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Probabilistic forecast for climate change over Northern Eurasia

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In this study, we investigate possible climate change over Northern Eurasia and its impact on hydrological and carbon cycles. Northern Eurasia is a major player in the global carbon budget because of boreal forests and wetlands. Permafrost degradation associated with climate change could result in wetlands releasing large amounts of carbon dioxide and methane. Changes in the frequency and magnitude of extreme events, such as extreme precipitation, are likely to have substantial impacts on Northern Eurasia ecosystems. For this reason, it is very important to quantify the possible climate change over Northern Eurasia under different emissions scenarios, while accounting for the uncertainty in the climate response.

For several decades, the Massachusetts Institute of Technology (MIT) Joint Program on the Science and Policy of Global Change has been investigating uncertainty in climate change using the MIT Integrated Global System Model (IGSM) framework, an integrated assessment model that couples an earth system model of intermediate complexity (with a 2D zonal-mean atmosphere) to a human activity model. Since the IGSM includes a human activity model, it is possible to analyze uncertainties in emissions resulting, for example, from different future climate policies. Another major feature is the flexibility to vary key climate parameters controlling the climate response: climate sensitivity, net aerosol forcing and ocean heat uptake rate. The IGSM has long been used to perform probabilistic forecasts based on estimates of probability density functions of climate parameters.

The MIT IGSM-CAM framework links the IGSM to the National Center for Atmospheric Research (NCAR) Community Atmosphere Model (CAM), with new modules developed and implemented in CAM to allow climate parameters to be changed to match those of the IGSM.

The simulations discussed in this paper were carried out for two emission scenarios and three sets of climate parameters. The “business as usual” and a 660 ppm of CO_2-equivalent stabilization scenarios are similar to, respectively, the Representative Concentration Pathways RCP8.5 and RCP4.5 scenarios. Values of climate sensitivity and net aerosol forcing used in the provide a good approximation for the median, and the lower and upper bound of 90% probability distribution of 21st century climate change. Five member ensembles were carried out for each choice of parameters using different initial conditions. Presented results show strong dependency of simulated changes in precipitation on initial conditions, indicating that multiple simulations a required to isolated forced climate system response from natural variability.

Results of the IGSM-CAM simulations are compared with a pattern scaling method that extends the latitudinal projections of the IGSM 2D zonal-mean atmosphere by applying longitudinally resolved patterns from climate model projections archived from exercises carried out for the 4th Assessment Report (AR4) of the IPCC. The IGSM-CAM physically simulates climate change using probability distributions for climate parameters constrained by the observed climate record, but relies on one particular model. On the other hand, the pattern scaling approach produces a meta-ensemble that can be treated as a hybrid frequency distribution (HFD) that integrates the uncertainty in the IGSM ensemble and in the regional patterns of climate change of different climate models. Together, the two approaches provide a comprehensive analysis of possible climate change over Northern Eurasia and its potential impacts.