

Canopy Metrics from Airborne LiDAR for Improved Forest Snow Models

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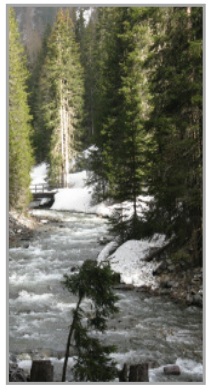
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Background:



Forested headwaters that are snowmelt dominated produce 60% of the freshwater runoff of the world.

As a model to other mountainous ecosystems, roughly 1/3 of Switzerland's land mass is covered by forests, 1/3 of the total annual precipitation is snowfall, and 1/3 of the winter precipitation fallen in forest regions is lost due to evaporation / sublimation of snow intercepted within the canopy.

Snow accumulation and ablation within forest structures also demonstrates much greater heterogeneity as compared to snow falling within open or alpine areas. Depending on the overlying structure, both maximum and minimum snow melt rates can be found under the canopy compared to open areas.

Experimental Design and Methods:

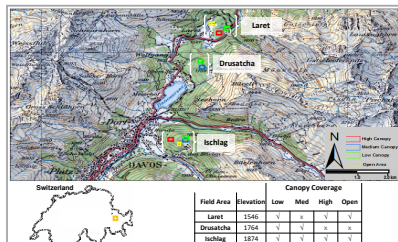


Figure 1. There are nine study areas surrounding Davos, Switzerland. High resolution LiDAR data is available for the majority of the green forested areas in the upper map.



Figure 2. (a) manual snow depth measurements (b) SWE (c) A low canopy closure field area, Laret low with sampling grid.

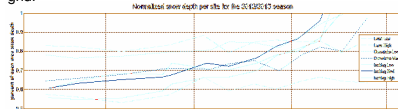


Figure 3. Forest area SD as a percentage of open area SD. Data integrated from approximately 45000 manual measurements.

Nine field areas were setup in 2012. Each forested field site is 50 x 50 meters in various canopy densities and consist of 12 transects per site. There are a total of 1982 surveyed points (± 50 cm).

Snow depth (SD) and **snow water equivalence (SWE)** measurements are taken on a storm-wise basis during accumulation and sampled regularly during ablation. **Total storm depth** is taken when conditions allow and is used as a proxy for canopy interception. Approximately 45000 manual measurements were taken for the 2012-/2013 winter season.

Hemispherical photographs (HP) were taken at 16 points per site (112 total) during uniform sky conditions in May 2013.

Radiometers were utilized during clear sky conditions to measure direct and indirect **incoming shortwave radiation** at 30 points in various canopy regimes in August 2013.

Results:

High resolution **aerial LiDAR** data has been manipulated to mimic the angular ground perspective of hemispherical photographs to estimate **canopy closure (CC)**, **leaf area index (LAI)** and **radiation transfer**.

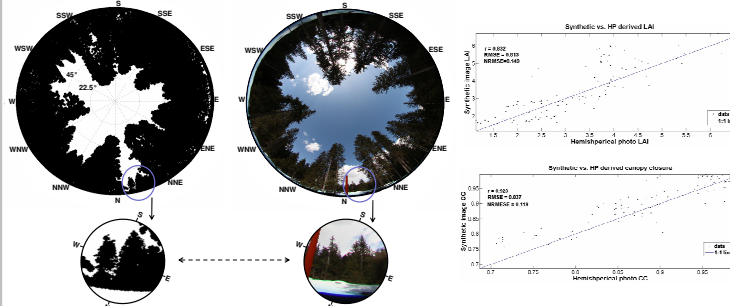


Figure 4. Hemispherical photo on right and synthetic image on left with distance integrated pixel print size, with canopy points closest to the origin represented as large pixels and points further as small pixels.

Figure 5. The upper graph compares LAI derived from synthetic images with HP values. The lower graph compares CC derived from synthetic images with HP values.

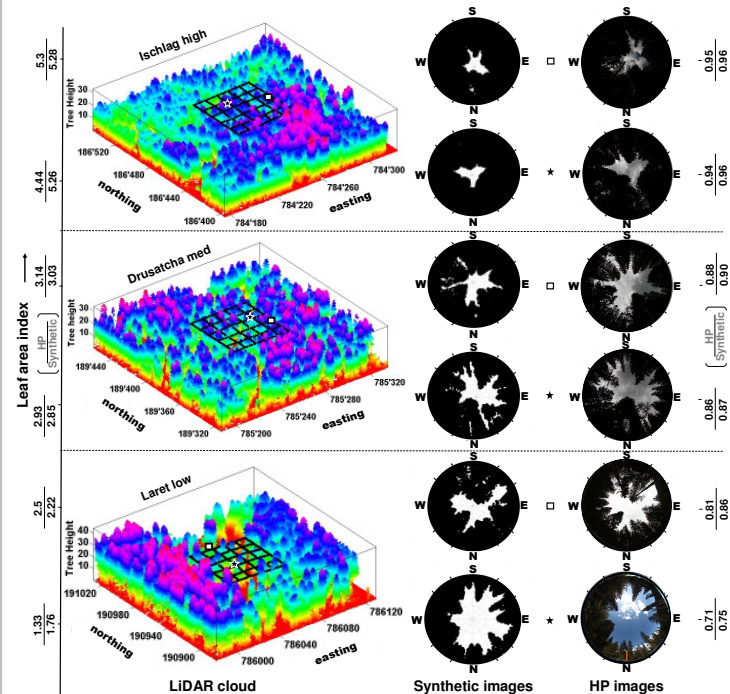


Figure 6. Examples of synthetic images from three field sites representing low, medium and high canopy closure. The y axis increases in CC and LAI values with the top number calculated from HP and the lower number from the synthetic images. The internal black lines in the LiDAR data represent the sampling grid (50 x 50m) where the hemispherical photos were taken. On the grid, a star and a square represent exact locations of the right hand photos.

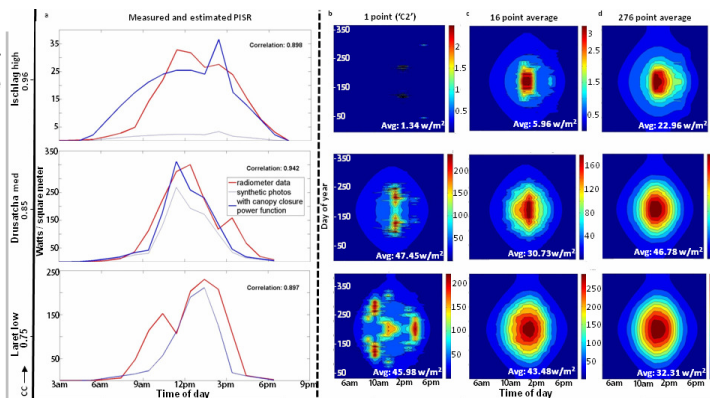


Figure 7. The y axis represents data from low to high CC with average field values below each name. Column 'a' is a comparison of incoming solar radiation from 10 radiometers (red) at each field site and the estimates from the synthetic images. Columns b,c,d show estimated yearly radiation regimes at the field areas derived from synthetic images. Column 'b' is estimation from one point (center of field area). Column 'c' is an average of 16 values from all primary intersection points. Column 'd' is an average of 276 values from all sampling points.

In Progress / Next Steps:

LiDAR data is available for all of Switzerland allowing for explicit and automated canopy structure calculations for various forest regimes. Correlations of snow and canopy metrics can then be compared at various scales.

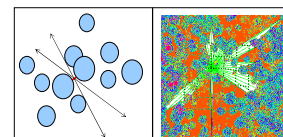


Figure 8. Graphics representing potential SD predictors from LiDAR: 'distance to stem' and 'realistic area.'

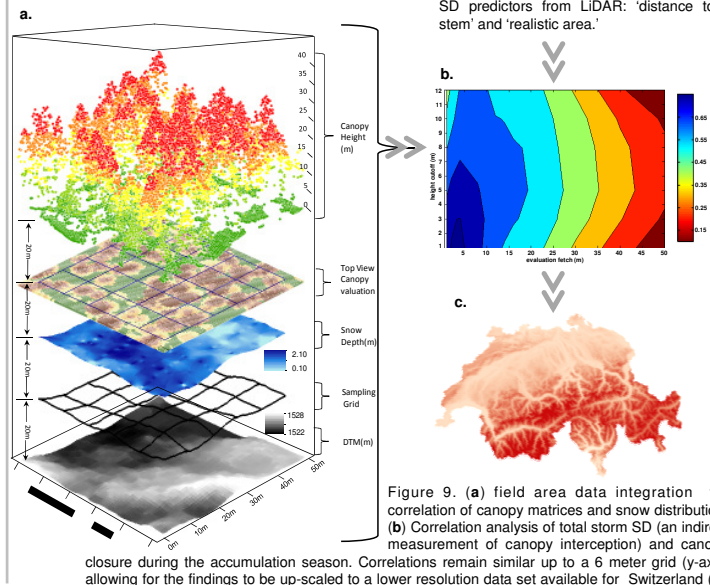


Figure 9. (a) field area data integration for correlation of canopy matrices and snow distribution. (b) Correlation analysis of total storm SD (an indirect measurement of canopy interception) and canopy closure during the accumulation season. Correlations remain similar up to a 6 meter grid (y-axis) allowing for the findings to be up-scaled to a lower resolution data set available for Switzerland (c).