A laboratory study of the ice nucleating ability of pollen in Beijing

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Abstract

Immersion freezing is an important heterogeneous ice nucleation process in mixed-phase clouds. Many researches on immersion freezing focus on the parameterization using the classical nucleation theory. However, the ice nucleating abilities of the atmospheric aerosol particles are not well understood, and therefore cause difficulties of the parameterization of immersion freezing. In this study, we investigate the ice nucleating ability of Marigold pollen from the Beijing area by doing drop immersion freezing experiments in the laboratory. Marigold pollen are first mixed with pure water. A population of drops with a volume of 10 mL from the mixture are then put on a PE film in a chamber with a cooling rate of about 0.5 °C min-1. We find that the median freezing temperature of drops with pollen as ice nuclei is -17 °C. The contact angle parameterization of immersion freezing using the classical nucleation theory is also given in this study. We use the single-ϑ and the ϑ-pdf parameterization schemes to explain the data. The results show that the ϑ-pdf parameterization scheme is better for describing the ice nucleating behavior of the pollen in Beijing.

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Objectives

- To study the ice nucleating ability of pollen in Beijing in immersion freezing.
- To parameterize ice nucleation for model research.

Experiment

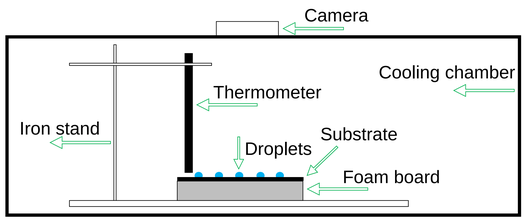

Fig. 1 Experiment schematic diagram

- **Exp. A**: 100 drops of distilled water
- **Exp. B**: 100 drops of distilled water mixed with pollen

Get fresh pollen of *Tagetes erecta* in Dec. 2017 in Beijing. The number density of pollen is about 2.5×10^{10} /L ,counted with microscope.

- **Exp. C**: 100 drops of melted hail water

Get hails in Jun. 2016 in Beijing. Some pollen is also found in these hails with scanning electron microscope.

- Other setup

Drop volume: 10 μL (equivalent to D ~2.7 mm)

Substrate: Polyethylene

Time resolution: 1s

Take pictures every second and record the temperature at the same time.

Cooling process and data analysis

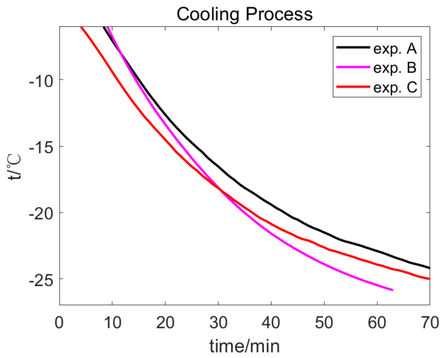

Fig. 2 Cooling process of each experiment. Exp. A (black line), exp. B (magenta line) and exp. C (red line) start at about 0 °C and end at about -26 °C.

- Cooling rate: 0.40~0.50 °C/min at -15 °C, 0.35~0.45 °C/min at -17 °C.
- The medium freezing temperature (T_m) is used to quantitatively compare the ice nucleating properties. Moreover, 25 and 75 percentile number of temperature (T_{25} and T_{75}) are used as supplement.
- **Exp. A**, T_m(water)= -22.9 °C.

T_{25} and T_{75} are -24.3 °C and -22.2 °C.

Exp. B, T_m(pollen)= -17.3°C.

T_{25} and T_{75} are -18.0 °C and -16.4 °C.

Exp. C, T_m(hail)= -14.9 °C.

T_{25} and T_{75} are -15.9 °C and -13.0 °C.

- In contrast, **exp. C** has the highest T_m and the widest freezing temperature distribution.

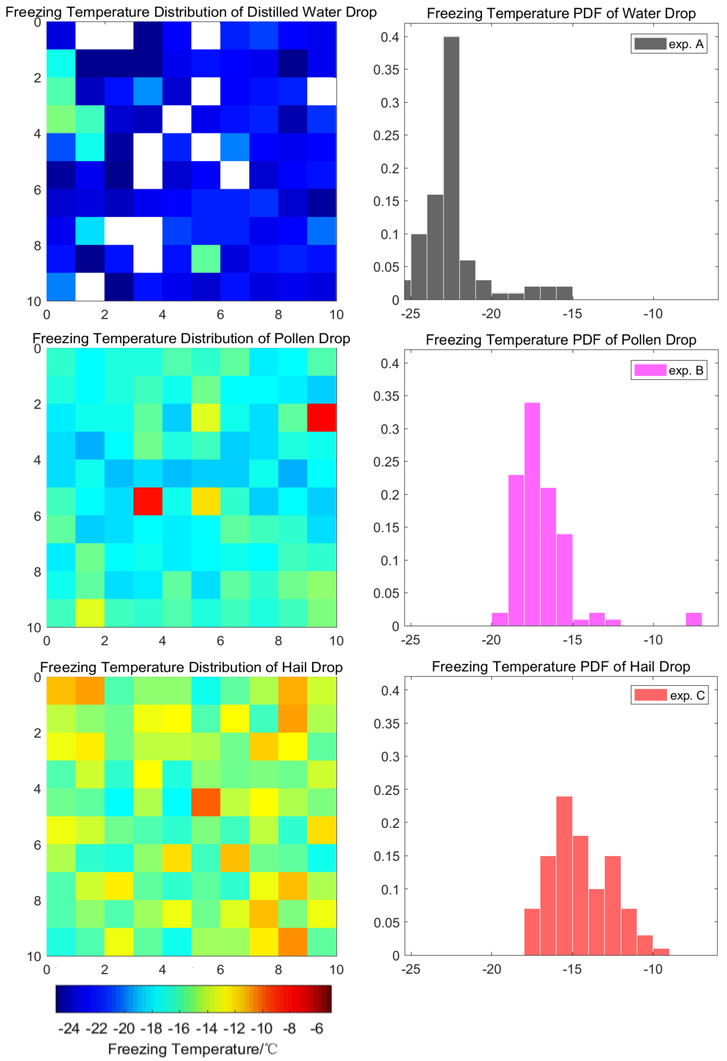

Fig. 3 Freezing temperature of each experiment. Freezing temperature distribution shows the relative position of drop freezing temperature in an experiment. Freezing temperature probability density distribution (PDF) shows the number proportion in every temperature bin. There are still 14 drops unfreezing at -25.4 °C in exp. A (white blocks).

Other factors

- Use another pollen sample to study how drop size and substrate influence immersion freezing process.
- **Exp. D**, T_m(pollen)= -16.2°C , T_m(water)= -16.5°C.

Exp. E, T_m(pollen)= -16.6°C , T_m(water)= -18.9°C.

Exp. F, T_m(pollen)= -15.3°C , T_m(water)= -23.2°C.

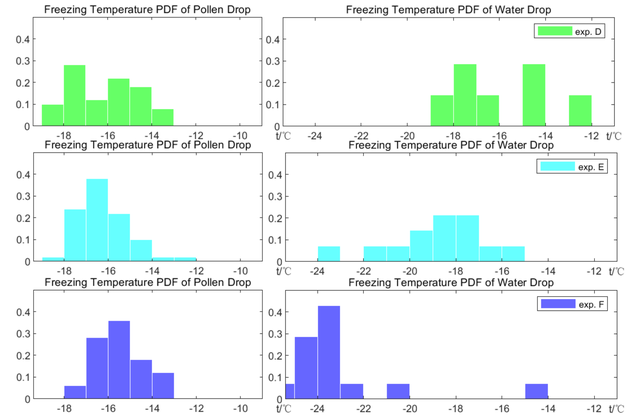

Fig. 4 Freezing temperature PDF of each experiment. There are 14 drops of distilled water and 50 drops of distilled water mixed with pollen in an experiment. Drop size is changed to 100μL in exp. D (green). Substrate is changed to glass in exp. E (blue). Drop size and substrate are not changed in exp. F (cyan). There is still one water drop unfreezing under -25.4°C in exp. E.

Conclusions

- *Tagetes erecta* pollen can be effective ice nuclei particles (INPs), but not as good as other INPs in hails in Beijing.
- Drop size and substrate affect immersion freezing process of distilled water, but not significantly if distilled water is mixed with pollen.

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