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Evaluating radiative transfer schemes treatment of vegetation canopy architecture in land surface models

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Incoming shortwave radiation is the primary source of energy driving the majority of the Earth's climate system. The partitioning of shortwave radiation by vegetation into absorbed, reflected, and transmitted terms is important for most of biogeophysical processes, including leaf temperature changes and photosynthesis, and it is currently calculated by most of land surface schemes (LSS) of climate and/or numerical weather prediction models. The most commonly used radiative transfer scheme in LSS is the two-stream approximation, however it does not explicitly account for vegetation architectural effects on shortwave radiation partitioning. Detailed three-dimensional (3D) canopy radiative transfer schemes have been developed, but they are too computationally expensive to address large-scale related studies over long time periods. Using a straightforward one-dimensional (1D) parameterisation proposed by Pinty et al. (2006), we modified a two-stream radiative transfer scheme by including a simple function of Sun zenith angle, so-called "structure factor", which does not require an explicit description and understanding of the complex phenomena arising from the presence of vegetation heterogeneous architecture, and it guarantees accurate simulations of the radiative balance consistently with 3D representations. In order to evaluate the ability of the proposed parameterisation in accurately represent the radiative balance of more complex 3D schemes, a comparison between the modified two-stream approximation with the "structure factor" parameterisation and state-of-art 3D radiative transfer schemes was conducted, following a set of virtual scenarios described in the RAMI4PILPS experiment. These experiments have been evaluating the radiative balance of several models under perfectly controlled conditions in order to eliminate uncertainties arising from an incomplete or erroneous knowledge of the structural, spectral and illumination related canopy characteristics typical of model comparisons with in-situ observations. The structure factor parameters were obtained for each canopy structure through the inversion against direct and diffuse fraction of absorbed photosynthetically active radiation (fAPAR), and albedo PAR. Overall, the modified two-stream approximation consistently showed a good agreement with the RAMI4PILPS reference values under direct and diffuse illumination conditions. It is an efficient and accurate tool to derive PAR absorptance and reflectance for scenarios with different canopy densities, leaf densities and soil background albedos, with especial attention to brighter backgrounds, i.e. snowy. The major difficulty of its applicability in the real world is to acquire the parameterisation parameters from in-situ observations. The derivation of parameters from Digital Hemispherical Photographs (DHP) is highly promising at forest stands scales. DHP provide a permanent record and are a valuable information source for position, size, density, and distribution of canopy gaps. The modified two-stream approximation parameters were derived from gap probability data extracted from DHP obtained in a woody savannah in California, USA. Values of fAPAR and albedo PAR were evaluated against a tree-based vegetation canopy model, MAESPA, which used airborne LiDAR data to define the individual-tree locations, and extract structural information such as tree height and crown diameter. The parameterisation improved the performance of a two-stream approximation by making it achieves comparable results to complex 3D model calculations under observed conditions.