Satellite-Based Estimates of Cropland Burning and Related Emissions: Results from the Contiguous United States and the Russian Federation

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13 July 2010

Rationale for the study: Contiguous U.S.

- **Agricultural and Rangeland Biomass Burning Emissions**
- **Air Quality**
  - **Health and Safety Issues**
    - **Cardiopulmonary diseases**
    - **Visibility**
  - **CO, SO_2, NO_2, $PM_{2.5}$, PM_{10}**
    - **National Ambient Air Quality Standards (NAAQS)**
- **Climate Change**
  - **CO_2, CO, CH_4**
    - **North American Carbon Program (NACP)**
- **Carbon Budget**
  - **Integrate into existing carbon models for wildland fire**

Rationale: Russian Federation

- **Agricultural Biomass Burning Emissions**
- **Black Carbon**
  - **Arctic highly sensitive to short-lived climate forcers (SLFs); black carbon**
  - **Black carbon may account for 30% of Arctic warming**
  - **Ag fires occur during Arctic spring – when ice/snow melting**
- **Regulations have poor enforcement**
  - **Crop residue burning is technically illegal**
  - **Monitoring systems are ground-based**

Smoke from field burning in distance in eastern Russia (Clean Air Task Force)

Definitions

- Croplands
  - Established crop areas that produce food, fiber, and seeds
  - Fallow fields
- CONUS: Bluegrass, Corn, Cotton, Rice, Soy, Sugarcane, Wheat, Other/Fallow
- Russia: Wheat, Canola, Sugarbeets, Other/Fallow

- Crop Residue Burning:
  1. Post-harvest or pre-planting burning for removal of ground-level senescent vegetation;
  2. Pre-harvest burning for removal of leaves and other biomass (sugarcane).


Wheat residue burning in Arkansas


Sugarcane burning in Florida

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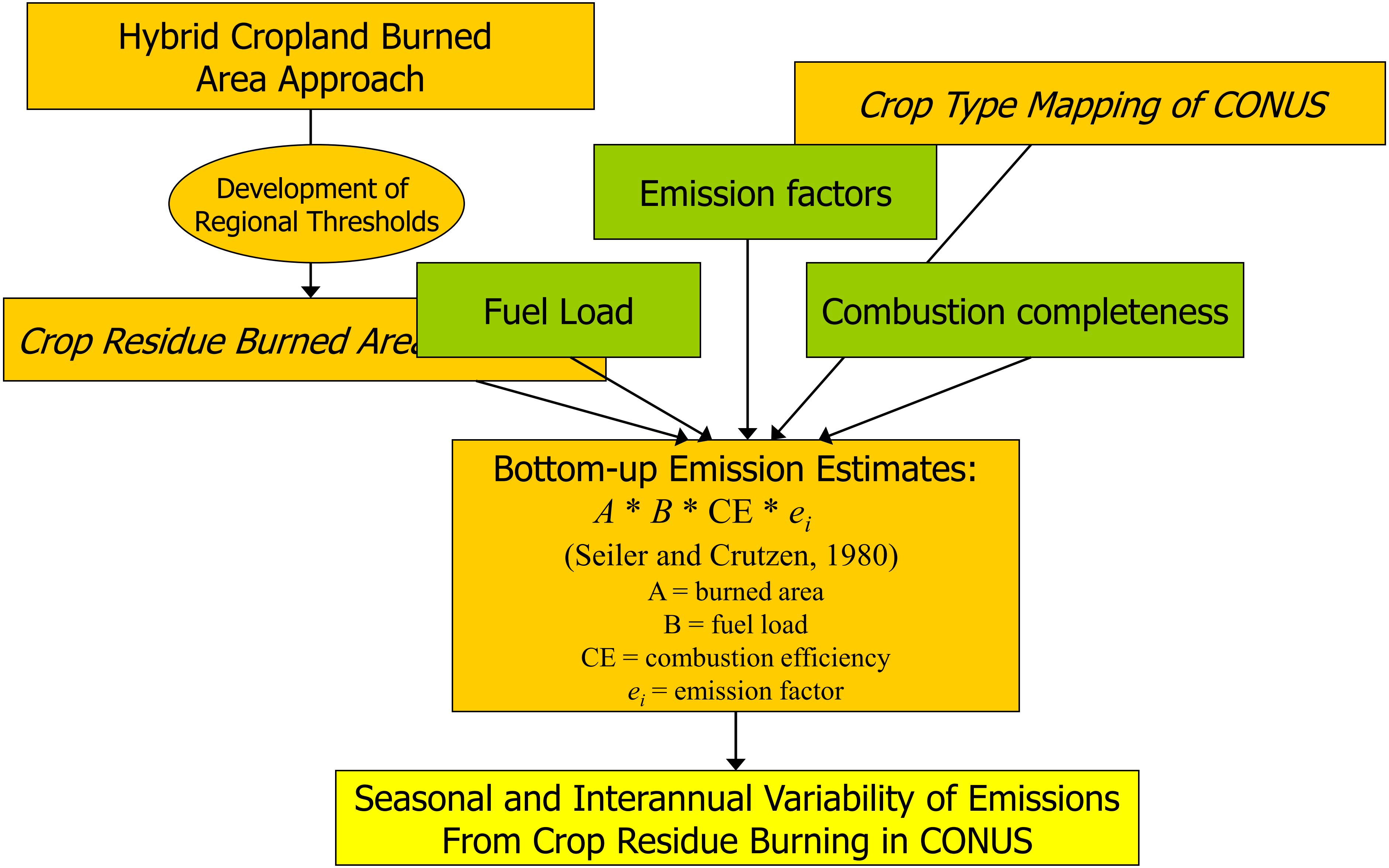
Focus: Crop Residue Burning in CONUS

Research Design



Cropland Burned Area

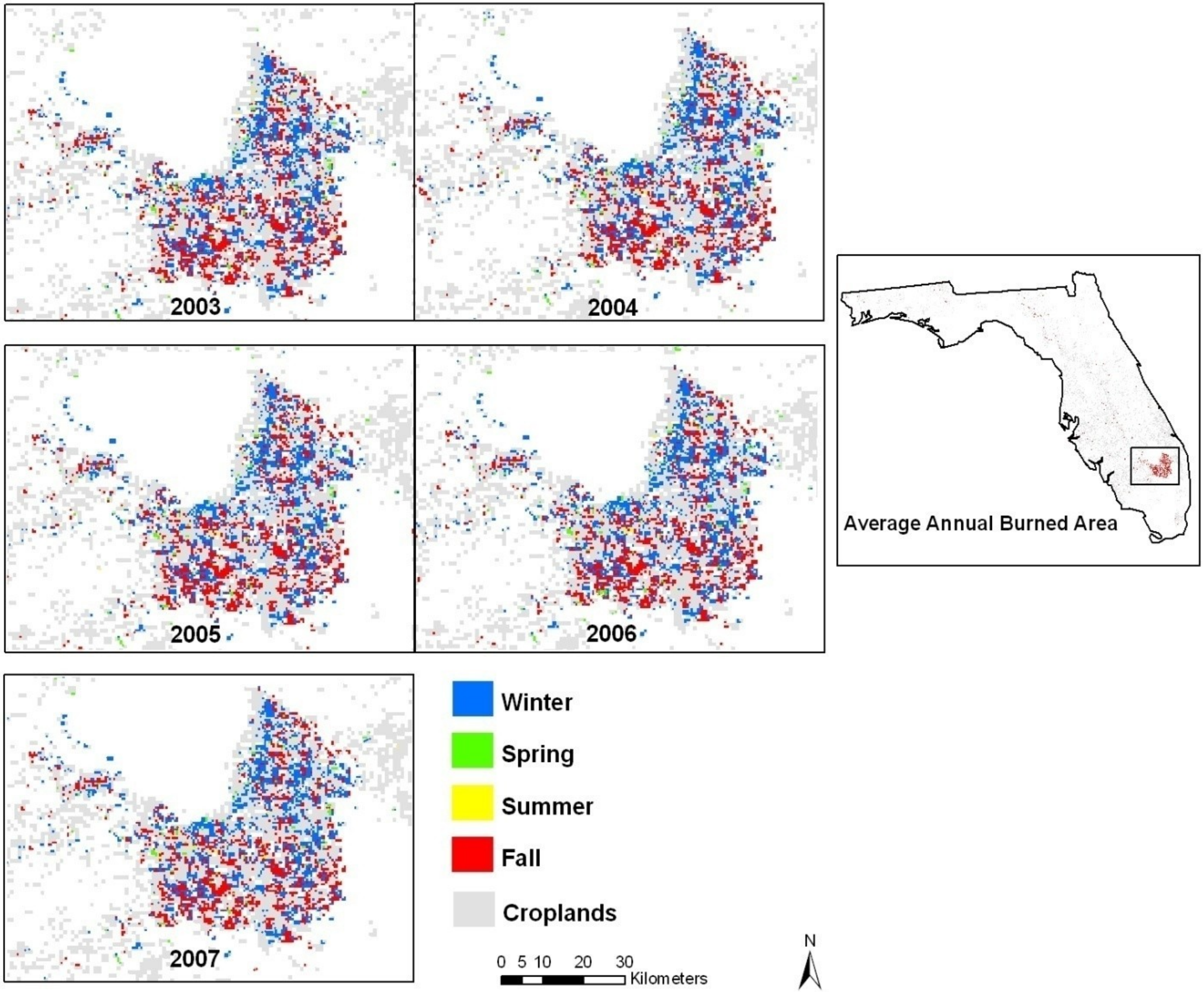
Hybrid approach (McCarty et al., 2008)

- Difference Normalized Burned Area (dNBR)

  NBR = (band2 – band7)/(band2 + band7)

  - 500 m MODIS 8-day surface reflectance (MOD09A1)
    - ~ 2.1 μm range (band 7)
- Regional thresholds development *in-situ* data and high resolution burn scar maps
  - High resolution data (ASTER and Landsat)
  - GPS data from field campaigns
- Average burned area for active fire detections
  - 1 km MODIS Active Fire/Thermal Anomalies (MOD14)
    - Detect fires as small as 100 m^2 (Giglio et al., 2003)

- Combine remotely sensed burned area estimates with active fire detections
- Validation with *in-situ* data and high resolution burn scar maps


2003
2004
2005
2006
2007
Winter
Spring
Summer
Fall
Croplands
0 5 10 20 30
Kilometers
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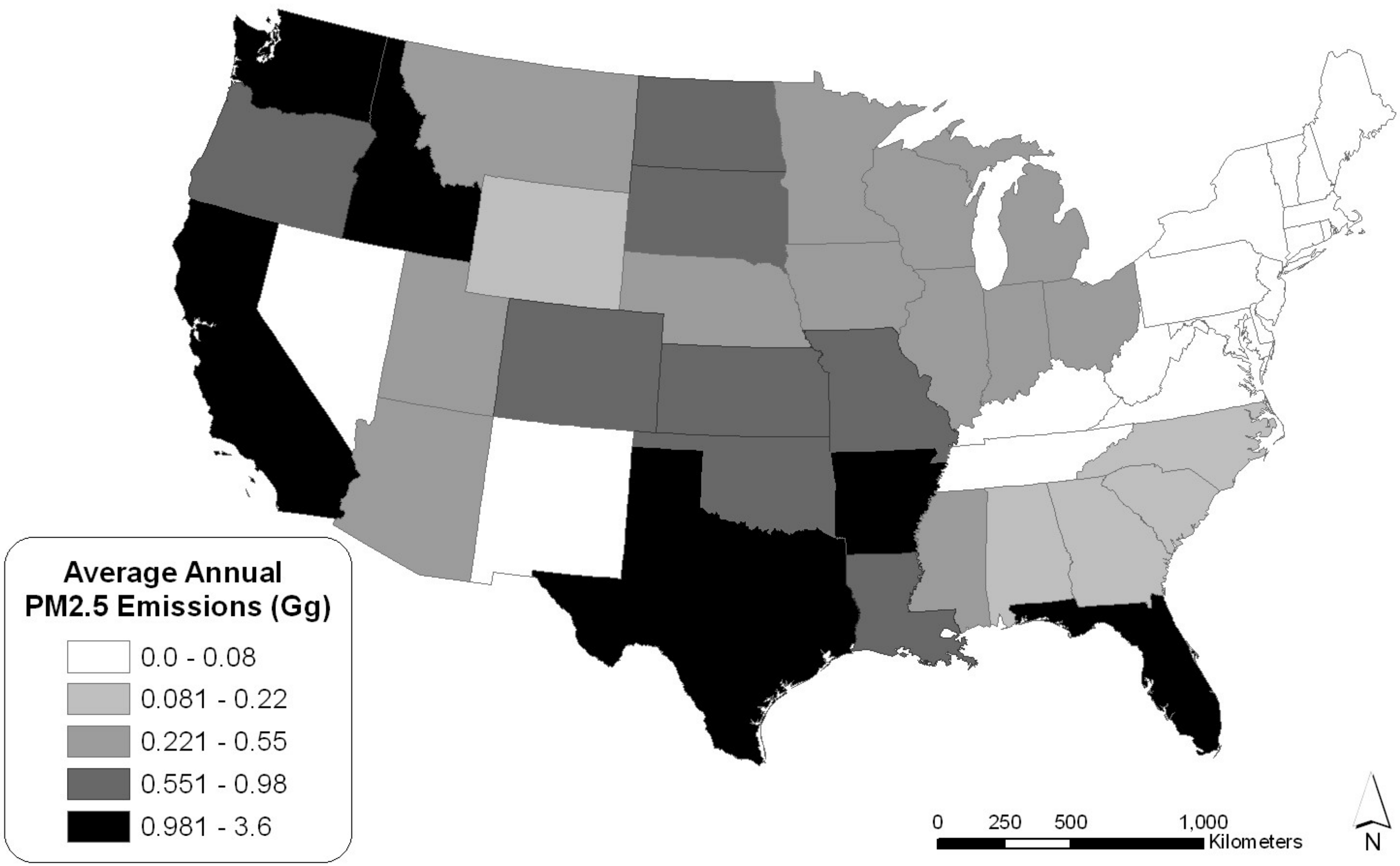
Average Annual Burned Area

Comparison with Wildland Burned Area

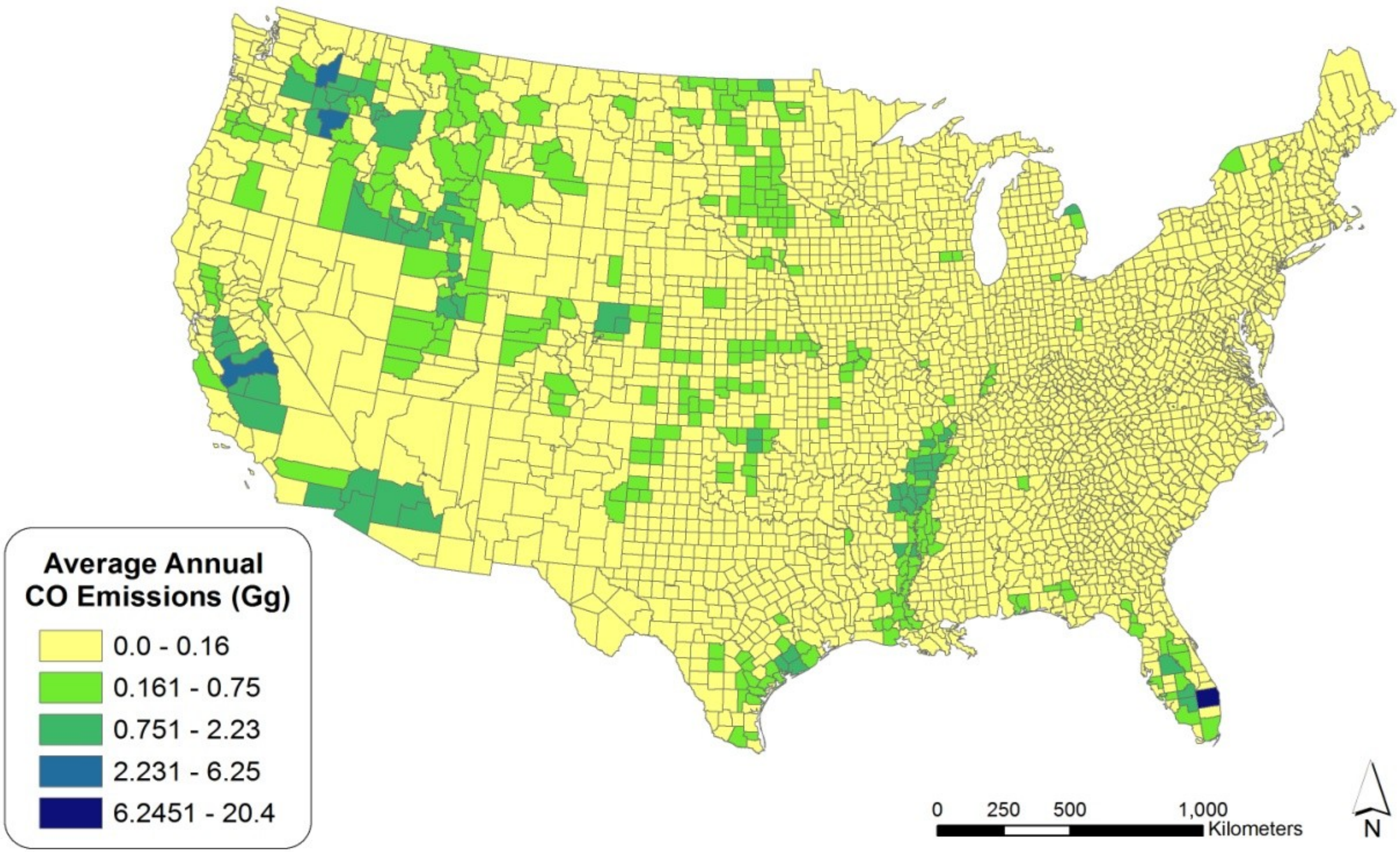
- National Interagency Fire Center
  - Burned area of wildland fires for 50 states (average area)
  - CONUS crop residue burning ≈ 43% of total wildland burned area

Year	Wildland burned area (ha)	Cropland burned area (ha)	% Cropland burned area
2003	1,623,945	1,276,310	78.59%
2004	3,320,131	1,134,918	34.18%
2005	3,562,834	1,291,003	36.24%
2006	4,048,235	1,209,415	29.88%
2007	3,824,498	1,286,437	33.64%

State-level Emissions from Crop Residue Burning

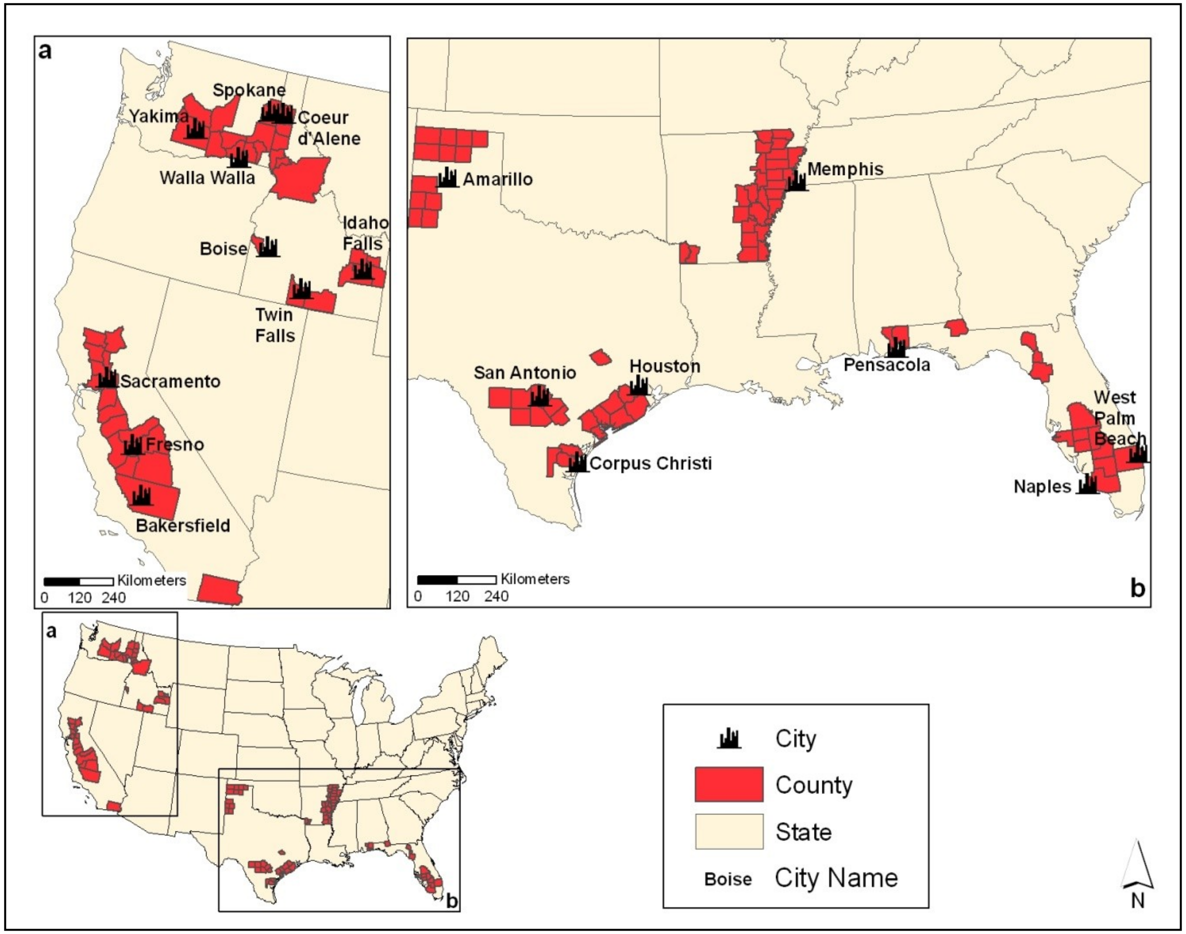


County-level Emissions from Crop Residue Burning

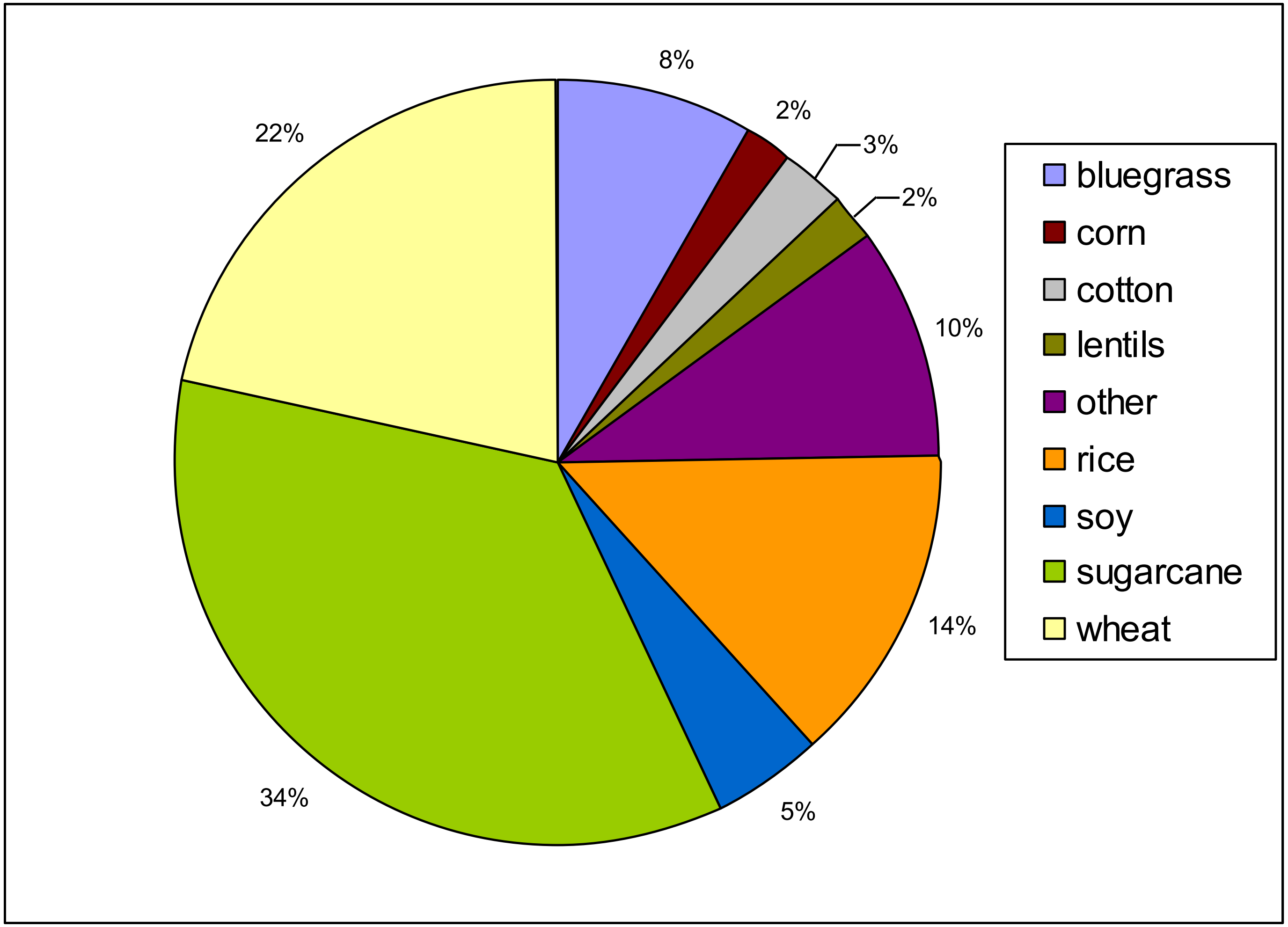


Source Counties for Crop Residue Burning Emissions

- ~ 15.5 million people directly affected
- 5.2% of the total population of the CONUS.
- TX = 13.8%; WA = 17.5%; CA = 17.3%; FL = 17.9%; AR = 25%; ID = 46.6%.



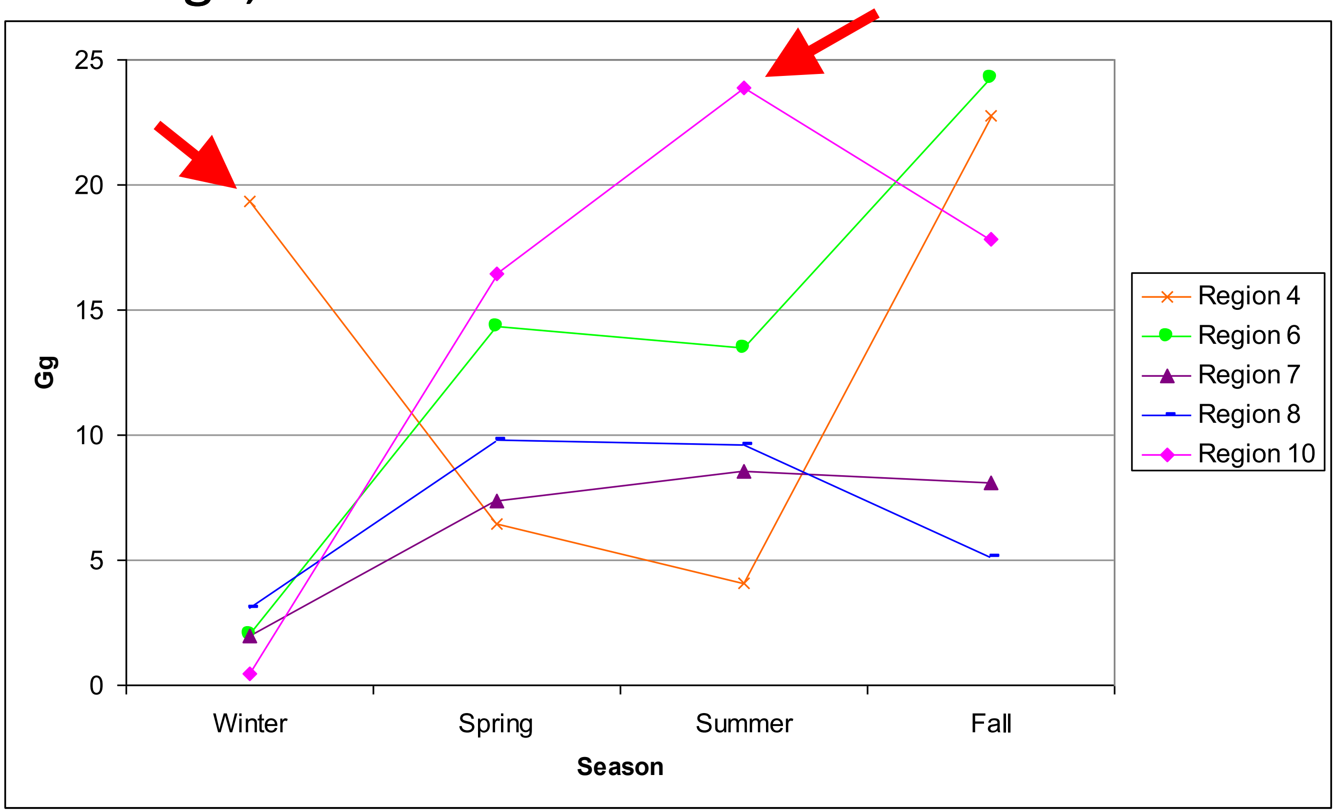
Emissions by Crop Type



Average contribution of emissions by crop type for the EPA source regions for years 2003-2007.

Seasonal Variability of Emissions

– CO emissions for source EPA regions
  - Average, 2003-2007



– Most burning in fall and spring

Interannual Variability of Emissions

Years	CO_2 (Tg)	CH_4 (Gg)	CO (Gg)	NO_2(Gg)	SO_2 (Gg)	$PM_{2.5}$ (Gg)	PM_{10} (Gg)
2003	6.5	9.1	252.1	12.2	5.2	22.3	29.0
2004	6.0	9.2	230.4	11.3	4.3	21.1	28.2
2005	6.1	9.4	234.0	11.1	4.4	21.4	29.1
2006	5.7	8.4	212.3	9.4	4.0	19.2	26.4
2007	6.2	9.3	240.2	11.1	5.1	21.0	29.2
Average	6.1	9.1	233.8	11.0	4.6	21.0	28.4
Average Interannual Variability (%)	5.1%	5.9%	7.8%	9.1%	10%	7.1%	7.1%

- Varied less than 10% over five years

Uncertainties: Fuel Load and Combustion Efficiency

Uncertainties: Emission Factors

- Crop Specific Emission Factor Database
  - Eleven sources from the scientific literature and governmental reports
    - Few seasonal emission factors available; spring EFs 40% less but Fuel Loads were 3% higher
    - Uncertainty estimations?

	CO_2	CH_4	CO	NO_2	SO_2	$PM_{2.5}$	PM_{10}
Bluegrass 2,3,7,8,9,10	1551.22 50.25	5.11 4.32	91.05 43.79	2.16 0.64	0.40	11.61 7.69	15.82 10.40
Rice 2,5,6,7,9,10,11	1515.69	2.09 0.94	52.63 28.07	3.12 1.25	1.38 1.72	5.76 4.82	3.31 0.22
Sugarcane 2,3,9,10,11	1515.69	1.19 1.31	58.48 27.54	3.03 1.65	1.66 2.00	4.35 0.57	4.92 0.73
Wheat 1,2,3,4,5,6,7,9,10,1 1	1631.97 135.78	2.12 1.20	55.14 22.04	1.99 0.83	0.44 0.04	4.03 1.46	6.61 2.98

Emission factors for various crop types (g/kg); sources include: [1]Air Sciences, Inc. (2003); [2]Andreae and Merlet (2001); [3]Dennis et al. (2002); [4]Dhammapala et al (2006); [5]Hays et al. (2005); [6]IPCC (1996); [7]Jenkins et al. (1996); [8]Johnston and Golob (2004); [9]Lemieux et al. (2004); [10]UK EFDB (2000); [11]WRAP (2005).

Comparison with U.S. Agriculture and Forestry Greenhouse Gas Inventory, 1999-2005 (USDA GCPO, 2008)

- Crop residue burning emission estimates from the EPA Greenhouse Gas Inventory (CH_4 emissions);
  - USDA ranks (descending order): Iowa, Illinois, Minnesota, Nebraska, Arizona, Indiana, Kansas, Arkansas, Ohio, and South Dakota.
  - This analysis (descending order): Idaho, Washington, Florida, Texas, Arkansas, Kansas, Oregon, South Dakota, North Dakota, and Missouri.
    - **Arkansas, Kansas, and South Dakota in both studies.**

  - USDA overestimates the contribution of crop residue burning emissions from the Midwestern states of Illinois, Iowa, Indiana, Minnesota, Nebraska, and Ohio;
    - Mainly corn and soy emissions.
    - Missing wheat, rice, and sugarcane emissions.

Transfer of results

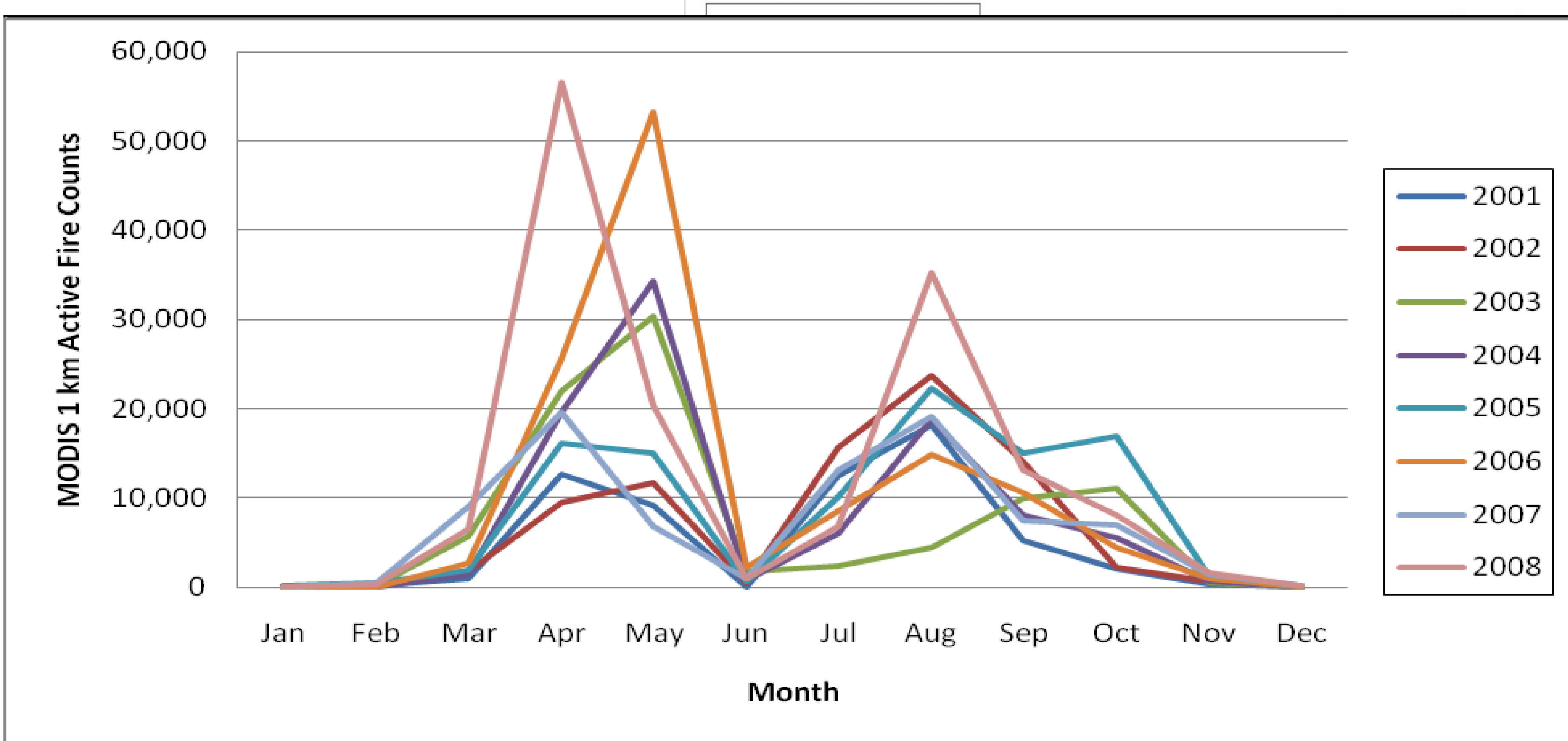
- Linking satellite data and science to enhance fire emissions within the EPA's National Emissions Inventory (NASA Decisions Support)
    - EPA, NASA Langley, National Institute of Aerospace, Michigan Tech, U of L
  - – Deliver 2003-2012 cropland/rangeland BA and emissions to EPA for integration in NEI; Integrate trajectory calculations from CALIPSO
  - – Integrate cropland and rangeland BA data with Wildfire Emissions Information System (Nancy French, MTRI)
    - Developed CONUS-specific dNBR and other existing burned area datasets

Improve Crop Type Mapping

- USDA/NASS Cropland Data Layer
  - Crop type mapping using 56 m AWiFS/30 m Landsat/ 10 m SPOT/250 m MODIS data
  - Spatial extent: CONUS-wide mapping for 2009, 2010
  - Current Decisions Project with SDSU, USDA/NASS, UMd, U of L
  - Integrating MODIS crop characterization capabilities with AWiFS and agricultural survey data to improve the accuracy and timeliness of national crop acreage forecasts provided by the USDA NASS Cropland Data Layer Decision Support System.
  - **Result: increased accuracy of mapping winter wheat to 93% from 78%**

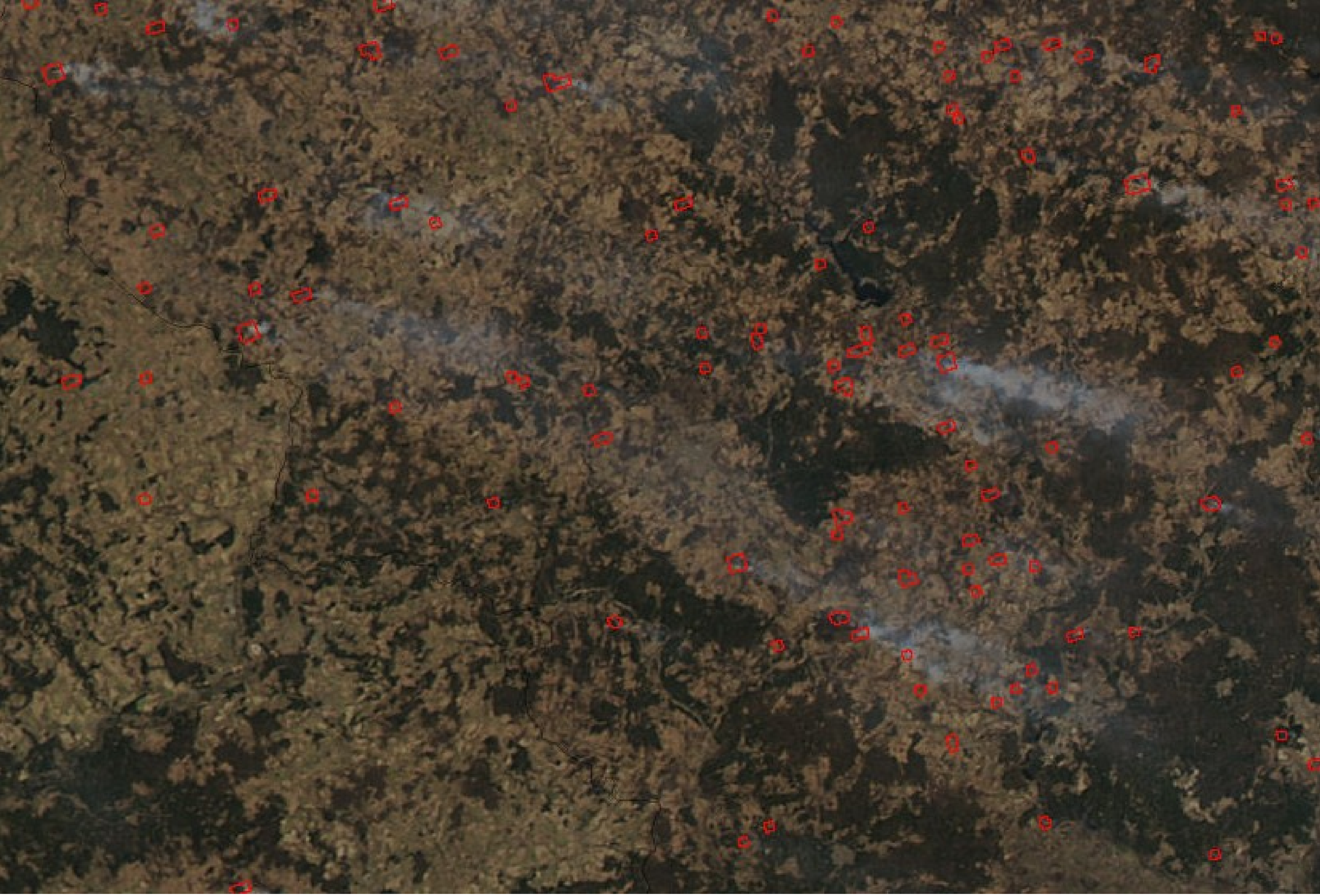
Preliminary Results: Crop Residue Burning in Russia

Crop Residue Burning in Russia

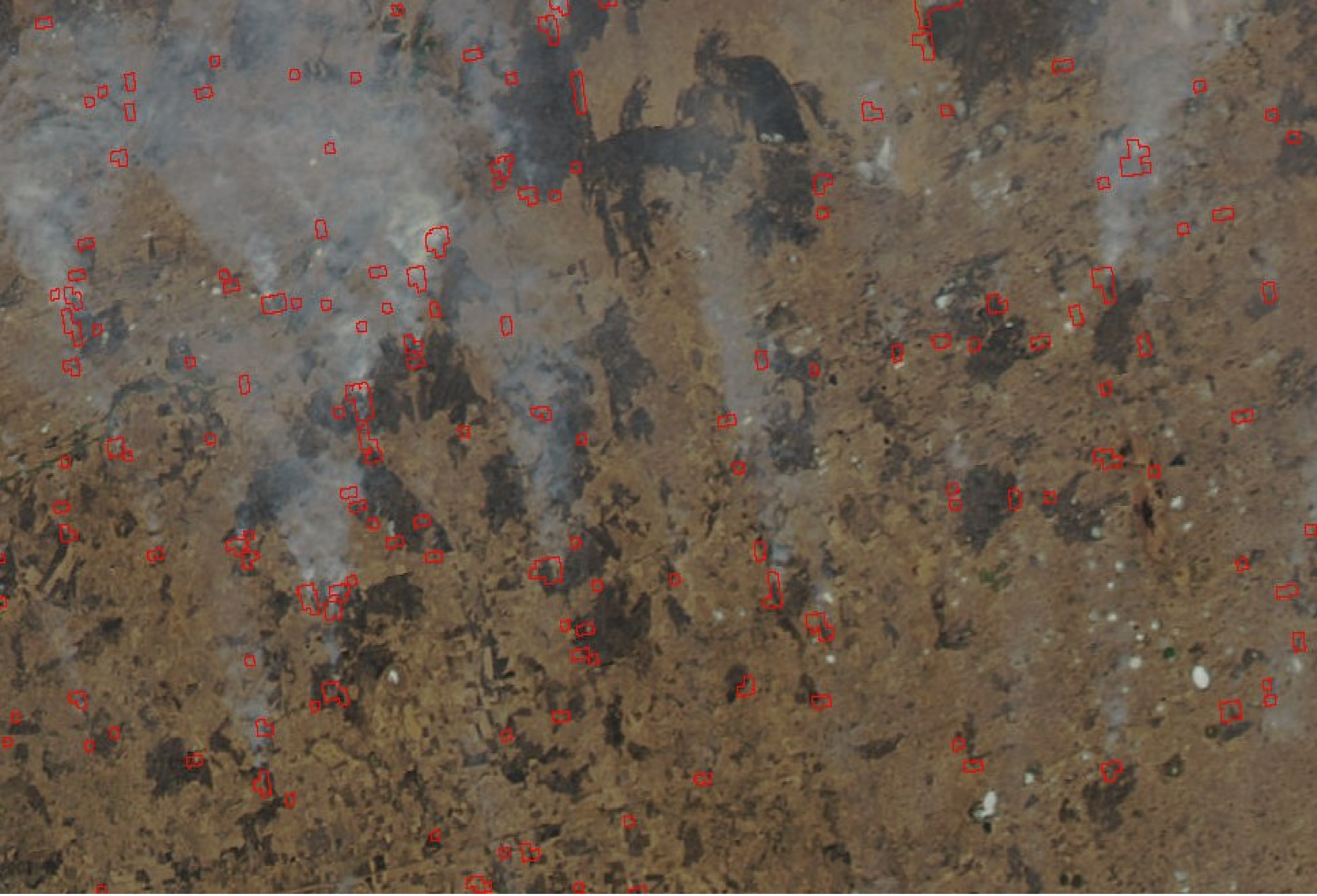


Monthly cropland fires detected by 1km MODIS active fire, defined as IGBP classes 12 and 14, in Russia, 2001- 2008.

northeast, where black carbon emissions are most likely to affect the Arctic. The United States and Canada have rules varying by state and province that aim to limit the impact of agricultural fires on air quality and surrounding property, while allowing "necessary" burning to take place.



Zoom in of MODIS (Aqua) Image on 24 April 2009: Agricultural fields burning near Moscow



Zoom in of MODIS (Aqua) Image on 26 April 2010: Agricultural fields burning in western Siberian Plain

Limitations with existing data and previous methods

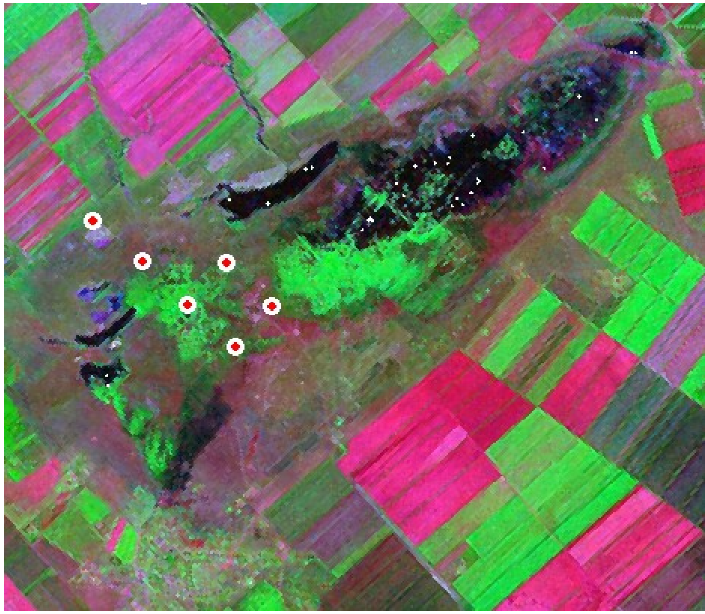
- Initial research: Assign 1 km MODIS Active Fire (MOD14/MYD14) with land cover from 1 km MODIS Land Cover Dataset (MOD12) (Korontzi et al., 2006)

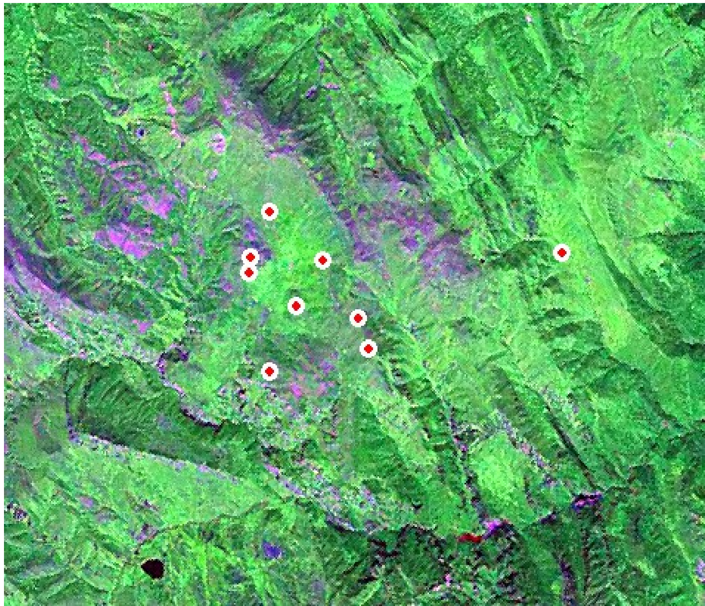
- Accuracy assessment of active fire detections
  - Limited coincidental high resolution data (ASTER, Landsat)

- Accuracy of land cover dataset
  - According to collaborators, Russia has not produced moderate to high resolution land cover map
  - Limited ground-level crop data (compared to USDA CDL)

Identifying Cropland Burning in Russia

- MODIS best instrument to create daily/weekly BA and/or active fire record of ag burning
- Land cover data sets must be improved
  - Ground truth data from Soil Institute
- Next step: compile and compare existing BA datasets and Russia-specific dNBR for emissions calculations





Questions?

Comparison with National Emissions Inventory

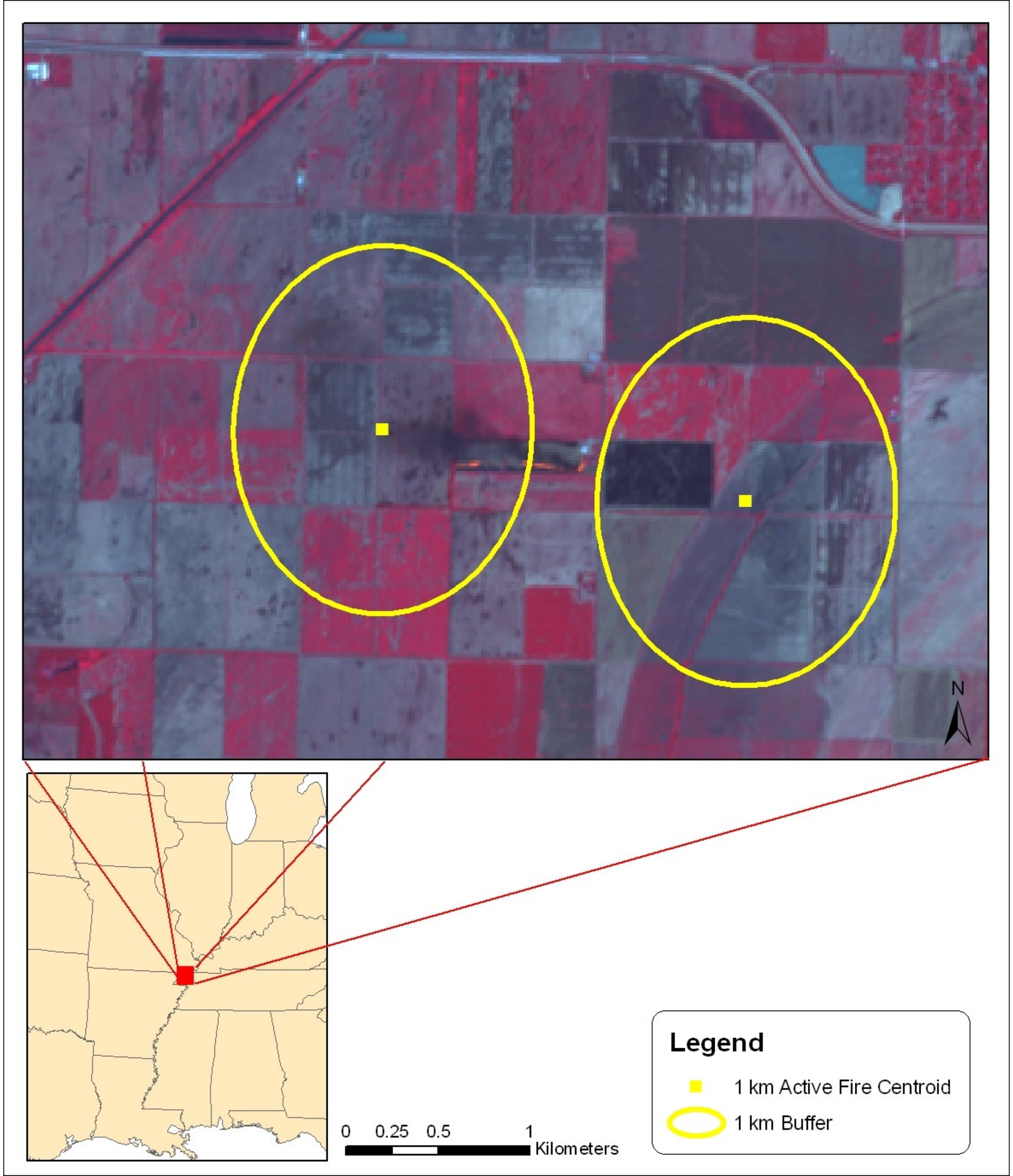
- CONUS crop residue burning emissions accounted for ~ 6% of total CO, $PM_{2.5}$, PM_{10}, and SO_2 emissions of all burning activity reported in the 2002 NEI
- Crop residue burning emissions accounted for ~ 0.04% from all SO_2 emissions, 1% of total $PM_{2.5}$ emissions, 0.2% of total PM_{10} emissions, and 0.3% of total CO emissions
- Exceeded and/or nearly exceeded emissions from various industrial sources
  - storage and transport of petroleum and petroleum products, chemical manufacturing, petroleum and related industries, and metals processing

Comparison with Other Agricultural Burning Emission Estimates

- CONUS CO_2, CO, and CH_4 emissions accounted for 0.6% and 2.1% of total global agricultural emissions from Andreae and Merlet (2001) and Yevich and Logan (2003)
  - All agricultural burning
- CONUS crop residue burning emissions accounted for an average of 14.3% of CO and 15.9% of $PM_{2.5}$ emissions from all agricultural burning in North America (Wiedinmyer et al., 2006)
- Remote sensing-based studies
  - CONUS crop residue burning emissions accounted for an average of 26.3% of emissions from residue burning for China and India



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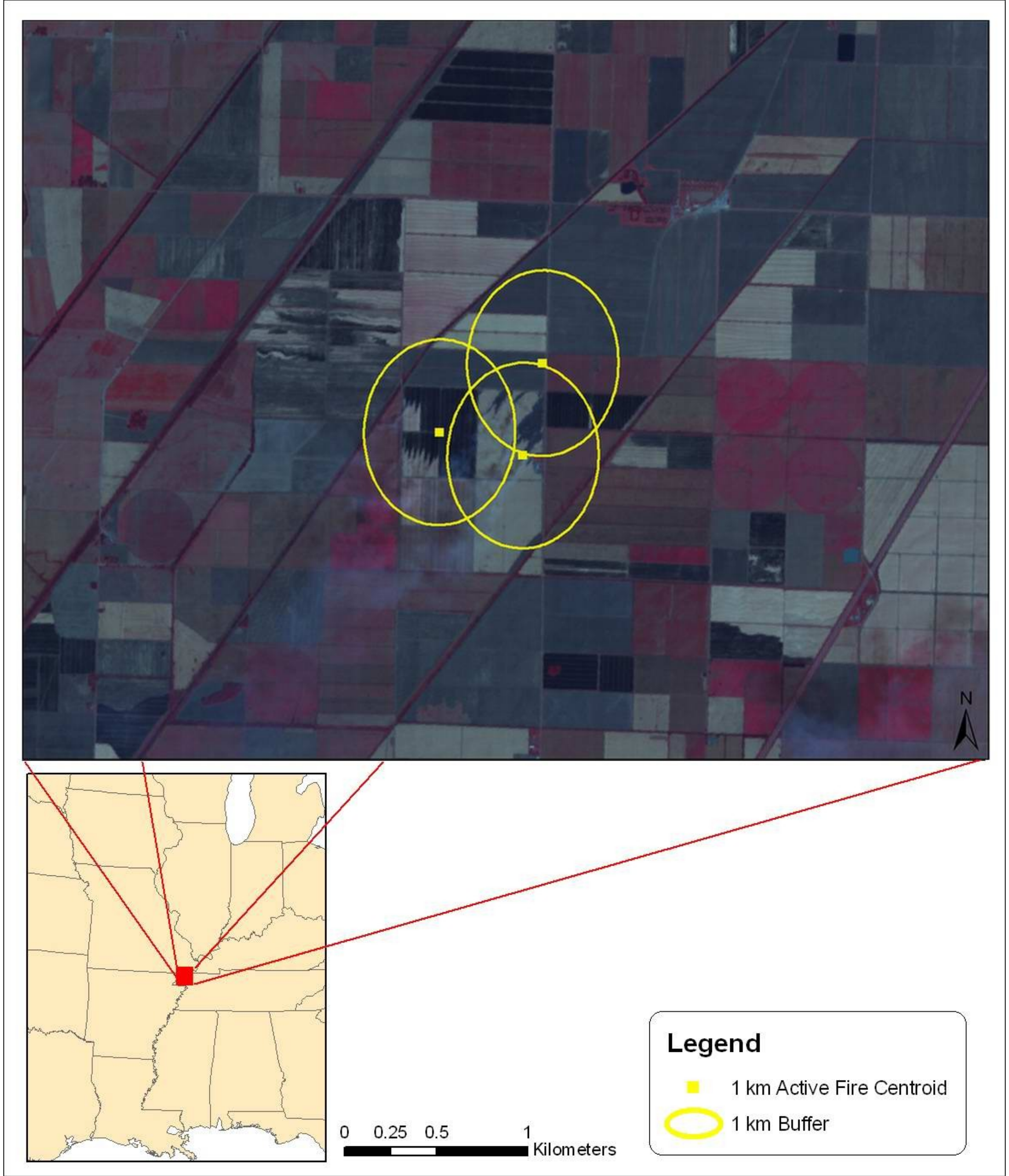
Kilometers
Legend
1 km Active Fire Centroid
1 km Buffer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