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Atmospheric transport, clouds and the Arctic longwave radiation paradox

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Clouds interact with radiation, causing variations in the amount of electromagnetic energy reaching the Earth's surface, or escaping the climate system to space. While globally clouds lead to an overall cooling radiative effect at the surface, over the Arctic, where annual cloud fractions are high, the surface cloud radiative effect generally results in a warming. The additional energy input from absorption and re-emission of longwave radiation by the clouds to the surface can have a profound effect on the sea ice state. Anomalous atmospheric transport of heat and moisture into the Arctic, promoting cloud formation and enhancing surface longwave radiation anomalies, has been identified as an important mechanism in preconditioning Arctic sea ice for melt. Longwave radiation is emitted equally in all directions, and changes in the atmospheric infrared emission temperature and emissivity associated with advection of heat and moisture over the Arctic should correspondingly lead to an anomalous signal in longwave radiation at the top of the atmosphere (TOA). To examine the role of atmospheric heat and moisture transport into the Arctic on TOA longwave radiation, infrared satellite sounder observations from AIRS during 2003-2014 are analyzed for summer (JJAS). Thermodynamic metrics are developed to identify months characterized by a high frequency of warm and moist advection into the Arctic, and segregate the 2003-14 time period into climatological and anomalously warm, moist summer months. We find that anomalously warm, moist months result in a significant TOA longwave radiative cooling, which is opposite the forcing signal that the surface experiences during these months. At the timescale of the advective events, 3-10 days, the TOA cooling can be as large as the net surface energy budget during summer. When averaged on the monthly time scale, and over the full Arctic basin (poleward of 75°N), summer months experiencing frequent warm, moist advection events are observed with a TOA longwave flux to space that is 2 to 4 W m-2 larger than climatology. This represents a significant climate cooling signal, suggestive of a regional climate buffering mechanism to combat excessive Arctic warming.