OVERVIEW

• Background on past approaches
• Updates for 2014 National Emissions Inventory (NEI)
• Initial challenges
• Example cases
• Limitations and possible future directions
### DATA USED IN PREVIOUS VERTICAL ALLOCATION EFFORTS

- Latitude and longitude
- Daily emissions (tons/day)
  - Particulate Matter < 2.5 Microns (PM$_{2.5}$), Oxides of Nitrogen (NO$_x$), Volatile Organic Compounds (VOC), etc.
  - Wildfire and prescribed fires identified by source classification code (SCC)
    - Used to determine which diurnal profile to apply
    - Includes emissions from **all combustion phases in one source estimate**
- Daily acres burned
  - Used to distribute emissions to different vertical layers
- Heat Release (BTU/day)
  - From the CONSUME model in BlueSky Framework
  - Used to distribute emissions to different vertical layers
SUMMARY OF CURRENT PLUME RISE ALGORITHM

• For both the Sparse Matrix Operator Kernel Emissions (SMOKE) system and the Community Multiscale Air Quality (CMAQ) inline approaches
• Calculate plume bottom and plume top
  • Briggs plume rise algorithm
• Determine smoldering fraction (Pouliot, 2005)
  • Buoyancy efficiency = 0.0703*ln(acres_burned) + 0.3
  • Smoldering fraction = 1 – Buoyancy efficiency
• Assign smoldering emissions between ground level and plume bottom
• Assign flaming emissions between plume bottom and plume top
VERTICAL ALLOCATION PROCESS: PRIOR TO 2014 NEI
DATA AVAILABLE FOR 2014 NEI V1
VERTICAL ALLOCATION EFFORTS

• Same as prior efforts
  • Daily emissions
  • Daily acres burned
  • Heat release

AND...

• Wildfire and prescribed fire emissions further divided by:
  • Flaming
  • Smoldering (all)
COMBUSTION PHASES

• Flaming
  • Most efficient phase of combustion
  • Produces the least amount of smoke per unit of fuel consumed

• Smoldering
  • Wrapped up in convective plume
  • Less efficient phase of combustion
  • Occurs during flaming

• Residual smoldering
  • Continued smoldering after flaming
  • “Unlofted” emissions

2014 NEI v1 smoldering
2014 NEI v1: Smoldering Contribution and Heat Flux Application

- PM$_{2.5}$: Smoldering = 60% of total national fire PM2.5 emissions (870k tons)
- VOC: Smoldering = 65% of total national fire VOC emissions (2,550k tons)
- NO$_X$: Smoldering = 19% of total national fire NOx emissions (48k tons)

All 2014 NEI v1 emissions get same heat flux value. If we put 2014 NEI v1 smoldering in layer 1.....

Can we estimate the residual smoldering part of the 2014 NEI v1 smoldering emissions?
Variables used from BlueSky Framework output:
- Consumption during flaming (tons/acre)
- Consumption during smoldering (tons/acre)
- Consumption during residual smoldering (tons/acre)

Estimate redistribution of smoldering emissions using following equations:
- Non-residual smoldering = 2014 NEI v1 smoldering emissions X (consumption due to smoldering)/(consumption due to smoldering + consumption due to residual smoldering )
- Residual smoldering = 2014 NEI v1 smoldering emissions X (consumption due to residual smoldering)/(consumption due to smoldering + consumption due to residual smoldering )
# RESULTS OF REDISTRIBUTING SMOLDERING EMISSIONS

<table>
<thead>
<tr>
<th>CONUS Fire Emissions Totals</th>
<th>NOX</th>
<th>PM2_5</th>
<th>VOC</th>
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<tr>
<td>2014 NEI v1 Flaming</td>
<td>197,066</td>
<td>598,115</td>
<td>1,334,362</td>
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<tr>
<td>2014 NEI v1 All smoldering</td>
<td>48,154</td>
<td>870,276</td>
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<td>2014 NEI v1 Total</td>
<td>245,220</td>
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<td>Estimated Flaming + non-residual smold</td>
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<td>Estimated Residual smoldering</td>
<td>25,218</td>
<td>461,919</td>
<td>1,361,617</td>
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<td>Estimated Residual smold % of total</td>
<td>10.28%</td>
<td>31.46%</td>
<td>35.06%</td>
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**REDISTRIBUTION OF SMOLDERING EMISSIONS IMPACTS**

- **Flaming**
  - Most efficient phase of combustion
  - Produces the least amount of smoke per unit of fuel consumed

- **Smoldering**
  - Wrapped up in convective plume
  - Less efficient phase of combustion
  - Occurs during flaming

- **Residual smoldering**
  - Continued smoldering after flaming
  - “Unlofted” emissions

Same heat flux value applied to each

Low heat flux value applied: put in surface layer
Examined the following weeks in 2014:

- July 15-22: Major wildfires in West and Louisiana (grass)
  - 12k tons NO\(_x\), 75k tons PM\(_{2.5}\), 205k tons of VOC
- Aug 1-7: Major wildfires contained in OR; Major CA fires
  - 15k tons NO\(_x\), 120k tons PM\(_{2.5}\), 330k tons of VOC
- March 25-31: High amount Rx burns in eastern US period
  - 11k tons NO\(_x\), 50k tons of PM\(_{2.5}\), and 123k tons of VOC
PM2.5 VERTICAL ALLOCATION (% PER LAYER)
MARCH 2014

RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE
PM2.5 VERTICAL ALLOCATION (% PER LAYER) JUL/AUG 2014

RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)  
GREEN: RESIDUAL HFLUX SET TO LOW VALUE
VOC VERTICAL ALLOCATION (% PER LAYER)  
MARCH 2014

RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)  
GREEN: RESIDUAL HFLUX SET TO LOW VALUE
VOC VERTICAL ALLOCATION (% PER LAYER)
JUL/AUG 2014

- RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
- GREEN: RESIDUAL HFLUX SET TO LOW VALUE
NOX VERTICAL ALLOCATION (% PER LAYER)
MARCH 2014

RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE
NOX VERTICAL ALLOCATION (% PER LAYER) JUL/AUG 2014

RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE
MAJOR WILDFIRES IN OREGON (firs and pines)

MAJOR Rx BURNS IN MISSOURI

RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE
• For both SMOKE and CMAQ-inline approaches
• Calculate Plume bottom and Plume top
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• Assign flaming emissions between plume bottom and plume top
REVISIT INFORMATION FROM EMISSIONS INVENTORY (BLUESKY-SMARTFIRE)

• Same as prior efforts
  • Daily emissions
  • Daily acres burned
  • Heat release

With further revisions being considered shown in yellow...

• Wildfire and prescribed fire emissions further divided by:
  • Flaming
  • Smoldering (separate out residual smoldering)

• Heat release (BTU/hr)
  • Revisit the heat release calculation so flaming and smoldering could have different heat release approaches

• All residual smoldering in surface layer?
• Fire emissions inventories are now allowing for closer look at smoldering emissions (non-residual and residual smoldering) and the impact on air quality modeling

• Estimates show a very large part of the PM$_{2.5}$ and VOC fire emissions coming from smoldering phases (60-65%); NOX (19%)

• Estimates show about a third of the PM$_{2.5}$ and VOC fire emissions are from residual smoldering phase (30-34%); NOX (10%)
  • If residual smoldering emissions “un-lofted,” put in layer 1

• If residual smoldering emissions not separated out of smoldering, then current plume rise algorithm allocates about 3-10% of PM$_{2.5}$ and VOC emissions in layer 1
CONCLUSIONS AND FUTURE DIRECTIONS (2)

- Fire emissions inventories need to separate out residual smoldering emissions
- Heat release estimates and emissions factors need to be revisited for smoldering emissions
- Revisit the smoldering fraction parts of the current plume algorithm in SMOKE/CMAQ
- Application of the fire inventories that separate out residual smoldering is needed in air quality modeling and field studies
- Examine other plume rise algorithms
REFERENCE

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