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Usability of multiangular imaging spectroscopy data for analysis of vegetation canopy shadow fraction in boreal forest

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Imaging spectroscopy is a remote sensing technology which records continuous spectral data at a very high (better than 10 nm) resolution. Such spectral images can be used to monitor, for example, the photosynthetic activity of vegetation. Photosynthetic activity is dependent on varying light conditions and varies within the canopy. To measure this variation we need very high spatial resolution data with resolution better than the dominating canopy element size (e.g., tree crown in a forest canopy). This is useful, e.g., for detecting photosynthetic downregulation and thus plant stress. Canopy illumination conditions are often quantified using the shadow fraction: the fraction of visible foliage which is not sunlit. Shadow fraction is known to depend on view angle (e.g., hot spot images have very low shadow fraction). Hence, multiple observation angles potentially increase the range of shadow fraction in the imagery in high spatial resolution imaging spectroscopy data.

To investigate the potential of multi-angle imaging spectroscopy in investigating canopy processes which vary with shadow fraction, we obtained a unique multiangular airborne imaging spectroscopy data for the Hyytiälä forest research station located in Finland (61°50'N, 24°17'E) in July 2015. The main tree species are Norway spruce (*Picea abies* L. karst), Scots pine (*Pinus sylvestris* L.) and birch (*Betula pubescens* Ehrh., *Betula pendula* Roth). We used an airborne hyperspectral sensor AISA Eagle II (Specim – Spectral Imaging Ltd., Finland) mounted on a tilting platform. The tilting platform allowed us to measure at nadir and approximately 35 degrees off-nadir. The hyperspectral sensor has a 37.5 degrees field of view (FOV), 0.6m pixel size, 128 spectral bands with an average spectral bandwidth of 4.6nm and is sensitive in the 400-1000 nm spectral region.

The airborne data was radiometrically, atmospherically and geometrically processed using the Parge and Atcor software (Re Se applications Schläpfer, Switzerland). However, even after meticulous geolocation, the canopy elements (needles) seen from the three view angles were different: at each overpass, different parts of the same crowns were observed. To overcome this, we used a 200m x 200m test site covered with pure pine stands. We assumed that for sunlit, shaded and understory spectral signatures are independent of viewing direction to the accuracy of a constant BRDF factor. Thus, we compared the spectral signatures for sunlit and shaded canopy and understory obtained for each view direction. We selected visually six hundred of the brightest and darkest canopy pixels. Next, we performed a minimum noise fraction (MNF) transformation, created a pixel purity index (PPI) and used Envi's n-D scatterplot to determine pure spectral signatures for the two classes. The pure endmembers for different view angles were compared to determine the BRDF factor and to analyze its spectral invariance.

We demonstrate the compatibility of multi-angle data with high spatial resolution data. In principle, both carry similar information on structured (non-flat) targets thus as a vegetation canopy. Nevertheless, multiple view angles helped us to extend the range of shadow fraction in the images. Also, correct separation of shaded crown and shaded understory pixels remains a challenge.