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Model for land surface reflectance treatment: physical derivation and evaluation on airborne and satellite measurements

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Intrinsic reflectance properties of surfaces are described by the bidirectional reflection matrix (BRM), which provides a relation between the Stokes parameters of scattered and incident radiation. On the basis of knowledge of the BRM the surface properties can be retrieved from the remote sensing measurements. Moreover, accurate models of BRM at visible and infrared wavelengths are required for retrieval of aerosols properties over land surfaces. To describe separately the surface contribution into intensity and polarization characteristics of scattered radiation, the bidirectional reflection distribution function (BRDF) and bidirectional polarization distribution function (BPDF) are often used. For land surfaces albedo characterization from satellite data as well as for aerosol properties retrieval over land, the semi-empirical models of BRDF and BPDF are usually applied. The crucial problem of the semi-empirical models is related to the fact that free parameters of the semi-empirical models are slightly related or not related at all to the actual physical parameters of the scattering surfaces. Moreover, existent semi-empirical BRDF and BPDF models are not related to each other. That complicates the surface properties characterization and introduces a lot of uncertainties into the problem of aerosol properties retrieval over land.

Here we present a model of BRM derived from the general solution of the electromagnetic scattering problems by random media. The equation for the reflection matrix is obtained within the far-field approximation when the ladder scattering diagrams only are taken into account. Also, to perform analytical averaging over orientation of the surface elements we assume that at different scales the surface can be considered as the Gaussian surface. In general, we can present the reflection matrix as sum of three other matrices: the first one describes Fresnel part of the scattered radiation, the second one describes diffuse radiation emerging from the single surface element, and the third matrix takes into account the multiple scattering between different surface elements. In the presented model the BRDF and BPDF are simply follow from the elements of the reflection matrix. The model applies strong constraints on the spectral dependence of the model parameters.

We use multi-angle photopolarimetric airborne measurements of the Research Scanning Polarimeter (RSP) and satellite PARASOL (Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observation from LIDAR) measurements to investigate the performance of the above described BRM model in terms of the three aspects for BRDF and BPDF models: (i) there must be known constraints on and invariances of the spectral and angular dependences of the BDRF and BPDF; (ii) BRDF and BPDF models should be able to describe correctly the surface signal with the geometry of the measurements (flexibility), as well as (iii) for all other geometries (predictability). The results of the comparison are discussed.