Monitoring Freeze-Thaw of Alaskan Boreal Forest with ADEOS NSCAT and ERS SAR

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introduction

The annual duration of frost-free period bounds the period of photosynthetic activity and defines the limits of the growing season for coniferous tree species in the boreal forest. Furthermore, anomalous freeze/thaw events that may occur in boreal forests through much of the year cause varying degrees of frost damage or drought stress. Latent heat exchange between the atmosphere and the boreal zone land surface is also dominated by the freeze/thaw process.

inasmuch as radar backscatter is sensitive to the dielectric properties of the scattering medium, and the dielectric properties of a vegetated landscape change dramatically with freeze-thaw state of the water within the vegetation and land surface, radar offers a unique opportunity to monitor the duration of the growing season in the boreal zone from spaceborne platforms. Such information would be useful in augmenting ecosystem carbon flux models and thus in assessing the annual carbon budget within boreal forests.

In this study, wc will be using NSCAT to monitor the temporal change in the radar backscatter signature of the Alaskan boreal forest along a north-south transect extending from Prudhoe Bay to the Kenai Peninsula. By comparing the multi-temporal radar backscatter signature against reference winter frozen conditions, wc will derive maps depicting landscape freeze/thaw state along this transect. These maps will be quantitatively compared to similar estimates derived from ERS-2 SAR observations, thereby assessing the utility of using low spatial resolution scatterometer data (NSCAT) to obtain the global temporal coverage required to accurate] y characterize freeze/thaw state throughout the boreal zone. Freeze/thaw state as determined with radar observations will be verified against ground-based *in situ* temperat urc and meteorological observations obtained at several sites along the north-south transect.

Background

Radar backscatter measurements of freeze/thaw cycles in natural surfaces have previously been studied with ground-based scatterometers and both aircraft- and satellite-borne SAR systems, The effects of seasonal change on radar backscatter within the boreal forest ecotone of interior Alaska has been under study since 1988, As part of that effort, backscatter as observed with aircraft borne SAR was shown to be sensitive to freeze/thaw events occurring within forest canopies. In this case, backscatter decreased on the order of 4-6 dB as spruce and poplar canopies froze. These trends were observed at 1.-band for several stands within the Bonanza Creek Experimental Forest, near Fairbanks.

More recently, ERS- 1 SAR imagery has been used to map freeze/thaw state regionally within the Alaskan boreal forest, A temporal series of ERS - 1 SAR mosaics along the same north-south transect utilized in this NSCAT study indicate approximately a 3-4 dB decrease in C-band backscatter as canopies froze in autumn 1991.

As part of the Boreal Ecosystem-Atmosphere Study (BOREAS) in Canada, the ERS- 1 SAR was used to monitor freeze/thaw state along a north-south transect intersecting the BOREAS southern study area near Candle Lake, Saskatchewan. Acquisition of ERS- 1 SAR data over the BOREAS region has been underway since 1993, with the major field campaigns taking p] acc throughout 1994. Comparison of SAR observat ions of this region with measured soil and vegetation tissue temperature demonstrate that changes observed in backscatter were correlated with both the soil thaw and the vegetation thaw events. Moreover, measured and modeled canopy carbon flux indicated that these thaw events marked the beginning of periods of increased soil respiration and of vegetation photosynthetic activity in black spruce canopies, thus marking the start of the 1994 growing season.

ADEOS NSCAT Study

Although the resolution of the ERS SAR provides useful spatial information about the landscape, this instrument dots not provide adequate temporal coverage to assess the freeze/thaw state over the entire circumpolar boreal region. Furthermore, results from Alaska and Canada indicate that the freeze/thaw process occurs generally on a landscape scale and thus the large data volumes generated by SAR may not be necessary for monitoring these processes.

The focus of this study is to assess the utility of low resolution scatterometer data to monitor freeze/(haw events in the boreal forest. To this end, our study focuses on a north-south transect extending across Alaska from Prudhoe Bay at the northern edge, across the northern boreal extreme, through the central boreal region near Fairbanks, and continuing to the maritime climate of the Kenai Peninsula at the southern edge. We will assess the capability of the low spatial resolution/high temporal repeat coverage of NSCAT to monitor freeze/thaw processes along this transect. We will compare low spatial resolution scatterometer data with high resolution ERS SAR data for differentiating freeze/thaw events within the boreal landscape. The high temporal repeat coverage provided by the scatterometer will be assessed for its utility in improving estimates of the beginning of the growing season in coniferous tree species.

Ground measurements used to derive and validate the vegetation and land surface freeze/thaw state include data from a network of eight temperature monitoring stations centered around five locations along the north-south transect, along with data from the network of meteorological stations presently in place throughout Alaska. Each of the eight stations consists of a set of thermistors for direct observation of air, soil and tree tissue temperatures and a 60 channel data logger powered by a 12 volt DC bank of deep-cycle batteries. The thermistors are implanted directly into the tree boles and branches and at various depths in the soil.

Of the eight temperature monitoring stations, seven are functioning as of September 1995. The remaining site will be installed during 1996. The five locations around which the eight stations are centered are, in order from north to south:

(1) Toolik Lake Long-Term Ecological Research (LTER) Site (one station). This is the only non-forested site, It is located on the north slope of the Brooks Range and is characterized by tundra. This site is maintained by the LTER project. The ground measurements arc available through collaborative efforts with the LTER researchers from the University of Alaska.

(2) Coldfoot, Alaska (one station). This site is located north of the Arctic circle, near the extreme limit of the Alaskan boreal forest, Tree growth is limited by the extreme northern latitude. As of the end 1995, this was the only site not yet installed.

(3) Bonanza Creek Experimental Forest (BCEF) LTER Site, near Fairbanks (three stations). These stations are located in the central boreal region of interior Alaska, in an area dominated by dry, continental climate. Three stations have been situated at the BCEF in order to increase spatial sampling within a defined area. Two stations have been installed along the flood plain of the Tanana River and one has been

installed in the neighboring upland region. These sites are dominated by black spruce, white spruce, balsam poplar and aspen. Equipment in place at the BCEF includes xylem water flux sensors that monitor the trees' water use. These instruments will be used to monitor water transport in the stems of selected trees in order to correlate freeze/thaw state with the beginning of water transport.

(4) Denali National Park (two stations). Here, one station has been installed in a location representative of the southern edge of the Alaskan boreal ecotone. This site is dominated by well developed white spruce. The second station is located at tree line in an area where tree growth is limited by altitude. These stations are being maintained with the cooperation of the U. S, Park Service.

(5) Chugach National Forest, Kenai Peninsula (one station). This station is located in an area representative of a coastal maritime climate. Climate is generally warmer and wetter than in the continental climate of the Alaskan interior.

NSCAT backscatter data will be obtained along the north-south transect intersecting these sites. These data will be collected with high repeat frequency (2-3 days) concentrating on the spring thaw and autumn freeze-up periods. Using NSCAT data, freeze/thaw condition will be inferred by examining change in measured backscatter relative to winter frozen conditions. NSCAT and ERS SAR freeze/thaw mosaics will be validated against data from the eight temperature monitoring stations and with data from the existing meteorological network. Comparing the freeze/thaw state as determined with NSCAT to that determined with the ERS SAR will allow us to address issues related to scaling between the higher resolution SAR data (200 meter resolution) and the lower resolution scatterometer data (25 km resolution). We may then assess the tradeoffs of each radar in estimating growing season length in the boreal forest.

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