Using analytical description of snow BRDF for visible channel calibration

Igor Appel, iappel@earthlink.net

Environmental data derived from remotely sensed information depend on the quality of radiance measurements. Retrieval of high quality data, especially for the purpose of studying long-term climate changes, requires reliable calibration. Many instruments, in particular AVHRR, one of widely used for climatic studies, do not have onboard calibration.

Vicarious calibration using different types of land surface and deep convective clouds is considered as a mode to monitor the sensor performance. Snow cover as the brightest and in many cases spatially uniform surface has a significant potential as a calibration target. Proposed in this presentation approach is based on the creation and implementation of analytical bidirectional reflectance distribution functions (BRDF) model as distinct from the empirical and semi-empirical ones obtained in other works. An accurate analytical description of snow BRDF makes calibration possible without using in-situ observations.

It has been previously demonstrated [1] that snow cover at high elevations in Antarctica and Greenland is characterized by stable climate values of reflectivities, first of all, for close to nadir satellite observations, which is used as a principal basis for calibrations.

The same high altitude regions are chosen for this presentation to simulate BRFD and monitor degradation of visible channels. The analysis is limited by the areas of dry snow characteristic for high parts of Antarctica and Greenland not undergoing summer melting. The zones of dry snow are determined in [2] using comparative analysis of simultaneous nadir observations from altimeter and radiometer sensors on Envisat and correspond to the classification of dry snow zones developed in [3].

Different theoretical approaches -- two-stream theory, Mie discrete scattering, and geometric optics -- were expediently compared to assess their ability to calculate diffusive radiation from snow cover at a visible wavelength for the snow conditions at high elevations in Antarctica and Greenland. Various descriptions of absorption, transmission, reflectance, and multiple scattering were taken into consideration. It has been demonstrated that only means of geometric optics could describe angular dependencies related to bidirectional snow reflectance, and a simple asymptotic analytical model could be used to calculate theoretically bidirectional reflectance.

For visible wavelengths, typical grain sizes for conditions under consideration belong to the regime of geometric optics and Mie description could be replaced by the results from geometric optics when optical properties approach to asymptotic values. The comparison of results based on Mie theory and the ray-tracing tools of geometric optics demonstrates close correspondence for values of absorption coefficients, scattering coefficients, as well as the scattering phase function, which means that the values of those parameters could be used from numerous available observations.

The techniques of geometric optic is used to develop the asymptotic analytical equation to describe BRDF [4], which significantly simplifies the calculations without using any assumptions about the distribution of radiation intensities within snow and demonstrates obvious advantages even in calculating integrated characteristic of radiation transfer.

The quality of the analytical BRDF model was estimated on the basis of comparison with MODIS observations used as a standard of radiative measurements. The model robustly simulates MODIS directional reflectance fraction measurements. The use of the analytical model shows advantages in comparison with other methods of calibration and works reliably for large zenith angles. In particular, the analytical model of BRDF simplifies a combination of data from different instruments to form long-term uniform series of data, theoretically transforming various observations to single standard without using traditional cross-calibration techniques [5].

Potential applications of the analytical BRDF model go far beyond means of calibration. The model could be used to calculate snow albedo including large zenith solar and viewing angles (the analysis of the model sensitivities demonstrates high accuracy of simulation for the cases with large solar or viewing angles). The analytical model of BRDF in combination with a specific scattering phase functions is able to describe a wider variety of snow conditions than best-fit semi-empirical models of BRDF based on decomposition of the reflectance factor into a number of geometric kernel functions and characterized by large errors for low solar elevations.

The analytical BRDF model could be also used to normalize reflectances for the purpose of creating seamless mosaics without showing edges of individual scenes. The approach developed in [6] could be realized with high accuracy using the analytical BRDF model as simulated BRDF results reliably reproduce pronounced dependence of LANDSAT reflectance upon sun elevation obtained on the basis of processing numerous observations.

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