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Carbon and nitrogen emissions due to vegetation fire in Russia in 2004-2008

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The paper presents estimates of the emissions of major greenhouse gases (CO_2, CO, CH_2, N_20, NO_x, and others) caused by vegetation fires in Russia between 2004-2008. Major goals of the assessment were: (1) to provide spatial and temporal quantification of the emissions on a monthly basis; and (2) to minimize the uncertainties of the assessment, taking into account the fuzzy character of the problem. A hybrid land cover (LC) developed as a baseline dataset of all relevant information sources (different maps, multi-sensor remote sensing data, results of different land and forest inventories, measurements *in situ*) was used as an information background for the assessment. The multilayer hierarchical classification of land classes allowed detailed parameterization of vegetation and surface soil layers with respect to indicators used in the calculation of fire emissions. The approach resulted in a comprehensive numerical description of stock and structure of vegetation combustibles (e.g., for forests: stem wood, branches, foliage, understory, green forest floor, coarse woody debris – snags, logs, dry branches of live trees, on-ground litter, organic matter of the upper soil layer) for each 1 km pixel. Burnt areas were estimated on a monthly basis by remote sensing data (mostly based on thermal channels of AVHRR and MODIS, data obtained by Sukachev Institute of Forest, Krasnoyarsk, Russia) and superimposed with the LC. The modeling framework included regional regularities of (1) long period seasonal distribution of burnt areas by type of fire (five types have been used for forests: crown, superficial ground, stable ground, peat (soil), underground fires); (2) average intensity of burning (amount of consumed combustibles) dependently on time of fire season, type of fire, and vegetation class; (3) partition of consumed carbon (gas composition, particles); (4) content of nitrogen in major types of combustibles; (5) expected amount of post fire dieback in perennial vegetation; and others. Intensity of fire was corrected based on average monthly weather conditions. Amount of emitted nitrogen was estimated based on its proportion to carbon by types of combustibles. Gas composition was estimated based on published results of measurements. The results obtained indicate high variability of emissions by land classes, type of fire, time of fire season, specifics of weather with overall consumption of combustibles over the country in the range 140 to 330 Tg C $year^{-1}$ for the period under the study. On average, the uncertainty of the annual emissions was estimated at the level of about 20% (CI 0.9) assuming that the empirical models used have no substantial bias.