Deep Learning on a Novel Ising Model To Study Arctic Sea Ice Dynamics

Wang, Ellen (School: Horace Mann School)

The centennial Ising model, which was initially proposed to explain ferromagnetism and phase transitions, has become a central pillar of statistical physics and a powerful tool in diverse applications. In this study, the Ising model is combined with modern deep learning methods to examine Arctic sea ice dynamics, a crucial indicator of climate change. Upon the classical binary-spin Ising setup, continuous spin values are introduced to capture the real-world ice/water phase transitions, and an innovative inertia factor is incorporated to represent the natural resistance to state changes. The generalized model is then utilized for the Monte Carlo simulation of sea ice evolution in a large focus area of the Arctic region, by engaging the Metropolis-Hastings algorithm and training a convolutional neural network. Using the sea ice concentration data collected by the National Snow and Ice Data Center, our model proves to have strong explanatory power. The simulated configurations exhibit striking similarity with the actual ice/water images, and two numerical measures calculated from the simulation results—the ice coverage percentage and the ice extent—match closely with the data statistics. Moreover, the Ising parameters predicted by the convolutional neural network demonstrate the substantial impact of the external forces, which can be further enriched and linked to the environmental factors in other global warming analyses. This study identifies the fundamental physical mechanism governing sea ice dynamics. It also validates the vast potential of pairing classical physics with cutting-edge technologies in climate science, thereby presenting ample possibilities for future interdisciplinary research.