The Use of Airborne Optical Spectrometer Data in Snow Cover Monitoring

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ABSTRACT

In this study the usability of optical airborne spectrometer data in snow cover monitoring is examined and discussed. Snow-covered area (SCA) estimation, specifically during the spring melt period, is important both for hydrological forecasting and climatological studies. The results of this study are used in accuracy assessment and further development of the Finnish Environment Institute's satellite data-based SCA-algorithm. The algorithm applies an empirical reflectance model that describes the reflectance from target area as a function of forest, snow and bare ground reflectance, SCA and average forest transmissivity.

COLLECTING AISA DATA

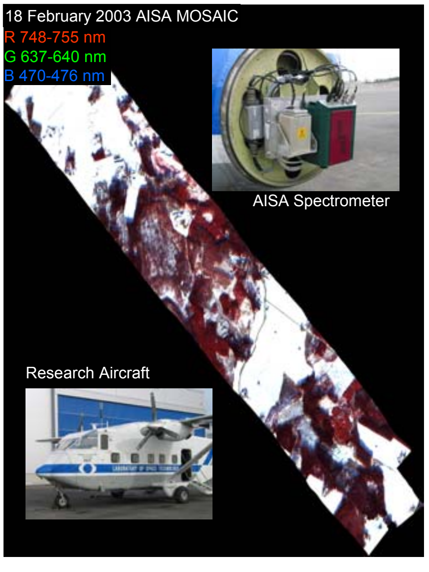

Figure 1. High resolution airborne optical images of boreal forest and related ground truth data were acquired in March 2002 and in February 2003 (this image). A pushbroom type imaging spectrometer AISA was used to investigate various land cover spectral properties. The 1000 m flight altitude and the 21º field of view resulted in a pixel size of 1m x 1m and a swath width of roughly 380 m. The wavelength range was 440 nm - 890 nm. The March 2002 imaging was carried out during snowmelt period. The February 2003 images were acquired under dry snow conditions.

STUDY AREA

Figure 2. The boreal test site of this study is located in South Finland, in latitude 60 N (red square). The land cover is mainly coniferous forest and agricultural land.

ANALYSES

The sensitivity of SCA-algorithm to variations in snow, forest and ground reflectance is analysed. The other focus is on determining the influence of forest characteristics to the standard values of transmissivity used in SCA-estimation. The used AISA wavelengths were chosen to simulate MODIS channel 4. In the model, reflectance from target is expressed as a function of SCA, forest canopy transmissivity and generally applicable reflectance values for wet snow ($\rho_{wetsnow}$), snow-free ground (ρ_{ground}) and forest canopy (ρ_{forest}):

$$\rho(SCA) = (1-t^2)*\rho_{forest} + t^2\left[SCA*\rho_{wetsnow} + (1-SCA)*\rho_{ground}\right] \quad (1)$$

ρ(SCA) stands for observed reflectance at current SCA. Transmissivity t^2 describes how much of the upwelling radiance is originated underneath the forest canopy. With full snow cover (SCA=1), a simple expression for t^2 is obtained from (1):

$$t^2 = \frac{\rho(SCA=1) - \rho_{forest}}{\rho_{drysnow} - \rho_{forest}} \quad (2)$$

The value of SCA is calculated by inverting (1), as follows:

$$SCA = \frac{\frac{1}{t^2}*\rho(SCA) + (1-\frac{1}{t^2})*\rho_{forest} - \rho_{ground}}{\rho_{wetsnow} - \rho_{ground}} \quad (3)$$

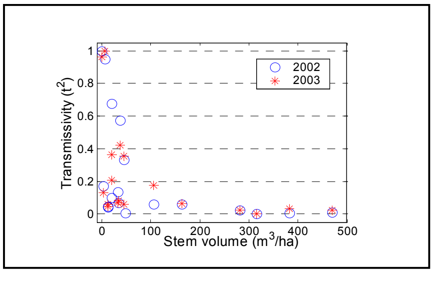

Figure 3. The AISA-derived estimates for the forest canopy transmissivity from (2) as a function of forest stem volume show lower level for dense forest and high level for nearly open areas. Now, the gained maximum radiance from forest opening represents $\rho_{drysnow}$ while minimum radiance from dense forests represents ρ_{forest}. ρ(SCA=1) is here the radiance observation for each stem volume case under full snow cover situation.

ANALYSES

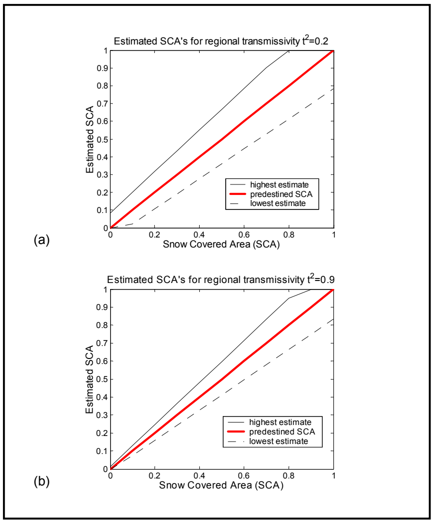

Figure 4. Results from the SCA algorithm sensitivity analysis show the largest possible differences between predestined SCA's and re-estimated SCA's for a) relatively dense forest and b) sparsely forested area with a high transmissivity. The analysis was carried out with model simulations by replacing standard snow, ground and forest reflectances in (1) with their AISA derived max. and min. values to obtain the maximum error limits for SCA-estimates. First, the simulated observations with the extreme reflectances were calculated for various SCA-values using (1). Then, from those observations, SCA was calculated using (3), but now with the average reflectance values observed with AISA. The results show that the model is more sensitive to reflectance variation in forest with low transmissivity.

CONCLUSIONS

- The acquired AISA data are applicable to the development and validation of snow covered area (SCA) retrieval algorithms due to the high spatial and spectral resolution of airborne spectrometer.
- The airborne spectrometer observations are feasible for the assessment of the accuracy of operative satellite data-based SCA algorithms in the boreal forest zone.
- Spectrometer is very useful in gathering spectra when SCA-algorithm is modified for other satellite instruments like ENVISAT/MERIS.

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