Effects of natural GHG emissions under climate changes due to anthropogenic scenarios in the 21st century: Model estimates

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An analysis of the ability of natural carbon reservoirs to take up and release carbon requires an adequate account of the carbon balance of boreal forests, wetlands and other ecosystems. We performed simulations with the Earth system model of intermediate complexity developed at the A.M. Obukhov Institute of Atmospheric Physics of Russian Academy of Sciences (IAP RAS CM) to assess the contribution of natural fluxes of carbon dioxide and methane for the major regions of Earth in the 21st century to global climate change under various scenarios of anthropogenic impact. The cumulative influence of the natural CO_2 and CH_4 fluxes to the surface air temperature trends in the 21st century is estimated using the cumulative temperature potential CTP [1] based on global temperature change potential (GTP), which was modified to account for changing background conditions.

The IAP RAS CM belongs to the class of the global climate models of intermediate complexity. It contains modules of the carbon cycle, including partly interactive methane cycle, and a module for calculation of emissions from deforestation and from natural fires. Using the IAP RAS CM, we performed numerical experiments for 1765–2100 with scenarios of anthropogenic impacts on climate due to changes in the content of greenhouse gases in the atmosphere, tropospheric and stratospheric volcanic sulfate aerosols, changes in the total solar irradiance, and changes in the area of agricultural lands. For 1700–2005, these forcings were given in accordance with the "Historical Simulations" of the CMIP5 project. For 2006–2100, the anthropogenic forcings were given prescribed in accordance with the anthropogenic impact scenarios RCP 2.6, 4.5, 6.0 and 8.5.

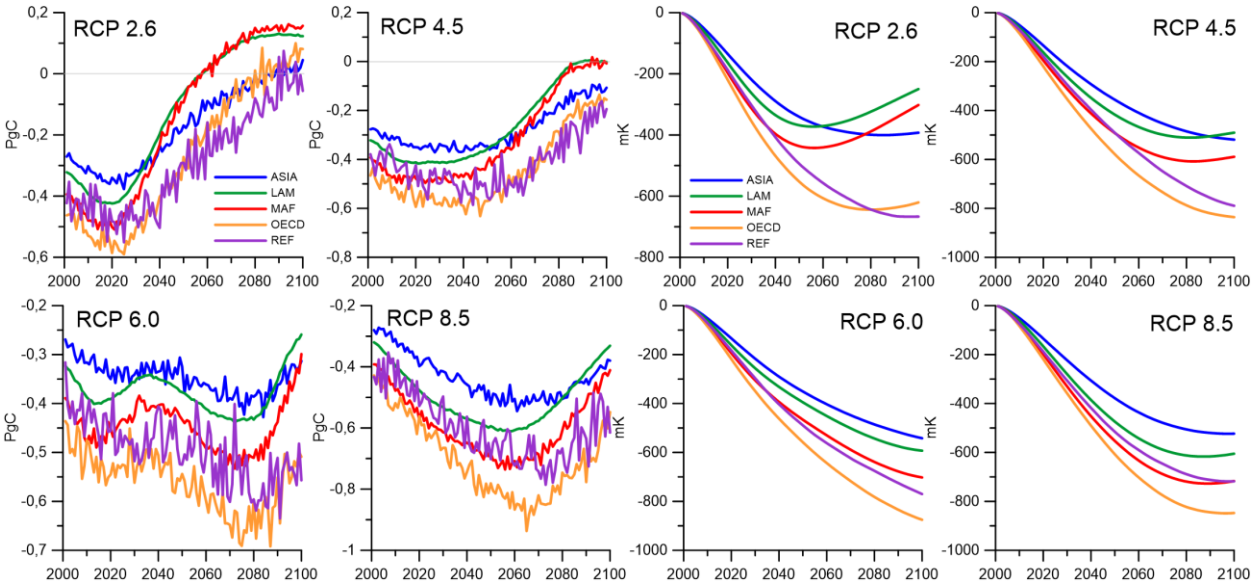

Figure 1. Natural fluxes [PgC] of CO_2 (left) from the RCP regions and their cumulative temperature potential (right).

Cumulative impact on climate was estimated for natural fluxes of CO_2 and CH_4 in the RCP regions, i.e., ASIA (Eastern Asia), MAF (Middle Asia and Africa), LAM (Latin America), OECD (Organization for Economic Co-operation and Development, Western Europe, North America, Australia, Japan), and REF (former USSR, Eastern Europe).

CO_2 uptake (Fig.1) by terrestrial ecosystems for all scenarios and regions considered increases at the beginning of the 21st century. Further in the first (RCP 2.6 and 4.5) or in the second (RCP 6.0 and 8.5) half of the 21st century the maximum absorption is reached after which carbon dioxide uptake begins to decrease. It even switches to emission for LAM and MAF regions under the RCP 2.6 scenario, which can also be observed by the rapid growth of CTP value in the second half of the 21st century. Due to the reduction of CO_2 uptake, the growth of its stabilizing impact on climate slows down noticeably by the

end of the 21st century, except for the RCP 6.0 scenario.

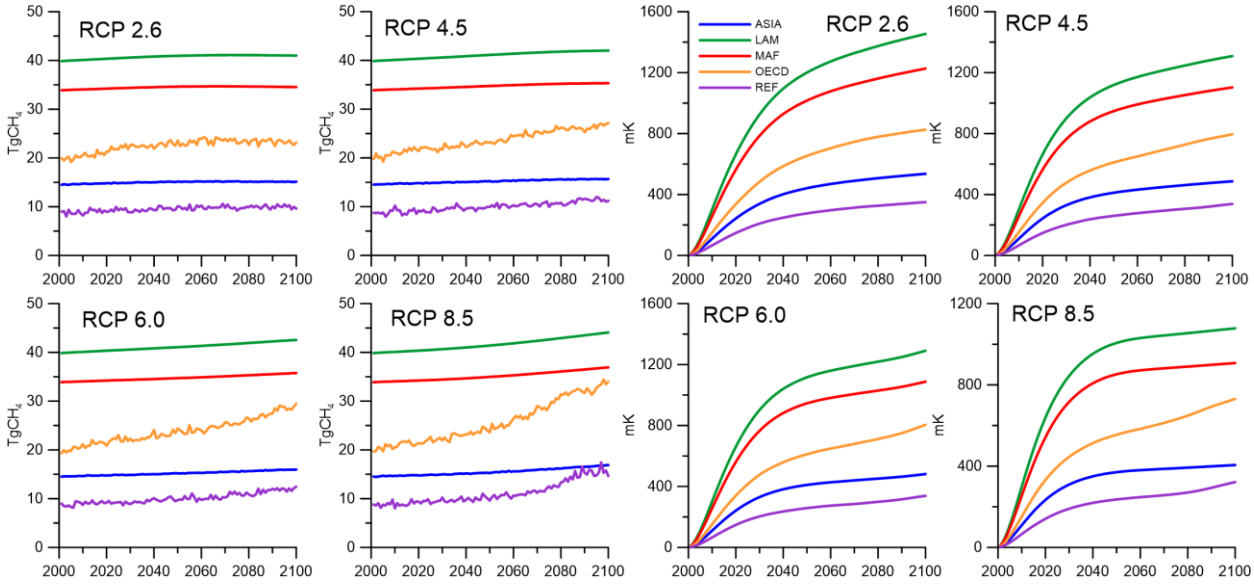

Figure 2. Natural fluxes [$TgCH_4$] of CH_4 (left) from the RCP regions and their cumulative temperature potential (right).

Natural methane emissions from wetlands and the corresponding CTP grow in the 21st century for all scenarios and regions (Fig. 2) due to the growth of the atmospheric temperature. The strongest increase occurs in the OECD and REF regions under the RCP 8.5 scenario where emissions are calculated to double by the end of the century, while in other regions the growth equals to 10-20%. This is due to the fact that in boreal latitudes not only temperature increases faster than average, but also the warm season lengthens.

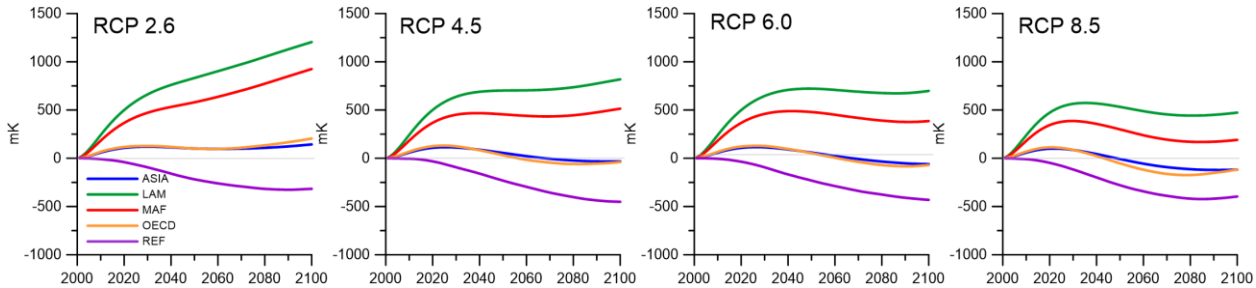

Figure 3. Total natural cumulative temperature potential of the RCP regions.

The total impact of the natural GHG fluxes on global temperature in the 21st century (Fig. 3) clearly supports stabilization of climate only for the REF region. For the ASIA and OECD regions the effects of CO_2 uptake and CH_4 release nearly compensate each other. Relatively high methane emissions from the LAM and MAF regions lead to positive total impact on temperature. The feedback of CO2 flux on higher anthropogenic impact for all regions except REF is stronger than the feedback of CH4 emissions. It leads to lower CTP values for more aggressive anthropogenic scenarios, while for the REF region the total CTP does not differ much between scenarios.

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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.