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Polarimetric remote sensing of clouds in polar regions

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Cloudiness plays a significant role in the radiation balance of polar latitudes, which are highly sensitive to climatic changes. Remote sensing of clouds in polar regions is particularly challenging due to the low visible and thermal contrast with the underlying surface. However, the polarization of radiation resulting from scattering by cloud particles can serve as a key parameter for retrieving their microphysical and optical properties.

To evaluate the potential of polarimetric measurements, numerical experiments were conducted using the Fast Line-by-Line Model (FLBLM), a radiative transfer model that calculates Stokes parameters for outgoing solar and thermal radiation in the visible, near-infrared, and thermal infrared ranges. Various cloud scenarios (optical thickness, altitude, phase composition) and surface types (ice/open water) were investigated. Results revealed that linear polarization of solar radiation exhibits ~10% sensitivity to changes in cloud structure, while maintaining consistent polarization levels even with reduced albedo and satellite-detected signal intensity. Thermal radiation showed weak polarization (~1%), detectable only in limb-viewing geometries, limiting its utility but not excluding it entirely. All experiments utilized high spectral resolution (0.1 cm^{-1} or better), enabling layer-by-layer atmospheric analysis by isolating altitude-dependent contributions through variations in radiation penetration depth within spectral lines. Specifically, high spectral resolution aids in mitigating the influence of the underlying surface and lower atmospheric layers in strong gas absorption bands.

Current satellite systems rarely combine high spectral resolution with polarimetric capabilities, reducing their effectiveness for cloud remote sensing. Developing new instruments with both features could significantly enhance the accuracy of cloud parameter retrieval in polar regions. The FLBLM model can be employed to optimize future satellite experiments, including the selection of spectral ranges and observation geometries. Thus, passive polarimetric remote sensing holds substantial potential for cloud monitoring in polar latitudes but requires further advancements in instrumentation.

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