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Estimation of future glacier mass balances with an atmosphere/glacier hierarchical modeling system

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Airborne laser altimetry has shown rapid ice loss from glaciers in northwestern North America. During the mid-1990's to 2000/'01 these glaciers lost mass at a mean rate of about 96 +/- 35 km3/yr water equivalent (w.e.), accounting for roughly 6 to 12% of observed global sea-level rise during that time period. This rapid ice loss is likely attributable to the strongest land warming in northern high latitudes during the past 4 centuries (NRC, 2006). If warming continues as projected by the most recent IPCC AR4 climate model simulations, thinning and retreat of these glaciers, as well as other glaciers worldwide, is likely to accelerate. Thus, there is strong motivation for quantitative estimation of the probable changes in mass balance that will be caused by continued climate change.

In this study, the response of glaciers to changing climate is explored with an atmosphere/glacier hierarchical modeling approach, in which global simulations are downscaled with an Arctic MM5 regional model which provides temperature and precipitation inputs to a glacier mass balance model. The modeling system is first verified by hindcasting the mass balances of Gulkana Glacier (an index glacier in the Alaska Range, U.S.A.) over the ten-year period from October 1994 to September 2004, using bias-corrected Arctic MM5 downscalings. The results are compared to the annual mass balances measured independently by the U.S. Geological Survey (USGS); the comparisons show that this modeling system is promising for realistic estimation of tfuture glacier mass balances. The hierarchical modeling system is then applied to Hubbard Glacier (a large tidewater glacier) and Bering Glacier (a large surge-type glacier) in the St. Elias Mountains of south-central Alaska. Hindcast simulations from October 1994 to September 2004 are first performed for these two glaciers. Then the responses of the Hubbard and Bering mass balances to the future climate scenario

CCSM3 A1B, a “middle-of-the-road” future climate in which fossil and non-fossil fuels are assumed to be used in balance, are investigated for the time period October 2010 - September 2018. Hubbard and Bering Glaciers are projected to have increased accumulation, particularly on the upper glaciers, and greater ablation, particularly on the lower glaciers. The annual net balance for the entire Bering Glacier is projected to be significantly more negative, on average (-2.0 m/yr w.e. compared to -1.3 m/yr during the hindcast), and for the entire Hubbard Glacier somewhat less positive (0.3 m/yr w.e. compared to 0.4 m/yr during the hindcast).