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Statistical Mechanics and the Climatology of the Arctic Sea Ice Thickness Distribution

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We study the geophysical-scale evolution of Arctic sea ice using concepts from statistical physics. The original evolution equation for the sea ice thickness distribution function by Thorndike *et al.* (J. Geophys. Res. 80(33), pp. 4501 — 4513, 1975) is transformed to a Fokker-Planck-like conservation law. The steady solution is $g(h) = \mathcal{N}(q)h^q\mathrm{e}^{-\ h/H}$, where q and H are expressible in terms of moments over the transition probabilities between thickness categories. The solution exhibits the functional form used in observational fits and shows that for $h \ll 1$, $g(h)$ is controlled by both thermodynamics and mechanics, whereas for $h \gg 1$ only mechanics controls $g(h)$. We also derive the underlying Langevin equation governing the dynamics of the ice thickness h, from which we predict the observed $g(h)$. Further, seasonality is introduced by using the Eisenman-Wettlaufer model (Proc. Natl. Acad. Sci. USA 106, pp. 28-32, 2009) for the thermal growth of sea ice. The time-dependent problem is studied by numerically integrating the Fokker-Planck equation. The results obtained from these numerical integrations and their comparison with satellite observations are discussed.