Satellite Remote Sensing of Landscape Freeze/Thaw State Dynamics for Complex Topography and Fire Disturbance Areas Using Multi-Sensor Radar and SRTM Digital Elevation Models

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The annual freeze/thaw cycle drives the length of the growing season in the boreal forest, and is a major factor determining annual productivity and associated exchange of CO_2 with the atmosphere. Variations in freeze/thaw processes are spatially and temporally complex in boreal environments, particularly in areas of complex topography and in fire disturbance regimes. We investigate the spatial and temporal characteristics of seasonal freeze/thaw dynamics in complex boreal landscapes, as derived from radar backscatter measured with ERS (C-band, VV polarization, 200m resolution) and JERS-1 (L-band, HH polarization, 100m resolution) Synthetic Aperture Radars (SARs), and with the SeaWinds scatterometer (Ku-band, 25km resolution). C- and L-band backscatter are applied to characterize freeze/thaw transitions for a chronosequence of recovering burn sites near Delta Junction, Alaska, and for a region of complex topography on the Kenai Peninsula, Alaska. We characterize differences in radar-derived freeze/thaw state, examining transitions over complex terrain and landscape disturbance regimes. In areas of complex terrain, we explore freeze/thaw dynamics related to elevation, slope aspect and varying landcover. In the burned regions, we explore the timing of seasonal freeze/thaw transition as related to the recovering landscape, relative to that of a nearby control site. We apply in situ biophysical measurements, including flux tower measurements to validate and interpret the remotely sensed parameters. A multi-scale analysis is performed relating high-resolution SAR backscatter and moderate resolution scatterometer measurements to assess trade-offs in spatial and temporal resolution in the remotely sensed fields.

A temporal change discriminator is applied to classify time series radar imagery to classify the landscape freeze-thaw state. We apply a 30m-resolution digital elevation model (DEM) derived from Shuttle Radar Topography Mission (SRTM) data to orthorectify the time series SAR imagery over the complex terrain site. This DEM was integrated with the SAR imagery to examine elevation and slope aspect effects on freeze/thaw transitions. Scaling assessments of the relationship between SAR and SeaWinds backscatter provide a means for determining sub-grid spatial variability in land cover, terrain and freeze/thaw processes, based on semi-variogram analyses.

Results show that the high-resolution SARs may be applied to map freeze/thaw transitions in complex landscapes. In regions of complex terrain, dynamics related to elevation and slope aspect are delineated. Fusion with accurate DEM information as provided by SRTM facilitates orthorectification and analysis of terrain effects. The SARs also observe distinguishable differences in backscatter amplitude response and in the timing of freeze/thaw transitions associated with varying disturbance regimes driven by forest fire. These findings demonstrate the importance of considering landscape heterogeneity for development of remote sensing techniques for monitoring phenological processes across complex, heterogeneous landscapes in boreal ecosystems.

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