Integrating Remote Sensing-Based Estimates of Crop Residue Burning into an Emissions Inventory: Results from a Collaboration with the U.S. Environmental Protection Agency

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Mapping Cropland Burning

Available Satellite-Based Products

were compared to provide the U.S. Environmental Protection Agency (EPA) with a complete overview and analysis of potential burned area sources for inclusion in the National Emissions Inventory (NEI), including the Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE) version 1 (Raffuse et al., 2009), the Moderate Resolution Imaging Spectroradiometer (MODIS) Official Burned Area Product (MCD45A1) (Roy et al., 2005; 2008), the MODIS Active Fire Product (MOD/MYD14) (Giglio et al., 2003; 2006), and a regionally-tuned 8-day cropland differenced Normalized Burn Ratio product for the contiguous U.S. (McCarty et al., 2008; 2009). The 2005 SMARTFIRE product , which combines multiple sources of fire information, including the National Oceanic and Atmospheric Administration (NOAA) Hazard Mapping System (HMS) and state-level ICS-209 reports, was incorporated into the 2005 NEI to estimate cropland burning emissions. An estimate of 100 acres per burn was applied to all cropland burn locations. This analysis found that only 51% of 'agricultural' burns from the 2005 SMARTFIRE product actually occurred in cropland areas when overlaid on the MODIS Land Cover Dataset agricultural classes of croplands and croplands/natural vegetation mosaic from the IGBP schema (Figure 1).

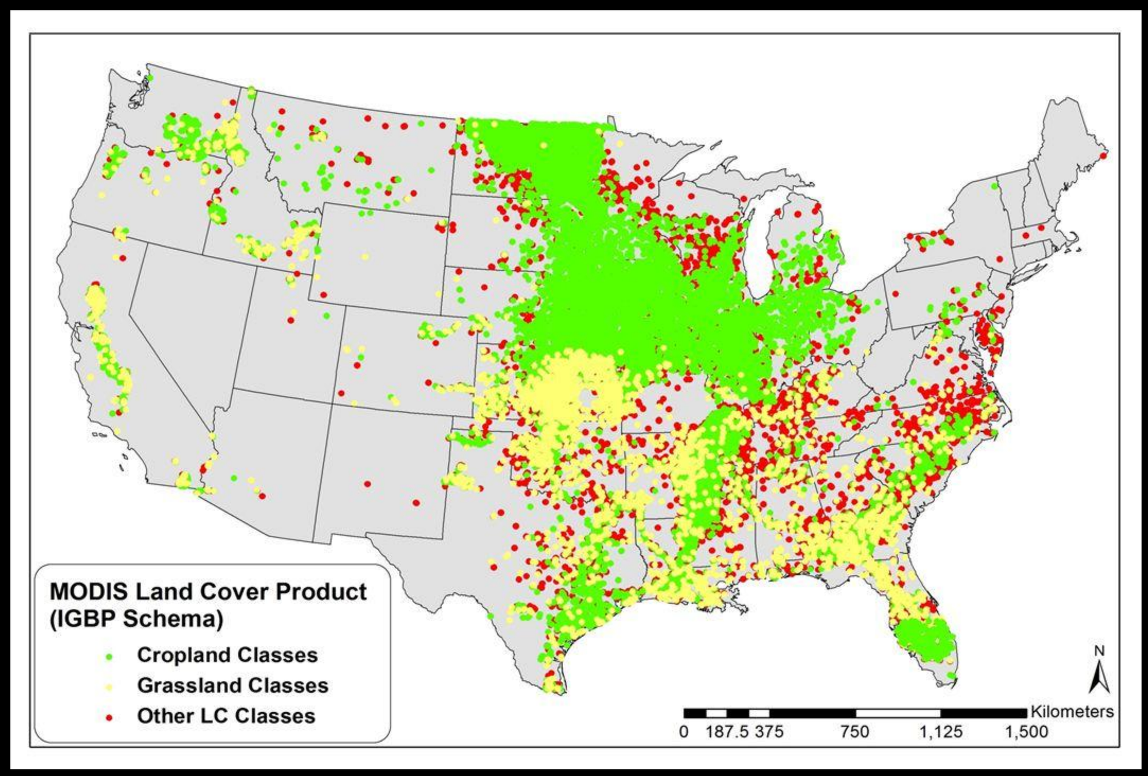

Figure 1. 2005 SMARTFIRE 'Agriculture' fire location points assigned Cropland, Grassland, or Other (Non-Cropland/Non-Grassland) Land Cover Values from the MODIS Land Cover Classification Product (MOD12).

The 2005 SMARTFIRE, and the 2005 NEI, was overestimating the emissions from cropland burning and its impacts on air quality. Available MODIS-based burned area products were compared with SMARTFIRE (Figure 2). In general, the MCD45A1 product corresponded well with the cropland-specific McCarty et al. dNBR product (~50% agreement), with the McCarty product estimating more cropland burned areas. Combining MCD45A1 with MOD/MYD14 and accounting for detecting the same fires, the spatial agreement of cropland burned area increased to 63% with the McCarty product.

Cropland Burning Emissions from Satellite Fire Products

To integrate the remote sensing-based cropland burning emission estimates into the Sparse Matrix Operational Kernel Emissions (SMOKE) system to produce emissions input files for the Community Multiscale Air Quality (CMAQ) model. The 8-day regionally-tuned cropland burned area estimations (McCarty et al., 2008) and daily cropland burned areas from the combined MCD45A1 and

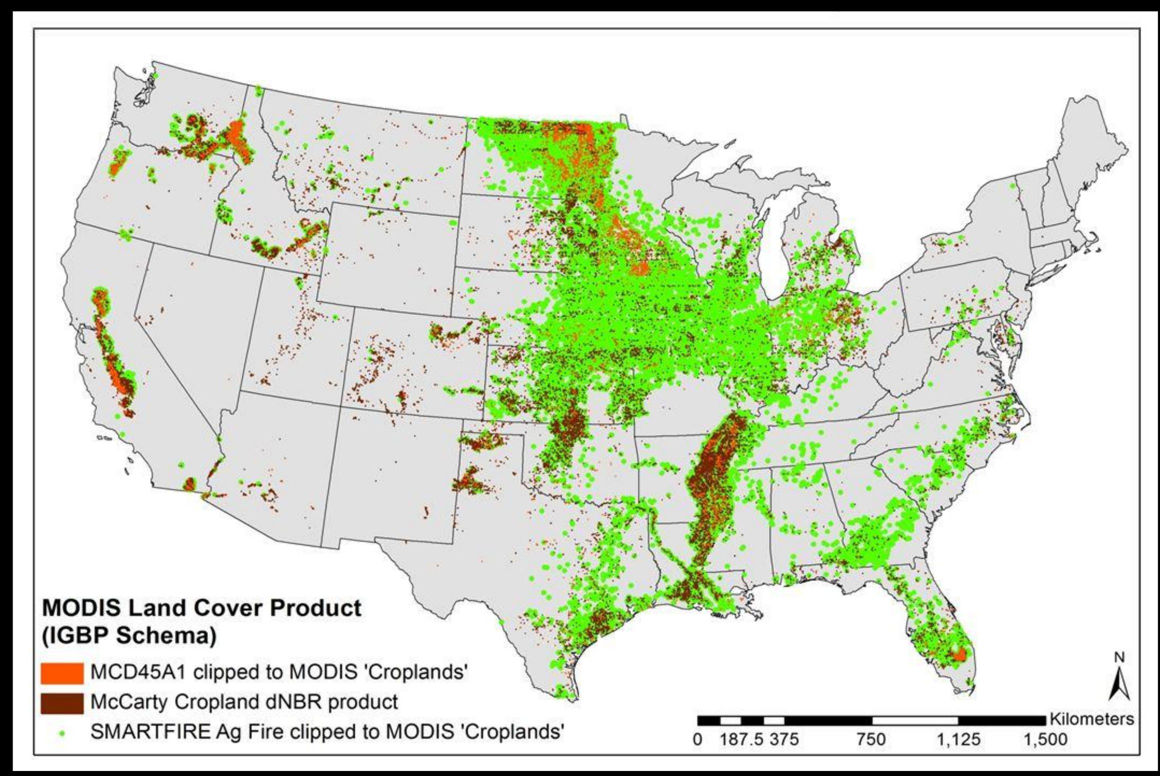

Figure 2. Comparison of 2005 SMARTFIRE 'Agriculture' fire location points assigned to MCD45A1 Burned Area Product and the McCarty et al. Cropland dNBR Product clipped to the cropland and cropland/natural vegetation mosaic values of the MODS Land Cover Classification Product (MOD12).

MOD/MYD14 products were compared using the same cropland extent from the MODIS Land Cover Dataset, emission factors, and fuel load and combustion completeness values (McCarty, 2011) to create ArcGIS shapefiles of cropland burned area with associated emissions for CO, $PM_{2.5}$, PM_{10}, SO_2, and No_x. Total annual emissions between the 8-day and daily combined products were similar (~ 62% agreement between the two approaches) but monthly and seasonally were different (Figure 3).

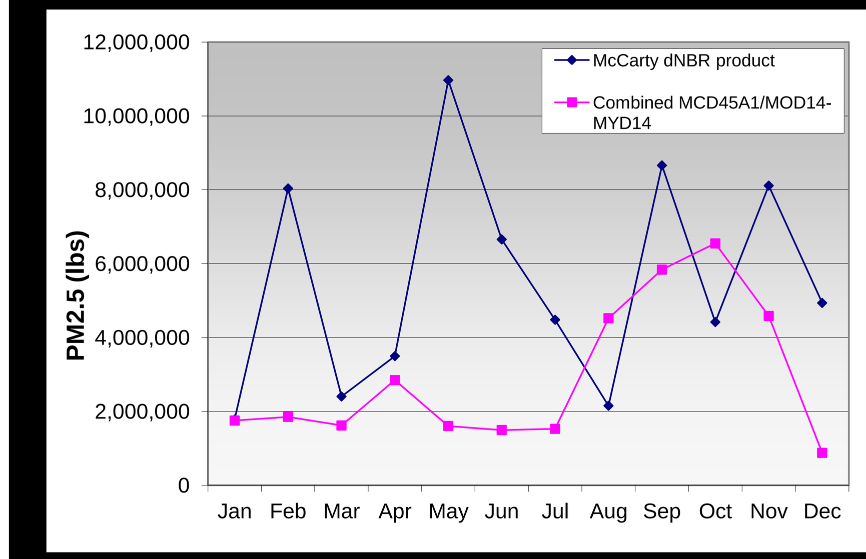

Figure 3. Comparison of PM2.5 emissions from cropland burning in the contiguous U.S. for year 2006 from the McCarty dNBR product and the combined MCD45A1/MOD14-MYD14 products; emissions calculated using same emission factors, fuel loadings, and combustion completeness in the bottom-up emissions approach (Seiler and Crutzen, 1980).

Emission factors and diurnal cropland fire cycle for input into SMOKE/CMAQ

To expand the current EPA emission factor database, crop type-specific emission factors from McCarty (2011) were tested. Species of interest included CO, SO_2, $PM_{2.5}$, PM_{10}, and No_x. In addition to average emission factors, high and low emission factors were developed via standard deviation calculations. Based on this analysis, a new ratio of $PM_{2.5}$:PM_{10} was calculated for use specifically for estimating crop residue burning emissions within EPA's air quality models and the NEI. This new $PM_{2.5}$:PM_{10} is 1.40.

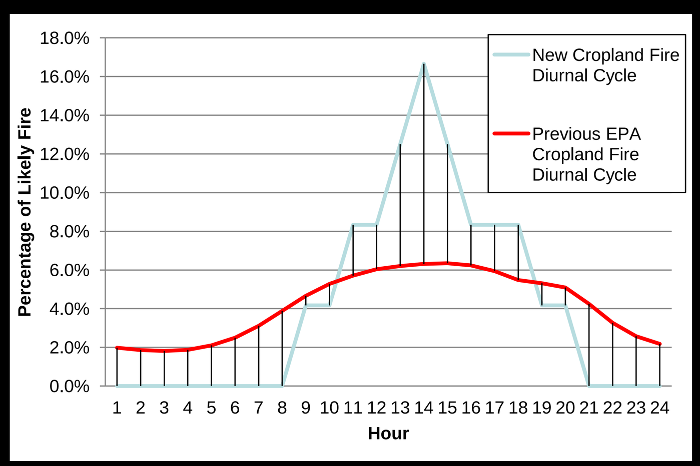

Figure 4. Comparison of the cropland-specific fire diurnal cycle with the previous normal distribution employed by the EPA.

A cropland-specific fire diurnal cycle was developed based on field observations in Arkansas, Florida, Idaho, Louisiana, Kansas, and Washington, and results from cropland areas in the southeastern U.S. as observed by the MODIS Active Fire Product (Giglio, 2007) (Figure 4).

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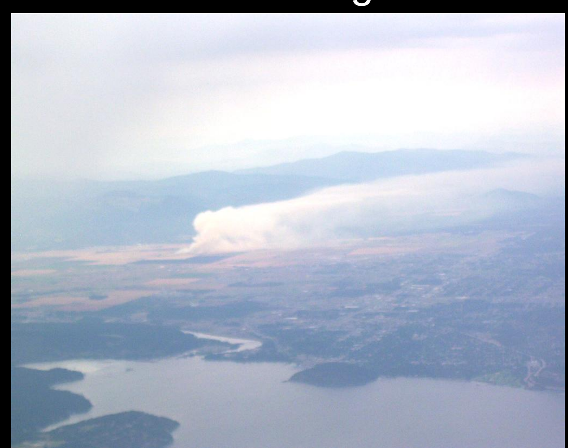
Preliminary results from SMOKE/CMAQ

Annual and monthly $PM_{2.5}$ emissions and concentrations were modeled from the daily combined MCD45A1 and MOD/MYD14 product for 2006. These daily cropland emissions , calculated from the highest $PM_{2.5}$ emission factor from McCarty (2011), were processed through SMOKE version 2.7 and then summed back together to produce 12 km X 12 km annual emission input files for 2006. The new cropland-specific fire diurnal cycle (Figure 4) was also applied. Both the 2006 annual emission input files and September 2006 monthly emission input files were modeled through CMAQ version 5 beta. Figures 5 and 6 depict the CMAQ modeled annual and September $PM_{2.5}$ emissions (Mg) from cropland burning, respectively. Both the annual and the September emission estimates show concentrations in the Pacific Northwest , the northern Great Plains, and the Everglades Agricultural Area in south Florida.

Emission concentrations (µg/m³) were modeled to estimate the background surface $PM_{2.5}$ concentrations at the surface during September 2006 with cropland burning emissions removed from CMAQ (Figure 7). Cropland burning $PM_{2.5}$ concentrations were then modeled and subtracted from the total monthly average $PM_{2.5}$ concentrations. The resulting difference highlights the areas in the contiguous U.S. that in September 2006 produced the highest concentration of $PM_{2.5}$ (Figure 8). The Pacific Northwest and small areas of central California, northern Minnesota, North Dakota, and southeast Missouri show the largest $PM_{2.5}$ concentrations from cropland burning.



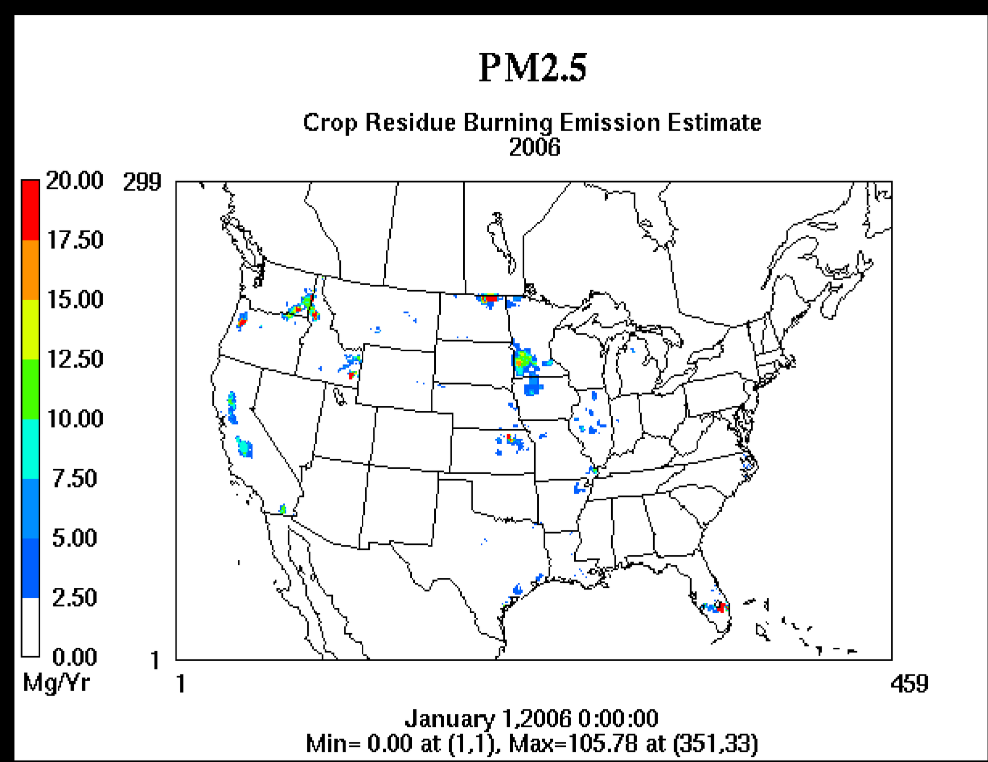


Figure 5. Annual $PM_{2.5}$ emission estimates from satellite-based cropland burning in the contiguous U.S. for 2006 as modeled through SMOKE v. 2.7 and CMAQ v. 5 beta; emissions reported in Mg.

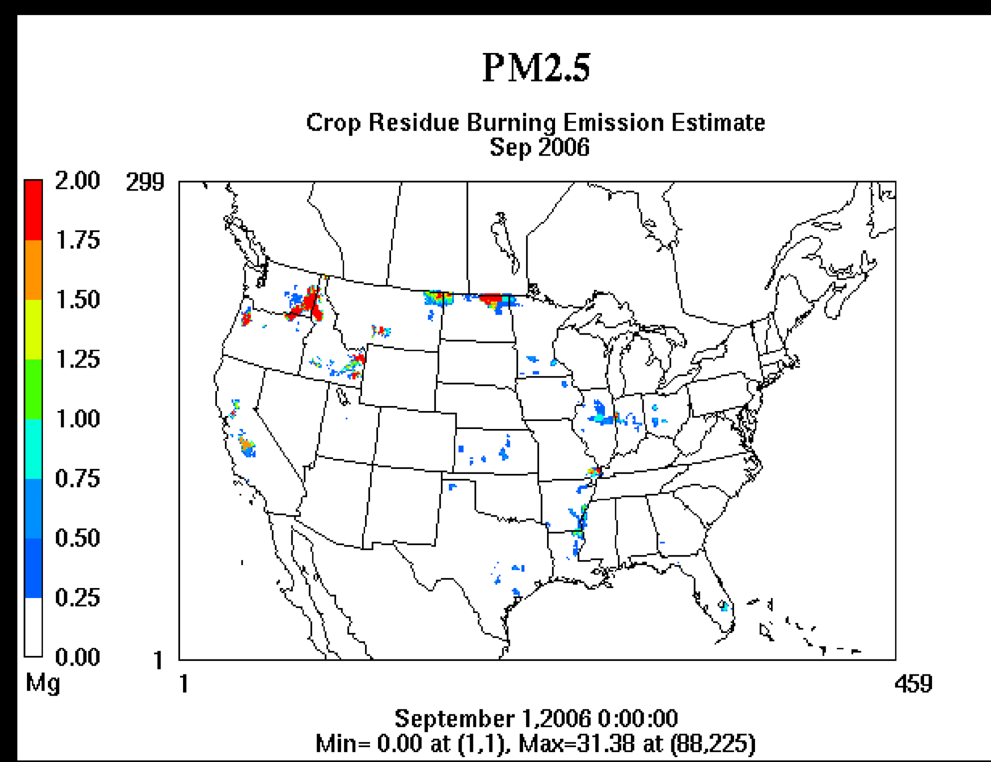


Figure 6. Monthly $PM_{2.5}$ emission estimates from satellite-based cropland burning in the contiguous U.S. for September 2006 as modeled through SMOKE v. 2.7 and CMAQ v. 5 beta; emissions reported in Mg.

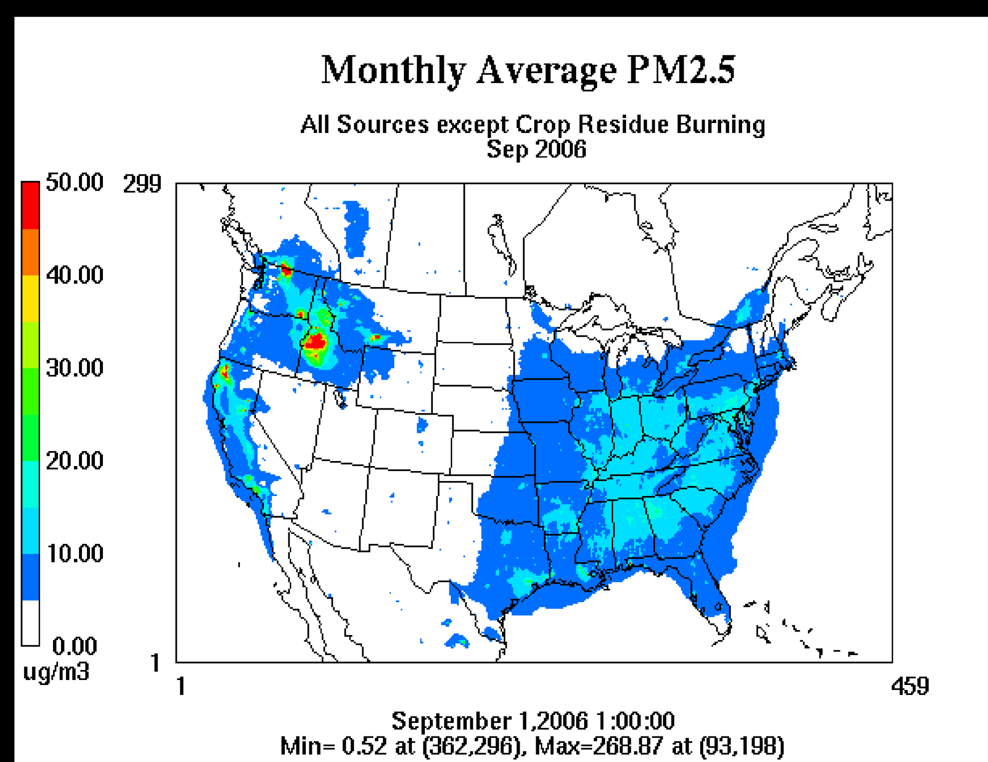


Figure 7. Monthly average $PM_{2.5}$ concentrations from all sources except cropland burning in the contiguous U.S. for September 2006 as modeled through SMOKE v. 2.7 and CMAQ v. 5 beta; concentrations reported in µg/m³.

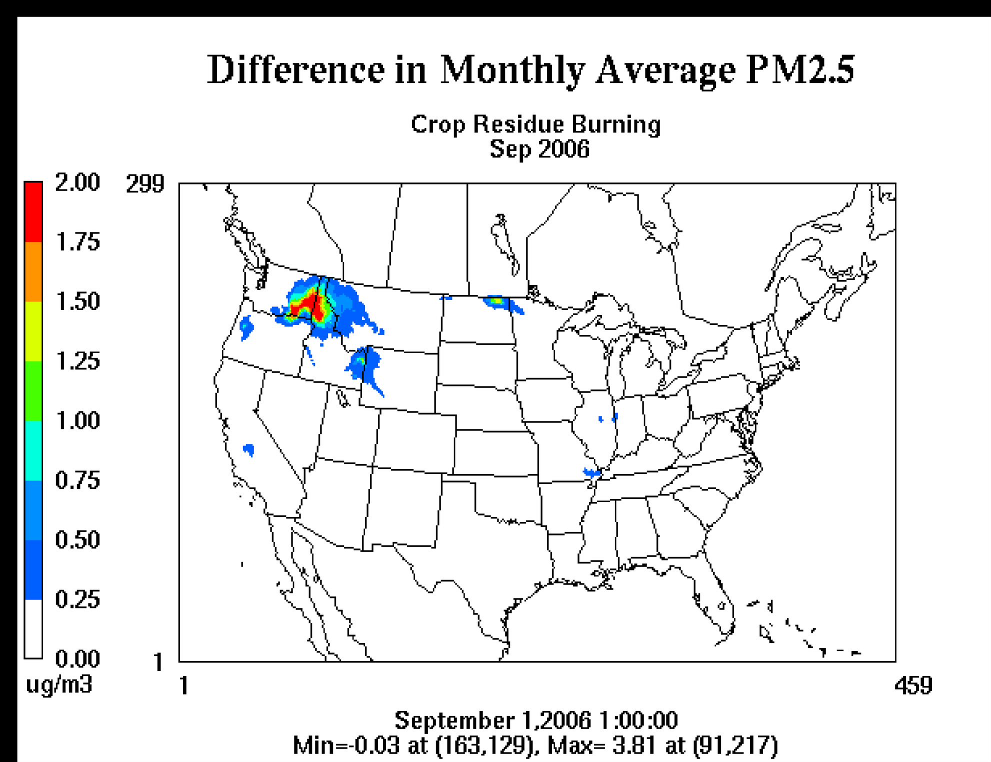


Figure 8. Monthly average $PM_{2.5}$ concentrations from satellite-based cropland burning in the contiguous US for September 2006 as modeled through SMOKE v. 2.7 and CMAQ v. 5 beta; concentrations reported in µg/m³.

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