Forecasting Air Quality Effects of Fire Emissions in the United States

Daniel Tong

With Contribution from:
Daewon W. Byun, Pius Lee, Hsin-Mu Lin, Ariel Stein, Roland Draxler

NOAA Air Resources Laboratory

Boulder, CO
July 14, 2010

National Air Quality Forecast Modeling Capability (NAQFC)

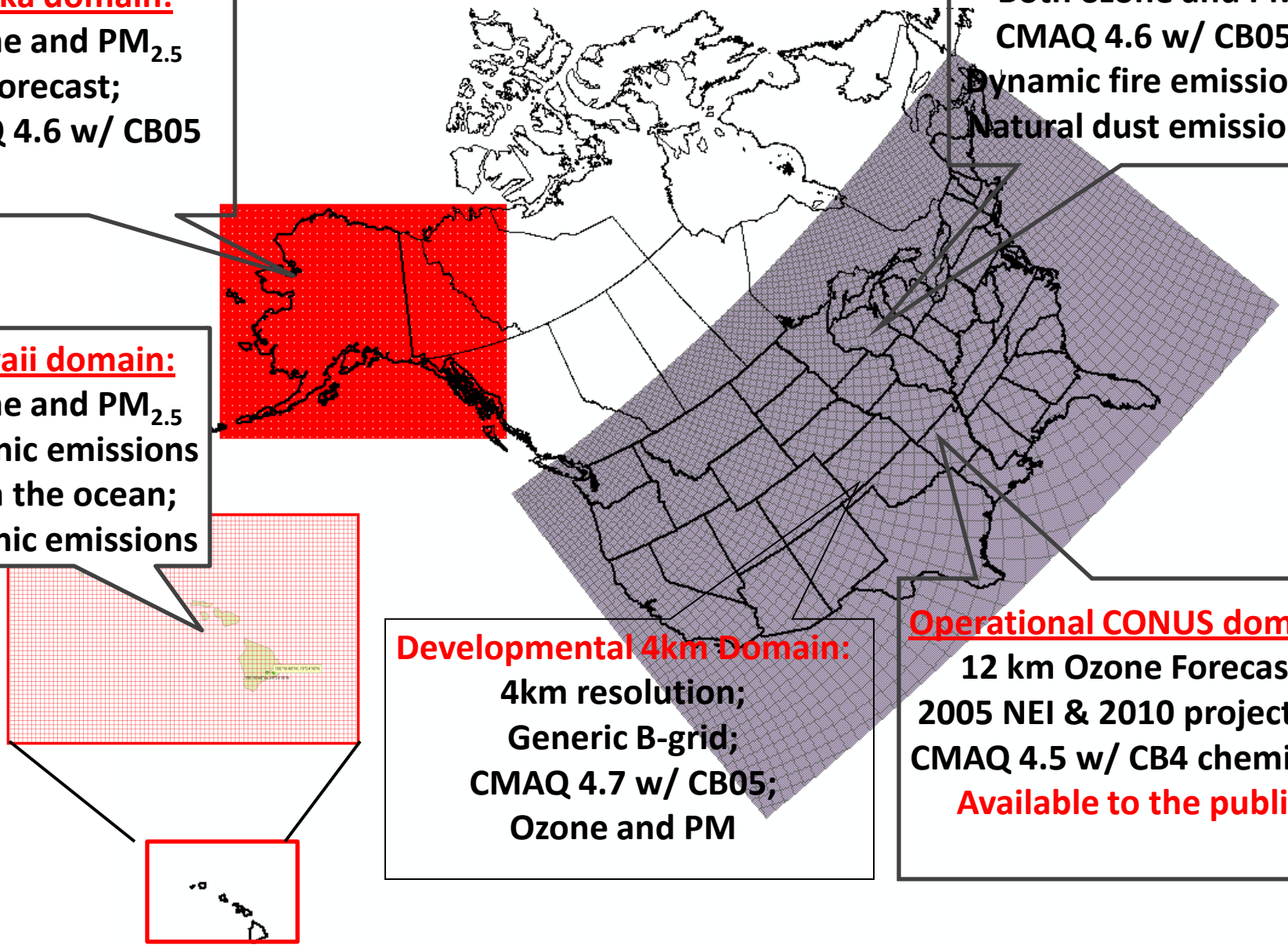
- Models used
  - NCEP operational North American Mesoscale (NAM) model called Non-hydrostatic Mesoscale Model (NMM) (Janjic et al., 2003) and
  - U.S. EPA's Community Multiscale Air Quality (CMAQ) model (Byun and Schere, 2006).
- Operational ozone forecasting
  - CONUS at ~12 km since September 2007 with Carbon Bond-IV (CB-IV) mechanism.
  - EPA's national emission inventories (NEIs) for base year 2001, 2002, and 2005
- Experimental O3 & Developmental PM2.5 forecasts (w/ CMAQ4.6)
  - CONUS at ~12 km, with CB05^{+} and speciated aerosols using multimodal distributions

  $^{+}$ CB05 is expected to be more scientifically valid and needed for aerosol (PM) modeling
- Developmental systems
  - Hawaii domain at ~12 km resolution (CB05 & modal aerosol)
  - Alaska domain at ~12 km resolution (CB05 & modal aerosol)
  - CONUS at ~4 km resolution (on-going development, CB05 & improved PM in CMAQ4.7)

NAQFC Model Domains

Alaska domain:
Ozone and $PM_{2.5}$ forecast;
CMAQ 4.6 w/ CB05

Hawaii domain:
Ozone and $PM_{2.5}$ biogenic emissions from the ocean;
Volcanic emissions

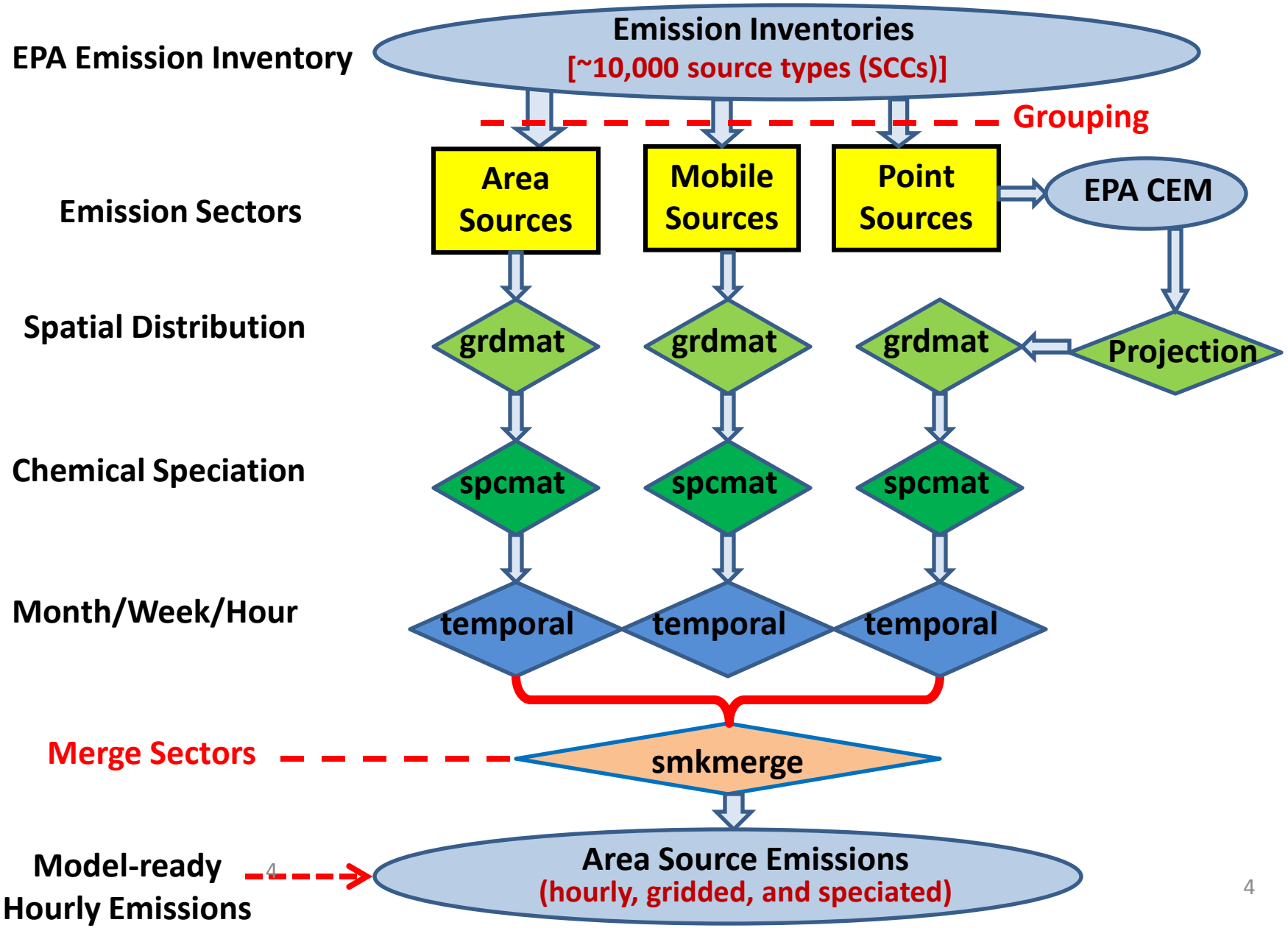


Experimental CONUS :
Both ozone and PM
CMAQ 4.6 w/ CB05;
Dynamic fire emissions;
Natural dust emissions;

Developmental 4km Domain:
4km resolution;
Generic B-grid;
CMAQ 4.7 w/ CB05;
Ozone and PM

Operational CONUS domain:
12 km Ozone Forecast
2005 NEI & 2010 projection
CMAQ 4.5 w/ CB4 chemistry
Available to the public

NAQFC Emission Modeling: *1. Anthropogenic Emissions*



4

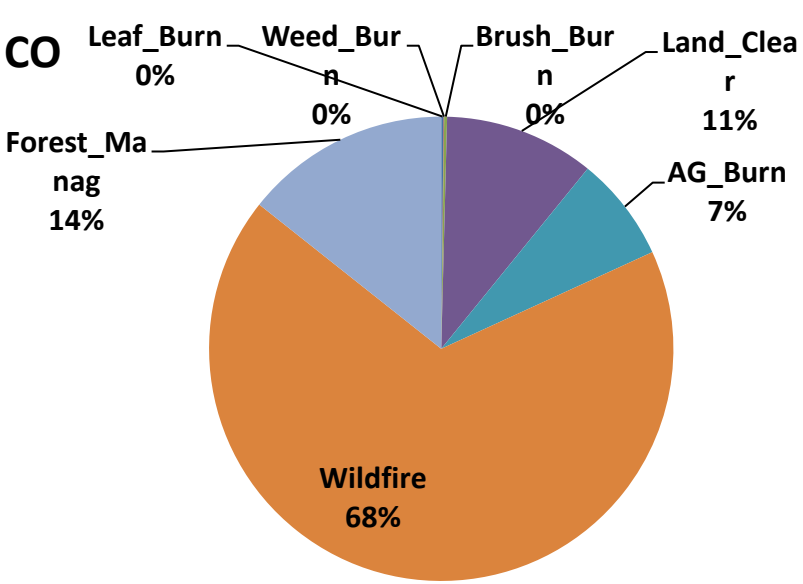
NAQFC Emission Modeling: *2. Natural Emissions*

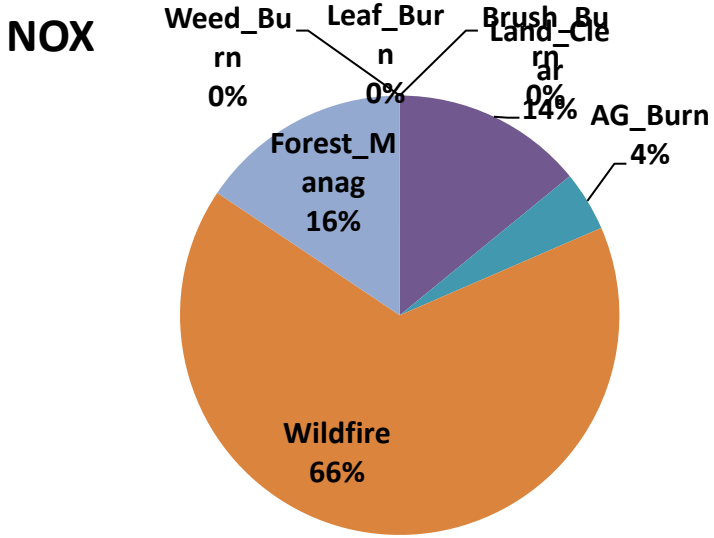
- **Terrestrial biogenic emission**: EPA BEIS3 Model (Pierce et al., 2003)
- **Ocean biogenic emission**: ARL Marine Emission Module (Tong et al., 2010);
- **Sea-Salt emission** from surf zone (Zhang et al., 2005);
- **Wind-blown dust emission**: CMAQ Dust Algorithm (Tong et al., 2008, 2009);
- **Volcanic emission**: ARL Volcanic Emission Module (Tong et al., 2010)
- **Biomass Burning**: 1) EPA Climatological NEI 2002;
  2) HYSPLIT fires (Rolph et al, 2009)

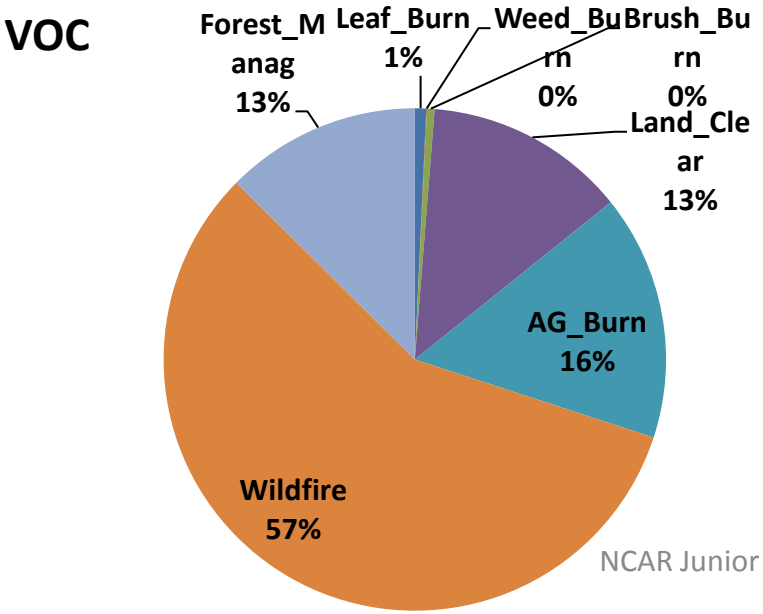
EPA Fire Emission Inventory (2002)

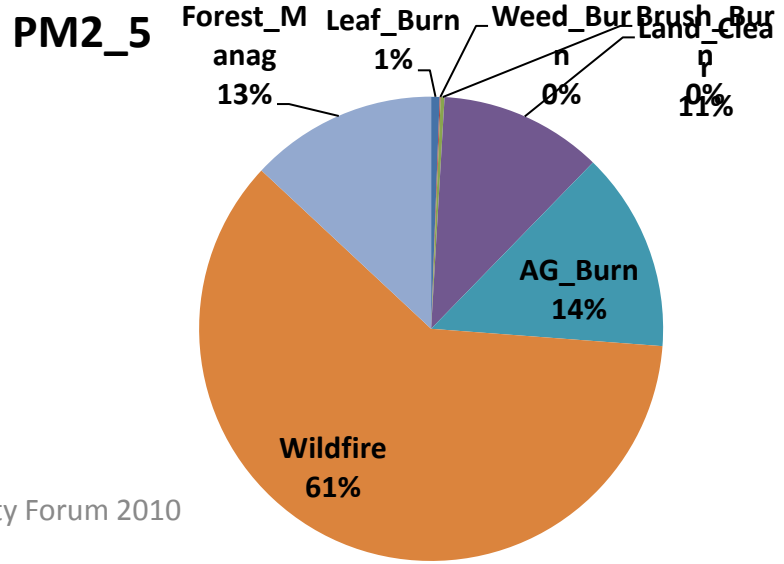
- **Purpose**
  - **Account for *background* contributed by fire emissions**
- **Methods**
  - **Fire activities and burn area data provided by state and local agencies for seven years (1996 – 2002)**
  - **Emission factors from EPA AP-42 method, updated by Battye & Battye, 2002)**
  - **Temporal profiles retained for each states, but averaged over six years;**

Fire types and emissions









Ratio to CO

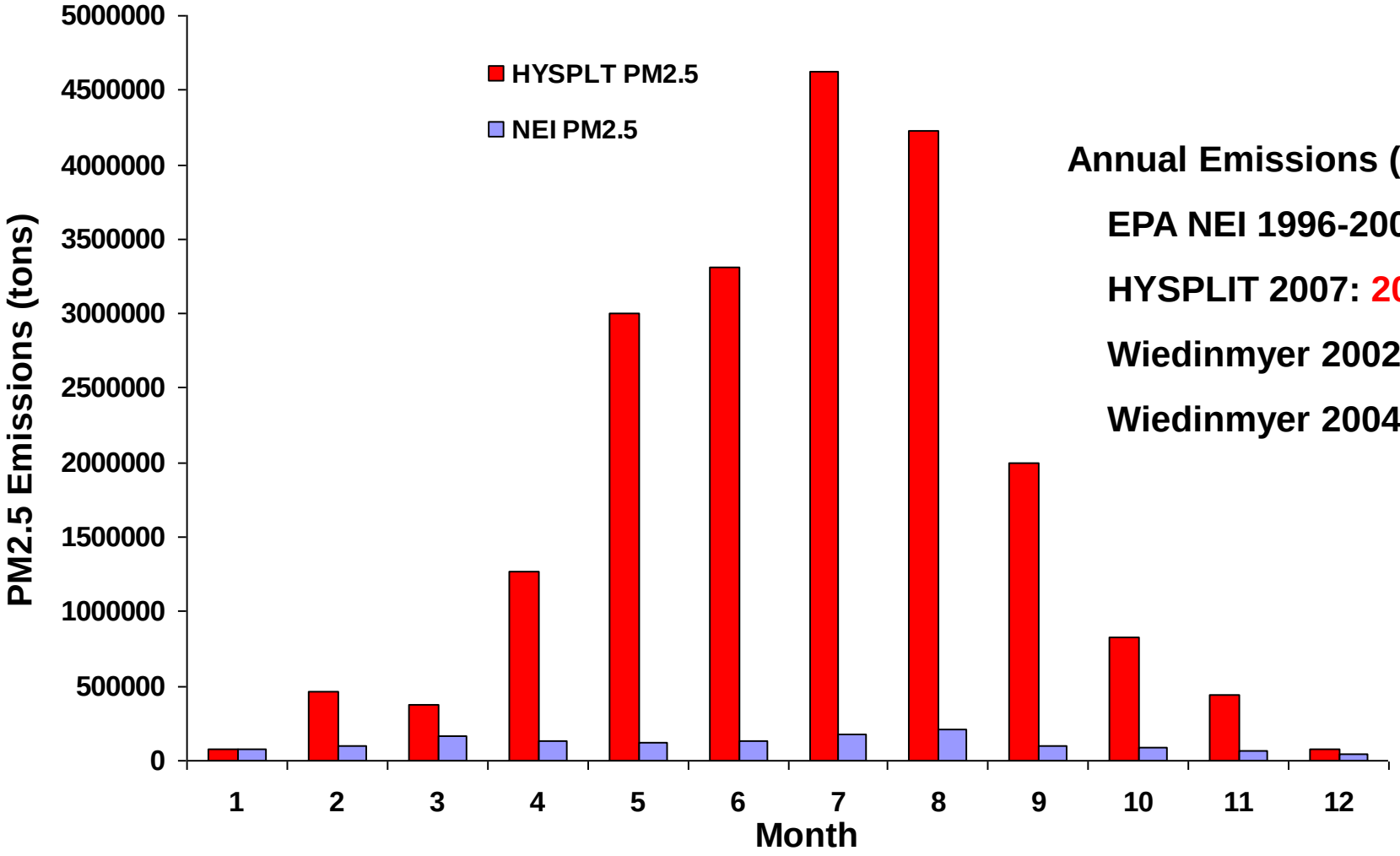
Source Description	Source Classification Code (SCC)	NO_X	VOC	NH_3	SO_2	PM10	$PM_{2.5}$
Leaf Burning	2610000100	0.000	0.250	0.000	0.000	0.339	0.339
Weed Burning	2610000300	0.002	0.057	0.000	0.000	0.162	0.162
Brush Burning	2610000400	0.000	0.136	0.000	0.000	0.121	0.121
Land Clearing	2610000500	0.030	0.069	0.000	0.000	0.101	0.101
Agricultural Burning	2801500000	0.013	0.120	0.002	0.000	0.190	0.176
Wildfire	2810001000	0.021	0.047	0.004	0.006	0.097	0.083
Forest Management	2810015000	0.024	0.049	0.005	0.007	0.098	0.084

(Derived from EPA SPECIATE , 2010)

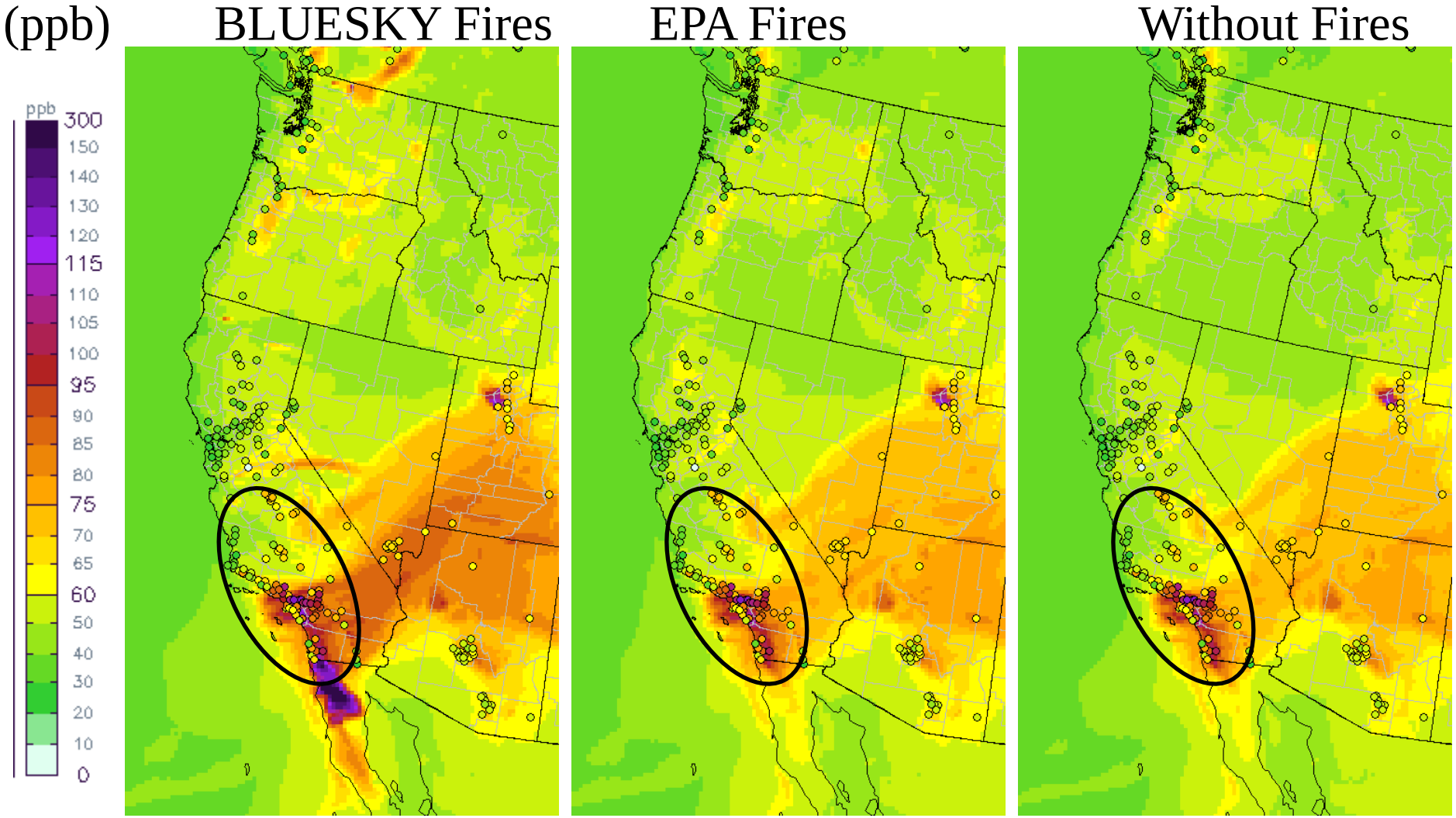
Dynamic fire Emissions based on HMS & BlueSky

- **Purpose**
  - **Replace climatological fire inventory with time- and space-resolved fire emissions.**
- **Methods**
  - **Fire detection from NOAA Hazard Mapping System (HMS) Fire and Smoke Products;**
  - **Fuel load, combustion efficiency, and emission factors based on USDA BlueSky algorithm;**
  - **Fire plume rise using UNC SMOKE algorithm;**
  - **Remove "climatic" background fire emissions from inventories**

Comparisons of EPA Fires Emissions and HYSPLIT Fire Emissions



Impacts of Wildfire Emissions on Max. 8-hr O_3 08/30/2009



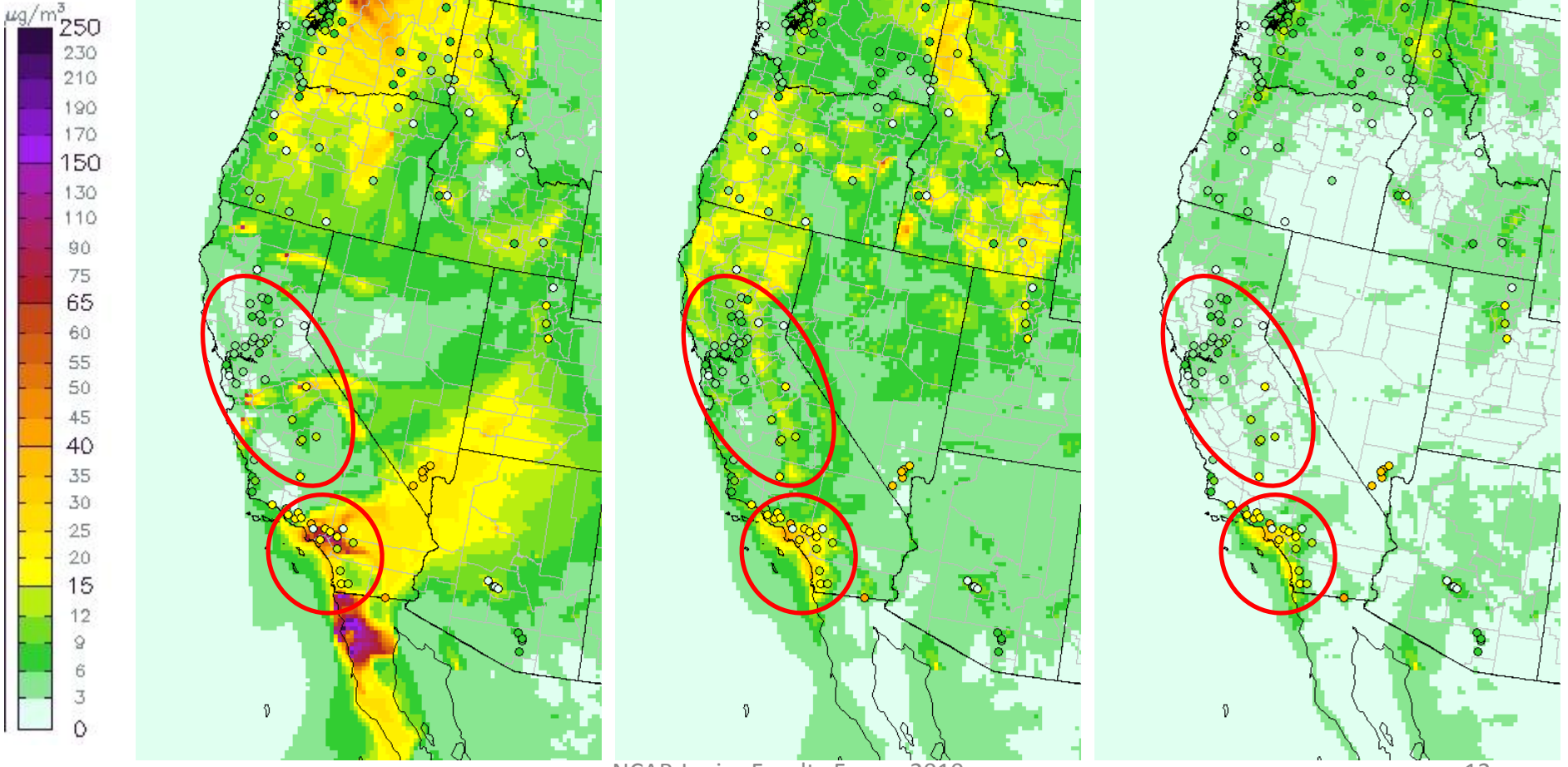
Impacts of Wildfire Emissions on Daily-average of $PM_{2.5}$ 08/30/2009

($\mu g\ m^{-3}$)

BLUESKY Fires

EPA Fires

Without Fires



Health Effects of Wildfire Emissions

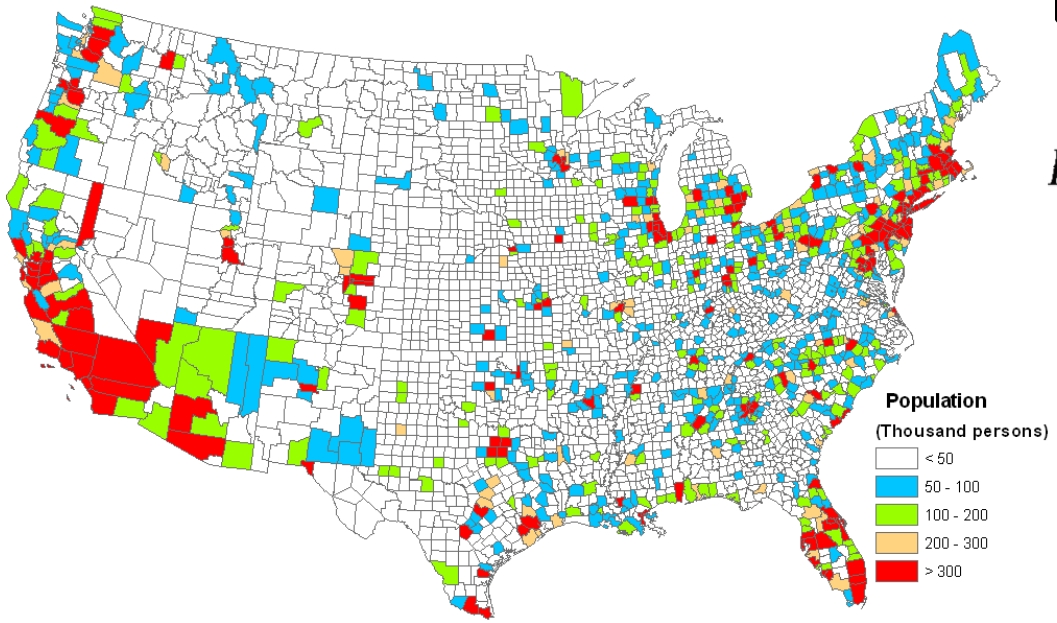
- **Question:**
  - What is the health consequence of degraded air quality due to wildfire emissions?
- **Method:**
  - Air Pollution Impact Model (APIM) (Tong et al., 2006);
  - Calculate mortalities resulting from O_3 or $PM_{2.5}$ exposure using dose-response functions from epidemiological literature.

$$\Delta M = Y_0 * Population* [exp (\beta*\Delta c)-1]$$

ΔM = change in number of deaths.
Y0 = annual baseline mortality rate.
Population = size of affected population.
β = relative risk per unit change in concentration.
Δc = changes in ambient O_3 or $PM_{2.5}$ concentrations

Concentration-Response Functions

Pollutant Metrics	β (95% CI)	Age Group	Study Type	Reference
O_3 1-hr. average	0.00052 (0.00027-0.00077)	All ages	Time-series	*Bell et al.*, 2004
$PM_{2.5}$ Annual average	0.0058 (0.0020-0.01044)	Adults, 30+	Cohort	*Pope et al.*, 2002



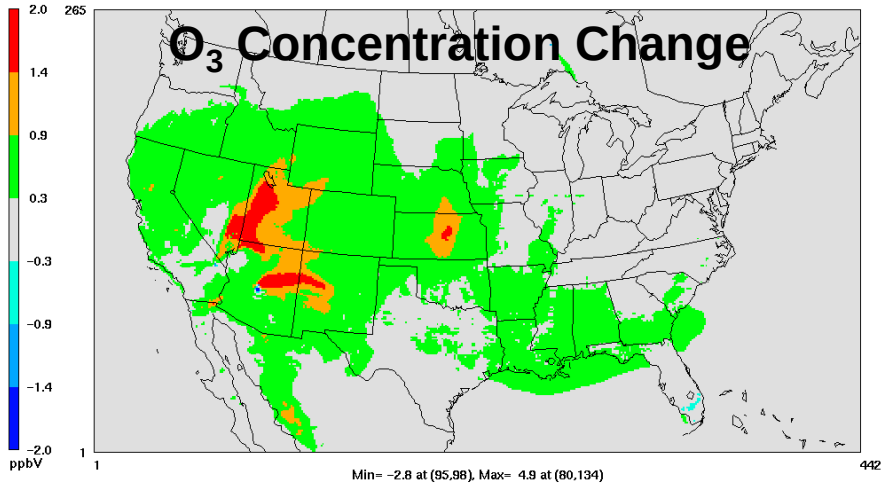
Calculating Health Days Lost

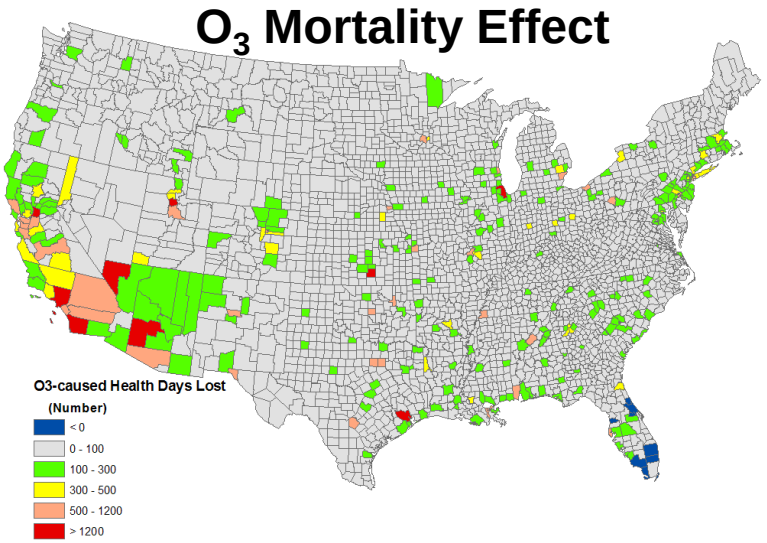
$$HealthDaysLost = \sum_{i}^{N} (Mortality)_i \times (LifeExpectation)_i$$

i – Age group i,

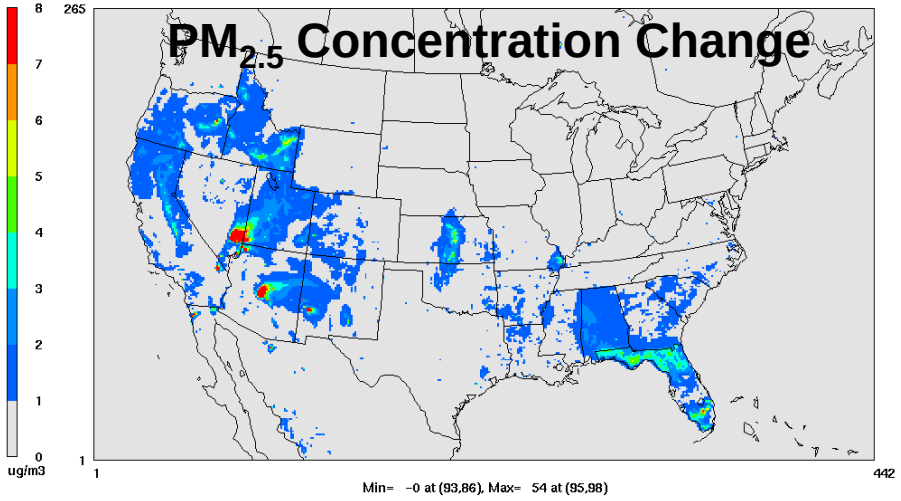
N – Number of age groups

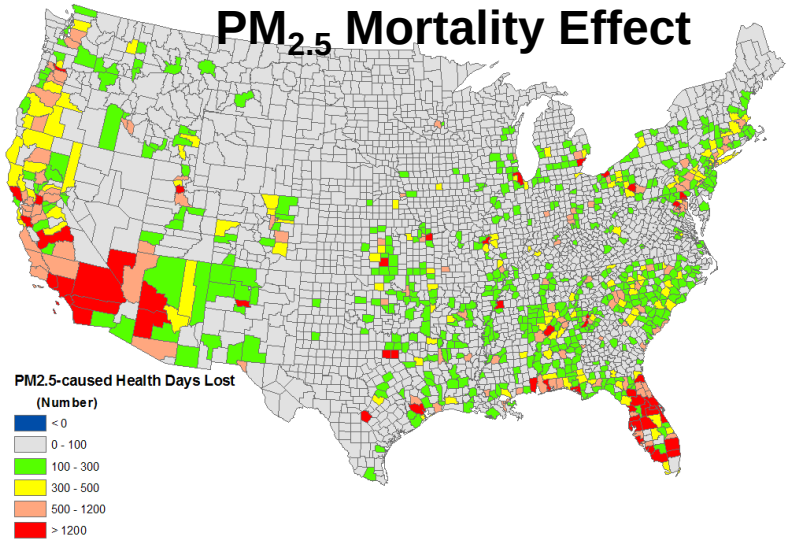
Health Impact of O_3 and $PM_{2.5}$ Exposures





Total: 160,591 (83,544 – 237,329, 95% CI) health days lost





Total: 465,198 (242,010 – 687,490 for 95% CI) health days lost

Conclusion

- **Biomass burning emissions are important for air quality forecasting;**

- **Large discrepancies exist between EPA inventories and satellite-derived emissions;**

- **Indirect health impact of biomass burning is considerable;**

- **Hybrid biomass burning emissions;**

PM2_5