The Effects of Uncertainties in Fire Emissions Estimates on Predictions of Texas Air Quality

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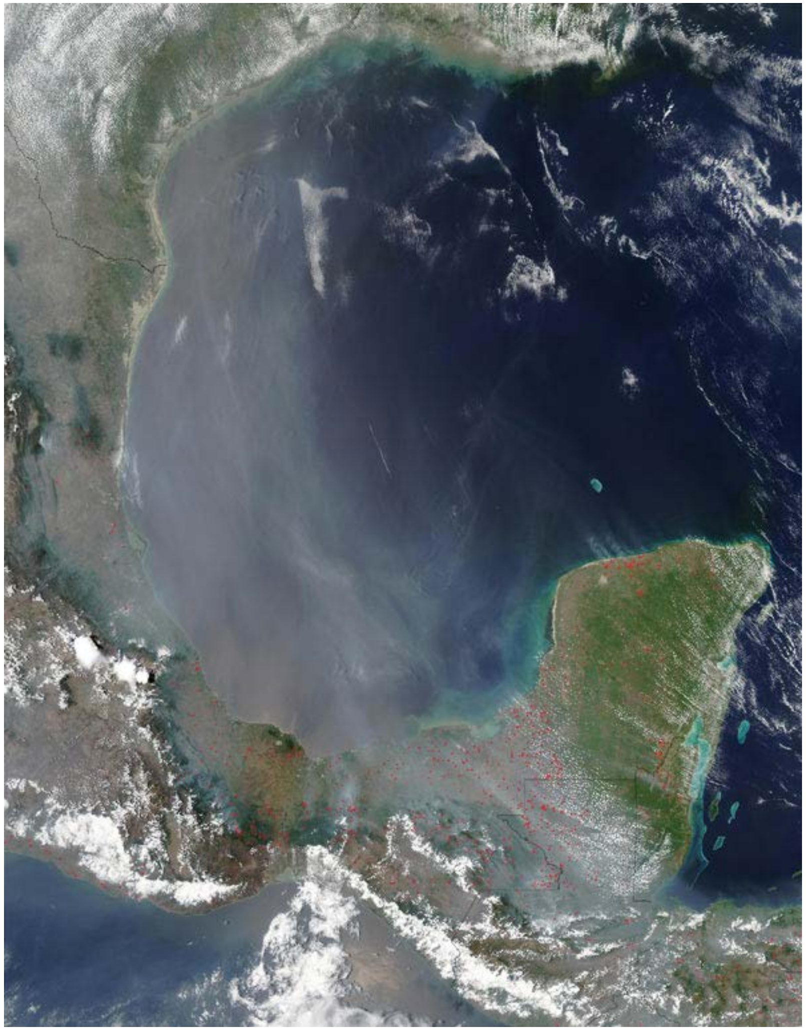
Influence of Fires on Air Quality

- Wildland fires and open burning can be substantial sources of ozone precursors and particulate matter.
- The influence of fire events on Texas air quality has been well documented by observational studies.
- Fire emissions are often transported over multiple spatial scales.



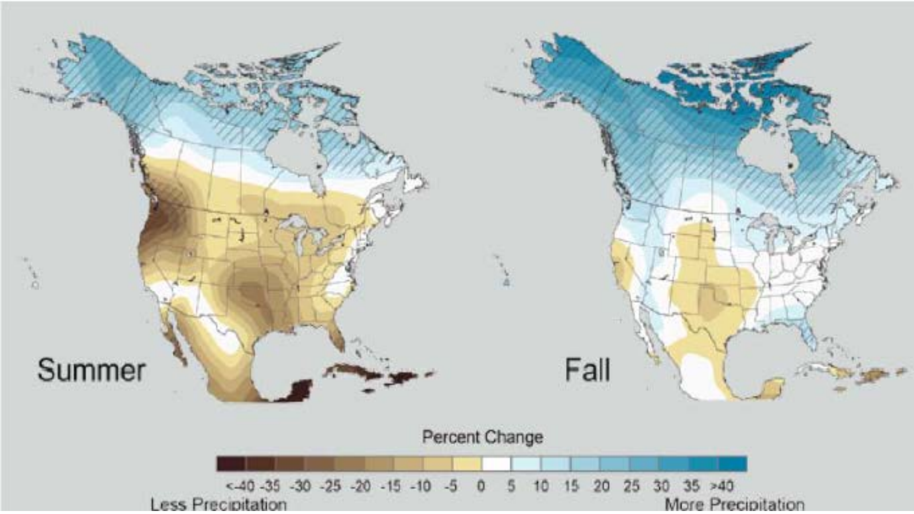
MODIS Image
May 9, 2003
Source:
http://www.nasa.gov/vision/earth/environment/central_am_fires.html

Study Motivation

Accurate characterization of fire events needed for:

- Exceptional event exclusions
- Air quality modeling for planning and attainment demonstrations
- Estimating NAB ozone concentrations

Climate models suggest increased frequency of drought in southwestern U.S. In Texas, 2011 was record year for drought and wildfires.



Projected future changes in precipitation as simulated by 15 climate models. Source: U.S. Global Change Research Report, 2009.

Bastrop County Complex Fire
Source: The Atlantic (9/6/2011)

Study Motivation

- Fire emissions estimates are used as inputs to chemical transport models.

- Required spatial and temporal resolution vary with application , e.g. global-scale studies (100 km and monthly time periods) versus regional-scale studies (< 10 km and daily time periods)*

- Many studies suggest substantial variability between models.

- Variability associated with fire detection and estimation of burned area and fuel composition, loading, vertical structure, and consumption, and characterization of conditions from preceding drought and heat.

Source: Urbanski et al., 2011; Al-Saadi et al., 2008.

Objectives

- This project evaluates the sensitivity of emissions estimates from the Fire INventory from NCAR (FINN) version 1 (referred to as the FINN default configuration in this work) to variability in input parameters and the effects on modeled ozone and particulate matter concentrations using CAMx.

- Major Tasks:
  1. Climatology of fires in Texas, Louisiana, Central and Western U.S., Mexico/Central America, western Canada between 2002-2012.
  2. FINN default vs. BlueSky/SmartFire comparison
  3. FINN sensitivity studies focusing on emission factors, land cover classification, fuel loading data, and fire detection and area burned estimation.
  4. Effects of FINN sensitivities on air quality using CAMx

FINN Default Configuration (Wiedinmyer et al., 2011)

- $E_i = A(x,t) * B(x) * FB * ef_i$

  where

  E_i = mass emission of species *i*

  $A(x,t)$ = area burned at time *t* and location *x*

  $B(x)$ = biomass loading at location *x*

  FB = fraction of biomass burned

  ef_i = mass of *i* emitted per mass of biomass burned.

- Fire Detection: MODIS Rapid Response (MRR) product; double counting of fires from Terra and Aqua observations addressed.

- Land Use/Land Cover Classification: MODIS Land Cover Type (LCT) product lumped into six categories: savanna/grasslands, woody savannas/shrublands, tropical forest, temperate forest, boreal forest, and croplands. MODIS Vegetation Continuous Fields (VCF) product used to identify vegetation density.

FINN Default Configuration (Wiedinmyer et al., 2011)

- Area Burned: Upper limit of 1 km^2; 0.75 km^2 for grassland and savannas. Scaled by percent bare cover in VCF product.

- Fuel Loading: Assigned to world regions according to 5 of 6 LULC classes. Croplands assigned same loading as grasslands of each world region, (e.g. North America, 976 g/m^2).

- Fraction of Biomass Burned: Assigned according to fraction of tree cover by MODIS VCF product and fuel loading.

- Emission Factors: Literature – Akagi et al. (2011).

- Chemical Speciation: Available for GEOS-Chem, MOZART-4, SAPRC99 chemical mechanisms. ENVIRON developed processing algorithm to obtain a profile for CB05 mechanism from MOZART-4 speciation.

Fuel Loading (g/m²) for FINN Default Configuration

Global Region	Tropical Forest	Temperate Forest	Boreal Forest	Woody Savanna/ Shrublands	Savanna and Grasslands
North America	28,076[b]	10,492	25000[a]	5,705	976
Central America	20,260	11000[a]		2,224	418
South America	25,659	7400[a]		3,077	552
Northern Africa	25,366	3,497		2,501	318
Southern Africa	25,295	6,100		2,483	360
Western Europe	28,076[b]	7,120	6,228	4,523	1,321
Eastern Europe	28,076[b]	11,386	8,146	7,752	1,612
North Central Asia	6181[c]	20,807	25000[a]	11,009	2,170
Near East	6181[c]	10,316		2,946	655
East Asia	6181[c]	7,865		4,292	722
Southern Asia	27,969	14,629		5,028	1,445
Oceania	16,376	11696[d]		1,271	245

Based on Akagi et al. [2010] and references therein, updated these values

Taken as the average of Tropical and Temperate forest for Oceania (to account for Eucalyptus forest in Australia

Added tropical forest to Western and Eastern Forest (equal to the value for North America)

[a] Akagi et al. [2010] and references therein

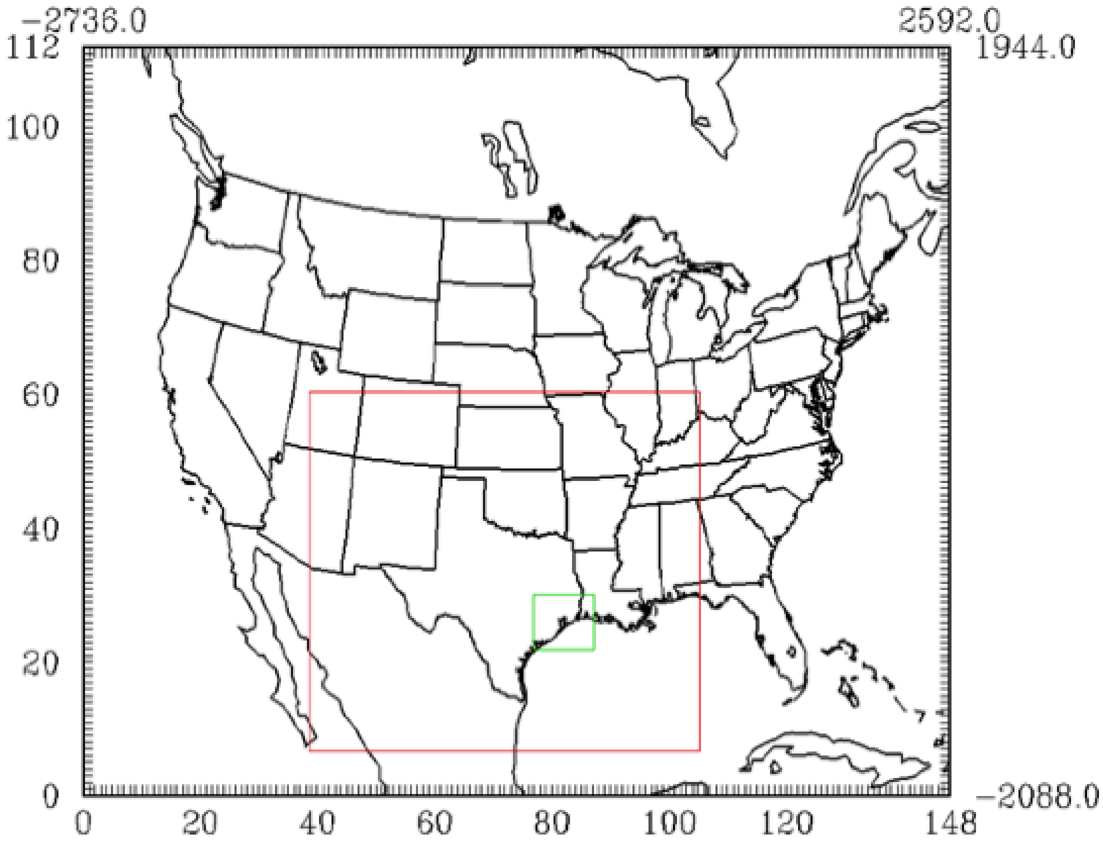
[b] Added a tropical forest class to North America and Europe (in LCT)

[c] All Asia assigned equal tropical forest values

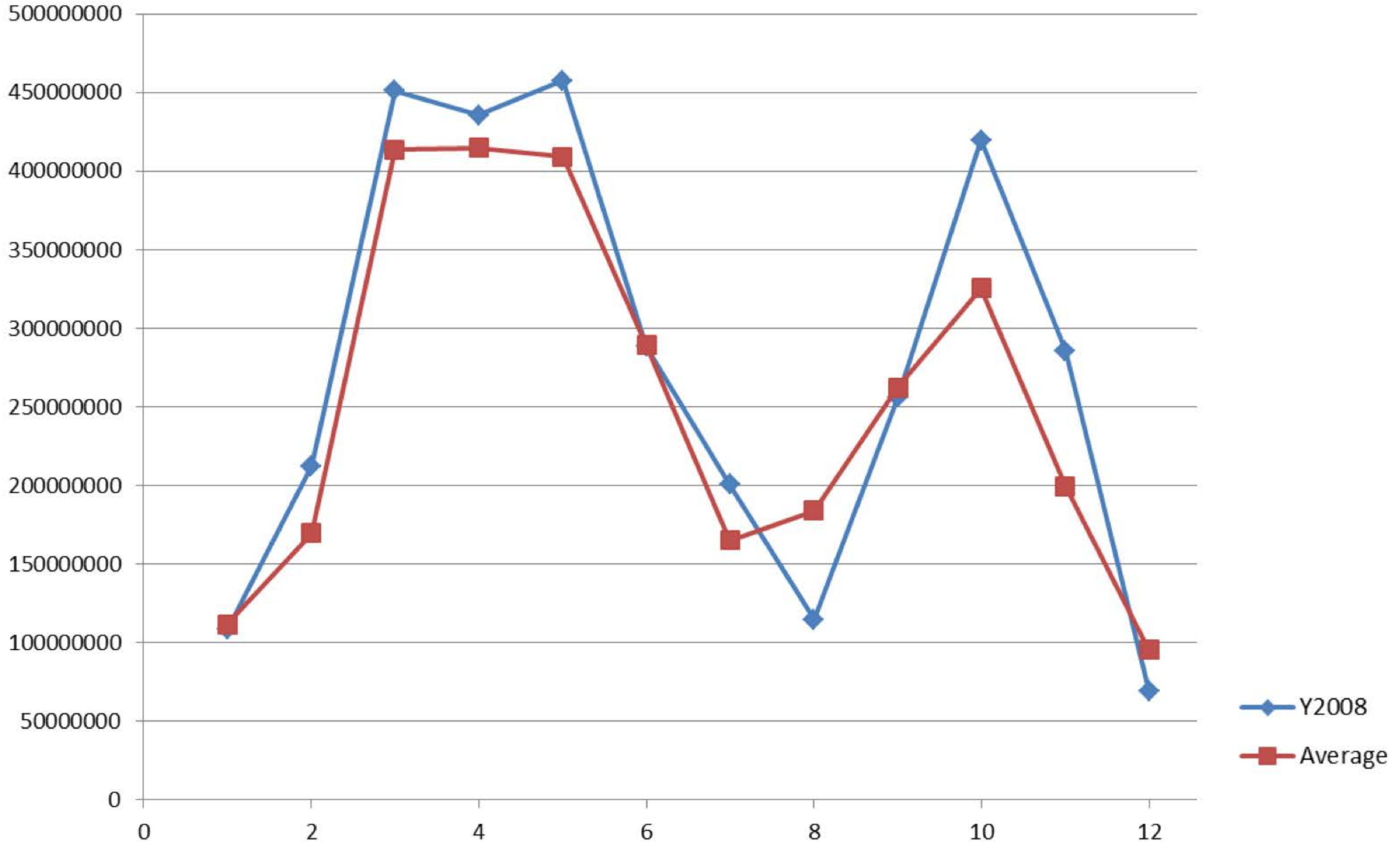
[d] Taken as the average of Tropical and Temperate forest for Oceania

CAMx Base Case

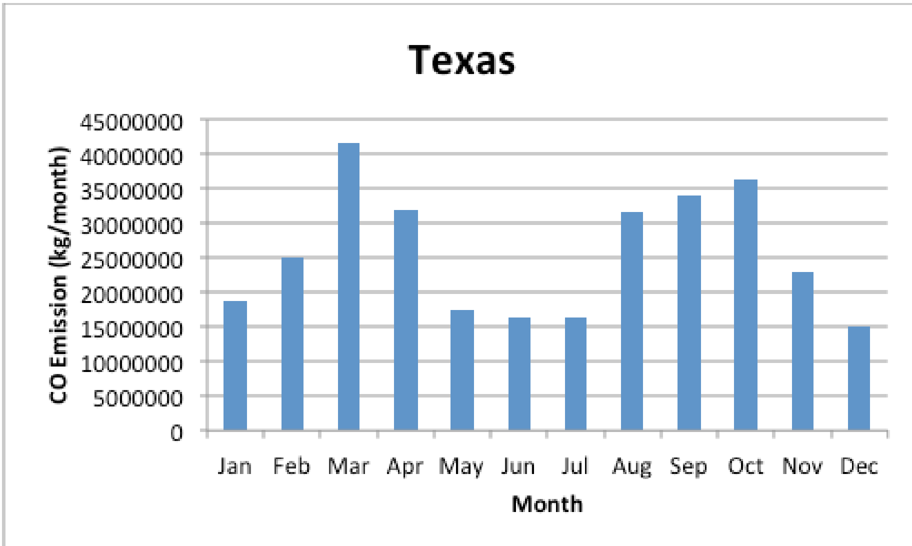
- April 1 - October 18, 2008
- Developed by Alpine Geophysics
- Fire emissions from BlueSky/EPA SmartFire2 by STI
- EPS3v3.20 processing of FINN emissions estimates for CAMx

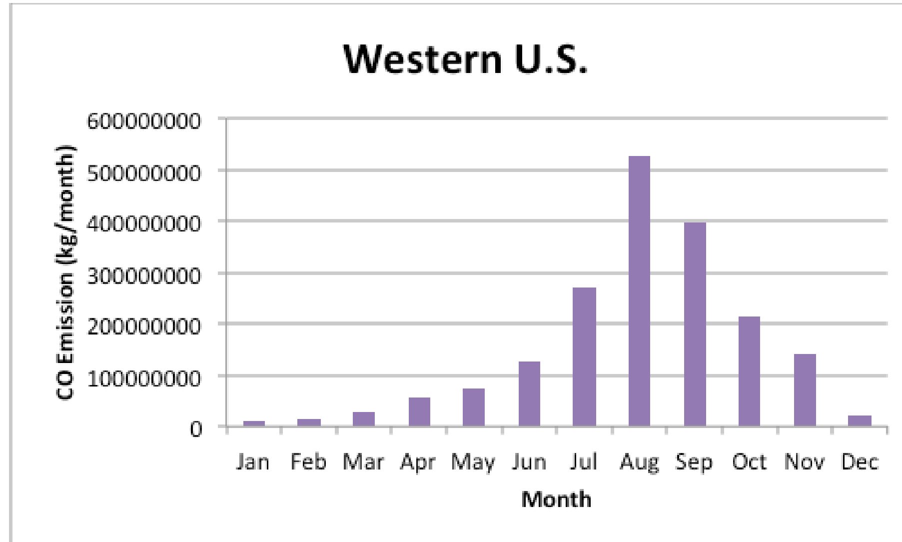


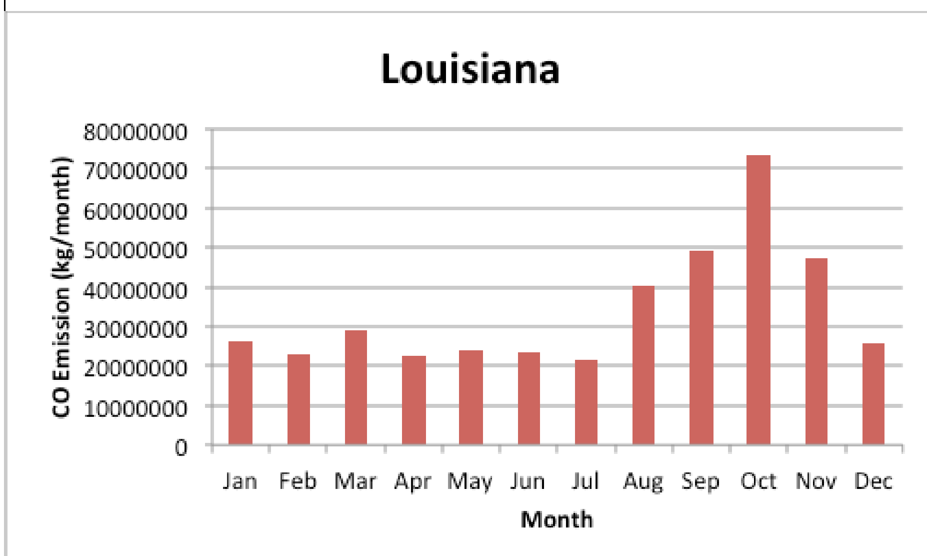
Comparison of CO Emissions (kg/month) in 2008 with 11-Year (2002-2012) Mean

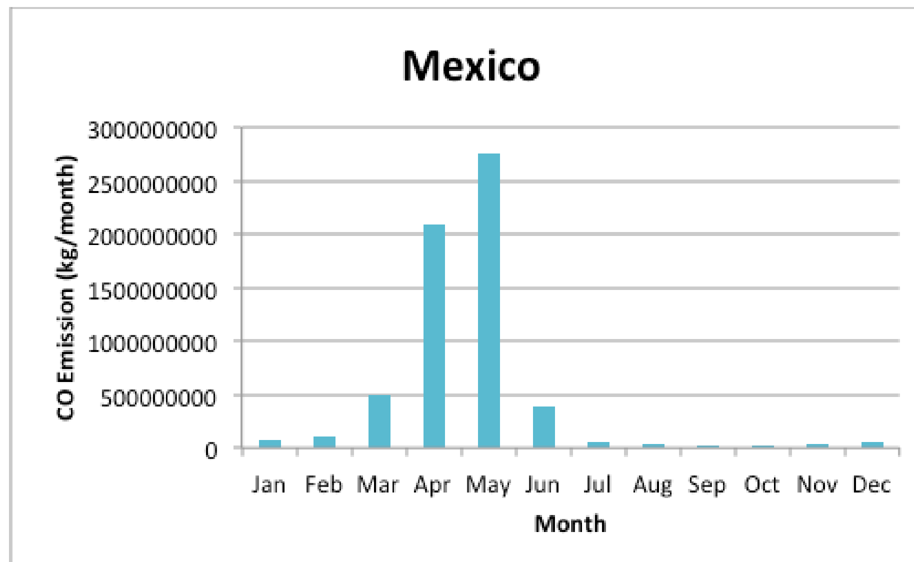


Climatology of Fires: 2002-2012









Monthly Average Interannual Variability in CO Emissions Estimates from FINN during 2002-2012

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Texas	46%	44%	34%	45%	40%	38%	27%	23%	21%	35%	26%	45%
Louisiana	50%	57%	40%	35%	23%	37%	27%	32%	23%	38%	22%	36%
Central States	55%	44%	11%	27%	38%	18%	22%	24%	29%	41%	30%	51%
Western U.S.	45%	38%	54%	32%	21%	56%	74%	65%	46%	24%	21%	33%
Mexico	45%	39%	55%	33%	30%	44%	39%	38%	36%	34%	33%	25%
Central America	31%	38%	76%	51%	47%	57%	59%	43%	45%	35%	29%	23%
Western Canada	64%	47%	39%	38%	91%	62%	77%	107%	83%	41%	29%	44%

* Interannual variability was determined as the average absolute percent departure from the 2002 through 2011 mean according to the approach of Tawfik et al. (2012):

$$IAV_m = \frac{1}{n}\sum_{y=2002}^{2011}\left|\frac{E_{y,m} - \overline{E_m}}{\overline{E_m}}\right| \times 100$$

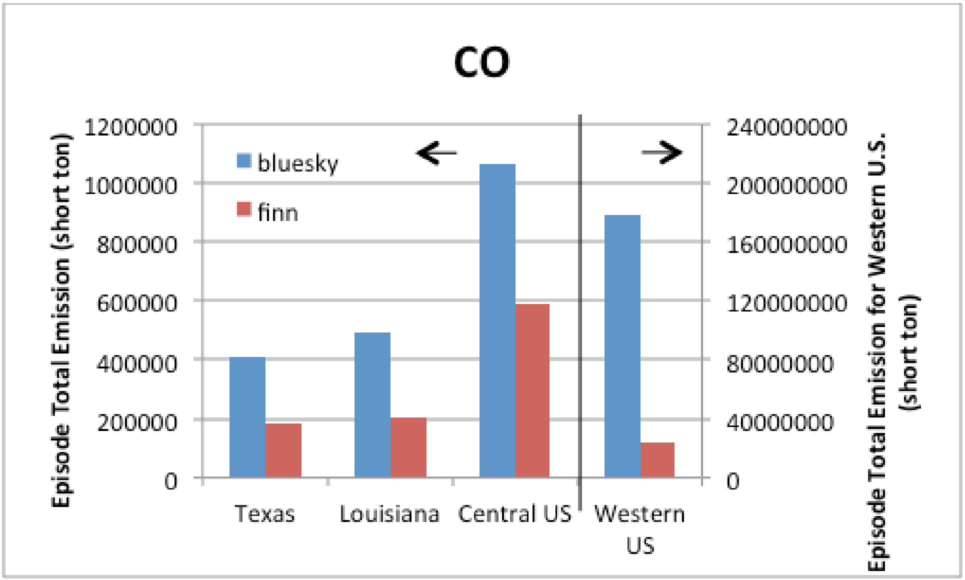
where $E_{y,m}$ is monthly CO emission for year y, month m, $\overline{E_m}$ is the average monthly emission across all years (2002 - 2011), n is number of years (n=10)

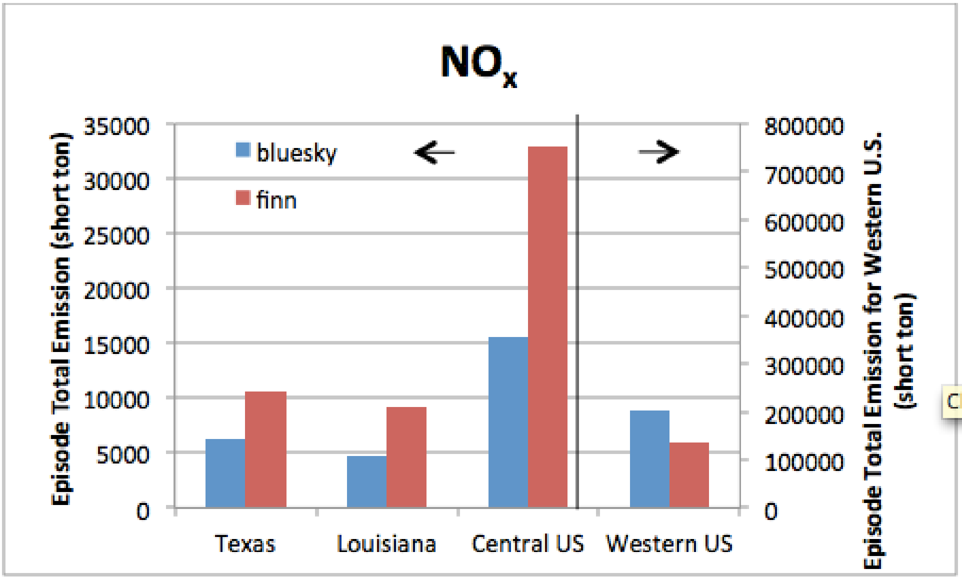
Comparison of FINN Default and BlueSky/SmartFire

BlueSky/SmartFire estimates were greater than FINN, except for NOx.

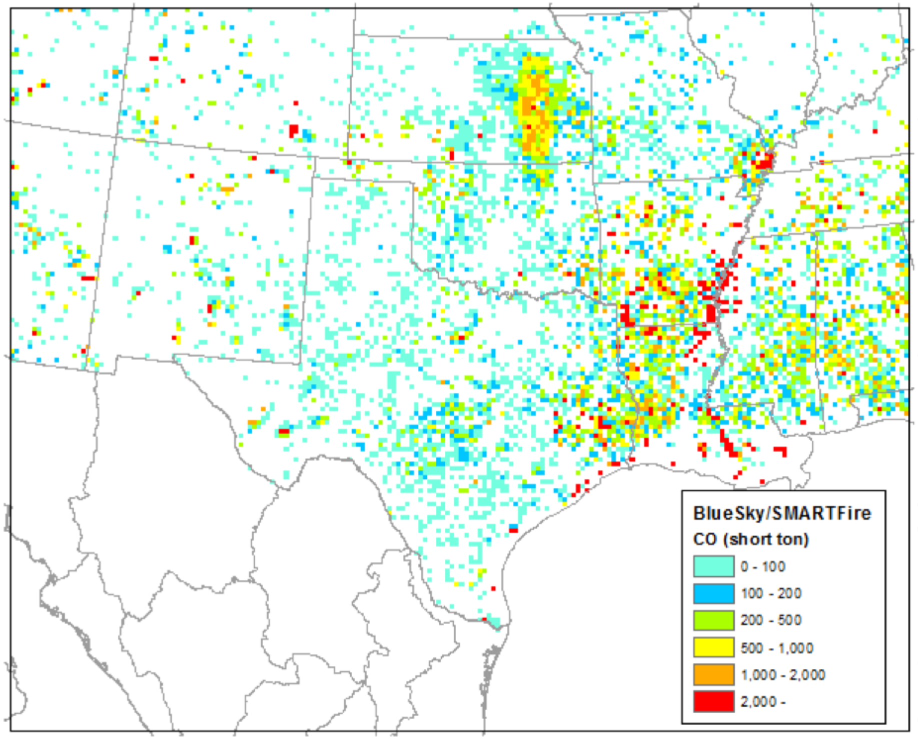
<u>Burned Area: </u>SmartFire uses reported area burned and multiple satellite detections. FINN relies on MODIS MRR.

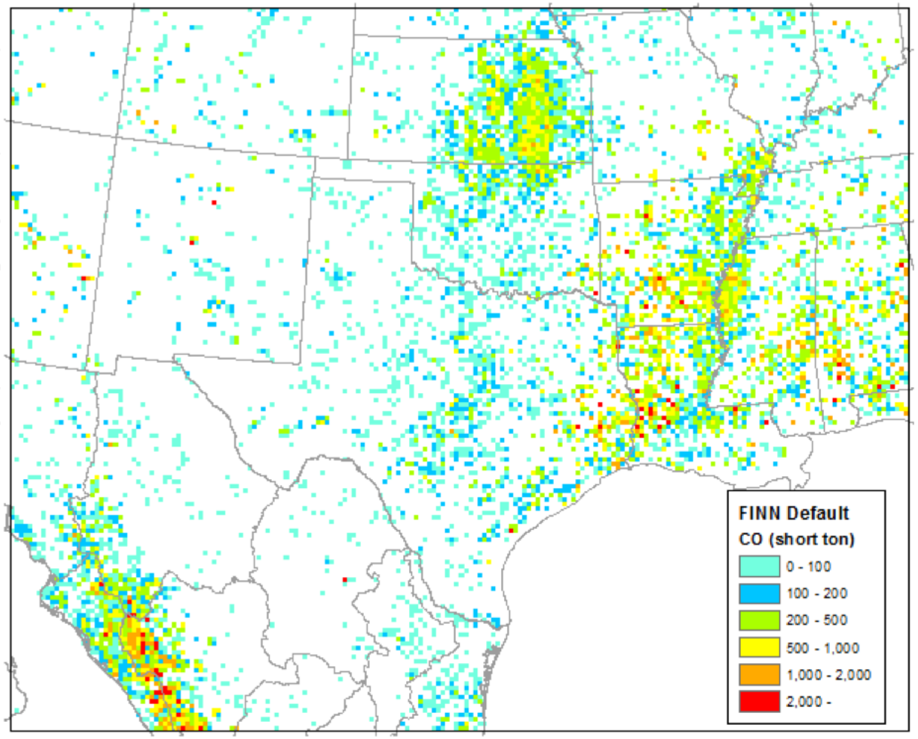
<u>Emission Factors: </u>FINN estimates greater for NO_x, especially for ag burning. Higher emission factors in FINN may compensate for lower estimates of acreage burned in the central US.





Episode Total CO Emissions (short tons) from BlueSky/SmartFire (left) and FINN [right)





FINN Sensitivity Studies

RUN NAME	LAND COVER	FUEL LOADING	EMISSION FACTOR	FIRE DETECTION/ BURN AREA
DEFAULT	default	default	default	default
GlobCover	GlobCover	default	default	default
NEWEMIS	default	default	NEW	default
HIGHEMIS	default	default	HIGH**	default
LOWEMIS	default	default	LOW**	default
NEWEMIS_TEMPFOR	default	default	NEW^	default
SmartFire	default	default	default	SmartFire
FCCS	default	FCCS	default	default

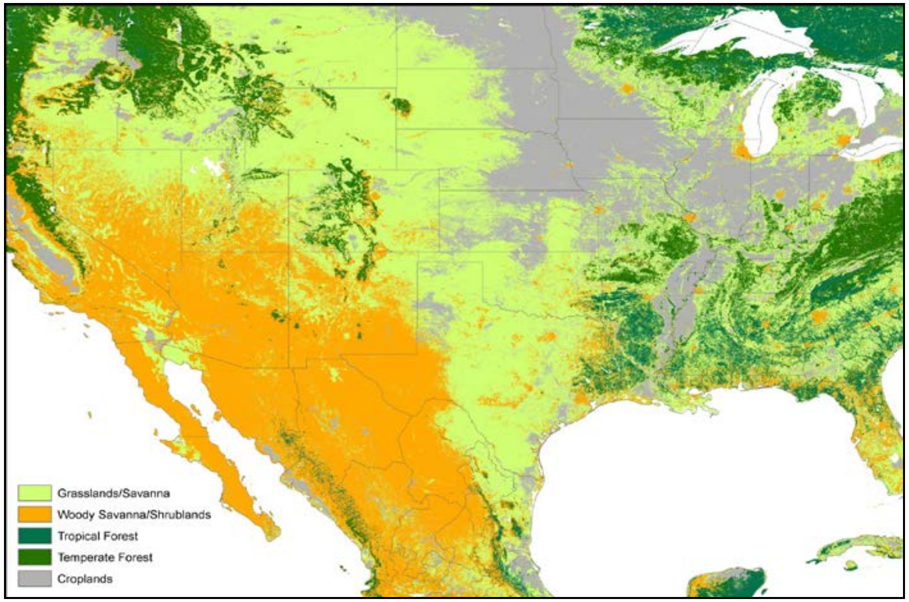
Emission Factors: Updates from Akagi et al. (2013), included uncertainty for high and low scenarios; new emission factors for temporal evergreen forests.

Land Cover: GlobCover product from MERIS sensor on ENVISAT

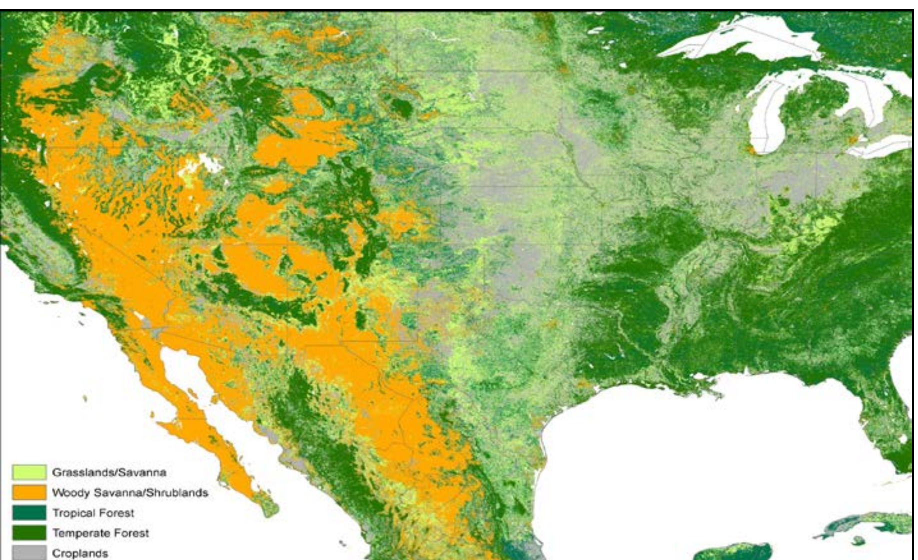
Fuel Loading: Fuel Characteristic Classification System for CONUS

Fire Detection and Area Burned: SmartFire for CONUS

Comparison of MODIS LCT and GlobCover



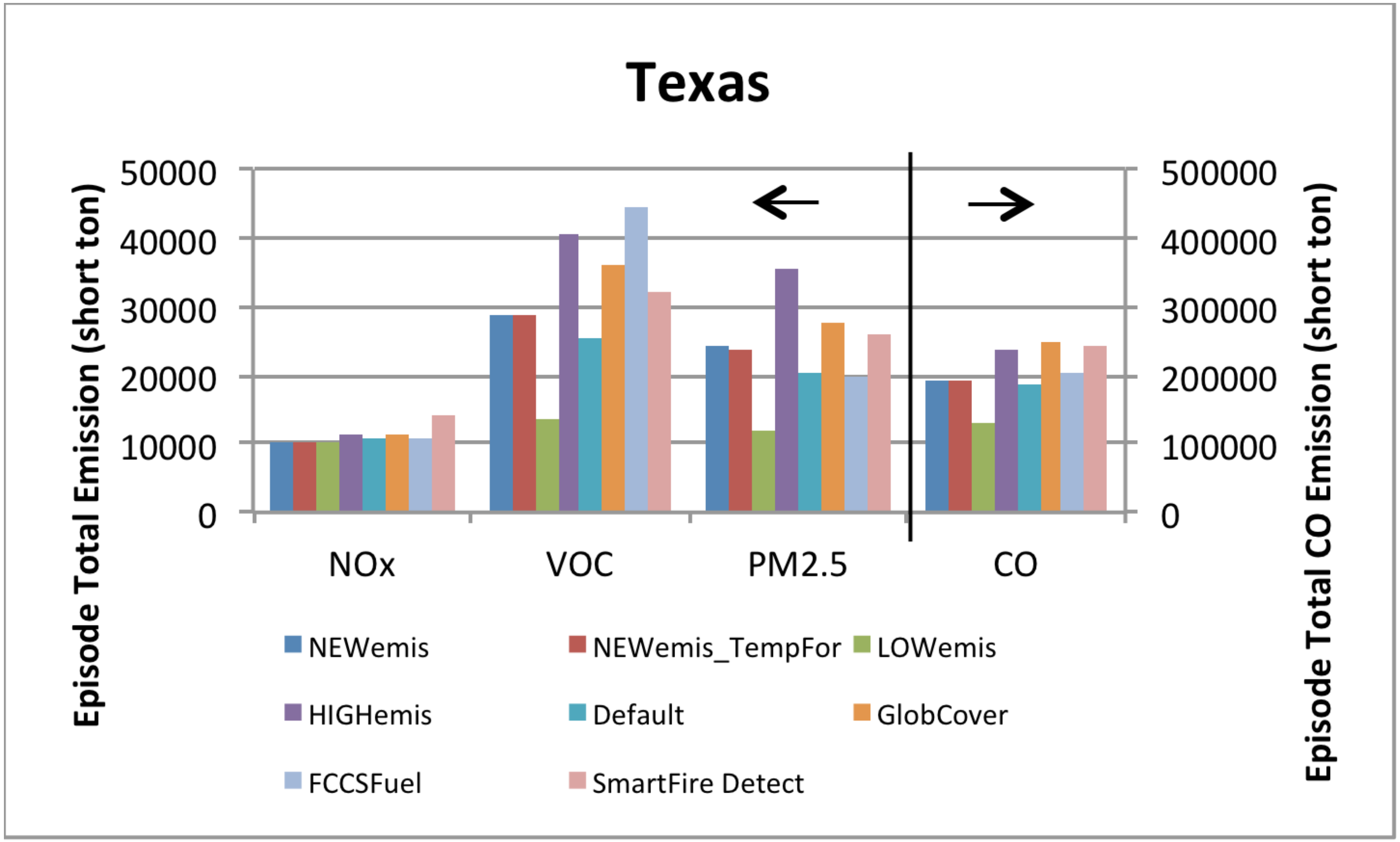
MODIS LCT



GlobCover

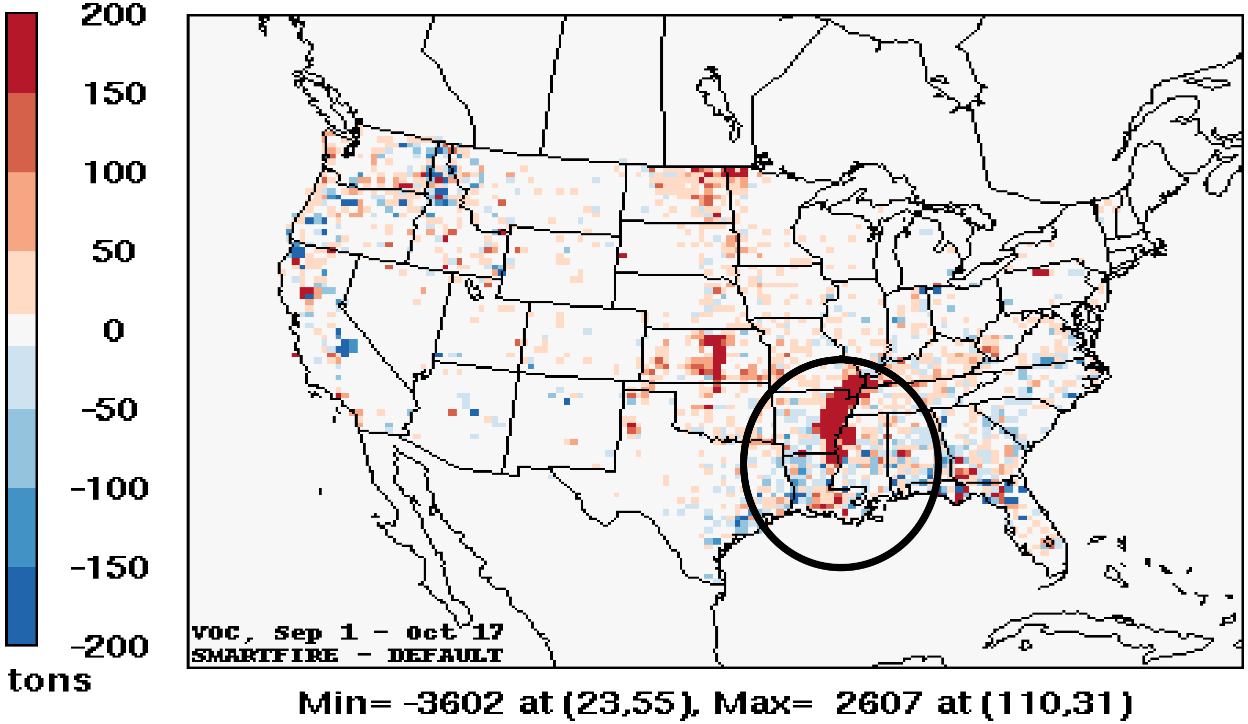
- Land cover classification influences fuel loading and emission factors.
- MODIS LCT has more area assigned as shrublands or grasslands in central and western U.S.
- GlobCover assigns more area as forest and shrublands.

Episode Total Emissions (short tons) from the FINN Default and Sensitivity Scenarios



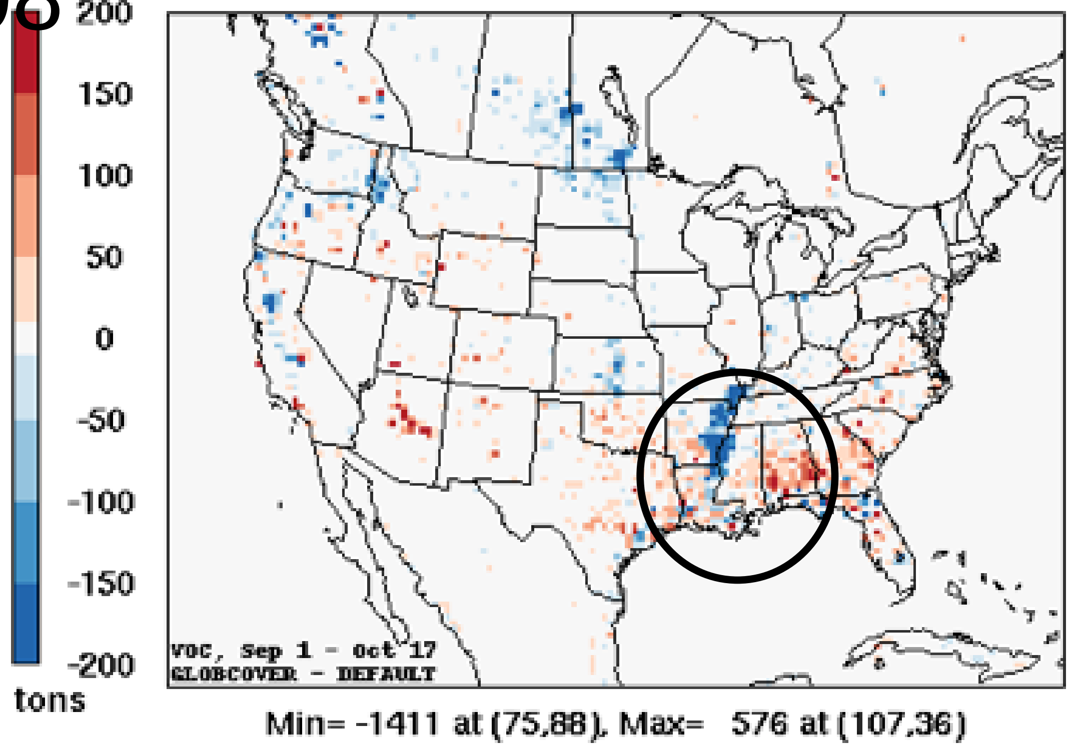
- Variability in emissions estimates can exceed a factor of two.
- Interactions between input parameters can be complex.
- Differences in geographic responses.

Difference in VOC Emissions Between SmartFire and FINN Default Scenarios: Sept. 1- Oct. 17 2008



- Arkansas: SmartFire identified 517 fires, 74,015 acres burned; 83% croplands. FINN default identified 261 fires, 53,000 acres burned, 54% croplands, 41% forests. VOC emission factor for croplands is double that for forests.
- In Texas, SmartFire identified 277 fires, 38,100 acres burned; FINN default identified 302 fires, 64,000 acres.

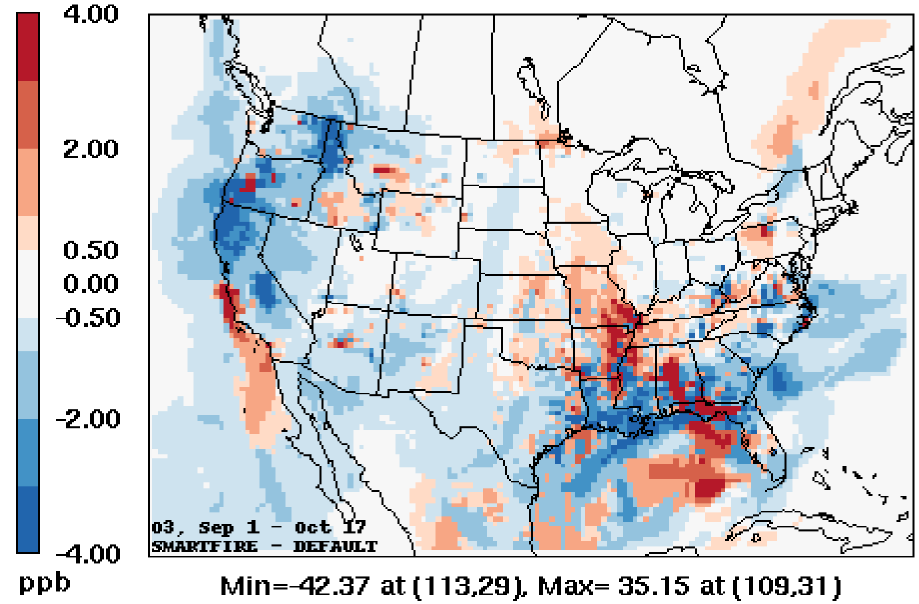
Difference in VOC Emissions Between GlobCover and FINN Default Scenarios: Sept. 1-Oct. 17 2008



- GlobCover land cover identified more forest than MODIS land cover product used in FINN default, which had more area identified as croplands, particularly in Arkansas.
- In most other areas, forests assigned by GlobCover produce higher emissions when they replace savanna/grasslands and shrublands.

Predicted Effects on Air Quality

- Minimal impacts on percentile concentrations over extended time.
- Maximum predicted differences in 8-hr ozone from modifications in FINN inputs ranged from 5 to >70 ppb.
- Particularly for FCCS and SmartFire scenarios in central and southeastern U.S. during spring and western and southern U.S. during late summer/early fall seasons and Globcover scenario in Mexico during spring.



Maximum absolute differences in 8-hour ozone (ppb) during September 1st – October 17th between the SmartFire and FINN default scenarios.

Recommendations

- Sensitivity simulations with FINN highlight potential variability in predicted fire emissions.

- Variability of region and season dependent.

- Key needs for improvement:
  - Fire detection
  - Croplands: Characterization and mapping; constrain estimates of burned area and fuel loading; reduce uncertainty in emission factors
  - Measurements and model validation
  - Land use/land cover mapping
  - Representation of U.S. forest types: classifications, specific fuel loadings and emission factors.