Improving the CFFDRS fuel moisture codes using SAR data

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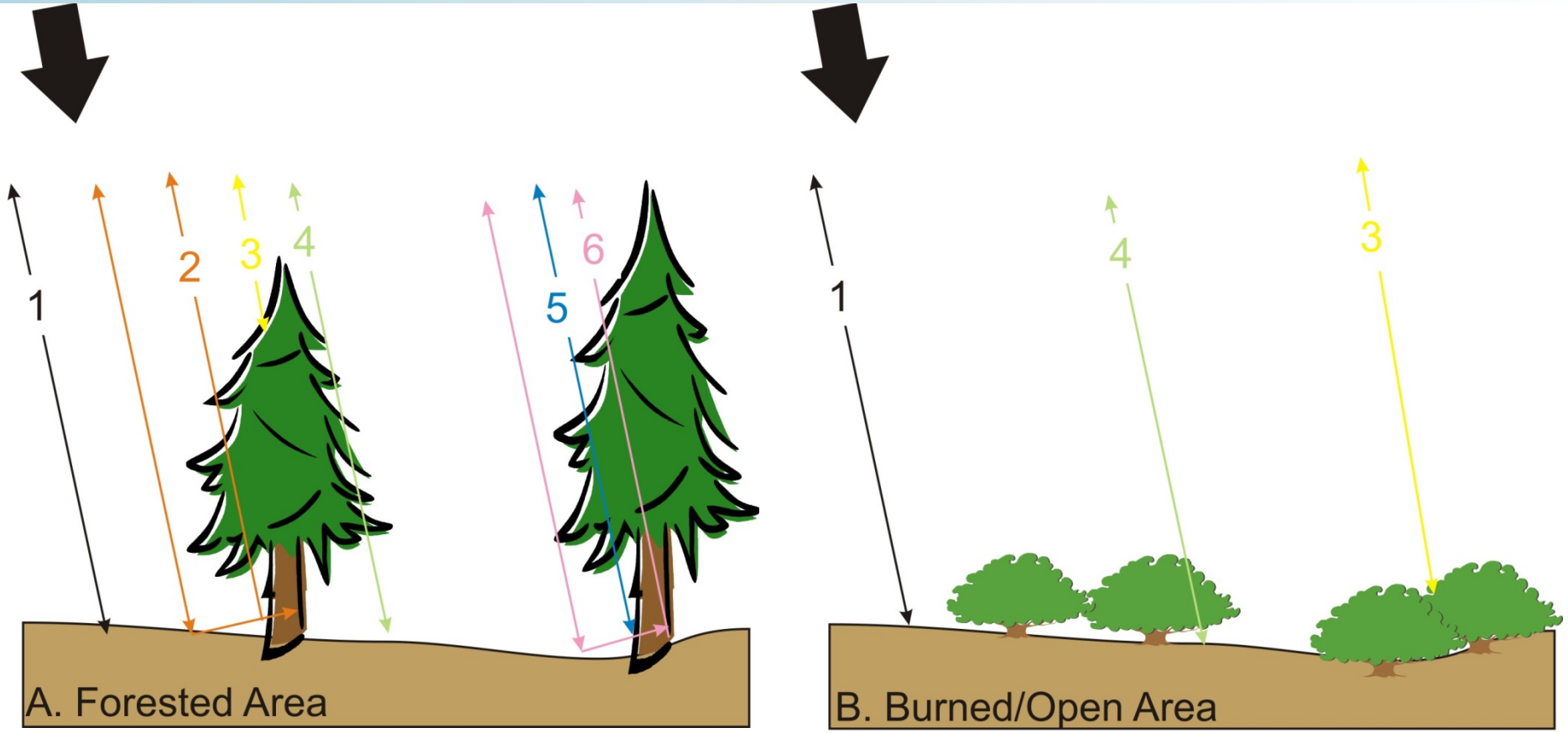
Developing Improved Predictions of Fuel Moisture with Radar in Alaskan Boreal Ecosystems

- Fire danger monitoring can be improved with the inclusion of remote sensing data.
- Specifically, satellite synthetic aperture radar (SAR) data can be used to provide a more direct measure of moisture conditions to improve Fire Weather Index (FWI) predictions.

- **Two Methods were Developed to Assess Fuel Moisture using C-band Radar**
  1. Application of SAR for FWI Drought Code Initialization in Spring and recalibration through the fire season using single channel C-band SAR data. Satellite sensors available since 1992.
  2. Advanced Polarimetric SAR retrieval of moisture for mapping capability. Satellites available since mid-2000s.



1) Surface scattering from soil

2) Double bounce scattering from trunk

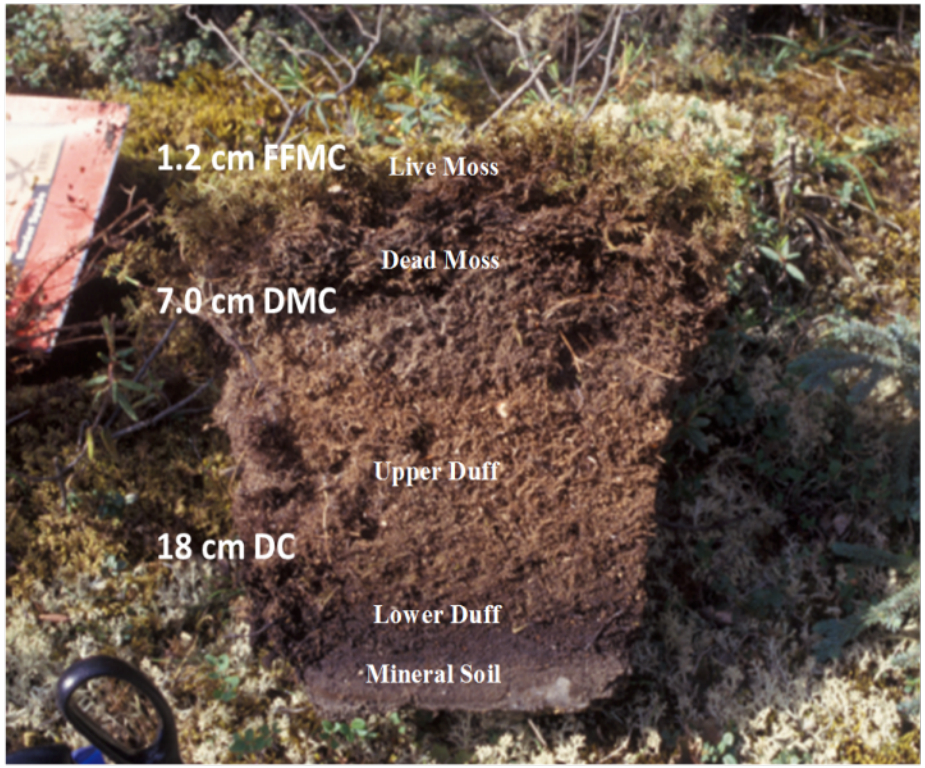
3) Volume scattering from canopy

4) Surface scattering after propagation through canopy

5) Single scattering from trunk

6) Double bounce scattering from ground-trunk-canopy

Organic Layer Fuel Moisture and CFFDRS - Fire Weather Index Sub-System

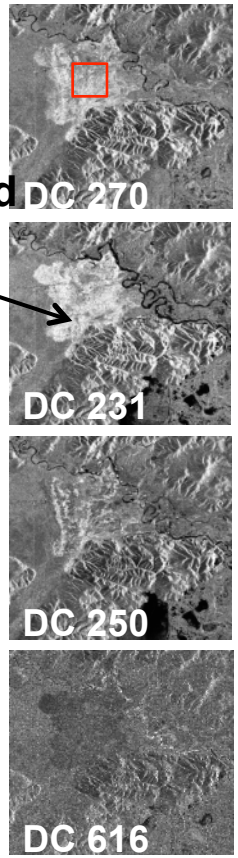


Moisture in the organic soil layers are important for fire ignition, rate of spread and fire sustainability

- Satellite Imaging Radar backcatter has been found to be highly correlated with the FWI Drought Code (DC)

- the long radar wavelengths penetrate the vegetation and ground to detect moisture in the deeper organic soil layers

Large Area C-band SAR backscatter Relationship to DC in low biomass sites

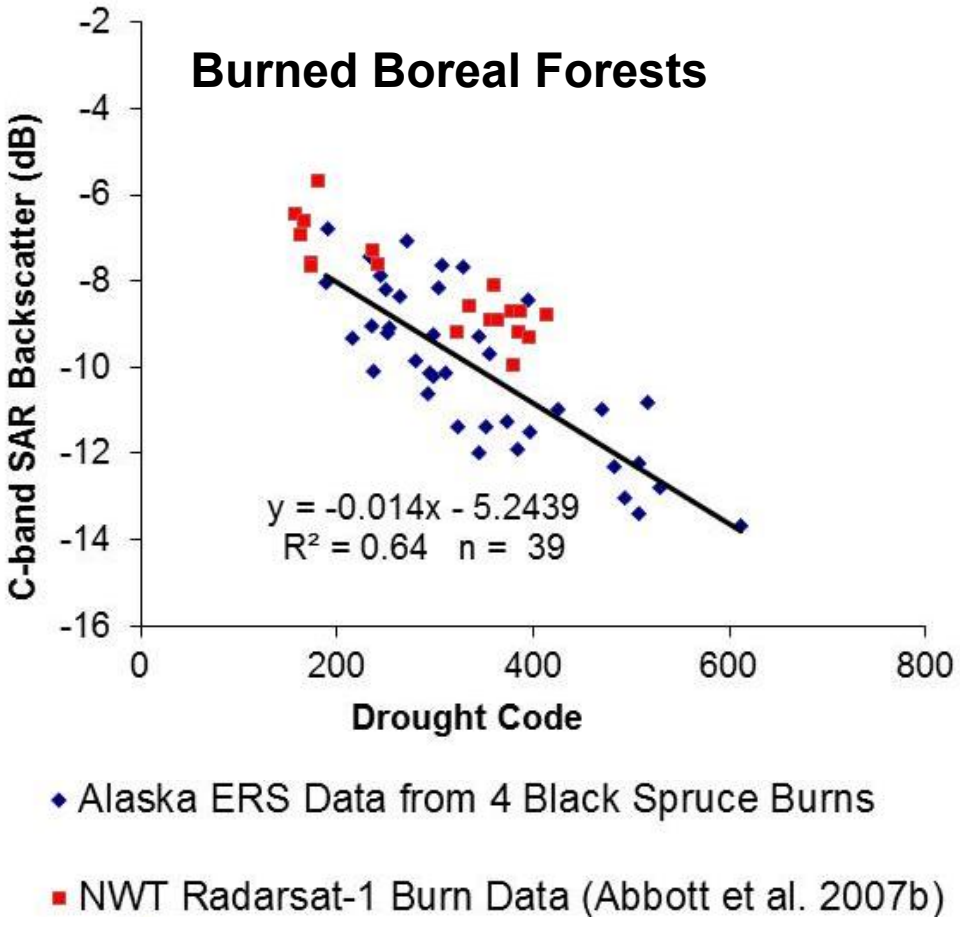


22 June 1992
Moderate Fire Danger

27 July 1992
Low Fire Danger

12 August 1992
High Fire Danger

26 August 1994
Extreme Fire Danger



Large area averaging normalizes spatial variation so that a relationship can be developed across many sites

Predictive Equation based on multiple sites
DC = -45.592 * (ERS-2 backscatter dB)-114.68

Application of SAR for DC Initialization in Spring

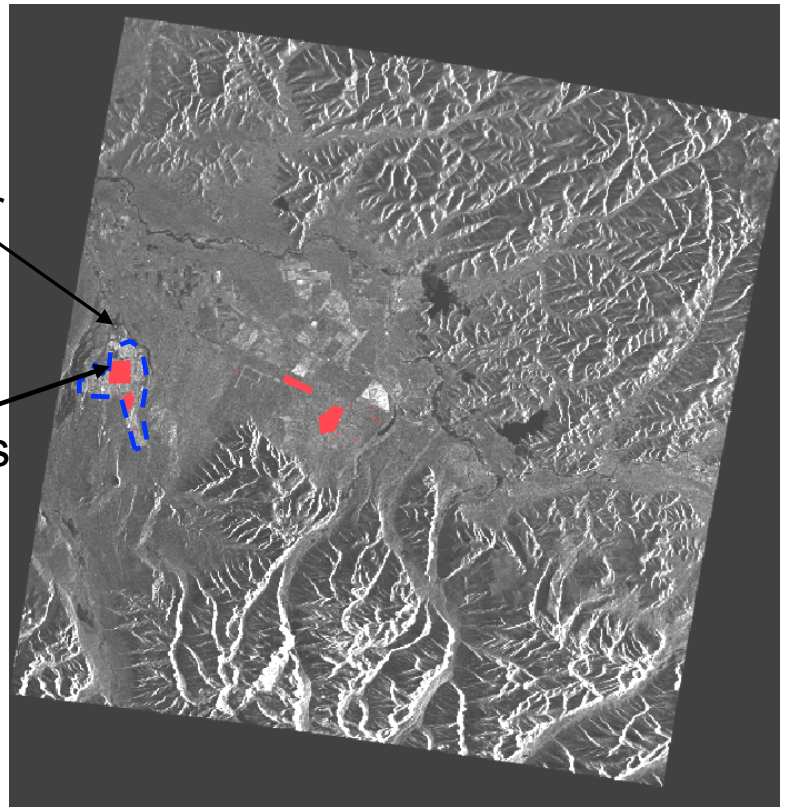
Delta Junction example 2003 fire season

Spring image (2 May 2003) used to initialize DC for the Ft. Greely weather station

- Donnelly interrogation area backscatter = -8.60 dB
- SAR-predicted DC = 281.7
- Weather-based DC = 79.4 on 2 May → **weather underestimated drought conditions***

**based on default DC (15) starting mid-April*

2 May 2003 ERS Image

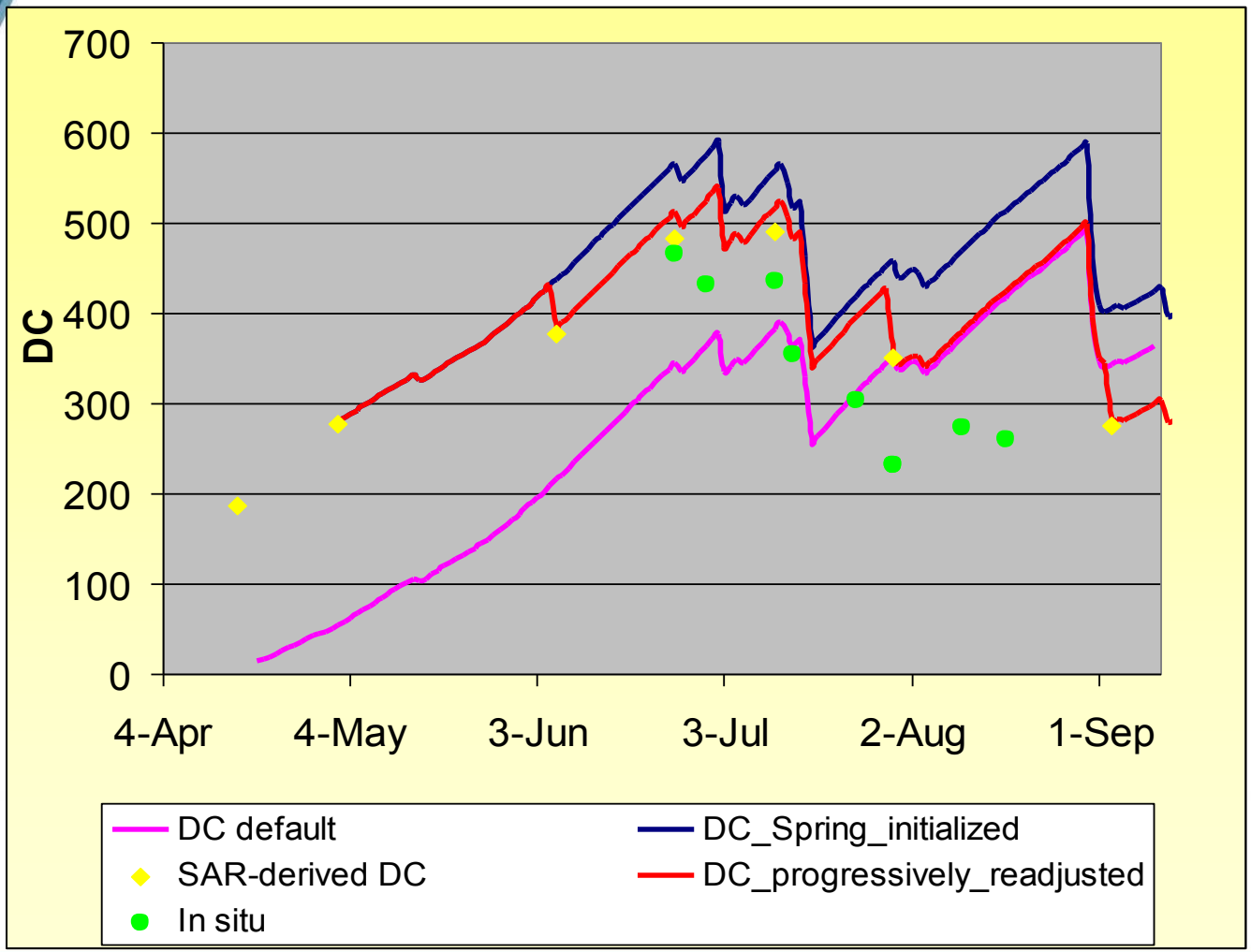


Predictive Equation

DC = -45.592 * (ERS-2 backscatter dB)-114.68

ERS Radar Drought Code Initialization vs. Default

Delta Junction example 2003 fire season



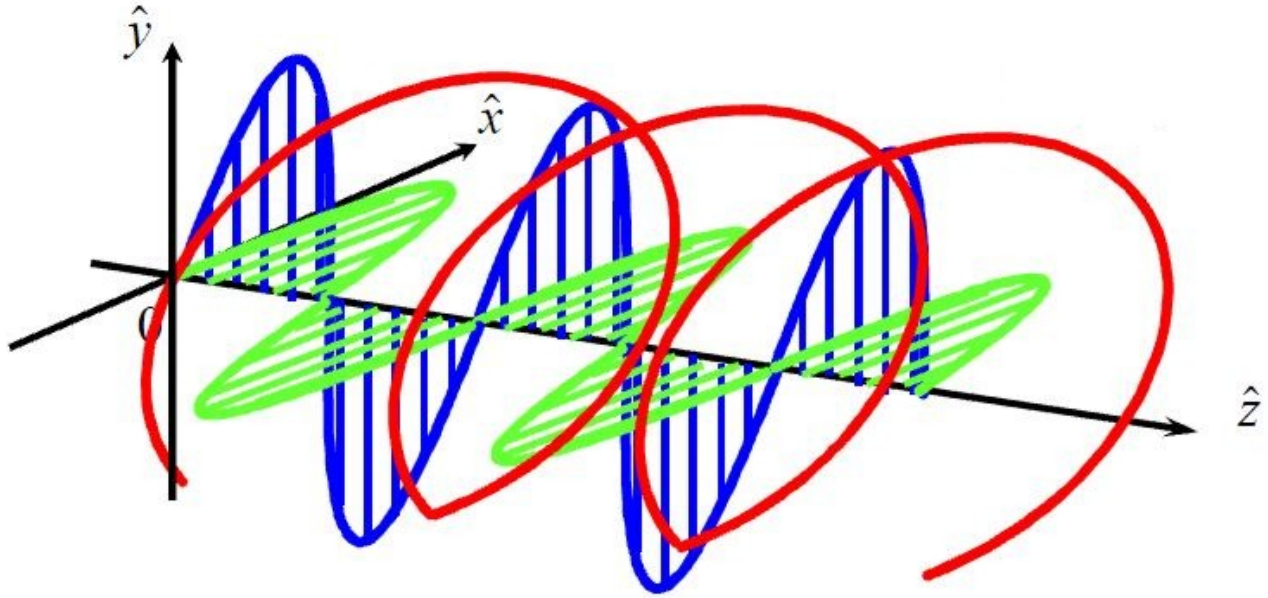
a) Corrects spring initialization values for existing weather stations

b) Correction of DC values in midsummer due to frozen soil thaw

c) Allows additional point locations to increase the sampling area

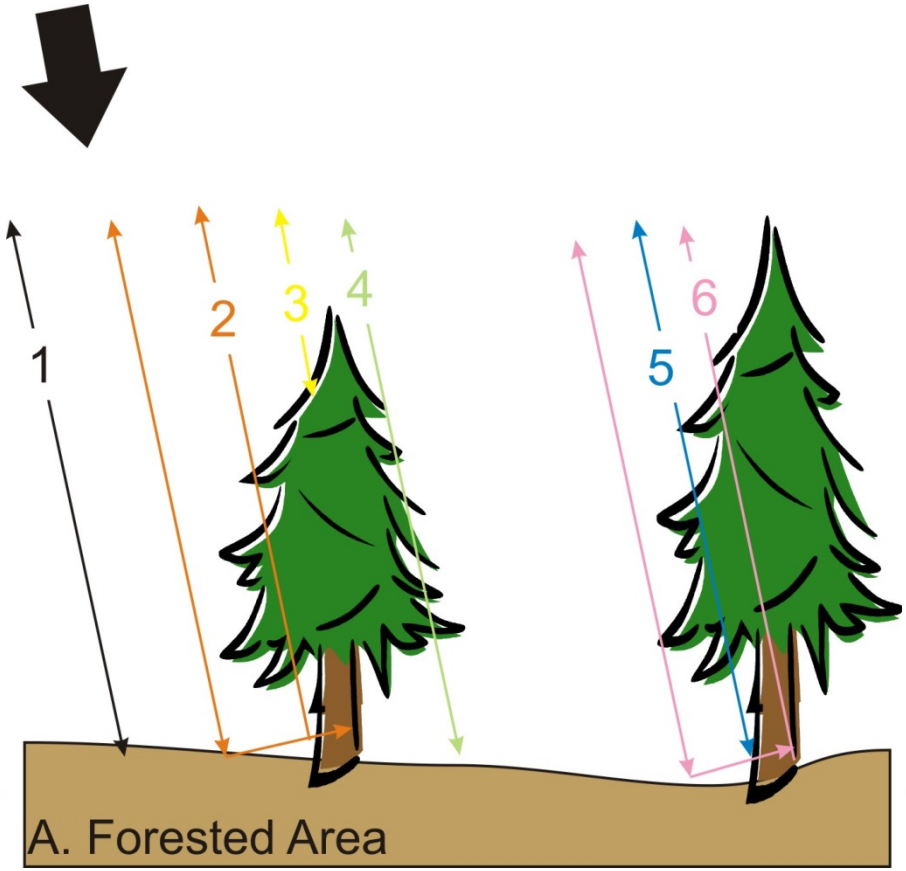
d) Moisture in burned areas demonstrated as strongly correlated to moisture patterns in unburned adjacent areas

Radar Polarimetry



Radar Polarimetry (Polar: polarisation Metry: measure) deals with the full vector nature of polarized electromagnetic waves.

Advantages of Radar Polarimetry



Moisture Content

1) Surface scattering from soil

4) Surface scattering after propagation through canopy

Surface Roughness

2) Double bounce scattering from trunk

6) Double bounce scattering from ground-trunk-canopy

Biomass

3) Volume scattering from canopy

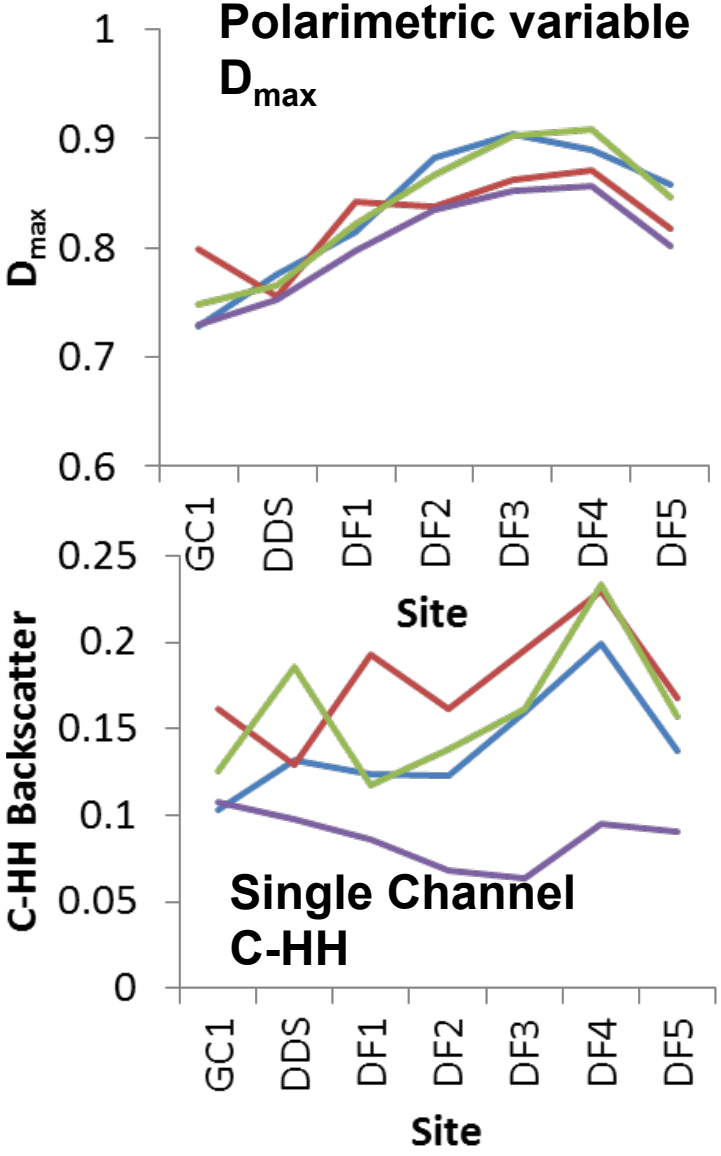
5) Single scattering from trunk

Radar Polarimetry to Improve Fuel Moisture Retrieval from Satellite Sensors

Goal: develop radar methods to monitor and map spatially explicit fuel moisture for fire danger prediction.

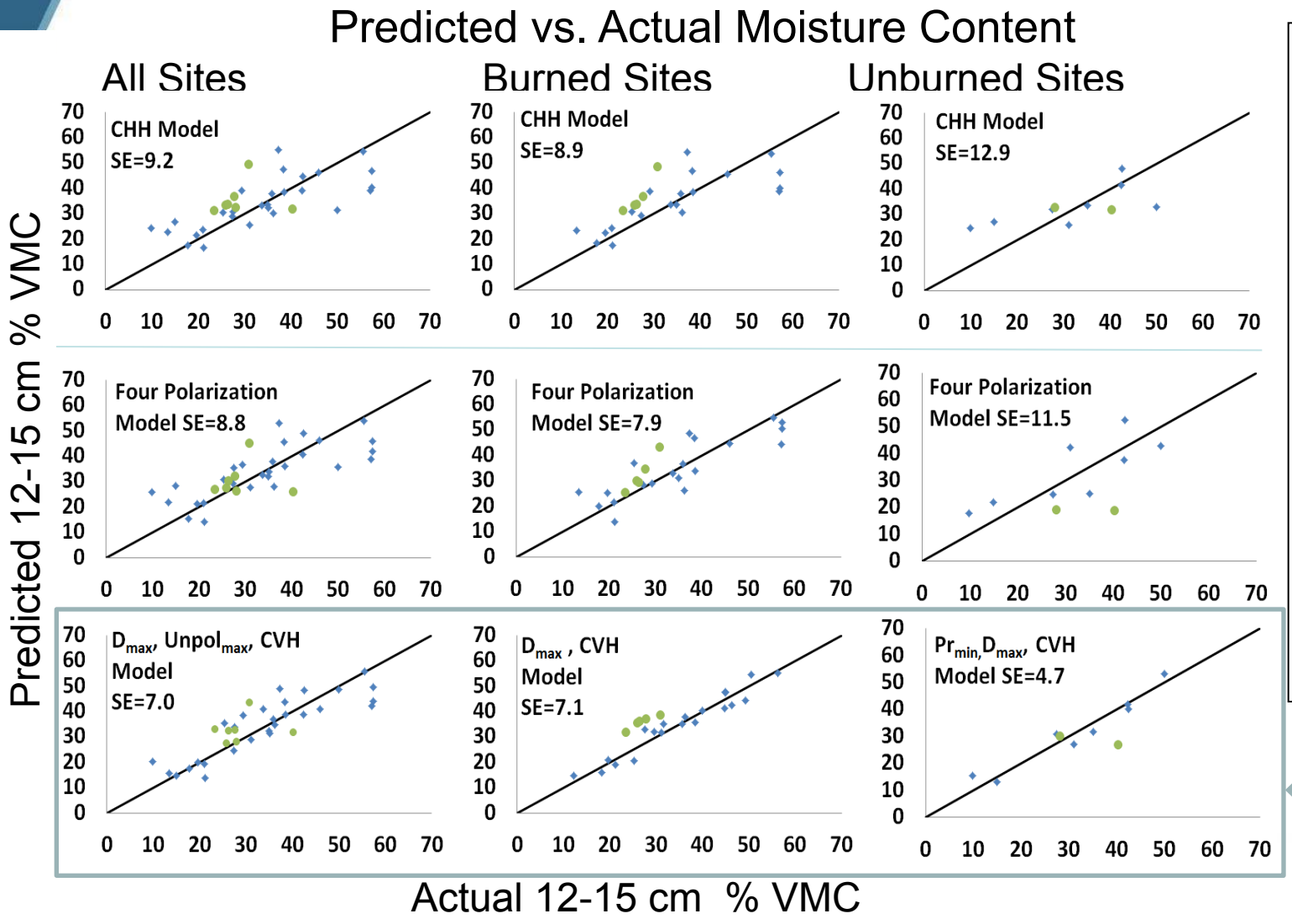
Caveat: SAR sensors are sensitive to moisture of image elements, but also vegetation structure and surface roughness.

Solution: Advanced Polarimetric SAR can help account for variability in these confounding factors and is promising for future application.



- **D_{max} – maximum degree of polarization does not vary much by date (moisture condition) and appears to increase with increasing structural complexity**
- **C-HH backscatter is strongly affected by moisture status**
- **In combination these variables improve fuel moisture retrieval capability**

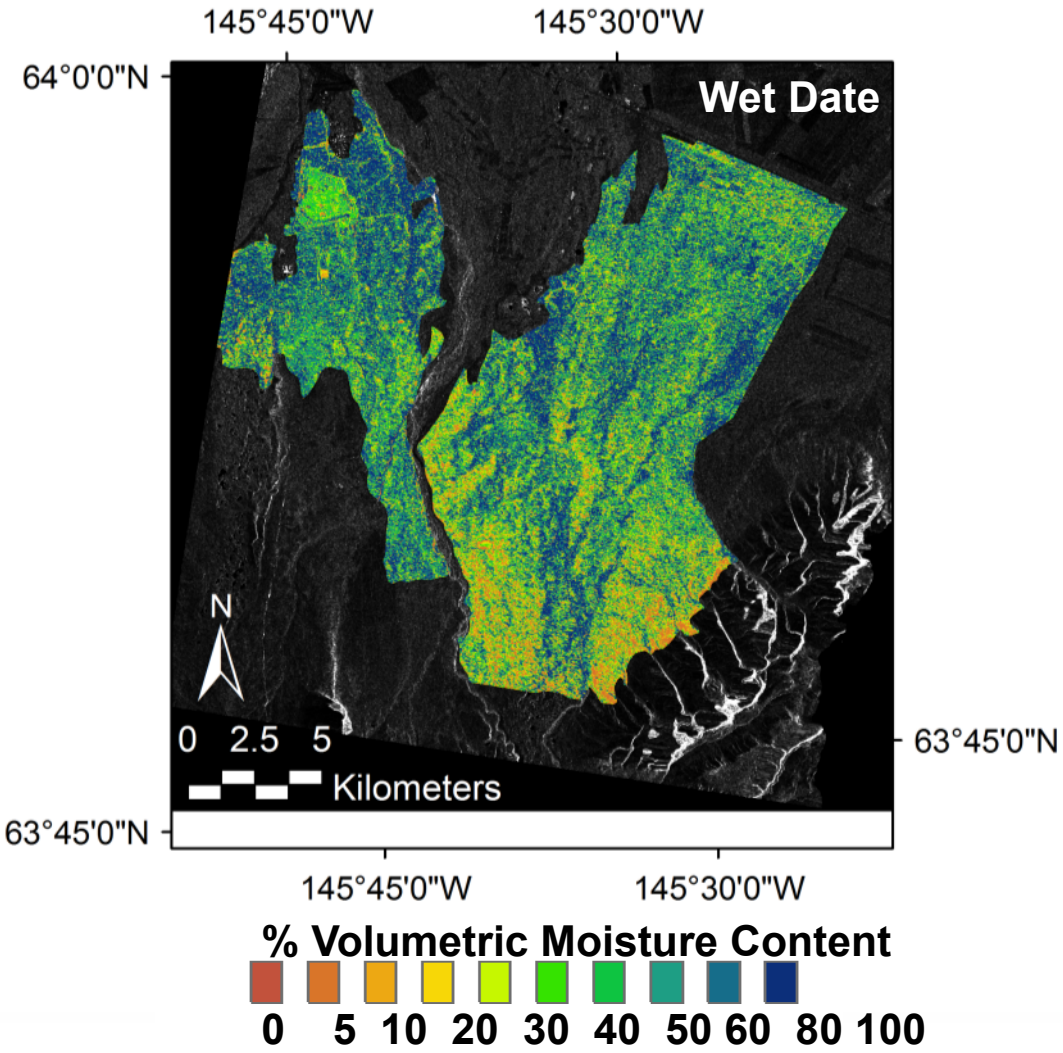
SAR Polarimetric Algorithms Improve Moisture Retrieval Accuracy



27-33% improvement in retrieval accuracy with Polarimetric SAR over traditional single channel CHH model and four polarization SAR backscatter capability.

Polarimetric SAR Derived Fuel Moisture Maps

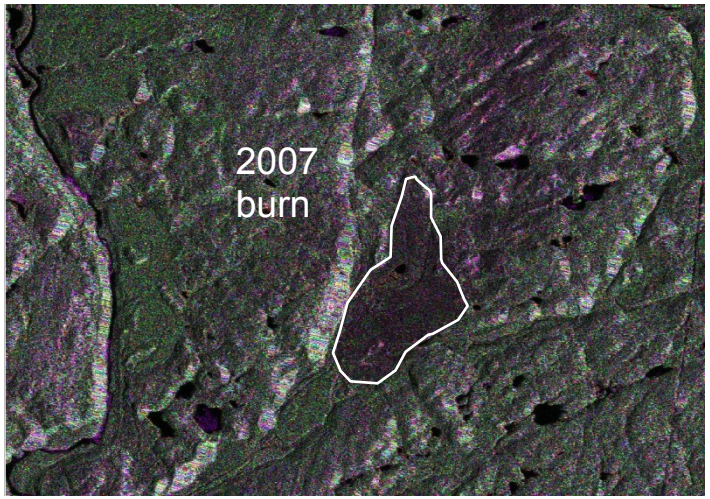
- Accuracy of 6.7% volumetric moisture content (RMSE).
- Note: Mature forest areas (> 1.7 kg/m^2 biomass) are removed from maps.
- More research is needed to extend the models to other regions and greater biomass areas



Predictive Algorithm for All Sites:

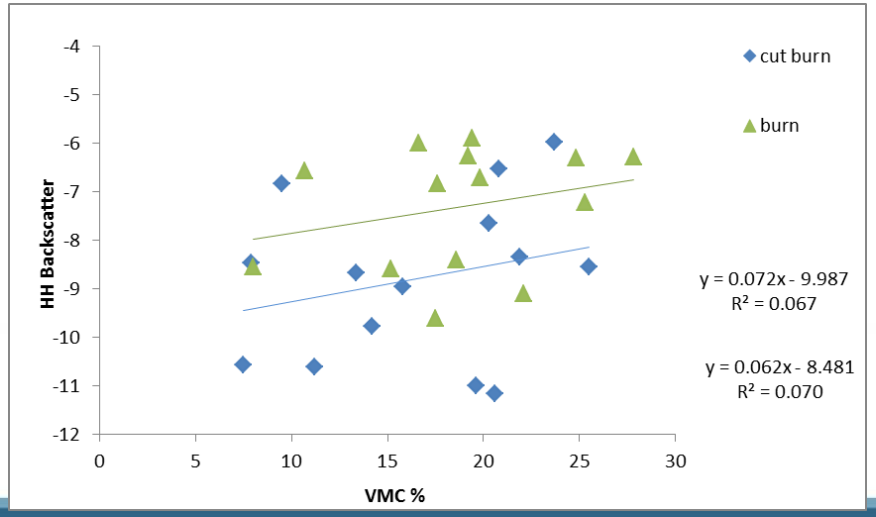
$\%VMC = 319.31\ D_{max} - 612.50\ Unpol_{max} + 5190.4\ C\text{-}VH - 266.37 \quad R^2 = 0.77$

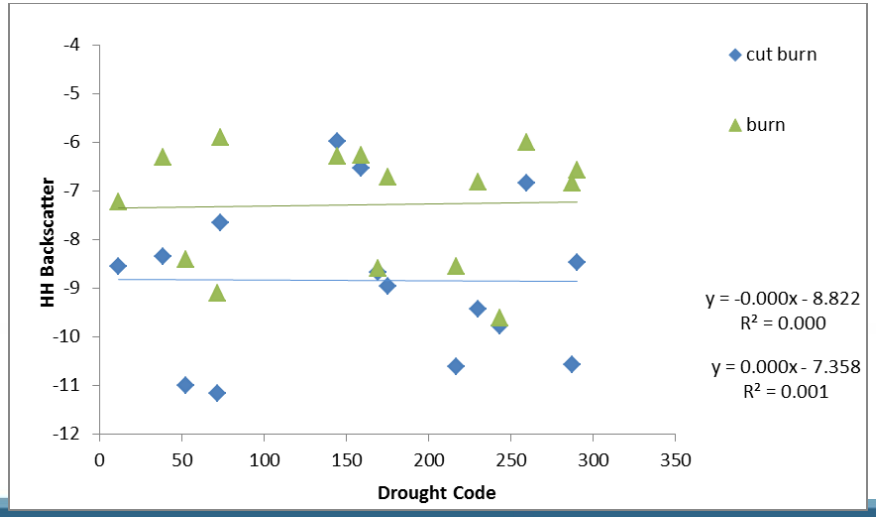
Caveats: e.g. Sharpsand Creek, ON



Jun 1, 2010 VMC 5.6%

October 18, 2011 VMC 23.7%

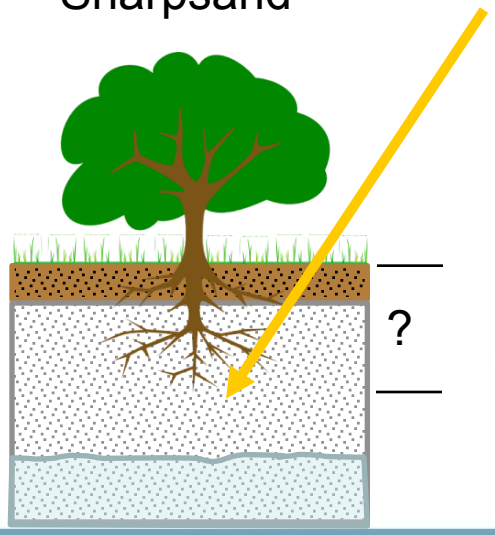




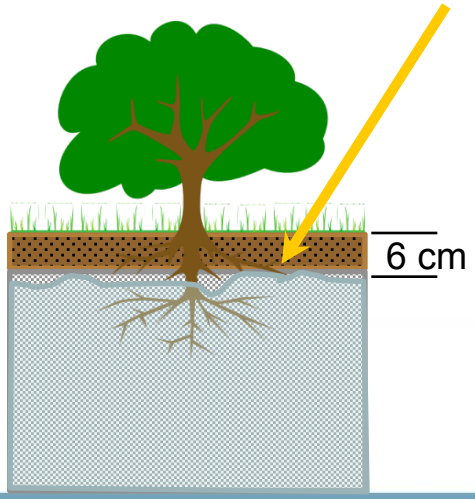
Variability in Penetration Depth

Site	Forest Type	Moisture Regime and Texture	Average Duff Depths (cm)	Average Organic Duff Bulk Density (kg/m^3)
Sharpsand	jack pine	Well drained sandy soils	5	160
NWT	jack pine	Poorly drained sandy loam soils	4	97
Alaska	black spruce	Poorly drained silty soils	>15	387

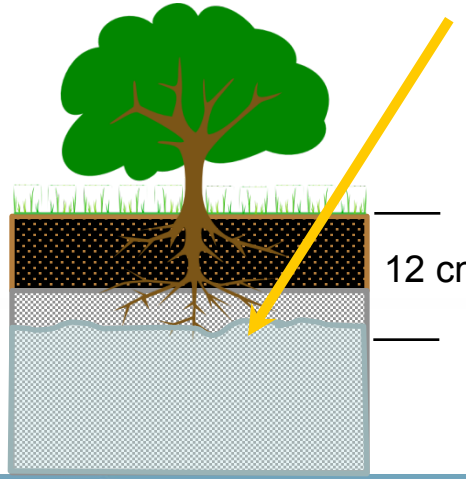
Sharpsand



NWT



Alaska

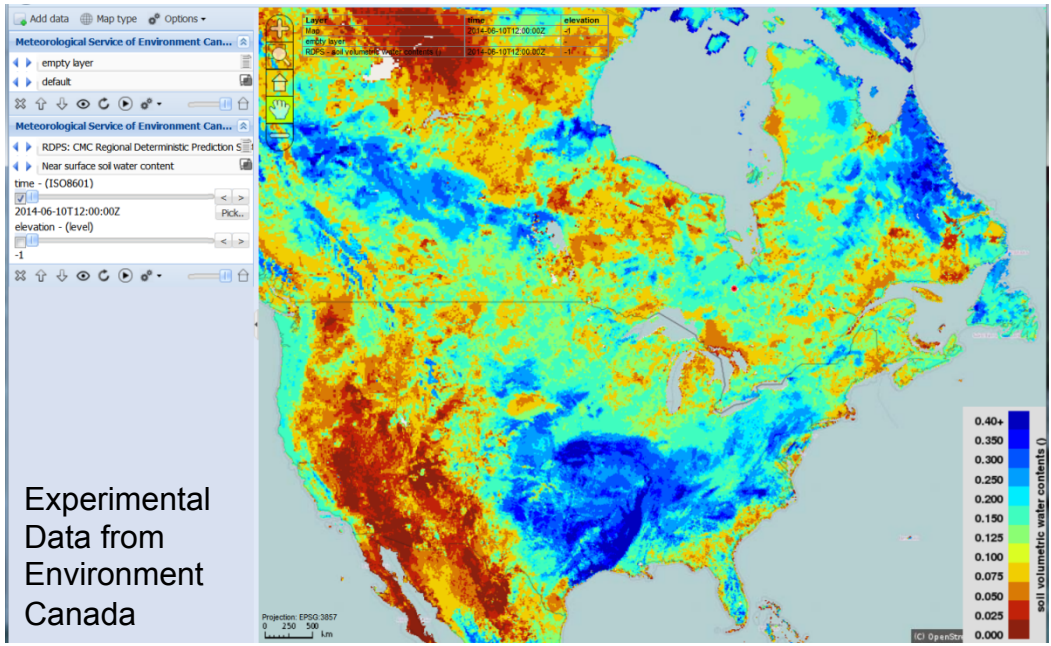


Canadian Forest Service Direction

Long Term:

- Continue collaboration with MTRI: expand into different regions; integrate data from new satellites

- Collaboration with Environment Canada to integrate organic soil moisture estimates into their Canadian Land Data Assimilation System which integrates landscape modelling and moisture estimates from SMAP and SMOS



Experimental Data from Environment Canada

Short Term:

- New DC overwinter model may solve spring initiation problems; not permafrost thaw

- Investigation of new precipitation analysis methods, developed by Environment Canada (Canadian Precipitation Analysis), compared to current weather station interpolations for FWI calculations; may improve moisture estimates between stations

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Forests

CWFIS

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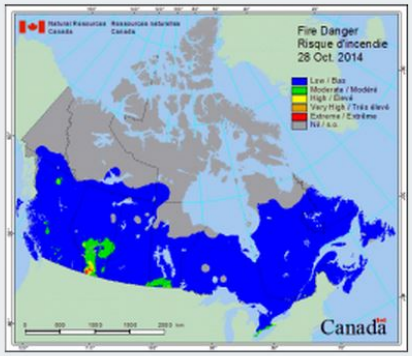
  - Fire Weather Normals
  - Fire Behavior Normals
  - Canadian National Fire Database
- CWFIS Datamart

Canadian Wildland Fire Information System

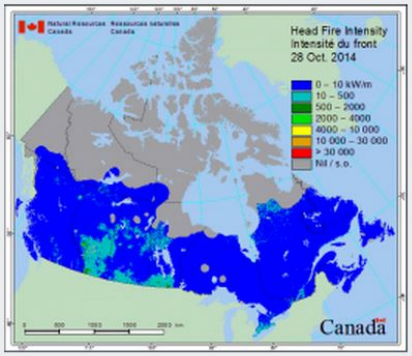
The **Canadian Wildland Fire Information System (CWFIS)** creates daily fire weather and fire behavior maps year-round and hot spot maps throughout the forest fire season, generally between May and September.

Fire Weather



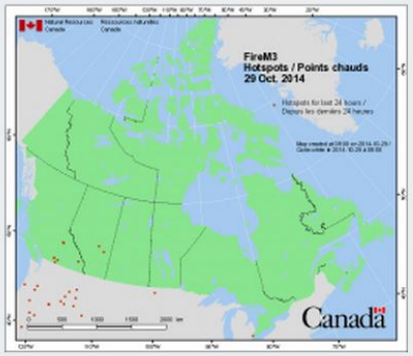
View the most recent Fire Danger map

Fire Behavior



View the most recent Head Fire Intensity

Fire M3 Hotspots



View the most recent Daily Hotspot map

http://cwfis.cfs.nrcan.gc.ca/home

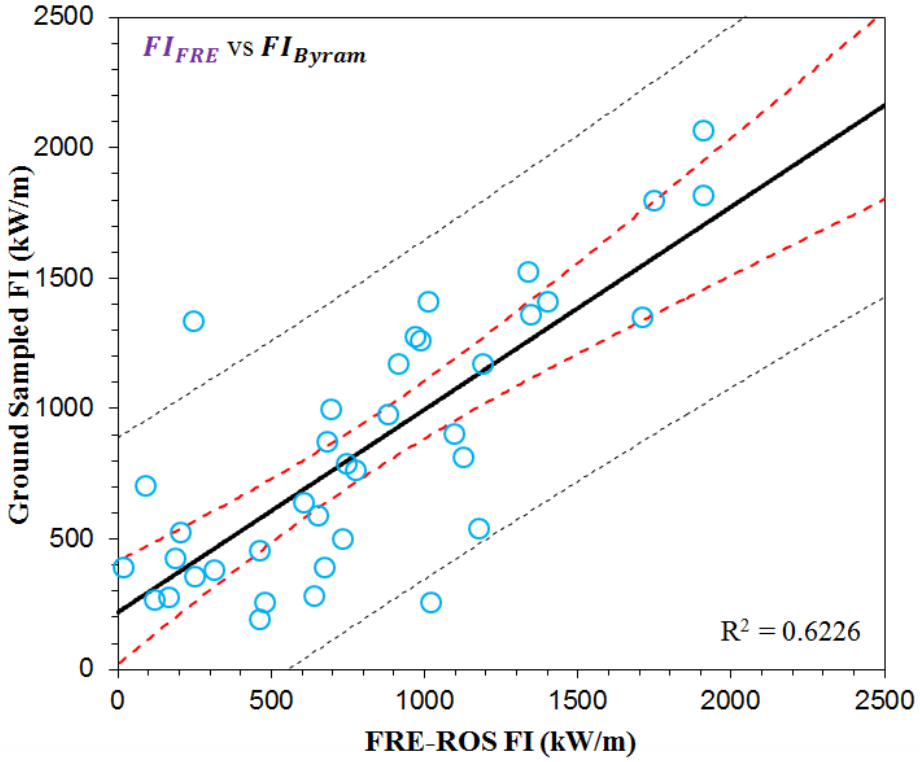
Other Remote Sensing and CFFDRS

Potential Areas of Future Research

- Green-up/Leaf out dates
- Grass curing
- Foliar Moisture Content

Research Currently Underway

- Fire Radiative Energy and ROS from thermal imagery to estimate fire line intensity
- Fire Radiative Energy to estimate fuel consumption



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