Ice nucleation activity of the particles emitted from sea surface microlayer in Tsukumo Bay, Japan

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Aerosol particles that act as ice nuclei are necessary for ice crystal formation in mixed phase clouds. Some previous studies have reported that the sea spray aerosols are important source of ice nuclei in clouds over on the ocean (e.g. Burrows et al., 2013). In particular, recent studies have suggested that sea surface microlayer (SML), where biological organic matters are concentrated in the sea surface, is enriched with ice nucleating substances (Irish et al., 2017). However, the understanding of the ice crystal formation by marine particles, especially the particles emitted from SML, are still limited in their spatio-temporal distribution, the quantitative characteristics, and the comparison with other atmospheric ice nucleating particles. In this study, we collected SML using drum sampler in Tsukumo Bay, Ishikawa, Japan in November 2016. In addition, Sea foam, which is characteristically formed along the coast of Japan Sea in winter by the concentration of biological organic matter, was collected at Maura beach, Ishikawa. The collected samples were measured for the freezing temperatures and the number concentrations of ice nucleating particles by the droplet freezing method.

In the freezing experiment, these samples froze in the temperature range of -15.5 degC to -24.1 degC, and the number concentrations of ice nucleating particles at -20 degC were calculated to be in the range 5.4 E + 4 pieces / L to 1.1 E + 6 particles / L. These results were consistent with the results reported for SML collected in the Arctic Ocean and North Atlantic (Wilson et al., 2015, Irish et al., 2017). Additionally, these freezing temperatures and number concentrations of ice nucleating particles of the SML and sea foam were significantly higher than the bulk seawater collected at the same location. These results suggested that the ice nucleating particles are ubiquitously concentrated in the sea surface microlayer. When compared with other environmental parameters, the freezing temperature of SML, sea foam and bulk seawater, was found not to correlate with the chlorophyll a concentration. Meanwhile, the concentrations of both the Coomassie Stained Particles (CSP) originating from protein, and the Transparent Exopolymer Particles (TEP) originating from polysaccharides correlated well with the freezing temperature (Fig. 1).

These results suggested that the ice nucleation by SML, sea foam, and sea spray aerosols emitted from the ocean in general are caused by organic matter originating from marine organisms such as protein and polysaccharide.

In order to compare the ice nucleation activities of SML relative to the mineral dust (Arizona Test Dust: ATD) having high ice nucleation activity, additional experiment was conducted by generating SML particles and measuring the particle number size distributions along with the sampling for the freezing temperature measurements. As a result, the SML particles were found to exhibit similar ice nucleation active site (INAS) density as the reference ATD. In other words, the particles emitted from SML are suggested to have ice nucleation activity comparable to mineral dust in the atmosphere.

Reference

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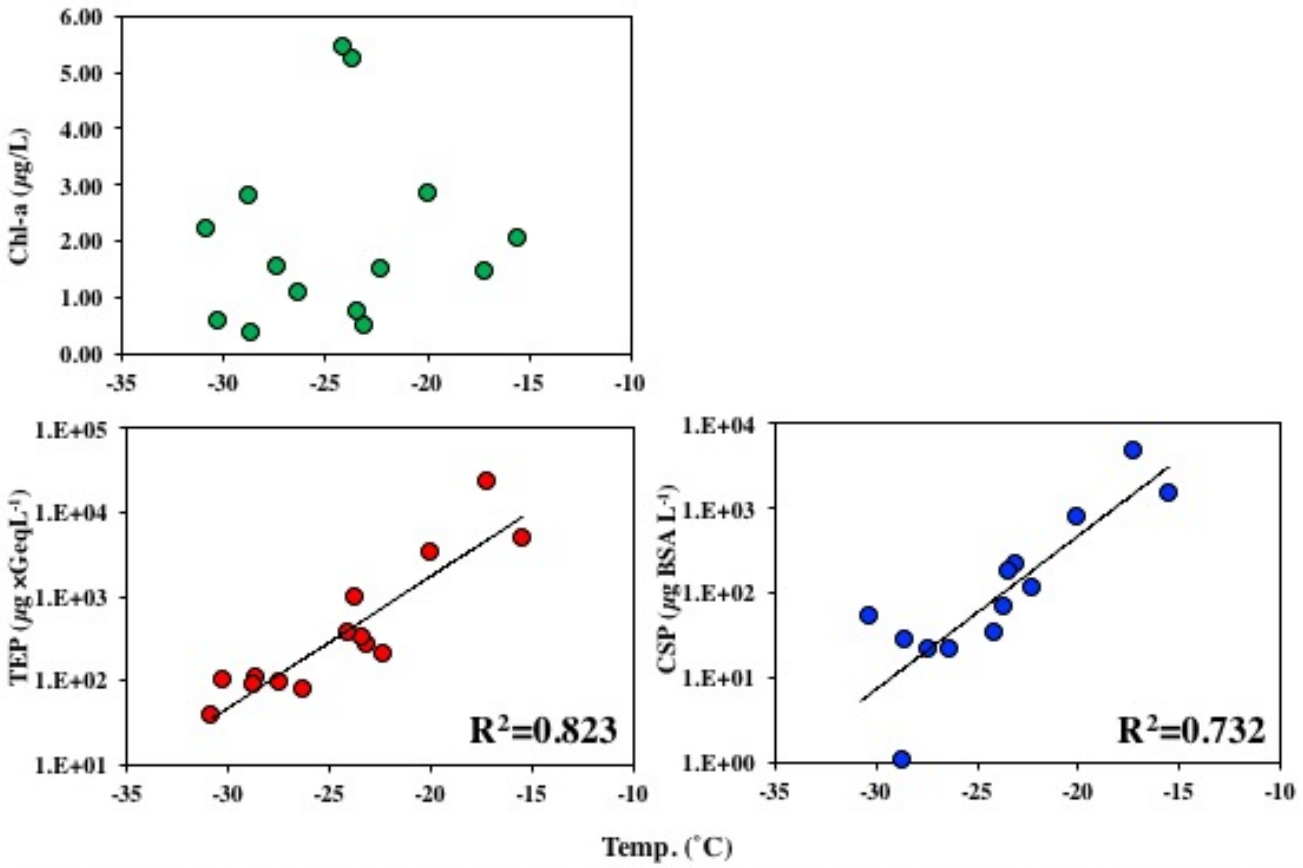

Fig.1: Correlations between the environmental parameters (Chl-a, TEP, CSP) and the freezing temperature of the SML, sea foam and bulk seawater.

