Characterization of Surface Directional Reflectance Properties over the US Southern Great Plains from Airborne Measurements and Surface Observations

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Abstract

Onboard the Jetstream-31 research aircraft (Fig. 1a), the NASA's Cloud Absorption Radiometer (CAR; Fig. 1b, shown in the nose cone) [1, 2] acquired angular reflectance measurements over the Atmospheric Radiation Measurement (ARM) Program's Southern Great Plains Central Facility (SGP-CF) during the 2007 Cloud and Land Surface Interaction Campaign (CLASIC) [3]. Results were used to quantify the differences in surface directional reflectance, and related measures of vegetation structure, at multiple spatial scales. Linking angular reflectance measurements for a given surface location yields the underlying reflectance anisotropy, or Bidirectional Reflectance Distribution Function (BRDF), for that location. Because of its impact on higher-level surface biophysical properties (e.g. vegetation indexes, surface albedo, LAI/FPAR, burned area, land cover, and land cover change), it is important to obtain an accurate representation of surface BRDFs across space and time. However, the high variability of BRDF measurements and the different levels of accuracy of the measuring instruments introduce major sources of uncertainties that are not properly accounted for with conventional validation methods. In particular, the vast differences in spatial sampling between satellite retrievals and *in-situ* measurements have thus far created a number of technical and logistical challenges for such direct "point-to-pixel" comparisons. Empirical quality of BRDF data is rarely certain; but knowledge of their uncertainties is essential to understand its effect on the higher-level (reflectance-based) products. In this effort, we introduce an algorithm suitable for such a task by using atmospherically-corrected surface directional reflectances acquired by the CAR instrument. Onboard the Jetstream-31, the CAR instrument flew a clockwise circular pattern above the surface repeatedly, drifting with the wind at different altitudes ranging from ~0.2 km to <8 km (Fig. 1c). The instrument then scanned the underlying surface, and much of the transmitted solar radiation from above, and made radiometric observations about every 1° in azimuth

and about 1° in zenith angle. To measure the BRDF, multiple circular orbits were acquired under clear sky conditions. The instantaneous retrievals were then analyzed over four uniform plots representative of the most common surface conditions of the SGP-CF domain during CLASIC (i.e. pasture (seen in Fig. 2), corn, winter-wheat, and stubble). The multi-scale results were partitioned into five spatial intervals and analyzed over three spectral bands (i.e. 0.472 µm, 0.682 µm, and 0.870 µm). RossThick-LiSparseReciprocal (RTLSR) BRDF model inversions [4-6] were then fitted to these retrieval scenarios to obtain a full BRDF model of the area. This new methodology results in accuracy assessments that enable evaluation and partitioning of measurement, scaling, and analytical (or model-driven) errors. Areal-mean, nadir-normalized, and angular indexes of vegetation structure were also analyzed. The impact of the uncertainties associated with these multi-scale retrievals where most influenced by: (i) the number of samples obtained for a particular spatial threshold; (ii) retrieval quality (both measured and model-based); and (iii) the degree to which directional effects are minimized. The results from this study will help to improve model parameterization of land surface reflectance and address upscaling needs for comparison with satellite measurements [7] and aerosol retrievals [8].

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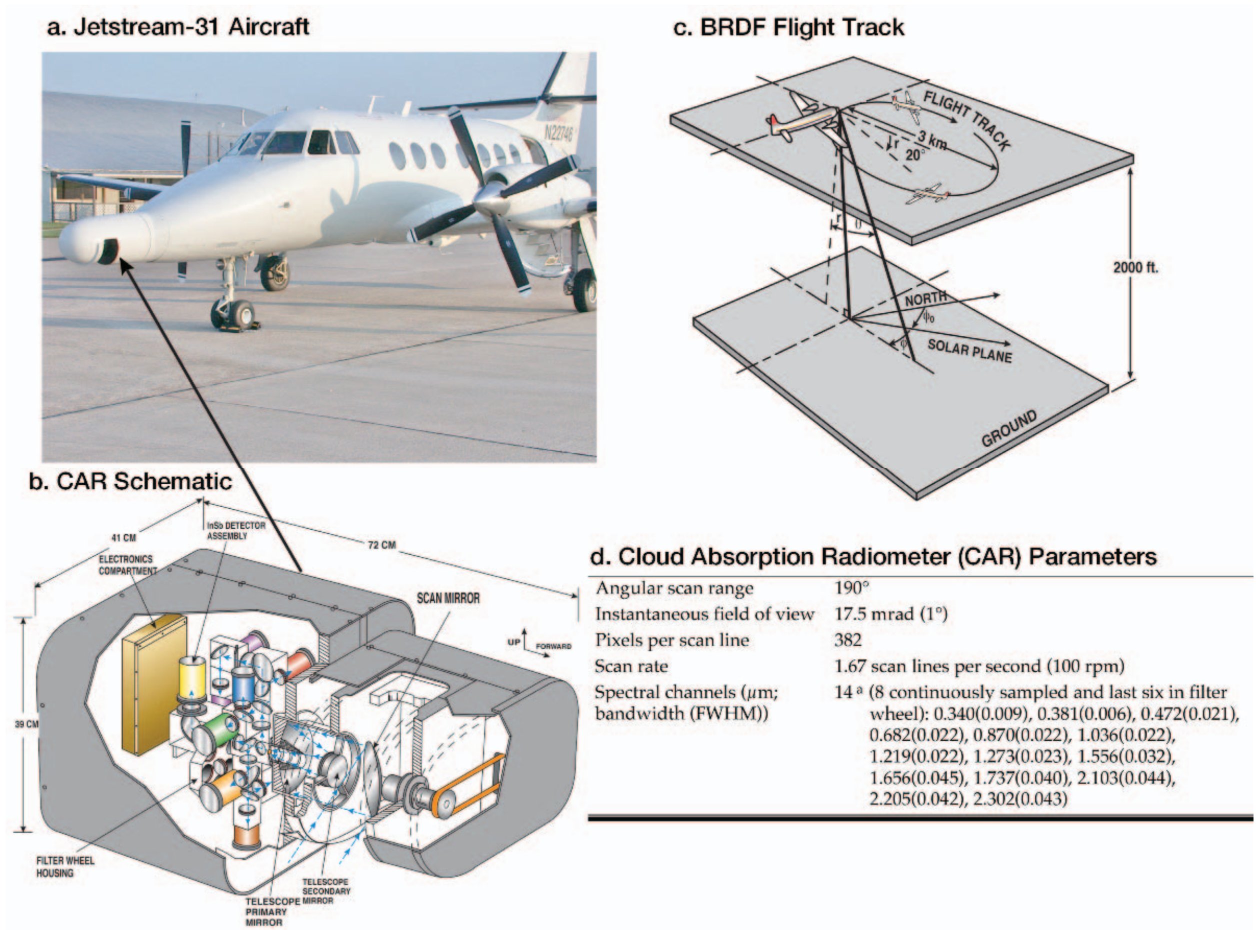

Fig. 1. (a) The N22746 aircraft registered to Sky Research Inc. (USA), also known as Jetstream-31 (J-31) in Ponca City Airport, Oklahoma, USA during the CLASIC Experiment. **(b)** Schematic of NASA's Cloud Absorption Radiometer (CAR), which is mounted in the nose cone of J-31. The CAR measured spectral and angular distribution of scattered light by clouds and aerosols, and obtained good imagery of cloud and Earth surface features over many areas in the Southern Great Plains (SGP). **(c)** Illustration of a clockwise circular flight track, which was used for measuring surface bidirectional reflectance distribution function (BRDF) over the SGP Central Facility during CLASIC. **(d)** The CAR has 14 narrow spectral bands between 0.34 and 2.30 μm, and flew 11 missions during CLASIC [1, 2].

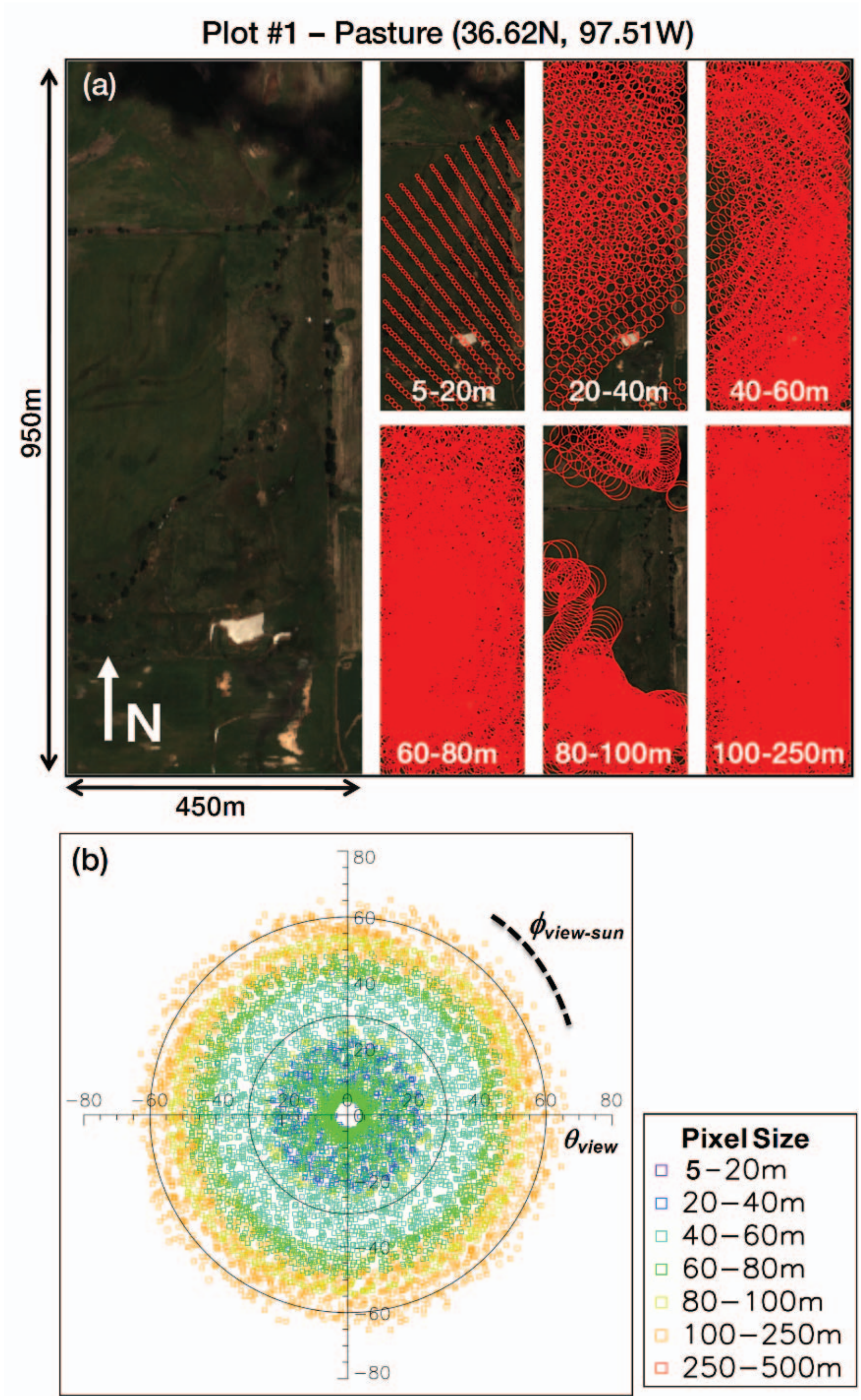

Fig. 2. (a) Instantaneous retrievals of surface directional reflectance, as retrieved from CAR during CLASIC Flight #1928 over a plot of pasture located outside of Lamont, Oklahoma. Results have been partitioned into five spatial intervals (from 5.0-250 m^2). **(b)** Polar plot showing the angular distribution of the CAR retrievals using the same spatial intervals as Fig. 2a. The viewing zenith angle is represented as the radial distance from the center and the relative (view-solar) azimuth angle as the length of the arc on the respective zenith circle. The principal plane resides in the vertical plane.