Using a Flux Footprint Model and Airborne LiDAR to Characterize Vegetation Structure and Topography Frequently Sampled by Eddy Covariance: Implications for MODIS GPP and Scaling

Exchanges of CO₂ transported to eddy covariance instrumentation, often assumed to be representative of site average characteristics and site heterogeneity, may not be well quantified. Heterogeneity could influence CO₂ exchanges if scalar fluxes from prevailing wind directions sample these parts more than others. This could have implications for site representation, model evaluation, and remote sensing product validation.

Combining footprint analysis with high resolution remote sensing data (e.g. LiDAR, Hyperspectral, etc.) provides a powerful tool for characterizing areas most frequently sampled by eddy covariance instrumentation.

In this study, we use a 3D classification methodology to characterize vegetation structural and topographic attributes most frequently sampled by eddy covariance within two contrasting mature boreal aspen stands. Characteristics most frequently sampled were used to classify the larger region for evaluation of the MODIS GPP product.

**Methods**

1. Footprint parameterization of Kljun et al. (2004) used to extract LiDAR data layers (canopy height, effective LAI, elevation, uplands and lowlands) from within half-hourly footprint source/sink areas.

2. Based on unique footprint 'signatures' of vegetation structural and topographic attributes, attribute ranges were used in a classification of heterogeneity within MODIS pixels.

**Results**

- Frequency of prevailing wind directions represented by wind roses during a) diurnal footprint periods (time of study: 10:00-16:30); b) over 24 hours; and c) 6-hourly represented by cumulative footprint area (grouped by frequency) and overlaid onto a 'biomass index' (canopy height x effective LAI/LALEH) LiDAR map.

- SOA: Footprints from NW have, on average, taller trees (7%), greater LAE (50%), denser understory (5%), fewer low-lying areas (topographic depressions) than from SE.

- UA: Footprints from NW have, on average, shorter than average canopy heights (11%), lower LAE (17%) and a greater proportion of topographic depressions than other scalar directions (due to peatlands).

**Objectives**

1. Quantify parts of the ecosystem that are most frequently sampled by eddy covariance instrumentation.

2. Use structural and topographic attributes within footprint source/sink areas to classify site representation within and beyond the 1 km radius of the eddy covariance.

3. Compare GPP estimates from eddy covariance with MODIS GPP and assign confidence limits to MODIS pixels (both temporally and spatially).

**Results**

- Classification of footprint signatures, site representation.

**Representative of Eddy Covariance Sampling: MODIS Pixels**

| MODIS GPP Method | Class | Window | Stand | Eddy Covariance
|------------------|-------|--------|-------|-----------------
| MODIS (9 km) | 28 | 1 | 1.0 ± 0.5 | 0.81 ± 0.45
| MODIS (9 km) | 28 | 2 | 0.87 ± 0.51 | 0.69 ± 0.44
| MODIS (9 km) | 28 | 3 | 0.68 ± 0.54 | 0.53 ± 0.43
| MODIS (9 km) | 28 | 4 | 0.40 ± 0.53 | 0.25 ± 0.42
| MODIS (9 km) | 28 | 5 | 0.15 ± 0.49 | 0.10 ± 0.44

**Take Home Message:**

1. Marriage of plot measurements with eddy covariance data and low resolution satellite data products is difficult given differing spatial and temporal scales.

2. Airborne LiDAR data and footprint analysis can be used to link between scales.

3. In this study, use of a footprint model and LiDAR data improved comparisons between MODIS GPP and eddy covariance-estimated GPP when pixels were selected based on structural and topographic similarity to source/sink areas as opposed to selecting pixels that are proximal.

4. Implications include: assessment of spatial variability/topography on NEE; identifying landscape features that are frequently sampled, classifying spatial heterogeneity; scaling.