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Remote Sensing on Carbon Budget in Alaska Based on Component Spectral Measurement (Extended Abstract)

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We proposed an estimation method of carbon storage, soil respiration, and Net Ecosystem Productivity (NEP) distribution in interior to northern Alaska from remotely sensed data. The estimation is based on satellite data interpretations and according field observations. Biome types, carbon accumulation, soil respiration, and plant species description were observed in seven permanent plots in different vegetation zones from interior Alaskan boreal forest to northern tundra. Radiative transfer models based on observed component spectral characteristics were used for the interpretation of remotely sensed data. We set 30 m × 30 m observation plots in (a) Coastal tundra (N70°01′), (b) Subarctic tundra (north slope) (N68°54′), (c) Alpine tundra (N68°10′), (d) Subarctic tundra (N68°03′), (e) Tundra-taiga transition (N67°59′), (f) Taiga (Coldfoot) (N67°11′), (g) Taiga (Fairbanks) (N65°39′) on an Alaskan north-south transect from Prudhoe Bay to Fairbanks. Spectral reflectances, carbon dioxide and methane fluxes from soil, and carbon and nitrogen accumulations were observed, and plant species were described in the plots. The spectral reflectances were measured at twenty points in August 2000, forty points in June-July 2001 in each of the plots, and forty to eighty points in plots (c), (f), and (g) in June-July 2002. Individual leaf and trunk reflectances were also measured. Carbon dioxide and methane fluxes were observed at seven to eight points where spectral reflectances were measured in each of the plots. Carbon and nitrogen accumulations in each of the tundra plots were observed in two to five different vegetation types by three repetitions. From the spectral data and satellite observation, we derived a linear mixture radiative transfer model for tundra and a turbid medium model for boreal forest. By integrating these models to the observed carbon budget and plant species data, we obtained geographical distribution of the carbon budget.

Spruce and birch are the dominant species in Interior Alaskan boreal forest. Previous studies show differences in Forest floor vegetation (sphagnum mosses (*Sphagnum* spp.), feather moss (for example, *Thuidium abietinum*) and lichen (*Cladina stellaris*)) cause large differences in Net Primary Production (NPP). Approaches in carbon budget estimation by satellite remote sensing, however, have not taken this effect into consideration before. In this study, we obtained relationships between satellite remotely sensed data and terrestrial components by observed component spectrums, linear mixture model of forest floors, and a turbid medium model of upper layer biomass. By applying these relationships to Landsat ETM+, we obtained geographical distribution of NPP and Net Ecosystem Production (NEP).

Spectral characteristics obtained in forest floor and leaf measurements were used as input parameters of a radiative transfer model to evaluate nadir reflectances of spruce communities in relation to varying upper layer Leaf Area Index (LAI), forest floor types, and leaf spectral characteristics. SAIL model (Verhoef, 1984) was used as the radiative transfer model. This model is a basic radiative transfer model for a vegetation canopy that assumes a canopy as horizontally homogeneous infinitely small leaves. SAIL model has been applied to various vegetation canopies (Goel *et al.*, 1985 ; Major *et al.*, 1992 ; Andrieu *et al.*, 1997 ; Duke *et al.*, 1998). Reflectance factor calculated by SAIL model is equal to that of forest floor when upper layer is 0, and come close to a certain value that is decided by both leaf spectral reflectance and transmittance, and forest floor reflectance. If the heterogeneity of the canopy is bigger, the reflectance comes closer to the certain value more gradually as upper layer LAI increases. In the following interpretation on the reflectance from plant communities in relation to the upper layer LAI and forest floor types, we have to take account that there are some variation of delays in coming closer to the convergent point of the reflectance as upper layer LAI increases. We defined effective LAI here for LAI including these effects.

Nadir reflectance factors of sphagnum mosses (*Sphagnum* spp.), feather moss (for example, *Thuidium abietinum*) and lichen (*Cladina stellaris*) in band 4 were so close that hardly reflect on influence of forest floor vegetation types, while that of band 1, 2, 3, and 5 reflect on influence of both forest floor vegetation types and aboveground LAI. Therefore, we assumed reflectances in band 4 and both of LAI and biomass as linear. By using the relationship between biomass and above ground NPP (ANPP) in Interior Alaska in the literature, we obtained relationships between band 4 and ANPP, and that of band 4 and LAI. By inputting the obtained LAI into the relationships among reflectances in bands 1, 2, 3, and 5, LAI, and forest floor types, and assuming forest floor as linear mixtures of sphagnum mosses (*Sphagnum* spp.), feather moss (for example, *Thuidium abietinum*) and lichen (*Cladina stellaris*), we calculated area ratio of the two mosses and lichen. Multiplying of each of the three area ratios by summation of corresponding NPP in the literatures and annual microbial soil respiration calculated from the observation and annual temperature, we obtained NEP without ANPP. By adding ANPP calculated with band 4 to these, NEP of the Landsat ETM+ each pixel corresponding to spruce forest was estimated. Finally, we obtained geographical distribution of ANPP and that of NEP. The fact that NEP is higher near rivers was appeared from the method. This analysis also suggest the improvement of the estimation of Interior Alaskan spruce carbon budget by choosing wavelength whose reflectance of the two mosses and lichen are closer in future satellite sensors.