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Pre-Industrial and current coupled Atmosphere sea-ice Simulations with ice dynamics

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Most speculation on the recent decline of arctic sea ice summer extent and thickness has emphasized either thermodynamic or wind forcing shifts in explaining the rapid changes. A more direct explanation of these shifts, based on non-linear ice mechanics and the constrained nature of Arctic pack ice, is a shift of the ice pack from a 'low flow' state with reduced ice outflow to a high flow ice state wherein the Arctic sea ice becomes similar to the Antarctic sea ice. Even with a modest warming this shift can substantially change the thickness and summer extent of the ice pack. In current simulation models high speed numerical solutions of the non-linear ice mechanics and/or low ice strengths prevent the realistic simulation of such states. Using the original Hibler(79) viscous plastic sea ice model and numerical method, Hibler and Hutchings(03) were able to obtain multiple equilibrium flow states for the same forcing which were shown to be induced by non-linear sea ice mechanics. These multiple states required about a 10Watts per meter squared cooling.

Recent circa 1700 Pre-industrial (Vavrus et al 08) and current simulations with an atmospheric circulation model coupled to thermodynamic sea ice on a slab ocean show about a 10 W/meter**2 reduction in Arctic forcing for the Pre-industrial period. To examine the likelyhood for a low flow state with such preindustrial forcing the pre-industrial (and current) simulations with this coupled model are modified to include full sea ice dynamics (Hibler, 79) in a true spherical co-ordinate sea ice model coincident with the AGCM lat long co-ordinates. Analysis of the ice model using off line forcing is also carried out to demonstrate the potential of multiple equilibrium states. Using these two end point simulations it is demonstrated that only a modest warming can account for a rather drastic decrease in the summer ice extent after the 1960's due

to the shift to a high flow state. A qualitative comparison to of this mechanistic study to observations is made. Basically, this low-high flow ice mechanics induced transition provides an alternative explanation (compared to rapid thermodynamic melting) of the current state of the sea ice portion of the cryosphere.