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A marine biogenic source of atmospherically relevant ice nucleating particles

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There are limited observations describing marine sources of ice nucleating particles (INPs), despite sea spray aerosol being one of the dominant sources of atmospheric particles globally. Evidence indicates that some marine aerosol particles act as INPs, but the source of these particles is unclear. The sea surface microlayer is enriched in surface active organic material representative of that found in sub-micron sea-spray aerosol. We show that the sea surface microlayer is enriched in INPs that nucleate ice under conditions pertinent to both high-altitude ice clouds and low to mid-altitude mixed-phase clouds. The INPs pass through 0.2 μm pore filters, are heat sensitive and spectroscopic analysis indicates the presence of material consistent with phytoplankton exudates. Mass spectrometric analysis of solid phase extracted dissolved organic material from microlayer and sub-surface water samples showed that the relative abundance of certain ions correlated with microlayer ice nucleation activity. However, these ions were not themselves directly responsible for ice nucleation. We propose that material associated with phytoplankton exudates is a candidate for the observed activity of the microlayer samples. We show that laboratory produced exudate from a ubiquitous marine diatom contains INPs despite its separation from diatom cells. Finally we use a parameterisation of our field data to estimate the atmospheric INP contribution from primary marine organic emissions using a global model and test the model against existing INP measurements in the remote oceans. We find that biogenic marine INPs can be dominant in remote marine environments, such as the Southern Ocean.