Aerosols and climate change in the Arctic in the historical experiments using the MRI Earth System Model

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Atmospheric aerosols modify the global radiation budget directly through scattering and absorption of solar radiation and indirectly through modification of the microphysical properties of clouds. However, there remain large uncertainties in estimates of aerosol effects on the climate system because of the insufficient prediction of aerosols in the Arctic by previous climate models.
Meteorological Research Institute (MRI) has developed a new version of MRI Earth System Model (MRI-ESM2) for participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). MRI-ESM2 is an updated version of MRI-ESM1 and consists of four major component models; an atmospheric general circulation model with land processes (a horizontal resolution of approximately 120 km), an ocean-sea-ice general circulation model, an aerosol model (approximately 180 km), and an atmospheric chemistry model (approximately 280 km). The number of vertical levels of MRI-ESM2 is 80 (model top at 0.01 hPa). As MRI-ESM2 shows the improvement of prediction of aerosol variations in the recent Arctic, we estimate effects of aerosols on climate change in the Arctic from the pre-industrial to present conditions.
We conducted the CMIP6 historical experiment (1850-2014) by MRI-ESM2 and compared the model results with the ice core data in Greenland. In the comparisons, we used three types of model calculation results; the MRI-ESM2 calculation with the CMIP6 emission inventory, the MRI-ESM2 calculation with the CMIP5 emission inventory, and the previous MRI-ESM1 calculation with the CMIP5 emission inventory. The comparison with the Greenland SouthEastern Dome (SE-Dome) ice core data shows that the MRI-ESM2 calculations successfully reproduce the temporal variation of deposition flux of sulfate, although the previous MRI-ESM1 calculation largely underestimates the sulfate. The historical experiments by MRI-ESM2 show that sulfate at SE-Dome was mostly originating from anthropogenic sources in winter, but natural sources also played an important role in summer. The comparison with the ice core data at the D4 site shows that the MRI-ESM2 calculation with the CMIP6 emission could not reproduce the enhancement of black carbon concentrations in the early 20th century, but the MRI-ESM2 calculation with the CMIP5 emission could. This result suggests that there still remain large uncertainties in the emission inventory of black carbon. The CMIP6 historical experiments by MRI-ESM2 suggest that the aerosols play an important role for temperature changes in the Arctic. The predictions of the surface air temperature changes by MRI-ESM2 are improved from the previous model both in global and the Arctic. These results indicate the importance of analyses of ice cores for improvement of predictions of climate models and the usefulness of climate models for interpretation of ice core data.

Keywords: Aerosol, Climate model, Ice core, Climate change, Environmental change, Arctic