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Exploring the role of aggregation in ice-nucleating macromolecules of Betula pendula pollen

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A wide range of aerosols, including dust, soot, and biological particles, can serve as ice nuclei, initiating the freezing of supercooled cloud droplets. This process significantly impacts cloud characteristics, and consequently, weather and climate. Among biological ice nuclei, some exhibit exceptionally high nucleation temperatures. While Ice Nucleating Macromolecules (INMs) found on pollen are typically not among the most active ice nuclei, they are abundant, as evidenced by their presence throughout the tissues of trees. Notably, recent studies have shown that certain tree-based INMs, such as those from Betula pendula, demonstrate ice nucleation activity above -10°C. These findings suggest that INMs emitted from the biosphere could play a more significant role in atmospheric processes than previously understood.

Our research delves into the properties of *Betula pendula* INMs through comprehensive ice-nucleation assays. We explore the stability of these INMs and the factors influencing their ice nucleation activity. Our approach integrates experimental data with size measurements and chemical analyses to better comprehend the underlying mechanisms.

Our findings reveal that Betula pendula INMs comprise three distinct classes active at -6°C, -15°C, and -18°C, each present in varying concentrations. We observed that freeze-drying and freeze-thaw cycles markedly alter their ice nucleation capacity. Additionally, heat treatments and chemical analysis suggest that these INM classes may be size-varying aggregates, with larger aggregates being more efficient at nucleating ice. This hypothesis aligns with previous studies on fungal and bacterial ice nucleators. Our research highlights the significance of birch INMs in atmospheric ice nucleation, not only because of their prevalence but also due to their occasional but notable high nucleation temperatures.