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Airborne hyperspectral observations of surface and cloud directional reflectivity using a commercial digital camera

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Spectral radiance measurements by a digital single-lens reflex camera were used to derive the directional reflectivity of clouds and different surfaces in the Arctic. The data have been collected by aircraft during the Solar Radiation and Phase discrimination of Arctic Clouds (SORPIC) campaign in May 2010 above the Greenland Sea. The camera has been calibrated radiometrically and spectrally to provide accurate radiance measurements with high angular resolution. Each camera pixel has covers a field of view of about 0.025° which allows to resolve detailed angular patterns in the directional reflectivity. A comparison with spectral radiance measurements with the Spectral Modular Airborne Radiation measurement sysTem (SMART-Albedometer) showed an agreement within the uncertainties of both instruments (6% for both). The agreement between both instruments shows that the digital camera is capable of quantitatively measuring the distribution of reflected radiances.

Using the radiance measurements of the camera, the directional reflectivity in terms of the hemispherical directional reflectivity factor (HDRF) was obtained for sea ice, ice-free ocean and clouds. The sea ice, with an albedo of ρ = 0.96 (at 530 nm wavelength), showed an almost isotropic HDRF, while sun glint was observed for the ocean HDRF (ρ = 0.12). For the cloud observations with ρ = 0.62 the cloudbow, a backscatter feature typically for scattering by liquid water droplets, was covered by the camera with high resolution. For measurements above a heterogeneous stratocumulus clouds the required number of images to obtain a mean HDRF which clearly exhibits the cloudbow has been estimated at about 50 images (10 min flight time). A representation of the HDRF as function of the scattering angle only, reduces the image number to about 10 (2 min flight time).

The measured cloud and ocean HDRF have been compared to radiative transfer simulations. The ocean HDRF simulated with the observed surface wind speed of 9ms-1 agreed best with the measurements. For the cloud HDRF, the best agreement was obtained by a broad and weak cloudbow simulated with a cloud optical thickness of 10.5 and a cloud droplet effective radius of 4 μm. This value agrees with the particle sizes derived from in situ measurements and retrieved from the spectral radiance of the SMART-Albedometer. This indicates that camera measurements can be used to systematically retrieve the cloud properties such as cloud optical thickness and cloud effective radius