Assessment of polarimetric SAR data for fuel moisture estimation: Analysis of wet *versus* dry conditions

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ABSTRACT : Radarsat-2 imagery from extreme dry versus wet conditions are compared in an effort to determine the value of using polarimetric SAR data for estimating ground fuel moisture in a chronosequence of Alaskan boreal black spruce ecosystems (recent burns, regenerating forests dominated by shrubs, open canopied forests, moderately dense forest cover). Results show utility of C-HH and C-RR polarized backscatter, as well as Freeman Durden and van Zyl Odd bounce decomposition parameters, for direct evaluation of within site surface soil moisture for the lower biomass vegetated and sparse canopy forest sites. These parameters also showed utility across sites for relative distinction between wet and dry conditions, however biomass and moisture interactions are not eliminated by a single decomposition variable. Future research will evaluate the use of multiple parameters in algorithm development.

Research Goal: Develop improved methods for monitoring surface soil moisture across a landscape using Polarimetric Synthetic Aperture Radar data

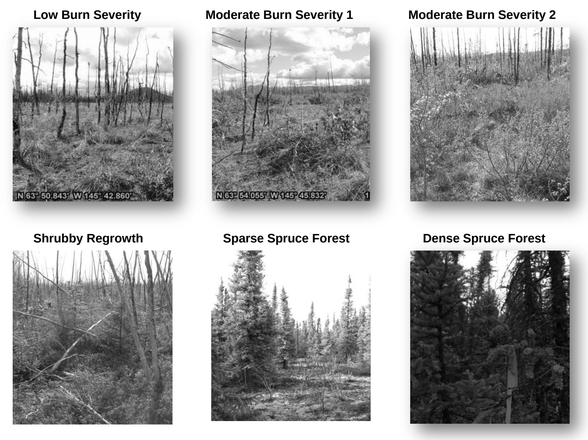
- Variability in surface roughness and vegetative biomass are confounding factors in estimation of spatially explicit surface soil moisture from Synthetic Aperture Radar (SAR) data
- Little research has been conducted in natural landscapes, most in bare agricultural lands because the confounding factor of vegetative biomass is difficult to model

Study Area: Delta Junction, AK including 6 recently burned and 2 mature black spruce forest sites located 200 km southeast of Fairbanks

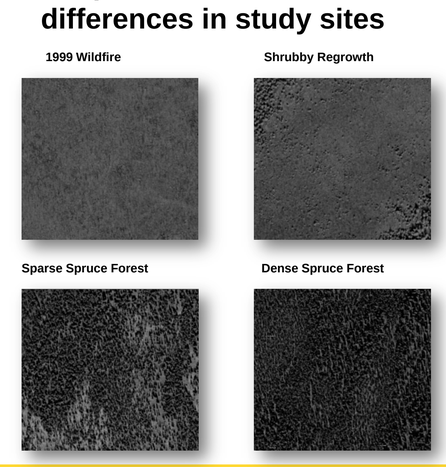
Why is it important? Fuel moisture is a controlling factor in wildfire danger, affecting the potential for fire ignition, rate of spread and fire sustainability. Current methods are limited in spatial resolution

Delta Alaska Boreal Burned and Unburned Study Sites

Ground photos of Study Sites



Air photos show textural differences in study sites



Radarsat-2 POLSAR Analyses Results

Approach: Use Radarsat-2 fully polarimetric C-band data to assess polarimetric and backscatter parameters during extreme wet vs. dry conditions in a chronosequence of black spruce post-wildfire regenerating forests.

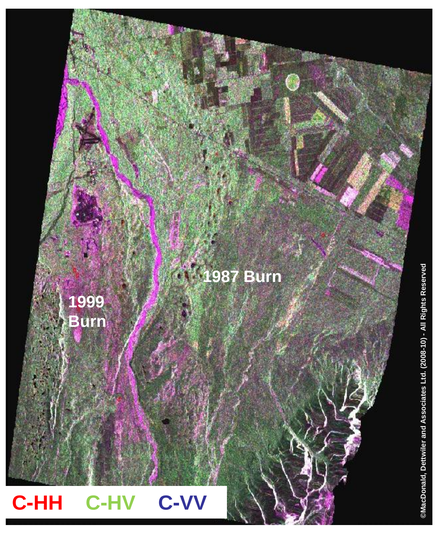
Decompostions evaluated: Cloude Pottier 1997, Freeman Durden 1997, vanZyl 2010

Polarizations evaluated: Linear C-HH, HV, VV, Circular C-LL, LR, RR

Statistical analysis: Data evaluated *by site* and *across sites*
- Normalized percent change *by site*
- Box plots and ANOVA *across sites*

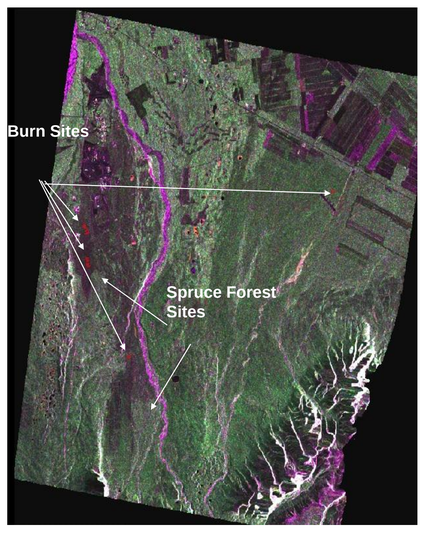
Radarsat-2 RGB Composites

Delta Junction, Alaska



Wet - 54% volumetric moisture
09 August 2008
(Drought Code 93)

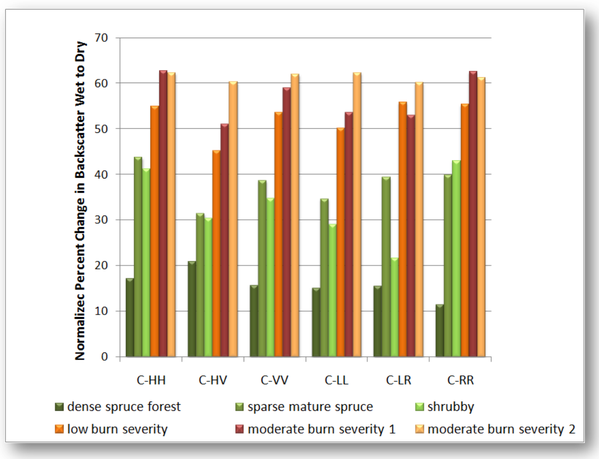
Dry - 18% volumetric moisture
23 August 2010
(Drought Code 570)



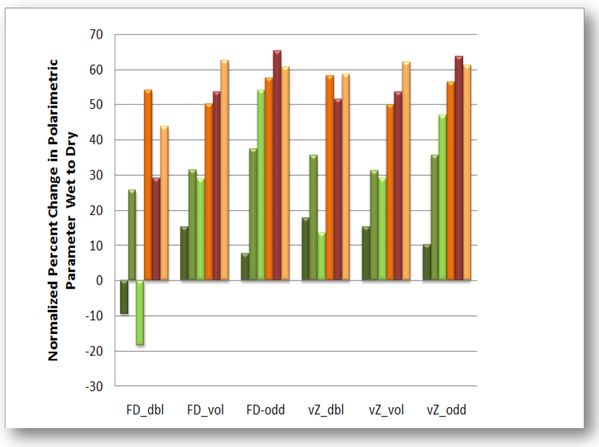
Evaluation of data by site

- Normalized percent change in each parameter was calculated for comparison by site

$$\%\,Difference = \frac{Wet\ date - Dry\ Date}{Wet\ Date}\ x\ 100$$



Change in Backscatter
- All polarizations show moderate (22-44%) change in backscatter for the *Sparse Spruce Forest* and *Shrubby Regrowth* sites
- All polarizations show high (45-62%) change for all the low biomass, *Low Burn Severity* and *Moderate Burn Severity* sites



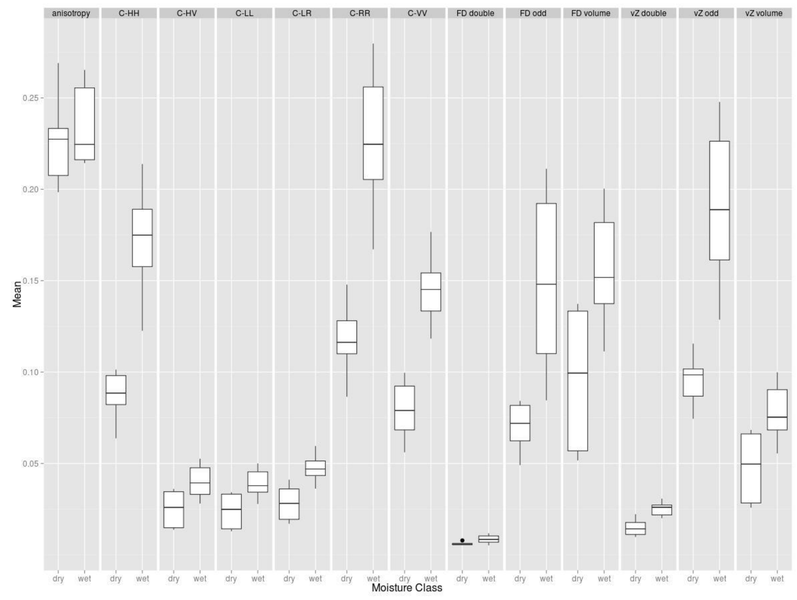
Change in Decomposition Parameters
- Change in Cloude-Pottier polarimetric parameters was much lower than the backscatter, Freeman-Durden or van Zyl parameters and was random (plots not shown, 18% greatest change)
- Largest overall percent change was with the Odd (surface) bounce parameters for both Freeman-Durden and van Zyl, for all but the *Dense Spruce Forest* site

Overall evaluation across sites

For a good distinction between wet and dry conditions the medians and interquartiles in the box plots should be far from each other, and the tails (minimum/ maximum) should not overlap.

For the backscatter polarizations, the box plots showing the best distinctions between wet and dry dates for all sites were the like-polarizations: C-HH, C-VV and C-RR.

Of the polarimetric decomposition parameters, van Zyl's Odd bounce decomposition parameter shows the greatest distinction between wet and dry conditions, followed by Freeman-Durden's Odd bounce.



One-way ANOVA tests with 95% confidence intervals were used for Statistical evaluations of the overall change in all six sites from wet to dry conditions for each parameter

p-value less than 0.05 means reject null hypothesis that there is not a difference in the parameter for the wet versus dry conditions

Parameter	p-value
C-HH backscatter	0.000
C-HV backscatter	0.031
C-VV backscatter	0.000
C-RR backscatter	0.000
C-LR backscatter	0.005
C-LL backscatter	0.020
Cloude-Pottier Alpha	0.698
Cloude-Pottier Anisotropy	0.577
Cloude-Pottier Entropy	0.609
Freeman Durden Double Bounce	0.052
Freeman Durden Odd Bounce	0.005
Freeman Durden Volume Scatter	0.020
van Zyl Double Bounce	0.003
van Zyl Odd Bounce	0.001
van Zyl Volume Scatter	0.020

SUMMARY AND FUTURE RESEARCH

- Our initial observations show potential for polarimetric variables to improve fuel moisture monitoring.
- The increased range in values of most parameters in the wet state (interquartiles of box plots) indicate that variability remains due to differences in scattering from the interaction of biomass and moisture condition across sites.
- Empirical relations between soil moisture and SAR backscatter/ polarimetric variables will be used to develop algorithms to better estimate fuel moisture from Radarsat-2 POLSAR data
  - Nine R-2 images from Summer 2008, 2009 and 2010 representing relatively wet to moderately dry conditions (DC range 93 to 570) will be used for algorithm development.
- Additionally, ALOS L-band PALSAR PolSAR data will be used to develop soil moisture retrieval algorithms from mature forest sites at Delta Junction.

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