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Simulating black carbon at Syowa station, Antarctica: long-range transport from various source regions

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This study evaluates long-range transport of black carbon (BC) to the Antarctic region in detail with a chemistry and aerosol coupled global climate model CHASER-SPRINTARS. BC, also called soot, is aerosol species emitted from fossil fuel combustion and biomass burning. BC is one of the most important air pollutants and also causes significant climate impacts with absorbing sunlight and melting snow/glacier. In this study, data derived from the continuous observation at Syowa station (69.0^{o}S, 39.6^{o}E) are used for a representative mass concentration of BC in the Antarctic region. It is found that the current version of the model tends to underestimate BC concentration all year round especially in polar region. This suggests that BC long-range transport process may not be simulated properly in the model, probably due to the model uncertainties in surface emission process and wet deposition process associated with precipitation. To reduce the model underestimation of BC in the Antarctic region, we perform several sensitivity experiments for improving reproducibility of BC long-range transport in the model. In the experiments we reduce the activity as CCN (cloud condensation nucleus) for hydrophobic BC and/or increase the fraction of BC in external mixing for surface emissions (the emission ratio of hydrophobic BC to total BC) to larger. The sensitivity experiments reproduce the observed BC level at Syowa station, but fail to reproduce the observed seasonal cycle of BC with winter high and summer low. Previous studies have suggested that aging process which changes hydrophobic BC to hydrophilic by coating it with water soluble species like sulfate during transport may play an important role in seasonal cycle of BC in remote regions. In this study, we examine the impacts of such aging process on BC in the Antarctic region, newly introducing an aging scheme for BC in the model. As a result, the model with aging process successfully reproduces the seasonal cycle of BC as well as the concentration level at the Syowa station. These sensitivity experiments reveal that long-range transport and subsequent concentrations of BC in remote areas are largely controlled not only by atmospheric transport, but also by BC mixing state and wet-deposition with precipitation and aging effect. In this study, a tagged tracer experiment is also conducted to estimate source region and transport pathway for BC at the Syowa station, Antarctica. The experiment indicates that about 50% of annual mean BC at the Syowa station comes from South America with ˜20% from South Africa and 15-20% from Australia. The model reveals two patterns of transport pathway. One is the case that BC is transported to the Syowa station in the lower troposphere (below 3 km altitude). The other case is that BC is first lifted up to the tropopause regions over source region and is transported toward Antarctica via the upper troposphere and lower stratosphere and eventually reaches to the Syowa station associated with Katabatic winds.

Keywords: Black Carbon, Antarctic, Long-range Transport, Chemical Transport Model