ASHES Science to Achieve Results (STAR) Webinar Series – #1

Cookstove Emissions, Climate, and Health Impacts: An Integrated Lab, Field, and Modeling Study

Brought to you by Colorado State University and Berkeley Air Monitoring Group

With funding from EPA #XA 83998701

Berkeley Air Monitoring Group

Colorado State University

Our Expert Panelists Include:

John Volckens is a professor of Mechanical Engineering and the Director of the Center for Energy Development and Health at CSU

Kelsey Bilsback is a Postdoctoral Researcher in Mechanical Engineering at CSU

Jeff Pierce is an Associate Professor of Atmospheric Science at CSU

Want to learn more?

See our website and join the conversation at *ashes-csu.org*

ASHES Science to Achieve Results (STAR) Webinar Series – #1

Cookstove Emissions, Climate, and Health Impacts: An Integrated Lab, Field, and Modeling Study

Brought to you by Colorado State University and Berkeley Air Monitoring Group

Find us at ashes-csu.org or email us at ashes-csu@colostate.edu

With funding from EPA #XA 83998701

Berkeley Air Monitoring Group

Colorado State University

Opening Remarks by John Mitchell

Image shared by Michael Johnson

Advancing Sustainable Household Energy Solutions (ASHES)

Images shared by Michael Johnson

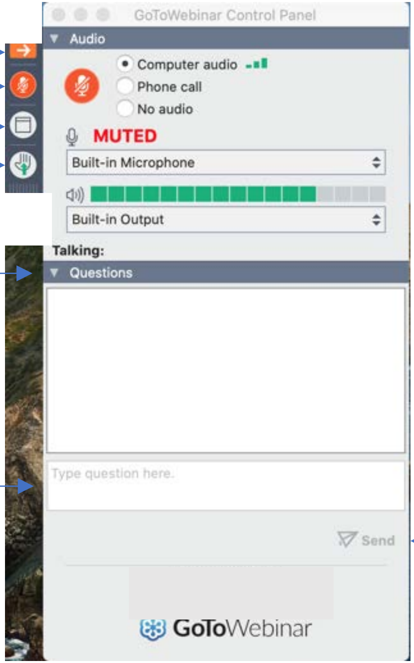
Webinar Control Panel

Minimize and maximize control panel

You are in ‘listen only’ mode

Minimize and maximize screen

We are not using this function today.



Questions pane

Type your question in here

Submit your question by clicking here

Science To Achieve Results (STAR) Extramural Research Grants

Measurements and Modeling for Quantifying Air Quality and Climatic Impacts of Residential Biomass or Coal Combustion for Cooking, Heating, and Lighting

- How would a feasible set of interventions for residential cooking, heating, or lighting in a developing part of the world impact air quality and climate?
- What is the realistic range and timeframe of foreseeable benefits to air quality and climate of various interventions in cooking, heating, or lighting practices in a developing part of the world, considering regional constraints (e.g., acceptability and availability of different technologies or fuels) and sustainability of alternate fuels or technologies?

RFA Published 2012, Projects Funded 2013/4 – 2018/9
Link to additional information and publications list:
https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/recipients.display/rfa_id/563
Terry Keating, EPA Project Officer, keating.terry@epa.gov

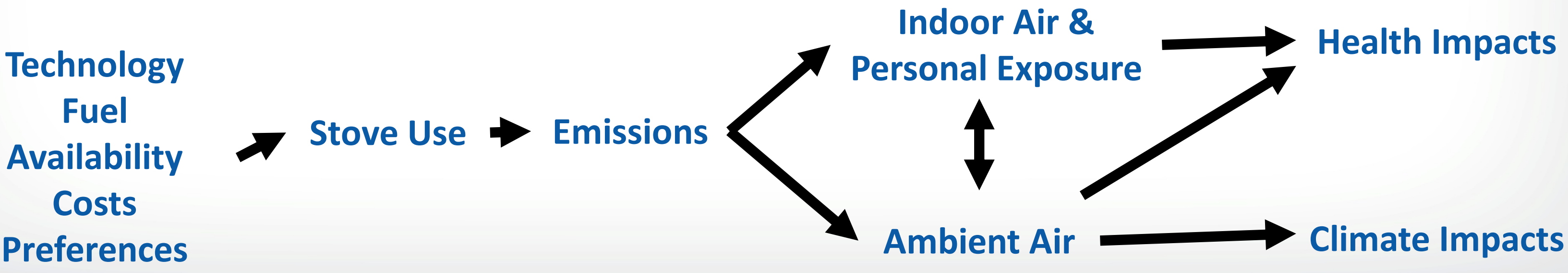
Science To Achieve Results (STAR) Extramural Research Grants

6 teams

8 countries

13 field locations

>70 Publications



Science To Achieve Results (STAR) Extramural Research Grants

- Household Sources of Primary and Secondary PM in Northern India
  Kirk Smith, UC Berkeley; Ajay Pillarisetti, Emory University

- Experimental Stove Interventions in Northern and Southern India
  Rob Bailis, Yale Univ/Stockholm Environment Institute

- Health Impacts of Household Energy Intervention in Tibet
  Jill Baumgartner, Univ of Minnesota/McGill University

- Mapping Feasible Residential Solutions for Cooking and Heating
  Tami Bond, Univ of Illinois/Colorado State University

- Air Quality and Climate Impacts of Cooking and Lighting Emissions in the African Sahel
  Michael Hannigan, Univ of Colorado, Boulder

- Quantifying the Benefits of Improved Cookstoves:
  An Integrated Lab, Field, and Modeling Study
  John Volckens, Colorado State University

Quantifying the climate, air quality, and health benefits of improved cookstoves:

an integrated laboratory, field and modeling study

John Volckens, Kelsey Bilsback, Jeff Pierce

ASHES Webinar, 14 Jan 2021

Colorado State University

With funding from EPA RD8354380 & NIEHS ES023688

Our Team

Jeff Pierce
Megan Benka-Coker
Kelsey Bilsback
Maggie Clark
Kristen Fedak
Nick Good
Kelley Hixson
Jack Kodros
Christian L'Orange
Jennifer Peel
Sarah Rajkumar
Brooke Reynolds
James Tillotson
Jessica Tryner
Lizette van Zyl

Allen Robinson
S. Rose Eisenberg
Jimmy Liacos
Georges Saliba
R. Subramanian
Antonis Tasoglou

BERKELEY AIR MONITORING GROUP

Michael Johnson
Ricardo Piedrahita

Penn State Greater Allegheny

Eric Lipsky
River Dolfi

Jim Jetter

SRI RAMACHANDRA UNIVERSITY Chennai

Kalpana Balakrishnan
Sankar Sambandam

CREEC
CENTRE FOR RESEARCH IN ENERGY AND ENERGY CONSERVATION

Agnes Naluwagga

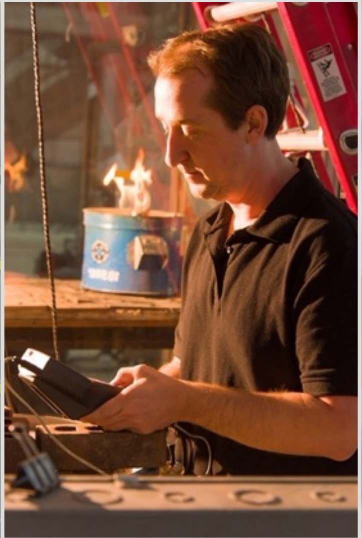
清華大學
Tsinghua University

Ming Shan

Our Driving Questions

- Why don’t lab measurements of cookstove emissions agree with field observations?
- What is the magnitude and variability of air pollution emitted form residential solid fuel combustion on the planet?
- What would happen to global climate and air quality if everyone who burns solid fuels could move up ‘one rung’ (or more) on the energy ladder?

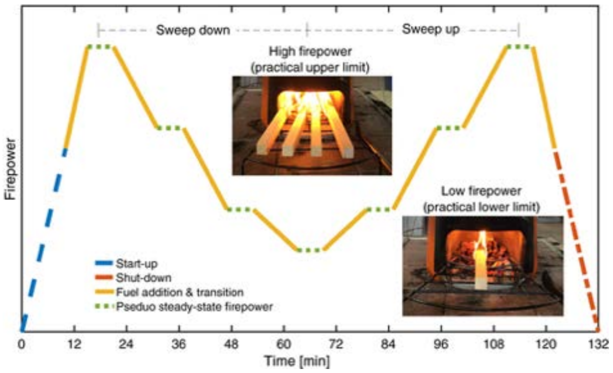
Labwork



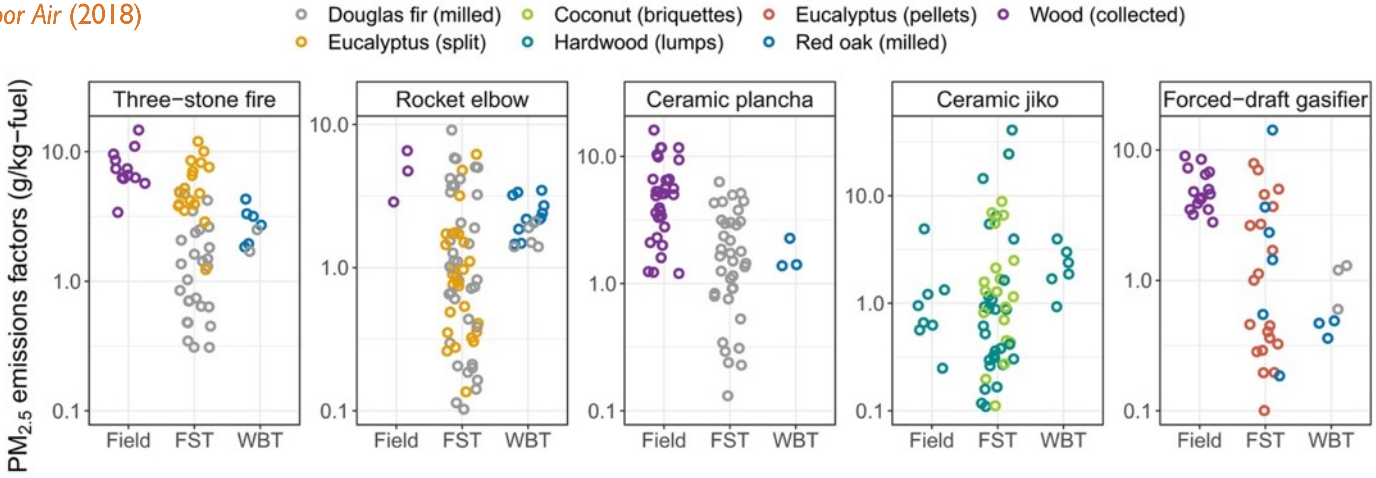
A "drive-cycle" approach to stove testing provides more realistic data on pollutant emissions (more on this from Kelsey Bilsback in a minute!)

*Methodology incorporated into **ISO 19867-1:** Laboratory Testing of Cookstoves*

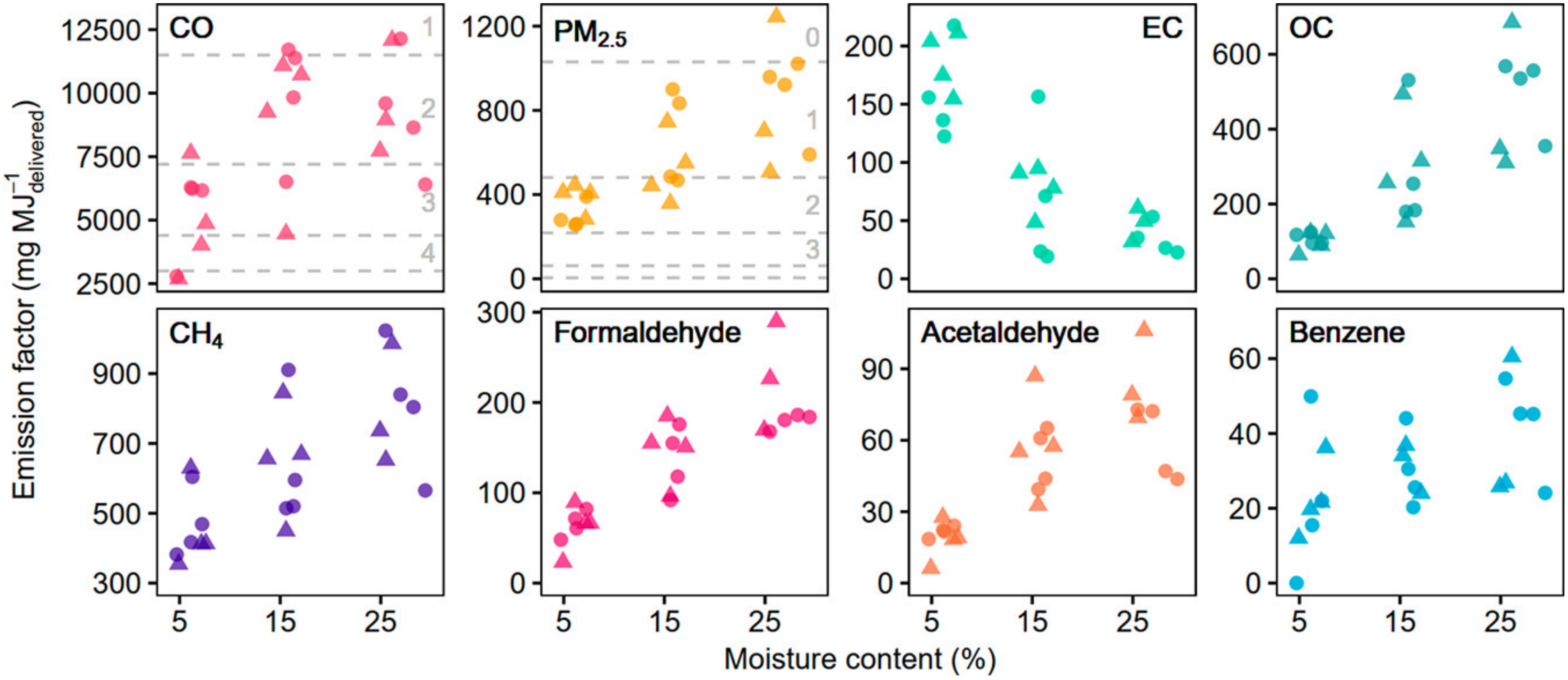
With thanks to Jim Jetter at US EPA for collaboration and confirmation for our work



Bilsback et al. *Indoor Air* (2018)



Cookstoves emit more than just PM and CO. Many factors combine to modulate air pollutant emissions.



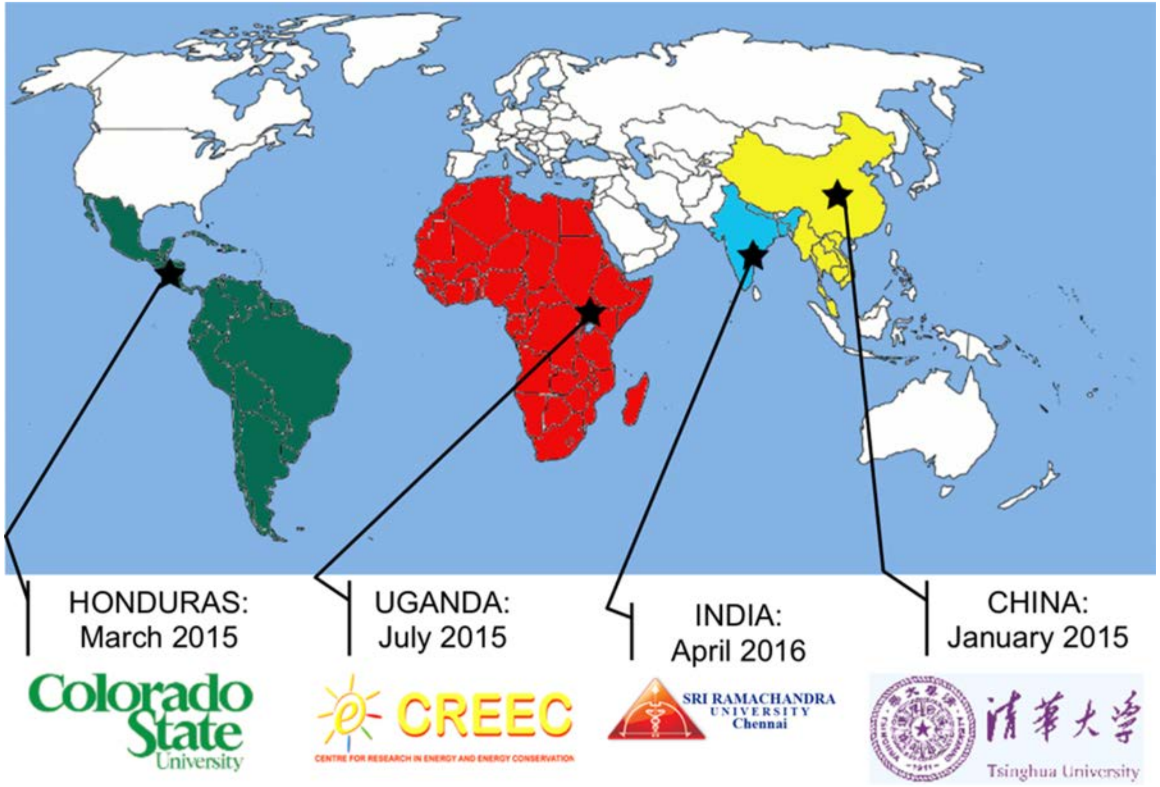
van Zyl et al. *ES&T* (2019)

Fieldwork

Goal: Characterize emissions from n=40 homes across 4 countries

Honduras

Uganda



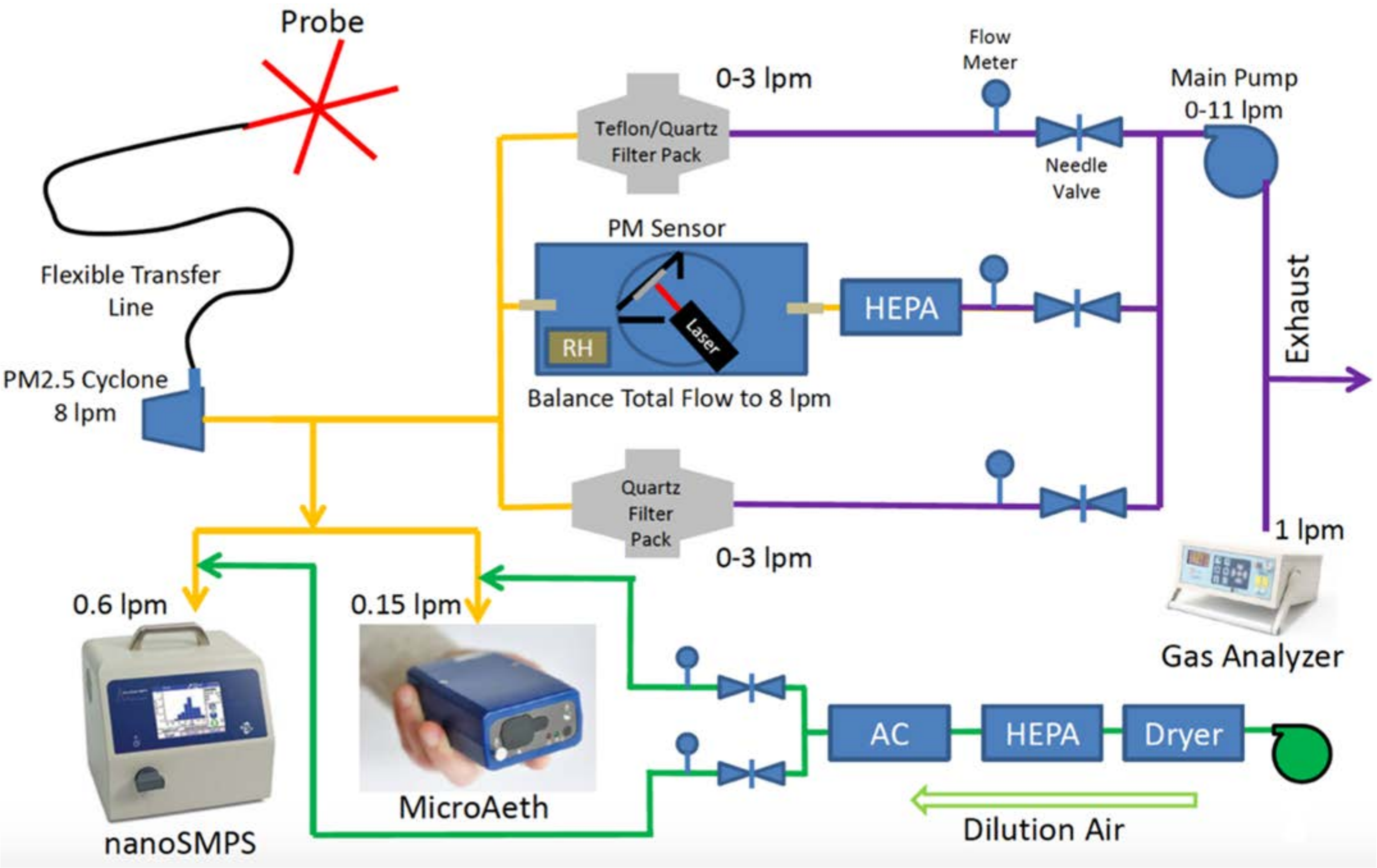
China

India

Quantifying cookstove emissions in the field **is not easy**

Particle Emissions
- Size distribution
- Elemental carbon
- Organic carbon
- $PM_{2.5}$ mass

Gas Emissions
- Carbon monoxide
- Carbon dioxide
- Total VOC



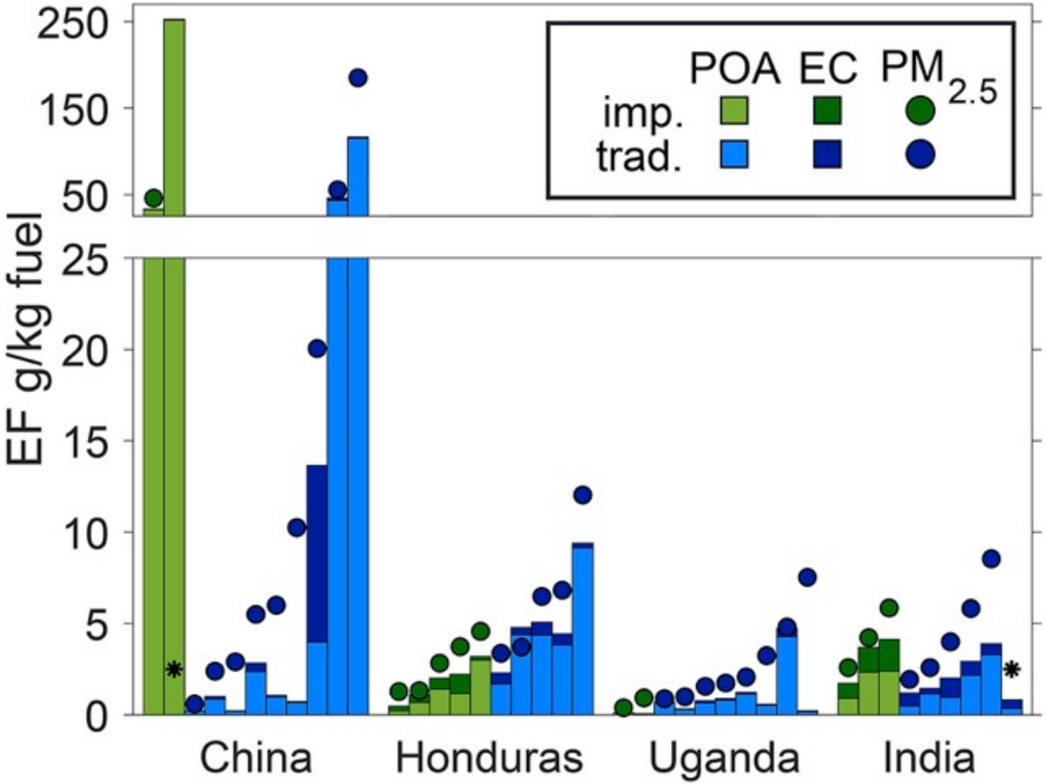

NANOSCAN


India

Uganda

India

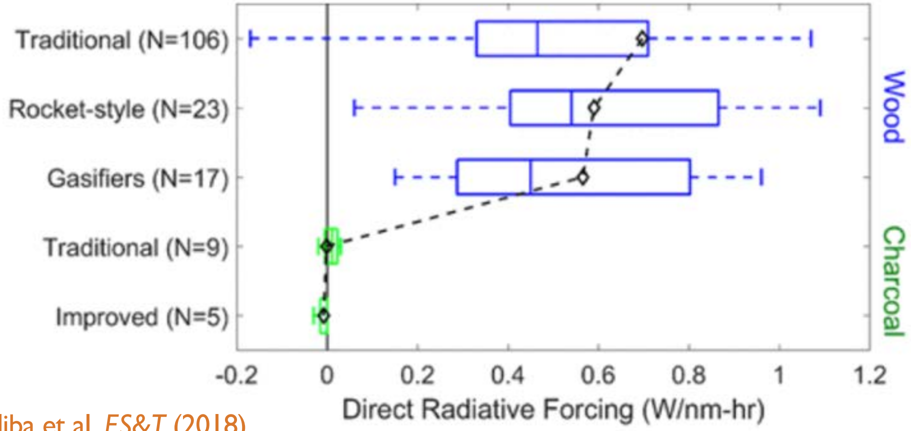
Stoves are just like vehicles. There are fleet-to-fleet differences and super-emitters, too.



Eilenberg et al. *Atmospheric Env.* (2018)

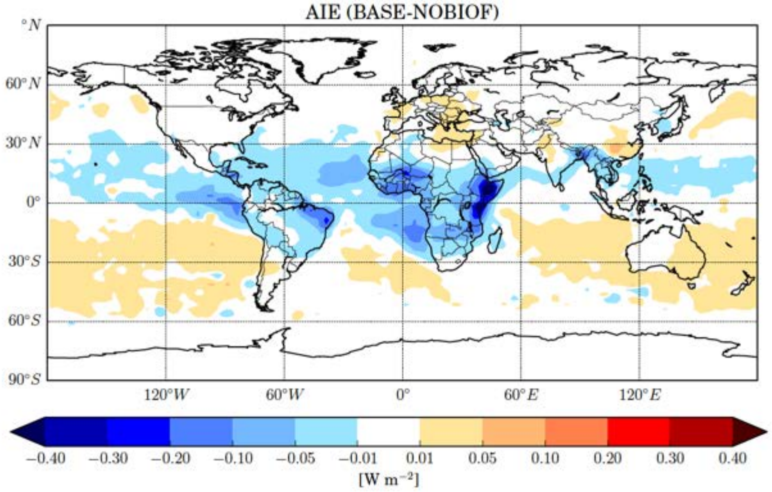
Modeling

Models suggest that a switch to "improved" solid-fuel stoves will have minimal impact on climate (more of this from Jeff Pierce in a minute!)

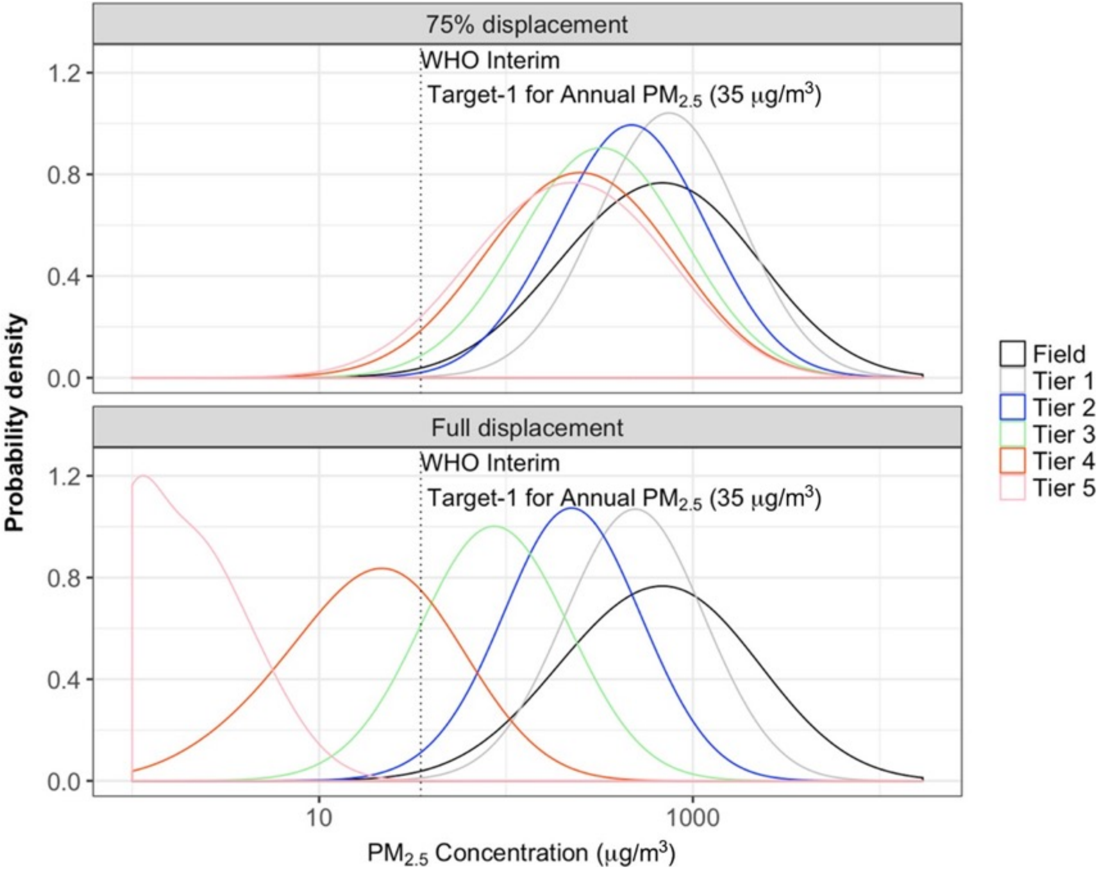


Saliba et al. *ES&T* (2018)

Kodros et al. *ACP* (2015)



Only stoves that meet "Tier 4 or 5" emissions guidelines can achieve household $PM_{2.5}$ levels at the WHO interim guideline of 35 μg/m³.



Piedrahita et al. *Indoor Air* (2020)

Kelsey Bilsback, PhD

Department of Atmospheric Science

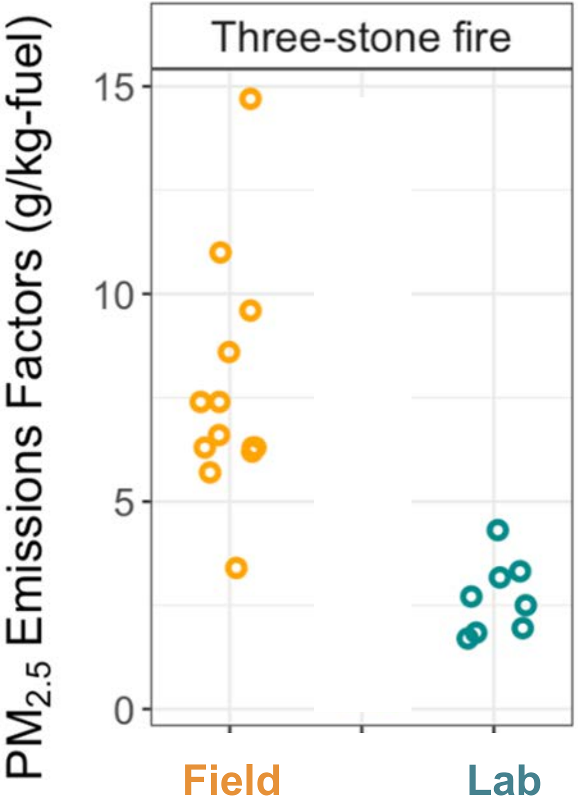
Colorado State University

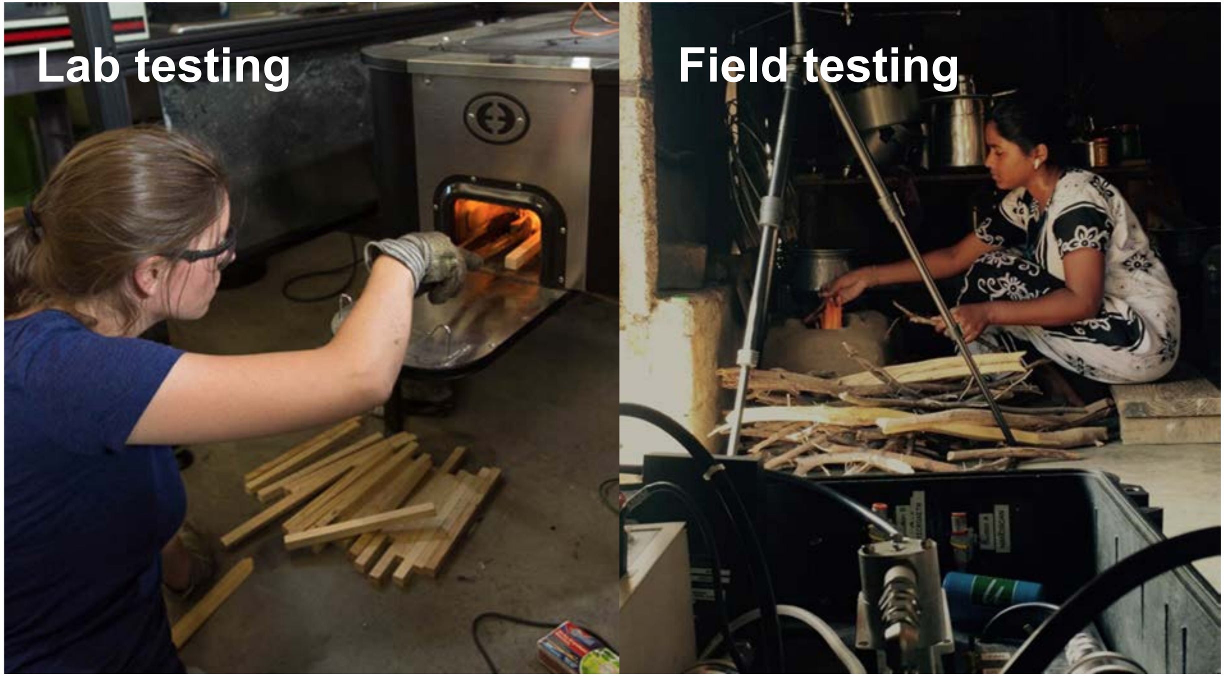
Kelsey.Bilsback@colostate.edu

Cookstove emissions are poorly quantified

https://phys.org/

Knowledge gap: Laboratory and real-world emissions measurements do not agree





Bilsback et al, *Indoor Air*, 2018

Firepower is the rate of heat released from combustion

High firepower

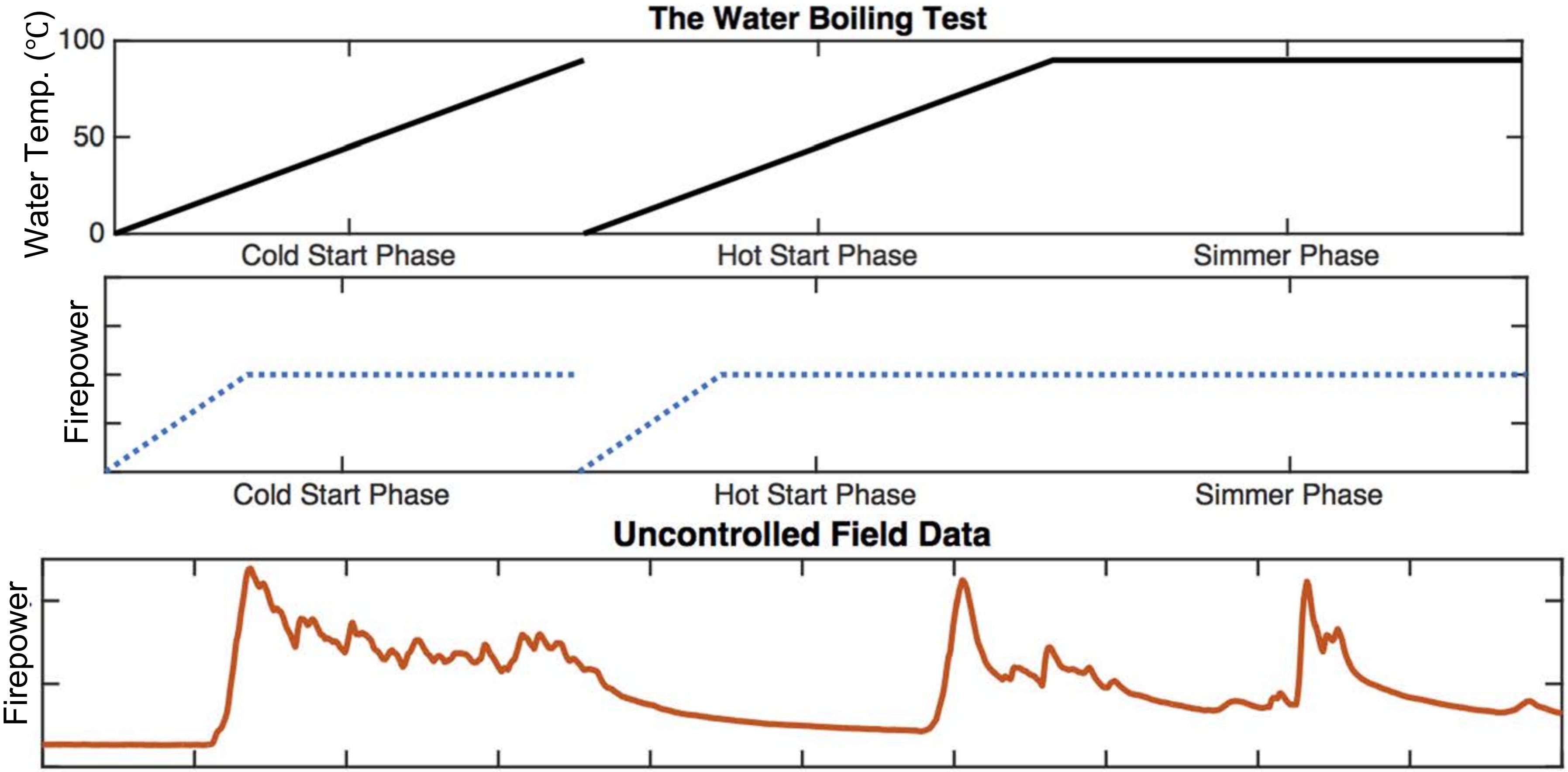
Low firepower

$$FP = LHV_{fuel} \cdot \dot{m}_{fuel}$$

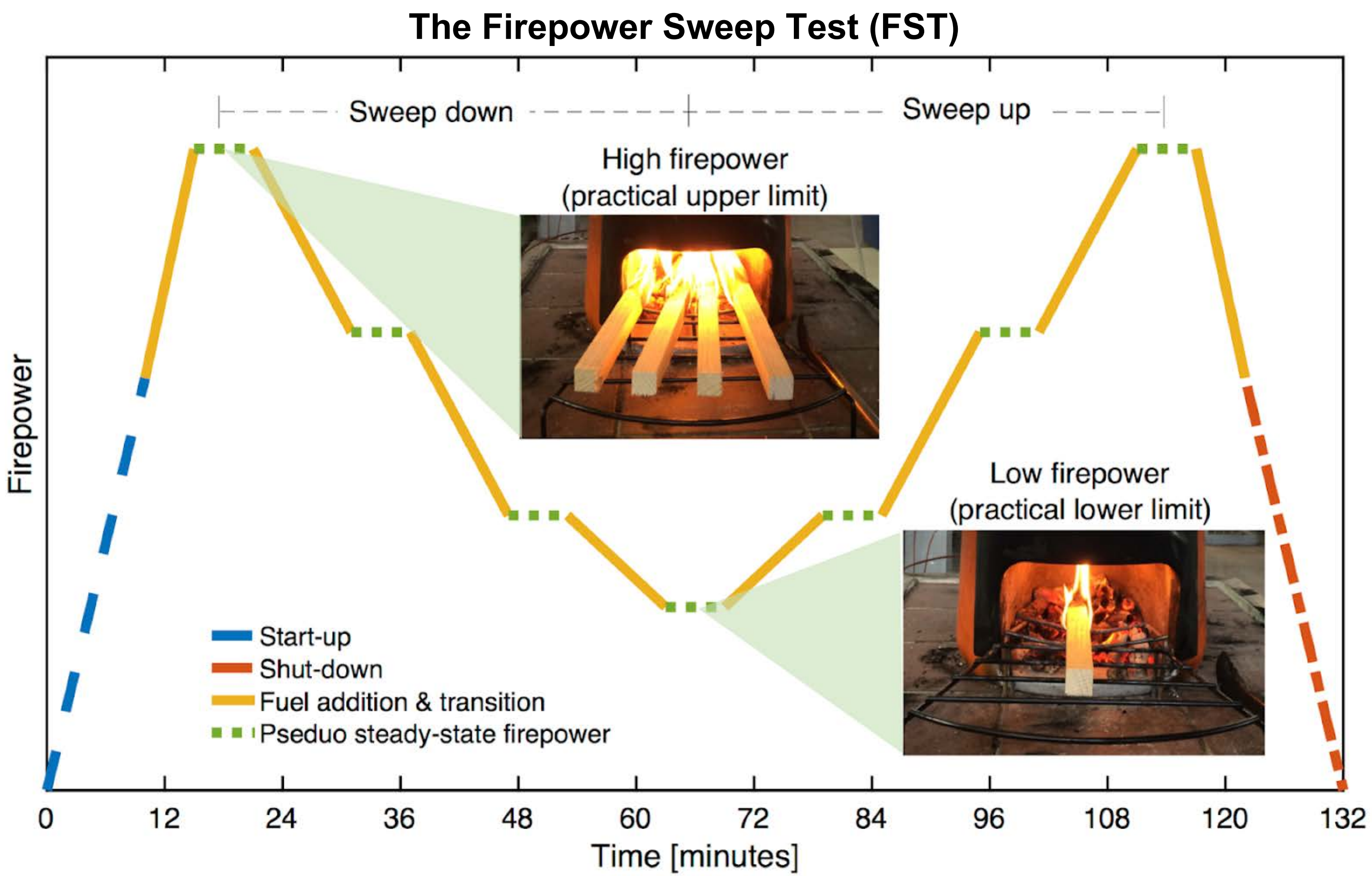
LHV_{fuel} Lower heating value of the fuel

$\dot{m}_{fuel}$ Fuel burn rate

Water Boiling Test (WBT) does not capture real-world operating conditions



We developed a lab protocol to test stoves under a range of operating conditions



We used the FST to test a range of stoves and fuels

Open fires

Improved forced-draft stoves

Improved natural-draft stoves

Charcoal stoves

Douglas fir (milled), Eucalyptus (split), Coconut charcoal (briquettes), Hardwood charcoal (lumps), Red Oak (milled), Eucalyptus (pellets)

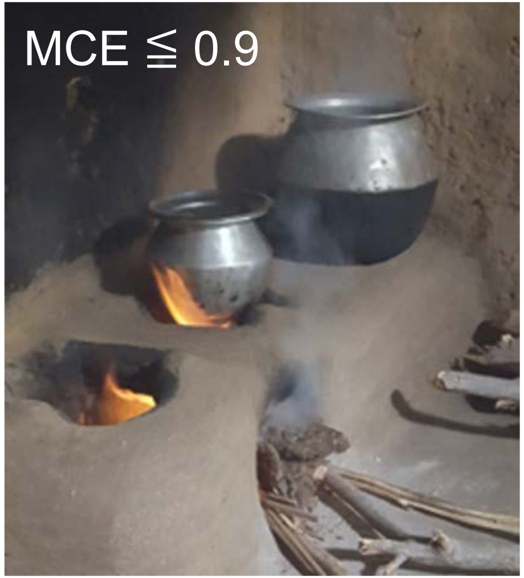
Modified combustion efficiency (MCE) is an indicator of combustion condition

$$MCE = \frac{\Delta CO_2}{\Delta CO + \Delta CO_2}$$

ΔCO_2 Background-corrected mixing ratio of CO_2

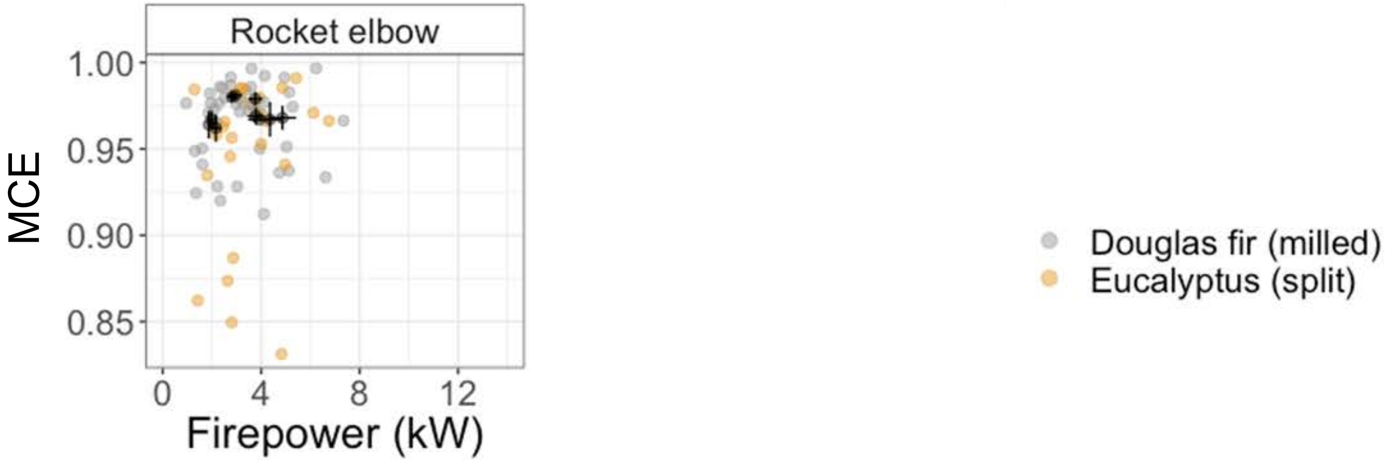
ΔCO Background-corrected mixing ratio of CO

Flaming combustion

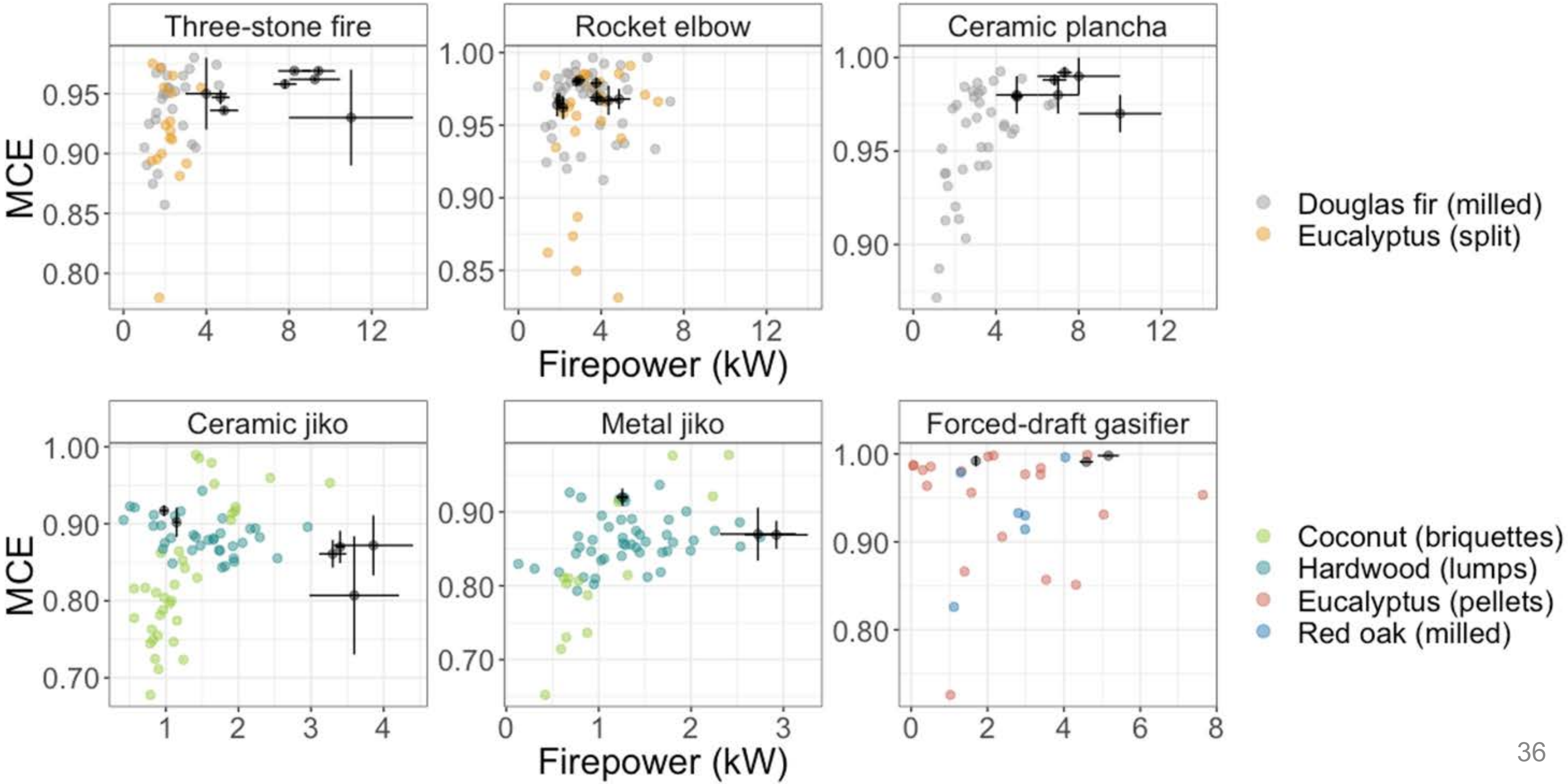


Smoldering combustion

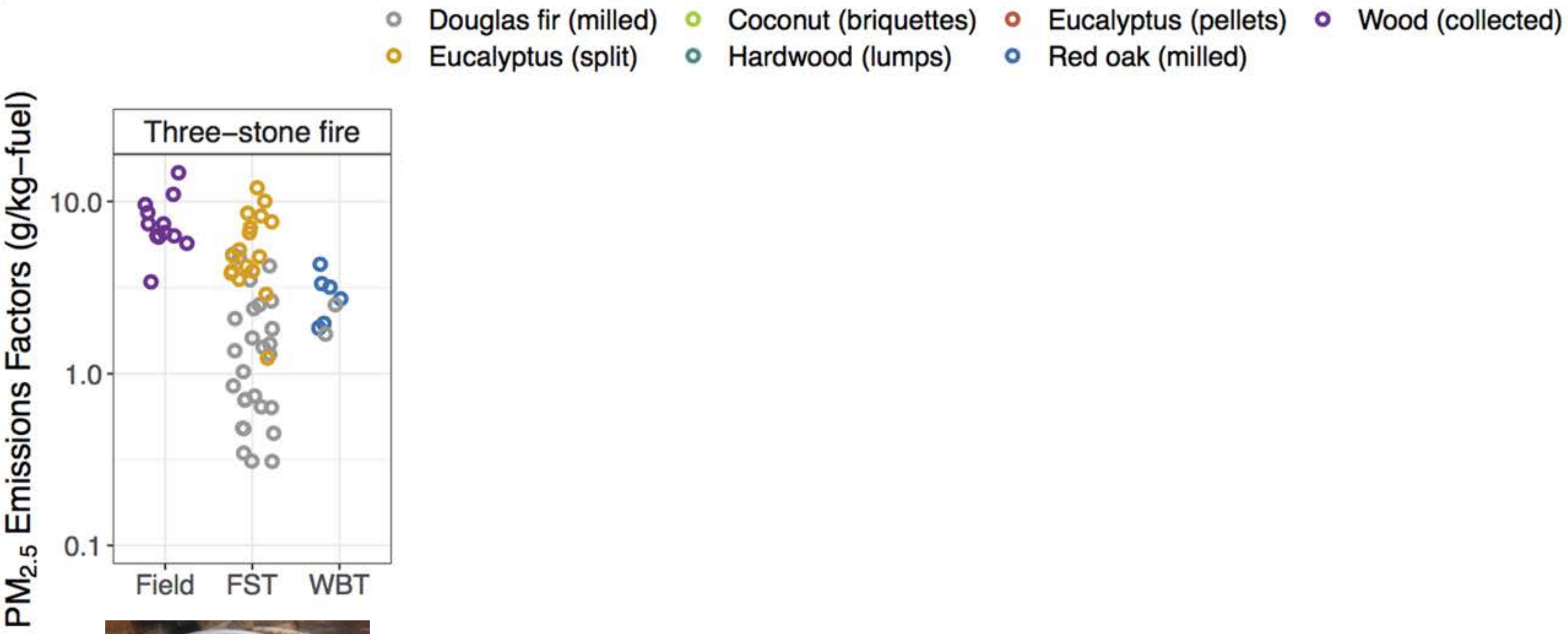
FST results in a wider range of operating conditions than the WBT



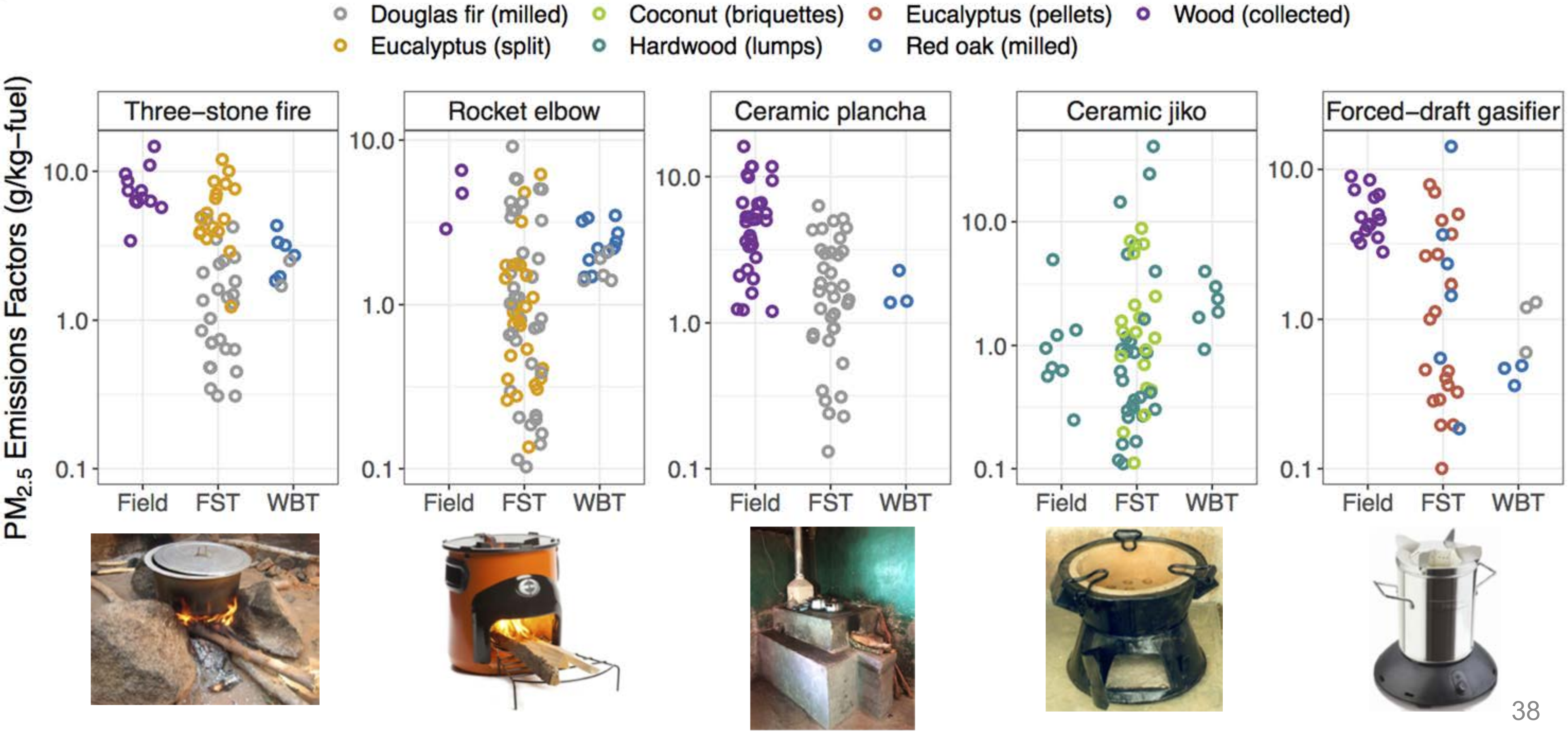
FST results in a wider range of operating conditions than the WBT



FST spans the range of emissions seen during in-home use



FST spans the range of emissions seen during in-home use



Practical Implications

- By varying firepower, real-world emissions can be better replicated.
- Multiple-firepower laboratory tests can better predict which stove technologies will lead to substantially improved indoor air quality.

Received: 18 March 2018 | Revised: 1 August 2018 | Accepted: 2 August 2018
DOI: 10.1111/ina.12497

ORIGINAL ARTICLE

WILEY

The Firepower Sweep Test: A novel approach to cookstove laboratory testing

Kelsey R. Bilsback[1] | Sarah R. Eilenberg[2] | Nicholas Good[3] | Lauren Heck[4] | Michael Johnson[5] | John K. Kodros[6] | Eric M. Lipsky[2,7] | Christian L'Orange[1] | Jeffrey R. Pierce[6] | Allen L. Robinson[2] | R. Subramanian[2] | Jessica Tryner[1] | Ander Wilson[4] | John Volckens[1]

INDOOR AIR
International Journal of Indoor Environment and Health

Free text available on ResearchGate

Knowledge gap: Cookstoves emit thousands of pollutants...

Carbon dioxide

Dioxins and furans

Heavy metals

Inorganic ions

Polycyclic aromatic hydrocarbons

CO

Nitrogen oxides

Carbohydrates

$PM_{2.5}$

Volatile organic compounds

Semi-volatile organics

Methane

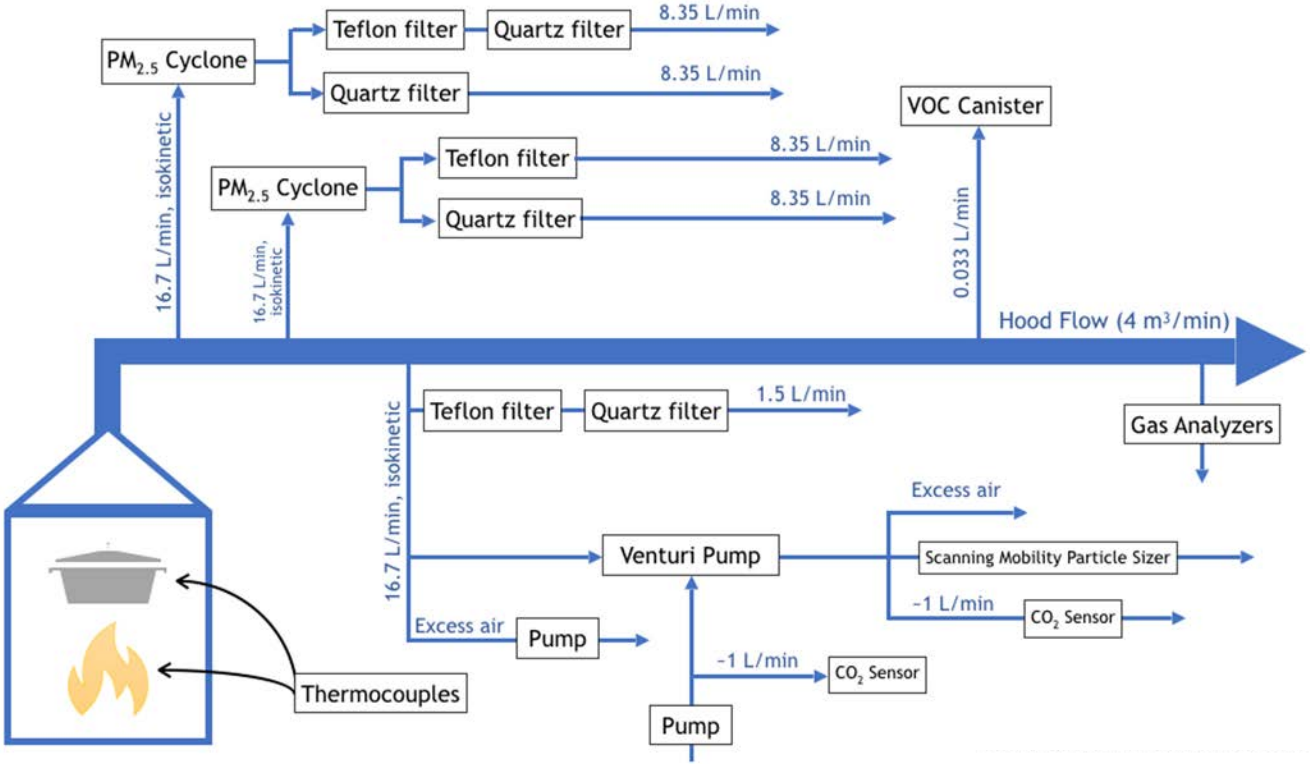
Organic carbon

Black carbon

Minerals

...but most studies only measure PM and CO, and most health studies only consider PM exposure.

We measured 120 smoke constituents



Particle Emissions

Size distribution (10- 400 nm)
Elemental carbon
Organic carbon
Light absorption and scattering
$PM_{2.5}$ mass
Inorganic ions
(SO4-, NO3-, NH4+, etc.)
Polycyclic aromatic hydrocarbons
Carbohydrates

Gas Emissions

Carbon monoxide
Carbon dioxide
Methane
Volatile organic compounds
(e.g., hydrocarbon alkanes,
alkenes, aromatics –
benzene, toluene, xylene, etc.)
Carbonaceous Carbonyls
(formaldehyde, acetaldehyde, etc.)
Polycyclic aromatic hydrocarbons

Bilsback et al, *ES&T*, 2019

We tested 26 stove-fuel combinations

Traditional open fires

Charcoal stoves

Insulated natural-draft stoves

Kerosene stoves

Insulated forced-draft stoves

LPG stove

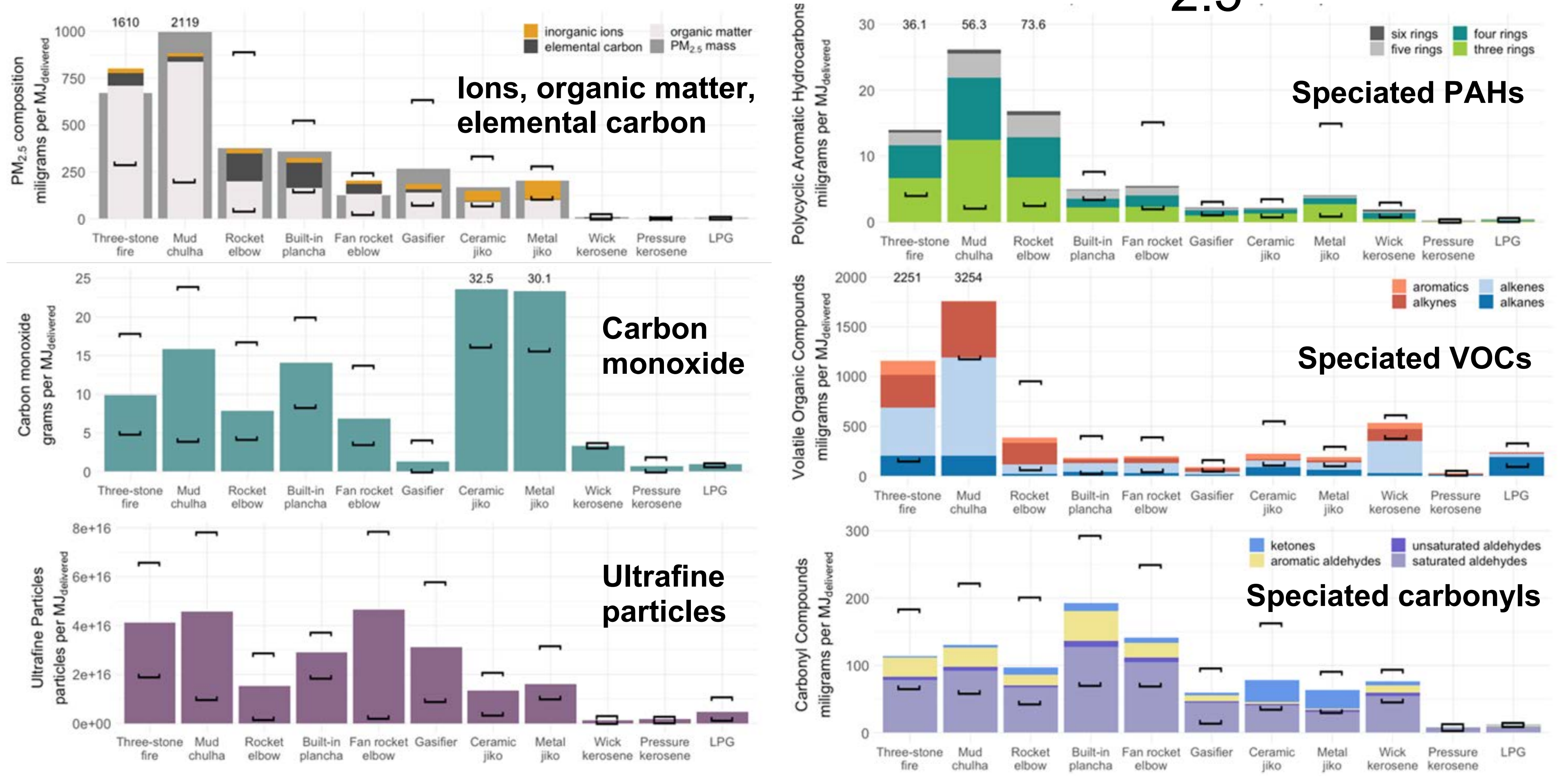
<u>Wood fuels:</u>
- Douglas fir
- Eucalyptus
- Oak

<u>Pellet fuels:</u>
- Eucalyptus pellets
- Lodgepole pine pellets

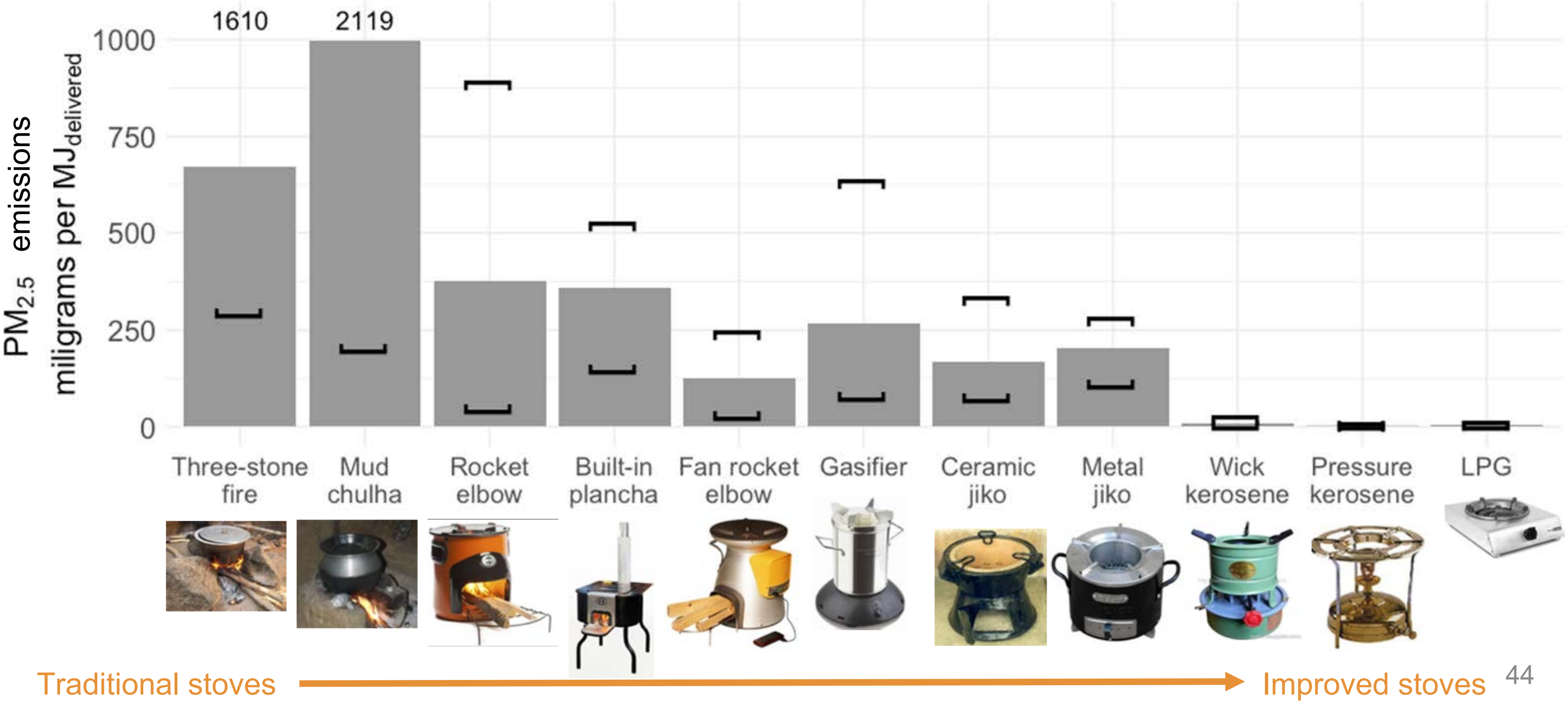
<u>Charcoal fuels:</u>
- Hardwood lumps
- Coconut briquettes

<u>Fossil fuels:</u>
- Kerosene
- LPG

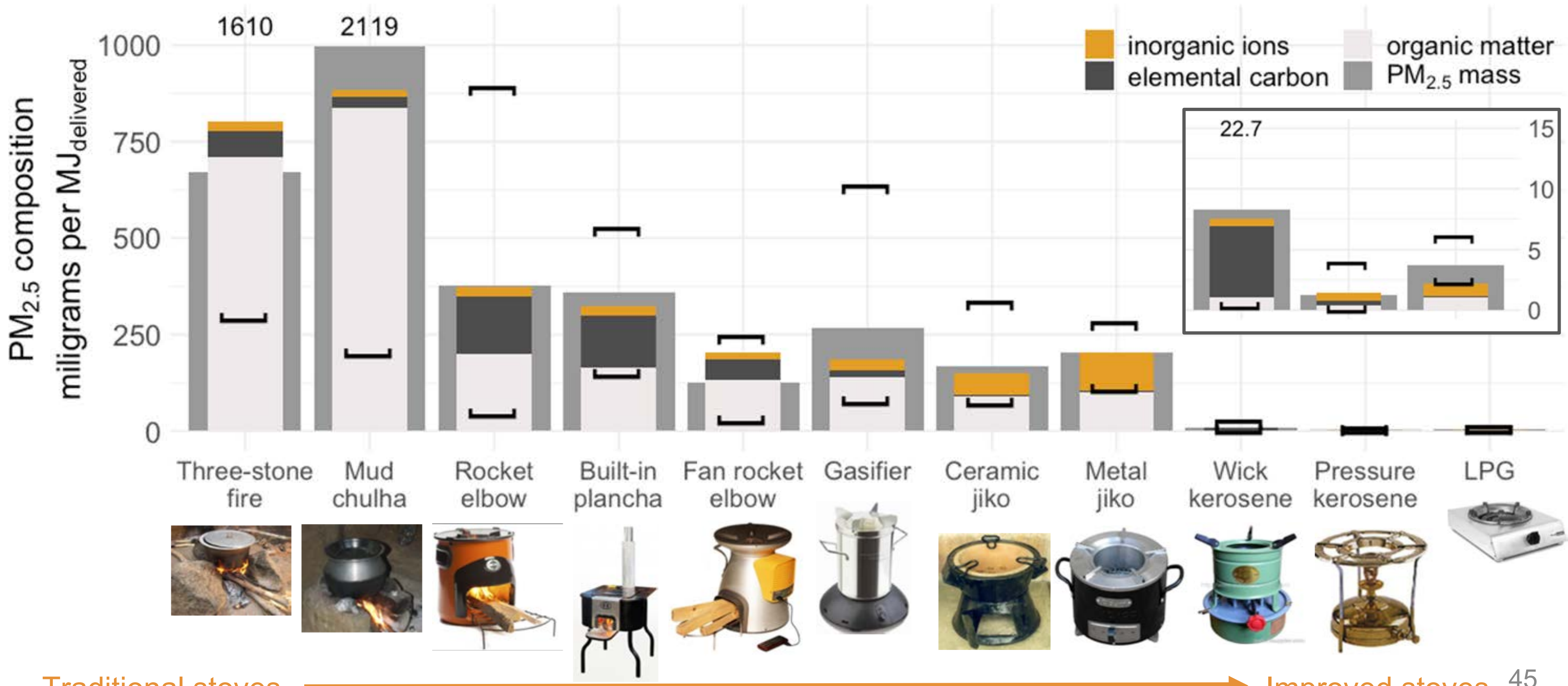
Stoves emit much more than $PM_{2.5}$ and CO



Improved stoves tend to emit less $PM_{2.5}$

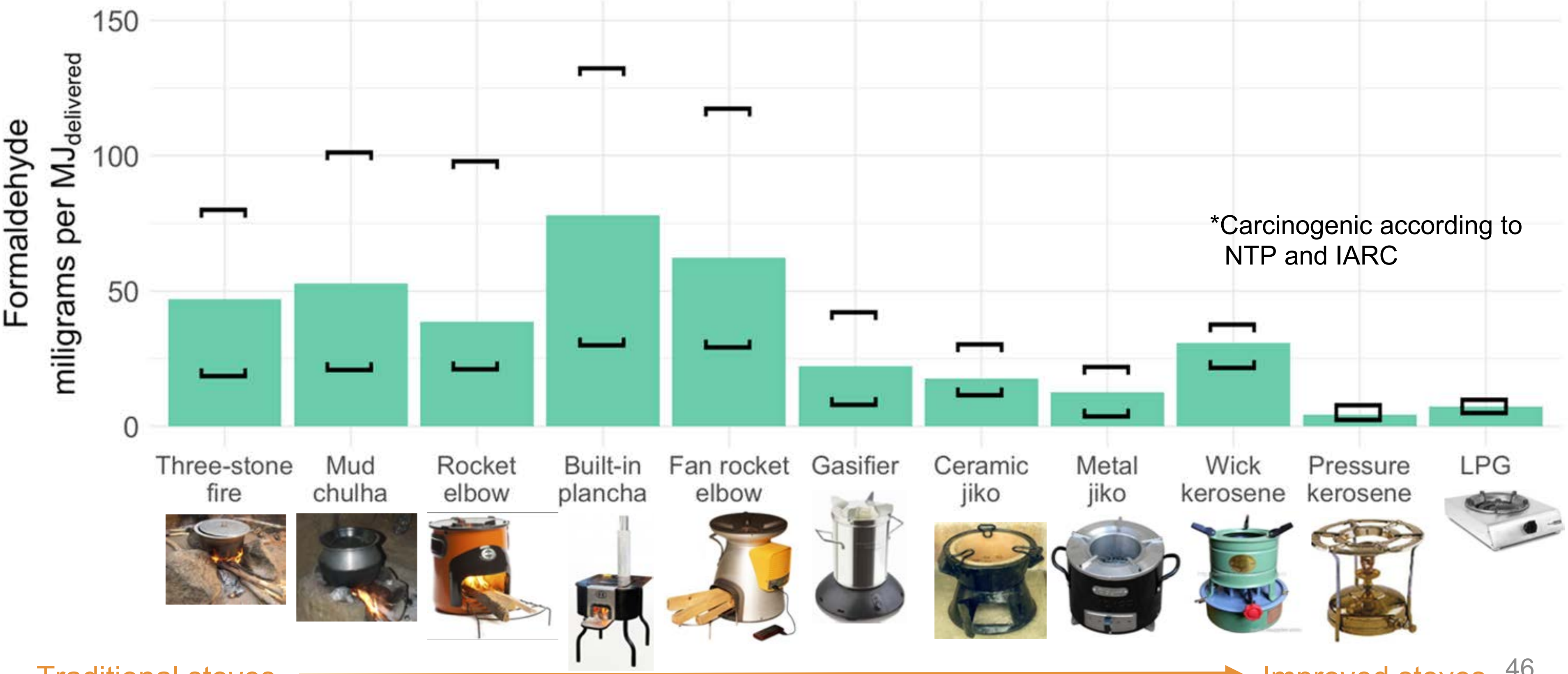


$PM_{2.5}$ composition varies by stove type



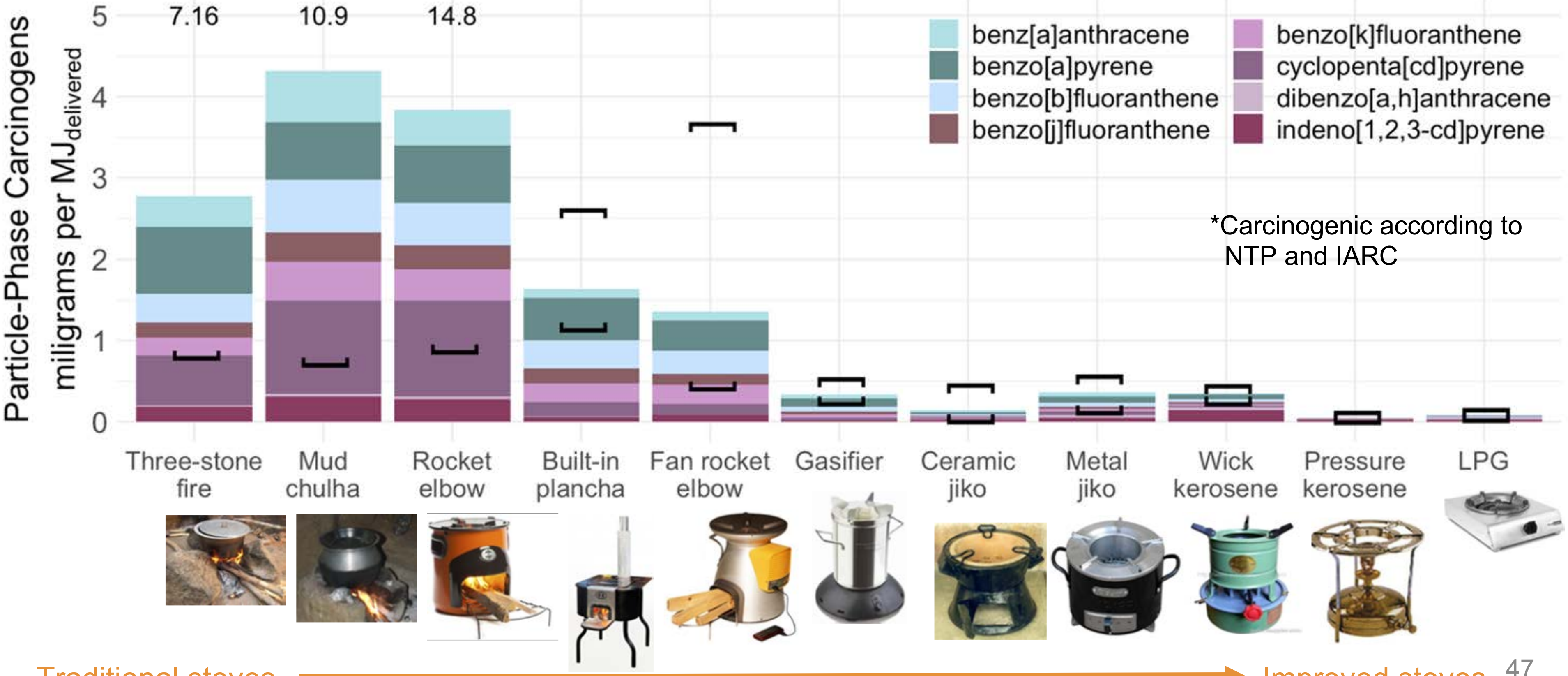
Traditional stoves → Improved stoves

Improved stoves do not always reduce all harmful pollutants



Traditional stoves → Improved stoves

Improved stoves do not always reduce all harmful pollutants



Traditional stoves → Improved stoves

Practical Implications

- Improved stoves reduce many but not all harmful pollutants.

- $PM_{2.5}$ and CO are not strong predictors of health and climate relevant pollutants.

- We recommend measuring pollutants, beyond $PM_{2.5}$ and CO, before new stoves are disseminated to users.

Environmental Science & Technology

Article

Cite This: Environ. Sci. Technol. 2019, 53, 7114–7125

pubs.acs.org/est

A Laboratory Assessment of 120 Air Pollutant Emissions from Biomass and Fossil Fuel Cookstoves

Kelsey R. Bilsback,[†] Jordyn Dahlke,[†] Kristen M. Fedak,[‡] Nicholas Good,[‡] Arsineh Hecobian,[§] Pierre Herckes,[||] Christian L'Orange,[†] John Mehaffy,[†] Amy Sullivan,[§] Jessica Tryner,[†] Lizette Van Zyl,[†] Ethan S. Walker,[‡] Yong Zhou,[§] Jeffrey R. Pierce,[§] Ander Wilson,[⊥] Jennifer L. Peel,[‡] and John Volckens[*,†]

Free text available on ResearchGate

Estimates of climate and health impacts from solid-fuel use:

How certain are we?
And what does this imply for decision making?

Jeff Pierce, Jack Kodros, and many others (acknowledged on papers throughout)

Outline

- Aerosol climate forcings from residential solid-fuel use (SFU)
  - Is there a “climate benefit” from switching to alternative energy sources?
- Estimated mortality due to exposure to aerosol from residential solid-fuel use (SFU)
- What does this all mean?

Outline

- Aerosol climate forcings from residential solid-fuel use (SFU)
  - Is there a “climate benefit” from switching to alternative energy sources?
- Estimated mortality due to exposure to aerosol from residential solid-fuel use (SFU)
- What does this all mean?

Climate effects from solid-fuel use

- Greenhouse gases: CO_2, CH_4, VOCs
  - Complicated: Was it biomass fuel? Will replacement energy also emit greenhouse gases?
- Aerosol effects:
  - Direct effect (scatter/absorb sunlight)
  - Indirect effect (changes in cloud properties)
  - Semi-direct effect (feedbacks of direct effect on clouds)

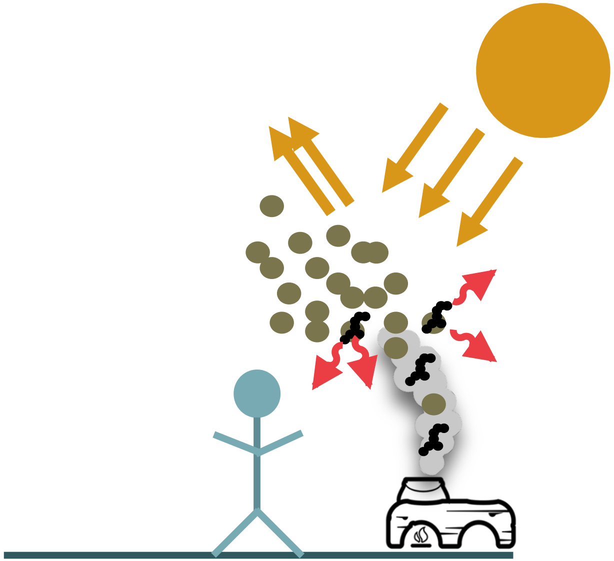
Climate effects from solid-fuel use

- Greenhouse gases: CO_2, CH_4, VOCs
  - Complicated: Was it biomass fuel? Will replacement energy also emit greenhouse gases?
- Aerosol effects:
  - Direct effect (scatter/absorb sunlight)
  - Indirect effect (changes in cloud properties)
  - Semi-direct effect (feedbacks of direct effect on clouds)

Aerosols emitted from solid fuel use impacts climate in a variety of ways

Direct radiative effect

- interact with solar radiation



↑ aerosol mass, ↑ extinction

Organic carbon (**scatters**)

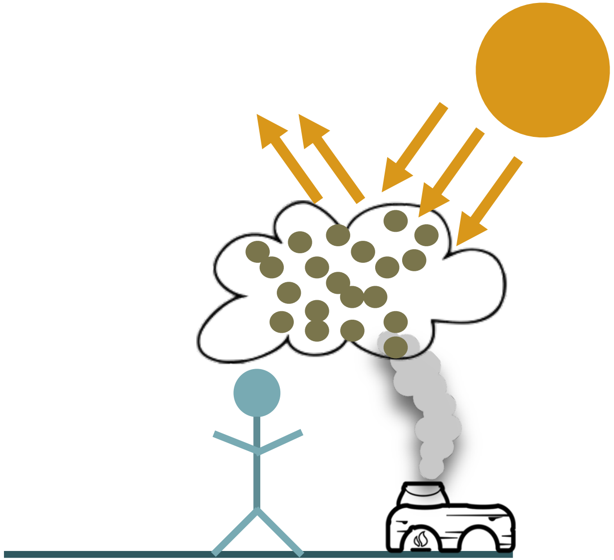
Black carbon (**absorbs**)

Aerosols emitted from solid fuel use impacts climate in a variety of ways

↑ aerosol number, ↑ **cloud reflectance**

<u>Aerosol indirect effect (AIE)</u>

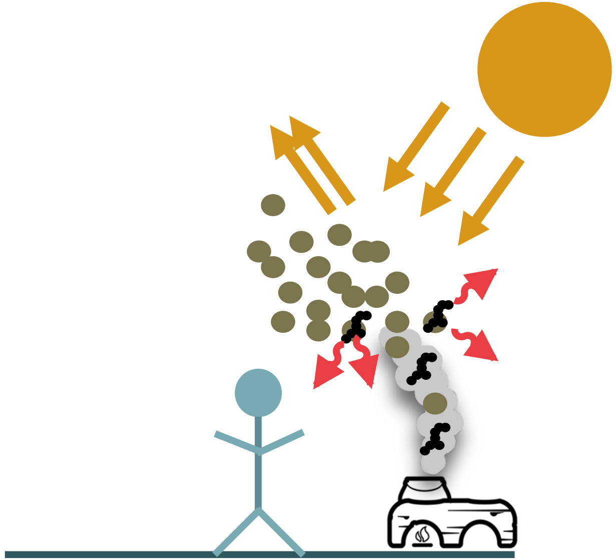
- alter cloud properties



Aerosols emitted from solid fuel use has both positive (warming) and negative (cooling) radiative effects

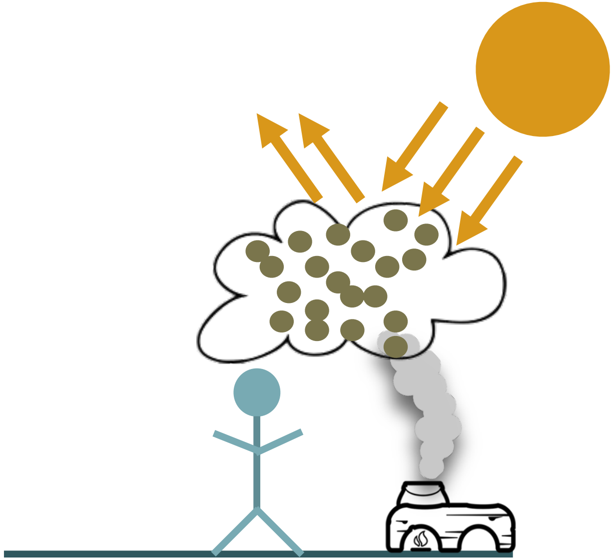
Direct radiative effect

- interact with solar radiation



Aerosol indirect effect

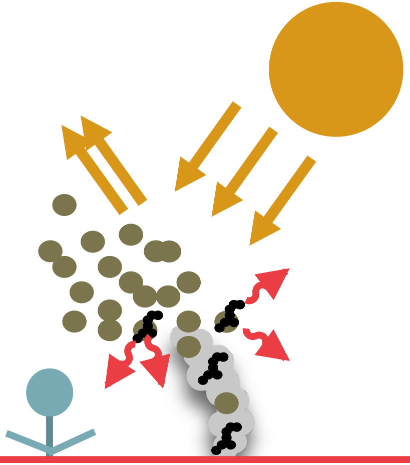
- alter cloud properties



Aerosols emitted from solid fuel use has both positive (warming) and negative (cooling) radiative effects

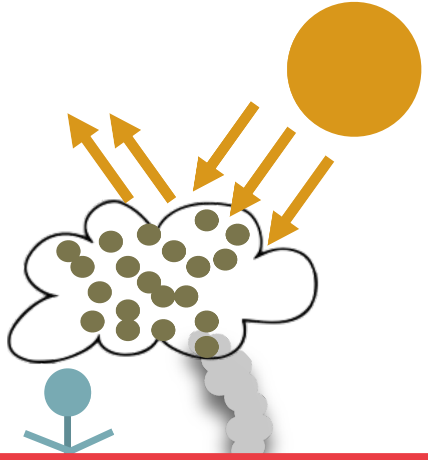
Direct radiative effect

- interact with solar radiation



Aerosol indirect effect

- alter cloud properties



What are the climate impacts of PM from SFU?

- **Black carbon** absorbs radiation contributing a positive direct effect.
- **Organic carbon** scatters radiation leading to a negative direct effect.
- Both species have a negative indirect effect.

A number of studies suggest reducing BC emissions to produce climate/health co-benefits

commentary

A black-carbon mitigation wedge

Andrew P. Grieshop, Conor C. O. Reynolds, Milind Kandlikar and Hadi Dowlatabadi

Comprehensive abatement strategies will be needed to limit global warming. A drastic reduction of black-carbon emissions could provide near-immediate relief with important co-benefits.

RESEARCH ARTICLE

Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security

Drew Shindell[1,*], Johan C. I. Kuylenstierna[2], Elisabetta Vignati[3], Rita van Dingenen[3], Markus Amann[4], Zbigniew Klimont[4], Susan C. Anenberg[5], Nicholas Muller[6], Greet Janssens-Maenhout[3], Frank Raes[3], Joel Schwartz[7], Greg Faluvegi[1], Luca Pozzoli[3,†], Kaarle Kupiainen[4], Lena Höglund-Isaksson[4], Lisa Emberson[2], David Streets[8], V. Ramanathan[9], Kevin Hicks[2], N. T. Kim Oanh[10], George Milly[1], Martin

Health and climate benefits of cookstove replacement options

Andrew P. Grieshop[a,b,1], Julian D. Marshall[c,2], Milind Kandlikar[d,*]

Global Air Quality and Health Co-benefits of Mitigating Near-Term Climate Change through Methane and Black Carbon Emission Controls

Susan C. Anenberg,[1] Joel Schwartz,[2] Drew Shindell,[3] Markus Amann,[4] Greg Faluvegi,[3] Zbigniew Klimont,[4] Greet Janssens-Maenhout,[5] Luca Pozzoli,[5] Rita Van Dingenen,[5] Elisabetta Vignati,[5] Lisa Emberson,[6] Nicholas Z. Muller,[7] J. Jason West,[8] Martin Williams,[9] Volodymyr Demkine,[10] W. Kevin Hicks,[6] Johan Kuylenstierna,[6] Frank Raes,[5] and Veerabhadran Ramanathan[11]*

A number of studies suggest reducing BC emissions to produce climate/health co-benefits

commentary

A black-carbon mitigation wedge

Andrew P. Grieshop, Conor C. O. Reynolds, Milind Kandlikar and Hadi Dowlatabadi

Comprehensive abatement strategies will be needed to limit global warming. A drastic reduction of black-carbon emissions could provide near-immediate relief with important co-benefits.

RESEARCH ARTICLE

Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security

Drew Shindell[1,*], Johan C. I. Kuylenstierna[2], Elisabetta Vignati[3], Rita van Dingenen[3], Markus Amann[4], Zbigniew Klimont[4], Susan C. Anenberg[5], Nicholas Muller[6], Greet Janssens-Maenhout[3], Frank Raes[3], Joel Schwartz[7], Greg Faluvegi[1], Luca Pozzoli[3,†], Kaarle Kupiainen[4], Lena Höglund-Isaksson[4], Lisa Emberson[2], David Streets[8], V. Ramanathan[9], Kevin Hicks[2], N. T. Kim Oanh[10], George Milly[1], Martin

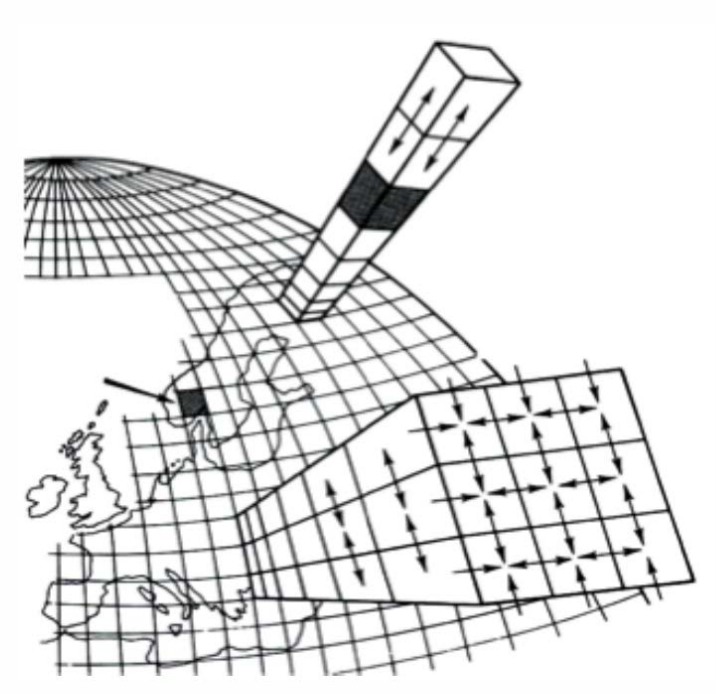
Hea

Andr

Our finding:
Uncertainties in solid-fuel use climate forcings are large.
Unclear if a co-benefit exists.

Susan C. Anenberg,[1] Joel Schwartz,[2] Drew Shindell,[3] Markus Amann,[4] Greg Faluvegi,[3] Zbigniew Klimont,[4] Greet Janssens-Maenhout,[5] Luca Pozzoli,[5] Rita Van Dingenen,[5] Elisabetta Vignati,[5] Lisa Emberson,[6] Nicholas Z. Muller,[7] J. Jason West,[8] Martin Williams,[9] Volodymyr Demkine,[10] W. Kevin Hicks,[6] Johan Kuylenstierna,[6] Frank Raes,[5] and Veerabhadran Ramanathan[11]*

Estimate climate forcings using a global chemical-transport model

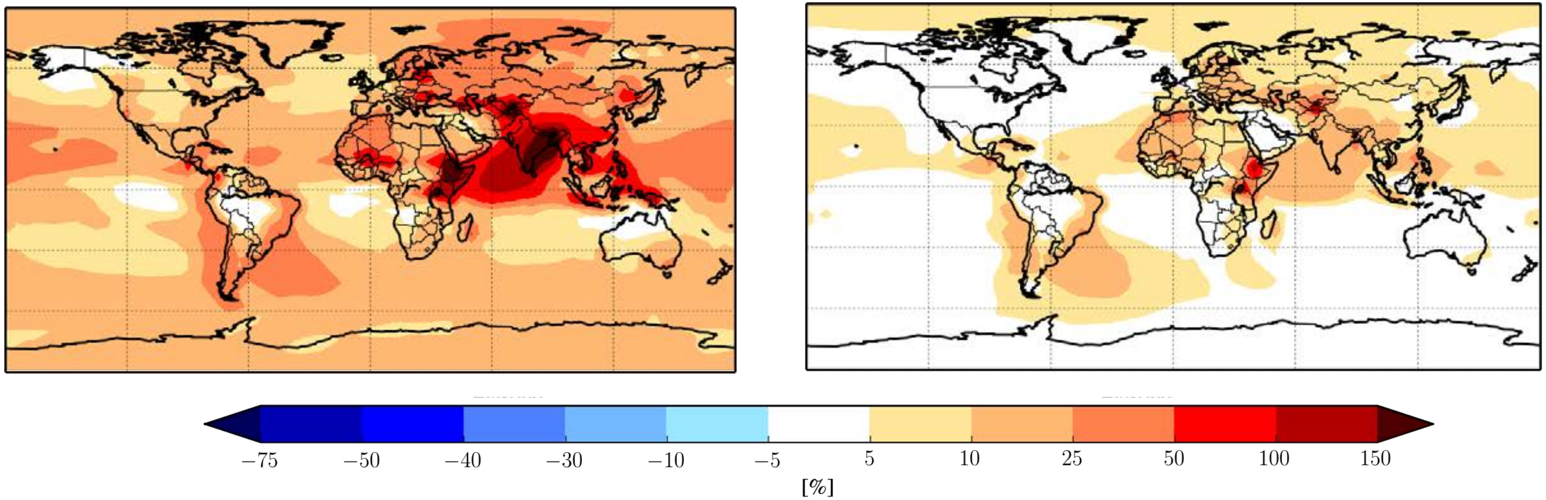


- GEOS-Chem-TOMAS
- Global model of gases and aerosol amount, composition, and size
- Includes
  - Emissions
  - Chemical/physical transformations
  - Transport by winds
  - Deposition (removal)

What happens when we "turn on" SFU emissions in the model?
BC and OA mass increases

Black carbon % change at surface
Global Mean: 30%

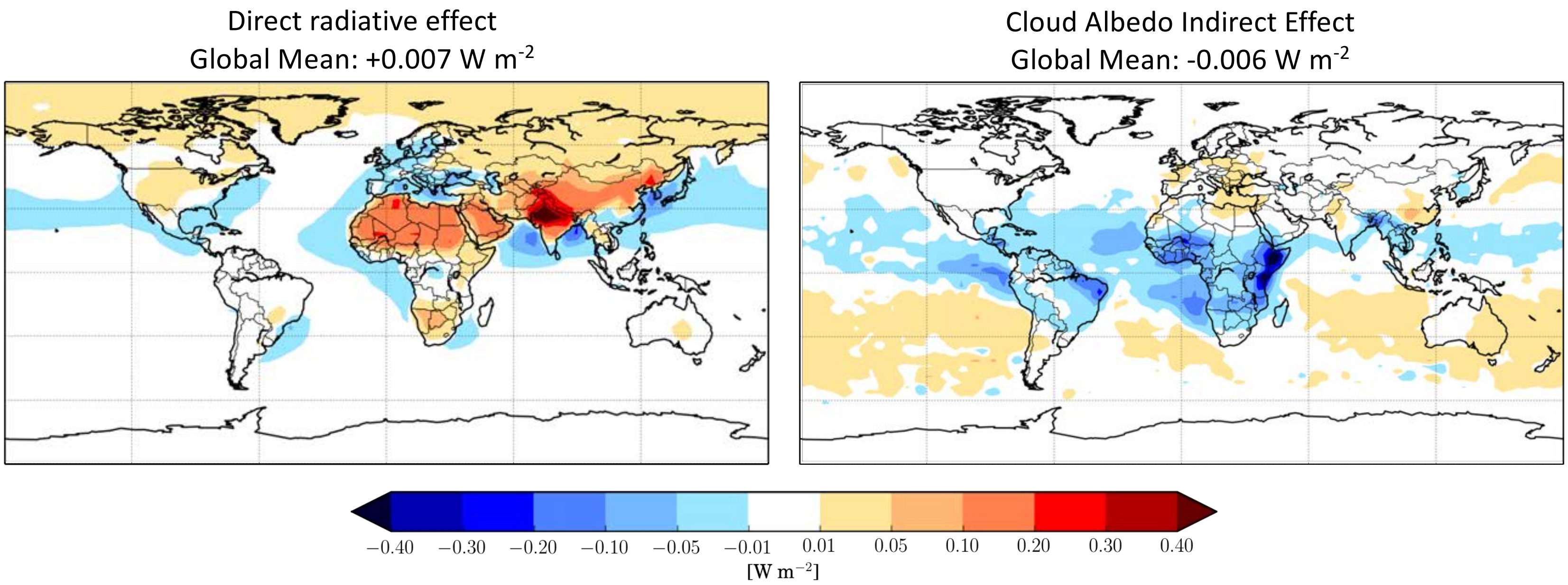
Organic aerosol % change at surface
Global Mean: 8%



Kodros, J. K., Scott, C. E., Farina, S. C., Lee, Y. H., L'Orange, C., Volckens, J., Pierce, J. R.: Uncertainties in global aerosols and climate effects due to biofuel emissions, Atmos. Chem. Phys., 15, 8577-8596, doi:10.5194/acp-15-8577-2015, 2015.

First estimates of climate forcings from SFU aerosols:

Slight *warming* from direct effect (*cooling* if SFU aerosols removed)
Slight *cooling* from indirect effect (*warming* if SFU aerosols removed)



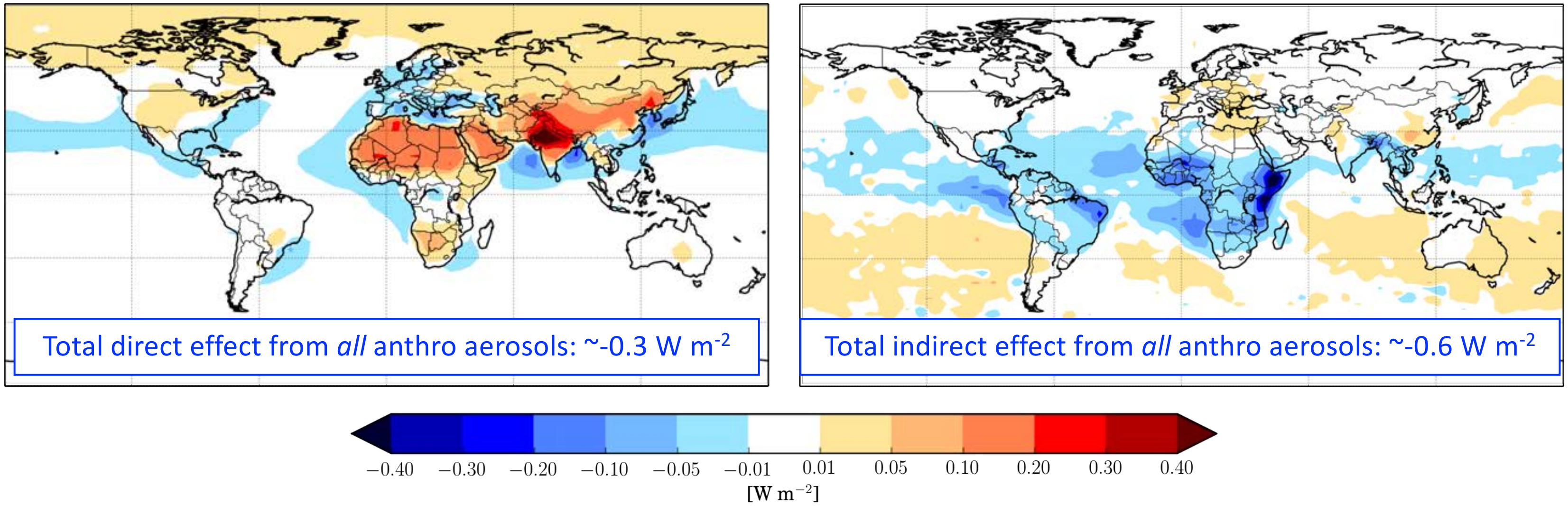
Kodros, J. K., Scott, C. E., Farina, S. C., Lee, Y. H., L'Orange, C., Volckens, J., Pierce, J. R.: Uncertainties in global aerosols and climate effects due to biofuel emissions, Atmos. Chem. Phys., 15, 8577-8596, doi:10.5194/acp-15-8577-2015, 2015.

First estimates of climate forcings from SFU aerosols:

Slight *warming* from direct effect (*cooling* if SFU aerosols removed)
Slight *cooling* from indirect effect (*warming* if SFU aerosols removed)

Direct radiative effect
Global Mean: +0.007 W m^{-2}

Cloud Albedo Indirect Effect
Global Mean: -0.006 W m^{-2}



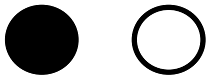
Kodros, J. K., Scott, C. E., Farina, S. C., Lee, Y. H., L'Orange, C., Volckens, J., Pierce, J. R.: Uncertainties in global aerosols and climate effects due to biofuel emissions, Atmos. Chem. Phys., 15, 8577-8596, doi:10.5194/acp-15-8577-2015, 2015.

There are many dimensions of uncertainty in the solid-fuel use (SFU) aerosol climate forcings

- Total SFU aerosol emission rates
- Black carbon vs. organic aerosol amounts
- Hygroscopicity (water uptake)
- Particle sizes
- Optical properties (scattering vs. absorption)
- Near-source evolution of all properties

Aerosol optical properties impact the direct effect

Black carbon and organic aerosol are "externally mixed"

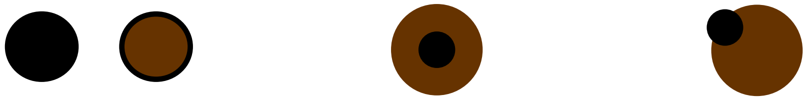


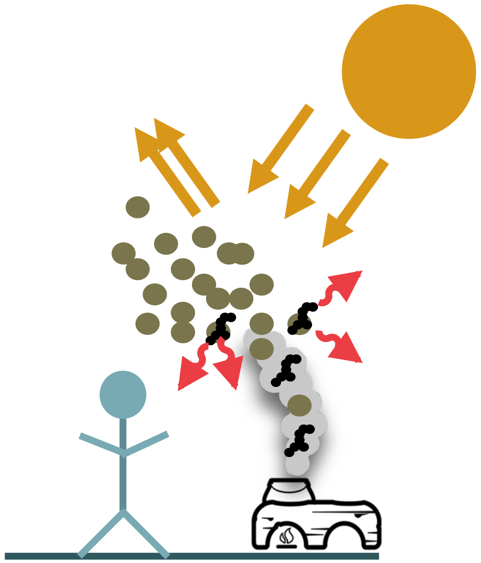
Black carbon and organic aerosol are "internally mixed"

Is black carbon at the core?

Or is it someplace else?

Is the organic aerosol significantly absorbing?

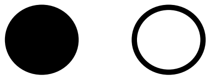




These different properties can vary regionally around the globe!
*We currently **assume** these properties in models.*

Aerosol optical properties impact the direct effect

Black carbon and organic aerosol are “externally mixed”

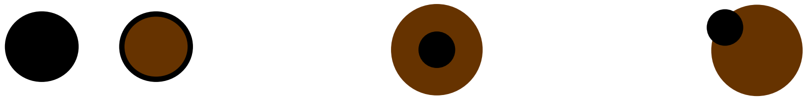


Black carbon and organic aerosol are “internally mixed”

Is black carbon at the core?

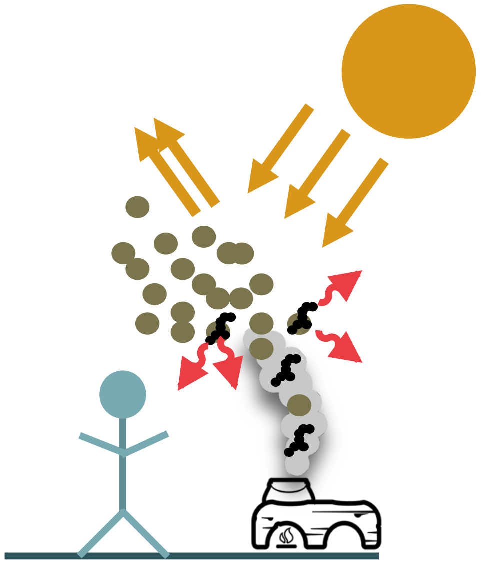
Or is it someplace else?

Is the organic aerosol significantly absorbing?



These different prop
*We currently **assum***

Global direct effect uncertainty: -0.008 to +0.02 W m^{-2}



There are many dimensions of uncertainty in the solid-fuel use aerosol (SFU) climate forcings

- Total SFU aerosol emission rates
- Black carbon vs. organic aerosol amounts
- Hygroscopicity (water uptake)
- Particle sizes
- Near-source evolution
- Optical properties (scattering vs. absorption)

Global *direct* effect uncertainty: -0.02 to +0.06 W m^{-2}

Global *indirect* effect uncertainty: -0.02 to +0.01 W m^{-2}

Residential solid-fuel use take home

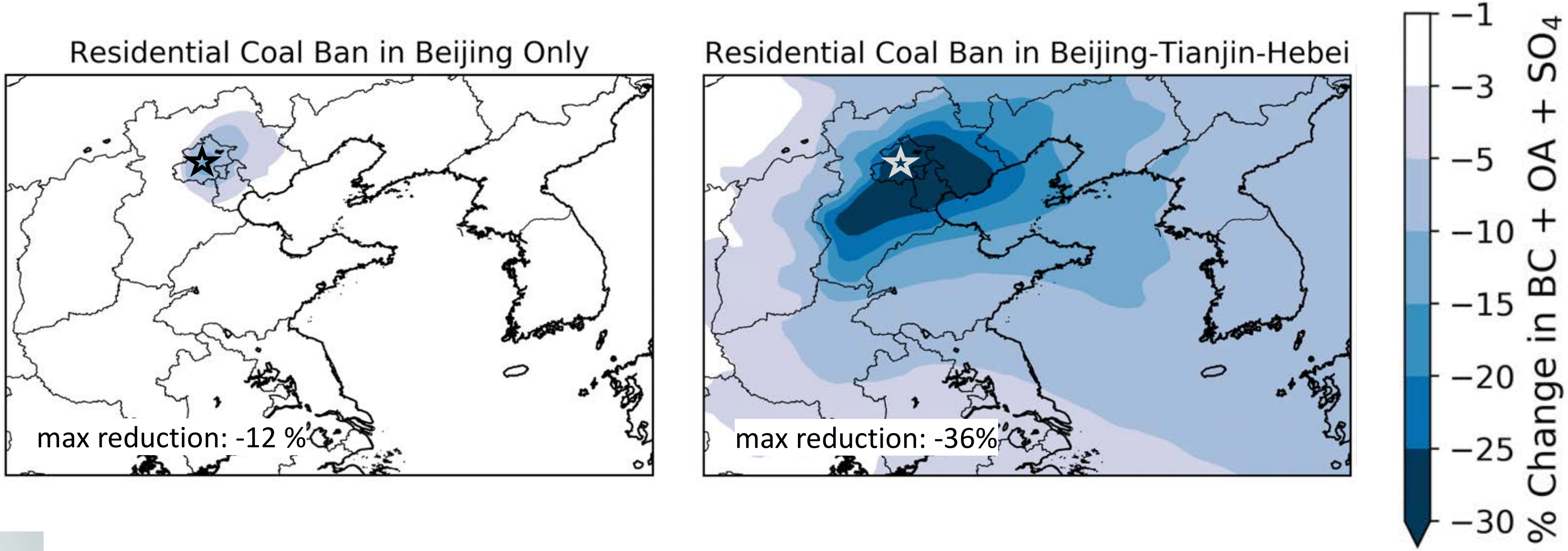
- Uncertainties in climate effects are larger than the signal
  - We don't even know the overall sign
- The “co-benefits” framing of SFU controls is oversimplified and uncertain*, in my opinion

*We did not estimate the aerosol “semi-direct effect” here, which may be the key to achieving a co-benefit; however, model estimates of the semi-direct effect are less certain than the direct and indirect effects

How to move forward…

- Need to big effort to convert lab and field findings into regionally relevant emissions and properties in models
  - We have *a lot* of information to work with
- Radiative closure experiments in regions undergoing rapid energy transitions (e.g. Beijing area)

Government-mandated switch from residential coal to electric heating is providing an “natural experiment” to test model estimates



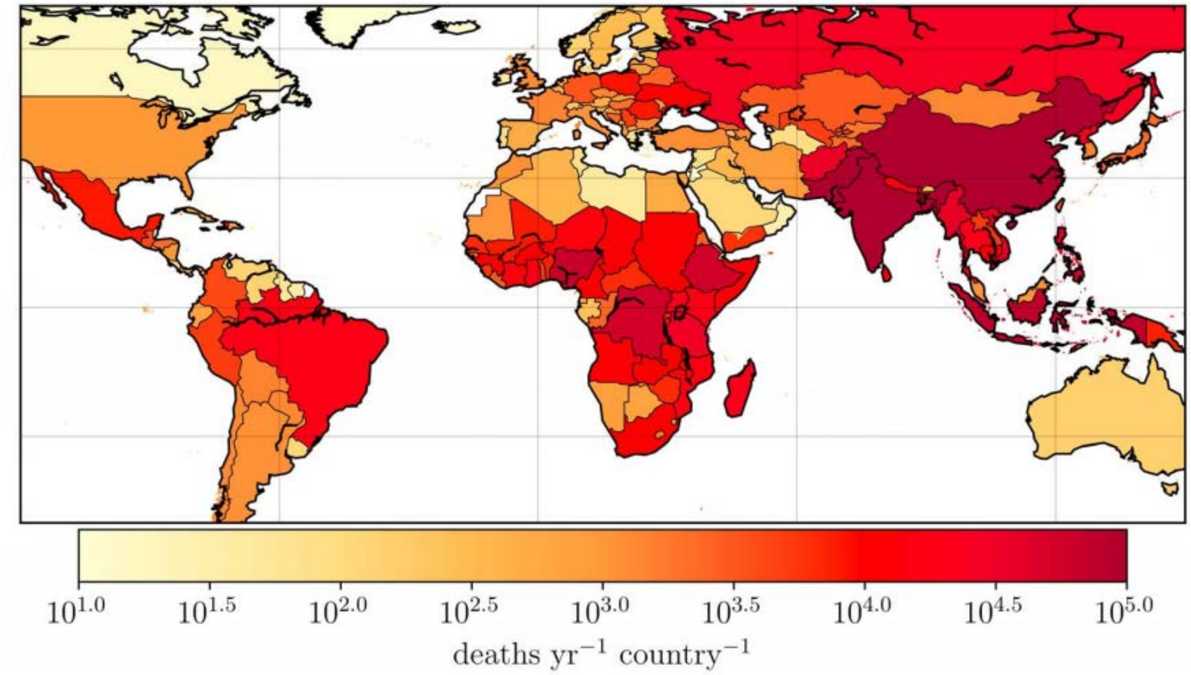
Kelsey R. Bilsback, Jill Baumgartner, Michael Cheeseman, Bonne Ford, John K. Kodros, Xiaoying Li, Emily Ramnarine, Shu Tao, Yuanxun Zhang, Ellison Carter, Jeffrey R. Pierce: Estimated aerosol health and radiative effects of the residential coal ban in the Beijing-Tianjin-Hebei region of China, Aerosol and Air Quality Research, 2020.

Outline

- Aerosol climate forcings from residential solid-fuel use (SFU)
  - Is there a "climate benefit" from switching to alternative energy sources?
- Estimated mortality due to exposure to aerosol from residential solid-fuel use (SFU)
- What does this all mean?

We estimate 2.5-3.5 million deaths* attributable to *indoor + outdoor* exposure to solid fuel use particulate matter

*About half of mortalities attributable to all particulate matter sources

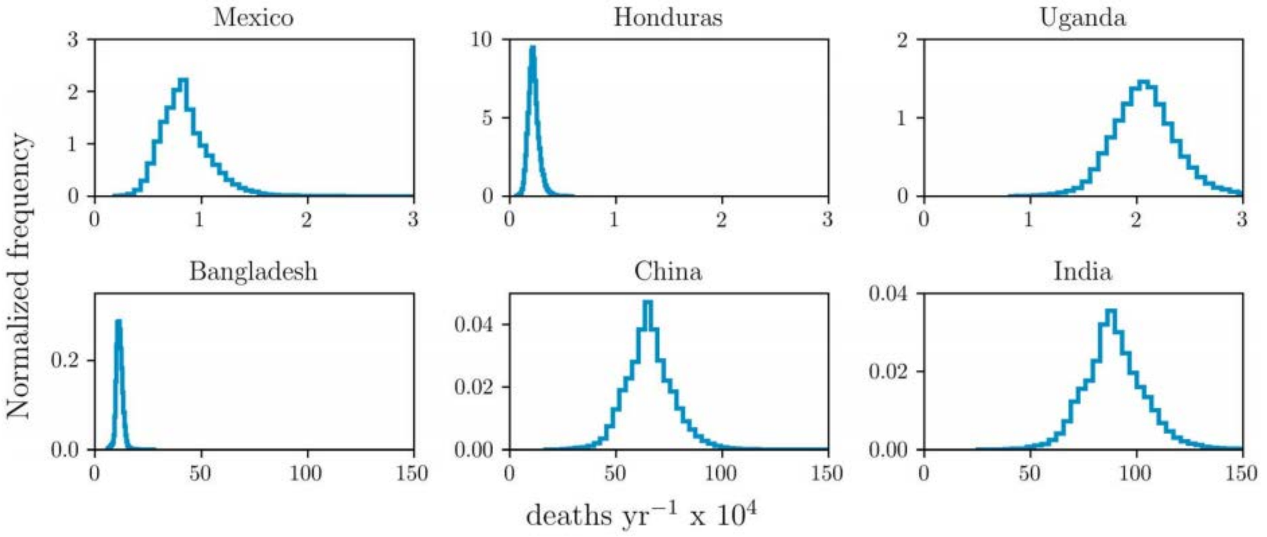


J. K. Kodros, E. Carter, M. Brauer, J. Volckens, K. R. Bilsback, C. L'Orange, M. Johnson, J. R. Pierce: Quantifying the contribution to uncertainty in mortality attributed to household, ambient, and joint exposure to $PM_{2.5}$ from residential solid-fuel use, GeoHealth, 2018.

There are also many dimensions of uncertainty in the solid-fuel use (SFU) *mortality estimates*

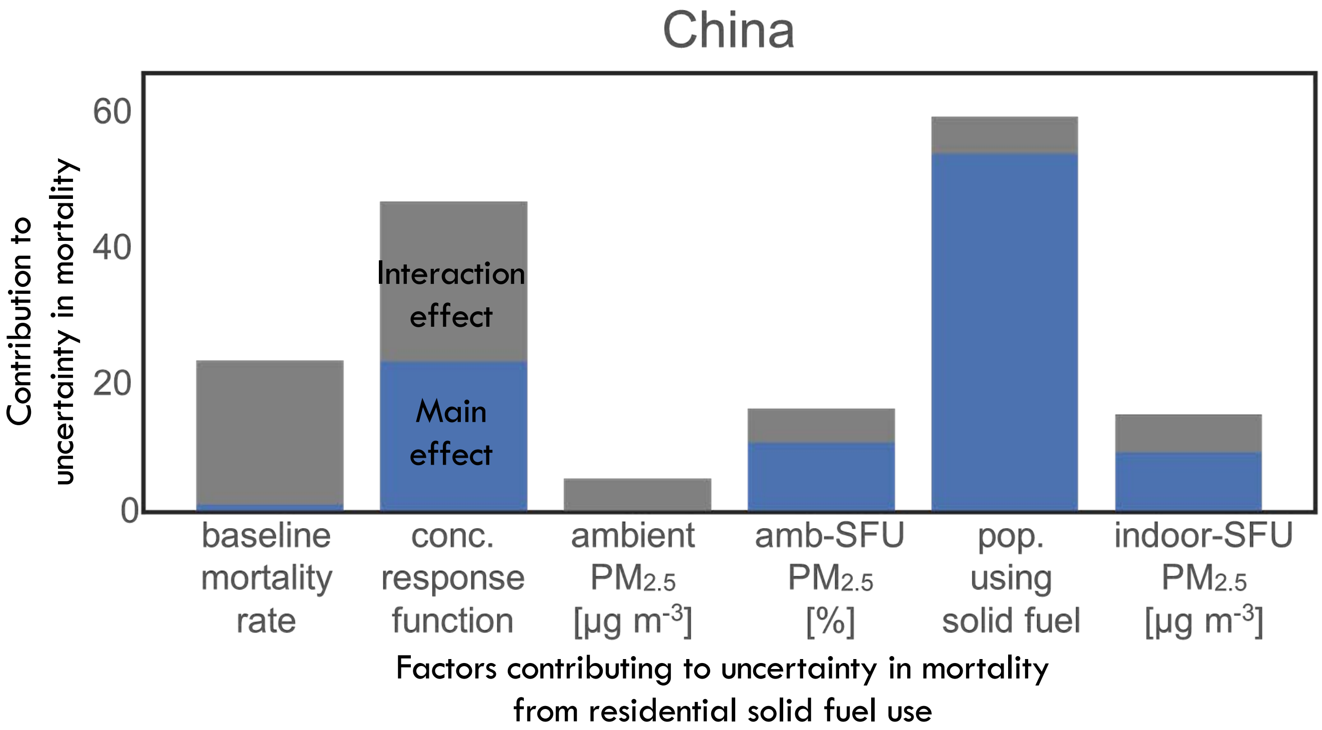
- Vital statistics (baseline mortality rates)
- Concentration response function (risk vs. exposure)
- Ambient (outdoor) particulate matter (PM) concentration
- Indoor PM concentration in homes w/ SFU
- % of ambient (outdoor) PM from SFU
- % of people indoors w/ SFU (and fraction of time indoors)

Uncertainties are substantial, but attributable mortality rates are always large



J. K. Kodros, E. Carter, M. Brauer, J. Volckens, K. R. Bilsback, C. L'Orange, M. Johnson, J. R. Pierce: Quantifying the contribution to uncertainty in mortality attributed to household, ambient, and joint exposure to $PM_{2.5}$ from residential solid-fuel use, GeoHealth, 2018.

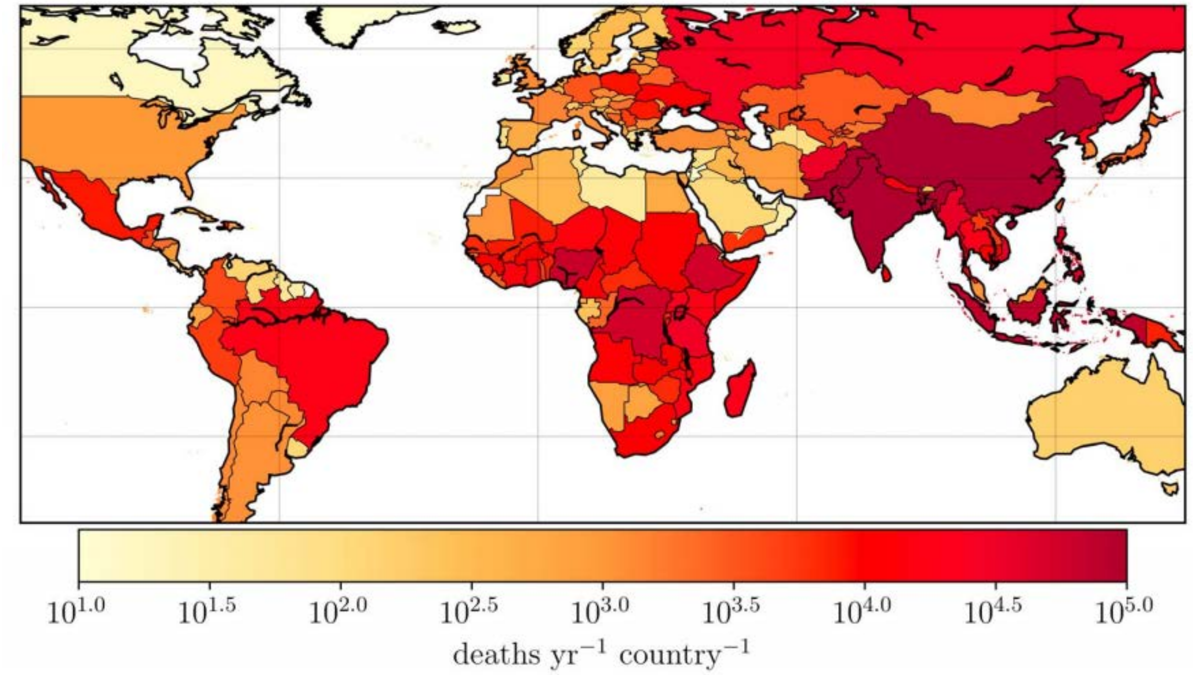
What dominates uncertainties in mortality estimates?
- *Concentrations response functions*
- *Estimates of who is inside SFU homes and how much*



J. K. Kodros, E. Carter, M. Brauer, J. Volckens, K. R. Bilsback, C. L'Orange, M. Johnson, J. R. Pierce: Quantifying the contribution to uncertainty in mortality attributed to household, ambient, and joint exposure to $PM_{2.5}$ from residential solid-fuel use, GeoHealth, 2018.

But unlike the climate effects, we are confident that the mortality rates from SFU aerosol are positive and large!

And a large fraction of the mortalities attributable to pollution



J. K. Kodros, E. Carter, M. Brauer, J. Volckens, K. R. Bilsback, C. L'Orange, M. Johnson, J. R. Pierce: Quantifying the contribution to uncertainty in mortality attributed to household, ambient, and joint exposure to $PM_{2.5}$ from residential solid-fuel use, GeoHealth, 2018.

Outline

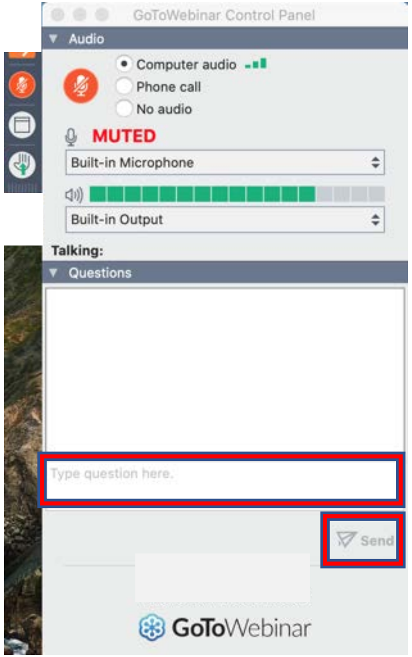
- Aerosol climate forcings from residential solid-fuel use (SFU)
  - Is there a “climate benefit” from switching to alternative energy sources?
- Estimated mortality due to exposure to aerosol from residential solid-fuel use (SFU)
- What does this all mean?

Take home

- The climate radiative effects of residential solid-fuel (SFU) use aerosol are relatively small
  - < ~10% of overall anthropogenic aerosol radiative effects
  - The magnitude/sign is very uncertain
- The estimated mortality rates attributable to SFU are large
  - ~50% of overall mortality due to all-source PM exposure (indoor + outdoor)
  - The uncertainty is smaller than the best estimate
- *The potential heath benefits should drive pushes to reduce emissions from residential SFU*

Question & Answer

You are in 'listen only' mode



Type your question here

Submit your question by clicking here

Question and Answer

Brought to you by Colorado State University and Berkeley Air Monitoring Group

Find us at ashes-csu.org

With funding from EPA #XA 83998701

Berkeley Air Monitoring Group

Colorado State University

Thank you for joining the ASHES Science to Achieve Results (STAR) Webinar Series – #1

COOKSTOVE EMISSIONS, CLIMATE, AND HEALTH IMPACTS: AN INTEGRATED LAB, FIELD, AND MODELING STUDY

Our next STAR webinar will be held February DATE at TIME
Registration will be open next week on our website at *www.ashes-csu.org*

Brought to you by Colorado State University and Berkeley Air Monitoring Group

With funding from EPA #XA 83998701

Berkeley Air Monitoring Group

Colorado State University