Satellite Based Wildland Fire Emission Inventories

Urbanski, S., **Nordgren, B**., Hao, W. M.

US Forest Service, RMRS

Fire Sciences Laboratory, Missoula, MT

Introduction

- Firelab Mandate

- Why MODIS Direct Broadcast Burned Area?

- What is MODIS Direct Broadcast Burned Area?

- Validation work.

Firelab Mandate

- National charter to conduct fundamental and applied research relating to wildland fire processes, terrestrial and atmospheric effects of fire, and ecological adaptations to fire

MODIS Direct Broadcast (DB) fire detection

Why use MODIS-DB for fire detection and burned area measurement?

• Timely, spatially resolved measurements of burned areas to provide emission estimates for air quality forecasting and management activities

• Temporal resolution for emissions inventories (Daily resolution is needed for emission inventories)

• Consistent methodology across regions

MODIS-DB Burned Area

The Fire Sciences Laboratory has developed a MODIS-DB burned area algorithm to:

- Develop wildland fire emission inventories for the western US

- Provide 'rapid response' wildland fire emissions for air quality forecasting/management activities

- Demonstrate a prototype smoke dispersion – air quality forecasting system (assimilation of MODIS derived emissions for predicting fire impacts on regional air quality)

MODIS-DB BAA

- Missoula-centric
- Near real time
- Two satellites, one antenna

August 16, 2004
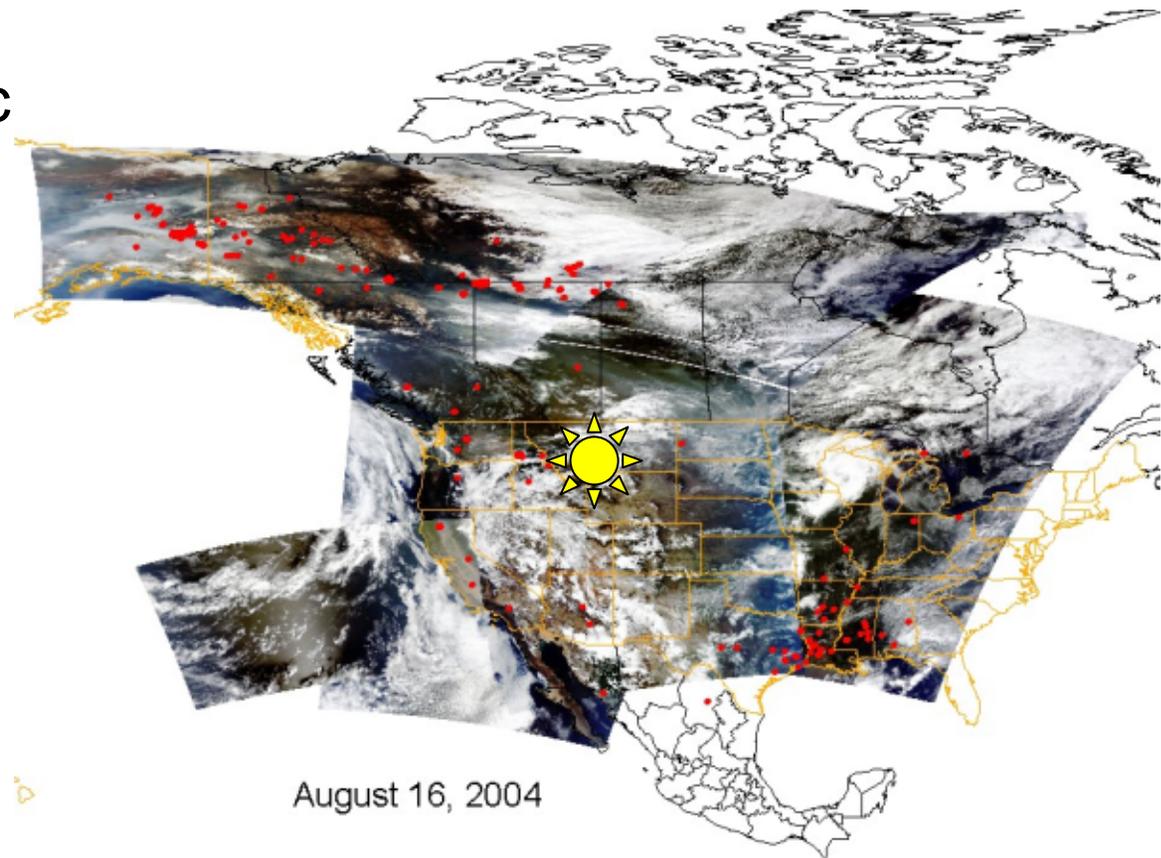
Raw MODIS to burned area

Active fire detection

- Thermal anomalies 4 µm, 10 µm band difference
- 1-km resolution, day and night

Burn scar detection

- Surface reflectance (1.24, 2.13 µm bands)
- 7 tests on 0.86, 1.24, 1.64, 2.13 µm bands to filter false alarms (sun glint, clouds, etc.)
- 500-m resolution, day only

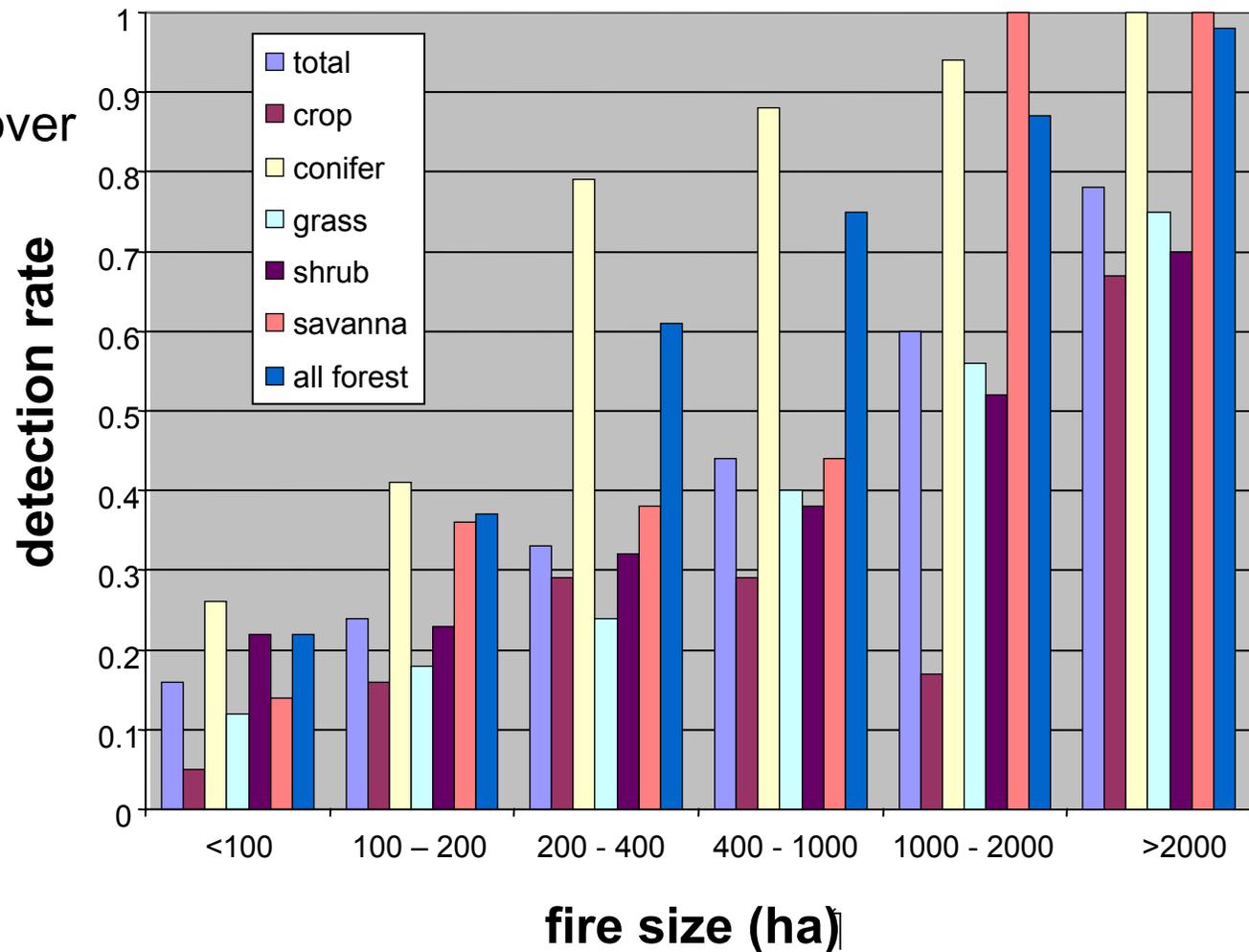$$\frac{1.24_m - 0.05}{2.14_m} \quad [0.8, 1.0]$$

Burn area product

- Fire perimeters created from active fire and burn scar detection products
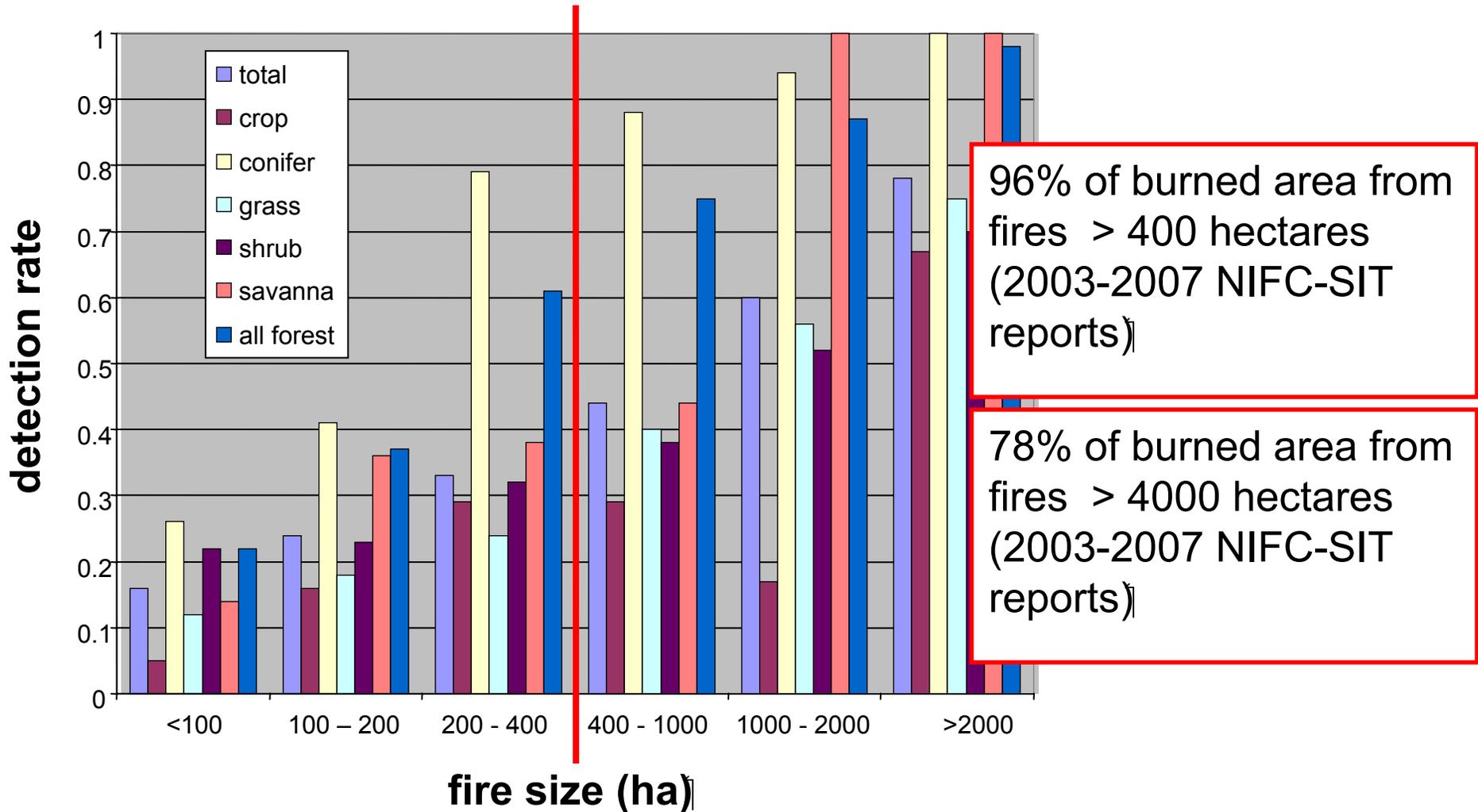- ~1-km resolution, up to 4 times daily per location

Detection Rate

MODIS fire detection
2006 SIT Reports (22 western states)
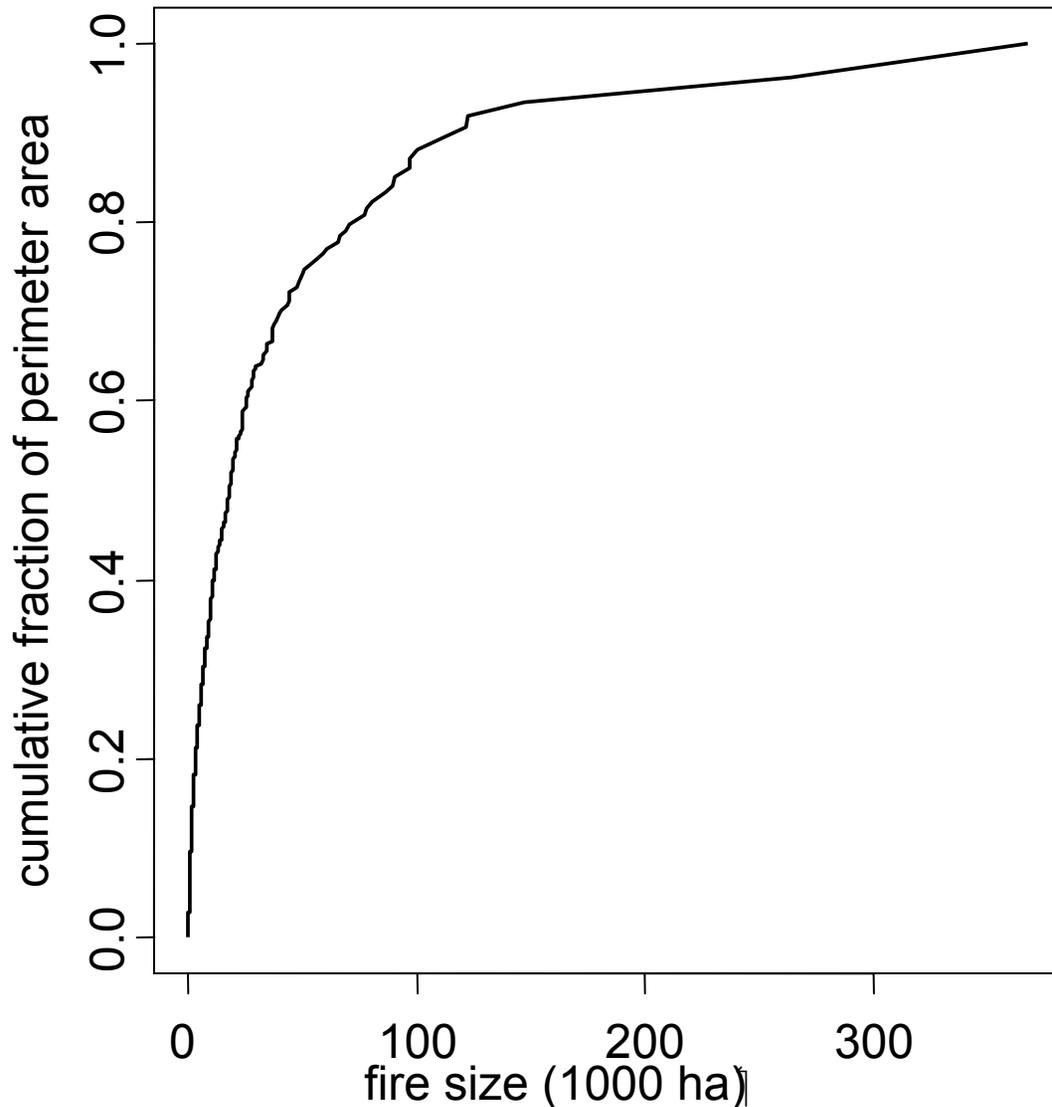
• n=1873
• MOD12 Land Cover

Detection Rate

MODIS fire detection
2006 SIT Reports (western states)

96% of burned area from fires > 400 hectares (2003-2007 NIFC-SIT reports)

78% of burned area from fires > 4000 hectares (2003-2007 NIFC-SIT reports)

Western 17 States Fire Occurrence in 2003-2007
NIFC-SIT data

2003 – 2007 NIFC–SIT Reports
western 17 states
- 5043 wildfire events, 9.59 million ha (23.70 million acres)
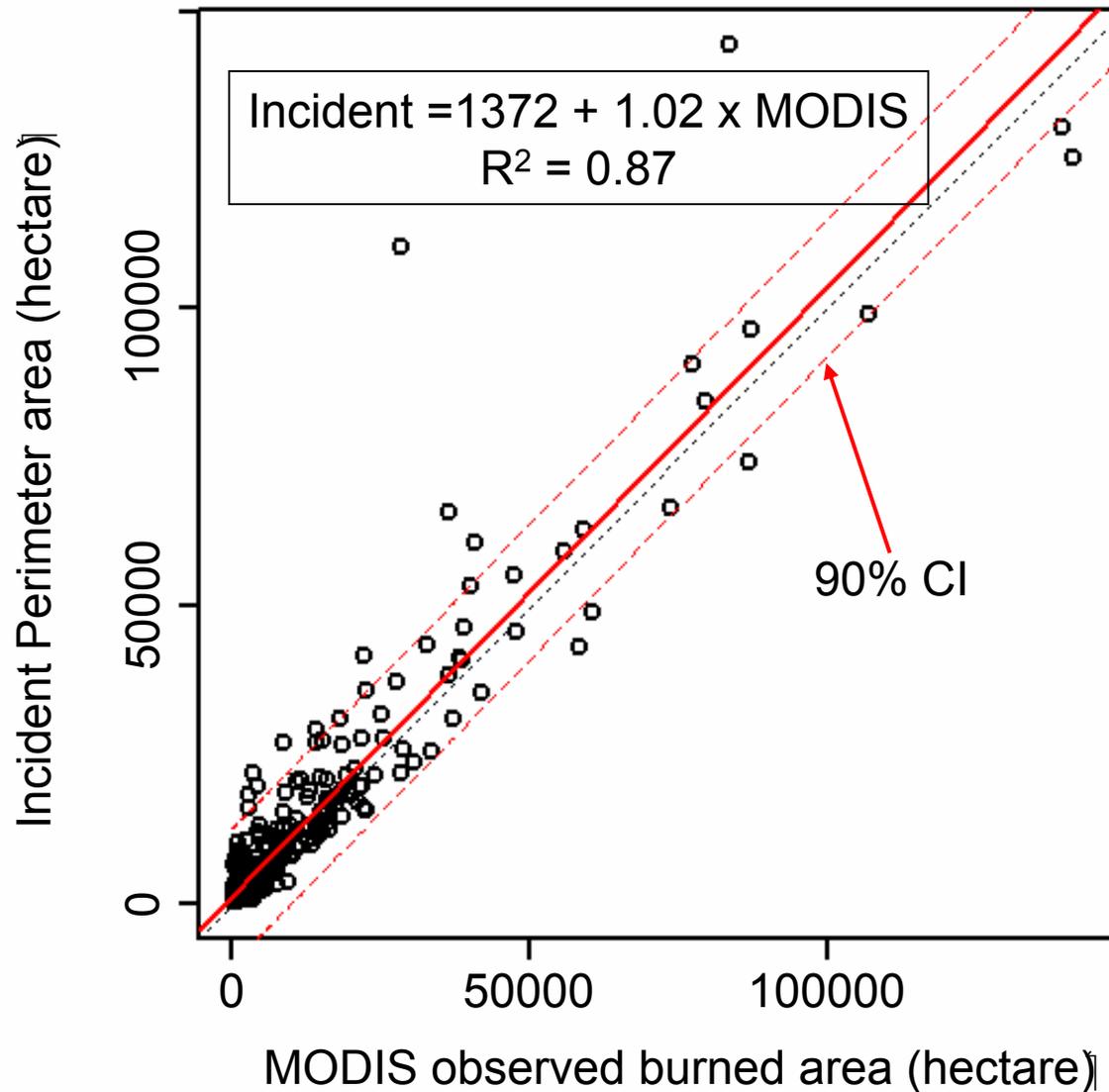- 45% of fires < 200 hectare (~500 acres)
- 58% of fires < 400 hectare (~1000 acres)
- fires > 400 ha (~1000 acre) account for 96% of burned area
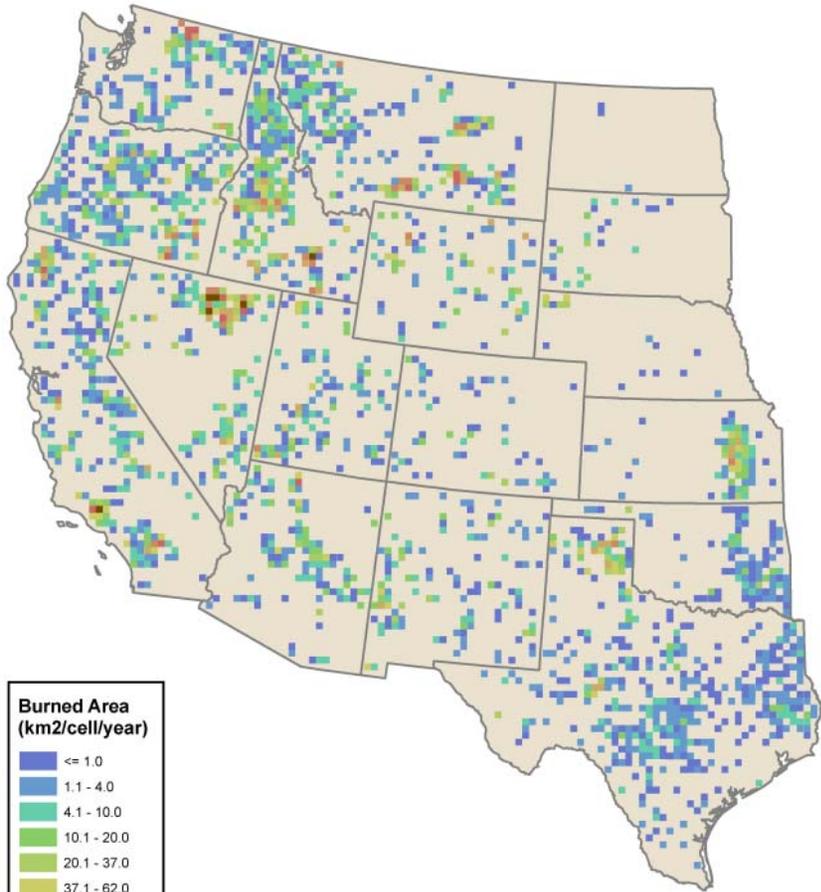- fires > 4000 ha (~10k acre) account for 78% of burned area

Validation of MODIS-DB Burned Area
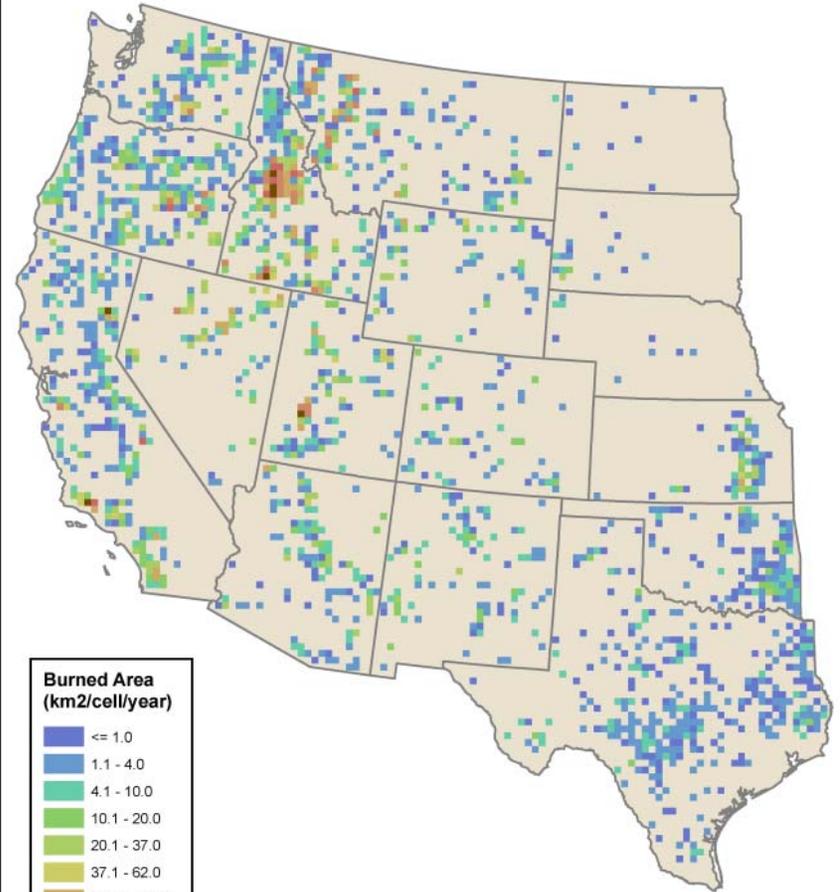
2006 -2007 Large Fires (> 400 hectare)

Annual MODIS Observed Burned Area

Fire Emissions for Air Quality Modeling

Fire Information

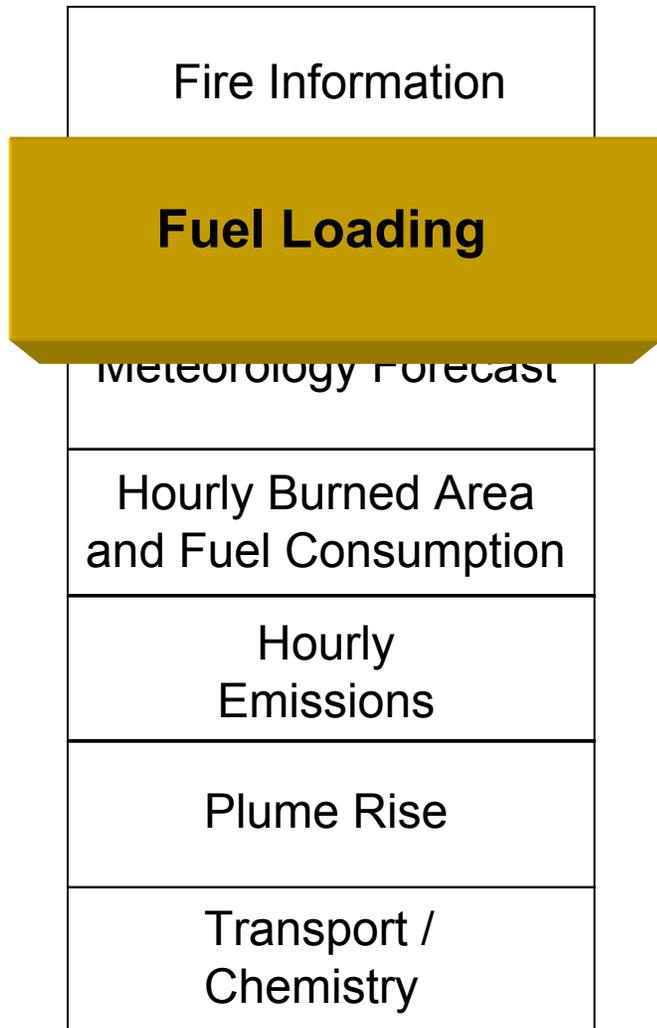| |
|---|
| Fuel Loading |
| Meteorology Forecast |
| Hourly Burned Area and Fuel Consumption |
| Hourly Emissions |
| Plume Rise |
| Transport / Chemistry |

MODIS - MODerate resolution Imaging Spectroradiometer

- Deployed on polar orbiting Terra and Aqua satellites
- 4 daily observations per location (a day & night pass for each satellite)
- Terra (Aqua) active since 2000 (2002)
- Fire Lab – DB receives up to 12 passes /day

Daily Fire Occurrence and Burned Area Growth with 1-km^2 resolution

Fire Emissions for Air Quality Modeling

At each 1-km^2 that burns

Fire Information

Fuel Loading

Meteorology Forecast

Hourly Burned Area and Fuel Consumption

Hourly Emissions

Plume Rise

Transport / Chemistry

Land Cover Map
Fuel Characteristic Classification System (FCCS)

Fuel Loading

FCCS

Or

FOFEM reference database

Fire Emissions for Air Quality Modeling

At each 1-km² that burns

Fire Information
Fuel Loading
Meteorology Forecast
Hourly Burned Area and Fuel Consumption
Hourly Emissions
Plume Rise
Transport / Chemistry

**NFDRS Equations**
fuel moisture

BEHAVE model (fireLib)
fire rate of spread, intensity

First Order Fire Effects Model (FOFEM)
fuel consumption and heat release by fire phase

Estimated hourly fire rate of spread provides weighting to derive hourly fire growth profile from satellite observed *daily* burned area
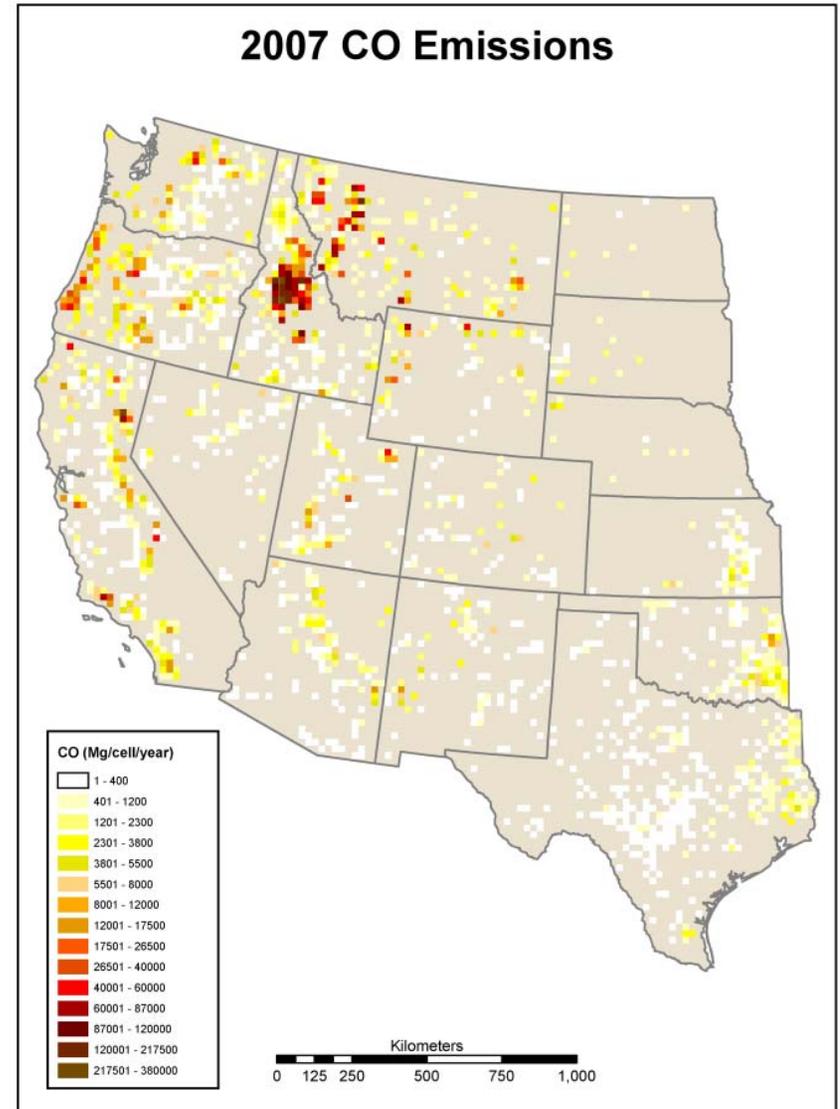
Fire Emissions for Air Quality Modeling

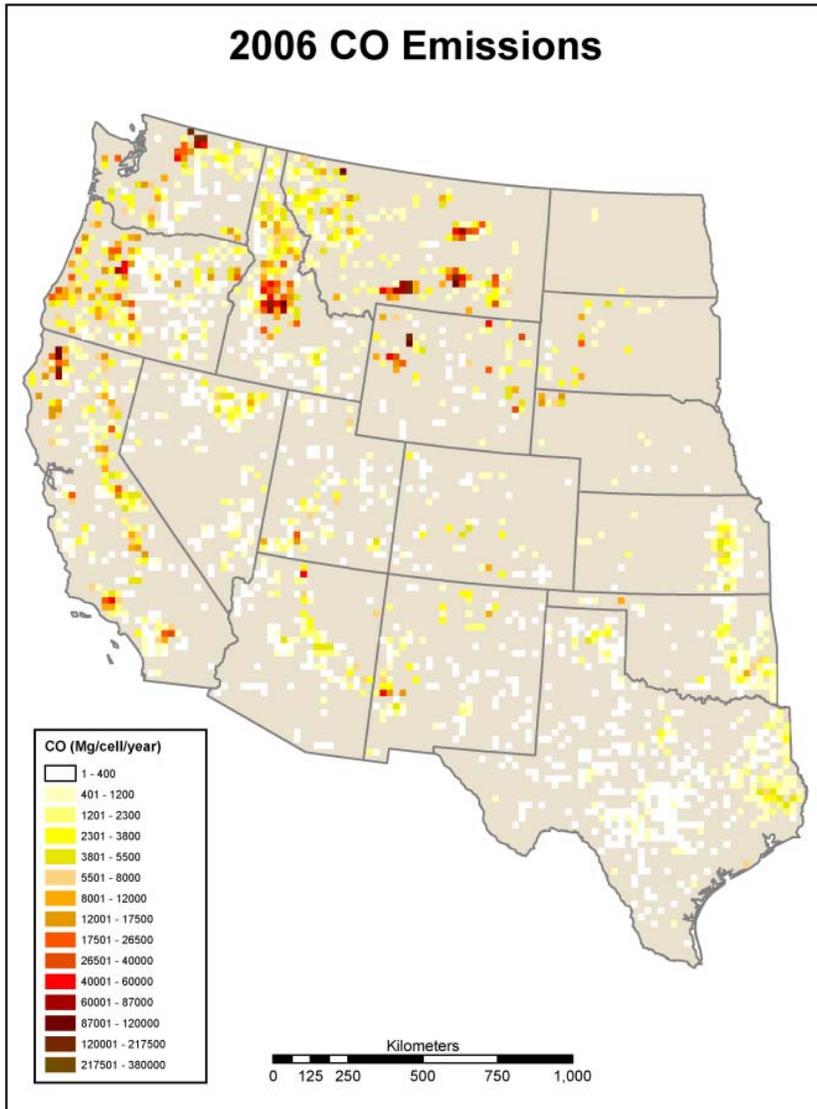| |
|---|
| Fire Information |
| Fuel Loading |
| Meteorology Forecast |
| Hourly Burned Area and Fuel Consumption |
| **Hourly Emissions** |
| Plume Rise |
| Transport / Chemistry |
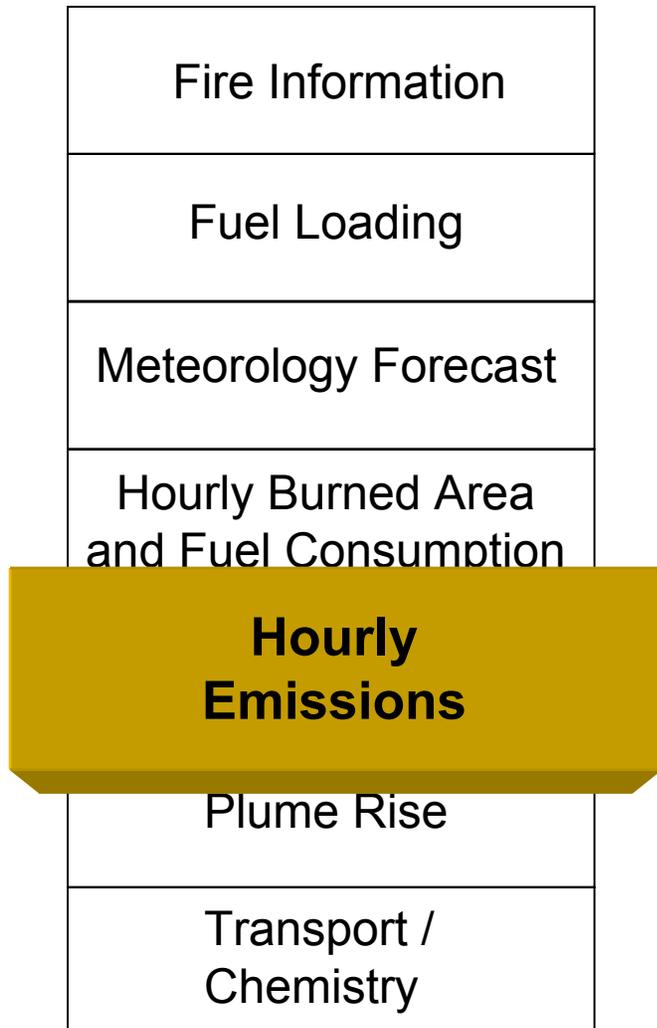
Hourly Emissions
Emission Factor Database

~ 65 gas-phase species and
organic, elemental-C, and total $PM_{2.5}$ & PM_{10}

Estimated Annual CO Emissions from Western Wildland Fires
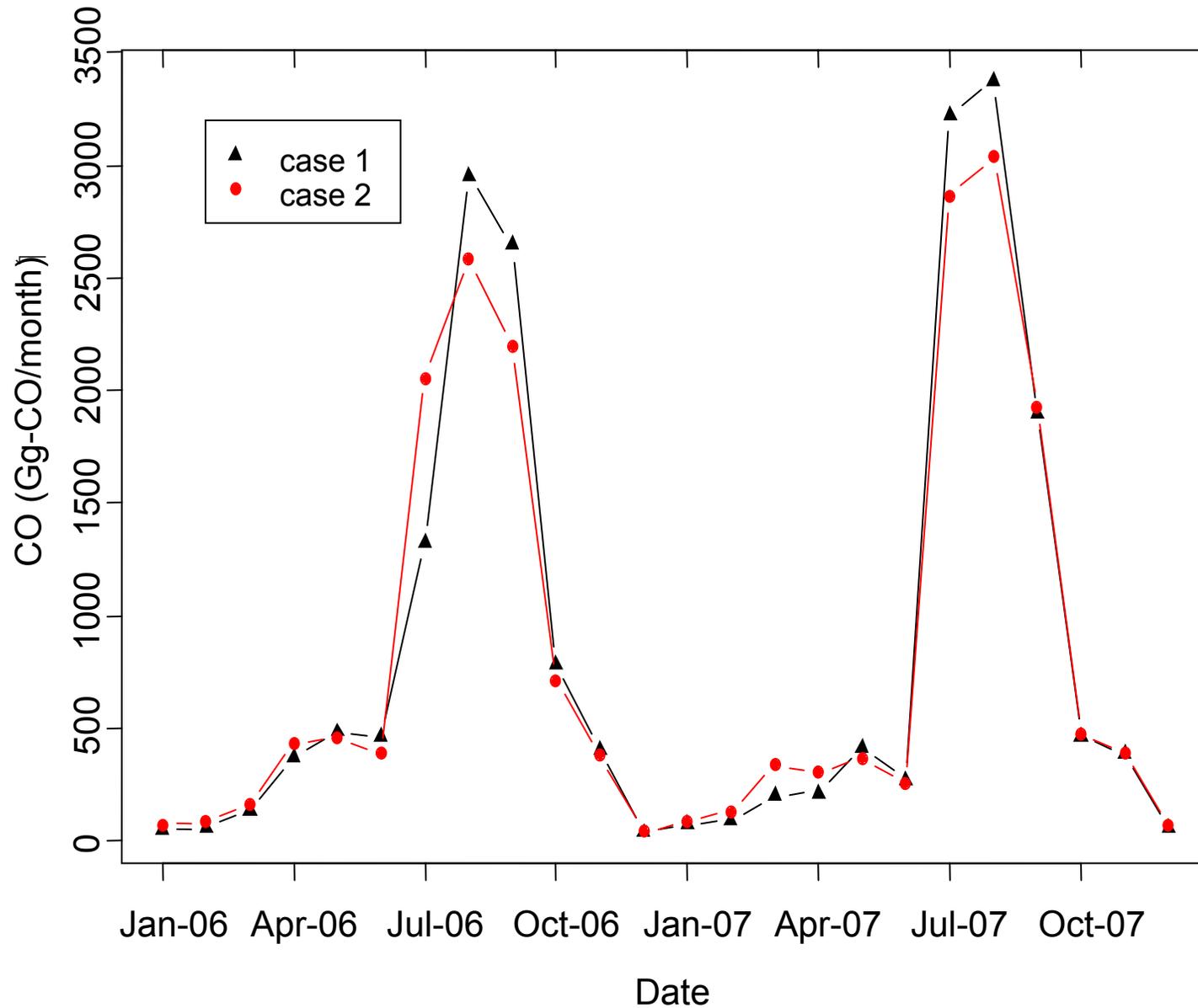
Sensitivity Analysis
Impact of Fuel Loading Model of Emissions
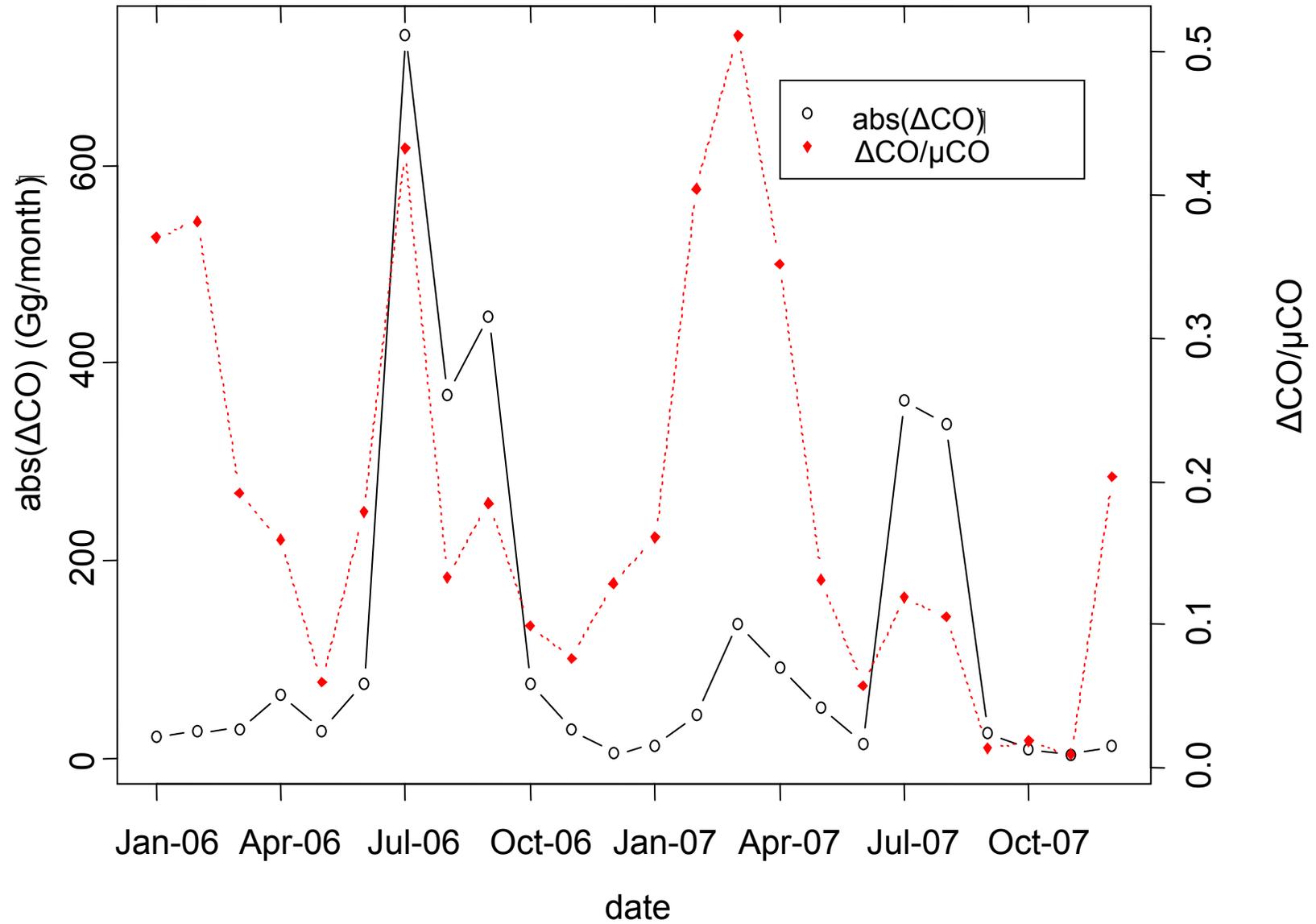
FCCS vs. FOFEM reference database

With the exception of the fuel loading model, the two emission scenarios were identical.

- MODIS-DB derived burned areas
- FCCS fuel map
- NFDRS based fuel moisture
- FOFEM for calculating fuel consumption
- Updated emission factor database

Sensitivity of Emissions to Fuel Loading

Fire, Fuel, and Smoke Science Program
5775 W US HIGHWAY 10 MISSOULA MT 59808-9361

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This page introduces and briefly explains all map products made available to the public by the Fire, Fuels, and Smoke program. To learn more about, download, or interact with a particular map (capabilities vary by map type), click on the "See more..." link next to the short description.
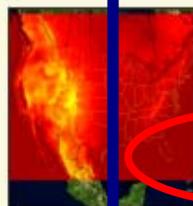
The interactive map generated by the WRF Chem Smoke Dispersion Model allows you to explore current hotspots, fire perimeters, and emissions due to fire activity in the United States. This map is updated in near real time based on data received by our MODIS Direct Broadcast receiving station.

See more...

Last Updated (Friday, 30 May 2008)

1

Go to http://www.firelab.org

2

Click on "Data" or "Maps"

3

Click "See more..." next to WRF Chem Smoke dispersion Model

Conclusions

MODIS-DB burned area algorithm validation

• Detection rate of ~80% of western fires larger than 5000 acres
• Fires >5000 acres comprised 86% of the total area burned in the western US
• Detection rate by land cover type :
    forest > grasslands > shrublands

• MODIS-DB burned area vs. 'ground truth':
High correlation (R^2=0.87) with the best fit linear regression not statistically different from 1:1 line at 90% CI

Emission Estimates

Choice in fuel loading model has a significant impact on emission estimates even with other critical components being identical (e.g. land cover map, fuel consumption model, fuel moisture, emission factors).

Acknowledgments

- Forest Service Research and Development, National Fire Plan

- NASA's North American Carbon Program

- Joint Fire Sciences Program, Project #01-1-5-03

NIFC-SIT data
Western 11 States Fire Occurrence in 2003-2007

cumulative fraction of perimeter area (y-axis)

fire size (1000 ha) (x-axis)

2003 – 2007 NIFC – SIT Reports
western 11 states
3632 wildfire events, 8.43 million ha (20.84 million acres)
40% of fires < 200 hectare (~500 acres)
52% of fires < 400 hectare (~1000 acres)
fires > 400 ha (~1000 acre) account for 97% of burned area
fires > 4000 ha (~10k acre) account for 80% of burned area