Comparative Fire Emissions Analysis: the DEASCO$_3$ Project and the EPA 2008 NEI

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ABSTRACT

As part of the Deterministic & Empirical Assessment of Smoke's Contribution to Ozone (DEASCO$_3$) project, we are building a national fire emissions inventory for year 2008 air quality modeling. For the western U.S., the analyses applied in building this detailed retrospective inventory supports subsequent air quality planning and possible future exceptional events analyses. Methods used were built off of previous inventory work done for the Western Regional Air Partnership (WRAP) and the on-going Fire Emissions Tracking System (FETS). The basis of the 2008 emissions inventory is the existing FETS database and methodology. To gather additional activity data, the FETS was expanded to accept data from the Monitoring Trends in Burn Severity (MTBS) data set, Hazard Mapping System (HMS) data, and ground-based reports from areas outside the WRAP region. A reconciliation process using date and proximity matched HMS detects with MTBS perimeters and ground-based activity to build daily fire growth for MTBS burns. Detects without a match were classified using a set of criteria including land ownership, land cover type, time of year, and proximity to classified burns. Emissions were calculated for all burns using Python-CONSUME, the latest 30m Fuel Characteristics Classification System (FCCS) layer, and MTBS burn severity. Other supporting information included daily precipitation maps and fuel moisture from the Weather Information Management System (WIMS). Calculated fire emissions were then compared to those from the EPA 2008 NEI for selected regions and time periods. We will present the differences in space, time, and emissions magnitudes to assist NEI and DEASCO$_3$ users in understanding the emissions results, evaluating the methodologies behind the reported emissions, and considering the applications of data for air quality planning and exceptional event analyses.

INTRODUCTION

Fire emissions from biomass burning on wildlands across the U.S. are a very large and episodic source, particularly in the western and southeastern regions. They often dwarf emissions of all other sources during large wildfires or concurrent regional groupings of multiple medium-to-smaller wildfires or prescribed fires, and may contribute to exceedances and violations of the Particulate Matter (PM) and/or Ozone National Ambient Air Quality Standards (NAAQS). Biomass burning on agricultural lands is seasonally large and can have noticeable local and regional impacts in those regions, along with Plains states centered on the 100th meridian. In 2013, the Environmental Protection Agency (EPA) will consider revisions to the Ozone NAAQS that would increase the stringency to a lower compliance value in the range of 60 to 70 parts per billion for an 8-hour average.[1] The Joint Fire Science Program has funded the $DEASCO_3$[2] study to evaluate fires' contribution to ozone in support of future regulatory air quality planning needs of Federal Land Managers and states in the State Implementation Plan (SIP) and Exceptional Events Analysis processes under the Clean Air Act.

The National Emissions Inventory (NEI) for all U.S. sources, compiled by EPA on a triennial basis (2008, 2011, etc.), gathers principally state, but also tribal and local air quality emissions data into a national database used to track national emissions trends. It is also used to provide input for air quality modeling and planning. A significant majority of states do not report fire emissions to the NEI, and EPA developed a hybrid approach that included federal fire wildfire activity data to estimate fire emissions to populate the 2008 NEI. That included using state wildland (wildfire and prescribed fire) emissions estimates where reported, a national top-down method executed by EPA to estimate agricultural burning emissions, and applying the SMARTFIRE[3] and BlueSky[4] systems through contractor support to estimate wildland fire emissions where states did not report. The comparison of the 2008 NEI and $DEASCO_3$ fire inventories reported here is an analysis of opportunity, whereas the fire emissions for wildfire, prescribed, and agricultural fires are independently developed in terms of methodology, using some of the same fire activity databases.

The analysis results reported here are focused on the quality, completeness, and representativeness of these data sets for retrospective air quality planning and exceptional event analyses in the context of the Ozone NAAQS, where emissions estimates from fire as a contributing source have to be at the same grade of quality and completeness of emissions estimates of other contributing sources in order to facilitate meaningful evaluation of contributions of different source types.

BODY

Methods

Because there is overlap between all the data sources in this comparative analysis, preparation, processing, and validation are required to create a complete, non-redundant data set. For the analysis in this paper, three case studies from the 2008 emissions inventory were identified: a "medium-sized" (~3,000 acre) wildfire from northwestern Oregon; a large complex of fires (200,000+ acres) from Northern California; and all fires reported by agencies and detected by satellites in November 2008 in southwestern Oregon. All processing steps described below are specific to this analysis; the methods may change as the final emissions inventory for the $DEACSO_3$ project is developed.

<u>Data Sources</u>

There are four primary sources of fire activity data available for the emissions inventory: ground-based reporting from the Fire Emissions Tracking System[5] (FETS), other ground-based reporting, including daily reports and monthly/annual summaries, Monitoring Trends in Burn Severity[6] (MTBS) fire perimeters, and satellite-detected activity from the Hazard Mapping System[7] (HMS). In addition, several spatial data layers supported the classification, reconciliation, and evaluation of data.

Ground-based Fire Data

Accomplished fire data reported to the FETS for the year 2008 will provide small wildfire, prescribed, and agricultural burn information for the WRAP region, covering 14 western states. Data are submitted continuously to the FETS by various state agencies and include burning on select federal, state, private, and tribal lands. In addition, some data sets are gathered *ex post* by soliciting agencies and downloading publicly available data sets.

Planned and accomplished fire reports for other states were added to the FETS and used in the same manner as data from WRAP region states, but they are beyond the scope of this paper as the case studies chosen will focus on fires in the Northwest United States. Planned burns (both reported to the FETS and added for non-WRAP states) not subsequently reported as accomplished were used to aid classification of HMS activity data.

The activity data are reported by WRAP members to the FETS from the state, tribal, and state-federal-private collaborative Smoke Management Programs (SMPs) developed as regulatory management tools by the various state and tribal governments. It is generally maintained that these SMPs are fundamentally "closer" to the details of prescribed and agricultural fire activity that occurs in their jurisdictions than other data-generators are to fire activity data. Because air quality planning objectives are at stake in the SMP decision-making process to permit and approve burns, the planned and accomplished acres are relatively precise (even for events of very small acreages and fuel consumption) and the start/end dates and accomplished acres well characterized. So confident are data-users in the accuracy and resolution of SMP-provided data that, usually, few QA/QC activities are performed on the fire activity and emissions data and the data are used "as-is."

By comparison, and largely due to the significant volume of data and the critical importance of federal fire activity tracking systems to support real-time and urgent operational decision-making (e.g., resource allocation, suppression management), activity data from federal tracking systems (see sidebar) are necessarily more broad-brush (addressing wildfires of more than 100 acres in grass and brush, and more than 300 acres in timber), and the specific temporal and spatial characteristics are often less refined. Fire event data are often updated with less than daily frequency, and these larger events can remain "active" for long periods of time with many days during which little or no burning or release of emissions actually occur. Air quality planning organizations (and others) have relied upon these federal activity tracking systems AND invested significant effort and financial resources to conduct retrospective analyses and QA/QC efforts in order to improve the accuracy and reliability of the data.

The comparison of SMP-provided data and federal activity data in no way diminishes the importance of the federal activity data to many applications (air quality planning, operational, resource management, public safety, and others). Historically in the West, large wildfires comprise only 10% of the number of wildland fire events but produce 90% of the emissions contributed by wildland fires. Data from federal tracking systems are critically important data streams being actively fed both of the fire emissions management systems that are the principal focus of this paper, SMARTFIRE and FETS.

Satellite-based Fire Data

MTBS data include fire perimeter and burn severity information for wildfires in the United States greater than approximately 500 acres, derived from Landsat scenes before and after the burn. The data will be used in conjunction with HMS satellite detections to create daily fire growth for large, multi-day fires, constrained in size by the perimeter information, as well as daily, composite severity for each burned area identified by HMS (on a detect-by-detect basis).

HMS activity data include the date, time, and location of the detection. The data set covers all of North America, allowing for inclusion of many fires from Canada and Mexico that would otherwise be unobtainable. HMS data will be used in two ways in the 2008 emissions inventory: to create daily fire growth patterns for large wildfires included in the MTBS data set, and to gap-fill areas of the modeling domain where ground-based reporting is lacking. In order for an HMS detect to be eligible for use in the inventory, there must be a positive result returned by the methods developed and implemented to classify a detect as wildfire, prescribed, rangeland, or agricultural burning. HMS fire detections for which a positive categorization result is not returned will be excluded from the inventory.

Spatial Data Sets

There were several GIS data sets that supported data preparation and emissions calculations:

- Fire Characteristics Classification System[8] (FCCS) 30-meter fuelbed layer for the conterminous United States, providing fuel-loading information for multiple strata in 250+ fuelbeds.
- Custom-built land ownership maps for the WRAP region and select states outside the WRAP to support fire classification analysis.
- A map of UTM zones for projecting data, used when calculating distance and area.
- Various boundary maps, including states, counties, tribal areas, and Public Land Survey System (PLSS) grids.
- Daily observed precipitation layers used as an input into the fire consumption model.[9]
- A map of the Bailey Ecoregions for North America,[10] used as an input to the fire consumption model. The map contains hierarchical classes of ecoregions, the broadest being western, southern, and boreal—these three are used by the consumption/emissions model. The next level, domain, is used to match fire locations with the "best-fit" fire weather station. There are seven domains in North America.
- A map of Weather Information Management System[11] (WIMS) fire weather station locations that are paired with daily fuel moisture and meteorological data, used as inputs to the fire consumption model.

2008 National Emissions Inventory (NEI) for Fire, Version 2

The comparative analysis in this paper relies on the daily fire emissions inventory built for the 2008 NEI. This data set was built using the SMARTFIRE system to capture daily fire activity, and using the BlueSky Framework to calculate emissions. (There are many pathways to calculate emissions in BlueSky. For this inventory, CONSUME4.1[2] was used to calculate consumption, and the Fire Emissions Production Simulator (FEPS) to calculate emissions.[13])

The developers made several enhancements to the SMARTFIRE algorithms for version 2 of the 2008 NEI[14] (NEIv2). MTBS data were employed to determine the location and final size of large fires, and the FACTS database was employed to create prescribed burn "climatologies" to help classify HMS detections. In addition, the multi-year MTBS burn perimeter data set was used to determine standard fire sizes for HMS detections that occurred in different fuel types.

<u>Fire Activity Data Processing</u>

The FETS is housed in a GIS-enabled database that allows storage of vector spatial data sets. MTBS and HMS data, as well as all supporting spatial data layers (with the exception of raster layers) were added to the FETS database. To build a reconciled, daily fire activity inventory using all these data sets, several spatial processing steps were followed.

Identify HMS Data (Detects) that are Associated with MTBS Burn Perimeters

Use the HMS data to create daily fire activity for MTBS burns. Figures 1 and 2 graphically illustrate this process and are described in more detail below.

1) For each MTBS record, identify detects that are located within the MTBS burn perimeter. If detects are earlier than the reported start date of the fire, add an "HMS start date" of the earliest detect. For fires with an HMS start date earlier than three weeks before the reported start date, starting with the earliest detect record, remove detects that are more than 14 days apart. If four or more detects occur within two days, only remove subsequent detects if more than 30 days apart. If nine detects occur within two days, no more detects are removed. The official start date of the fire is then set to the earliest retained detection.

2) Identify detects within six km of the perimeter after the start date is determined. Automatically retain any detect within a pixel distance of the fire (0.5 km)—this is shown as the gray and black-outlined circles in Figure 1.
3) Filter out the remaining nearby detects by date and/or distance: if a detect is more than two weeks away (black X's in Figure 1) from any other detect after the start date of the fire, or is more than two kilometers away from any other detect associated with the fire, disassociate the detect from the fire. Assign remaining detects as "associated but outside perimeter threshold" (gray circles in Figure 1). This ensures that detects are not double-counted as additional fires.
4) Calculate daily acres burned based on the intersection of the perimeter and the buffered detect (0.5 km buffer), divided by the number of days that the detect appears at that location, and summing across all detects for that day. In addition, calculate a scalar by dividing the total acres of the perimeter by the sum of all detect-perimeter intersections so the sum of daily acres matches that of the perimeter. This is shown as the circles in Figure 2. Circles on the edge of the burn perimeter contain dark and light portions; the dark portions are the detect-perimeter intersections. Circles with black outlines represent the growth for a single day.
5) Using the intersections of the perimeter and the buffered detects, partition the area for each detection by the frequency of FCCS fuelbeds that occur inside the region using the FCCS 30m layer, and calculate a composite burn severity using the MTBS severity layer (on a scale of 1 [little/no burning] to 4 [severe burning]) for each region.

Identify Ground-reported Data that Overlap MTBS Perimeters

MTBS perimeters take precedence over ground-based reports in the emissions inventory, and therefore ground-reported data within 0.5 miles of a burn perimeter were flagged as "redundant" and not used. The 0.5-mile threshold was determined to be the distance uncertainty for ground-based reports, based on the prevalence of state and federal agencies reporting the location of the centroid of PLSS sections. Further filtering based on identical fire names, as well as other criteria, will be done as part of the final DEASCO$_3$ inventory, but the results due to further filtering methods are beyond the scope of this paper.

Identify HMS Data that are Associated with Ground-based Reports

HMS data were reconciled with ground-based reports using a proximity algorithm. The HMS data set includes detections from three satellite sensors: MODIS, AVHRR, and GOES. The pixel size of the GOES detects is four km; MODIS and AVHRR are approximately one km. As mentioned above, the uncertainty associated with ground-based reports in the FETS was determined to be 0.5 miles.

HMS data were flagged as "associated" with ground-based reports if a buffer the diameter of the pixel size of the sensor around the detection location intersected a 0.5-mile buffer around the ground-based report location. Ground-based reports were not altered based on the number of detects associated with them; the detects were simply removed from the inventory as "redundant."

Identify Remaining, Unclassified, HMS Detects

Remaining, unclassified HMS data were handled in several ways. For detects that were coincident in space, but later in time than HMS data associated with ground-based reports, the unclassified detection was given the same source type (i.e., prescribed, agricultural, or wildfire) and marked as "smoldering" if the record was one day later. Otherwise, the detect was given the same source type but classified as an independent fire.

Next, detections were classified as "agricultural" that occur on agricultural fuelbeds. This categorizing step was not accomplished as of the submittal date of this paper. Therefore, the results of classifying HMS detects as agricultural burns are not included in the case studies considered here. We anticipate obtaining more detailed agricultural spatial information to augment the efficacy of the methods to categorize HMS detects as agricultural burns.

For remaining, unclassified HMS detections, a search was conducted for ground-based reports within 50 km. Detections were classified based on the most frequently occurring source type and the median size of fires for that source type. Agricultural fires, since they are classified separately, are excluded from this step. *Note: the scope of this algorithm was limited to November 2008 for an area in southwest Oregon for the purposes of this paper. To our knowledge, no agricultural burning occurs in this region in November.*

Figure 1. Map Depicting Selection of HMS Detects for the Gnarl Ridge Fire (3,502 acres).

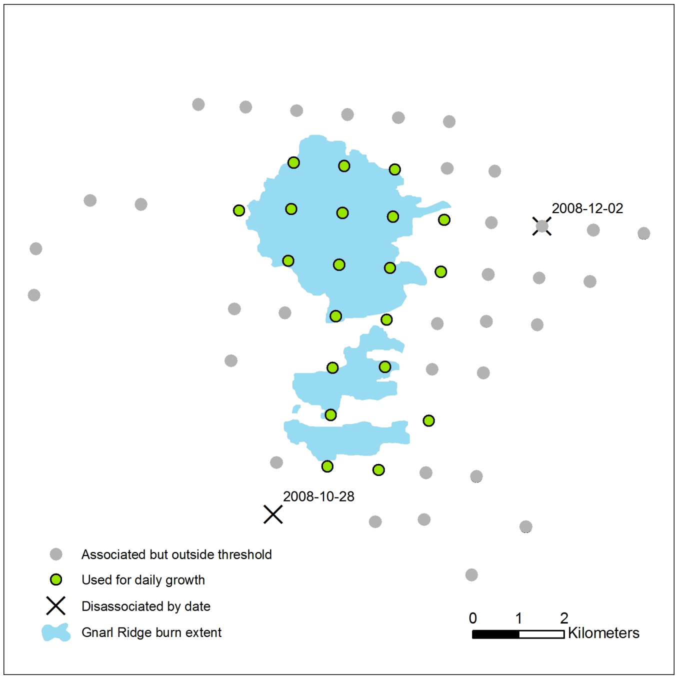
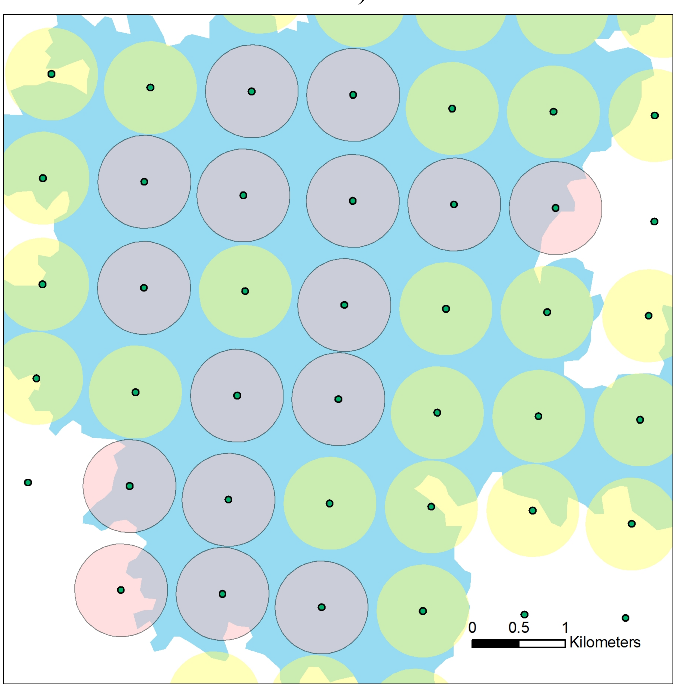


Figure 2. Buffered HMS Fire Detections and MTBS Perimeter, including Daily Fire Growth (Red Circles with Black Outlines). The calculated area for each detection is the darker portion in each buffer.



Emissions Calculations

To calculate consumption, heat release, and emissions in the $DEASCO_3$ emissions inventory, python-CONSUME (CONSUME4.0),[15] a version of CONSUME developed by Michigan Tech Research Institute (MTRI) as part of the Wildfire Emissions Inventory System (WFEIS), was implemented in the FETS. CONSUME4.0 requires several input parameters to calculate consumption and emissions, discussed below. CONSUME4.0 reports flaming, smoldering, and residual consumption and emissions, which were stored in the FETS database with the input parameters and summarized for each case study.

Fuel Loading

CONSUME4.0 allows for composite fuelbeds, organized as (Acres | FCCS class) pairs, to be entered for a single fire. This organization was employed for the $DEASCO_3$ inventory by determining the total acres of each FCCS fuelbed within the area of a fire. For MTBS events, the area was the intersection of each associated HMS detect with the burn perimeter; for point-location events (individual HMS detects and all ground-based reports), a buffer the size of the fire was drawn around the location. In all cases, the resulting polygon was overlaid on the FCCS layer and the frequency of each FCCS code extracted.

Fuel Moisture

CONSUME4.0 requires values for moisture, from 0-100%, for ten-hour, thousand-hour, and duff fuels. Daily measurements from the Weather Information Management System[11] (WIMS), including station locations, were loaded into the FETS database. Using the Bailey Ecoregions layer, each fire was given the ten- and thousand-hour fuel moisture values for the nearest WIMS station within the same ecoregion at the "domain" level (there are seven domains in North America), thus preventing a station from an inherently more arid region, for example, that is proximate to the fire location from being selected even if it is closer.

In addition, CONSUME4.0 requires a "days since significant rainfall" parameter that informs duff layer consumption. This was determined by loading daily, observed precipitation point vector layers from the National Weather Service into the FETS database, and by using a proximity calculation to select the closest value for a given day. If the value was less than 0.25 inches and was within 6 km, the previous day was examined, and so on, until a day met the threshold criteria.

Duff moisture was set to a default of 50% for every fire. The WIMS data set includes the Keetch-Byram Drought Index (KBDI), which is being investigated for use in estimating duff moisture in the final emissions inventory.

Canopy and Shrub Layer Consumption

CONSUME4.0 requires values for canopy consumption and, for fuelbeds with no canopy layer, the "percent shrubland blackened," both on a scale of 0-100%. These values were estimated for MTBS events by overlaying on the MTBS burn severity layer the area of the intersection of each associated HMS detect with the burn perimeter to obtain a composite severity value from 1 to 4. This value was multiplied by 22.5 (for a maximum value of 90%) and applied to both the canopy and shrubland parameters.

For all other burns (or MTBS events where the severity was indeterminate), canopy consumption was drawn from default values determined by MTRI for each FCCS fuelbed, and "percent shrubland blackened" was set to 50%.

Results and Discussion

The SMARTFIRE-based NEIv2 and the $DEASCO_3$ inventory use similar underlying data sets, fuel loading, and consumption models. Table 1 outlines the data and processing steps used in both inventories.

Table 1. Methods Used to Build Activity and Emissions Data Sets for 2008 NEIv2 and DEASCO$_3$

***Data Source / +Processing Step**	**2008 NEIv2**	DEASCO$_3$
*Ground-based reports	ICS-209, FACTS	FETS (incl. ICS-209)
*Satellite-based data	HMS; MTBS	HMS; MTBS
+Daily fire growth for large multi-day events	SMARTFIRE2 algorithm; scale total acres using MTBS perimeters.	Associate HMS detections with MTBS perimeter. Burns not covered by MTBS default to FETS.
+Classify satellite detections	Rx burn climatology for western states; USGS land cover for ag; remainder wildfire.	Reconcile with FETS; proximity to FETS; NASS CDL for ag; method for remainder undetermined.
+Determine size of unclassified satellite detections	Burn statistics by veg type from MTBS burn perimeters.	Avg size of nearby FETS burns; method for remainder undetermined.
CONSUME Inputs		
*Fuel loading data layer	Landfire-FCCS 1-kilometer	Landfire-FCCS 30-meter
+Fuel loading assignment	Not specified in documentation.	Partition frequency of FCCS classes over burned area to create (Acres | FCCS class) pairs.
*Duff moisture	Scaled based on 1000-hr moisture; value varies from 25–250.	Default value of 50% used for all burns.
*+Fuel moisture	Nearest WIMS station; >300km given default values.	Nearest WIMS station in same ecoregion domain. No distance threshold.
*+Precipitation (Days since rain)	Not specified in documentation.	Grid cell within 6 km ≥0.25in from daily NWS precipitation analysis.
*+Canopy consumption	CONSUME defaults; fuelbed-specific.	MTBS severity where available; CONSUME defaults elsewhere.
*+Percent shrubland blackened	Not specified in documentation.	MTBS severity where available; default of 50% elsewhere.
+Ground fuels consumption	Max 20 t/ac in West, 5 t/ac in East for prescribed burns.	CONSUME default
+Consumption calculations	CONSUME4.1	CONSUME4.0
+Emissions calculations	FEPS	CONSUME4.0

Selecting preferred data sources and data integration steps for retrospective fire emissions analyses, supporting regulatory activities such as air quality planning and exceptional event determinations, has to be done for both the NEI and other air quality planning activities. The combined attributes of data transparency, reproducibility, representativeness, and accuracy/precision of data are critical, especially in terms of comparability to other sources (e.g., anthropogenic sources such as industry, transportation, etc). To put these sources and steps in context, three case studies are shown next.

Daily emissions were calculated for three case studies that will be part of the DEASCO$_3$ emissions inventory: the Gnarl Ridge wildfire, the Panther – Siskiyou – Bear Wallow wildfire complex, and all fires in southwest Oregon in November 2008 (the town of Bend was the northeast corner of the bounding box; the Pacific Ocean and OR-CA border were the other boundaries). Daily emissions and activity were then compared to the NEIv2. Each case study is discussed separately.

Gnarl Ridge Fire

Based on a summary on InciWeb,[16] the Gnarl Ridge fire that ignited in August 2008 in Mt. Hood National Forest was contained at 500 acres by late August, then re-ignited in mid-September and moved very quickly to burn an additional 2,500 acres. The size of the fire was in the range of the most common found in the MTBS database between 2002 and 2009 (the median fire size for that period was 1,274 acres). It was selected as a case study because its size (1,000-5,000 acres) and timing (summer) were typical of events that land managers and air quality planners deal with on a regular basis. In addition, its behavior, with a long lull in burn activity, was interesting and presented a frequently encountered challenge from a fire tracking standpoint.

Table 2 summarizes the basic statistics for the Gnarl Ridge fire as characterized by each emissions inventory. Activity data were selected from each inventory based on the proximity of satellite detections (used to determine daily fire growth) to the MTBS perimeter, and the date range during which the fire was active.

The NEIv2 characterized the fire detections proximate to the perimeter as 31 unique events over 16 days: the Gnarl Ridge fire, 2 unnamed wildfires and 28 unnamed prescribed fires. The calculated area of the Gnarl Ridge fire (3,502 acres; see Table 2) in the NEIv2 was identical to the MTBS perimeter, with an additional 7,000 acres allocated to the unnamed fires. The DEASCO$_3$ inventory characterized the same fire detections as one fire, Gnarl Ridge, with a total of 3,497 acres over 10 days of burning (see Table 2).

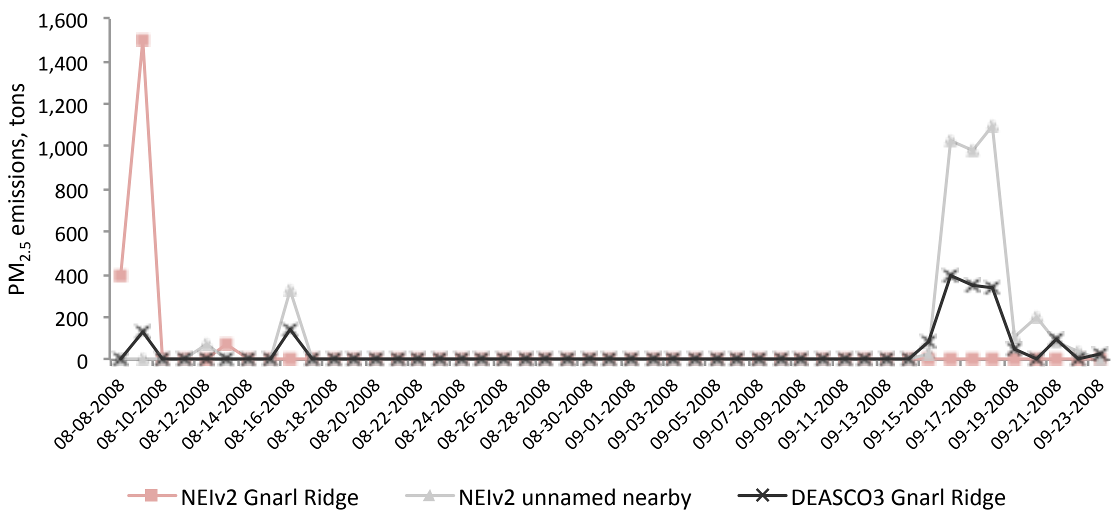
Figure 3 shows the calculated daily emissions for the period of August 8, 2008 – September 23, 2008, for both inventories. The NEIv2 data are split between emissions allocated to Gnarl Ridge (pink squares) and the other fires in the proximity (gray triangles). Emissions allocated to Gnarl Ridge by the NEIv2 ceased on August 13, with the peak of emissions occurring on August 8-9. The peak of emissions in the DEASCO$_3$ inventory occurred on August 16-18.

There is a significant departure between the two inventories in how the fire activity and emission sources in this location during this period are characterized. The DEASCO$_3$ methodology forces HMS detections within a certain proximity and timing to be associated with the MTBS burn perimeter, which is fundamentally different from the "organic" growth of groups of fire detections in the SMARTFIRE algorithm. SMARTFIRE uses the MTBS perimeter to scale the total acres, but apparently only for those detections already associated with the Gnarl Ridge event (i.e., it does not use MTBS to associate detections, only to scale daily growth to match the final size, and to determine the final shape/location of the burn). This resulted in 7,000 acres of additional fire activity (independent of the Gnarl Ridge event) and 4,000 tons of $PM_{2.5}$ being added to the NEIv2.

Table 2. Summary Statistics in Proximity of Gnarl Ridge Fire, 8/8/2008 – 9/23/2008
Values in parentheses for the NEIv2 are Gnarl Ridge event totals.

Inventory	Unique Events	Total Area, acres	$PM_{2.5}$ Emissions, tons	Days of Burning
NEIv2	31	10,494 (3,502)	6,008 (1,985)	16
$DEASCO_3$	1	3,497	1,614	10

Figure 3. Daily Emissions from Gnarl Ridge Fire in Oregon as Estimated by NEIv2 and $DEASCO_3$
Other burns in the proximity of Gnarl Ridge in the NEIv2 are included.



In terms of using NEIv2 Gnarl Ridge wildfire emissions shown in the time series in Figure 3 for air quality planning or exceptional events analysis, the NEIv2 method does not represent emissions magnitudes and timing reflected in the incident management record (e.g., on InciWeb). With the episodic nature of fire emissions, the fire activity data from ground-based tracking must be integrated with satellite detects in a space-time-emissions magnitude format that allows transparent concurrent review by smoke managers and air quality managers.

Panther – Bear Wallow Complex

In late June 2008 the Bear Wallow fire ignited in Northern California, marking the start of a complex group of fires that burned in excess of 225,000 acres over 3 ½ months. This was an example of a large, rare event (though increasingly common) that air quality planners may point to when attempting to declare air pollution events as "exceptional" under the Exceptional Events Rule.

Summary statistics for the complex of fires are summarized in Table 3, and daily emissions are presented in Figure 4. The two inventories are quite similar in their characterization of fire activity. Notable differences occur in the daily emissions calculations even though, as shown in Figure 4, the daily trend in emissions tracks closely throughout the life of the burn complex. The NEIv2 allocated all the area burned in the Bear Wallow fire to June 21, causing a large spike in emissions (lighter shade in Figure 4). Several more emissions spikes dwarf the emissions calculations of the $DEASCO_3$ inventory. Overall, the NEIv2 estimated 33,000 tons of $PM_{2.5}$ greater than $DEASCO_3$, despite an almost identical estimate of acres burned.

The two biggest differences in the emissions calculation methods that may explain the emissions discrepancy are fuel loading assignment and percent consumption of the canopy and shrub layers. Table 4 summarizes the burn-wide results for each of these parameters. The average burn severity calculated by $DEASCO_3$ for the entire burn period was 2.25, which translates to about 50% canopy and shrub layer consumption (*see* Canopy and Shrub Layer Consumption *on page 7)*. Following the method used by the NEIv2, where default canopy consumption values are assigned by CONSUME3 to FCCS fuelbeds, the area-weighted average consumption (by FCCS fuelbed) was 67%. In terms of emissions, a simple scenario set up in CONSUME3 that varied canopy consumption between 50% and 67% showed a 13% increase in total $PM_{2.5}$ emissions.

Table 4 also shows that, while the same 5 fuelbeds were identified by each inventory, the distribution was quite different. The NEIv2 identifies a much higher proportion of FCCS codes 7 (Douglas fir – Sugar pine – Tanoak forest, 45.6 t/ac) and 17 (Red fir forest, 31.4 t/ac), which have much higher available fuel loadings than codes 16 (Jeffrey pine – Ponderosa pine – Douglas fir – Black oak forest, 15.1 t/ac) and 38 (Douglas fir – Madrone/Tanoak forest 20.4 t/ac).

Table 3. Summary Statistics for Panther – Bear Wallow Complex, 6/20/2008 – 10/30/2008

Inventory	Unique Events	Total Area, acres	$PM_{2.5}$ Emissions, tons	Days of Burning
NEIv2	2	227,388	133,515	103
$DEASCO_3$	5	227,560	105,568	109

Figure 4. Daily Emissions from Panther – Bear Wallow Complex in California as Estimated by NEIv2 and $DEASCO_3$

The large spike on June 21 in the NEIv2 is attributed to Bear Wallow.

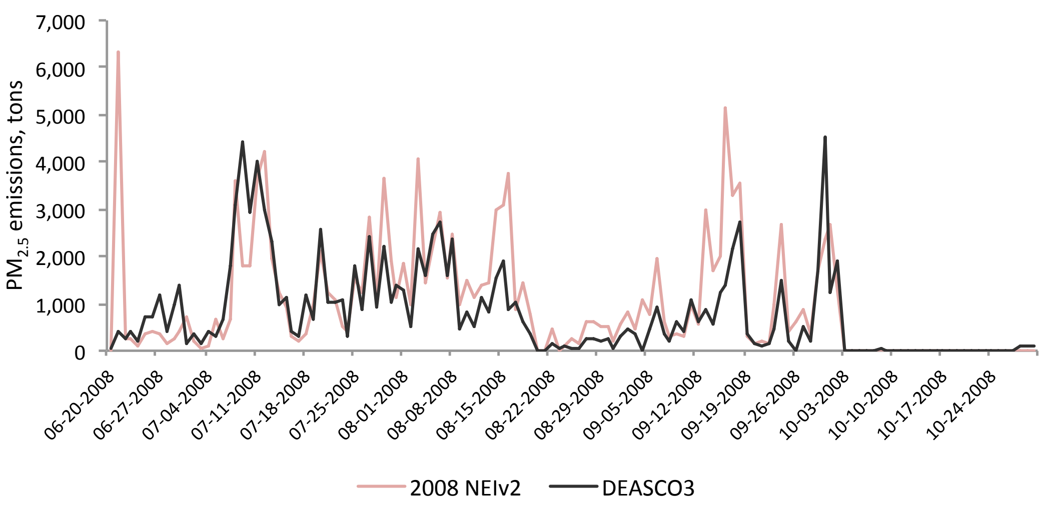


Table 4. Summary of Primary FCCS Codes Identified in Panther – Bear Wallow Complex and Average Canopy Consumption

	Top 5 FCCS Codes (% of area)	Area-weighted Average Canopy Consumption	Canopy Consumption Estimation Method
NEIv2	38 (30%) 7 (26%) 17 (23%) 47 (9%) 16 (5%)	67%	CONSUME3 provides default canopy consumption for each FCCS code.
$DEASCO_3$	38 (36%) 7 (18%) 16 (9%) 17 (9%) 47 (9%)	50%	Calculated from MTBS burn severity (*see page 7*).

November Fires in Southern Oregon

A significant amount of prescribed burning occurs in Oregon in the fall. The Oregon Department of Forestry Smoke Management Program regulates burning conducted by federal and state agencies, all of which is reported to the FETS. However, southwestern Oregon also experiences frequent burning on private lands that are not regulated and therefore not reported. Thus, fire occurrence information derived from satellite detections combined with ground-reported data is necessary to capture the full extent of burning in this area.

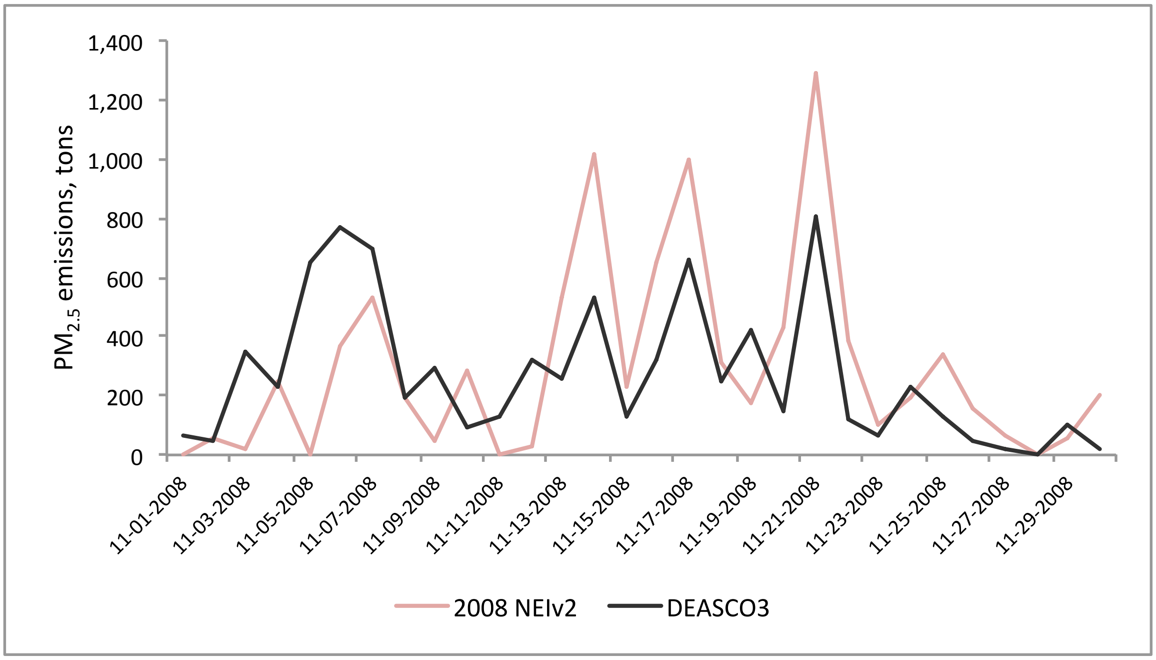
The summary statistics in Table 5 reveal distinct differences in fire activity characterization, and Figure 5 shows the similar daily trend in emissions estimates. Both inventories reported virtually all activity as prescribed burning, but the $DEASCO_3$ reported many more events. This is partly due to the availability of data from the FETS (262 events), but also because every fire detection in the HMS data set was considered a separate burn. Detections near FETS events in the $DEASCO_3$ inventory were removed (79 detections), leaving 535 unique HMS events. The SMARTFIRE algorithm lumps detections that are coincident in time and directly adjacent to each other, resulting in fewer unique events. Otherwise, one would expect the two inventories to have a similar number of HMS events.

The NEIv2 reported 37% more acres burned but only 10% more emissions. Examination of the identified FCCS fuelbeds in both inventories showed a similar distribution, so the difference in the proportion of emissions to acres burned must come largely from the other model parameters. Referring back to Table 1 (methods used to build activity and emissions data sets for the NEIv2 and $DEASCO_3$), the two inventories use different methods to estimate moisture parameters, and the NEIv2 caps ground fuel consumption for prescribed burns. In addition, the use of FEPS in the NEIv2 introduces additional calculations for combustion efficiency that may significantly affect emissions.

Table 5. Summary Statistics, Southwestern Oregon 11/1/2008 – 11/30/2008

Inventory	Unique Events	Total Area, acres	$PM_{2.5}$ Emissions, tons	Days of Burning
NEIv2	523	41,089	8,932	26
$DEASCO_3$	797	29,962	8,094	30

Figure 5. Southwestern Oregon Daily Emissions in Nov. 2008 as Estimated by NEIv2 and DEASCO$_3$



CONCLUSIONS/FINDINGS

The case studies presented in this paper represent a small portion of the total emissions on a national scale for 2008, but they illustrate how the different fire activity data sources and fire emissions inventory systems all contribute significantly to meet the needs of data-users. Our conclusions are as follows:

- It is important for end-users in need of emissions inventory data to make deliberate choices to use one tracking system or emissions inventory system over another depending on the specific needs/applications of the data. Features of the systems to consider could include:
    - Availability of data at the time the data are needed.
    - Representativeness of the activity and emissions data of on-the-ground conditions.
    - Reproducibility (and supporting documentation and underlying data) for the data used to support decision-making.
    - Importance of the accuracy of the spatial and temporal characteristics of the emissions data to the decision-making process.
    - Importance of the accuracy of the magnitude of the emissions estimate and the categorization of fire source types (wildfire, prescribed fire, agricultural burning).
- Improving and optimizing data sources for retrospective fire emissions analyses supporting regulatory activities such as air quality planning and exceptional event determinations should address the following elements, referencing Table 1 and the three aforementioned case studies:
    - Some categories require more analysis to optimize methods and/or determine methods for sub-categories such as those related to agricultural fire.
    - Emissions estimation tools used to populate the NEI and other regulatory air quality planning analyses must be fully documented, use open-source computer code, and be reproducible by peers.
    - Due to the episodic nature of fire, work on the SMARTFIRE and FETS emissions estimation systems both indicate the critical importance of the fullest possible use of ground-based fire activity tracking data for air quality analysis, particularly where fire

emissions are to be excluded or the level of culpability determined for episodic local and regional air quality impacts.

- Satellite detects of fire activity data help refine fire emissions data completeness in important ways. Continued support for satellite observation systems and advances in data processing are needed to allow further development of this "top-down" data collection resource for air quality planning applications.
- Displays for regulatory applications of fire emissions data should be done in an open and transparent environment, where smoke managers and air quality managers can "see the work" and understand the resulting fire emissions estimates.

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KEY WORDS

Fire Emissions Inventories
Ozone
Satellite Fire Detections
Fire Emission Models
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Exceptional Events
Smoke Management Programs