Model assessment of contribution of natural and anthropogenic GHG emissions from Russian regions to climate change in the 21st century

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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 Russian 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 to assess the contribution of anthropogenic and natural emissions from the territory of Russia in the 21st century to global climate change under various scenarios of anthropogenic emissions.

The climate change impacts of pulse emissions of different greenhouse gases can be compared using simplified metrics such as global warming potential and global temperature change potential. The Absolute Global Temperature change Potential (AGTP) is the change in global mean surface temperature at time H in response to a 1 kg pulse emission of gas x at time t = 0. It is often written as a convolution integral of the radiative forcing:

$$AGTP_x(H) = \int_0^H RF_x(t) R_T(H - t)\,dt\,, \qquad (1)$$

where RF_x is the radiative forcing due to a pulse emission of a gas x, and R_T is the temporally displaced climate response to a unit forcing. Equations for $AGTP_{CO2}$ and $AGTP_{CH4}$ in IPCC reports imply time constant CO2 and CH4 radiative forcing and CH4 lifetime.

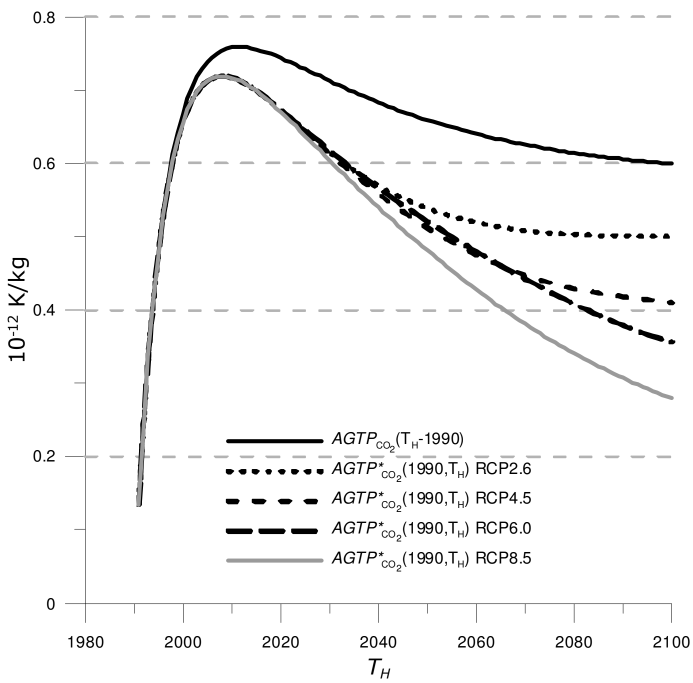

Fig. 1 AGTP and AGTP* for CO2 under various anthropogenic scenarios.

For changing background conditions AGTP can be modified and written as a sum of integrals for each year:

$$AGTP_x * (T_1, T_2) = \sum_{k=T_1+1}^{T_2} \int_{k-1}^{k} RF_{x,k}(t) R_T(T_2 - T_1 - t)\,dt\,, \qquad (2)$$

where T_1 is the year of emission and $T_2 = T_1 + H$. $RF_{x,k}$ can be achieved in assumption of CO2 and CH4 radiative forcing and CH4 lifetime being step functions, constant for each particular year k. The result of this modification can be seen in Fig. 1. It is shown that changes in climatic conditions under different anthropogenic emission scenarios can strongly influence the indicators of the impact of various greenhouse gas emissions on the climate system, especially at large time horizons.

Finally the cumulative potential, based on modified AGTP, is introduced to evaluate the impact of GHG sources and sinks:

$$CTP_x(T_0,T_H)=\sum_{t=T_0}^{T_H-1}E_x(t)AGTP_x*(t,T_H) \quad (3)$$

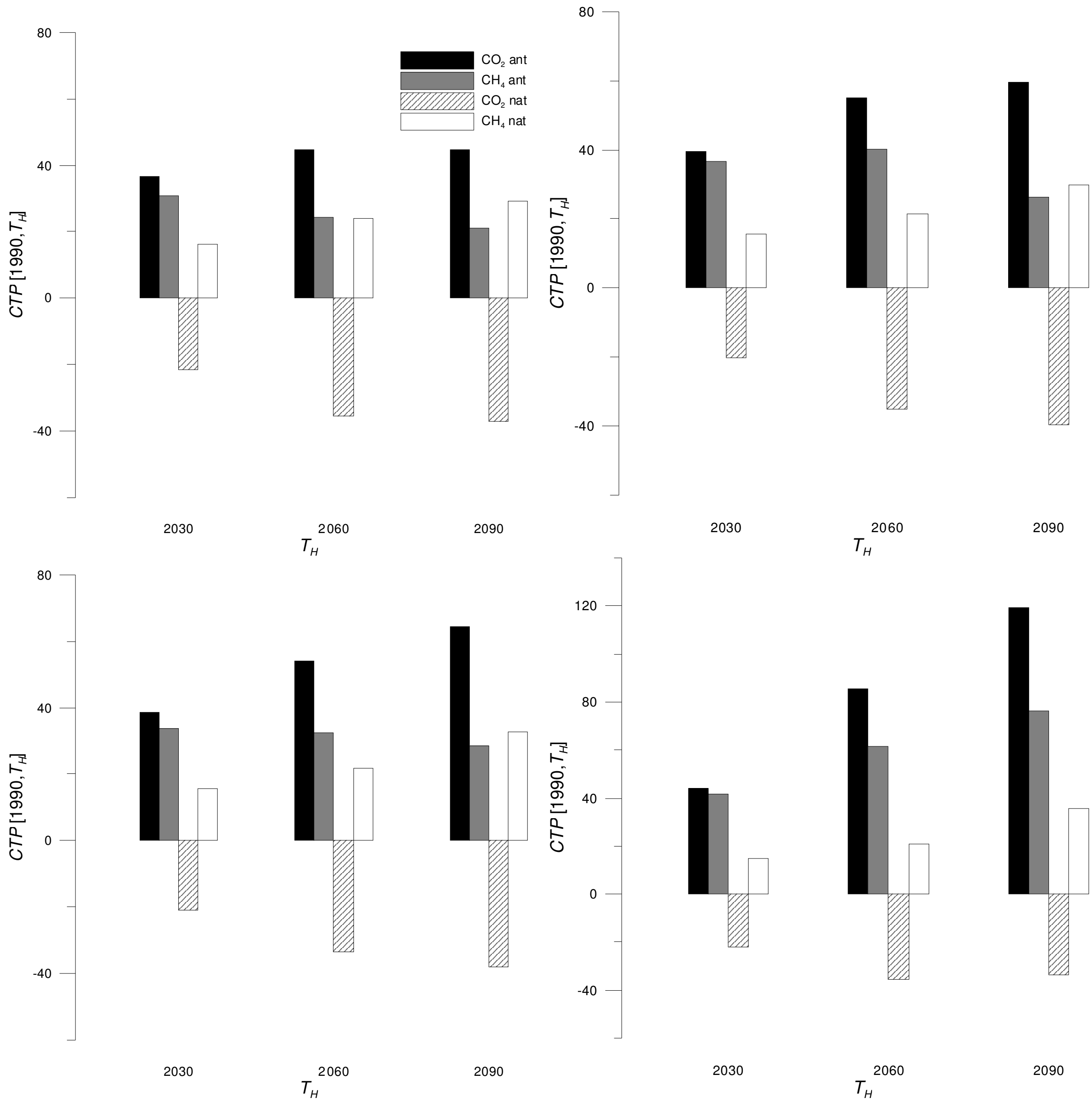

Fig. 2 CTP for anthropogenic and natural fluxes of CO2 and CH4 on [1990;2030], [1990,2060], and [1990,2090] time intervals

In current climate conditions, natural fluxes in the Russian regions have stabilizing effect on climate at relatively short time horizons (Fig. 2). To the end of the 21st century, their stabilizing ability is greatly reduced due to strong increase of natural CH4 emissions and decrease of CO2 absorption. Anthropogenic CTP of Russia stabilizes to the end of 21st century under RCP 2.6 and 4.5 scenarios and continue to rise under more intensive scenarios.

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