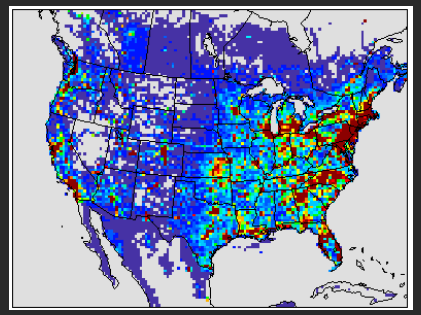

Applying Fire Emission Inventories in Chemical Transport Models

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Developing a Technical Protocol to prepare 2008-09-10 Fire Emissions Inventories for Regional Air Quality Analysis and Planning
Boise, ID August 31 – September 1, 2010

Outline

- Air quality modeling system overview
- Fire simulation and inventories
- State-of-the-science in fire emission modeling
- Recommendations

Air Quality Modeling Systems

- Air Quality Modeling system components
  - Meteorology
  - Emissions
  - Chemistry-Transport
  - Data analysis/Visualization
- Model distribution portals
  - NCAR: emissions, meteorology, CTM, analysis
  - CMAS: emissions, CTM, analysis
  - U.S. EPA
  - Primary developers (e.g. ENVIRON for CAMx)
- EPA does not prescribe specific models or approaches

Emission Modeling Systems

- Convert pollutant inventories to the terms required for chemistry-transport models

Inventory	→	CTM
Annual/daily/hourly		Hourly
NOx, NMVOC, $PM_{2.5}$		NO, NO_2, HCHO, ETH, PEC, POC, etc.
State/county/lat-lon		Grid cell
Release height (m)		Layer (sigma-p)

Fire Simulation and Inventories

- Area Inventories: state/county totals, no release heights
- Point Inventories: lat-lon coordinates, “stack” parameters/release heights
  - WRAP FEJF Inventory: pre-computed plume parameters (LAY1F, PTOP, PBOT)
  - Blue Sky Inventory: heat flux/area burned
- Gridded Inventories: pre-defined data grid, cell totals, no release heights

Fire simulation and Inventories

- Blue Sky Framework Fire Emissions Production Simulator (FEPS)
  - Remote sensed (AVHRR) fuel loads, either satellite (HMS) or manually added fire detects
  - Outputs point inventory with event locations and hourly WRAP FEJF plume parameters and emissions
  - CONSUME outputs heat flux, fuel loads, and acres burned
- National Emission Inventory (NEI)
  - County (area) inventories for ag and rx fires
  - CONSUME point inventories for large wildfires
- Global Fire Emissions Database (GFED)
  - Gridded 1° x 1° annual or 8-day average, global, MODIS-derived
  - No release height information

Fire Emissions Modeling

- Spatial allocation
  - Area inventory: Land cover Shapefile (forest, agricultural land, grass land) = spatial surrogate
  - Point: lat-lon mapped to grid cell by I/O API
  - Blue Sky disaggregates large fires into several smaller events, allowing hourly changes in fire location
- Chemical speciation
  - WRAP FEFJ $PM_{2.5}$ and SPECIATE NMVOC profiles
- Temporal allocation
  - Smaller fires (ag, rx) use regional generic seasonal profiles (annual → month)
  - Daily activity picked up by satellite detects
  - Blue Sky uses the Air Sciences hourly WF profile

Fire Emissions Modeling

- Vertical allocation/plume rise
  - Compute plume top, plume bottom
  - Locate within air quality model layers, weighting by layer thickness
  - May include a smoldering fraction
- Vertical allocation (FEPS)
  - Plume top = 2 x Plume bottom

Fire Emissions Modeling

- Vertical allocation (Briggs)
  - Briggs Plume Rise Algorithm

    Plume Rise ($F<55$) = $H_s + 21.313 \times F^{0.75}/U$

    Plume Rise ($F \geq 55$) = $H_s + 38.878 \times F^{0.6}/U$

    where, H_s = stack height (m), F = bouyancy flux (m^4/s^3),
    U = wind speed (m/s)
  - Conversion of heat flux to bouyancy flux

    $F = Q \times 0.00000258$

    where, Q = heat flux (BTU/hr)
  - Heat flux calculation for fires

    $Q = A \times L \times C \times (2000 lb/ton) \times (1/D)$

    where, A = acres burned (acres/day), L = fuel loading (tons/acre), C = heat content (BTU/lb), D = event duration (hr/day)

Fire Emissions Modeling

- Vertical allocation (Briggs con't)
  - Smoldering fraction

    BE = 0.0703 x ln(acres) + 0.3

    S_{fract} = 1 - BE

    where, BE = bouyancy efficiency

Fire Emissions Modeling

- Vertical allocation (Air Sciences)

  $Ptop_{hour} = (BE_{hour})^2 \times (BE_{size})^2 \times Ptop_{potential}$

  $Pbot_{hour} = (BE_{hour})^2 \times (BE_{size})^2 \times Pbot_{potential}$

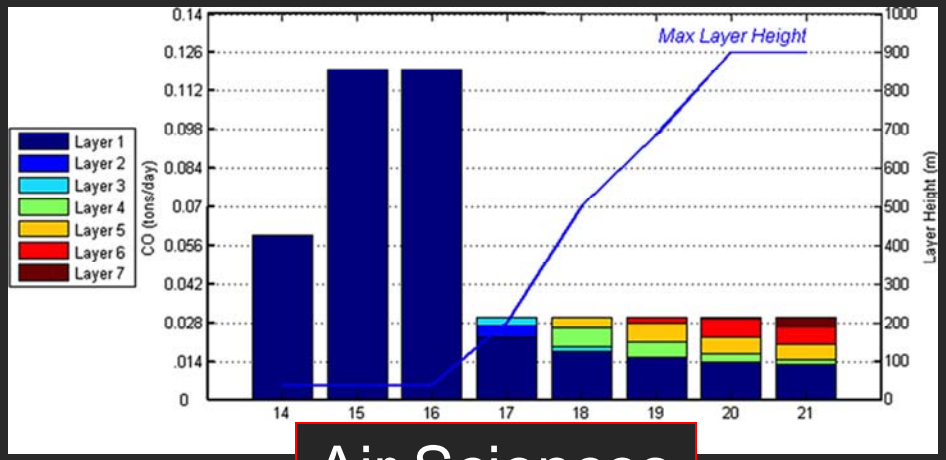
  $Lay1F_{hour} = 1 - (BE_{hour} \times BE_{size})$

  - Based on 5 fire size classes

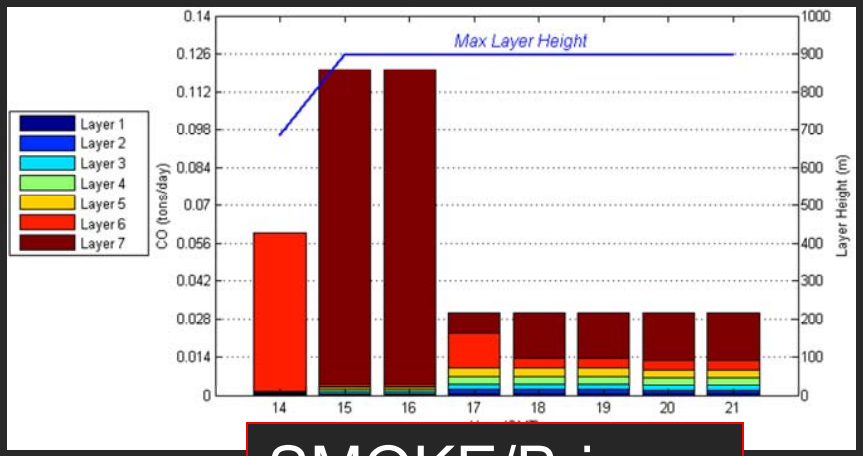
Class	1	2	3	4	5
$PM_{2.5}$ emissions (tons)	0.57	3.0	25.0	200.0	700.0
Virtual Fire Size (acres)	<10	10-100	100-1,000	1,000-5,000	>5,000
Frequency	0.62	0.33	0.045	0.002	0.0002
BE_{size}	0.4	0.6	0.75	0.85	0.9
$Ptop_{potenial}$ (m)	160	2,400	6,400	7,200	8,000
$Pbot_{potenial}$ (m)	0	300	800	1,600	1,600

Fire Emissions Modeling

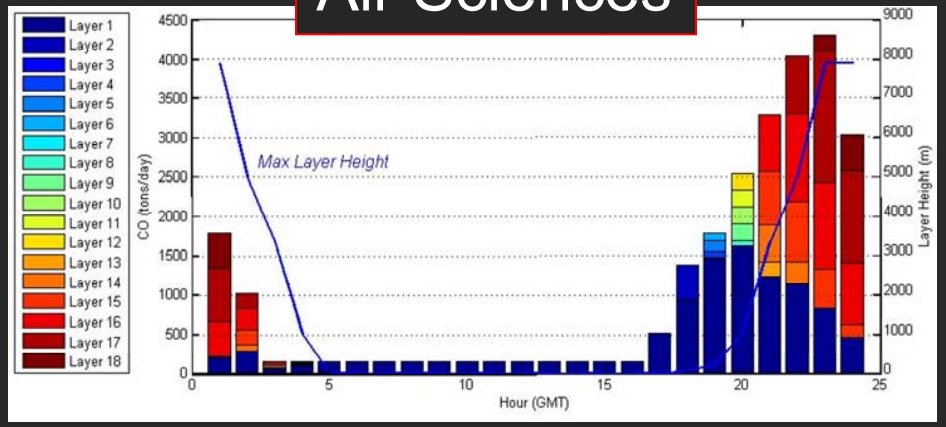
- Vertical allocation comparison: 50 acre fire (top) and 500,000 acre fire (bottom)

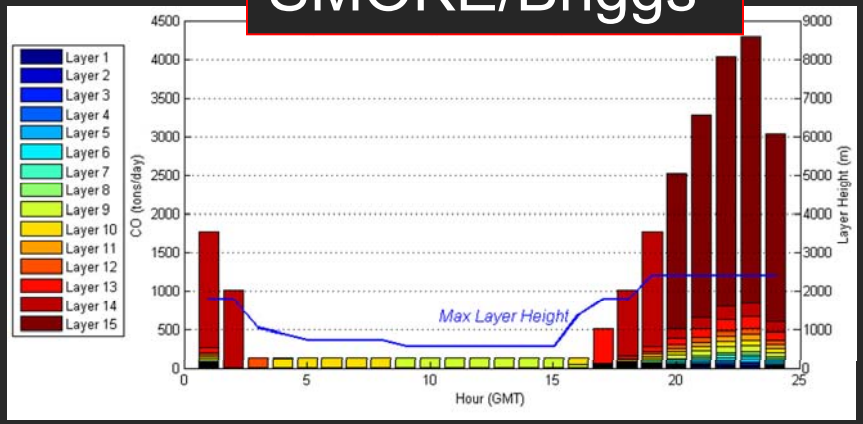


Air Sciences



SMOKE/Briggs

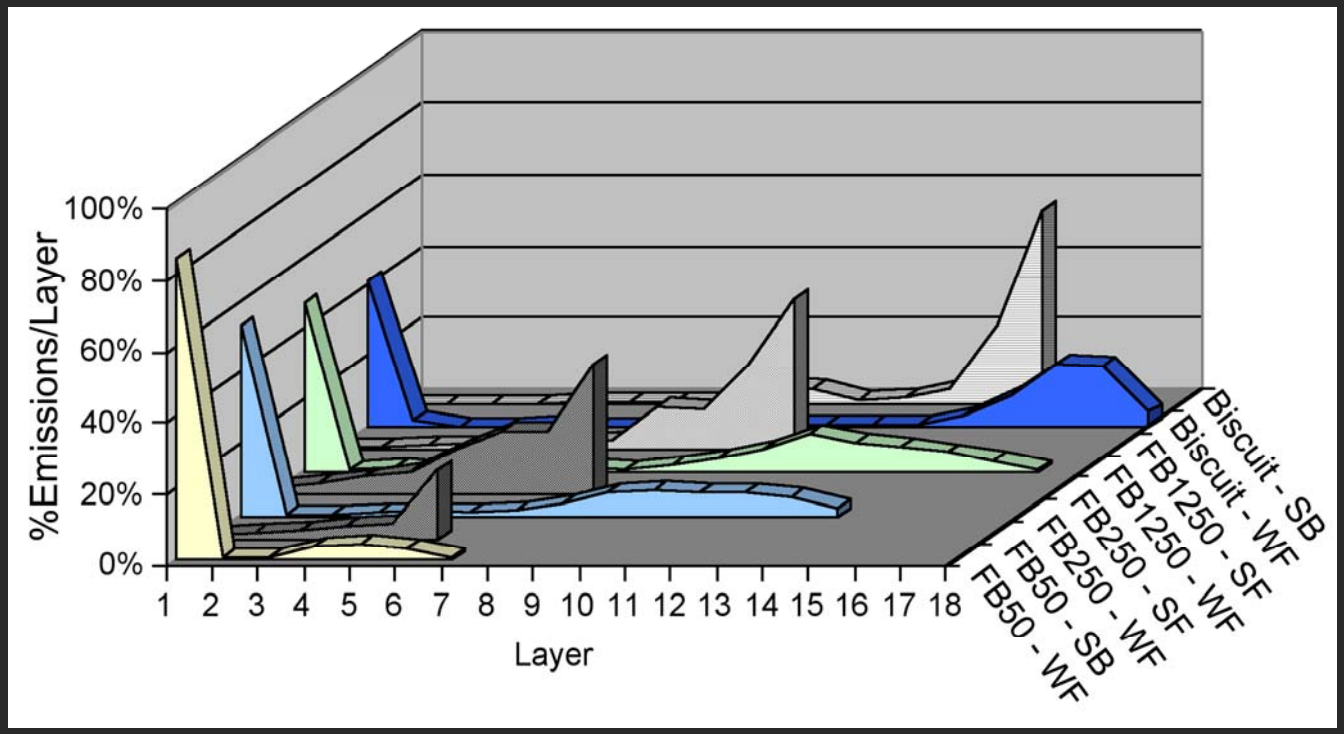




Fire Emissions Modeling

- Vertical allocation results

  SB = SMOKE/Briggs, WF = Air Sciences



Fire Emissions Modeling

- SMOKE summary
  - Area, point, and gridded inventories
  - Point fires with (a) heat flux, (b) fuel loads, acres burned, or (c) precomputed plume top, bottom, and smoldering fraction
- WRF-CMAQ summary
  - Area, point inventories
  - Point fires with (a) heat flux or (b) fuel loads, acres burned
- CAMx summary
  - Process 3-d emissions with SMOKE
  - Post processor to convert to low and elevated CAMx emissions files

Recommendations

- Develop a general file format for emissions data (text, ncf, Shapefile?)
- Observational study of plume vertical profiles to validate plume rise algorithms
- Large fires
  - Use the ORL hourly point source format for emissions and plume parameters (supports in-line emissions in CMAQ)
  - Modify Lay1F implementation in SMOKE to represent a smoldering fraction in the entire boundary layer?
- Small fires
  - Use the SMOKE point source format for lat lon location, don't need to include vertical profiles
  - Develop year-specific Shapefiles for fire locations if using the area source format
- Analysis: integrate remote sensing products (OMI AOD, CALIPSO vertical cross-sections) into fire modeling QA