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The radiative effect of supercooled liquid and mixed-phase clouds by active satellite remote sensing

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Supercooled liquid and mixed-phase clouds are important players in the global climate system with a strong impact on surface energy budgets. Yet, this impact remains a key uncertainty in climate models, currently limiting the reliability of future climate projections. Much is unknown about the physical properties of mixed-phase clouds, including frequency of occurrence of supercooled water, partitioning between ice and liquid, the sizes and concentrations of cloud droplets, and vertical distribution of liquid and ice water contents. Ground-based observations of mixed-phase clouds do not provide extensive spatial information, leaving the large-scale effects of these clouds unknown.

With the advent of the CloudSat and CALIPSO satellites, this limitation could potentially be overcome. The CloudSat fluxes and heating rates (FLXHR-LIDAR) product combines collocated CloudSat, CALIPSO and MODIS observations into vertical profiles of cloud microphysical properties and shortwave and longwave radiative fluxes. The combination of radar and lidar is especially useful for the retrieval of radiative forcing by mixed-phase clouds. We conducted an evaluation study over the Greenland ice sheet where low-level mixed-phase clouds occur frequently, showing that the FLXHR-LIDAR product retrieves the radiative fluxes at the surface with high accuracy. This radiative flux product, constrained by observations, is therefore capable of retrieving supercooled liquid and mixed-phase cloud forcing at the surface for the first time on a global scale. Our results show a high occurrence of mixed-phase clouds globally, with a consequently large impact on the surface energy budget. The highest probability of clouds containing supercooled liquid water is found in middle and high latitudes. Cloud radiative forcing strongly depends on microphysical properties of these clouds: for example, over Greenland optically thin clouds with liquid water path < 60 g m^{-2} have the strongest warming impact on the ice sheet surface energy balance. Our results urge the need for further improving the representation of clouds in climate models, to enhance the reliability of global future climate projections.