The Wildland Fire Emissions Information System

A web-based regional scale approach to mapping fire emissions in North America

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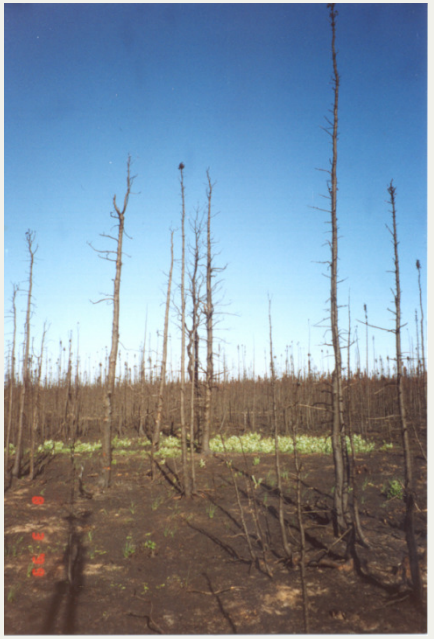
Presented
6th October 2010
Wildland Fire Canada 2010, Kitchener/Waterloo, Ontario

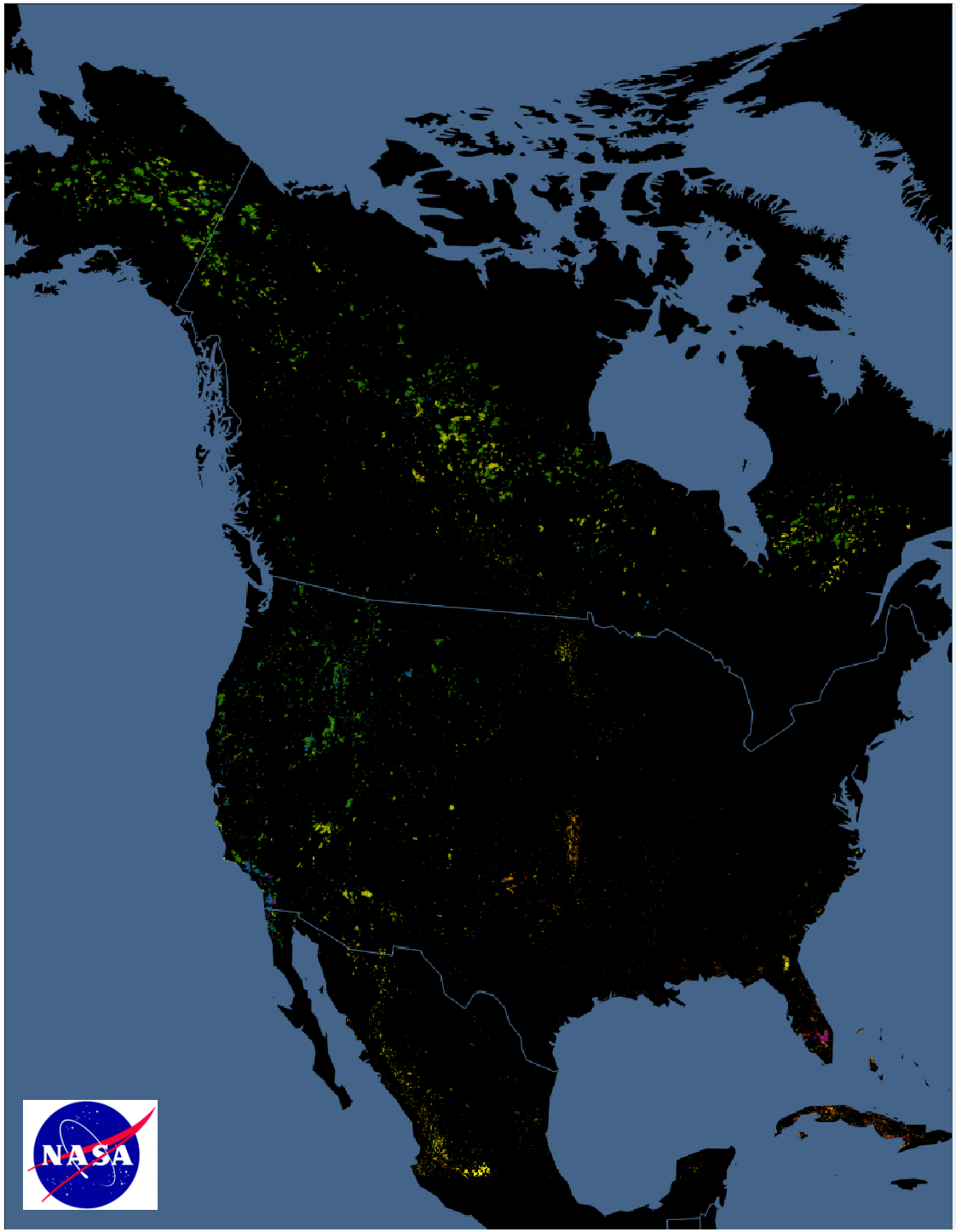
Presentation Overview

- Background
  - Importance & extent of fire across NA
  - Why quantify carbon?
  - How to estimate emissions of carbon and other gases
- The *Wildland Fire Emissions Information System* (WFEIS)
  - Overview
  - Initial results
- Comparison to other approaches



Fire & Carbon

- *GFED:* The global amount of carbon combusted through fires is about 2.0 Pg C year^{-1}, or about 22% of global fossil fuel emissions.
  van der Werf et al. 2010. Atmos. Chem. Phys. Discuss.,10:16153-16230, www.atmos-chem-phys-discuss.net/10/16153/2010/
- *CBM-CFS3:* From 1990 to 2006 Canada's managed forest was a Carbon Sink on average, but it was a Carbon Source in years with large burned area.
  Kurz, W.A. et al. 2008. PNAS 105:1551-1555.



Burn Area for North America

MODIS Direct Broadcast Burned Area Product*

2001 - 2009

Burn date

- Jan - Feb.
- March - Apr.
- May - June
- July - Aug.
- Sept. - Oct.
- Nov. - Dec.

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*Giglio, L. et al. 2009 Rem. Sens. Environ., 113(2), 408-420

Burn Area for North America

MODIS Direct Broadcast Burned Area Product

2001 - 2009

January - February

NASA

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Burn Area for North America

MODIS Direct Broadcast Burned Area Product

2001 - 2009

March - April

NASA

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Burn Area for North America

MODIS Direct Broadcast Burned Area Product

2001 - 2009

May

NASA

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Burn Area for North America

MODIS Direct Broadcast Burned Area Product

2001 - 2009

June

NASA

MichiganTech
Research Institute

Burn Area for North America

MODIS Direct Broadcast Burned Area Product

2001 - 2009

July

NASA

MichiganTech
Research Institute

Burn Area for North America

MODIS Direct Broadcast Burned Area Product

2001 - 2009

August

NASA

MichiganTech
Research Institute

Burn Area for North America

MODIS Direct Broadcast Burned Area Product

2001 - 2009

September - October

NASA

MichiganTech
Research Institute

Burn Area for North America

MODIS Direct Broadcast Burned Area Product

2001 - 2009

November - December

NASA

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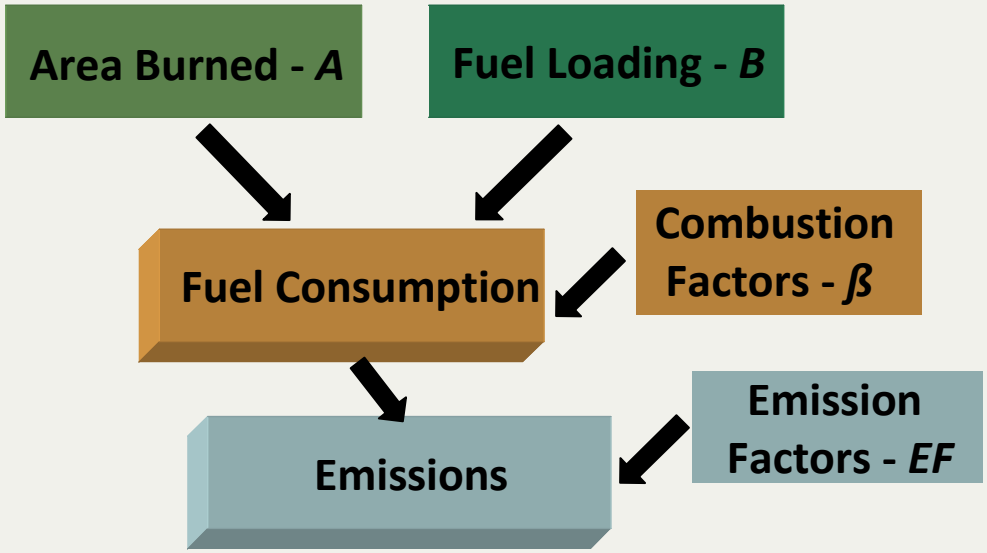
Estimating Emission Source

- Area burned – *A*
  - Records
  - Remote sensing
- Fuel loading (biomass) – *B*
  - Inventory
  - Models using remote sensing
- Combustion factors – *ß* (combustion completeness)
  - Field-derived
  - Model-based using weather & fuels
- Emission Factors – *EF*
  - Measured

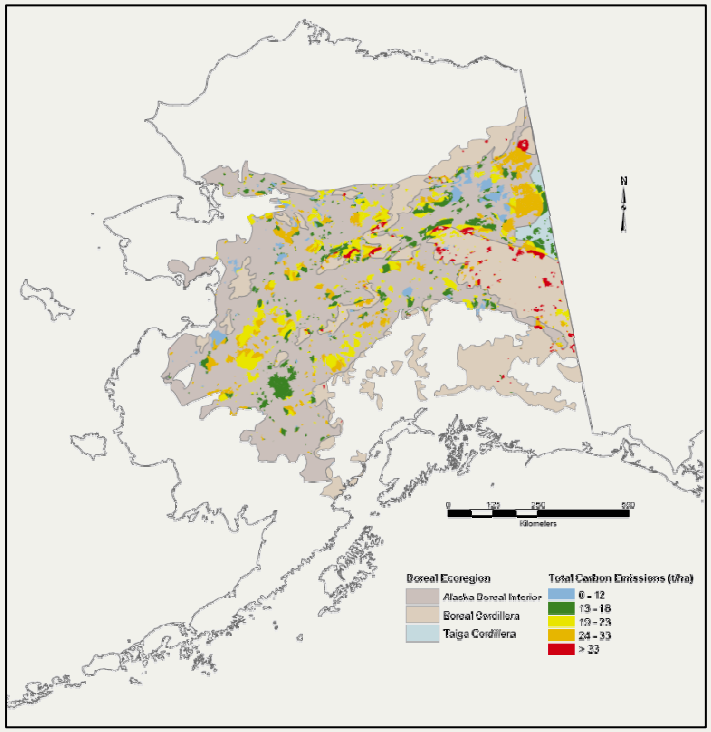


- Fuel loading and the proportion of fuel consumed (converted to emissions) have the highest uncertainty
- Emission factors depend on the relative prevalence of smoldering and flaming combustion, which is a function of the type of fuel and other factors.

Regional-scale Emissions Estimates

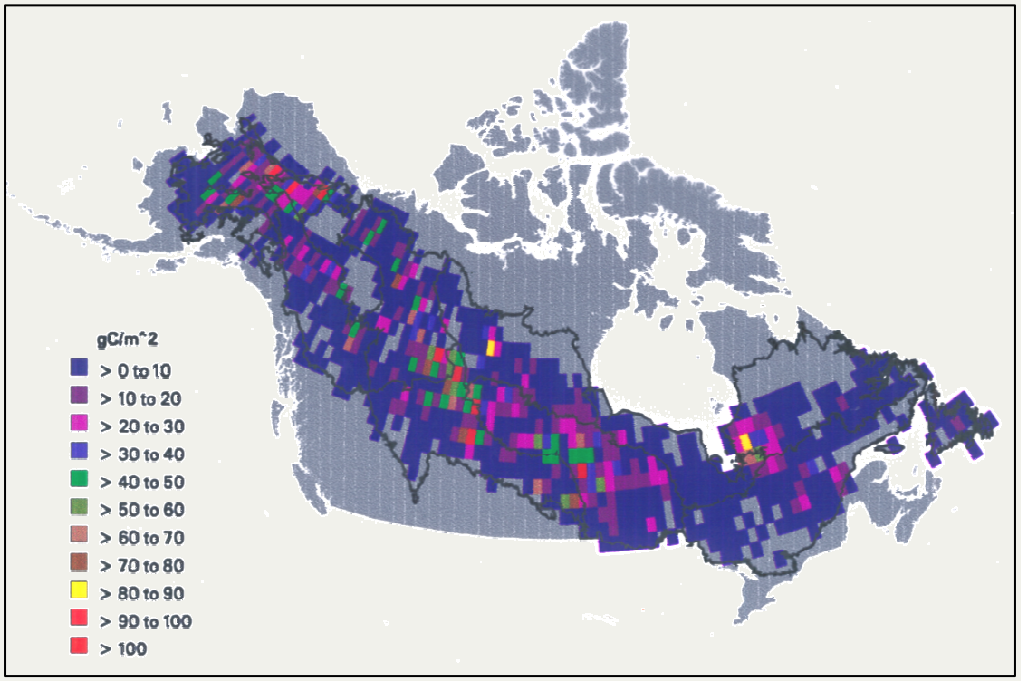
- Geospatial approach assumed single value by ecoregion
  - Biomass (fuel) density (for surface and aboveground)
  - Fuel consumption (combustion completeness)

Average Annual Emissions for Alaska



French NHF, et al. 2002 *J. of Geophy. Res*

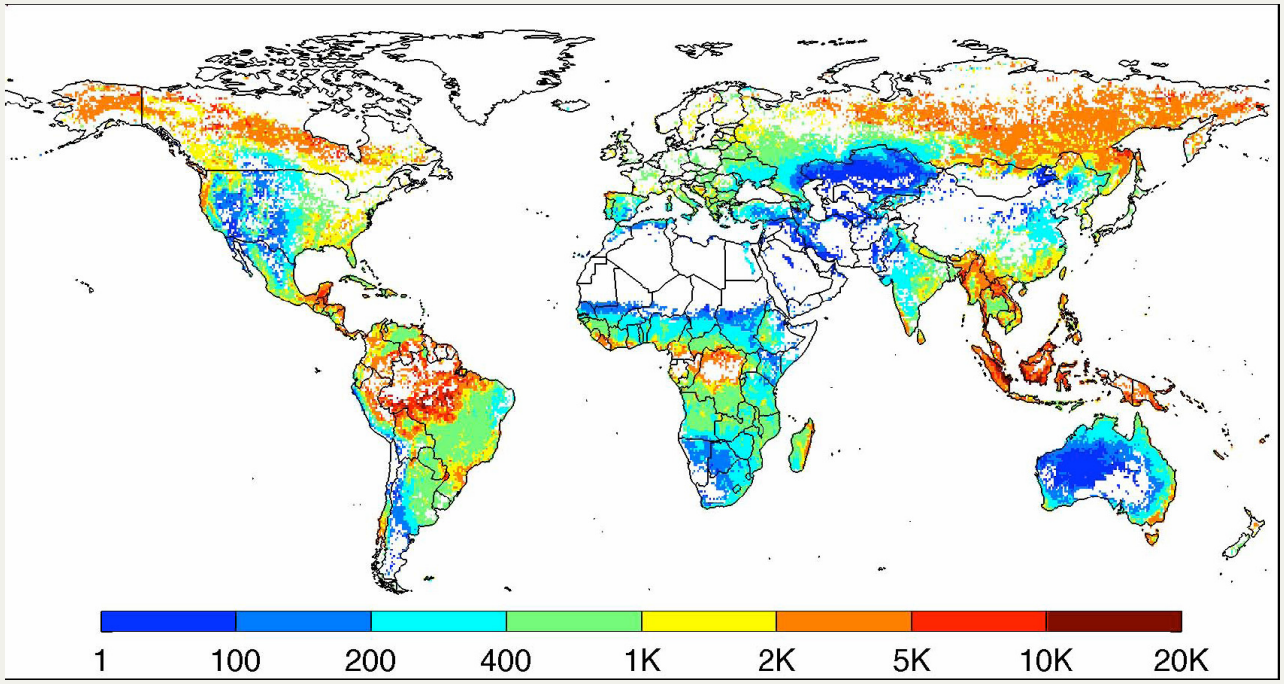
Average Annual Emissions for Boreal North America



French NHF, et al. (2000) In 'Fire, Climate Change, and Carbon Cycling in the Boreal Forest'. Springer-Verlag: New York (Eds Kasischke and Stocks)

Global Fire Emissions Database (GFED)

- MODIS-derived burn area scaled to 0.5º (for 2000 -2009)
- Monthly model-based fuel loadings (CASA)
- Field-informed consumption (combustion completeness) based on vegetation type and moisture



Fuel consumption (gC m^{-2} of area burned), averaged over 1997–2009.

van der Werf et al., *Atmos Chem Phys* Discussion 2010.


The Wildland Fire Emissions Information System (WFEIS)
http://wfeis.mtri.org/
Michigan Tech Research Institute
NASA
FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE
Photo courtesy NFIC

Wildland Fire Emissions Information System (WFEIS)

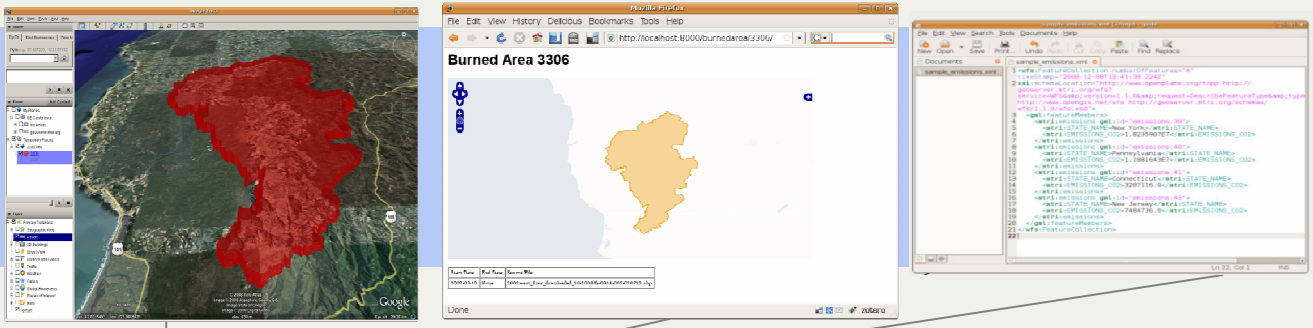
Project Goal: To improve information products for modeling and estimating fire emissions across North America for users who manage carbon, need emissions information, or model the carbon cycle.

WFEIS Purpose:

- Improve access to emissions model inputs and results for targeted users
- Provide best estimates of total carbon emissions and some emission components to user community
  - Geospatially at 1km resolution
  - At daily to annual temporal resolution
  - For recent fire years (1980's to 2009)

WFEIS System Design

Output formats: KML, GeoTIFF, NetCDF, SHP, TXT



Client Interface & Output

Application Servers

WFEIS Web Framework

Emissions Model

Consumption Model

USFS CONSUME

Geospatial Database

Area burned

Fuel loading

Region/time of interest

Data Sources

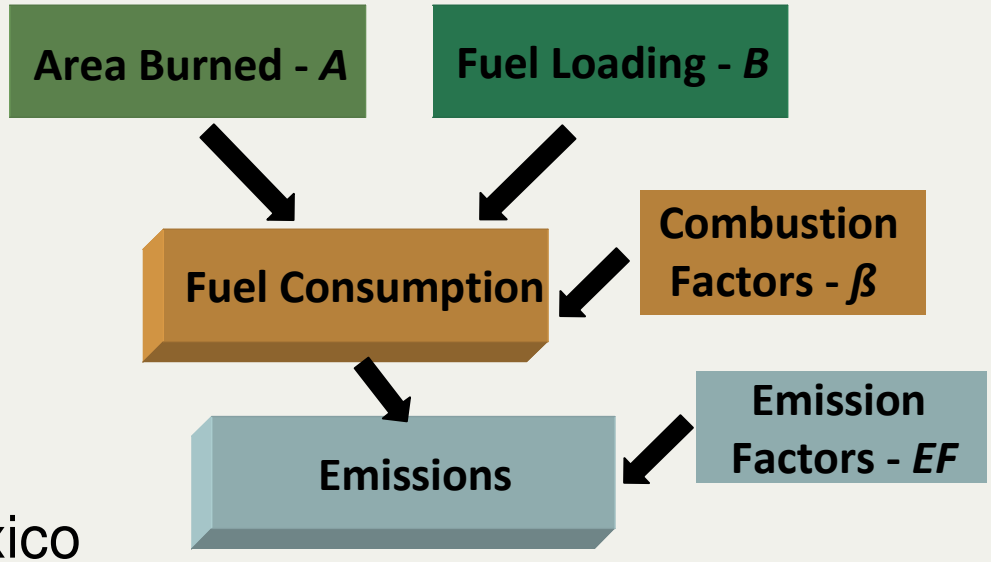
MTBS or MODIS Burned Area

USFS FCCS Fuelbeds

ecoregions, airsheds, park boundaries

WFEIS – Data Inputs

- Burned area - *A*
  - MODIS DBBAP
  - MTBS
- Fuel loads (biomass) - *B*
  - US Forest Service's FCCS* 1-km fuelbeds mapped for US & Mexico



- Fuel consumption (combustion completeness) - β
  - US Forest Service's CONSUME fuel consumption and emissions model
  - Default fuel moisture inputs derived from daily weather data
- Emissions factors - *EF*
  - Included in CONSUME model

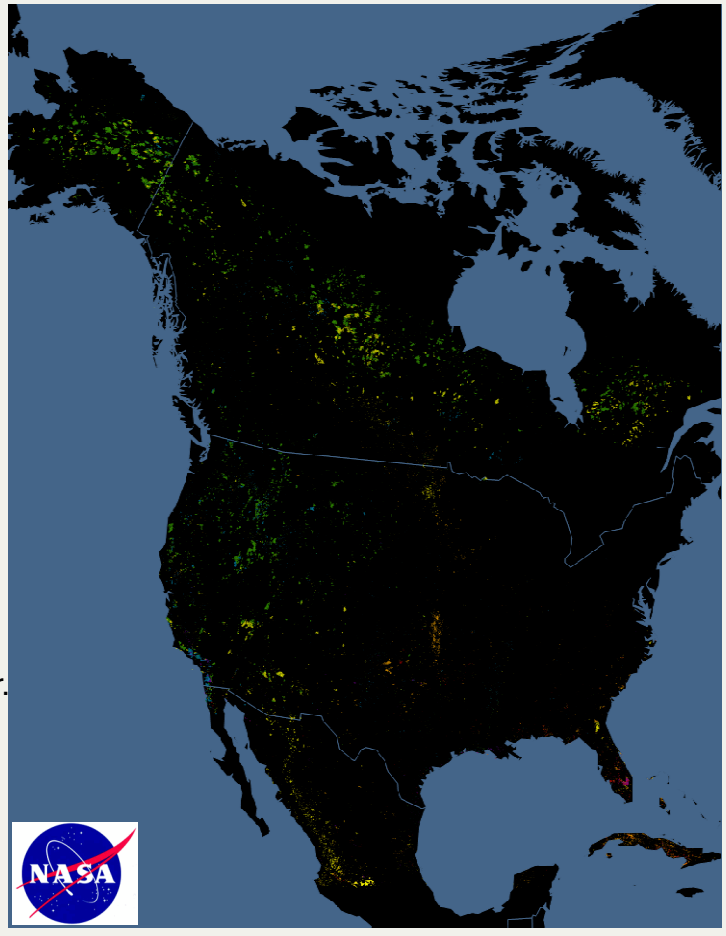
***Fuel Characteristic Classification System** (http://www.fs.fed.us/pnw/fera/fccs/index.shtml)

Burn Area Datasets

- Perimeters from Monitoring Trends in Burn Severity (MTBS) *http://mtbs.gov*
  - US only
  - Landsat-based
    - 30 m resolution
    - Fires with pre and post-fire images mapped from 1982 to 2009
  - Fire start date and peak burn date identified

Burn Area Datasets

- MODIS-derived Direct Broadcast Burn Area Product (DBBAP) – see *Giglio et. al 2009*
  - 500 m spatial resolution
  - Algorithm uses MODIS surface reflectance, daily active fire, and land cover products
  - Burn cells tagged by approximate burn date
  - North America-wide for 2001 to present



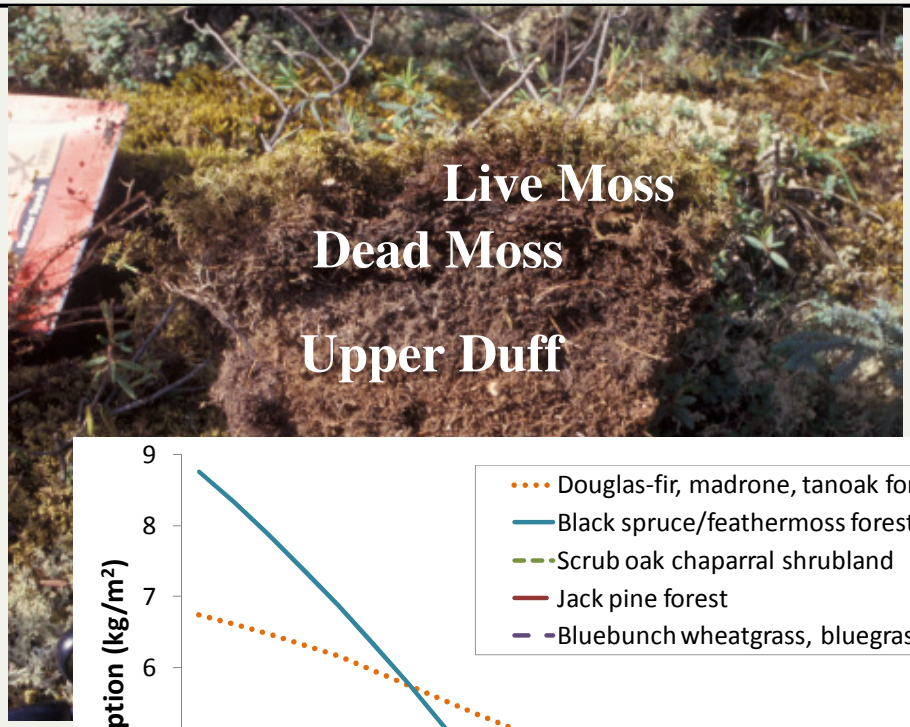
Variability of Fuels & Consumption

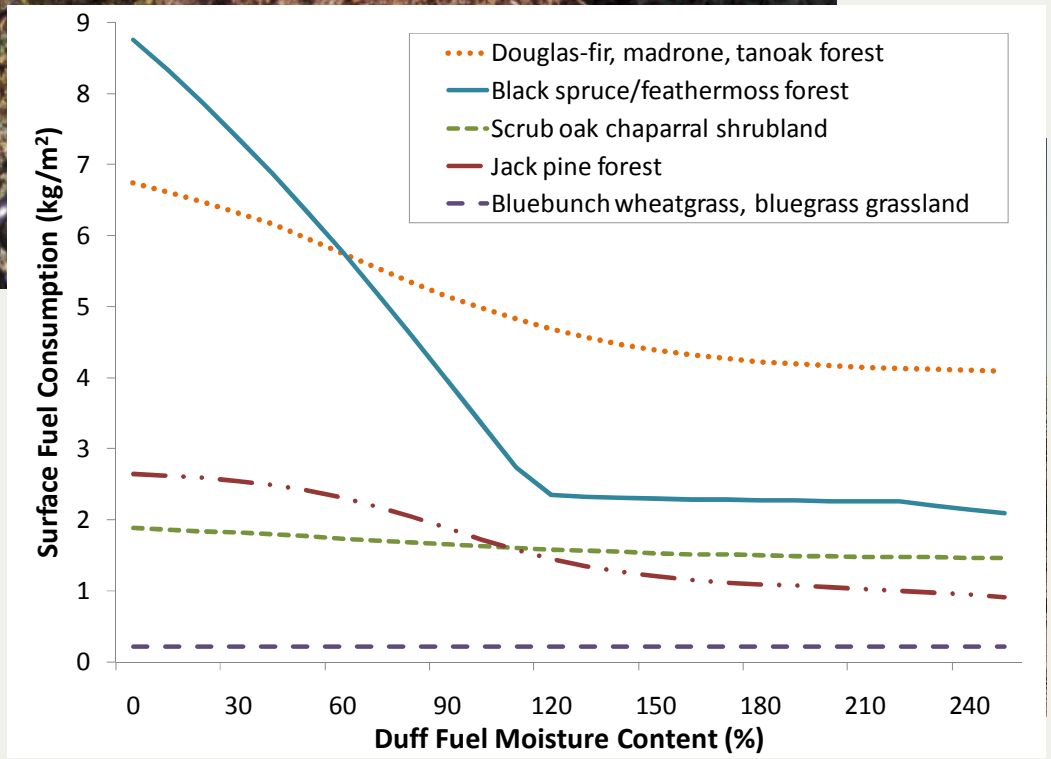
Forest/vegetation type

- Conifer, deciduous, shrub, herbaceous
- Forest/vegetation structure & density
- Duff depth

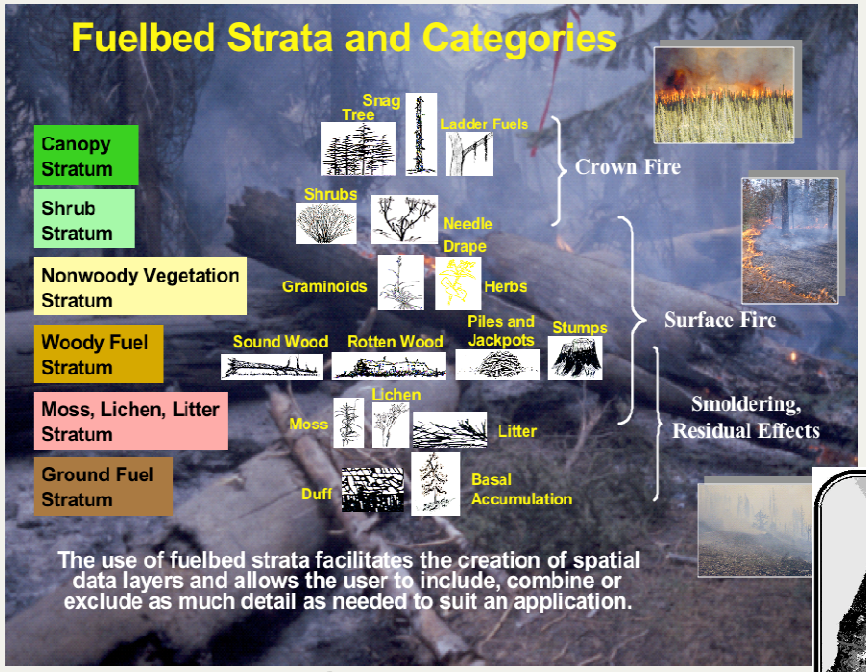
Fuel moisture conditions

- Precip & ET
- Seasonal climatic patterns
- permafrost melting



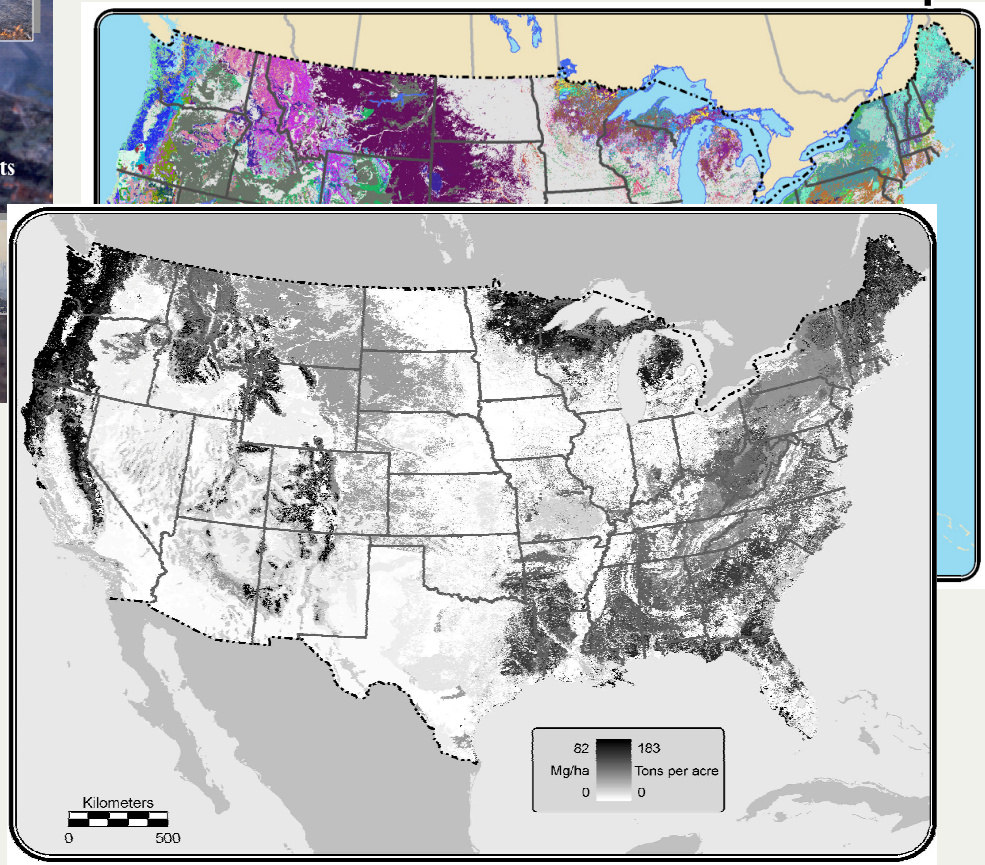


Fuel Characteristics Classification System (FCCS)



Fuelbed Components

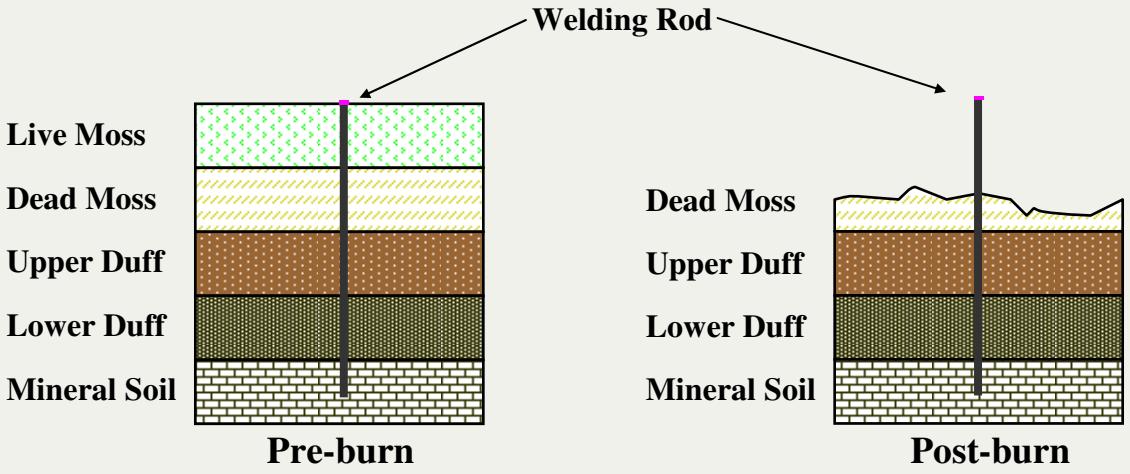
Fuelbed Map



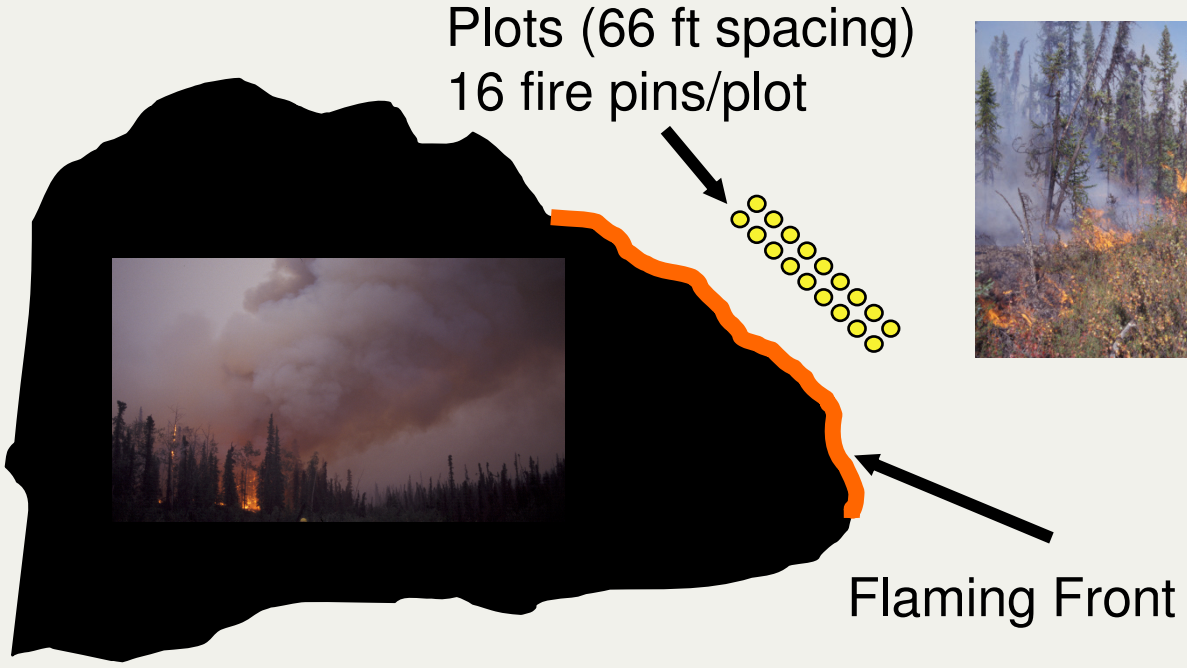
includes fuel loadings by type

http://www.fs.fed.us/pnw/fera/fccs/index.shtml

Fuel Consumption and Emissions: CONSUME



CONSUME uses information collected on fuel consumption and emissions through field collections



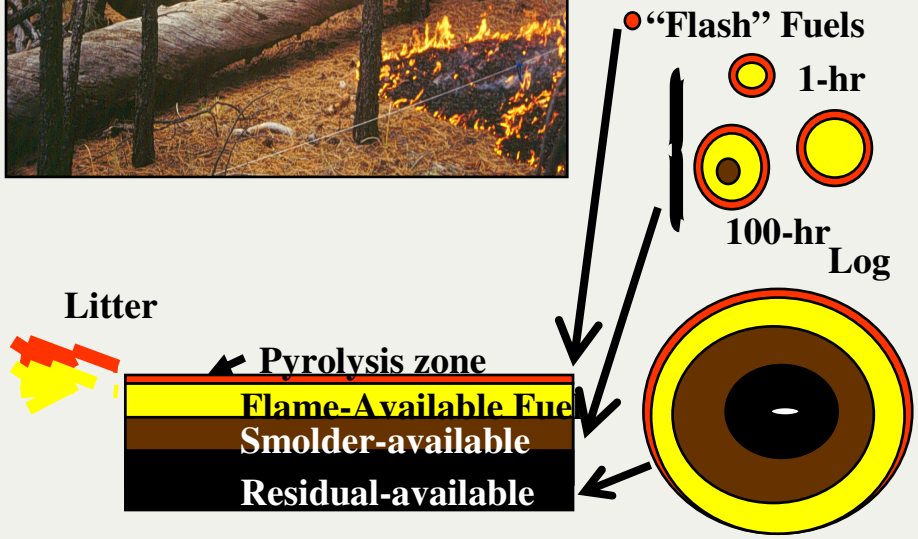
Pre-fire

Post-fire

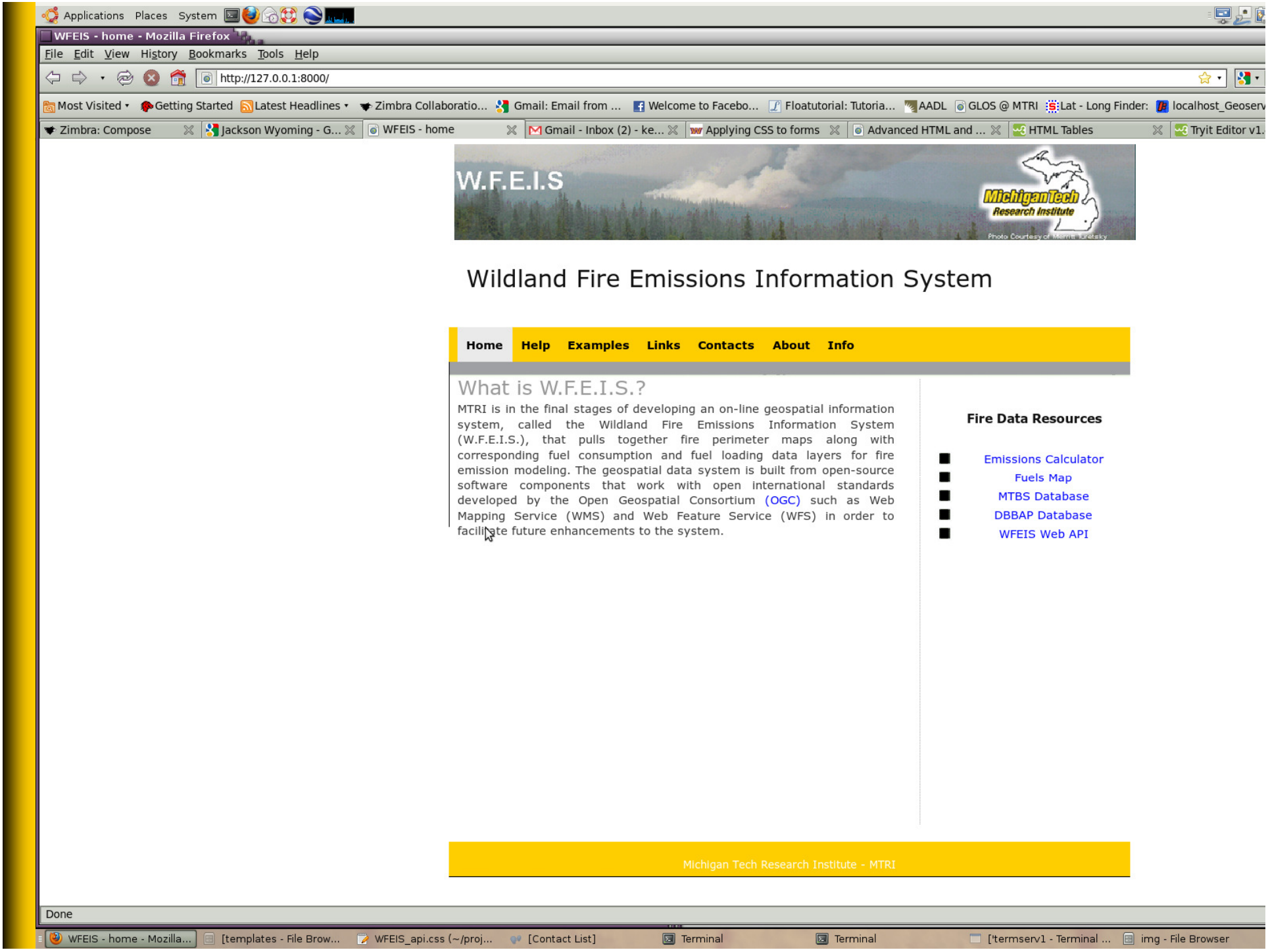
Fuel Consumption and Emissions: CONSUME

CONSUME estimates fuel consumption and emissions for prescribed and wildland fire. It imports fuelbed data directly from the FCCS, and can be used for all forest, shrub, and grassland types in North America.

- Low-intensity prescribed fire and high-intensity crown fire consume different proportions of each stratum in each combustion phase.
  - Estimates combustible biomass of woody fuels in each of the three stages of combustion.
  - Predicts fuel consumption, pollutant emissions, and heat release based on:
    - fuel loadings
    - fuel moisture
    - and other environmental factors



http://www.fs.fed.us/pnw/fera/research/smoke/consume/


Applications Places System
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Zimbra: Compose Jackson Wyoming - G... WFEIS - home Gmail - Inbox (2) - ke... Applying CSS to forms Advanced HTML and ... HTML Tables Tryit Editor v1.
W.F.E.I.S
MichiganTech
Research Institute
Photo Courtesy of Merritt Kretsky
Wildland Fire Emissions Information System
Home Help Examples Links Contacts About Info
What is W.F.E.I.S.?
MTRI is in the final stages of developing an on-line geospatial information system, called the Wildland Fire Emissions Information System (W.F.E.I.S.), that pulls together fire perimeter maps along with corresponding fuel consumption and fuel loading data layers for fire emission modeling. The geospatial data system is built from open-source software components that work with open international standards developed by the Open Geospatial Consortium (OGC) such as Web Mapping Service (WMS) and Web Feature Service (WFS) in order to facilitate future enhancements to the system.
Fire Data Resources
Emissions Calculator
Fuels Map
MTBS Database
DBBAP Database
WFEIS Web API
Michigan Tech Research Institute - MTRI
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WFEIS: Open Source Technology

- Benefits
  - Code is highly customizable (great for research)
  - Multiple servers can be setup with no licensing cost

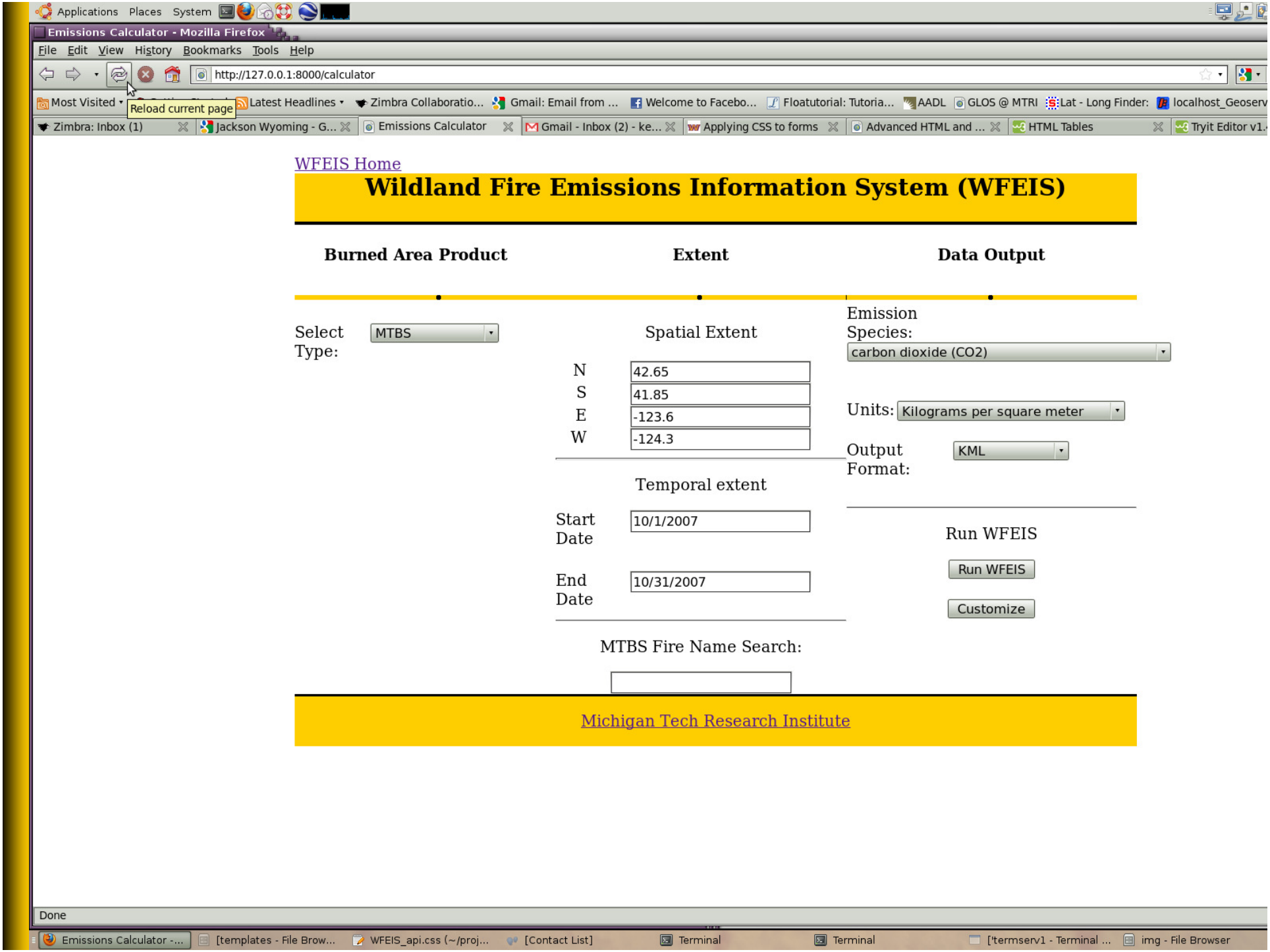
There are <u>many</u> benefits to <u>giving away</u> your data, source code, and model output!

- Specific Open Source Technologies
  - GeoDjango - web framework
  - GDAL / OGR - raster / vector manipulation libraries
  - Proj4 - projection library
  - PostGIS - geospatial relational client-server database
  - Python - scripting language for integrating components
  - Ubuntu - Linux operating system distribution

WFEIS: Open Source Technology

- Developed a Python version of CONSUME that allows flexible use of the software with many systems
  - Full implementation of CONSUME equations in Python completed soon
  - Useful for applications beyond WFEIS
  - http://code.google.com/p/python-consume/
- Coded the Canadian Fire Weather Index (FWI) components into Python script for WFEIS
  - All FWI codes are calculated
  - Includes equations for computing % moisture content from the Duff Moisture Code (DMC) and a batch csv calculator
  - http://code.google.com/p/pyfwi/

BOTH TOOLS ARE PUBLICALLY AVAILABLE


Applications Places System
Emissions Calculator - Mozilla Firefox
File Edit View History Bookmarks Tools Help
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Reload current page
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Gmail: Email from ...
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WFEIS Home
Wildland Fire Emissions Information System (WFEIS)
Burned Area Product
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End Date
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MTBS Fire Name Search:
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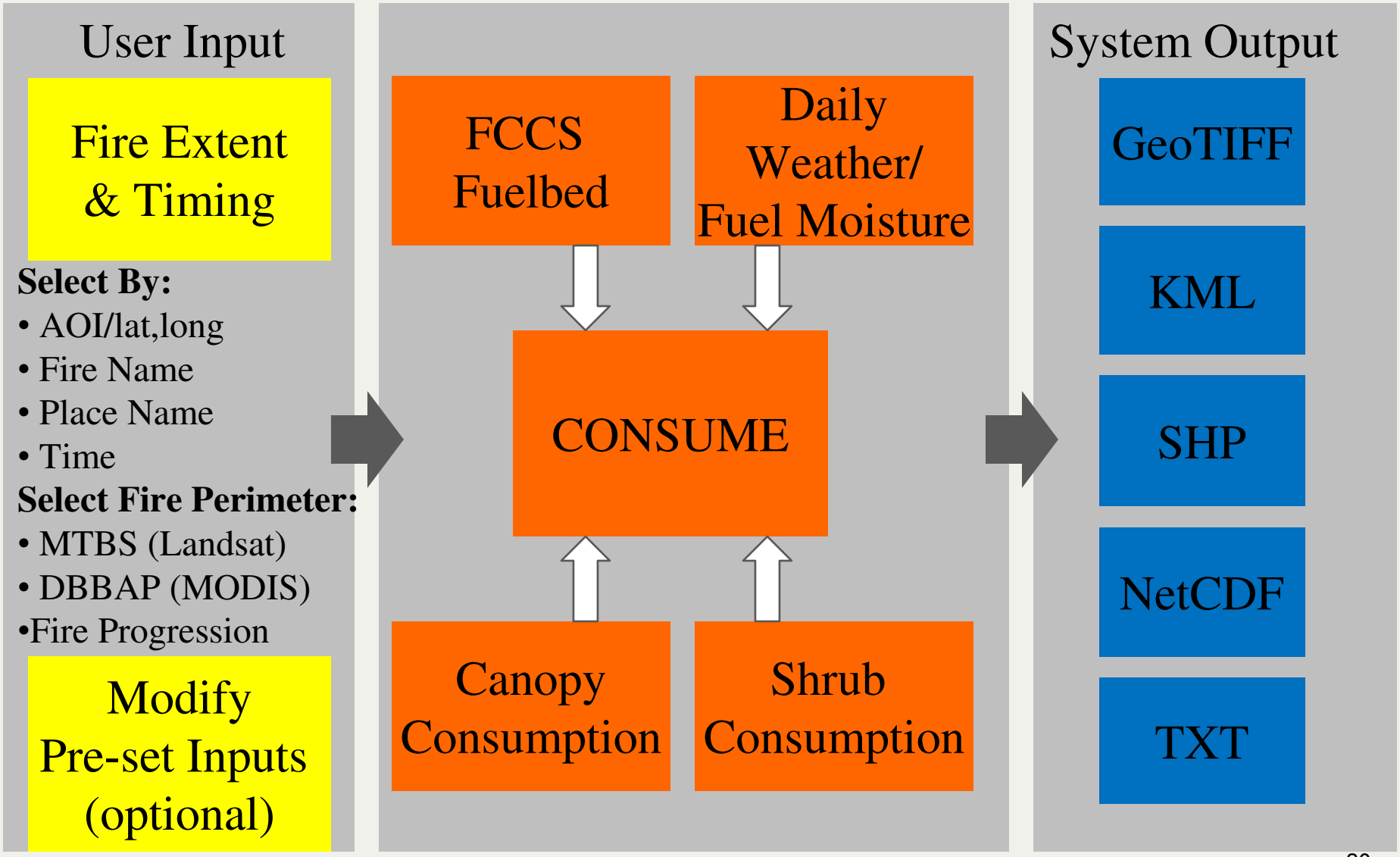
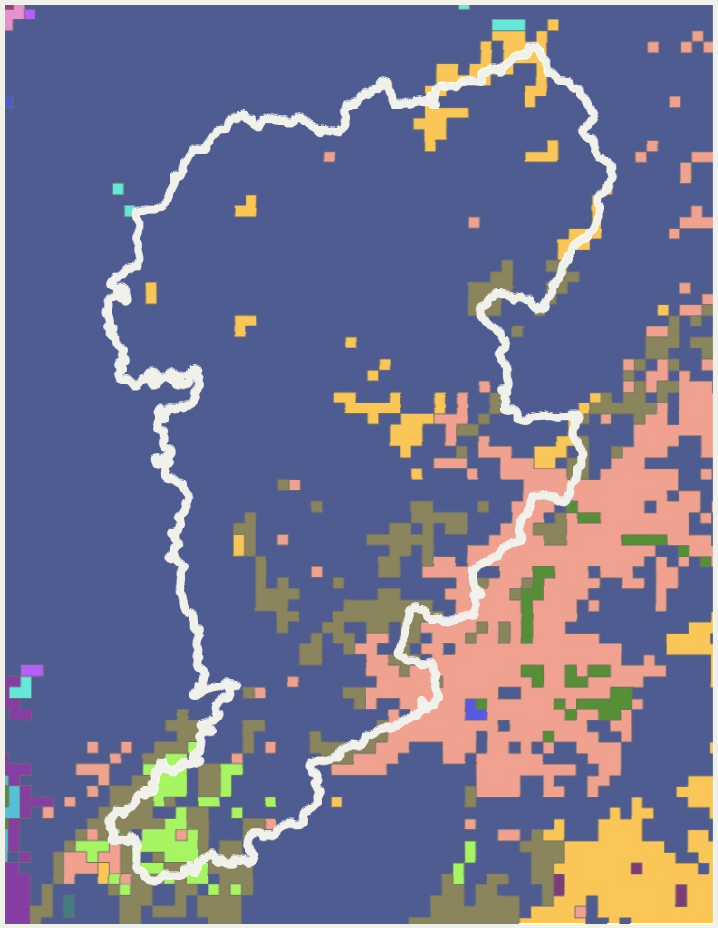
WFEIS Components



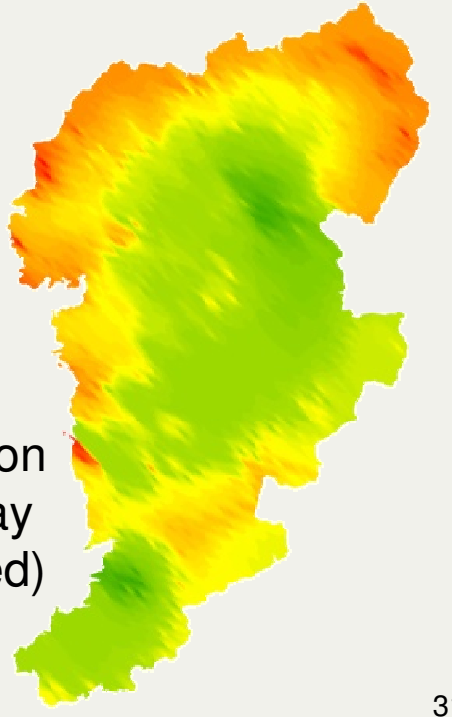
WFEIS Example: Biscuit Fire



FCCS

- 7 Douglas-fir, sugar pine, tanoak forest
- 16 Jeffrey pine, ponderosa pine, Douglas-fir, California black oak forest
- 24 Pacific ponderosa pine–Douglas-fir forest
- 38 Douglas-fir, madrone–tanoak forest
- 44 Scrub oak chaparral shrubland

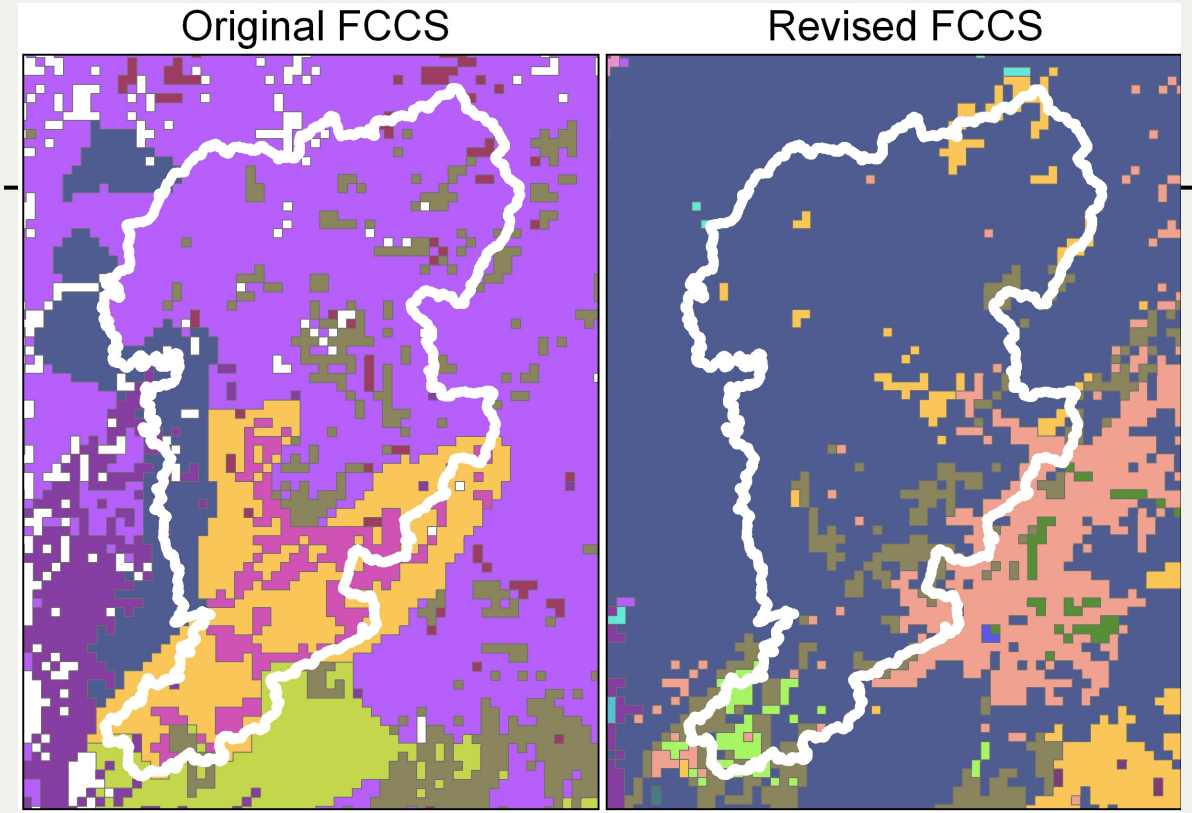
- The Biscuit Fire burned in 2002 approximately 200,000 ha of conifer forestland in southeastern Oregon (US Pacific Northwest)
- Site is dominated by Douglas-fir forest communities with a ponderosa pine component



Fire Progression
Julian Day
195 (green) – 244 (red)

Biscuit Fire FCCS Maps

- Original fuels mapped as 50% Western Hemlock (purple) with Doug-fir and Ponderosa Pine
- New FCCS map agrees more with inventory data with 85% Doug-fir (blue) with Ponderosa pine
- Western Hemlock holds nearly 2X fuel as Douglas-fir (mainly in the ground-layer)



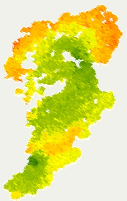
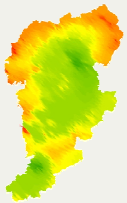
FCCS (Original)

- 2 Western hemlock, western redcedar, Douglas-fir forest (50%)
- 7 Douglas-fir, sugar pine, tanoak forest (19%)
- 24 Pacific ponderosa pine–Douglas-fir forest (8%)
- 28 Ponderosa pine savanna (9%)
- 38 Douglas-fir, madrone–tanoak forest (8%)
- 47 Redwood, tanoak forest (1%)
- 52 Douglas-fir, Pacific ponderosa pine/oceanspray forest (1%)
- 59 Subalpine fir, Engelmann spruce, Douglas-fir, lodgepole pine forest (2%)

FCCS (Revised)

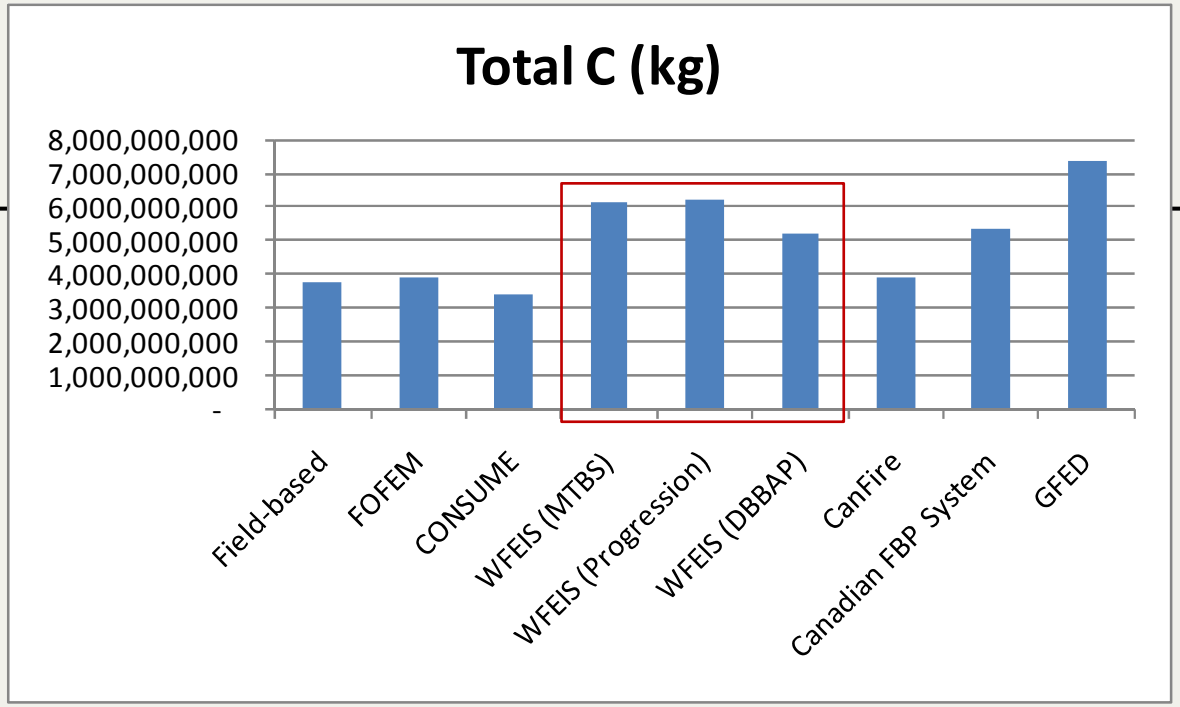
- 7 Douglas-fir, sugar pine, tanoak forest (4%)
- 16 Jeffrey pine, ponderosa pine, Douglas-fir, California black oak forest (5%)
- 24 Pacific ponderosa pine–Douglas-fir forest (8%)
- 38 Douglas-fir, madrone–tanoak forest (82%)
- 44 Scrub oak chaparral shrubland (2%)

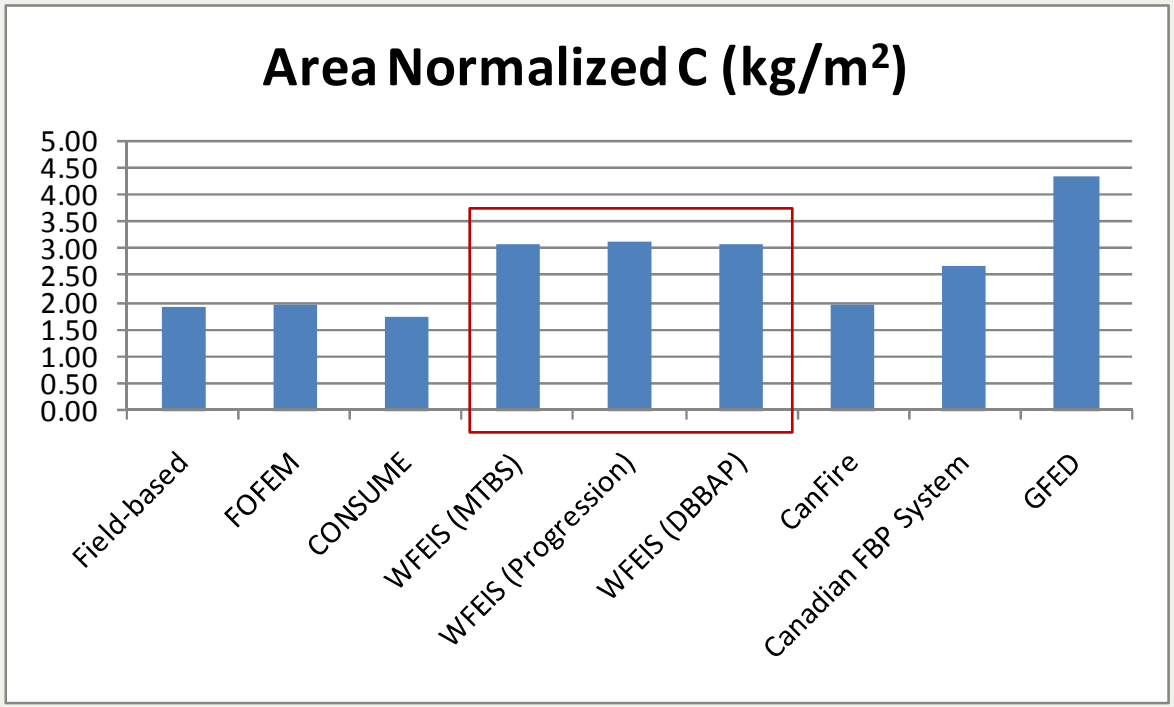
WFEIS Example: Biscuit Fire

Fire Extent Type	Weather Type (determined by fire extent type)	Fuelbed Type	Burned Area, Total Carbon, Area Normalized Carbon
 Landsat MTBS	Ignition Date Weather	Original FCCS	2,001 km^2 13,616,021,811 kg 6.80 kg/m^2
	Ignition Date Weather	Revised FCCS	2,001 km^2 6,173,613,898 kg 3.08 kg/m^2
 MODIS DBBAP	Daily Weather	Revised FCCS	1,696 km^2 5,209,859,642 kg 3.07 kg/m^2
 Fire Progression	Daily Weather	Revised FCCS	1,998 km^2 6,201,327,760 kg 3.10 kg/m^2

WFEIS Results: Biscuit Fire

(preliminary) Comparison to other emissions methods





WFEIS is consistent with other model results for this and five additional cases analyzed

French, de Groot, et al. in preparation *for Journal of Geophysical Research special issue on disturbance and carbon*

Summary

- WFEIS provides a method to quantify emissions for regional-scale applications that is easy to use.
- Provides information at moderate spatial scales and for multiple timeframes for landscape to regional applications
- Flexible, open source web-based system
- Includes a choice of fire perimeter inputs
- Useful for scientists and land managers
- Initial tests have shown reasonable results
- Now in final stages of development and testing – full functionality by the end of 2010
- Is currently being used in three projects at MTRI

http://wfeis.mtri.org/

Effects of Wildfire Emissions on Respiratory Health in San Diego County, California

A woman suffers from an asthma attack after breathing wildfire smoke (Photo courtesy of CBS.com, 9/2/2009)

October 2003 Cedar Fire surrounding San Diego

Impacts and Implications of Increased Fire in Tundra Regions of North America

Anaktuvuk River tundra fire, North Slope, Alaska (Photo courtesy of the U.S. Bureau of Land Management)

Cropland Fire Emissions

Linking NASA Satellite Data and Science to Enhance Fire Emissions within the EPA's National Emissions Inventory

Principal Investigator: Amber J. Soja,
National Institute of Aerospace (NIA)

- Use satellite-based fire data to enhance fire emissions within the NEI, with a particular focus on poorly represented agricultural and rangeland fires.;
- Synthesize agricultural and rangeland fire research into a format usable by the Wildland Fire Emissions Information System, an existing NASA Carbon Cycle

Sugar Cane fire, Photo courtesy of Wbshots.com

Co-Investigators

- *Tyler Erickson*

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- *Roger D. Ottmar*
- *Ernesto Alvarado*

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  Great Lakes Forestry Centre, Canadian Forest Service

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Thank-You