Satellite-Based Detection and Monitoring of Fire and Fire Effects in the North American Tundra

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Observed warming in the high northern latitudes has implications related to increased fire in both boreal forest systems and tundra. Warming and modifications to climate patterns has led to an increase in fire occurrence in the tundra, a biome not known for broad-scale fire. The overarching question we are addressing is:

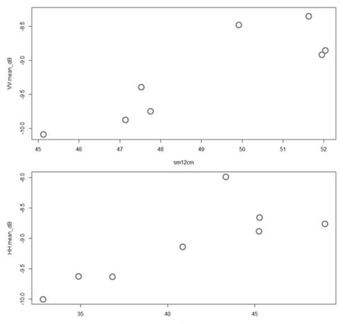
If fire increases in landscapes where fire is neither currently nor historically of great importance, what impacts will this have on ecosystems and ecosystem services?

Current accounting of historical fire for the circumpolar arctic is not complete, partly due to lack of developed algorithms for tundra fire detection. Current satellite-based methods for mapping fire at northern latitudes are focused on algorithms tuned to forested landscapes rather than treeless tundra types, and characteristics of fire effects in tundra are not well understood for development of such algorithms. Fire regime, including the occurrence and severity of fire, is most likely changing, and will be changing quickly since fire is strongly driven by climate. This has important implications regarding carbon cycling and impacts on ecosystems and ecosystem services.

Field Assessment

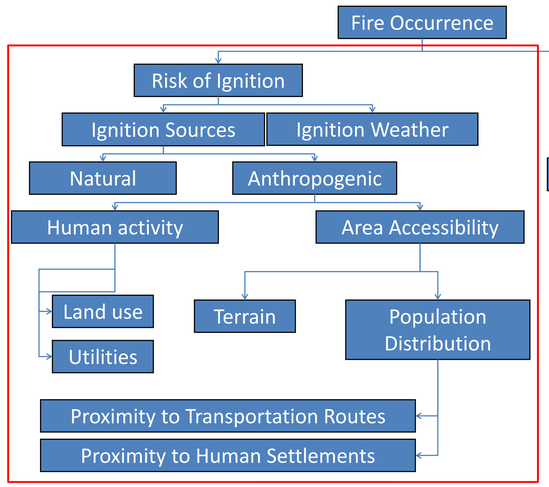
- Field Sites
  - 2012 Kucher Creek Fire, North Slope, AK, early spring, light severity fire
  - 2010 Kaluktavik River Fire, Noatak National Preserve, AK
  - Other field data: five 2010 burn sites in the Noatak, data collected by NPS (Jennifer Barnes, et al.)
- Data Parameters Collected:
  - Latitude/longitude, date, time
  - GPS-tagged photographs in 4 cardinal directions (N, E, S, W) and nadir
  - Site description
  - Burn severity assessment
  - Soil organic material profile
  - Vegetative cover (%, average height, and distribution)
  - Tussocks characteristics
  - Shrubs
  - Soil moisture
  - Soil temperature
  - Active layer depth (Kucher Creek only)
- Kucher Creek, burn versus unburn, significant parameters: active layer, soil moisture 6 cm, soil moisture 12 cm, and soil temperature
- Generalized linear models to predict to parameters as a function of burn severity, significant parameters
  - Active layer ***
  - Soil moisture 6 cm ***
  - Soil moisture 12 cm **
  - Depth to mineral soil *
- Fully-polarimetric Radarsat-2 synthetic aperture radar (SAR) data collection coincident with Kucher Creek field campaign
  - Soil moisture: best correlation between VV and soil moisture at 12 cm (R2=0.87), good correlations were also found between HH and soil moisture at 6 cm (R2=0.80)
  - SAR data will be used to look at burn severity in our field sites
- Plans for 2013 summer field work in the Noatak National Preserve

Soil Moisture Versus SAR Backscatter



Additional Research Team Members: Michael Flannigan, Carolyn Harf, Randi Jandt, Evan Kane, Eric Kasischke, Charles Racine, David Riano

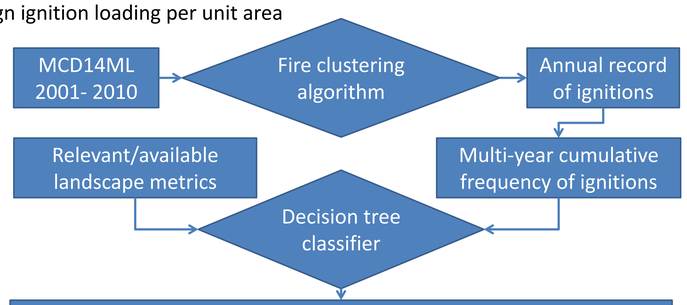
Fire Occurrence Modeling (FOM)

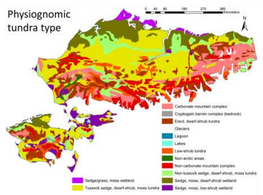


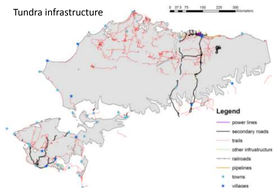
- A regional satellite-data driven North American instance of the FOM – FOM-NA is under development.
- It will be used to assess potential change in future fire occurrence under projected climate change

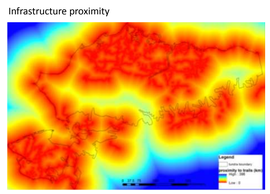
Risk of Ignition Module

- Based on MODIS observations of active fires (MCD14ML) clustered in space-time to identify the proxy for the point of ignition (Loboda and Csiszar, 2007)
- Ignition-driven spatial clustering to define contiguous landscape sections with similar ignition patterns
- Assign ignition loading per unit area





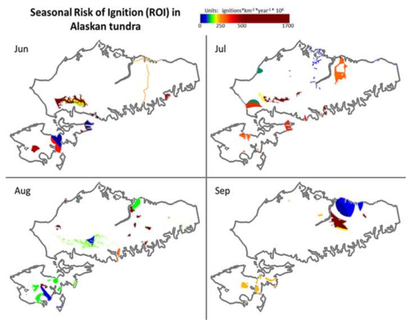




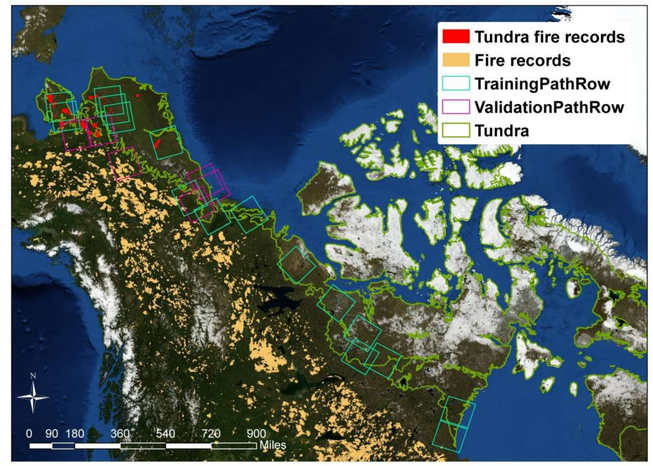
Landscape Variables (n = 15):
Proximities to: roads, trails, railroads, power lines, pipelines, other infrastructure, landing strips, towns, villages
Topography: elevation, slope, aspect
Human activity and vegetation: land ownership, tundra type, land cover

Spatial clustering outcomes:

	Jun	Jul	Aug	Sep
Res mean deviance	0.02	0.02	0.01	0.01
Top variables:	tundra type	tundra type	tundra type	powerlines
	village	powerline	village	land ownership
	landing	trails	elevation	town



Historical Fire Database



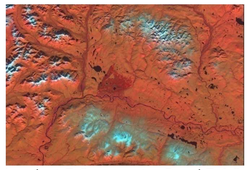
An important component of our work is gathering historical fire locations. The data set is dynamic, and the assembled data will serve as validation and training data for further research activities. Perimeters and points are obtained and derived from numerous sources and methods:

- Canadian Large Fire Database (publically available)
- AICC (Alaska Interagency Coordination Center)
- MTBS (Monitoring Trends in Burn Severity)
- Yukon fire service
- Northwest Territories fire service
- Navy FLAMBE website for GOES and MODIS hotspots
- GPS perimeters (walking, helicopter, aerial)
- Digitization of historical aerial imagery
- Hand drawn
- IR imagery
- Landsat, MODIS, and AVHRR derived perimeters

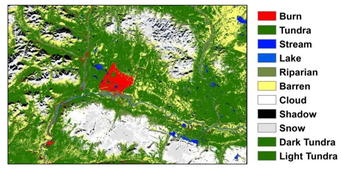
Landsat-Based Fire Detection

Tundra Fire Random Forest Algorithm
- Set of 500 classification trees (a forest)
- Thresholds for classification based on randomly selected variables
- Final pixel class decided by majority vote
- Training data from 23 Landsat scenes, hand delineated by land cover class using fire records from the Alaskan Tundra between 1984 – 2010 for platforms L4 – L7.
- Validation data set currently consists of 14 Landsat scenes.
- Initial post clumping fire commission and omission error < 10%.

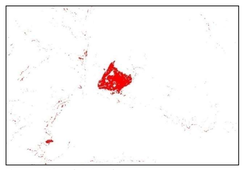
Input Data:
- Landsat Bands 1 – 7
- Normalized Temperature
- NDVI
- GEMI
- MIRBI
- BAIM-l, BAIM-s, BAI
- NBR-s, NBR-l



Landsat 7 Composite: Band 7,4,3
Path 79 Row 12 9/22/2002

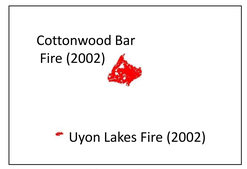


Classified Image:
Classified using Random Forest in R



Burn Pixel Mask

Fire Seeds: 200 Burn pixels in 15 x 15 neighborhood



Final Burn Pixels: Restore burned clusters with seeds.

Classified	Ground Truth Values														
	Burn	Water	Barren Shadow	Tundra Shadow	Ice	Cloud	Dark Shadow	Snow	Light Tundra	Conifers	Light Barren	Dark Barren	Sum	Comm-ission	User Acc.
Burn	1440	0	314	48	0	0	17	0	47	102	102	229	2299	37%	63%
Water	1	3323	180	311	1358	3	638	486	0	3	1	1	6305	47%	53%
Barren Shadow	0	26	811	8	2	25	97	0	47	2	10	239	1267	36%	64%
Tundra Shadow	1	18	1067	728	0	0	120	1	281	205	1	211	2633	72%	28%
Ice	0	407	73	0	1984	0	2	408	2	0	22	15	2913	32%	68%
Cloud	0	0	9	5	0	5324	0	8	72	0	315	31	5764	8%	92%
Dark Shadow	2	644	1158	237	15	1	4903	15	5	65	1	51	7097	31%	69%
Snow	0	0	9	5	0	0	0	4600	24	0	36	8	4682	2%	98%
Light Tundra	4	5	43	295	0	24	0	0	3160	519	310	165	4525	30%	70%
Conifers	34	11	159	872	0	3	234	0	269	2058	32	54	3726	45%	55%
Light Barren	23	2	121	5	0	112	0	2	1063	55	2107	1288	4778	56%	44%
Dark Barren	13	12	567	5	13	25	1	2	1051	7	585	2727	5008	88%	12%
Sum	1518	4448	4511	2519	3372	5517	6012	5522	6021	3016	3522	5019	50997	Sum	
Omission	5%	25%	82%	71%	41%	3%	18%	17%	48%	32%	40%	74%			
Prod. Acc.	95%	75%	18%	29%	59%	97%	82%	83%	52%	68%	60%	26%			