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Atmosphere-Ice-Ocean Interactions During Early Autumn Freeze-up: Boundary-Layer and Surface Observations from the ACSE Field Program

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Surface energy fluxes are key to the annual summer melt and autumn freeze-up of Arctic sea ice, but are strongly modulated by atmospheric, ocean, and sea-ice processes. This paper will examine direct observations of energy fluxes during the onset of autumn freeze-up from the Arctic Clouds in Summer Experiment (ACSE), and place them in context of those from other observational campaigns. The ACSE field program obtained measurements of surface energy fluxes, boundary-layer structure, cloud macro- and microphysical structure, and upper-ocean thermal and salinity structure from pack-ice and open-water regions in the eastern Arctic from early July to early October 2014. Late August and September measurements showed periods of energy flux deficits, leading to freeze-up of sea ice and the ocean surface. The surface albedo and processes impacting the energy content of the upper ocean appear key to producing a temporal difference between the freeze-up of the sea ice and adjacent open water. While synoptic conditions, atmospheric advection, and the annual solar cycle have primary influence determining when energy fluxes are conducive for melt or freeze, mesoscale atmospheric phenomena unique to the ice edge region appear to also play a role. For instance, low-level jets were often observed near the ice edge during the latter part of ACSE, and may have enhanced the turbulent energy loss. In conjunction with observations of summer melt, these observations of the onset of freeze-up suggest scenarios of key atmospheric processes, including thermal advection on various scales, that are important for the annual evolution of melt and freeze-up.