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Sensitivity of simulated forest canopy photosynthesis to cloud-induced variation in the spectral composition of diffuse and global photosynthetically active radiation

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Numerous studies have confirmed that rates of photosynthesis and ecosystem-atmosphere carbon dioxide exchange of forests are strongly dependent on diffuse light conditions, i.e. the partitioning of the total downwelling photosynthetically active radiation (PAR, 400-700 nm) between diffuse and beam fluxes. It has been widely shown that, for equal fluxes of total (global) PAR, the light-use efficiency of canopy photosynthesis increases with the diffuse fraction of PAR. This increase has been attributed to the efficient distribution of photons in the diffuse flux to the shaded leaves in the canopy interior. In forest ecosystems, clouds typically are the predominant agents of atmospheric scattering that determine the magnitude and variation of diffuse PAR. Recent research has shown that scattering of PAR by clouds causes predictable changes in the spectral composition of the global and diffuse PAR fluxes, as measured by the quanta-to-energy ratio (micromoles of photons per Joule). This study examines the sensitivity of forest canopy photosynthesis to cloud-induced spectral variation in PAR, as simulated with a sun-shade type model. A time series of 1-min spectral measurements of diffuse and global PAR collected for 102 days in the spring and summer of 2000 at a site in temperate North America was applied to the model for a theoretical temperate forest canopy (LAI=6). The results indicate that an increase in the diffuse photon flux associated with the scattering-related enhancement of radiation at longer (green-to-red) PAR wavelengths is responsible for an increase in photosynthesis of up to +7% by the shaded portion of the canopy. A subtle but opposite shift in the spectral composition of the global (beam + diffuse) PAR flux causes a smaller (up to -5%) decrease in photosynthesis by the sunlit leaves. The maximum net effect of the spectral changes on (gross) photosynthesis of the whole canopy is between 1-2%

under moderately cloudy conditions (diffuse fraction = 0.5). These results suggest that cloud-induced changes in the spectral composition of diffuse and global PAR affect forest photosynthetic rates at sub-canopy scales, and improved accuracy of detailed process models may require accounting for these effects. Because the net effect on whole-canopy photosynthesis is small, many general applications may neglect typical cloud-induced spectral variations in diffuse and global PAR without significant errors.