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Stochastic Arctic sea ice model : The influence of stochastic noise in the decay of Arctic sea ice

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To understand the characteristics of the variability embedded in the recent decline of Arctic sea ice, a simple stochastic Arctic sea ice model including the effect of global warming is devised. The model consists of the deterministic part representing the seasonal evolution of sea ice thickness driven by monthly-averaged heat fluxes over sea ice and the stochastic forcing implying the sum of small time-scale physics. The effect of global warming on the sea ice is introduced by including an external heat flux in the deterministic part. Mathematically, the model is shown as a periodic non-autonomous stochastic ordinary differential equation. A stochastic perturbation theory of general relevance to non-autonomous systems is developed and then applied to find a perturbed solution around the given deterministic steady state solution with a fixed external heat flux. The validity of the proposed theory is confirmed by numerical simulations. The stochastic solution can be interpreted by several important statistical moments including standard deviation, mean and skewness, which are represented by delay integral equations. The integral forms of the statistical moments enable us to gain the insightful physical arguments about how the variability of Arctic sea ice is generated at a certain stage of global warming. The stability of the deterministic steady state, the asymmetry contained in the nonlinearity of the deterministic part and the magnitude and structure of the stochastic noise are combined to determine the stochastic solution. In other words, how the variability of Arctic sea ice is increased, shrunk or even biased from the deterministic steady state is understood by the interplay between the noise and the main physics, the sea-ice albedo feedback during summer and the longwave stabilizing during winter. This stochastic framework is expected to engage in the practical questions such as the role of human-induced global warming on the decay and variability of Arctic sea ice.