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THOR – Cloud Thickness from Offbeam Lidar Returns

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Conventional wisdom is that lidar pulses do not significantly penetrate clouds having optical thickness exceeding about T = 2, and that no returns are detectible from more than a shallow skin depth. Yet optically thicker clouds of $T >> 2$ reflect a larger fraction of visible photons, and account for much of Earth's global average albedo. As cloud layer thickness grows, an increasing fraction of reflected photons are scattered multiple times within the cloud, and return from a diffuse halo that grows around the incident pulse, increasing in horizontal area with layer physical thickness. The reflected halo is largely undetected by narrow field-of-view (FoV) receivers commonly used in lidar applications. THOR – Thickness from Offbeam Returns – is an airborne wide-angle detection system with multiple FoVs, capable of observing the diffuse halo as a wide-angle signal, from which the physical thickness of optically thick clouds can be retrieved. In this paper we describe the THOR system, demonstrate that the halo signal is stronger for thicker clouds, and validate physical thickness retrievals for clouds having $T > 20$, from NASA P-3B flights over the Department of Energy/Atmospheric Radiation Measurement/Southern Great Plains site, using the lidar, radar and other ancillary ground-based data.