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

*an integrated laboratory, field and modeling study*


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# Big Picture Questions

- How much air pollution is emitted by all the residential solid fuel combustion on the planet?
- What would happen to climate, air quality, and health if everyone who burns solid fuels could move up ‘one rung’ on the energy ladder?
- Why doesn’t our laboratory-generated data on emissions agree field observations?

# The Challenge of Field Studies

- Between 2009 and 2010, CSU and Berkeley Air conducted approximately 260 field tests in India to evaluate stove performance.

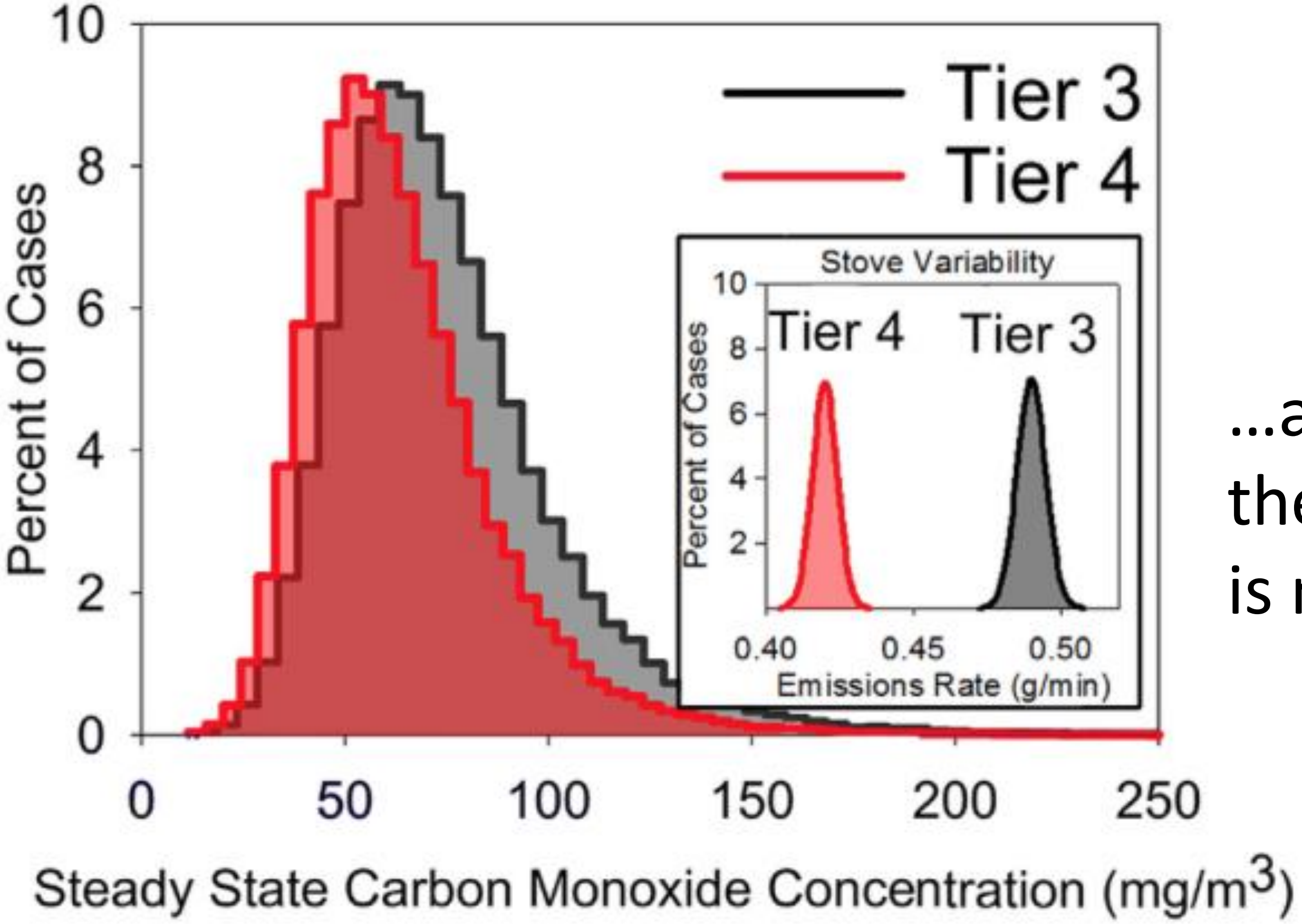
*"no significant difference was found in IAP concentrations"*

*"there was no statistical difference between the stove types"*

*"no statistically significant difference in black carbon"*

- Why would a stove that showed marked improvement in the lab show minimal improvement in the field?

# A 15-20% Improvement in the Lab is Difficult to Detect in the Field




…and reliability of the measurements is not the problem

L'Orange et al., *Biomass & Bioenergy* (2015)

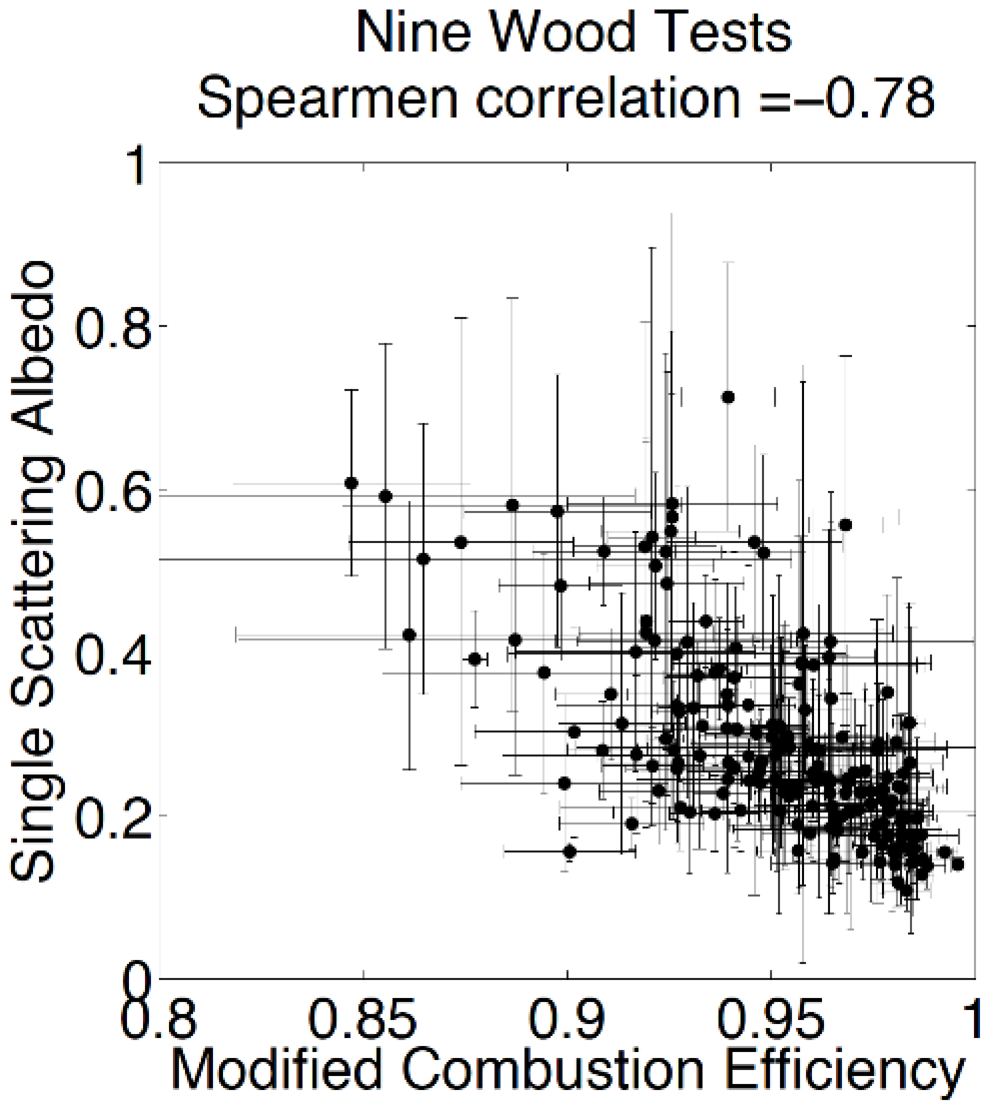
Stove ‘performance’ can vary for many reasons

We must understand what governs stove performance if we are to rely on laboratory data to predict performance in the field

…*and there are good reasons why we would want to do this*.

We want to predict stove performance in the field so that intervention programs produce impact as planned: *on health, on climate, on economics*

# Modified Combustion Efficiency (MCE):
# Helpful? *Yes*. Perfect? *No*. Practical? *Not really*.




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

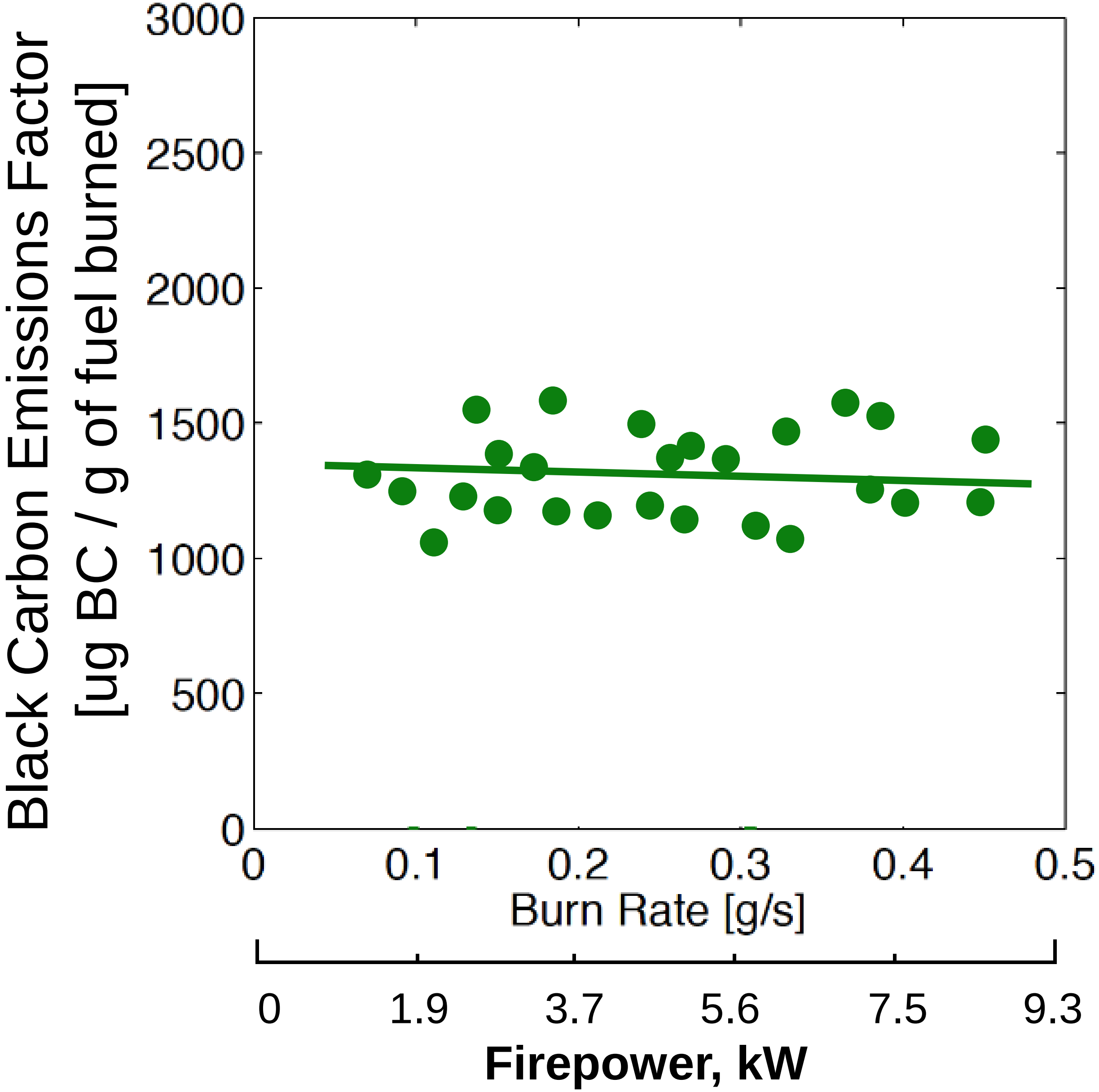
# All stoves have a working range of power output

**Low Power**

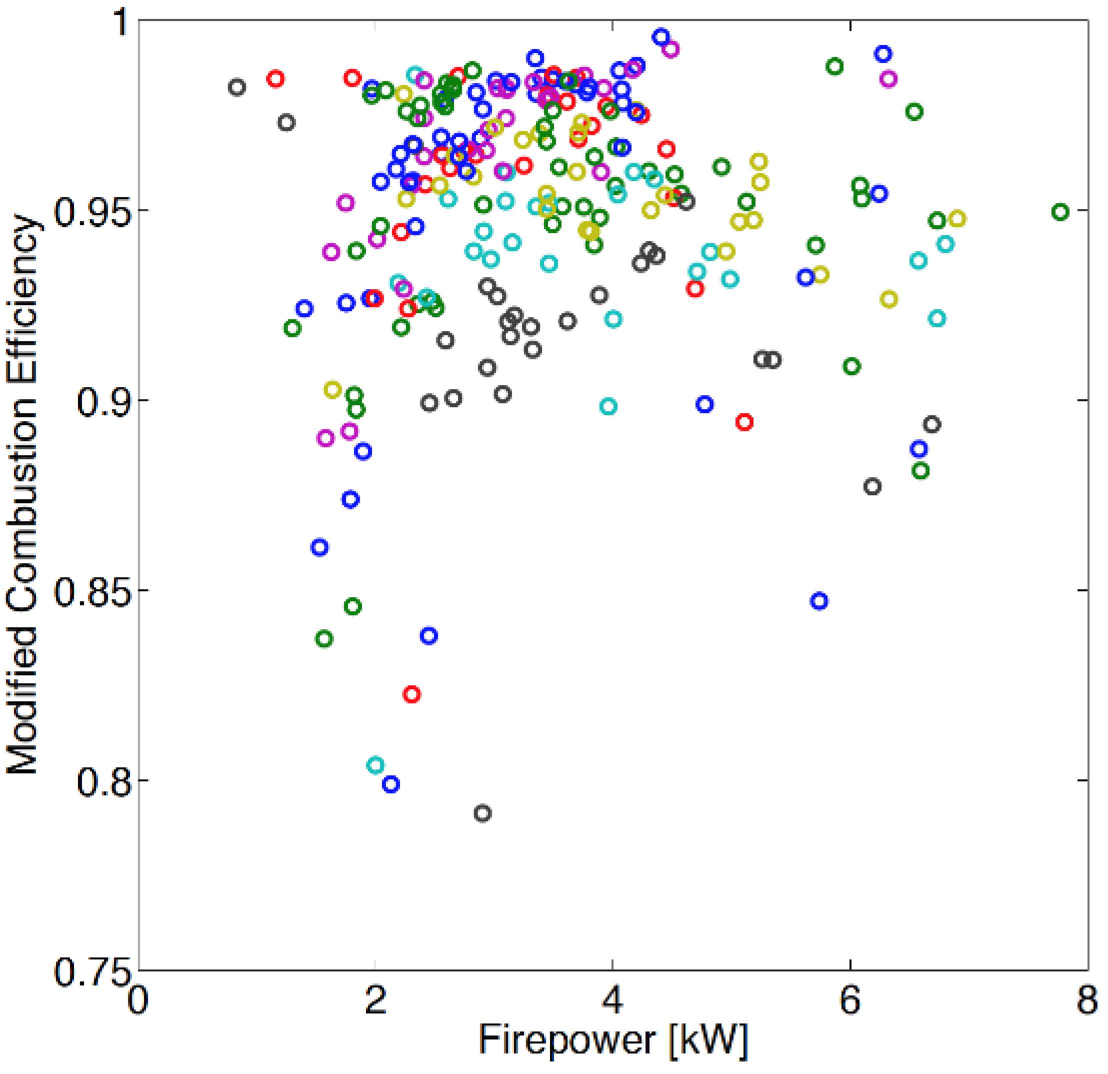

**High Power**

$$Firepower(kW) = \frac{Stove\ Energy\ Output\ (kJ)}{Time\ (s)}$$

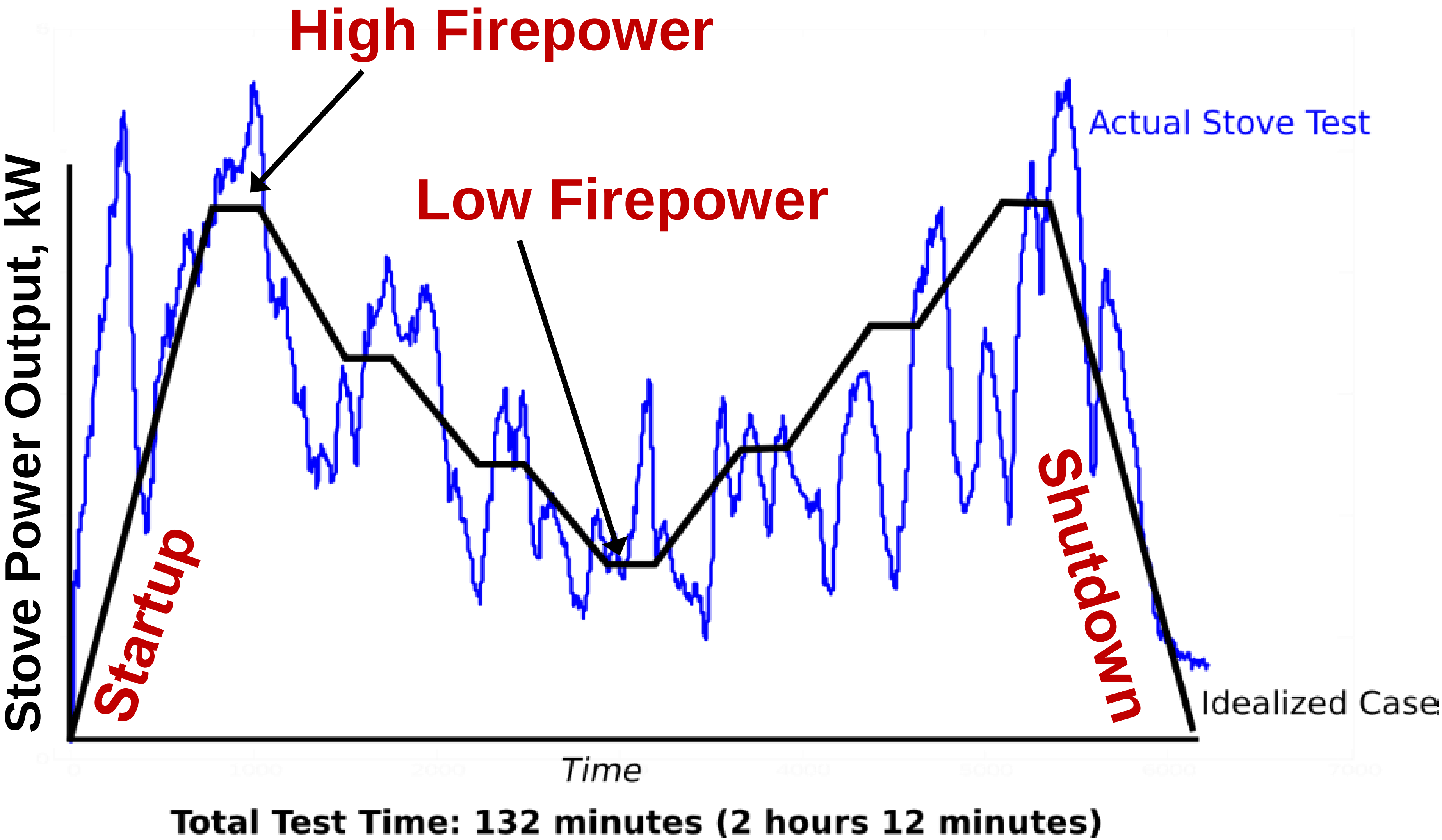
# Black Carbon and Stove Firepower



# Modified Combustion Efficiency vs. Firepower



# The Firepower Sweep Test

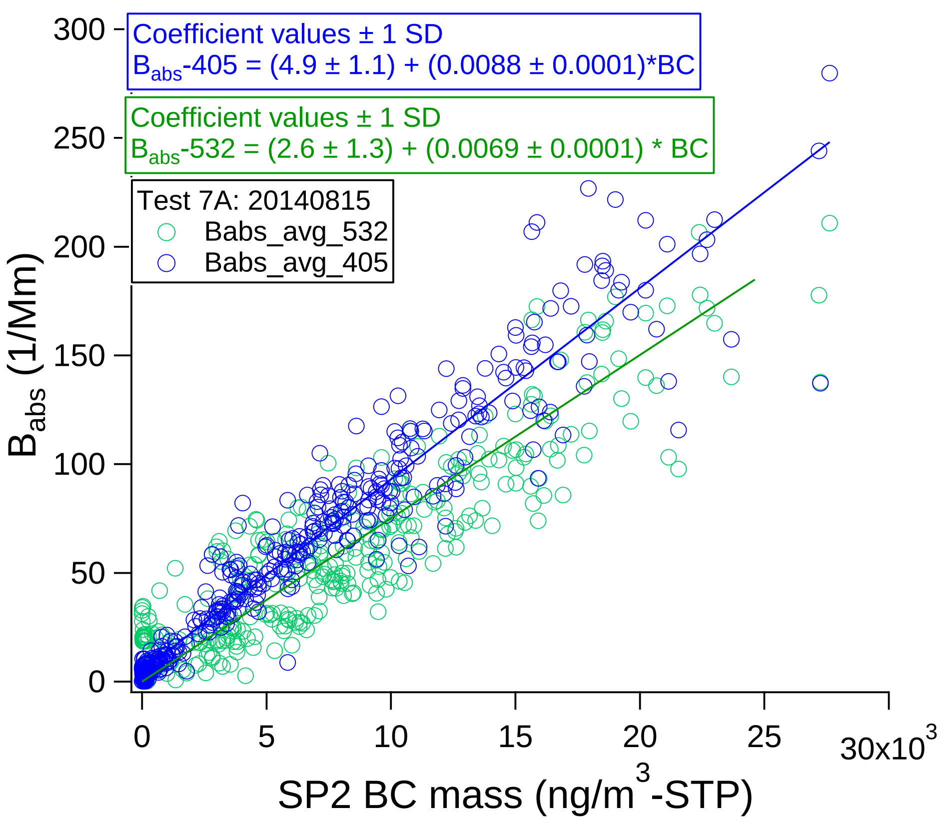


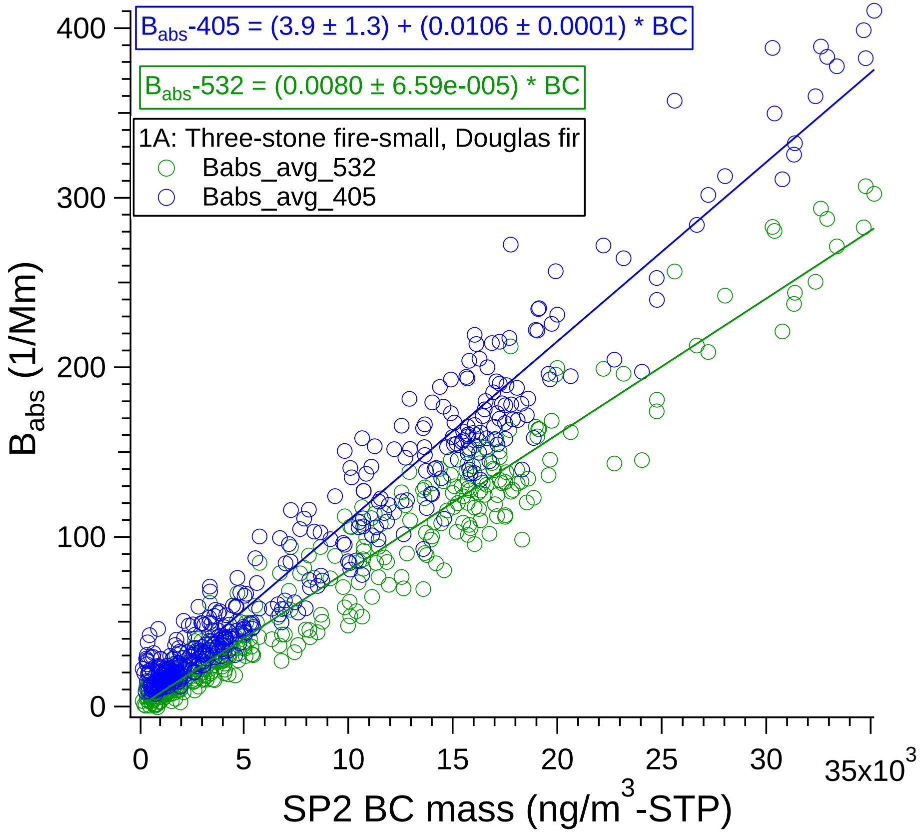
# 2014 Front Range Cookstove Study (FRaCs)

| Stove Type | Versions | Fuels |
|---|---|---|
| Three Stone Fire | Small | Douglas Fir |
| | | Okote |
| | | Eucalyptus |
| Tradiational Built In | Justa | Douglas Fir |
| | Sunken Pot | Douglas Fir |
| | | Okote |
| Improved Plancha | HM 5000 | Douglas Fir |
| Ceramic Jiko | Small | Lump hardwood |
| | | Coconut |
| | Large | Lump hardwood |
| | | Coconut |
| Metal Jiko | Large | Lump hardwood |
| | Small | Lump hardwood |
| Improved Charcoal | BURN Design | Lump hardwood |
| Artisan Clay | Version 1 | Douglas Fir |
| | | Eucalyptus |
| Enclosed Metal | Version 1 | Douglas Fir |
| | | Eucalyptus |
| Rocket Elbow | Version 1 | Douglas Fir |
| | | Eucalyptus |
| | Version 2 | Douglas Fir |
| Semi Gasifier | Philips | Wood Pellets |
| | | Red Oak |
| | Concept Gasifier | Wood Pellets |
| | | Red Oak |

- 21 days
- 25 Stove/Fuel Combinations
- 70 tests (3hrs ea.)
- 17 participants
- 10 research groups
- 1400 person-hrs

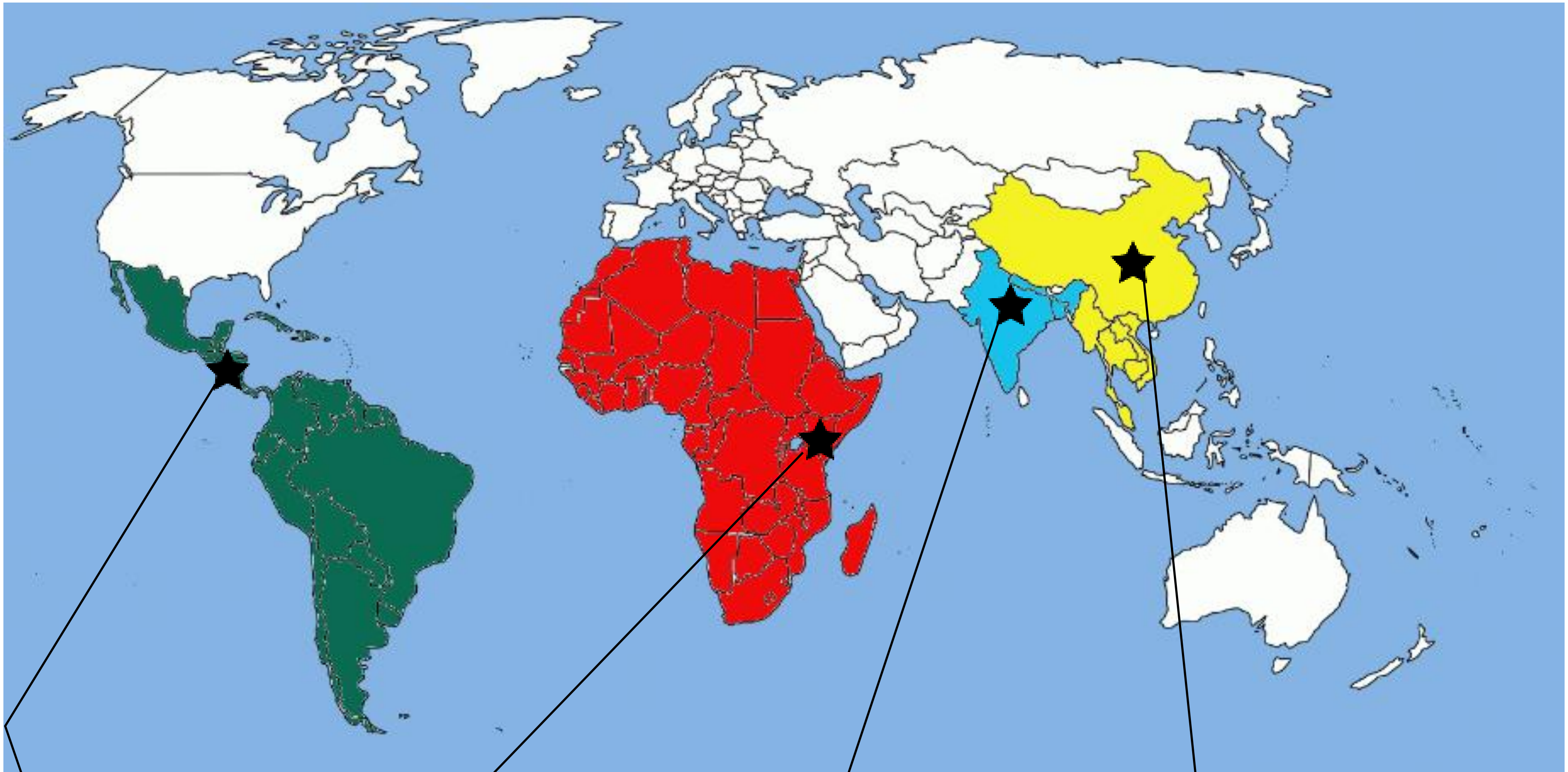
# BC mass absorption cross-section: Similar to fresh combustion soot




| Plancha (HM5000) with Douglas fir | | 3-stone fire with Douglas fir |
|---|---|---|
| **MAC-532 = 6.9 m²/g** | **(Bond et al. 7.75)** | **MAC-532 = 8 m²/g** |
| **MAC-405 = 8.8 m²/g** | **(Bond et al. 10.2)** | **MAC-405 = 10.6 m²/g** |

# Field Work: Emissions, Exposures, Model Validation



HONDURAS:
March 2015

KENYA:
July 2015

INIDA:
Winter 2016

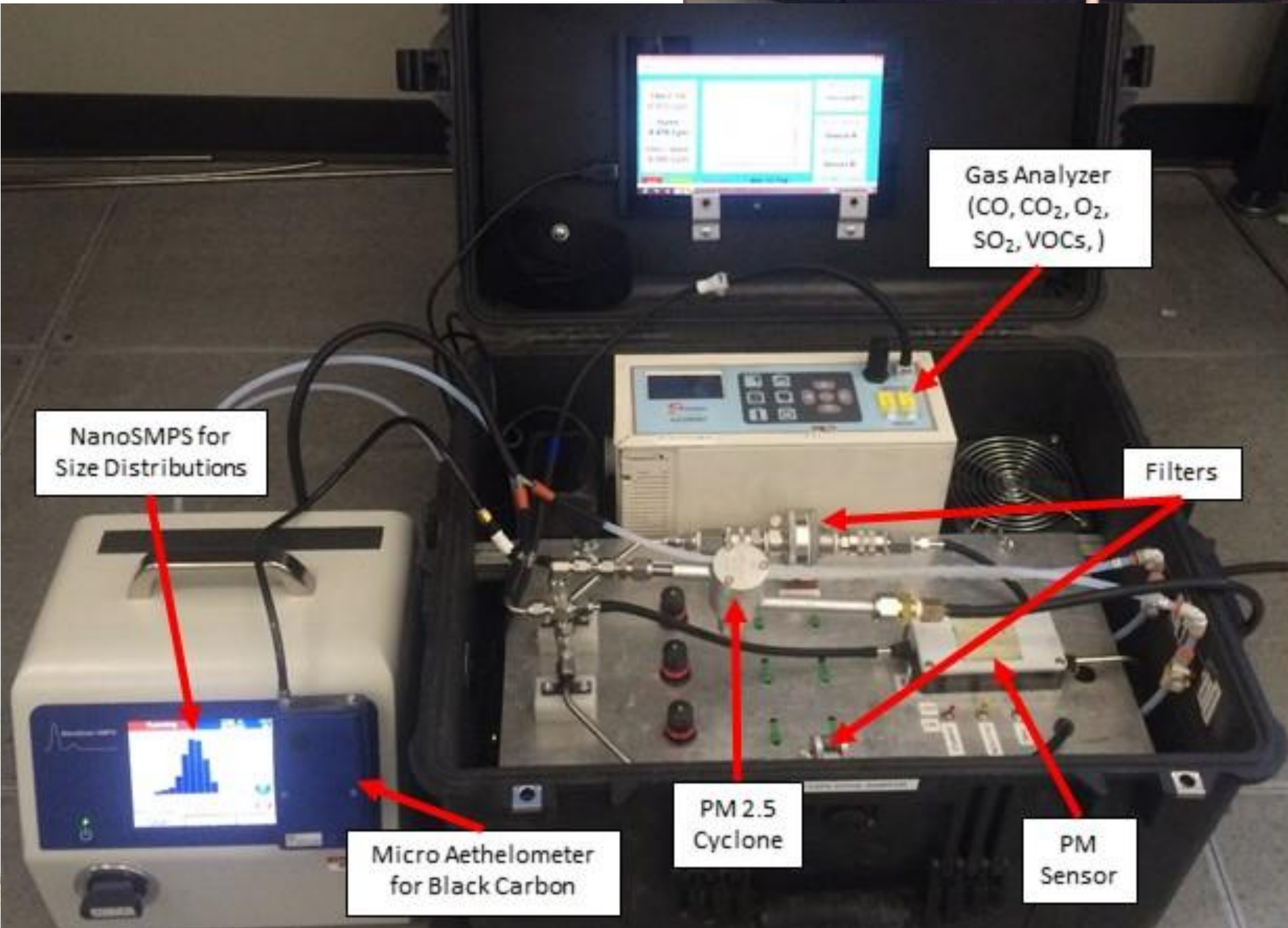
CHINA:
January 2015

Colorado State University

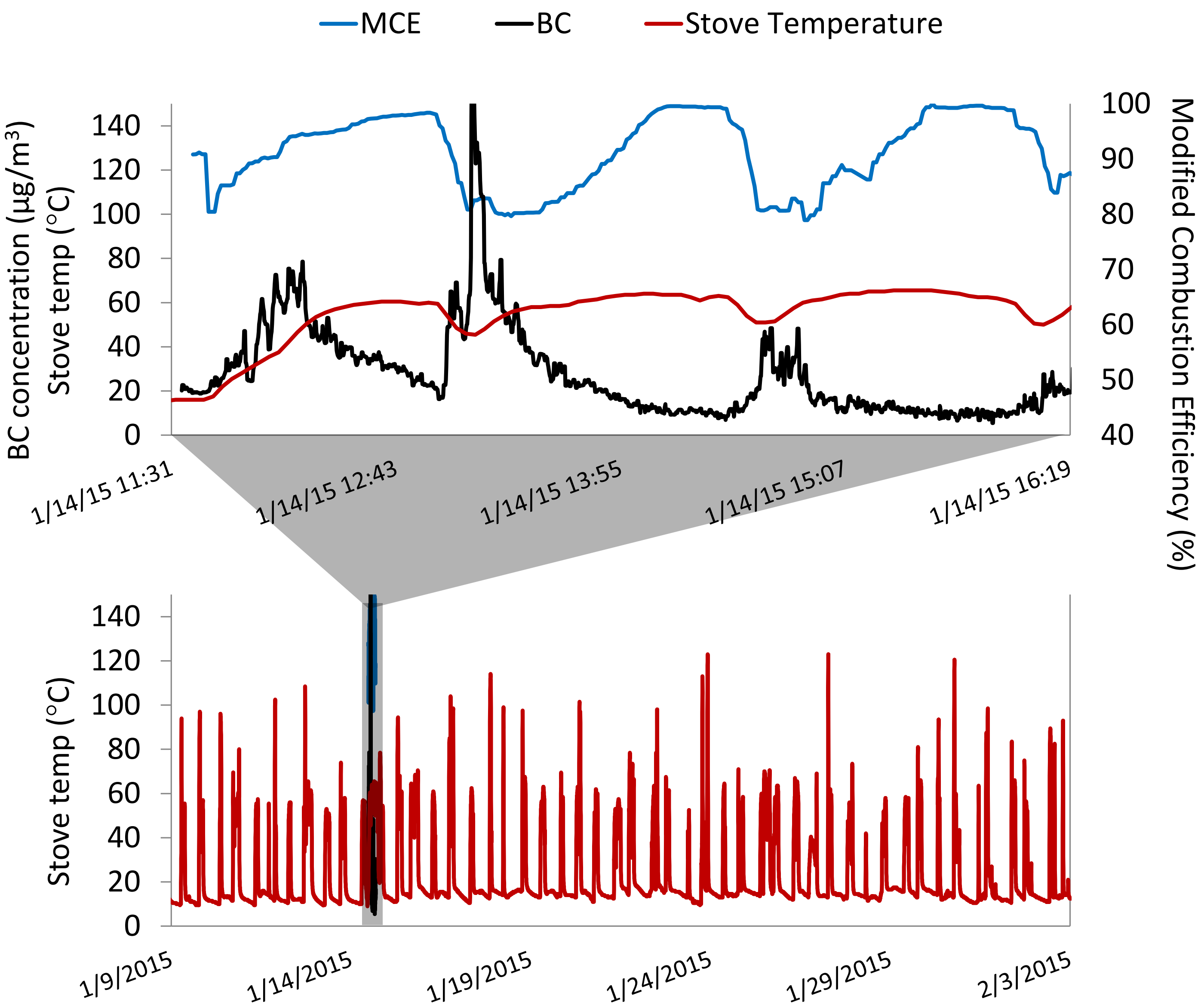
WINROCK INTERNATIONAL

ENVIROFIT

清華大學 Tsinghua University


Gas Analyzer
(CO, $CO_2$, $O_2$,
$SO_2$, VOCs, )
NanoSMPS for
Size Distributions
Filters
PM 2.5
Cyclone
PM
Sensor
Micro Aethelometer
for Black Carbon

# Example emissions and usage data of a coal stove




BC emissions and combustion efficiency shows relationships with usage patterns

# Ongoing work

- Atmospheric aging experiments
  - What happens to emissions as they are processed in the atmosphere?
- Global emissions inventory development
- Health impact and climate modeling
- Lab-to-field models