Monitoring Boreal Landcover and Ecosystem Dynamics at Regional Scales using Integrated Spaceborne Radar Remote Sensing and Ecological Modeling

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Abstract

This investigation combines mapping and monitoring of boreal landcover with ecological modeling for assessment of regional and continental scale carbon flux dynamics. We are utilizing imagery from the JERS Synthetic Aperture Radar (SAR) to develop a landscape segmentation map for use in an ecosystem process model. The segmentation map is coupled with landscape freeze/thaw dynamics derived using temporally dense spaceborne scatterometer data. These combined features allow determination of the timing of seasonal transitions for all regions of the land cover classification. Integration of an ecosystem model with the remote sensing-derived products will allow improved quantification of carbon flux dynamics on regional and continental scales. Each element in this suite of products will be assessed using existing data sets and *in situ* biophysical data collected under other activities. Integrating the suite of monitoring tools within a common framework will allow assessment of landcover change, making possible evaluation of landcover changes on carbon flux dynamics and regional and local scale ecological processes in general. Our development and validation efforts are first focused on intensive study regions in Alaska and the Boreal Ecosystem-Atmosphere Study (BOREAS) region of Canada. The methods developed will be extrapolated to other North American boreal regions and will be applicable to Eurasian boreal regions as well, with our intent being to apply these techniques to derive contiguous products for the circumpolar boreal and arctic regions.

Keywords:

(1) Research Fields: carbon cycle, freeze/thaw, vegetation structure
(2) Geographic Areas/Biome: North America, boreal forest
(3) Remote Sensing: SAR, scatterometer, radars
(4) Methods/scales: regional scale, time series analysis, land cover classification

Questions, Goals and Approaches

This investigation focuses on development of forest monitoring techniques. We integrate a landscape mapping with scatterometer-based spatio-temporal estimates of freeze/thaw dynamics and an ecosystem process model to combine mapping and monitoring of boreal landcover for assessment of regional and continental scale carbon flux dynamics. The proportion of social science is 0 %. We estimate the theme breakdown to be 50% carbon and 50% GOFC.

Major tasks include acquisition and processing of spaceborne scatterometer data into freeze/thaw phenology products, processing of JERS SAR imagery into landcover maps, acquisition of ancillary data products for product validation, parameterization of the ecological process model for application to the boreal landcover classes, and integration of the landcover product, the freeze/thaw product and the process model in an common framework. Our original approach has not been modified.

Our first-year goals have addressed each of the three key elements of this investigation, as well as the integration of these elements into an analysis structure. Our goals are:

(1) Obtain or develop initial landscape classifications of intensive study sites in Alaska and Canada based on radar and other sources,

(2) Development of landscape phenology products utilizing spaceborne scatterometers, focusing on Alaska and Canada.

(3) Initiate assessment of boreal landscape processes with an ecological process model.

(4) Integrate the landcover mapping and phenology products with the ecosystem process model into a test-bed structure for analysis of the intensive sites.

We have progressed on all these goals, although goal 3 had not been an initial first-year objective. The test-bed structure integrating elements from the first three goals is presently under development (Goal 4).

Narrative Statement of Progress

Progress during the first year has proceeded along all three elements of our investigation:

(1) We have begun classifications of JERS-1 Global Boreal Forest Mapping Project imagery with exploratory use of Isodata clustering algorithms, to examine correspondence with existing classifications, for discrimination of land cover classes at well known sites, and for determining how widely land cover algorithms can be used for extrapolations across physiographic regions and continents. We have acquired several TM-based and AVHRR-based land cover classifications covering both Canada and Alaska and are comparing our JERS-based classifications with these data.

(2) We have been developing scatterometer-based phenology products utilizing existing NSCAT and QuikScat (SeaWinds) data. Development of phenology products has focused on Alaska and BOREAS regions. The time series Quikscat data stream has been assembled across the pan-boreal region. (See accompanying animation.)

(3) We have been using an ecological process model (BIOME-BGC) to assess boreal landscape hydrologic and carbon dynamics using spatially explicit landcover and freeze/thaw state information, as well as ancillary soil, terrain and regional daily weather information. Model simulations are also being conducted over a range of spatial scales (30m to 50km) to assess the importance of sub-grid scale spatial variability on regional biogeochemical characterizations.

A web-based test-bed structure for integration of these three elements is presently under development.

Summary of Findings:

At the Bonanza Creek Experimental Forest, a well-characterized site near Fairbanks, Alaska, unsupervised clustering discriminates six ecologically distinct landscape segments (Figure 1.) These segments have distinct seasonal patterns, vastly different carbon fluxes, and different responses to changing climates.

An unsupervised classification of a midsummer mosaicked-swath of JERS-1 imagery extending across Alaska, between the Brooks and Alaska Ranges, show that the within-class identifications appear consistent. Backscatter is responding to vegetation density, biomass, and moisture. Broadleaf and coniferous forest types are not separated except when they correlate with density. Our next step is to refine these classes with supervised classification. Comparison of this classified swath to a widely available AVHRR-based classification highlights the significance this improved spatial resolution will have for our ecological modeling of carbon fluxes.

In the Porcupine River (Alaska) region, the classes show general correspondence to the spatial patterns of inundation, wetlands, and woody biomass, which are crucial to estimates of carbon flux. In contrast to our classification, this region is classified as uniform coniferous forest in AVHRR-based classifications

From our preliminary classifications of the BOREAS mosaics (Figure 2.) we conclude that winter imagery provides information about the spatial distribution of woody biomass, whereas summer imagery combines information about both moisture levels and biomass. Combining the two will improve the ultimate discrimination of our land cover characterizations. We are comparing our JERS-based classification s with several TM-based and AVHRR-based land cover classifications covering both Canada and Alaska. Our next step is quantitative assessment and accuracy estimates of these classifications.

At the BOREAS study region of central Canada, respective reductions in annual NPP of approximately 17 and 22% for 1995 and 1996 were attributed to 3- and 5-week delays in spring thaw relative to 1994. Sensitivities of boreal stands to spring thaw timing, however, vary significantly between major landcover types. Boreal stands with greater proportions of deciduous vegetation appear to be more sensitive to the timing of spring thaw than evergreen coniferous stands. Conifer stands on drier upland areas are also less sensitive to spring thaw timing than stands in wetter areas, possibly because of greater water stress during longer growing seasons.

Initial tests for incorporating radar remote sensing measures of freeze-thaw state into the ecosystem model framework appear to be a useful means for defining seasonal controls on canopy resistance and thus the effective growing season for evergreen coniferous vegetation. Radar freeze-thaw state information was also found to be useful for defining model timing of snow pack ripening and subsequent thaw of surface soil layers in the spring.

Conclusions

During the first year of our investigation, we have initiated the three primary segments required for development of the proposed monitoring technique. These include development of phenology estimates from spaceborne scatterometers, development of landscape segmentation products, and assessments of boreal carbon flux dynamics. Utility of these assessments will be exploited more fully once our integrated analysis system is fully developed.

Publications

Kimball, J., K. C. McDonald, A. R. Keyser, S. Frolking, and S. W. Running, 2000. "Application of the NASA Scatterometer (NSCAT) for Classifying the Daily Frozen and Non-Frozen Landscape of Alaska," *Remote Sensing of Environment*, 75:113-126.

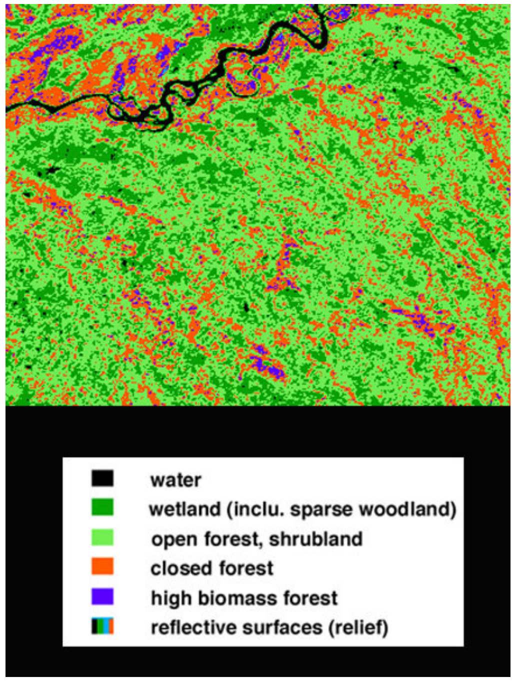

Figure 1. Segmentation of Bonanza Creek Experimental Forest, Alaska based on unsupervised clustering. Six ecologically distinct segments are discriminated.

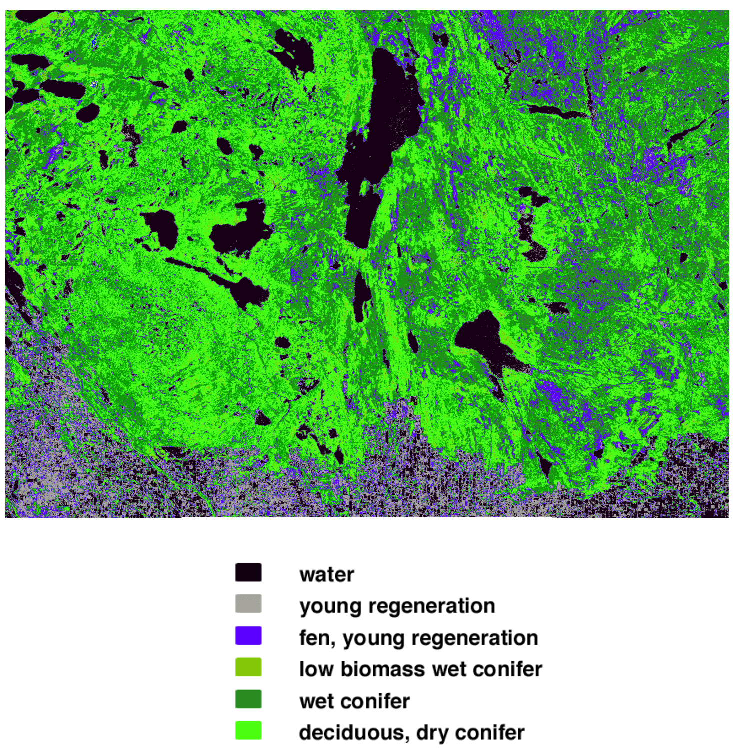

Figure 2. Classification of BOREAS Southern Study Area based on JERS SAR summertime imagery.