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Sensitivities of sea-ice export through Fram Strait in a coupled ocean/sea-ice adjoint modeling framework

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The sensitivity of sea-ice export through Fram Strait to changes in various elements of the ocean and sea-ice state, and to elements of the atmospheric forcing fields through time and space is assessed by means of a coupled ocean/sea-ice adjoint model. The adjoint model furnishes full (two- or three-dimensional) spatial sensitivity maps (also known as Lagrange multipliers) of the export metric to a variety of model variables at any chosen point in time, providing the unique capability to quantify major drivers of sea-ice export variability. The underlying model is the MIT ocean general circulation model (MITgcm), which is coupled to a Hibler-type dynamic/thermodynamic sea-ice model. The configuration is based on the Arctic face of the ECCO2 high-resolution cubed-sphere model, but coarsened to 36-km horizontal grid spacing. The adjoint of the coupled system has been derived by means of automatic differentiation using the software tool TAF. To assess the sensitivity behavior with respect to different basic states, three five-year adjoint simulations have been performed, using realistic atmospheric forcings, (1) covering a phase of high NAO (1977 to 1981), (2) covering a phase of low NAO (1989 to 1993), and (3) covering the recent period (2003 to 2007). The results show a complex interplay between atmospheric forcing patterns, heat transport carried by extensions of the North Atlantic current, and sea-ice evolution. Apparent dominant patterns on various time scales underline the transient nature of the problem.