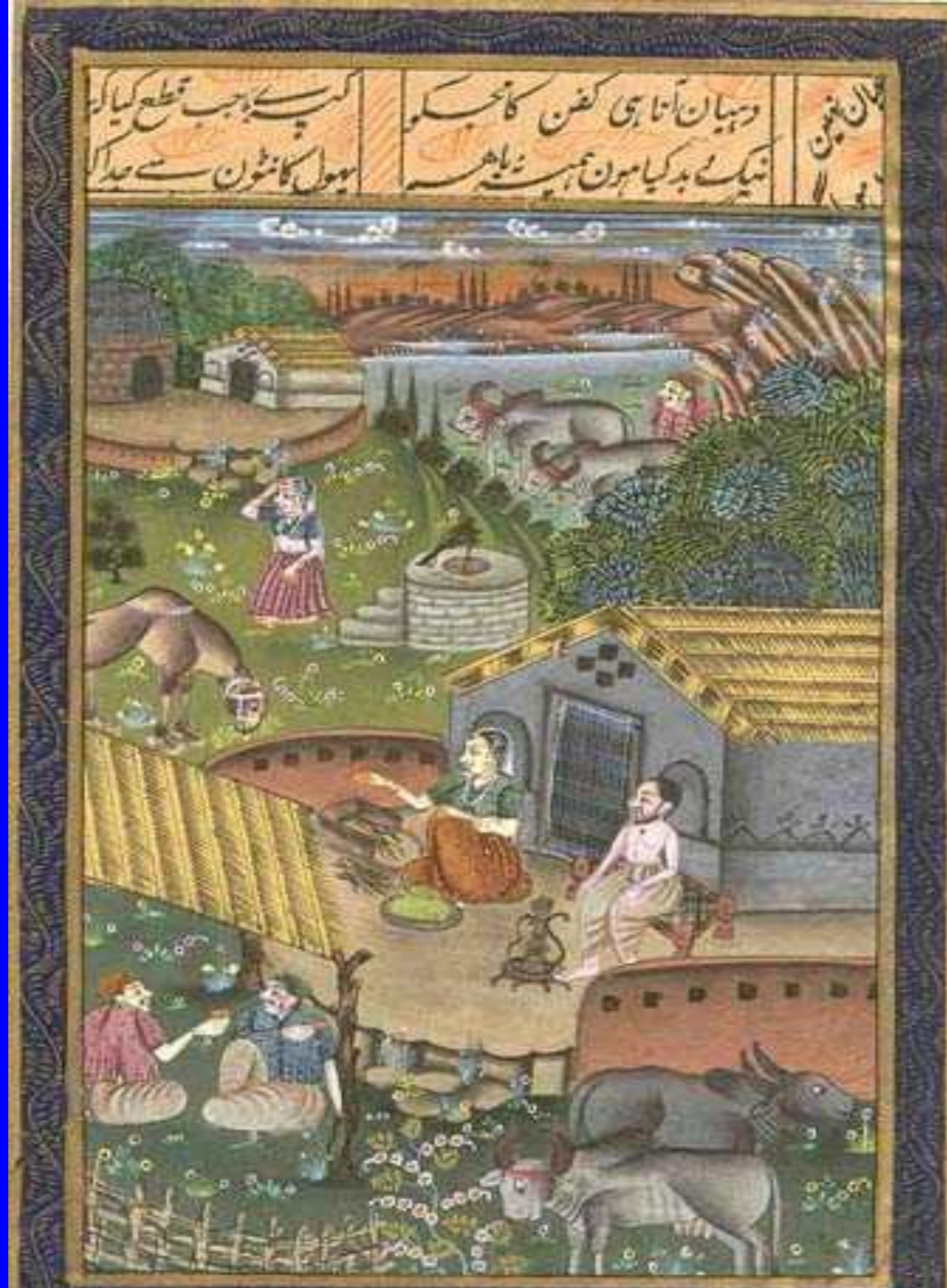


COOKFIRES, CLIMATE, AND HEALTH:

THE UNFINISHED AGENDA OF INCOMPLETE COMBUSTION

Kirk R. Smith
Professor of Global
Environmental Health
University of California
Berkeley

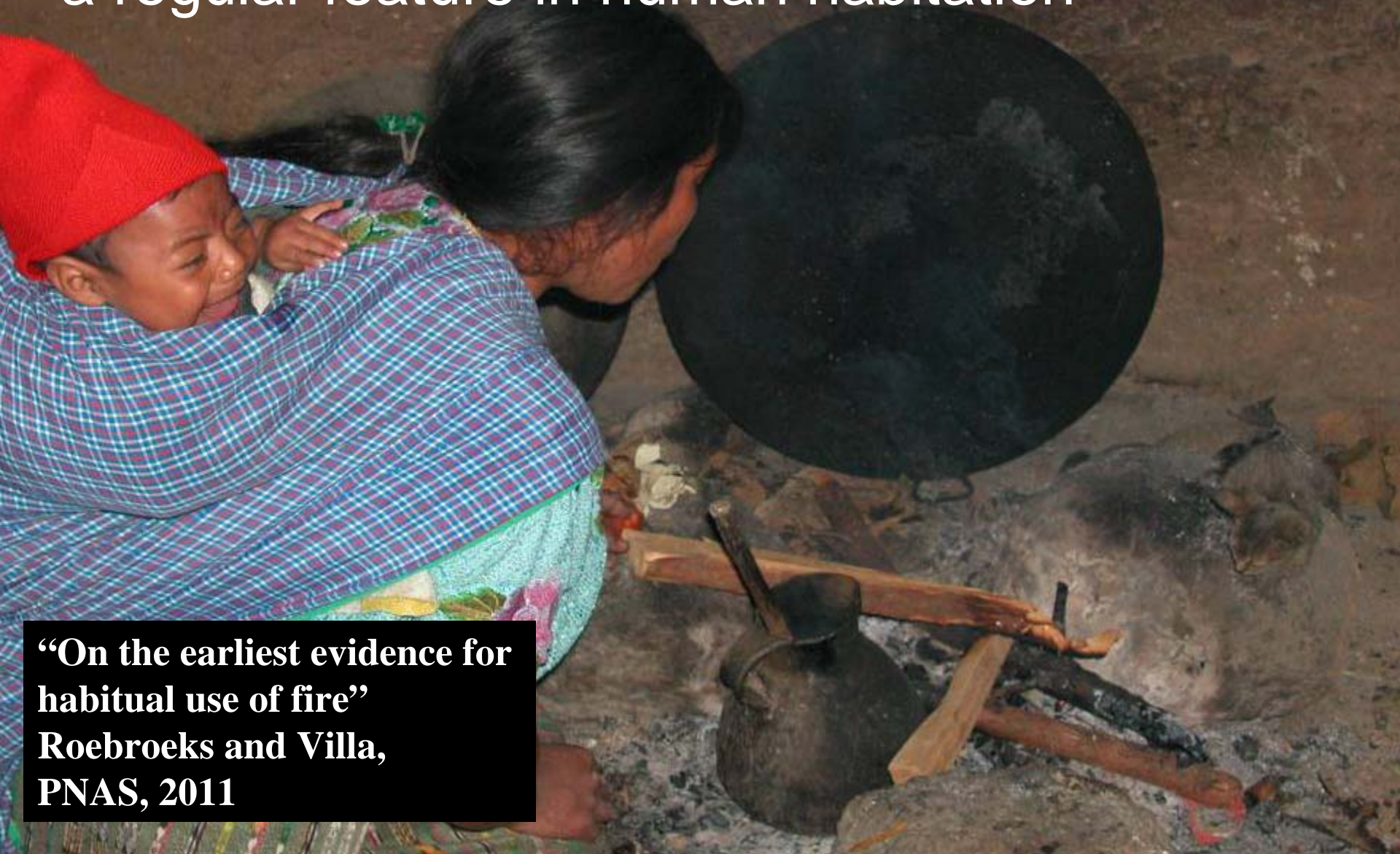
TERI University
Dehi, Sept 21, 2011



Road Map

- Why a problem?
- What health effects are found?
- What are climate implications?
- Importance of monitoring
- Principles for moving forward

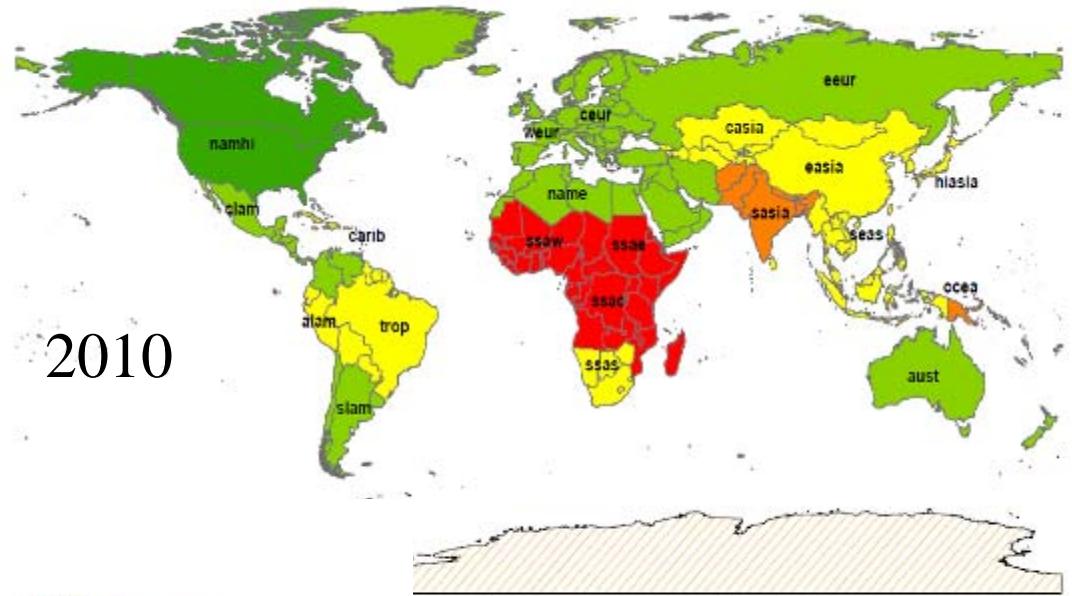
300-400 thousand years ago, hearths became
a regular feature in human habitation



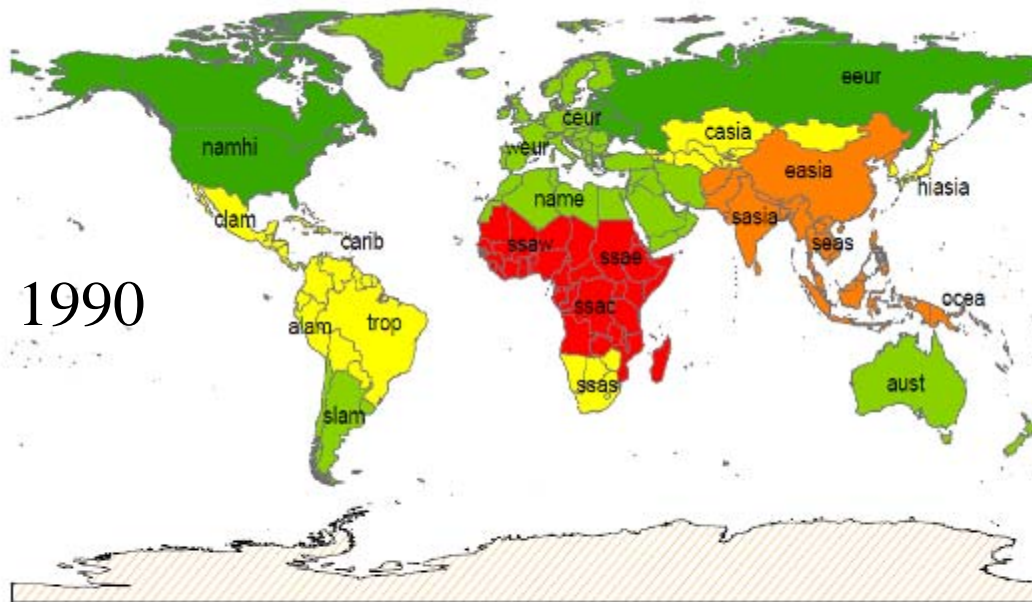
**“On the earliest evidence for
habitual use of fire”
Roebroeks and Villa,
PNAS, 2011**

Households using biomass or coal to cook

2010



1990



% of HH Exposed to HAP

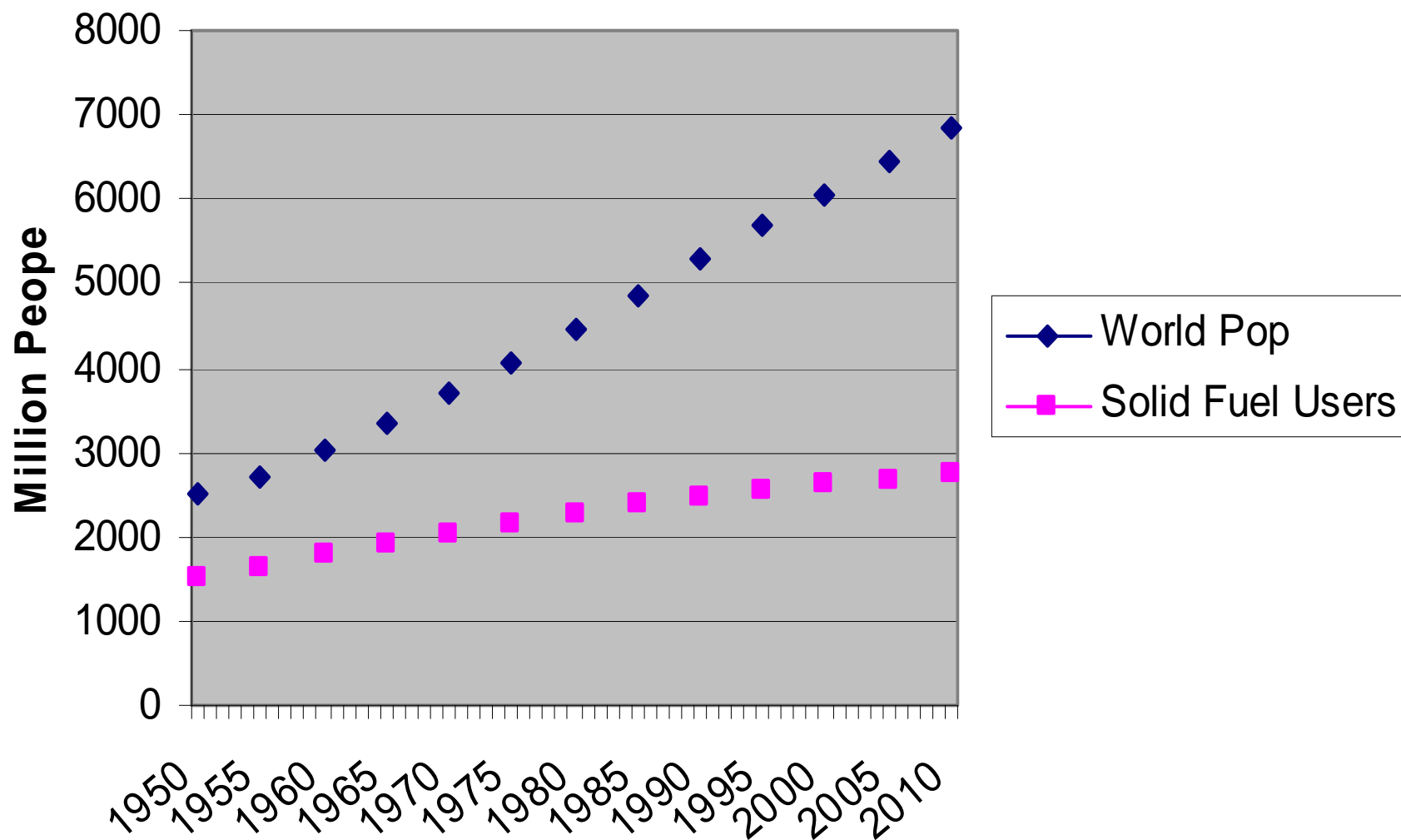


**Comparative Risk
Assessment (CRA)
2011- preliminary,
Adair, et al.**

The three major solid fuels



World Population Using Solid Fuels



Biomass Cooking in History

- Today, ~43% use solid fuels, about 3 billion people
- Although the percentage is dropping, the absolute number is still rising.
- Perhaps 20 million people a year are added to the total each year.
- Indeed, there are more people using solid fuels today for cooking than the total world population in 1950
- Or any year previously

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)?

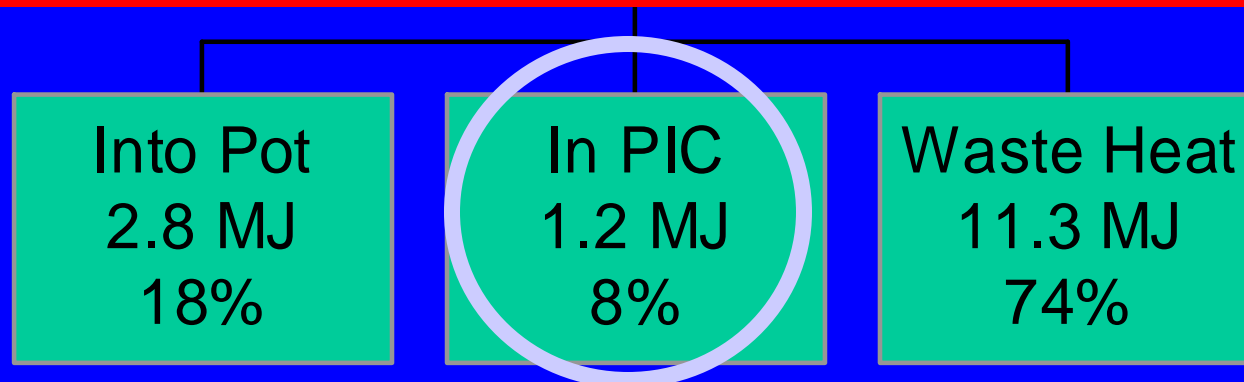


Reason: the combustion efficiency is far less than 100%

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

Source: Naeher et al,
J Inhal Tox, 2007

- Small particles, CO, NO₂
- Hydrocarbons
 - 25+ saturated hydrocarbons such as *n-hexane*
 - 40+ unsaturated hydrocarbons such as *1,3 butadiene*
 - 28+ mono-aromatics such as *benzene & styrene*
 - 20+ polycyclic aromatics such as *benzo(α)pyrene*
- Oxygenated organics
 - 20+ aldehydes including *formaldehyde & acrolein*
 - 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*

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

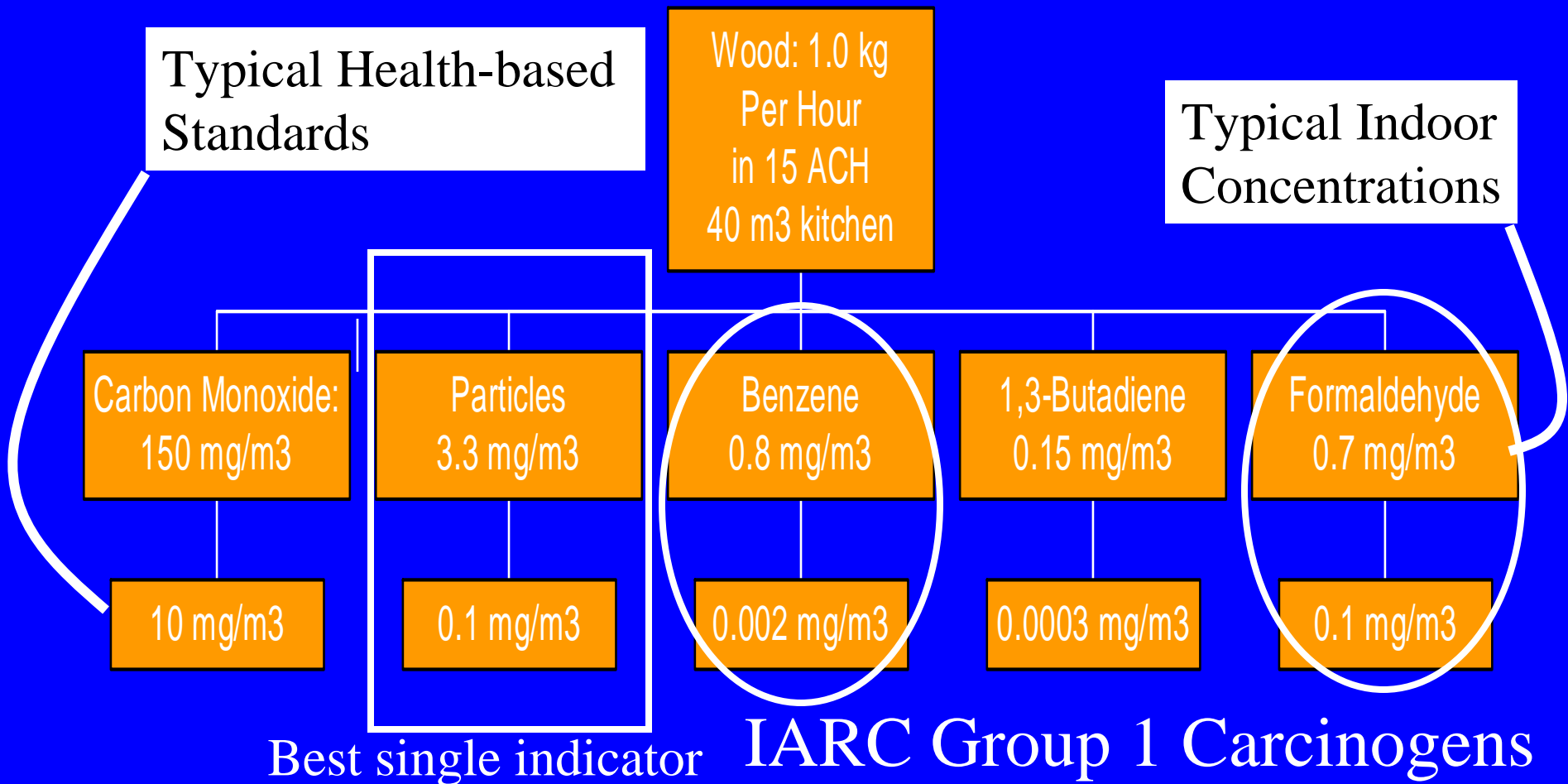
Organics known to be mutagens, immune system suppressants, severe irritants, inflammation agents, central nervous system depressants, cilia toxins, endocrine disrupters, or neurotoxins.

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.



First person in human history to have her exposure measured doing the oldest task in human history

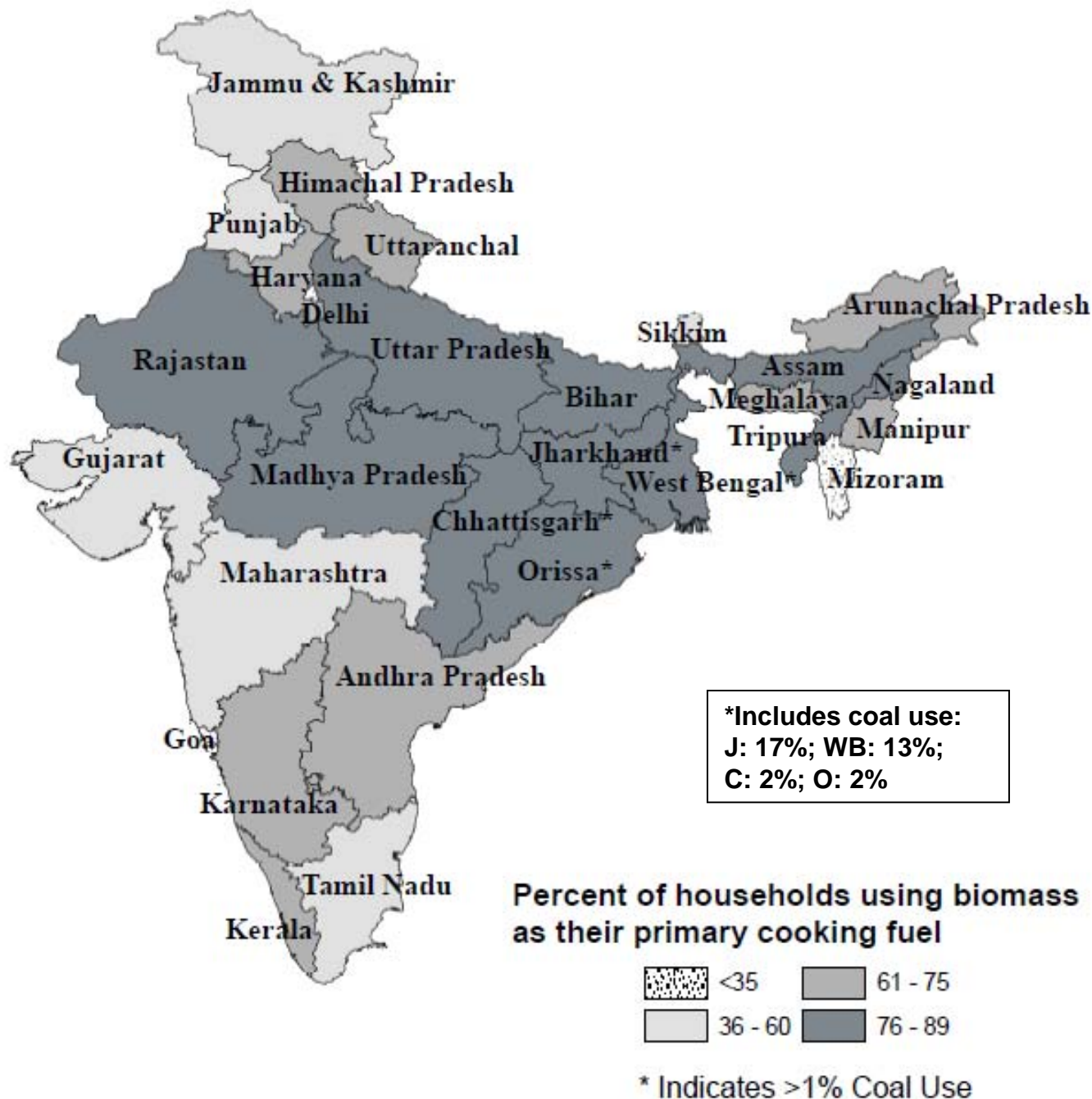
Emissions, yes,
but what about
exposures?

Kheda District,
Gujarat, 1981



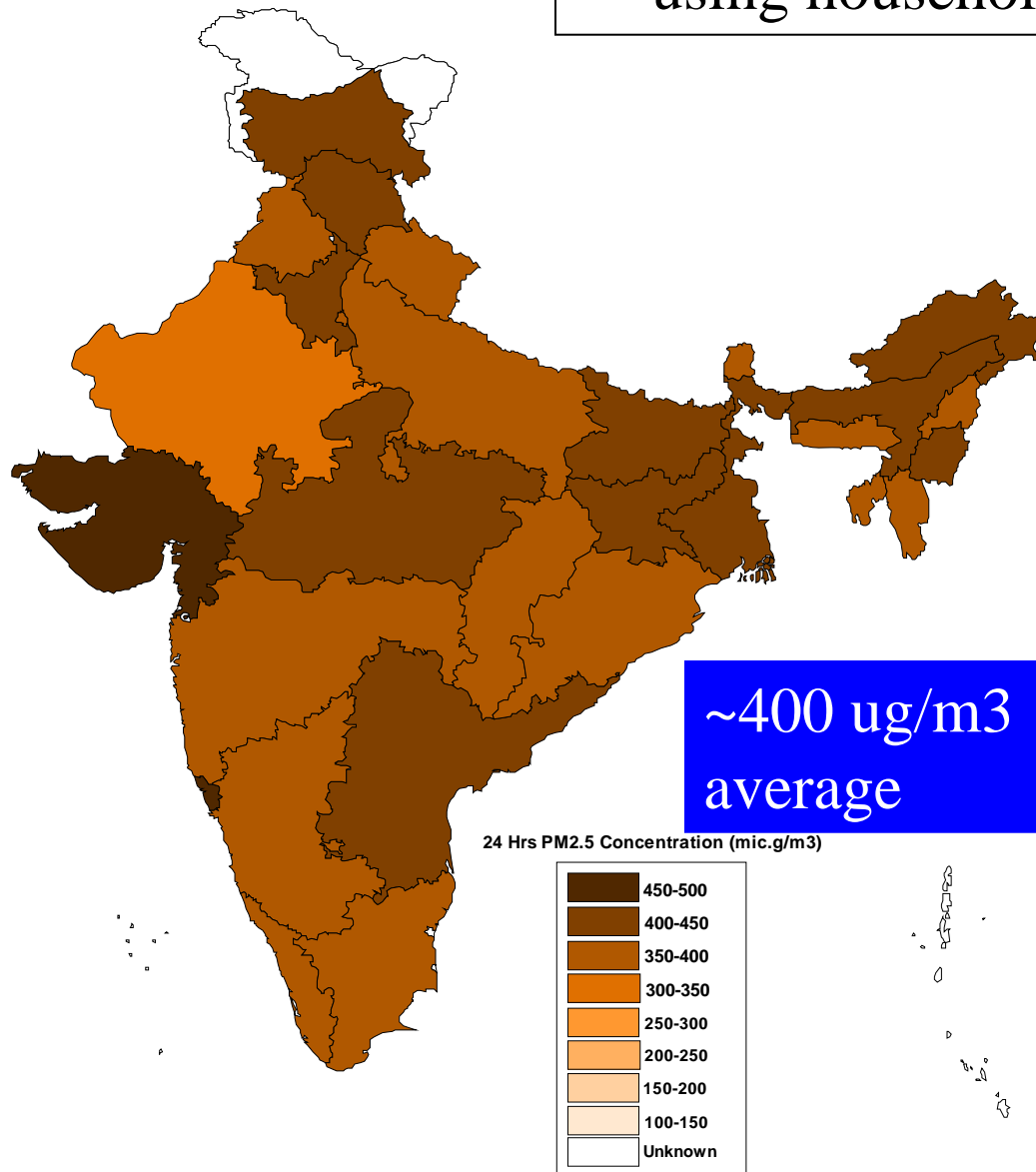
India in 2005

71%
households
use solid fuel
for cooking



Venkataraman
et al. 2010

Estimated PM_{2.5} for solid fuel using households in India



USEPA Standard
15 ug/m³

WHO Guideline
10-35 ug/m³

~400 ug/m³
average

Preliminary
result from
CRA

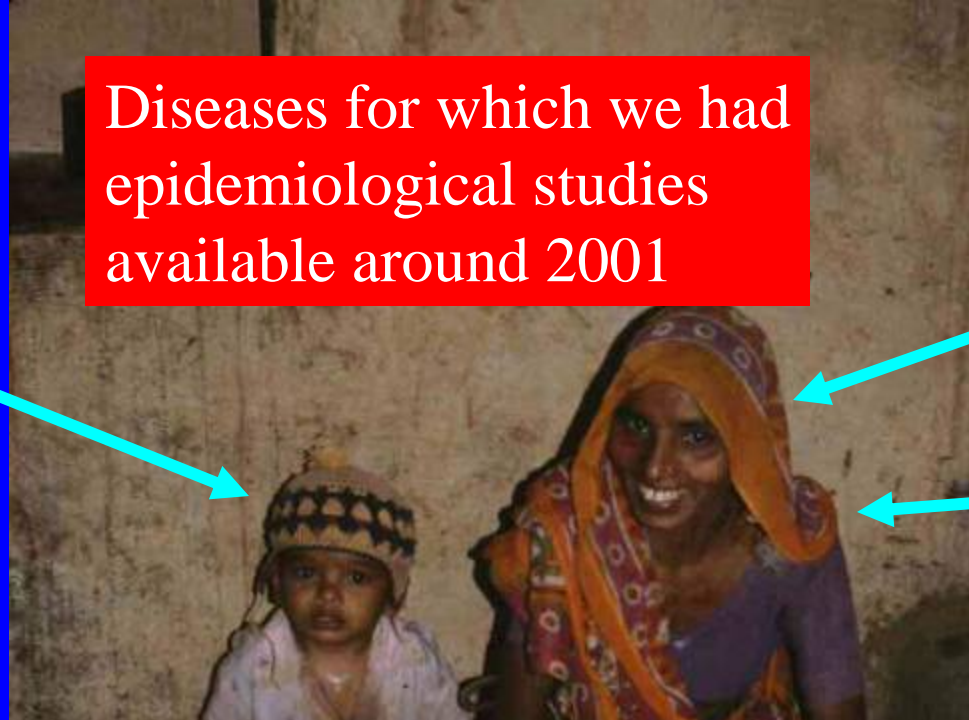
Balakrishnan
et al.

Diseases for which we had
epidemiological studies
available around 2001

ALRI/
Pneumonia

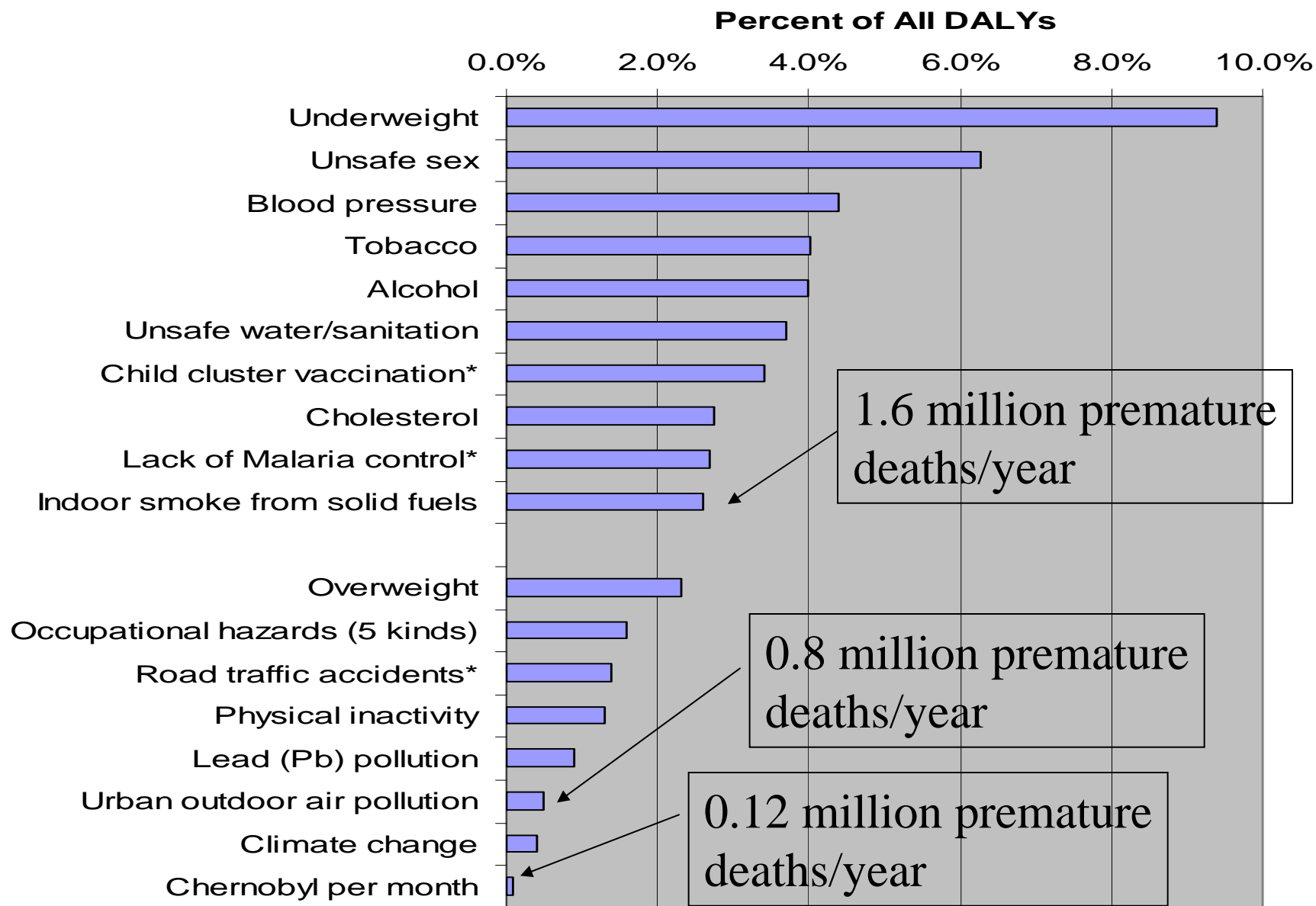
Chronic
obstructive
lung disease

Lung cancer
from coal only

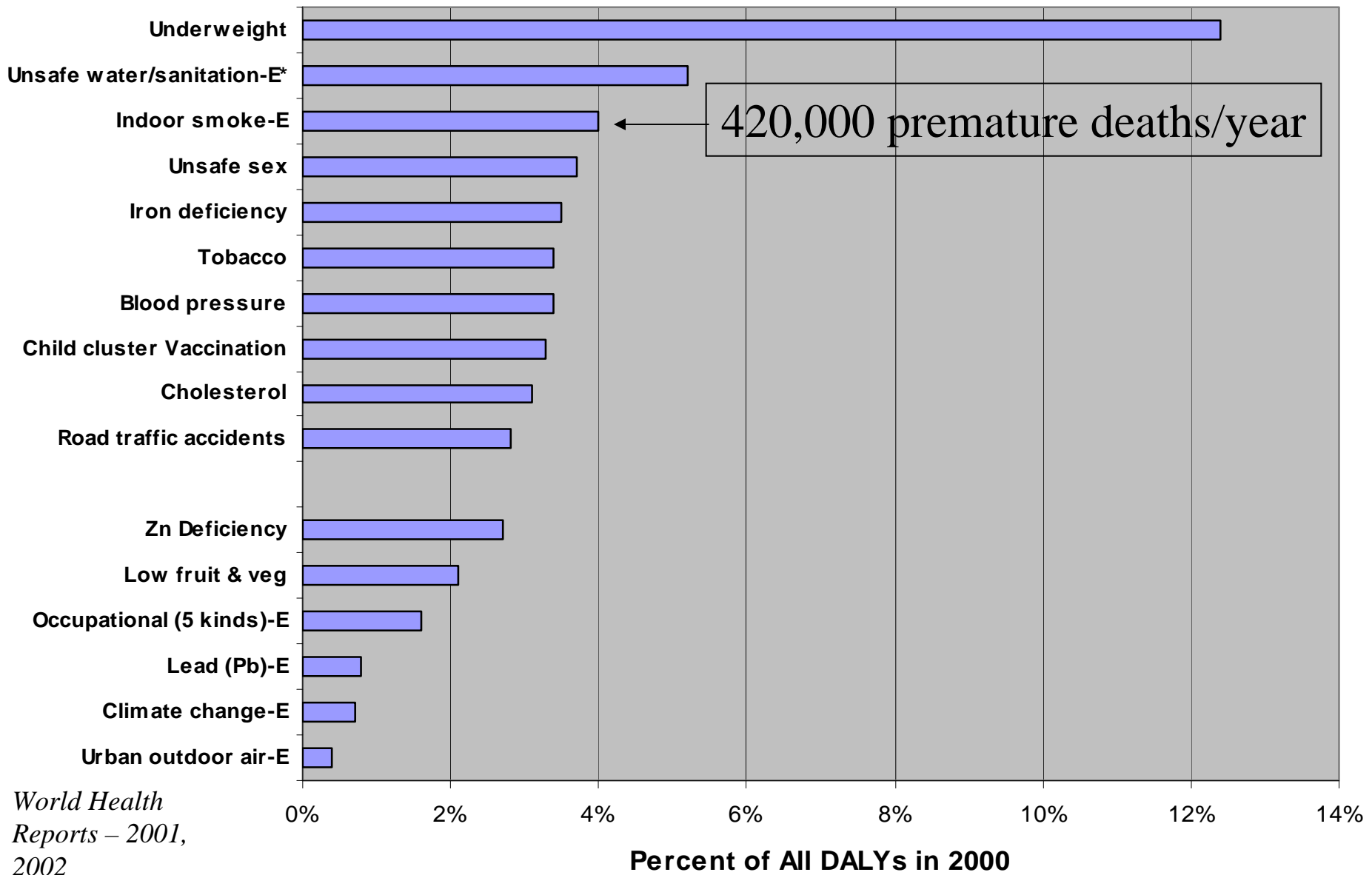


Three outcomes qualified
with sufficient evidence to be
included in the WHO CRA
of 2004

Global Burden of Disease from Top 10 Risk Factors plus selected other risk factors



Indian Burden of Disease from Top 10 Risk Factors and Selected Other Risk Factors



| File Edit View Insert Format Tools Data Window Help Adobe PDF | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|------------|-----------|----------|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----|---|---|
| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y |
| 1 | Population (thousands) | | | | | 6224984.81 | 317077.27 | 622741.78 | 817442.67 | 662866.38 | 427071.29 | 166160.20 | 30443.11 | 26149.24 | 317072.05 | 301091.79 | 589228.74 | 782026.21 | 646518.90 | 427846.74 | 181806.42 | 181 | | |
| 2 | GBD 2002: DALYs by age, sex and cause for the year 2002 | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | WORLD | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | Code | Cause | Total | 0-4 | 5-14 | 15-29 | 30-44 | 45-59 | 60-69 | 70-79 | 80+ | Total | 0-4 | 5-14 | 15-29 | 30-44 | 45-59 | 60-69 | | | | | | |
| 6 | U000 | All Causes | 1490125643 | 222552079 | 56142418 | 141637847 | 130501742 | 115374678 | 60641455 | 36229210 | 3832834 | 712912264 | 211279454 | 54553890 | 141633214 | 108257333 | 90621463 | 53460940 | 40 | | | | | |
| 7 | U001 | I. Communicable, maternal, perinatal and nutritional conditions | 616319250 | 8888888 | 26975612 | 25721869 | 56146775 | 16651072 | 5676054 | 2913759 | 645869 | 8888888 | 8888888 | 25246712 | 53740250 | 35379204 | 11499502 | 4476564 | 25 | | | | | |
| 8 | U002 | A. Infectious and parasitic diseases | 350332571 | 879777510 | 12810197 | 25516201 | 33372707 | 14085712 | 3710016 | 1519252 | 315539 | 179307135 | 89749119 | 13534884 | 31549467 | 23070592 | 8616676 | 2658113 | 14 | | | | | |
| 9 | U003 | 1. Tuberculosis | 34735908 | 839261 | 782431 | 5497848 | 7335503 | 4868489 | 1832663 | 658401 | 90612 | 21905208 | 738745 | 821735 | 4163278 | 3822011 | 2041939 | 833205 | 3 | | | | | |
| 10 | U004 | 2. STDs excluding HIV | 11347067 | 1521528 | 26245 | 1080828 | 660600 | 423721 | 103004 | 31641 | 7415 | 3854983 | 1726606 | 97221 | 1158088 | 1147558 | 260537 | 71612 | 3 | | | | | |
| 11 | U005 | a. Syphilis | 4200039 | 1039452 | 2292 | 151945 | 285546 | 354596 | 99162 | 30394 | 6987 | 1970375 | 1265722 | 3432 | 521758 | 262487 | 107605 | 42492 | 3 | | | | | |
| 12 | U006 | b. Chlamydia | 3571404 | 1199 | 7209 | 241593 | 50929 | 1169 | 136 | 0 | 0 | 302234 | 1152 | 69338 | 2635460 | 439449 | 109658 | 14084 | 3 | | | | | |
| 13 | U007 | c. Gonorrhoea | 3365159 | 462945 | 16559 | 692964 | 201215 | 6664 | 719 | 91 | 2 | 1472160 | 147789 | 24323 | 989323 | 422675 | 6262 | 1616 | 3 | | | | | |
| 14 | U008 | d. Other STDs | 2104 | | | | | | | | | | | 127 | 11546 | 22947 | 37012 | 13420 | 3 | | | | | |
| 15 | U009 | 3. HIV/AIDS | 844577 | | | | | | | | | | | 1878957 | 17299389 | 13746555 | 2624463 | 230670 | 3 | | | | | |
| 16 | U010 | 4. Diarrhoeal diseases | 619661 | | | | | | | | | | | 754533 | 652616 | 545936 | 373258 | 201900 | 1 | | | | | |
| 17 | U011 | 5. Childhood-cluster diseases | 414795 | | | | | | | | | | | 1447659 | 172987 | 53966 | 19174 | 4837 | 3 | | | | | |
| 18 | U012 | a. Pertussis | 12594 | | | | | | | | | | | 50717 | 34 | 0 | 13 | 0 | 3 | | | | | |
| 19 | U013 | b. Poliomyelitis | 1506 | | | | | | | | | | | 8675 | 28237 | 16931 | 3822 | 615 | 3 | | | | | |
| 20 | U014 | c. Diphtheria | 184 | | | | | | | | | | | 19365 | 523 | 386 | 572 | 29 | 3 | | | | | |
| 21 | U015 | d. Measles | 214754 | | | | | | | | | | | 1269212 | 84741 | 29 | 30 | 0 | 3 | | | | | |
| 22 | U016 | e. Tetanus | 70736 | | | | | | | | | | | 98690 | 59452 | 36620 | 14737 | 4192 | 3 | | | | | |
| 23 | U017 | 6. Meningitis* | 61917 | | | | | | | | | | | 734345 | 341757 | 167759 | 110215 | 48775 | 3 | | | | | |
| 24 | U018 | 7. Hepatitis B | 21703 | | | | | | | | | | | 62506 | 173729 | 115391 | 110437 | 36630 | 3 | | | | | |
| 25 | U019 | Hepatitis C | 10036 | | | | | | | | | | | 24200 | 67867 | 53705 | 61307 | 30322 | 3 | | | | | |
| 26 | U020 | 8. Malaria | 464858 | | | | | | | | | | | 601958 | 689661 | 453207 | 280704 | 99111 | 3 | | | | | |
| 27 | U021 | 9. Tropical-cluster diseases | 122454 | | | | | | | | | | | 1203242 | 1297027 | 593336 | 496341 | 75537 | 3 | | | | | |
| 28 | U022 | a. Trypanosomiasis | 15254 | | | | | | | | | | | 237244 | 149181 | 79329 | 46509 | 3694 | 3 | | | | | |
| 29 | U023 | b. Chagas disease | 6667 | | | | | | | | | | | 193 | 198737 | 51644 | 48058 | 15987 | 3 | | | | | |
| 30 | U024 | c. Schistosomiasis | 17017 | | | | | | | | | | | 221149 | 232053 | 128589 | 58850 | 17056 | 3 | | | | | |
| 31 | U025 | d. Leishmaniasis | 20896 | | | | | | | | | | | 367279 | 246063 | 67203 | 30097 | 11647 | 3 | | | | | |
| 32 | U026 | e. lymphatic filariasis | 57774 | | | | | | | | | | | 349733 | 425651 | 206680 | 266630 | 15772 | 3 | | | | | |
| 33 | U027 | f. Onchocerciasis | 4842 | | | | | | | | | | | 27645 | 45343 | 59892 | 46198 | 11380 | 3 | | | | | |
| 34 | U028 | 10. Leprosy | 1987 | | | | | | | | | | | 23264 | 16689 | 15828 | 9135 | 4389 | 3 | | | | | |
| 35 | U029 | 11. Dengue | 6155 | | | | | | | | | | | 215987 | 23174 | 10408 | 6396 | 2644 | 3 | | | | | |
| 36 | U030 | 12. Japanese encephalitis | 709219 | 100148 | 92418 | 61558 | 70268 | 9948 | 2292 | 1205 | 279 | 338116 | 160556 | 131203 | 41495 | 26926 | 7282 | 2513 | 3 | | | | | |
| 37 | U031 | 13. Trachoma | 2328780 | 1861 | 2594 | 32532 | 183952 | 201068 | 111206 | 597093 | 10162 | 597093 | 1973 | 7118 | 68754 | 517423 | 559520 | 344796 | 1 | | | | | |
| 38 | U032 | 14. Intestinal nematode infections | 2951341 | 257716 | 1196068 | 14526 | 7512 | 8174 | 4301 | 1450 | 492 | 1490238 | 273831 | 1158847 | 12068 | 5192 | 5921 | 3469 | 3 | | | | | |
| 39 | U033 | a. Ascariasis | 1816942 | 157488 | 751279 | 695 | 270 | 222 | 11 | 15 | 40 | 910021 | 171105 | 735150 | 311 | 161 | 21 | 111 | 3 | | | | | |
| 40 | U034 | b. Trichuriasis | 1006248 | 82408 | 432805 | 1371 | 908 | 699 | 367 | 108 | 27 | 518693 | 74437 | 411117 | 823 | 388 | 433 | 238 | 3 | | | | | |
| 41 | U035 | c. Hookworm disease | 58617 | 339 | 3937 | 11312 | 5396 | 5924 | 3091 | 1074 | 262 | 31336 | 0 | 4583 | 9796 | 4212 | 4859 | 2723 | 3 | | | | | |
| 42 | U036 | Other intestinal infections | 69534 | 17481 | 8047 | 1148 | 937 | 1329 | 831 | 252 | 163 | 30188 | 28290 | 7997 | 1138 | 432 | 607 | 397 | 3 | | | | | |
| 43 | U037 | Other infectious diseases | 41445320 | 8567237 | 2450753 | 2311612 | 2584703 | 2021325 | 757612 | 461907 | 118307 | 19273457 | 10586539 | 4372108 | 2370886 | 1795391 | 1650048 | 667703 | 3 | | | | | |
| 44 | U038 | B. Respiratory infections | 94603349 | 32429989 | 6247258 | 2411409 | 1749936 | 1847020 | 1735082 | 1261667 | 494366 | 48176727 | 30184256 | 6903318 | 2987156 | 1481589 | 1357246 | 1460806 | 13 | | | | | |
| 45 | U039 | 1. Lower respiratory infections | 91373521 | 31836027 | 5573644 | 2310964 | 1655193 | 1773743 | 1682121 | 1232996 | 482877 | 48547564 | 29539590 | 6167276 | 2198287 | 1434738 | 1329549 | 1425397 | 3 | | | | | |
| 46 | U040 | 2. Upper respiratory infections | 1795292 | 458484 | 84253 | 86969 | 82518 | 70655 | 51526 | 28370 | 11405 | 874181 | 513743 | 201270 | 59304 | 45228 | 26339 | 34405 | 3 | | | | | |
| 47 | U041 | 3. Otitis media | 1434536 | 135477 | 589362 | 13476 | 12225 | 2623 | 1435 | 300 | 84 | 754982 | 130923 | 534772 | 9565 | 1622 | 1358 | 1004 | 3 | | | | | |
| 48 | U042 | C. Maternal conditions | 33631593 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 226832 | 23053758 | 9947305 | 403615 | 19 | 3 | | | | | |
| 49 | U043 | 1. Maternal haemorrhage | 4437585 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 332 | 2359228 | 1944088 | 133887 | 0 | 3 | | | | | |
| 50 | U044 | 2. Maternal sepsis | 6903085 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 144 | 5204511 | 1625431 | 72999 | 0 | 3 | | | | | |
| 51 | U045 | 3. Hypertensive disorders* | 2162701 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 975 | 1398598 | 722909 | 40216 | 0 | 3 | | | | | |
| 52 | U046 | 4. Obstructed labour | 3048291 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2241561 | 794568 | 12162 | 0 | 3 | | | | | |
| 53 | U047 | 5. Abortion | 4652171 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 223411 | 3721304 | 705860 | 1536 | 0 | 3 | | | | | |
| 54 | U048 | Other maternal conditions | 12427759 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1970 | 8128555 | 4154451 | 142755 | 19 | 3 | | | | | |
| 55 | U049 | D. Perinatal conditions* | 97335086 | 53209265 | 1343 | 1031 | 347 | 89 | 12 | 9 | 0 | 53212095 | 44121066 | 1195 | 498 | 158 | 34 | 29 | 3 | | | | | |
| 56 | U050 | 1. Low birth weight | 46334234 | 25061999 | 52 | 13 | 20 | 0 | 9 | 0 | 0 | 25062092 | 21272111 | 51 | 0 | 0 | 0 | 0 | 3 | | | | | |
| 57 | U051 | 2. Birth asphyxia and birth trauma | 34445758 | 19353003 | 790 | 302 | 73 | 33 | 3 | 0 | 0 | 19354204 | 15090851 | 373 | 107 | 0 | 15 | 0 | 3 | | | | | |
| 58 | U052 | Other perinatal conditions | 16555094 | 8794262 | 502 | 716 | 253 | 56 | 0 | 9 | 0 | 8795799 | 7758104 | 591 | 392 | 158 | 19 | 29 | 3 | | | | | |
| 59 | U053 | E. Nutritional deficiencies | 34416632 | 10258276 | 1921013 | 1793247 | 1025783 | 698252 | 230984 | 132931 | 39983 | 16100369 | 10385030 | 2582483 | 2149411 | 1479558 | 1121930 | 357998 | 1 | | | | | |
| 60 | U054 | 1. Protein-energy malnutrition | 16910328 | 7556012 | 560106 | 156056 | 69278 | 103279 | 7114 | 45451 | 18671 | 8579966 | 7350453 | 620870 | 66437 | 68728 | 8148 | 70683 | 3 | | | | | |
| 61 | U055 | 2. Iodine deficiency | 3519322 | 1283895 | 471857 | 528 | 748 | 1215 | 641 | 236 | 50 | 1759171 | 1305105 | 450178 | 1681 | 1046 | 1287 | 439 | 3 | | | | | |
| 62 | U056 | 3. Vitamin A deficiency | 792562 | 257306 | 84825 | 3330 | 6358 | 7864 | 3519 | 983 | 100 | 364284 | 320394 | 84034 | 10506 | 3807 | 6687 | 3 | | | | | | |

Global Burden of Disease Database and Comparative Risk Assessment

Being completely updated for late 2011 release

Start

Eudora - [In]

5 Microsoft Office ...

12 Microsoft Office...

5 Microsoft Office...

Windows Media Player

WHO Statistical Infor...

Type to search

9:36 AM

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?



Summary of Endpoints in New CRA for Household Air Pollution

- New estimates for diseases in previous CRA
 - Pneumonia in children
 - COPD in adults (male and female)
 - Lung cancer in adults (male and female)
- Diseases now included
 - Low birth weight
 - Cataracts
 - Heart disease
- Still unclear – not included
 - TB
 - Asthma
 - Other cancers

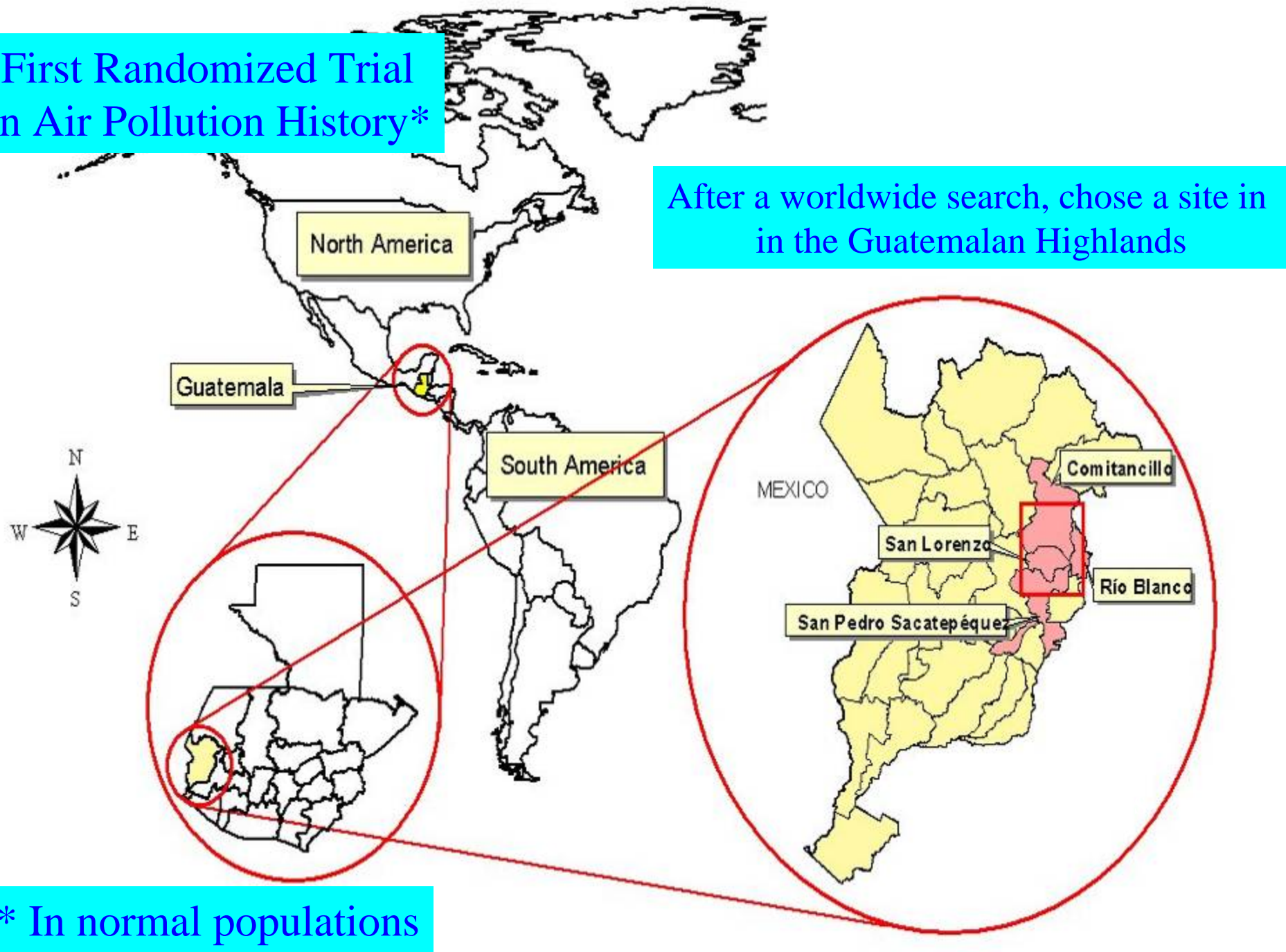
Story of Two Conferences

- 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

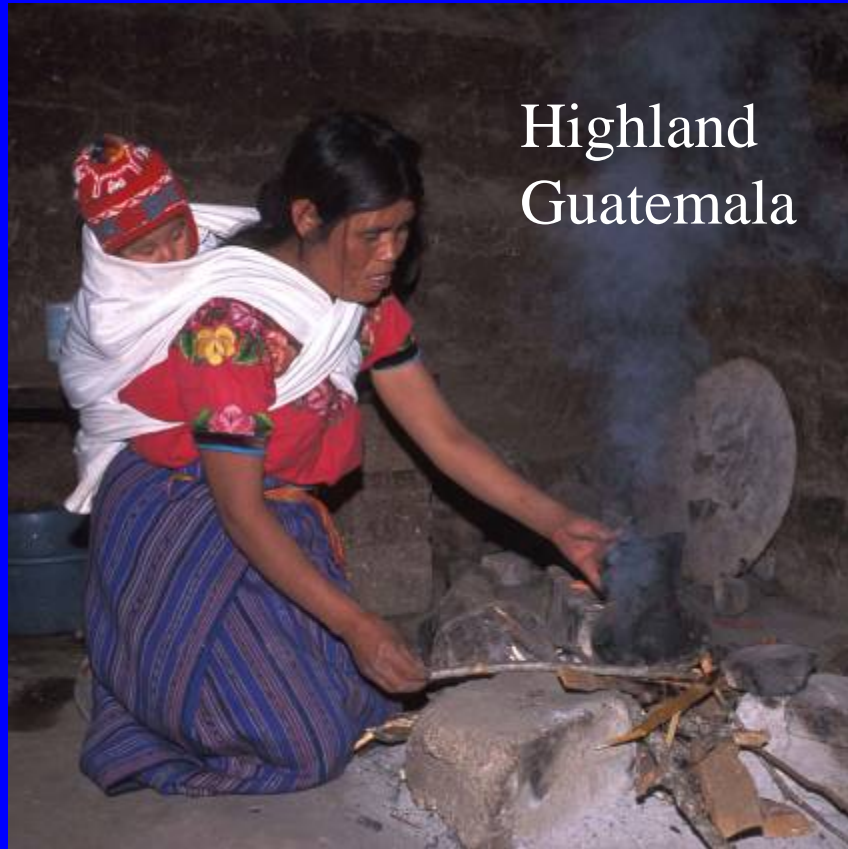
- ~1980: Early studies of health effects in Nepal and elsewhere
- 1981: First measurements of pollution levels in India
- 1984: International meeting to decide on needed research
 - Chose randomized control trial (RCT) of ALRI
- 1986-89: Unfunded proposals to do RCT in Nepal
- 1990: WHO establishes committee 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 – in press Sep
- 25+ years from deciding to conduct RCT to results!

First Randomized Trial In Air Pollution History*



* In normal populations

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



Traditional 3-stone open fire

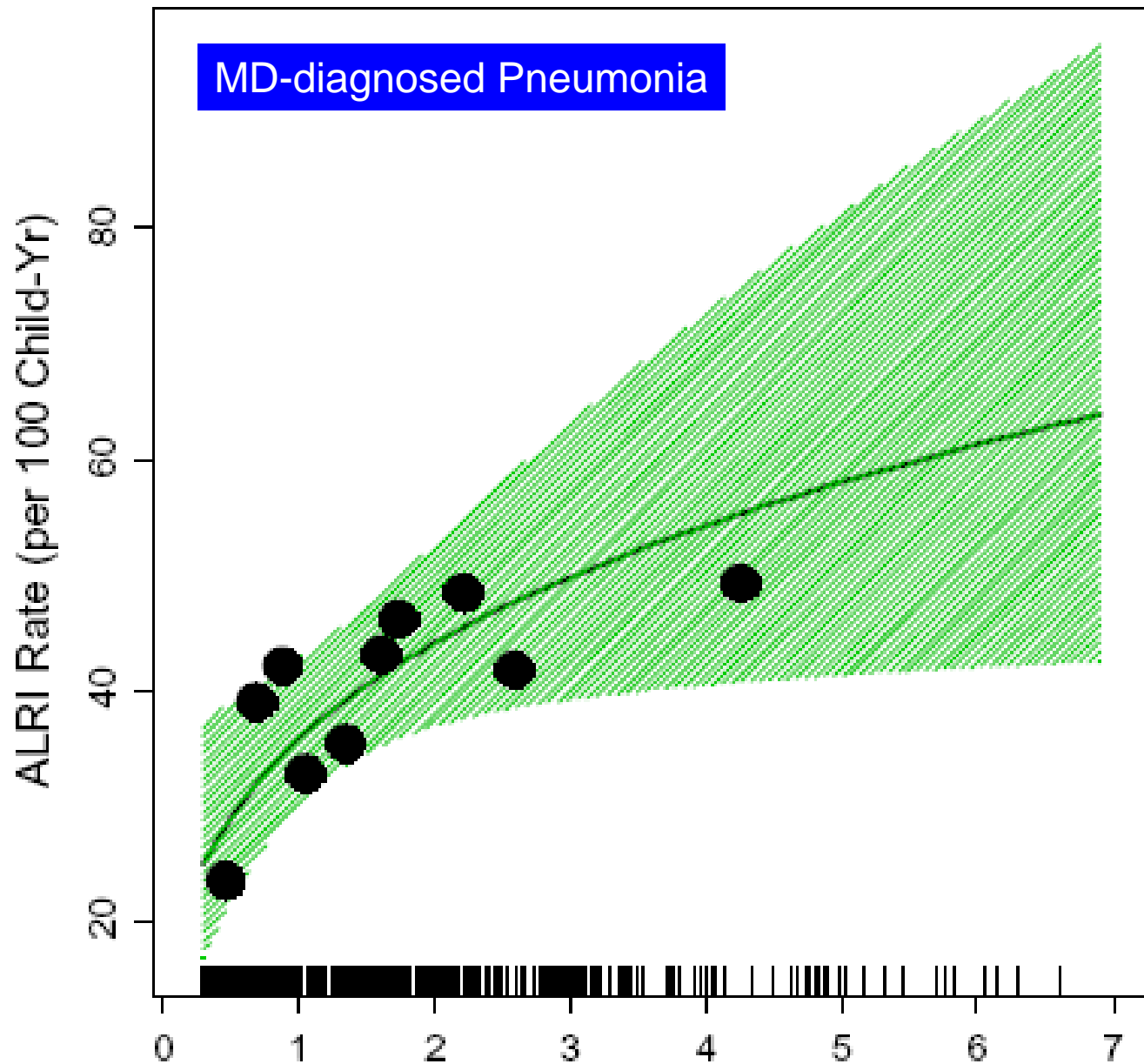


Chimney woodstove

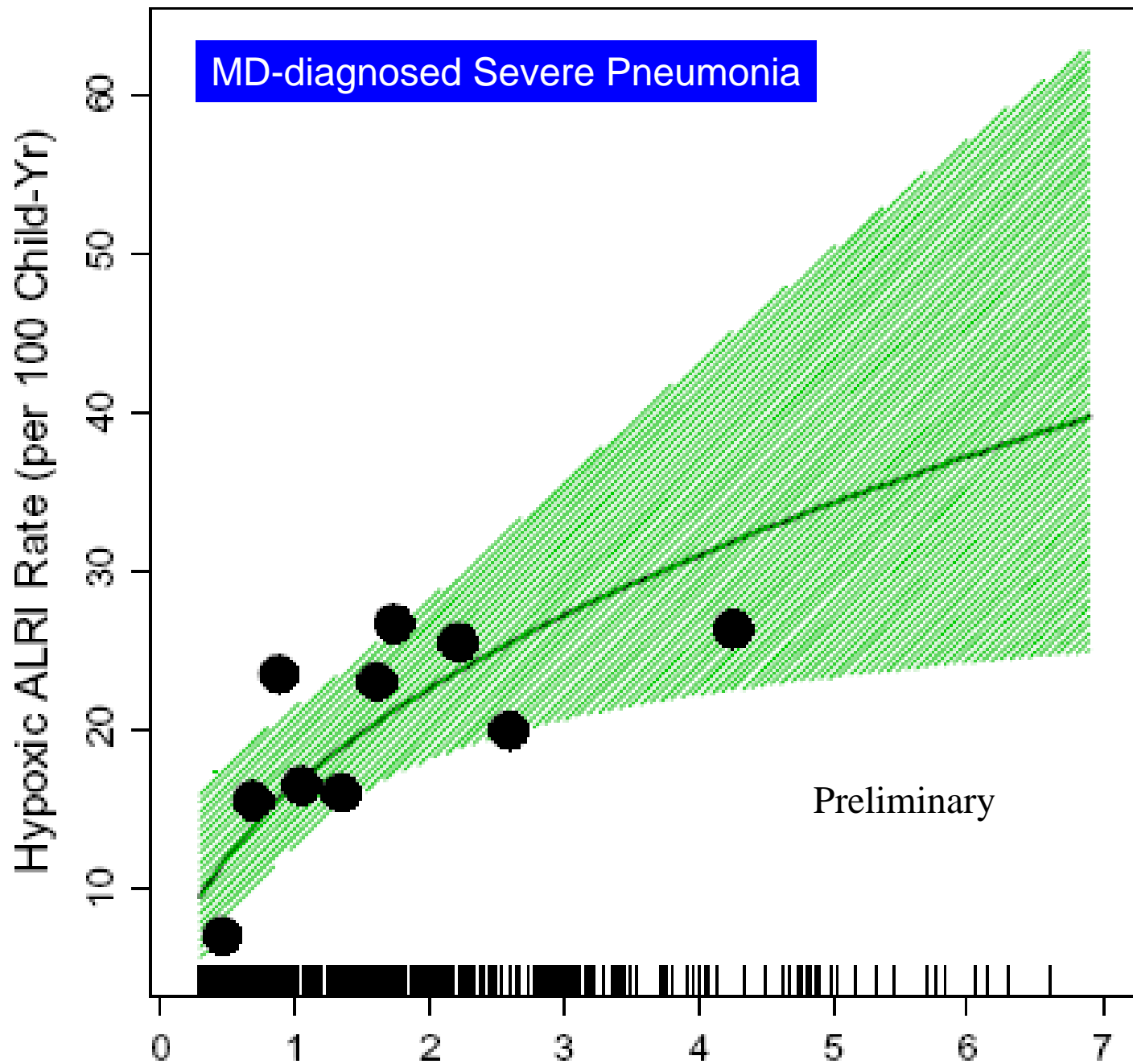


Tubito

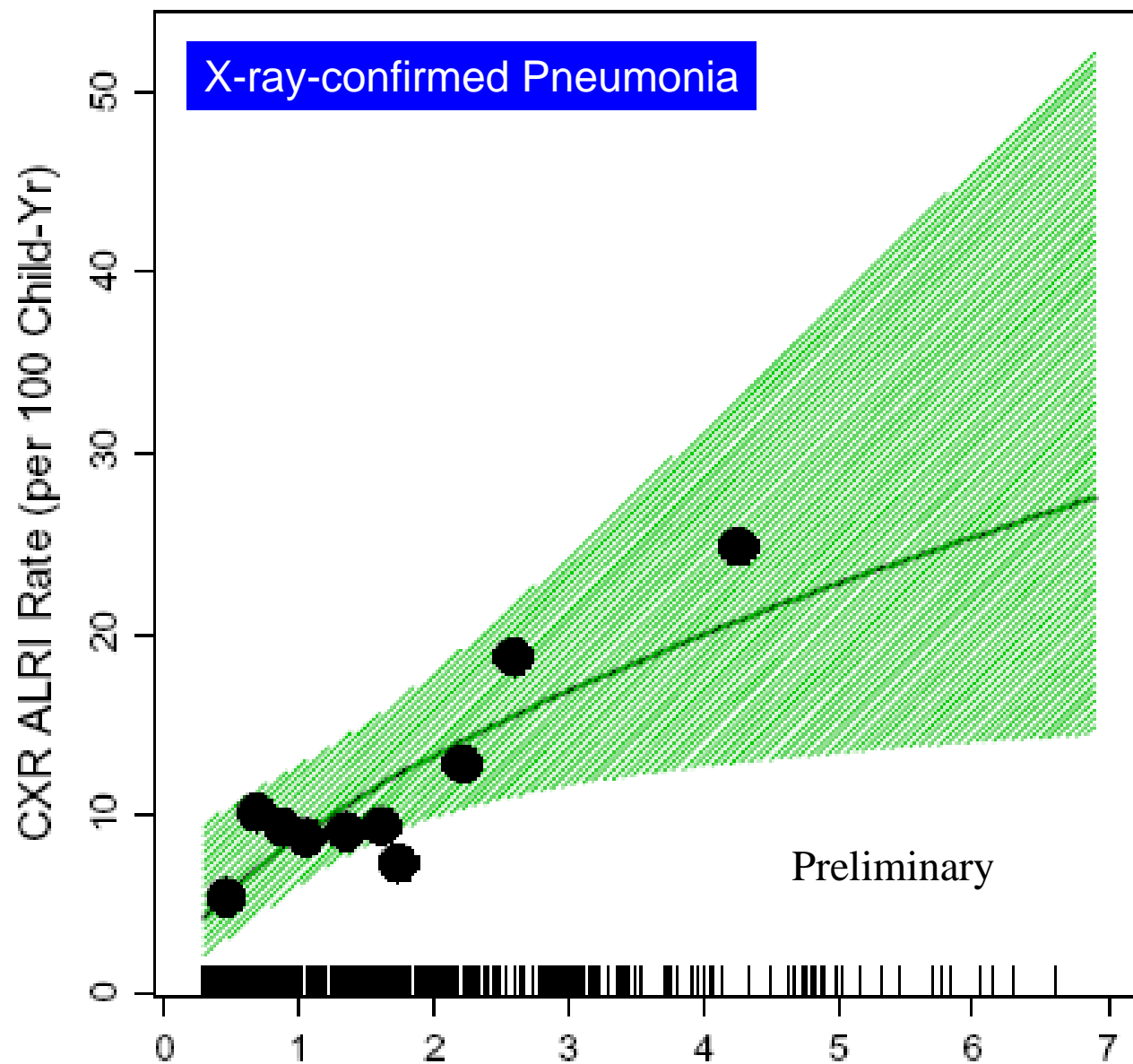
Tubito



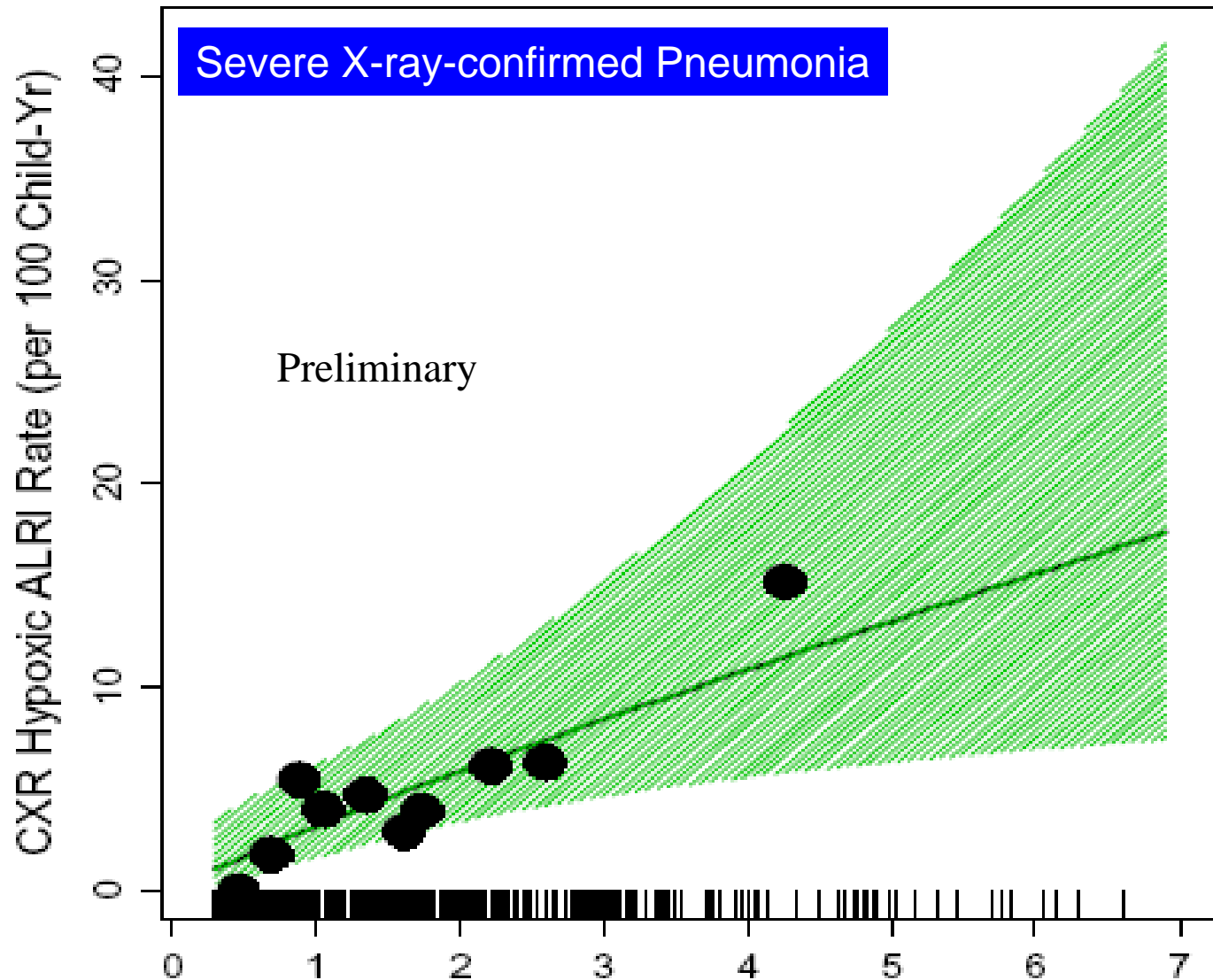
Approximate Mean PM2.5 exposure in 100s of ug/m3



Approximate Mean PM2.5 exposure in 100s of $\mu\text{g}/\text{m}^3$



Approximate Mean PM2.5 exposure in 100s of ug/m3

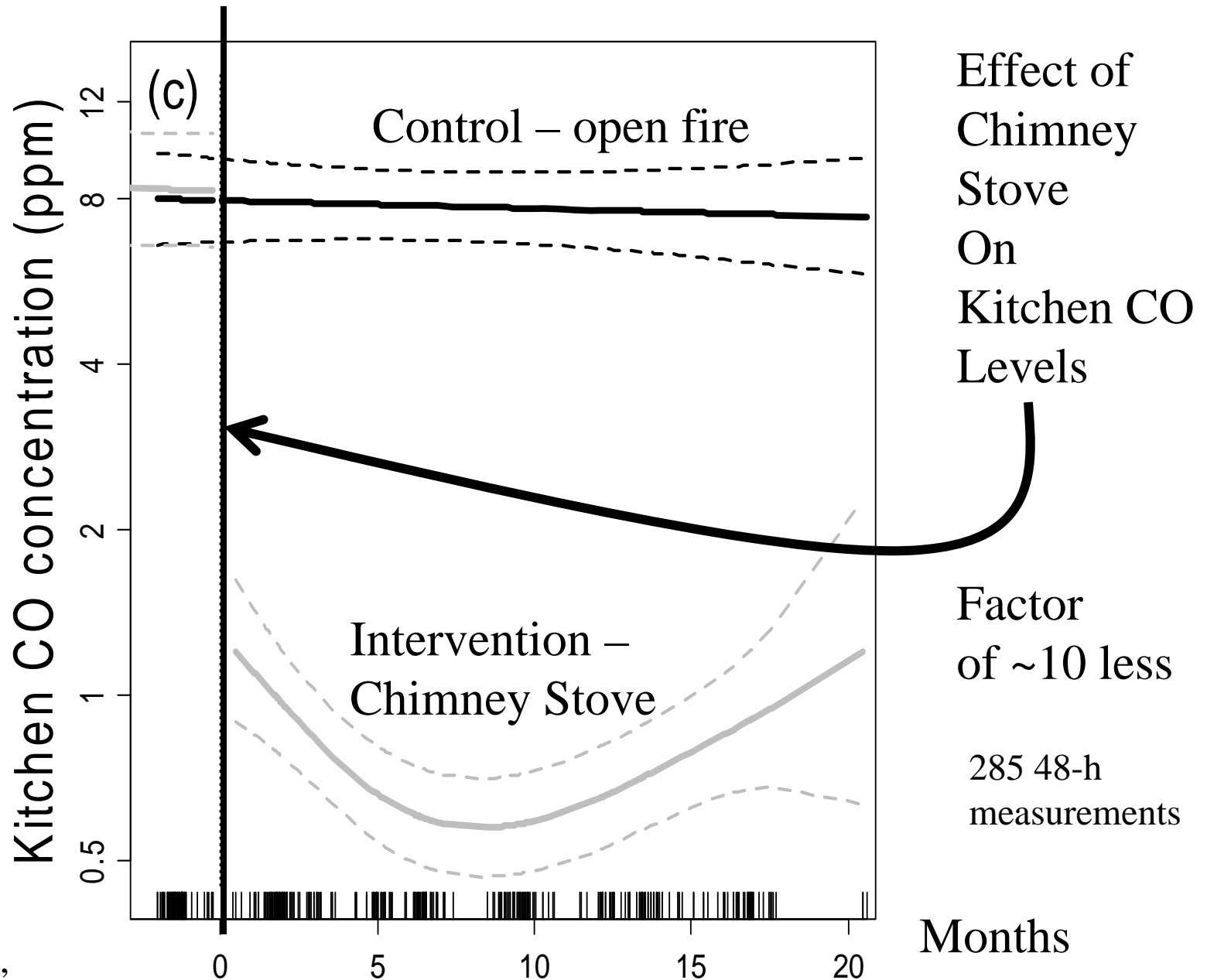


Approximate Mean PM2.5 exposure in 100s of ug/m3

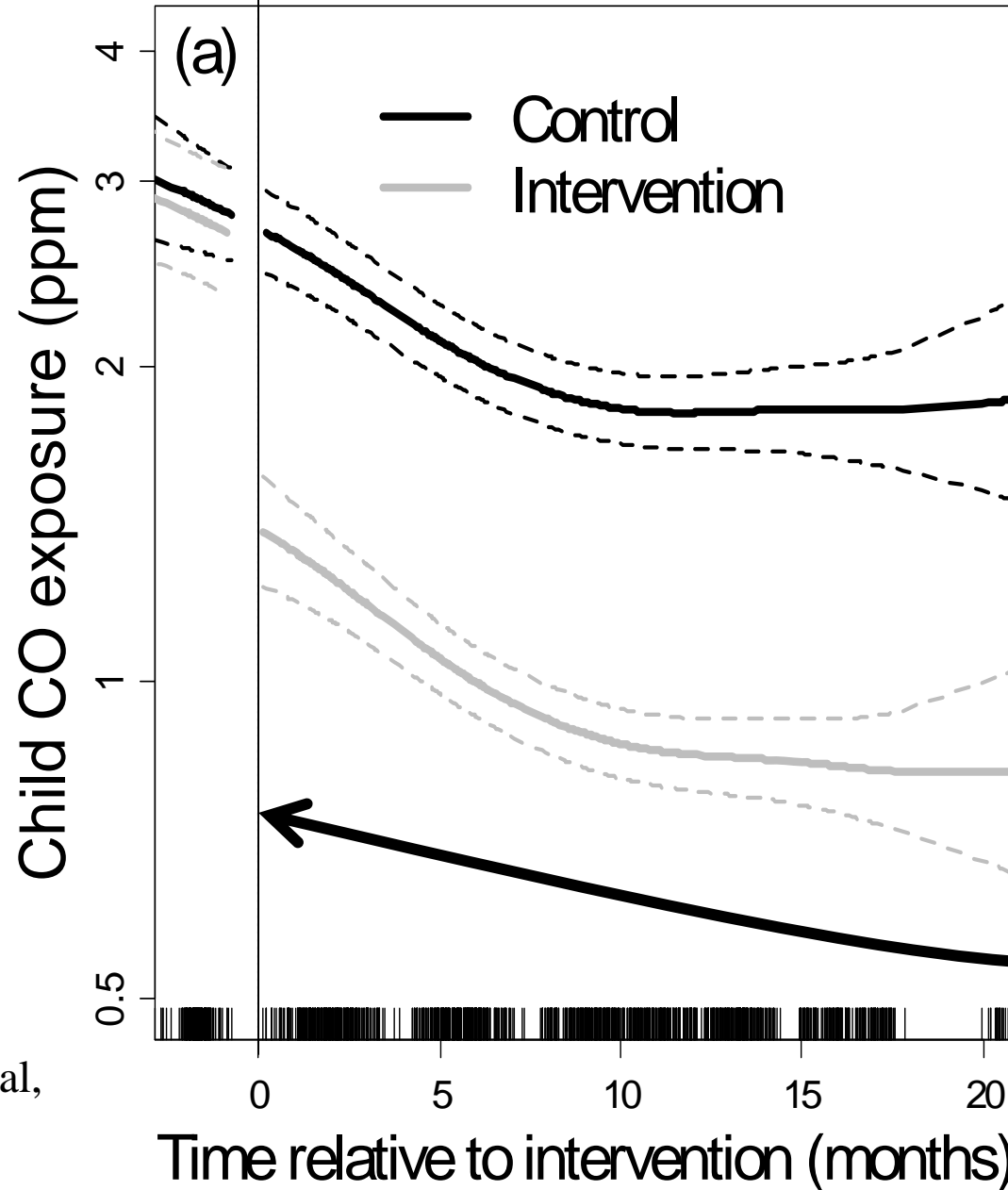
RESPIRE: Pneumonia Reductions with Exposure Reduction Preliminary Results

| Exposure reduction | Overall MD-pneumonia | Severe (hypoxic) MD-pneumonia | CXR pneumonia | Severe (hypoxic) CXR pneumonia |
|--------------------|----------------------|-------------------------------|-------------------|--------------------------------|
| 25% | 0.92 (0.86, 0.99) | 0.88 (0.80, 0.97) | 0.84 (0.74, 0.96) | 0.79 (0.69, 0.95) |
| 50% | 0.82 (0.70, 0.98) | 0.73 (0.59, 0.92) | 0.66 (0.49, 0.91) | 0.56 (0.40, 0.88) |
| 75% | 0.67 (0.50, 0.96) | 0.53 (0.35, 0.84) | 0.44 (0.24, 0.83) | 0.31 (0.16, 0.78) |
| 90% | 0.51 (0.31, 0.93) | 0.35 (0.17, 0.76) | 0.26 (0.09, 0.74) | 0.15 (0.05, 0.67) |

Guatemala RCT: Kitchen Concentrations



Infant Exposures

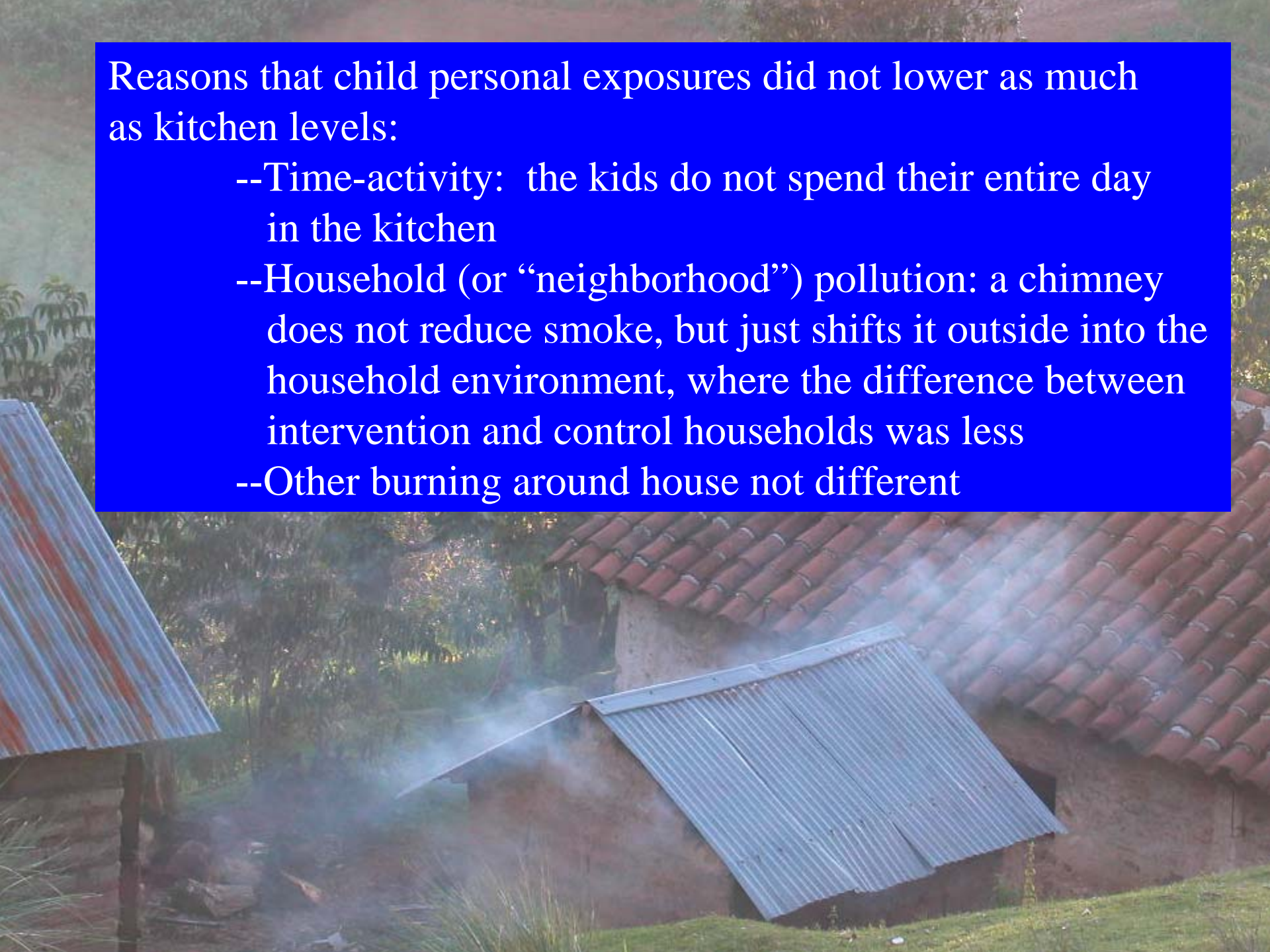


1888 48-h
measurements

Effect of
Chimney
Stove
On
Infant
Exposures
- 2x less

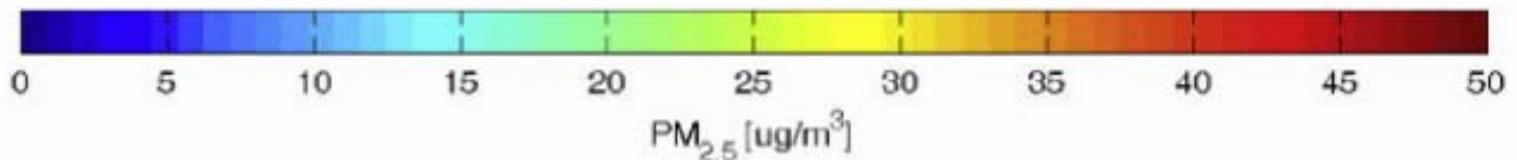
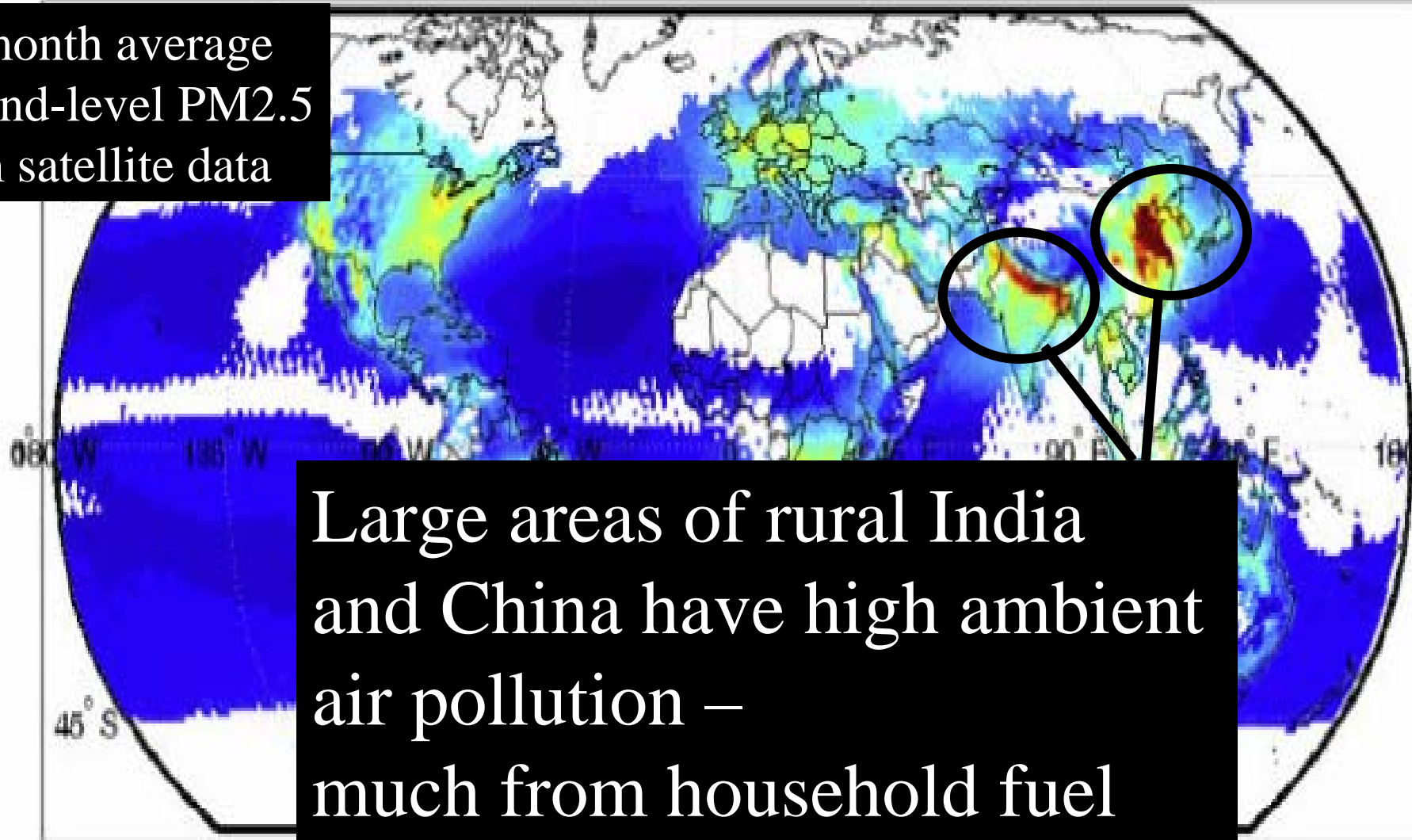
Reasons that child personal exposures did not lower as much as kitchen levels:

- 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



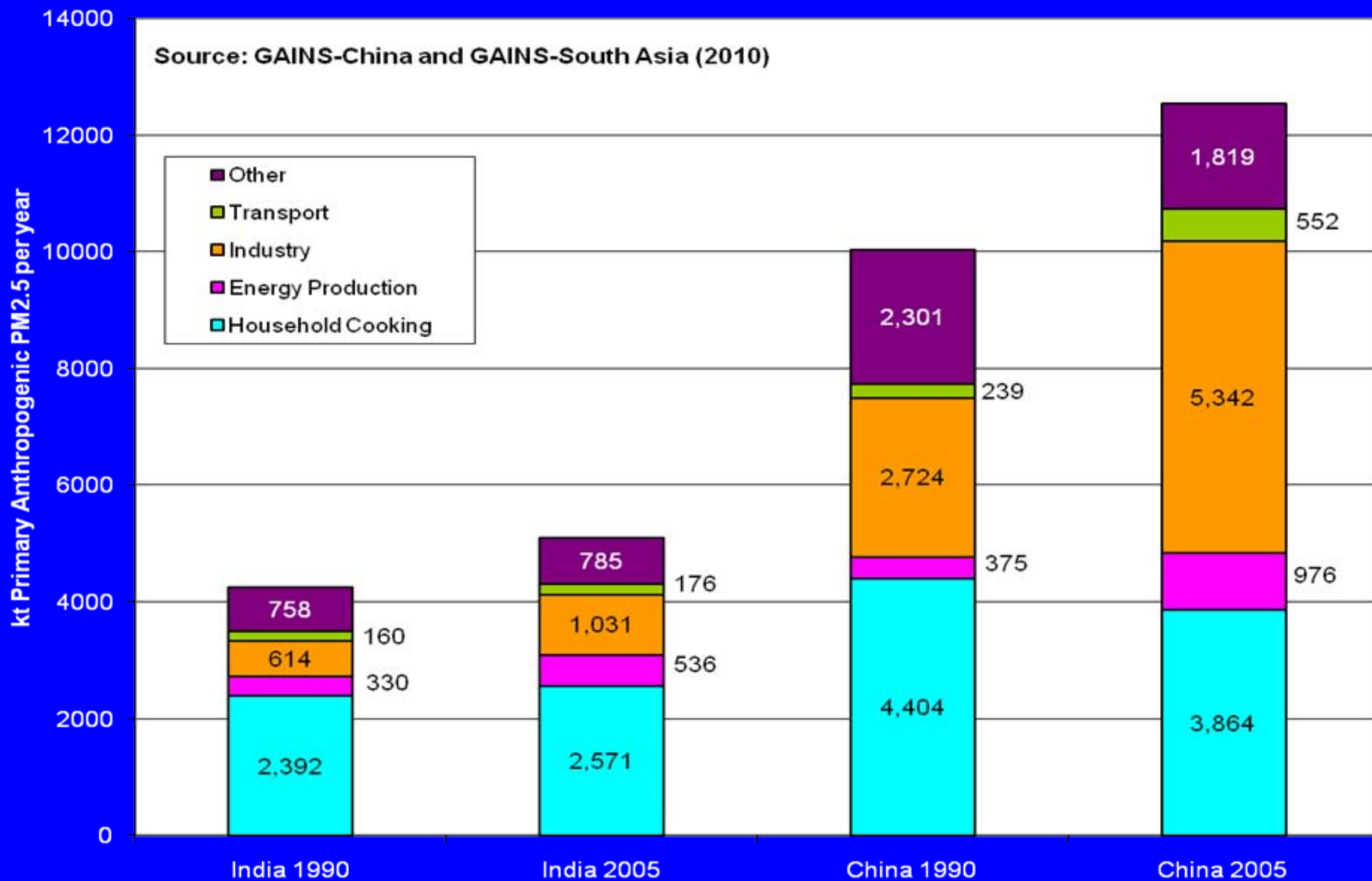
20-month average
ground-level PM_{2.5}
from satellite data

MODIS



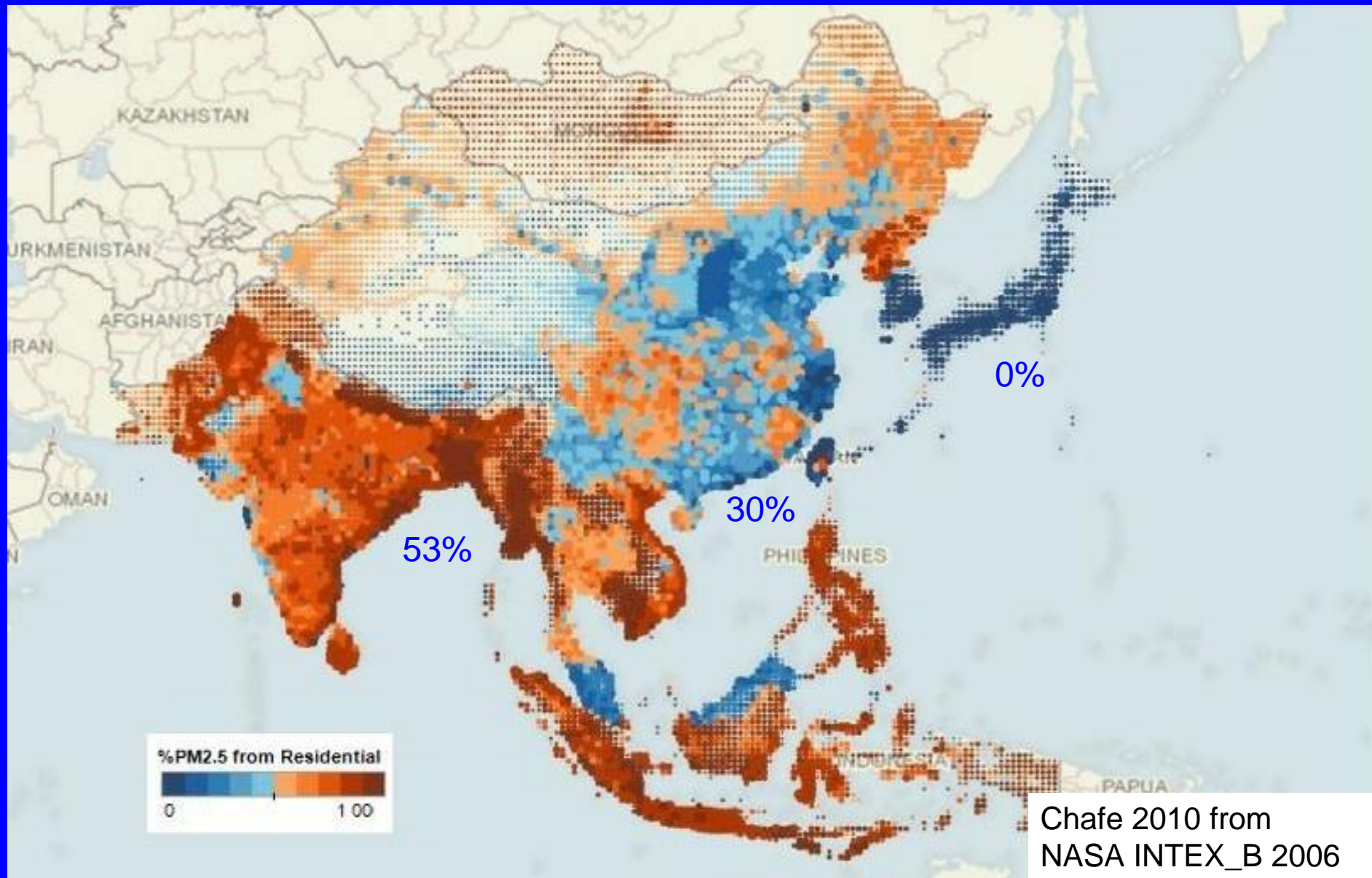
Sources of Primary PM_{2.5}: India and China

Source: GAINS-China and GAINS-South Asia (2010)

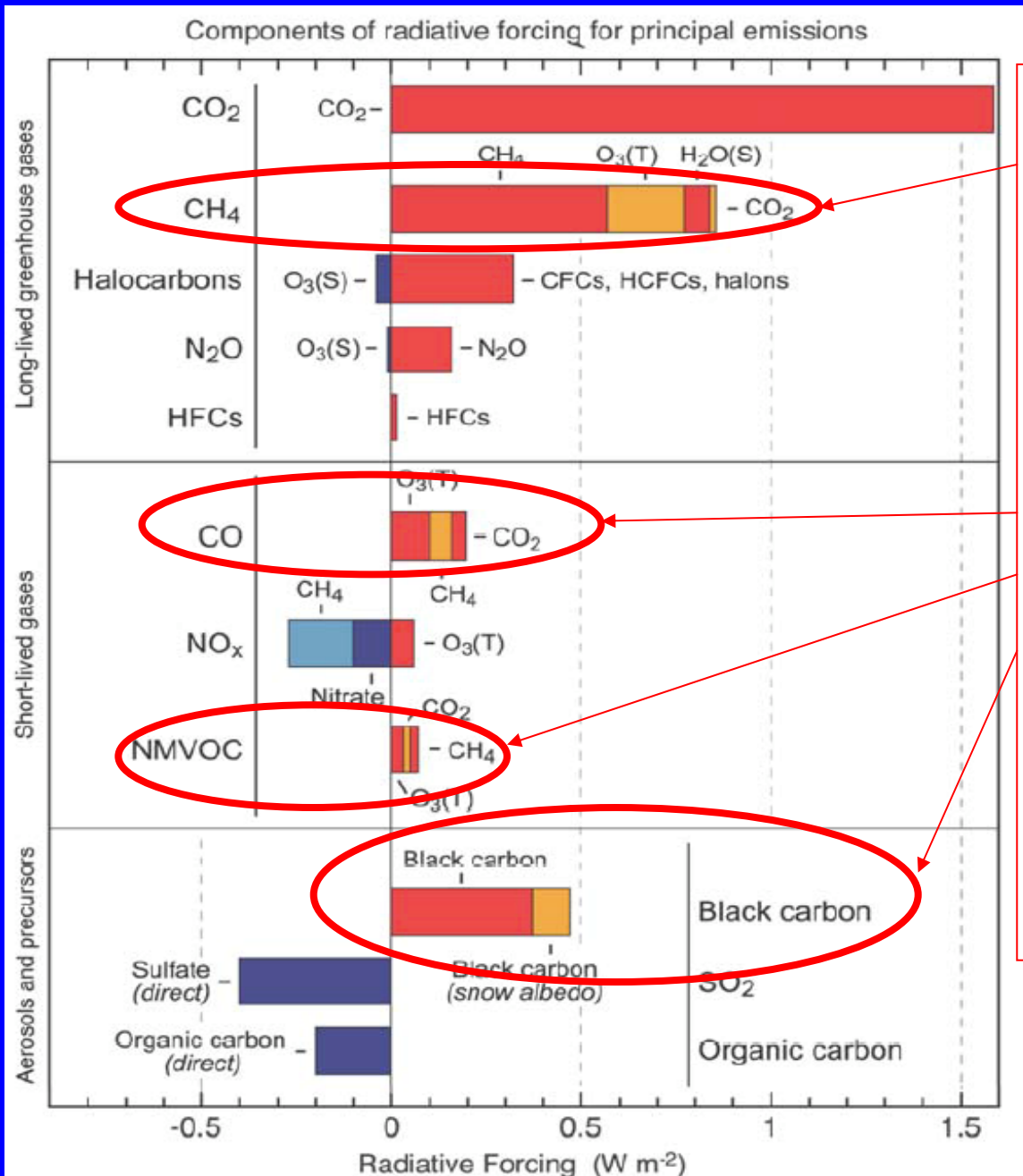


NASA INTEX_B Database

Percent PM_{2.5} emissions from households

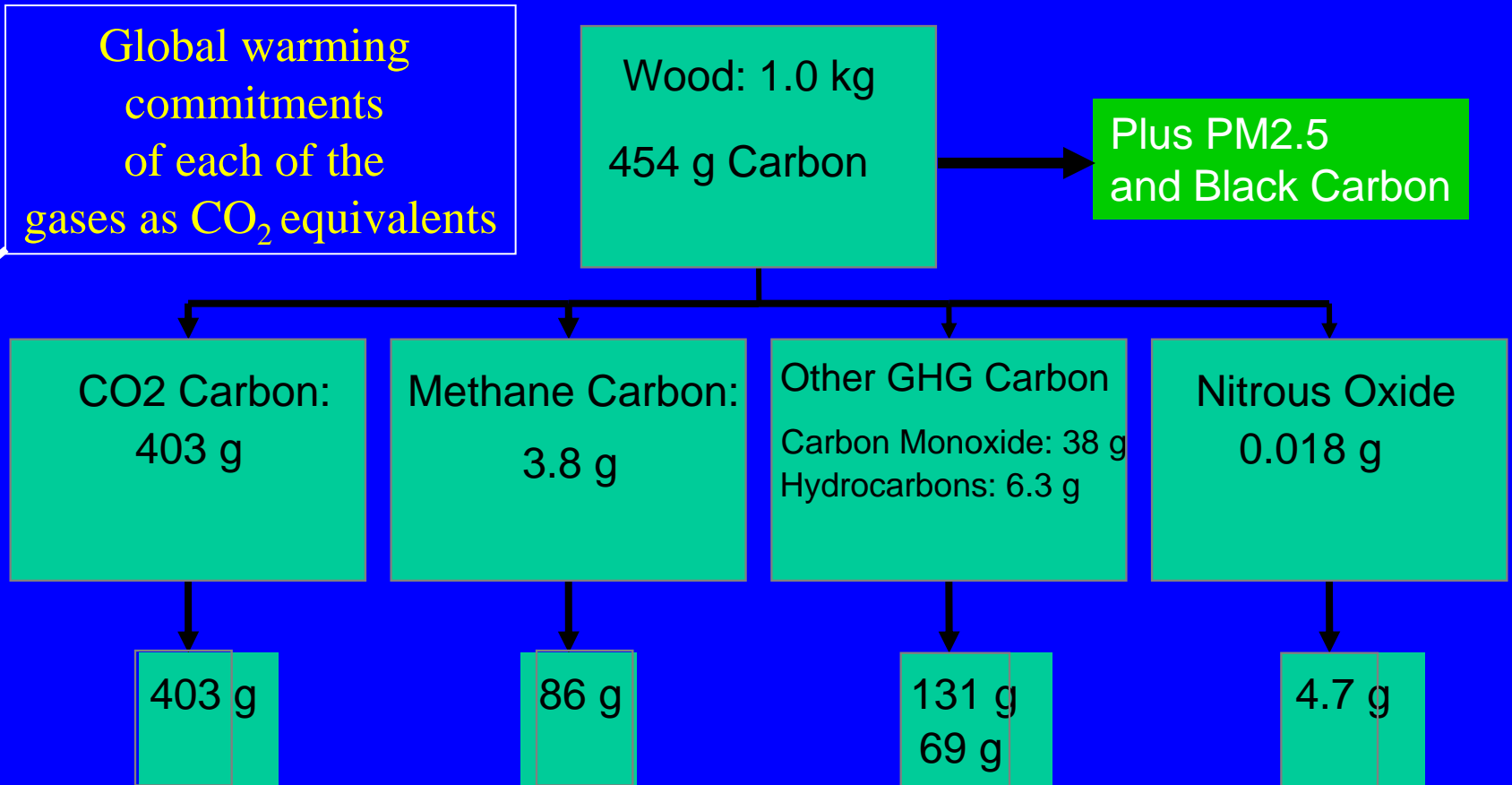


Global warming in 2005 due to all human emissions since 1750



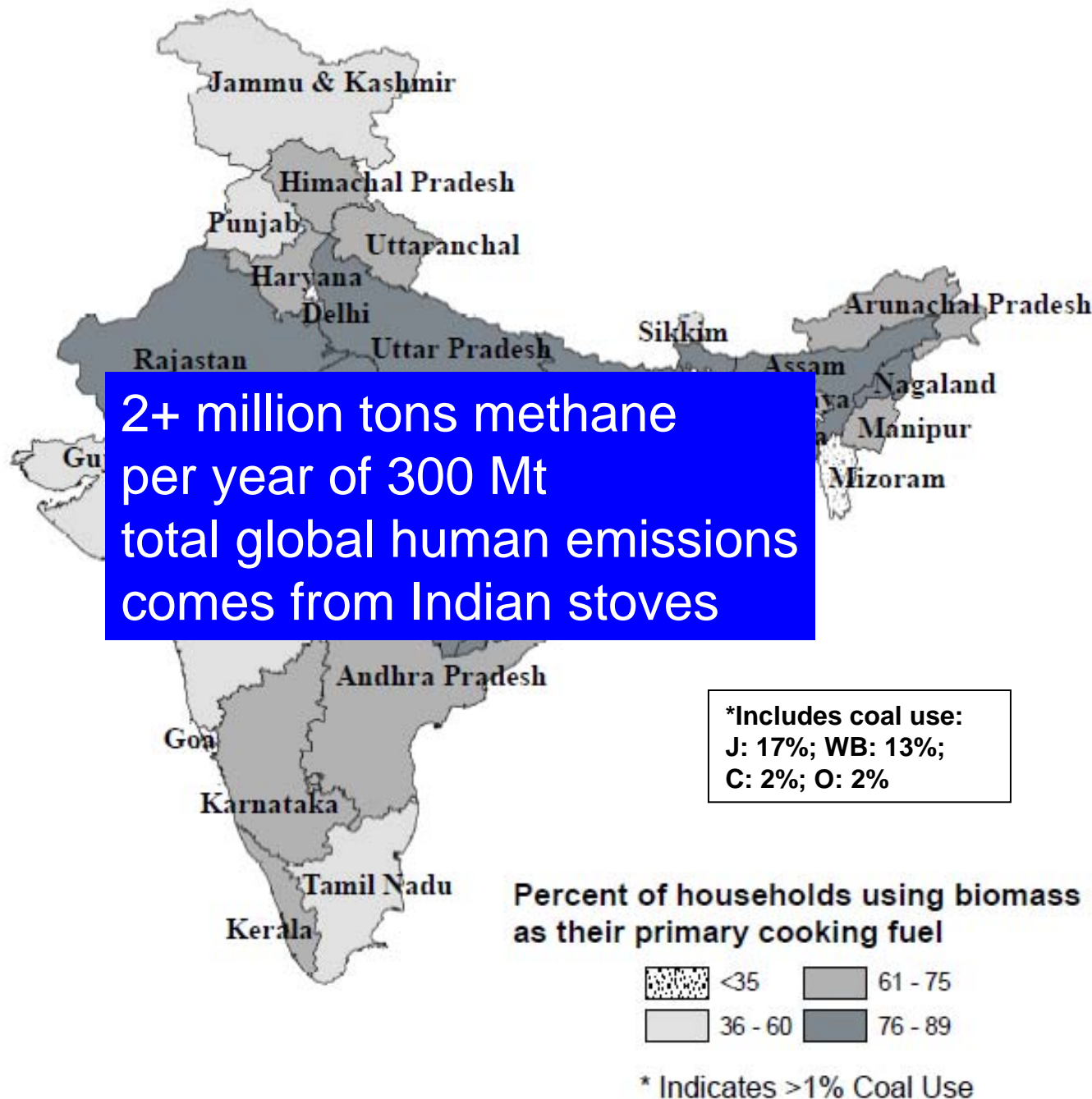
CO₂ is important for climate, but so are many other pollutants, including the ones circled that, unlike CO₂, also have significant health as well as climate impacts. All of these are products of incomplete combustion, in some cases the only source

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



India in 2005

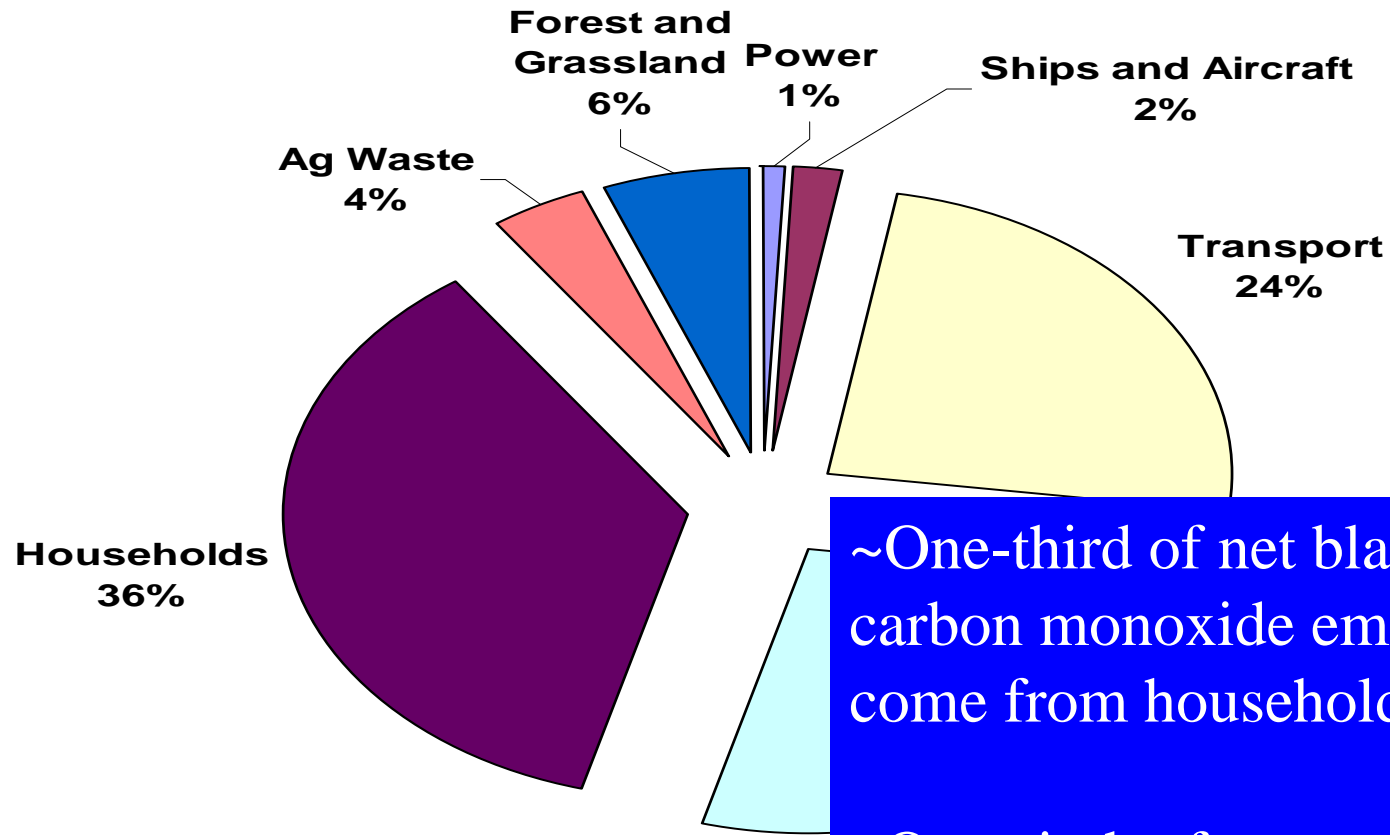
2+ million tons methane
per year of 300 Mt
total global human emissions
comes from Indian stoves



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

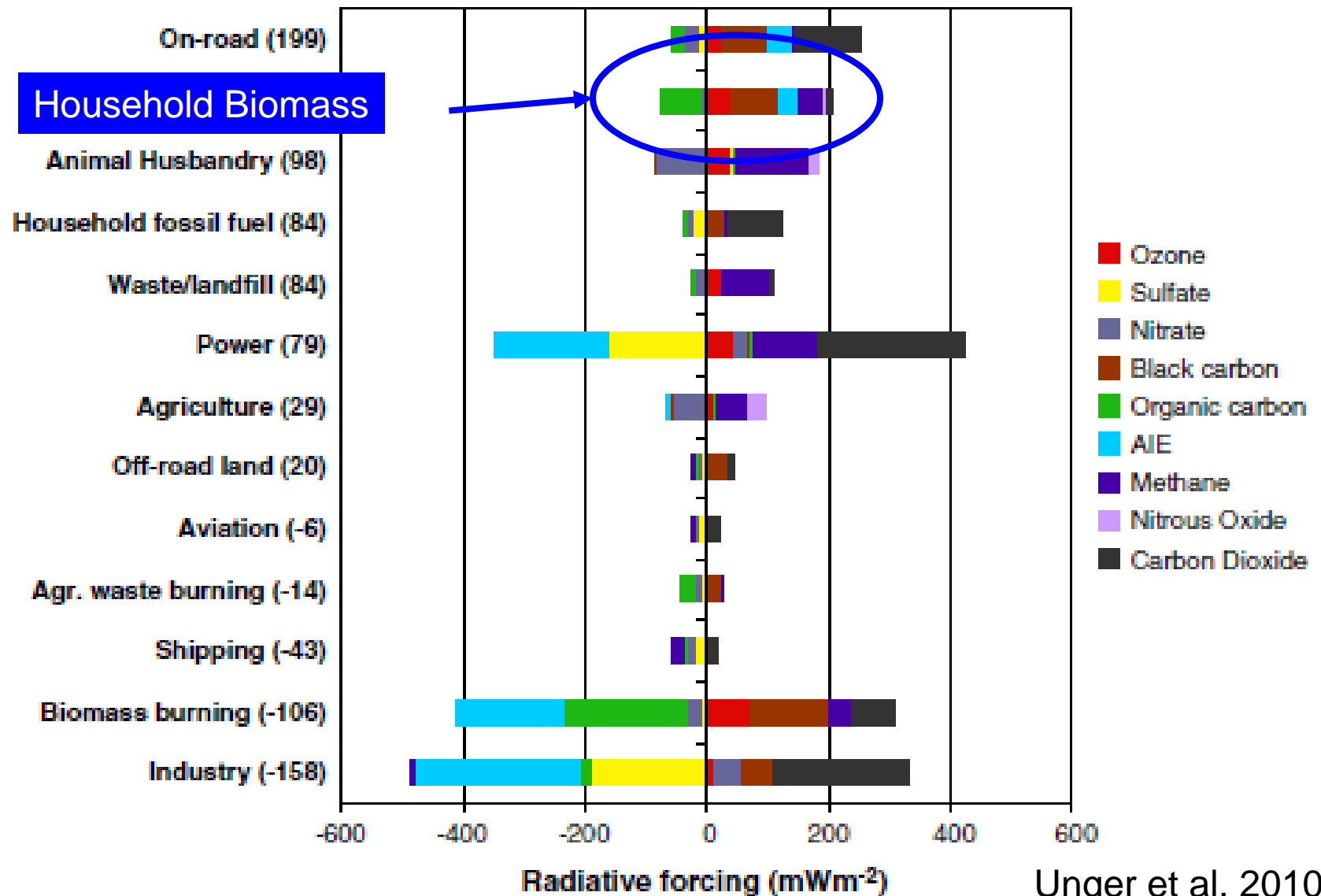


~One-third of net black carbon and carbon monoxide emissions globally come from household fuels

~One-sixth of ozone causing pollution

~One-twentieth of methane

Climate Warming in 2020 Under Present Trends

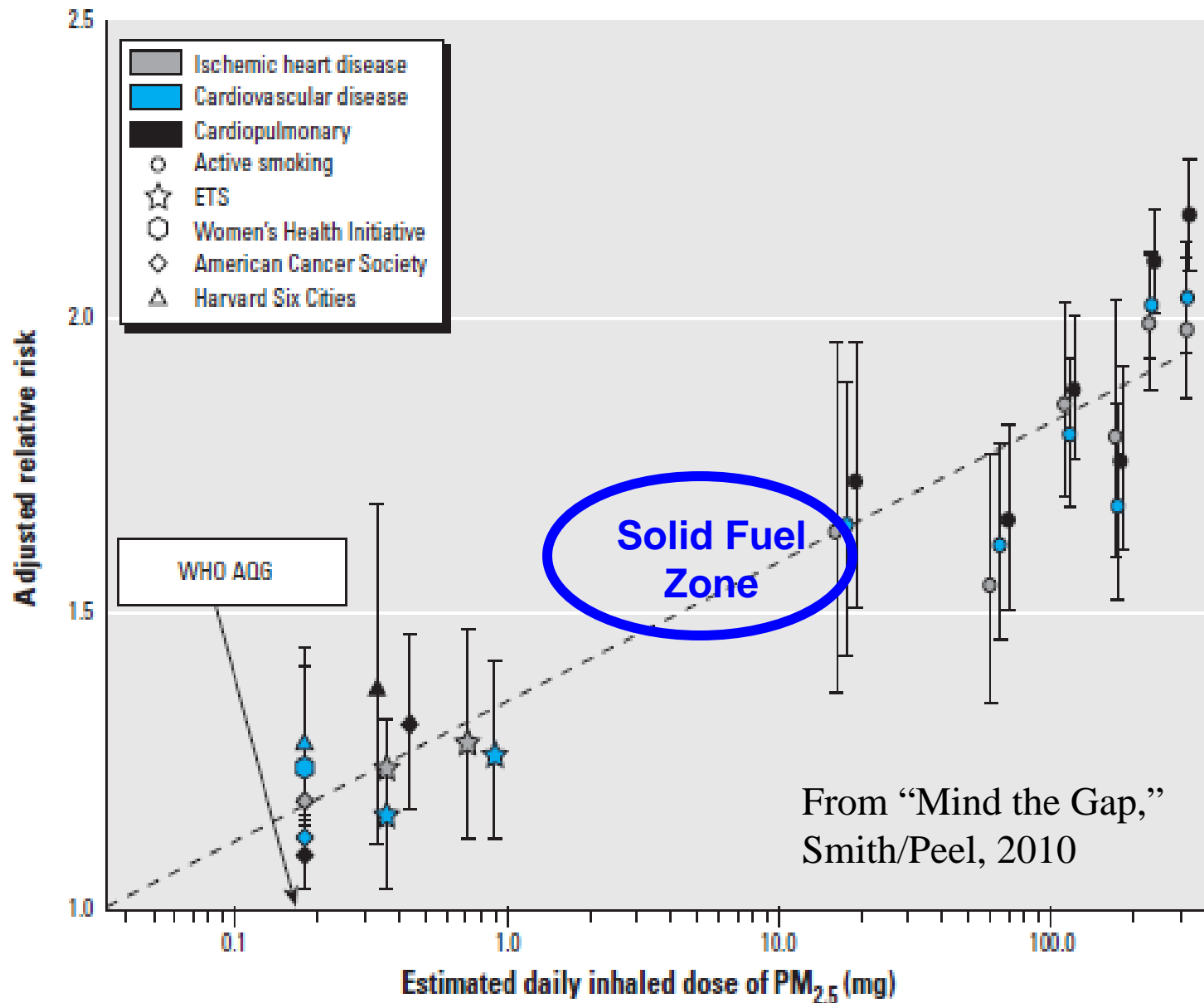


Unger et al. 2010

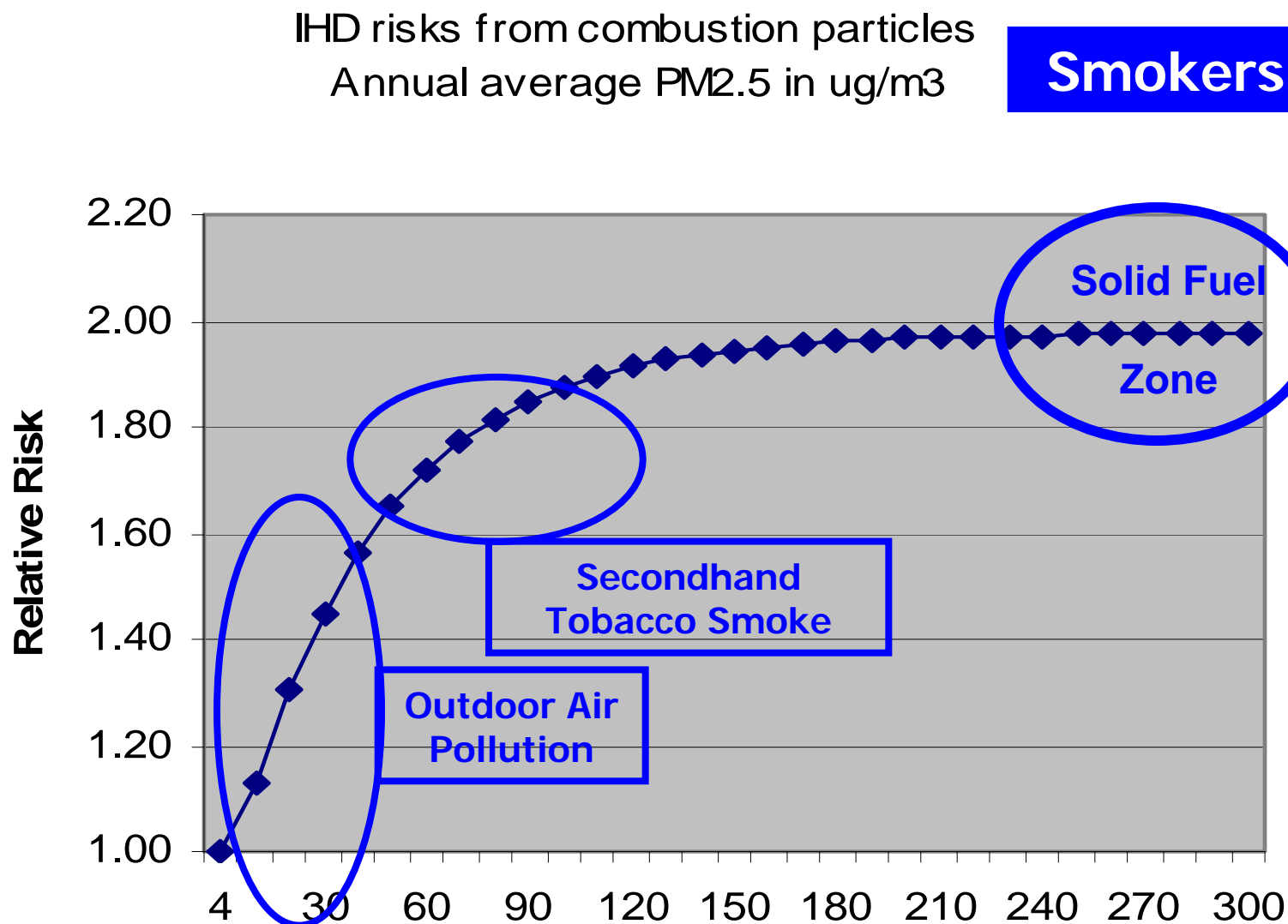
Household Fuels and Climate

- Climate impacts come from non-renewable wood, i.e., from net CO₂ emissions due to deforestation
- 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

Heart Disease and Combustion Particle Doses



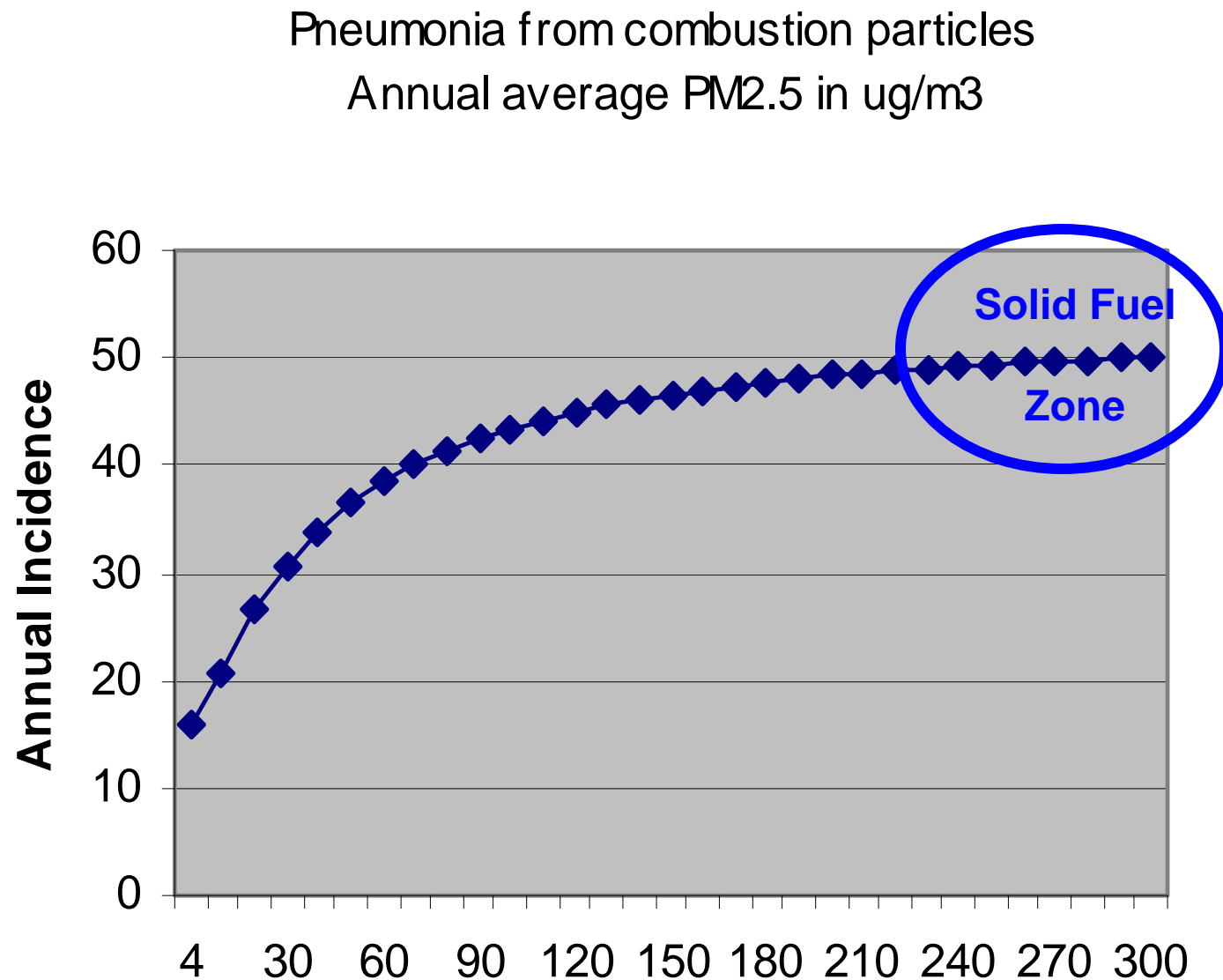
Generalized Exposure-Response: Outdoor Air, SHS, and Smoking



Smokers →

CRA,
2011

Generalized Exposure-Response: Outdoor Air, SHS, and HAP



Why M&E?

You don't get what you expect,
but what you inspect





SMALL, SMART, FAST, & CHEAP

monitoring devices for household energy & health

Ajay Pillarisetti, Ilse Ruiz-Mercado, and Nick Lam on behalf of Prof. Kirk R. Smith's Research Group at University of California, Berkeley
Visit obs.sph.berkeley.edu/krsmith for more information



STOVE USE MONITORS UTILIZATION

Time-of-use measuring devices allow more accurate estimations and objective definitions of usage patterns including cooking periods, meal times, and technology adoption rates.

Stove Use Monitors (SUMS) quantify utilization of cookstoves to improve estimates of personal exposure and environmental benefits related to household energy use. SUMS are based on commercially available, low-cost, small temperature loggers.



The stainless steel temperature sensors are the size of a coin and can record time, date, and temperature. Programming and downloading data can be easily performed in the field. They are easy to use, unobtrusive, waterproof and tamper-resistant. They come with algorithms and software to systematically assess stove use patterns.

Measurements of stove surface temperature can be used to test the effectiveness of behavioral interventions on stove use. Because they give precise, unbiased measures of a simple physical parameter, statistically reliable information is provided using smaller sample sizes than required for a household survey.

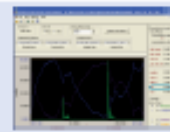
PARTICLE AND TEMP SENSOR CONCENTRATION

The ability to measure concentrations of small airborne particles is vital in understanding adverse health effects from combustion-derived air pollution. Available instrumentation to conduct such measurements is complex and expensive. Such devices are appropriate for developed countries and ambient air monitoring stations. However, their routine use in real-world household environments is expensive & cumbersome. Monitoring locations may also be remote, where security is questionable and electrical power not available, limiting the applicability of conventional instruments. In an effort to fulfill the needs for small, smart, fast, and cheap particle monitors that could be deployed easily in remote settings, a commercial smoke detector that uses optical scattering was identified and modified so that real-time signals could be logged continuously. This modified particle and temperature sensor is dubbed the UCB-PATS. Customized software handles data importing, graphing, and manipulation.



Device Software & Sample Output

Each device is controlled by software allowing equipment launch, data download and manipulation, and reporting of data files for further analysis. Devices connect with the software over a serial port or via an USB to Serial converter.

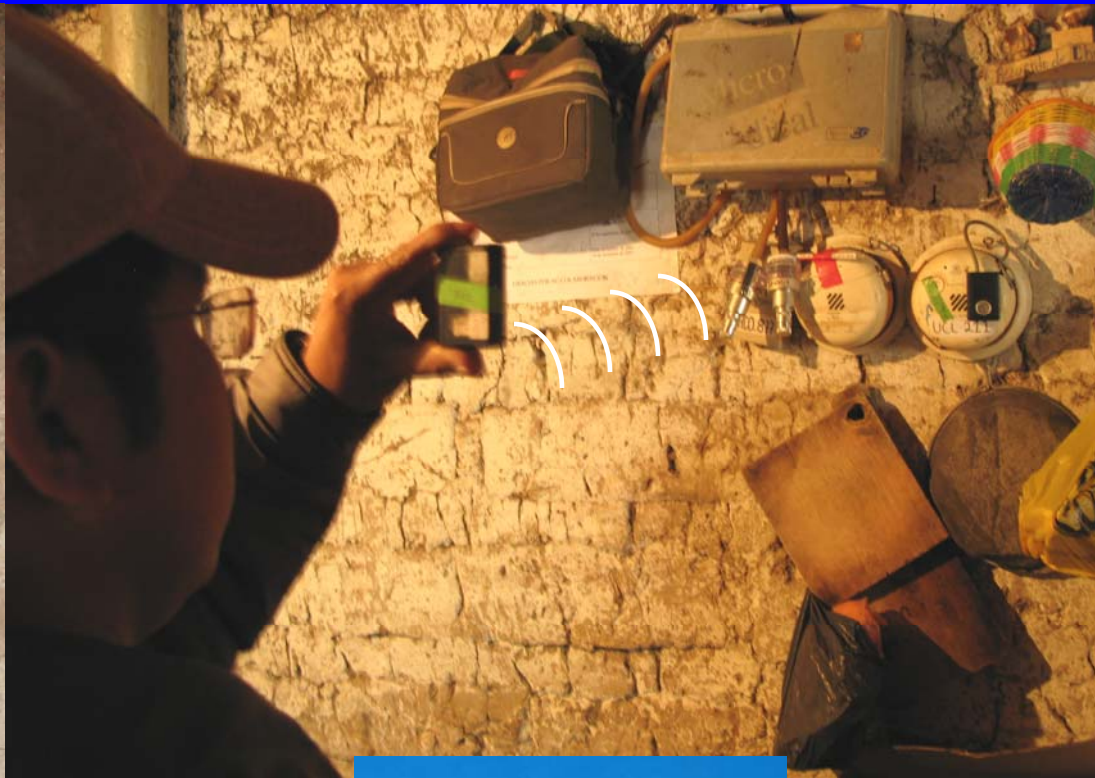


Monitoring and processing downloaded data in the UCB-PATS data browser.



Stratified time of activity in Room 1003 - 1004, 1005, 1006, 1007, 1008, 1009, 1010, 1011, 1012, 1013, 1014, 1015, 1016, 1017, 1018, 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027, 1028, 1029, 1030, 1031, 1032, 1033, 1034, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1042, 1043, 1044, 1045, 1046, 1047, 1048, 1049, 1050, 1051, 1052, 1053, 1054, 1055, 1056, 1057, 1058, 1059, 1060, 1061, 1062, 1063, 1064, 1065, 1066, 1067, 1068, 1069, 1070, 1071, 1072, 1073, 1074, 1075, 1076, 1077, 1078, 1079, 1080, 1081, 1082, 1083, 1084, 1085, 1086, 1087, 1088, 1089, 1090, 1091, 1092, 1093, 1094, 1095, 1096, 1097, 1098, 1099, 1100, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1109, 1110, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1118, 1119, 1120, 1121, 1122, 1123, 1124, 1125, 1126, 1127, 1128, 1129, 1130, 1131, 1132, 1133, 1134, 1135, 1136, 1137, 1138, 1139, 1140, 1141, 1142, 1143, 1144, 1145, 1146, 1147, 1148, 1149, 1150, 1151, 1152, 1153, 1154, 1155, 1156, 1157, 1158, 1159, 1160, 1161, 1162, 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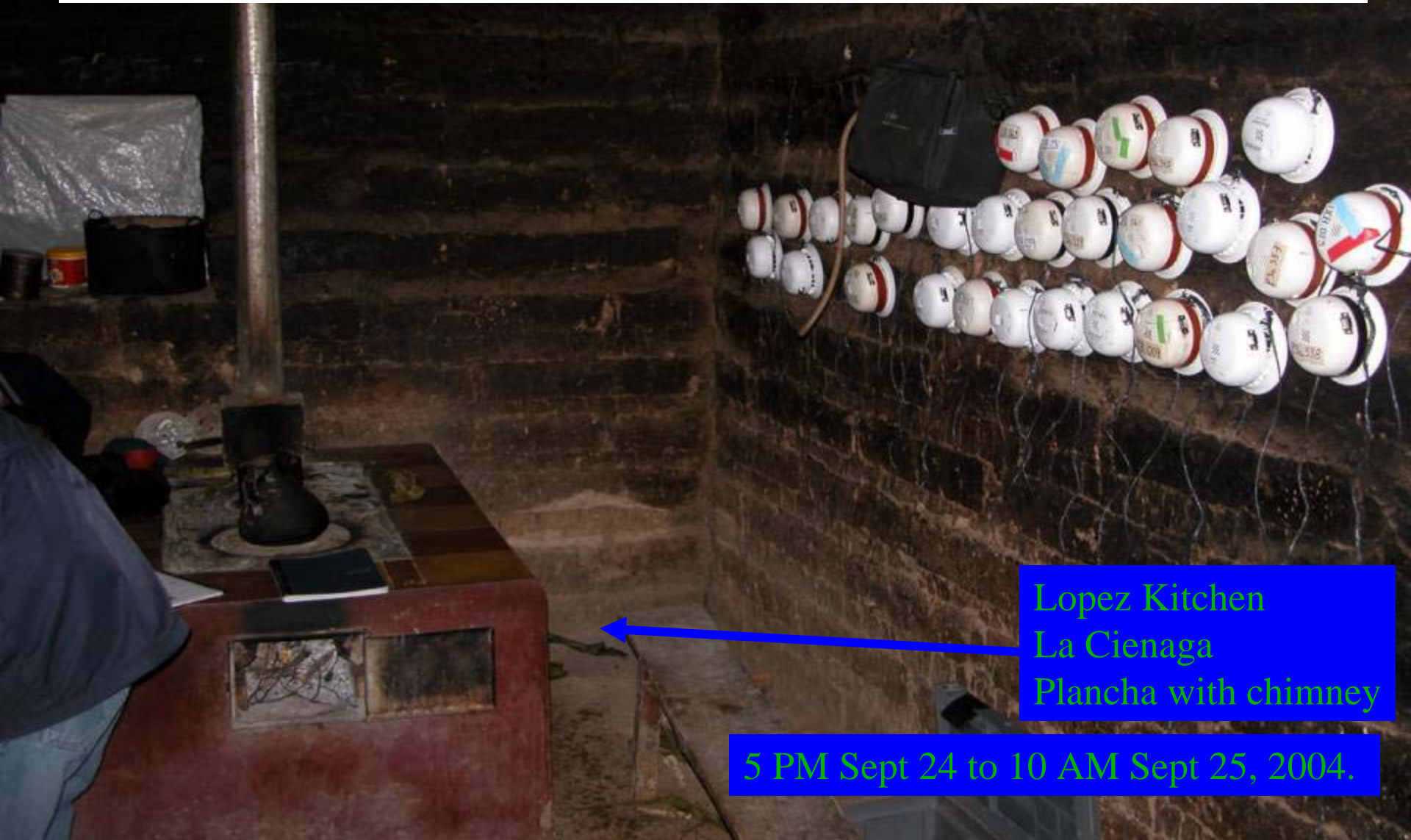
The Time-Activity Monitoring System: UCB-SUMS



Inter-instrument Comparison: 30 UCB-PATS

UCB Particle and Temperature Monitoring System

(custom PM monitor using smoke alarm technology)

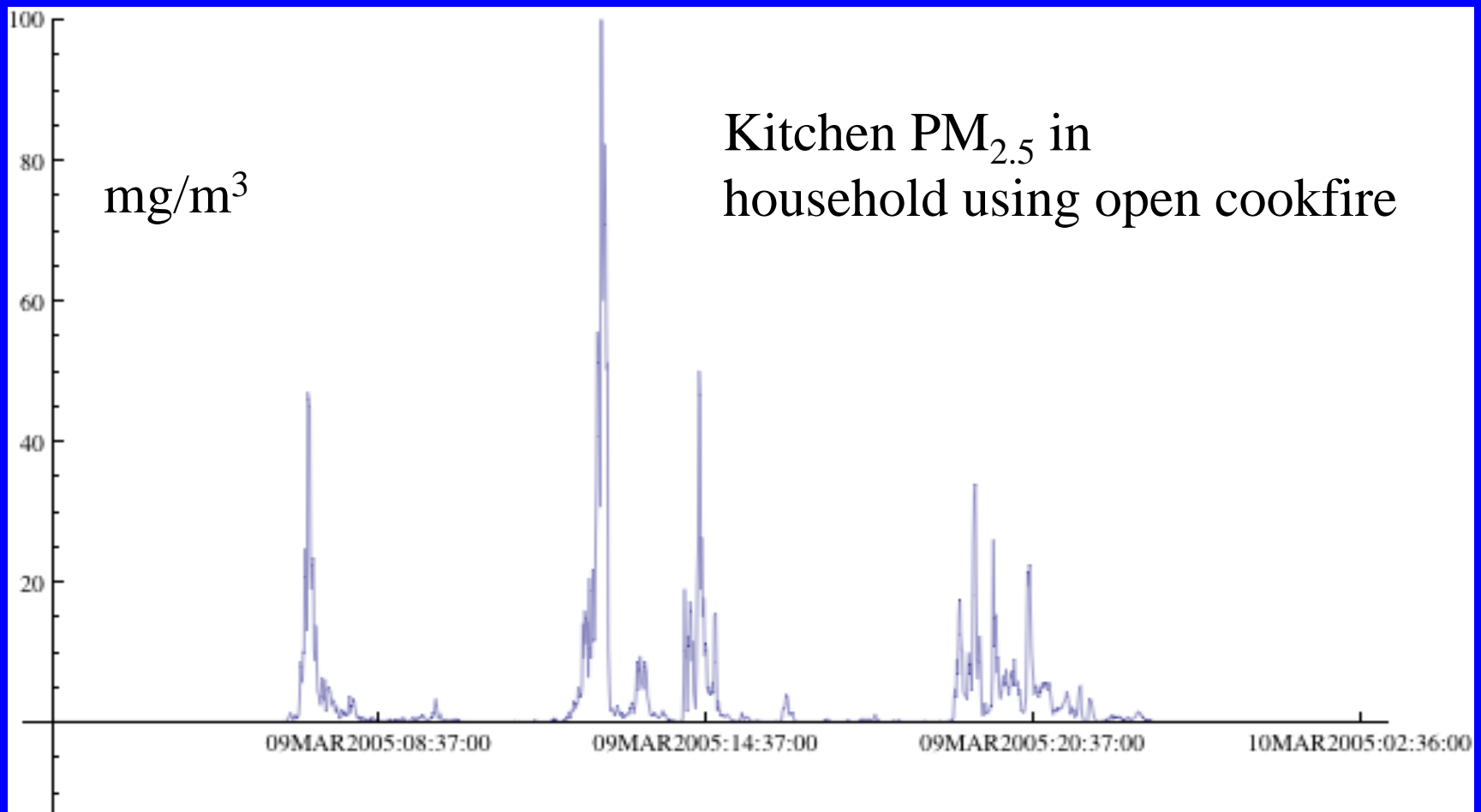


Lopez Kitchen
La Cienaga
Plancha with chimney

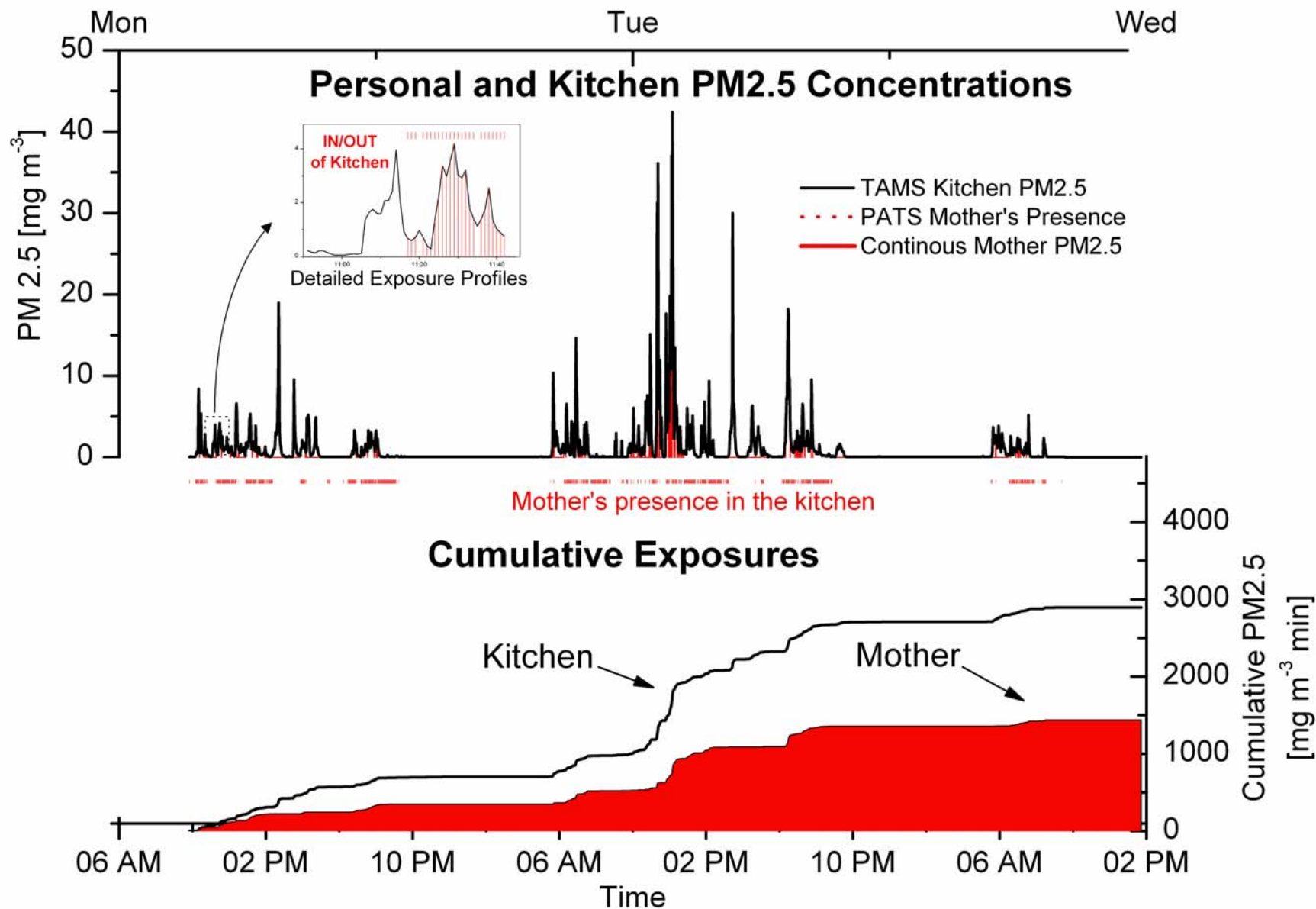
5 PM Sept 24 to 10 AM Sept 25, 2004.

UCB Particle Monitor

How many hours should we measure to obtain good estimate of the long-term mean?



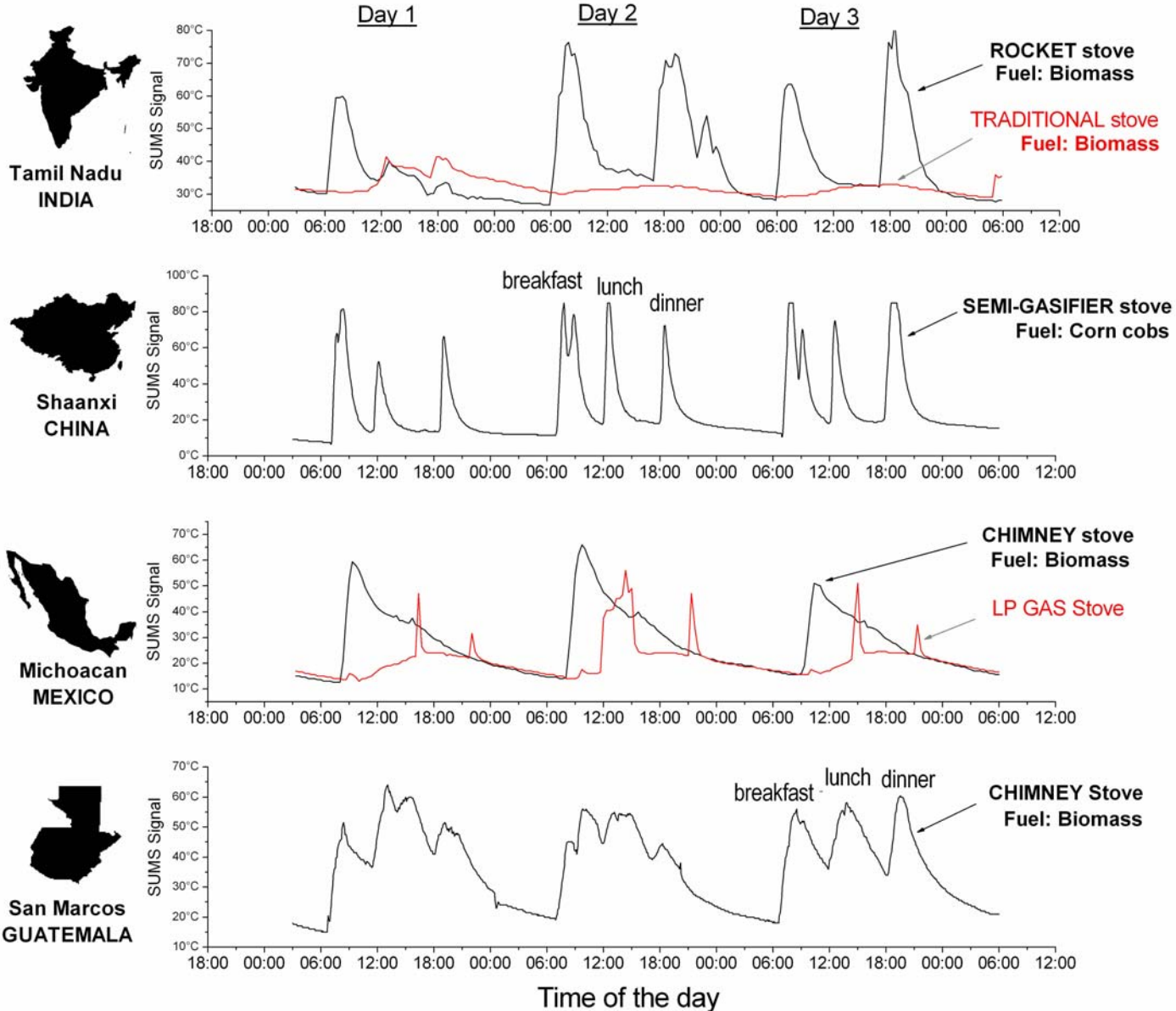
Estimating Mother's Personal Kitchen PM2.5 Exposure Pattern by Combining Time-Activity Data (TAMS) with Continuous PM2.5 Kitchen Area Measurements (PATs)



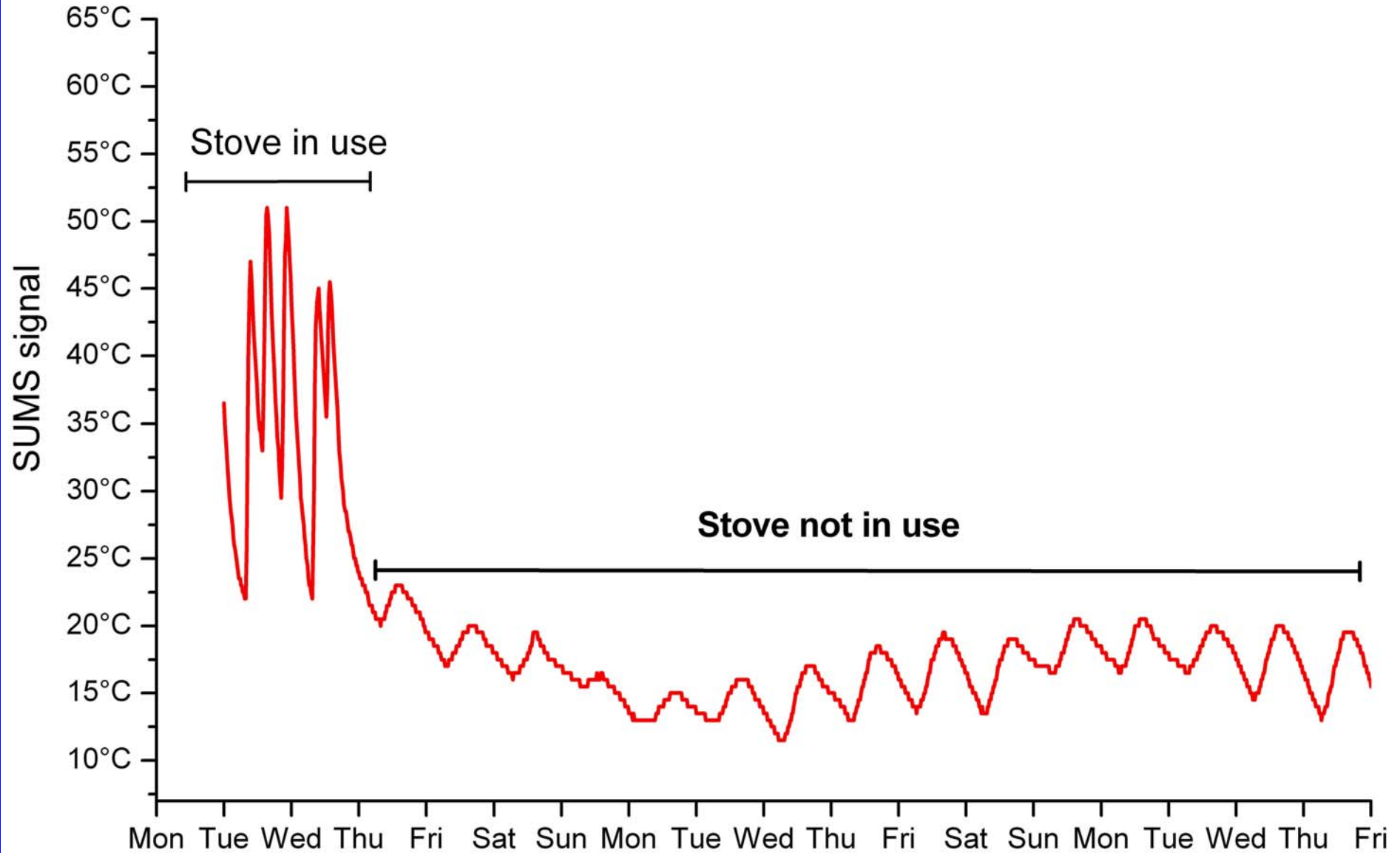
The Stove Use Monitoring System: UCB-SUMS



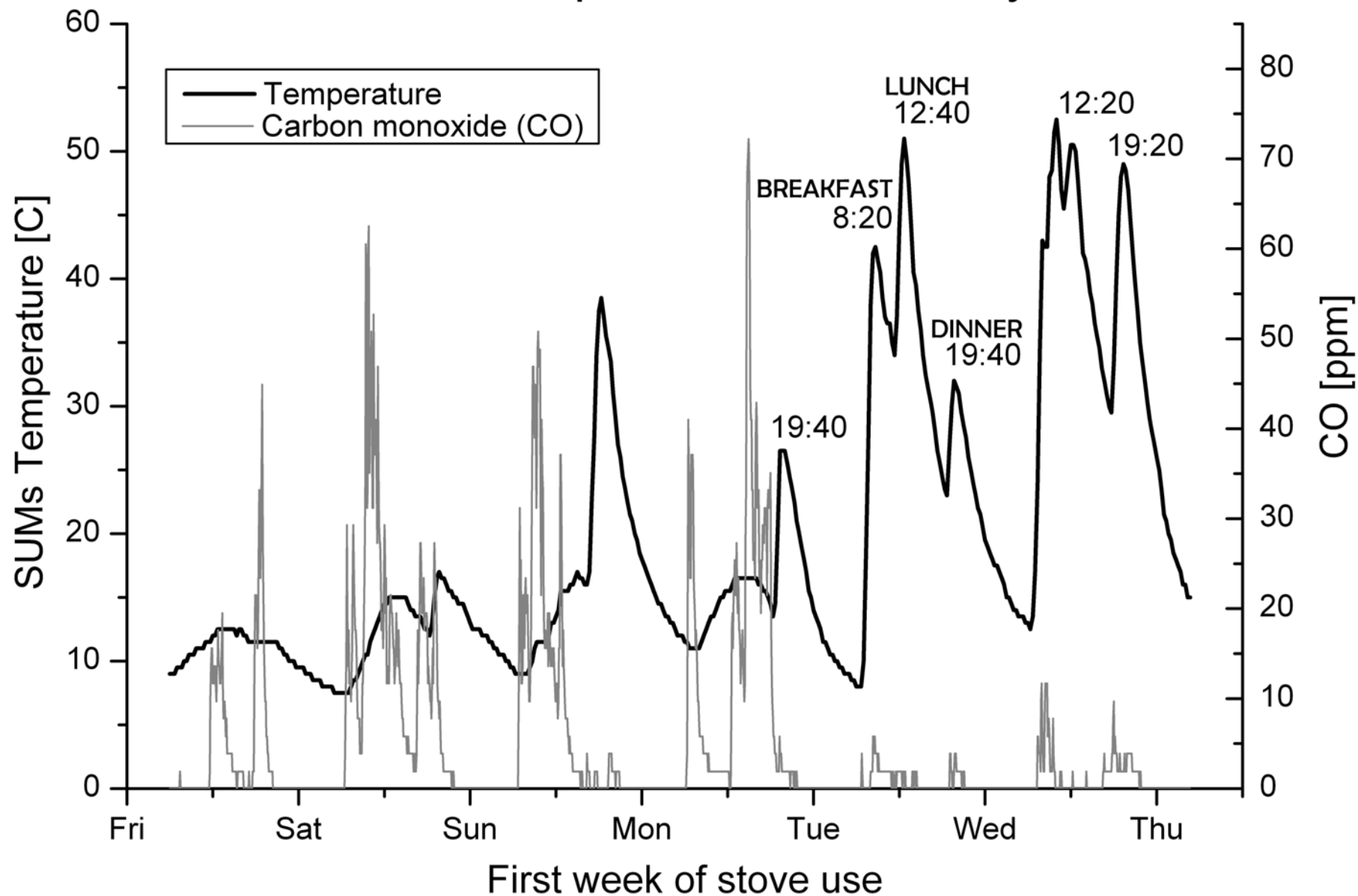
Patterns of Stove Use from Around the World Captured with the UCB-SUMS



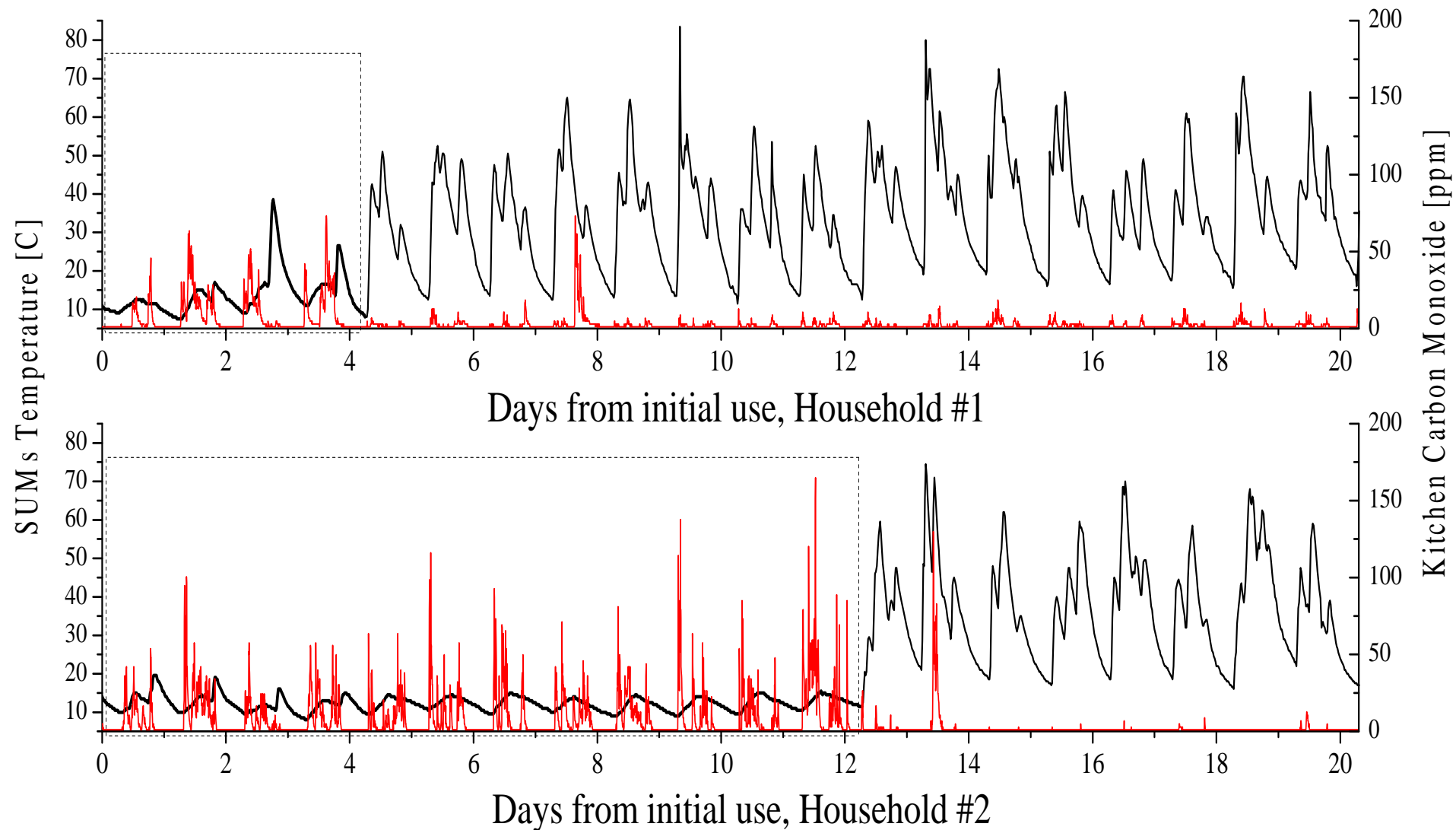
Objective Monitoring with the UCB-SUMS System

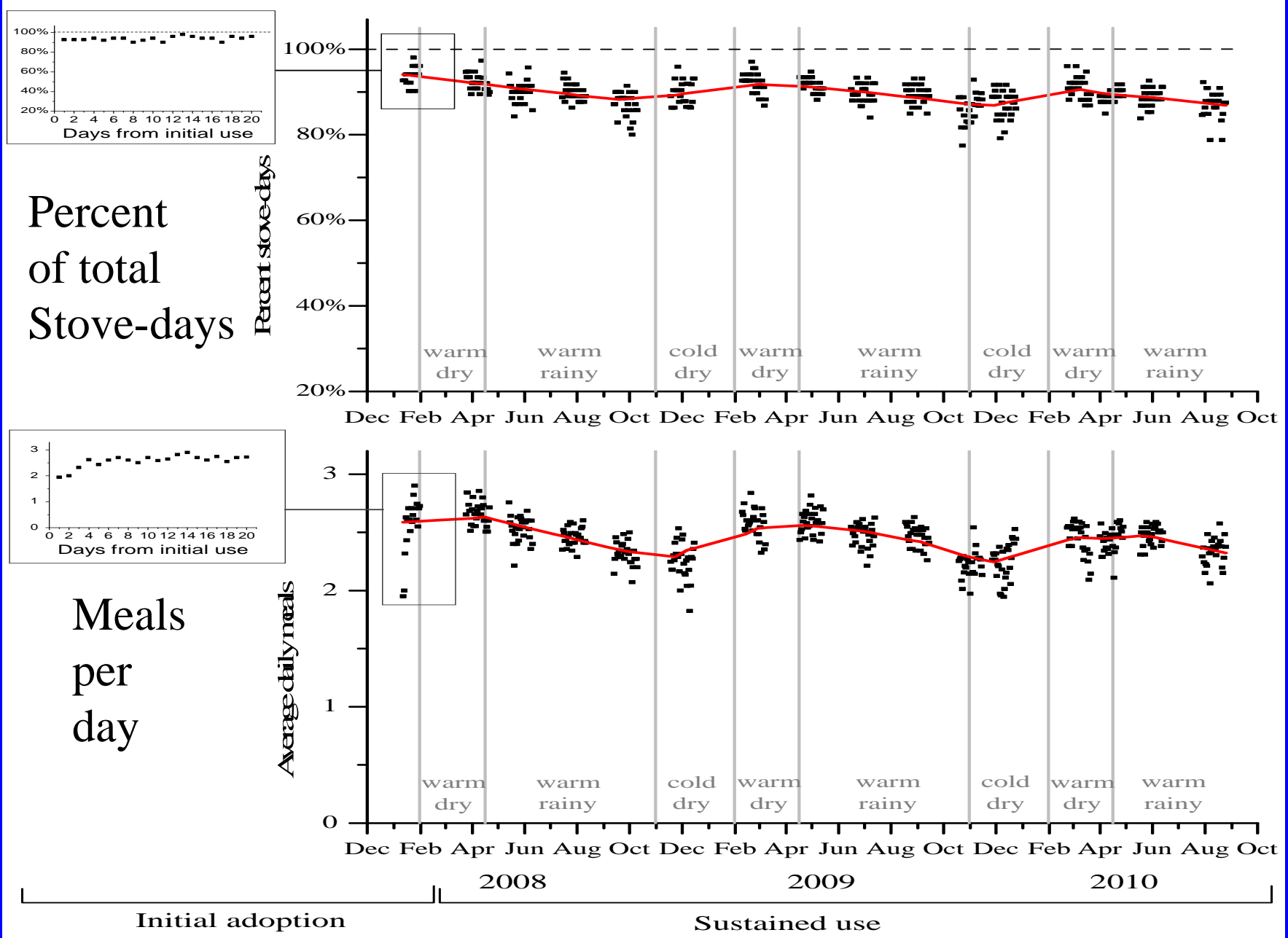


Transition from open fire to a chimney stove



Stove Use Monitors (SUMs) in Action





Wireless Stove Use Monitors Being Field Tested in Mexico This Month – India next year



Principles by Which to Move Forward

- “Get rid of incomplete combustion” – bad for health, climate, ecosystems, agriculture and resource efficiency
- “You don’t get what you expect, but what you inspect” -- need to monitor in the field for both technical performance and usage
- “Not all stoves are equally bad” -- need to target vulnerable populations

Stoves, a few principles.

- “Improved” has not meant clean. Need to combust cleanly, not just have good fuel efficiency or a chimney
 - Truly clean stove/fuel systems are very few in number today, and field experience even more scarce
 - All truly clean (“advanced”) stoves use blowers, but with TEG technology, there is no constraint imposed by lack of electrical supply
- “The poor cannot afford to pay” --need to realign financing so that everyone pays, since all benefit – households, nations, globe
 - Poor will only pay for fuel savings, but many do not buy fuel and thus have little incentive
 - Cost of stoves that merely save fuel are much lower than those that are also clean -- thus sales will not bring health/climate benefits

Many thanks

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

Or just Google “Kirk R. Smith”