complex mosaic of crop areas, grasslands, pastures, mires and groves. The very heterogeneous vegetation cover and complex dissected relief make very difficult an adequate determining the local and regional CO_2 fluxes using experimental methods only.

The two-dimensional model based on solution of the Navier–Stokes and continuity equations using well-known one-and-a-half order (TKE) closure scheme is applied. For description of the plant canopy photosynthesis and respiration rates the model uses an aggregated approach based on the model of Ball et al (1987) in Leuning modification (1990, 1995), the Beer-Lambert equation for the description of solar radiation penetration within a plant canopy (Monsi, Saeki 1953), and also an algorithm describing the response of stomatal conductance of the leaves to incoming photosynthetically active radiation. All necessary input parameters describing the photosynthesis and respiration properties of different plants and soil types in the study region were measured in the field or taken from the literature.

The system of differential equations in the model is numerically solved by the finite-difference method. It is assumed that the influence of ground surface heterogeneities at the upper boundary of computing domain is very low and the pressure excess can be therefore considered as zero. The concentration of CO_2 at the upper boundary of computing domain is assumed to be equal to some background value. It is also assumed that all boundaries between different vegetation and land-use types are situated far enough from the domain boundaries. It enabled us to assume that near these boundaries the values of vertical and horizontal wind components are independent on x coordinate.

To quantify the possible effects of relief and vegetation heterogeneity on CO_2 fluxes the three transects crossing the study area were chosen. For each transect the 2D patterns of wind speed components, turbulent exchange coefficients, CO_2 concentrations and fluxes were calculated. The modeled vertical CO_2 fluxes were compared with the fluxes calculated without allowing for turbulent disturbances due to relief and vegetation heterogeneity. All modeling experiments were provided for different weather conditions.

The results of modeling experiments for different transects under various meteorological conditions showed that relief and vegetation heterogeneity have a significant impact on CO_2 fluxes within the atmospheric surface layer and their ignoring can results in uncertainties in flux estimations.

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