Development of a Crop Residue Burning Emission Inventory for Air Quality Modeling

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Abstract

Biomass burning has been identified as an important contributor to the degradation of air quality because of its impact on ozone and particulate matter. One component of the biomass burning inventory, crop residue burning, is poorly characterized in the National Emissions Inventory. We summarize a new method to estimate crop residue burning emissions using remote sensing data and field information. We will focus on the both post harvest and pre-harvest burning that takes place with bluegrass, corn, cotton, rice, soybeans, sugarcane and wheat. Estimates for 2006 indicate that over the continental United States (CONUS), crop residue burning occurred over 5.8 million acres of land and produced 53,000 short tons of PM2.5. Estimates for 2007 indicate that over the CONUS, crop residue burning occurred over nearly six million acres of land and produced 58,000 short tons of PM2.5. Preliminary modeling results using this new inventory within a chemical transport model are also summarized.

Introduction

Biomass burning is one of the primary causes of elevated airborne particulate matter, ozone precursors and regional haze. Particulate Matter (PM) is one of six pollutants for which the EPA has set National Ambient Air Quality Standards (NAAQS). $PM_{2.5}$ describes particles found in the air, including dust, dirt, soot, smoke, and liquid droplets, with a mean diameter of 2.5 microns or less. Biomass burning is an important source of primary $PM_{2.5}$ emissions and other pollutants that can form secondary $PM_{2.5}$. $PM_{2.5}$ has been linked to a series of significant health problems, including aggravated asthma, increases in respiratory symptoms like coughing and difficult or painful breathing, chronic bronchitis, decreased lung function, and premature death. Currently, approximately 90 million people live in areas that do not meet the $PM_{2.5}$ NAAQS. Reducing emissions of PM is a crucial component of EPA's strategy for cleaner air and improved visibility.

Over the last several years, wildfire emissions to the NEI have vastly improved, however agricultural burning emission estimates are deficient. In 2002, only 23 states reported emissions from this source[1] and in 2005, this source was not even updated in the NEI. In the 2008 NEI, crop residue emission estimates have been developed using uncertain field sizes or have been sporadically reported by a handful of states. However, a consistent methodology across multiple years for the CONUS has not yet been developed. The goal of this work is to develop a simple and efficient method to estimate emissions from crop residue burning that can be easily applied across multiple years over the CONUS at minimal cost. The approach being developed improves on previous estimates as follows: (1) Multiple satellite detections are used to locate fires using an operational product (2) Field Size estimates are based on field work studies in multiple states (rather than a one size fits all approach); (3) This method allows for intra-annual as well as annual changes in crop land use. We will show CONUS emission estimates from crop residue burning for 2006-2007 using a consistent methodology.

Inputs Used to Create Inventory

The Hazard Mapping System (HMS) satellite product [2,3] is an operational satellite product showing hot spots and smoke plumes indicative of fire locations. It is a blended product using algorithms for the Geostationary Operational Environmental Satellite (GOES) Imager, the Polar Operational Environmental Satellite (POES) Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS). A quality control procedure is performed by an analyst on the automated fire detections. Significant smoke plumes that are detected by the satellites are outlined by the analyst. This product is created and updated as needed between 1 PM and 11 PM Eastern time. After 11 PM the analysis is fine-tuned as time permits. The fine-tuned analysis was used for this study.

Crop-type information for this analysis was based on the work of McCarty 2011[4]. Crop type information was derived from regional crop-type maps following the classification tree method developed by Hansen et al 2002[5]. The analysis targeted the crop types of Kentucky bluegrass, corn, cotton, rice, soybean, sugarcane, wheat, and other and/or fallow rotation crop class. The classification tree approach was utilized to produce regional and seasonal (spring and fall) crop-type classifications using the multiyear and multi temporal 250-m MODIS U.S. VI product, which is a 16-day composite of red, near-IR, and Normalized Difference Vegeatation Index (NDVI) bands.

Field Size information was obtained from McCarty et al 2009[6]. This data represents typical field sizes for each state.

Emission Factors for CO, NO_x, SO_2, $PM_{2.5}$ and PM_{10} were based on Table 1 from McCarty 2011[4]. Emission Factors for NH_3 were derived from the 2002 NEI ratios of NH_3/NO_x and the NO_x emission factor in Table 1 from McCarty 2011[4]. AP-42 Emission Factor ratios for VOC/CO and the CO emission factors from Table 1 in McCarty 2011[4] were used to estimate VOC Emission Factors. Table 1 summarizes emission factors, fuel loading, and combustion completeness used in this analysis.

Table 1: Emission Factors, Fuel Loading, Combustion Completeness

Crop Type	Fuel Loading	Combustion Completeness	CO	NOX	SO2	PM2_5	PM10	VOC	NH3
	tons/acre		lbs/ton	lbs/ton	lbs/ton	lbs/ton	lbs/ton	lbs/ton	lbs/ton
corn	4.19	0.75	106.10	46.00	2.38	9.94	21.36	19.10	19.32
cotton	1.70	0.65	146.12	68.90	3.13	12.38	17.73	10.23	48.92

Kentucky bluegrass	2.91	0.85	182.11	43.10	0.80	23.23	31.64	9.11	12.50
other crop/fallow	2.95	0.75	127.79	56.00	2.34	12.31	17.00	6.39	16.24
rice	2.99	0.75	105.27	62.30	2.77	4.72	6.61	10.53	26.17
soybean	2.50	0.75	127.70	63.30	3.13	12.38	17.73	19.16	44.94
sugarcane	4.46	0.65	116.95	60.60	3.32	8.69	9.83	12.86	43.03
wheat	1.92	0.85	110.28	47.50	0.88	8.07	14.10	11.03	33.73

Method Description

Along with the HMS satellite detects, a year specific crop map was employed to identify the satellite detections as crop residue burning and the type of crop. If the satellite detection was within 2 km and at the same time as GOES detections, the detections were deemed to be a duplicate and one was removed. This process only removed a small number of detections over the year, less than 0.1% of all detections. The crop maps were seasonal in that a different map for crop burning was used before July 1 of any given year. After identifying the satellite detection as crop residue burning, state specific field size information was used to estimate the acres burned. Combined with emission factors for the criteria pollutants, daily emission estimates of crop residue burning for the CONUS were obtained.

Emission Estimates for 2006 and 2007

Table 2 summarizes state level estimates of crop residue burning by acres burned and $PM_{2.5}$ for 2006. These estimates were derived used the method described above.

Table 2: Acres Burned and PM2.5 Emission Estimates for 2006 and 2007

State	2006 Acres	2006 PM2_5 (short tons/yr)	2007 Acres	2007 PM2_5 (short tons/yr)
Alabama	106,920	1,024	119,040	1,144
Arizona	8,560	53	8,800	62
Arkansas	227,960	1,625	278,560	2,204
California	279,720	2,263	330,360	2,892
Colorado	29,040	210	44,240	411
Delaware	1,360	18	1,400	20
Florida	549,060	6,297	467,760	4,885
Georgia	321,520	2,991	335,840	3,204
Idaho	241,560	2,593	316,080	4,016
Illinois	66,600	1,013	86,580	1,315
Indiana	18,660	286	27,360	403

Iowa	109,620	1,113	99,360	1,037
Kansas	594,720	5,789	658,880	6,445
Kentucky	24,360	326	30,360	403
Louisiana	205,000	2,000	229,400	2,446
Maine	240	3	400	5
Maryland	4,800	62	3,440	54
Massachusetts	40	1	0	0
Michigan	6,280	78	9,640	135
Minnesota	120,900	844	159,360	1,214
Mississippi	94,560	753	142,920	1,191
Missouri	224,340	2,797	302,880	3,670
Montana	385,200	2,773	223,800	2,268
Nebraska	111,060	734	110,340	758
Nevada	2,120	14	3,440	23
New Hampshire	160	2	120	2
New Jersey	2,960	44	2,240	35
New Mexico	3,120	24	4,960	48
New York	2,440	33	2,280	34
North Carolina	60,720	613	76,920	917
North Dakota	389,640	2,566	286,500	1,887
Ohio	8,960	135	9,200	133
Oklahoma	233,440	1,622	333,360	2,618
Oregon	115,320	996	117,600	1,353
Pennsylvania	4,640	61	5,280	81
South Carolina	68,200	670	84,640	834
South Dakota	53,460	354	68,760	491
Tennessee	42,560	323	52,160	474
Texas	762,080	6,632	672,160	6,286
Utah	13,960	118	22,960	251
Vermont	240	3	280	4
Virginia	10,720	135	9,520	145
Washington	316,560	2,265	184,080	1,478
West Virginia	1,400	17	1,640	26
Wisconsin	17,560	238	22,120	329
Wyoming	23,600	178	34,560	304
TOTAL	5,865,940	52,689	5,981,580	57,936

Preliminary Modeling Results

A consistent methodology was employed to estimate crop residue burning emission estimates for the CONUS using available operational satellite products, emission factors derived from McCarty 2011, and year specific crop maps. A pair of chemical transport modeling simulations using CMAQ version 5 (beta release) for the months of September, October, and November 2006 have been completed. One simulation contains these new emission estimates and the other simulation has crop residue burning emissions removed. Since crop residue burning emissions are confined to agricultural areas at specific time periods, the analysis is focused at specific locations and dates when these activities occur. Figure 1 shows a time series of hourly PM2.5 CMAQ5 model results compared to observations at a single Air Quality System (AQS) site in western Tennessee during the October wheat field burning season. The blue line indicates the model results without any crop residue burning emissions and the red line indicates the method described in this paper. Note that the model shows improvement at this one site for a limited number of hours, which highlights the challenge associated with evaluating air quality modeling results for changes to an emission inventory sector, such as crop residue burning.

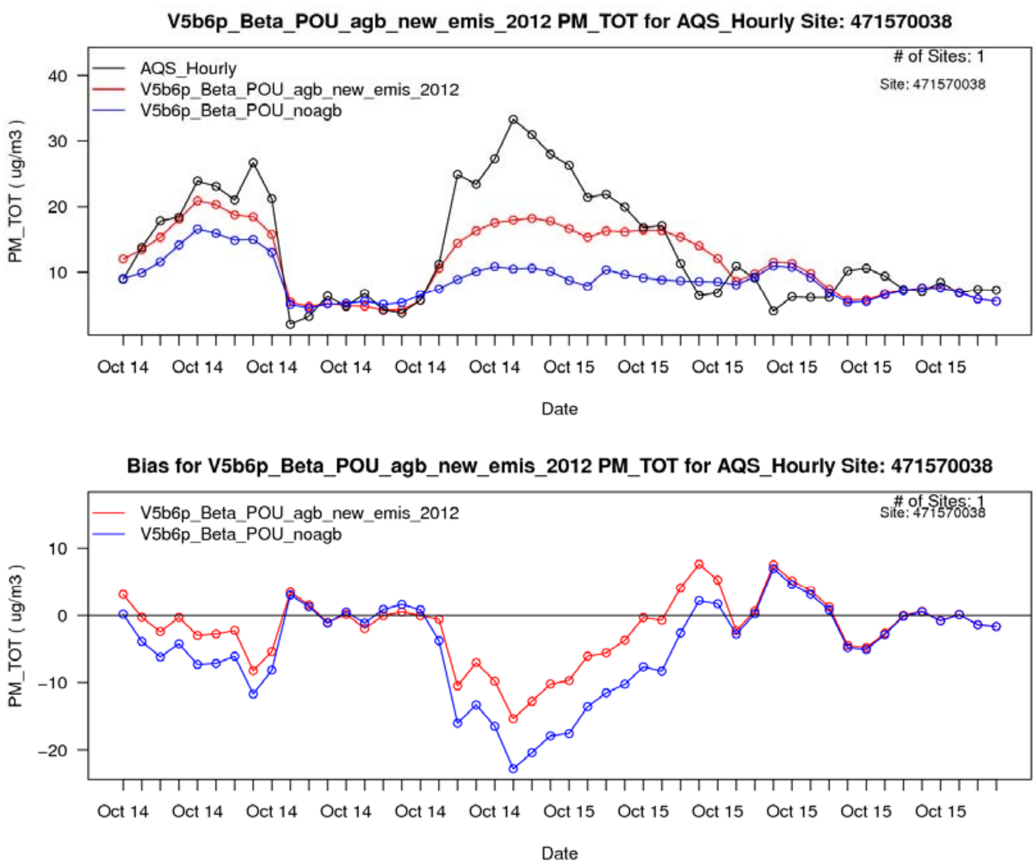

Figure 1. Time Series of PM2.5 at one site in Western Tennessee Oct 14-15, 2006. Top figure shows observed PM2.5 concentrations vs modeled values. Bottom Figure shows model bias over the same time period. The red line shows model predictions using the emission inventory described herein. The blue line shows model predictions without any crop residue burning.

Summary

The inputs used to create a national crop residue burning emission inventory for 2006 and 2007 have been outlined. An easy, simple, and efficient method that can be easily applied across multiple years over the CONUS at minimal cost has been summarized. Finally, preliminary chemical transport modeling results using the beta version of CMAQ5 have been examined.

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Disclaimer and Acknowledgements

This paper has been reviewed in accordance with the United States Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication. The authors wish to thank Computer Science Corporation for their assistance in processing the emission data used in this paper.

Keywords

Emission Inventory
Crop Residue Burning Emissions
Air quality modeling
PM2.5