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Changes in Surface Energy Budget and Firn Structure on the Accumulation Area of the Greenland Ice Sheet Revealed by Weather Station Observations and Modelling

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Recent Arctic atmospheric warming has induced more frequent surface melt on the Greenland ice sheet and caused changes in firn structure that could hamper the ice sheet's capacity to retain meltwater through refreezing. Few long-term observational records in the accumulation area are available to determine the magnitude, evolution and drivers of surface and subsurface processes. In this study, we compile respectively 16-18 years of climate data from the Crawford Point, Dye-2, NASA-SE and Summit Greenland Climate Network (GC-Net) automatic weather stations between 1996 and 2014. We use nearby stations and output from a regional climate model to gap-fill these records that then force a coupled surface energy balance and firn evolution model. Over the study period, all sites exhibit statistically insignificant increases in air temperatures (0.3 - 0.9 oC/decade for annual and 0.6 - 1.3 oC/decade for summer temperature). Increasing summer latent and sensible heat fluxes are compensated by decreasing net radiative fluxes at all sites, leading to an insignificant melt magnitude increase, not taking into account the extreme melting in 2012. Yet the simulations reveal that the density of the top 20 m of firn at Crawford Point and Dye-2 increased by 9.3% and 17.3%, reducing pore space by 12% and 25%, respectively. Firn density at high-elevation sites NASA-SE and Summit was found to be stable since the mid-1990s. The simulations indicated that the year-to-year changes in density were driven for a large part by inter-annual variability in precipitation, and should therefore not be attributed melt variability alone.