Freezing and the Associated Latent Heat of Fusion in Earth's Atmosphere: A Talk in Two Parts

Will Cantrell
Department of Physics
Michigan Technological University

Ice in Earth's atmosphere affects climate through its interactions with radiation (both solar and terrestrial) and through its role in precipitation. (Much of the rain we see at the ground started as ice.) The creation of ice in the atmosphere is poorly understood, especially at temperatures high enough that homogeneous nucleation is unlikely $\sim -40°C$). For such temperatures, ice forms heterogeneously, catalyzed by a subset of aerosol particles known as ice nuclei. In general, effective ice nuclei are insoluble and have at least one low index crystallographic plane which has lattice constants close to those of ice. While the rules-of-thumb allow gross divisions into effective (e.g. silver iodide) and ineffective (e.g. soot) ice nuclei, a more quantitative formulation remains elusive.

In part one of the talk, I will present insights into heterogeneous nucleation of ice from experiments with films of high molecular weight organic compounds (e.g. triacontanol). We have shown that the characteristic freezing temperature of an aqueous solution (sodium chloride or ammonium sulfate) catalyzed by a film of a long chain alcohol can be predicted from the water activity of the solution. Additional investigations of the system with infrared spectroscopy suggest that the alcohol head groups, interacting with water, stabilize water clusters at the alcohol-water interface, reducing the barrier to nucleation.

The freezing process affects cloud dynamics through the release of latent heat. In the second part of the talk, I will address, what once seemed to me to be, an innocuous question - How much heat does freezing water exchange with the atmosphere at a given temperature? I will discuss a lower bound to the heat associated with freezing supercooled water, and present a model of droplet freezing, which predicts that the ice-water interface in a freezing droplet of water is always at the normal melting point. Finally, I will touch on how the inherent irreversibility affects the amount of heat released in the process.