Application Note

Estimation of stand productivity from multi-angular optical remote sensing

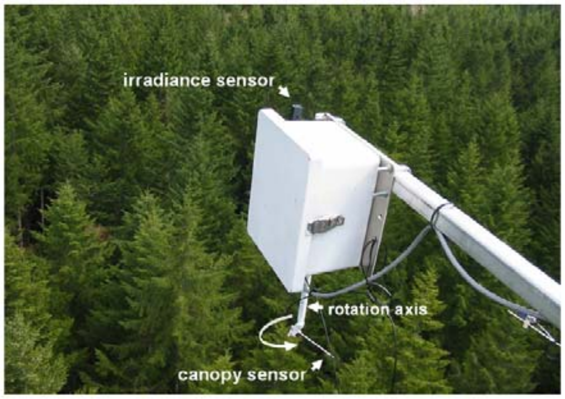

Fig 1:Multi-angular Spectroradiometer (AMSPEC) at the Research site near Campbell River (BC). The instrument is installed on a flux tower of the Canadian Carbon Program (CCP)

Global modeling of gross primary production (GPP) is a critical component of climate change research. On local scales, GPP can be assessed from measuring CO_2 exchange above the plant canopy using tower-based eddy covariance (EC) systems. The limited footprint inherent to this method however, restricts observations to relatively few discrete areas making continuous predictions of global CO_2 fluxes difficult. Recently, the advent of high resolution optical remote sensing devices has offered new possibilities to address some of the scaling issues related to GPP using remote sensing.

Detection of GPP from remote sensing is based on the awareness that photosynthesis is related to the biochemical composition of plant foliage. This biochemical composition is being expressed in leaf spectral properties and can be detected from high resolution optical remote sensing instrumentation. One key component for inferring GPP spectrally is the efficiency (ε) with which plants can use absorbed photosynthetically active radiation to produce biomass.

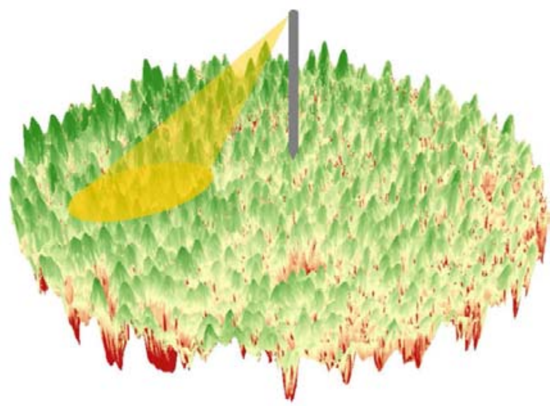

Fig 2: AMSPEC observes the forest canopy around the flux tower every 15 minutes; one scan is taken every 5 seconds. Data were collected over a one year period

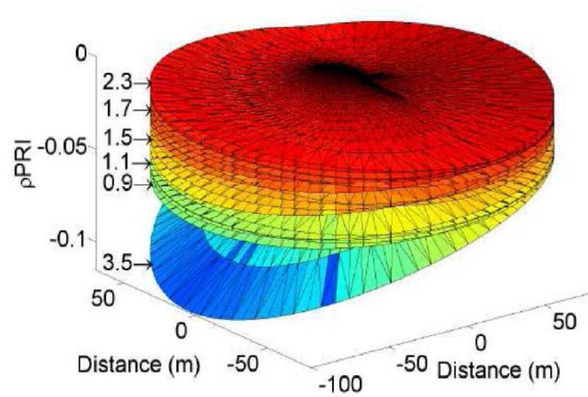

Fig 3: Bidirectional reflectance distribution model (BRDF) of multi-angular AMSPEC observations. The PRI reflectance observed is a function of directional and physiological reflectance effects of the canopy

While recent years have seen progress in measuring ε using the photochemical reflectance index (PRI), little is known about the temporal and spatial requirements for up-scaling these findings continuously throughout the landscape. Satellite observations of canopy reflectance are subject to view and illumination effects which can confound the desired PRI signal. Further uncertainties include dependencies of PRI on canopy structure, understorey, species composition and leaf pigment concentration.

The objective of this research was to investigate the effects of these factors on PRI to facilitate the modeling of GPP in a continuous fashion. Canopy spectra were sampled over a one-year period using an automated tower-based, multi-angular spectroradiometer platform (AMSPEC), based on a UniSpec-DC radiometer (PP Systems), designed to sample high spectral resolution data. The wide range of illumination and viewing geometries seen by the instrument permitted comprehensive modeling of the the bi-directional reflectance distribution, used to isolate physiologically induced changes in PRI reflectance. The developed model yielded a high correlation (r^2=0.82, $p<0.05$) to EC-measured ε, thereby demonstrating the capability of PRI to model ε throughout the year. The results were extrapolated to the landscape scale using airborne laser-scanning (light detection and ranging, LiDAR) and high correlations were found between remotely-sensed and EC-measured GPP (r^2>0.79, $p<0.05$). Permanently established tower-based canopy reflectance measurements are helpful for ongoing research aimed at up-scaling ε to landscape and global scales and facilitate a better understanding of physiological cycles of vegetation and serveas a calibration tool for broader band satellite observations.

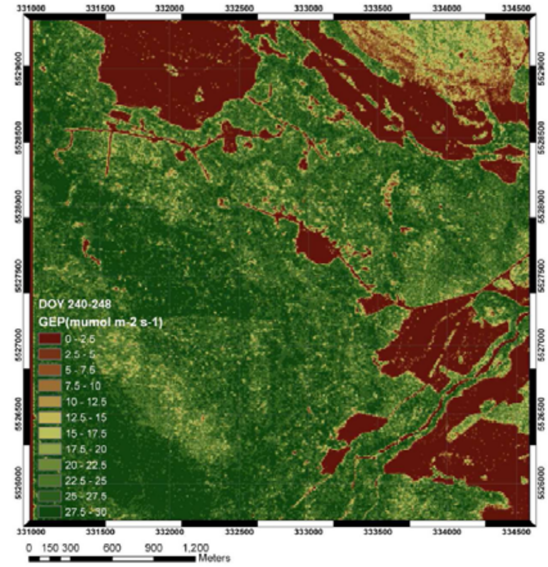

Fig 4: Vertically and horizontally integrated estimates of GPP of the research site using the results from AMSPEC and LiDAR data to determine the fraction of shadow per unit area

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References

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