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Assessment of Asian dust emission and transport variability to the Arctic during the past 120 years using the NASA GISS ModelE and an array of ice core dust records

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The role of aerosols in climate forcing is significant but poorly understood. Unlike well-mixed greenhouse gases, aerosol concentrations vary in time and from region to region. When deposited to highly reflective surfaces such as snow, even minute amounts of dust, black carbon, and other aerosols will decrease albedo – leading to warming, enhanced melting, and highly non-linear snow/albedo feedbacks. Dust, particularly from Asia, and other aerosols from mid-latitude emissions are transported to the Arctic although emissions and transport pathways are uncertain. We used simulations of dust emission and transport in the NASA GISS ModelE general circulation model, together with detailed records of dust concentration and deposition from an array of ice cores, to investigate the importance of emission strength and transport on Arctic dustiness during the past 120 years.

The GCM climate simulation included major aerosol and short-lived gaseous species, on-line and coupled, with the atmosphere coupled to the deep ocean. Five-member ensemble simulations were initiated from a pre-industrial control run and then run through the 20th century. The twentieth century climate was driven by anthropogenic changes in aerosols, gaseous species, long-lived greenhouse gases, volcanic emissions, etc. All short-lived species, including dust, are coupled to model radiation. Dust emissions depend upon wind-speed and soil moisture. To increase the temporal agreement of model deposition with the observed ice core records, an additional ensemble simulation including only dust was carried out with prescribed 20th century sea-surface temperatures with intent of recreating the observed circulation and transport anomalies. All ensembles were used to investigate the influence of Asian dust source variability and transport (characterized by annular and North Atlantic Oscillation indices) on dust deposition variability in the Arctic.

We evaluated the model simulations using comparisons to observed dust deposition at an array of ice core locations in Greenland and western Canada. For the eight Greenland sites, we used Positive Matrix Factorization (PMF) to determine concentrations of sea salt, carbonate dust, and aluminus dust from high-depth-resolution measurements of sodium, magnesium, aluminum, calcium, manganese, rubidium, and strontium. Records of both carbonate and aluminus dust were used in the evaluation of the model simulations. Glaciochemical measurements in the western Canada core were more limited so we used high-depth-resolution measurements of aluminum and cerium to determine concentrations of aluminus dust at that site.