ASSESSMENT OF BIOMASS CONSUMPTION VARIABILITY IN FOREST FIRES USING SATELLITE REMOTE SENSING

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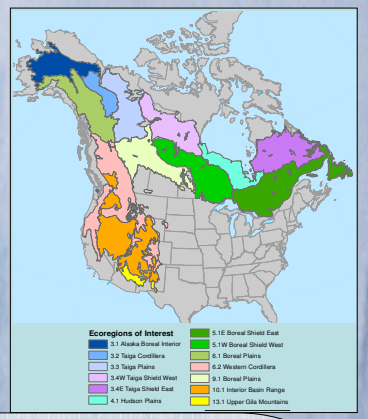
Objectives

For this NASA-funded research project, biomass consumption levels in forested regions of northern and western North America are being measured and modeled with a goal of learning how variable consumption can be within a given ecoregion. The result will be a more complete view of the amount of biomass consumed during burning so that estimates of carbon emissions can be better quantified.

Approach

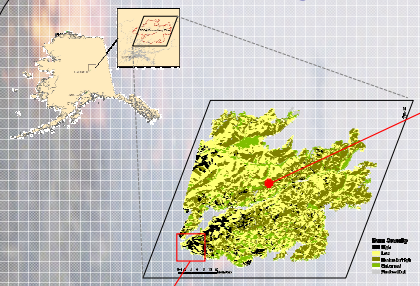
Fuel consumption for 13 Ecoregions of North America is the focus. We use measured or modeled fuel consumption estimates, in kg-m^{-2}, combined with the spatial distribution of fire severity, which provides a measure of the amount of landscape burned at various fuel consumption levels. Due to differing types of data available for the three geopolitical regions, three different approaches are used for Alaska, Canada, and the Lower-48.



Abstract

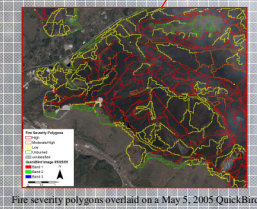
Under this NASA New Investigator project, Dr. French is continuing research to quantify variables important in estimating carbon emissions from biomass burning. In particular, this project aims to assess the variability in the amount of biomass consumed during forest fires, one of the most difficult variables to measure for fire emissions work and the most variable. In this poster we report results from this study on the level and variability of biomass (fuel) consumption in wildland fires in forest regions of western and northern North America. The results can be used to improve model inputs and to better define the uncertainty in model-based estimates of fire emissions. Remote sensing-based maps of severity are used to partition fires into severity classes. Field measures of consumption and model outputs relating fuel moisture to consumption are used to quantify fuel consumption as a function of severity class and fuel type. Demonstration of empirically-driven fuel consumption models to derive consumption levels is presented as well as methods to use remote sensing to map fire severity in temperate and boreal regions. The results found in this study allow for a more accurate accounting of the amount of biomass consumed during burning for improved estimates of carbon emissions.

ALASKA



Field Collection

Left/Below: 2004 Boundary Fire : Object-based classification of fire severity



Fire severity polygons overlaid on a May 5, 2005 QuickBird image

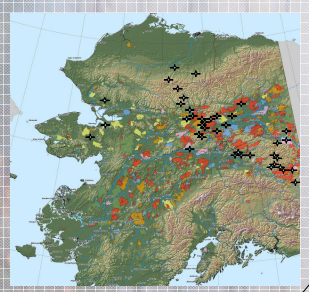
Class	Acres	Sq. Km	Percent
Low	217603	880.6	45.4%
Moderate/High	172269	687.1	36.0%
Unburned	52732	213.4	11.0%
High	31033	125.6	6.5%
Unclassified	5224	21.1	1.1%
TOTAL	478861	1937.9	100.0%

Left: Burn severity mapped at the 2004 Boundary Fire complex using an object-based classification approach. The percentages of each class are displayed in the table.

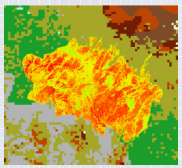
Right Field data was used to measure fire severity and surface fuel consumption in black spruce forests.

Data was collected from 36 fire events and unburned stands by researchers at ERIM, UMD, MSU, UAF, USFS, MTRI, USGS, USFWS.

From 749 plots, **18,587** organic layer depth measurements were taken and >2,000 organic layer samples were collected for lab analysis to determine bulk density and % C

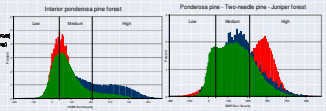


LOWER-48

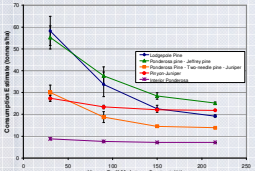


Left: Burn severity mapped using the dNBR approach by the Monitoring Trends in Burn Severity program is compared to the Fuel Characteristic Classification System (FCCS) fuelbed map, developed by FERA, to learn the distribution of fuels burned at various severities.

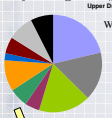
Below: Distribution of dNBR severity values for two main fuel types by ecoregion



Below: Fuel consumption can be estimated using the CONSUME 3.0 model developed by FERA. Consumption as a function of fuel moisture for five of the most common fuelbeds that burn in Western US (below ***left***). Equating consumption estimates to dNBR severity values yields estimates of total consumption from fires for each fuel type and ecoregion (below ***right***).



Ecoregion	FCCS Category	Area Estimate (sq. km)	Area (% of ecoregion)	Fuel Consumption (tonnes/ha)
Western Cordillera	Other forest types	844.9	15.3	63.7
	Ponderosa pine - Jeffrey pine forest	825.3	14.9	28.2
	Lodgepole pine forest	728.4	13.1	22.4
	Pacific ponderosa pine - Douglas-fir forest	676.9	12.2	17.6
	Douglas-fir - ponderosa pine forest	452.8	8.2	50.3
	Western hemlock - Western redcedar -	314.9	5.7	73.6
	Pinyon - Juniper forest	314.4	5.7	7.1
	Pacific ponderosa pine forest	281.4	5.1	25.3
	Western juniper / Huckleberry oak forest	233.0	4.2	13.5
	Interior ponderosa pine forest	128.5	2.3	22.1
	Ponderosa pine - Two-needle pine - Juniper	12.1	0.2	14.4
	Non-forest/Shrubland/Grassland	509.1	9.2	4.6
	Urban - Agriculture - Barren	217.3	3.9	0.0
	TOTAL	5539.1		30.5
Upper Gila Mountain	Pinyon - Juniper forest	509.8	41.1	7.1
	Ponderosa pine - Two-needle pine - Juniper	215.6	17.4	13.8
	Engelmann spruce - Douglas-fir - White fir	161.5	13.0	38.9
	Interior ponderosa pine forest	72.6	5.8	21.9
	Subalpine fir - Engelmann spruce -	8.0	0.6	56.3
	Non-forest/Shrubland/Grassland	263.4	21.2	2.7
	Urban - Agriculture - Barren	9.6	0.8	0.0
	TOTAL	1240.4		12.6
Interior Basin Range	Pinyon - Juniper forest	624.8	43.4	7.1
	Ponderosa pine - Two-needle pine - Juniper	144.9	10.1	14.4
	Other forest types (7 types)	26.4	1.8	36.2
	Subalpine fir - Lodgepole pine - Whitebark	24.2	1.7	34.4
	Pacific ponderosa pine forest	20.0	1.4	25.3
	Ponderosa pine - Jeffrey pine forest	7.3	0.5	25.0
	Interior ponderosa pine forest	5.0	0.3	21.9
	Lodgepole pine forest	0.5	0.0	18.5
	Non-forest/Shrubland/Grassland	469.3	32.6	2.9
	Urban - Agriculture - Barren	117.8	8.2	0.0
	TOTAL	1440.2		7.3



Fuel consumption (tonnes/ha) for 5 fuelbeds by severity level

Severity	Lodgepole pine	Ponderosa pine - Jeffrey pine	Ponderosa pine - Two-needle pine - Juniper	Pinyon - Juniper	Interior ponderosa pine
High	58.2	59.3	30.0	27.3	8.8
Moderate-High	33.8	37.7	18.7	23.4	7.6
Moderate-Low	22.6	28.4	14.5	22.1	7.2
Low	19.2	25.1	13.9	21.9	7.1

Left/Below: Assuming fuelbed distribution as found from FCCS in burns (pie chart) and applying consumption from each fuel (table ***left***) yields estimates of typical consumption levels by ecoregion (table ***below***).

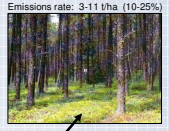
Ecoregion\ Fire size:	Consumption Estimates by Fire Size (tonnes) Small (1k ha)	Average (4k ha)	Large (50k ha)
Western Cordillera	28,880 - 33,100	115,520 - 132,400	1,444,000 - 1,655,000
Interior Basin Range	7,110 - 7,710	28,440 - 30,840	355,500 - 385,500
Upper Gila Mountains	12,480 - 12,850	49,920 - 51,400	624,000 - 642,400

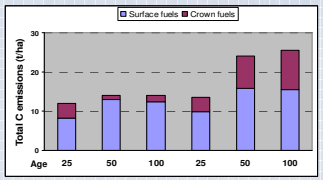
See D McKenzie, RD Ottmar, and DV Sandberg, *Fuel loading and consumption models for assessing carbon release from wildland fires*, this poster session.

CANADA

Below: Models developed by the CFS Carbon Emissions Team show total carbon emission range at experimental burns in jack pine (*Pinus banksiana*) stands is 4-27 t/ha, with most emissions originating from surface fuel consumption. Field measures of forest floor fuel consumption show good agreement with the model predictions.

Forest Overstory
Carbon storage: 34-90 t/ha
Emissions rate: 3-11 t/ha (10-25%)

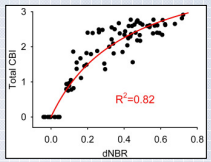


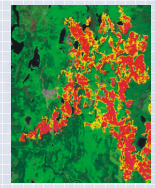


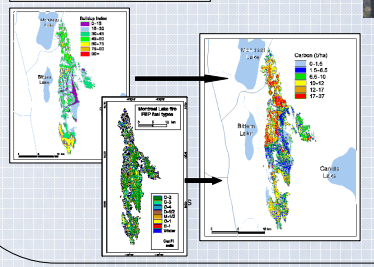
Modeled emissions for jack pine (*Pinus banksiana*) by age using fire weather index variables.

Forest Floor
Carbon storage: 2-28 t/ha
Emissions rate: 1-14 t/ha (28-74%)

Below: Strong relationship is found between severity of fire in the field (Total CBI) and satellite remote sensing (dNBR) at Canadian fires.







Left: Research is underway to model burn conditions and use remotely sensed burn severity (dNBR) connected with fuels maps to map fire emissions at the landscape scale.

Collaborations & Related Programs

Under a NASA Carbon Cycle Science Program grant to Eric Kasischke of the University of Maryland, drivers of fire emission variability are being investigated.

The United States Department of Interior, National Park Service and the US Geologic Survey are using the Normalized Burn Ratio (NBR), derived from Landsat, and the Composite Burn Index (CBI), a field measurement protocol, to assess burn severity in fires within the NPS system.

The United States Department of Agriculture, Forest Service uses remote sensing imagery in it Burn Area Emergency Response Program (BAER) to help map and target critical areas for assessment and rehabilitation.

The United States Forest Service, Fire and Environmental Applications Team (FERA) have developed models to quantify fuel and fuel consumption variability. The CONSUME 3.0 model provides estimates of fuel consumption for fuel beds in the US.

The Joint Fire Science program is an interagency program providing funding for science-based investigations that help in wildland fire management.

Natural Resources Canada, Canadian Forest Service is currently assessing fire emissions as part of an effort to make a full carbon budget for Canada. The Carbon Emissions Team (CET) is running a 3-year project to deliver a turnkey system that goes from fire monitoring, mapping to calculating carbon emissions from fires. The CET plans to use remote sensing combined with field data for a country-wide assessment by the year 2008.

References

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