VERTICAL ALLOCATION OF WILDLAND FIRE EMISSIONS USING THE 2014 NATIONAL EMISSIONS INVENTORY: INITIAL CHALLENGES AND FUTURE DIRECTIONS

JEFFREY M. VUKOVICH, V. RAO, G. POULIOT, A. EYTH, USEPA

J.BEIDLER, CSRA

EPA EMISSIONS CONFERENCE
AUGUST 18, 2017

OVERVIEW

- Background on past approaches
- Updates for 2014 National Emissions Inventory (NEI)
- Initial challenges
- Example cases
- Limitations and possible future directions

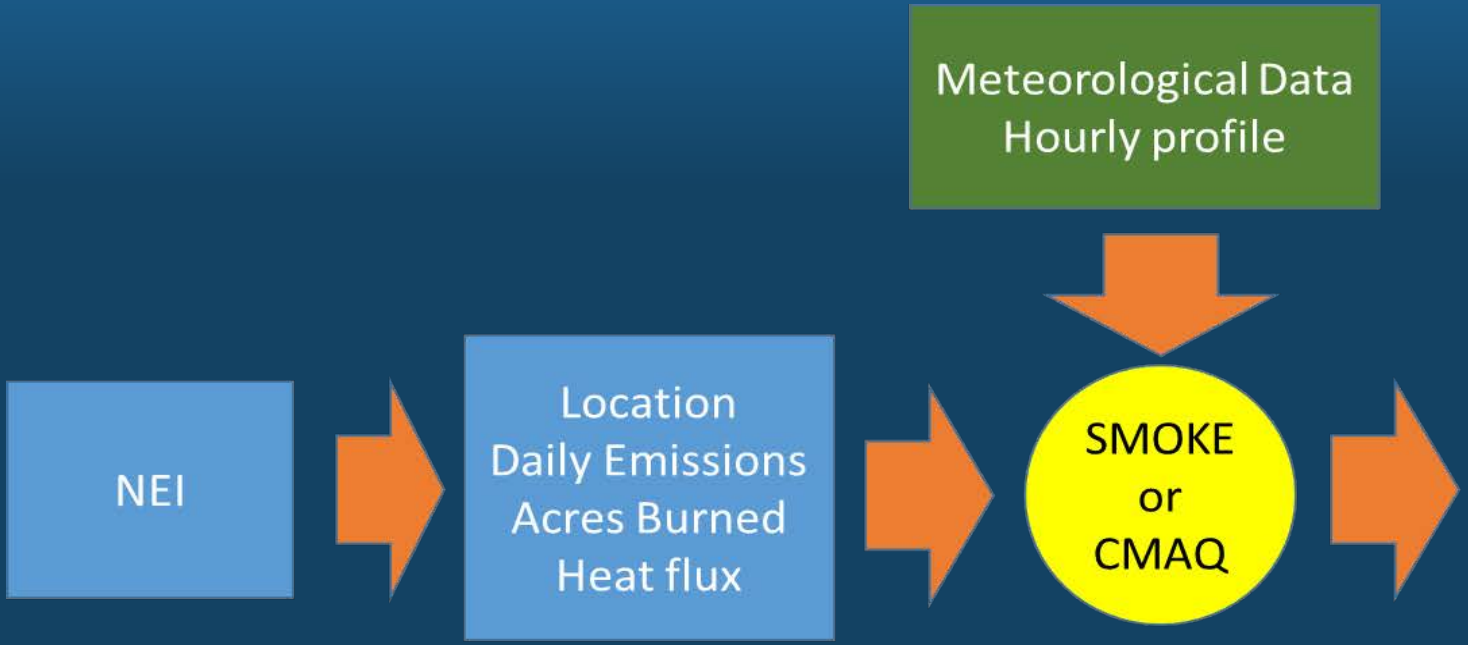
DATA USED IN PREVIOUS VERTICAL ALLOCATION EFFORTS

- 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

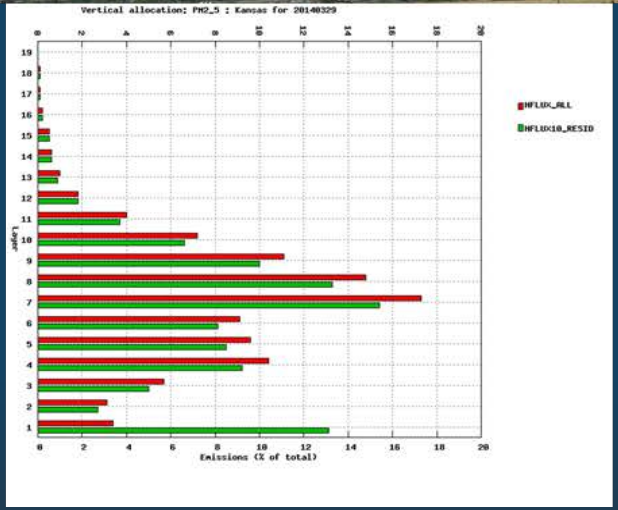


NEI

Location
Daily Emissions
Acres Burned
Heat flux

Meteorological Data
Hourly profile

SMOKE
or
CMAQ



DATA AVAILABLE FOR 2014 NEI V1 VERTICAL ALLOCATION EFFORTS

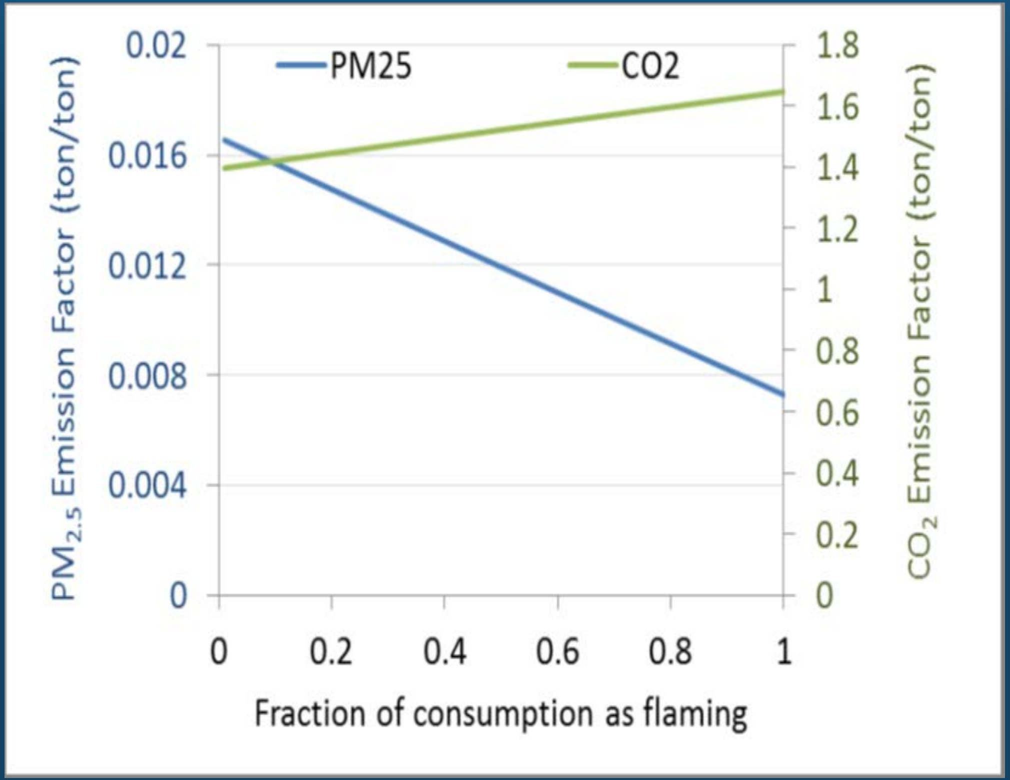
- Same as prior efforts
  - Daily emissions
  - Daily acres burned
  - Heat release

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

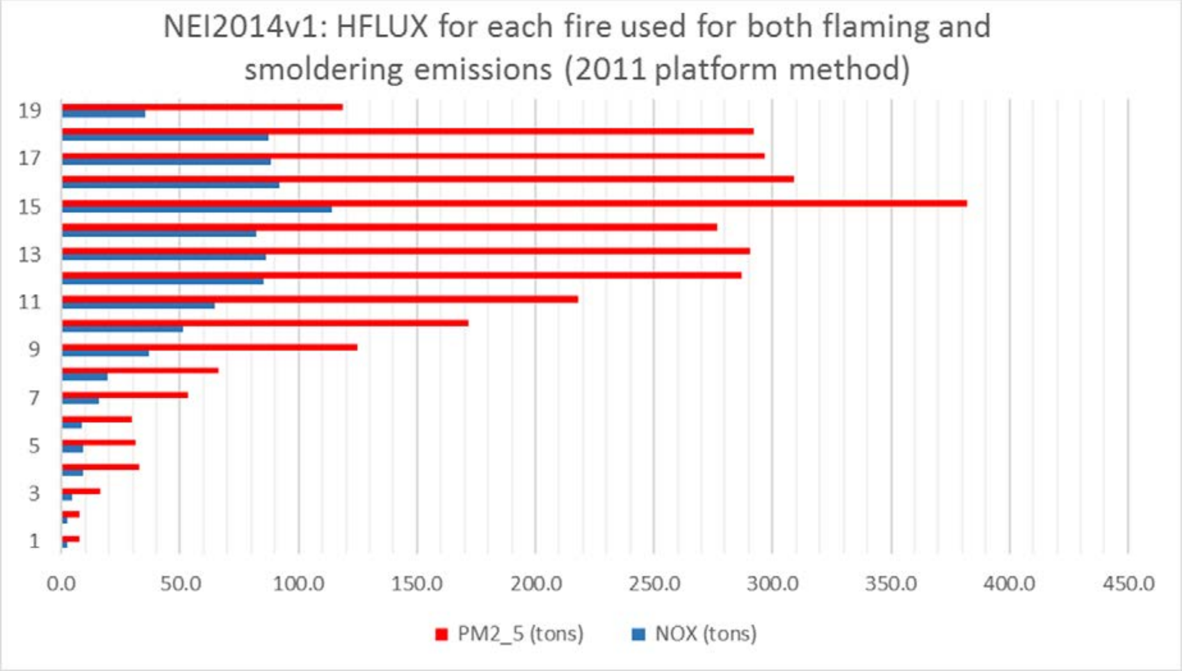


2014 NEI v1 smoldering

2014 NEI V1: SMOLDERING CONTRIBUTION AND HEAT FLUX APPLICATION

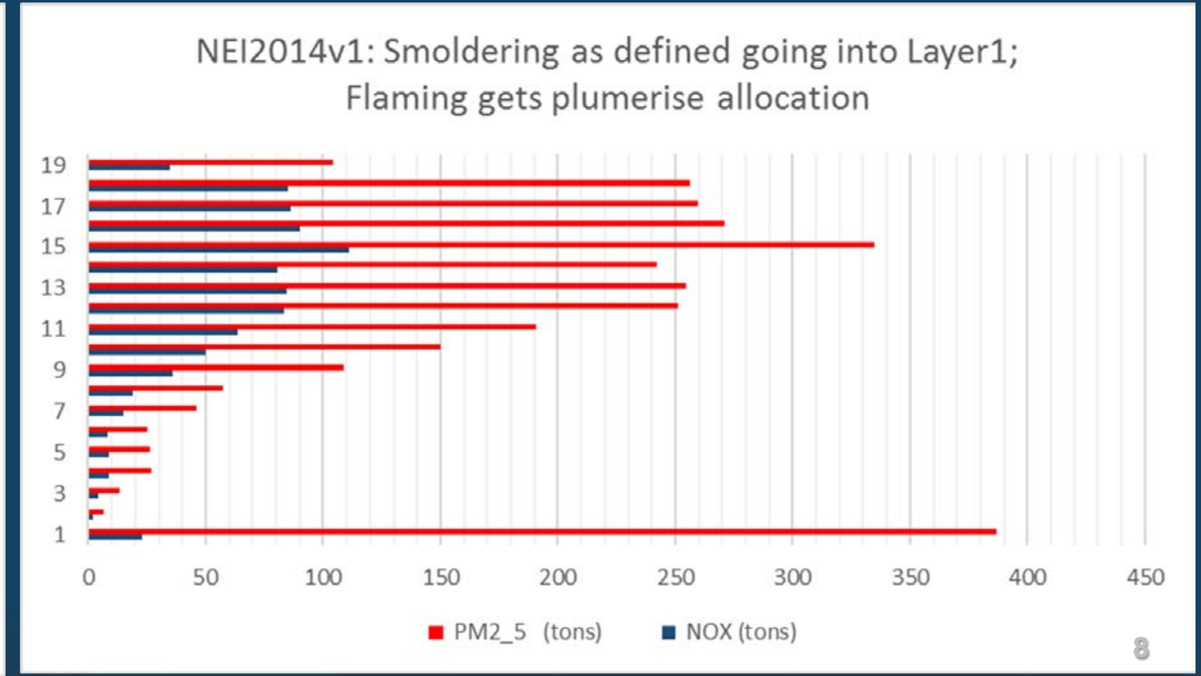
- $PM_{2.5}$: Smoldering = 60% of total national fire PM2.5 emissions (870k tons)
- VOC: Smoldering = 65% of total national fire VOC emissions (2,550k tons)
- NO_X: Smoldering = 19% of total national fire NOx emissions (48k tons)

All 2014 NEI v1 emissions get same heat flux value



NEI2014v1: HFLUX for each fire used for both flaming and smoldering emissions (2011 platform method)

If we put 2014 NEI v1 smoldering in layer 1.....



NEI2014v1: Smoldering as defined going into Layer1; Flaming gets plumerise allocation

Can we estimate the residual smoldering part of the 2014 NEI v1 smoldering emissions?

REDISTRIBUTING THE 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

CONUS Fire Emissions Totals		NOX	PM2_5	VOC
2014 NEI v1	**Flaming**	**197,066**	**598,115**	**1,334,362**
2014 NEI v1	**All smoldering**	**48,154**	**870,276**	**2,548,830**
2014 NEI v1	Total	245,220	1,468,391	3,883,191
Estimated	**Flaming + non-residual smold**	**220,002**	**1,006,472**	**2,521,575**
Estimated	**Residual smoldering**	**25,218**	**461,919**	**1,361,617**
Estimated	Residual smold % of total	10.28%	31.46%	35.06%

REDISTIBUTION 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

Same heat flux value applied to each

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

Low heat flux value applied: put in surface layer

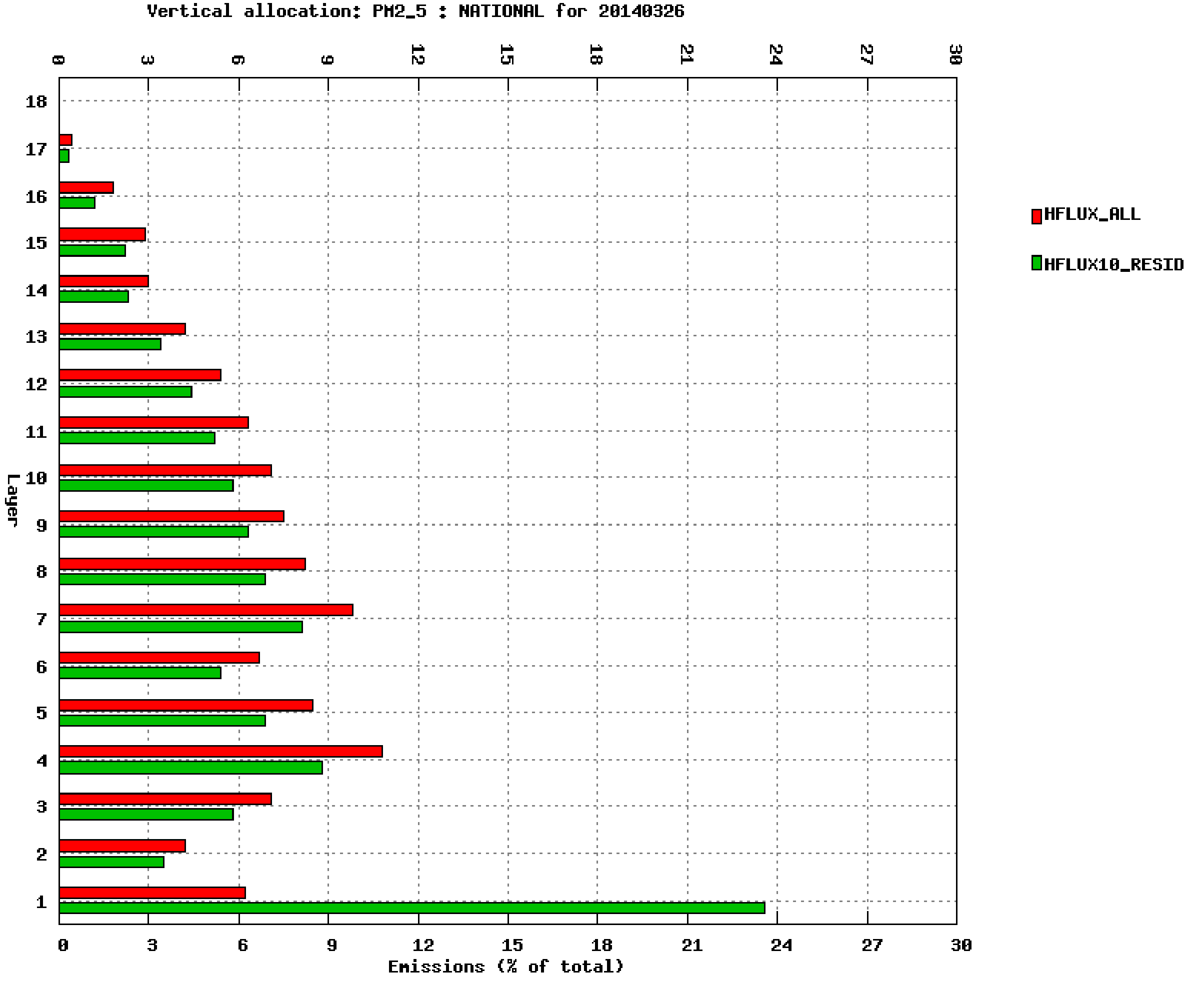
EXAMINING THE REDISTRIBUTION OF THE SMOLDERING EMISSIONS

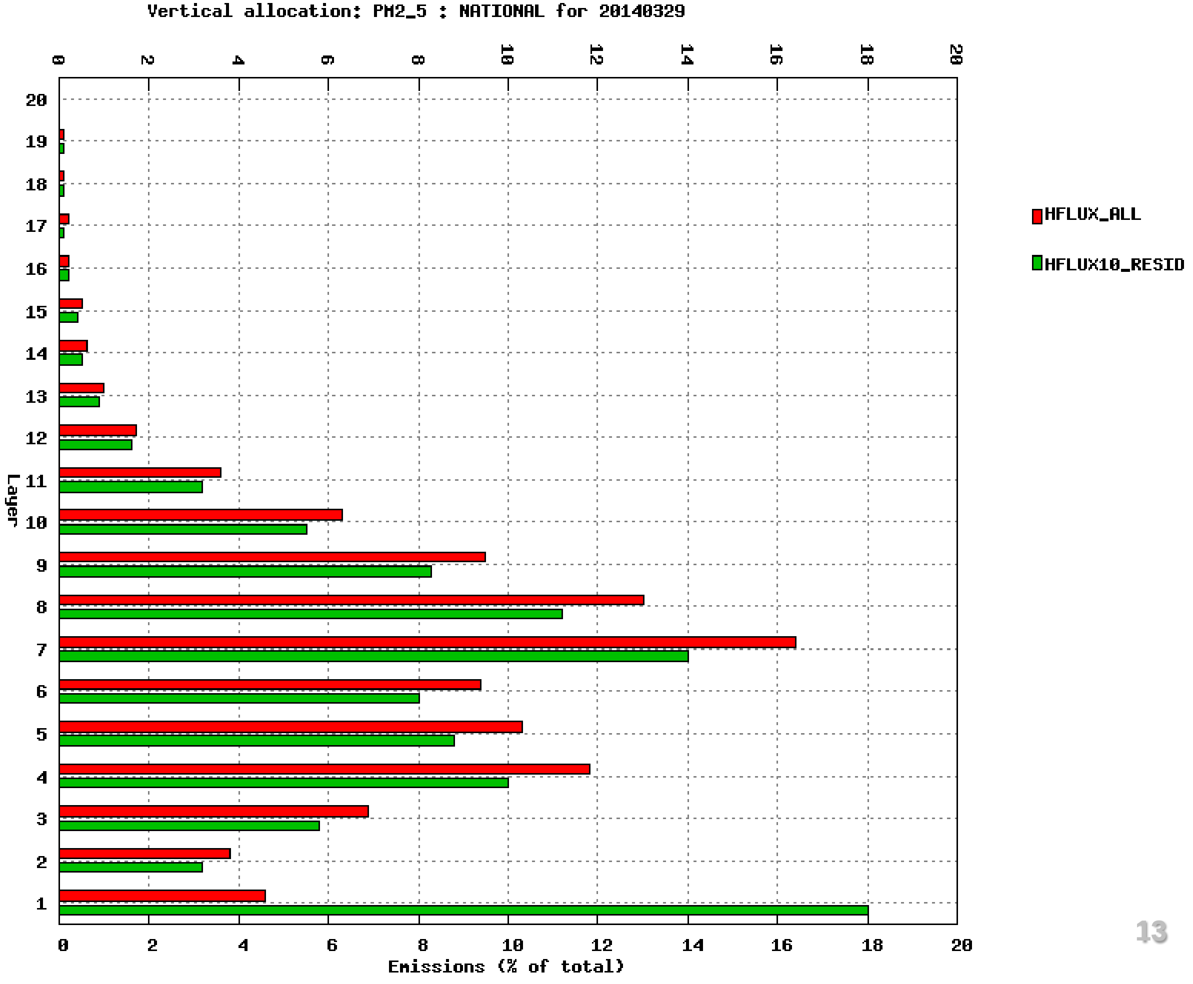
Examined the following weeks in 2014:

- 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

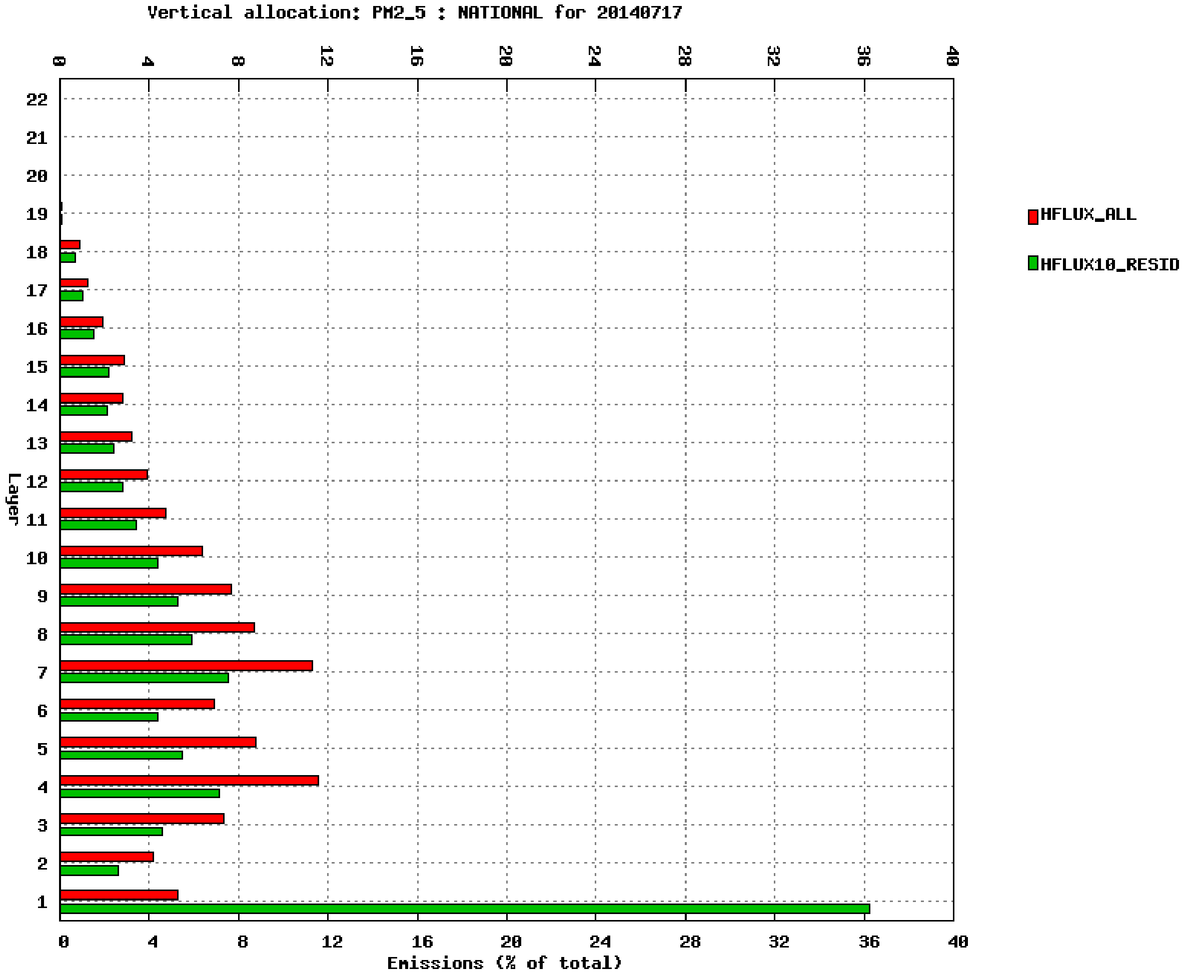
RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE

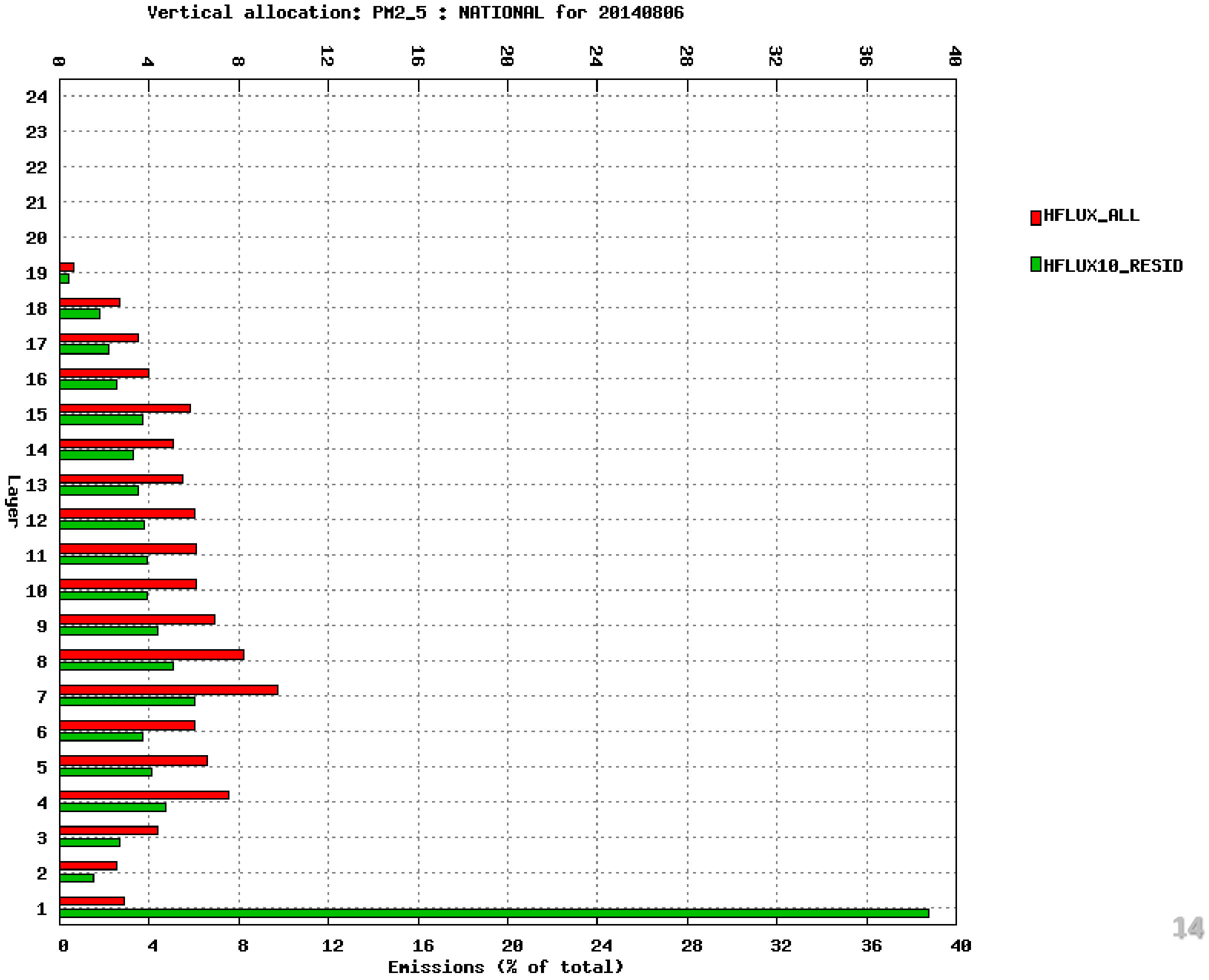

Vertical allocation: PM2_5 : NATIONAL for 20140326


Vertical allocation: PM2_5 : NATIONAL for 20140329

PM2.5 VERTICAL ALLOCATION (% PER LAYER) JUL/AUG 2014

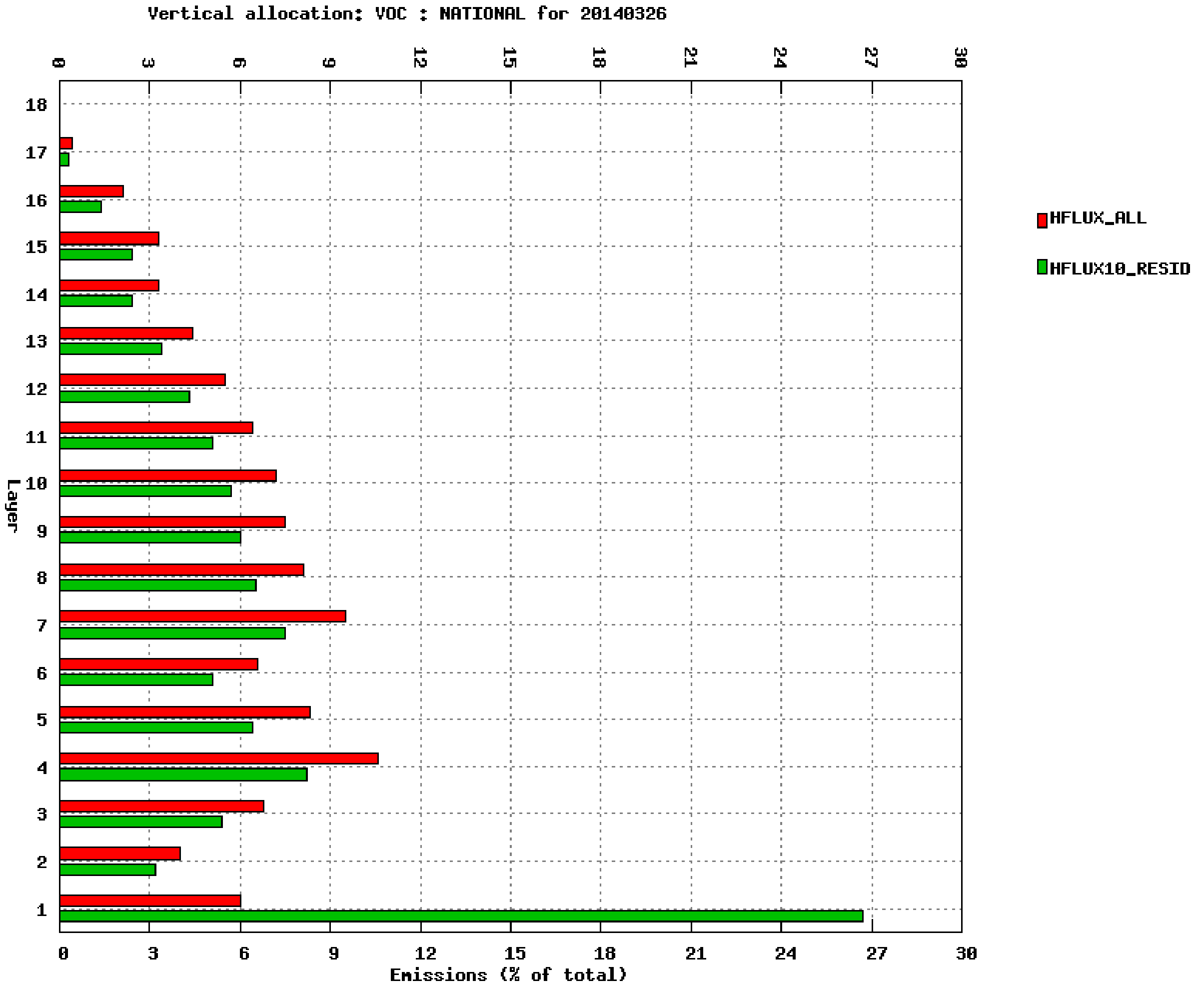
RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE

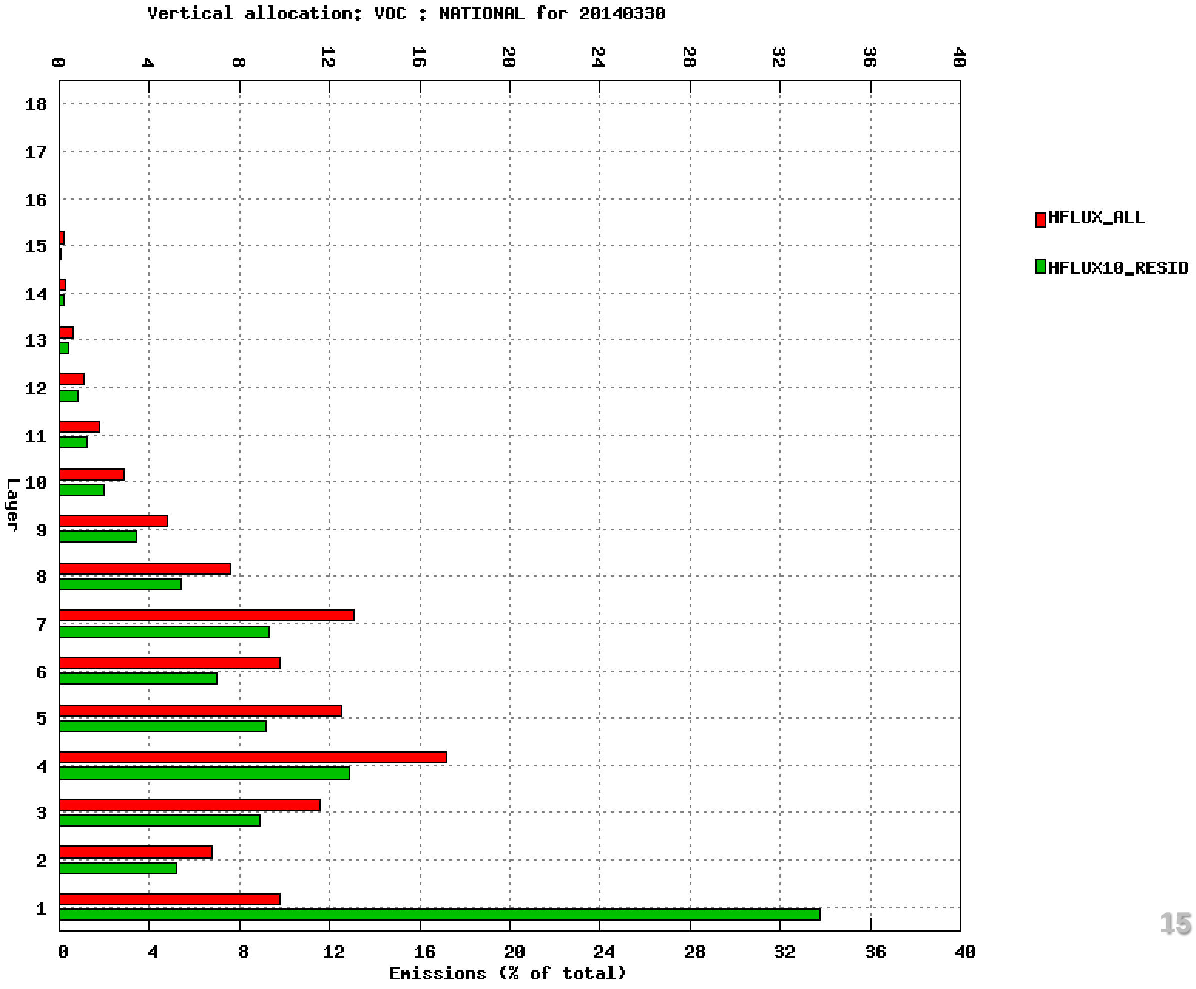




VOC VERTICAL ALLOCATION (% PER LAYER)
MARCH 2014

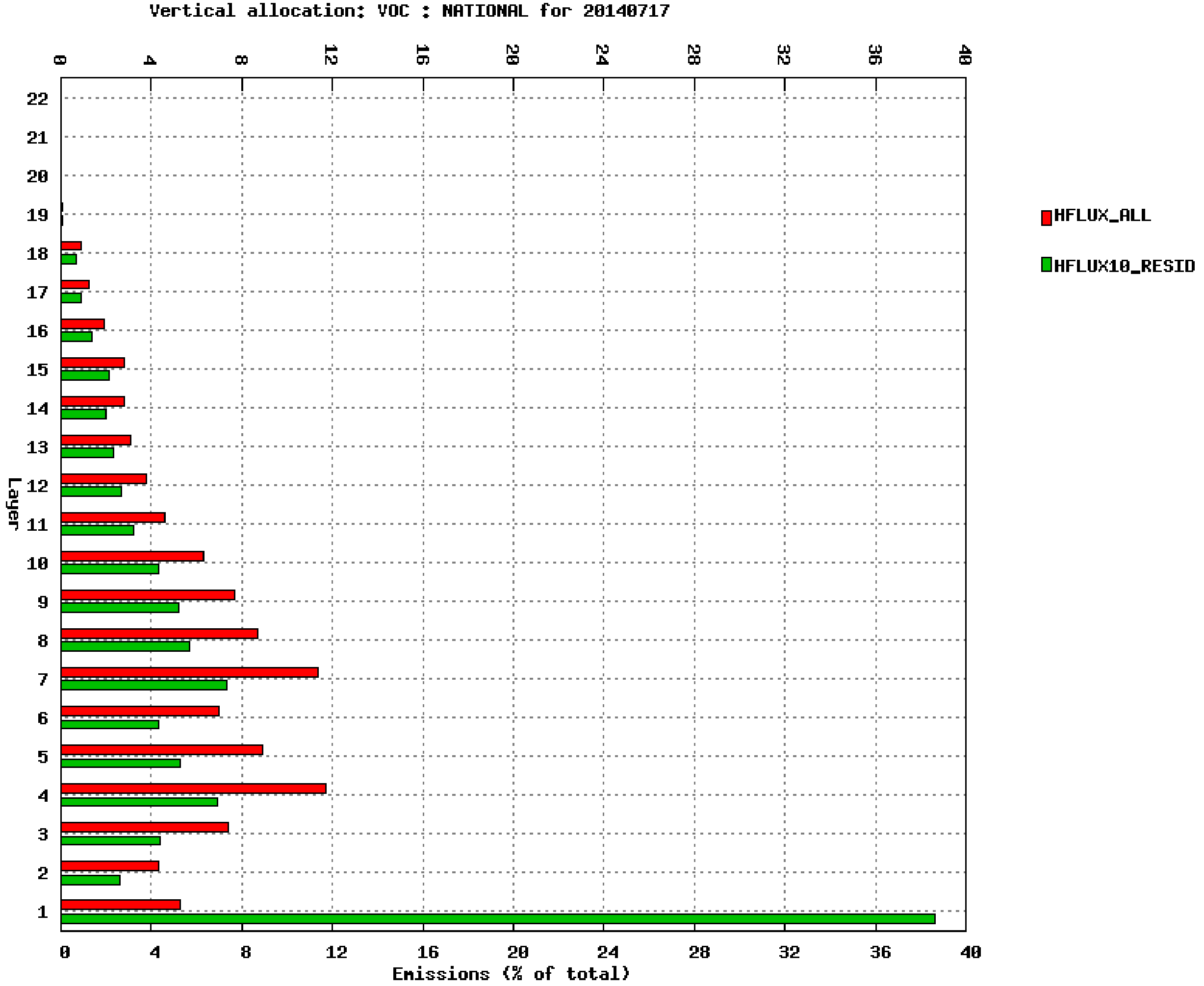
RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE

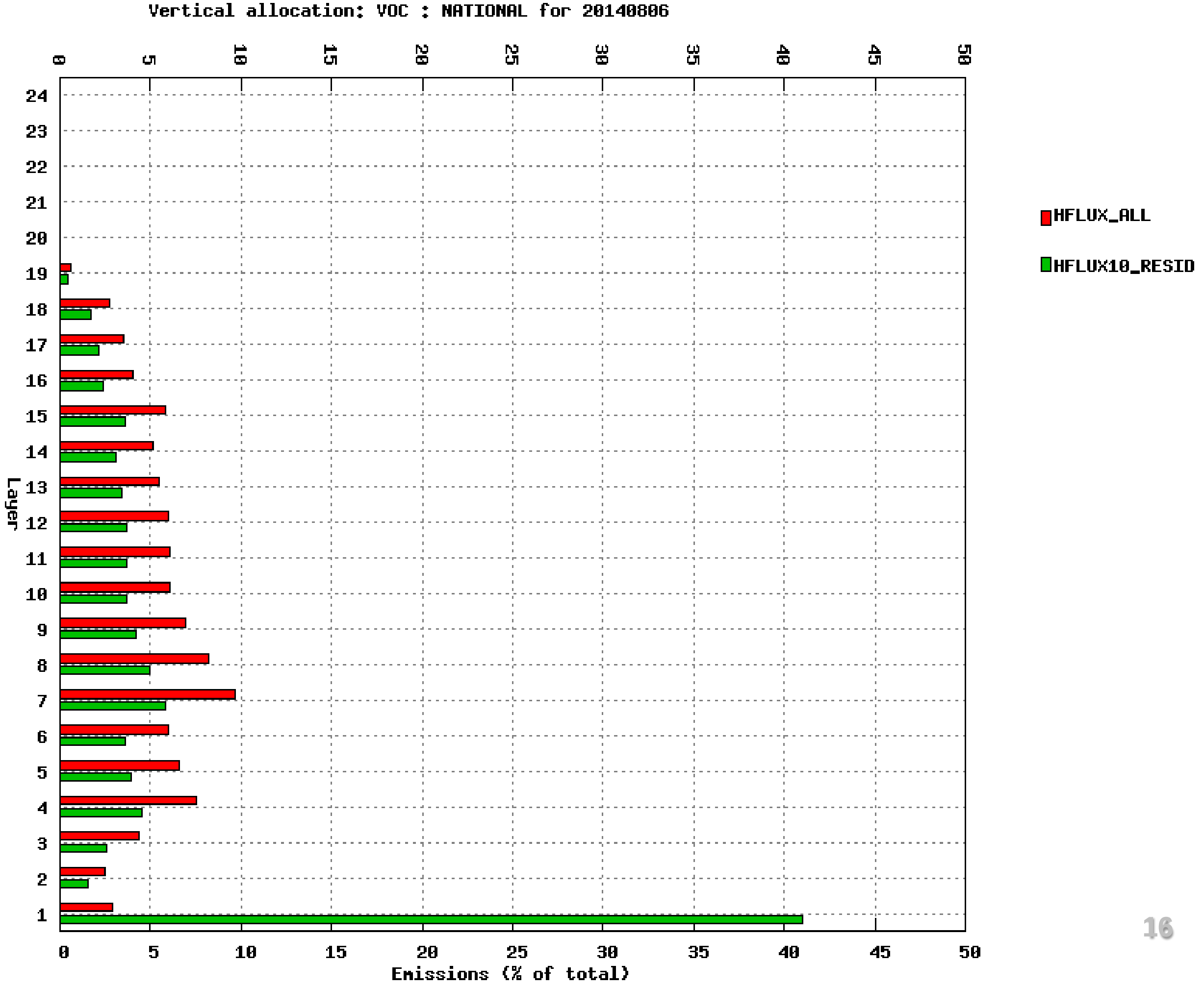

Vertical allocation: VOC : NATIONAL for 20140326


Vertical allocation: VOC : NATIONAL for 20140330

VOC VERTICAL ALLOCATION (% PER LAYER) JUL/AUG 2014

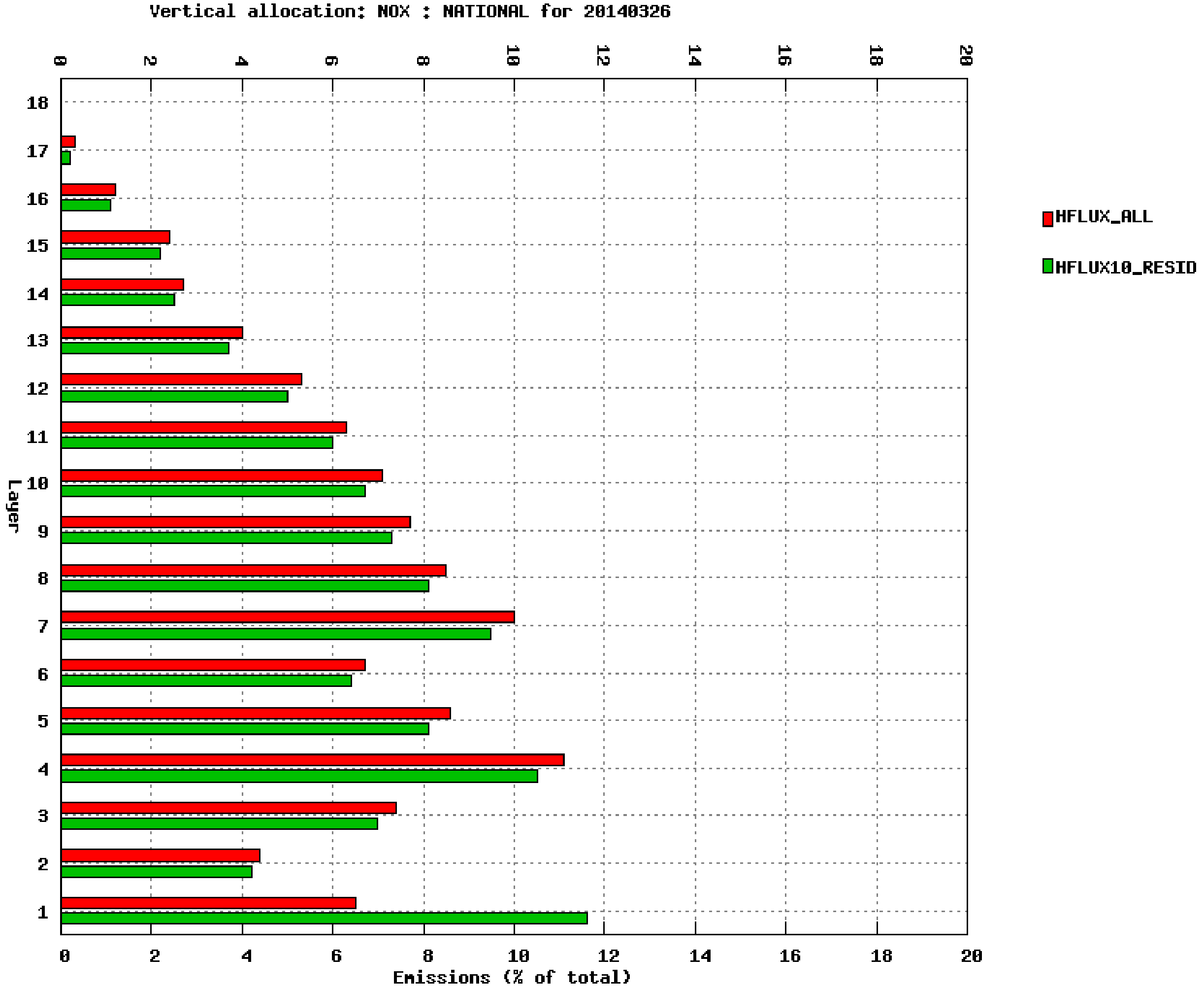
RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE

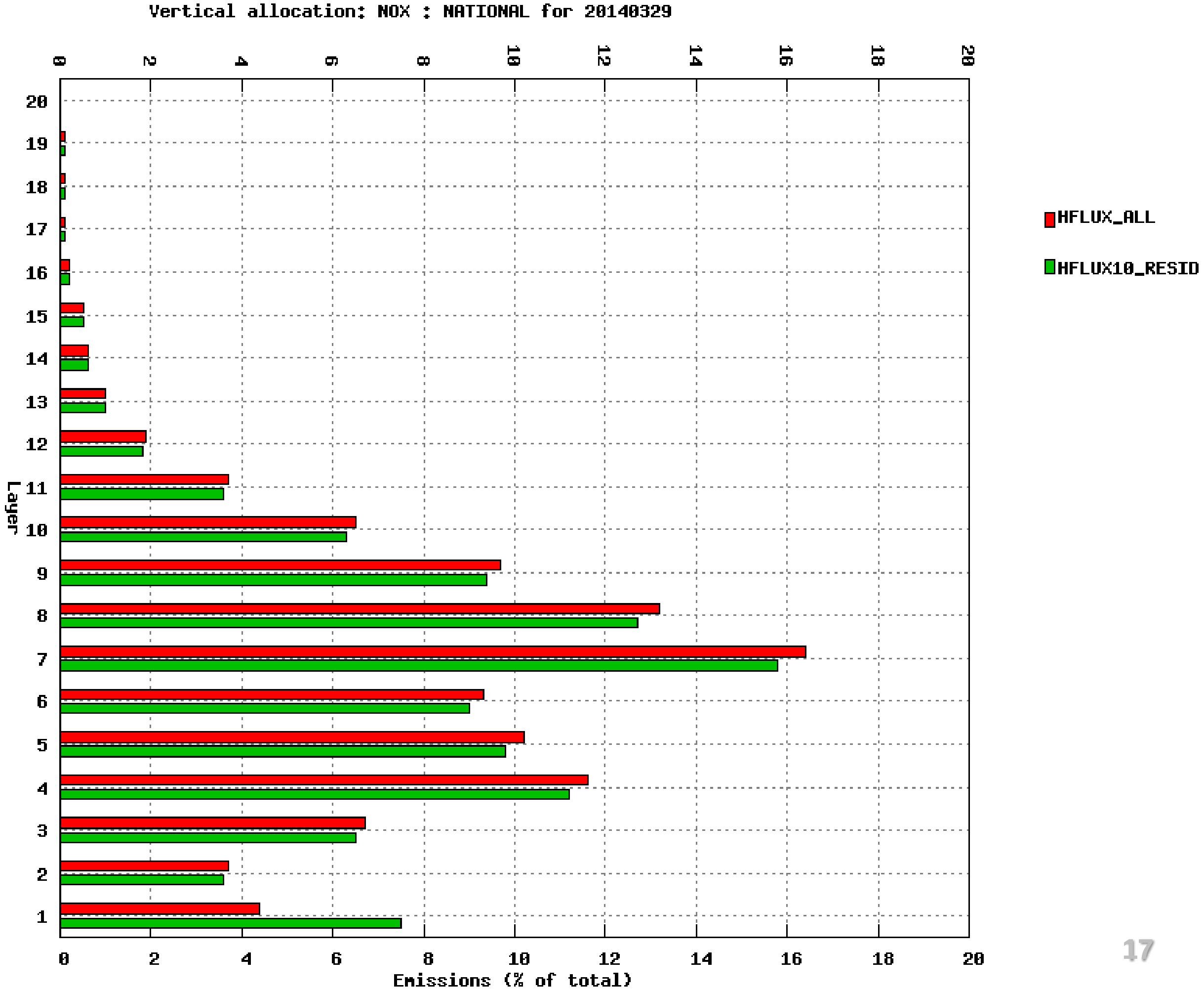

Vertical allocation: VOC : NATIONAL for 20140717


Vertical allocation: VOC : NATIONAL for 20140806

NOX VERTICAL ALLOCATION (% PER LAYER) MARCH 2014

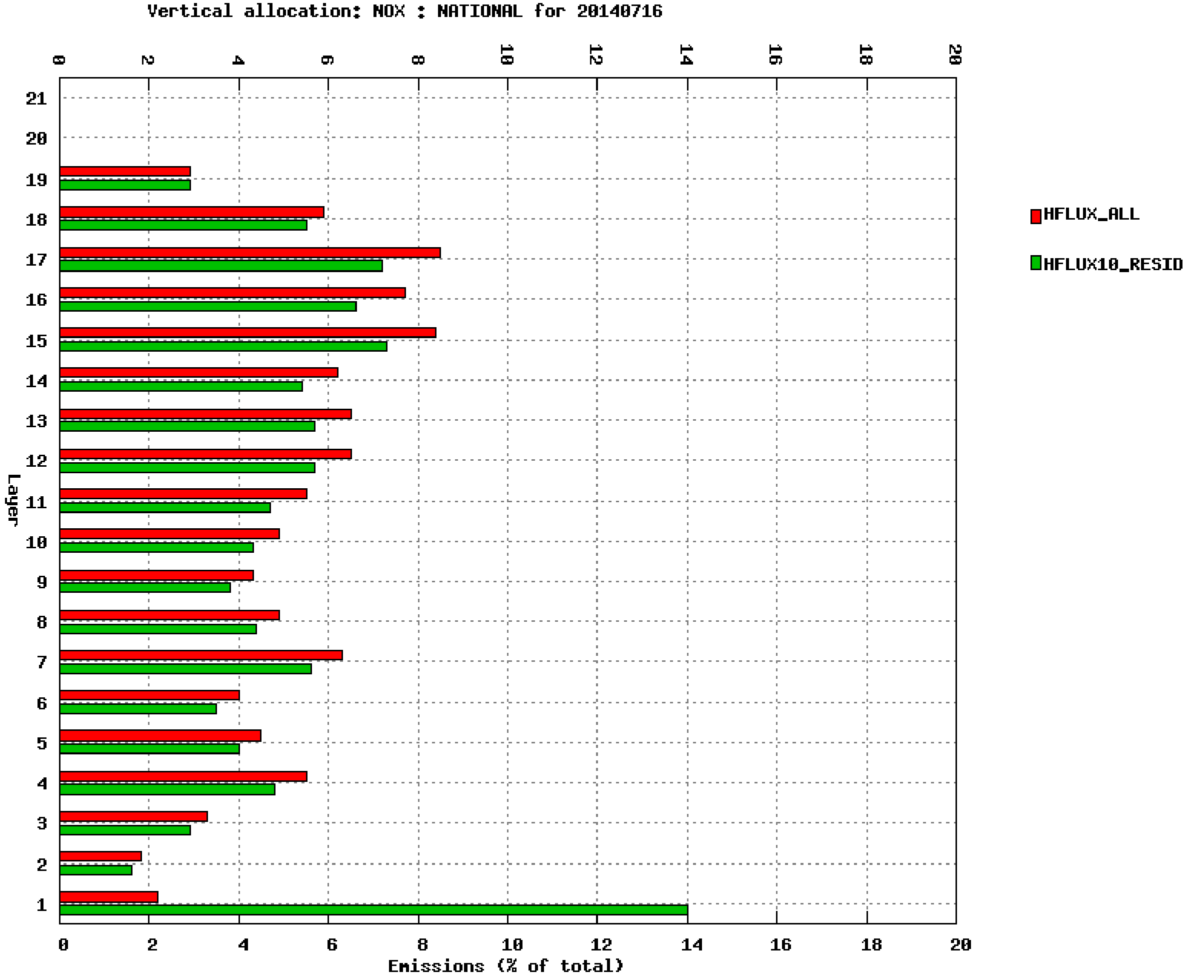
RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE

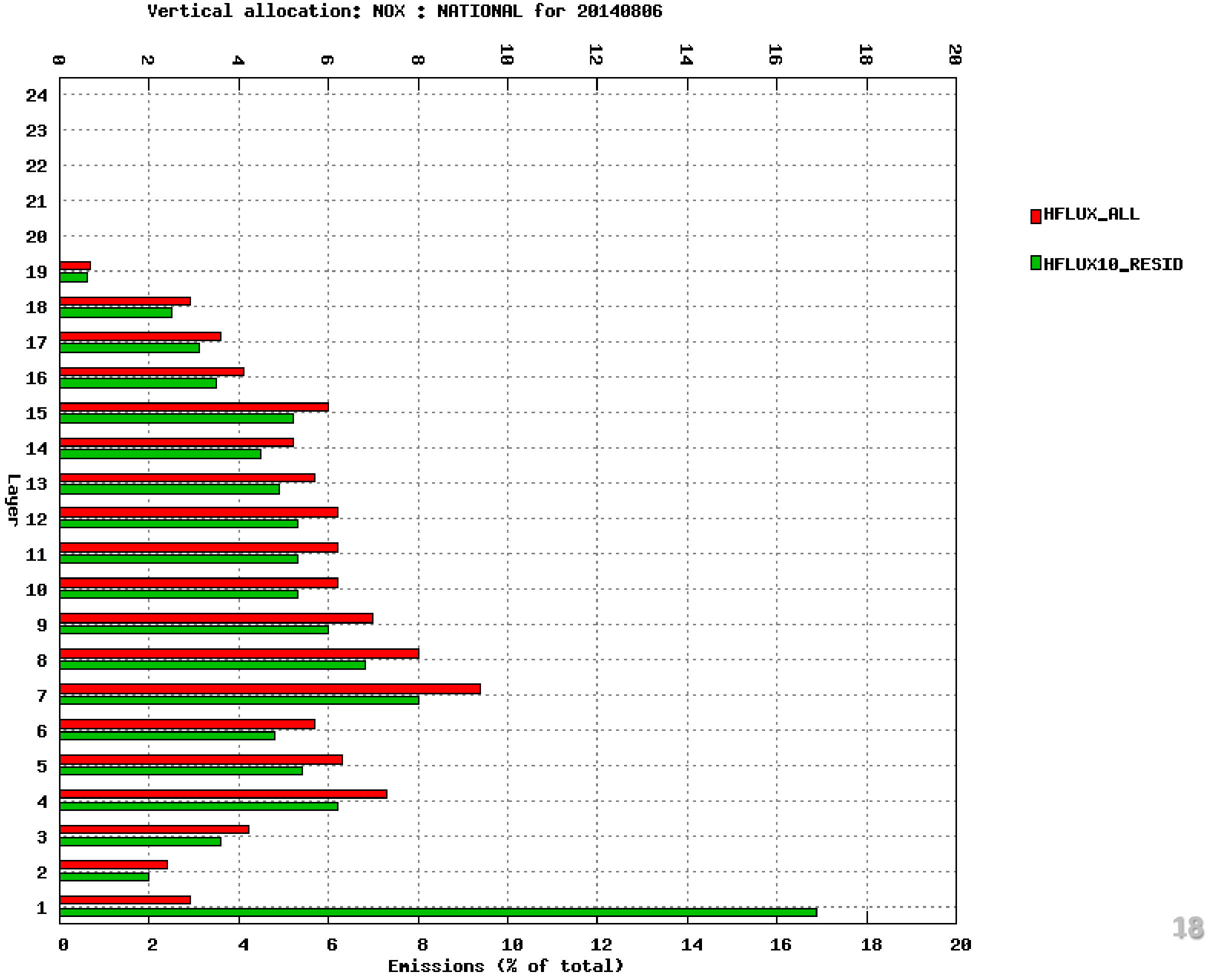

Vertical allocation: NOX : NATIONAL for 20140326


Vertical allocation: NOX : NATIONAL for 20140329

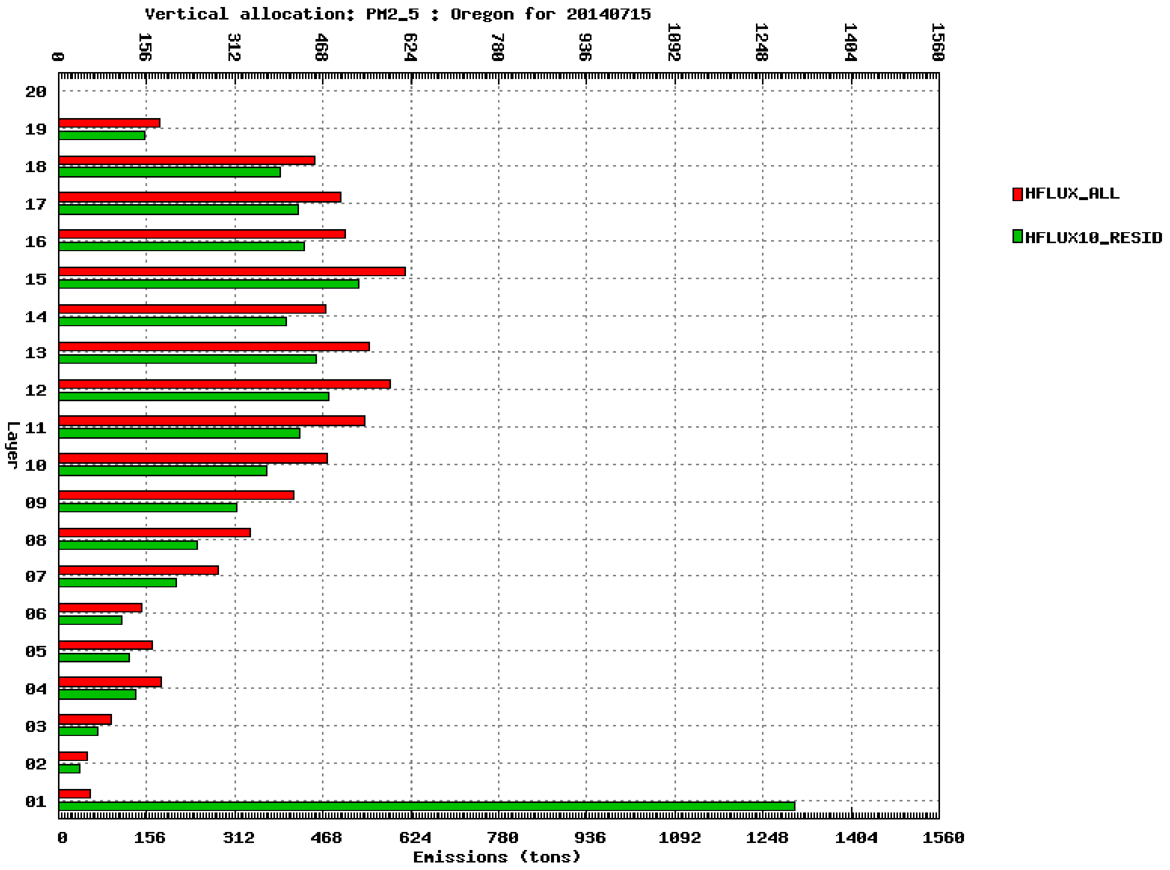
NOX VERTICAL ALLOCATION (% PER LAYER) JUL/AUG 2014

RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE



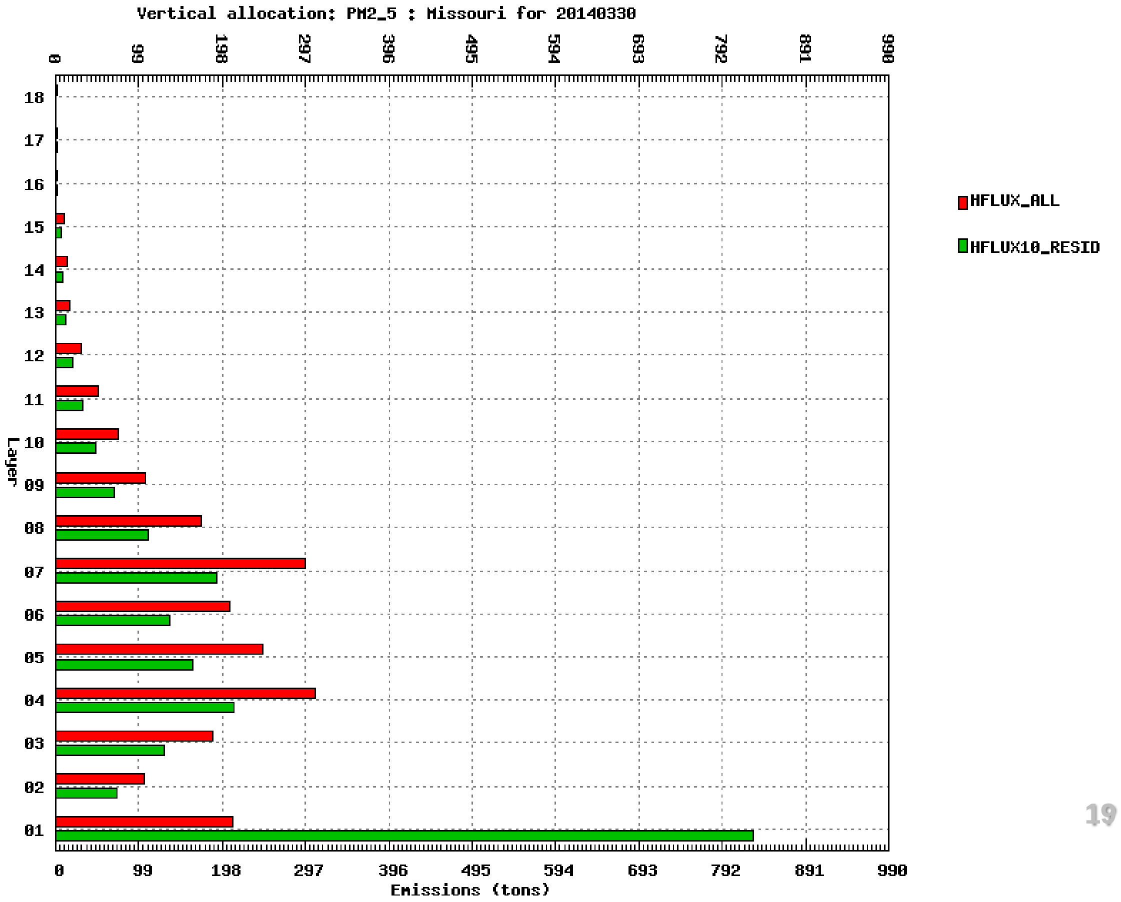


RED: SAME HFLUX ALL EMISSIONS (OLD METHOD)
GREEN: RESIDUAL HFLUX SET TO LOW VALUE



MAJOR WILDFIRES IN OREGON (firs and pines)

MAJOR Rx BURNS IN MISSOURI



REVISIT CURRENT PLUME RISE ALGORITHM

- For both SMOKE and 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

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?

CONCLUSIONS AND FUTURE DIRECTIONS

- 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 smoldeing is needed in air quality modeling and field studies
- Examine other plume rise algorithms

REFERENCE

Pouliot, G., Pierce, T., Benjey, W., O’Neill, S.M., Ferguson, S.A., 2005. Wildfire emission modeling: integrating bluesky and SMOKE. Presentation at the 14th International Emission Inventory Conference, Transforming Emission Inventories Meeting Future Challenges Today, 4/11–4/14/05 Las Vegas, NV.

CMAQ layer	Sigma	Mid-layer height 12US2 CMAQ (m)	Mid-layer pressure 12US2 CMAQ (mb)
1	0.9975	10	1016
2	0.995	32	1013
3	0.99	64	1010
4	0.98	128	1002
5	0.97	215	992
6	0.96	302	983
7	0.94	435	968
8	0.92	613	948
9	0.9	793	929
10	0.88	977	909
11	0.86	1160	890
12	0.84	1350	870
13	0.82	1540	851
14	0.80	1740	832
15	0.77	1990	807
16	0.74	2300	778
17	0.70	2670	745
18	0.65	3170	701
19	0.6	3570	653
20	0.5	4710	580
21	0.4	6150	484
22	0.3	7850	387
23	0.2	9930	291
24	0.1	12600	195
25	0.0	16,800	98