Estimates of contemporary natural carbon dioxide fluxes in Russia and their uncertainties based on CMIP6 ensemble data

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A detailed and comprehensive analysis of the impact of changes in the carbon cycle in the Earth's climate system requires, among other things, adequate consideration of the carbon balance of boreal forests, wetlands and other ecosystems. It has previously been shown that natural carbon dioxide fluxes on the territory of Russia can change significantly at the scale of decades in model experiments [1], which can lead to changes in the role of natural terrestrial ecosystems in global climate change.

To understand the ability of current global climate models to adequately reproduce natural carbon dioxide fluxes we analyzed data from global climate models of the CMIP6 project, designed for multi-model assessments. Such multi-model results can provide some perspective on errors and uncertainty in model simulations.

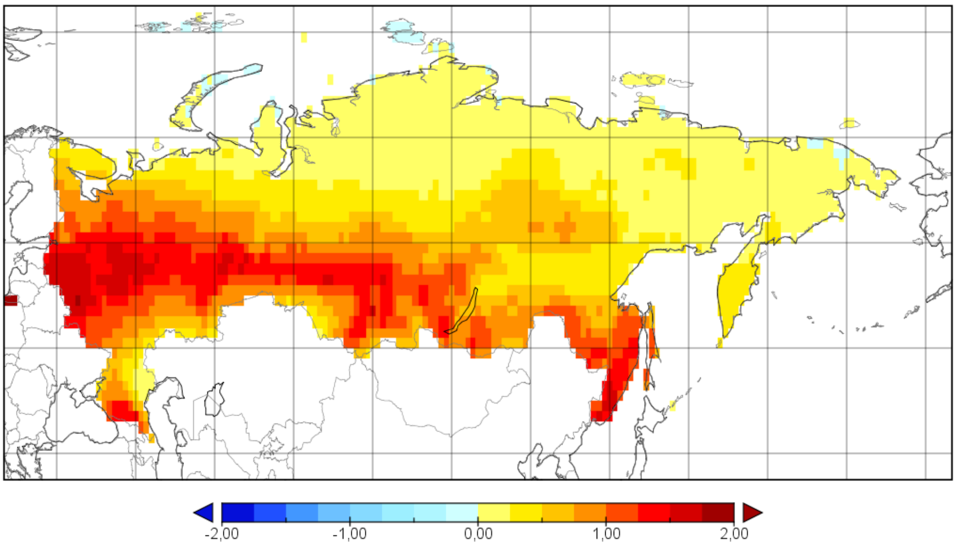

Figure 1. Ensemble mean annual uptake [μg s^{-1} m^{-2}] of carbon dioxide from the territory of Russia.

The end of the "historical" calculation period (1990-2014) was chosen for the analysis. The data from 18 models were considered, most of which had several variants with different initial conditions. Figure 1 shows the average spatial distribution of ensemble mean annual CO_2 fluxes in 1990-2014 over the ensemble of models, obtained by interpolating data from all models on a 1x1-degree grid. The main amount of carbon dioxide is absorbed on the European territory of Russia and in general in the western and southern regions of the country, excluding areas adjacent to Kazakhstan and the Caspian Sea. The net absorption of CO_2 at a rate of 0.5 - 2 μg s^{-1} m^{-2} is characteristic for almost the entire territory, except for some Arctic regions.

At the same time, the standard deviation of CO2 fluxes on the annual mean scale (Fig. 2) is generally all over Russia except for Primorsky Krai exceeding the corresponding mean with typical values of 1-2 μg s^{-1} m^{-2}. Total annual carbon dioxide uptake by Russian terrestrial ecosystems amounts to 0.37±0.38 PgC.

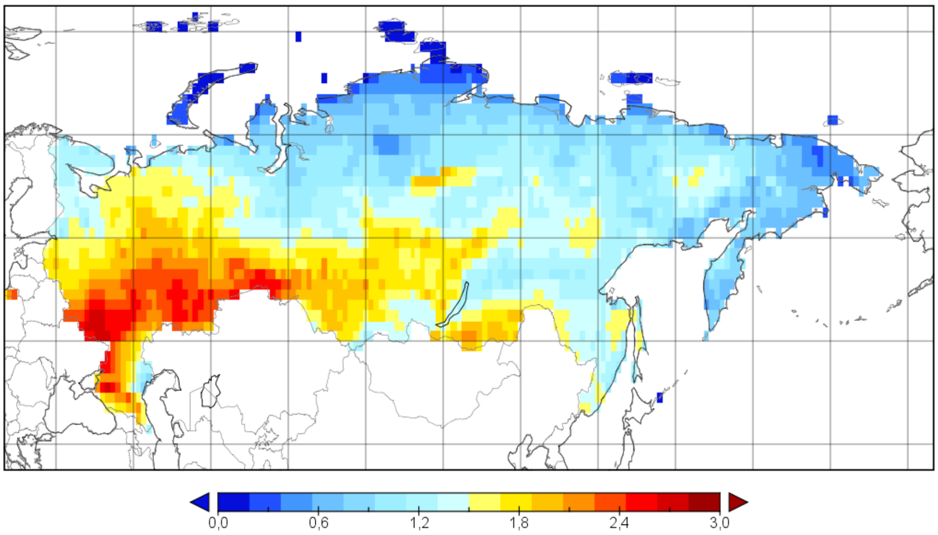

Figure 2. Standard deviation of CO_2 annual flux [$\mu g\ s^{-1}\ m^{-2}$] from the territory of Russia.

Such inter-model discrepancy can also be seen on the average monthly scale (Fig. 3). While most models show maximum CO_2 uptake in July, August and September, the BCC-CSM2-MR model and 3 models of the EC-Earth3 family show a significant decrease in uptake by this point. For the BCC-CSM2-MR model, the maximum CO_2 emission into the atmosphere is reached in the late summer and early autumn. This probably makes the BCC-CSM2-MR the only model that consistently shows negative values (-0.67 PgC on average) of CO2 uptake by terrestrial ecosystems in Russia over the considered period.

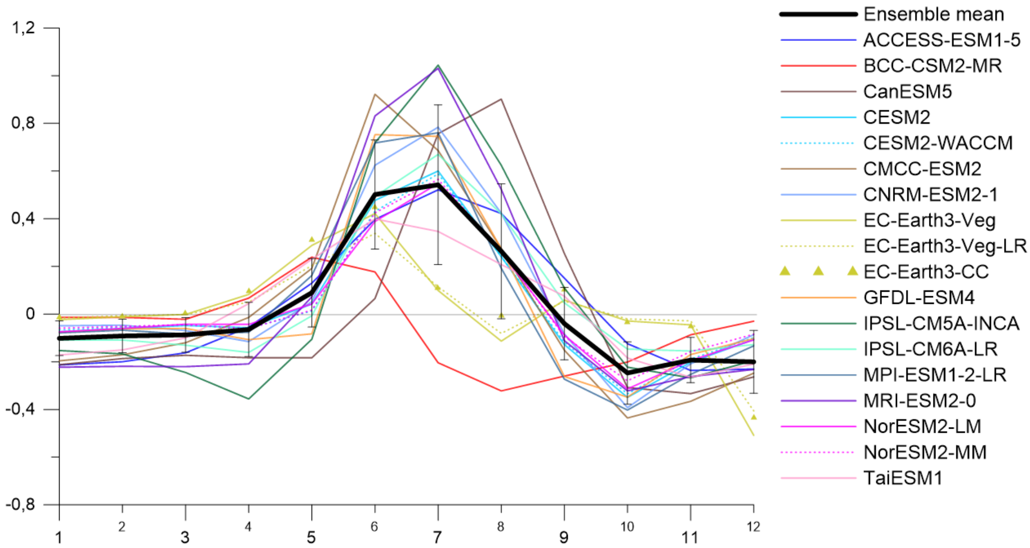

Figure 3. Monthly mean net CO_2 fluxes [PgC] from the territory of Russia simulated by CMIP6 models.

In general, although most of the models show similar behavior on an intraannual timescale, estimates of total carbon dioxide uptake on the spatial scale of even such large regions as the territory of Russia differ significantly. Net annual emission ranges from -0.67 to 0.83 PgC, whereas the individual models represent the entire range of positive values (except for BCC-CSM2-MR) and no modality is observed.

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1. S.N. Denisov, A.V. Eliseev, I.I. Mokhov Contribution of natural and anthropogenic emissions of CO_2 and CH_4 to the atmosphere from the territory of Russia to global climate change in the 21st century // Doklady Earth Sciences. 2019. V.488. N.1. pp. 1066–1071.