Incorporating diffuse radiation into a light use efficiency and evapotranspiration model: An 11-year study in a high latitude deciduous forest - DTU Orbit (11/01/2019)

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The fraction of diffuse photosynthetic active radiation (PAR) reaching the land surface is one of the biophysical factors regulating carbon and water exchange between terrestrial ecosystems and the atmosphere. This is especially relevant for high latitude ecosystems, where cloudy days are prevalent. Without considering impacts of diffuse PAR, traditional 'top-down' models of ecosystem gross primary productivity (GPP) and evapotranspiration (ET), which use satellite remote sensing observations, are biased towards clear sky conditions. This study incorporated a cloudiness index (CI), an index for the fraction of diffuse PAR, into a joint 'top-down' model that uses the same set of biophysical constraints to simulate GPP and ET for a high latitude deciduous forest. To quantify the diffuse PAR effects, CI along with other environmental variables derived from an eleven-year eddy covariance data set were used to statistically explore the independent and joint effects of diffuse PAR on GPP, ET, incident light use efficiency (LUE), evaporative fraction (EF) and ecosystem water use efficiency (WUE). The independent and joint effects of CI were compared from global sensitivity analysis of the 'top-down' models. Results indicate that for independent effects, CI increased GPP, LUE, ET, EF and WUE. Analysis of joint effects shows that CI mainly interacted with the radiation intercepted in the canopy (PAR, net radiation and leaf area index) to influence GPP, ET and WUE. Moreover, Ta and vapor pressure saturation deficit played a major role for the joint influence of CI on LUE and EF. In the growing season from May to October, variation in CI accounts for 11.9%, 3.0% and 7.8% of the total variation of GPP, ET and transpiration, respectively. As the influence of CI on GPP is larger than that on ET, this leads to an increase in WUE with CI. Joint GPP and ET model results showed that when including CI, the root mean square errors (RMSE) of daily GPP decreased from 1.64 to 1.45 g C m−2 d−1 (11.7% reduction) and ET from 15.79 to 14.50 W m−2 (8.2% reduction). Due to the interaction of diffuse PAR with plant canopies, the largest model improvements using CI for GPP and ET occurred during the growing season and for the transpiration component, as suggested by comparisons to sap flow measurements. Furthermore, our study suggests a potential biophysical mechanism, not considered in other studies: under high diffuse PAR conditions, due to the increased longwave emission from clouds, canopy temperature gets higher and enhances GPP and transpiration in this temperature-limited high latitude ecosystem.