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Correcting the relationship between PRI and shadow fraction for the blue sky effect

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The Photochemical Reflectance Index (PRI) is defined as the normalized difference ratio of leaf reflectance at two specific wavelengths in the green spectral region. Its value depends on the status of leaf carotenoid content, and especially that of the xanthophyll cycle pigments. Due to the dependence on the xanthophyll cycle, when the photosynthetic apparatus of green leaves is close to the saturation limit, their PRI becomes dependent on light conditions. Therefore, by measuring the PRI of leaves in the same canopy under different local irradiance conditions on a sunny day, it should be possible to determine the saturation level of the leaves. In turn, this gives information on the light use efficiency (LUE) of the vegetation canopy. The average light conditions of visible foliage elements are often quantified with the shadow fraction – the fraction of visible foliage not lit by direct sunlight.

The dependence of PRI on the shadow fraction has been used to remotely measure canopy LUE on clear days. Variations in shadow fraction have been achieved with multiangular measurement. However, besides photosynthetic downregulation, the dependence of canopy PRI on shadow fraction is affected by the blue sky radiation caused by scattering in the atmosphere. To quantify this effect on remotely sensed PRI, we present the underlying definitions relating leaf and canopy PRI and perform the required calculations for typical midsummer conditions in Central Finland. We demonstrate that the effect of blue sky radiation on the variation of PRI with canopy shadow fraction is similar in shape and magnitude to that of LUE variations reported in literature.

Next, we propose a new method to assess these PRI variations in structured vegetation. We investiagate this blue sky effect on the PRI – shadow fraction relationship with high spatial (60 cm) and spectral (9.8 nm) resolution airborne imaging spectroscopy data from Hyytiälä, Finland. We evaluate the spectral irradiance in different locations inside the canopy and calculate a correction term for the canopy PRI estimates defined using top-of-canopy irradiances. We determine the maximum value of the correction term by sampling the most sunlit and shaded road surface locations adjacent to tree crowns. Results indicate that under the particular illumination-view geometry, irradiance variations decreased the canopy PRI by as much as 0.06. The correction depended only slightly on atmospheric correction parameters. Other than the blue sky effect, PRI showed no correlation with the shadow fraction, indicating a lack of down-regulation at the time of measurement.