Ice cloud formation related to oceanic supply of ice-nucleating particles: A case study in the Southern Ocean near an atmospheric river in late summer

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Polar region clouds play a key role in Earth's climate. Knowledge of the cloud phase (i.e., water, ice, or mixed) is important for determining the surface heat budget because the reflection of solar radiation at the cloud top depends on the cloud phase. Although the development of numerical climate models allows the investigation of clouds globally, the simulated cloud phase has a certain bias in some numerical climate models. Therefore, an observational study is required to investigate cloud formation environments. During a cruise in the Southern Ocean by a research ship, ice clouds were observed at relatively high temperatures in the mid-troposphere at high latitudes. This study investigated ice cloud formation associated with marine bioaerosols over the Southern Ocean using a combination of cloud particle sensor (CPS) sonde observations, satellite products, reanalysis data, and backward trajectory analysis. The CPS sonde detected ice clouds at temperatures higher than −10 °C in the mid-troposphere near an atmospheric river at high latitudes over the Southern Ocean during the 64th Japanese Antarctic Research Expedition cruise. Backward trajectory analyses indicated that a mid-latitude air mass with a high concentration of atmospheric dimethylsulfide (DMS) in the atmospheric boundary layer (<1 km) arrived at the ice cloud formation layer over the high latitudes. The DMS in the boundary layer began to increase under high wave conditions, coincident with the highest chlorophyll-*a* concentrations in the ocean. These results suggest that bioaerosols emitted from the ocean over the mid-latitudes acted as ice-nucleating particles for ice cloud formation over high latitudes.