Relationship between Anthropogenic Aerosol Increase and Arctic Surface Cooling in mid-20th Century

Takuro Aizawa[1,2], Naga Oshima[2] and Seiji Yukimoto[2]

[1]*National Institute of Polar Research , Tachikawa, Japan*

[2]*Meteorological Research Institute, Tsukuba, Japan*

Observational records show Arctic surface cooling of −0.95°C–−0.70°C during the mid-20th century (1940–1970) followed by ongoing rapid warming since 1970 (Figure.1). Long-term global warming has been extensively researched and has been primarily ascribed to anthropogenic greenhouse gas forcing. However, the factors contributing to the mid-20th century Arctic surface cooling remain poorly constrained. We conducted the multimodel analyses using the state-of-the-art climate models and quantified contributions to the Arctic surface cooling from greenhouse gases, aerosols, natural forcings, and multidecadal internal variabilities.

Multimodel ensemble mean using all historical simulations in 35 Coupled Model Intercomparison Project Phase 6 (CMIP6) models exhibited weak Arctic surface cooling in 1940–1970, which could be attributed to external forcings. Multimodel ensemble means of using all historical simulation in 13 CMIP6 Detection and Attribution Model Intercomparison Project (DAMIP) models exhibited Arctic surface cooling of −0.22°C (±0.24°C) in decadal mean temperature in 1970 versus that in 1940 and showed that anthropogenic aerosol forcings contributed to a cooling of −0.65°C (±0.37°C), which was partially offset by a warming of 0.44°C (±0.22°C) due to well-mixed greenhouse gases (Figure. 2). The range of the multidecadal internal variability (−0.47°C–0.47°C) is similar to the range of −0.42°C to 0.33°C reported by England et al. (2021). When the multidecadal internal variability was combined with the cooling response to all forcings, its value reached −0.69°C (−0.93°C–−0.45°C), which is comparable to the observed cooling of −0.81°C (Figure. 2). The ranges of 30-year Arctic SAT trends for weak and strong cooling fluctuations caused by the internal variability were estimated to be −0.6°C and −1.2°C with reemergence periods of approximately 70 and 2000 years, respectively. The ongoing warming signal will override the fluctuations due to internal variabilities in the Arctic (Figure. 1). As anthropogenic sulfur emissions and sulfate aerosols contributing to cooling at Earth's surface will decrease in any future scenarios of shared socioeconomic pathways (SSP) (Gidden et al., 2019), Arctic warming will continue over the near-term future even under strong cooling fluctuations generated by internal variability.

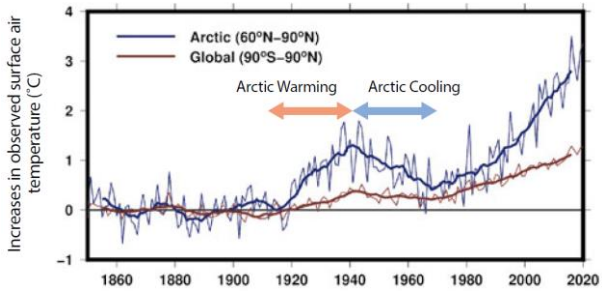

Figure 1. Observed surface air temperature changes in the Arctic (blue line) and Global (red line) relative to the 1850-1900 mean by HadCRUT5. Thick lines indicate 9-year running mean values.

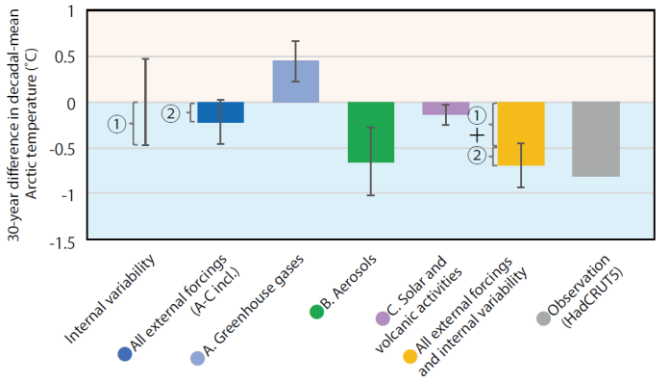

Figure 2. Thirty-year changes (the values in 1970 minus the values in 1940) in the decadal-mean Arctic-averaged SAT due to each external factor, as estimated by multiple climate model analysis. Decadal mean values in 1970 and 1940 are calculated averaging over 1965-1974 and 1935-1944, respectively. Reference: modified from Aizawa et al. (2022) Figure 4.

References

Aizawa, T., N. Oshima, and S. Yukimoto, Contributions of anthropogenic aerosol forcing and multidecadal internal variability to mid-20th century Arctic cooling—CMIP6/DAMIP multimodel analysis, Geophysical Research Letters, 49, e2021GL097093, 2022.

England, M. R., I. Eisenman, N. J. Lutsko, and T. J. W. Wagner, The recent emergence of Arctic Amplification, Geophysical Research Letters, 48, e2021GL094086, 2021.

Gidden, M., K. Riahi, S. Smith, S. Fujimori, G. Luderer, E. Kriegler et al., Global emissions pathways under different socioeconomic scenarios for use in CMIP6: A dataset of harmonized emissions trajectories through the end of the century, Geoscientific Model Development, 12(4), 1443–1475. 2019