# Open Burning Sources of Air Pollution

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# Content

- Sources
- Pollutants
- Perspective
- Quantification

# Sources

- Our traditional view of pollution sources
  - Power generation
  - Industrial processes
  - Automobiles
  - Diesel trucks

# Sources

## Internationally

- Waste fires
  - Backyard barrel burning
    - USA, developing nations
    - Equivalence with MWCs
    - Emission data
  - Dump and community fires
  - E-waste recycling
  - Demilitarization fires and detonations

# Sources

- Agricultural burns
  - Sugar cane
  - Rice, wheat, alfalfa, Kentucky Bluegrass
  - Grasslands

Society of Toxicology, So. Central Chpt.

# Sources

- Wildland fires
  - Wildfires
    - Out West (e.g., Oregon fires)
    - Peat fires
  - Prescribed fires
    - Species preservation (e.g., red cockaded woodpecker & long leaf pine), Flint Hills (cattle grazing grasslands)
  - International
    - Palm oil, rain forest

# Sources

- Accidental fires
  - BP Deepwater Horizon
    - Platform
    - In situ oil burns (purposeful)
  - Train wrecks
  - Industrial fires
    - Houston

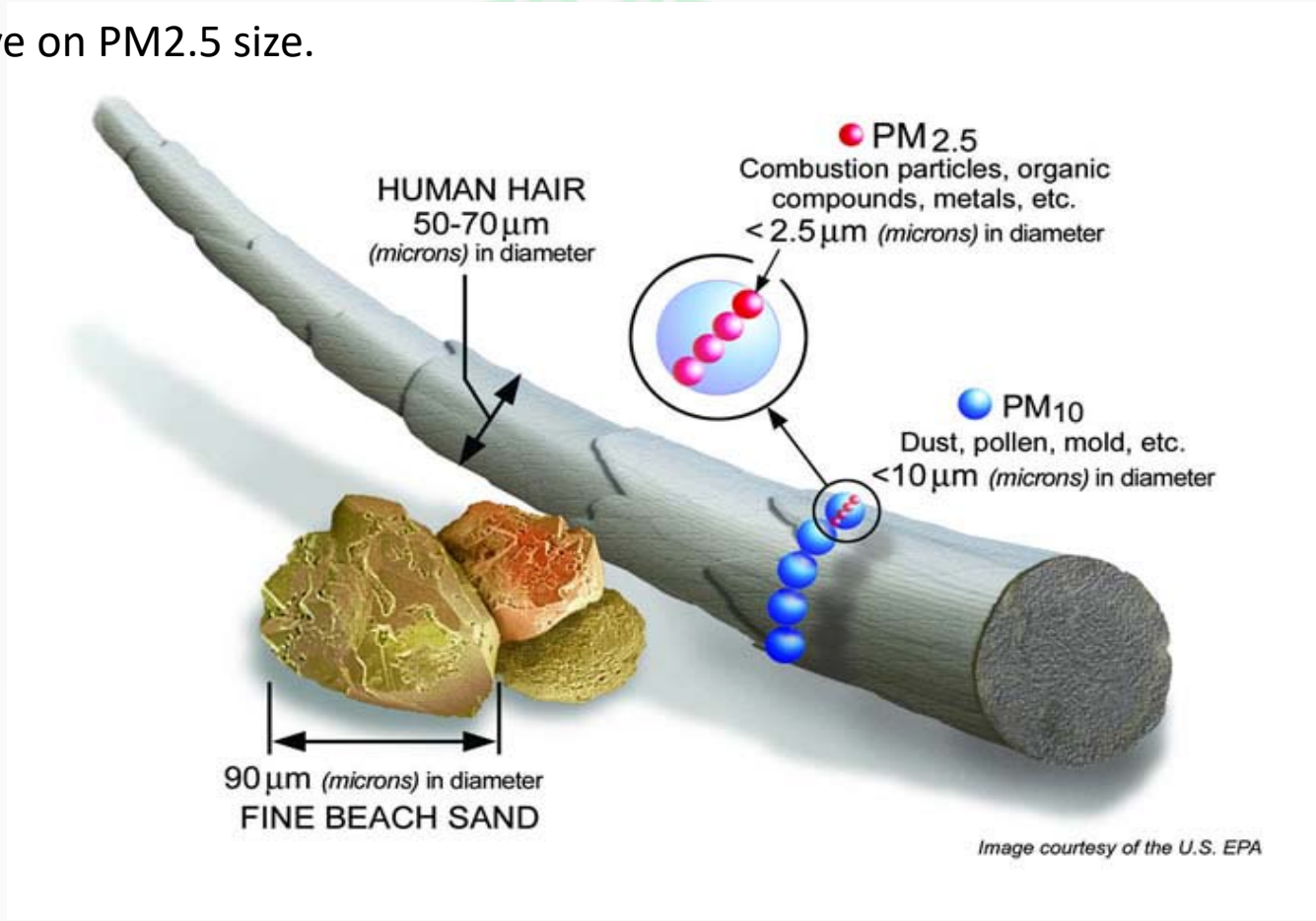

# Pollutants

- $PM_{10}$ and $PM_{2.5}$
  - lung irritation, cardiopulmonary effects, metal carrier.
- CO
  - Susceptible populations are those with cardiovascular or respiratory diseases
  - Asthma, myocardial ischemia, cardiovascular disease
- Black Carbon, BC
  - light absorbing carbon leads to warming of lower atmosphere, meteorological effects
- Environmentally Persistent Free Radicals, EPFRs
  - oxidative stress.
  - Precursors to toxics: chlorinated dioxins/furans
- $NO_x$ and VOCs, $O_3$
  - Photochemical atmospheric reactions form ozone in the troposphere (smog)
  - Aggravates bronchitis, asthma, emphysema
- $CH_4$, $NH_3$
  - Global warming agent (21 times that of CO2)
  - CH4 and VOCs can produce CO from photochemical oxidation reactions
  - NH3 combines with sulfates and nitrates to form PM2.5
- PAHs, Benzene
  - Carcinogenic
  - Oxidative stress
- Metals
  - Cardiovascular and pulmonary inflammation, cancer, vital organ damage, cellular oxidant
  - EPA's HAP list:  Sb, As, Be, Cd, Cr, Co, Pb, Mn, Hg, Ni, Se

HM1

# Fine Particulate Matter

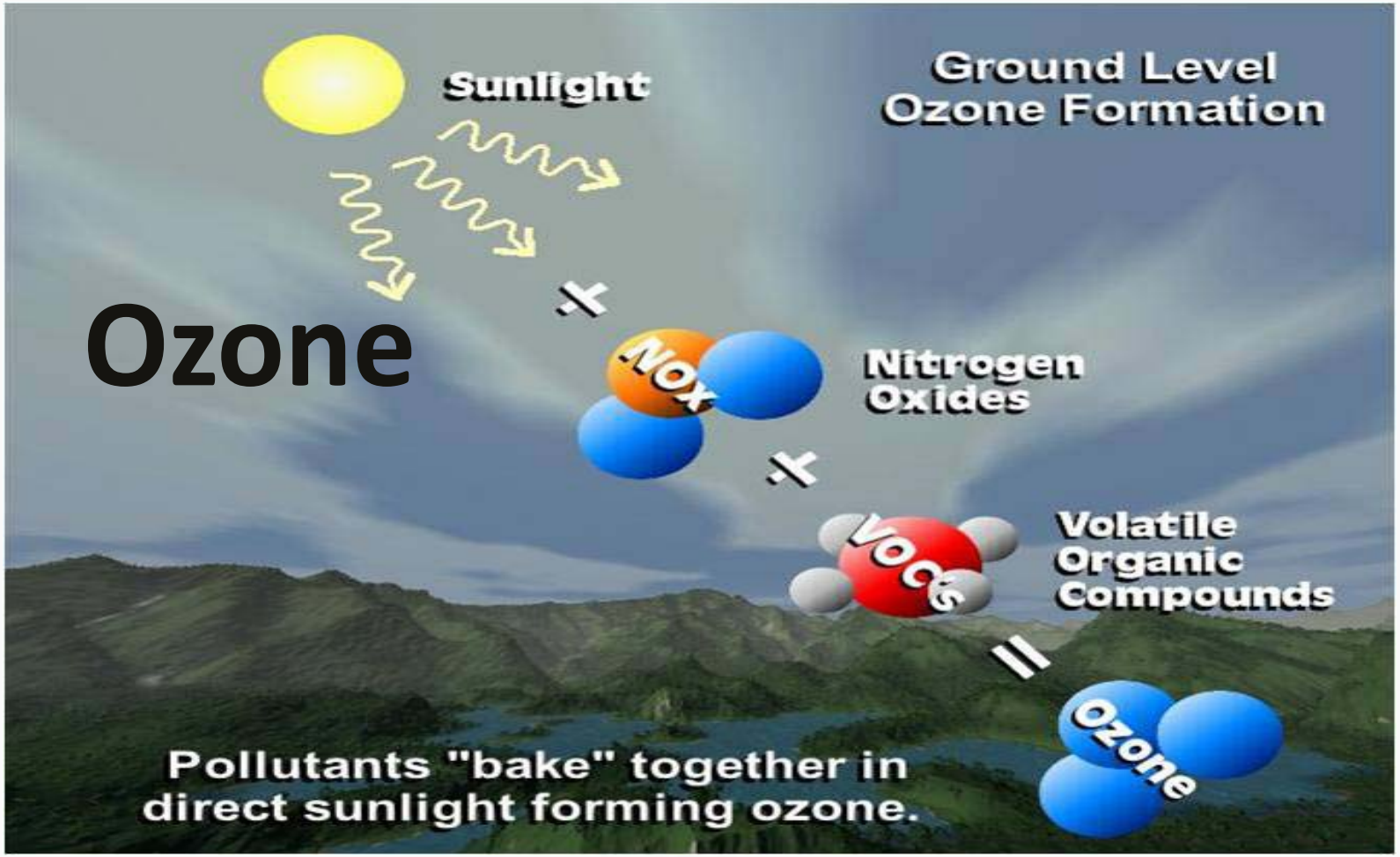
Perspective on PM2.5 size.



**Slide 9**

**HM1** This slide should probably come earlier.
Hays, Michael, 10/3/2017

# Ozone Formation



# Perspective

- Open burning is significant in regional and episodic occurrences
  - Equal to 22% of China's anthropogenic PM10 (Wiedinmyer et al., 2014)
  - A disproportionate contribution of air toxics
- Burn barrel & burn piles vs. Municipal Waste Combustion
  - 250-800x more PCDD/PCDF per unit mass than MWC (EPA AP-42 and Woodall et al., 2012; and Gullett et al., 2013)
  - 50x more PCDD/PCDF than Air Curtain Incinerators (Aurell et al., 2012)
- Dioxin inventory
  - 35% of US 2000 PCDD/PCDF was from burn barrels (EPA Inventory of sources p. xliv, 2006)

# Perspective

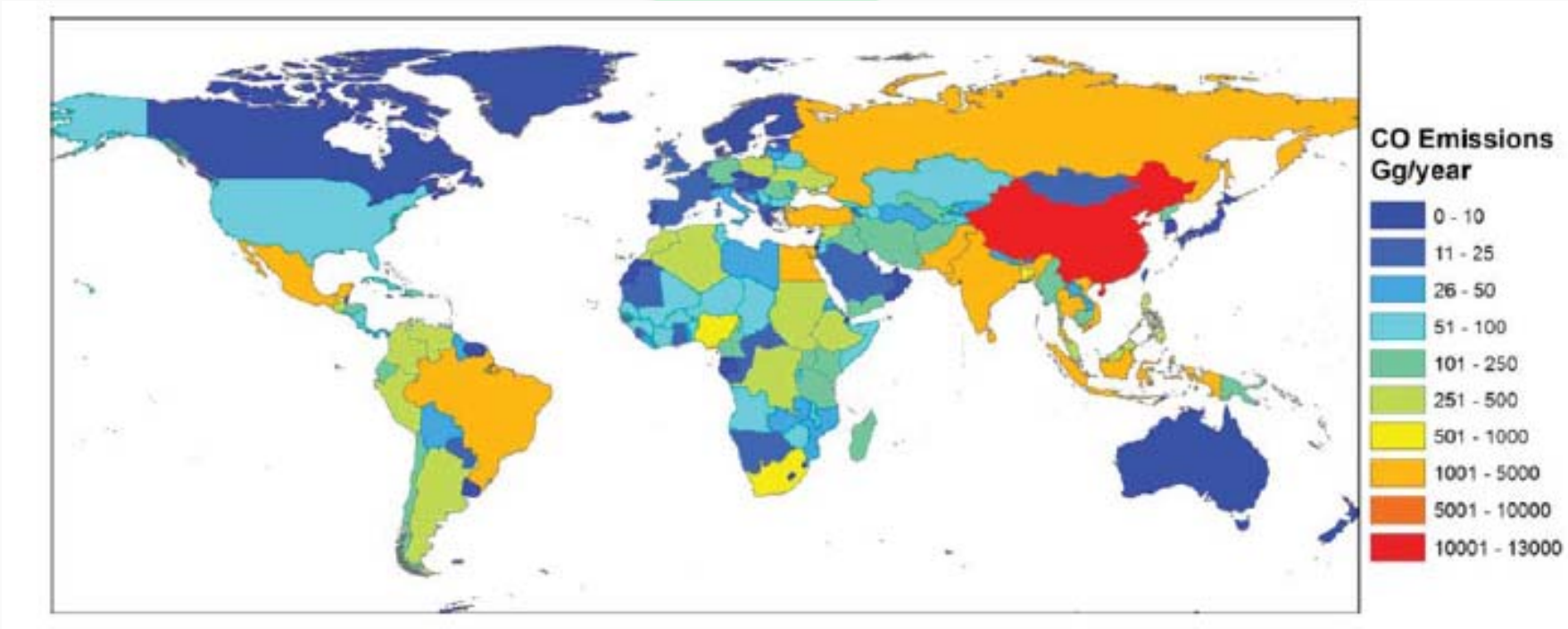
Percentage of global anthropogenic pollutants from residential waste burns:

- $PM_{2.5}$: 30%
- CO: 7%
- BC: 11%
- PAHs: 64% and organics
- Benzene: 25%

Data from Wiedinmyer et al., 2014, Table 3, and sources therein

# Perspective

Global CO emissions from open combustion of residential waste

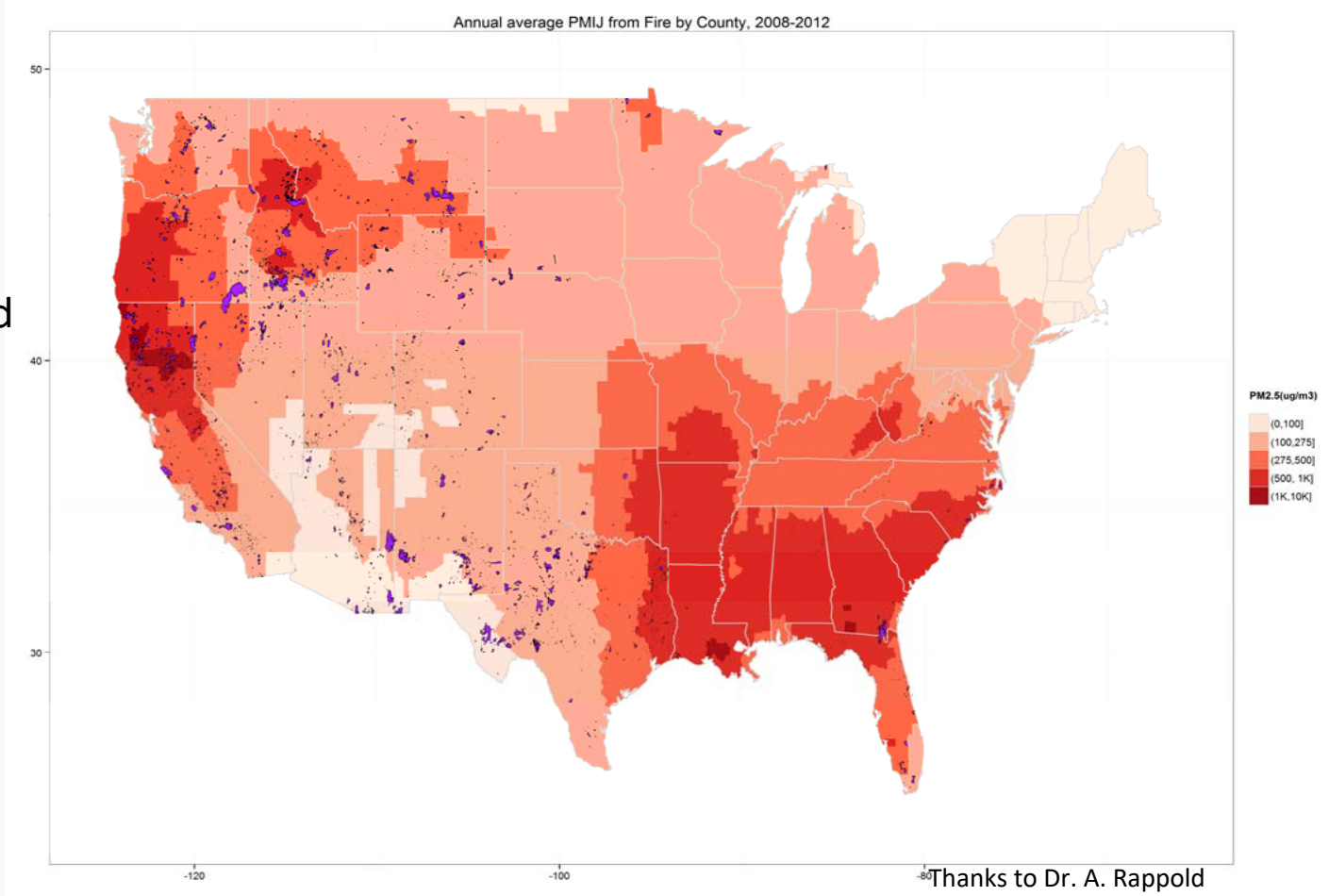



Wiedinmyer et al., 2014

# $PM_{2.5}$ fire footprint for 2008-2012

## *Community Multiscale Air Quality Model (CMAQ)*

Smoke impacts in the Southeast (prescribed burning) and Northwest (wildfires)

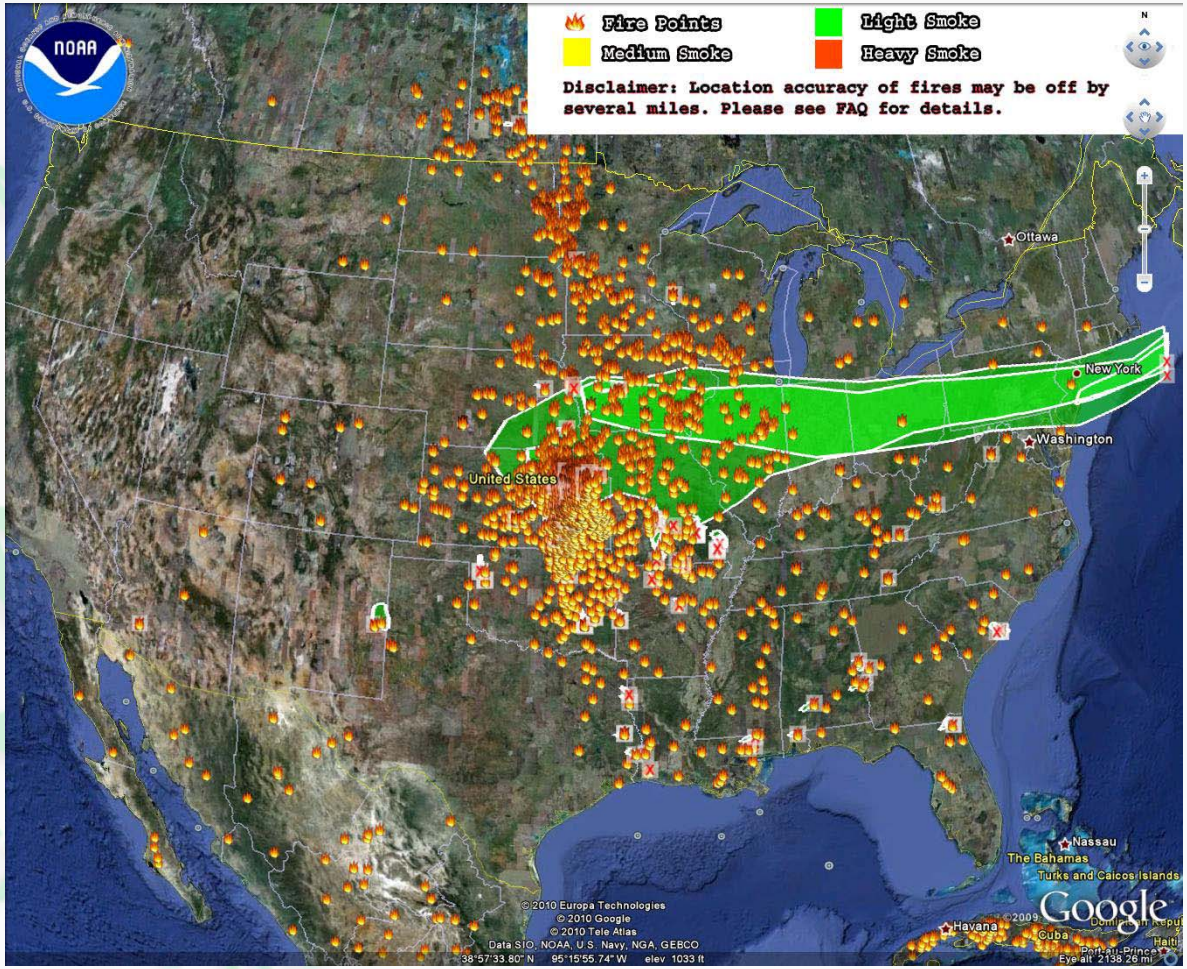



Thanks to Dr. A. Rappold

# Perspective

Sunday, April 11, 2010

Smoke from three days of fires in the Kansas Flint Hills region (2010) impacting neighboring and distant states



HM2

# Perspective – Health Effects

- Respiratory (Ozone and PM)
  - Coughing, wheezing, reduced lung capacity
  - Reduced resistance to infection
  - Aggravation of asthma, emphysema, and bronchitis
- Cardiovascular (PM2.5)
  - Inflammation
  - Heart failure
  - Cardiac Arrhythmia
  - Hardening of the arteries
  - Stroke
  - Heart Attack

Josh Tapp, EPA Region 3

**Slide 16**

**HM2** I thought this was already presented at slide 8?
Hays, Michael, 10/3/2017

# Perspective – Health Effects

2008 Pocosin Lakes National Wildlife Refuge Peat Fire

Photo Credit: USFWS




Percent change in relative risk by discharge diagnosis category for exposed and referent counties.

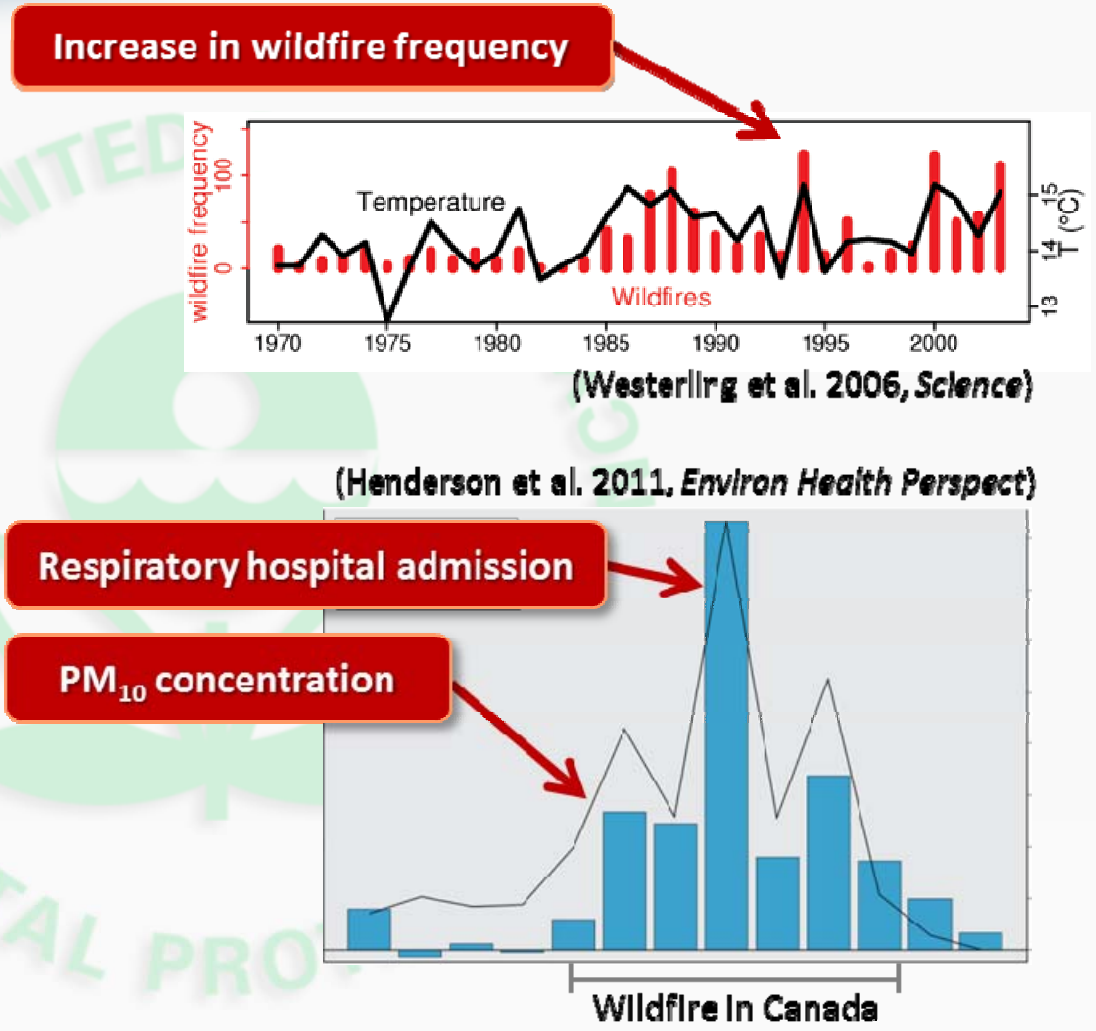


*Rappold AG et al. Environ. Health Perspectives 2011*

HM3

# Perspective – Health Effects

Epidemiological observations of wildfire effects have been observed but little information is available on the toxicity of wildfire smoke.




NIEHS upload

**Slide 18**

**HM3** Really? There is more information available thru Ian Gilmour's group. I think there has been quite a bit of tox work especiallly if you include the DDT assay. DeMarini has done some also. I did a quick search of 'biomass fire' and 'toxicity' and about 50 articles showed up many of which looked relevant. A Web of Science search would probably net quite a few more. Maybe these aren't all 'wildfire' related per se but there is information available of biomass smoke and you'd be hard pressed to say wildfire smoke is that unique in many cases. I'd be careful with this one at a tox sci conference.

Hays, Michael, 10/3/2017

HM4

# Research questions and methods

- What are the health effects from smoke exposure?  Versus urban air?
- Who is most at risk?
- What are the physiological mechanisms of action?
- Do smoldering and flaming phases have different species, different health effects?
- What communication strategies are most effective in protecting public health?
- What are the environmental, social and economic impacts of wildfire emissions?

- Animal toxicology studies
- Ambient measurements and multi-year photochemical modeling
- A crowdsourcing study with a smartphone app – SmokeSense

**Slide 19**

**HM4** Again...you better get up with Ian becasue we just had a paper accepted  in EHP that does tox effects of smoldering versus flaming.
Hays, Michael, 10/3/2017

# Research questions and methods

- Do smoke pollutants vary with vegetation types?
- How does the intensity of a fire affect the emissions of air pollution and the greenhouse gases and black carbon that contribute to climate change?
- What is the estimated smoke exposure for those near fires, and how does it relate to observed health effects?
- Does prescribed burning reduce air pollution effects?

- Application of small, low cost sensors
- Updated National Emission Inventory
- Models (CMAQ) track and evaluate impacts of smoke on air quality.

# Laboratory burns with toxicity testing

JFSP FY 15-17 Project #14-1-04

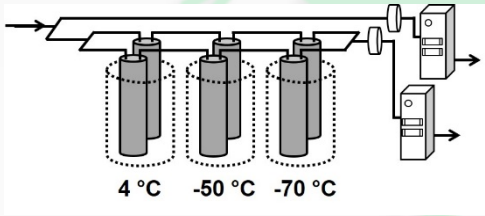
- **Compare the relative cardiopulmonary toxicity and mutagenicity of coarse and fine/ultrafine emissions from four distinct fuel types**
- **Provide a potency ranking and compare effects to size-fractionated ambient PM samples collected from urban and rural sites.**

## Combustion

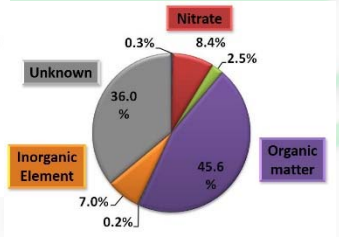
Fire enclosure
(28 $m^3$)
Mixed fuels

## Collection/ Analysis

Cyclone/Cryotrap system



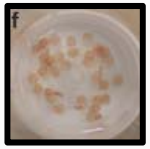

Particle and gas phase chemistry and mass balance



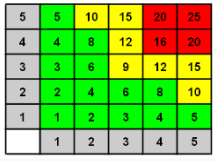

## Toxicity Test

WT and K/O mice

Cells, Tissue slices



Toxicity Ranking matrix




Dr. Ian Gilmour, EPA/NHEERL

# Quantification

- The difficulty in quantifying open burns has led to underestimation or even exclusion of these sources in national inventories and in policy considerations
- Quantification = Emission factor x Activity level
  - Emission factor = mass of pollutant/mass of fuel
  - Activity level = acres burned, mass combusted, widgets produced
- Both of these terms are hard to define for open burning

# Quantification

**How do we determine emission factors?**

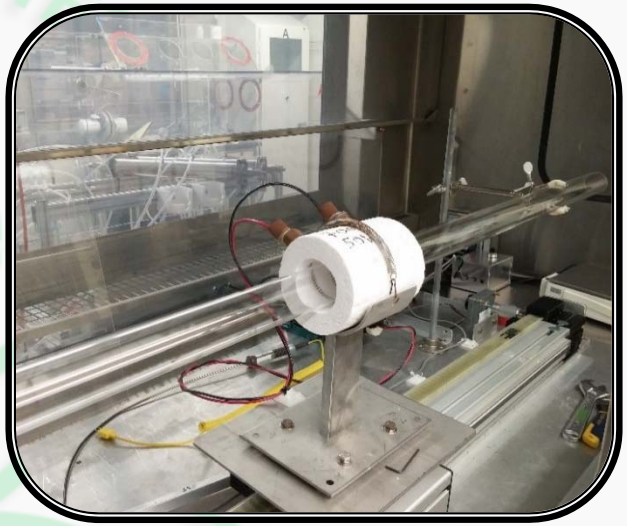
- Simulations
  - Laboratory
  - Open Burn Test Facility
  - Open simulation
- Field sampling
  - Ground
  - Airplane
  - Aerostat
  - Drone

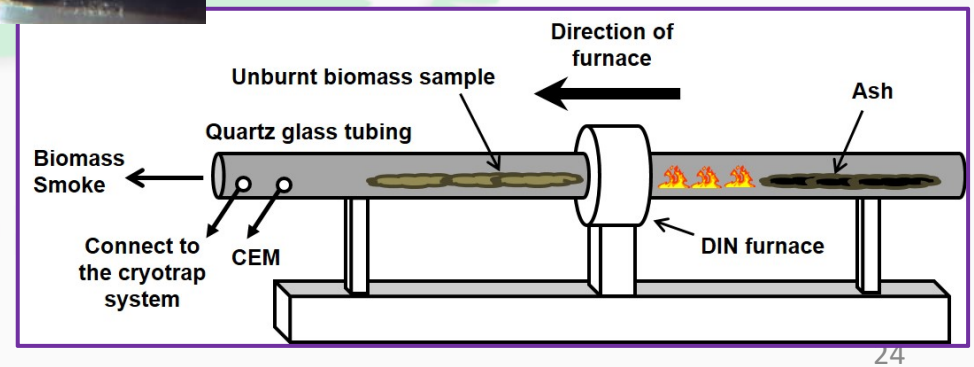
# Quantifying Emission Factors

## Laboratory Emission Sampling Facilities

### Open Burn Test Facility


### Laboratory Furnace





## Slide 24

**HM5** That pic of refuse is bad.
Hays, Michael, 10/3/2017

# Quantification

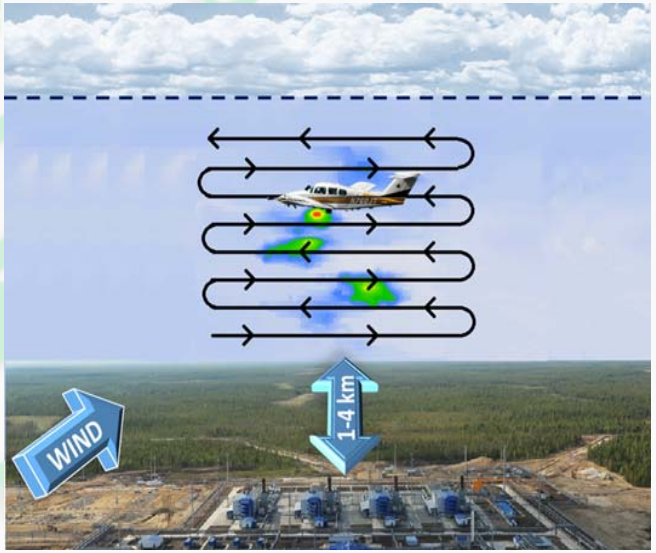
**How do we determine emission factors?**

- Simulations
  - Laboratory
  - OBTF
  - Open simulation
- Field sampling
  - Ground
  - Airplane
  - Aerostat
  - Drone

# Quantification

On-ground, smoke chasing

In-air, smoke chasing



# Quantification

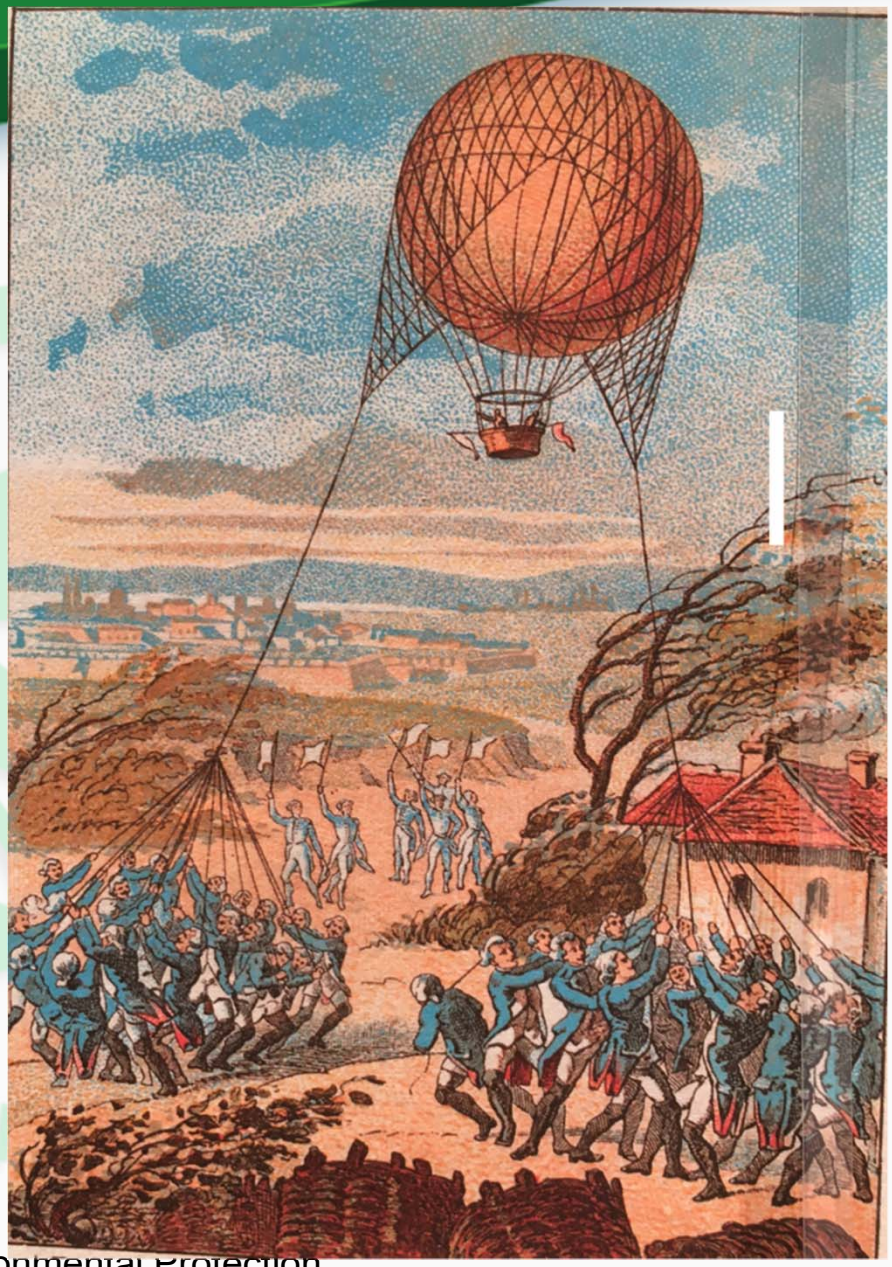
Open Burning and Open Detonation (OB/OD) of propellants and ordnance

# Quantification

How do we safely (people and equipment), representatively, and accurately sample these plumes?

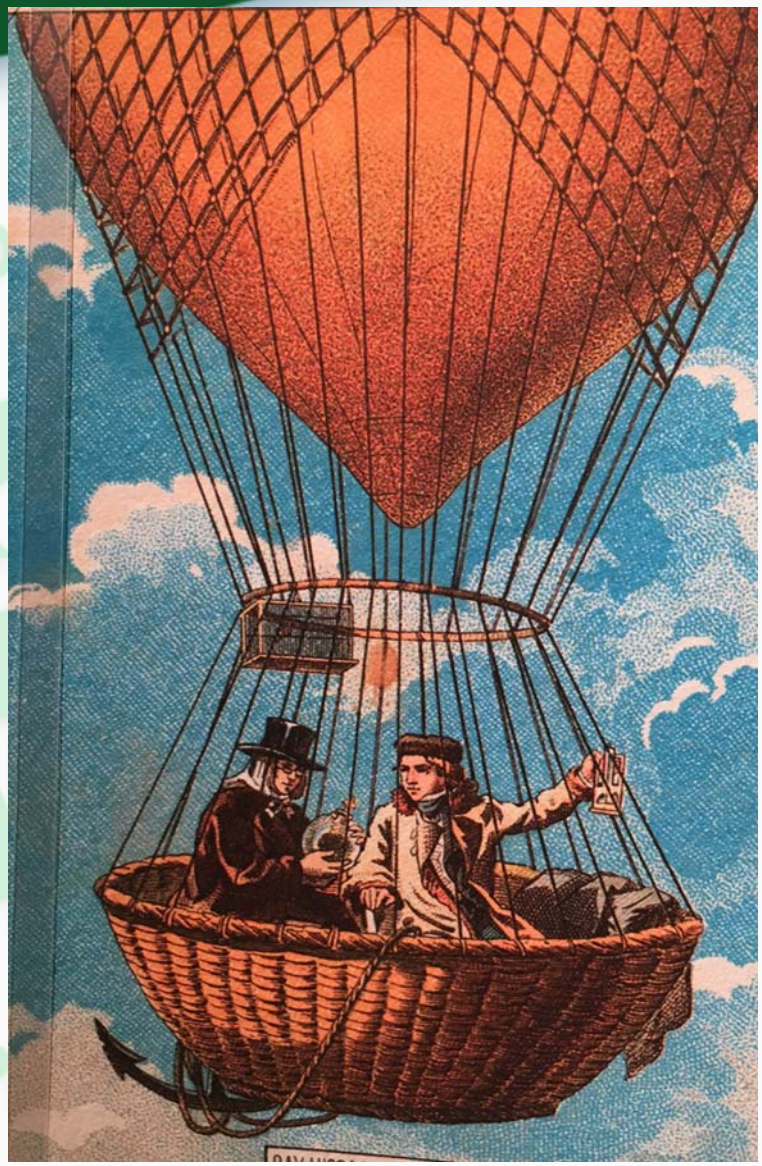
# Quantification

Idea #1. A balloon, loaded with sampling equipment, and an army of post-docs.



# Quantification

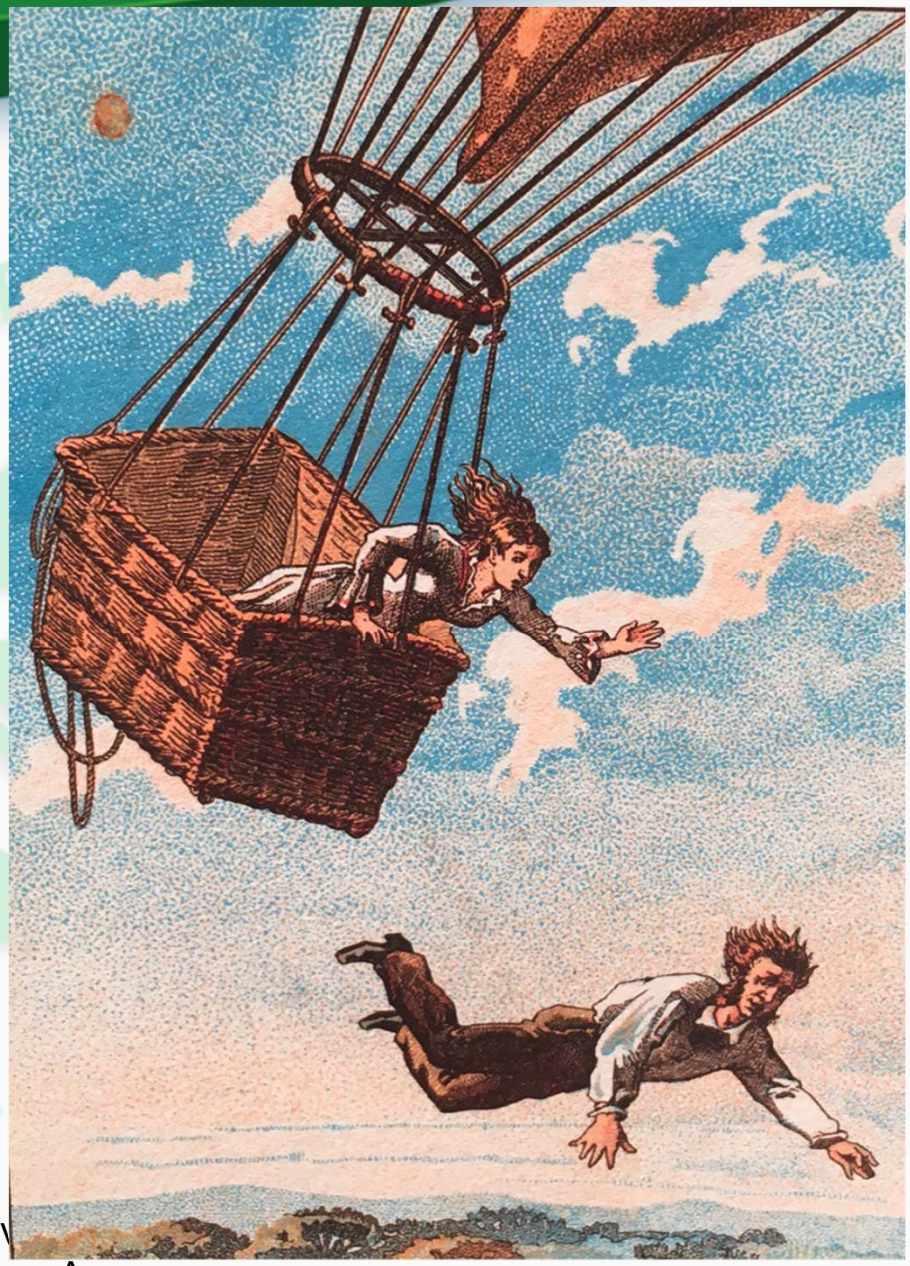
Researchers on balloon turn on samplers, collect sample.



HM6
HM7

# Quantification

Potential drawbacks.



## Slide 31

**HM6** ha ha...she loves me NOT!
Hays, Michael, 10/3/2017

**HM7** that'll take the shine right off your shoes!
Hays, Michael, 10/3/2017

HM8

# Quantification

**The Kolibri coupled to a NASA multicopter drone**


## Slide 32

**HM8** Cool....

Hays, Michael, 10/3/2017

# Sampling open burning of propellant

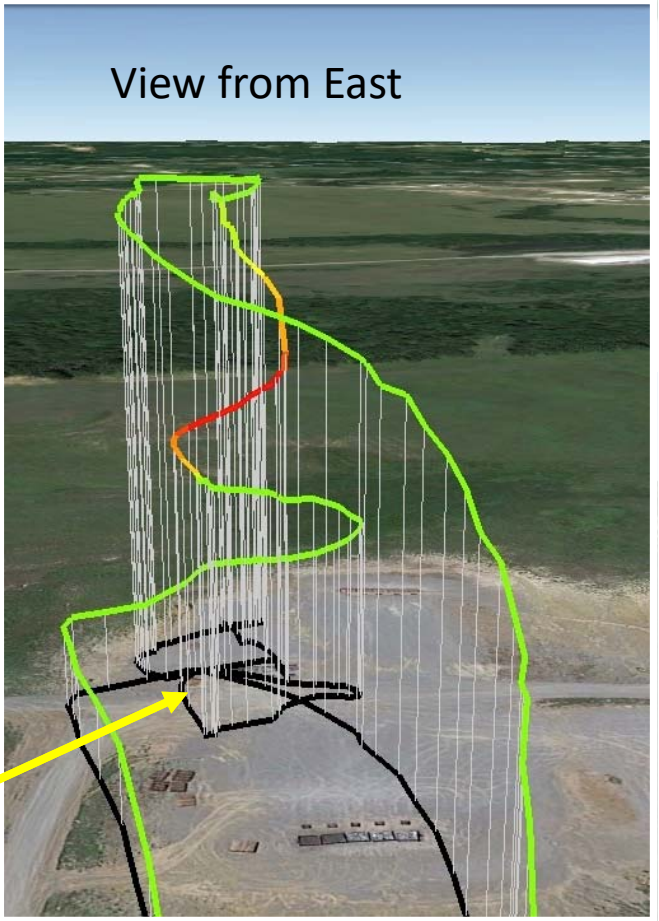

Society of Toxicology, So. Central Chpt.

# View from the pilot's perspective – 250 m

HM9

# Flight Path

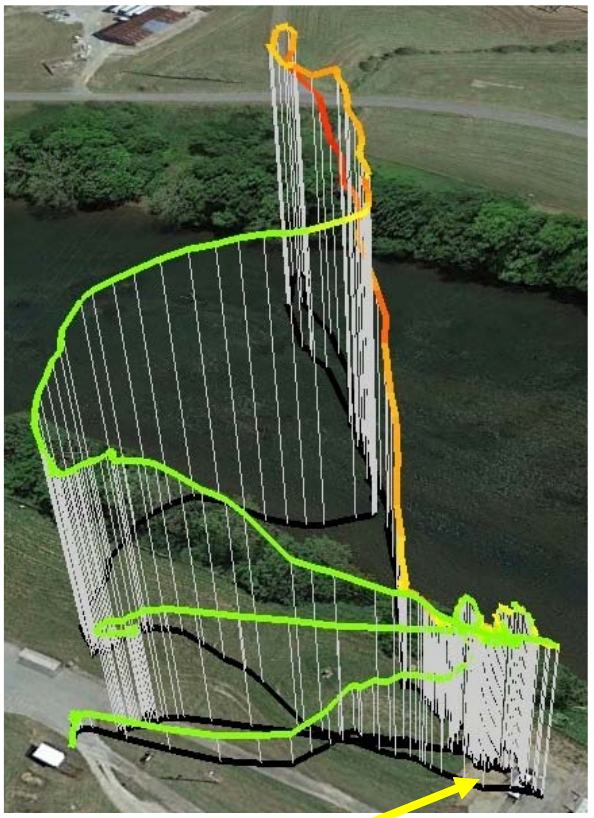
| Mark [#] | Time [mm:ss] | Height ASL [m] | $CO_2$ [ppm] |
|---|---|---|---|
| 1 | 00:00 | 254 | 416 |
| 2 | 00:20 | 259 | 408 |
| 3 | 01:23 | 289 | 2427 |
| 4 | 01:26 | 290 | 3778 |
| 5 | 01:31 | 297 | 4599 |
| 6 | 01:34 | 304 | 3075 |
| 7 | 02:07 | 331 | 408 |
| 8 | 02:37 | 302 | 410 |



**Slide 35**

**HM9** Vertical distributions are important and missing from the lit!

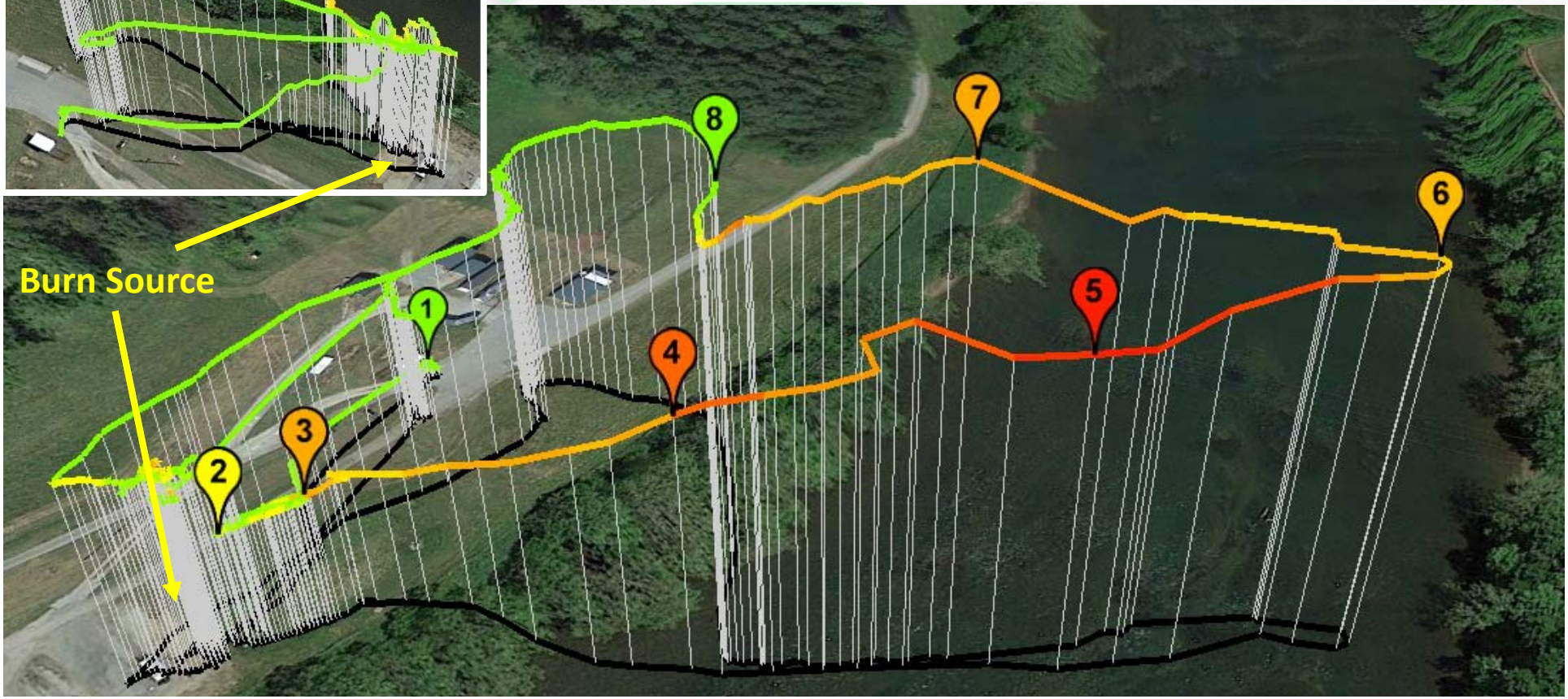
Hays, Michael, 10/3/2017



View from South east

| Mark [#] | Time [mm:ss] | Height ASL [m] | $CO_2$ [ppm] |
|---|---|---|---|
| 1 | 00:00 | 524 | 431 |
| 2 | 00:49 | 542 | 1851 |
| 3 | 02:25 | 544 | 2831 |
| 4 | 02:39 | 561 | 3441 |
| 5 | 02:47 | 572 | 4085 |
| 6 | 02:54 | 583 | 2562 |
| 7 | 03:02 | 602 | 2678 |
| 8 | 07:13 | 586 | 436 |

View from Northeast



# Activity Level

## Fires are hard to detect

- MODIS satellites, by means of pixel temperature, detected only 82% of fires.
  - If the fire is small, the satellite won't see it
- Hard to reconcile fire incidences with reporting.
  - Various protocols for reporting
  - Discrepancy between burn permits and actual burns
- The result is uncertainty in the activity level of fires, or how much biomass is consumed.

Hawbaker, T., et al., Detection rates of the MODIS active fire product in the United States, Remote Sensing of Environ. (2008) 2656-2664. 1 km resolution (http://yceo.yale.edu/what-kinds-modis-data-are-available).

HM10

# Summary

- Open area fires are significant contributors to air pollution resulting in health and environmental impacts
- They are “under-appreciated” sources because they are hard to quantify - both emission factors and activity levels
- They often have local, episodic effects and are often in proximity to populations
- There is a disconnect between emissions characterization and health effects – high emitters are not necessarily the most toxic.
  - We need to combine chemical and biological information to identify causal compounds of toxicity

**Slide 38**

**HM10** Didn't see much on the secondary chemical processes that these plumes can undergo while aging. That may be worth mentioning. What you measure as PM on the ground may look very different aloft especially as time goes on. Also, really light on the physics and PM chemistry that can cause the toxicity in humans. You mention dioxins but nothing about PAH and nothing about the new particle formation downwind that can produce ultrafines.

Hays, Michael, 10/3/2017

# Acknowledgements




Society of Toxicology, So. Central Chpt.

# References, Sources

- https://www.epa.gov/air-research/wildland-fire-research-protect-health-and-environment
- Dr. Ian Gilmour (EPA/NHEERL)
  - Direct rat inhalation studies of biomass combustion
- Dr. Ana Rappold (EPA/NHEERL)
  - Wildland fire smoke effects on public health
- Dr. David DeMarini (EPA/NHEERL)
  - Oxidative stress from combustion sources
- Dr. Amara Holder (EPA/NRMRL)
  - Particle characterization
- Dr. Johanna Aurell (UDRI)
  - Aerial methods of pollutant sampling
- Dr. Ralf Zimmermann (U Rostock)
  - Chemical and biological effects of pollutants


13 6:26PM