Exploring the Vertical Distribution of Wildland Fire Smoke in CMAQ

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Disclaimer: The views expressed in this presentation are those of the author and do not necessarily reflect the views or policies of the U.S. EPA.
Motivation

Worldwide

~300k annual deaths
~300 M ha burned

Continental U.S.

~8k annual deaths
~2 M ha burned
~ billions in cost

Numbers have grown by 50% in 20 years

1 M ha = 104 km², 1 ha = 2.47 acres
Fire Detection Techniques

Pre 1980’s
- Watch Towers

Post 1980’s
- Airplanes

Current
- Remote Sensing
The Fire Modeling Process

Input
Detection

Framework
Math & Stuff

Output
Prediction
Current Status

- Plume Rise-in-line module in CMAQ needs updating (10+ years old)
- Post CMAQv5.3 development users selectable plume rise modules.
- More obs (Lidar and Satellite) validations — plume tops and fire detections.

Test three sensitivities:
- Grid spacing (12km vs 4km)
- Briggs vs alt. algorithms (SOFIEV and PBL + 500m)
- Temporal allocation (diurnal vs 4hr).
### Episode information

<table>
<thead>
<tr>
<th>Episode</th>
<th>Prescribed fire</th>
<th>Wild fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Konza Prairie Biological Station in Flint Hills, Kansas</td>
<td>Stanislaus National Forest in California</td>
</tr>
<tr>
<td>Detection method</td>
<td>Mini Micro Pulse Lidar</td>
<td>CALIOP and GOES</td>
</tr>
<tr>
<td>Acres burned</td>
<td>1500 ha total <em>(83 ha)</em></td>
<td>104K ha total <em>(6,562 ha)</em></td>
</tr>
</tbody>
</table>

**Image**

![Image 1](image1.png)  
![Image 2](image2.png)

**References**

Wilkins et al., in prep  
Peterson et al., 2014 BAMS
Episode information

Plume structure

MiniMPL

Konza 3/16/2017

Prescribed
Plume vert dist
Non uniform
Top @ 1100 m

CALIOP

Rim Fire 8/21/2013

Wildfire
Plume vert dist.
Uniform
Top @ 6502 m
MiniMPL – plume top heights

Height (m)

Model hour (LST)
MiniMPL – plume top heights

**Temporal**

- Lidar
- K8 BRIGGS12KM4HR
- BASE12

MB -155.7

**Spatial**

- K8 BRIGGS4KM12HR

MB 87.4

**Both**

- K8 BRIGGS4KM4HR

MB 271
MiniMPL – plume top heights

Sofiev-Temporal

Sofiev-Spatial

PBL500

![Graphs showing plume top heights for MiniMPL, Sofiev-Temporal, Sofiev-Spatial, and PBL500.](graph.png)
CALIOP – plume top heights
CALIOPI – plume top heights

Sofiev

Plume Height (m)

Time (UTC)

PBL500

Plume Height (m)

Time (UTC)
Preliminary conclusions

• Temporal resolution (time of burn) shows most improvement overall.

• Algorithms are highly dependent on input information and design

• Nighttime plume rise needs investigation

• WF needs to be treated different than RX
Future work

A lot of work remains; the solution to a changing climate is to increase research efforts, knowledge, and action.
Acknowledgements

Thanks to co-authors and collaborators at NASA, US Forest Service, US Dep. of Agriculture, and the U.S. EPA.
<table>
<thead>
<tr>
<th>Number</th>
<th>Simulation name</th>
<th>Plume rise method description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BASE12</td>
<td>Briggs simulation using 12 hour and 12 km grid</td>
<td>Pouliot et al. 2005</td>
</tr>
<tr>
<td>2</td>
<td>BRIGGS12KMHR</td>
<td>Modified Briggs using field data for duration of fire (3 and 4 hr)</td>
<td>Luxi et al. 2018</td>
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<td>3</td>
<td>SOFIEV12KMHR</td>
<td>Sofiev simulation using hour (3 and 4) modification and 12 km grid</td>
<td>Sofiev et al. 2012</td>
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<tr>
<td>4</td>
<td>PBL50012KM</td>
<td>Plume height top is set to the boundary layer top plus 500 m</td>
<td>Kahn et al. 2007</td>
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<tr>
<td>5</td>
<td>BRIGGS4KMHR</td>
<td>Modified Briggs using 4km grid resolution, 12, 4, and 3 hours</td>
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<tr>
<td>6</td>
<td>SOFIEV4KMHR</td>
<td>Modified Sofiev using 4km grid resolution, 12,4, and 3 hours</td>
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<td>7</td>
<td>BRIGGS4KM12HR</td>
<td>Briggs simulation using 12 hour and 4 km grid</td>
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<tr>
<td>simulation</td>
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<tr>
<td>Burn</td>
<td>BASE12</td>
<td>BRIGGS12KMHR</td>
<td>SOFIEV12KMHR</td>
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<tr>
<td>1</td>
<td>-2356.2</td>
<td>—</td>
<td>-3420.7</td>
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<tr>
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<td>-3341.7</td>
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<td>-215.5</td>
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<tr>
<td>5</td>
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<td>-3405.0</td>
<td>-2975.1</td>
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</tbody>
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| root mean square error |  |  |  |  |  |  |  |  |
|------------------------|-----|-----|-----|-----|-----|-----|-----|
| simulation             | BASE12 | BRIGGS12KMHR | SOFIEV12KMHR | PBL50012KM | BRIGGS4KMHR | SOFIEV4KMHR | BRIGGS4KM12HR |
| 1                      | 2803.9 | — | 3519.8 | 3315.2 | — | — | — |
| 2                      | 3215.0 | — | 3667.1 | 2325 | — | — | — |
| 3                      | 459.6 | 391.6 | 546.4 | 746.0 | 358.8 | 705.8 | 349.6 |
| 4                      | 717.8 | 330.3 | 496.3 | 484.1 | 450.8 | 818.2 | 371.6 |
| 5                      | 3169.5 | 3056.2 | 2715.5 | 2904.9 | 2916.5 | 2826.6 | 3091.6 |