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Representation and Predictability of Northern Hemisphere Snow Trends with Large Ensembles of Climate Simulations

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Recent trends reflecting controls by anthropogenic forcing and natural variability in Northern Hemisphere seasonal snow cover are analyzed in large ensembles of multidecadal climate integrations of the National Center for Atmospheric Research's Community Earth System Model 4. Two 40-member ensembles driven by historical radiative forcings are generated, one coupled to a dynamical ocean and the other driven by observed sea surface temperatures (SSTs) over the period 1981-2010. These experiments, representing many independent climate realizations, are closely compared to recently available multidecadal observational datasets of snow cover extent and snow water equivalent. The simulations reproduce many aspects of the observed climatology and variability of snow cover extent, as well as snow water equivalent to a lesser degree of fidelity. Ensemble spread in the climate response quantifies the impact of natural climate variability in the presence and absence of coupling to the ocean, and places some constraints on the predictable forced signal. Both coupled and uncoupled ensembles indicate an overall decrease in springtime snow cover that is consistent with observations, although springtime trends in most climate realizations are weaker than observed. In the coupled ensemble, a trend towards excessive warming in wintertime leads to a strong wintertime snow cover loss that is not found in observations. The wintertime warming bias and snow cover reduction trends are reduced in the uncoupled ensemble with observed SSTs. Natural climate variability generates widely different regional patterns of snow trends across realizations; these patterns are related in an intuitive way to temperature, precipitation and circulation trends in individual realizations. In particular, regional snow loss over North America is strongly influenced by zonal gradients in North Pacific SST trends, manifested as Pacific Decadal Oscillation (PDO) variability. Removing PDO signals from both observations and models brings the pattern of simulated trends into closer agreement with the observations. This suggests that regional scale forced signals of seasonal snow cover change can be potentially well predicted by models.