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Charging of ice-vapor interfaces: applications to thunderstorms

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Abstract. The build-up of intrinsic Bjerrum and ionic defects at ice-vapor interfaces electrically charges ice surfaces and thus gives rise to many phenomena including thermoelectricity, ferroelectric ice films, sparks from objects in blizzards, electromagnetic emissions accompanying cracking in avalanches, glaciers, and sea ice, and charge transfer during ice-ice collisions in thunderstorms. Fletcher's theory of the ice surface in equilibrium proposed that the Bjerrum defects have a higher rate of creation at the surface than in the bulk, which produces a high concentration of surface D defects that then attract a high concentration of OH^- ions at the surface. Here, we add to this theory the effect of a moving interface caused by growth or sublimation. This effect can increase the amount of ionic surface charges more than 10-fold for growth rates near 1 $\mu m\ s^{-1}$ and can extend the spatial separation of interior charges in qualitative agreement with many observations. In addition, ice-ice collisions should generate sufficient pressure to melt ice at the contact region and we argue that the ice particle with the initially sharper point at contact loses more mass of melt than the other particle. A simple analytic model of this process with parameters that are consistent with observations leads to predicted collisional charge exchange that semiquantitatively explains the negative charging region of thunderstorms. The model also has implications for snowflake formation, ferroelectric ice, polarization of ice in snowpacks, and chemical reactions in ice surfaces

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