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Effect of spatial vegetation and relief heterogeneity on vertical CO_2 fluxes between land surface and the atmosphere

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The main goal of the study is to describe the influence of spatial vegetation and relief heterogeneity on turbulent CO_2 fluxes between land surface and the atmosphere using a process-based two-dimensional turbulent exchange models. As a key area for this modeling study the hilly territory situated at the southern boundary of broadleaf forest community in European part of Russia (Tula region) was selected. The vegetation cover in the study region is mainly represented by mosaic of agricultural areas, grasslands, mires and groves that makes very difficult an adequate determining the local and regional CO_2 fluxes using experimental methods only.

Applied two two-dimensional models based on solution of the Navier–Stokes and continuity equations using the first-order and one-and-a-half order (TKE) closure schemes. Numerical scheme of the first-order closure model is based on the theory of contrast structures (Levashova et al 2005). For description of the plant canopy photosynthesis and respiration rates 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 is used.

All necessary input parameters describing the photosynthesis and respiration properties of different plants and soil types in the study region were obtained from the field measurements or taken from the literature.

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 both for actual vegetation structure and for additional scenario assuming the total area deforestation. All modeling experiments were provided for different combinations of incoming solar radiation, air temperature, wind speed and directions.

The modeling results provided by both models for different transects and 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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