Reducing Uncertainties in National Smoke Emissions Modeling as Applied in the BlueSky Framework

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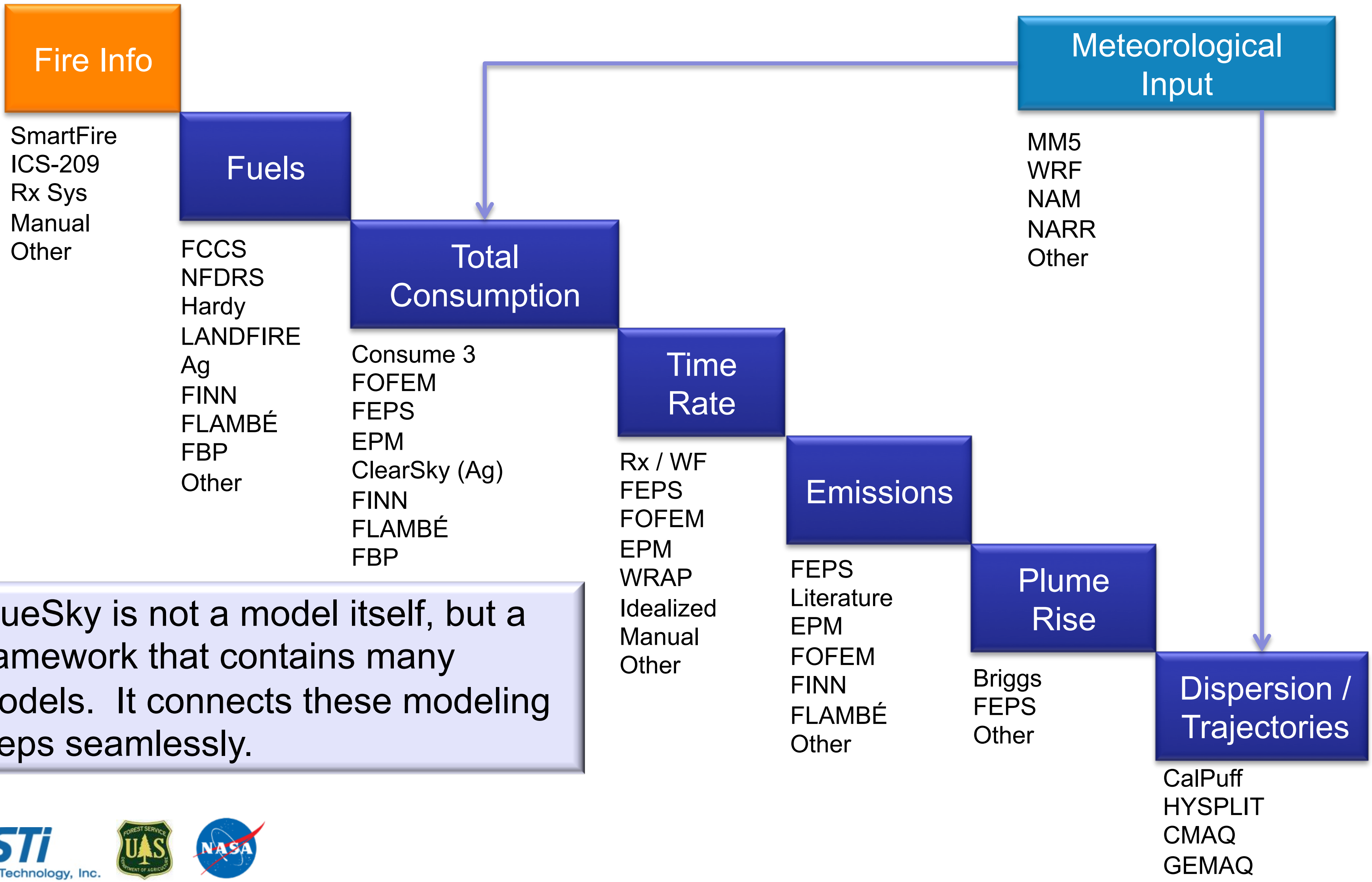
What Are the BlueSky Systems?

- BlueSky Framework and SmartFire
  - Decision-support systems (DSS): (1) a modeling framework and (2) a fire information processing and reconciliation system
  - Function: facilitate modeling of the air quality and climate impacts of smoke and fire
- Examples of decisions supported include
  - Air quality management (prescribed burning: burn/no-burn)
  - Air quality forecasting (public health: air quality alerts)
  - Forest management (prescribed burn mid- to long-range planning)
  - National emissions inventory (climate change, National Ambient Air Quality Standards [NAAQS])
  - And others: research, incident command, interdisciplinary collaboration with other DSS

The BlueSky Smoke Modeling Framework



BlueSky is not a model itself, but a framework that contains many models. It connects these modeling steps seamlessly.

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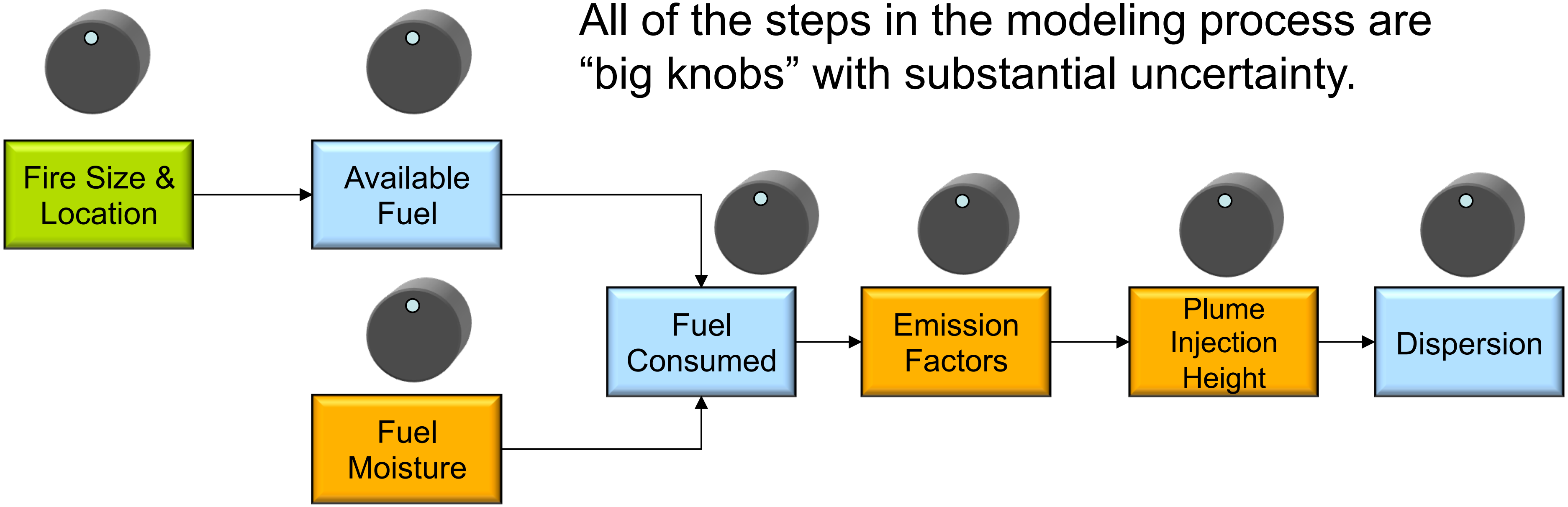
Project Objective: Reduce Key Uncertainties and Information Gaps

All of the steps in the modeling process are “big knobs” with substantial uncertainty.



- **Addressed by previous NASA ROSES (2006–2009)**
- **Addressed by current project (new or improved modules)**
- **Other modeling steps**

ROSES: NASA’s Research Opportunities in Space and Earth Sciences program

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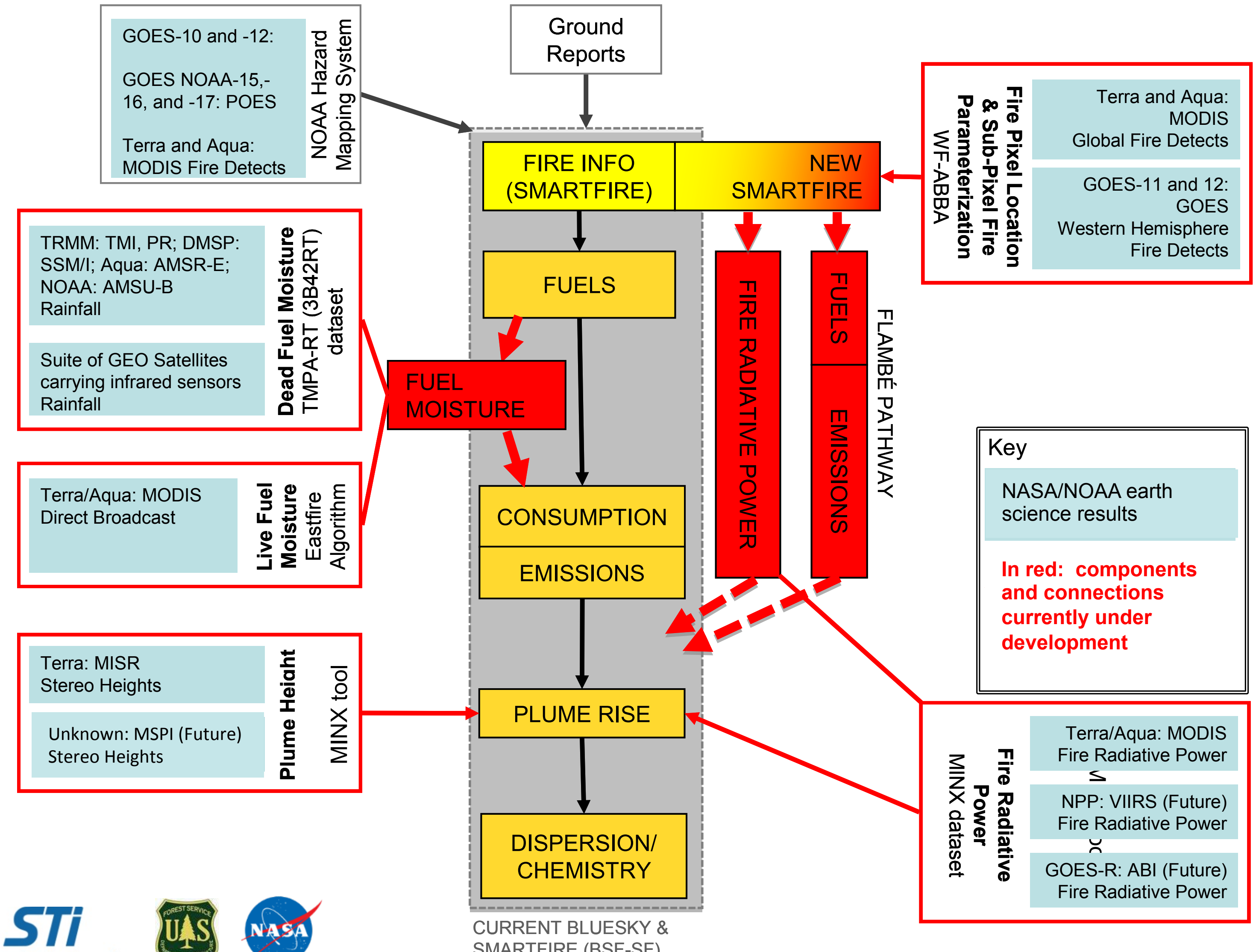
Overview of NASA Earth Science in BlueSky



TRMM (Tropical Rainfall Measuring Mission)

MODIS (Moderate Resolution Imaging Spectroradiometer)

MISR (Multi-angle Imaging Spectroradiometer)

MINX: MISR Interactive Explorer

Follow-on
- NPP–VIIRS
- GPM

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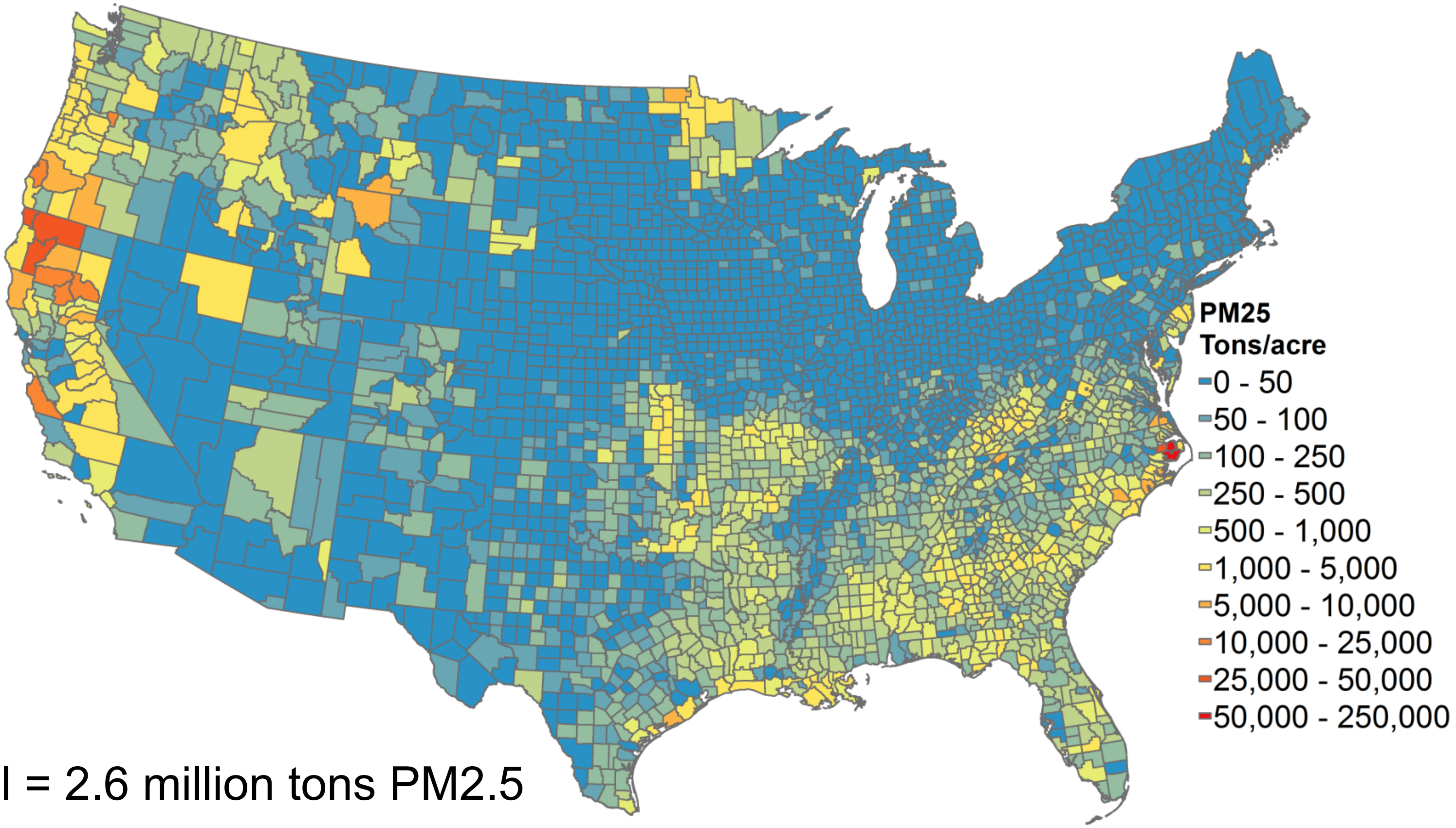
New Modules Created with Earth Science Data Sources and Expert Collaborators

- Dead fuel moisture
  - TRMM Multisatellite Precipitation Analysis (TMPA)
  - George Huffman (NASA), collaborator
- Live fuel moisture
  - EastFIRE live fuel moisture content retrieval data set
  - John Qu and Xianjun Hao (George Mason University), co-investigators
- Plume injection height
  - MINX, MODIS fire radiative power
  - David Diner (NASA), collaborator
- Fire Locating and Modeling of Burning Emissions (FLAMBÉ)
  - Emission factors
  - Ed Hyer (Naval Research Laboratory), collaborator
- Fire radiative energy emissions
  - Fire Energetics and Emissions Research (FEER) global coefficients
  - Charles Ichoku, FEER Team (NASA)

Quantitative Comparisons to Base Case



Total = 2.6 million tons PM2.5

Base Case: 2008 Emissions, default BlueSky Framework pathway: FCCS version 2, Consume version 4.1, and FEPS version 2

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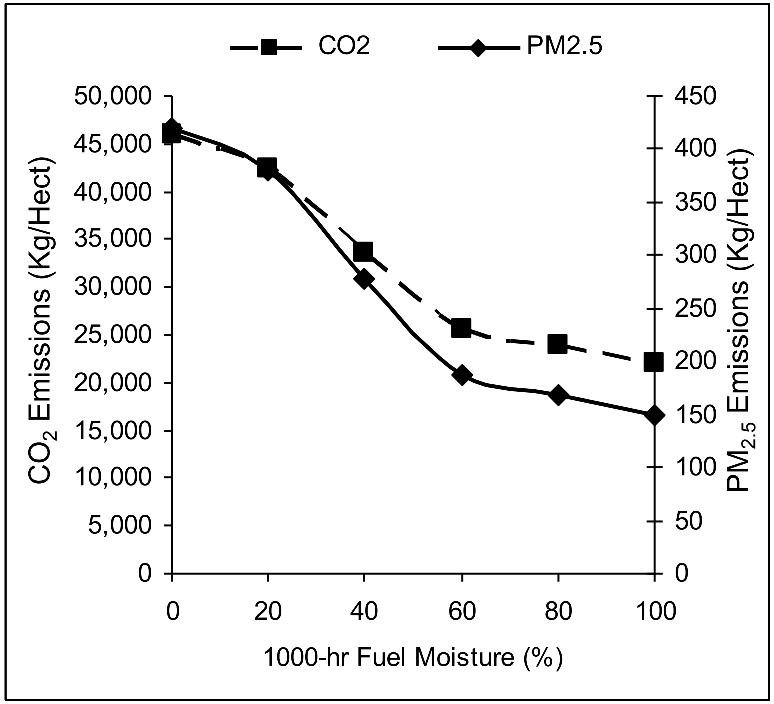
Dead Fuel Moisture



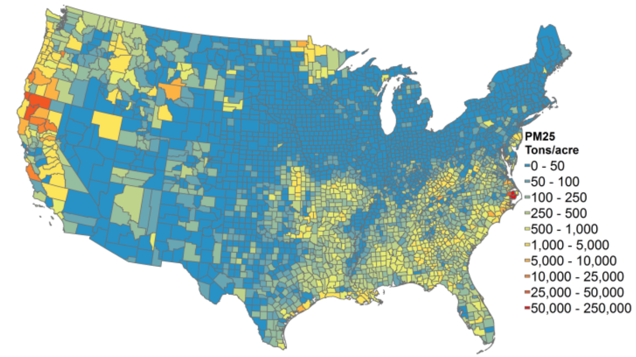
- Dead fuel moisture content (DFMC) directly influences modeled emissions (i.e., greenhouse gases, fine particulate matter [$PM_{2.5}$]).
- BlueSky previously defaulted to static DFMC (absent user-supplied values).

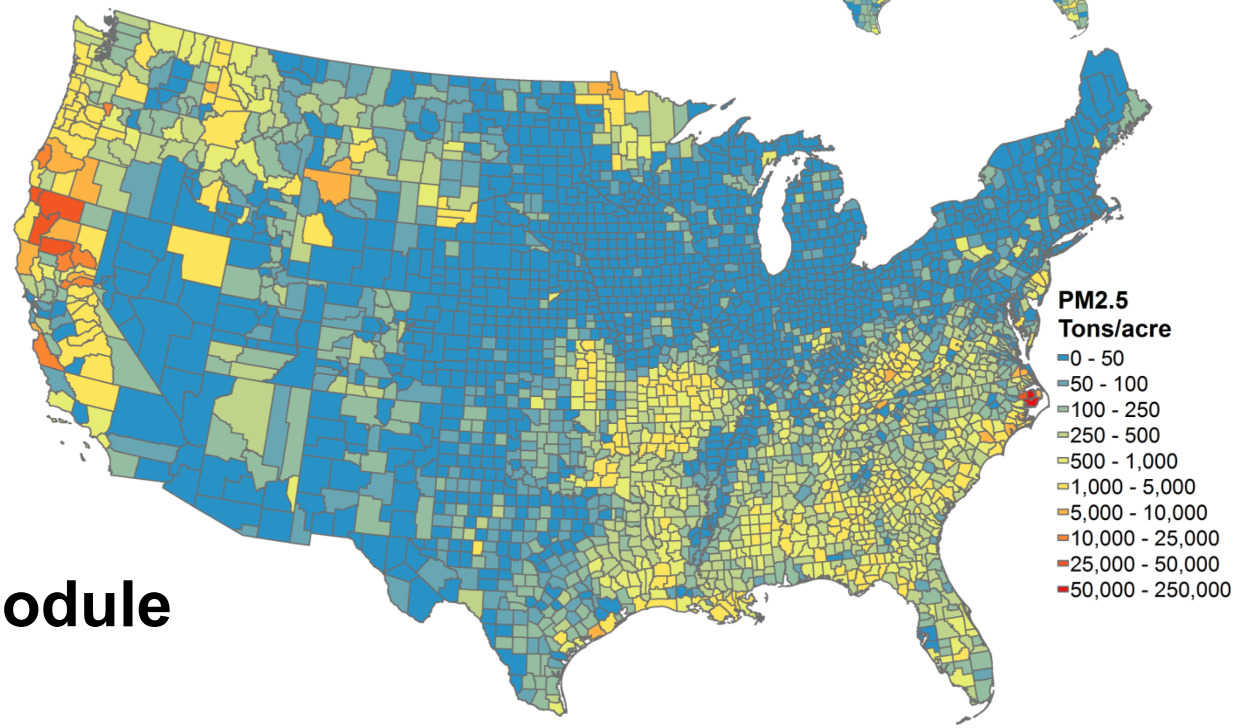
Improvement

- Calculate dynamic DFMC default values over contiguous United States using daily real-time precipitation data from **TMPA** real-time data set.

Dead Fuel Moisture Module (TMPA): Comparison to Base Case $PM_{2.5}$ Emissions

Base Case





TMPA Module

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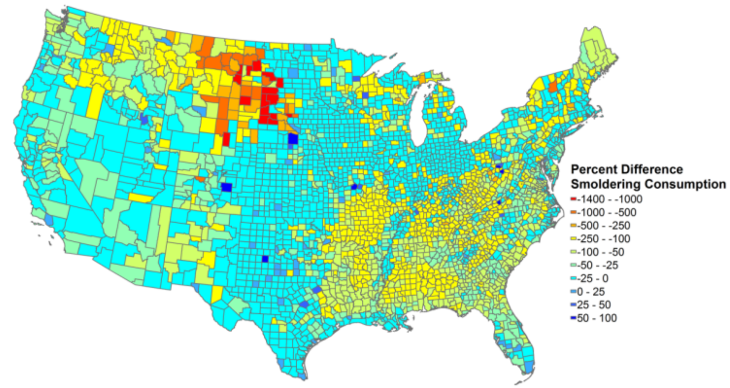
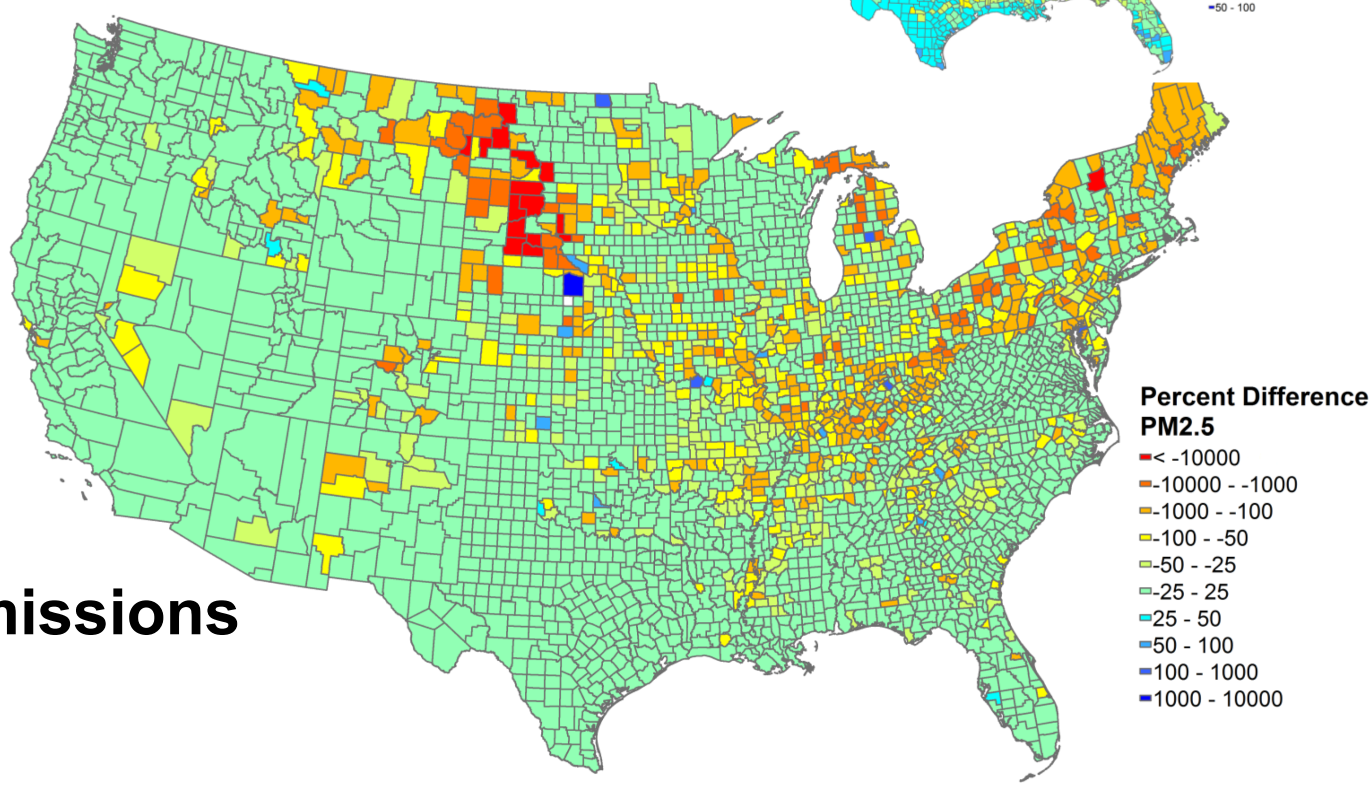
Dead Fuel Moisture Module (TMPA): Relative Differences from Base Case

Smoldering Consumption





$PM_{2.5}$ Emissions

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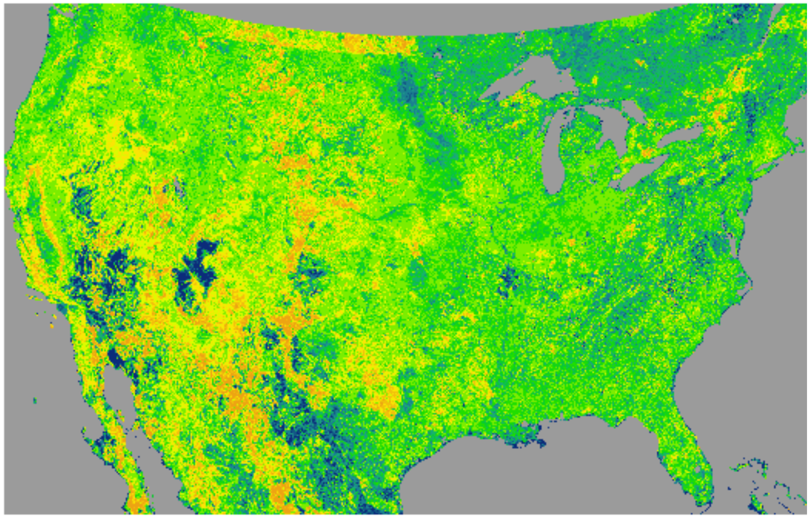
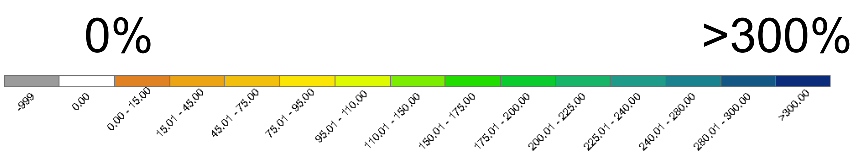
Live Fuel Moisture



Example: daily LFMC image for July 4, 2008.



- Live fuel moisture content (LFMC) affects fire intensity, rate of spread, and duration, all of which affect pollutant concentrations and transport.
- BlueSky previously defaulted to the static DFMC for large woody fuels (absent user-supplied LFMC).

Improvement

- Use **EastFIRE Lab's** data products to provide dynamic estimation of LFMC at 1-km spatial resolution.

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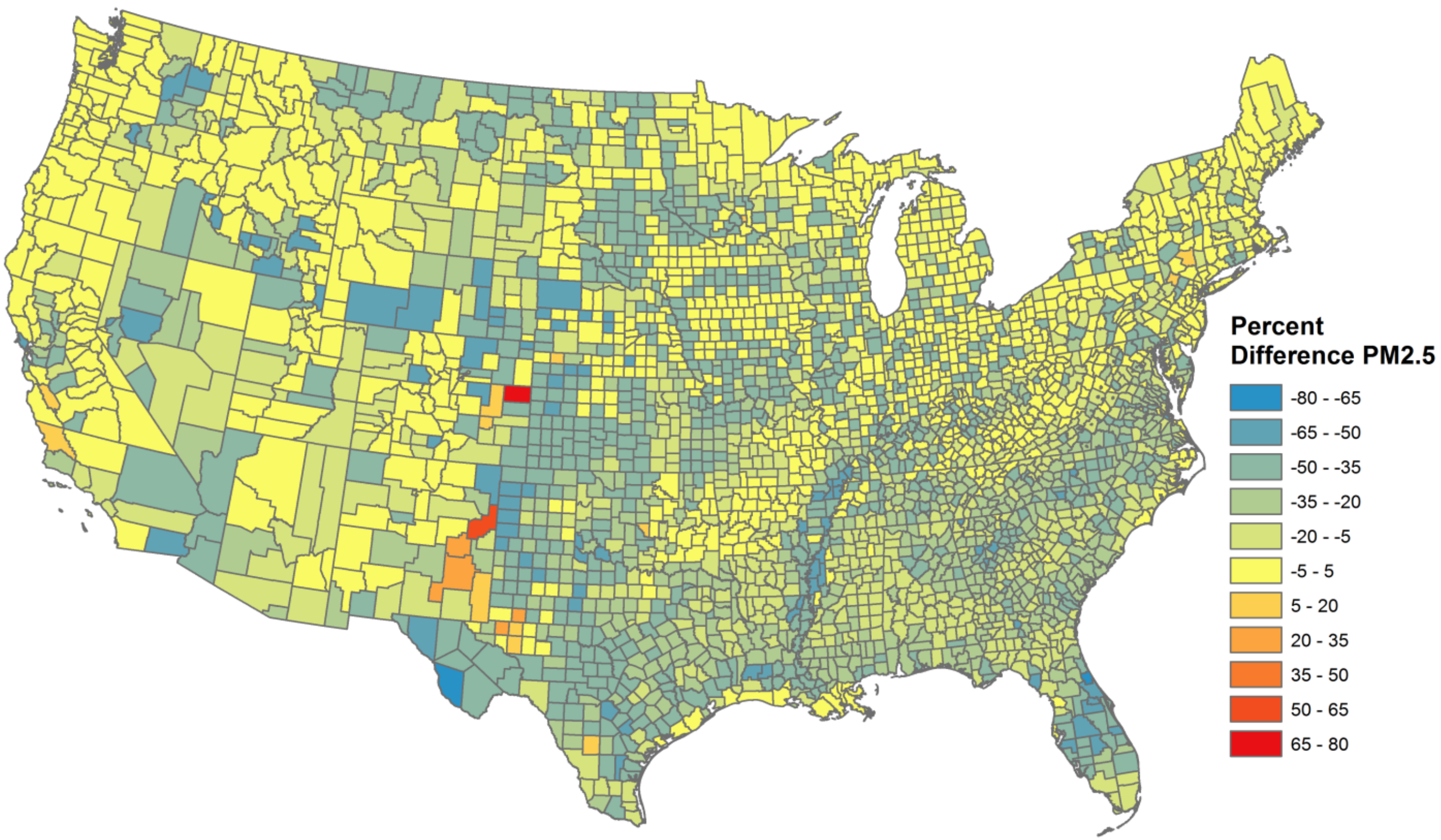
Live Fuel Moisture Module: Differences from Base Case

$PM_{2.5}$ Emissions



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Plume Injection Height

- Plume rise models were designed for industrial sources (e.g., Briggs equation).
- A high degree of uncertainty arises when applying these models to smoke plumes from fires.

Improvements

- Fire radiative power (FRP) and local meteorological data are applied in a new module.

  Based on research by Sofiev, Ermakova, and Vankevich (2012).

- MINX/MISR data were used to develop and explore a plume-rise data set (continuous from 2000), but results were uncertain.

  Analyses led by Fok-Yan Leung, Washington State University (WSU).

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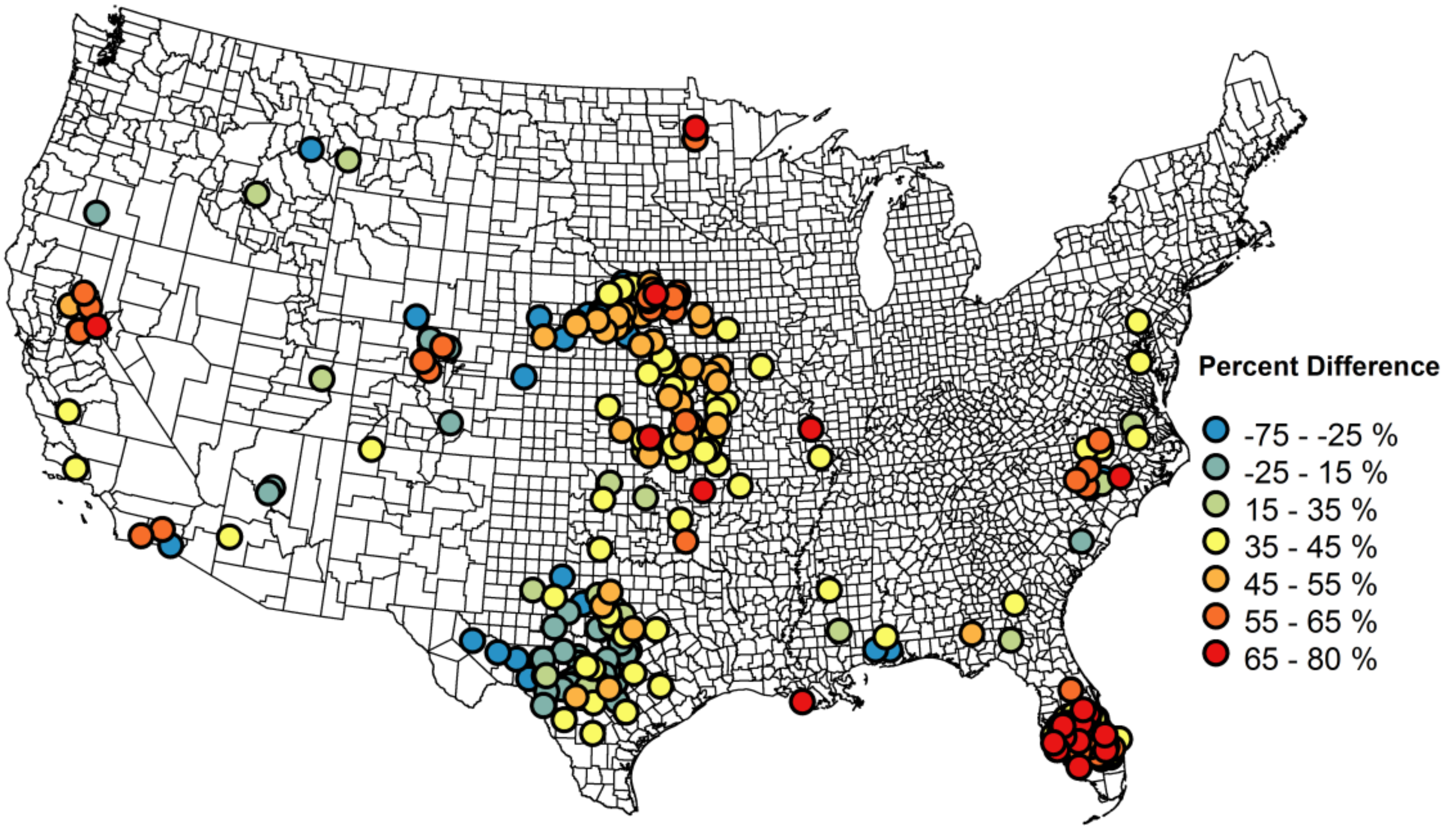
Plume Height Module (SEV): Differences from Base Case

Maximum Plume Heights for February 14, 2008



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Alternative Emissions Models

- BlueSky lacked fuelbed data outside the United States.
- Methods to calculate smoke emissions outside the United States will facilitate North American emissions inventories and modeling of transboundary smoke transport.

Improvements

- Add modules to estimate emissions globally.
- Parts of the FLAMBÉ program
  - WF_ABBA (area burned)
  - Global fuels database
  - FLAMBÉ emissions pathway
- Incorporate MODIS Fire Radiative Energy (FRE) pathway based on FEER results (by Ichoku, NASA).

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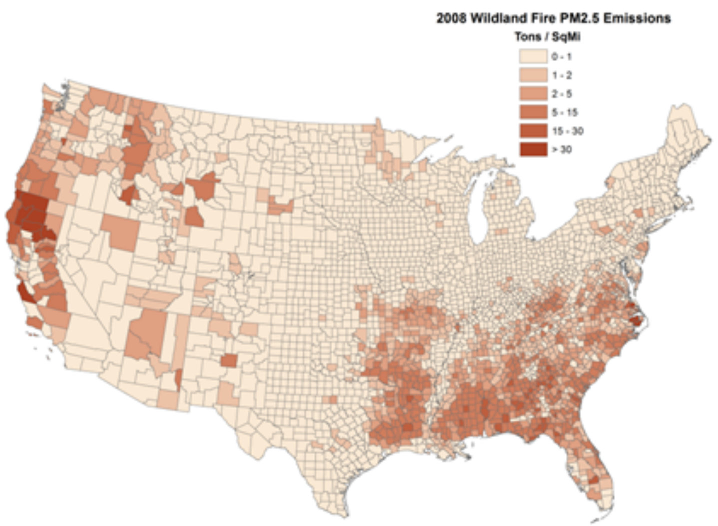
Image source: http://trendsupdates.com/wp-content/uploads/2009/04/forest-fires-smoke.jpg

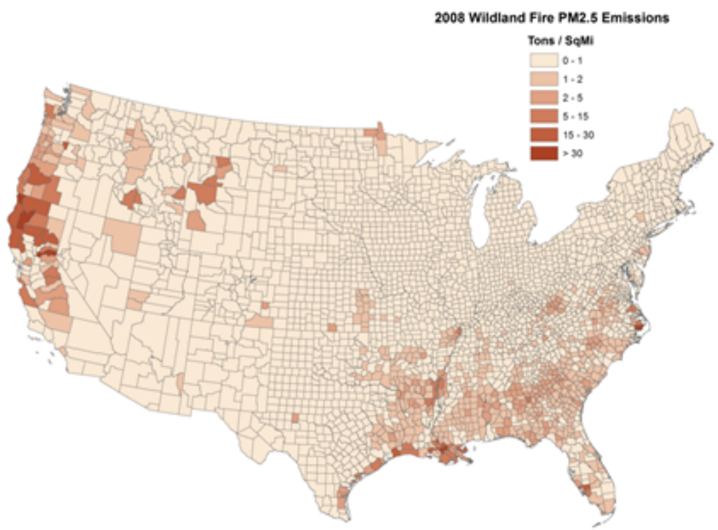
FLAMBÉ Module: Differences from Base Case

Results vary from prior methods, but are within a range of uncertainty that is typical for the present time (a factor of 5 to 10) and with the ability to cover regions outside the United States.



5,937,409 Tons

FLAMBÉ Emissions Pathway



2,597,043 Tons

Base Case

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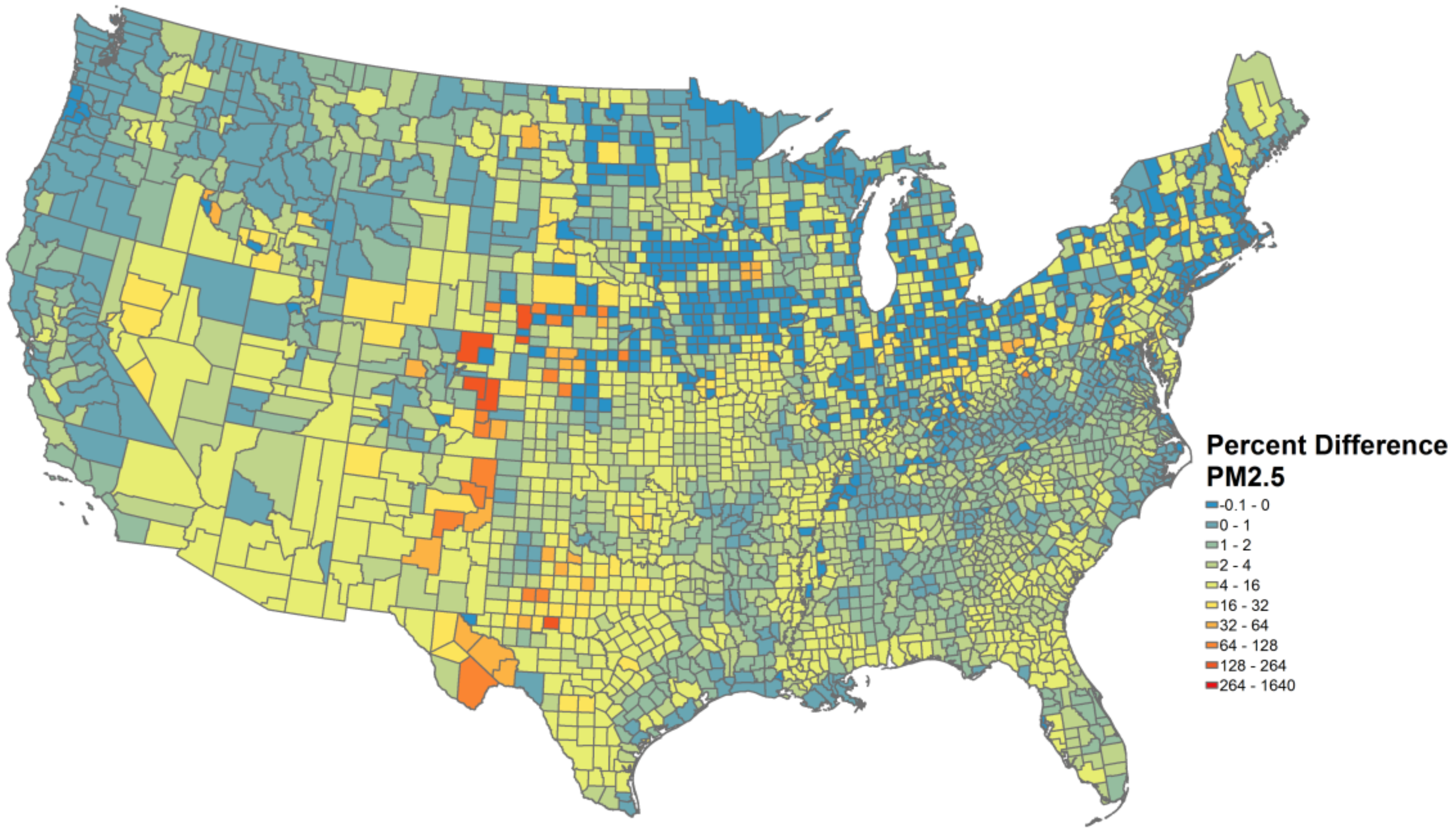
Fire Radiative Energy Module (FEER-FRE): Differences from Base Case

$PM_{2.5}$ Emissions



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Summary Status Assessment

- Analyses of plume rise and fire radiative power were challenging, but were resolved
- Project goals are on track to be met by March 2014
- Key accomplishments
  - Completion, quantitative intercomparisons, and release (this month) of modules at Technology Readiness Level for Applications (TRL-A) Level 9 (details next slide)
  - Presentations and publications
- Current activities (complete in six months)
  - Socioeconomic benefits study
  - Qualitative benchmarking survey
  - Prepare further peer-reviewed publication(s) for submittal

Technology Readiness Level for Applications (TRL-A)

- Current status: New modules are integrated with existing BlueSky systems at TRL-A Level 9
- At project start (2009)
  - BlueSky Framework and SmartFire were at TRL-A Level 9 before project start—i.e., approved, in operational deployment, and in use for decision making (by U.S. Environmental Protection Agency [EPA], USDA Forest Service [USFS], and other agencies)
  - The new modules and algorithms for BlueSky, developed under the current ROSES project, began at various TRL-A Levels
    - Fuel moisture modules . . . . Level 3: Proof of Concept
    - Plume rise algorithm . . . . Level 3: Proof of Concept
    - FLAMBÉ emissions model . . . . . Level 6: Demonstration in Relevant Environment
    - FRP emissions model . . . . Level 3: Proof of Concept

Socioeconomic Benefits Study

- Key questions
  - Effectiveness of prescribed burn decisions
    - Prevention of adverse air quality impacts
    - Achievement of prescribed burning program goals
  - Efficiency gains by producers of decision-support information (reported anecdotally)
    - Reduced cost to EPA for comprehensively estimating fire emissions for the NEI (20-fold reduction)
    - Improved productivity of USFS smoke forecasters (more spot smoke forecasts per forecaster)
  - Consider current scenarios compared with future likely scenarios—i.e., with BlueSky systems versus without

Benefits Study: Methods (1 of 2)

Investigate anecdotal reports of efficiency gains

- Perform in-depth interviews of key agency staff at EPA and USFS
- Analyze business processes, budget data, and value-added information

Benefits Study: Methods (2 of 2)

Investigate prescribed burn outcomes for 2012–2013 season

- Recruit 30–40 land managers: survey goals, decisions, and outcomes
- Categorize decision outcomes in near real time
  a. canceled appropriately, smoke forecast (averted air quality impacts)
  b. proceeded appropriately with confidence (accomplished burn)
  c. canceled due to reasons unrelated to air quality (no effect)
  d. proceeded with no credible concern about smoke (no effect)
  e. proceeded inappropriately—inaccurate smoke forecast (potential negative effect)
  f. canceled inappropriately—inaccurate smoke forecast (potential negative effect)
- Apply surrogate data to extrapolate benefits to a wider geographic area and into the future
- Project expected incremental benefits from improved forecast accuracy

Anticipated Outcomes

- Enhance and expand smoke modeling capabilities
- Boost user confidence in modeling results
- Broaden audience of end users
- Improve decision-making activities
- Improve understanding of benefits
  - $$ saved
  - Adverse air quality events avoided
  - Fire hazards safely reduced

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Thank You

Our Co-Investigators: Fok-Yan Leung (WSU); John Qu and Xianjun Hao (EastFIRE Lab, George Mason University).

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