Scaling Potential Macroeconomic Impacts of Climate Effects of Siberian Wildfires: Insights from MIROC-SPRINTARS AOGCM Experiments

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Abstract

A broad range of attempts have been made to quantify the macroeconomic impacts of climate change, such as those of intensifying weather extremes and of yield losses of major crops, which have been synthesized by the efforts to estimate the Social Cost of Carbon (e.g., the US Interagency Working Group, 2016). However, up to the present, few insights have been fed into these debates as to the economic impacts associated with climatic responses of aerosol emissions from wildfires. In this study, we shed light on the potential scale of macroeconomic impacts of Siberian wildfires' climatic effects by drawing on results of sensitivity experiments on enhanced biomass burning (BB) emissions over the defined Siberian domain using a global aerosol climate model, MIROC-SPRINTARS, in which the model was coupled with the ocean model (i.e., Atmosphere-Ocean coupled Global Climate Model: AOGCM) – the scientific results of these simulations are also discussed in detail by our companion paper, Yasunari and Takemura (2019), in the same session at this AGU Fall Meeting 2019. We used sets of simulation results differing in the conditions of BB emissions and climate, in which three different reference levels of BB emissions over the defined Siberian domain were used under the present (RCP scenario in 2005) or future climate (RCP2.6 and RCP8.5 in 2030) conditions. Differentials of annual average temperatures estimated by the simulations were used to compute monetary-equivalent economic impacts attributable to climatic effects of BB by applying the functions of the RICE-2010 model (the 2010 version of the regional integrated model of climate and the economy model: Nordhaus, PNAS, 2010), which is a regionally disaggregated version of the most widely used climate-economy model, the DICE model. The economic impacts were estimated for the most affected countries and regions by Siberian wildfires, such as Russia, China and Europe.

GC11F-1161: Scaling Potential Macroeconomic Impacts of Climate Effects of Siberian Wildfires: Insights from MIROC-SPRINTARS AOGCM Experiments

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Please also visit the poster of our companion study in this poster session: Yasunari and Takemura, Impacts of increased Siberian wildfire on air pollution, radiative forcing, and climate at present and in the future assessed with MIROC AOGCM (GC11F-1156)

Main Points

- We attempt to shed light on the potential scale of macroeconomic impacts of Siberian wildfires' climatic effects
- Macroeconomic impacts of enhanced BB over Siberia are estimated by using the data of sensitivity experiments of the MIROC-SPRINTARS AOGCM model (for detail, see the poster in this session) together with the regional climate-economy relationships based on the RICE-2010 model (Nordhaus, 2010), a version of the most widely recognized climate-economy Integrated Assessment Model.
- Results show significant scales of potential macroeconomic impacts from climatic effects of Siberian BB, calling for further research on this issue

1. Scope of the study

A broad range of attempts have been made to quantify the macroeconomic impacts of climate change, such as those of intensifying weather extremes and of yield losses of major crops, which have been synthesized by the efforts to estimate the Social Cost of Carbon (e.g., US Interagency Working Group on Social Cost of Carbon, 2016). However, up to the present, few insights have been fed into these debates as to the economic impacts associated with climatic responses of aerosol emissions from wildfires.

Siberia is one of the areas in the world whose wildfire incidences draw global attention. In this study, we attempt to shed light on the potential scale of global macroeconomic impacts of Siberian wildfires' climatic effects by drawing on results of sensitivity experiments on enhanced biomass burning (BB) emissions over the defined Siberian domain using a global aerosol climate model, MIROC-SPRINTARS, in which the model was coupled with the ocean model (i.e., Atmosphere-Ocean coupled Global Climate Model: AOGCM).

2. Simulations

2-1. General approach

We use sets of simulation results differing in the conditions of BB emissions and climate, in which different reference levels of BB emissions over the defined Siberian domain were used under the present or future climate conditions. Differentials of annual average temperatures estimated by the simulations were used to compute monetary-equivalent economic impacts attributable to climatic effects of BB by applying the functions of a widely known climate-economy model (the RICE-2010 model). The economic impacts were estimated for potentially most affected countries and regions by Siberian wildfires, namely Russia, China, Europe and US & Canada (See Figure 1).

2-2. Simulations of climate impacts of enhanced BB

We use data of three sensitivity experiments out of six cases simulated by Yasunari and Takemura (see poster in this session). The Yasunari and Takemura study carried out MIROC/SPRINTARS AOGCM (Atmosphere-Ocean General Circulation Model) sensitivity experiments to assess the impact of increased Siberian biomass burning (BB) emissions at present (2005) and under multiple RCP scenarios in 2030. The used model is MIROC version 5.9.0 with SPRINTARS, and coupled atmosphere-ocean simulations were performed. The simulations conducted 100-year integration, and the data for the last 50 years were used for analyses. For estimations of economic impacts of regional climate change, we utilize the regional annual averages of 2-m temperature data of these sensitivity experiments.

Cases of sensitivity experiments used in this analysis
With varied Siberian BB emissions and RCP scenarios: for a full description of experiments, please see Yasunari and Takemura in this poster session (GC11F-1156)

Exp-0 (baseline case): Using daily GFED BB emissions in 2004 (BC, OC, & SO_2); GHG emissions at present (*RCP in 2005)
Exp-2: Same as Exp-0 except for replacing the BB emissions over the Siberian domain (70°-140°E; 42.5°-70°N: Black box shown in Figure 1) to the doubled levels of a high BB emission year, 2003
Exp-4: Same as Exp-2 except for using the GHG emissions in 2030 (*RCP2.6)

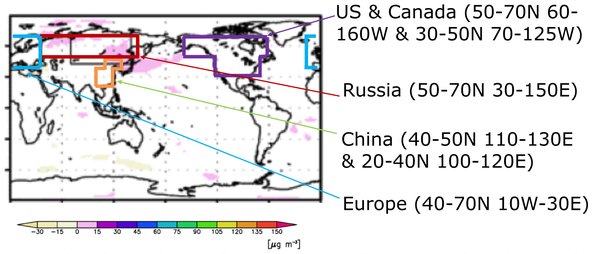

Figure 1 *Study regions of simulations. The black box is the Siberian region where BB emissions are enhanced in the sensitivity experiments. The colored distributions on the map are of differences of March-August average PM2.5 levels for Exp 2 - Exp 0)*

2. Estimation of macroeconomic impacts of climate change due to enhanced Siberian BB

For estimation of macroeconomic impacts of climate change associated with Siberian BB, we draw on the recently growing literature of climate change economics, in particular, that of climate-economy Integrated Assessment Models (IAMs), which quantitatively estimate macroeconomic impacts of climate change and also economically desirable stringency of climate change policies. Generally, IAMs incorporate the "damage function," which is a relationship between economic output and the degree of surface warming obtained from the sum of sectoral impacts of climate change including:

- Effects on agriculture and water resources
- Health impacts and changes in energy use
- Intensification of weather-related disasters
- Infrastructure impacts of sea-level rise

IAMs quantify these economic impacts by using the data of existing empirical and modeling studies of climate change impacts. In our study, we utilize the regionally-disaggregated damage functions (exclusive of the effect of sea level rise) of the RICE-2010 model (Nordhaus, *PNAS*, 2010), which is a regional version of the DICE model developed by William Nordhaus. Since the DICE model is the most widely recognized IAM, the use of the model's damage function has the advantage of comparability with other economic studies of climate change. The damage functions used in our analysis are shown in Figure 2.

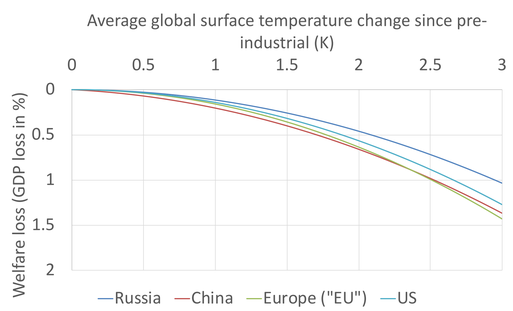

Figure 2 *Damage function of regional impacts of climate change as used by the RICE-2010 model (Nordhaus, PNAS, 2010)*

Macroeconomic impacts of climate change are often shown as percentage changes of GDP (Gross Domestic Product). In this sense, to obtain absolute monetary values of future climate change impacts, we need GDP projections. For that purpose, we draw on the latest GDP forecasts published by the OECD

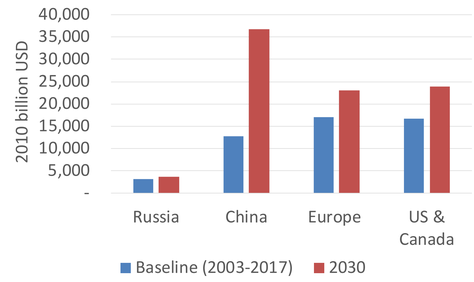

Figure 3 *Baselines and projections of regional GDP used in our estimations of economic impacts (based on OECD projections)*

3. Results and their implications

Table 1 shows our estimations for four regions/countries and also for the world, which is estimated by using the damage function of DICE-2007, which is in the same family of climate-economy models as in the RICE-2010. The estimates are presented as differentials of variables for the sensitivity experiments only differing in Siberian BB emissions (Exp2-Exp0: see description in the yellow box on the left bottom) and for the experiments representing the baseline and a Siberian BB-enhanced future inclusive of general global climate change towards 2030 (Exp4-Exp0). The estimates in the upper part (blue-shaded) in the table, which correspond to pure effects of enhanced Siberian BB on climate, suggest significant mitigation of warming due to Siberian BB being present in a broad range of areas. The effects commensurate to nearly 0.1% of GDP for China and North America (US & Canada) and to over a billion USD annually for Europe and North America. Note, however, that the figures represent only BB's effects on climate and do not include its negative consequences of tropospheric air pollution. Meanwhile, the estimates in the lower part (orange-shaded) of the table for Exp4-Exp0 suggest that enhanced Siberian BB emissions do not cancel the general progression of climate change due to the emissions of other greenhouse gases.

These results suggest potentially large implications of Siberian BB on the global economy through its climatic effects and call for further research on this topic.

	Russia	China	Europe	US & Canada	*World (DICE 2007)*
ΔT for Exp 2 - Exp 0 in K	-0.17	-0.28	-0.09	-0.33	*-0.07*
Δ[CC damage] for Exp 2 - Exp 0 in % GDP	-0.04	-0.09	-0.03	-0.09	*-0.04*
in 2003-2017 GDP (million 2010 USD)	-1,219	-11,882	-4,677	-15,441	*-29,956*
ΔT for Exp 4 - Exp 0 in K	0.28	0.18	0.40	0.20	*0.22*
Δ[CC damage] for Exp 4 - Exp 0 in % GDP	0.07	0.06	0.13	0.06	*0.13*
in 2030 GDP (million 2010 USD)	2,398	22,381	29,645	13,645	*185,350*

Table 1 *Estimation results for the studied regions (set as in Figure 1). It shows differentials of variables for the experiments only differing in Siberian BB emissions (Exp2-Exp0: see description in the yellow box on the left) and for the experiments representing the baseline and a Siberian BB-enhanced future inclusive of general global climate change towards 2030 (Exp4-Exp0)*

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