Development of the 2008 Wildland Fire National Emissions Inventory

Sean Raffuse and Yuan Du
Sonoma Technology, Inc.
Petaluma, California

Sim Larkin and Pete Lahm
USDA Forest Service, Seattle, Washington

Presented at the 2012 Emission Inventory Conference
Tampa, Florida
August 14, 2012

STi
Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

A I R F I R E
ATMOSPHERE & FIRE INTERACTIONS
RESEARCH & ENGINEERING

912012-4340

How Fire Emissions Are Modeled

$$E_{(s)} = A \times AFL \times \beta \times Ef_{(s)}$$
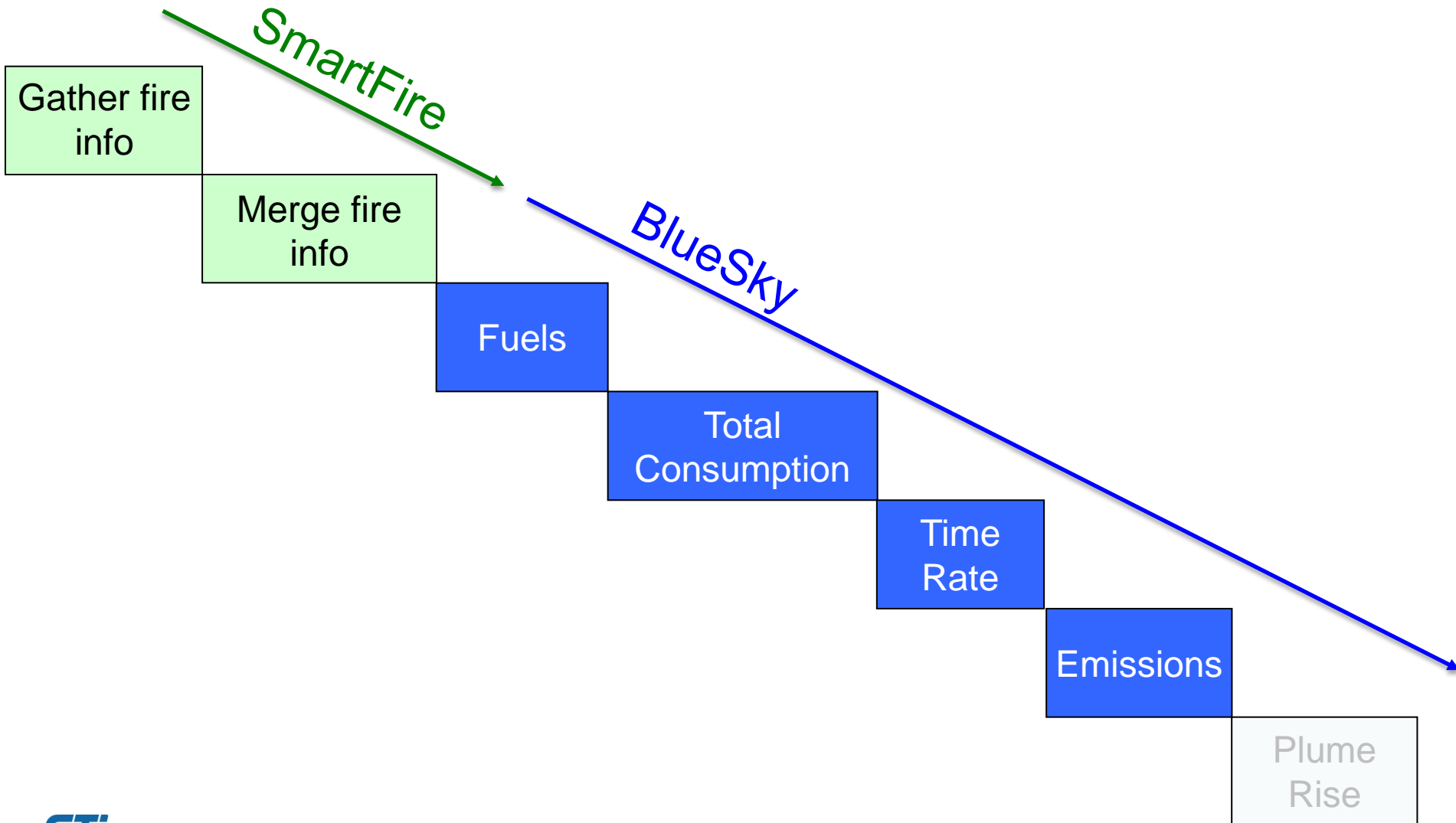
Emissions of species *s* =

Area burned x

Available fuel load x

Burning efficiency x

Emission factor of species *s*

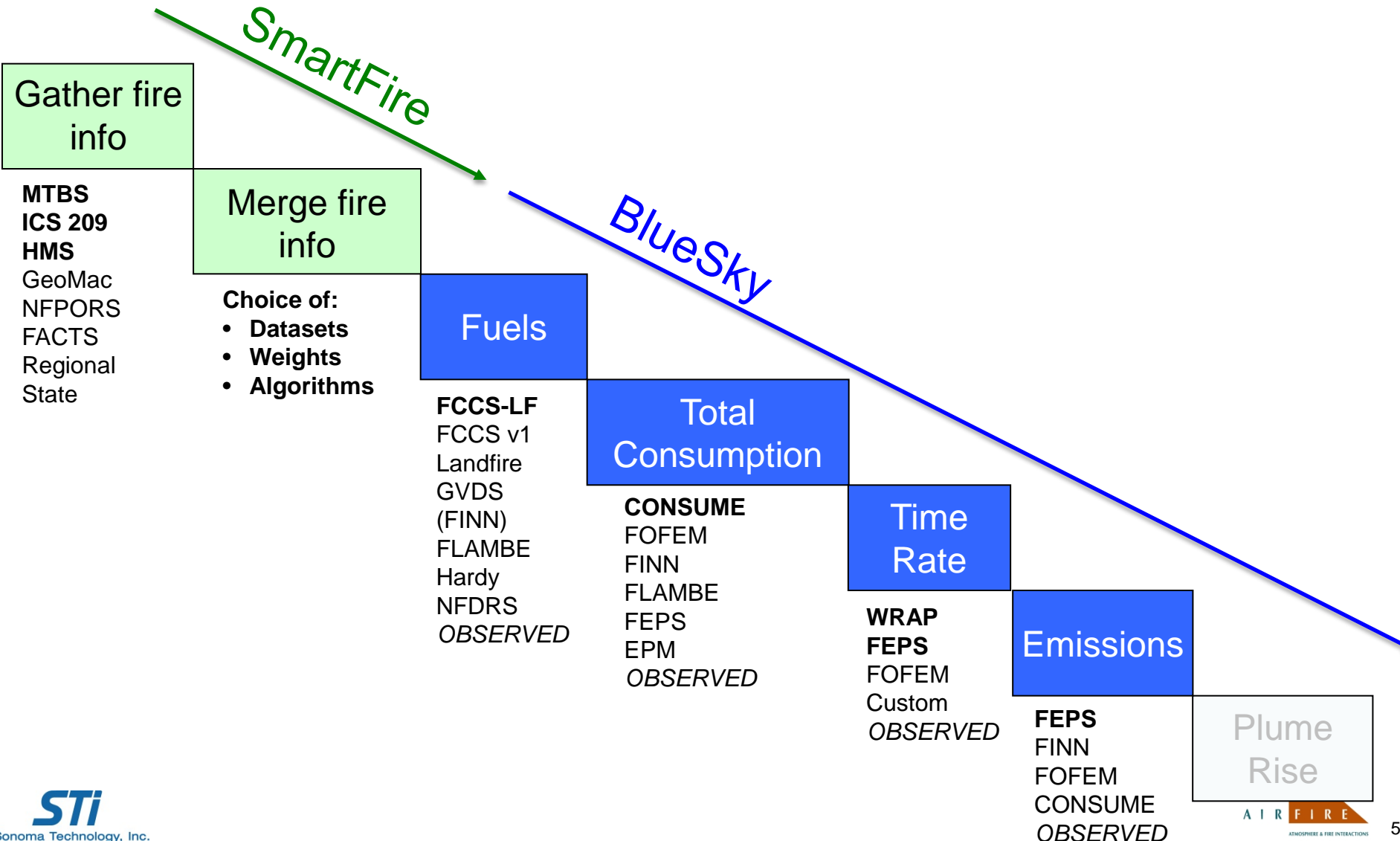All these terms must be correct to produce correct emissions estimates

Modeling Steps

Gather fire info

Merge fire info

SmartFire

Fuels

BlueSky

Total Consumption

Time Rate

Emissions

Plume Rise

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

SmartFire

BlueSky

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

STi
Sonoma Technology, Inc.

AIR FIRE
ATMOSPHERE & FIRE INTERACTIONS
RESEARCH & ENGINEERING

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
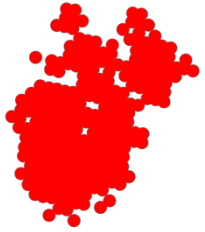 - Data for all fires > 500 acres in the east; > 1,000 acres in west

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)
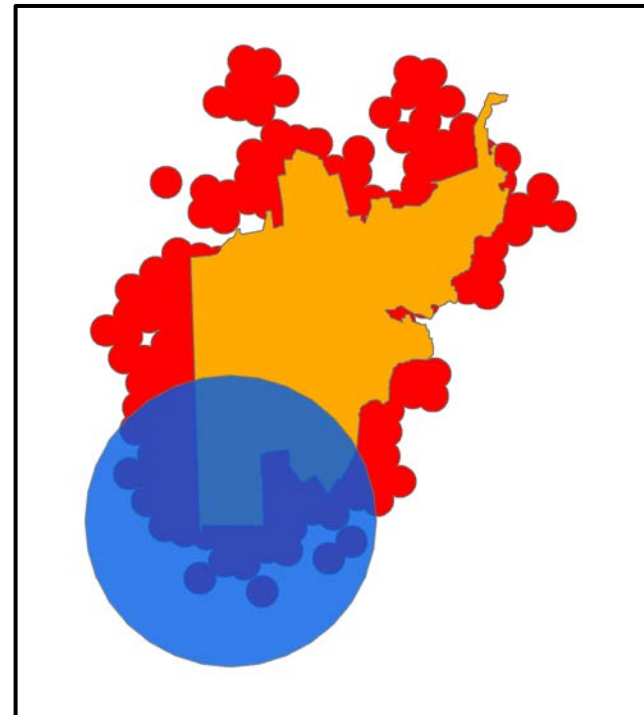 - Available mostly for wildfires

- **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)
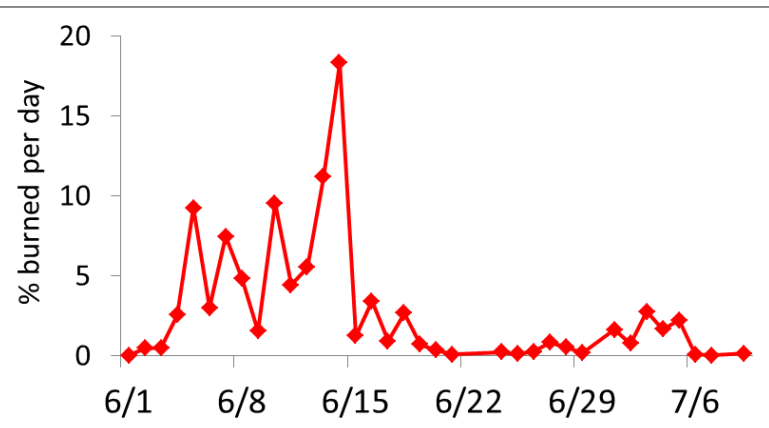
2008 NEI Reconciliation

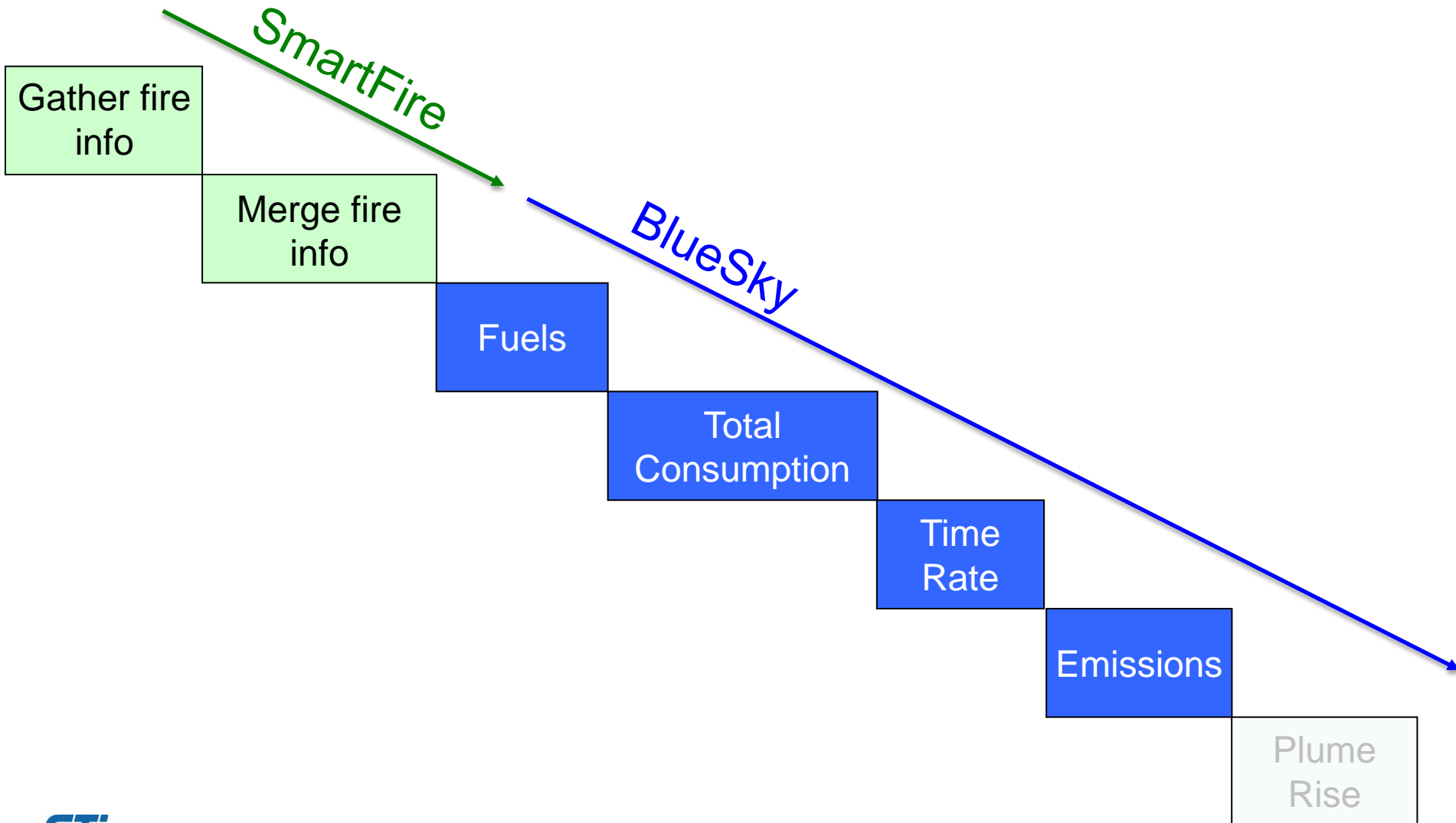| Data Element	First Choice	Second Choice	Third Choice
Location/shape	MTBS	HMS	ICS-209*
Final size	MTBS	ICS-209	HMS*
Daily activity	HMS	ICS-209	MTBS*
Fire type (WF/Rx)	ICS-209	MTBS*	HMS*
Name	ICS-209	MTBS	HMS*
Start date	First reported		
End date	HMS	ICS-209	MTBS*

* 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*

From MTBS

Modeling Steps

Gather fire info → Merge fire info → Fuels → Total Consumption → Time Rate → Emissions → Plume Rise

SmartFire

BlueSky

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

AIR FIRE
ATMOSPHERE & FIRE INTERACTIONS
RESEARCH & ENGINEERING

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)

Total	RX	WF
Area	13.4 M acres	5.0 M acres
$PM_{2.5}$	0.72 M tons	0.92 M tons
CO_2	108 M tons	104 M tons
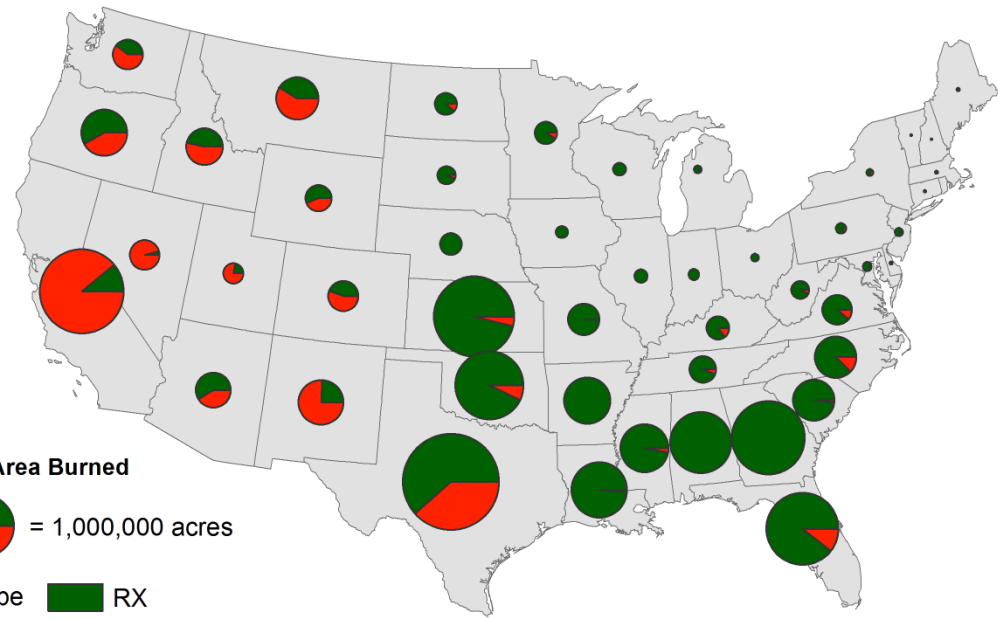
28% of the total NEI for $PM_{2.5}$

Total Area Burned
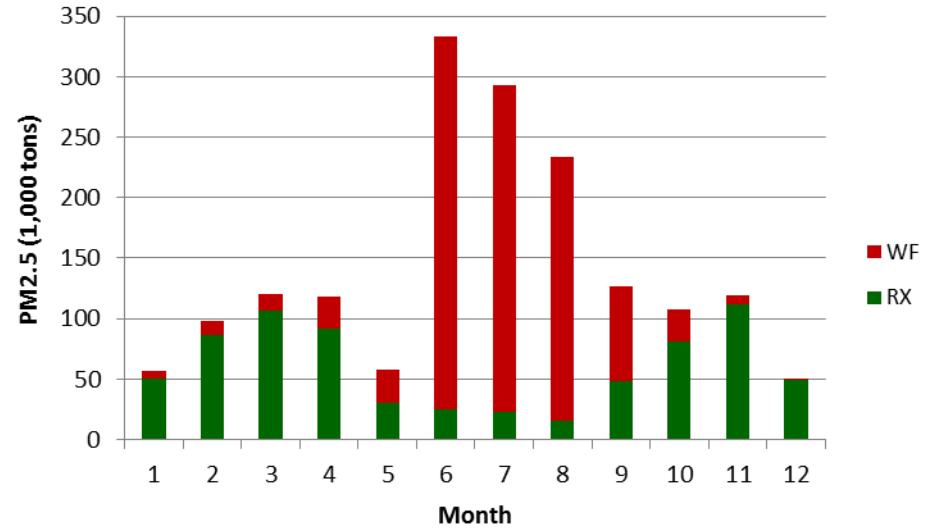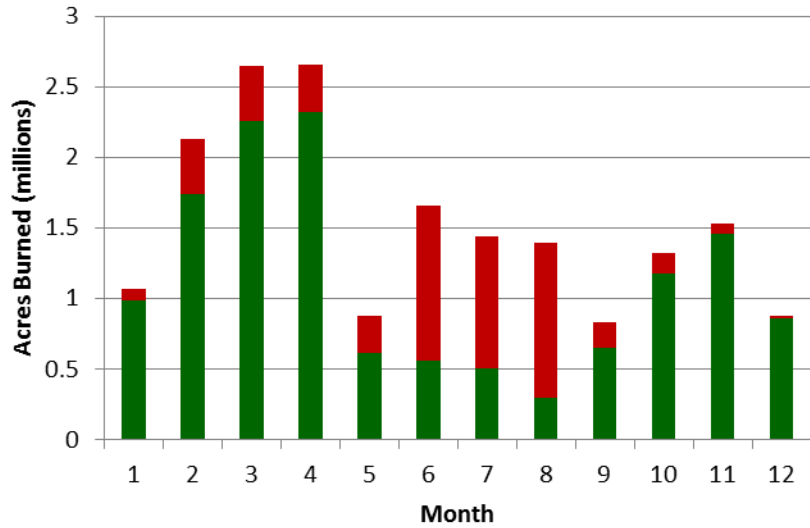
= 1,000,000 acres

Type
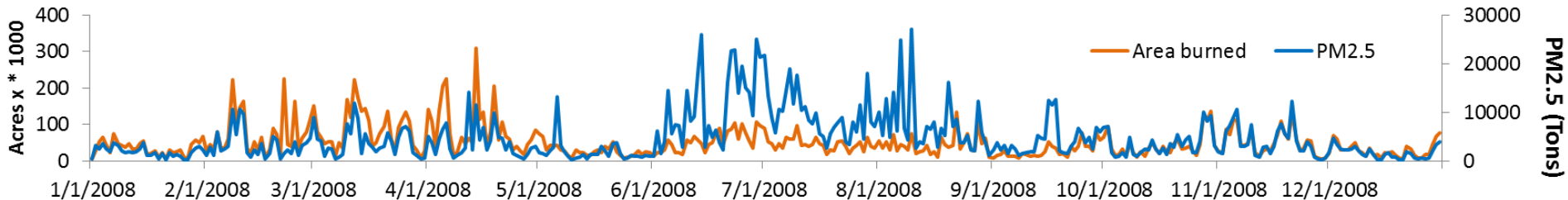RX
WF

Total PM2.5

= 50,000 tons

Type
WF
RX
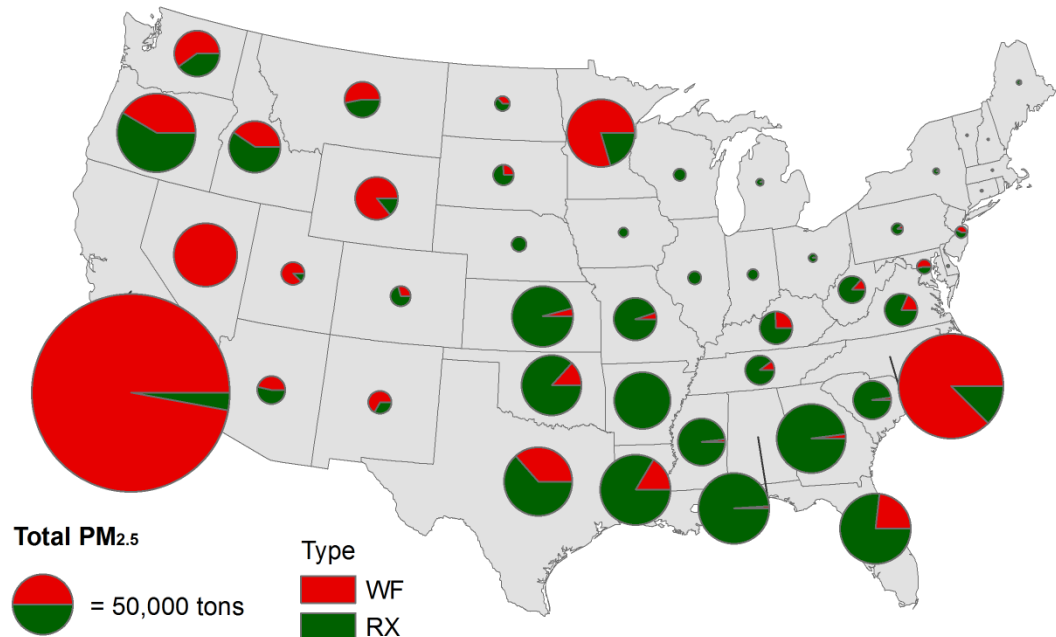
Temporal Patterns

Monthly

Daily

Comparisons

Area burned versus official databases and land manager surveys

Category and Database	Database (acres)	This Inventory (acres)
Wildfires (NICC–National Interagency Coordination Center)	5,191,000	4,900,000
Forest Service Rx (FACTS–Forest Service ACtivity Tracking System)	1,312,000	1,380,000
Department of Interior Rx (NFPORS–National Fire Plan Operations and Reporting System)	561,000	710,000
2011 Forested Rx (National Prescribed Fire Use Survey)	7,880,000	10,360,000

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

Funding from USFS; U.S. Department of the Interior; Joint Fire Science Program; U.S. Environmental Protection Agency; NASA; National Fire Plan; and the USDA Cooperative State Research, Education, and Extension Services' National Research Initiative.

Sean Raffuse
(707) 665-9900
sraffuse@sonomatech.com

Narasimhan ('Sim') Larkin
(206) 732-7849
larkin@airfire.org

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

Issues and Improvements

2. Significant variability among models
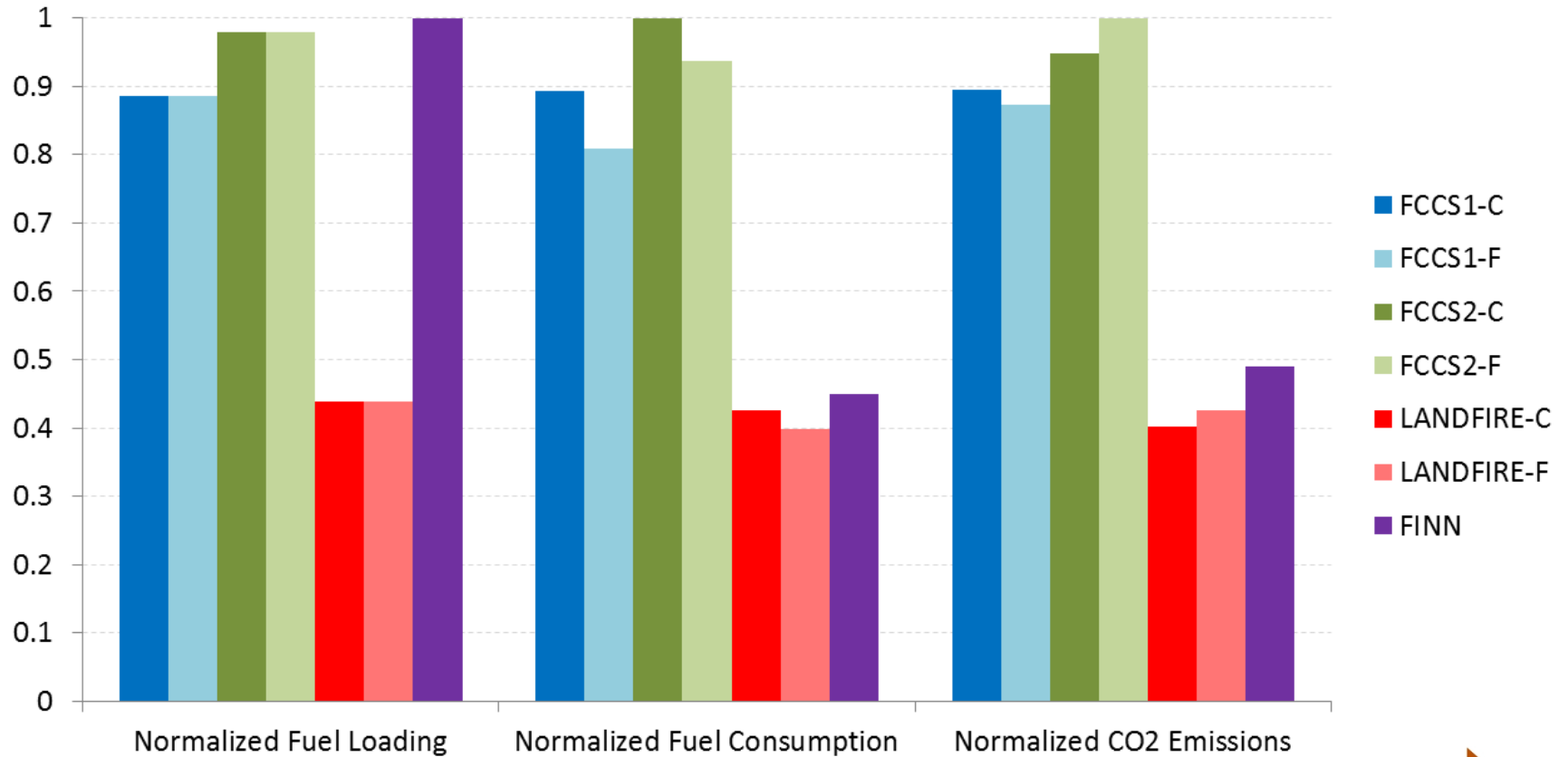
Issues and Improvements

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*