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TITLE: Integration of airborne LiDAR data and voxel-based ray tracing to determine high-resolution solar radiation dynamics at the forest floor: implications for improving stand-scale distributed snowmelt models

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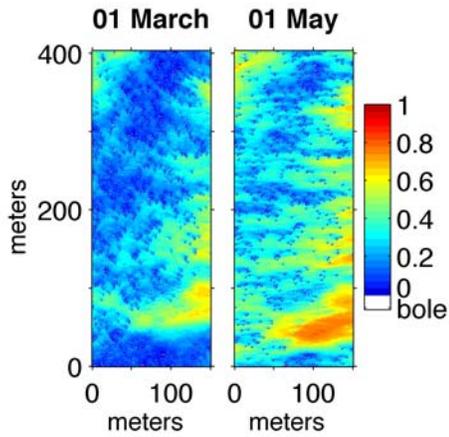
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ABSTRACT BODY: Forest architecture dictates sub-canopy solar irradiance and the resulting patterns can vary seasonally and over short spatial distances. These radiation dynamics are thought to have significant implications on snowmelt processes, regional hydrology, and remote sensing signatures. The variability calls into question many assumptions inherent in traditional canopy models (e.g. Beer's Law) when applied at high resolution (i.e. 1 m). We present a method of estimating solar canopy transmissivity using airborne LiDAR data. The canopy structure is represented in 3-D voxel space (i.e. a cubic discretization of a 3-D domain analogous to a pixel representation of a 2-D space). The solar direct beam canopy transmissivity (DBT) is estimated with a ray-tracing algorithm and the diffuse component is estimated from LiDAR-derived effective LAI. Results from one year at five-minute temporal and 1 m spatial resolutions are presented from Sequoia National Park. Compared to estimates from 28 hemispherical photos, the ray-tracing model estimated daily mean DBT with a 10% average error, while the errors from a Beer's-type DBT estimate exceeded 20%. Compared to the ray-tracing estimates, the Beer's-type transmissivity method was unable to resolve complex spatial patterns resulting from canopy gaps, individual tree canopies and boles, and steep variable terrain. The snowmelt model SNOWPACK was applied at locations of ultrasonic snow depth sensors. Two scenarios were tested; 1) a nominal case where canopy model parameters were obtained from hemispherical photographs, and 2) an explicit scenario where the model was modified to accept LiDAR-derived time-variant DBT. The bulk canopy treatment was generally unable to simulate the sub-canopy snowmelt dynamics observed at the depth sensor locations. The explicit treatment reduced error in the snow disappearance date by one week and both positive and negative melt-season SWE biases were reduced. The results highlight the utility of LiDAR canopy measurements and physically based snowmelt models to simulate spatially distributed stand- and slope-scale snowmelt dynamics at resolutions necessary to capture the inherent underlying variability.

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LiDAR-derived solar direct beam canopy transmissivity computed as the daily average for March 1st and May 1st.

(No Table Selected)

Additional Details

Previously Presented Material:

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