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Atmospheric Measurement Techniques Discussions

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Interactive Comment

Interactive comment on "Influence of spatial heterogeneity of local surface albedo on the area-averaged surface albedo retrieved from airborne irradiance measurements" *by* E. Jäkel et al.

Anonymous Referee #1

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Title: Influence of spatial heterogeneity of local surface albedo on the area-averaged surface albedo retrieved from airborne irradiance measurements

Author(s): E. Jäkel et al.

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General Comments

This paper describes the ability of aircraft irradiance measurements to resolve/retrieve the small-scale variability in spectral surface albedo from flight altitude. Although over-simplified, I view this paper as providing a means to 'down-scale' aircraft measurements to the surface point-of-view versus the 'up-scale' approach required to validate satellite retrievals of surface albedo. The authors determine under what a) flight conditions (altitude, and distance from boundary of surface types) and, b) atmosphere conditions between flight level and the surface (aerosols, molecules) the retrieved airborne or satellite surface albedo is equivalent to what would be measured at the surface, what the authors call the local surface albedo.

For hemispheric irradiance measurements and isotropic radiation, half of the signal measured by airborne radiometers will come from 45 degrees of normal incidence (i.e. from an area with radius roughly equal to the flight altitude above ground). Components of the real atmosphere and surface, such as aerosols and surface features, have anisotropic scattering signatures. The authors quantify the variability to this signal due to anisotropic scattering from aerosols between the surface and flight level and from the surface itself. Above some flight altitude, the increased contributions to the measured signal (i.e. a larger half-power area) and from multiple scattering effects will 'smear' out the variability from these anisotropic contributions. The authors investigate these effects through a series of 3-dimensional modeling studies of vertically resolved irradiance fields for a broad array of surface boundary conditions (heterogeneous albedo maps of varying grid size, albedo magnitude, and surface types - ocean, soil, field, forest), atmospheric profile, aerosol content and scattering phase function, and solar zenith angle. From this analysis, they come up with a parameterization relating the mean deviation between local 'true' surface albedo and the area-averaged surface albedo retrieved from aircraft. The parameterization is valid for the wavelength range 400-1000 nm and moderate aerosol conditions. The authors demonstrate, through an introduced parameter called the critical distance, the horizontal distance away from a surface albedo boundary (their example is a coastline between land and sea surface) from which the area-averaged albedo from flight altitude will not be impacted by the boundary between the surfaces (i.e. the point at which the signal measured at the aircraft comes only from one lower boundary). Such a parameterization allows users of remote sensing applications requiring knowledge of local surface albedo to filter area-averaged airborne retrieved so that the aircraft retrievals will also be representative of the local surface albedo. The authors show deviations between local and area-averaged surface albedo can reach 100%.

For retrievals of surface albedo made from aircraft altitudes, the authors find the prime variables controlling the critical distance are the maximum magnitude range in the local surface albedos across the boundary and the aerosol optical depth between the surface and the level of flight; responsible for contributing to scattering of the reflected surface signal referred to as the 'atmospheric masking' of the surface albedo. (The assumption for the aerosols being that they are scattering and therefore increase the signal measured at flight level; not correcting for this increase in scattering would result in a surface albedo larger than the truth. To my knowledge, the authors do not address the possibility of an absorbing aerosol over a reflective surface, in which case the measured signal at flight level would be less than that at the surface.)

The authors also investigate satellite retrievals of surface albedo. In this case, the "flight" altitude is much greater than the horizontal extent of any particular individual region of homogeneous albedo within an overall heterogeneous surface albedo scene. Here, they find the greatest dependency predicting the point at which the 'smearing' or averaging out of surface scattering contributions to be the physical area of each individual homogenous surface (within the larger heterogeneous context); the atmospheric contributions to the scattering are second order so long as the aerosol loading is moderate (they define to be AOD < 0.4) and the spectral band is free of strong molecular absorption. Hence, they find the parameterization to hold for these aerosol conditions and the visible to near-infrared regions (400-1000 nm). (Note, the authors in the abstract refer to the parameterizations for the 'visible' region, which should be corrected).

I find the authors work and methodology sound and I recommend acceptance.

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Specific Comments

I would suggest several items of clarification.

First, a statement regarding impacts of absorbing aerosol in the layer between the surface and the level of flight, and a statement to the geographical regions where aerosol conditions are nominally outside of the sensitivity analysis performed. In particular, an absorbing aerosol above a reflective surface could result in a measured albedo at flight level less than at the surface [Torres, O. et al., 1998, for example]. I did not see that the authors investigated the robustness of their fits and parameterizations to absorbing aerosols (the paper mentions only an aerosol single scattering albedo = 0.98). Per Bergstrom et al. [2007], who compiled a library of these values over a number of intensive measurement campaigns conducted in different geographical regions, some representative values of aerosol ssa were as low as 0.75 over the 400-1000 nm spectral range.

Second, it is implicit in the iterative approach to correct for the nonlinear atmospheric contributions to the measured signal at flight level [Wendisch et al., 2004] that the measured and modeled downwelling irradiance at flight level are equivalent. Although I'm sure this condition was met in the current work, it is not mentioned in the manuscript and it likely should be; the implications of an uncorrected mismatch between a measured and modeled downwelling irradiance at flight level would imply a mismatch in the reflected signal from the surface even for the same surface conditions.

Third, please discuss the application of equation (10) to spectral bands where the local surface albedo of the sea is higher than that of land, which is shown to be the case from 400-500 nm (per your Figure 4a).

Lastly, I'm having some difficulty interpreting the results of Figure 2b with respect to Figure 2a. I was assuming that I could "reverse" the direction of flight from land toward sea, say at 2 km flight altitude. According to Figure 2b, I would expect that the corresponding critical distance from coastline would be 4 km, at which point there would

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be no land surface ‘contamination’ in the measurements at flight altitude. However, if I then examine the AOD = 0.3 for ‘sea’ (filled triangle symbols) in Figure 2b), it suggests a critical distance of 6 km. I’m not sure if a) I’m simply not seeing the convergence to a 10% threshold criterion line on the left-hand side of the plot, or b) I have misinterpreted the approach.

Technical Comments/Corrections

Listed below are clarification requests and suggestions for minor grammatical errors that do no impact the readability of the manuscript.

p. 7458, Line 19 – “For moderate aerosol conditions (optical depth less than 0.4) and the visible wavelength range,..” please amend specified wavelength range to reflect your analysis out to 1000 nm.

p. 7460, Line 8 – “In remote sensing applications instead of irradiances, radiances are measured...”. Perhaps you are referencing strictly to satellite measurements? Airborne (remote) measurements can be irradiances, as does the SMART-Albedometer presented in your work.

p. 7460, Line 26 – Indent for new paragraph.

p. 7463, Line 22 – “ The up- and downward irradiances in flight level zflight were used in to...”. Remove the last occurrence of word ‘in’.

p. 7464, Line 20 – “In case no atmospheric masking...”. Add word “where” in between “case” and “no”.

p. 7462, Line 6 – “gets about one in Eq. (15)”. Awkward phrasing. How about “approaches unity” instead?

Figure 8 – It would aid interpretation if a distance (km) scale could be added to the x- and y- axis of longitude and latitude.

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 7457, 2012.