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Repeatability and randomness in heterogeneous freezing nucleation

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Abstract. This study is aimed at clarifying the relative importance of the specific character of the nuclei and of the duration of supercooling in heterogeneous freezing nucleation by immersed impurities. Laboratory experiments were carried out in which sets of water drops underwent multiple cycles of freezing and melting. The drops contained suspended particles of mixtures of materials; the resulting freezing temperatures ranged from −6°C to −24°C. Rank correlation coefficients between observed freezing temperatures of the drops in successive runs were >0.9 with very high statistical significance, and thus provide strong support for the modified singular model of heterogeneous immersion freezing nucleation. For given drops, changes in freezing temperatures between cycles were relatively small (<1°C) for the majority of the events. These frequent small fluctuations in freezing temperatures are interpreted as reflections of the random nature of embryo growth and are associated with a nucleation rate that is a function of a temperature difference from the characteristic temperatures of nuclei. About a sixth of the changes were larger, up to ±5°C, and exhibited some systematic patterns. These are thought to arise from alterations of the nuclei, some being permanent and some transitory. The results are used to suggest ways of describing ice initiation in cloud models that account for both the temperature and the time dependence of freezing nucleation.

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