AirFire/STI National Wildland Fire Emission Inventory for 2008

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The AirFire/STI National Wildland Fire Emissions Inventory for 2008 (hereafter referred to as the inventory) follows a bottom-up methodology. That is, an attempt is made to catalog each fire on the landscape (activity data), calculate emissions estimates for those fires, and then sum all emissions for the final inventory. The information needed to calculate emissions for each fire is shown in Figure 1. In this figure, arrows show dependency and data flow. For example, the calculation of consumption depends upon fire location, fuels, moisture, and fire type, while moisture depends upon fire location and date. Items in parenthesis indicate the specific models or systems that provide the estimations.

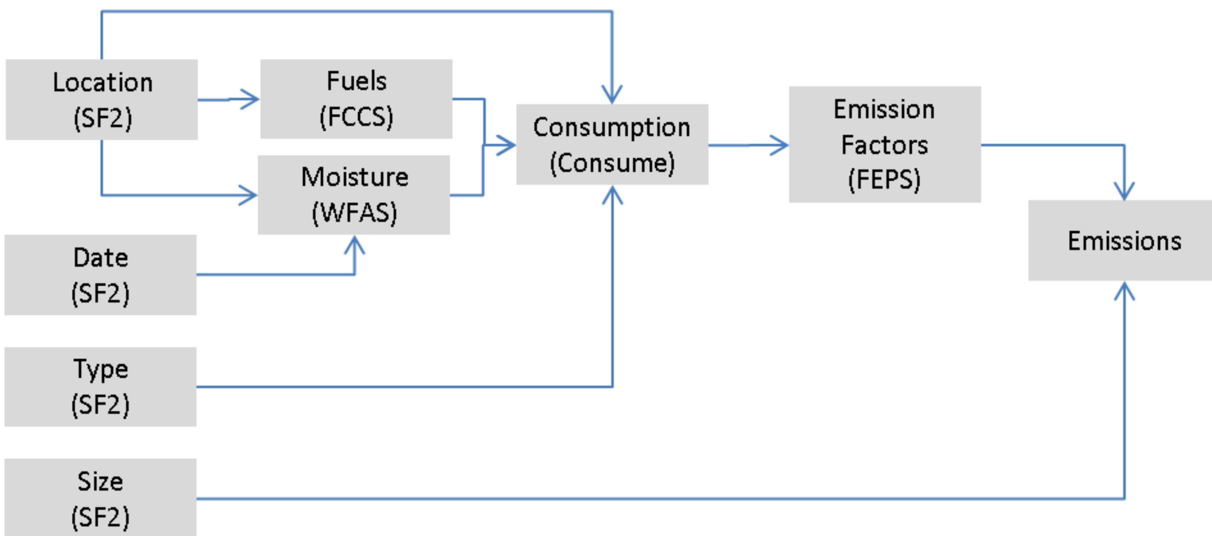

Figure 1. Information dependency and process flow for the inventory.

The inventory processing was performed using two software frameworks: SmartFire version 2 (SF2) and the BlueSky Framework version 3.3 (BlueSky). SF2 is a framework for collecting, associating, and reconciling data sets of wildland fire activity into unified data streams. SF2 provides the activity data for the inventory in the form of daily location, size, and type (wildfire or prescribed burn) assignments. BlueSky is a framework that links multiple sub-models into processing chains for estimating emissions and dispersion from wildland fires (Larkin et al., 2009). Because SF2 and BlueSky are frameworks, and not specific models, the detailed inputs, settings, and processing pathways used to create the inventory are described here.

Activity Data

Wildland fire activity data (i.e., fire locations, sizes, types, and timings) were generated within SF2. SF2 harvests and reconciles information from multiple data sets that themselves provide activity data. For this inventory, three fire activity data sets (sources) were used.

Monitoring Trends in Burn Severity (MTBS)

The MTBS project has produced burn scar information from large fires for 2008 (MTBS ref). This inventory used the burn perimeter outlines that were generated for each MTBS fire. The MTBS project seeks to analyze all fires in the U.S. greater than 1000 acres in the West and 500 acres in the East (ref). Therefore, MTBS perimeters are only available for those large fires. Both wildfires and prescribed burns are included in the project.

[Map?]

[Stats: Number of records, number of unique fires, number undetected in other sources]

Incident Command Summary Reports (ICS-209)

Though it is not their primary purpose, ICS-209 reports contain fire activity information that can be used in emissions inventories. ICS-209 reports are created for all fires for which there is a federal response, which could include monitoring only. Though all fire types are represented in the ICS-209 database, the vast majority of ICS-209 fires are wildfires or wildland fire use (WFU).

[Map?]

[Stats: Number of records, number of unique fires, number undetected in other sources]

Hazard Mapping System (HMS)

The National Oceanic and Atmospheric Administration (NOAA) HMS is an operational effort to collect, assess, and human quality control fire detection data from several satellite-based remote sensors. HMS includes automated detections from geostationary (e.g., GOES) and polar-orbiting (e.g., MODIS) satellites. HMS also includes manually detected fires, where a trained analyst observes smoke plumes in visible satellite imagery. Though the HMS data includes many fires, the likelihood of detection of a specific fire depends on many parameters, including size, intensity, land type, timing, cloud cover, and others.

[Map?]

[Stats: Number of records, number of unique fires, number undetected in other sources]

Association

While each input data source detects a different subset of fires, there is significant overlap among the sources, with more than one source detecting the same fire. In order to prevent double counting, SF2 associates fires from different sources that are collocated in space and time, taking into account spatiotemporal uncertainty for each data source. Association is illustrated conceptually in Figure 2. In Figure 2(A), fires from two data sources overlap in time, but do not overlap in space. Further, they do not overlap even when taking into account their uncertainties. Thus, they are not associated and treated as two separate fires. In Figure 2(B), a fire from a third data source overlaps the fire from source 2 in space and time. In addition, source 3 overlaps source 1 in time and its spatial uncertainty range also overlaps source 1. In this case, all three fires would be associated and treated as a single fire in reconciliation. Table 1 shows the uncertainty ranges used in the inventory.

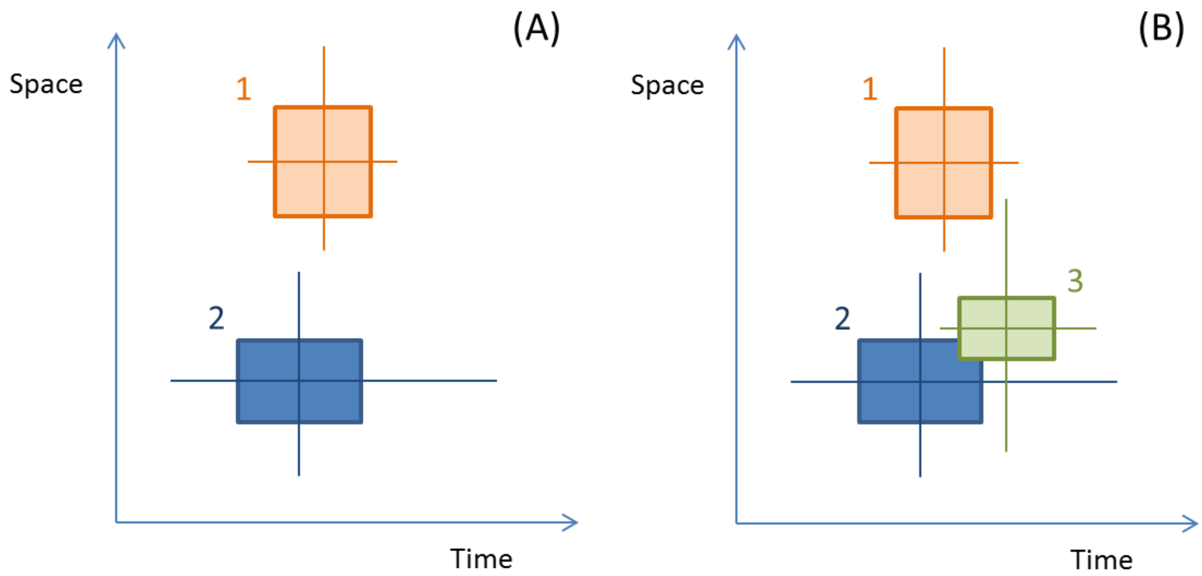

Figure 2. Conceptual illustration of non-association of fires from two data sources (A) and association with a third data source (B). Boxes represent the area and timespan of the fires, while the lines represent the spatiotemporal uncertainty ranges for that data source.

Table 1. Uncertainty ranges used in the inventory for associating fires from multiple data sources.

Data Source	Spatial Uncertainty (km)	Start Uncertainty (days)	End Uncertainty (days)
MTBS	0.5	1	30
ICS-209	5	1	4
HMS	4	2	3

Reconciliation

If a fire is identified by more than one data source, the information must be reconciled to produce a single data set that avoids double counting fires. Rather than selecting all of the information from a single data source, SF2 splits fire information into several elements that are treated separately. For example, the MTBS data set may provide the most accurate estimate of the location and shape of a burn, but it does not provide information about the end date of the fire. SF2 allows for the estimation of each element to use whichever data source is expected to provide the most accurate information. The key elements that SF2 estimates are:

- Location and shape
- Final size
- Daily fractional growth
- Fire type (e.g., wildfire or prescribed burn)
- Name
- Start Date
- End Date

In this inventory, the reconciliation methodology was simple precedence. For each key element, each data source was assigned a rank. For a given fire, the data source with the highest rank in an element provided the estimate for that element. Table 2 shows the ranks that were assigned to each data source for each data element. Table 3 shows the data sources that provided each element for the different possible combinations of the three data sources.

Table 2. Data source precedence for the key data elements estimated by SF2.

Data Element	First Choice	Second Choice	Third Choice
Location/shape	MTBS	HMS	ICS-209
Final size	MTBS	ICS-209	HMS
Daily growth	HMS	ICS-209	MTBS
Fire type (WF/Rx)	ICS-209	MTBS	HMS
Name	ICS-209	MTBS	HMS
Start date	First reported		
End date	HMS	ICS-209	MTBS

Table 3. First choice data sources for the key data elements depending on which data sources were available for a given fire.

Data Sources Present	Location/shape	Final Size	Daily Growth	Fire Type	Name
MTBS; ICS-209; HMS	MTBS	MTBS	HMS	ICS-209	ICS-209
MTBS; ICS-209	MTBS	MTBS	ICS-209	ICS-209	ICS-209
MTBS; HMS	MTBS	MTBS	HMS	MTBS	MTBS

ICS-209; HMS	HMS	ICS-209	HMS	ICS-209	ICS-209
MTBS	MTBS	MTBS	MTBS	MTBS	MTBS
ICS-209	ICS-209	ICS-209	ICS-209	ICS-209	ICS-209
HMS	HMS	HMS	HMS	HMS	HMS

Each of the data sources included fires that were not present in any other data set. Therefore, estimation methods were required for all of the key elements for all data sources. These are presented below in precedence order for each element. Note that for each fire only the highest ranked data source was used to determine the values for each element.

Location/shape

Location and shape refers to the geographic location of the fire and its burn perimeter. Figure 3 shows the shape of the Basin Complex fire as represented by all three input data sources. Note that, in this case, two ICS-209 reports were merged into this fire.

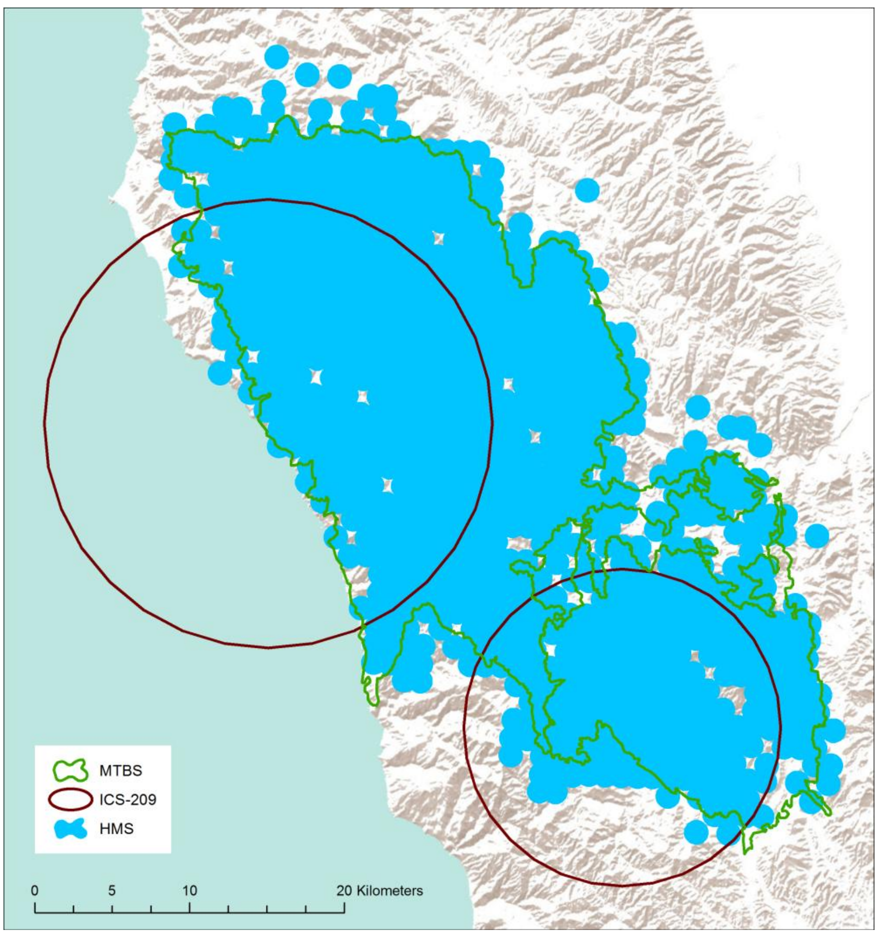

Figure 3. The Basin Complex fire on the California coast as represented by the MTBS, ICS-209, and HMS data sources.

MTBS

MTBS perimeter shapefiles were derived from the LANDSAT burn severity imagery analysis produced by the MTBS project team. They provide the most explicit estimate of the shape of the fire and are georeferenced accurately. The MTBS burn perimeter was used directly.

HMS

HMS data are "hot spot" pixels, which are the detections of actively burning area fires from satellite sensors. The pixels from each sensor (and from analysts) are archived onto a single 1-km resolution grid. There is no explicit spatial information. To estimate a fire shape from HMS, a circle with a radius of 800 m was created for each pixel. Large fires are typically detected by more than one pixel. Overlapping circles were then merged to produce the final fire shape.

ICS-209

The spatial data in ICS-209 data are limited to a single latitude and longitude pair that represents the ignition point of the fire. There is no explicit spatial information. To estimate the shape of a fire from an ICS-209, a circle centered on the reported ignition point with a total area equal to the area reported in the ICS-209 report was created.

Final Size

Final represents the total burned area of the fire. Note that SF2 allows the final size to be different from the geometric area of the shape.

MTBS

MTBS burn perimeters are created well after the fire has died. The final size was calculated as the total area of the burn scar. Note that this may include unburned islands.

ICS-209

The ICS-209 report database includes an "area" field that provides an estimate of the total cumulative area burned at the time of the report. Final size in the inventory was calculated using the area field for the last ICS-209 report for the fire.

HMS

HMS hot spot pixels do not provide information on area burned intrinsically, so final size must be inferred. Final size was estimated by assigning an area burned per pixel (A_p) and multiplying by the number of pixels in the fire. The value of A_p depends on ecosystem because the same fire size will be detected differently in each. For example, rangeland burns move quickly and produce less heat relative to forest burns. Both of these traits result in fewer pixels per acre burned in the rangelands. To develop the area per pixel relationships, MTBS burn perimeters for 2003-2008 were intersected with the Fuel Characteristic Classification System (FCCS) 1-km resolution map (http://www.fs.fed.us/pnw/fera/fccs/maps.shtml). Each FCCS fuelbed was assigned to one of 12 broad vegetation classes and each MTBS perimeter was also assigned to one of the vegetation classes. Linear area per pixel relationships were developed for all fires as well as fires that were less than 10,000 acres. Table 4 shows the statistics for each vegetation type along with the final value of A_p that was used in the inventory. Figure 4 shows how A_p varies spatially.

Table 4. Area burned per HMS hot spot pixel statistics and final A_p.

Vegetation Type	All Fires			Fires < 10,000 acres			Final A_p
	Area/ Pixel	R-Squared	No. of Fires	Area/ Pixel	R-Squared	No. of Fires	Area/ Pixel
Closed Conifer	47.6	0.92	485	46.5	0.4	371	46
Boreal	322.6	0.69	8	322.6	0.69	8	100
Aspen	91.7	0.94	26	384.6	0.13	24	80
Grassland	172.4	0.85	476	126.6	0.29	414	150
Other	135.1	0.62	848	163.9	0.23	800	100
Eastern Deciduous	122.0	0.66	175	122.0	0.2	169	122
Juniper	90.1	0.75	206	70.9	0.47	180	80
Open Conifer	69.4	0.75	812	73.0	0.31	754	70
Pacific Broadleaf	303.0	0.49	69	147.1	0.26	53	150
Shrubland	196.1	0.47	811	212.8	0.19	643	200
Savanna	500.0	0.26	151	101.0	0.46	137	100
Riparian	75.2	0.98	149	114.9	0.1	144	75

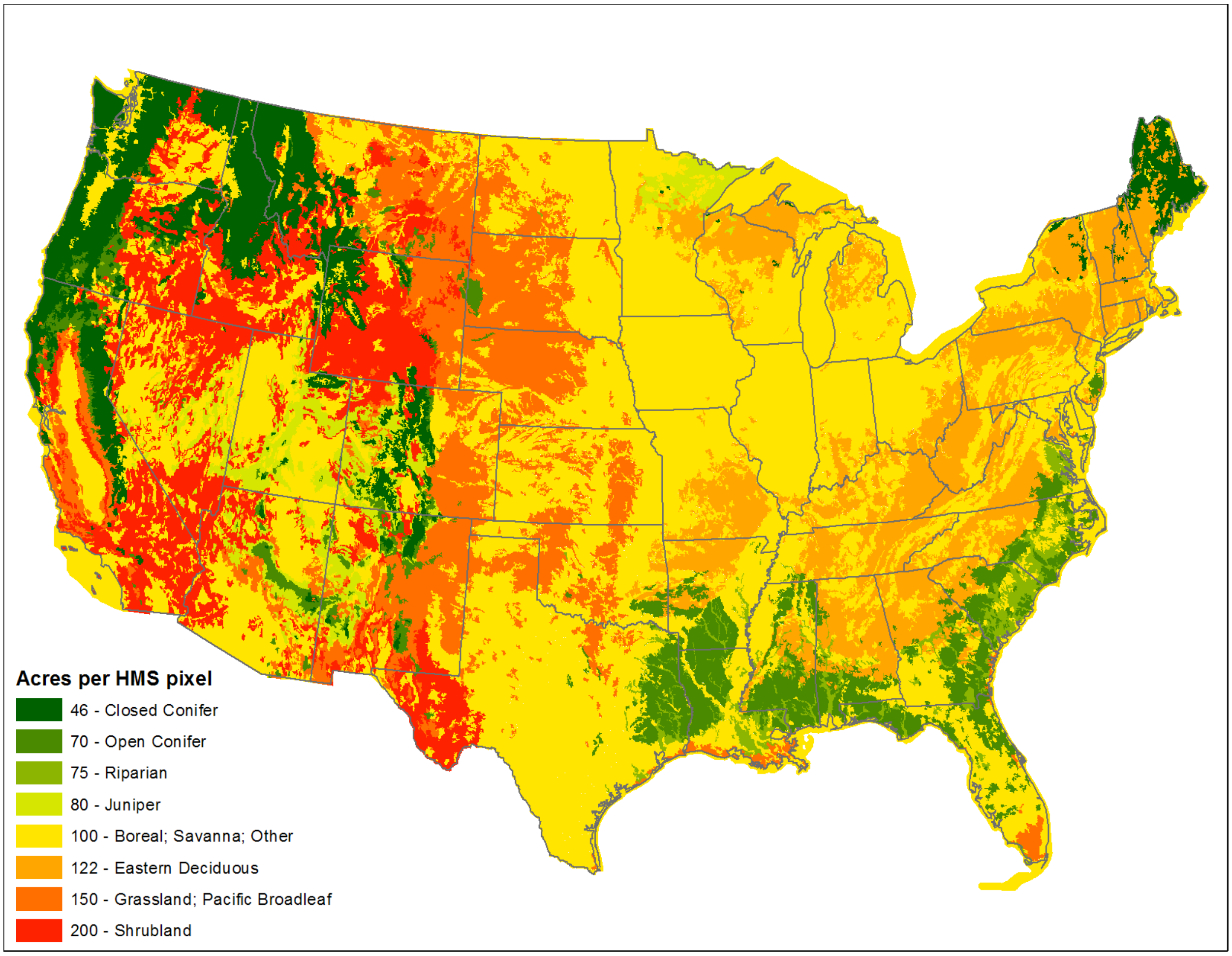

Figure 4. Mapped values of A_p used for the determination of final size from HMS data.

Daily Fractional Growth

The total fire size is sufficient to produce an overall estimate of emissions from the entire fire. However, to support air quality modeling, the inventory must provide emissions estimates that are temporally resolved. The daily fractional growth is used to allocate total area burned over the lifetime of the fire into daily totals. During emissions processing, BlueSky further subdivides these daily totals into hourly estimates of emissions.

HMS

In clear conditions, HMS provides a daily snapshot of fire activity. Though HMS may be less reliable at estimating total area (and is therefore ranked last for determining final size), the fraction of total pixels on a given day provides a proxy for the fraction of emissions that occur that day. Daily fractional growth in the inventory was determined by dividing a fire's daily HMS pixel count by its total HMS pixel count.

ICS-209

For large fires, ICS-209 reports are typically produced daily or more. Each report provides a cumulative area burned to date estimate. Daily area burned was estimated by subtracting the area from the last report for the day from the last report on the previous day. If this value was less than zero, it was set to zero. Then the daily area was divided by the area in the final report to produce the daily fractional growth.

MTBS

The MTBS perimeter files provide no temporal information aside from the start date of the fire. For the inventory, the daily fractional growth was assigned as 100% on the start date of the fire.

Fire Type

The type of fire (wildfire, prescribed burn, WFU) is important for at least two reasons. As shown in Figure 1, the type of fire affects the consumption model. Second, for modeling and policy purposes, it is important to understand the fraction of emissions that are coming from each fire type. The inventory assigns a fire type to each fire.

ICS-209

ICS-209 reports provide fire type explicitly. These types are used in the inventory directly. The majority of ICS-209 reports are for wildfires.

MTBS

The MTBS perimeters do not explicitly provide fire type; however, fire type can sometimes be inferred from the fire name field. In the inventory, fires were assumed to be wildfires unless they had “Rx” or “unnamed” somewhere in their name field.

HMS

HMS data provide no fire type information. Therefore, to assign fire types to all fires, an educated guess is required. A fire type climatology map was developed to assign HMS fires as either wildfire or prescribed burn depending on the state and month of the burn (Figure 5). Fires were presumed to be prescribed burns unless they fell within the “distinct wildfire season” for the state. . The fire season map was developed by analyzing the Monitoring Trends in Burn Severity (MTBS) data set for the years 1984-2006 to determine the typical wildfire season for each state and analyzing the Forest Service Activity Tracking (FACTS) prescribed burn data set for one year (10/1/2009 to 9/30/2010) to estimate the prescribed burning season. For many states in the West, the seasonal patterns of wild and prescribed fires were distinct and separable (e.g., Colorado in Figure 6). In other states, particularly in the southeastern United States, the seasons were not separable (e.g., North Carolina in Figure 7). For those states, fires detected by HMS only are presumed to be prescribed burns. HMS fires were presumed to be prescribed burns by default because wildfires were more likely to be represented in the other data sets as well.

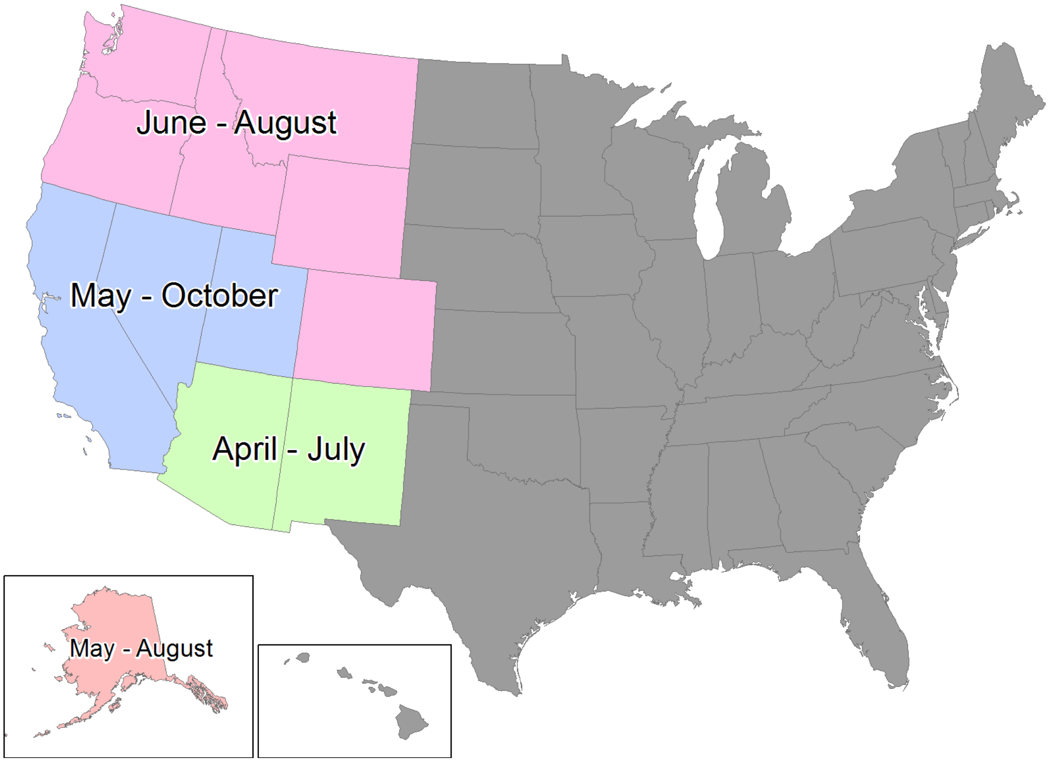

Figure 5. HMS wildfire assignment map. If an HMS fire fell within the states and months shown, they were assigned as wildfires. Otherwise, they were assumed to be prescribed burns.

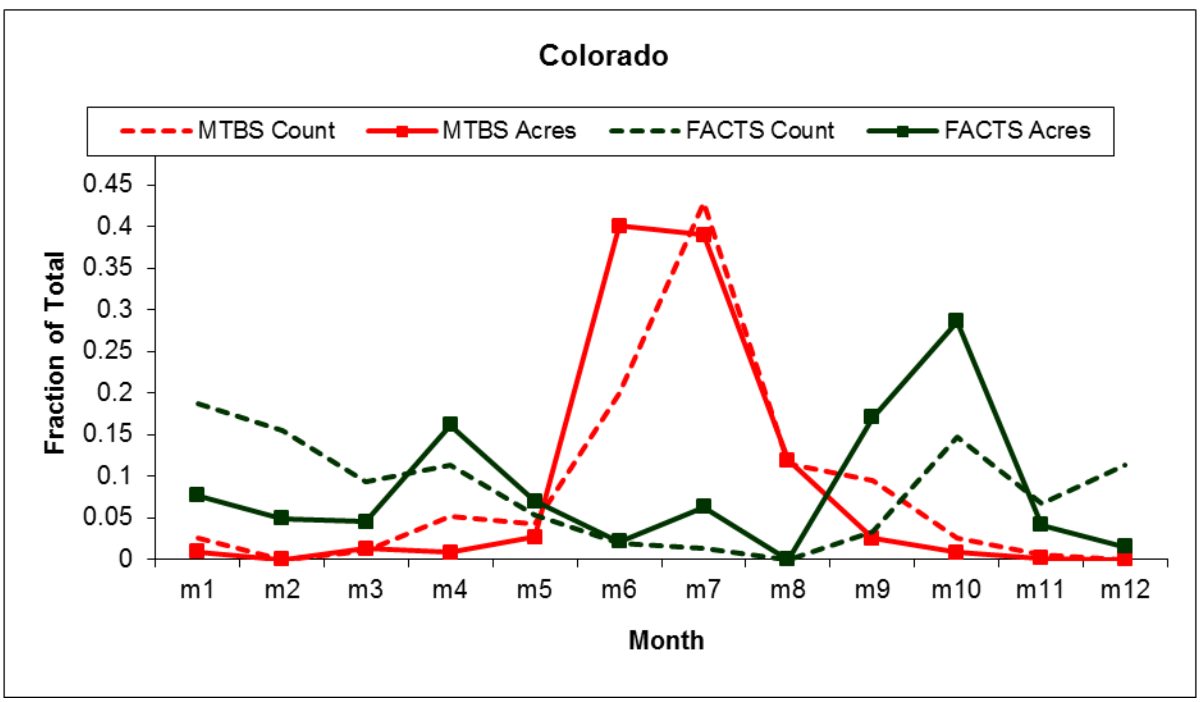

Figure 6. Monthly fractions of fire activity (total count and acres burned) for historical MTBS data (primarily wildfire) and 2009 FACTS data (prescribed burns) for Colorado.

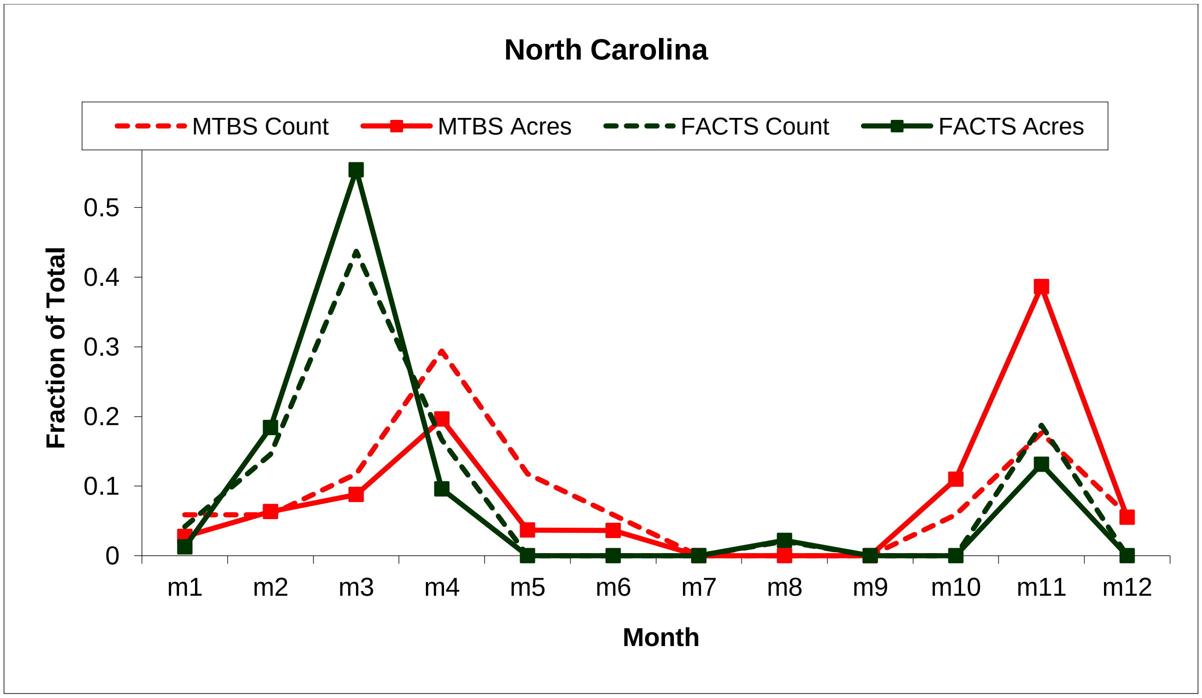

Figure 7. Monthly fractions of fire activity (total count and acres burned) for historical MTBS data (primarily wildfire) and 2009 FACTS data (prescribed burns) for North Carolina.

Name

Although the name of the fire has no bearing on the calculated emissions in the inventory, it is still useful for post analysis and quality control because it makes finding results from specific important fires easier and is helpful for quality control.

ICS-209

ICS-209 reports contain a name field, though sometimes the name changes over the course of the fire. In the inventory, the name from the last ICS-209 report was used.

MTBS

The MTBS perimeter data includes a name field which is used in the inventory.

HMS

HMS data do not have any information that can be used to determine the fire name. HMS fires in the inventory were assigned the name “Unnamed Fire.”

Start Date

Fire start date was treated differently from the other elements in that there was no source that took precedence over another. Rather, the source with the earliest start date was used. This was because data sources sometimes first report the fire late, but they do not report early.

ICS-209

ICS-209 reports contain a start date field, which was used directly.

MTBS

The MTBS perimeter data includes a start year, month, and day. These were combined to form the MTBS start date.

HMS

HMS data are of daily resolution. In the inventory, the start date of an HMS fire was the date of the first detected fire pixel.

End Date

Start and end date provide the temporal bounds of a fire that can be used in associating fires from multiple data sources.

HMS

HMS data are of daily resolution. The end date of an HMS fire was the date of the last detected fire pixel. Note that HMS detects actively burning area, including smoldering. Thus, detections can occur after the fire has stopped expanding. For emission inventory purposes, it is desirable to model emissions for the duration of burning.

ICS-209

ICS-209 reports include a status field that can be "initial," "update," or "final." When the status is not final, it indicates an incident in progress. In this case, the end date was set to the date of the report. When the report is final, however, the report date is unreliable as the final report is often created well after the fire has completed. There are several fields that can be used to estimate the end date from a final ICS-209 report, but they are not guaranteed to be populated. The inventory used these fields in descending order of preference: declared controlled date, estimated control date, and expected containment date. If none of those fields were populated, the end date was set to the same day as the start date.

MTBS

MTBS perimeters contain no information about the end date of the burn. In the inventory, the end date was set to the same day as the start date.

Emissions Processing

The activity data produced by the SF2 processing described above provided inputs to emissions modeling within BlueSky. SF2 was used to produce reconciled fire activity output in the BlueSky standard file format. The following steps were applied:

1. Segregate agricultural fires
2. Assign fuel moistures
3. Process through BlueSky:
    a. Fuel loading (FCCS)
    b. Consumption (Consume)
    c. Emissions (FEPS)

These steps are detail in this section.

Segregate Agricultural Fires

BlueSky does not currently provide methods for estimating emissions from agricultural burns. Activity data from SF2 were intersected with the U.S. Geological Survey (USGS) 2001 30-m National Land Cover Dataset (NLCD). The NLCD classifies all area in the United States into one of 19 land cover types (Figure 8). Fires that fell within land cover types 81-Pasture Hay or 82-Cultivated Crops were assumed to be agricultural burns and removed from the inventory.

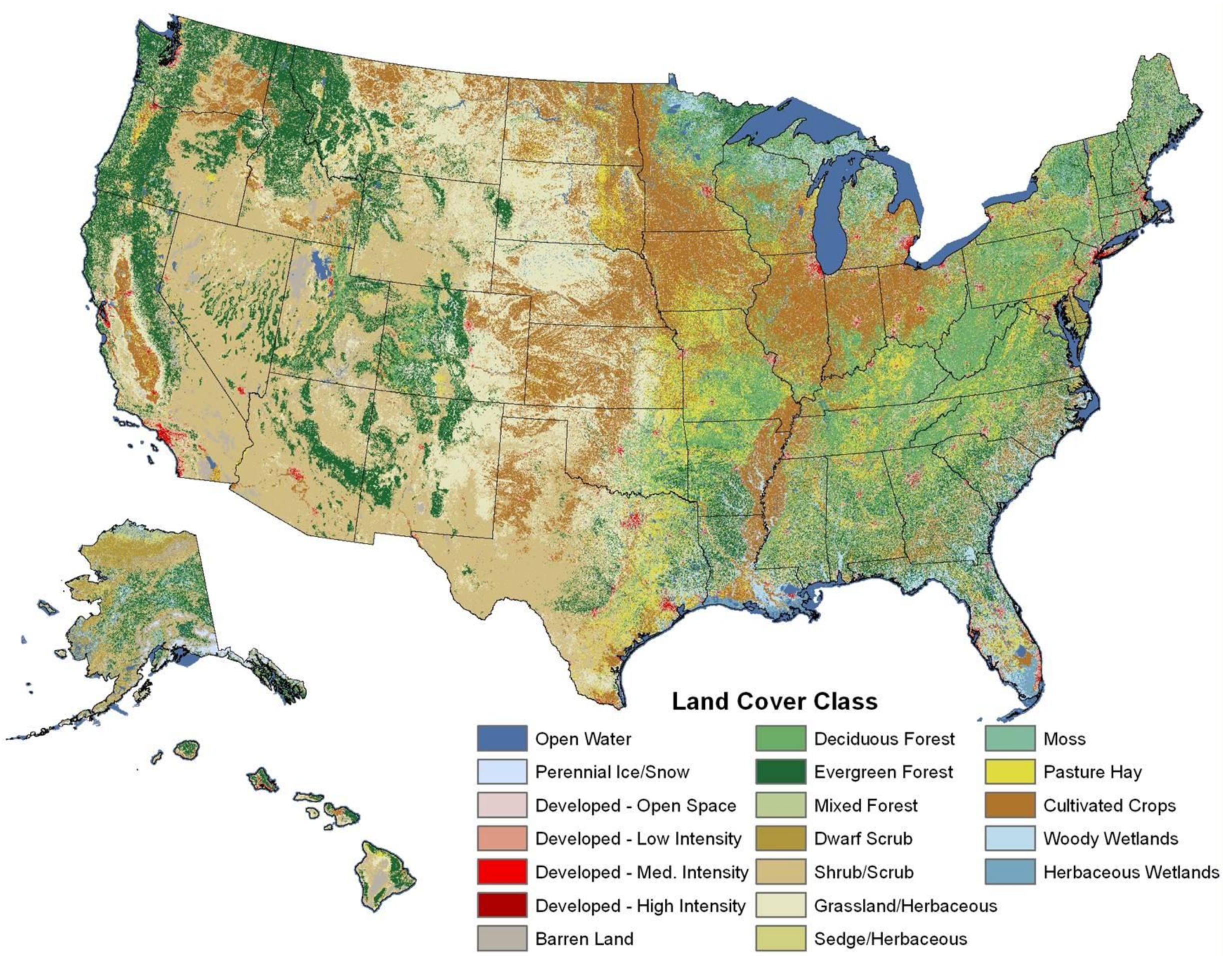

Figure 8. NLCD map used to identify and segregate agricultural burns.

Assign Fuel Moistures

The Consume consumption model requires 10-hour, 1,000-hour, and duff fuel moisture values. Daily fuel moistures for each fire were assigned to nearby fire weather stations where available. Daily fire weather observation files were acquired from the USFS Wildland Fire Assessment System (WFAS) archive. 10-hour and 1,000-hour fuel moistures were assigned from the nearest reporting weather station if it was within 300 km. If no reporting weather station was found within 300 km for that day, default values were assigned (10-hour = 9%; 1,000-hour=12%). Duff moisture values for each fire were then assigned based on the 10-hour fuel moisture according to Table 5.

Table 5. Duff moisture lookup for 10-hour fuel moisture values.

10-hour fuel moisture range (%)	Duff moisture assigned (%)
0-7	25
8-9	40
10-11	70

12-19	150
20-29	250
>29	400

Process through BlueSky

General info and specific version information

Fuel Loading

Consumption

Emissions

Results

1. Activity Results
    a. Overview - table and map by state, fire type, month
    b. Comparison to federal databases
        i. FWS
        ii. FACTS
        iii. NIFC
        iv. NICC
    c. Comparison to 2008 version 1

    Emissions results

. Overview - table and map by state, fire type, month
    a. Comparison to 2008 version 1

Discussion

1. Critical uncertainties
2. Known issues
3. Suggested improvements