IONE GRANT FINAL REPORT

Project Title:	Stove Change-Out: A 'Win-Win-Win' for Development, Environment & Health		
Project Number:	DG-0007-11	**Project Start Date:**	01/01/2011
Today's Date:	01/30/2014	**Project End Date:**	12/31/2013

A. PROJECT PERSONNEL

Role	Name	U of M Dept. or External Org	Email
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Collaborator	Alexander, Bruce	School Of Public Health	balex@umn.edu
Collaborator	Millet, Dylan	Atmospheric Chemistry	dbm@umn.edu
Collaborator	Cox, Prentis	Law School	coxxx211@umn.edu
Grad Student	Bechle, Matthew	Civil Engineering	bechl002@umn.edu
Co-PI			
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IONE GRANT FINAL REPORT

PROGRAM AREAS (check all that apply)

- ☐ Bioenergy & Bioproducts
  - ☐ Algae
  - ☐ Biological Catalysis
  - ☐ Biomaterials
  - ☐ Biopower
  - ☐ Chemical Catalysis
  - ☐ Next Generation Feedstock
  - ☐ Transportation Fuels
  - ☐ Waste Stream Remediation - Bio
- ☐ Conservation & Energy Efficiency
- ☐ Hydrogen Production, Storage & Use
- ☐ Policy, Economics & Ecosystems
  - ☐ Life Cycle Analysis
  - ☐ Carbon Sequestration
- ☐ Solar
  - ☐ Photovoltaic
  - ☐ Thermal Energy
  - ☐ Waste Stream Remediation – Solar
- ☐ Wind, Hydro & Geothermal
  - ☐ Geothermal
  - ☐ Hydroelectric
  - ☐ Wind
  - ☐ Waste Stream Remediation – Geothermal

B. EXTERNAL COLLABORATIONS

Name	Company/Organization	Explanation of Relationship
Andrew Grieshop	Civil Engineering, N.C.S.U.	Collaborator
Ther Wint Aung	Resource Management Envt Studies, U.B.C.	Graduate Student
Michael Brauer	School Population & Public Health, U.B.C.	Collaborator
Hisham Zerriffi	Liu Institute for Global Issues, U.B.C.	Collaborator
T. Pradeep	Samuha, Karnataka, India	Collaborator
M Narayanswamy	Samuha, Karnataka, India	Collaborator

Megha Shenoy	Resource Optimization Initiative, Bangalore, India	Collaborator
Grishma Jain	Resource Optimization Initiative, Bangalore, India	Field Research Manager
Karthik Sethuraman	Resource Optimization Initiative, Bangalore, India	Field Research Manager

C. LEVERAGED FUNDS

Status: Awarded Award Date: ______

Project Title: ______

FOA # or Title: ______

Primary Funding Org: ______ Amount: $ ______

Other Matching Org: ______ Amount: $ ______

Other Matching Org: ______ Amount: $ ______

Other Matching Org: ______ Amount: $ ______

Other Matching Org: ______ Amount: $ ______

Status: Awarded Award Date: ______

Project Title: ______

FOA # or Title: ______

Primary Funding Org: ______ Amount: $ ______

Other Matching Org: ______ Amount: $ ______

Other Matching Org: ______ Amount: $ ______

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Other Matching Org: ______ Amount: $ ______

Status: Awarded Award Date: ______

Project Title: ______

FOA # or Title: ______

Primary Funding Org: ______ Amount: $ ______

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Status: Awarded | Award Date: ____________

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FOA # or Title: ______________________________

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Other Matching Org: ______________________ Amount: $ __________

Other Matching Org: ______________________ Amount: $ __________

Other Matching Org: ______________________ Amount: $ __________

E.1 PUBLICATIONS

List the publications to date (including in-press and accepted) that have resulted from funding to support this research. Please include the full citation: Last Name, First Initial.; Last Name, First Initial. Title. *Journal*. **Year**, *Volume*, Pages.

Status	Full Citation (see format instructions above)
Published	
Published	
Published	
Published	
Published	
Published	
Published	
Published	
Published	
Published	
Published	
Published	
Published	
Published	

Additional publications may be submitted in a separate document as an appendix.

E.2 PRESENTATIONS

List all of the presentations to date that have resulted from funding to support this research.

Type	Full Citation
Presenter	T Aung, JD Marshall, T Pradeep, S Narayanswami, G Jain, K Sethuraman, A Grieshop, J Baumgartner, C Reynolds, M Brauer. "Air Quality and Health Evaluation of a Climate Financed Cookstove Intervention in Rural India", International Society of Exposure Science, International Society for Environmental Epidemiology, and International Society of Indoor Air Quality and Climate (ISES/ISEE/ISIAQ) Joint Annual Meeting, August 19-23, 2013. Basel, Switzerland.
Speaker	T Aung, G Jain, K Sethuraman, A Greishop, T Pradeep, S Narayanswami, JD Marshall, M Brauer. "Air Quality and Health Evaluation of a Climate Financed Cookstove Intervention in Rural India", Institute for Heart + Lung Health FEST, February 19-23, 2013. Vancouver, Canada.
Speaker	T Aung, G Jain, K Sethuraman, A Greishop, T Pradeep, S Narayanswami, JD Marshall, M Brauer. "Evaluating Climate Financed Cookstove Intervention in Rural Karnataka, India", Symposium on Atmospheric PM Research in British Columbia, December 10, 2012. Vancouver, Canada.
Speaker	G Jain, K Sethuram, T Aung, MJ Bechle, A Grieshop, J Baumgartner, T Pradeep, M Narayanswamy, C Reynolds, M Brauer, JD Marshall. "Stove Emissions and Indoor and Outdoor Pollution Levels from a Randomized Cook-stove Exchange in Karnataka, India", International Society of Exposure Science (ISES) Annual Meeting, October 28-November 1, 2012. Seattle, WA.
Speaker	T Aung, JD Marshall, J Baumgartner, B Alexander, G Ramachandran, A Grieshop, C Reynolds, M Brauer, S Narayanswami, T Pradeep, G Jain, K Sethuraman. " Emissions, Health, and Livelihood Impacts of a Randomized Cookstove Exchange in Karnataka, India", International Society for Environmental Epidemiology (ISEE) Annual Meeting, August 26-30, 2012. Columbia, SC.
Speaker	JD Marshall. “Verifying Health and Emission Improvements from a Stove Change-Out”, AAAS Annual Meeting, February 16-20, 2012. Vancouver, Canada.
Keynote speaker	
Keynote speaker	
Keynote speaker	
Keynote speaker	
Keynote speaker	
Keynote speaker	

Keynote speaker	
Keynote speaker	

Additional presentations may be submitted in a separate document as an appendix.

F. PATENTS

Status	Patent Information
Pending	
Pending	
Pending	
Pending	

G. POSTDOCS

Name	Current Professional Position
Baumgartner, Jill	Assistant Professor, McGill University

H. DEGREES AWARDED

Name	Degree Type	Major	Title of Dissertation/Thesis
	PhD		
	PhD		
	PhD		
	PhD		
	PhD		

I. WEBSITE

J. PROJECT OVERVIEW

Combustion of solid fuels in household stoves in developing countries causes local health and global climate impacts. This project aims to implement a neighborhood-scale stove change-out program to reduce emission of locally- and globally-important pollutants. Nearly half of the world's population use poorly-vented stoves or three-stone open fires to cook or heat their homes. Air pollution emitted from these inefficient burning methods of biomass (wood, dung, and crop residue) has been associated with adverse health and climate impacts. Fuelwood collection and purchase pose additional burden on household expenses, and energy and time of women and children who are often responsible for collecting fuelwood in rural communities.

A local Indian non-governmental organization, SAMUHA, plans to distribute 40,000 improved biomass cook stoves (called Chulikas) in 110 villages in rural Karnataka, India, as part of its efforts to reduce air pollution, improve health and rural livelihoods. Researchers at the University of Minnesota, the University of British Columbia, SAMUHA, and an Indian research organization, Resource Optimization Initiative (ROI), have conducted a study to evaluate this cook stove change-out program. The goal of the study is to quantify how much the improved stoves reduce harmful air pollutants, greenhouse gas and fuelwood use and collection time, and ultimately improve cardiovascular health and rural livelihood. The study took place in the first village where stove change-out is occurring. Approximately 187 households in the village agreed to participate in the randomized controlled trial where the households are randomly assigned to intervention and non-intervention groups. Households in the intervention group received improved stoves, and both groups were to be monitored in three seasons (monsoon, winter, and summer; one pre-intervention season and two post-intervention seasons) over a one-year period. Owing to equipment difficulties in the field and other logistical delays, post-intervention measurements were conducted for only one season rather two seasons.

The following measurements on exposure and cardiovascular health monitoring were conducted:

(1) Air sampling for particulate matter less than 2.5 µm (PM2.5) over a 24-hour period in breathing zone of women cooks in kitchens; (2) Blood pressure measurements on women participants before and after cooking events; (3) Anthropometric measurements of women participants and questionnaires on medical history of diabetes and hypertension; and (4) Ambulatory blood pressure measurements and real-time personal exposure monitoring for black carbon on a subset of women participants.

The measurements conducted for livelihood impact assessment were:

(1) Fuelwood weighing before and after cooking events; and (2) Survey questionnaire on occupation, income, distance travelled to collect fuel wood, and duration of travel, fuel wood processing, and cooking.

Emission measurements conducted were:

(1) Simultaneous time-resolved (1 minute resolution) measurements of concentrations indoor and outdoor for PM mass, PM light-scattering, CO2, CO, BC (Real-time air quality (RTAQ)); and (2) Time-resolved (1 second resolution) measurements for PM mass, PM organic speciation, PM light-scattering, CO2, CO, black carbon (Stove Emissions Monitoring System (STEMS)).

Adoption of the new stoves was modest, with 38% of intervention households using one or two of the new stoves while continuing to use a traditional stove. As a result, when conducting the data analyses the intervention group was divided into two groups; (1) households using only the new stove, and (2) households using a combination of new and traditional stoves.

K. PROJECT IMPACTS

Consequences from inefficient burning of biomass for heating and cooking disproportionately affects the world's rural poor, particularly women and children who spend a lot of their time indoors near stoves. Given that nearly three billion people in the world rely on biomass for cooking, including an estimated 668 million in India, studies targeting key data gaps would benefit rural poor communities, as well as non-governmental organizations, policy makers, and public health and climate researchers. There are important knowledge gaps about changes in key health and livelihood indicators, and emissions (related to both air quality and climate change) that may be associated with replacing traditional three-stone fires with improved stoves. The exposure-response relationship between indoor air pollution (IAP) and health outcomes is still uncertain; we do not know how much reduction is needed to realize health benefits. Cardiovascular health risks from IAP exposure are beginning to be realized and further studies are needed. Quantification of livelihood impacts resulting from switch to improved stoves is particularly lacking in the literature. Understanding of cook stoves' contribution to climate impact is also in nascent stage. The impact of stove emission reductions on indoor concentrations versus on neighbourhood- or village-scale concentrations, and the relative importance of outdoor versus indoor air pollution, is poorly studied. The study aims to shed light on these key data gaps.

Adoption of the improved stoves was moderate; 38% of intervention households used both the traditional and improved stoves at the same time. One of the more common reasons given for this behavior was difficulty cooking certain foods with the new cook stoves. Additionally, there was no significant change in fuel wood usage for households using improved cook stoves. This may suggest a rebound effect (i.e., people are using their stoves more because they are more efficient) or that real world usage differs dramatically from the laboratory conditions. These findings indicate that the users' preferences are an important aspect of stove adoption. Future research on the behavioral aspects of switching to improved cooks stoves is needed.

While laboratory measurements of the improved cook stove employed in this study suggests improved thermal efficiency over traditional stoves (31% vs. 10%, respectively), our measurements of its performance in the field did not exhibit large changes in fuel usage, IAP, or the blood pressure of those cooking. These findings indicate that laboratory conditions may not accurately indicate cook stove performance in real world settings, and illustrates the need for more studies of this nature.

Technical report for " Stove Change-Out: A 'Win-Win-Win' for Development, Environment & Health" (DG-0007-11)

PI: Julian Marshall

Introduction

A local Indian non-governmental organization, SAMUHA, plans to distribute 40,000 improved biomass cook stoves (called Chulikas) in 110 villages in rural Karnataka, India, as part of its efforts to reduce air pollution, improve health and rural livelihoods. This is the first cook stove project in India approved under the Clean Development Mechanism (CDM), a market based tool under the United Nations Framework Convention on Climate Change where certified credits are generated by investing in emission reduction projects, such as improved cook stoves. The study took place in the first village where stove change-out occurred. Of approximately 300 households in the village, 202 households were CDM eligible and 187 households in the village agreed to participate in the randomized controlled trial where the households are randomly assigned to intervention and non-intervention groups. Households in the intervention group received improved stoves, and both groups were to be monitored in three seasons (monsoon, winter, and summer; one pre-intervention season and two post-intervention seasons) over a one-year period. Owing to equipment difficulties in the field and other logistical delays, post-intervention measurements were conducted for only one season rather two seasons.

Figure 1: Study location.

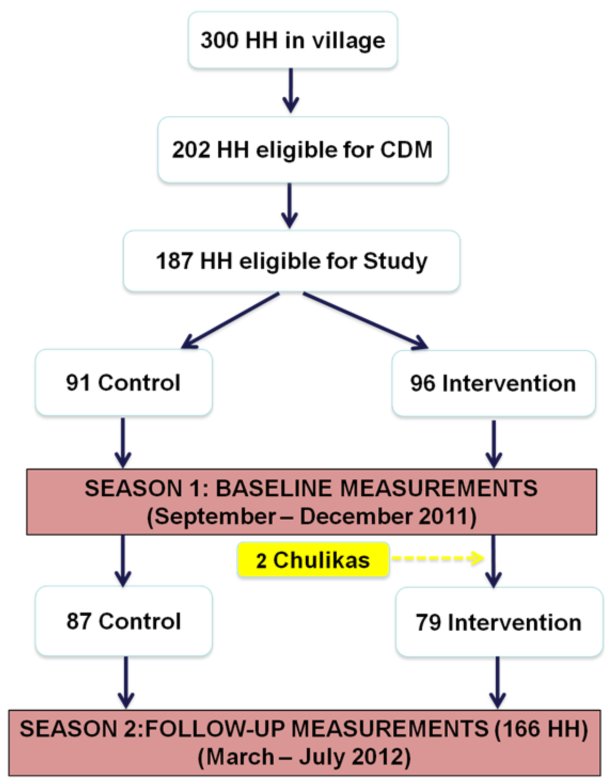

Figure 2: Study design.

Adoption of the new stoves was modest, with 38% of intervention households using one or two of the new stoves while continuing to use a traditional stove. As a result, when conducting the data analyses the intervention group was divided into two groups; (1) households using only the new stove, and (2) households using a combination of new and traditional stoves.

Exposure and cardiovascular health monitoring

The following measurements were conducted for all households:

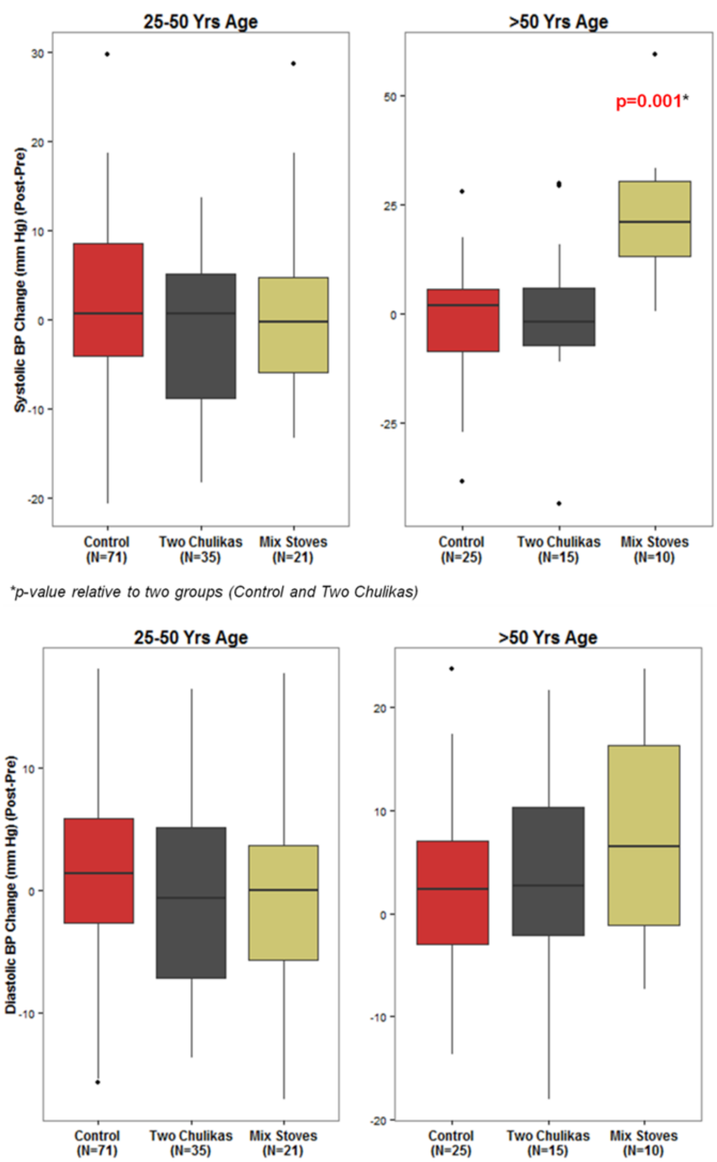

Figure 3: Change (season 2- season 1) in systolic and diastolic blood pressure.

(1) Air sampling for particulate matter less than 2.5 µm (PM2.5) over a 24-hour period in breathing zone of women cooks in kitchens; (2) Blood pressure measurements on women participants before and after cooking events; (3) Anthropometric measurements of women participants and questionnaires on medical history of diabetes and hypertension; and (4) Ambulatory blood pressure measurements and real-time personal exposure monitoring for black carbon on a subset of women participants.

Figure 3 shows the change in systolic (top) and diastolic (bottom) blood pressure between pre- and post-intervention measurements. Neither the intervention nor control group exhibited significant change in blood pressure between seasons. However, there is a modest increase in systolic blood pressure for women over 50 year of age that used both stove types. The reason for this difference is unclear.

Figure 4 shows indoor 24-hr gravimetric $PM_{2.5}$ measurements by season and stove type. The control group and mixed stove intervention group exhibited a small but significant increase in $PM_{2.5}$ concentration from season 1 to season 2, the intervention group following protocol (using both improved stoves and not using a traditional stove) did not exhibit a significant change between seasons. This finding may suggest a slight performance improvement for households employing the two improved cook stoves. However, differences between seasons appear to be similar or greater than differences between groups, complicating interpretation of these results. Conducting pre- and post-intervention measurements over several seasons or identical seasons may help avoid this issue in the future.

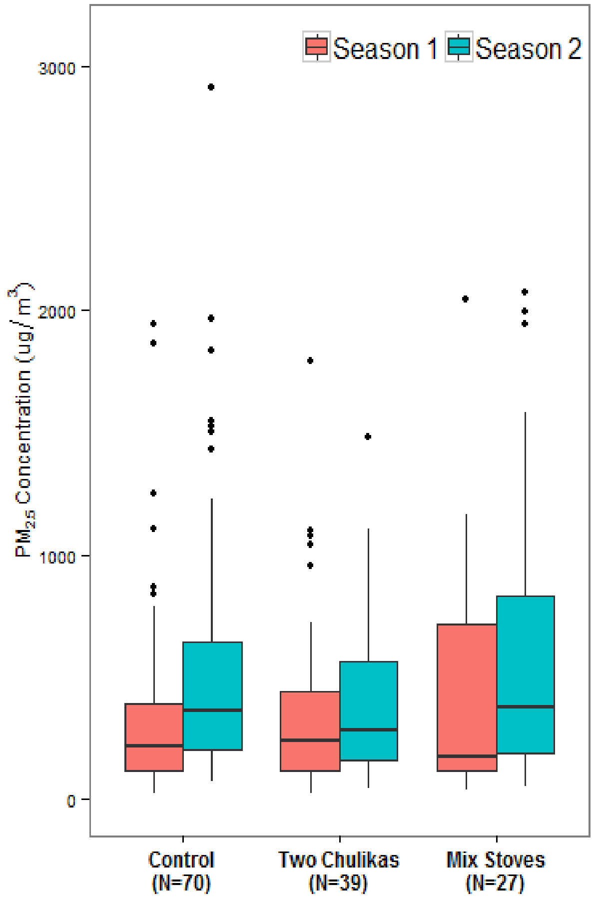

Figure 4: Indoor 24-hr gravimetric $PM_{2.5}$ measurements by season and stove type

Livelihood and fuel wood usage

The following measurements were conducted households:

(1) Fuel wood weighing before and after cooking events; and (2) Survey questionnaire on occupation, income, distance travelled to collect fuel wood, and duration of travel, fuel wood processing, and cooking.

No significant changes in fuel wood usage were found between pre- and post-intervention measurements. There were also no significant differences in fuel wood usage between control households and the two intervention sub-groups.

Emissions and real-time air quality

The following measurements were conducted for a subset (30) of households:

(1) Simultaneous time-resolved (1 minute resolution) measurements of concentrations indoor and outdoor for PM mass, PM light-scattering, CO2, CO, BC (Real-time air quality (RTAQ)); and

(2) Time-resolved (1 second resolution) measurements for PM mass, PM organic speciation, PM light-scattering, CO2, CO, black carbon (Stove Emissions Monitoring System (STEMS)). STEMS and RTAQ measurements were conducted simultaneously in each household.

Preliminary analysis of emission factors from the STEMS measurements are shown in Figure 5. PM emission factors (Figure 5a) exhibit a small decrease for all households in season 2, differences between intervention and control households are minor. BC emission factors (Figure 5b) exhibit no discernible change between seasons and between intervention and control households. These findings suggest that the improved cook stoves used here may not offer emissions benefits for PM or BC in real-world settings. Moreover, these initial findings highlight the need for future research on the performance of cook stoves in real-world settings. Additionally, large between-household variability (Figure 5) for both intervention and control groups suggests that individual- or household-level factors (e.g., fuel type, ventilation, cooking activity, fire-tending practices, cook stove modifications) likely play an important role in the performance of cook stoves. These factors need to be better understood in order for cook stove change outs to be successful in the future.

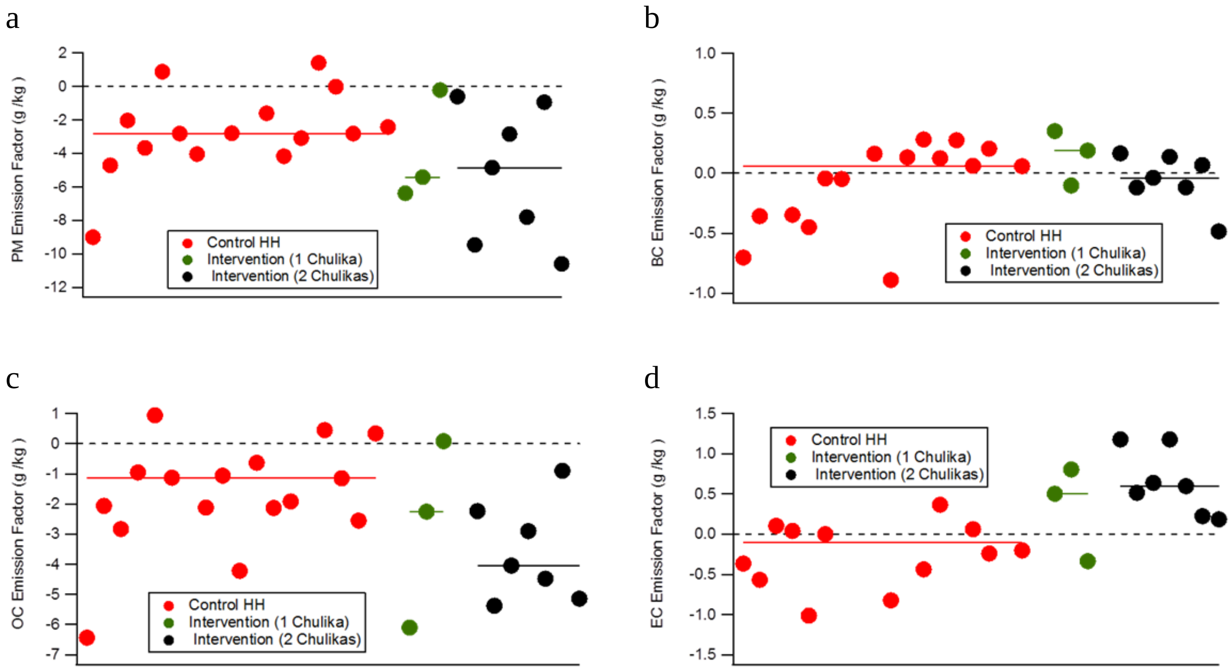

Figure 5: Change in emission factors (season 2 - season 1) by household for (a) particulate matter, (b) black carbon, (c) organic carbon, and (d) elemental carbon.

The organic carbon emission factors (Figure 5c) are significantly lower for intervention households than for control households in season 2. Elemental carbon emission factors (Figure 5d) are significantly higher for intervention households. These findings show that the absorption properties of aerosols differ for the traditional and intervention stoves. These differences complicate the interpretation of the real-time BC measurements, which rely on optical measurements of BC. For further analysis we plan to correct optical BC measurements using the STEMS measurements.

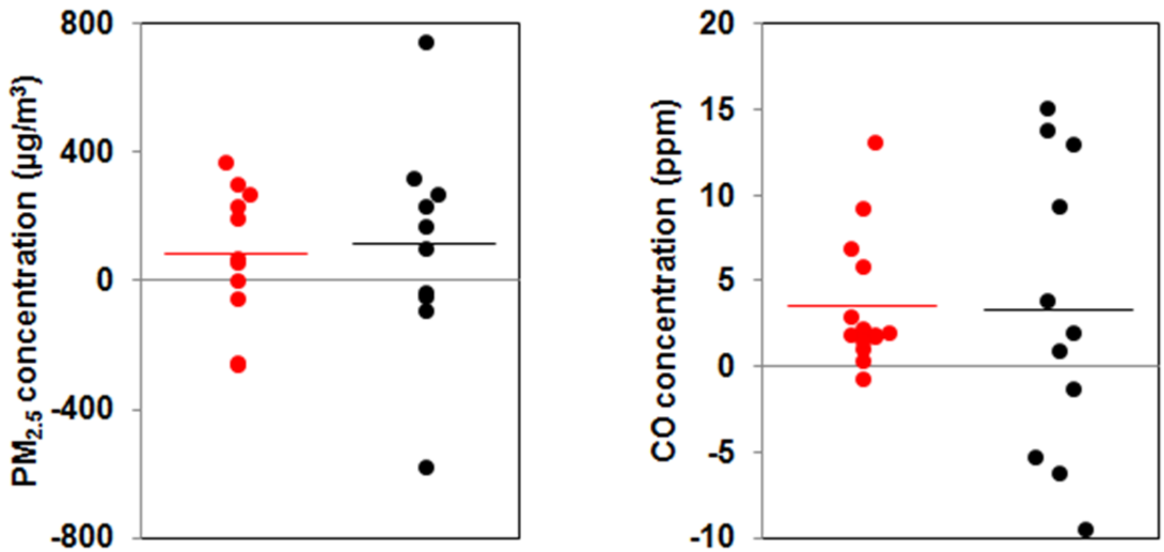

Figure 6: Change in cooking time concentration (season 2 - season 1) by household for $PM_{2.5}$ and CO.

Indoor concentrations during cooking were estimated from the RTAQ measurements by integrating real-time measurements during the STEMS deployment which coincided with the beginning and end of cooking activities. Figure 6 shows the change in cooking time concentration by household for $PM_{2.5}$ and CO from the RTAQ measurements; BC concentrations are not shown owing to the fact that they still need to be corrected for changes in the aerosol absorption properties. The control group exhibits a small but significant increase for indoor CO concentrations, all other changes are not statistically different from zero. This figure also shows the large between-household variability as is seen with the emission factor data (Figure 5).

Summary

The preliminary results of a cook stove change-out presented here illustrate that laboratory conditions are not comparable to real world conditions. Despite laboratory measurements suggesting that the cook stove employed in this change-out had improved efficiency, the field measurements did not observe major differences between households using the improved cook stoves. Moreover, stove adoption was found to be moderate, with many households opting to use both new and traditional stoves for cooking. This type of behavior not only complicated the analysis of results for this study, but also points towards a need for further study related to the behavior of stove adoption and stove use. Large between-household variability in concentrations and emissions complicated the analysis real-time measurements, owing to the small subset of households (30 households of ~187 participating households) where these measurements were conducted. Additionally, differences in emissions and concentrations between measurement seasons observed for all households complicated the analysis of results. Future studies measuring the impacts of cook stove change outs may benefit from conducting several days of measurements to avoid the impact from possible atypical cooking days or conditions.