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# Space and time scaling of sea ice deformation

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Sea ice extends across the entire Arctic Ocean in winter with an average thickness of two to three meters. The ice drifts under the influence of wind, currents, and internal stress gradients, producing spatial gradients in the ice velocity that we refer to as deformation. Sea ice deformation, recognized as an important process controlling the ice thickness distribution and hence the sea ice mass balance, occurs across a wide range of space and time scales. Scaling analysis attempts to statistically relate quantities measured at different scales. The scaling laws derived from such an analysis can be used to estimate sub-grid scale variability in models and its impact on ice production. They also provide a basis for comparing disparate measurements of sea ice deformation from models, buoys, and satellite sensors, each with different grid sizes, spatial arrangements, and resolutions.

The RADARSAT Geophysical Processor System (RGPS) uses synthetic aperture radar images of the Arctic Ocean as input to an ice-tracking algorithm that follows more than 40,000 points on the sea ice, from which the components of the sea ice strain rate tensor are computed. RGPS provides the first and only basin-wide, high resolution time series of sea ice deformation, giving a perspective that is unprecedented for any deforming geophysical material in terms of its detail and extent. In previous work with RGPS data based on a single snapshot in time, we found that the mean sea ice deformation $< e >$ depends on the spatial scale $L$ over which it is computed according to a power law: $< e > \quad \sim \quad L^H$ where $H = -0.2$. The distinguishing feature of a power law is the invariance of the exponent with respect to changes in scale. We also conducted a joint space/time scaling analysis using data from drifting buoys, in which deformation was characterized in terms of the dispersion of pairs of buoys, finding that the space- and time-scaling laws were coupled.

In the present work, we conduct a joint space/time scaling analysis with RGPS data from 1997 through 2002, spanning spatial scales from 10 to 1000 km and temporal scales from 2 to 50 days. This extensive analysis allows us to characterize the scaling properties of sea ice deformation by region and season. We parameterize the resulting distributions of deformation in terms of stretched-exponential functions that depend on the spatial and temporal scales. We then run a model of the ice thickness distribution, driven by climatological thermal forcing and scale-dependent sea ice deformation rates. The values of deformation used as input to the model are drawn at random from our parameterized distribution with spatial scale $L$ and time scale $T$. In this way the model is forced with statistically appropriate deformation rates. We then look at the volume of sea ice produced by the model, as a function of $L$ and $T$. Results will be presented showing the extent to which sea ice models underestimate ice production that should be occurring at space and time scales below the model resolution.