



Landsat TM and Synthetic Aperture Radar Data to Determine Burn Severity in the Boreal Forest



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1. Background:

Fire is an important disturbance mechanism in many ecosystems and is the dominant form of disturbance in boreal forests (Baltzer 2001, Conrad 2002, Wagner 2002). From the 1960's to the 1990's, the annual area burned in boreal forests has increased from an average of 1.4 to 3.1 million hectares per year (Kasischke 2002). The greatest increase in fires has occurred across Siberian Russia. This region contains nearly 60% of the world's boreal forests, making it a primary sink for carbon dioxide (Huang 2005, Shvidenko 2003, Stocks 1998).

The 2 fires in this study are located in the foothills of a low mountain range along two tributaries of the Kolyma River, one of the largest rivers in the world by volume. The fires occurred independently of one another but on similar dates, according to the MODIS Level 5 active burn product. Using the GLCF global land cover product layer and performing a simple overlay of the fire polygons, the fires occur entirely within the taiga forest, composed of Dahurian larch (*Larix gmelinii*) and dwarf birch trees (*Betula platyphylla*) along water bodies and in wetlands (Ponomarenko 2001). The origin of the fires is unknown and to our knowledge no human settlements have been identified in the region, therefore, it is very likely the fires were ignited by lightning (Baltzer 2005).

2. Study Area:

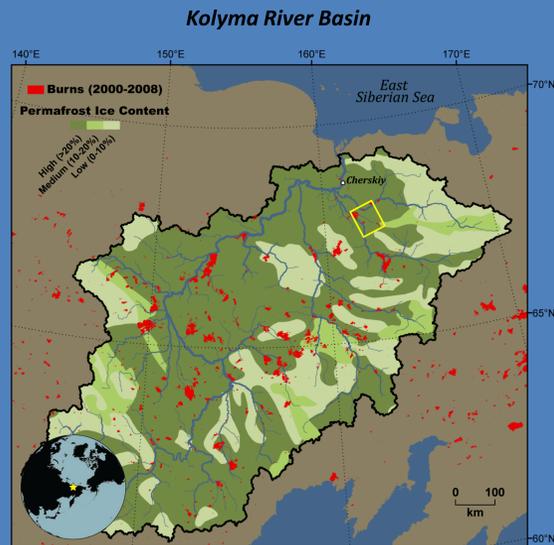
Most of Siberian Russia is situated among perennially frozen soils known as permafrost. Permafrost in northern regions contains large quantities of labile carbon (upwards of 2.6%) in a subsurface zone known as the yedoma ice complex. Stand-reducing forest fires with residual smoldering will often burn portions of the active, organic layer and expose large swaths of labile carbon. The increase of fires in these areas throughout the past decade has significant implications for carbon dioxide release and a climate warming feedback, perpetuating carbon dioxide emissions and removing an important sink (Baltzer 2005, Stocks 1998, Tucker 2001).



Active burn along the Kolyma River detected in 2005 Landsat TM data



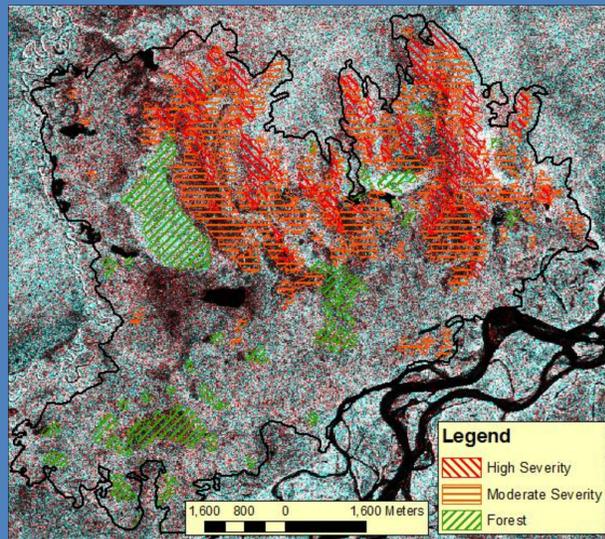
Boreal forest burn in Alaska (NASA)



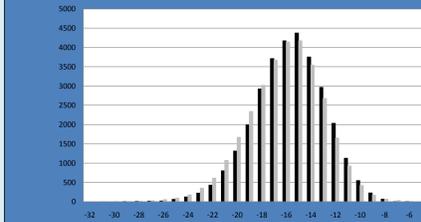
5. Methods:

Image statistics are calculated based on the unburned, high severity, and moderate severity bins identified in the dNBR image and a statistical analysis is performed between the values in the 2007 radar image and the 2008 radar image at the HV polarization. Due to expected changes in vertical roughness, the HV polarization is selected for analysis. The dNBR image is used as a reference image for the L-band data and a comparison of quantified burn severity between the two data types is made.

6. dNBR Classes and Radar:

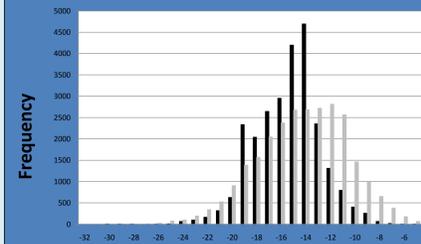


7. PALSAR Statistics



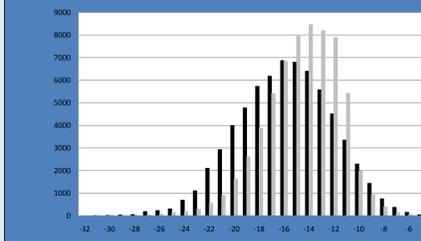
Unburned

SUMMARY STATISTICS	2007 Unburned	2008 Unburned
Mean	-16.474	-15.879
Observations	30756	30756
Pearson Correlation	0.993967423	
Hypothesized Mean Diff.	0	
t Stat	0	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.701130908	
P(T<=t) two-tail	1	
t Critical two-tail	2.048407115	



Moderate Severity

SUMMARY STATISTICS	2007 Mod. Severity	2008 Mod. Severity
Mean	-17.172	-15.976
Observations	66893	66893
Pearson Correlation	0.201317779	
Hypothesized Mean Diff.	0	
t Stat	0.386927116	
P(T<=t) one-tail	0.093508677	
t Critical one-tail	1.701130908	
P(T<=t) two-tail	0.101735393	
t Critical two-tail	2.048407115	



High Severity

SUMMARY STATISTICS	2007 High Severity	2008 High Severity
Mean	-15.595	-16.501
Observations	25383	25383
Pearson Correlation	0.633001162	
Hypothesized Mean Diff.	0	
t Stat	-0.340926219	
P(T<=t) one-tail	0.056785206	
t Critical one-tail	1.701130908	
P(T<=t) two-tail	0.435704129	
t Critical two-tail	2.048407115	

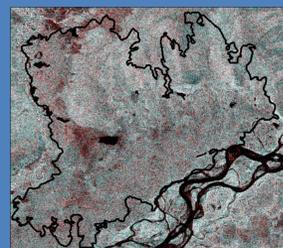
Bin Range (decibels)

The mean values of the unburned category are shown to be strongly correlated with a high Pearson's correlation coefficient. Moderate severity pixels show the greatest difference in mean value and distribution of pixels across the moderate bins. High severity pixels have a significantly higher mean but remain statistically similar in terms of distribution and correlation.

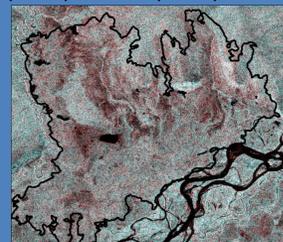
3. Data:



Landsat TM data was acquired from 6/30/2007 and 8/20/2007 and corrected for atmospheric contamination and geometric error. A false color composite depicts the burn scar along the banks of the M.Anui River, a tributary of the Kolyma.



PALSAR L-band synthetic aperture radar data was acquired on 6/30/2007 and 7/2/2008 at HH and HV polarizations. Images of composite HH/HV/HV for 2007 (above) and 2008 (below).



4. Differenced Normalized Burn Ratio (dNBR):

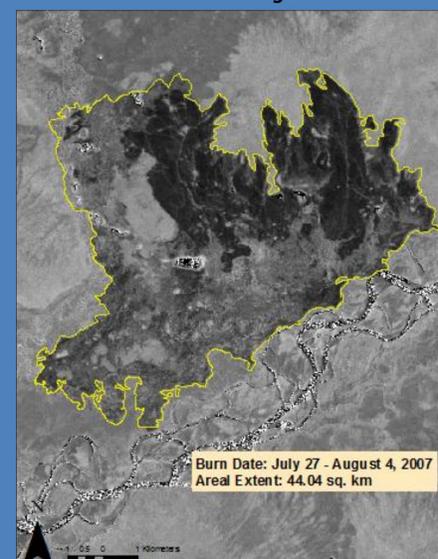
The differenced Normalized Burn Ratio (dNBR) is a common index used to assess burn severity in optical imagery and to detect burn scars. The dNBR quantifies the observed changes in forest biomass and moisture content before and after a burn event using near-infrared and shortwave infrared bands. The burn scar in this study is detectable with this index (right). The raw image is binned into severity classes based on pixel value.

$$NBR = (R_4 - R_2) / (R_4 + R_2)$$

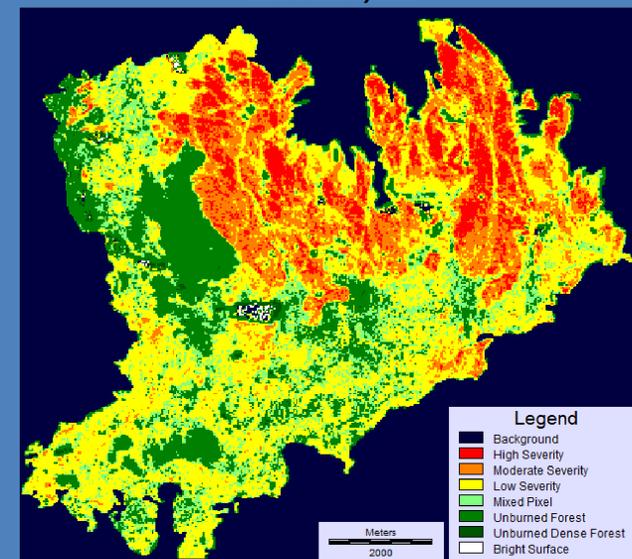
$$dNBR = NBR_{prefire} - NBR_{postfire}$$

*where R is the band converted into radiance from Dn after correction and 4 is the NIR and 7 is the SWIR band

dNBR Image



Burn Severity Bins



8. Discussion:

The dNBR index detected areas of high severity, moderate severity, and low severity burn along with persistent unburned segments. Extracting backscatter values from the identified segments suggests the dNBR can adequately identify areas of unburned, high severity, and moderate severity burn in a boreal forest environment in Eastern Siberia. The results suggest the dNBR can best map moderate severity burns, as the lowest correlation between 2007/2008 backscatter was observed for this category.

Backscatter data reflects changes in surface moisture and the HV polarization reflects vertical changes in surface roughness, suggesting that the shift in mean values is related to an increase in soil moisture after the burn from permafrost thaw and reduced stand density in high and moderate severity pixels.

References

Allen, J. L. S., B. (2008) Assessing the differenced Normalized Burn Ratio's ability to map burn severity in the boreal forest and tundra ecosystems of Alaska's national parks. *International Journal of Wildland Fire*, 17, 463-475.

Baltzer, H., Genard, F.F., George, C.T., Rowland, C.S., Jupp, T.E. (2005) Impact of Arctic Oscillation pattern on interannual forest fire variability in Central Siberia. *Geophysical Research Letters*, 32, 1029-1035.

Conard, S.G., Sukhinin, A.I., Stocks, B.J., Cahoon, D.R., Davidenko, E.P., Ivanova, G.A. (2002) Determining effects of area burned and fire severity on carbon cycling and emissions in Siberia. *Climatic Change*, 55, 197-211.

Epling, J., Verbyla, D., Sorbel, B. (2005) Evaluation of remotely sensed indices for assessing burn severity in interior Alaska using Landsat TM and ETM+. *Remote Sensing of Environment*, 96, 328-339.

Escobar, S., Navarro, R., Fernandez, P. (2007) Fire severity assessment by using NBR (Normalized Burn Ratio) and NDVI (Normalized Difference Vegetation Index) derived from Landsat TM/ETM images. *International Journal of Remote Sensing*, 29, 1053-1073.

French, N.H.F., Bourgeau-Chavez, L.L., Wang, Y., Kasischke, E.S. (1999) Initial Observations for RadarSat Imagery at Fire-Disturbed Sites in Interior Alaska. *Remote Sensing of Environment*, 68, 89-94.

Stocks, B. J., Forberg, M.A., Latham, T.J., Meams, L., Wotton, B.M., Yang, Q., Jin, J.Z., Lawrence, K., Hartley, G.R., Mason, J.A., McKenney, D.W. (1998) Climate change and forest fire potential in Russian and Canadian boreal forests. *Climatic Change*, 38, 1-13.

Zimov, S.A., Schuur, E.A.G., Chapin, F.S. (2006) Permafrost and the Global Carbon Budget. *Science*, 312, 1612-1613.

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