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Mechanisms of multiple, anomalous melt events at Summit Station, Greenland in summer 2019

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Above freezing temperatures and melting surface snow have occurred at Summit Station (3250 m asl), atop the Greenland Ice Sheet, only five times in the last 800 years, including once in 2012 and twice 2019 (June 12; July 29-31). Such events are linked to southerly advection of continental air that cross the North Atlantic as atmospheric rivers (ARs). The specific mechanisms that are responsible for these rare events appear to be varied and complex. While the 2012 event was supported by anomalous cloud forcing caused by thin, liquid-bearing clouds, the two events in 2019 occurred under both clear and cloudy conditions. The net surface radiation measured during the 2019 events was actually similar between clear (~47 W m^{-2}) and cloudy (~52 W m^{-2}) conditions, and, surprisingly, these values are unremarkable for afternoon conditions in summer at Summit Station.

Observations from the ICECAPS-ACE project at Summit Station (including radiative and turbulent fluxes, surface skin temperature, snow pit stratigraphy) allow a process-level analysis of the mechanisms that transfer energy from the AR events into local melting. By combining the measurements with a finite-volume diffusion model of the sub-surface temperature field, we find that a concentration of energy in the surface layer caused by converging fluxes toward the surface from both directions (upward from within the snowpack and downward from the atmosphere) led to initiation of both of the 2019 melt events. Thus, coupling between the atmosphere and the snowpack, and the timing of atmospheric fluctuations, appear important, and are suggestive that preconditioning of the snowpack from events prior to the day of melt may be a factor. Both sensible and latent heat fluxes were relatively small during these melt events while several regimes of commonly occurring radiative processes were observed. Under cloudy conditions, longwave cloud radiative forcing played a role, while under clear skies, lower surface albedo was sufficient to make up the difference of the absence of cloud forcing. For example, during the July 2019 event, the surface snow albedo decreased significantly from 0.86 to 0.80, which facilitated greater absorption of solar radiation. These findings are supportive of the notion that longwave processes are triggers of melt while shortwave processes persist melt. he co-dependent roles of

the radiative and subsurface heat fluxes during the 2019 events suggest that the rarity of melt at Summit Station may be explained by preconditioning processes, and that a particular sequence of events over several days leading up to melt may be important.