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Quantifying regional (∼10ˆ3 – 10ˆ5 kmˆ2) CO_2 fluxes is a key to improve our understanding of the terrestrial carbon cycle. Four independent techniques were used to estimate daily regional gross primary productivity (GPP) for a tall-tower CO_2 concentration footprint area (∼10ˆ3 – 10ˆ5 kmˆ2) in central Saskatchewan, Canada, which is characterized as a spatially heterogeneous boreal forest-agriculture transition region. These techniques include three bottom-up methods (a processed based ecosystem modeling approach using Dynamic Land Model (DLM), a flux-tower based upscaling approach, a "two-leaf" light use efficiency modeling approach based on remote sensing, and MODIS GPP products (MOD17A3)) and one simply top-down approach based on tall tower equilibrium boundary layer (EBL) budget analysis that allows the estimation of regional GPP at daily time steps from hourly CO_2 concentration measurements.
The top-down EBL method was applied to two CO_2 concentration towers (the East Trout Lake 106-m tall tower (54°21'N, 104°59'W) with 4-height measurements (95, 55, 33, 22 m) and the Candle Lake 28-m high tower (53°59'N, 105°07'W).The daily concentration footprints were estimated using the authors previously developed footprint model (SAFE-C) based on Eulerian similarity theory. The estimated monthly and annual footprints for each height were similar in orientation and shapes but apparently different in size. The areas of footprints were significantly increased with heights. The 90% accumulative footprint areas for the heights of 22 m to 95 m varied from ∼150 – 500 kmˆ2 and ∼10ˆ4 – 10ˆ5 kmˆ2 at daily and annual time scales, respectively.
The spatial representativeness of the GPP values extracted from CO_2 mixing ratio data using the EBL method for each measured heights is theoretically associated with each-level's footprints. These bottom-up estimated GPP values weighted with concentration footprints were highly correlated with tower-based atmospheric top-down estimates for the corresponding measured heights (rˆ2 = 0.80 - 0.85 for 2006-2008). This study shows that atmospheric CO_2 concentration data can be used effectively to retrieve regional GPP and flux tower measurements can also be reasonably extrapolated to a region based on remote sensing based ecosystem modeling. Combining and mutually constraining these independent methods to reduce their uncertainties using data assimilation technique is a practical and effective means to derive regional GPP with reasonably high accuracy.