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In the summer of 2012, the area of the Arctic Ocean covered by sea ice reached its lowest level ever recorded in more than three decades of satellite measurements. In fact, compared to the 1980's and 1990's, this represents a loss of almost half of the summer Arctic sea ice pack. While global climate models generally predict sea ice declines over the 21st century, the precipitous losses observed so far have significantly outpaced most projections. In this lecture I will discuss how mathematical models of composite materials and statistical physics are being used to study key sea ice processes such as its freezing and melting. Such processes must be better understood to improve projections of the fate of Earth's sea ice packs, and the response of polar ecosystems. Video from recent Antarctic expeditions where we measured related sea ice properties will be shown. (Received June 25, 2012)