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Sea ice dynamics as a climatic feedback: Multiple equilibium states of the Arctic ice cover due to sea ice mechanics

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Sea ice dynamic-thermodynamic coupling is highly nonlinear, such that sea ice maintains a variety of negative and positive feedbacks in the climate system that interact with each other and are not well resolved with linear analysis. These feedbacks are highly dependent on the state of the sea ice (thickness, divergence and lead opening, extent, summer melt rates etc etc). We show that sea ice may have characteristically different states in a similar climate depending on whether the state resulted from a thin or thick initial ice pack (i.e. during cooling or warming trends). In order to investigate the possible effects of ice mechanics on inducing multiple equilibrium states of the arctic ice cover, a non-dimensional analysis of stoppage of flow through narrow passages due to ice arching arising from uniaxial plastic compressive strength is carried out. By adding growth rates to this analysis it is shown that multiple equilibrium states of a given ice cover under appropriate fixed thermodynamic and wind forcing are possible depending on when the ice flow is restricted. The potential of such mechanical effects for inducing multiple equilibrium states for the Arctic Basin ice cover is investigated using realistic mean monthly winds and an idealized thermodynamic model. The analysis indicates three possible states, two of which are found to be stable. Integrations from fixed thickness initial conditions demonstrate the existence of these states under moderate climate cooling. The ramifications of this phenomenon to numerical investigations of climate employing dynamic-thermodynamic sea ice models is discussed, with emphasis on the role sea ice mechanics may play in climate feedback