Targeted Improvements in the Fire INventory from NCAR (FINN) Model for Texas Air Quality Planning

Elena McDonald-Buller[1] (PI), Christine Wiedinmyer[2] (Co-PI), Yosuke Kimura[1], Chris Emery[3] (Co-PI), Zhen Liu[3]

[1]The University of Texas at Austin
[2]National Center for Atmospheric Research
[3]Ramboll Environ

AQRP Data Workshop – June 17-18, 2015
Project 14-011

NCAR | National Center for
UCAR | Atmospheric Research

RAMBOLL ENVIRON

Fires and Texas Air Quality

- Well-documented influence of fire events on Texas air quality.

  e.g., Junquera er al., 2005; Morris et al., 2006; McMillan et al., 2010; Villanueva-Fierro et al., 2009.

- The National Climate Assessment (2014) indicates increases in the number of days with temperatures over 100° F and the number of consecutive dry days and changes in water availability in Texas over the next several decades.

- Challenges of more stringent federal ozone standards will require accurate characterization fire events for air quality planning, exceptional event exclusions, estimates of NAB ozone concentrations.

MODIS imagery of detected fires in Texas on April 15, 2011, following the driest March on record.

Source: http://earthobservatory.nasa.gov/IOTD/view.php?id=50168

Understanding and Improving Estimates of Emissions from Fire Events

•During the current and previous AQRP cycles, our teams have collaborated to examine the effects of uncertainties in input parameters for the Fire INventory from NCAR (FINN) on emissions estimates, to improve the FINN model configuration, and to understand the influences on regional air quality.

- The Effects of Uncertainties in Fire Emissions Estimates on Predictions of Texas Air Quality (12-018). The project examined fire climatology in Texas and U.S. regions, compared emission estimates between FINN and BlueSky/SmartFire, evaluated the sensitivity of FINN emissions estimates to input parameters and data sources, and assessed the effects of FINN sensitivities on Texas air quality.

- Targeted Improvements in the Fire INventory from NCAR (FINN) Model for Texas Air Quality Planning (14-011). On-going project investigating targeted improvements in the characterizations of burned area, croplands, and plume rise and the sensitivity to land cover products.

Background

- FINN* is a global fire emissions model providing daily estimates of trace gases and particles from the open burning of biomass (wildfires, agricultural fires, and prescribed burning) at a resolution of ~1 km^2.

  **Wiedinmyer et al, 2011.*

- Widely used for global and regional air quality modeling studies**
  - High spatial and temporal resolution
  - Consistency across geopolitical boundaries
  - Chemical speciation profiles for VOCs (GEOS-Chem, MOZART-4, SAPRC99, MOZART-4 to CAMx CB05 and CB6)

  ***e.g., Tsao et al, 2011; Lin et al. (2012); Jiang et al. (2012); Young et al. (2012), Loughner et al. (2014)*

- FINN v.1 was released in 2010 and updated in 2011
- FINN v. 1.5 was released in 2014.

FINN Default Configuration and Data Sources

Emissions are estimated as:

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

where

E_i is the mass emission of species i (kg day^{-1})

$A(x,t)$ = area burned at time t and location x (km^2 day^{-1})

$B(x)$ = biomass loading at location x (g m^{-2})

FB is the fraction of biomass burned

ef_i is the emission factor of species i (g kg biomass burned^{-1})

- **Fire Detection:** MODIS Rapid Response (MRR) product provides daily fire detections with a nominal horizontal resolution of ~1 km^2. Constraints of one fire per day for each 1-km^2 hot spot and detection confidence $\geq$ 20%.

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

- **Land Cover:** MODIS Land Cover Type (LCT) product with a spatial resolution of 1 km^2 and 17 IGBP classifications mapped to 6 FINN categories associated with emission factors and fuel loadings.

- **Vegetation Density:** MODIS Vegetation Continuous Fields (VCF) product with spatial resolution of 500 m (scaled to 1 km^2) Describes percent tree, herbaceous, and bare ground cover.

- **Emission Factors:** From Akagi et al. (2011), Wiedinmyer et al. (2011), references therein for boreal forest, tropical forest, temperate forest, savanna and grasslands, woody savannas and shrublands, croplands.

- **Fuel Loading:** From Hoelzemann et al. (2004) modified according to Wiedinmyer et al (2011). Specified by global region (e.g. North America).

Insights from AQRP 12-018 and Previous Projects

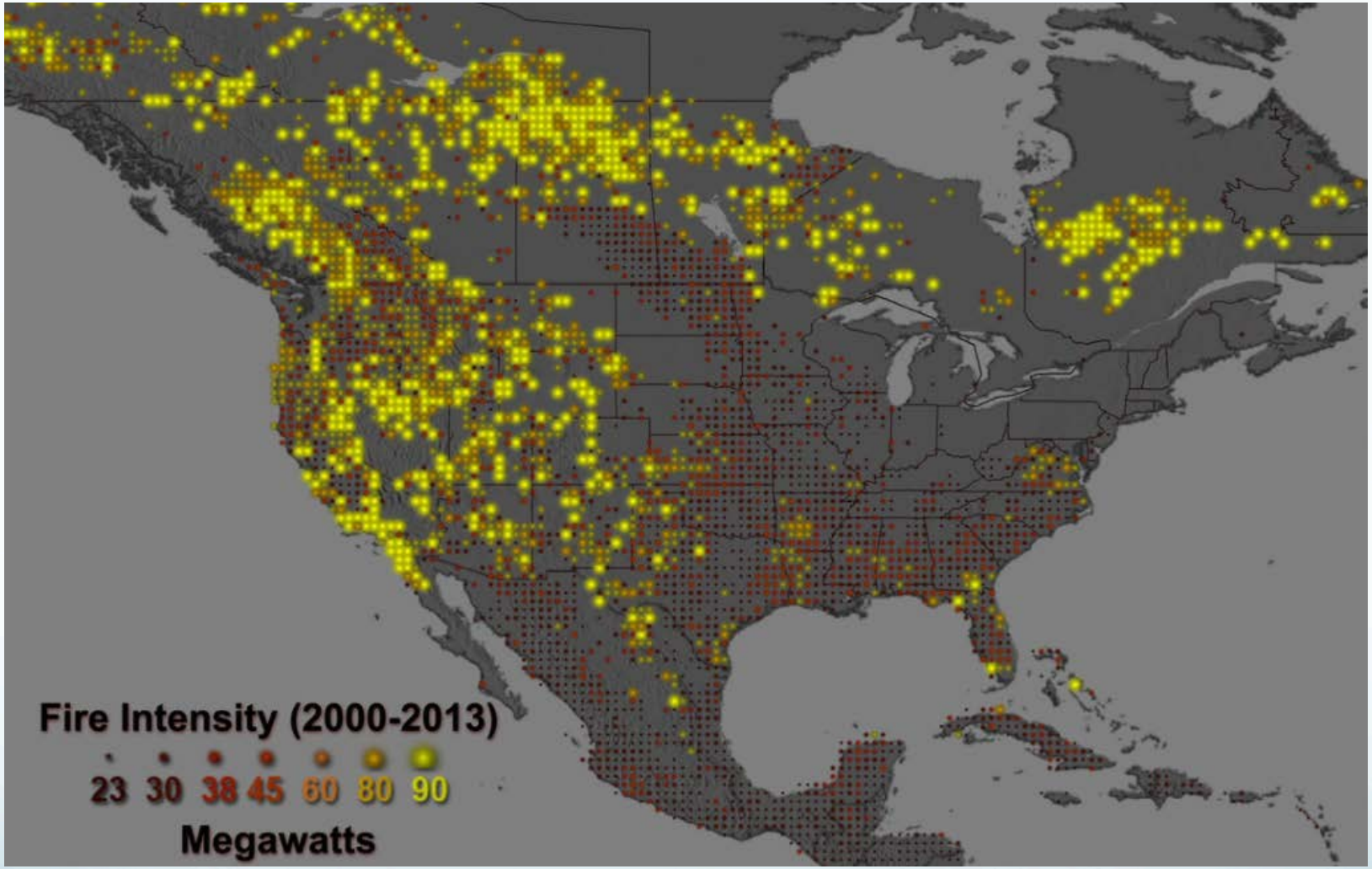
- Sensitivity studies used different input data sources for land cover, emission factors, fire detection/burned area, and fuel loading in FINN
  - Variability in fire emissions were season and region dependent
  - Differences in emissions estimates could exceed a factor of two
  - Substantial impacts on CAMx predictions of ozone and fine particulate matter concentrations during fire events
- Extensive efforts for land cover characterization within and surrounding Texas had not been leveraged for fire emissions modeling.
- Better characterization and constraints needed for agricultural areas with high fire activity.
- FINN algorithm tends to underpredict area burned especially for large wildfires.

Research Objectives

- *Make targeted improvements to the FINN model that will benefit the global and regional air quality management and research communities, with a special focus on needs for Texas.*

- Develop a new approach for estimating area burned of fire detections.
- Apply alternative land cover representations from emerging global, U.S. national, and Texas regional land cover products.
- Characterize croplands and incorporate new emission factors.
- Develop an initial approach for partitioning NO_x into aged NO_z forms to account for rapid NO_x oxidiation in fire plumes.
- Focus on FINN estimates and regional air quality predictions for fire events in 2012 to support TCEQ air quality modeling efforts.

Fire Activity in North America



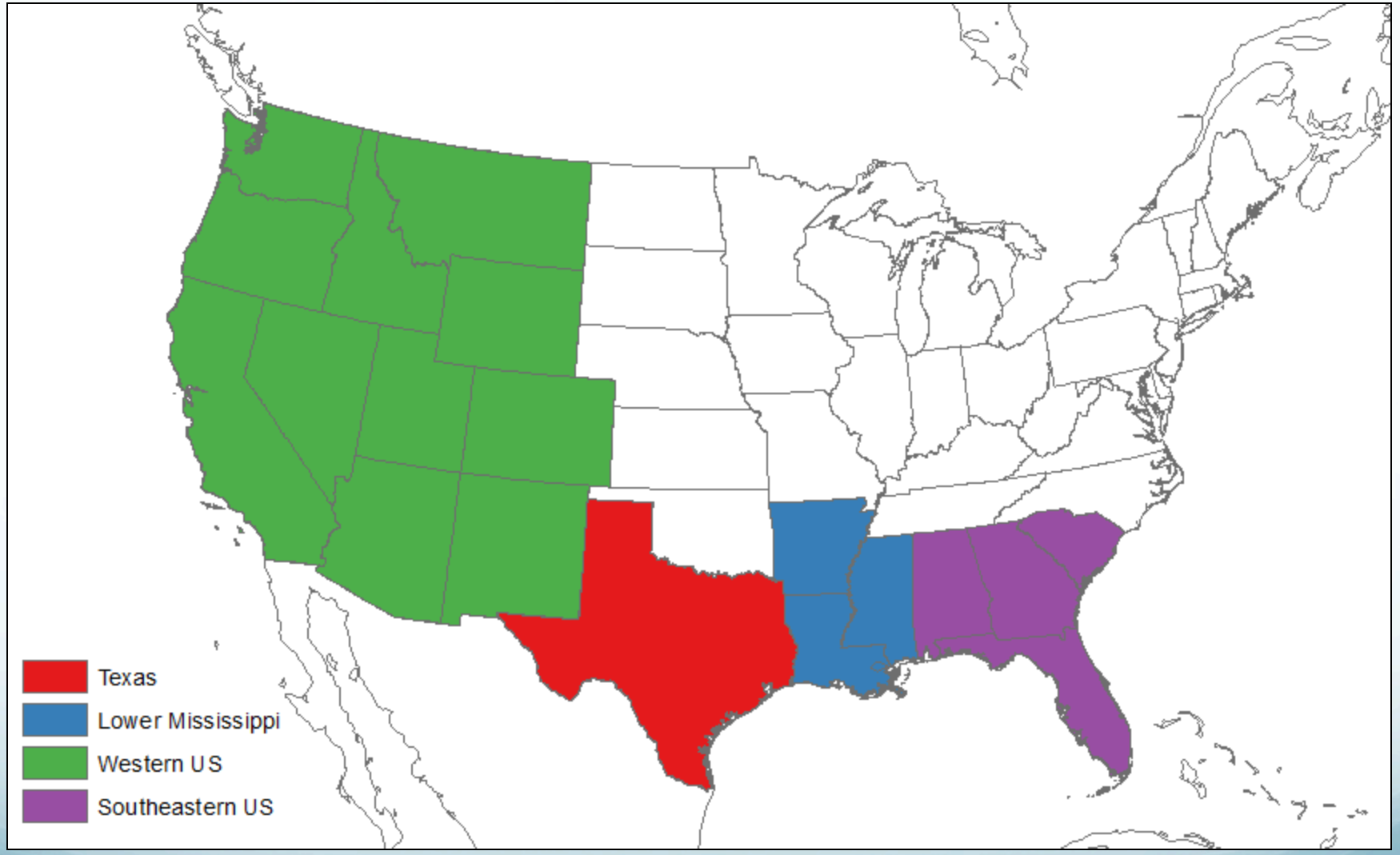
MODIS Mean Fire Radiative Power (FRP)

(high) – wildfires (yellow)

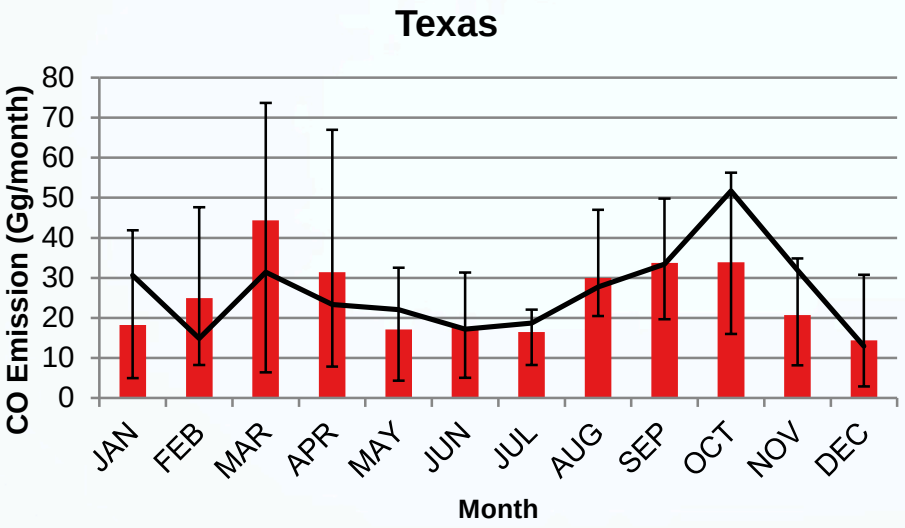
(low) – prescribed & agricultural fires (red)

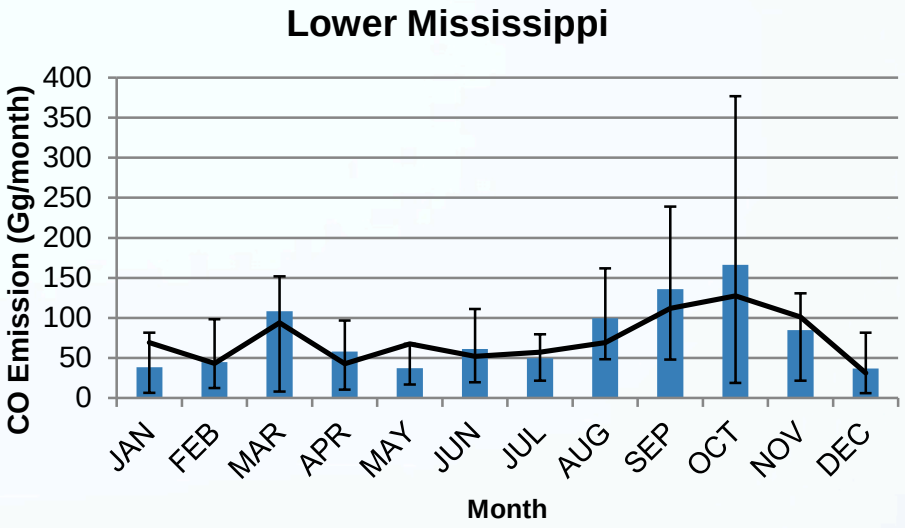
Source: http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4093

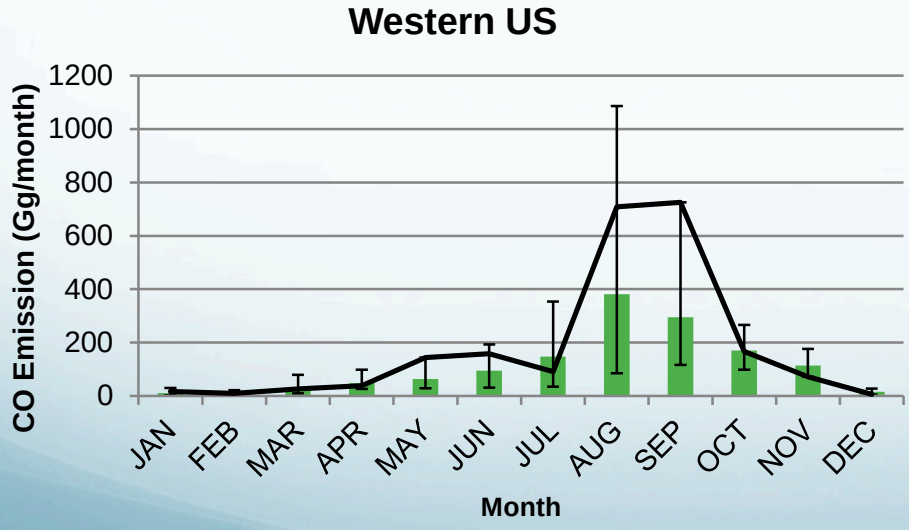
Geographic Focus

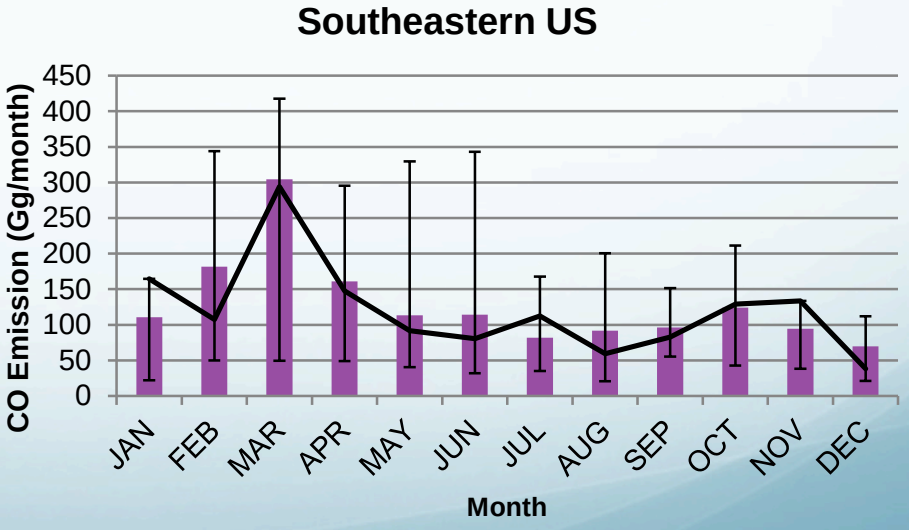


Distinct Seasonal Patterns Represented by Monthly CO Emissions: 2002-2014



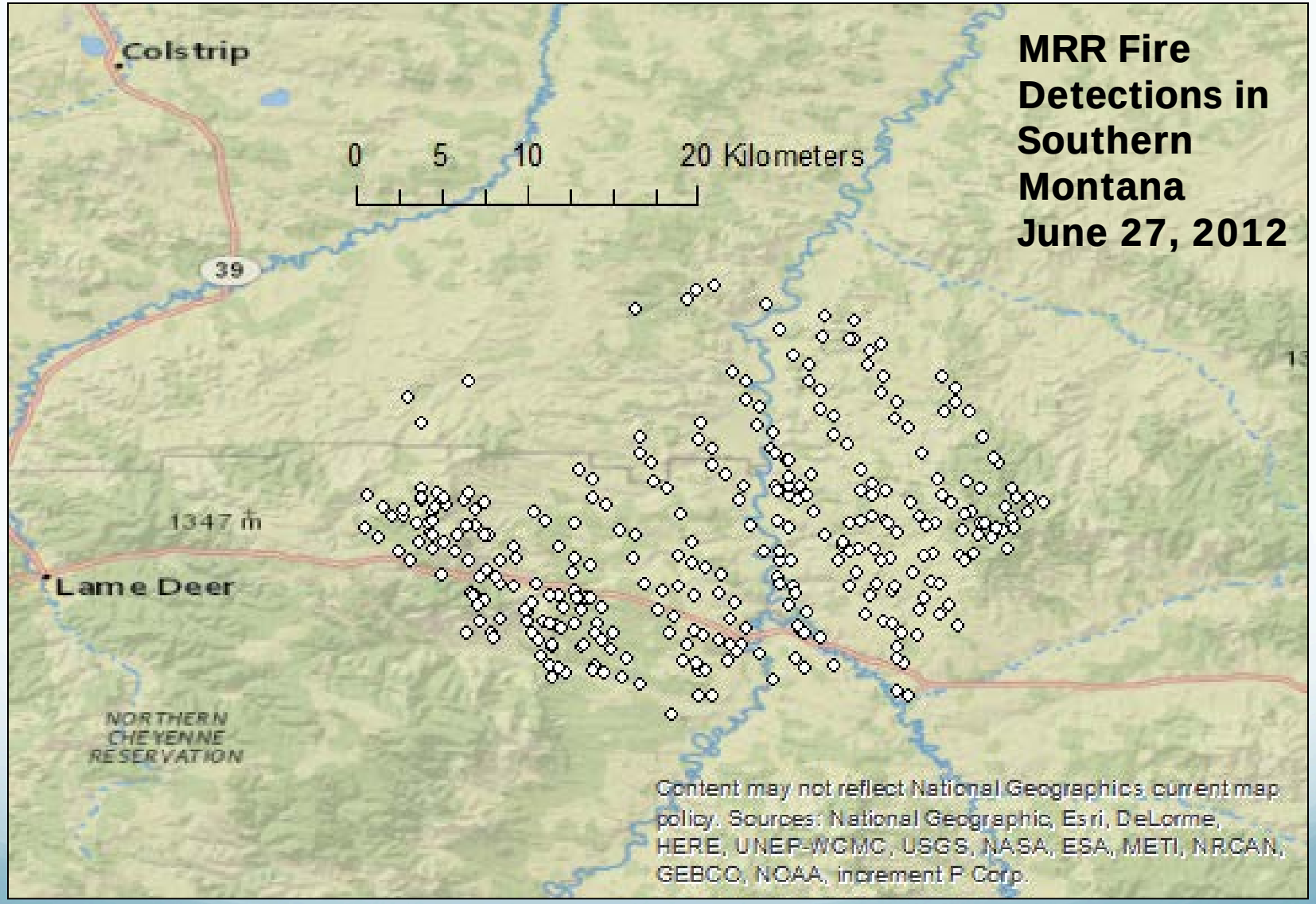




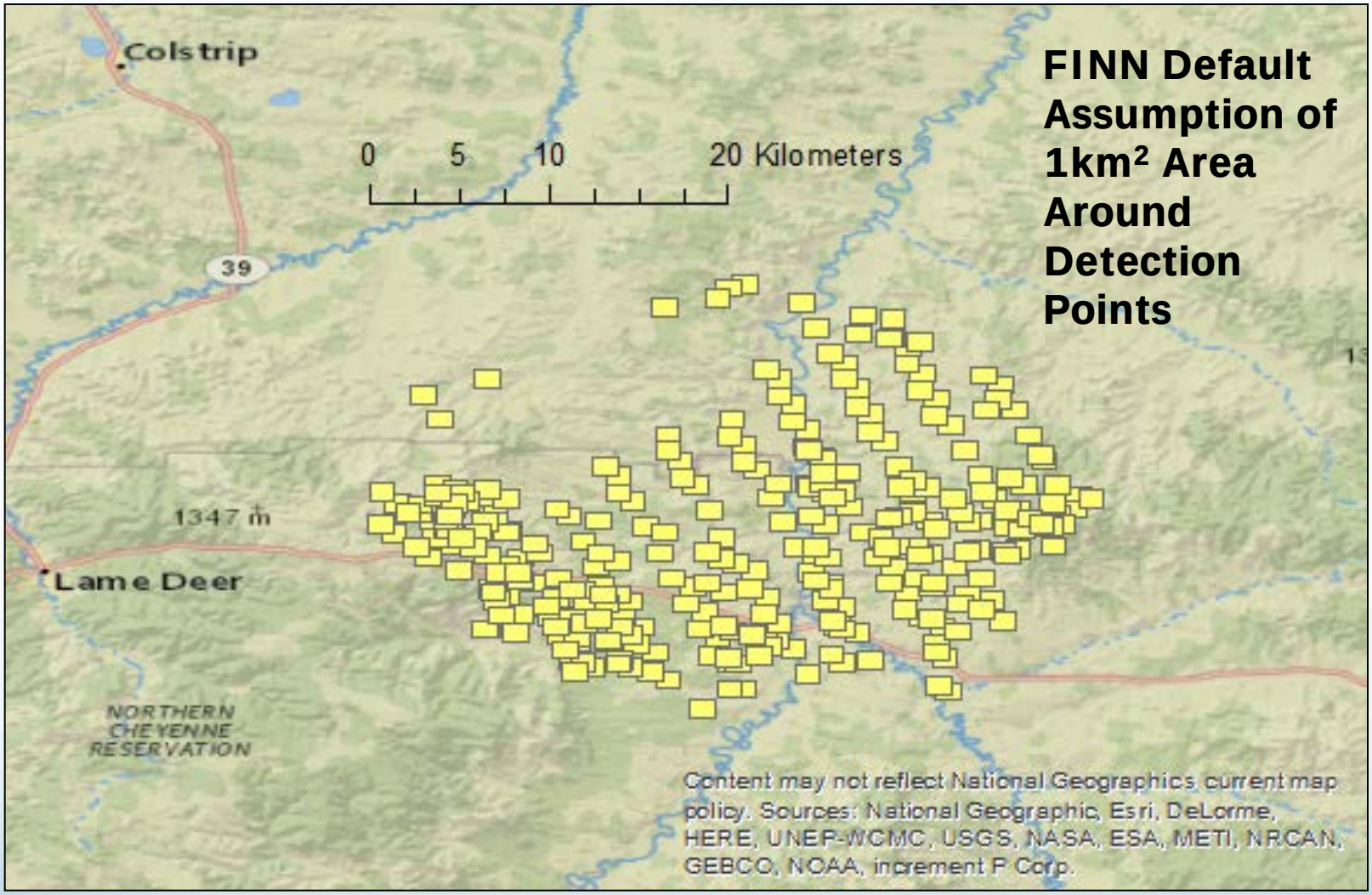


Columns shows 12-yr average FINNv1.5 with min/max as error bar.
Solid lines show emissions in 2012.

New Burned Area Algorithm



New Burned Area Algorithm



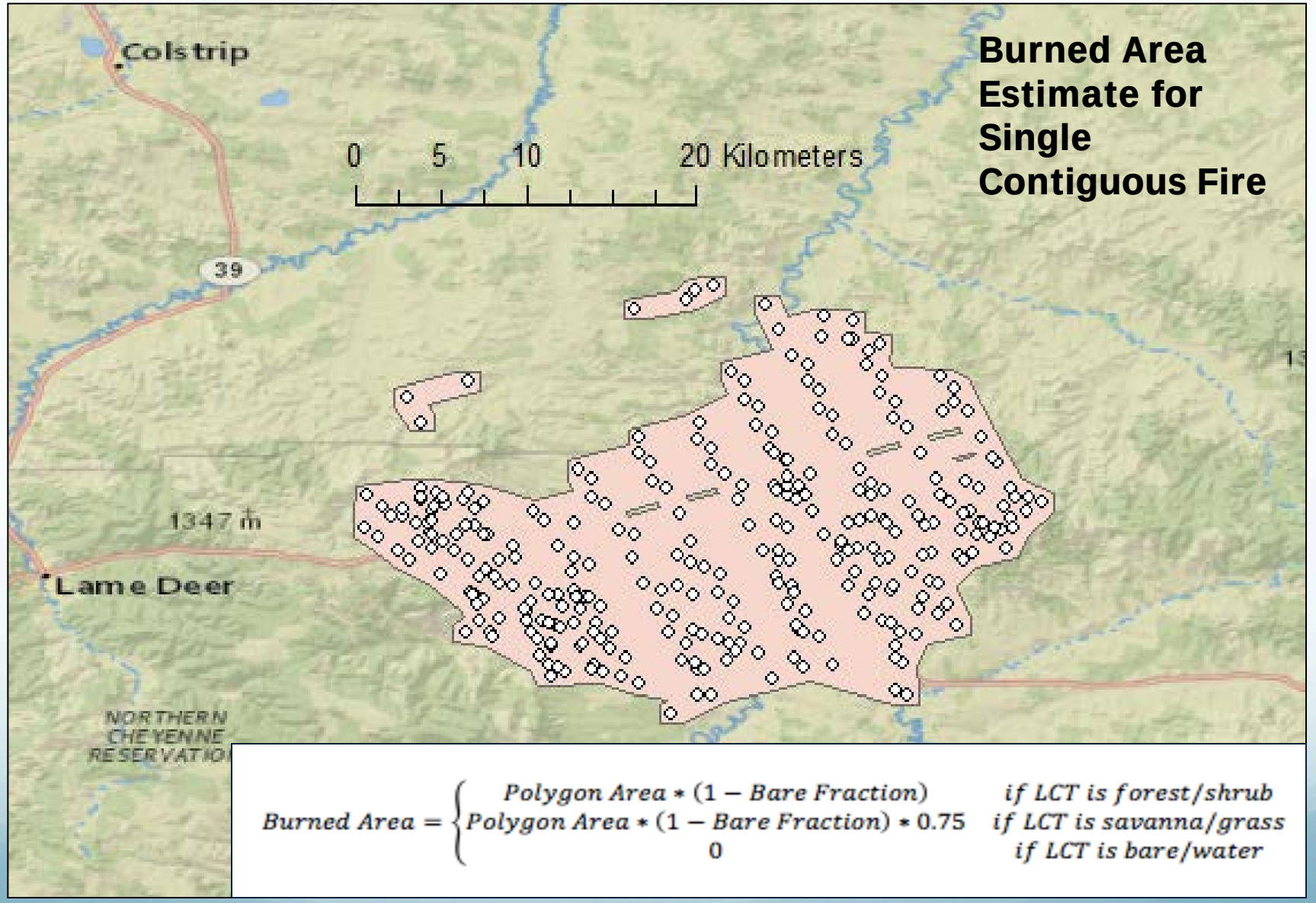
Part 1:

(1) Generate “detection rectangles” based on scan and track sizes of pixels

(2) Generate “detection clusters” based on overlap

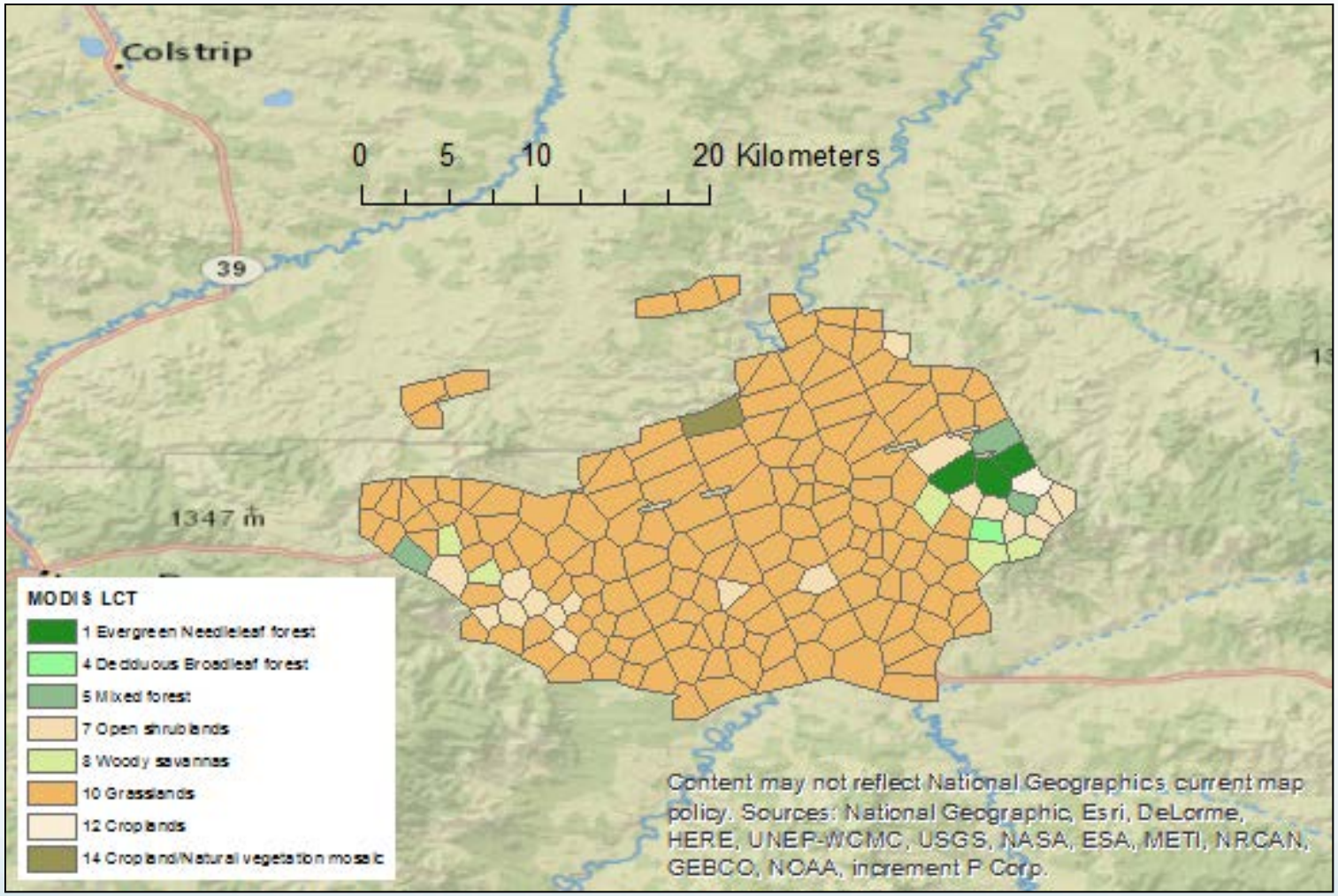
(3) Form convex hulls for intersecting clusters and dissolve to form fire polygon

New Burned Area Algorithm



$$Burned\ Area = \begin{cases} Polygon\ Area * (1 - Bare\ Fraction) & if\ LCT\ is\ forest/shrub \\ Polygon\ Area * (1 - Bare\ Fraction) * 0.75 & if\ LCT\ is\ savanna/grass \\ 0 & if\ LCT\ is\ bare/water \end{cases}$$

Land Cover within Fire Polygon

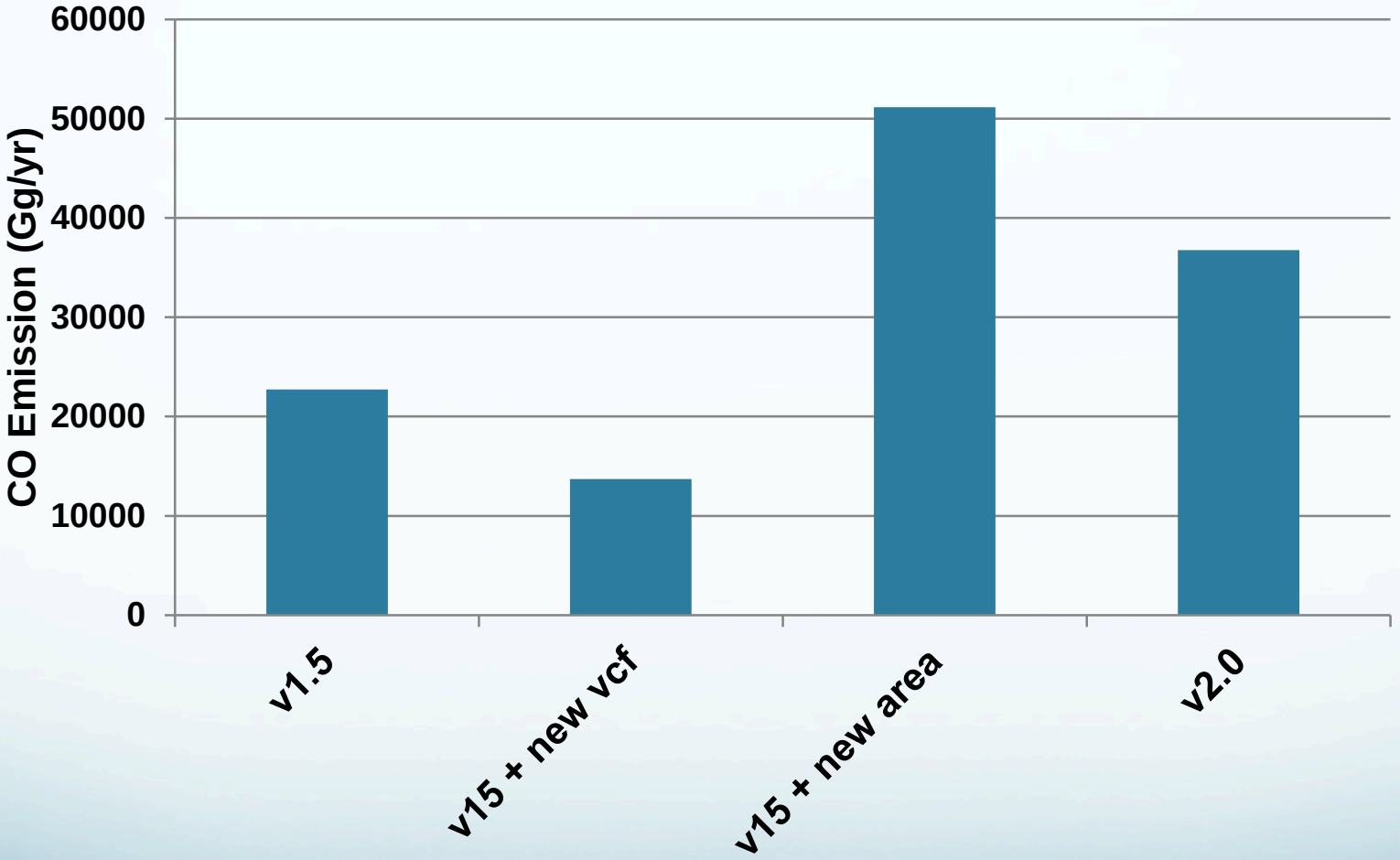


Part II:

(1) Process subdivided fire polygon with a specific land cover raster

(2) Overlay fuel loading data: The U.S. Forest Service's Fuel Characteristic Classification System (FCCS) was used for CONUS; FINN default elsewhere.

Changes CO Emissions Estimates Due to FINN Updates

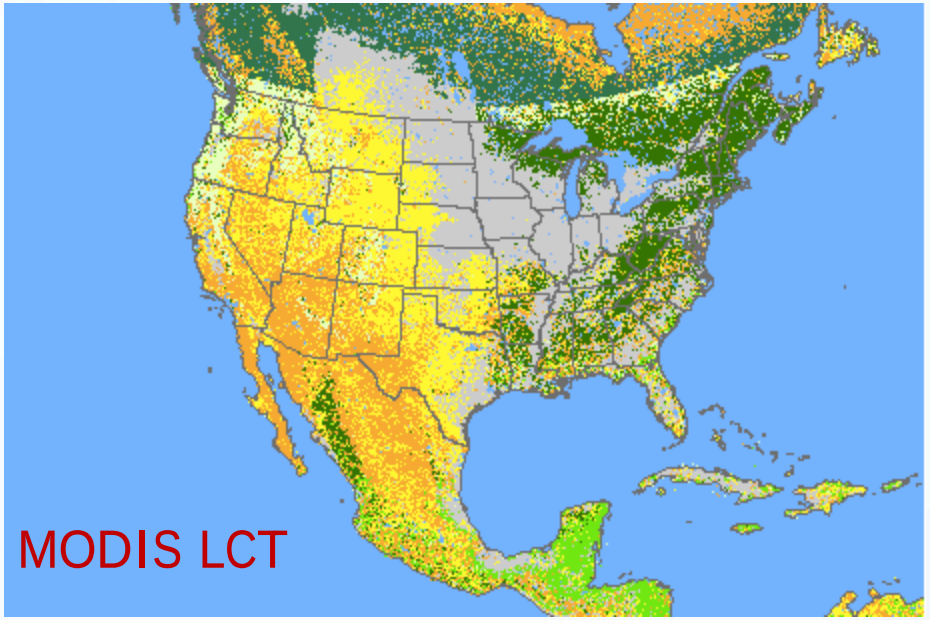


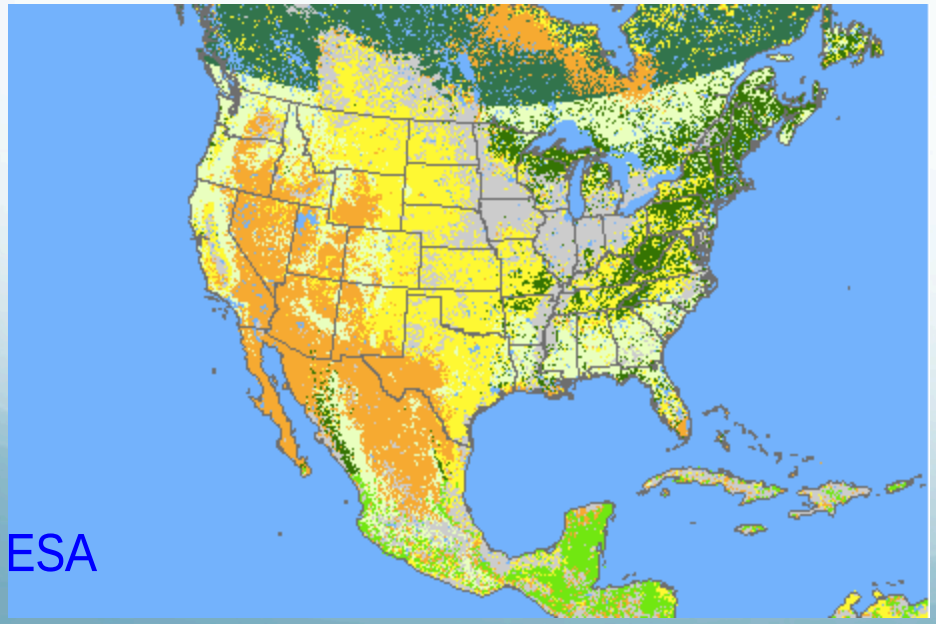
Values show annual emissions for RPO 36-km domain (outer-most CAMx domain)
All results based on use of MODIS LCT for land cover type

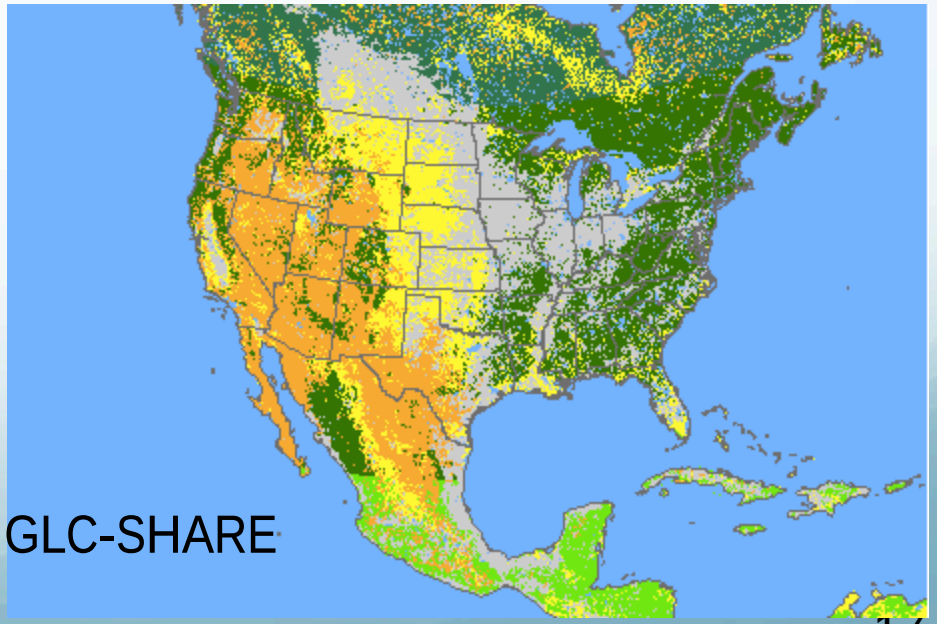
Alternative Land Cover Representations: Global Products

- MODIS LCT (FINN default)
- Global Land Cover – SHARE (GLC-SHARE) from the United Nations Food and Agriculture Organization
- European Space Agency (ESA) Climate Change Initiative (CCI)

Land Cover
Grassland
Shrub
Tropical Forest
Temperate Forest
Boreal Forest
Temperate Evergreen Forest
Crop (Generic)



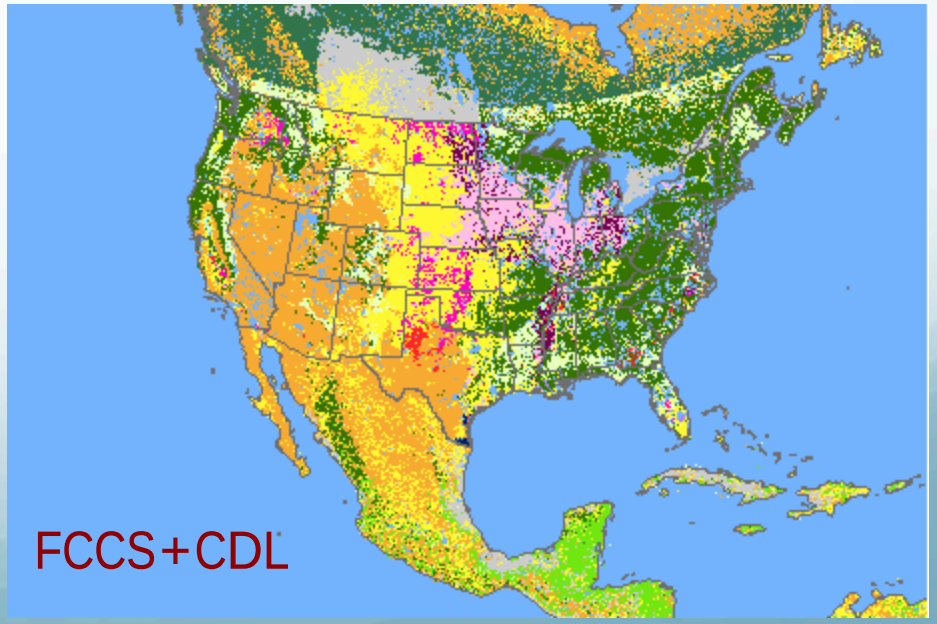




Alternative Land Cover Representations: U.S. National Products

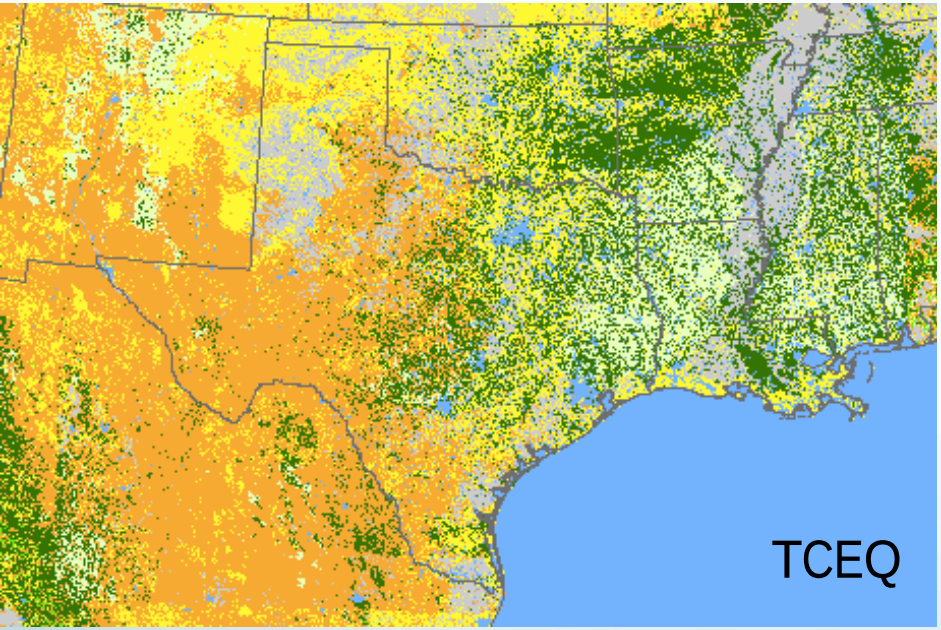
- U.S Forest Service Fuel Characteristic Classification System (FCCS)
- National Agricultural Statistical Service Cropland Data Layer (CDL)

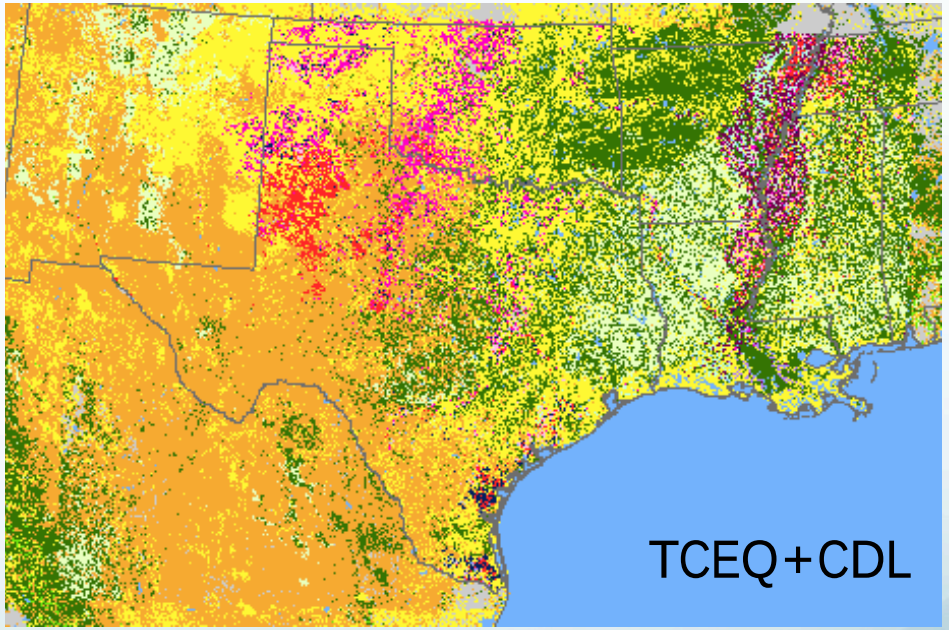
	Fuel Loading (kg/m^2)	CO Emisssion Factor (g/kg)
Crop (Generic)	0.66	53
Rice	0.67	64
Wheat	0.66	55
Cotton	0.38	73
Soy Bean	0.56	69
Corn	1.62	53
Sorghum	0.66	64
Sugar Cane	1.50	59



Alternative Land Cover Representations: Texas Regional Product

- Developed by Popescu et al. (2011) for the TCEQ.





Sensitivity Studies: Alternative Land Cover Representations

Global:

SCENARIO #1 = MODIS LCT ONLY
SCENARIO #2 = GLC-SHARE ONLY
SCENARIO #3 = ESA ONLY

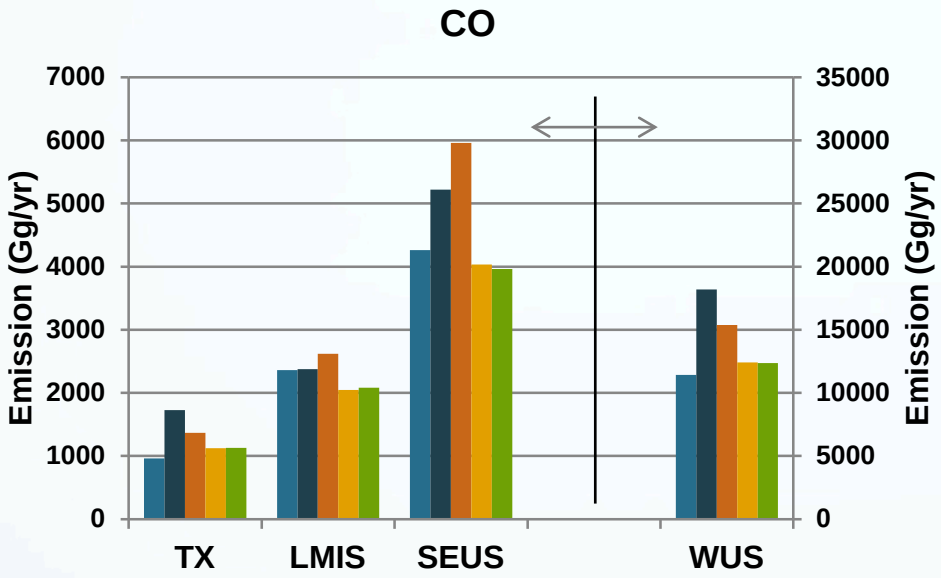
U.S. National:

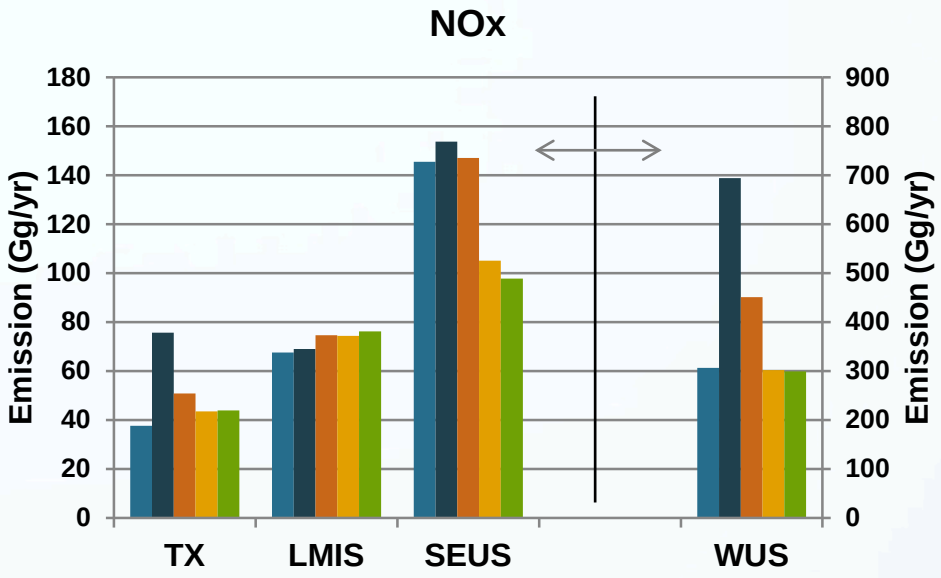
SCENARIO #4 = FCCS in CONUS & MODIS LCT Elsewhere
SCENARIO #5 = FCCS/CDL in CONUS & MODIS LCT Elsewhere

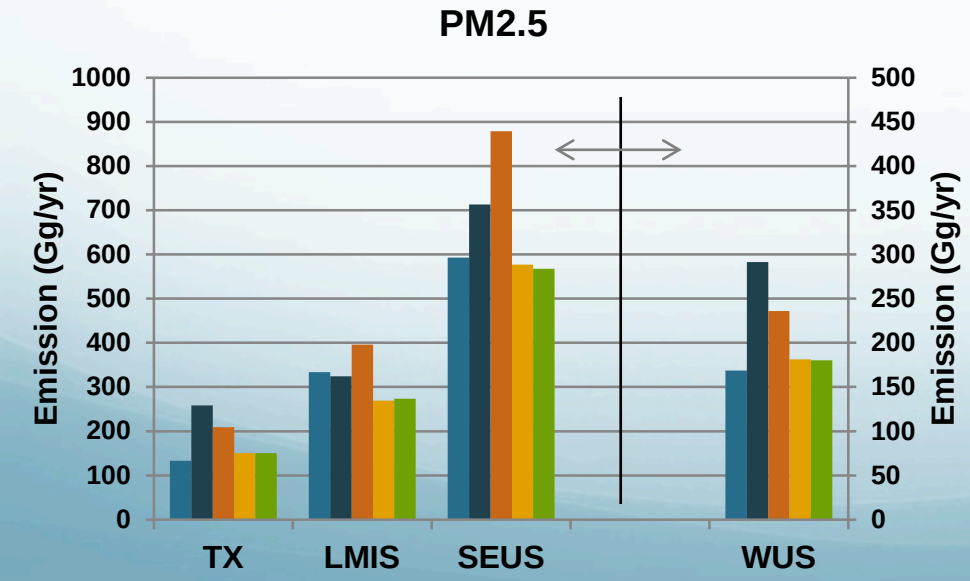
Texas Regional:

SCENARIO #6 = TCEQ in Texas Regional Domain, FCCS in rest of CONUS, LCT Elsewhere
SCENARIO #7 = TCEQ/CDL in Texas Regional Domain, FCCS/CDL in rest of CONUS, LCT Elsewhere

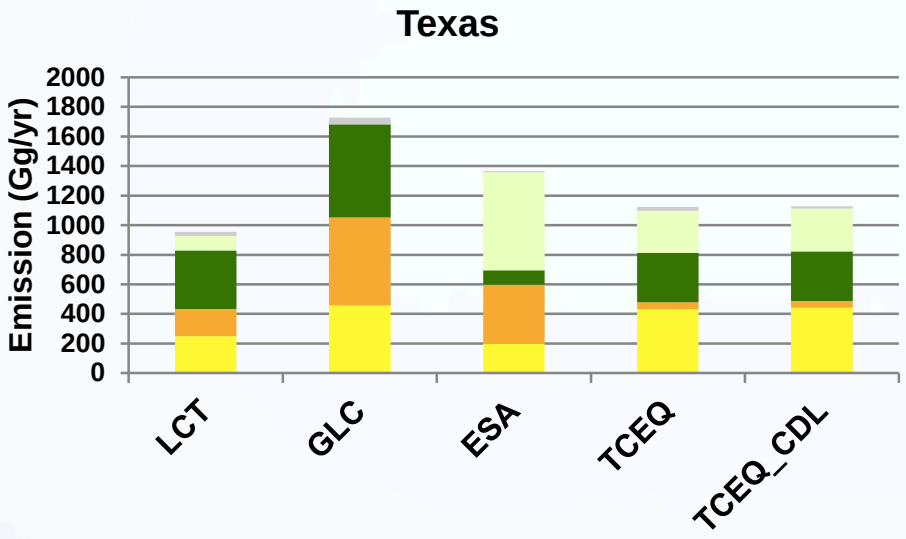
Annual Emissions By Region

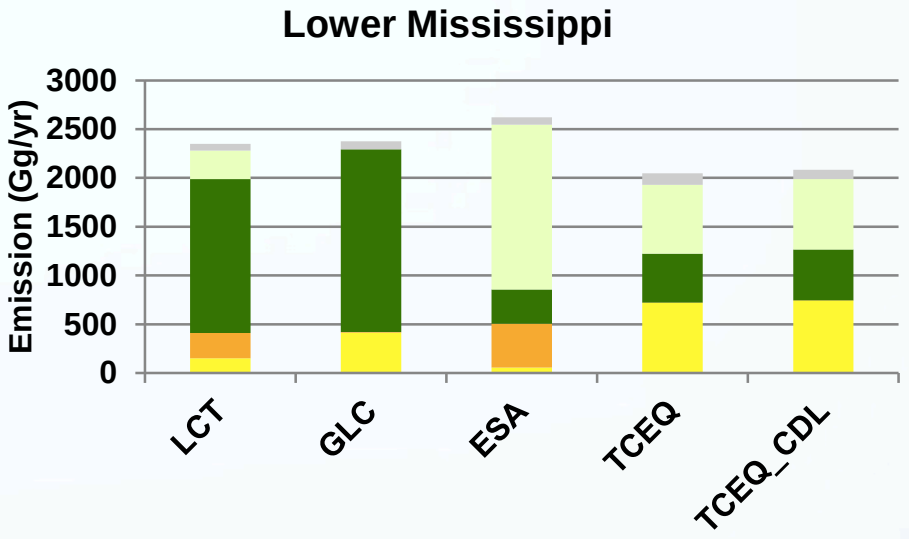


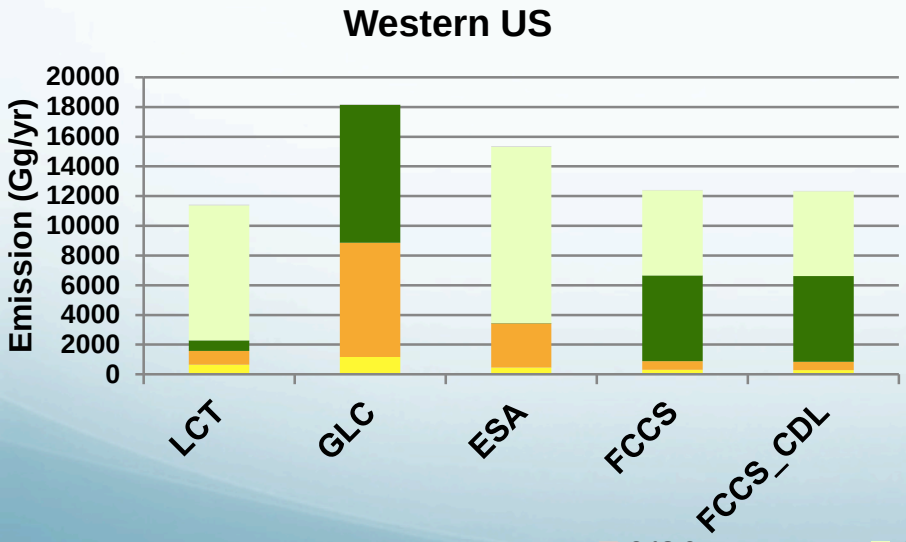


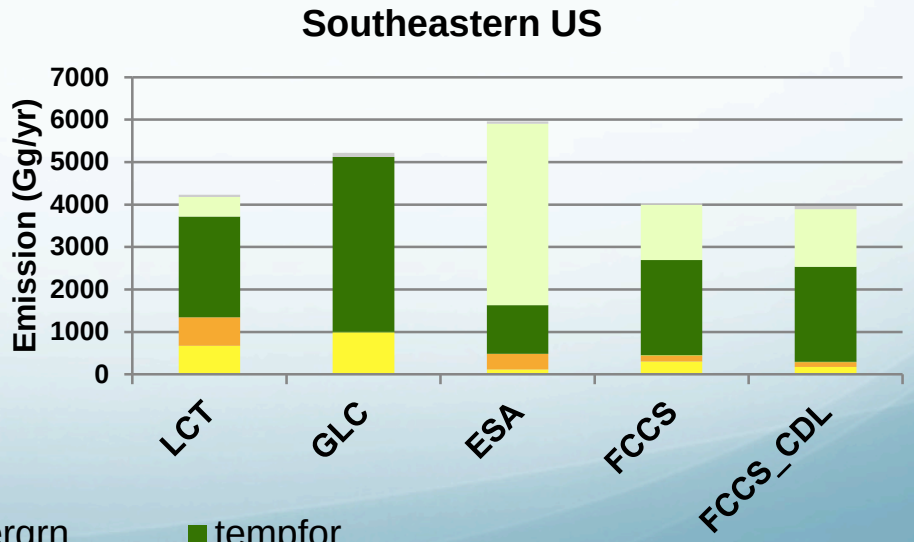


Annual CO Emissions By Land Cover Class



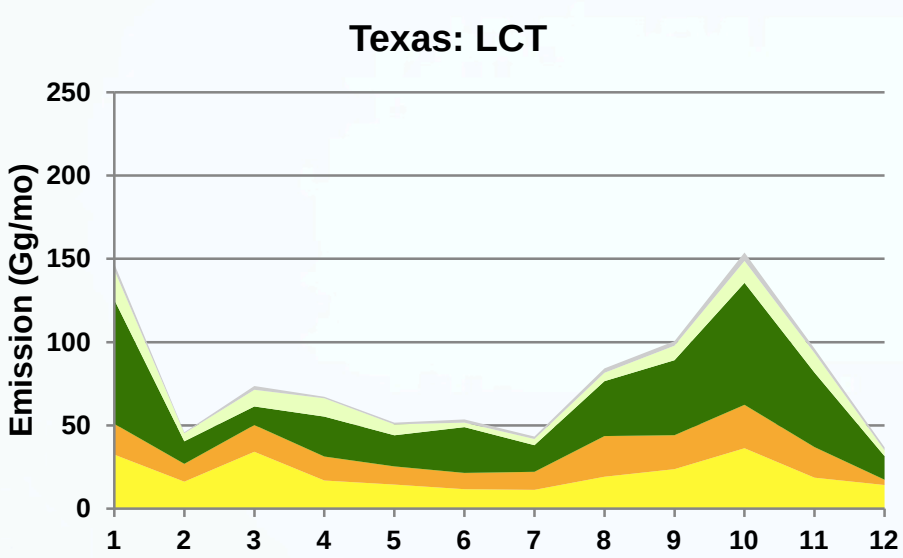


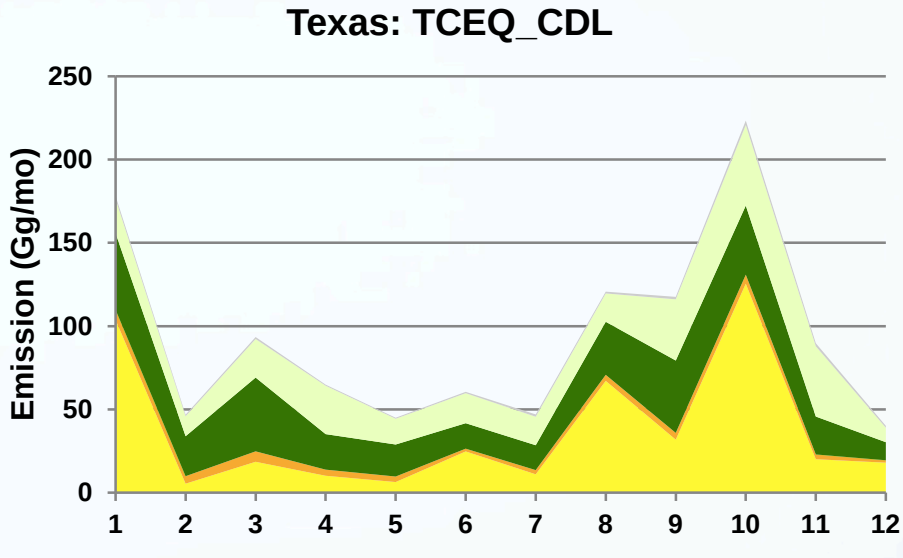


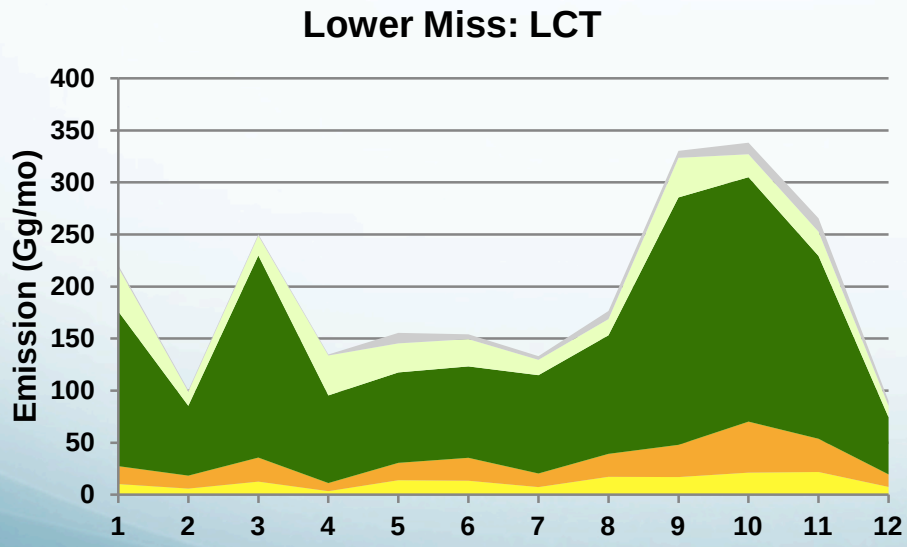


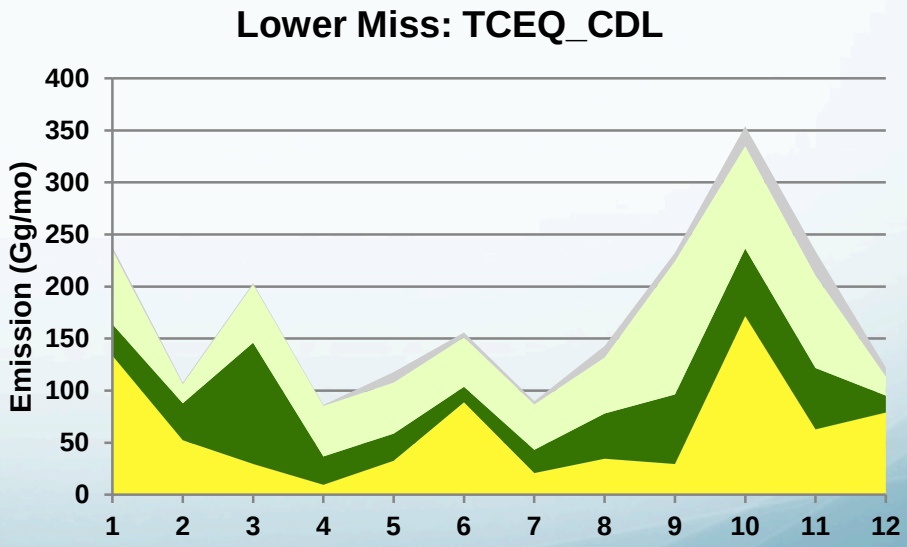
crop evergrn tempfor
tropfor shrub grass

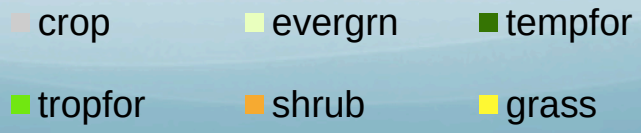
Monthly CO Emissions By Land Cover Class



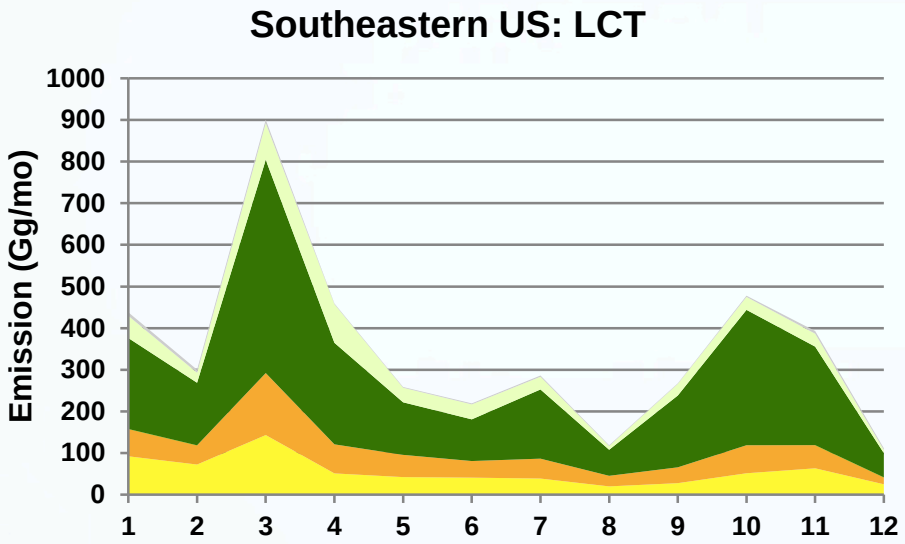


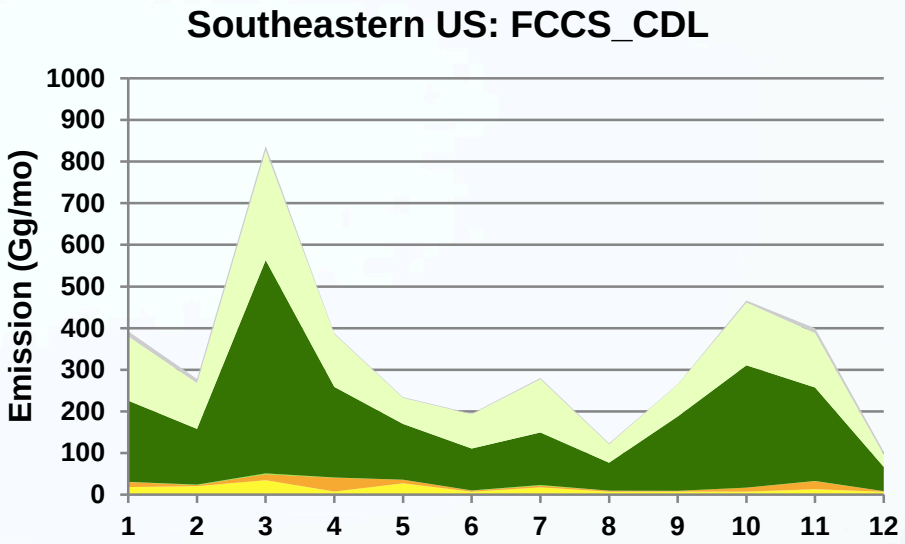


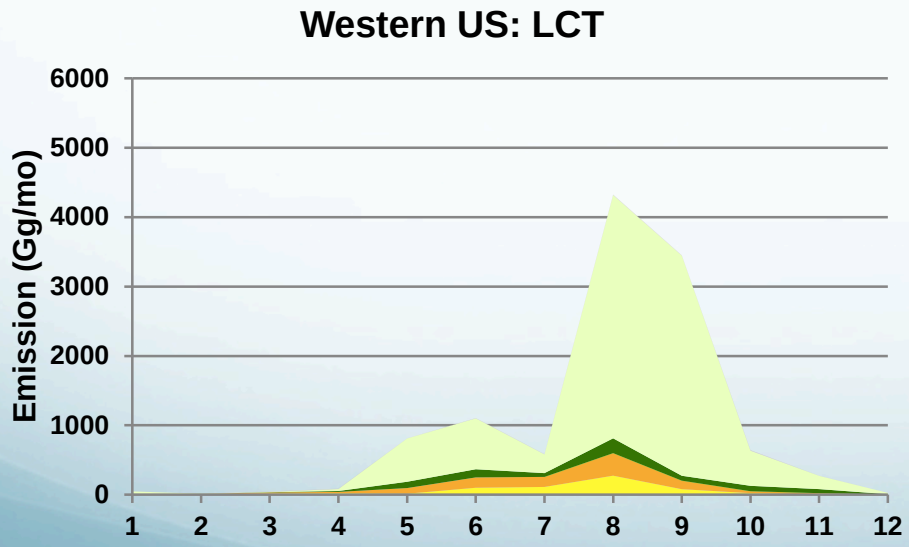


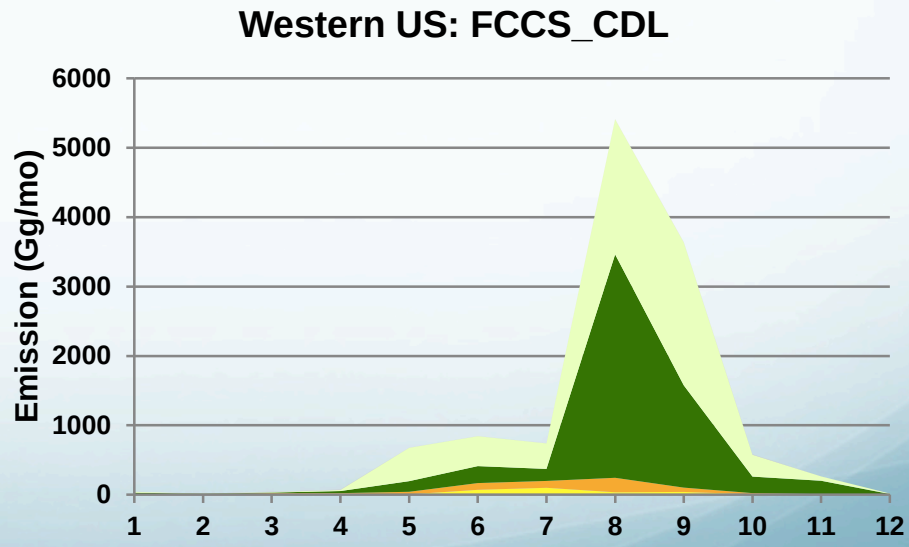


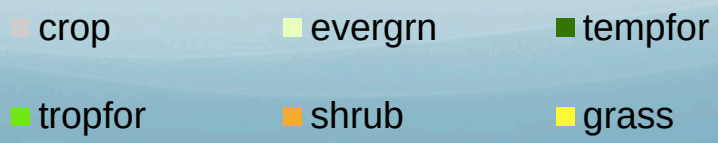
Monthly CO Emissions By Land Cover











Sub-Grid Scale Partitioning of NO_x Emissions to NO_z in Fire Plumes

- *Observations via surface and aircraft monitoring indicate mixed ozone impacts from fires. Yet chemical transport models consistently show large surface ozone impacts from fire sources. Representation of chemical processes may contribute to discrepancies between modeled and observed ozone impacts.*

- Investigate approaches to partition NO_x emissions to aged NO_z compounds (e.g., HNO_3 and PAN) to account for rapid NO_x oxidation in fire plumes at sizes below grid scales

- ENVIRON conducted a literature review of field studies (ARCTAS-B) and modeling approaches (e.g., Alvarado et al., 2013).

- Developing approach to re-speciate FINN NO_x emissions to NO_z compounds in EPS by fire size relative to grid resolution and plume rise.

CAMx Sensitivity Studies

- 2012 Episode
- Earlier version of FINN used for fire emission estimates
- Sensitivity studies will examine effects of land cover and burned area characterization and plume chemistry

Nested Modeling Domain

Summary

- Updates and improvements made to FINN that will result in next generation public release (FINN v.2)
  - Emission factors
  - Burned area processing
  - Land cover and fuel loading

- Sensitivity of model upgrades and input choices are being evaluated
  - Emissions are highly sensitive to land cover inputs, in particular representation and validation of forest coverage is critical
  - Greater specificity in crop types in Texas and surrounding states does not appear to have substantial impacts on emission estimates, but we will look at other regions of US this summer.
  - We will examine CAMx O_3 predictions from “high” and “low”

Acknowledgments

- Kevin Sampson – NCAR
- Jim Mackay – TCEQ Liaison
- Dave Sullivan - AQRP Project Manager
- Maria Stanzione - AQRP Grant Manager