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A three-dimensional simulation and process analysis of tropospheric Ozone Depletion Events (ODEs) during the springtime of Arctic using CMAQ

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The tropospheric Ozone Depletion Event (ODE), first observed at Barrow, Alaska (now known as Utqiagvik), is a phenomenon that occurs during the springtime of Arctic. During ODEs, the surface ozone declines rapidly from a background level of 40-60 ppbv to a few ppbv, within a couple of days or even hours. In the present study, we made a three-dimensional simulation of ODEs occurring during March 28 to April 5, 2019 at Barrow and its surrounding areas, using a 3-D multi-scale air quality model, CMAQ.

Three ODEs observed at Barrow were accurately captured in the model and analyzed thoroughly using the tool of process analysis. It was found that the first ODE occurred on March 29 was mostly caused by a transport of a low-ozone air to the west of the Chukchi Sea. In contrast, the occurrence of another ODE between March 30 and 31 is attributed to a horizontal transport of the ozone-lacking air from the Beaufort sea. This ozone-lacking air ascribes to a release of abundant sea-salt aerosols from the Bering Strait under a strong wind condition, resulted from a cyclone formed at the Chukotka Peninsula. Afterwards, bromine is activated from the sea-salt aerosols, consuming ozone over the sea. It was found that over the sea, the consumption of the surface ozone due to chemical processes reaches as large as 10 ppb. During this ODE, ozone drops to a level lower than 5 ppb. In contrast, BrO attains a maximum of approximately 100 ppt. This ozone-lacking air over the sea thus leads to the partial ODE occurring at Barrow through the horizontal transport. The third ODE occurring on April 2 was also found to be mainly caused by the horizontal advection from the sea. Later on, on April 3, ozone in the boundary layer is replenished by the strong vertical diffusion of ozone-rich air from the free troposphere, leading to the termination of this ODE.

Our 3-D simulations also indicate that the vertical properties of the atmosphere exert a remarkable impact on the vertical distribution of chemical species. Under strong uplifting and warm underlying surfaces, the ozone-lacking air can break through the top of the boundary layer, affecting the free atmosphere.