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Bioaerosols and biogenic ice nucleation particles at the high Arctic site Villum Research Station: concentrations, sources and seasonal variability

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Introduction
The radiative balance that is the driver for climatic changes in the arctic region responds to in-cloud processes, which heavily depend on the ice nucleation particle (INP) budgets. The most active INP are associated to either bioaerosols or compounds of biogenic origin attached to mineral particles. The types and concentrations of arctic bioaerosols are, however, virtually unknown and even though these particles may be an important missing link for predicting the radiation balance in the arctic, their possible influence on the formation of clouds and precipitation has not been determined. We investigated the concentration and sources of bioaerosols and biogenic INP in the high Arctic atmosphere, during spring and summer.

Methods
In total, 60 air samples and 11 snow samples were collected with a high-flow-rate impinger or on filters over a period of 38 days in spring 2015 and 33 days in spring and summer 2016 at the Villum Research Station, Station Nord. These samples were analysed for microbial cell concentrations, 16S rRNA bacterial gene concentrations, as well as total and biogenic INP concentrations using the droplet freezing assays.

Results
In spring, microbial cell concentrations were 1.7*104 cell m-3 and we found low rRNA gene concentrations likely due to efficient wet precipitation, with a periodic increase. On average, snow contained very low cell concentrations of 410 microbial cells mL-1. INP were found at high concentrations of 1.4 INP-10 mL-1 and 8.3*101 INP-20 mL-1 of snow-melt. The majority of the highly active INP-10 (82%) and over 60% of all INP-20 were proteinaceous. In summer, we found on average 17.8 INP-10 and 71.5 INP-15 per m3 or air. The concentration of both INP-10 and INP-15 were significantly correlated to the 16S rRNA concentration in air, which suggests that the origin of these INP may be bacterial cells that get aerosolized together with soil dust. One sample was analysed for proteinaceous INP, which represented the majority of total INP (82%-100%).

Conclusions
In conclusion, there are bioaerosols present both in spring and summer, with higher average concentrations in summer originating locally from soil dust. The majority of INP was of biogenic origin and is found in air during summer and was likely precipitated with snowfall during springtime.