Development of the 2008 Wildland Fire National Emissions Inventory

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How Fire Emissions Are Modeled

\[ E_s = A \times AFL \times \beta \times Ef_s \]

Emissions of species \( s \) = 

Area burned \( x \)

Available fuel load \( x \)

Burning efficiency \( x \)

Emission factor of species \( s \)

All these terms must be correct to produce correct emissions estimates
Modeling Steps

Gather fire info

Merge fire info

Fuels

Total Consumption

Time Rate

Emissions

Plume Rise

SmartFire

BlueSky
BlueSky and SmartFire

• **The BlueSky Framework** was developed to compute smoke emissions (and impacts) given known fire information.

• **The SmartFire 2 System (Framework)** was later developed to help reconcile disparate sources of fire information into a useful data stream.

• **Together, SmartFire 2 → BlueSky** can take in multiple heterogeneous fire information datasets and create a unified fire emissions inventory suitable for further modeling.
Lots of choices

Gather fire info
- MTBS
- ICS 209
- HMS
- GeoMac
- NFPORS
- FACTS
- Regional State

Merge fire info
- Choice of:
  - Datasets
  - Weights
  - Algorithms

Fuels
- FCCS-LF
  - FCCS v1
  - Landfire
  - GVDS (FINN)
  - FLAMBE
  - Hardy
  - NFDRS
  - OBSERVED

Total Consumption
- CONSUME
  - FOFEM
  - FINN
  - FLAMBE
  - FEPS
  - EPM
  - OBSERVED

Time Rate
- WRAP
- FEPS
- FOFEM
- Custom
- OBSERVED

Emissions
- FEPS
- FINN
- FOFEM
- CONSUME
- OBSERVED

Plume Rise

SmartFire

BlueSky
The Fire Information Problem

There is no single complete, best fire information data source

- Coverage is limited (by size, type, jurisdiction)
- Timeliness varies from near-real-time data to data being available only years later
- Each data source has strengths and weaknesses
How SmartFire Works

• Gathers datasets
• Processes individual datasets
• Associates data between datasets
• Creates one or more unified data streams by reconciling data
The 2008 NEI v2: Fire Activity Data Sources

• **NOAA HMS**
  – Automated detection from seven satellites
  – Quality control by human analysts

• **Incident Command Summary Reports (ICS-209)**
  – Daily reports prepared by wildfire incident teams

• **MTBS**
  – Burn scars derived from high-resolution satellite imagery
  – Data for all fires > 500 acres in the east; > 1,000 acres in west

**NEI:** National Emissions Inventory
**NOAA:** National Oceanic and Atmospheric Administration
Three Views of the Same Fire (Evans Road, NC 2008)

- **HMS**: Approximate shape; inferred size; daily activity information
  - Available for many fires (when not cloudy)

- **ICS-209**: No shape information; reported size; additional information (type, name, start/end date)
  - Available mostly for wildfires

- **MTBS**: Accurate size and shape; no daily information
  - Available for fires > 500 acres
Association

- Fires from multiple data sources that are nearby in time and space are associated in the SmartFire 2 (SF2) database
- SF2 now knows these are three views of the same fire
Reconciliation – Merging the Data

• We now have three sizes, three start dates, three names, etc. for this fire. Reconciliation gets us back down to one size, one start date, one name, and so on

• The default SF2 method for reconciliation uses a ranking for each data element (size, date, etc.) for each source (MTBS, ICS-209, HMS)
# 2008 NEI Reconciliation

<table>
<thead>
<tr>
<th>Data Element</th>
<th>First Choice</th>
<th>Second Choice</th>
<th>Third Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location/shape</td>
<td>MTBS</td>
<td>HMS</td>
<td>ICS-209*</td>
</tr>
<tr>
<td>Final size</td>
<td>MTBS</td>
<td>ICS-209</td>
<td>HMS*</td>
</tr>
<tr>
<td>Daily activity</td>
<td>HMS</td>
<td>ICS-209</td>
<td>MTBS*</td>
</tr>
<tr>
<td>Fire type (WF/Rx)</td>
<td>ICS-209</td>
<td>MTBS*</td>
<td>HMS*</td>
</tr>
<tr>
<td>Name</td>
<td>ICS-209</td>
<td>MTBS</td>
<td>HMS*</td>
</tr>
<tr>
<td>Start date</td>
<td></td>
<td>First reported</td>
<td></td>
</tr>
<tr>
<td>End date</td>
<td>HMS</td>
<td>ICS-209</td>
<td>MTBS*</td>
</tr>
</tbody>
</table>

* These values must be inferred
Reconciliation Example – Evans Road

• Name: Evans Road  
  – From ICS-209

• Size: 41,561 acres  
  – From MTBS

• Type: WF  
  – From ICS-209

• Dates: 6/1/08-7/9/08  
  – First reported, HMS

• Growth curve:  
  – From HMS
Fuels

• How much fuel is available to burn?
• Fuel loadings from FCCS
  – Map with 1-km resolution assigns fires to one of several hundred “fuelbeds”
    • Based on LANDFIRE existing vegetation crosswalk
  – A fuelbed describes the live and dead vegetation structure of a region for use in fire effects models
    • Tons/acre available to burn in the canopy, shrubs, ground fuels, fallen wood, etc.

LANDFIRE: Landscape Fire and Resource Management Planning Tools Project
Consumption

• What fraction of the available fuel burns?
• Consumption from the Consume 4.0 model
  – Designed for use with FCCS fuelbeds
  – Consumption by phase (flaming and smoldering)
  – Dependent on fuel moisture values, type, and location
    • Daily fuel moistures assigned based on nearest fire weather station
  – Capped consumption of ground fuels for prescribed fires
    • 5 tons per acre in the east
    • 20 tons per acre in the west
Emission Factors

• How much does the fire emit, and of what?

• Emissions from the FEPS model
  – Emission factors from literature for flaming and smoldering combustion
  – Particulate matter (PM$_{2.5}$, PM$_{10}$, total PM), oxides of nitrogen (NO$_x$), carbon monoxide (CO), carbon dioxide (CO$_2$), methane (CH$_4$), ammonia (NH$_3$), sulfur dioxide (SO$_2$), volatile organic compounds (VOCs), non-methane hydrocarbons (NMHC)
  – 35 hazardous air pollutants (HAPs)
  – Total heat

• FEPS also provides hourly profiles and plume injection heights for further modeling
Results (Overall)

<table>
<thead>
<tr>
<th></th>
<th>RX</th>
<th>WF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>13.4 M acres</td>
<td>5.0 M acres</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>0.72 M tons</td>
<td>0.92 M tons</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>108 M tons</td>
<td>104 M tons</td>
</tr>
</tbody>
</table>

28% of the total NEI for PM$_{2.5}$
Temporal Patterns

Monthly

![Monthly chart showing data for different months.]

Daily

![Daily chart showing data for different dates.]

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Comparisons

Area burned versus official databases and land manager surveys

<table>
<thead>
<tr>
<th>Category and Database</th>
<th>Database (acres)</th>
<th>This Inventory (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wildfires (NICC–National Interagency Coordination Center)</td>
<td>5,191,000</td>
<td>4,900,000</td>
</tr>
<tr>
<td>Forest Service Rx (FACTS–Forest Service ACTivity Tracking System)</td>
<td>1,312,000</td>
<td>1,380,000</td>
</tr>
<tr>
<td>Department of Interior Rx (NFPORS–National Fire Plan Operations and Reporting System)</td>
<td>561,000</td>
<td>710,000</td>
</tr>
<tr>
<td>2011 Forested Rx (National Prescribed Fire Use Survey)</td>
<td>7,880,000</td>
<td>10,360,000</td>
</tr>
</tbody>
</table>
Issues and Improvements

1. Limited information on Rx fires
   – Working to include more Rx databases

2. Duff and peat consumption are poorly modeled
   – Improving our corrections and working with model developers

3. Significant variability among model choices
   – E.g., results vary by a factor of two by selecting a different fuel loading map
Thank You

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Issues and Improvements

1. Limited information on Rx fires
   – 60,000 fires in the 2008 NEI
   – 58,000 have information only from HMS; most of these are Rx
   – Next round should include USFS’s FACTS and state-submitted data

**FACTS**: Forest Atmosphere Carbon Transfer and Storage
**USFS**: United States Department of Agriculture Forest Service
2. Significant variability among models
3. Duff (ground fuel) consumption is a source of major uncertainty

- Current version of Consume does not handle duff consumption properly in areas with a deep duff layer

- Options:
  - Apply refined cap on duff consumption (improve current method)
  - Switch to FOFEM consumption model
  - Await revised version of Consume (in development)

**FOFEM:** First Order Fire Effects Model