

# REACTING

RESEARCH ON EMISSIONS AIR QUALITY, CLIMATE,  
AND COOKING TECHNOLOGY IN NORTHERN GHANA



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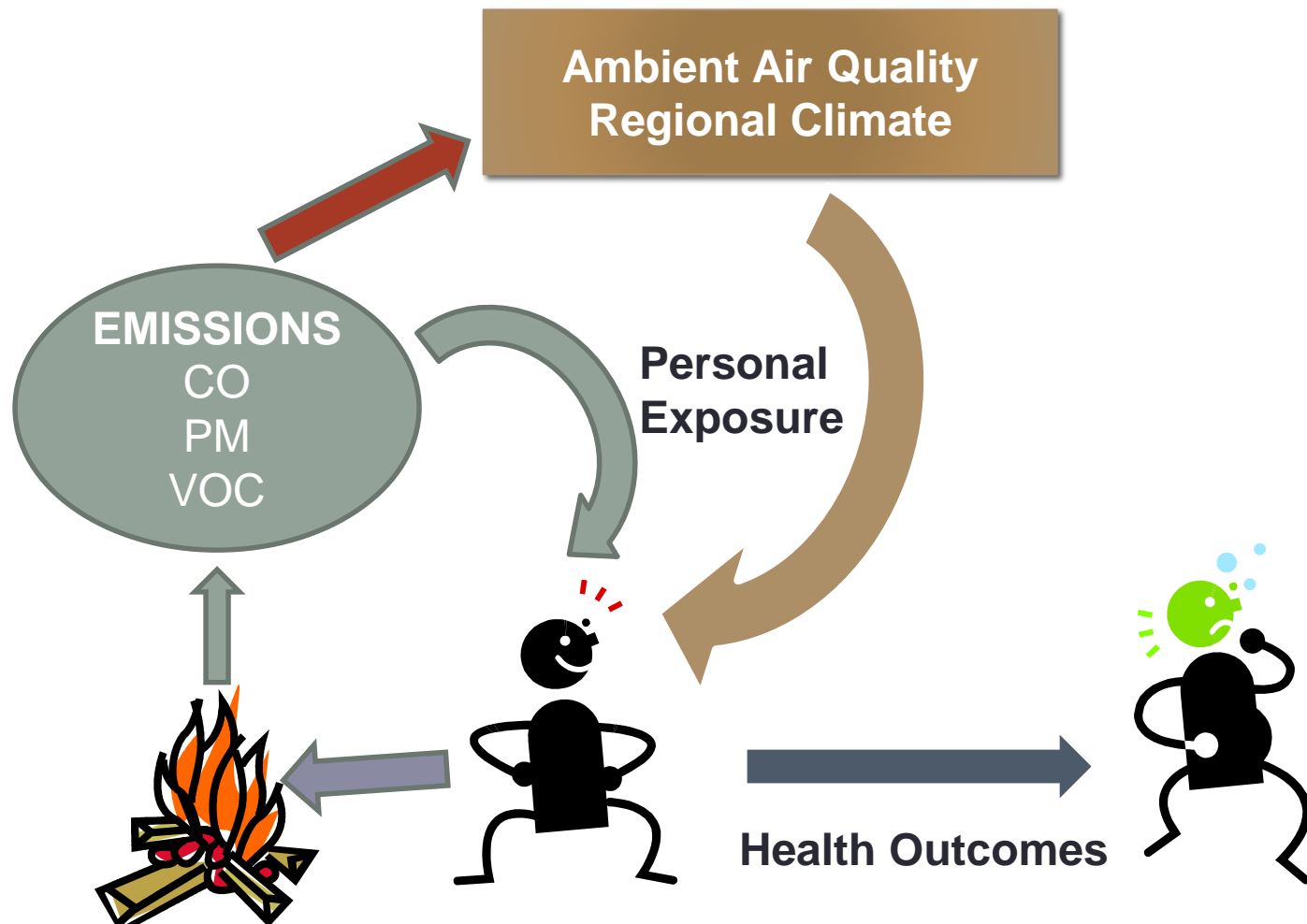
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# REACTING

## Research of Emissions, Air Quality, Climate, and Cooking Technologies in Northern Ghana



# Why Ghana?

- Strong ties with Navrongo Health Research Center (NHRC) from prior research
- Poverty affects the Northeast region
- Mostly cook with biomass
- Safe and stable work environment

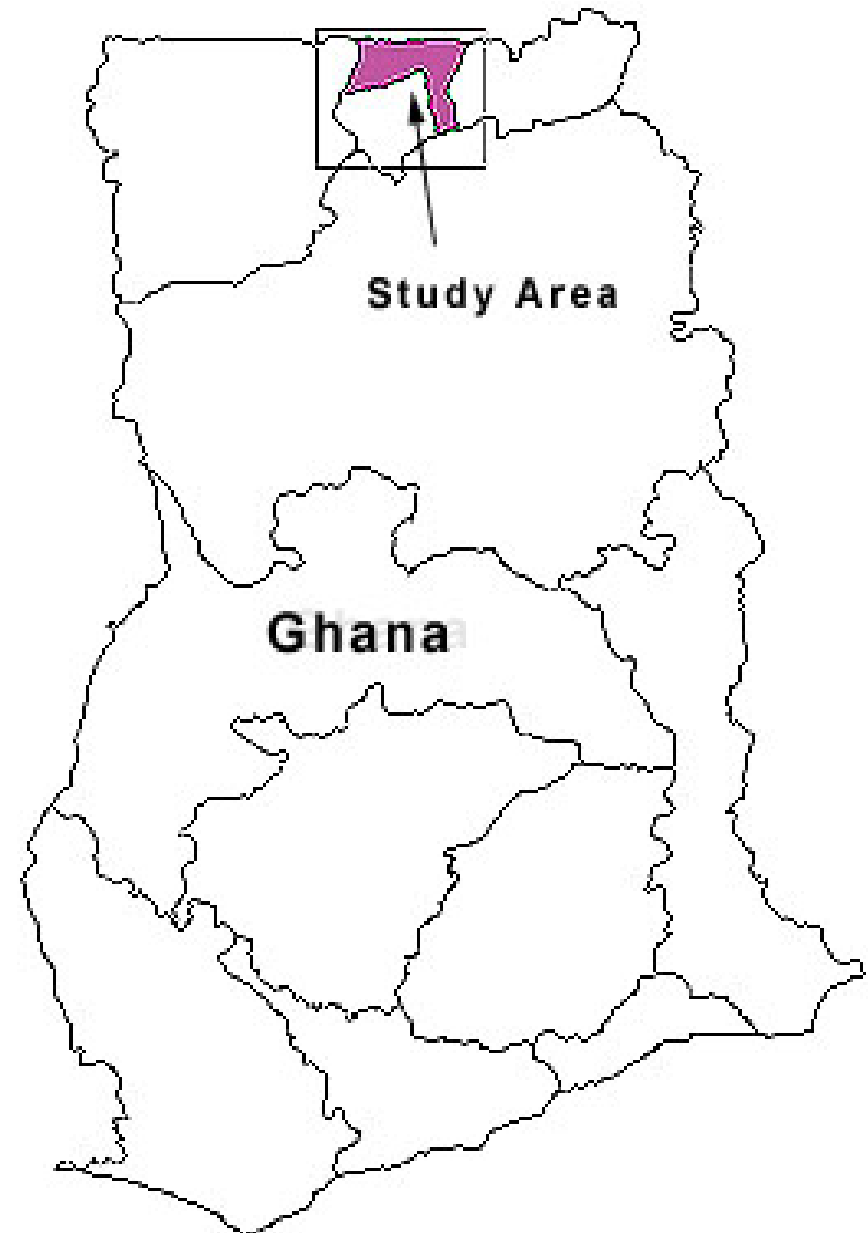


# Study Area

*Region:* Upper East

*District:* K-N

*Town:* Navrongo



# Traditional Cooking

- 3-stone stove
- Biomass for fuel





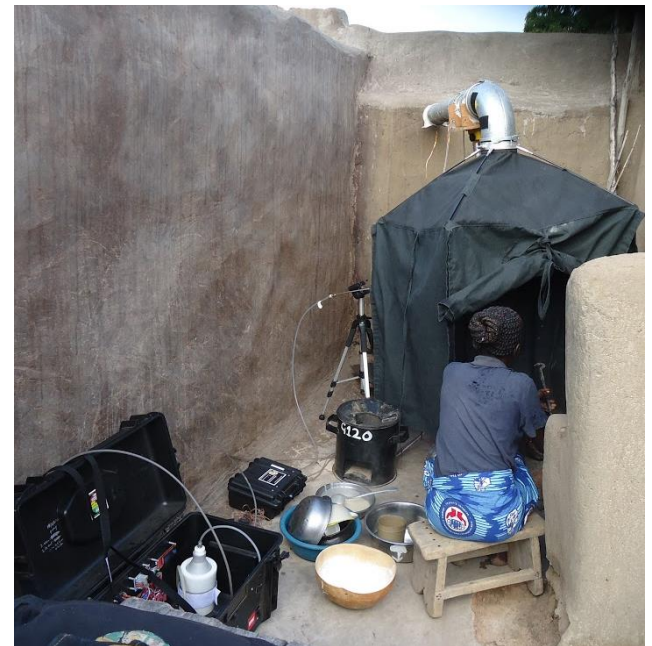
# REACTING

## Intervention Study



rural households (200)

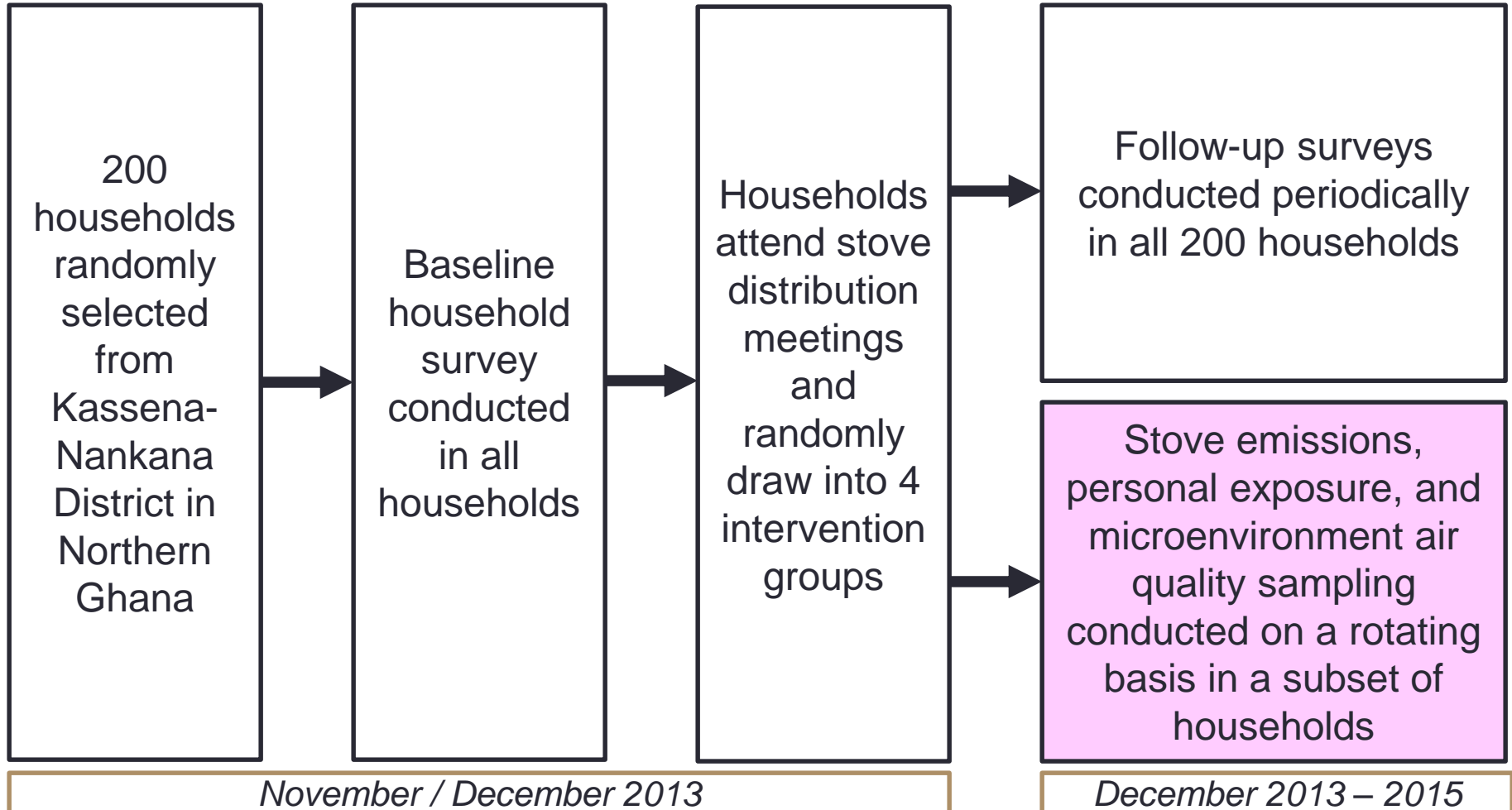
## Sources and Exposure Characterization



urban and rural regions  
(50 households)



# Intervention Study Design



# Intervention Groups

- 200 households, each with one woman aged 18-55, one child aged 0-5

Group A:



Group B:



Group C:



Group D:



# Kassena-Nankana District Snapshot

Variable	K-N District (N, E, S, W Regions)	Intervention Study Sample	P-value
# households	25,458	200	
Ethnicity: Kasem	51.5%	50.0%	0.68
Ethnicity: Nankam	44.5%	45.5%	0.79
Cooking fuel: Biomass	84.3%	100%	0.000***
Location: Rural	90.0%	100%	0.000***
Water source: Borehole	86.4%	100%	0.000***
Sanitation: No facility	95.5%	96.5%	0.32
Has Electricity	13.1%	6.0%	0.003***
Owns Motorcycle	14.9%	10.0%	0.049**
Owns Bike	77.5%	87.0%	0.001***
Owns Mobile phone	69.0%	81.0%	0.000***
# Livestock	7.07	10.9	0.000***

# Measurement Approach

- Surveys
  - Cooking behavior
  - Health burden
- Emission
  - Field Portable Emission Monitor for cookstoves
  - Other sources
- Ambient
  - Regional low-cost monitors
  - Reference monitors at NHRC
- Household
  - Air (CO and PM2.5)
  - Stove use
- Personal
  - Air (CO and PM2.5)
  - Location

## **UPOD**

(yoo-päd)

*An open source platform  
for mobile air quality monitoring*











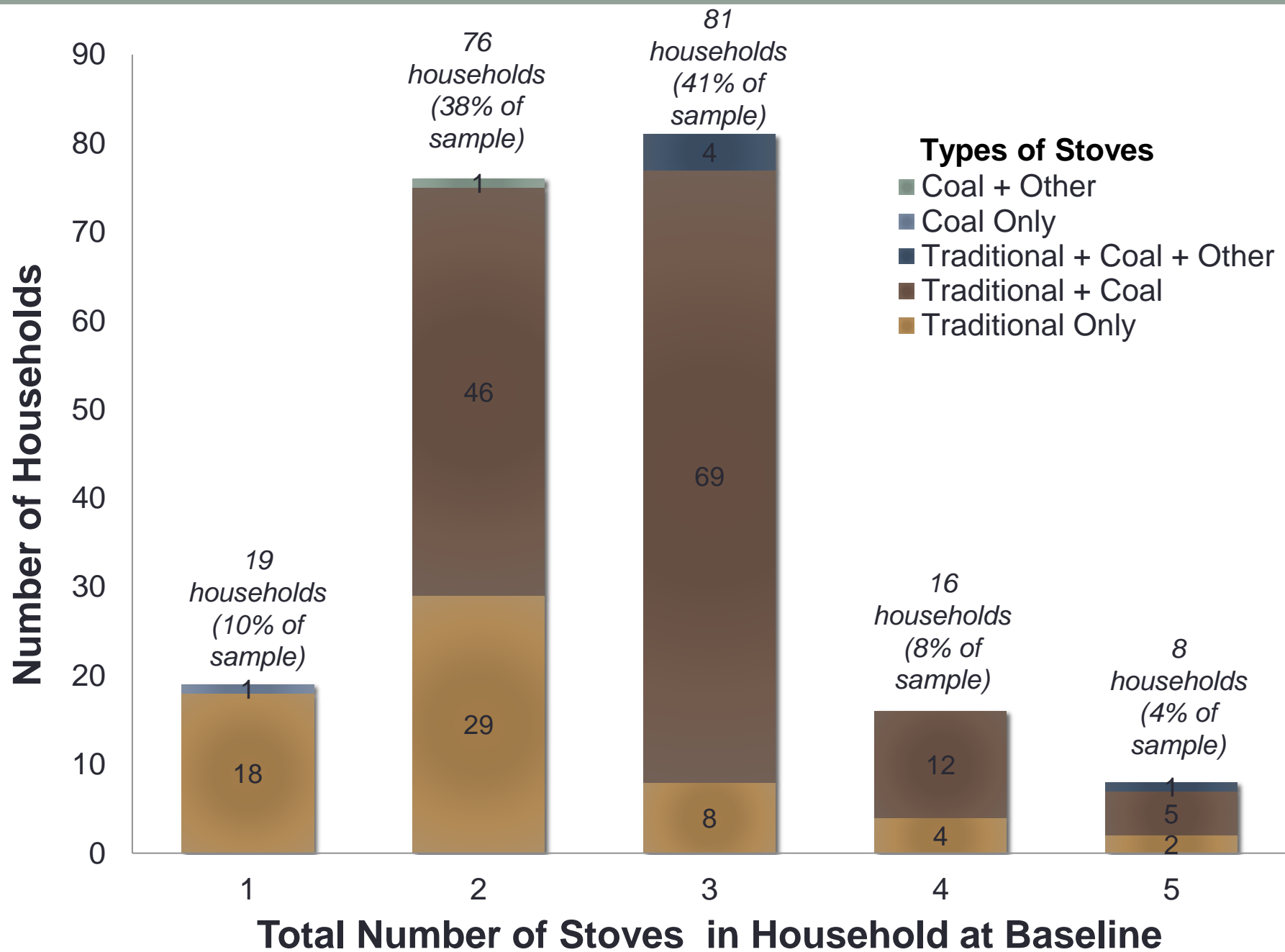
<http://mobilesensingtechnology.com/>



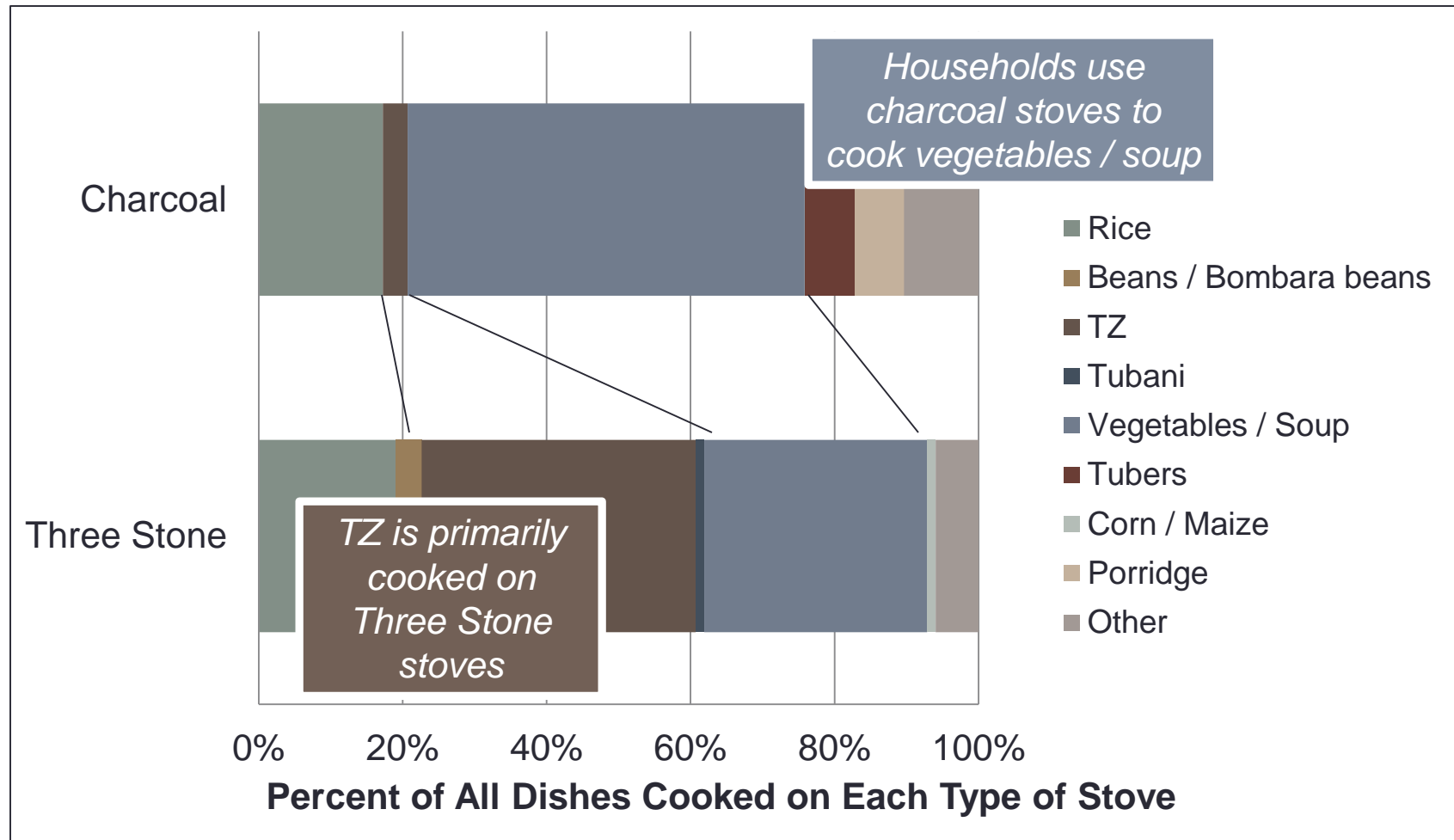
Fourth survey pretest: Dominic (Nankai)

# Behavioral Surveys

	STOVE A	STOVE B	STOVE A	STOVE B
SMOKE				
FUEL USE				
TIME TO COOK RICE	<b>30 MINUTES</b>	<b>60 MINUTES</b>	<b>60 MINUTES</b>	<b>60 MINUTES</b>
WHERE WAS THE STOVE MADE?	<b>GHANA</b>	<b>GHANA</b>	<b>GHANA</b>	<b>GHANA</b>
COST	<b>15 Cedis</b>	<b>30 Cedis</b>	<b>15 Cedis</b>	<b>30 Cedis</b>



# What dishes were cooked yesterday on each stove?





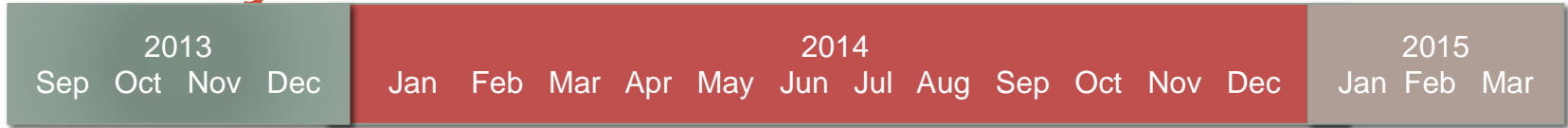
# Health Measures

## For Respondent and Children Under Five

- Self-Reported Illness
- Blood Spots
- Anthropometrics:
  - Height
  - Weight
  - Arm circumference



# Air Quality Measurement Timeline



## NHRC Reference Measurements



## Regional G-Pods



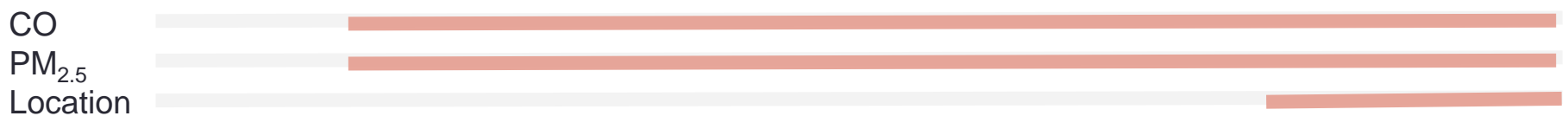
## Household Measurements



## PATS/Beacon



## Rural Personal Measurements



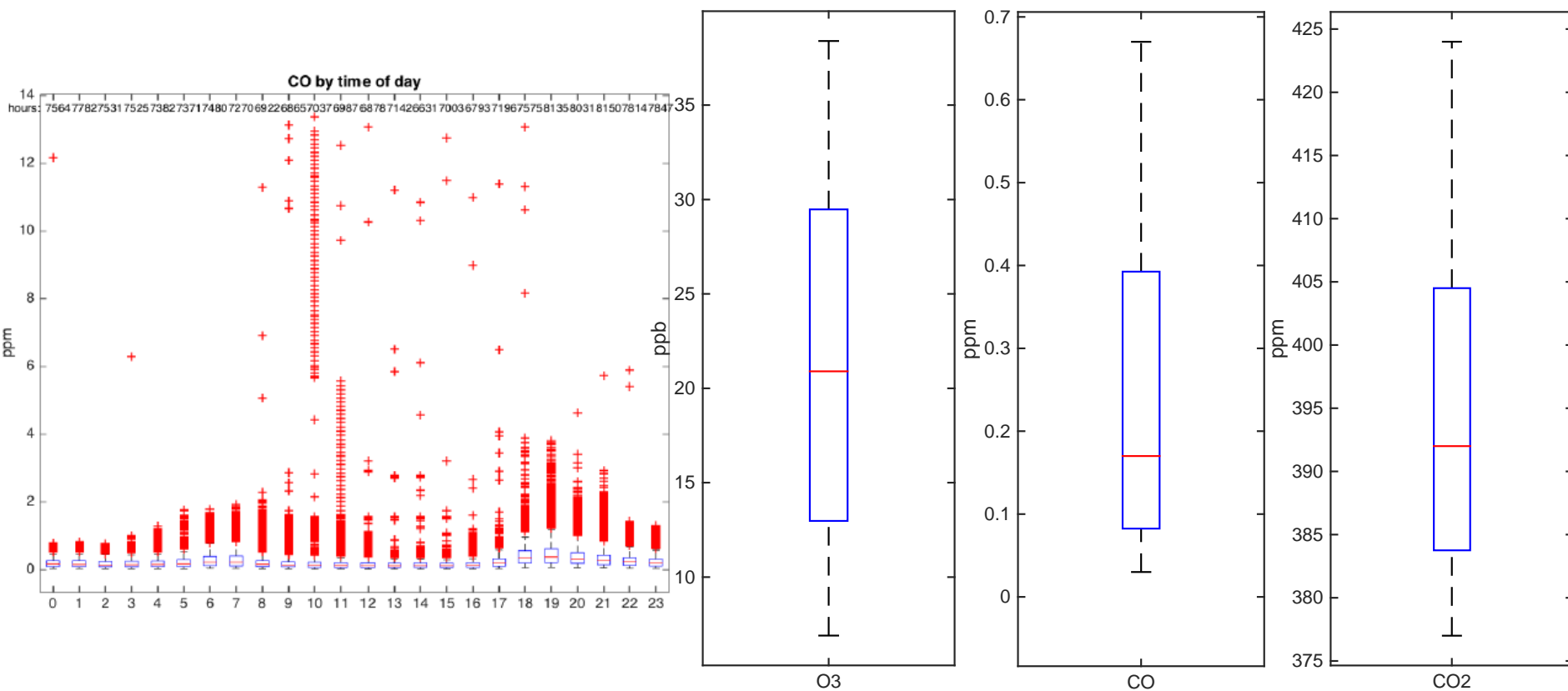
## Urban Personal Measurements



# NHRC Reference Measurements



# Ambient Air Quality at NHRC

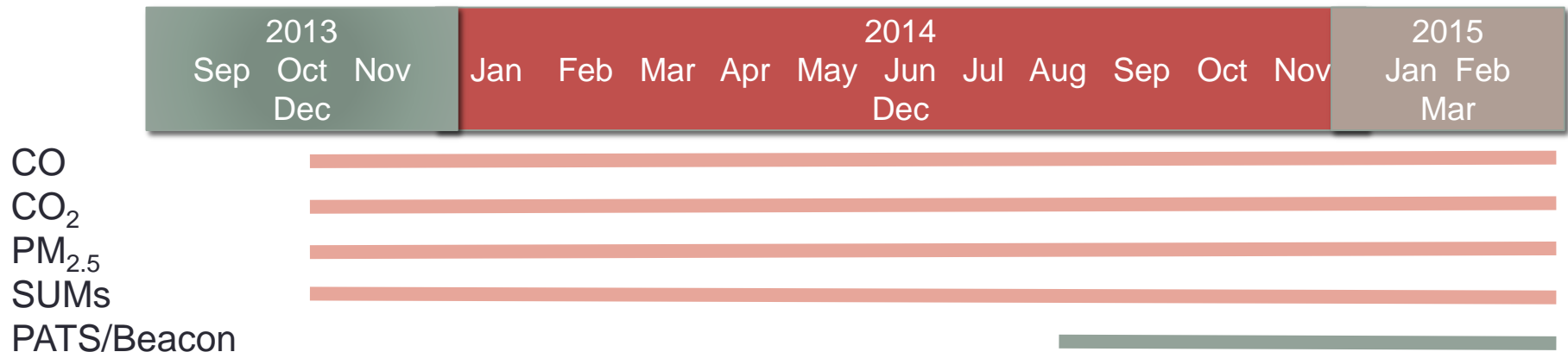


# Regional G-Pods



# Household Measurements

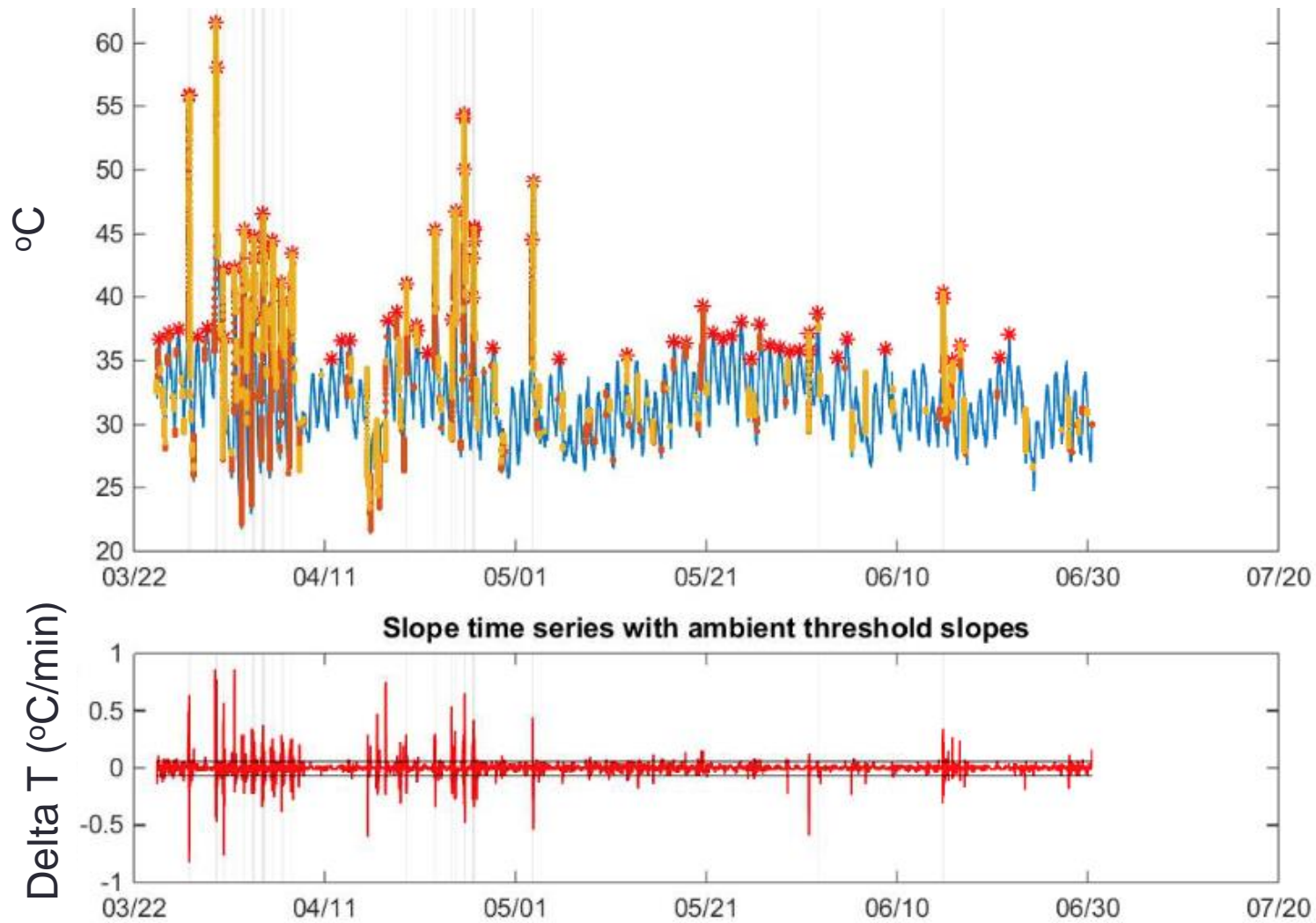
- Stove usage monitors (SUMs)
  - 110 SUMs over 35 households
  - CRECER/RESPIRE studies
    - Proposed standard methods and algorithms for SUMs in Ruiz-Mercado et al., 2012
- Microenvironment monitoring
  - CO, PM<sub>2.5</sub>, CO<sub>2</sub>



# Household Measurements

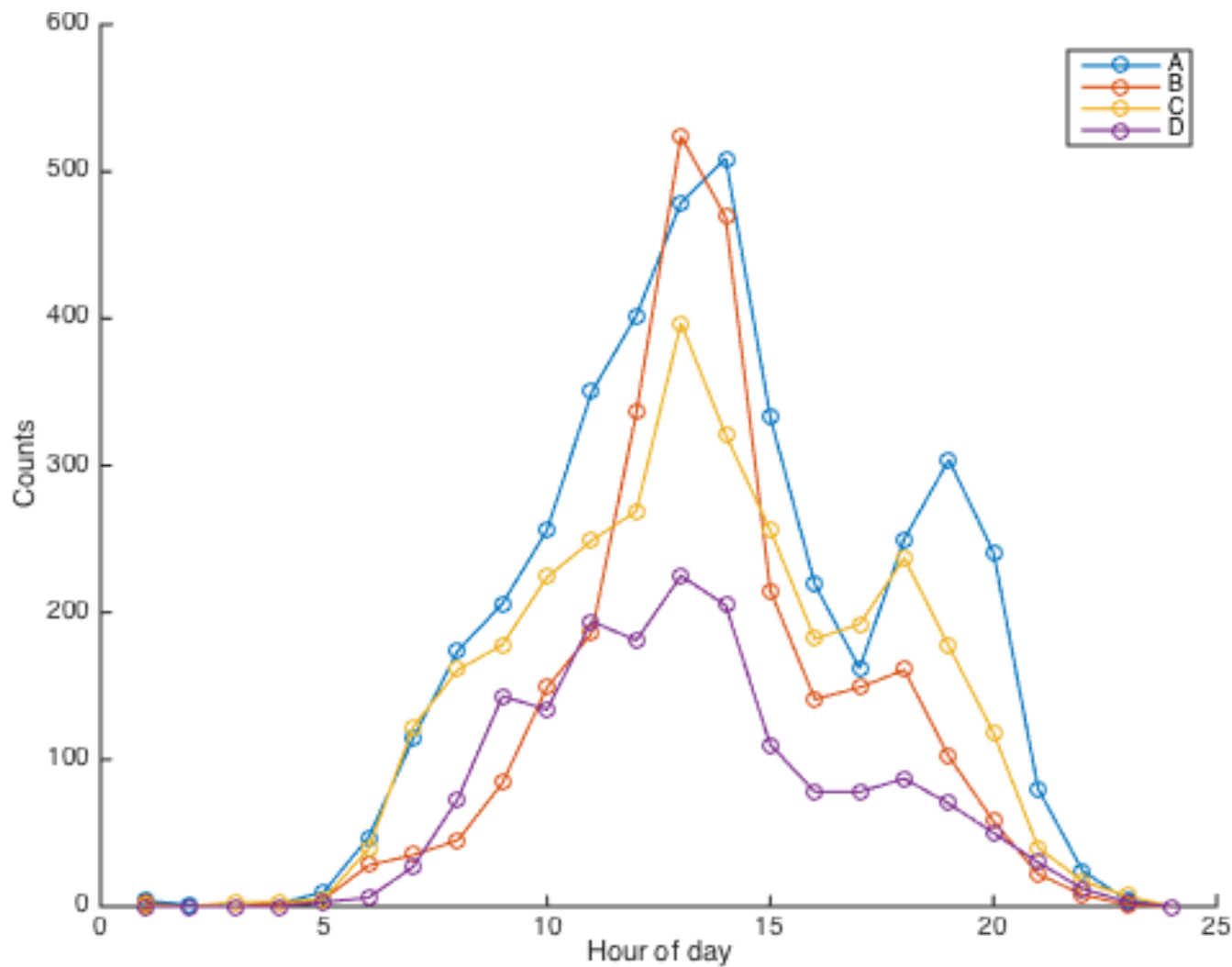


# Example SUMs Data

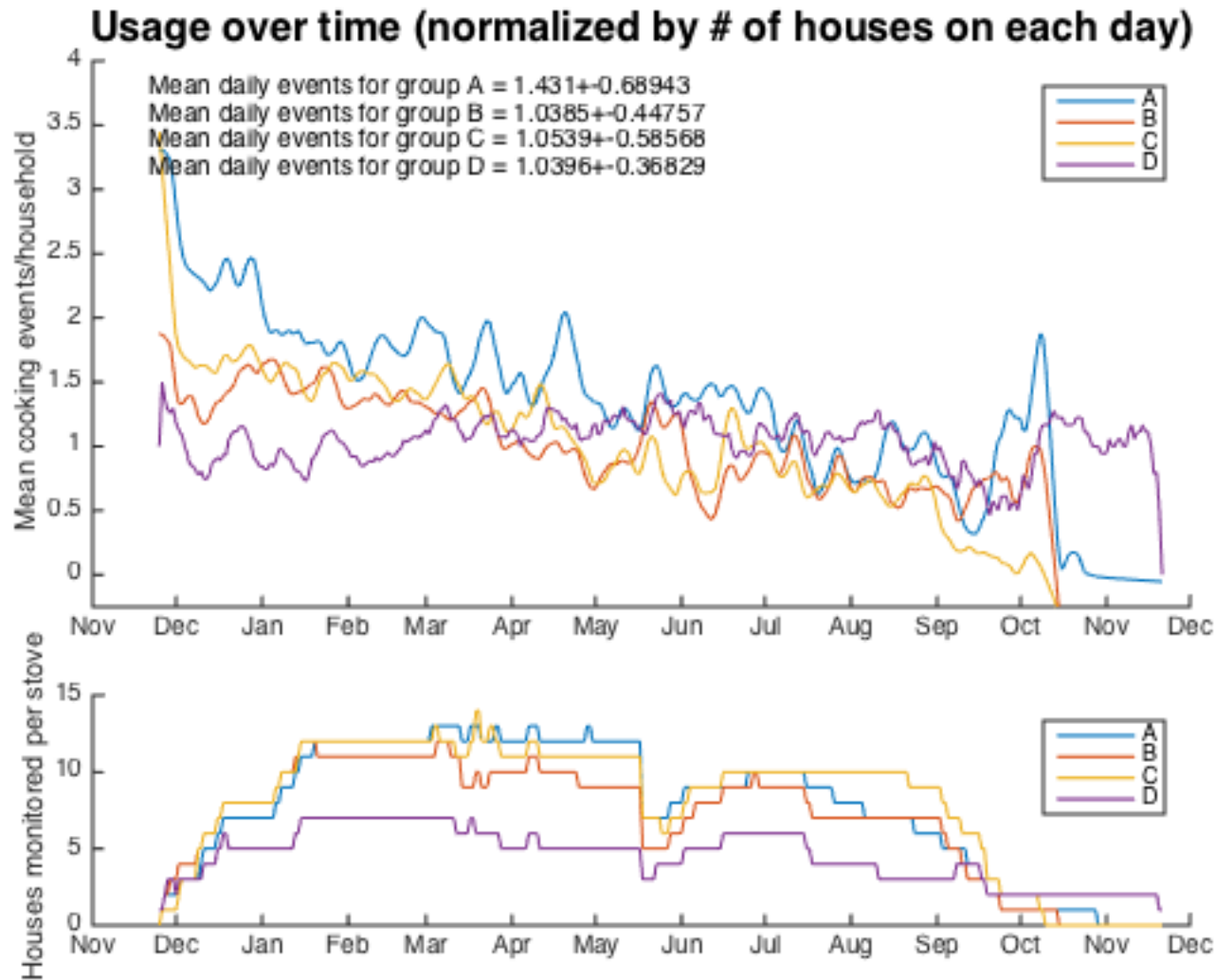




# Peak cooking time distribution by study arm

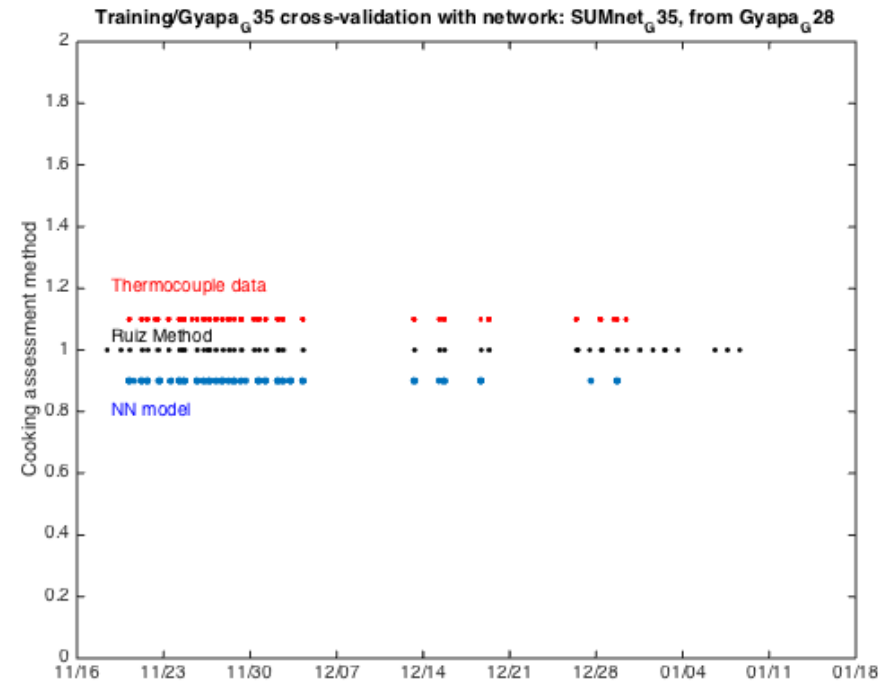
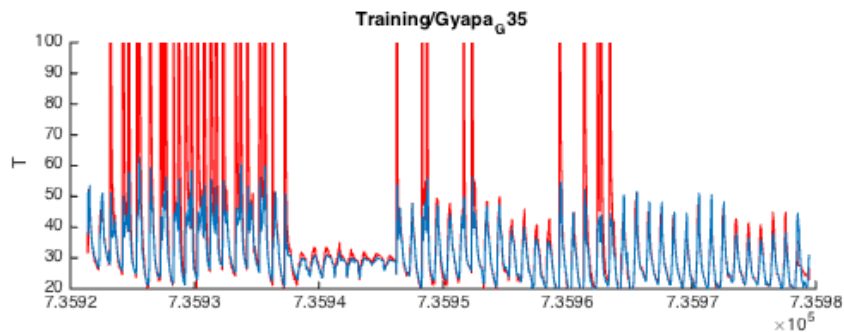
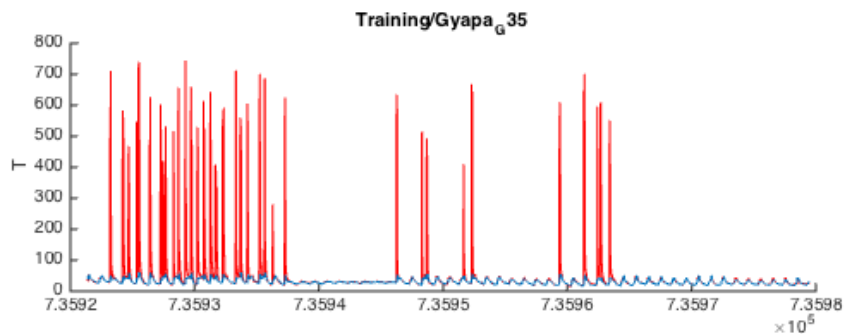


# Stove Use Over Time

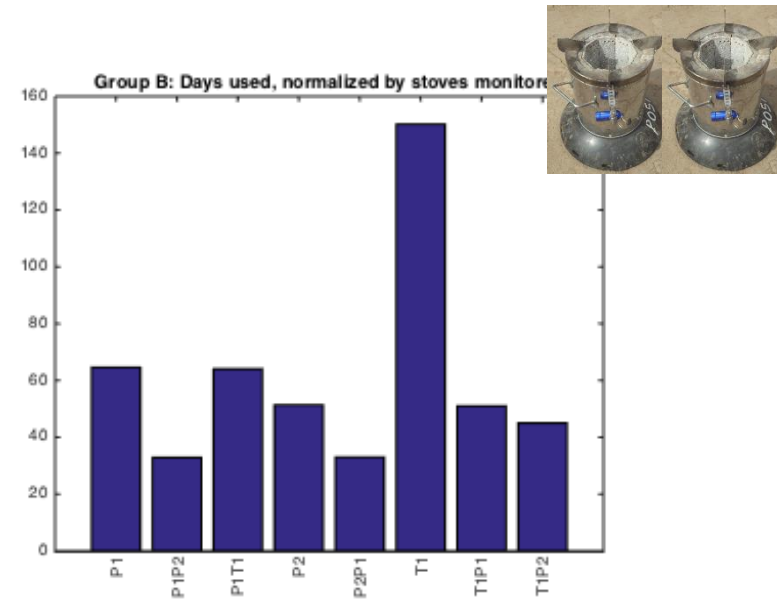
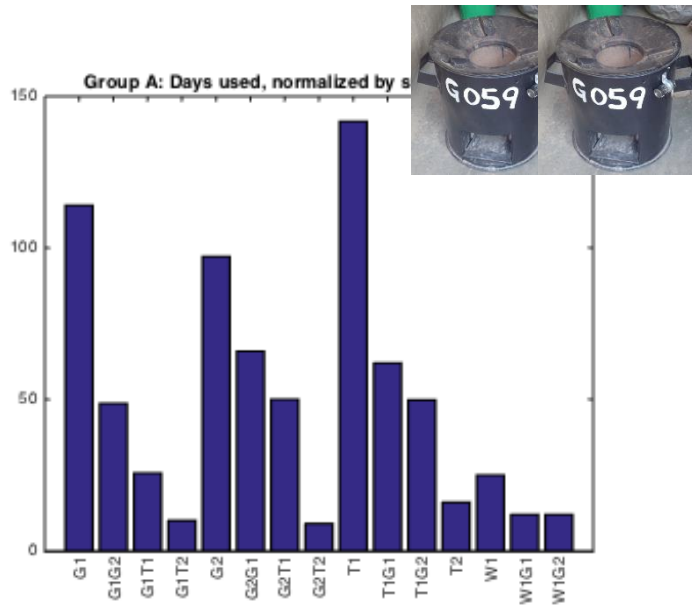


# Assessing cooking event detection algorithm

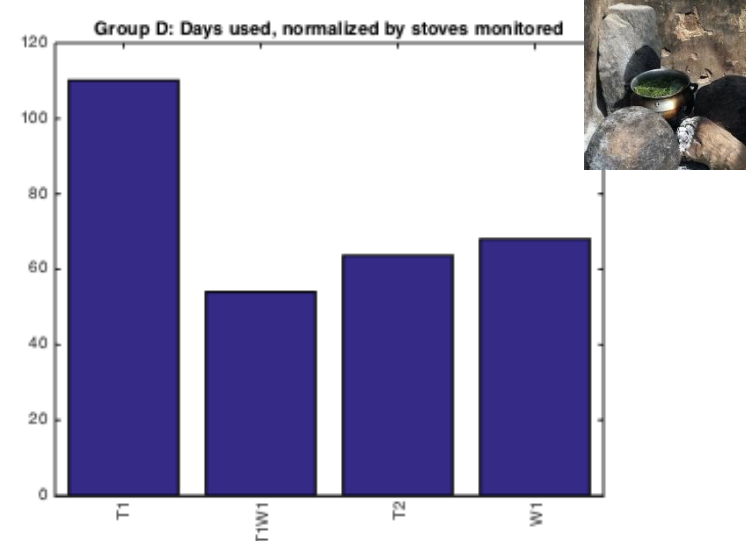
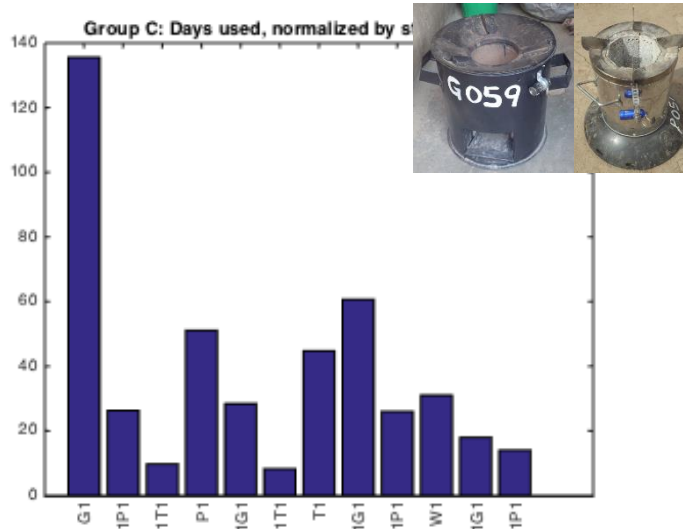
- Develop a test data set to assess cooking event detection
- 8+ week of thermocouple in fire box + SUMs on 5-7 stoves



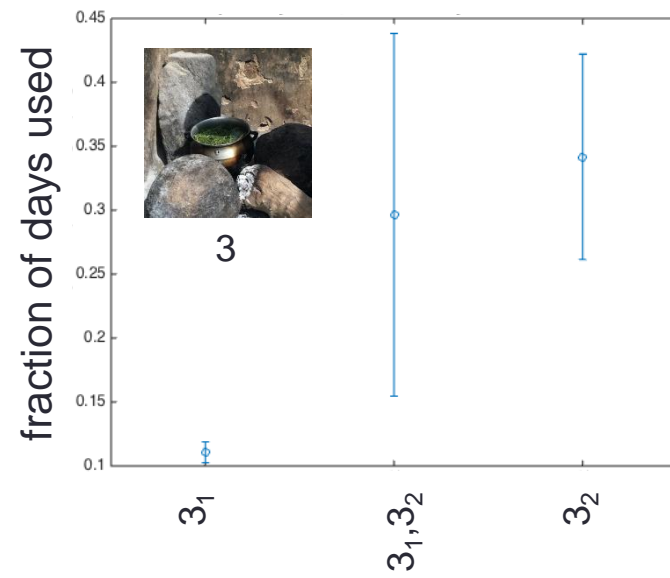
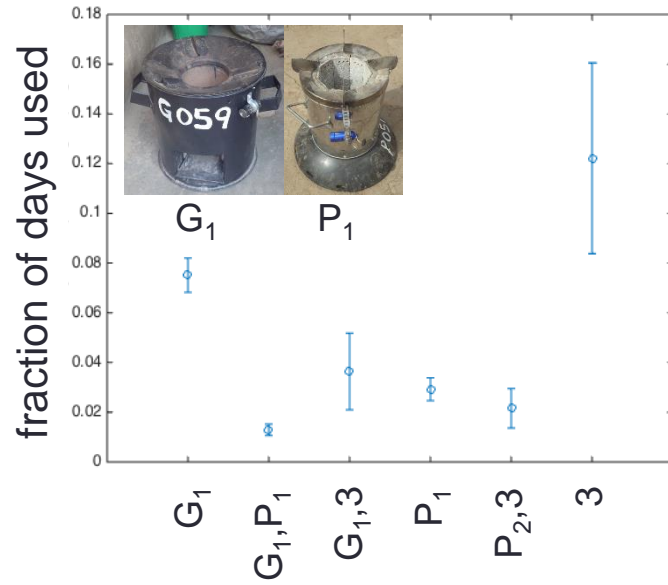
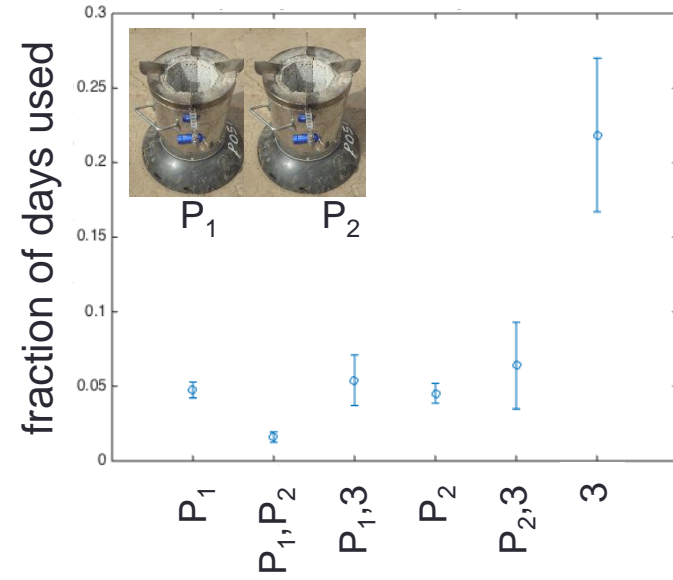
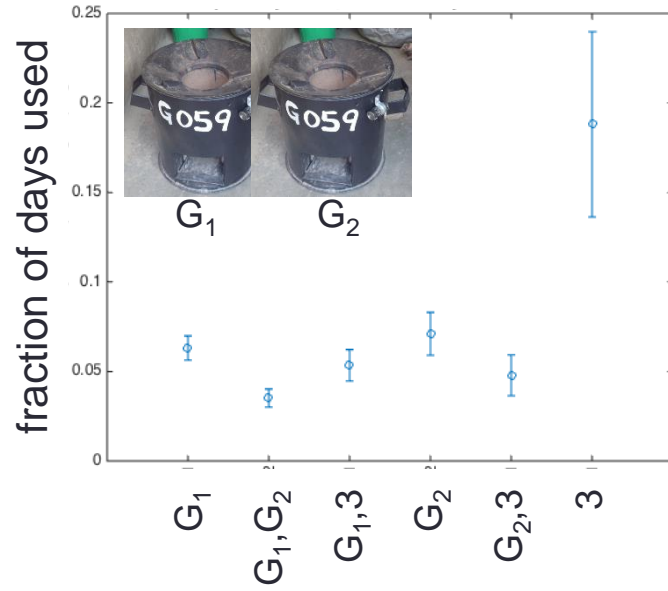
# SUMs Stacking Results



G = Gyapa  
T = 3-stone  
P = Philips



# SUMs Stacking Results



# Personal Measurements

- 48-hr personal exposure monitoring periods rotating through study households
- 4 families/households monitored from each study arm per deployment period
- 2 deployment periods per week
  - Mon-Wed, Wed-Fri



- Monitoring
  - cooks
  - school children
  - children under 5
  - available males

# Personal Measurements



- Battery operated
- Calibrated weekly at NHRC

## Carbon monoxide (CO)

- Real-time CO loggers worn by participants
  - Around necks or in “child-proof” pockets
- Lascar EL-USB (electrolytic)
  - 1-minute logging interval
  - Range: 0-300 ppm
  - 0.5 ppm resolution



# Personal Measurements and Methods



## Particulate Matter (PM<sub>2.5</sub>) Sampling

- Monitors worn in small backpacks or fanny packs
- SKC pump running at 2 LPM
  - Calibrated biweekly
- 25mm quartz filters with URG impactor upstream
- Battery powered to last over 48 hours
- Filters returned to US for EC/OC analysis

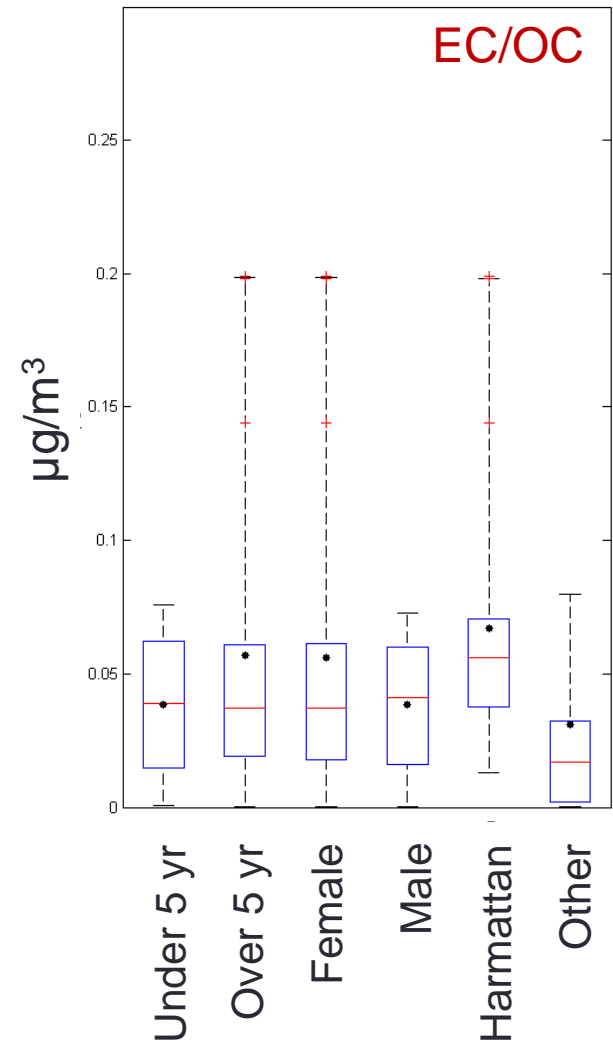
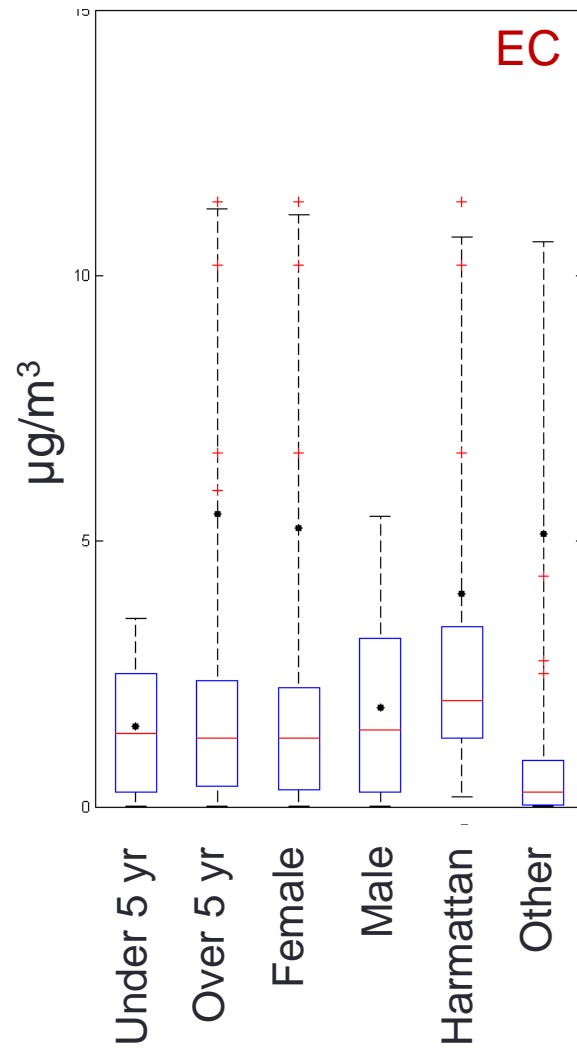
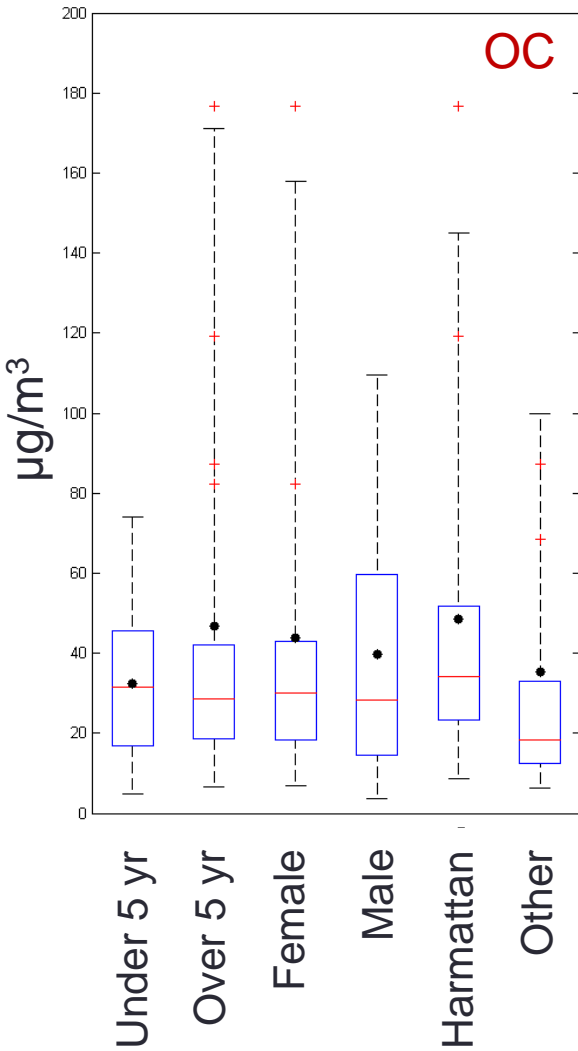




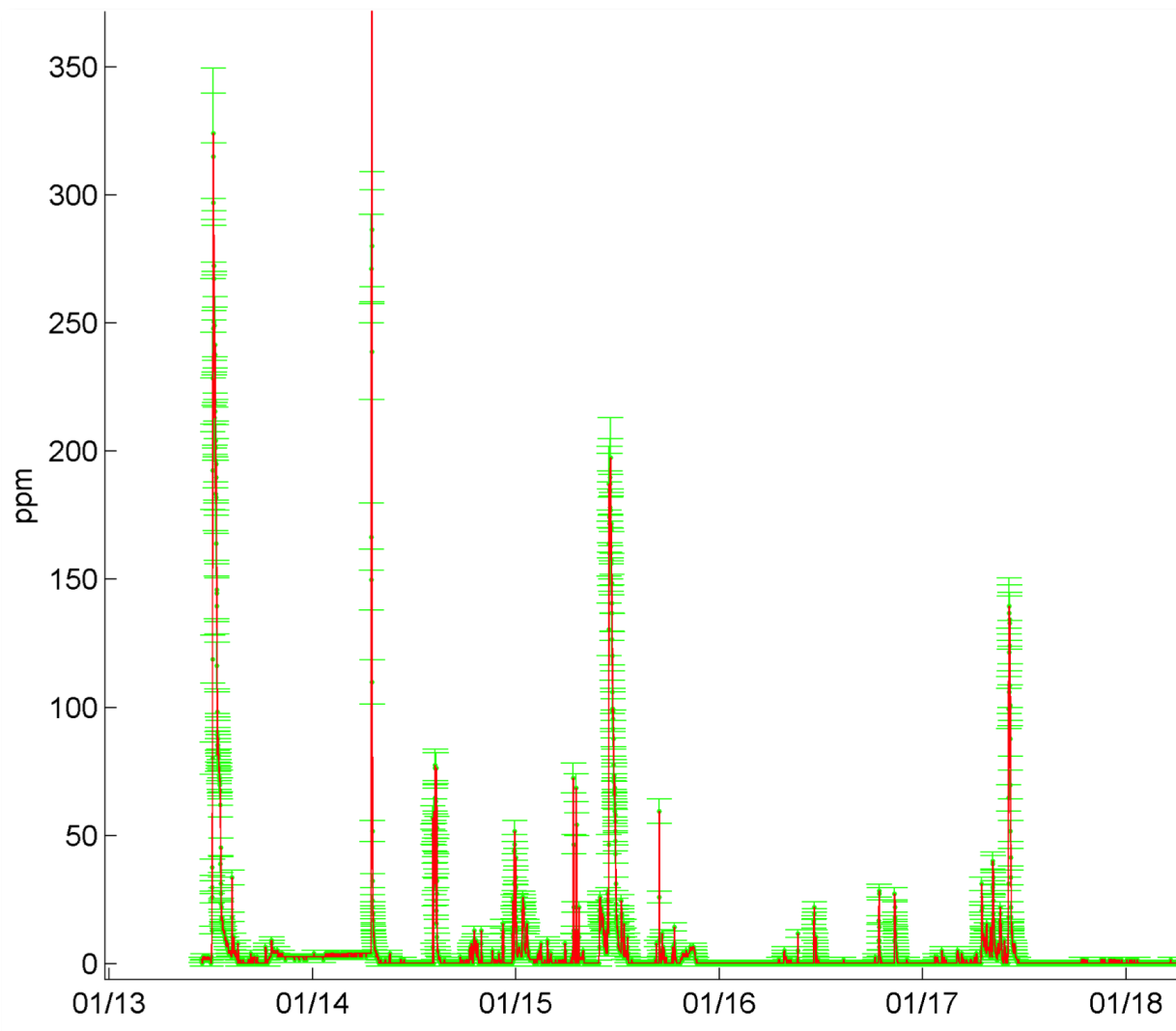
# Measurements Stats

	Personal PM	Personal CO
Analyzed Sampling Interval	Nov 2013 – May 2014	Nov 2013 – July 2014
N Individuals	70 total 18 children 16 males	266 adults 112 children from 118 households (over 1.2 million minutes)
Analysis Type	EC/OC Sunset Analyzer	Matlab code
Future	Over 100 more to analyze	Over 500,000 more minutes to analyze

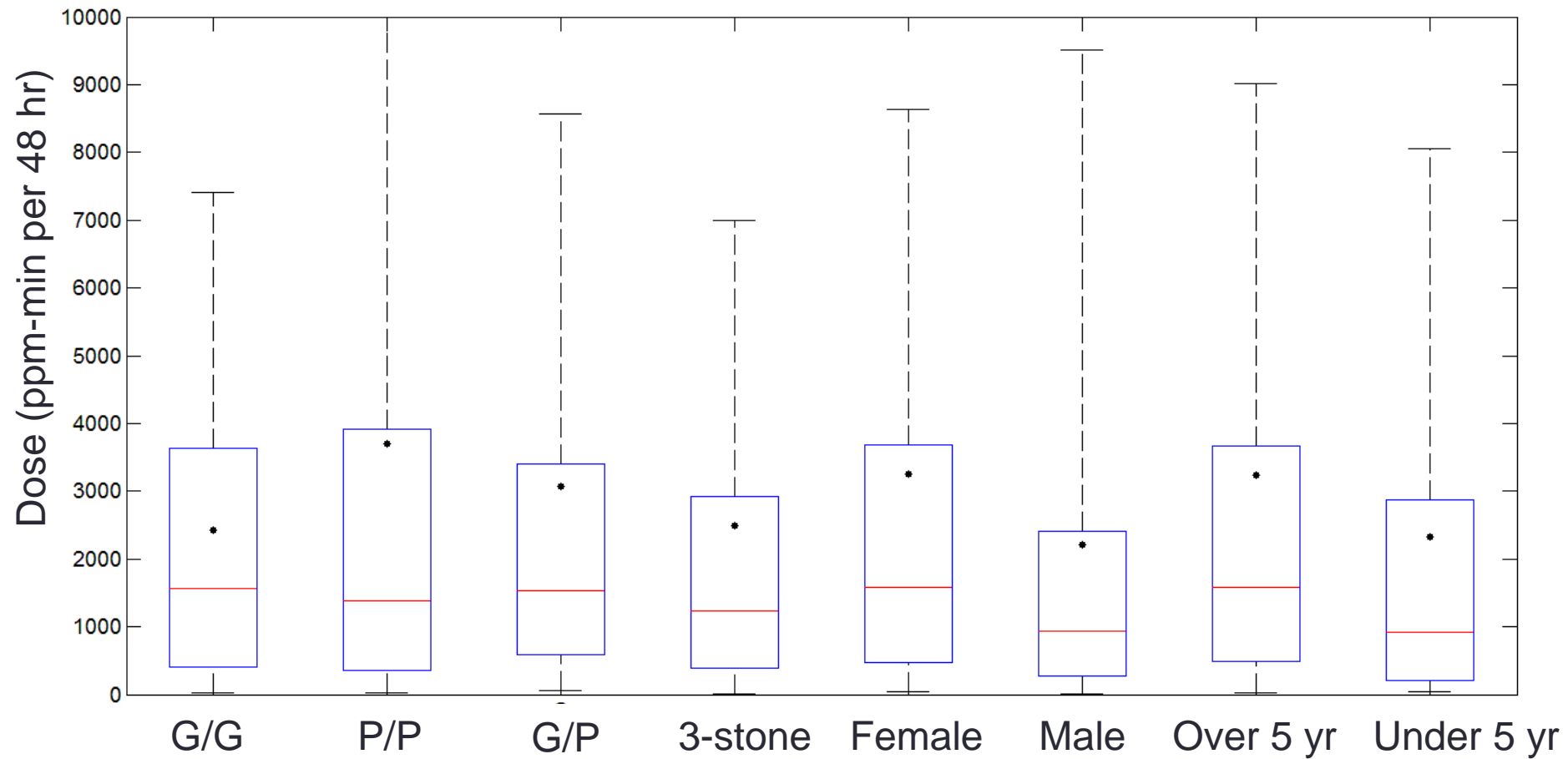
# Personal EC/OC of PM2.5



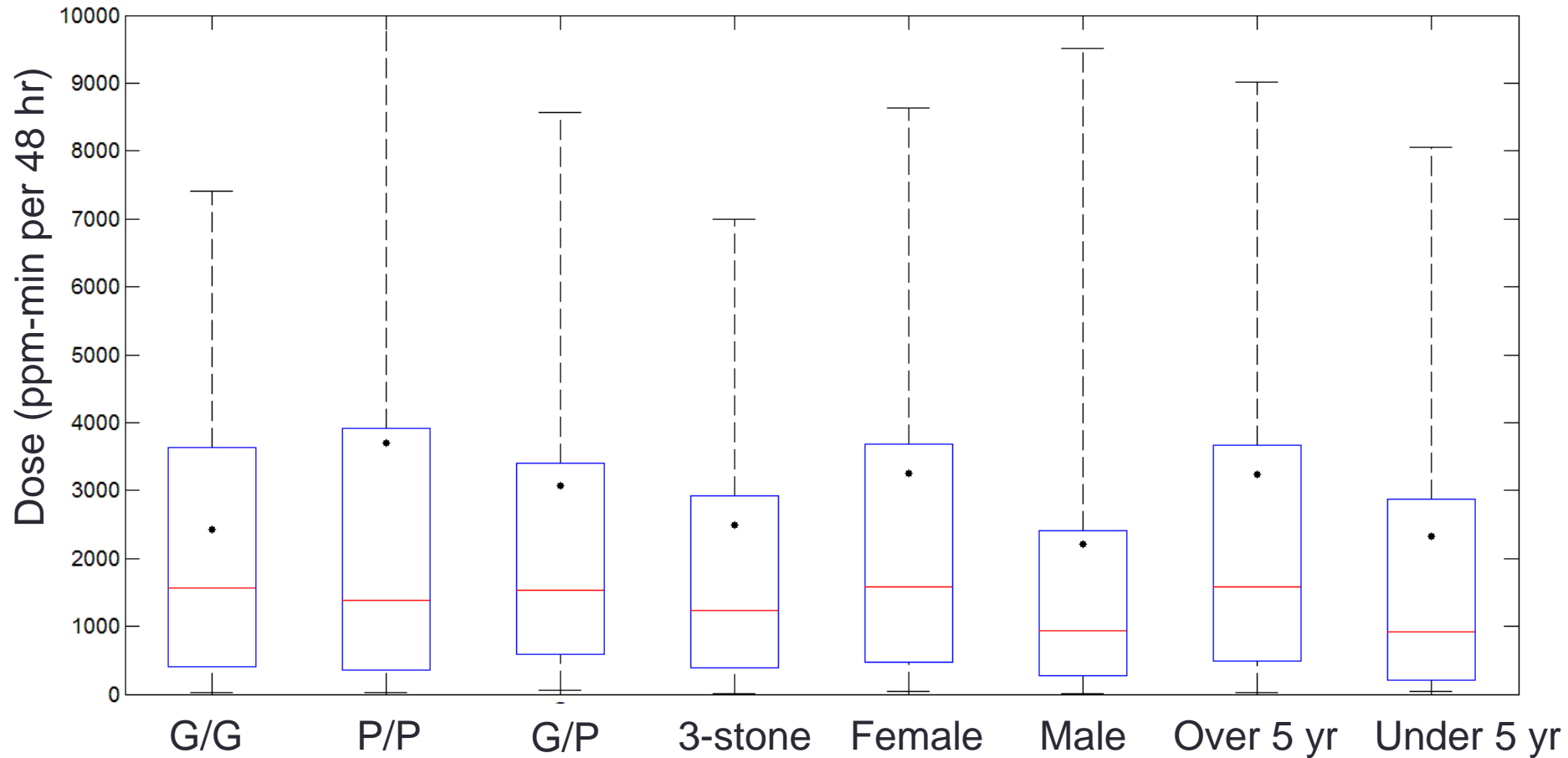
# Example CO personal exposure



# Personal CO Doses

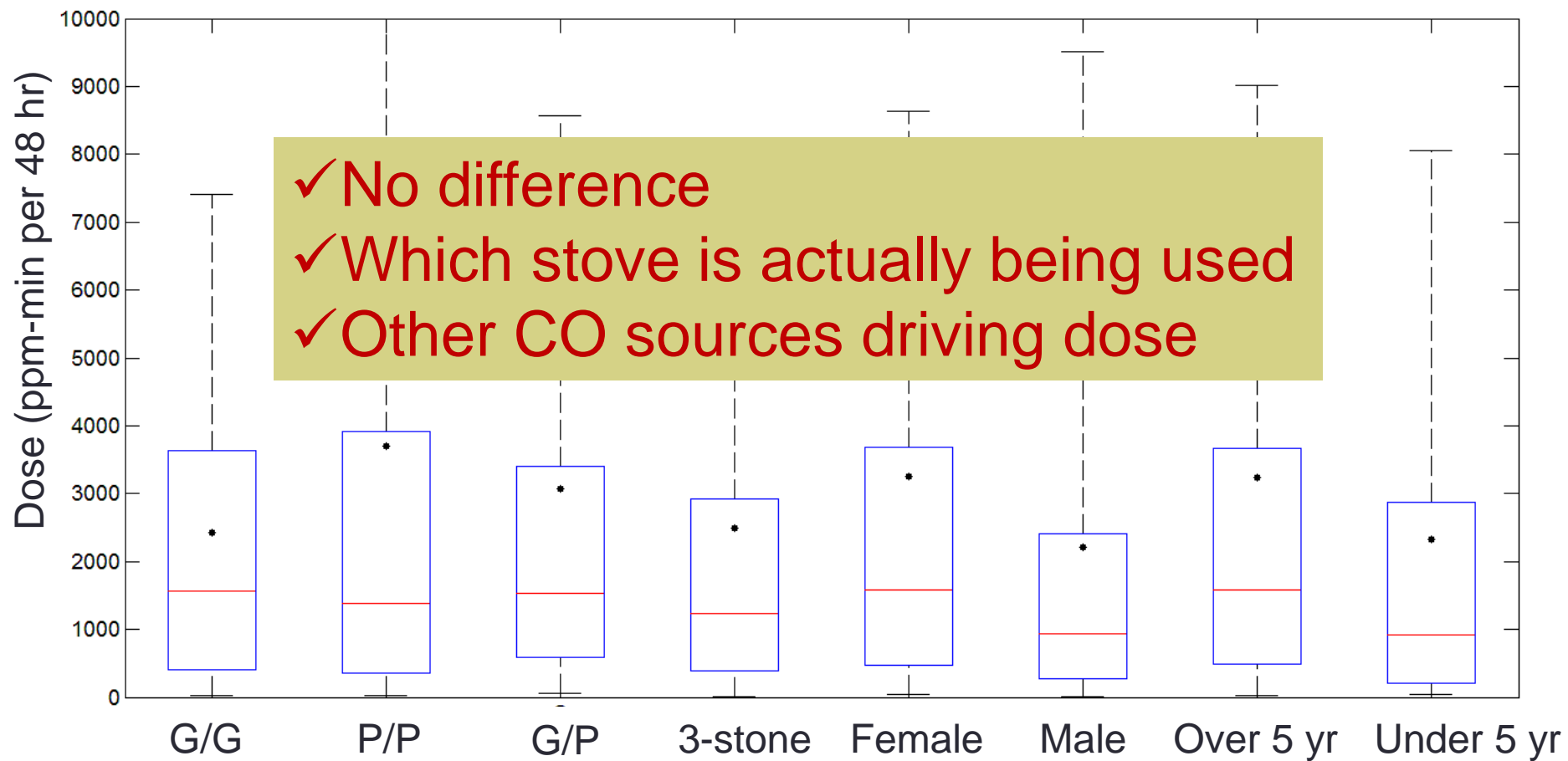


# Personal CO Doses



Why aren't we seeing differences in CO exposure?

# Personal CO Doses



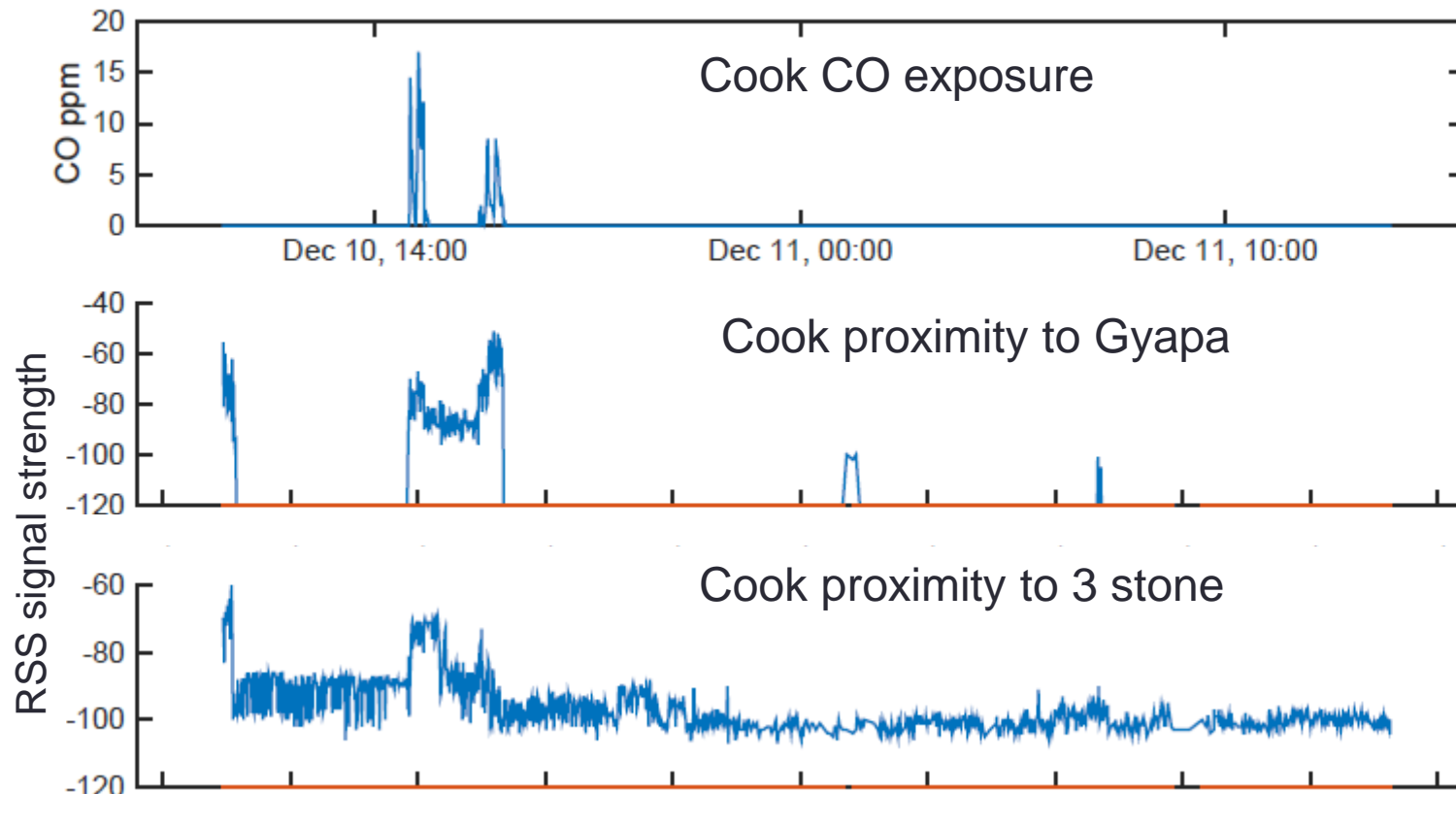
Why aren't we seeing differences in CO exposure?

# Improve link between CO exposure and stove use

- Additional microenvironmental monitoring
  - UCB PATS
- Personal monitoring with iBeacons



# Apportioning CO exposure





# Where do we want to end up ...

Estimate ...

$\text{CO}_{\text{dose}}$

$$= \sum_i \text{function}_i(\text{stove}_i T(t), \text{proximity to stove}_i(t)) + \text{CO}_{\text{other sources}}$$

derive via regression



measure using SUMs

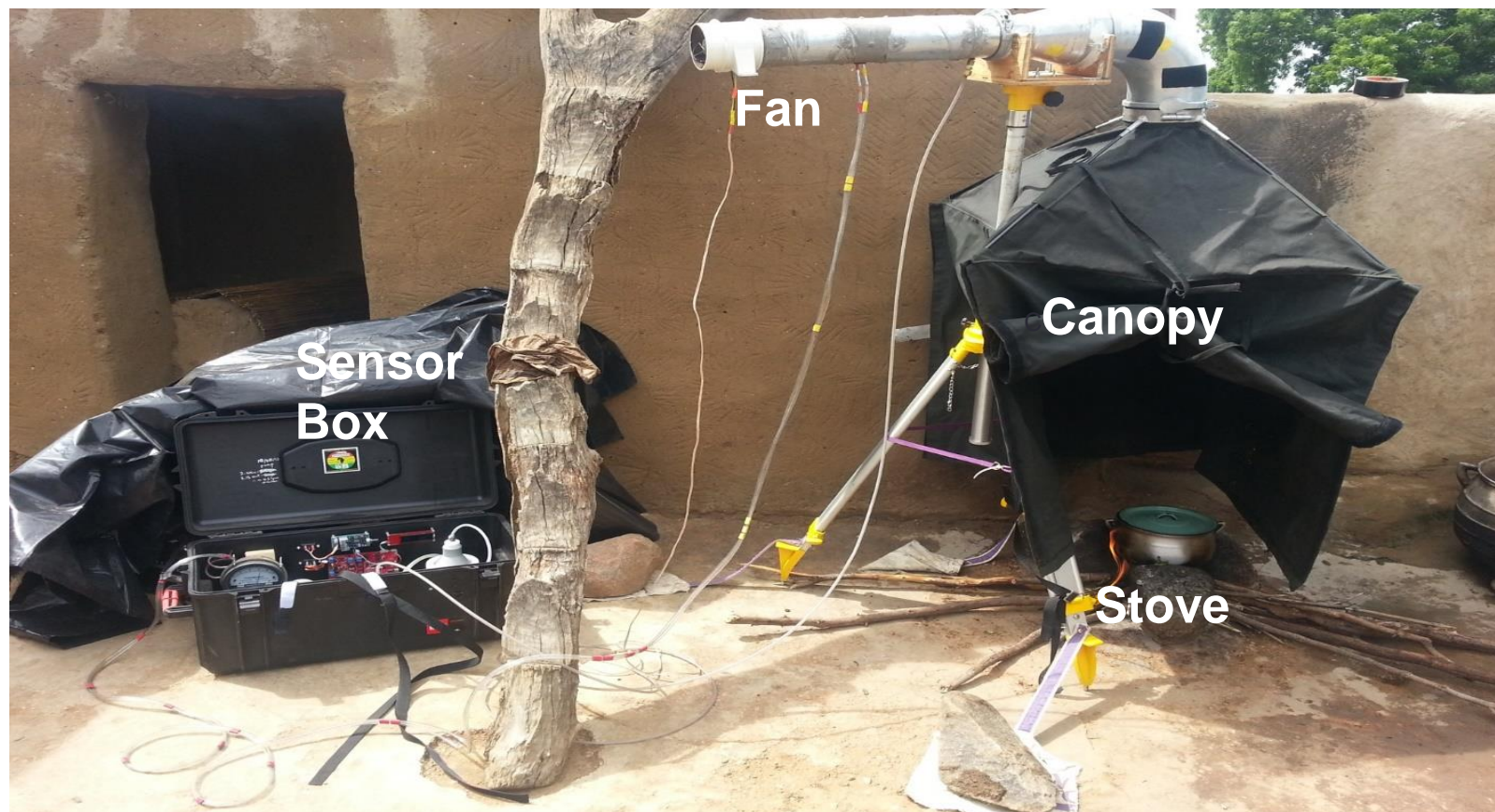


measure using beacon



PM2.5 too

# Cooking Emissions Measurements

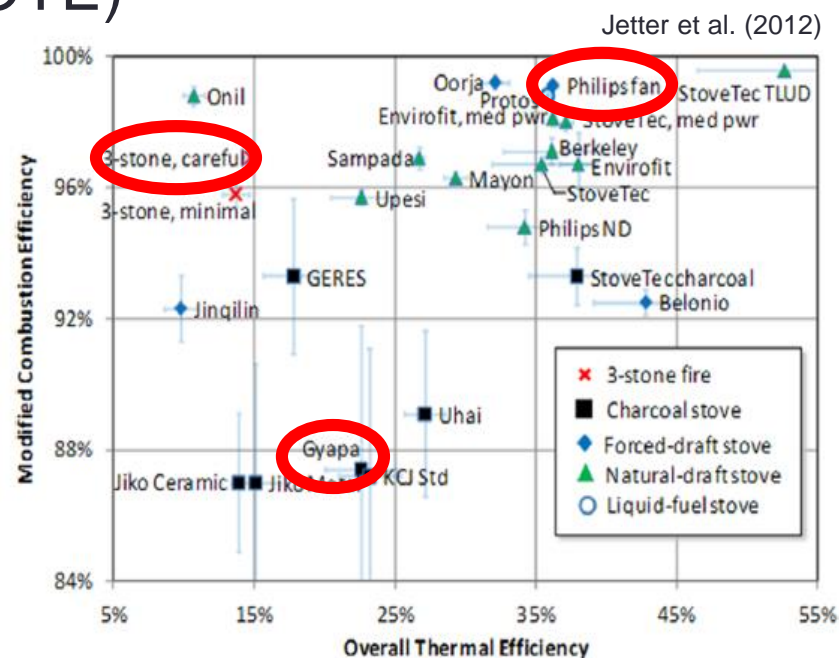


# Evaluation of Stove Performance

- Using Controlled Cooking Test
- Efficiencies
  - Heat Transfer Efficiencies ( HTE) and Combustion Efficiency (FCE)
  - Overall Thermal Efficiency (OTE)

- Emission Factors

- CO
- NO and NO<sub>2</sub>
- total VOCs
- PM2.5 (cumulative)
  - speciation of PM2.5



# Sampling Procedures/Techniques

- Be at household before evening cooking starts
- Let cook follow her normal practices
- Set up PEMs and measure emissions during the entire cooking period (2-4 hours)
- PM collection on 90 mm quartz-filters for integrated sample
- Gas phase emissions (CO, CO<sub>2</sub>, NO, NO<sub>2</sub>, TVOCs)
- Measure the weight of the fuel used and food cooked



# Total samples collected

As of 02/22/2015

	Gyapa	Phillips	Three-Stone	Total
North	4	6	5	15
South	4	3	3	10
East	4	4	4	12
West	4	4	4	12
<b>Residential/Total</b>	<b>14</b>	<b>15</b>	<b>14</b>	<b>49</b>

## Typical Emission Factor (mass of pollutant per mass of fuel used)

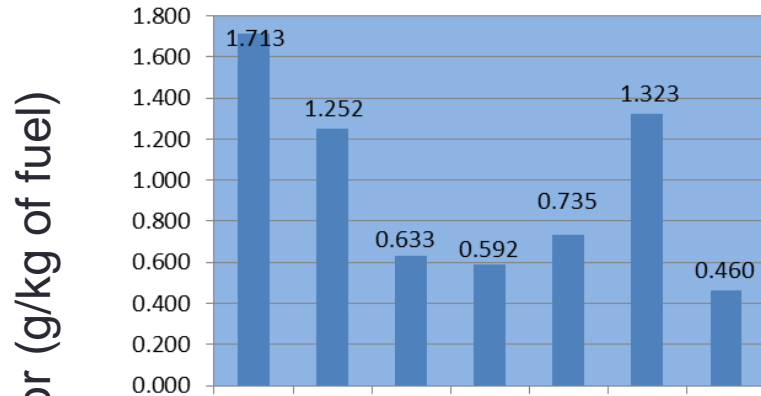
- Emissions= Function (stove type, fuel type, fuel moisture content, ambient T, food type)

## Secondary analysis

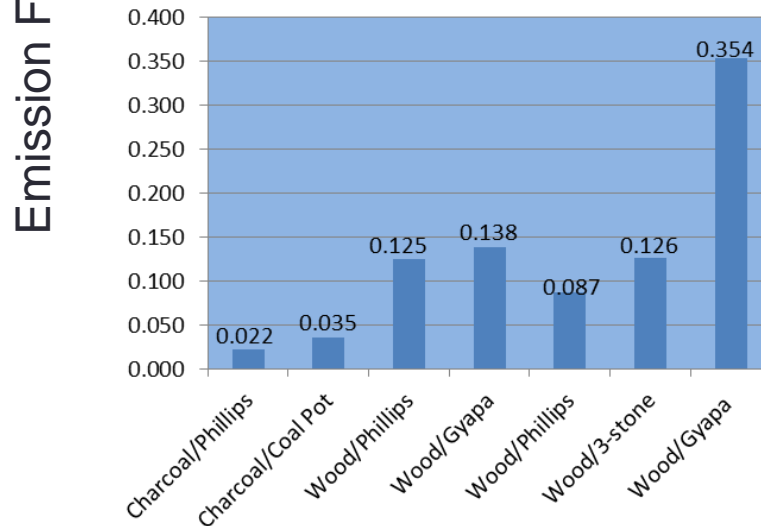
- Task based emission factors (mass of pollutant per mass of food cooked)
- Heat transfer efficiency in the field

# Initial PM<sub>2.5</sub> Results

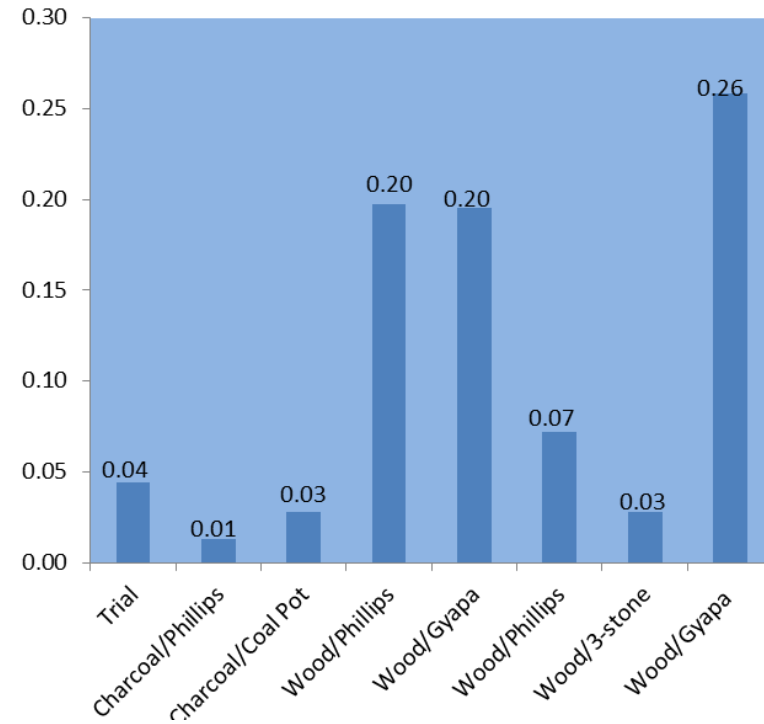
## OC



## EC



## EC/OC ratio



# Other source sampling



24 events to date  
Trash burning  
Traffic  
Pito brewing  
Commercial cooking



## The Pleasures of Cookstove Assessment....

*A Norwegian an American and a Rwandan are sitting at a campfire in the middle of a Boulder, CO parking lot.*

*The Rwandan has two pairs of pants, one fleece, a winter jacket and a beanie on...  
while*

*The Norwegian has shorts and a light sweater on and is asking for sunscreen...  
while*

*The American is wondering what fast food restaurant to swing by for dinner!*



**Research translates to engaging class.**



# Questions?

