Fire emissions from North America: *A Simple Modeling Approach*

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Emissions from Fires

- Fire emissions impact air quality, visibility, and climate
- Emissions from fires can have local, regional and even continental impacts
  - transport from Central America, Mexico, Canada

Moderate-Resolution Imaging Spectroradiometer (MODIS) • 16 :55 UTC May 2, 2002

Sea-viewing Wide Field of View Sensor (SeaWIFS) • ~17:50 UTC May 2, 2002

Emissions from Fires

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Important to include fire emissions with regional and global chemical and climate models

Fire Emissions Modeling for North America

Goals

- Create a consistent framework for modelers to quickly and efficiently estimate fire emissions
- Create an inventory to be readily used by air quality modelers
  - Base years: **2002 - 2005**

Specifications:

- High resolution (~ 1km, hourly-daily)
- Include all of North America...
  - 10^{o}-71^{o} N and 55^{o}-175^{o} W
- Include emissions from all fires
  - wildfires
  - prescribed fires
  - agriculture fires

Modeling Fire Emissions

$$Emission_i = A * B * CE * e_i$$

A: Area Burned

B: Biomass burned (biomass burned/area)

- type of vegetation (ecology)
- fuel characteristics:
  - amounts of woody biomass, leaf biomass, litter, ...
- fuel condition
  - moisture content

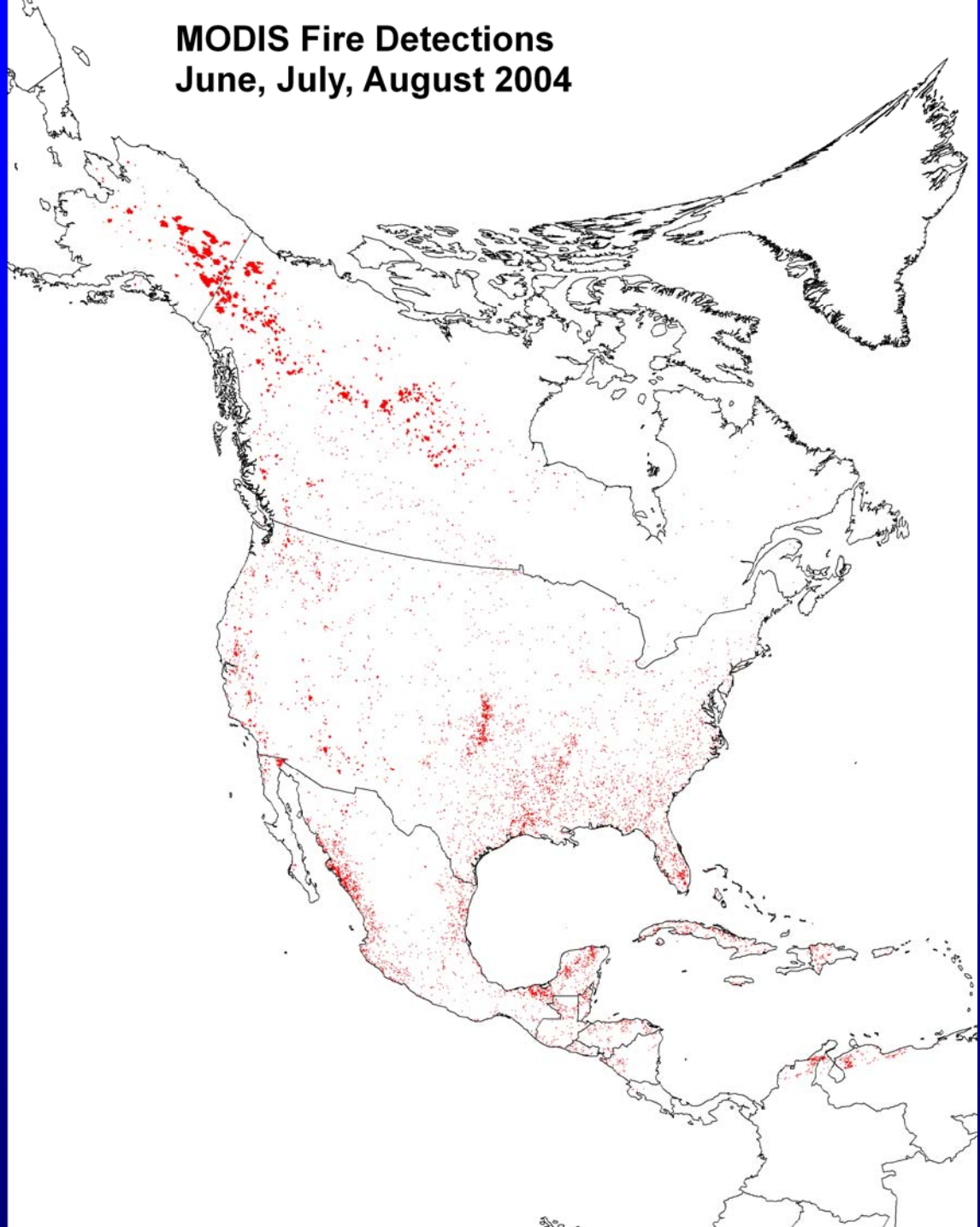
CE: Combustion Efficiency

e_i: Emission factor (mass emission$_i$ /biomass burned)

- fuel characteristics
- fuel condition
- fire phase (flaming versus smoldering)

Fire Identification

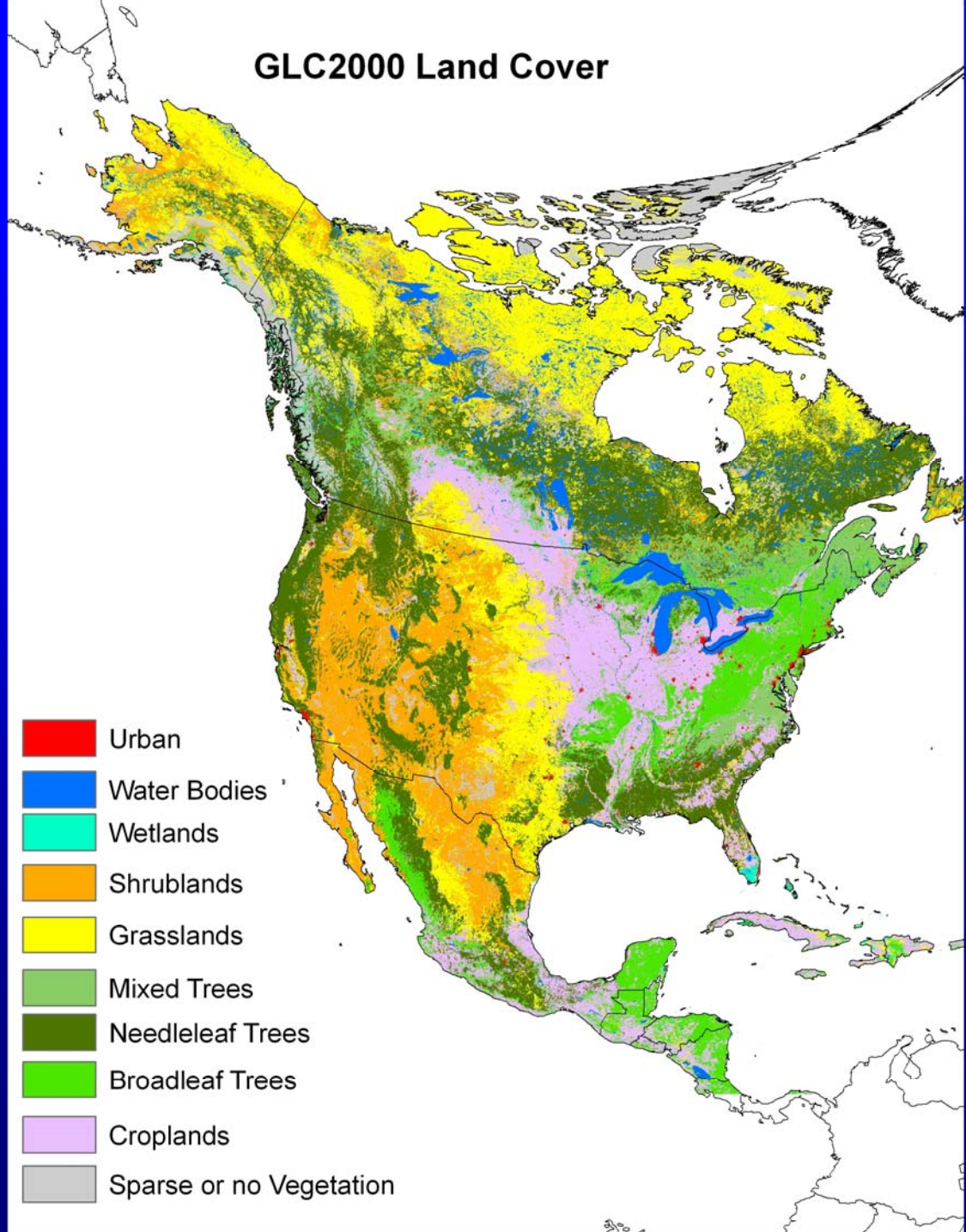
- MODIS Thermal Anomalies Product
  - global coverage (~daily)
  - 1 km^2 pixels
  - Available from several sources
    - University of Maryland/NASA
      http://maps.geog.umd.edu/default.asp
    - USFS Remote Sensing Application Center (RSAC)
      http://activefiremaps.fs.fed.us/fireptdata.php
    - NASA Earth Observing System Data Gateway
      http://delenn.gsfc.nasa.gov/~imswww/pub/imswelcome


MODIS Fire Detections
June, July, August 2004

Fuel Characterization

- Global Land Cover 2000 (GLC2000) coverage
  - based on SPOT Vegetation product
  - 1 km resolution
  - 29 vegetation classifications
    - temperate, tropical, and boreal vegetation distinguished
  - available at:

    http://www.gvm.sai.jrc.it/glc2000/


GLC2000 Land Cover
Urban
Water Bodies
Wetlands
Shrublands
Grasslands
Mixed Trees
Needleleaf Trees
Broadleaf Trees
Croplands
Sparse or no Vegetation

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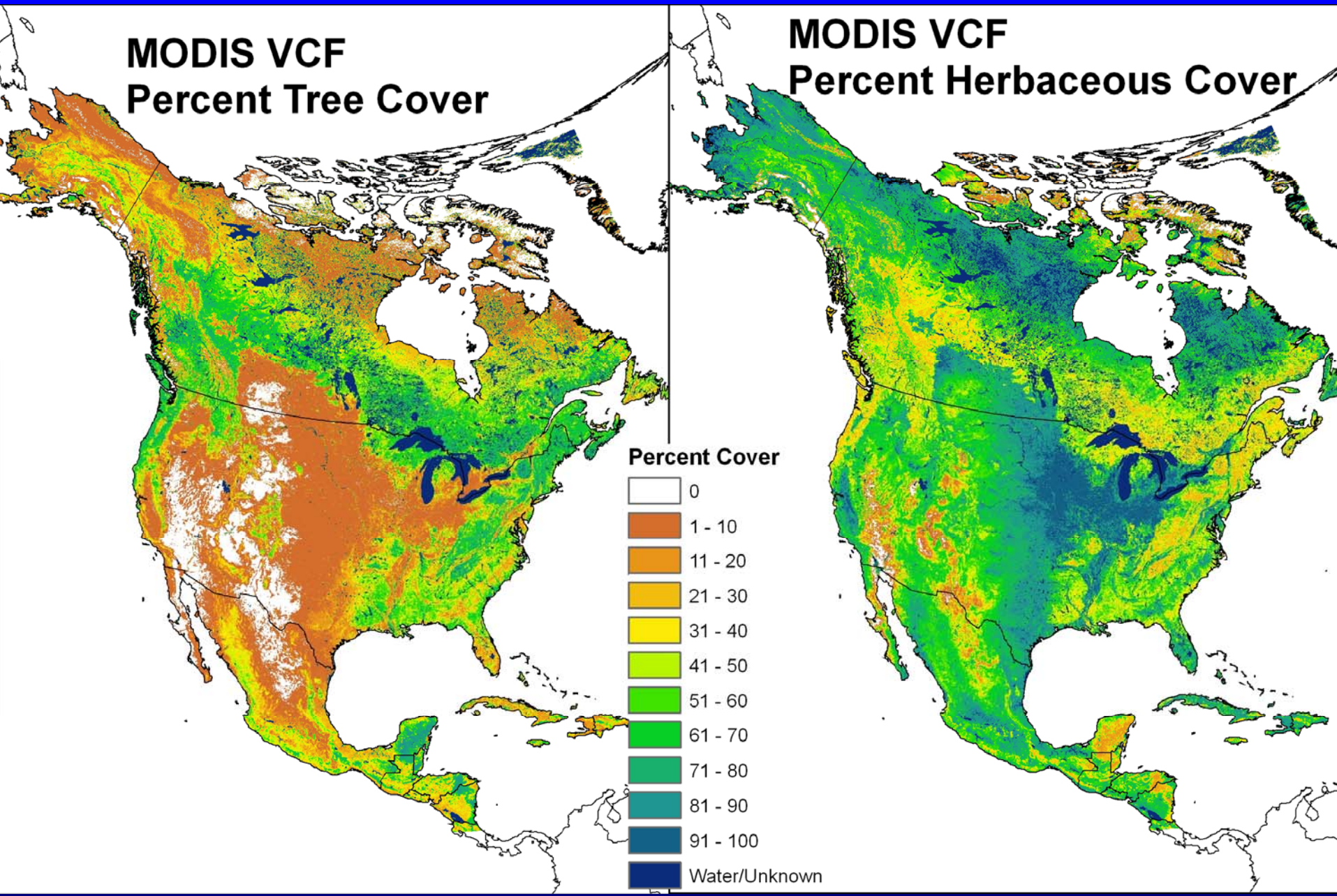
- MODIS Vegetation Continuous Fields (VCF)
  - 500m resolution
  - percent forest, herbaceous, bare cover
  - Available from the Univ. of Maryland
    http://glcf.umiacs.umd.edu/data/modis/vcf/


MODIS VCF
Percent Tree Cover
MODIS VCF
Percent Herbaceous Cover
Percent Cover
0
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
Water/Unknown

Fuel Loading

- Each GLC classification assigned woody and herbaceous fuel loading
  - fuel loading values from literature
  - woody and herbaceous fractions
    - determined with Fuel Characteristic Classification System (FCCS; McKenzie et al.)

Assumptions

- Each fire identification is assumed to be individual fire

  Area = 1 km^2 - Fraction bare cover

- Default land cover classification assumed to be grasslands

- Combustion Efficiency based on amount of forest/herbaceous cover
  - (based on *Ito and Penner, 2004*)

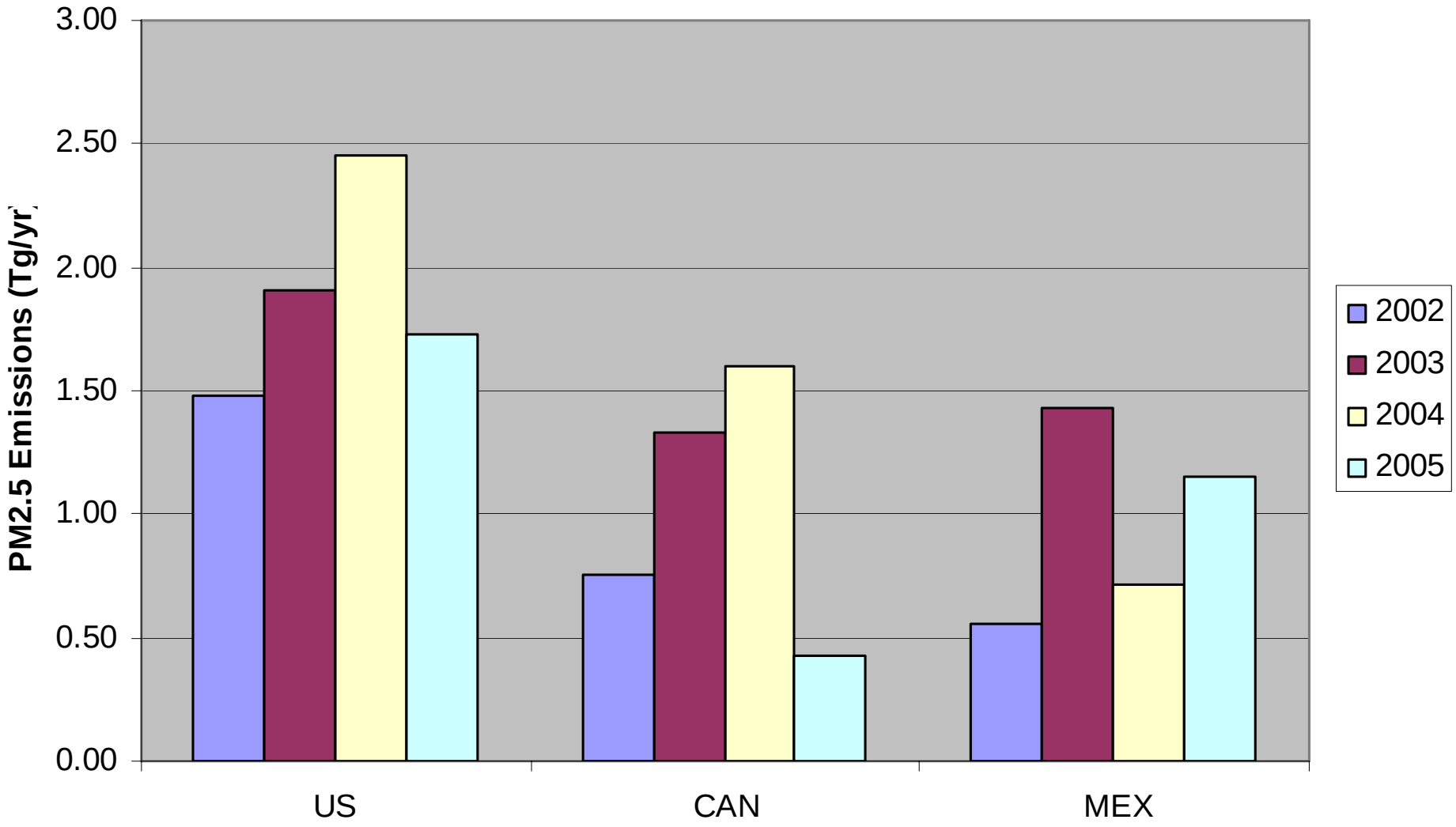
- Emission factors from literature

Fire Emissions Estimation

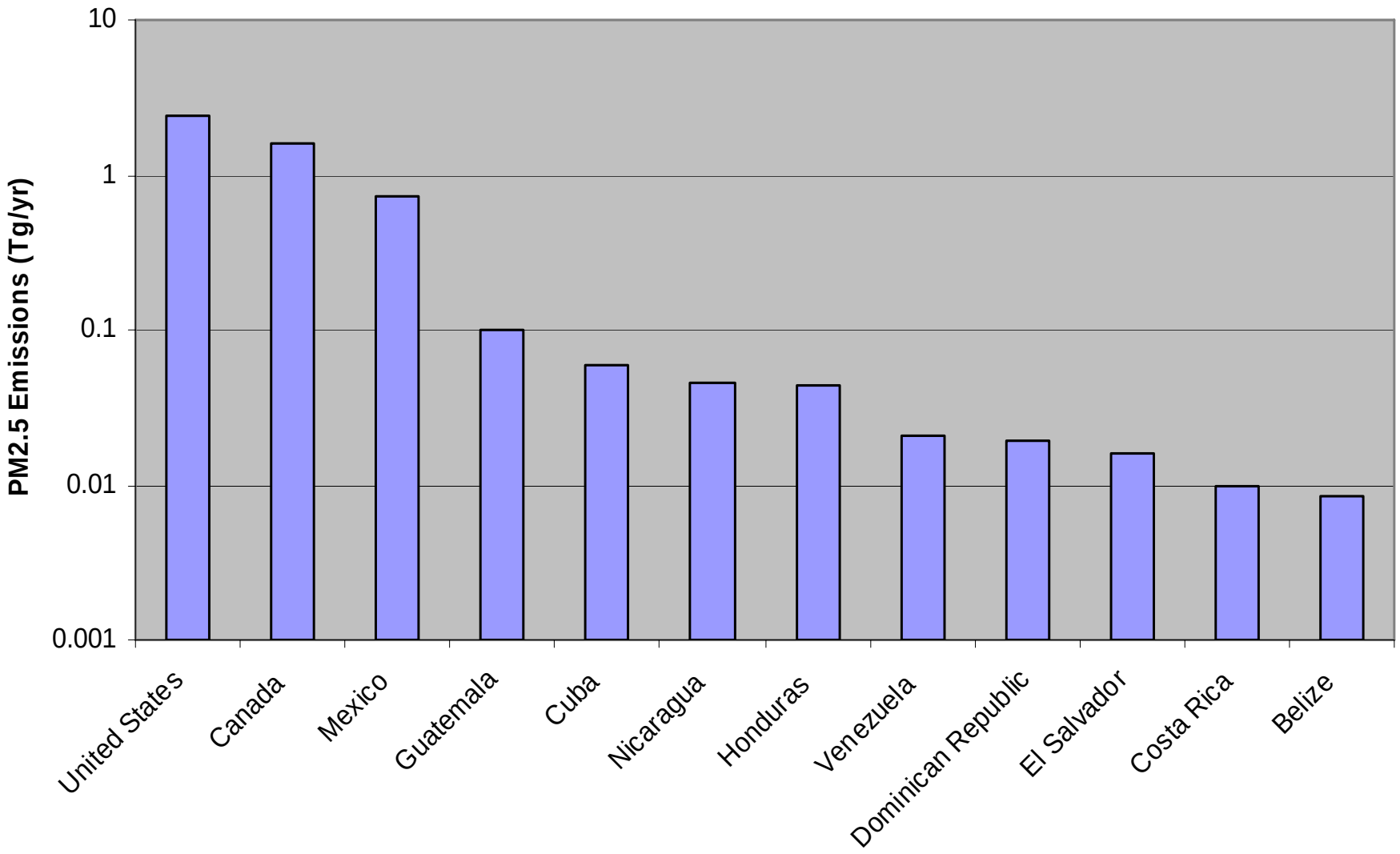
- Created daily emissions inventory
  - Includes fires in all of North and Central America
    - 10^{o}-71^{o} N and 55^{o}-175^{o} W
  - Daily emissions for 2002 through 2005
  - Inventory includes emissions of:

CO	PM_{10}
CO_2	$PM_{2.5}$
NO_x	CH_4
NH_3	NMHCs
SO_2	

Annual Emission Estimates

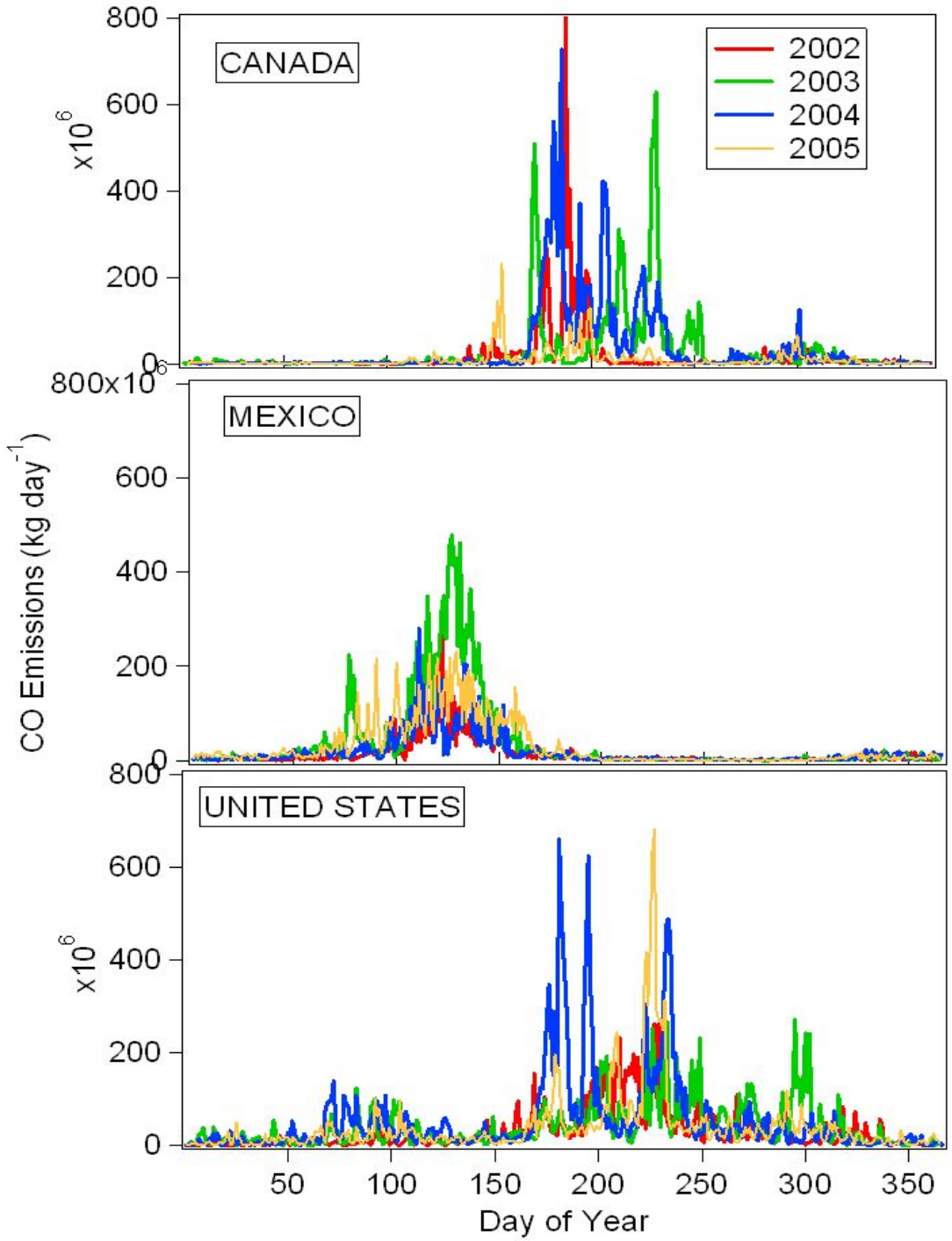


Emissions by Country

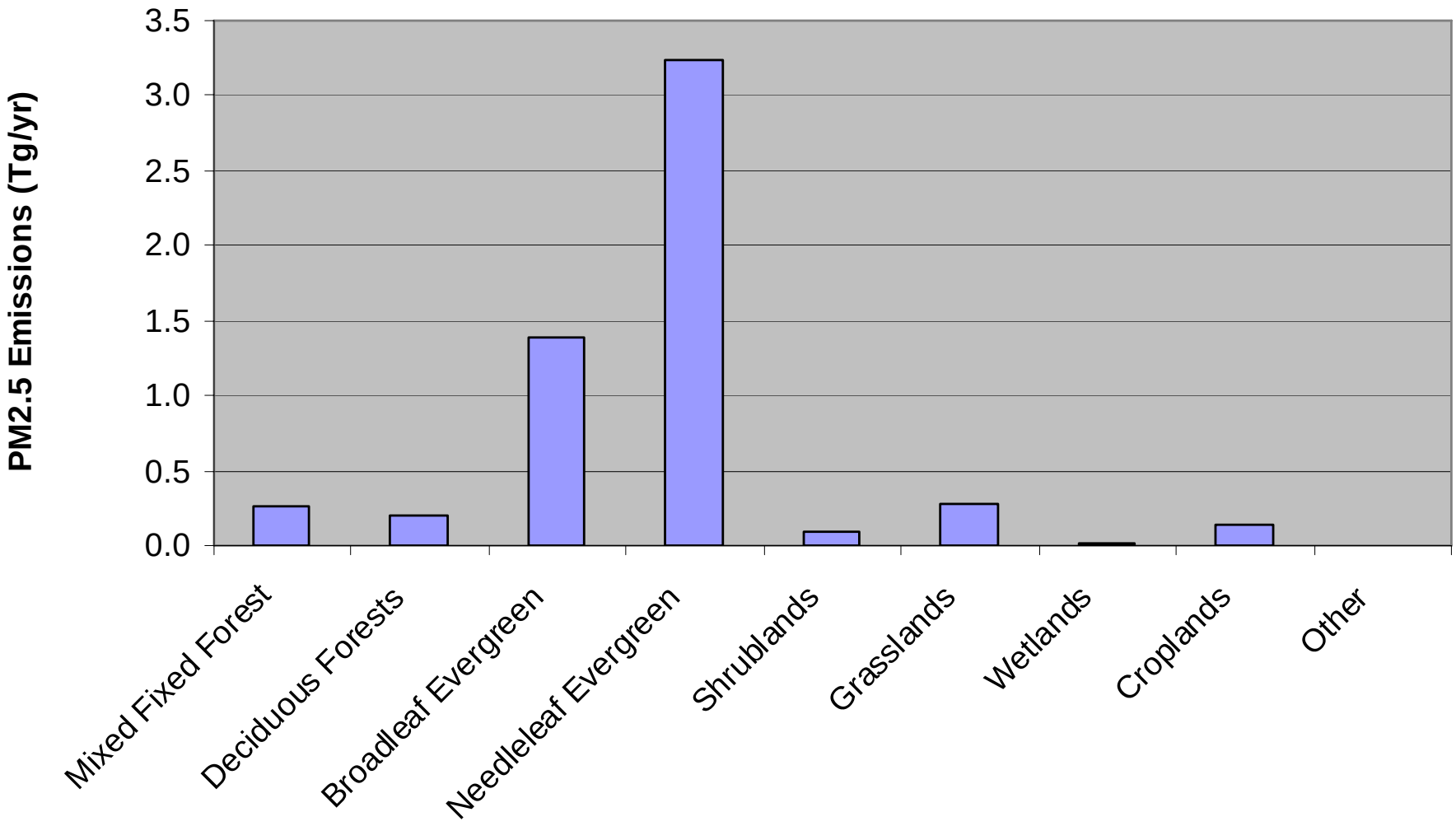


Daily Emission Estimates

- Canada and U.S- large emissions during summer wildfire season
- Mexican emissions during spring- brush clearing for agriculture
- U.S. has agriculture burning in spring and fall



Emissions by Land Cover Type



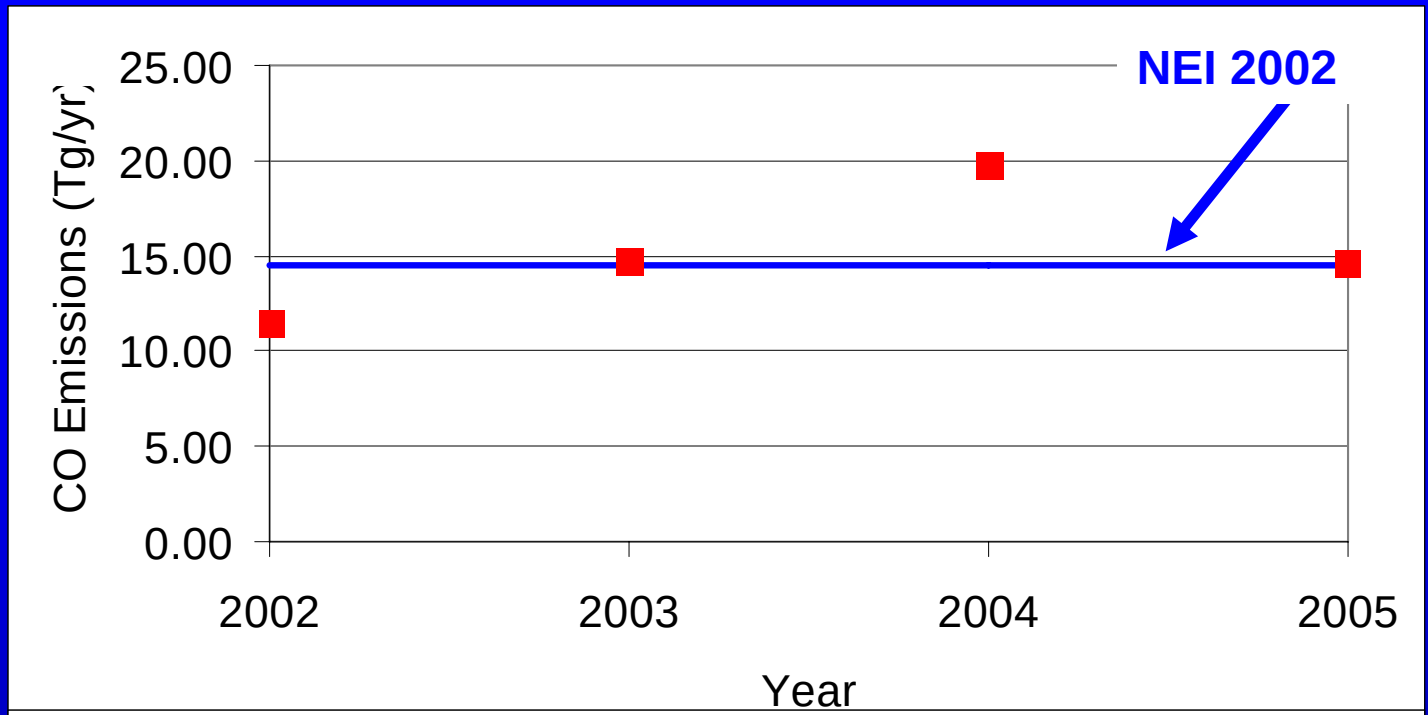
*** The total emissions from a single land cover category can vary by a factor of 2 from year to year**

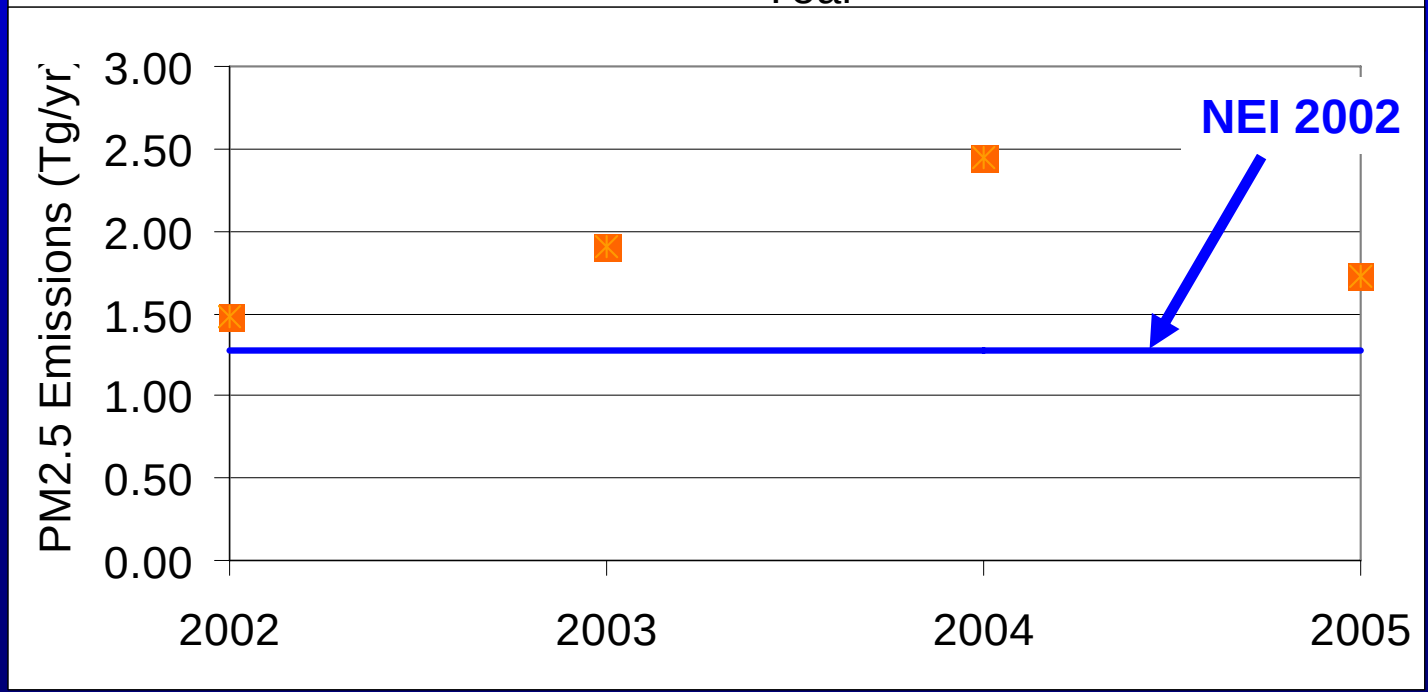
Comparison with other estimates

Study	CO Emissions ($Tg\ yr^{-1}$)	
Hoezelmann et al. [2004]	31.61 – 42.81	• for 2000
van der Werf et al. [2003; 2004]	26.12 +/- 22.99	• for 1997-2001 +/- standard deviation
This Study	32.54 +/- 8.19	• for 2002-2005 +/- standard deviation

Comparison with NEI values

reported 07/2005





Uncertainties

- Fire detections
  - missed fires due to cloud cover or overpass timing
    - missing prescribed/agriculture fires?
  - double detections from 2 satellites
  - “bow tie” effect (location within swath)

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- Area Burned

		Acres Burned	
Fire	**Location**	**This Study**	**BLM**
Cedar Fire	Southern California	275,750	281,000
Aspen fire	Arizona	59,500	164,000
Paradise Fire	Southern California	103,000	56,700

ftp://ftp.blm.gov/pub/gis/wildfire/firehistory2003/

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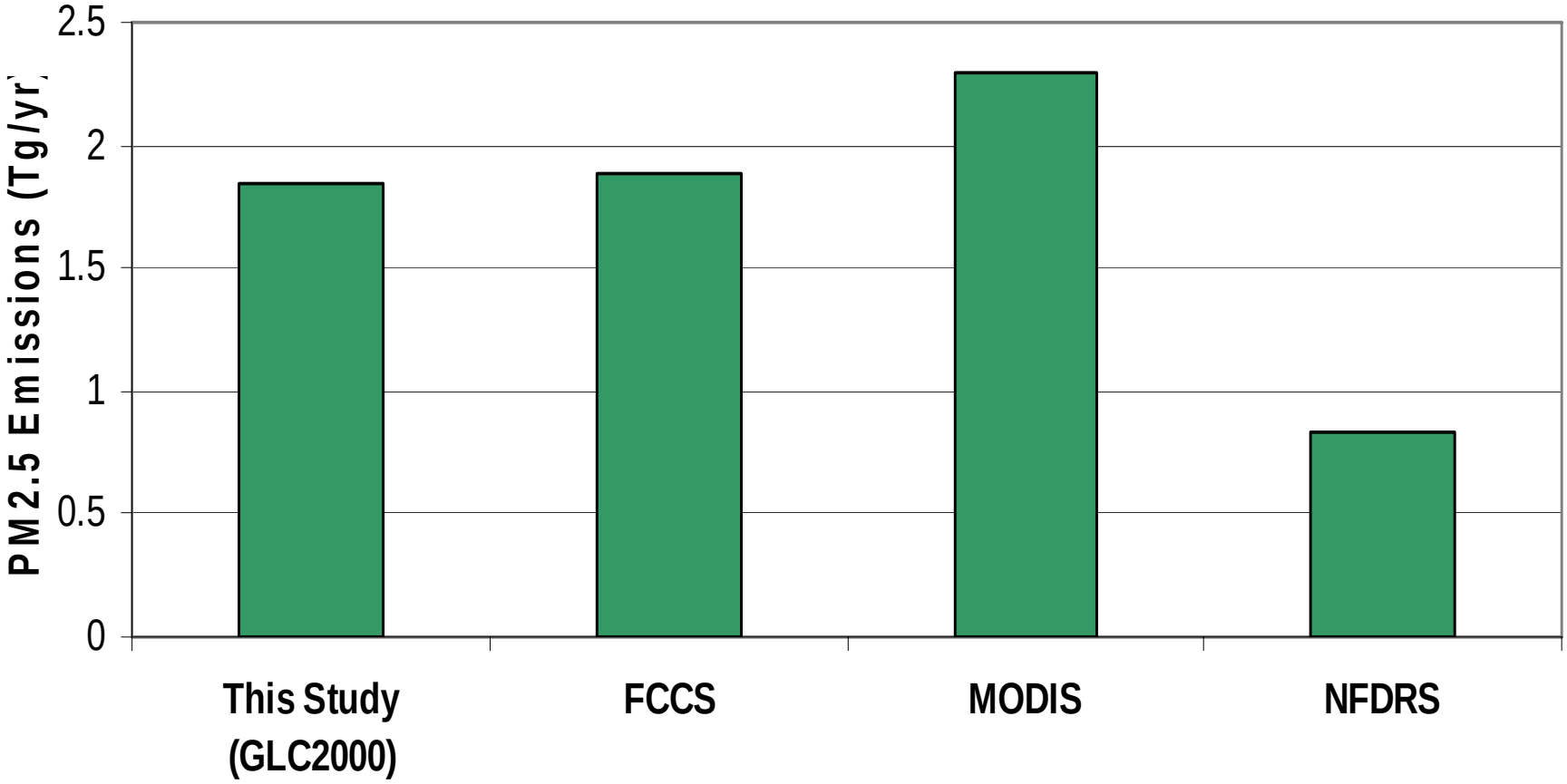
- Fuel Loadings

Uncertainties

- **Uncertainties associated with Fuel Loadings**



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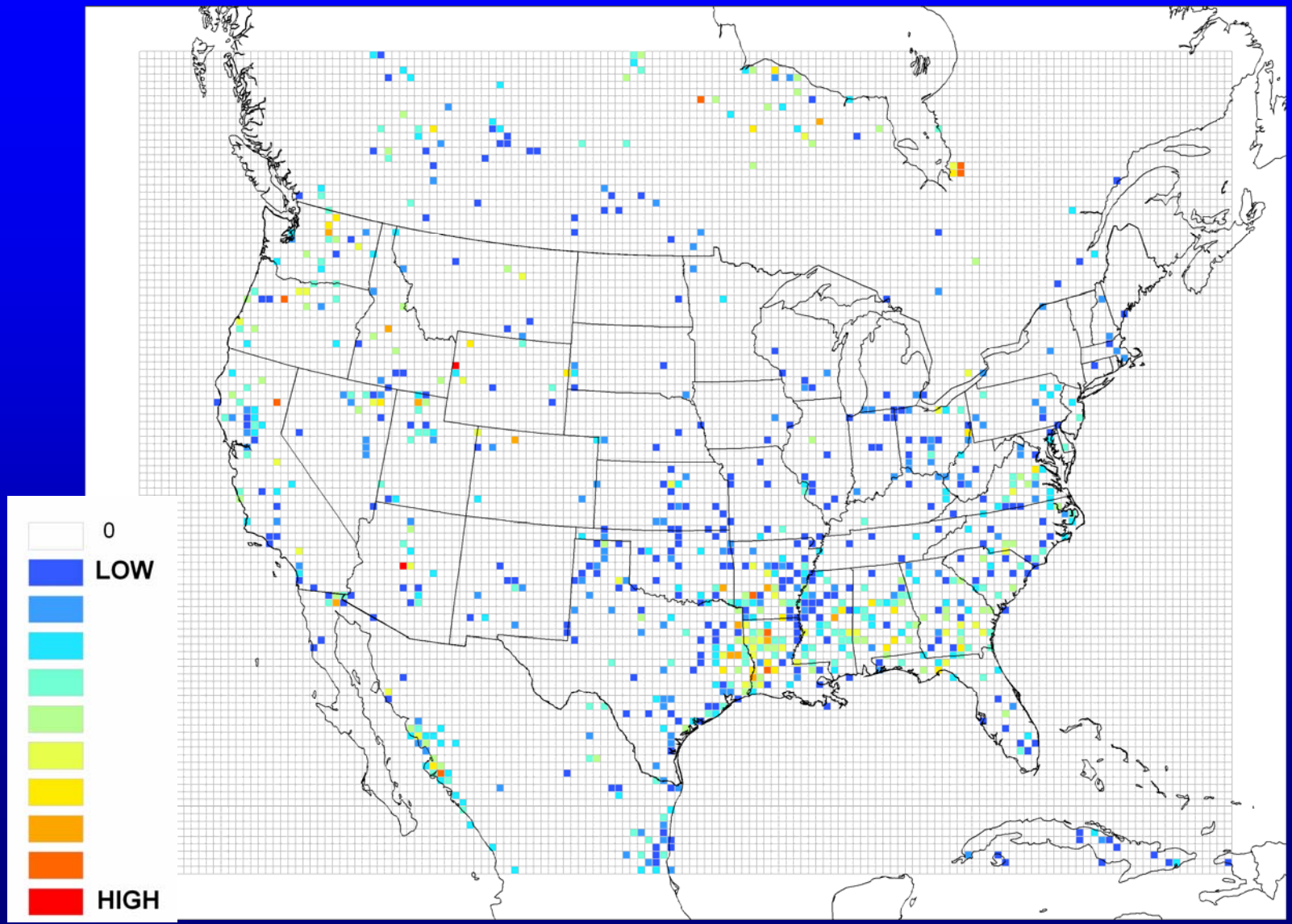
- Area Burned
- Fuel Loadings
- Fuel characteristics

Emissions used within the CMAQ framework

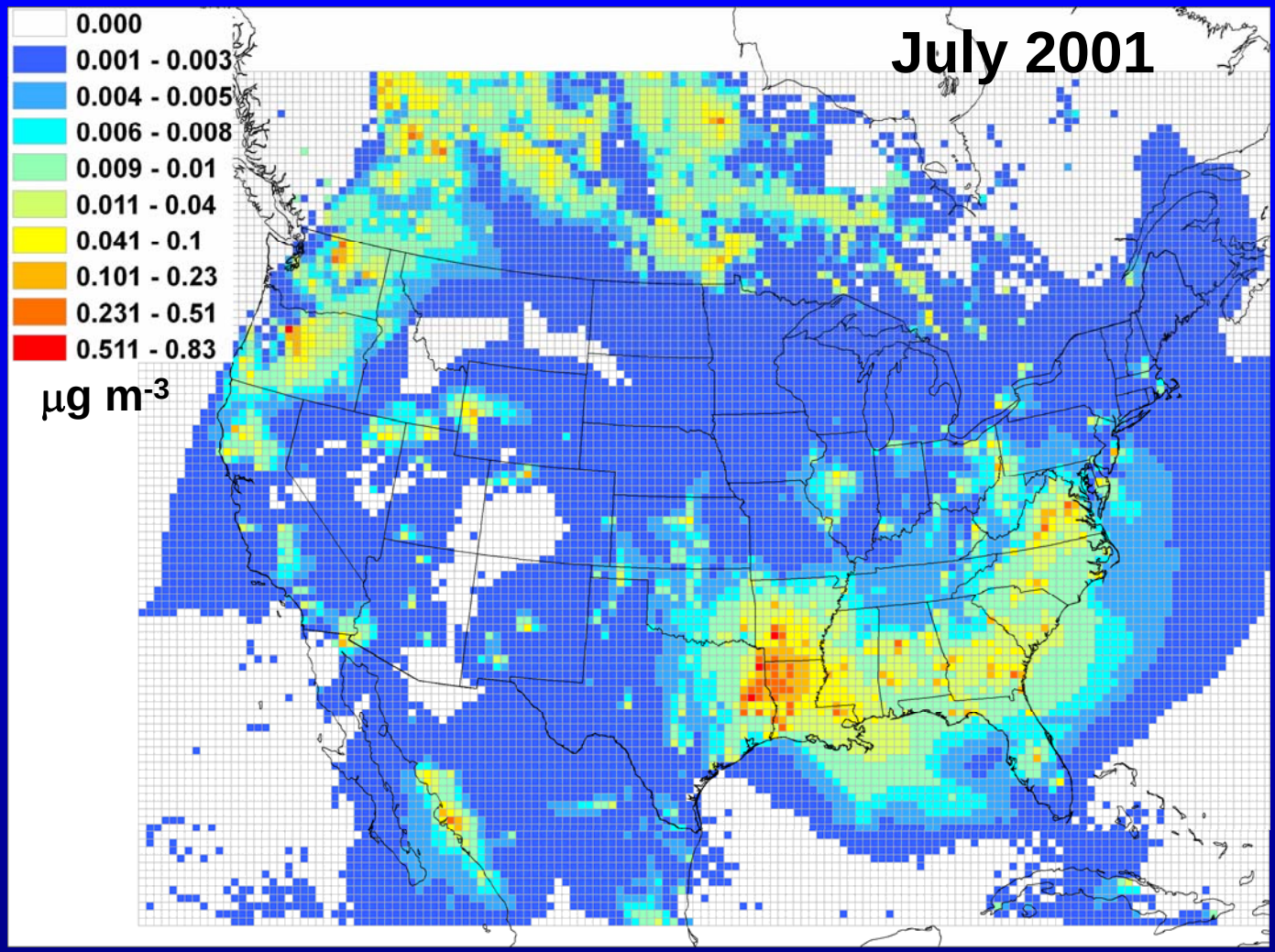
- Estimated emissions for July 2001
- Speciated emissions to SAPRC99 mechanism
  - VOCs based on land cover burned and reactivity (S. Nandi)
  - PM by WRAP method
- Applied hourly emissions based on EPA documentation
- Converted to IO/API format and merged with other emissions
  - All emissions in surface layer
- Ran CMAQ for July 2001 with emissions
  - 36 km continental domain

Fires in CMAQ



Spatial distribution of Fire Emissions assigned to 36 km domain in July 2001

Aerosol from fires



- Hourly modeled $PM_{2.5}$ concentrations increased by as much as 36 μg m^{-3}
  - hourly organic aerosol fractions changed as much as 90%
  - monthly organic aerosol fractions changed as much as 11%

Future Work

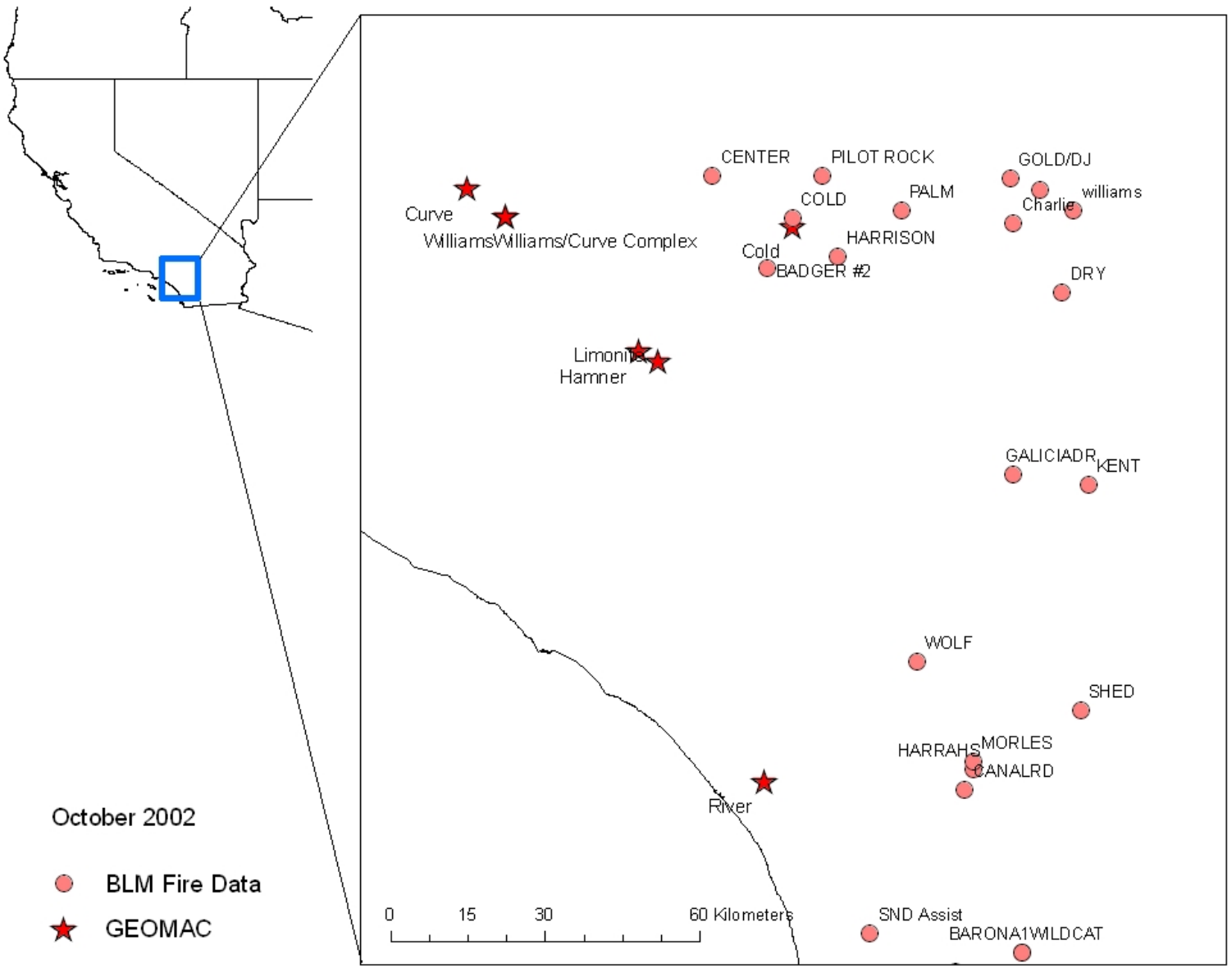
- Develop diurnal profiles for fire emissions
  - using WF_ABBA product (with Chris Schmidt, U. Wisc.)
- Develop parameterization for plume rise
- Incorporate other satellite data
  - fire detections (i.e., WF_ABBA)
  - fuel loadings (i.e., MODIS-derived, *Zhang)*
  - fuel conditions (i.e., NOAA VHI)
- Model Evaluation
- Forecast Modeling
  - MIRAGE and INTEX-B

Conclusions

- Simple fire emissions model has been developed
  - Provides modelers a quick way to include fires within simulations
- Emissions for 2002-2005 available
  - estimates compare well with other published values
  - estimates can impact air quality modeling results
- More work is needed

EXTRAS

Inconsistencies with available data



Uncertainties

- **Uncertainties associated with Fuel Loadings**