

Research Highlight

Frost flowers are clusters of highly saline ice crystals growing on newly formed sea ice or frozen lakes. They wick brine from the surface of sea ice, and typically last about a few days after the initial formation and then are buried by snow, sublimate as sea ice grows thicker, or are blown away by wind that lofts the non-volatile fraction into the atmosphere as aerosol particles. Frost flowers are found to be a major source of sea salt aerosol during winter and early spring in polar regions.

Based on observations of particles derived from frost flowers in the Arctic, scientists from the Scripps Institution of Oceanography and the National Oceanic and Atmospheric Administration Pacific Marine Environmental Laboratory made a first attempt to derive an observationally based parameterization to estimate sea salt production from frost flowers. They found that the particle flux from frost flowers in winter has the order of $10^6 \text{ m}^{-2} \text{ s}^{-1}$ at the wind speed of 10 m/s, but the source flux is highly localized to new sea ice regions and strongly dependent on wind speed as shown in Figure 1. In order to assess the influence of this “missing” sea salt containing wintertime particle source on clouds and their longwave radiation, they introduced this parameterization into the regional WRF-Chem model initialized for two wintertime scenarios. With this implementation, the daily average sea salt emission from frost flowers is similar in magnitude with that from open water, resulting in roughly a factor of two higher total sea salt flux when including salt source functions from frost flowers and open water as shown in Figure 2. The modeled sea salt explains half of the observed submicron salt mass concentration. Moreover, the addition of sea salt aerosol emissions from frost flowers increases averaged sea salt aerosol number concentrations and subsequent cloud droplet numbers. This change of cloud droplet number concentration increases downward, longwave, cloud radiative forcing through enhanced cloud optical depth and emissivity. The magnitude of this forcing of sea salt aerosols from frost flowers on clouds and radiation, however, contributes only a small amount to surface warming (0.02 W/m^2) in Barrow, Alaska, in the wintertime scenarios, but such differences may be large enough to be important for sea ice formation. This is the first study to quantify both the magnitude and uncertainty in the cloud radiative forcing exerted by frost flower salt particles during Arctic winter.

While this parameterization used an ad hoc scaling for the magnitude of the emission flux, the spatial distribution and size distribution of emitted salt aerosols from frost flowers were constrained, respectively, by observed source areas (based on satellite retrievals of potential frost flower regions) and measured salt particle size distributions (based on particle size distributions at Barrow). The dependence of this aerosol source on seasonal sea ice formation means that the magnitude and location of this Arctic salt particle source varies as a result of new sea ice formation, making this process coupled between the cryosphere and atmosphere. For example, a warmer Arctic may reduce wintertime sea ice formation but increase the open water fraction as well as polynyas and leads, yielding more frost flowers and providing a buffer to the wintertime Arctic aerosols in clean conditions. An Earth system model that incorporates frost flower aerosol emissions in addition to sea ice formation would be needed to explore this possibility. This study provides both a tested source parameterization that can be used in an Earth system model and some initial constraints on the likely magnitude of the cloud and radiative changes expected from salt aerosols emitted from frost flowers during the Arctic winter. Furthermore, this study may also motivate more measurements involved to help fill in the knowledge gaps associated with the physical processes or mechanisms involved with frost flower decay and aerosol production.

Reference(s)

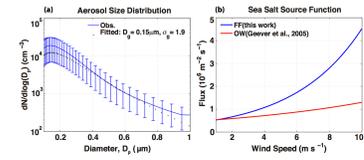


Figure 1. a) Observed and fitted mean aerosol size distribution in Barrow, Alaska, averaged during the period from November 2008 to February 2009; and b) Sea salt number flux from frost flowers (FF) parameterized in this work (blue line) in comparison to that from open water (OW) proposed by Geever et al. (2005).

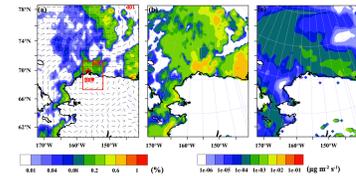


Figure 2. a) Daily averaged potential frost flower coverage (%) overlaid with daily average wind fields; b) Submicron sea salt aerosol emission from frost flowers (FF); and c) From open water (OW) on February 1, 2009. The “d01” in red represents Domain 1 while the “d02” in red and rectangular box represents Domain 2. The star symbol stands for the location of Barrow (i.e., BRW).

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Working Group(s)

Aerosol Life Cycle, Cloud-Aerosol-Precipitation Interactions