Combustion Particles and Global Health: Cooking and Climate

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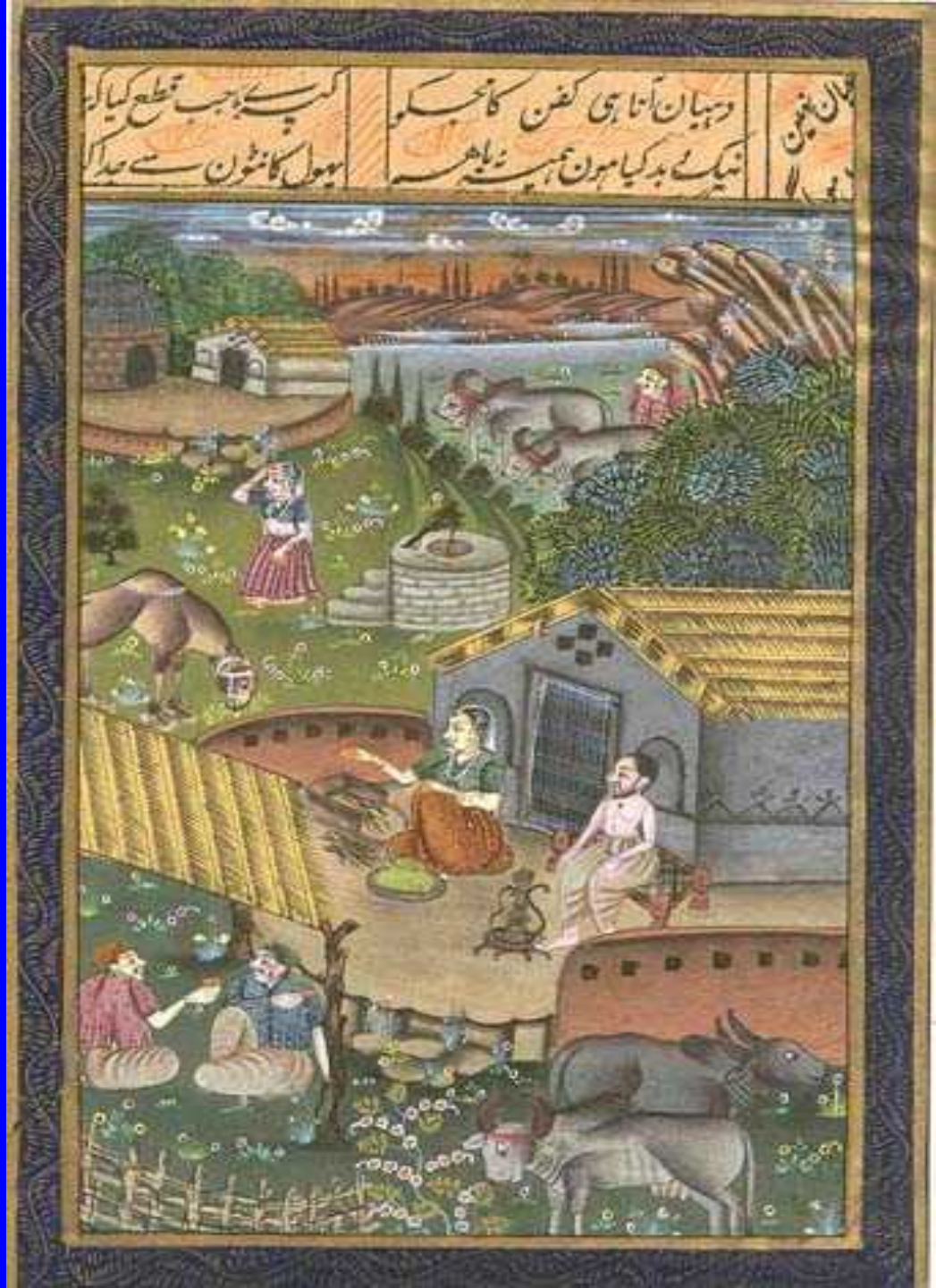
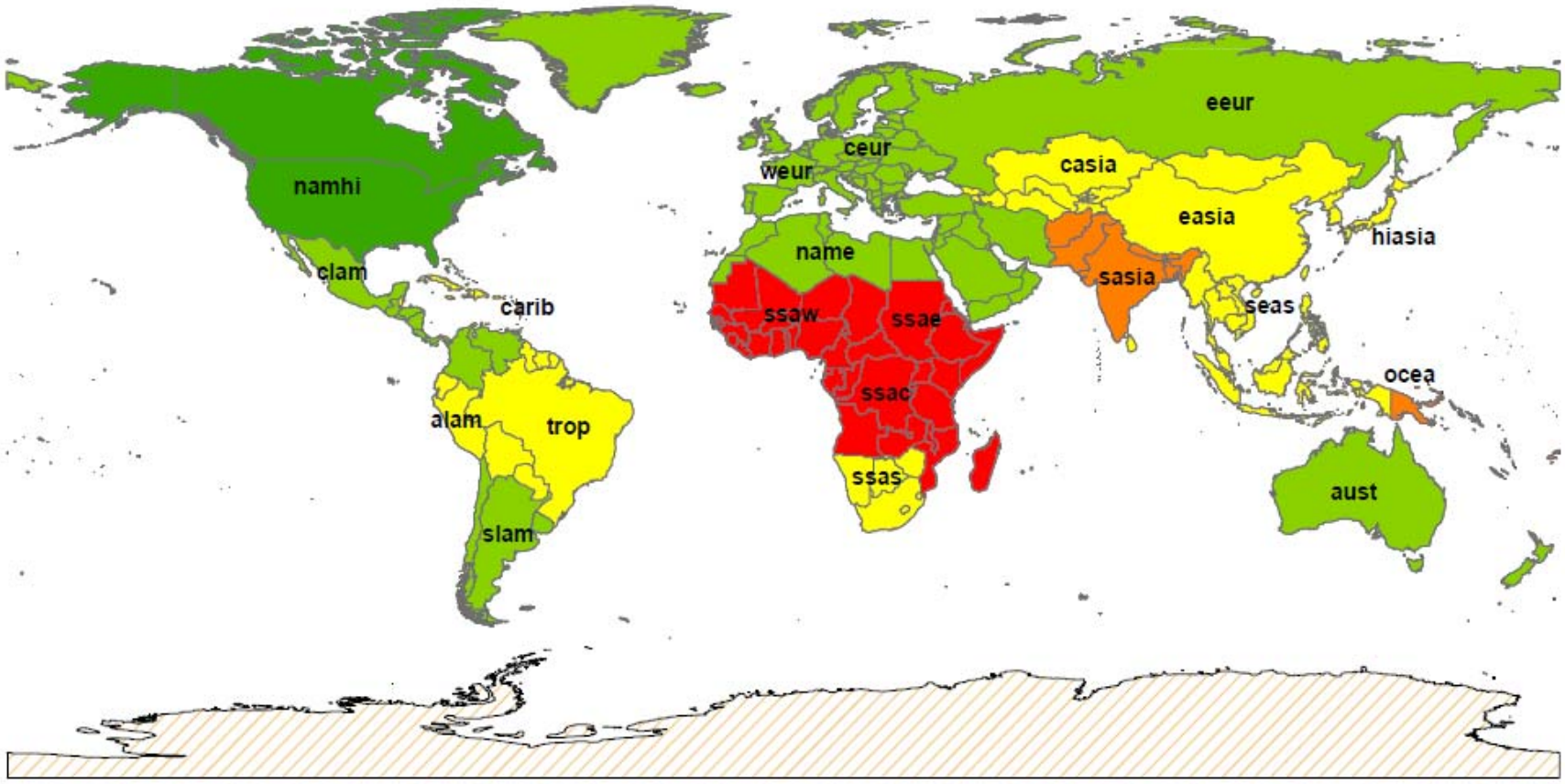
Presentations at University of Southern California and Stanford University – Feb 2011



Households Using Solid Cooking Fuels



% of HH Exposed to HAP

< 5	51 - 75
6 - 20	76 - 93
21 - 50	No Data

For 2005, CRA-10 preliminary

Woodsmoke is natural – how can it hurt you?

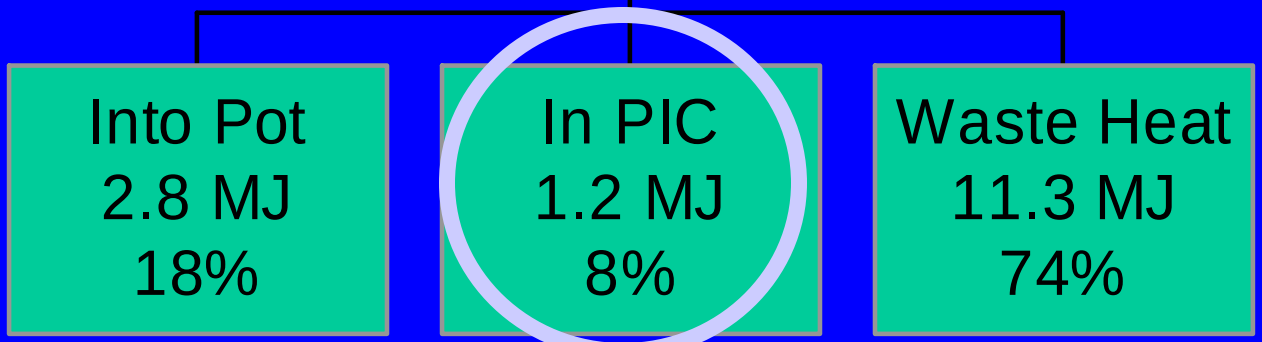
Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn't it just change to CO_2 and H_2O when it is combined with oxygen (burned)?

Reason: the combustion efficiency is far less than 100%

Energy flows in a well-operating traditional wood-fired Indian cooking stove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-20% of the fuel carbon to toxic substances



PIC = products of incomplete combustion = CO, HC, C, etc.

Source: Smith, et al., 2000

Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

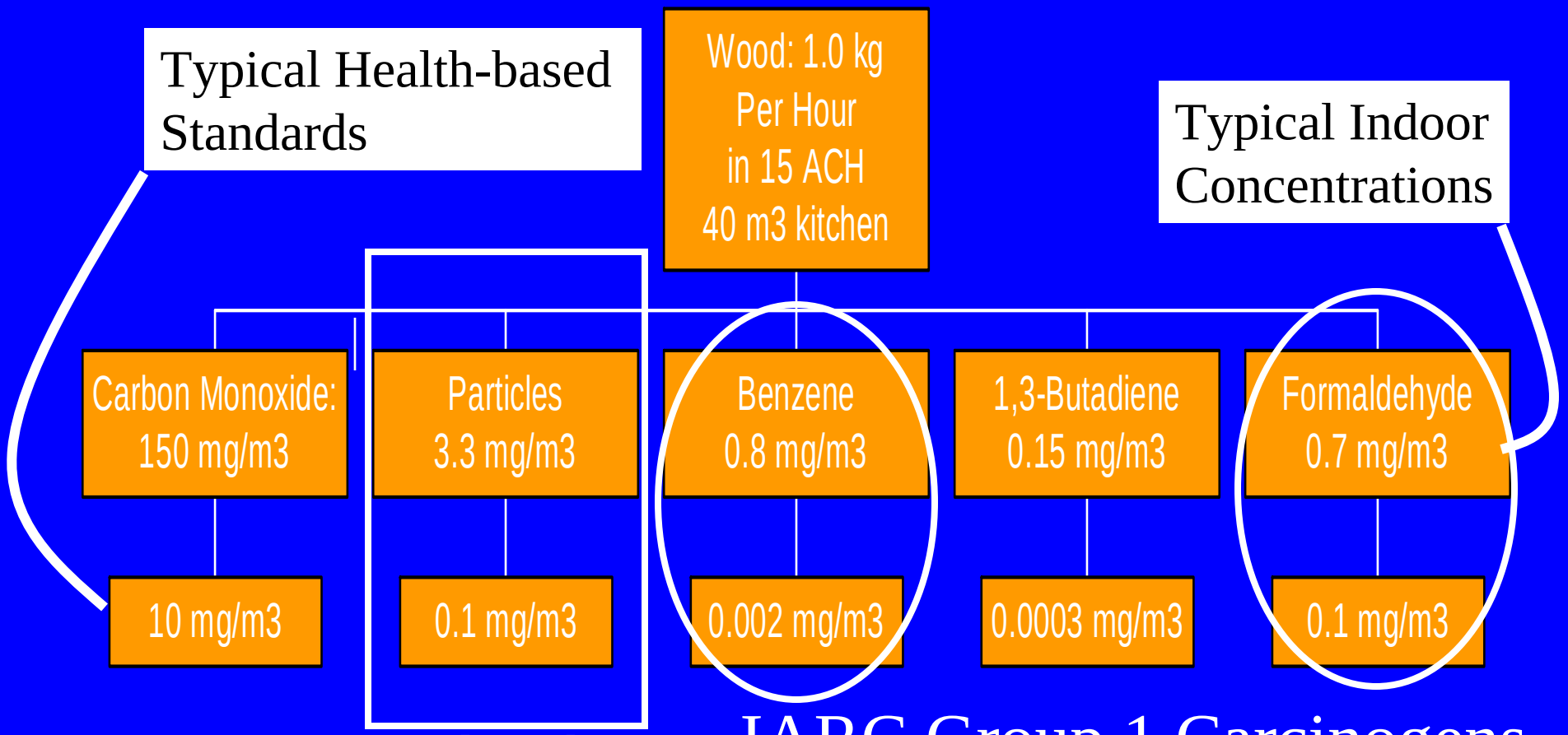
Organics known to be mutagens, immune system suppressants, severe irritants, inflammation agents, central nervous system depressants, cilia toxins, endocrine disrupters, or neurotoxins.

Several chemicals firmly established as human carcinogens.

Other toxic inorganic chemicals.

  - 25+ alcohols and acids such as *methanol*
  - 33+ phenols such as *catechol* & *cresol*
  - Many quinones such as *hydroquinone*
  - Semi-quinone-type and other radicals
- Chlorinated organics such as *methylene chloride* and *dioxin*

Health-Damaging Air Pollutants From Typical Woodfired Cookstove in India.



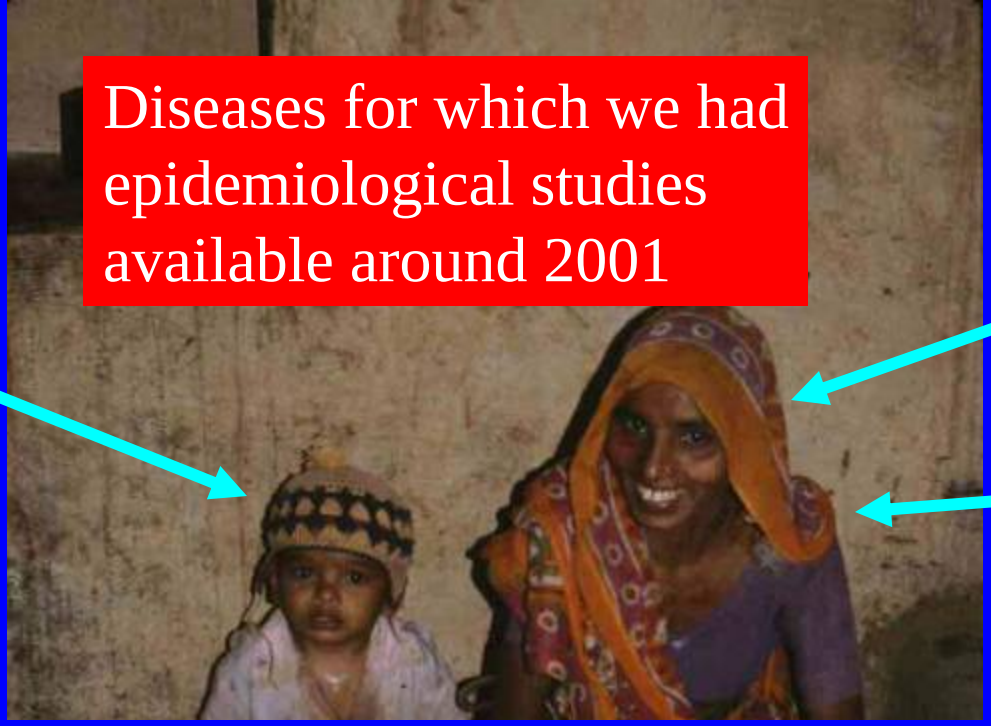
How much ill-health is due to these exposures?

WHO Comparative Risk Assessment Project

"Thank God! A panel of experts!"

Courtesy of Ross Anderson

Diseases for which we had epidemiological studies available around 2001



ALRI/
Pneumonia

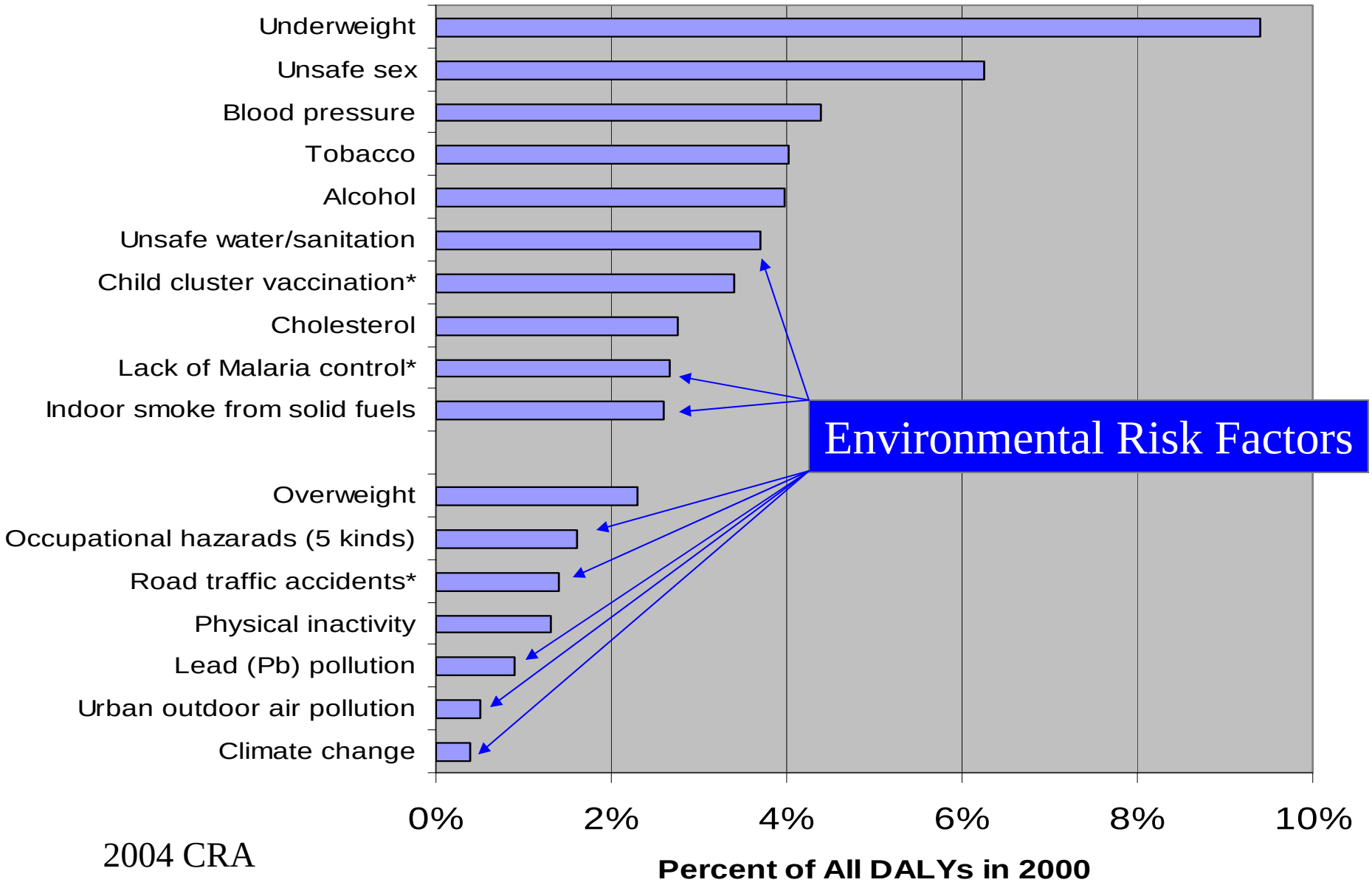
Chronic obstructive lung disease

Lung cancer from coal only

Three outcomes qualified with sufficient evidence to be included in the WHO CRA of 2004

Global Burden of Disease from Top 10 Risk Factors

plus selected other risk factors



2004 CRA

Diseases for which we have epidemiological studies - 2010

ALRI/
Pneumonia
(meningitis)

Low birth weight

Stillbirth

Cognitive Impairment

Birth defects?

Asthma?

Chronic obstructive lung disease

Interstitial lung disease

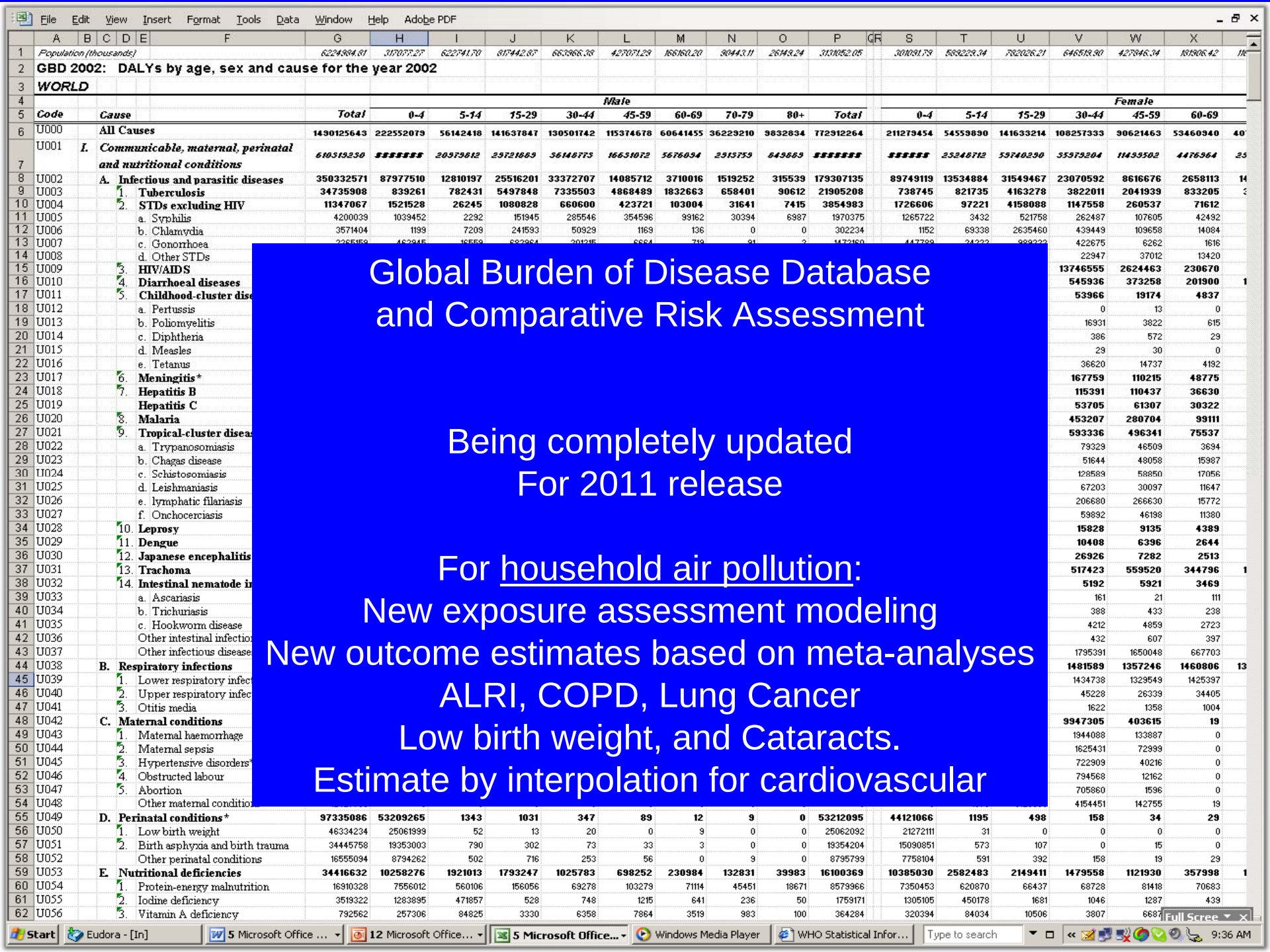
Cancer
(lung, NP, cervical, aero-digestive)

Blindness
(cataracts, opacity)

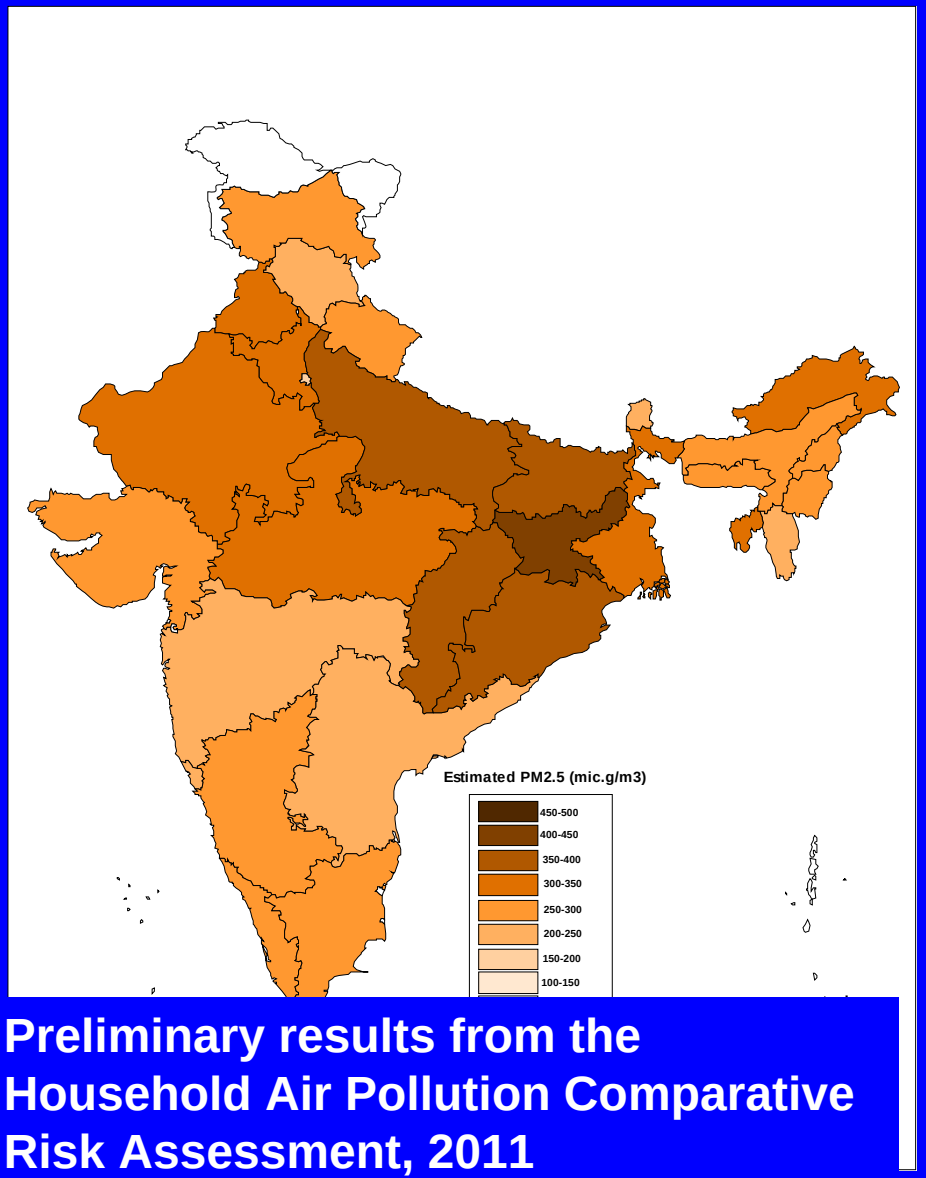
Tuberculosis

Heart disease?
Blood pressure
ST-segment

Burns, health and safety impacts of fuel gathering?


Global Burden of Disease Database
and Comparative Risk Assessment
Being completely updated
For 2011 release
For household air pollution:
New exposure assessment modeling
New outcome estimates based on meta-analyses
ALRI, COPD, Lung Cancer
Low birth weight, and Cataracts.
Estimate by interpolation for cardiovascular

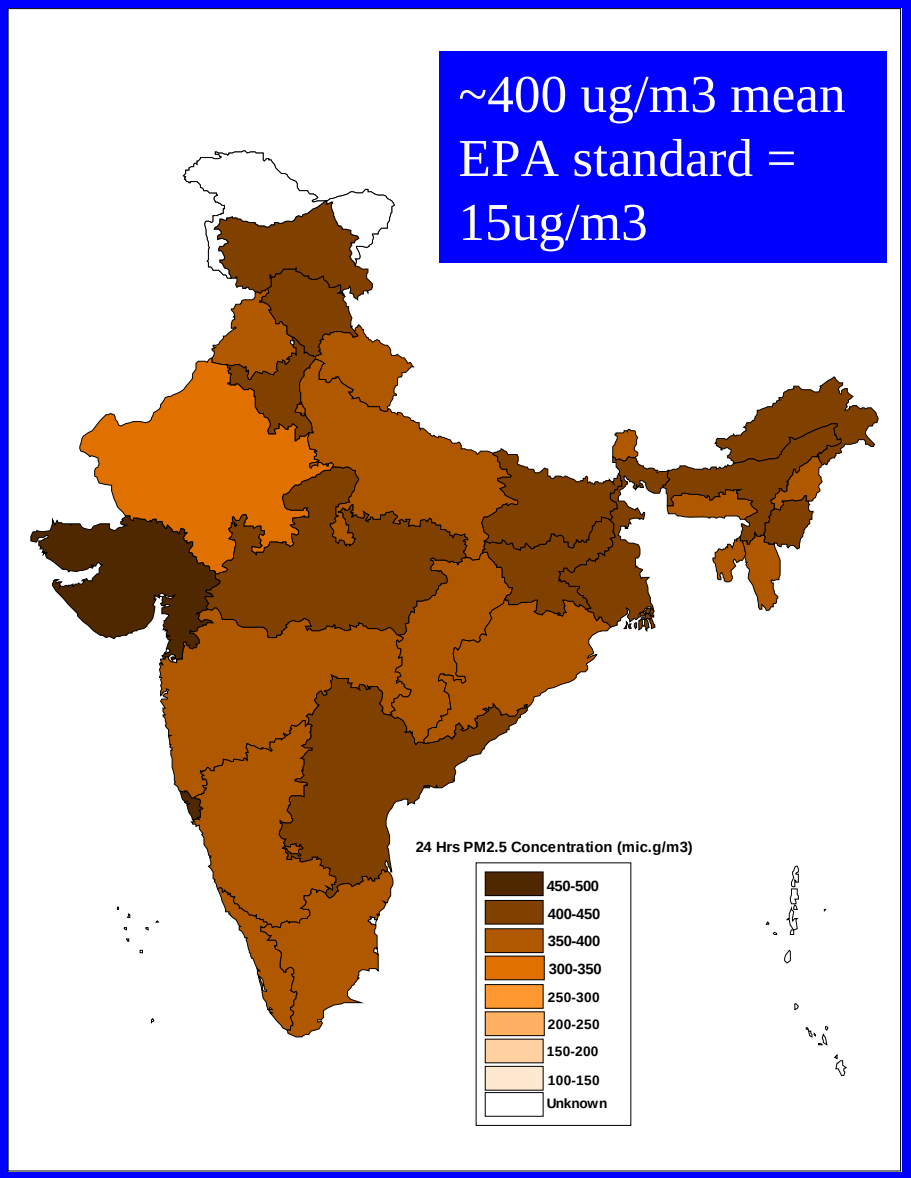
Estimated PM2.5 indoors for all households



Preliminary results from the Household Air Pollution Comparative Risk Assessment, 2011

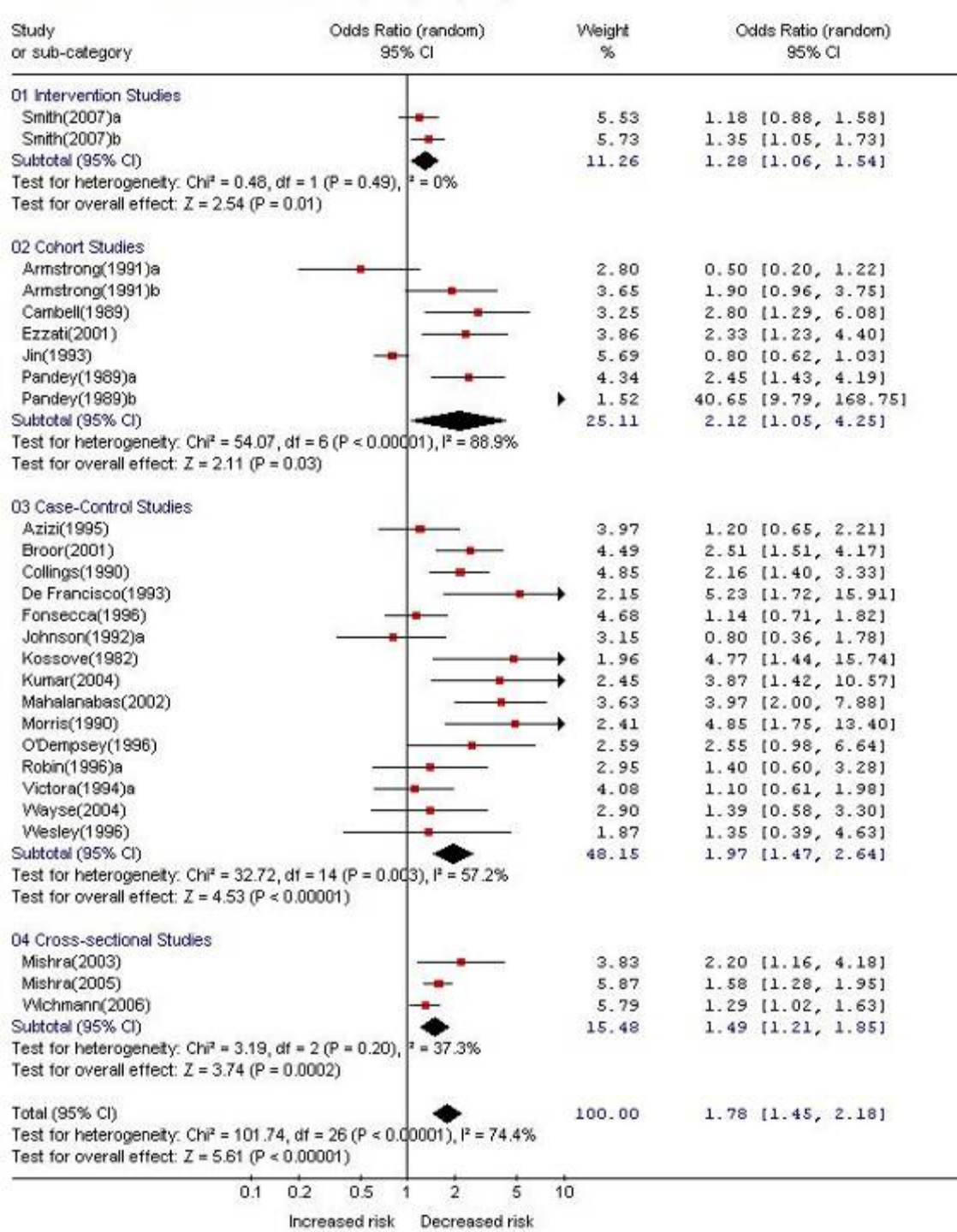
Estimated PM2.5 for only solid-fuel-using households

~400 ug/m3 mean
EPA standard = 15ug/m3



Study design	N*	OR	95% CI
Intervention	2	1.28	1.06, 1.54
Cohort	7	2.12	1.06, 4.25
Case-control	15	1.97	1.47, 2.64
Cross-sectional	3	1.49	1.21, 1.85
All	26	1.78	1.45, 2.18

Dherani et al Bull WHO (2008)



Preliminary CRA Effect Estimates

Health Outcome	Sex	Age	Level of Outcome	Risk Estimate
ALRI	M & F	< 60 mo	Ia	1.78 (1.45 to 2.18)
ALRI: exposure/response	M&F	< 60 mo	Ib	2.3 (95% CI ?)
COPD	F	>15 yr	Ia	2.7 (1.95 to 3.75)
COPD	M	>15 yo	Ia	1.9 (1.15 to 3.13)
Lung Cancer (coal)	F	> 15 yr	Ia	1.98 (1.16 to 3.36)
Lung Cancer (coal)	M	> 15 yr	Ia*	1.38
Cataract	F	> 30 yr	Ia	2.45 (1.61 to 3.73)
Cataract	M	> 30 yr	Ia	?
LBW (OR)	M & F	Perinatal	Ia	1.52 (1.25 to 1.80)
LBW (mean weight)	M & F	Perinatal	Ia	93.1g (64.6, 121.6)
Lung Cancer (biomass)	F	> 15 yr	Ia	1.81 (1.07 to 3.06)
Lung Cancer (biomass)	M	> 15 yr	Ia	1.26 (1.04 to 1.52)
CVD	F	> 30 yr	Ib	1.3 to 1.4 (95% CI)
CVD	M	> 30 yr	Ib*	1.16

Story of Two Conferences

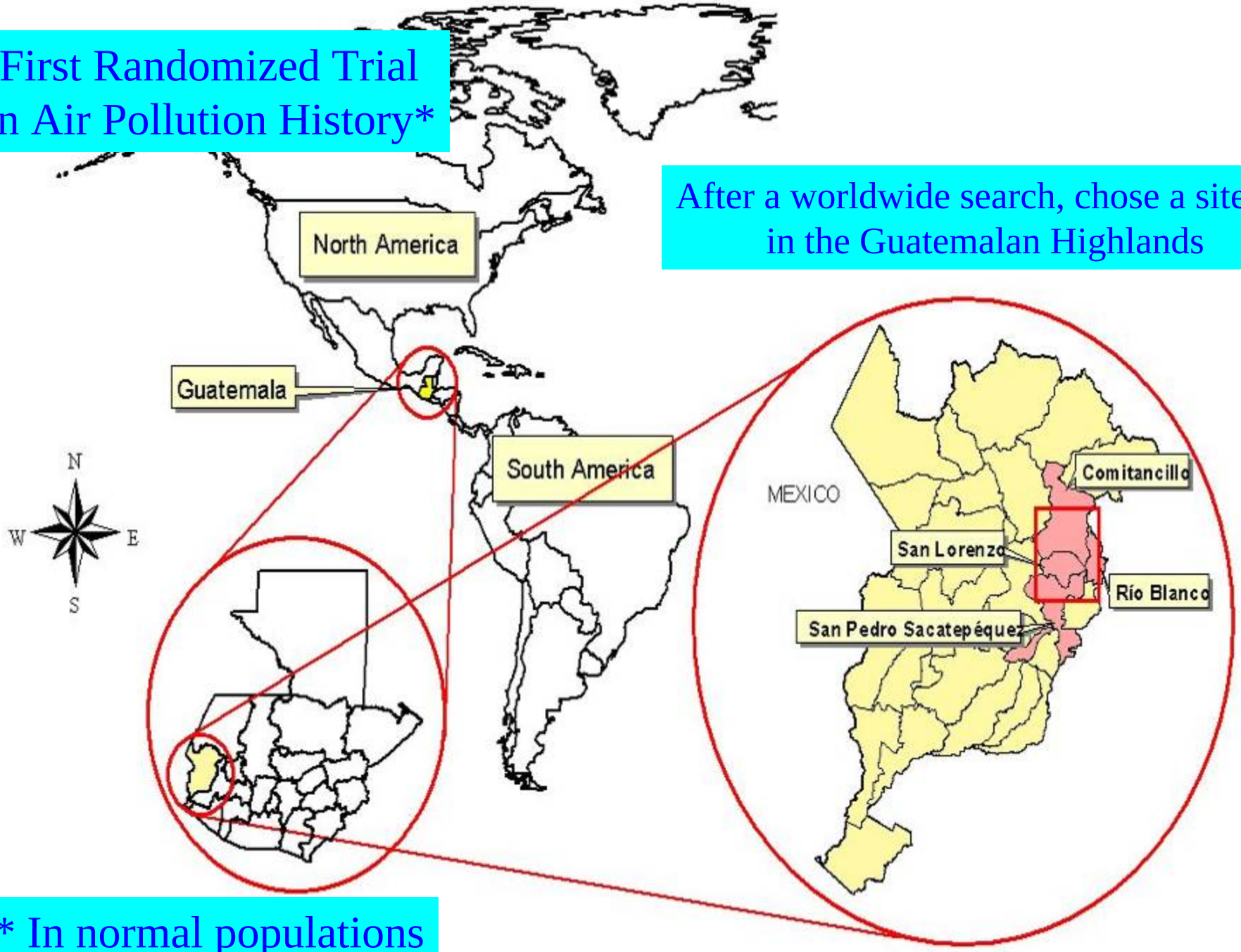
- Air pollution conference
  - High exposures to large vulnerable population
  - No more health effects work needed
- International health conference
  - Still doubt about causality
  - Need to know exact benefit to be expected
- Where are your randomized controlled trials?

History of an RCT

- ~1980: Early studies of health effects in Nepal and elsewhere
- 1981: First measurements of pollution levels in India
- 1984: International meeting to decide on needed research
  - Chose randomized control trial (RCT) of ALRI
- 1986-89: Unfunded proposals to do RCT in Nepal
- 1990: WHO establishes committee to find best sites
- 1990-1992: Criteria established and site visits made
- 1992: Highland Guatemala chosen
- 1991-1999: Pilot studies to establish data needed for proposal
- 1996-1999: Unfunded proposals
- 2001: NIEHS funding secured
- 2002-2005: Fieldwork completed
- 2011: Main results published
- 25+ years from deciding to conduct RCT to results!

First Randomized Trial In Air Pollution History*

After a worldwide search, chose a site in in the Guatemalan Highlands



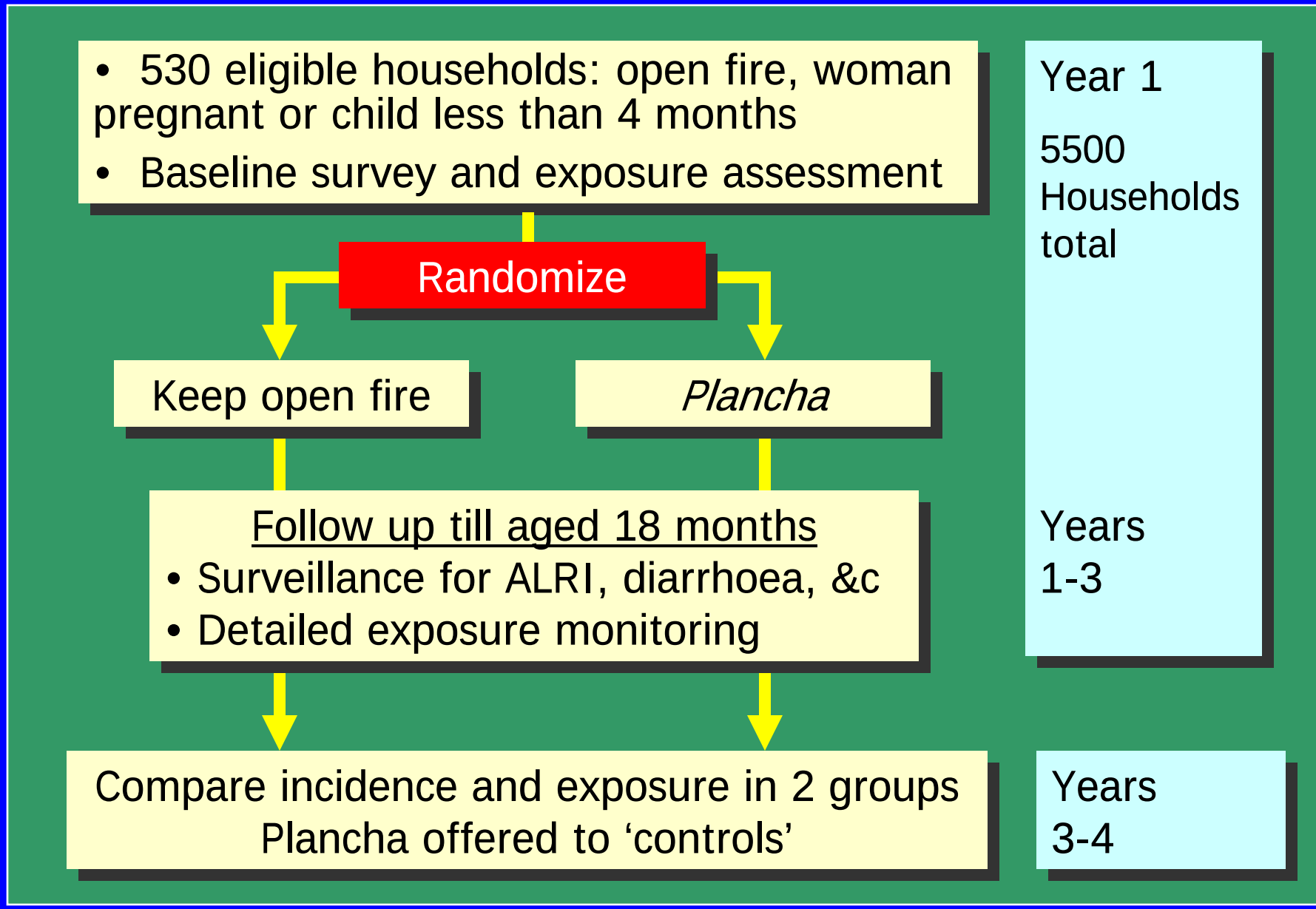
* In normal populations

RESPIRE: (Randomized Exposure Study of Pollution Indoors and Respiratory Effects)

Traditional 3-stone open fire

Chimney woodstove

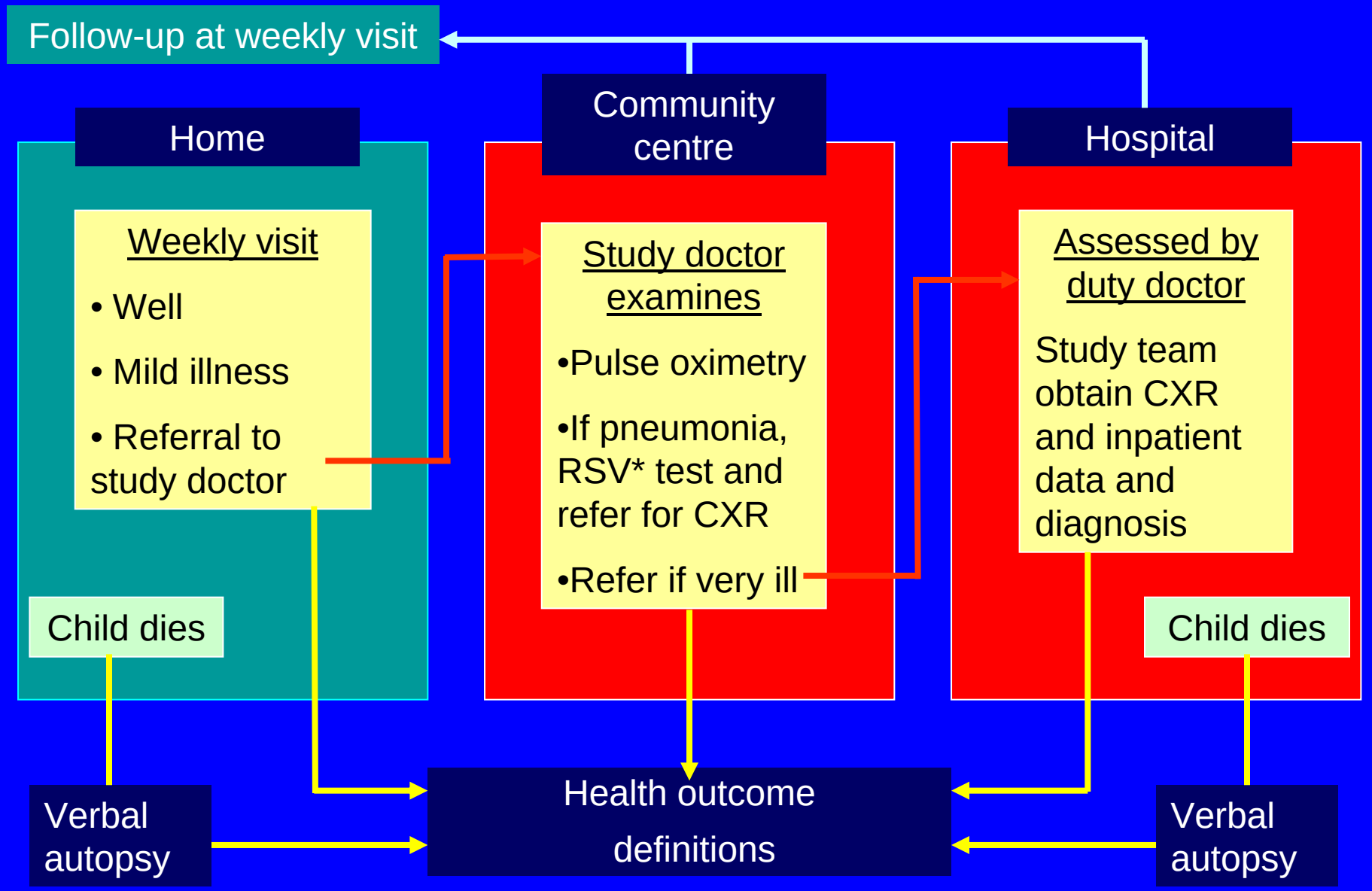
Overview of RESPIRE study design



Randomisation: balance of groups at baseline

Variable	Control	Intervention
Socio-demographic factors		
Mother's Age (years)	27.0	26.4
Pregnant at recruitment (%)	48.3	51.3
Own home (%)	92.8	94.1
Migrates part of year (%)	17.7	17.1
House structure		
Separate enclosed cooking area (%)	76.2	74.3
Completely open eaves (%)	42.7	40.6
Walls – adobe (mud) (%)	88.7	90.7
Roof – metal (%)	77.4	74.3
Floor – earth (%)	92.5	88.8
Leaks in roof (water) (%)	24.5	33.3
Electricity (%)	70.8	69.3
Other sources of smoke		
Other fire near house (%)	14.6	14.4
Smoking (tobacco) indoors (%)	26.8	20.4
Use traditional sauna bath (%)	84.5	87.8
Geographic		
Mean altitude (metres)	2613	2601

Overview of child health outcomes assessment



* Respiratory syncitial virus

Overview of weekly visits

		Plancha	Control
Number of children		265	253
Weekly visits	Total possible in follow up period	16,446	15,664
	Completed	14,756	14,369
% of possible weekly visits completed		89.7%	91.7%*
Mean (SD, range) visits per child		55.7 (17.8; 1 to 80)	56.8 (17.3; 2 to 81)
Number (%) children - no missed visit		17 (6.4%)	19 (7.5%)
Withdrawals		19 (7.2%)	14 (5.5%)

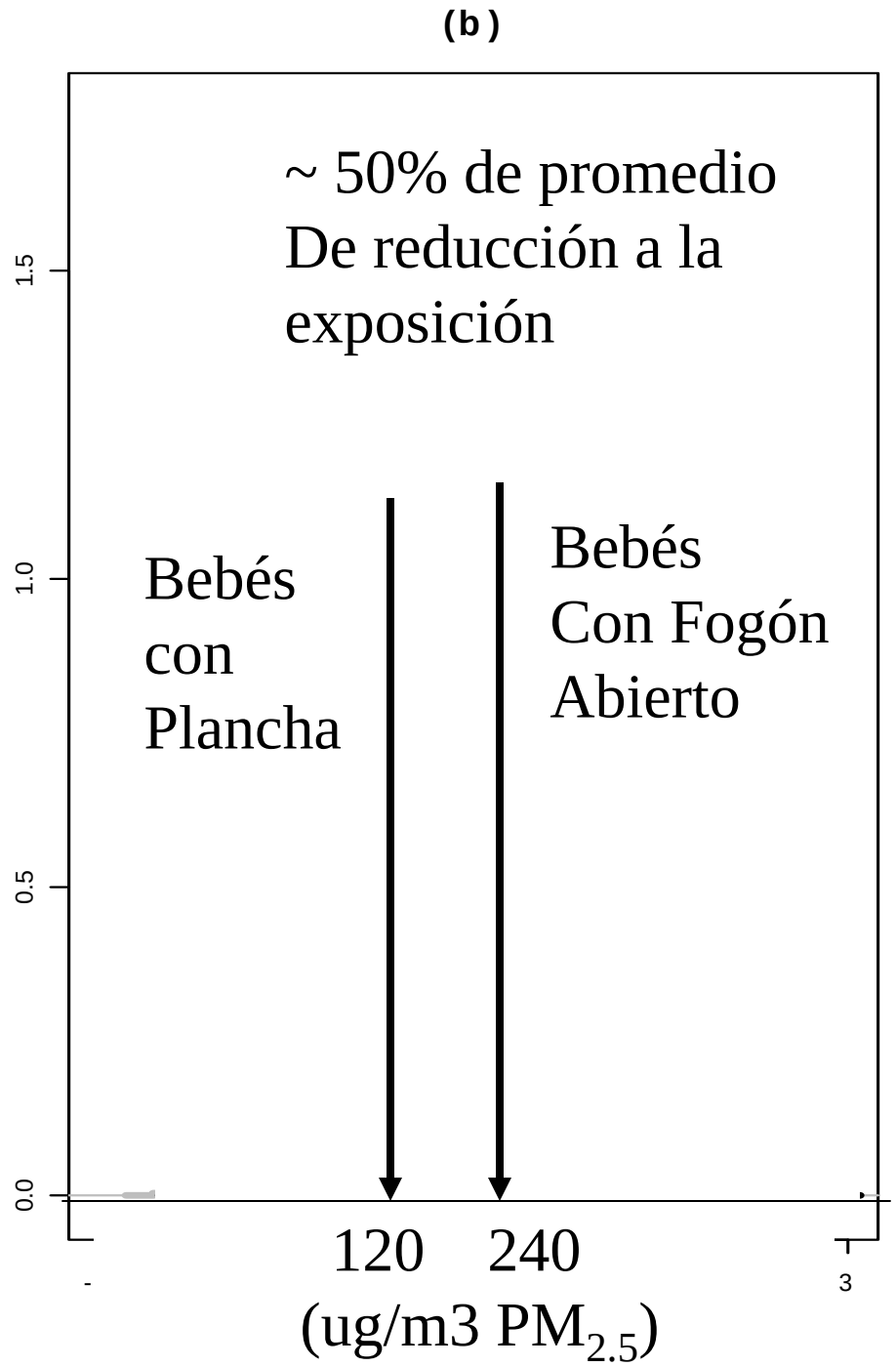
* $P < 0.001$

Unpublished results from RESPIRE have been removed

Watch the website below where they will be posted as soon as they are published.

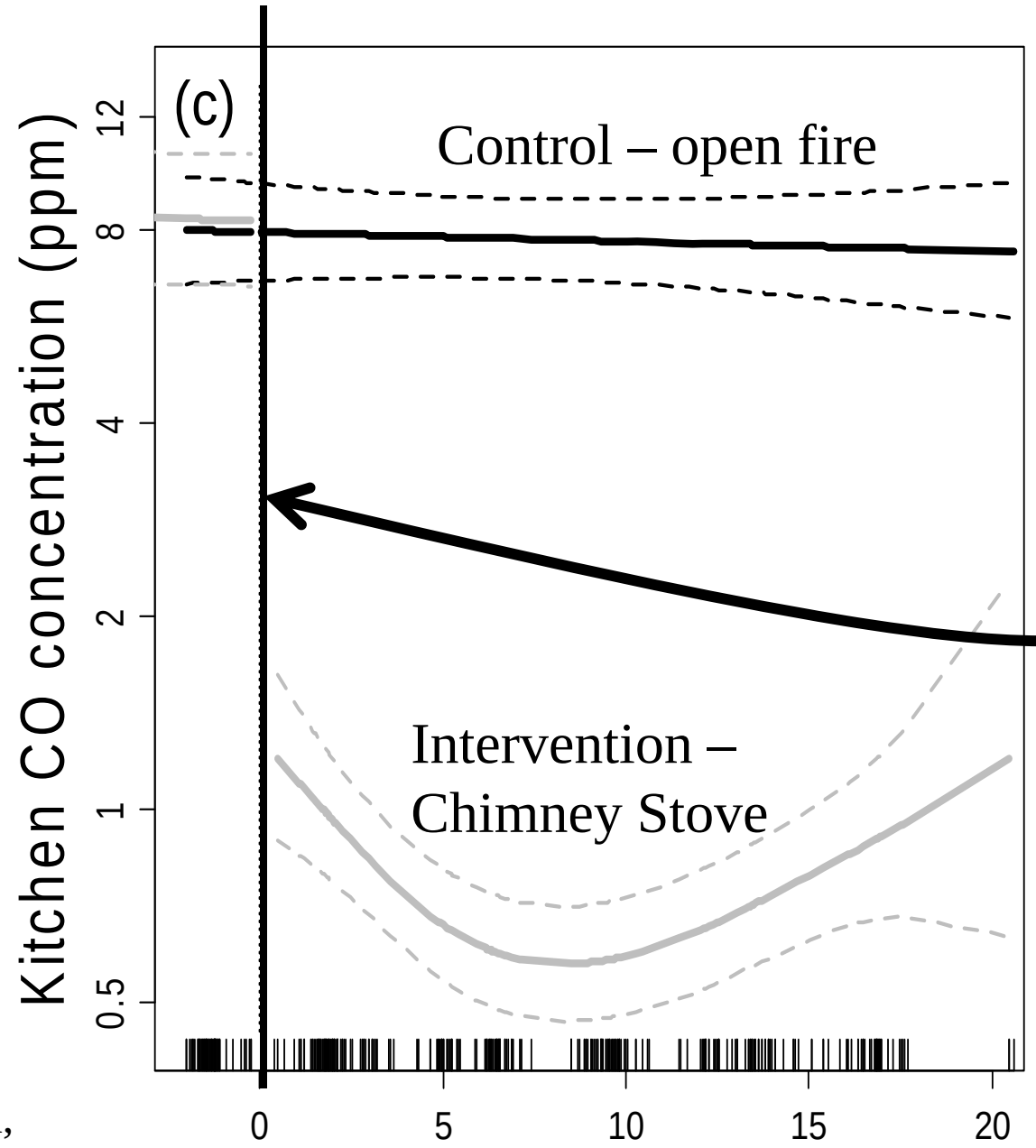
http://ehs.sph.berkeley.edu/krsmith/


Tubito
Tubito



Chimney stove did not protect all children

Guatemala RCT: Kitchen Concentrations



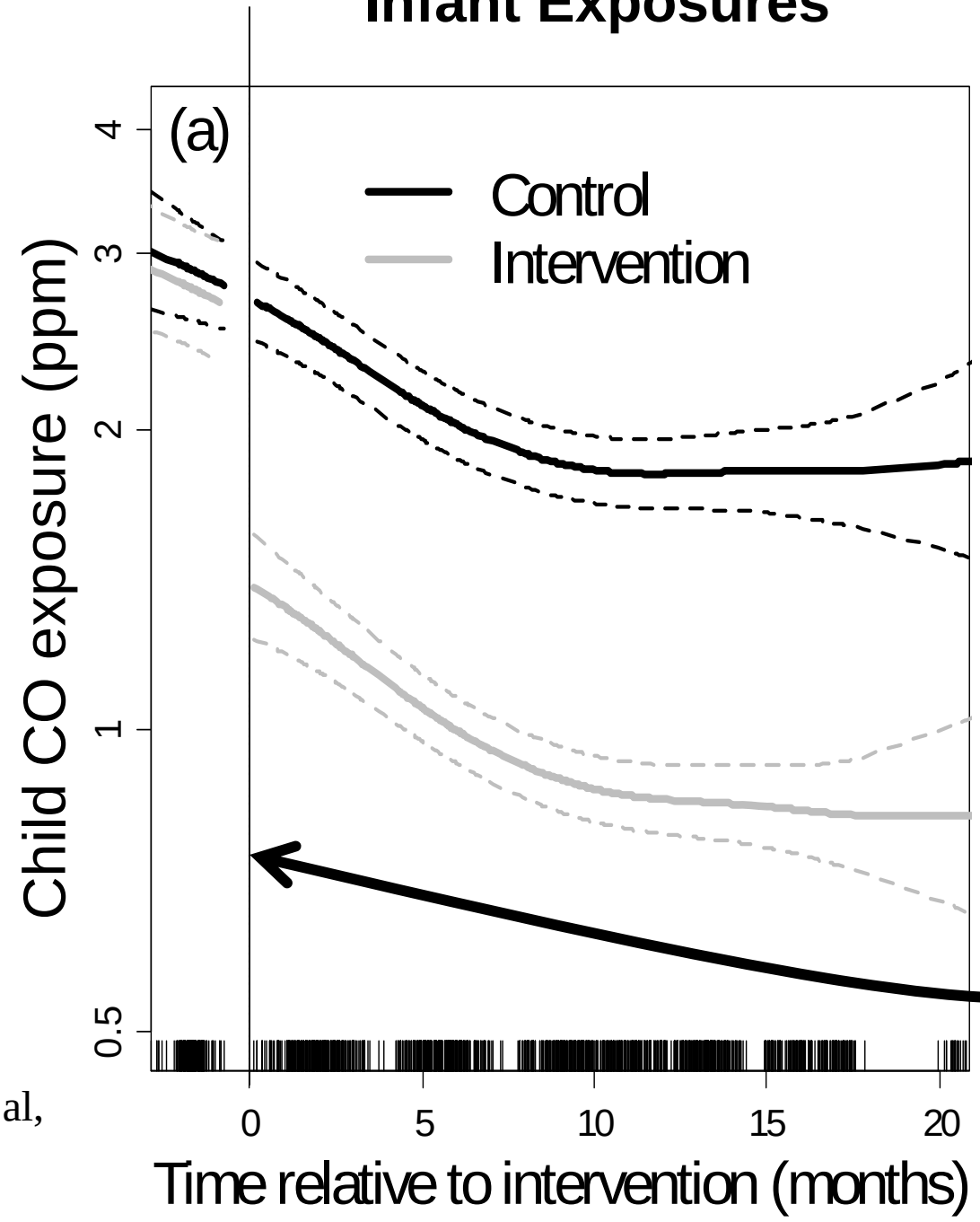
Effect of Chimney Stove On Kitchen CO Levels

Factor of ~10 less

285 48-h measurements

Smith, et al, 2010

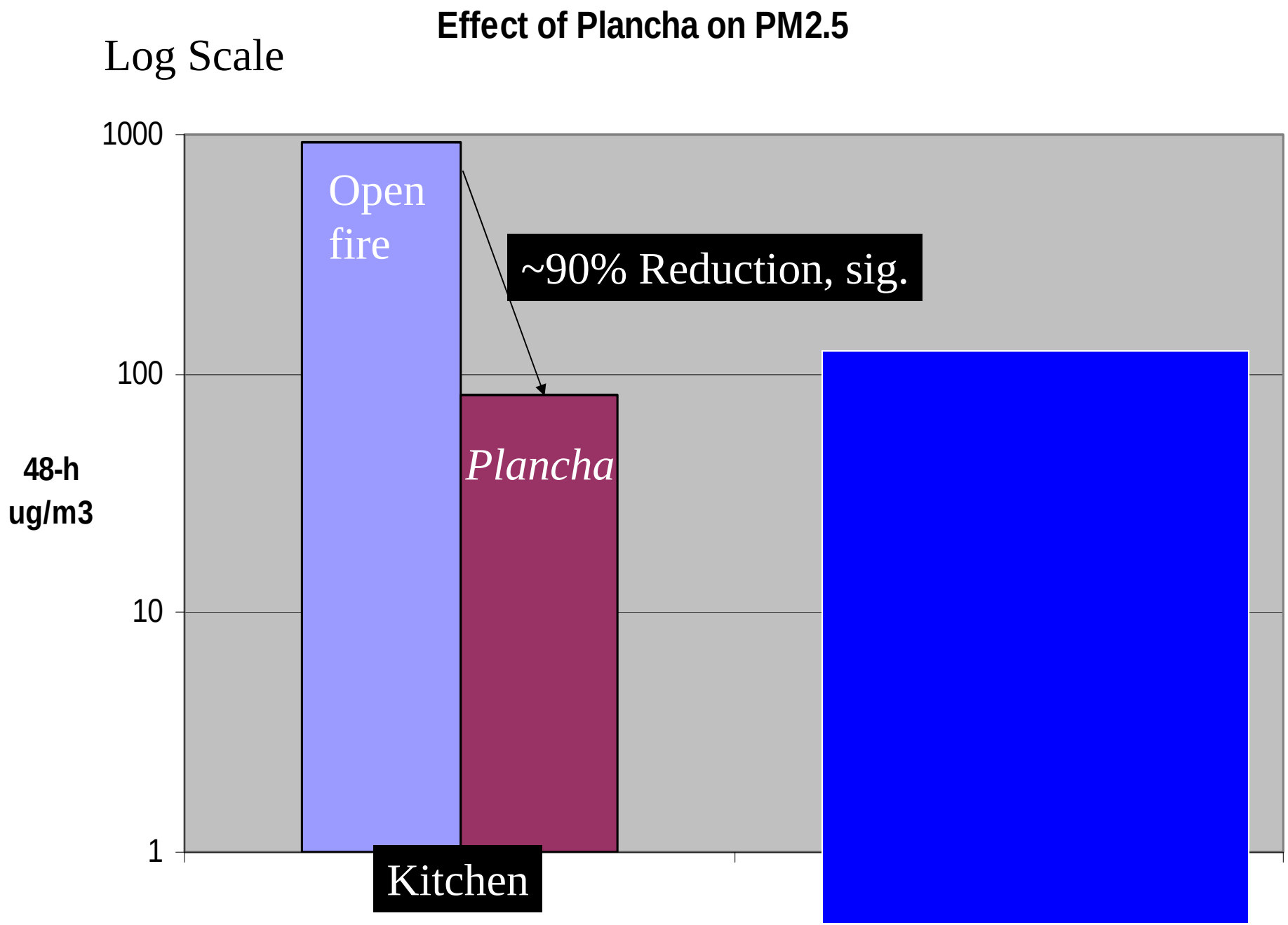
Infant Exposures

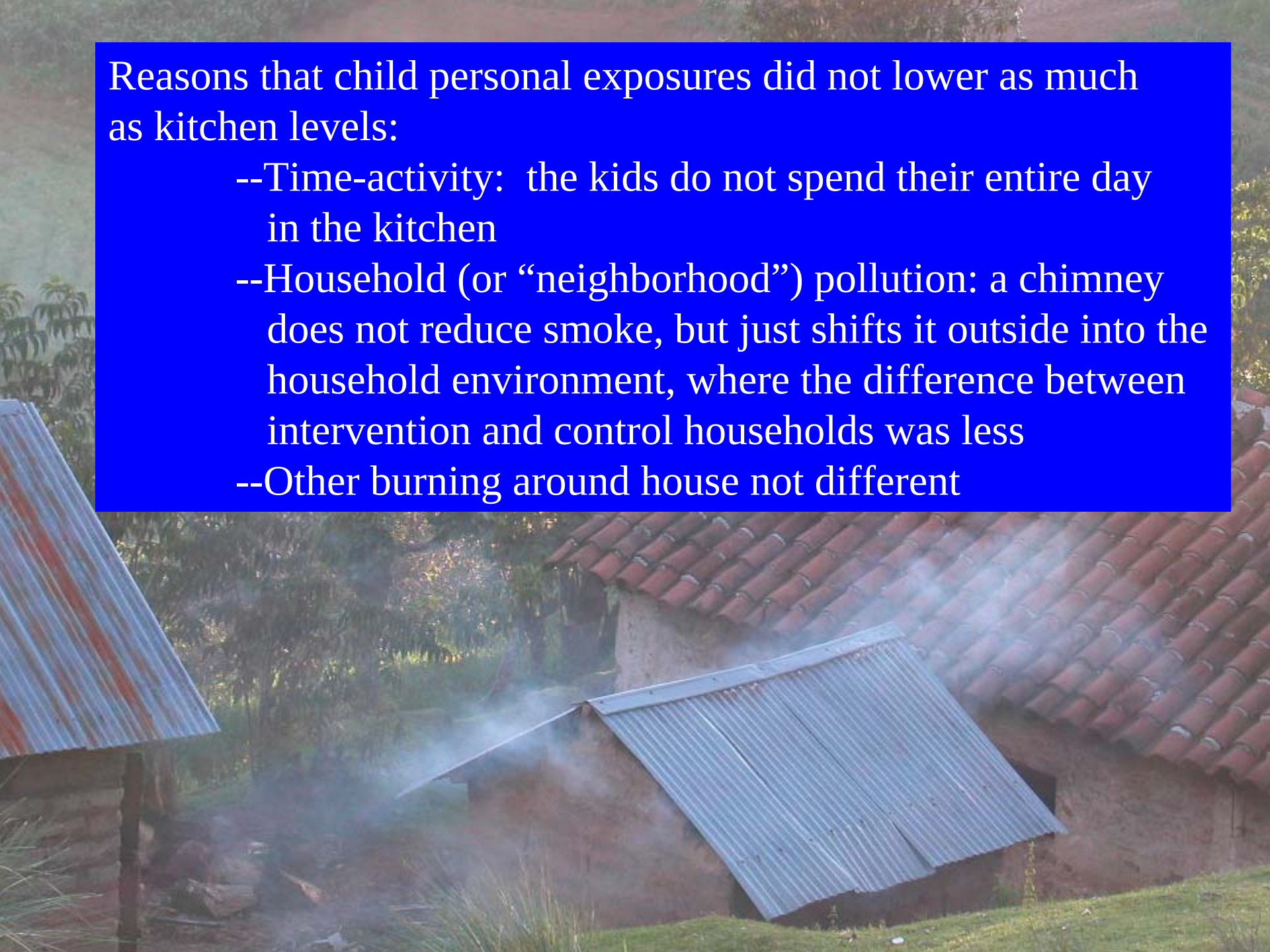


1888 48-h measurements

Effect of Chimney Stove On Infant Exposures - 2x less

Smith, et al, 2010


Effect of Plancha on PM2.5
Log Scale
1000
100
10
1
48-h
ug/m3
Open
fire
~90% Reduction, sig.
Plancha
Kitchen



Reasons that child personal exposures did not lower as much as kitchen levels:

--Time-activity: the kids do not spend their entire day in the kitchen

--Household (or “neighborhood”) pollution: a chimney does not reduce smoke, but just shifts it outside into the household environment, where the difference between intervention and control households was less

--Other burning around house not different

Child Cognitive Function: First Pilot Study

- [results removed until publication – watch website]

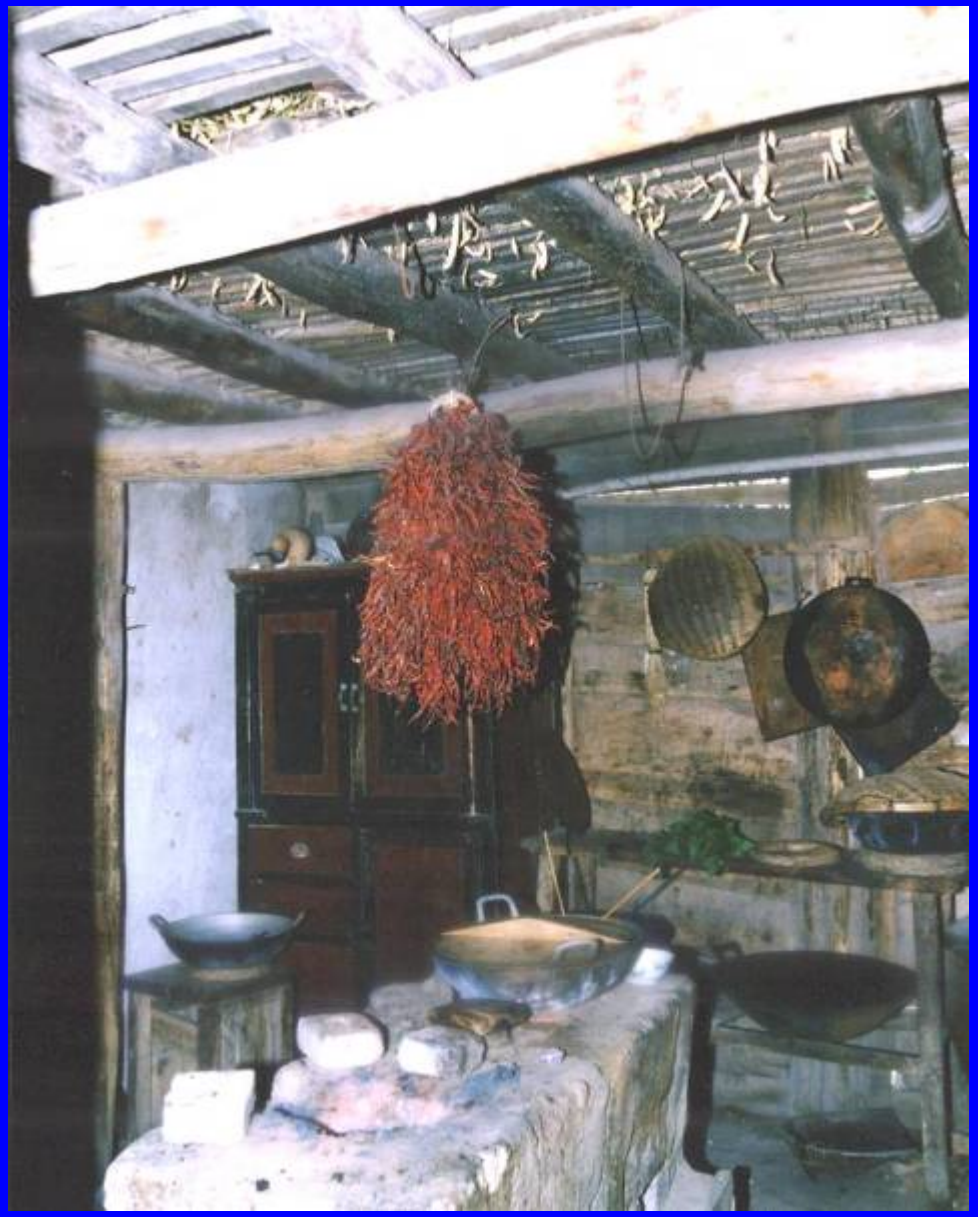
Increasing Number of Studies on Disease Signs: Objective Measures

- Lung function, cross-sectional
- Blood pressure, EHP, 2007
- ST-segment, EHP, forthcoming
- Opacity, submitted

Dioxin Daily Dose Estimates

[Unpublished results of measurements in households in Guatemala removed.

Watch website for publication]



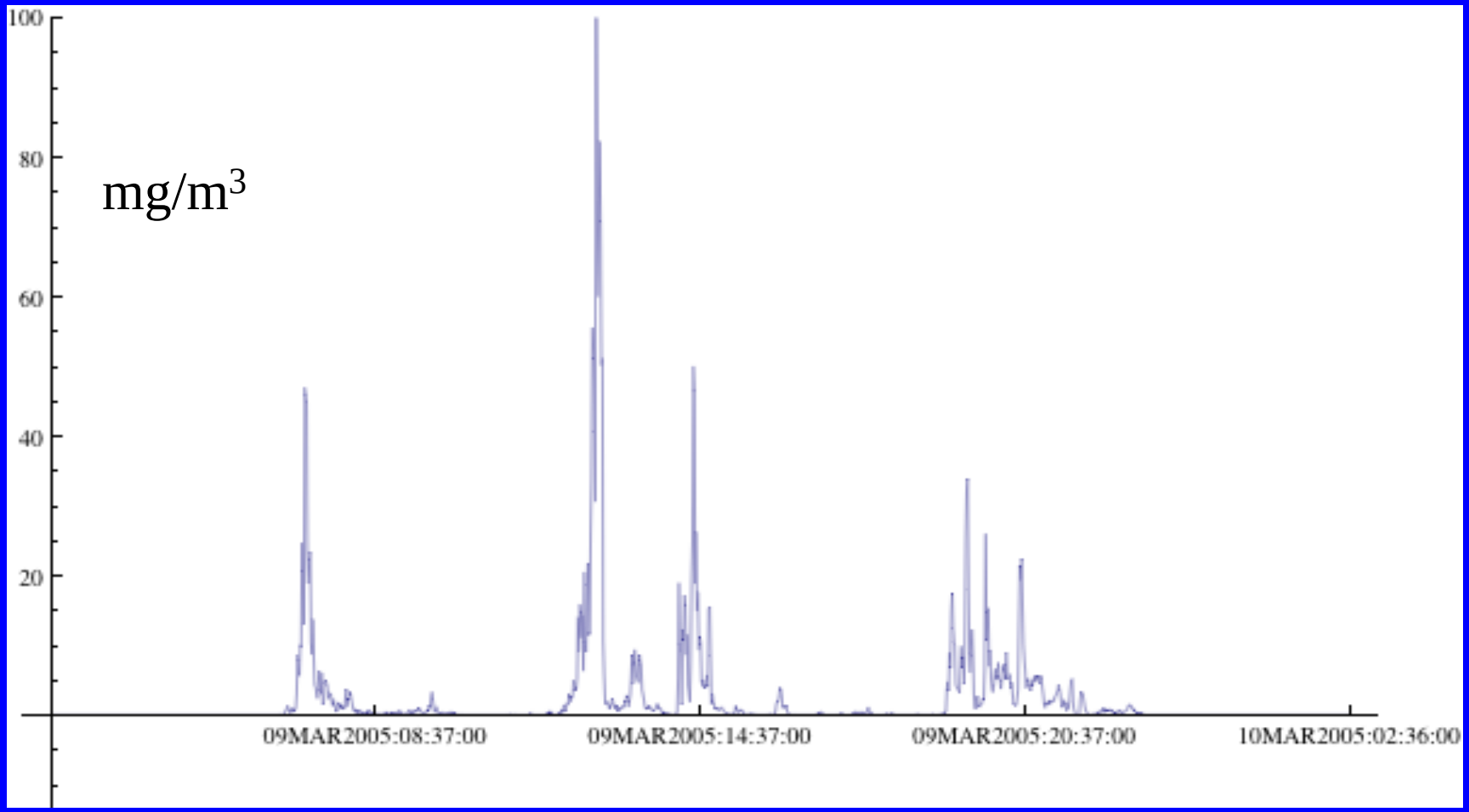
Poisonous Coal Use and Household Exposures

Arsenic and Fluorine Exposures in China from Household Coal Use

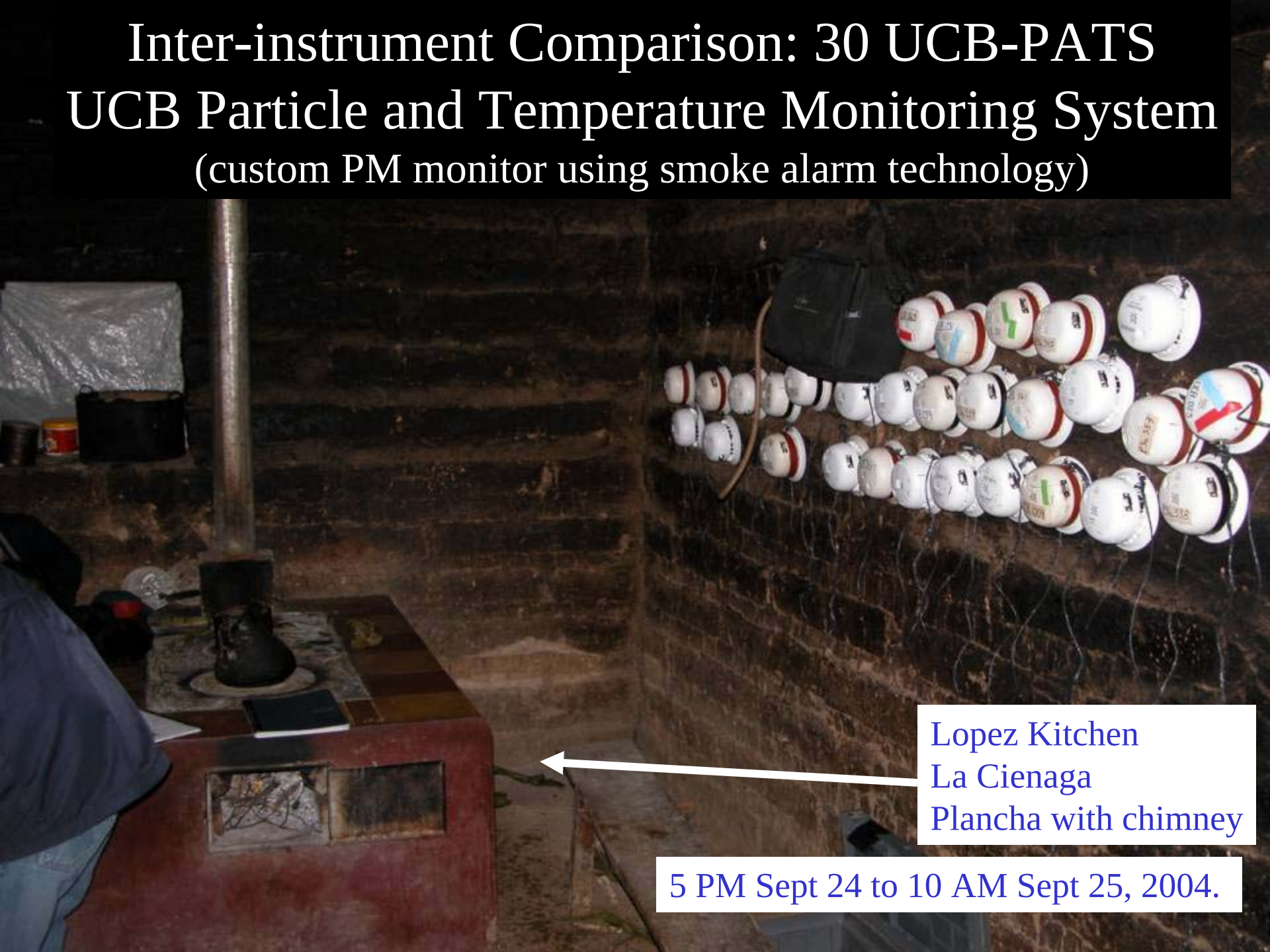
- More than 95% of the fluorine dose came from food consumption, with the rest mainly from direct inhalation of airborne fluoride -- Ando et al., *EHP* (1998)
- The estimated sources of total arsenic exposure are from arsenic-contaminated food (50-80%), air (10-20%), water (1-5%), and direct skin contact (<1%) -- Liu et al., *EHP* (2002)
- Dioxin might be expected to have a similar pattern.

Kitchen $PM_{2.5}$ in household using open cookfire

How many hours should we measure to obtain good estimate of mean?



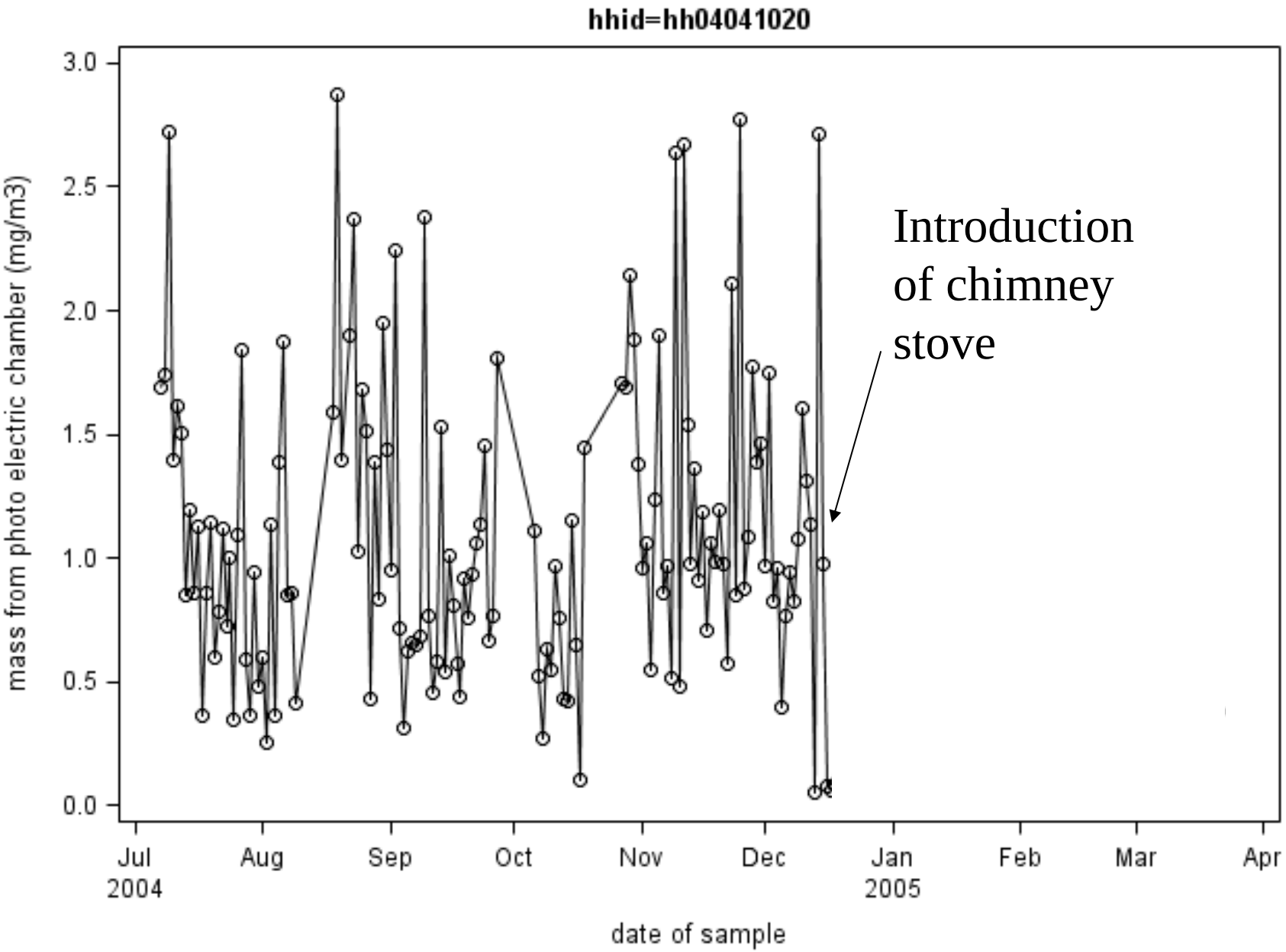
Inter-instrument Comparison: 30 UCB-PATS
UCB Particle and Temperature Monitoring System
(custom PM monitor using smoke alarm technology)



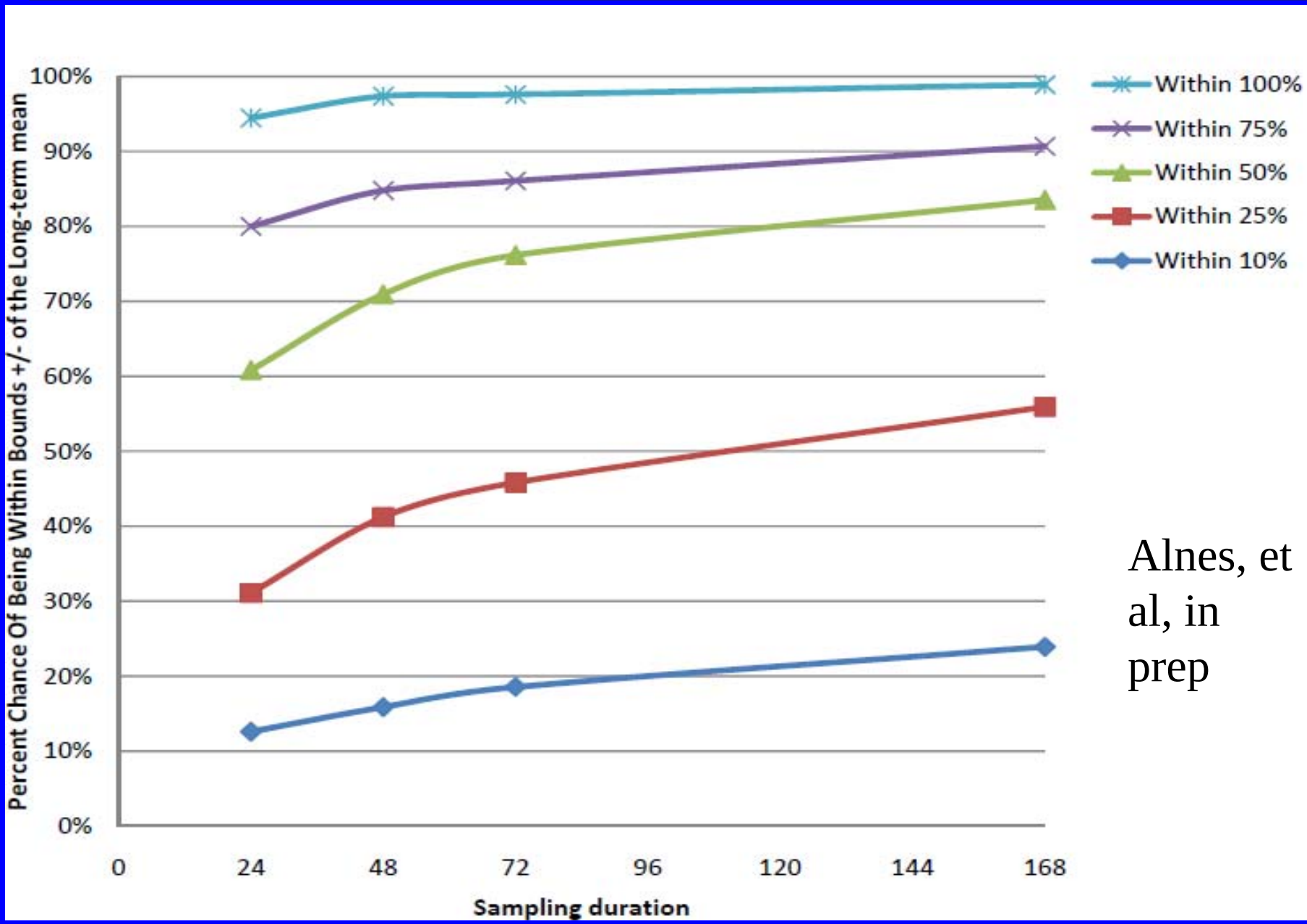
Lopez Kitchen
La Cienaga
Plancha with chimney

5 PM Sept 24 to 10 AM Sept 25, 2004.

Long-term Household Measurements

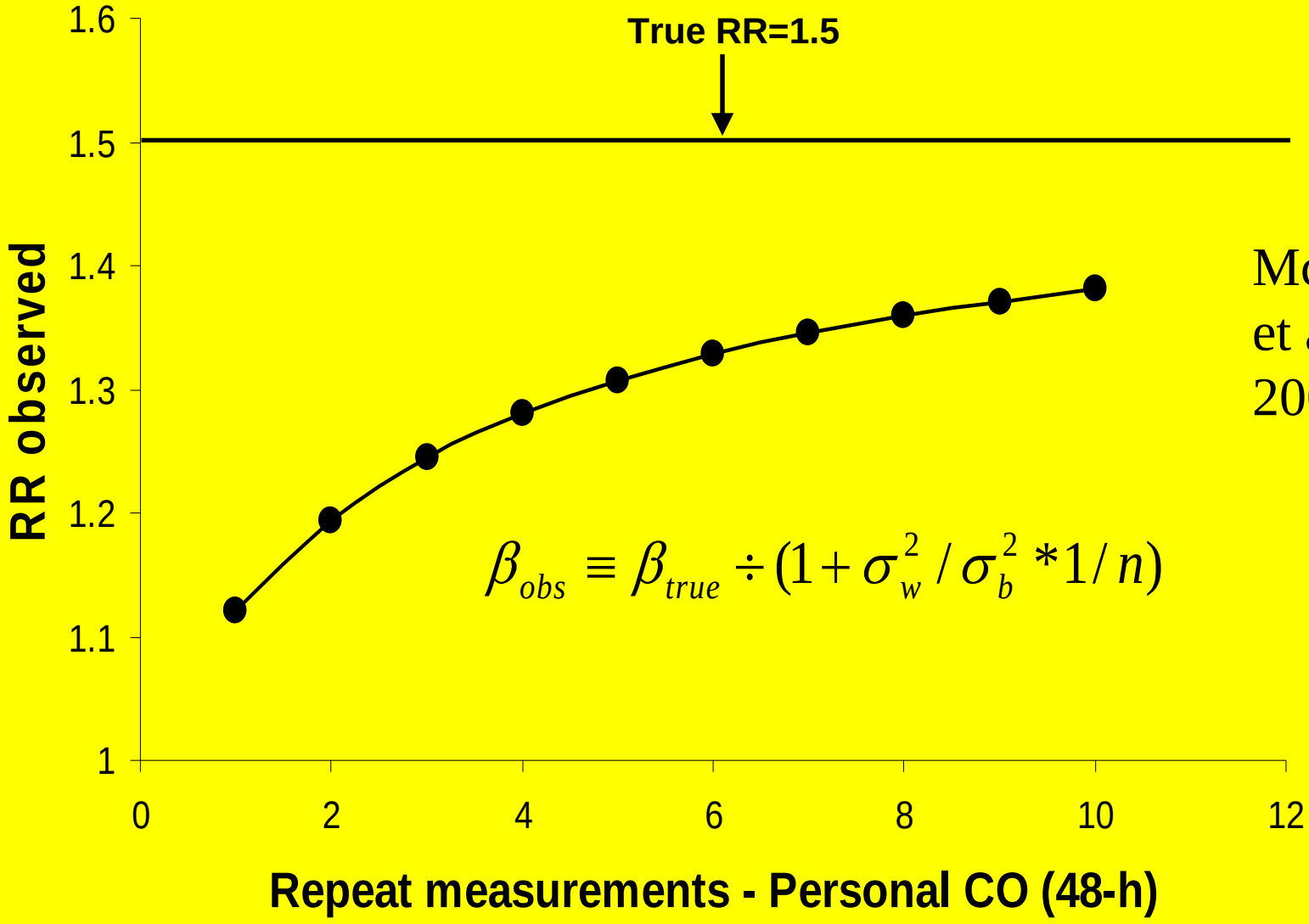


How Close to the True Mean With One Measurement?



Alnes, et al, in prep

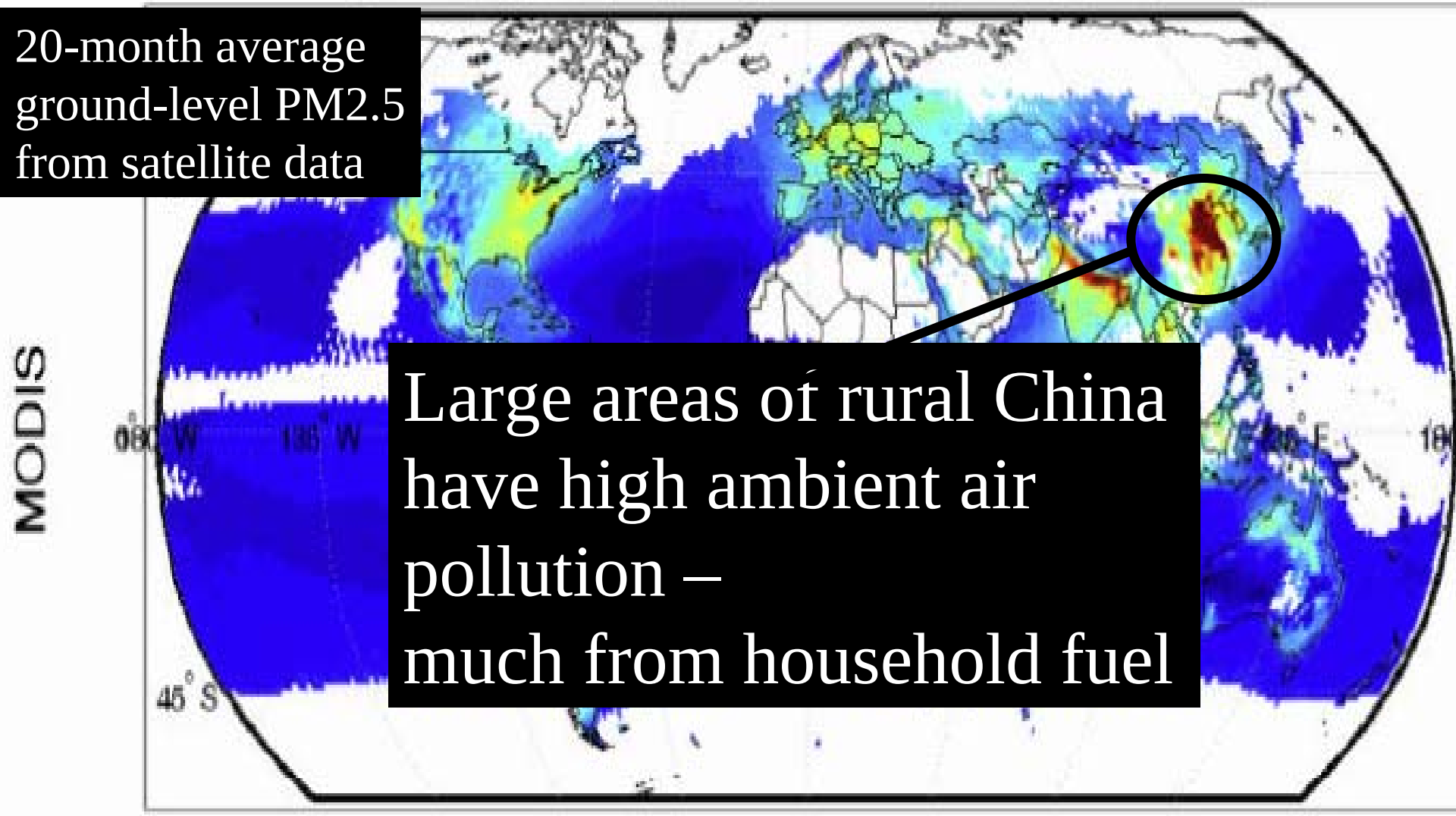
Attenuation Bias in Measurement Error



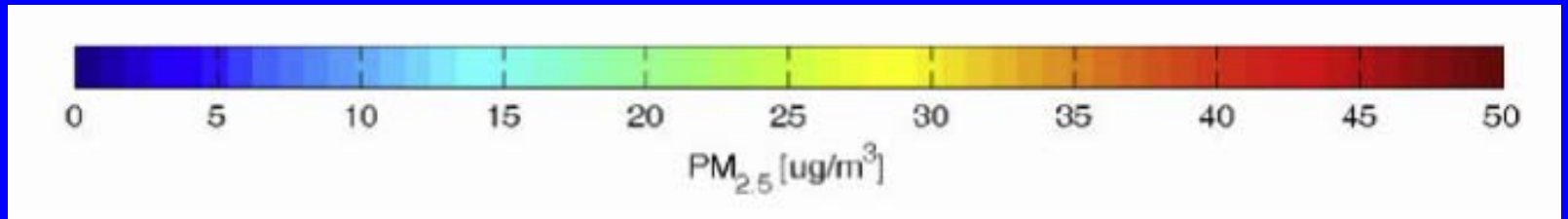
McCracken et al. 2009


Highland Guatemala
Friday, Feb 20, 2004
~6:15 AM

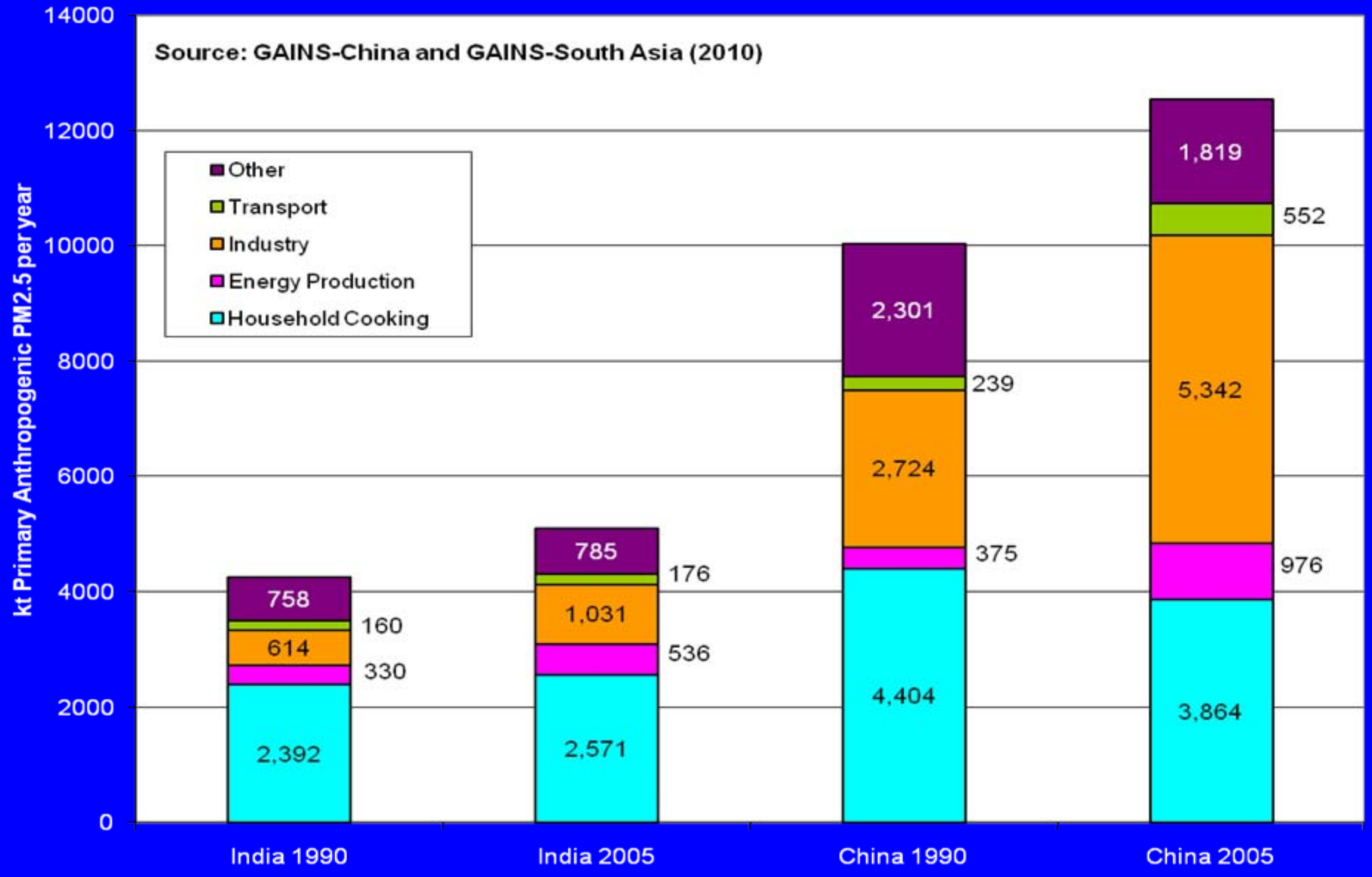
20-month average ground-level PM2.5 from satellite data



Large areas of rural China have high ambient air pollution –
much from household fuel

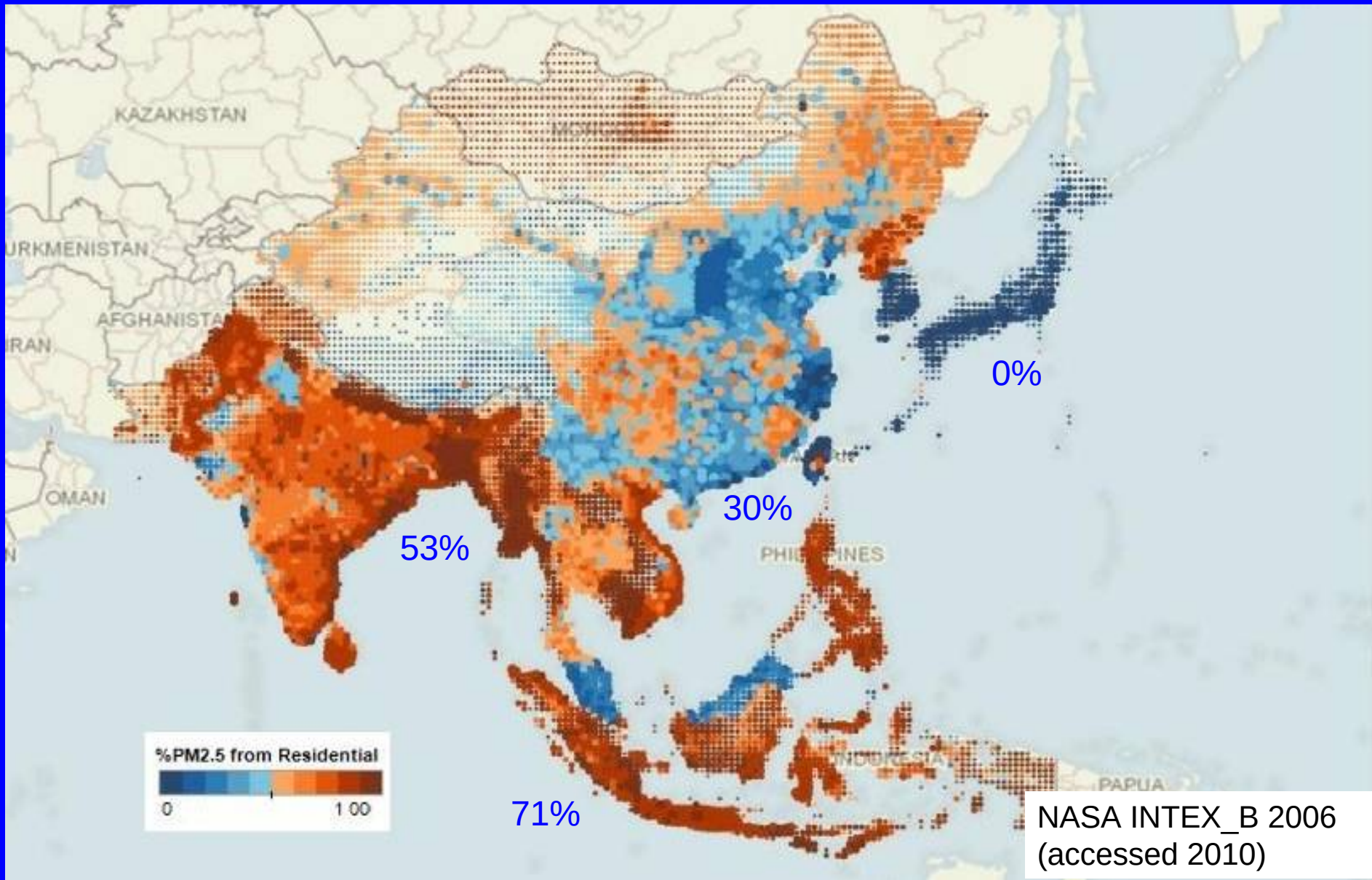


Sources of Primary $PM_{2.5}$: India and China

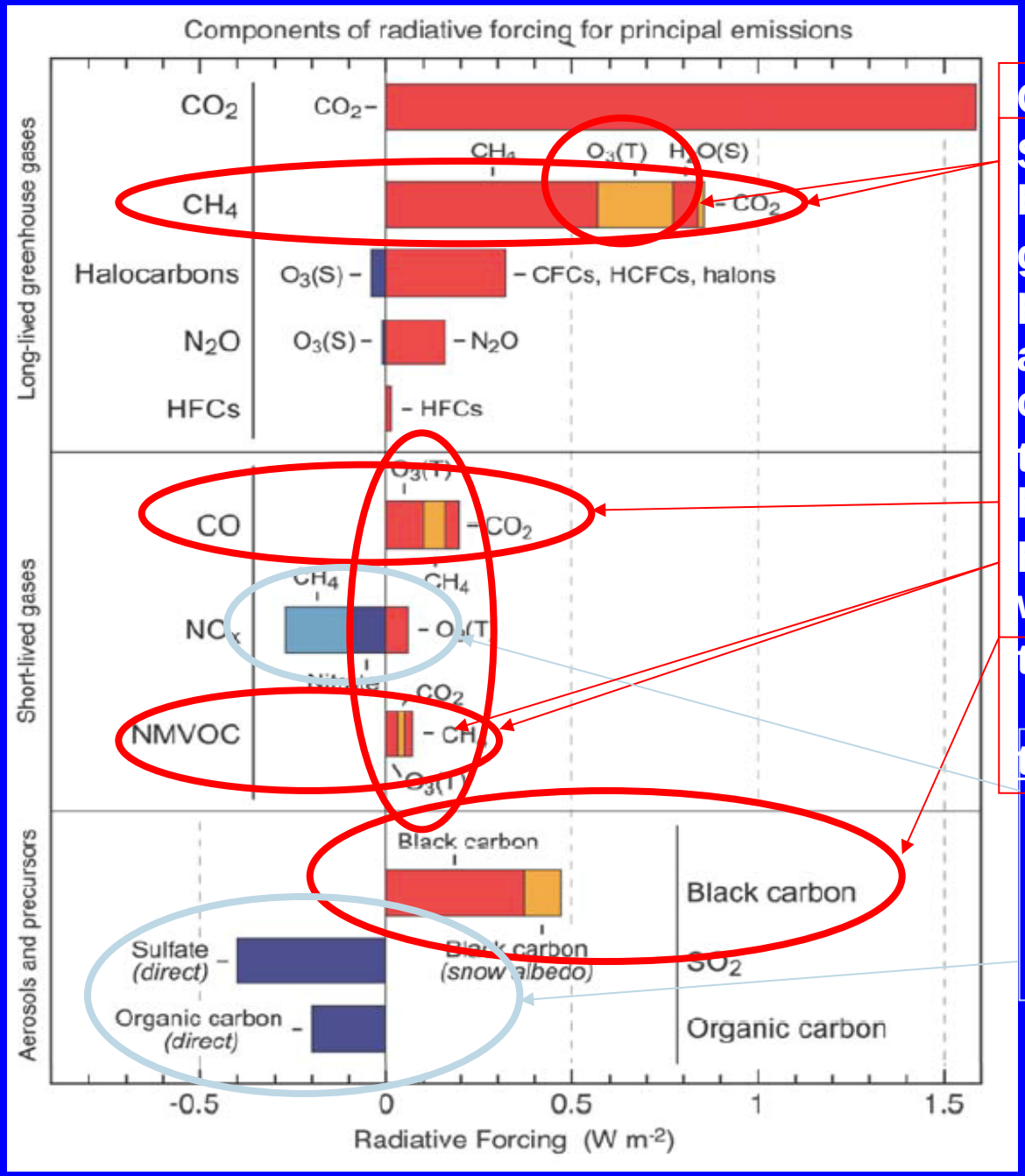


IIASA, 2010

NASA INTEX_B Database
Percent $PM_{2.5}$ emissions from households



Global warming in 2005 due to all human emissions since 1750



CO_2 is important for climate,
Several of the non-CO_2,
but so are many other
greenhouse gases create
pollutants, including the ones
a good proportion of both
circled that, unlike CO_2, also
their climate forcing and
have significant health as
health damage through
well as climate impacts
the secondary pollutant,

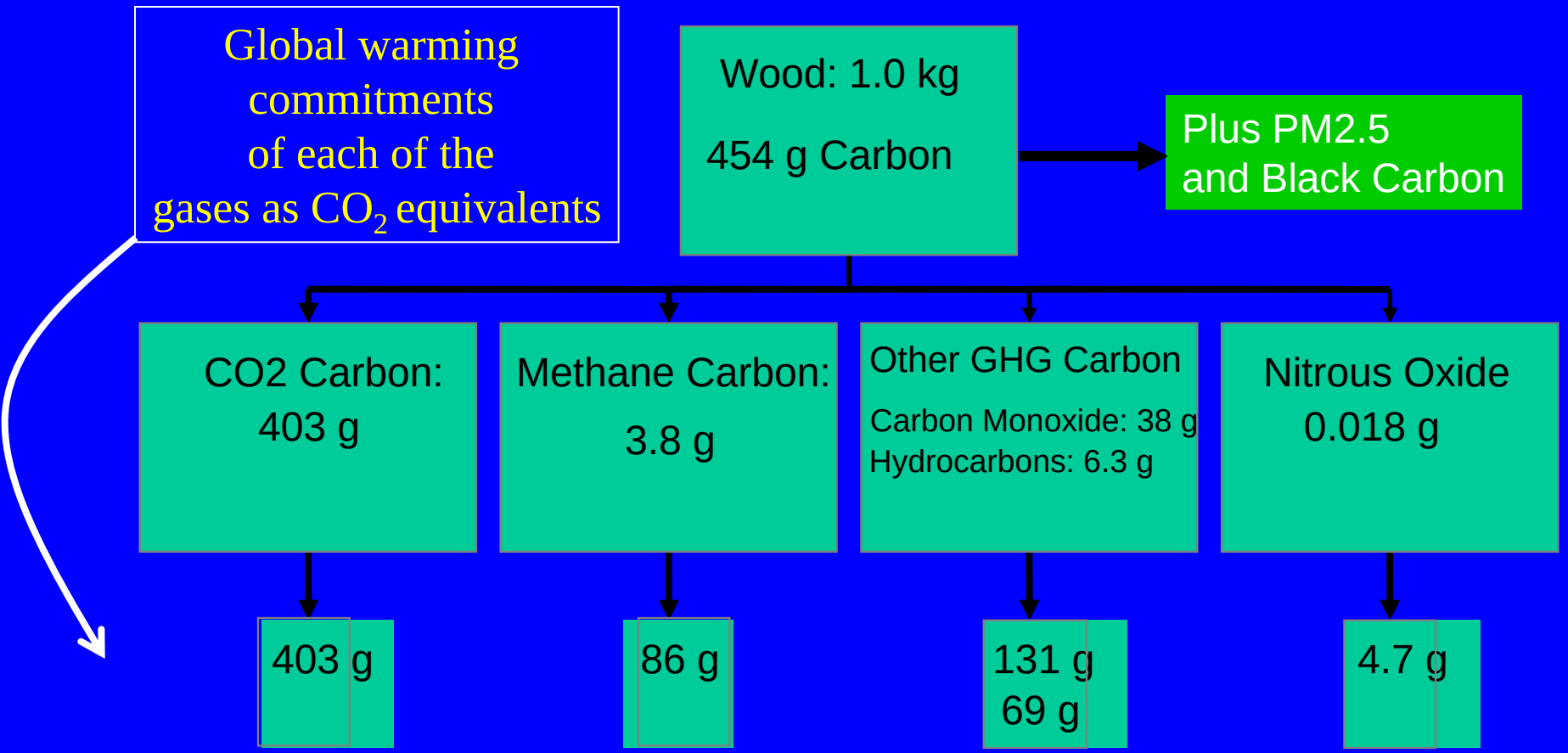
tropospheric ozone
organic carbon particles
however, have cooling
impacts on climate but
are still health damaging

IPCC, 2007

Household Fuels and Climate

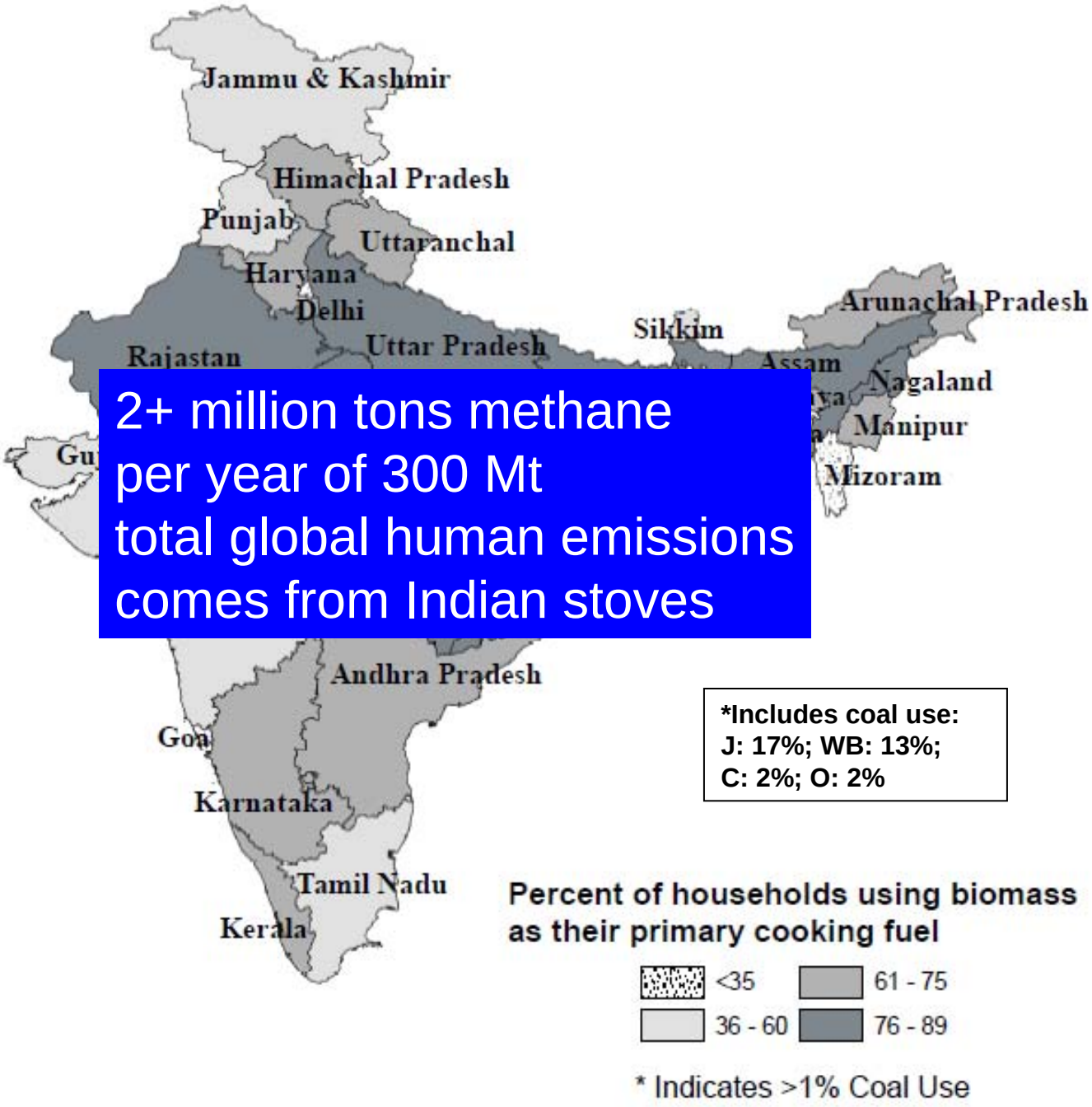
- Climate impacts come from non-renewable biomass and coal, i.e., from net CO_2 emissions
- Poor combustion also leads to other emissions such as the relatively well-understood GHGs – methane and nitrous oxide – which are "Kyoto" GHGs
- In addition, a wide range of less well-understood short-lived GH-related emissions are emitted including
  - CO and black carbon – warming agents
  - Ozone precursors – warming But also cooling agents such as sulfates and organic carbon particles
- There are also indirect climate impacts of these pollutants including
  - Reducing carbon capture of forests by ozone damage
  - Darkening of snow/ice by black carbon

Greenhouse warming commitment per meal for typical biomass-fired cookstove in China



Zhang, et al., 2000

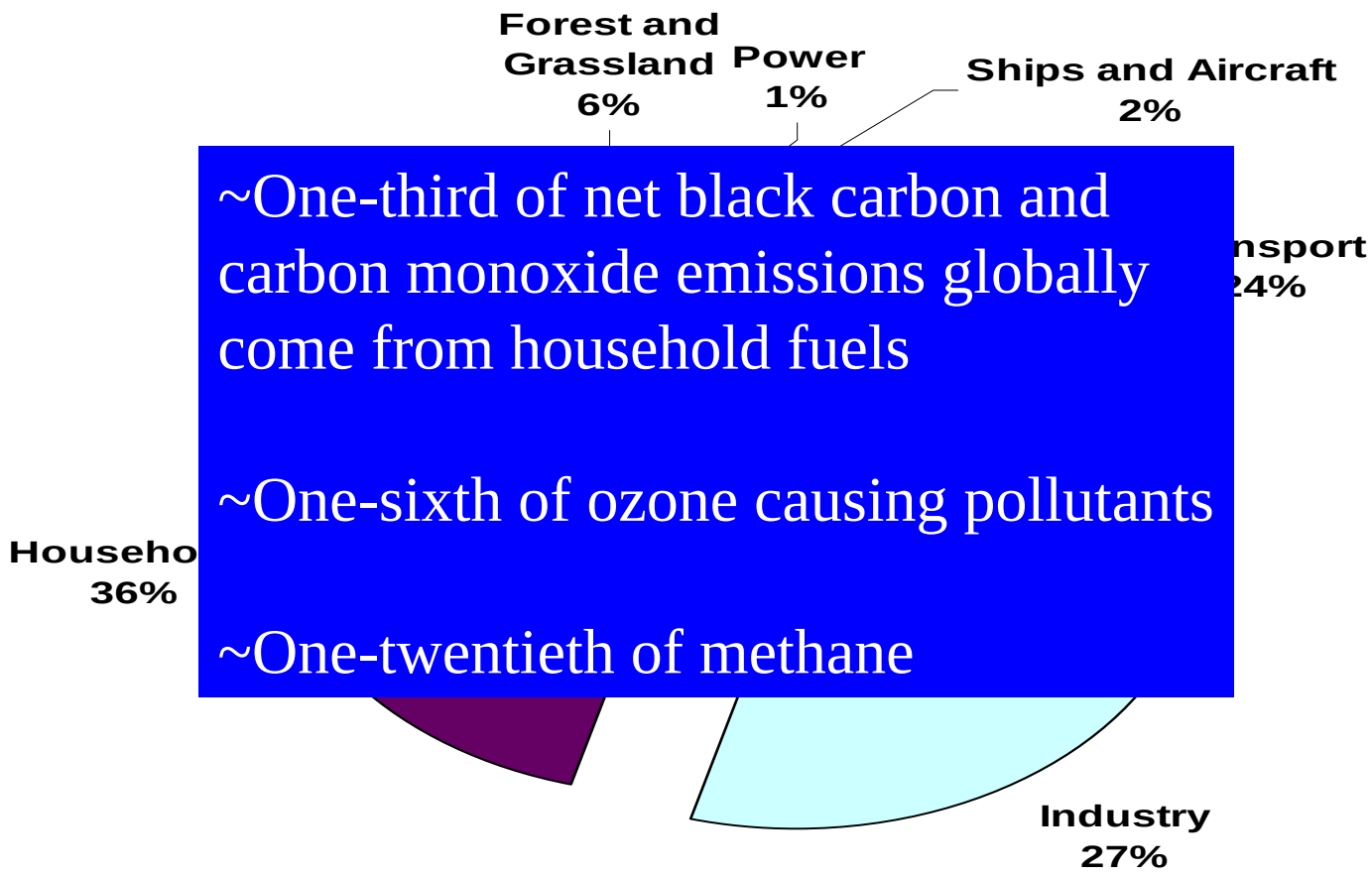
India in 2005



Venkataraman et al. 2010

Controllable Global Warming from Black Carbon Emissions

Net of OC, Forcings from IPCC, 2007: 0.25 W/m^2
Inventory from T Bond Database, V 7.1.1 Feb 2009

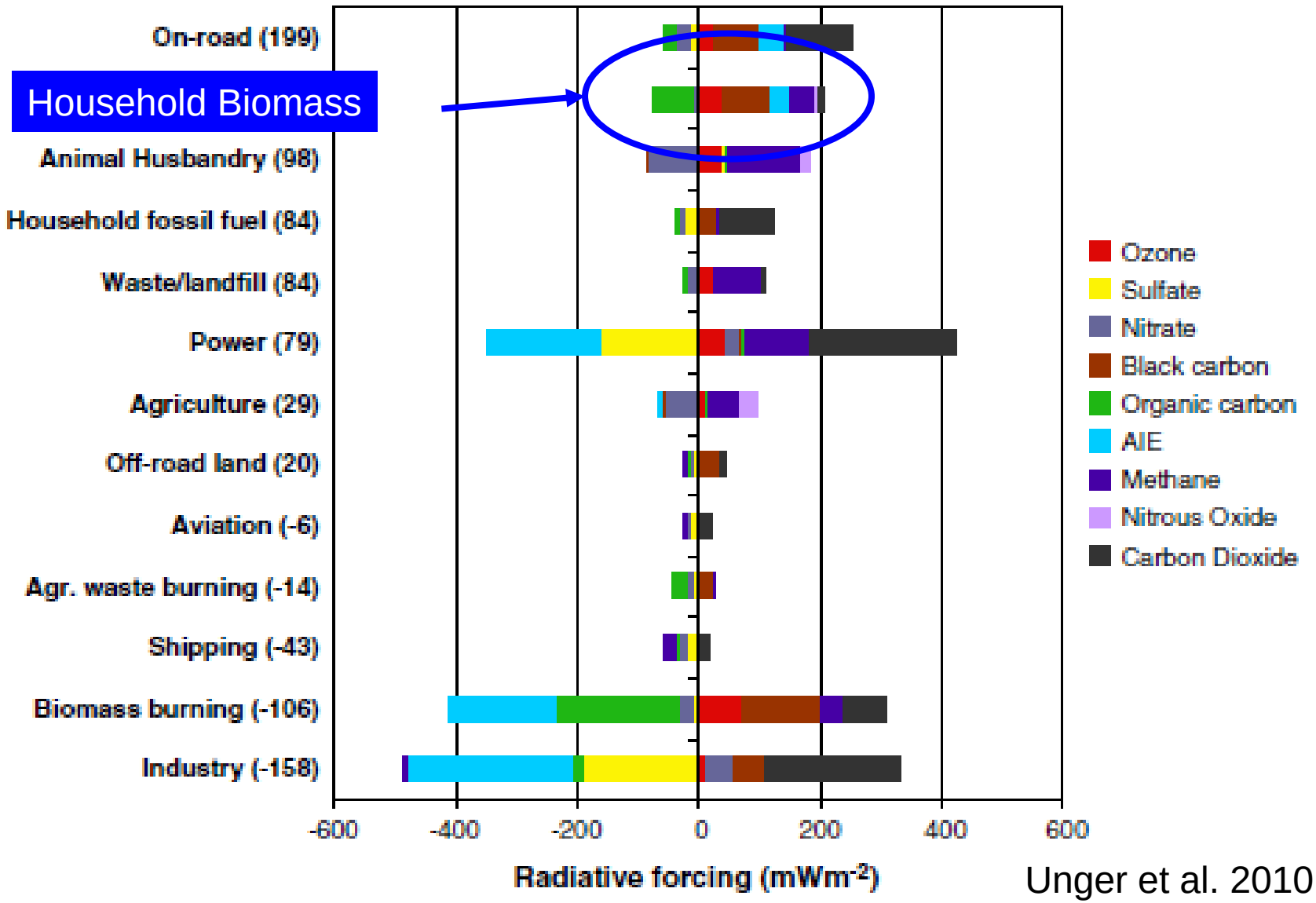


~One-third of net black carbon and carbon monoxide emissions globally come from household fuels

~One-sixth of ozone causing pollutants

~One-twentieth of methane

Climate Warming in 2020 Under Present Trends



Unger et al. 2010

Perfect Storm for Health Impacts

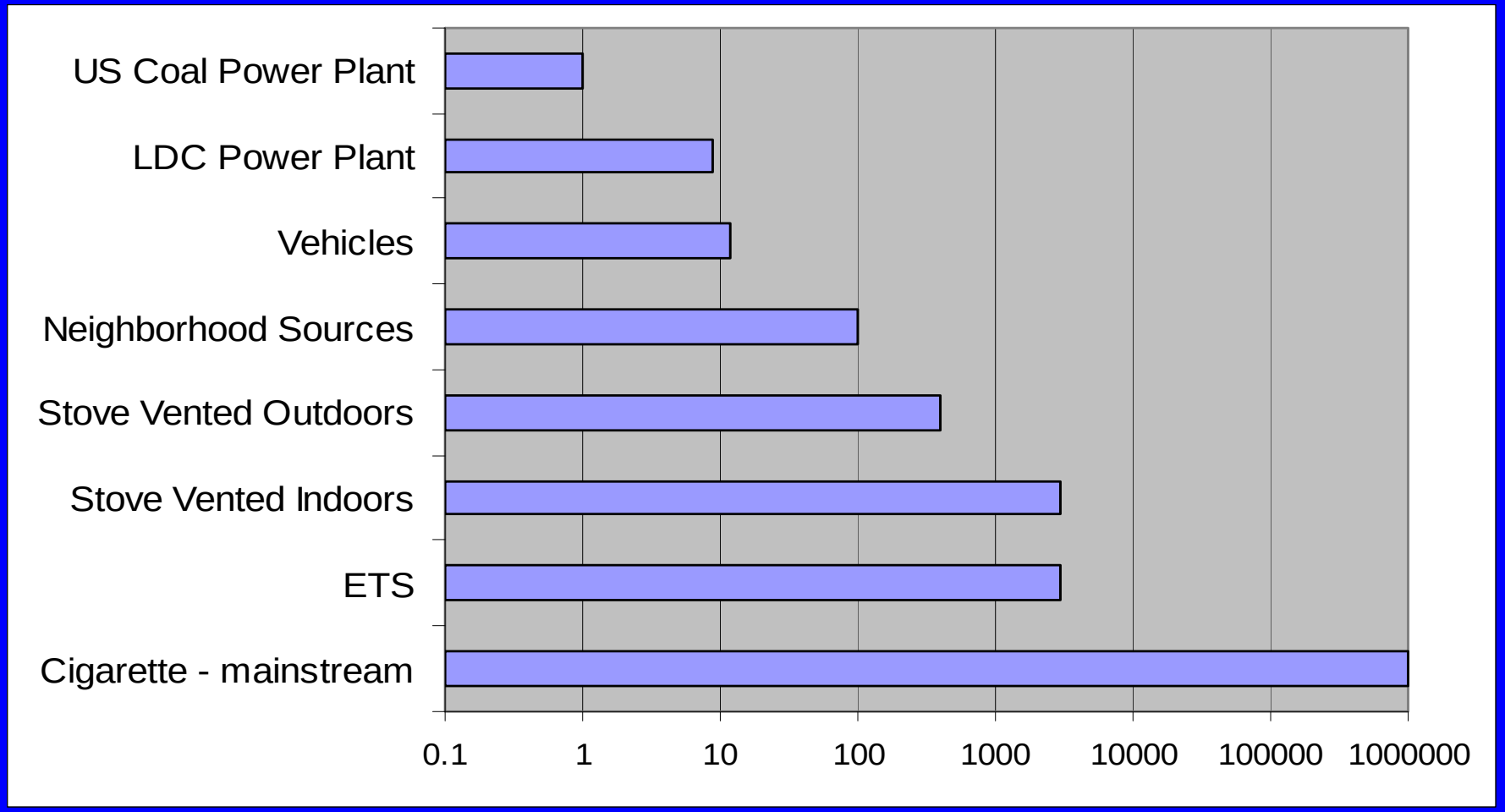
- Highly polluting activity
- Half of world households
- Several times a day
- Just when people are present
- Most vulnerable (women and young children) most likely to be there

In other words, the Intake Fraction is extremely large

IF is the fraction of material emitted that is actually breathed in by someone

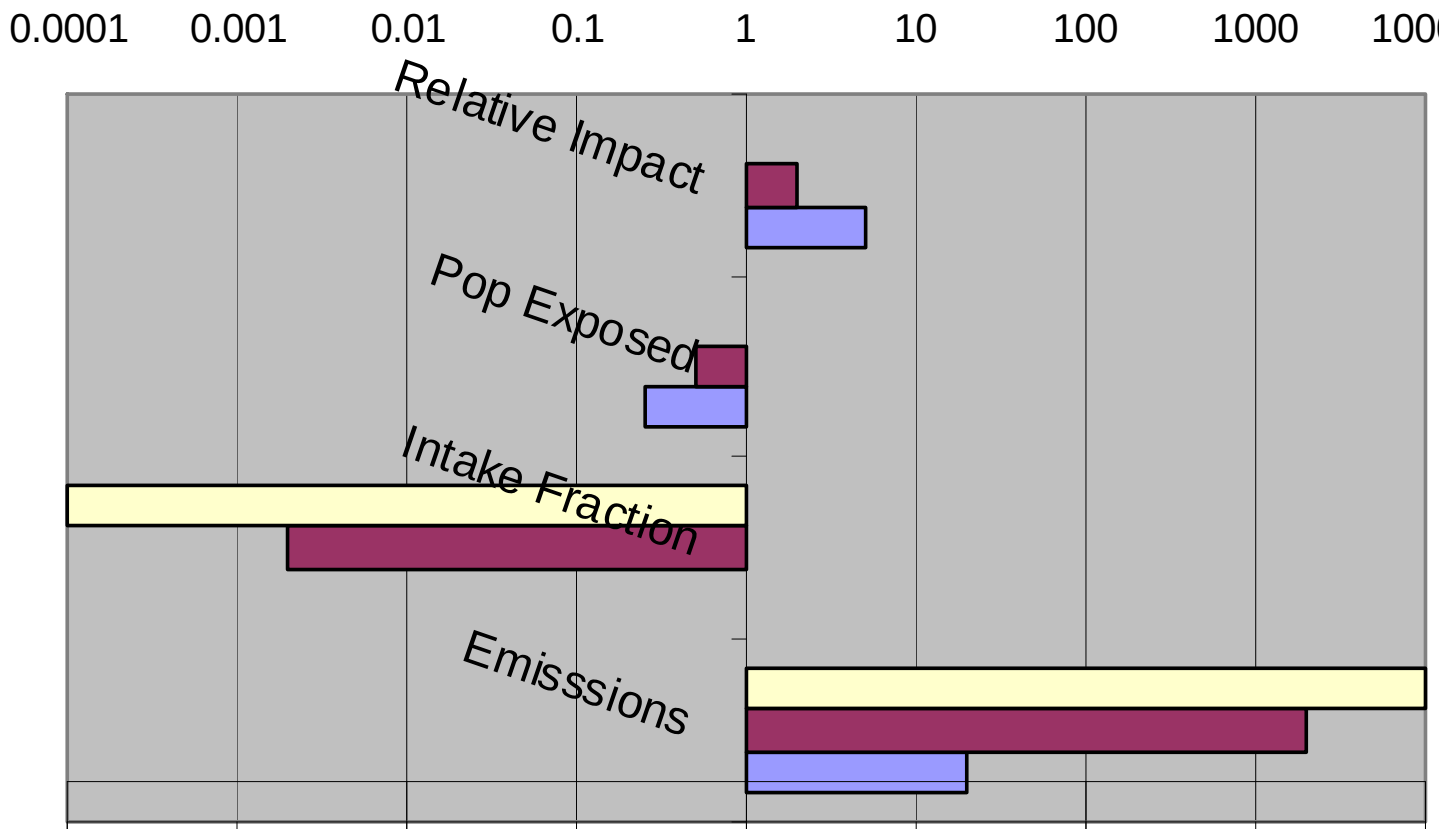
IF = 1.0

Intake Fractions : these are rough calculations for typical examples of sources in each class



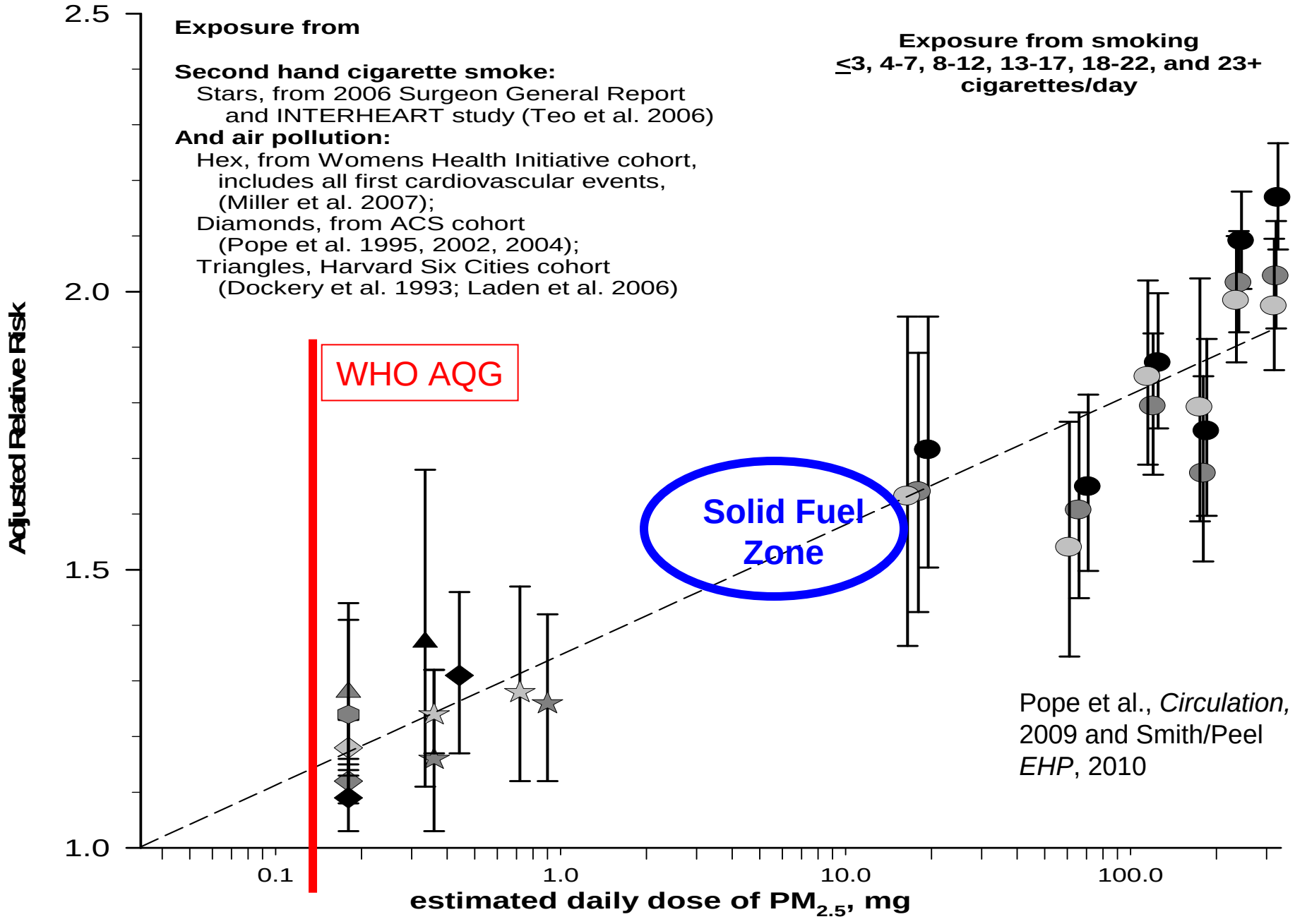
Smith, 1993

Grams Inhaled per Ton Emitted



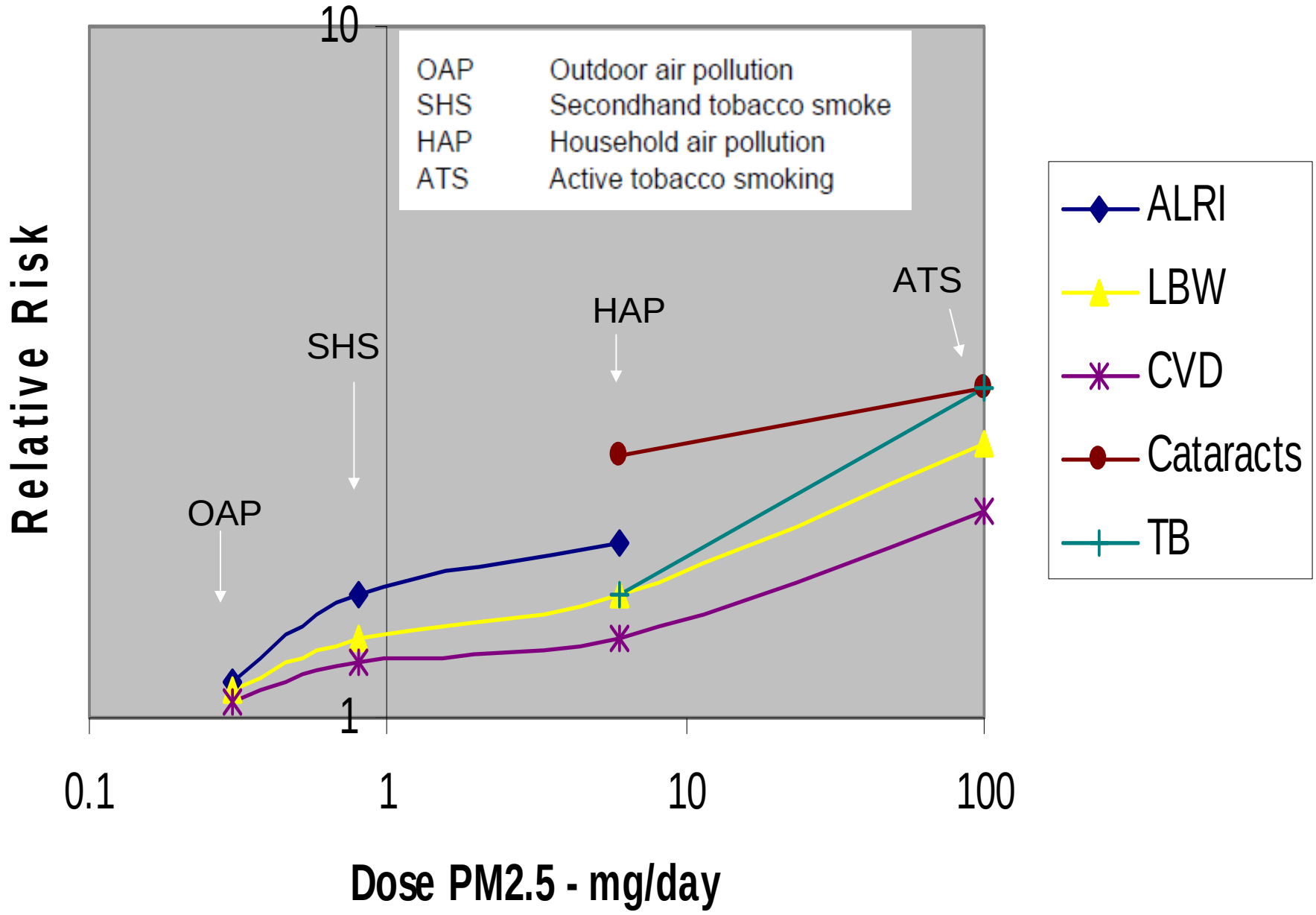
	Emisssions	Intake Fraction	Pop Exposed	Relative Impact
OAP	10000	1.00E-04	1	1
HAP	2000	2.00E-03	0.5	2
Smoking	20	1	0.25	5

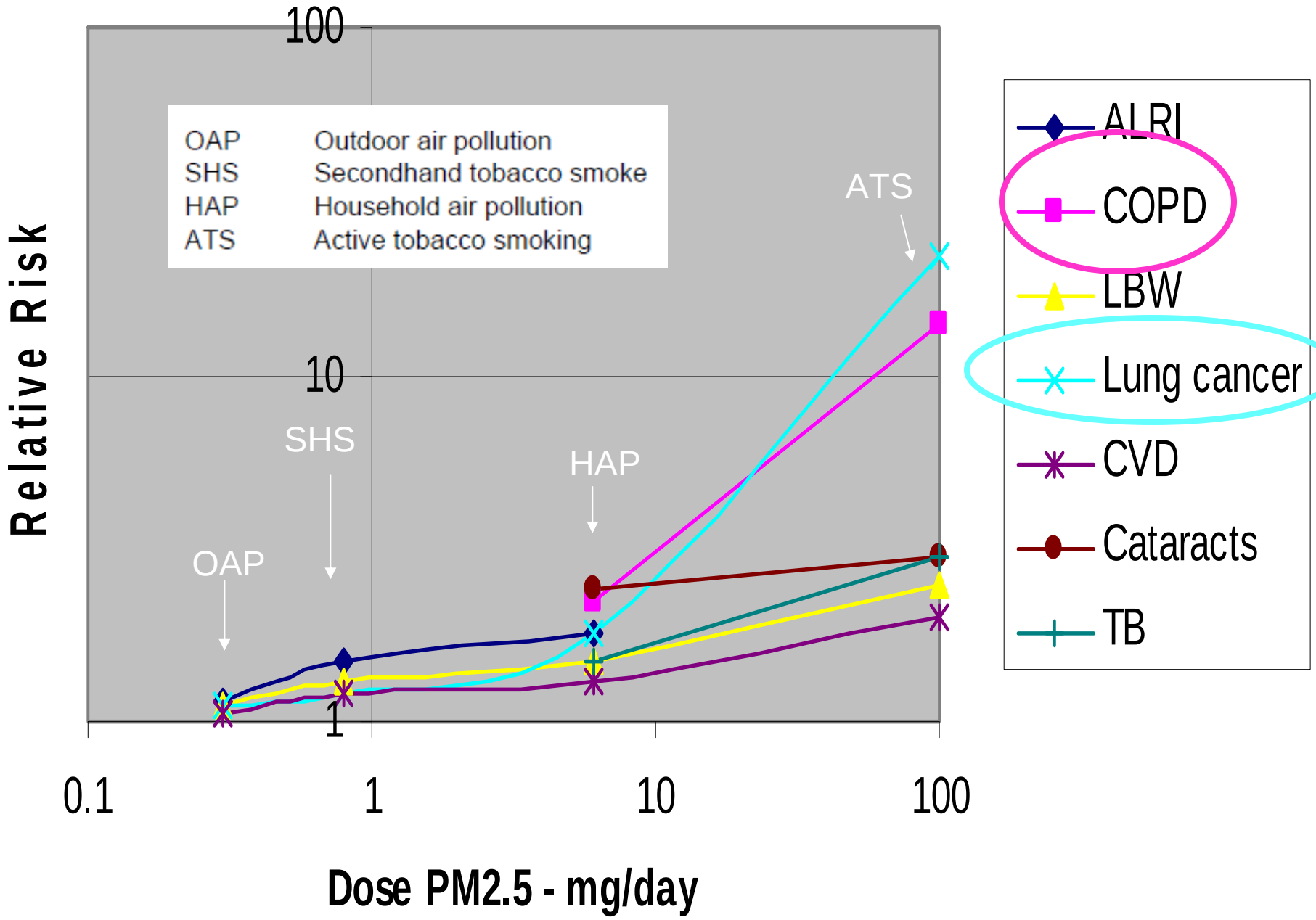
Heart Disease and Combustion Particle Doses



Argument from consistency across combustion particle exposure settings

- Assumes fine combustion particles are best measure of risk in each setting and have similar effects per unit mass across the four source types
  - Three are mainly biomass
  - OAP contains significant biomass particles
  - Probably difference by outcome, however – e.g., LBW and lung cancer may be related to other components as well
- Remarkable consistency across 3 orders of magnitude of dose measured in mg/day of $PM_{2.5}$
- Where HAP has no direct epi data, seems reasonable to interpolate for outcomes where there are well established effects at both lower and higher doses.


10
1
OAP Outdoor air pollution
SHS Secondhand tobacco smoke
HAP Household air pollution
ATS Active tobacco smoking
OAP
SHS
HAP
ATS
Relative Risk
0.1
1
10
100
Dose PM2.5 - mg/day
ALRI
LBW
CVD
Cataracts
TB


100
10
1
0.1
1
10
100
Relative Risk
Dose PM2.5 - mg/day
OAP Outdoor air pollution
SHS Secondhand tobacco smoke
HAP Household air pollution
ATS Active tobacco smoking
OAP
SHS
HAP
ATS
ALRI
COPD
LBW
Lung cancer
CVD
Cataracts
TB

Wood is the fuel that

- Heats you twice as Thoreau said?
  - Once when you chop it and
  - Once when you burn it
- Or four times?
  - The fever from respiratory infection and
  - Global warming
- Better combustion will get rid of the second pair

Many thanks

Publications and presentations available at my website: http://ehs.sph.berkeley.edu/krsmith/

Or just Google “Kirk R. Smith”