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An ensemble approach to simulate CO2 emissions from natural fires

Eliseev A., Mokhov I., Chernokulsky A.

Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

This paper presents ensemble simulations with the global climate model developed at the A. M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences (IAP RAS CM). These simulations are forced by historical reconstructions of concentrations of well-mixed greenhouse gases (CO2, CH4, and N2O), sulfate aerosols (both in the troposphere and stratosphere), extent of crops and pastures, and total solar irradiance for AD 850-2005 (hereafter all years are taken as being AD) and by the Representative Concentration Pathway (RCP) scenarios for the same forcing agents until the year 2300. Our model implements GlobFIRM (Global FIRe Model) as a scheme for calculating characteristics of natural fires. Comparing to the original GlobFIRM model, in our implementation, the scheme is extended by a module accounting for CO2 release from soil during fires. The novel approach of our paper is to simulate natural fires in an ensemble fashion. Different ensemble members in the present paper are constructed by varying the values of parameters of the natural fires module. These members are constrained by the GFED-3.1 data set for the burnt area and CO2 release from fires and further subjected to Bayesian averaging. Our simulations are the first coupled model assessment of future changes in gross characteristics of natural fires. In our model, the present-day (1998-2011) global area burnt due to natural fires is (2.1 ± 0.4) × 106 km2 yr^{-1} (ensemble mean and intra-ensemble standard deviation are presented), and the respective CO2 emissions to the atmosphere are (1.4 ± 0.2) Pg C yr^{-1}. The latter value is in agreement with the corresponding GFED estimates. The area burnt by natural fires is generally larger than the GFED estimates except in boreal Eurasia, where it is realistic, and in Australia, where it is smaller than these estimates. Regionally, the modelled CO2 emissions are larger (smaller) than the GFED estimates in Europe (in the tropics and north-eastern Eurasia). From 1998-2011 to 2091-2100, the ensemble mean global burnt area is increased by 13% (28%, 36%, 51%) under scenario RCP 2.6 (RCP 4.5, RCP 6.0, RCP 8.5). The corresponding global emissions increase is 14% (29%, 37%, 42%). From 2091-2100 to 2291-2300, under the mitigation scenario RCP 2.6 the ensemble mean global burnt area and the respective CO2 emissions slightly decrease, both by 5% relative to their values in the period 2091-2100. In turn, under scenario RCP 4.5 (RCP 6.0, RCP 8.5) the ensemble mean burnt area in the period 2291-2100 is higher by 15% (44%, 83%) than its mean value, and the ensemble mean CO2 emissions are correspondingly higher by 9% (19%, 31%). The simulated changes of natural fire characteristics in the 21st-23rd centuries are associated mostly with the corresponding changes in boreal regions of Eurasia and North America. However, under the RCP 8.5 scenario, the increase of the burnt area and CO2 emissions in boreal regions during the 22nd and 23rd centuries is accompanied by the respective decreases in the tropics and subtropics.

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