

# Sensitivity of Longwave Infrared Polarization to Ice Crystal Habit

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Ice clouds play a central role in regulating atmospheric circulation, radiative balance, and precipitation. However, representing ice cloud microphysical processes and radiative effects in atmospheric models remains challenging, due in part to limited constraints on ice crystal morphology and orientation. Polarimetric remote sensing provides a promising pathway for characterizing ice crystal complexity in high clouds. Existing and planned satellite polarimeters have primarily focused on the shortwave and microwave spectral regions (e.g., POLDER, CALIPSO, SPEXone, HARP2, and GPM-GMI), while polarization in the longwave infrared (LWIR) has remained comparatively unexplored despite the strong coupled emission–scattering behavior of ice clouds in this spectral region. The development of the CHanneled Infrared Polarimeter (CHIRP) creates new opportunities to investigate ice cloud polarimetric signatures in the LWIR

In this work, we present polarized LWIR radiative transfer simulations for a range of tropical ice cloud scenarios representative of developing convection and spreading anvils. Using a polarized Markov chain radiative transfer model, we compute the polarization difference (PD), defined as the difference between vertically and horizontally polarized brightness temperatures, at 8.5, 9.5, and 10.5  $\mu\text{m}$ . Simulations span broad ranges of cloud optical depth ( $\tau = 0.05\text{--}20$ ), cloud-top height (8.5–15.5 km), viewing zenith angle ( $0^\circ\text{--}70^\circ$ ), ice crystal effective radius (5–90  $\mu\text{m}$ ), surface emissivity (0.75–0.99), and randomly oriented ice crystal habits including droxtals, plates, solid columns, bullet rosettes, and 8-column aggregates.

Results show distinct horizontally polarized signatures for randomly oriented ice clouds, with PD magnitudes approaching  $-1$  K for optical depths near  $\tau \approx 5\text{--}7$ , particularly for the smallest and largest ice crystals ( $\text{reff} < 20$   $\mu\text{m}$  and  $\text{reff} > 40$   $\mu\text{m}$ ). Enhanced polarization signals also occur for oblique viewing geometries ( $50^\circ\text{--}70^\circ$ ) and for clouds near the tropopause. Transitions between ice crystal habits produce LWIR PD differences of up to 0.3 K at specific viewing angles, demonstrating sensitivity to particle morphology. Finally, we discuss ongoing efforts to extend these parameter sweeps to include preferentially oriented ice crystals and the implications for future spaceborne LWIR polarimetric observations.

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