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Dueling Mechanisms for Dry Zones around Frozen Droplets
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— Ice acts as a local humidity sink, due to its depressed saturation pressure relative to that of supercooled water. Hygroscopic chemicals typically exhibit annular dry zones of inhibited condensation; however, dry zones do not tend to form around ice because of inter-droplet frost growth to nearby liquid droplets that have already condensed on the chilled surface. Here, we use a humidity chamber with an embedded Peltier stage to initially suppress the growth of condensation on a chilled surface containing a single frozen droplet, in order to characterize the dry zone around ice for the first time. The length of the dry zone was observed to vary by at least two orders of magnitude as a function of surface temperature, ambient humidity, and the size of the frozen droplet. The surface temperature and ambient humidity govern the magnitudes of the in-plane and out-of-plane gradients in vapor pressure, while the size of the frozen droplet effects the local thickness of the concentration boundary layer. We develop an analytical model that reveals two different types of dry zones are possible: one in which nucleation is inhibited and one where the net growth of condensate is inhibited. Finally, a phase map was developed to predict the parameter space in which nucleation dry zones versus flux dry zones are dominant.

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