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Impacts of large-scale atmospheric circulation changes due to winter sea-ice retreat on Black Carbon transport and deposition to the Arctic

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The ongoing shrinkage of the Arctic sea ice cover is likely linked to the global temperature rise, the amplified warming in the Arctic, and possibly weather anomalies in the mid-latitudes. By applying a novel statistical method in climate science, the Independent Component Analysis (ICA), to global atmospheric anomalies in winters from 1980 to 2015 for two independent reanalysis products, we show the link between the sea ice melting in the Arctic and the combination of only three atmospheric oscillation patterns approximating observed spatial variations of near-surface temperature trends in winter. Two of these large scale atmospheric circulation patterns connect by independent dynamical processes the sea ice melting and related atmospheric perturbations in the mid-latitudes. Processing winter anomalies of meteorological fields from the global reanalysis together with black carbon (BC) concentrations and deposition fluxes simulated by a general circulation model coupled with atmospheric chemistry and physics (ECHAM5-HAMMOZ), we investigated the possible feedbacks of these independent dynamical processes on the long range transport of black carbon from the mid-latitudes to the Arctic. Using an approach based on Maximum Likelihood Estimate (MLE), we found that the three atmospheric patterns together determined a decreasing winter deposition trend of BC between 1980 and 2015 in the Eastern Arctic while they increase BC deposition in the Western Arctic. The increasing trend is mainly due to the more frequent occurrences of stable high pressure systems (atmospheric blocking) near Scandinavia favouring the transport in the lower troposphere of BC from Europe and North Atlantic directly into to the Arctic. The North Atlantic Oscillation has a smaller impact on BC deposition in the Arctic, but determines an increasing BC atmospheric load over the entire Arctic Ocean with increasing BC concentrations in the upper troposphere. The El Nino-Southern Oscillation does not influence significantly the transport and deposition of BC to the Arctic. The results show that changes in atmospheric circulation due to polar atmospheric warming and reduced winter sea ice significantly impacted BC transport and deposition. The anthropogenic emission reductions applied in the last decades were, therefore, crucial to counterbalance the most likely trend of increasing BC pollution in the Arctic.