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Understanding the sources of Arctic biological ice nucleating particles

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The Arctic is warming at an alarming rate, yet the wide range of processes that contribute to the surface energy balance are not well constrained. The effects of clouds and aerosols on the extent of sea ice is particularly not well represented in models. Specifically, relatively little knowledge exists regarding aerosols that serve as ice nucleating particles (INPs) and their subsequent impact on Arctic cloud ice formation. In general, biological aerosols such as bacteria, algae, and phytoplankton have been hypothesized to serve as some of the most efficient INPs in the Arctic region. The Arctic Ocean is a large vessel for biological productivity, but such productivity is highly variable depending on time of year and location. Here, we present results from ice nucleation studies in a relatively polluted coastal location in Prudhoe Bay, Alaska, USA during the spring and from a shipborne expedition through the Bering Strait and Chukchi Sea during the following summer of 2017. Prudhoe Bay is largely influenced by local oil extraction activities, while the marine measurements were conducted in a cleaner oceanic environment. INP concentrations and onset freezing temperatures were found to widely vary, but were highest in both locations when air masses originated from exposed ocean water from fresh sea ice melt and near phytoplankton blooms and coastal upwelling. For example, typical INP concentrations at -10˚C were up to 2 x 10^{-4} L^{-1} air, but up to 1 x 10^{-2} L^{-1} air during the period of marine air influence in Prudhoe Bay in the spring. Additionally, INPs in the 3 – 12 μm diameter size range were the most active compared to smaller particles. During the summer, typical INP concentrations at -10˚C in Arctic waters were up to 9 x 10^4 mL^{-1} seawater but were up to 3 x 10^5, 1 x 10^6, and 2 x $10^6$$mL^{-1}$ seawater near regions of blooms, oceanic upwelling, and freshly melted sea ice, respectively. Such concentrations were observed down to approximately 20 meters deep. Onset freezing temperatures for these unique waters were up to -4˚C. Overall, these results demonstrate the crucial role the ocean plays as a source of cloud nuclei in disparate Arctic locations.