MONITORING FUEL MOISTURE AND IMPROVING THE PREDICTION OF WILDFIRE POTENTIAL IN BOREAL ALASKA WITH SATELLITE C-BAND IMAGING RADAR

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ABSTRACT

Alaska currently relies on the Canadian Fire Weather Index (FWI) System for the assessment of the potential for wildfire and although it provides invaluable information it is designed as a single system which does not account for the varied fuel types and drying conditions (day length, permafrost, decomposition rate, and soil type) that occur across the North American boreal forest. Since 1999 research has been conducted to develop techniques for using Synthetic Aperture Radar to assess ground fuel moisture to improve the current fire danger prediction system in boreal Alaska. Research has been focused on recently burned forests using C-band satellite data. Analysis of the single channel SAR data resulted in two methods that can be used operationally, and a third time-series analysis method that is in need of further development but shows great promise in reducing the time-invariant confounding factors of surface roughness and aboveground biomass. Current and future research is focused on L-band PALSAR to expand to unburned areas, and the recently launched fully polarimetric Radarsat-II instrument.

Index Terms— boreal forest, SAR, ERS-1, fire scars, black spruce, fuel moisture

1. INTRODUCTION

Research was conducted to develop and demonstrate techniques for using single channel C-band Synthetic Aperture Radar (SAR) satellite imagery for assessing the potential for wildfire in Boreal Alaska. Preliminary research conducted in 1999-2000 demonstrated relationships between C-band backscatter in burned boreal forests and Fire Weather Index (FWI) system codes as well as *in situ* moisture [3,4]. More recently, research was expanded to further develop SAR techniques for the application of improving or augmenting the FWI system in boreal Alaska to aid resource managers (National Park Service, U.S. Fish and Wildlife Service and Forest Service) involved in wildfire danger assessment.

Wildfire is a natural successional process in boreal forests of Alaska, however it sometimes presents a natural hazard when human lives and property are at risk. Alaskan natural resource management agencies devote considerable resources to fire management and suppression, and tools to improve fire danger prediction would help tremendously in their efforts.

Our research was focused on recently burned (0-7 years) boreal forests because of their importance to management, ecology and carbon cycling and because they allow moisture in the ground layer to be measured directly from a satellite sensor without interference of a forest canopy. While early research revealed that the C-band (5.3 cm) VV-polarization data of ERS at 23 º incidence angle were related to *in situ* surface soil moisture in these recently burned forests, transferring the model developed from one site to another was not always possible, due to variable factors of surface roughness and vegetative biomass. Many scientists have struggled with methods of using the single-channel satellite SAR data for monitoring soil moisture at a variety of sites with mixed results. We have developed several methods specific to boreal Alaska, but which should be transferable to other spruce-moss dominated boreal forests of Canada and Russia, to reduce the influence of surface roughness and biomass, and extract the soil moisture information. The methods developed involve three different approaches: 1) taking the mean of backscatter pixels over large burn areas to reduce the variability between sites; 2) segmenting sites by burn severity using Landsat and developing SAR algorithms specific to severities of burn to predict moisture [1]; and 3) using time-series analysis to reduce the effects of relatively unchanging variables such as biomass and surface roughness while extracting soil moisture information [2]. In this presentation, we focus on the application of the first method which is currently under operational investigation by the Alaska Fires Service to augment/improve the current fire danger prediction system. Then we touch briefly on the other two approaches which continue to be developed.

2. CURRENT WEATHER-BASED FIRE DANGER SYSTEM

In Alaska, the Canadian Forest Fire Danger Rating System (CFFDRS) is used for assessment of the potential for wildfire (Fire Weather Index) and fire behavior prediction. The system is completely weather-based, consisting of a daily accounting of weather parameters from spring to fall. Although this system is essential to current practices and wildfire management, it is not without its shortcomings. It is a point based system, with a sparse network of weather stations located across the state of Alaska and interpolation between stations is necessary. Another issue with the Fire Weather Index System is the initialization of some of the codes and indices making up the system in early spring Default start-up values are not always appropriate (due to high end of season drought and low winter precipitation) and the information on which to base that decision (over-winter precipitation from RAWS) is often not available. This is particularly an issue for the drought code (DC) which is an estimate of moisture in the deeper compact organic soil layers of the ground, and which has a 52 day lag. Another problem with the DC in Alaska is that of mid-summer variations in measured moisture values within permafrost regions that are not accounted for in the FWI system. Melting of some of the frozen layers later in the summer may be a cause of increased moisture not accounted for in the weather-based system.

3. SAR FUEL MOISTURE MONITORING METHODS

We studied the relationship between seasonal C-band satellite SAR backscatter and *in situ* moisture and DC from fire scars at different locations around the interior of Alaska for several years post-burn. We found that we could combine data from multiple years and multiple burned areas to develop a generic algorithm relating backscatter to DC (Fig. 1). Using this generic algorithm, we could then use

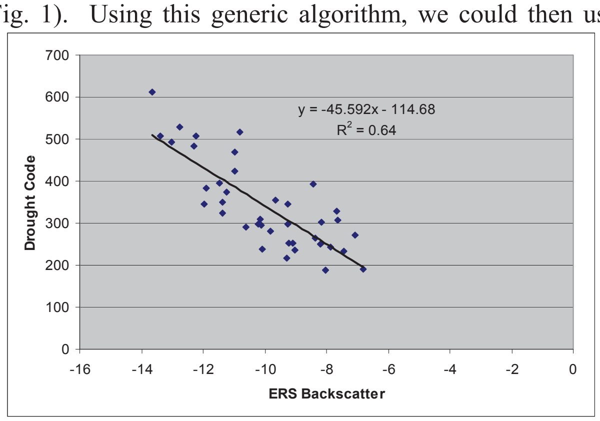

Figure 1. Linear Regression of DC vs. ERS-1 and 2 temporal backscatter for four study sites.

backscatter from a burned area in spring to initialize the DC weather-based system. By initialing the code in the spring and then calibrating throughout the season with backscatter-derived DC values, we were able to improve the current system. Since fire scars exist intermittently across the entire interior landscape, this procedure is plausible for operational use. It does not require georectification of imagery, only knowledge of the general area, comparison to fire scar maps and knowledge of weather-station locations. It is a quick and easy method for initializing the DC, and also calibrating it throughout the season. Further, these new data points derived from imaging radar can be used as additional point sources of information across the landscape. This methodology is currently being tested by the Alaska Fire Service.

Recent techniques have also been developed to map spatially varying soil moisture across a burned landscape using a combination of Landsat and C-band imaging radar. In this method, Landsat is used to map burn severity, and then SAR-soil moisture algorithms which were empirically developed for various degrees of burn severity are applied to the corresponding areas in the SAR imagery. This method works because the variation in surface roughness and forest regrowth that occurs in a black spruce-moss forest post-burn is related to burn severity of the ground surface. The last technique under investigation is the use of time series analysis to reduce the relatively time-invariant features of biomass and surface roughness in an Alaskan landscape and highlight the fuel moisture variations over time. This method continues to be developed.

4. CONCLUSIONS AND FUTURE RESEARCH

Two methods have been developed to improve fire danger and fuel moisture monitoring which can be implemented by scientists and resource managers. The Alaska Fire Service and Alaska Satellite Facility are currently evaluating the methods the authors have developed in this and previous research: mainly, the utility of SAR for mapping burned areal extent in real time, but also assessing the relationship of SAR to the fuel moisture codes. With the recent launch of fully polarimetric L-band satellite, ALOS PALSAR, and C-band Radarsat-II, we expect to expand the capabilities for assessing fuel moisture across a landscape. Research on data from these two new satellites over boreal Alaska is currently under investigation.

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