Improving air quality, health and the environment through household energy interventions in the Tibetan Plateau

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U.S. Environmental Protection Agency
Cookstove Research Meeting

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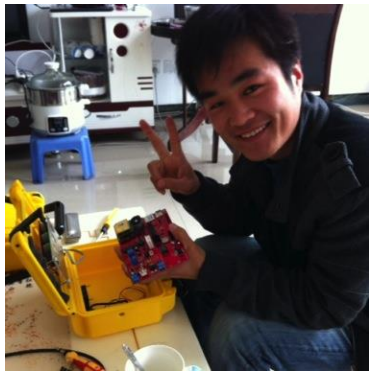
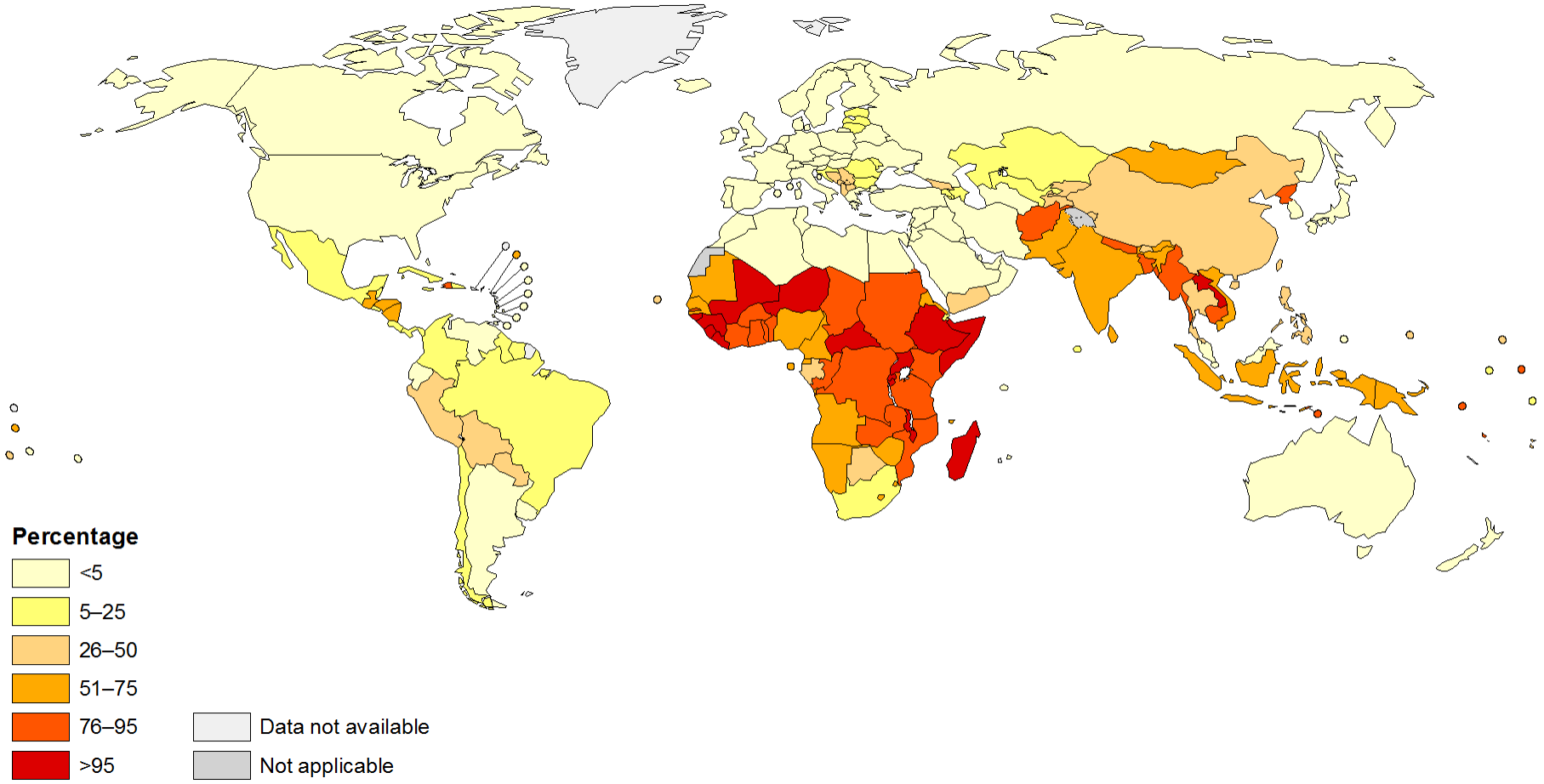
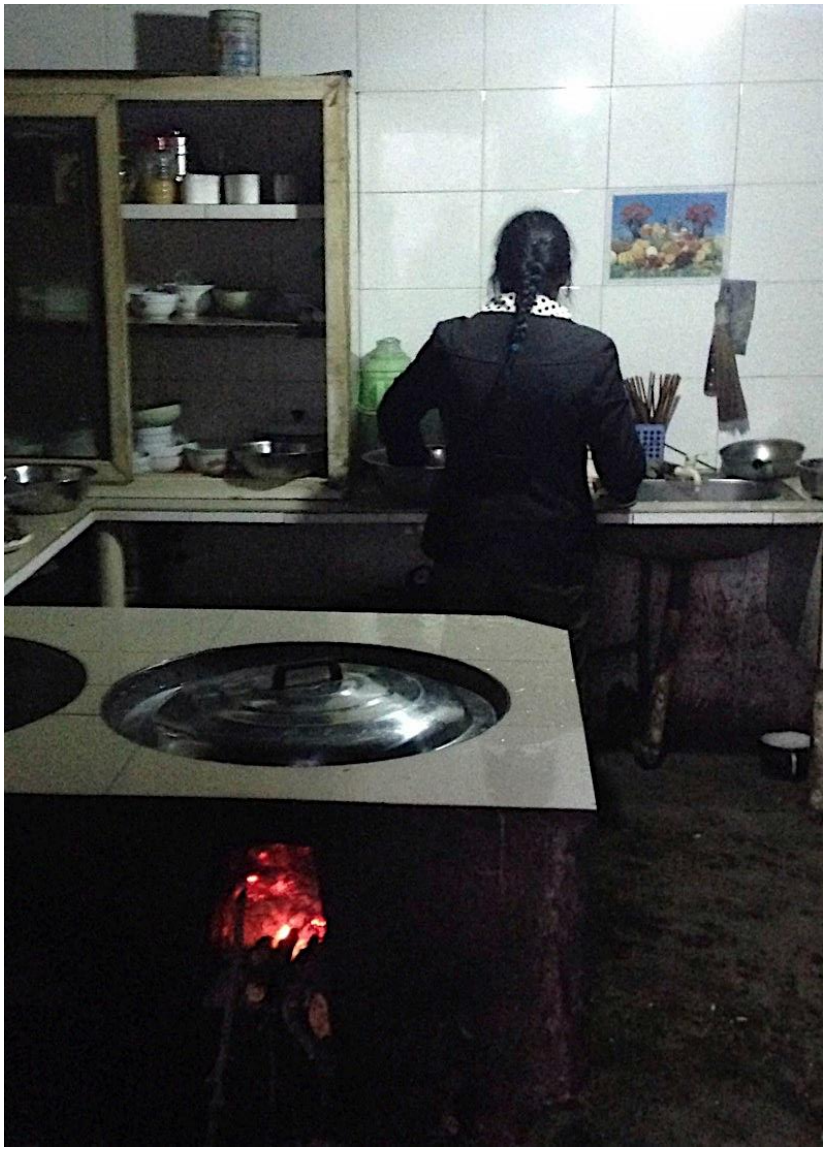


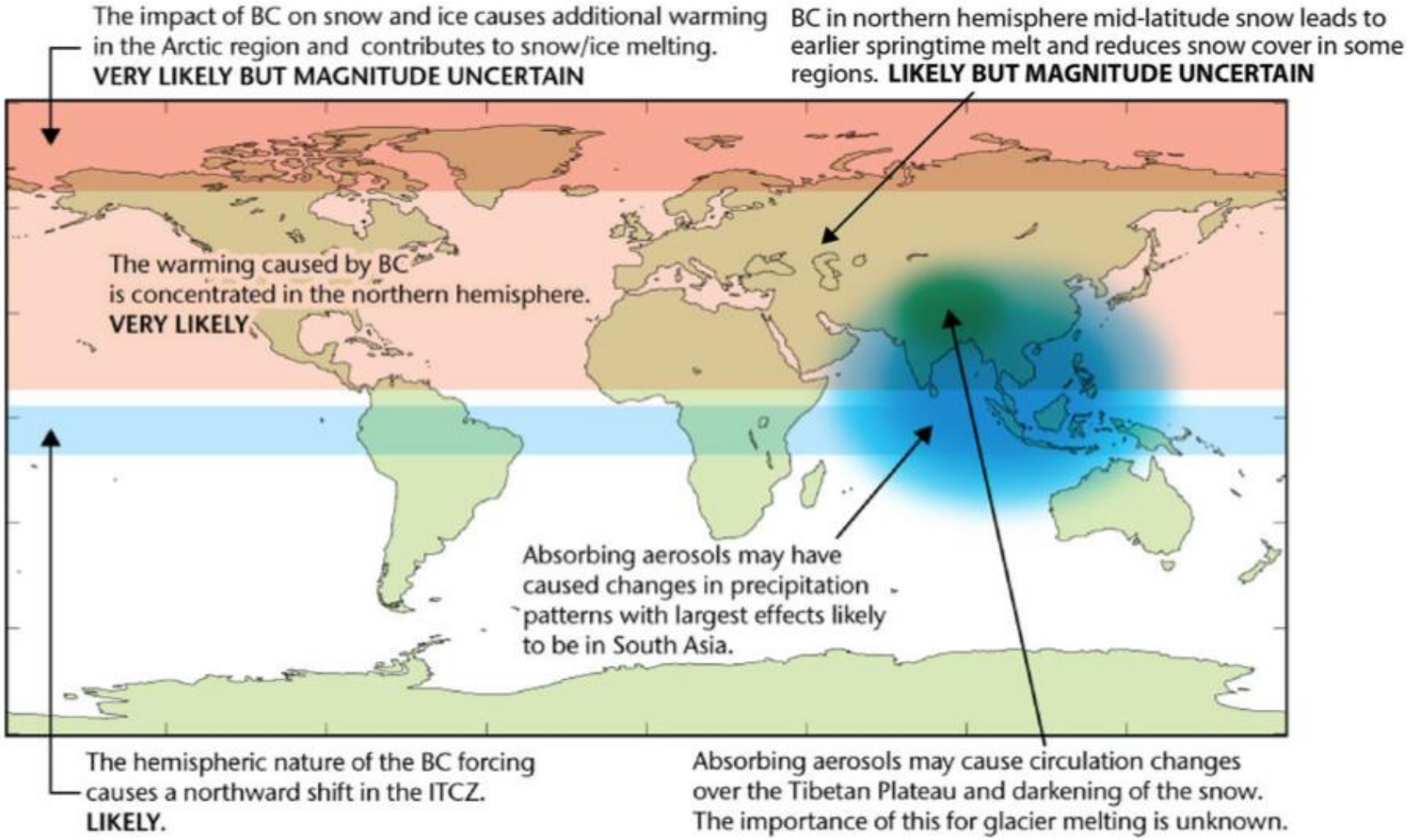
Population cooking with solid fuels (%), 2010



WHO, 2012; Bonjour et al., *Environ Health Perspect*, 2012



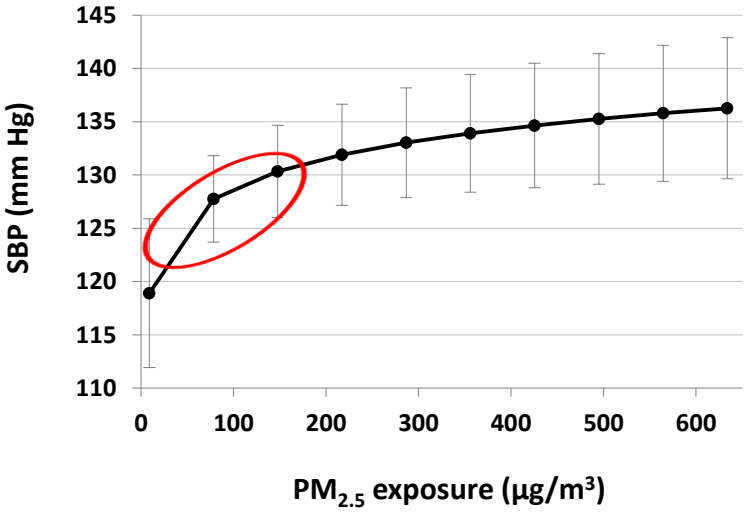
Climate effects of black carbon from solid fuel stoves in the Tibetan Plateau

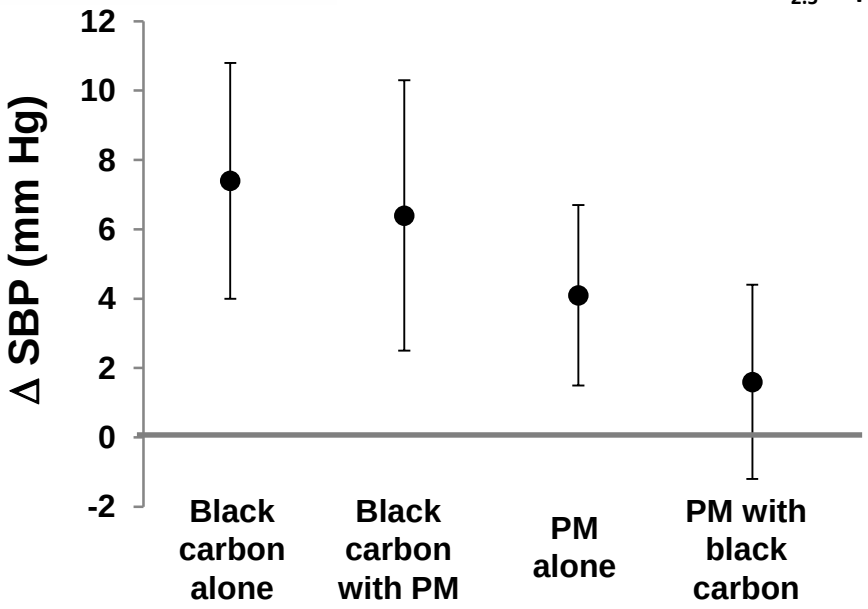


Bond et al., *J Geo Res*, 2013

Household air pollution and blood pressure, China

(n=280 women)

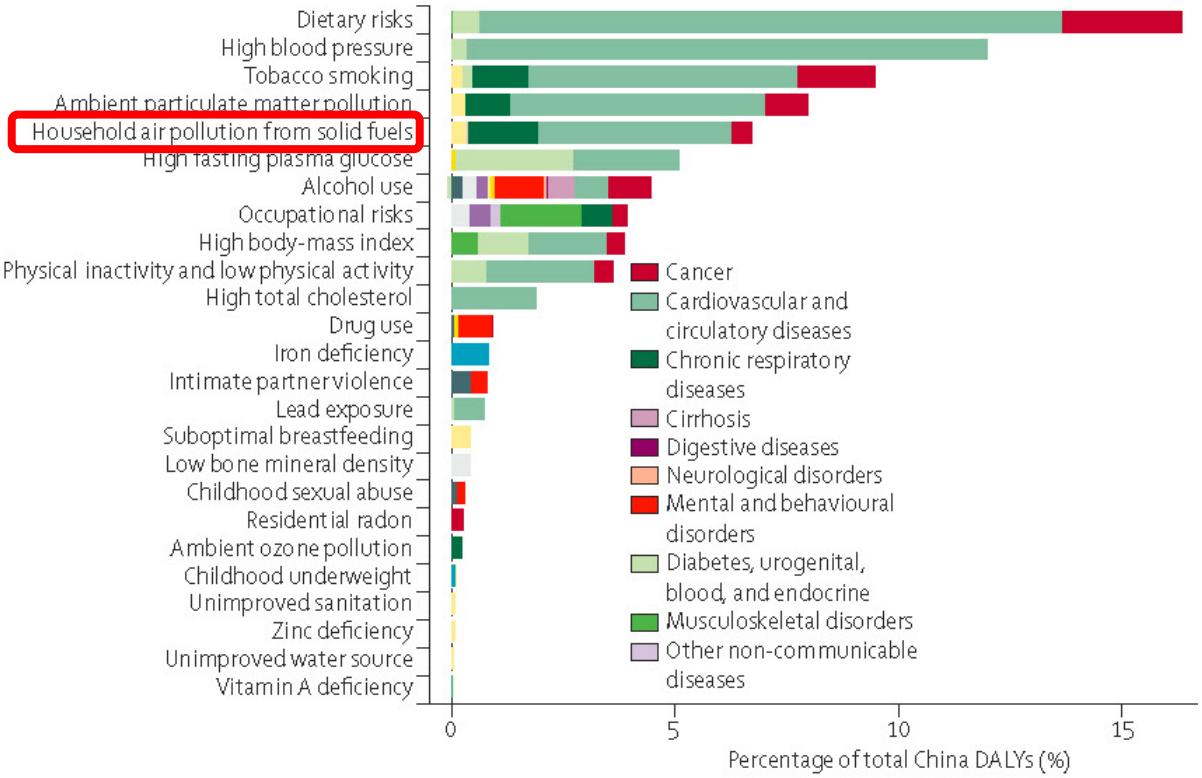




Baumgartner et al., *EHP* , 2011; *PNAS*, 2014

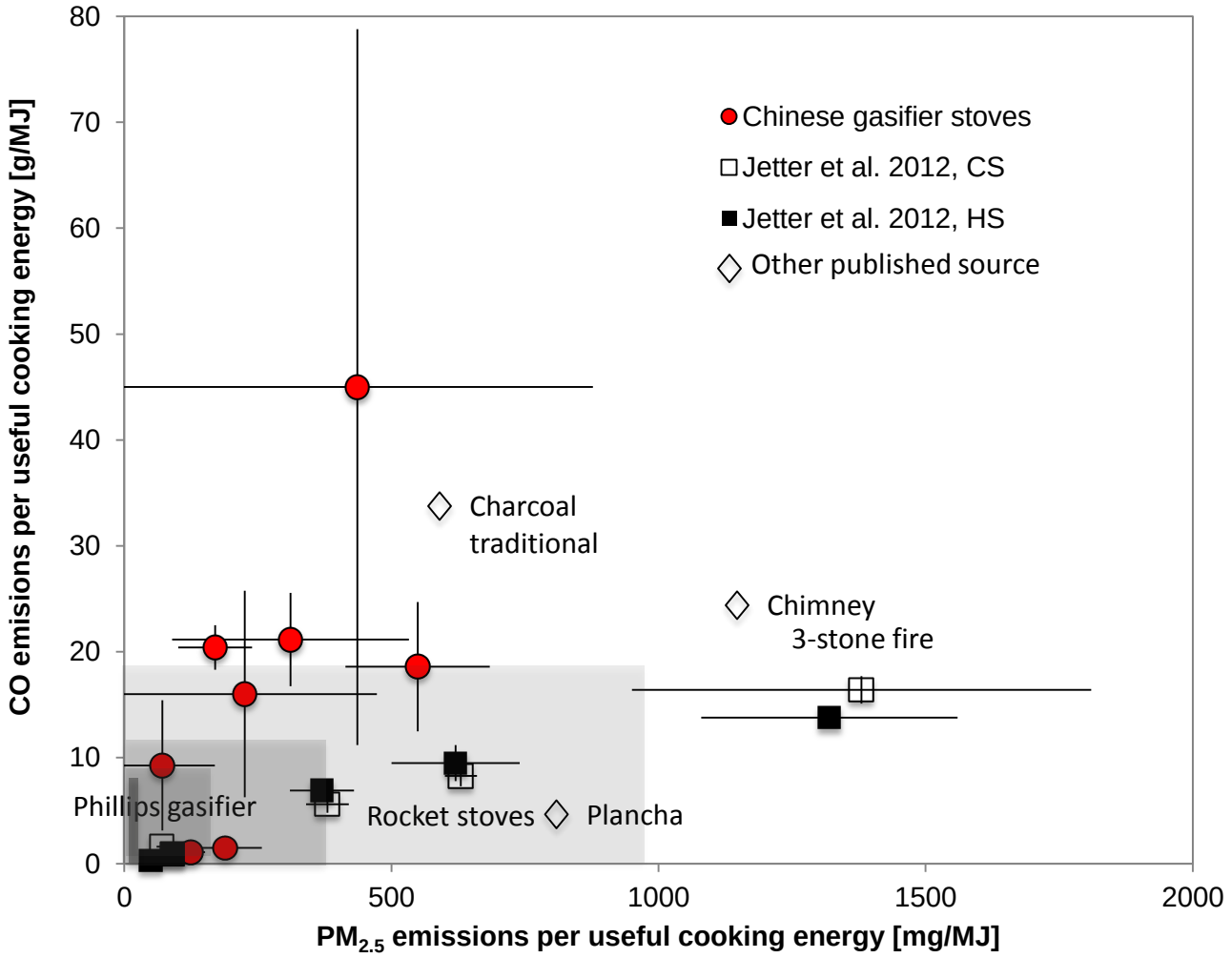
China's health transition: leading causes of death

1990		2010		
Mean rank (95% UI)	Disorder	Disorder	Mean rank (95% UI)	% change (95% UI)
1·6 (1 to 3)	1 Lower respiratory infections	1 Stroke	1·0 (1 to 1)	21 (−13 to 37)
2·2 (1 to 3)	2 Stroke	2 Ischaemic heart disease	2·1 (2 to 3)	81 (23 to 103)
2·2 (1 to 3)	3 COPD	3 COPD	3·3 (3 to 5)	−45 (−51 to −40)
5·2 (4 to 8)	4 Congenital anomalies	4 Road injury	4·1 (2 to 6)	64 (−9 to 188)
5·7 (4 to 10)	5 Drowning	5 Lung cancer	4·9 (3 to 7)	81 (27 to 112)
7·1 (4 to 12)	6 Neonatal encephalopathy	6 Liver cancer	5·7 (3 to 6)	37 (17 to 76)
7·6 (4 to 10)	7 Ischaemic heart disease	7 Stomach cancer	7·3 (7 to 9)	−11 (−24 to 5)



Yang et al *Lancet* 2013

Mean (SD) $PM_{2.5}$ and CO emissions per MJ of useful energy for different cookstoves



Carter et al., *ES&T,* 2014

Stove modification, testing, and adaptation to household set up

Technology development

Laboratory emissions testing

Testing in the rural energy lab

Village pilots & demonstration sites

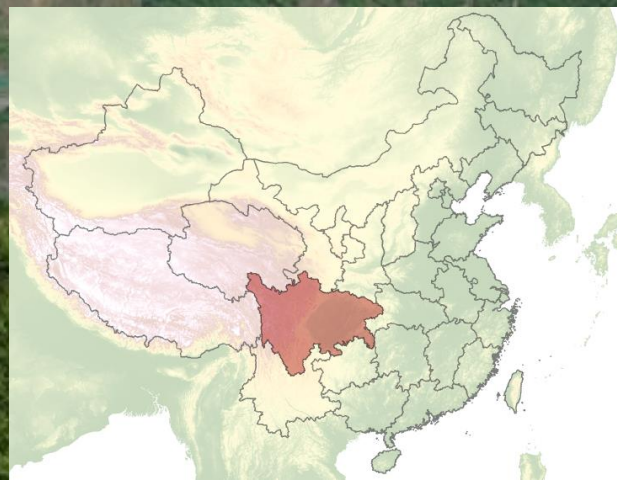
Small scale manufacturing of stoves in China

Can high efficiency, low polluting stoves improve climate and health?

Traditional stoves

Processed biomass + semi-gasifier stove for cooking & heating

Study site in the eastern Tibetan Plateau (Beichuan, Sichuan)



Pilot of village-level production of processed biomass fuel

Biomass pellet factory (completed 2012) and pellet machine

Stove pilot testing in villages

Pilot stove testing: Villagers cooked with stove prototypes for 3 months to assess stove appropriateness for different cooking tasks

Goal: Final stove design is responsive to regional preferences

Study concept

Design, development, and testing of improved energy packages

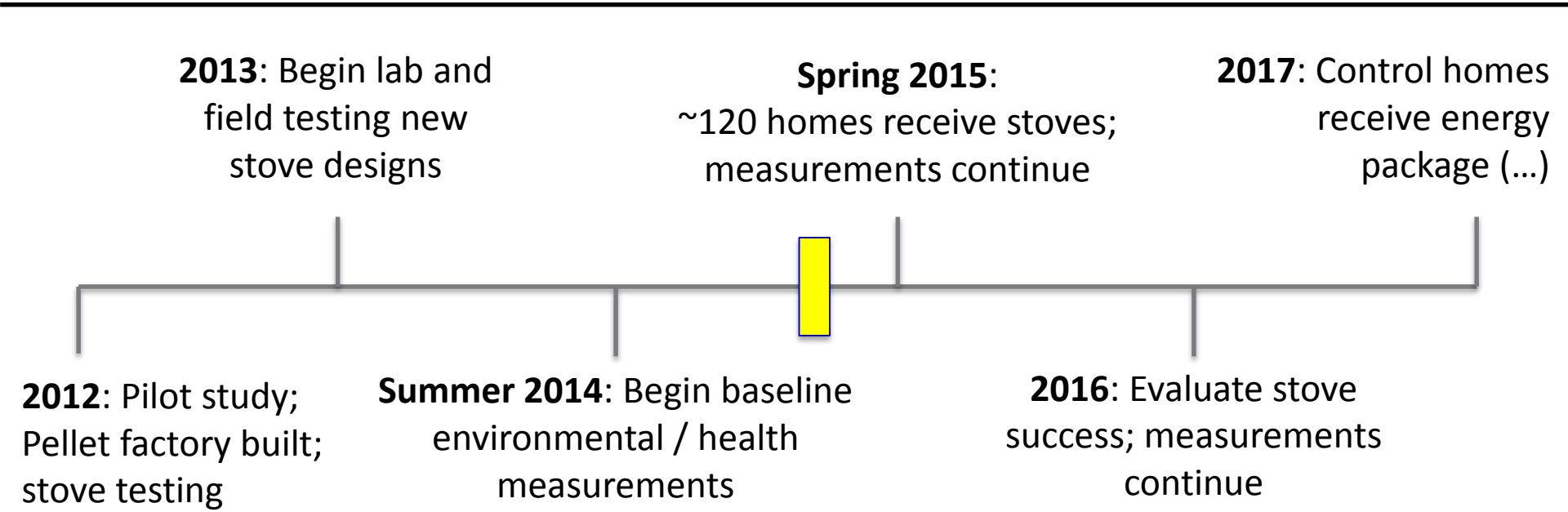
Baseline / post-stove measurements of air pollution and health indicators

Laboratory analysis of air pollution & biomarker samples

Air pollution emissions and exposures	Climate forcing	Cardiovascular impacts
Aim 1	Aim 2	Aim 3

Study design and intervention timeline

- Multi-year evaluation of an energy intervention
- Enrolled 202 homes in 4 administrative villages using biomass fuels and with an eligible participant for the health study
- ~120 intervention / 80 controls
- Air pollution and health measurements for 2-6 days every 6 months to capture seasonal and day-to-day variability



Study participants

- **Enrolment**: 202 women in summer 2014 (73% participation rate)
- **Inclusion criteria**: Female; >25 years old; cook with biomass, live in the study villages
- **Exclusion criteria**: Pregnant at enrollment; current/previous smoker

	Mean (Std Dev) or %	Range
Age [years]	52.2 ± 11.9	28 – 86
Household size [# occupants]	2.8 (1.1)	1 – 6
Socioeconomic status [land owned: mu]	20.6 ± 27.9	0 – 150
Socioeconomic status [assets] Motorcycle Car Computer	 56% 21% 22%	
Secondhand smoking	60% live with ≥ 1 smoker	

Aim 1: Measure reductions in pollution emissions and exposure with an improved energy package

- 48-hr kitchen monitoring: real time and integrated PM mass, EC/OC, gases (CO, CO2, NOx)
- 48-hr personal exposure: PM mass, black carbon, organic components
- Emissions measurements during cooking events
- Outdoor real time and integrated PM mass (~1 month per season)

Typical kitchen & traditional wood-burning cookstoves

Kitchen average 48-hr $PM_{2.5}$ concentration (summer; n=187):

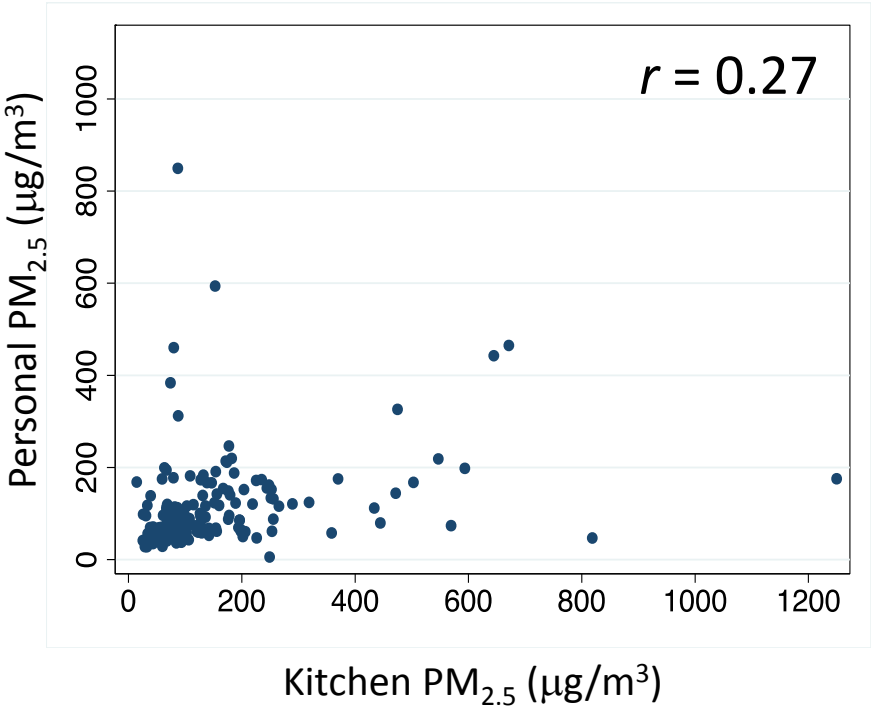
- GM (95% CI): 111 µg/m^3 (100, 123)
- Range: 35 - 1250 µg/m^3

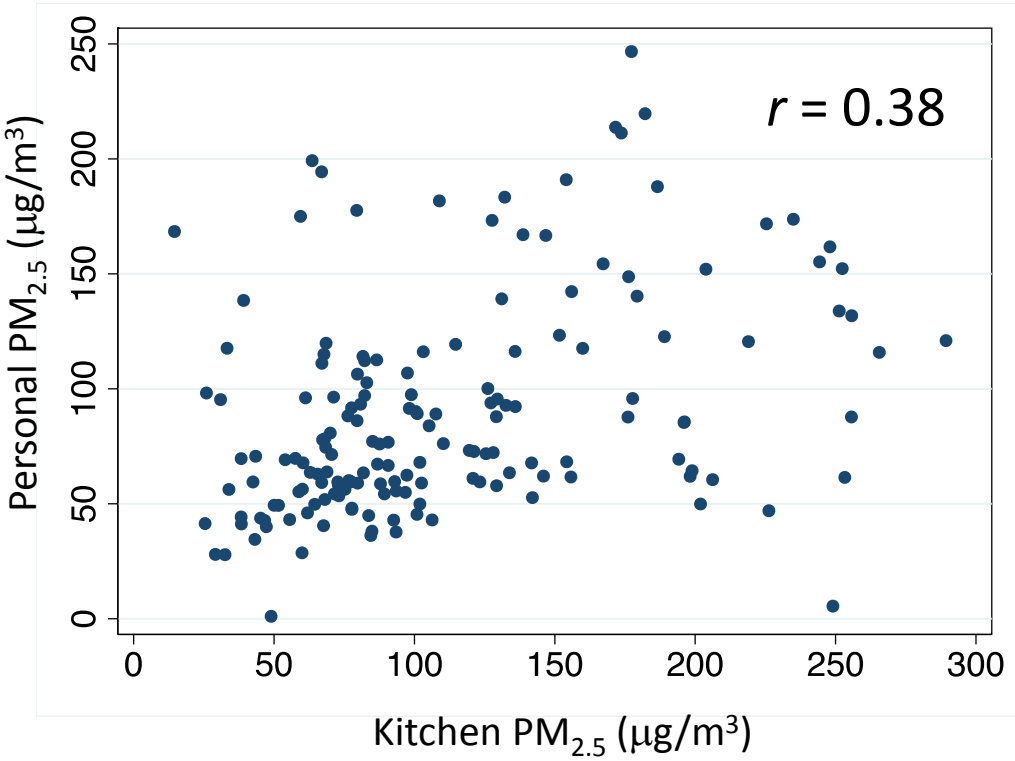
Women's average 48-hr $PM_{2.5}$ exposure (summer; n=192):

- GM (95% CI): 90 µg/m^3 (81, 99)
- Range: 27 - 1129 µg/m^3

Personal exposure and kitchen $PM_{2.5}$ concentrations, summer

	N	Geometric Mean (μg/m³), 95% CI	Range
Personal $PM_{2.5}$	190	91 (83,99)	28-1129
Kitchen $PM_{2.5}$	187	111 (100,123)	14-1249

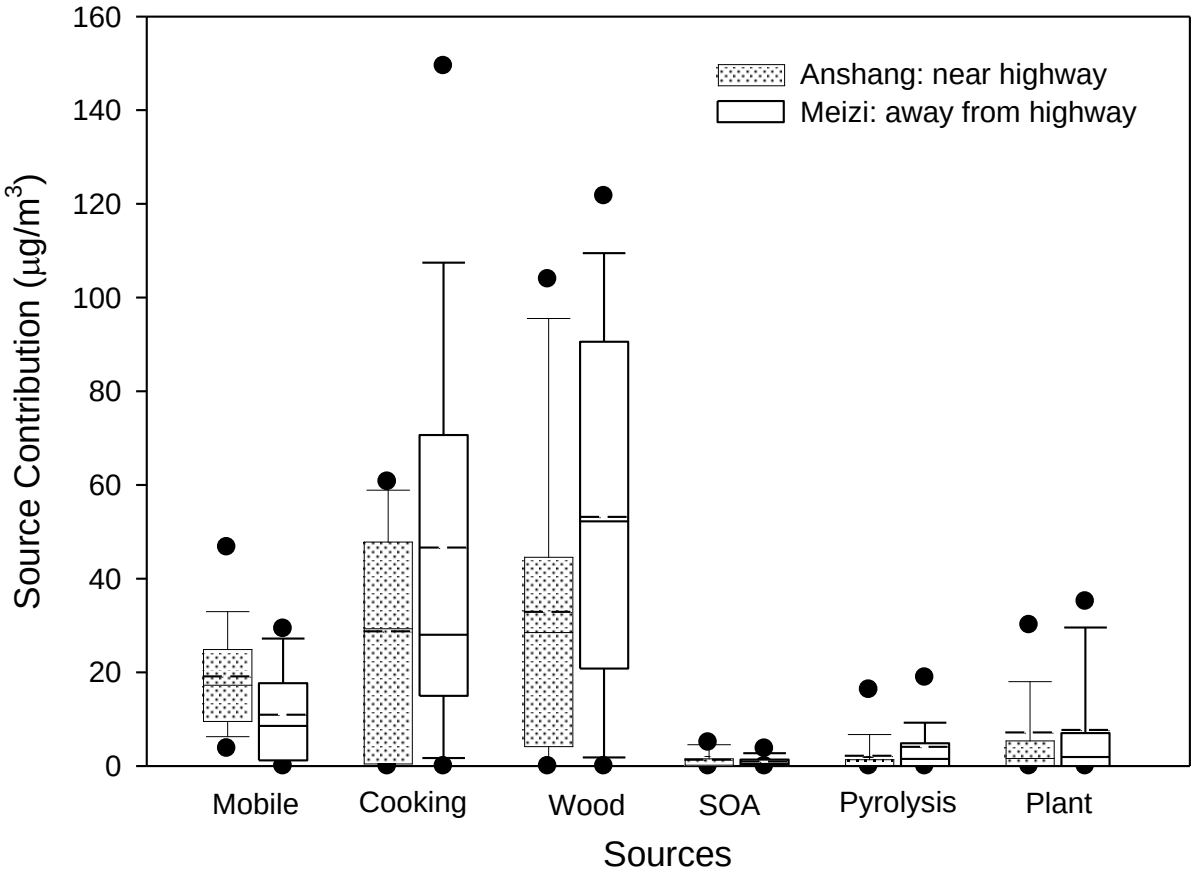




PM chemical analysis & source apportionment in women cooking with biomass, Yunnan

<u>Chemical Analysis</u>
Nominally 100 Samples analyzed for WSOC, BC, and Molecular Markers by GCMS

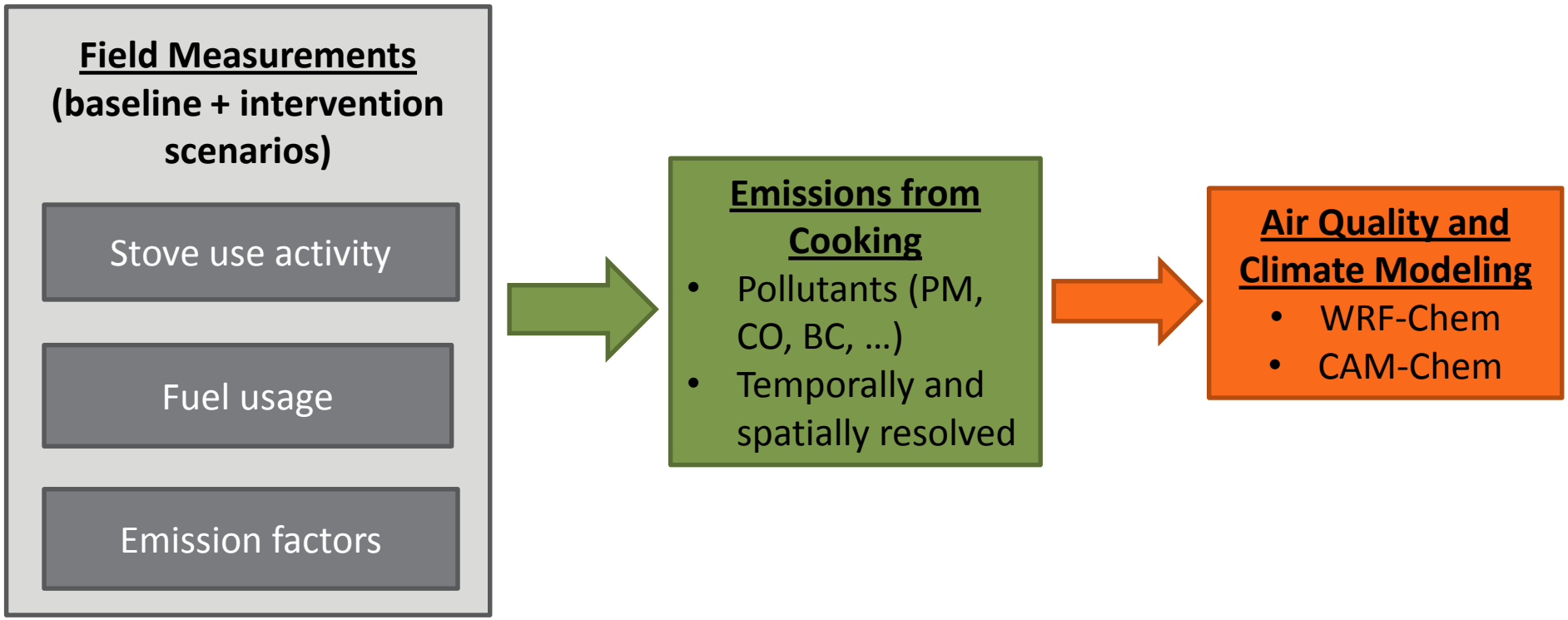
<u>Data Analysis</u>
Positive Matrix Factorization (PMF) – US EPA Source Apportionment Model



Huang et al, *Atmos Env*, 2015

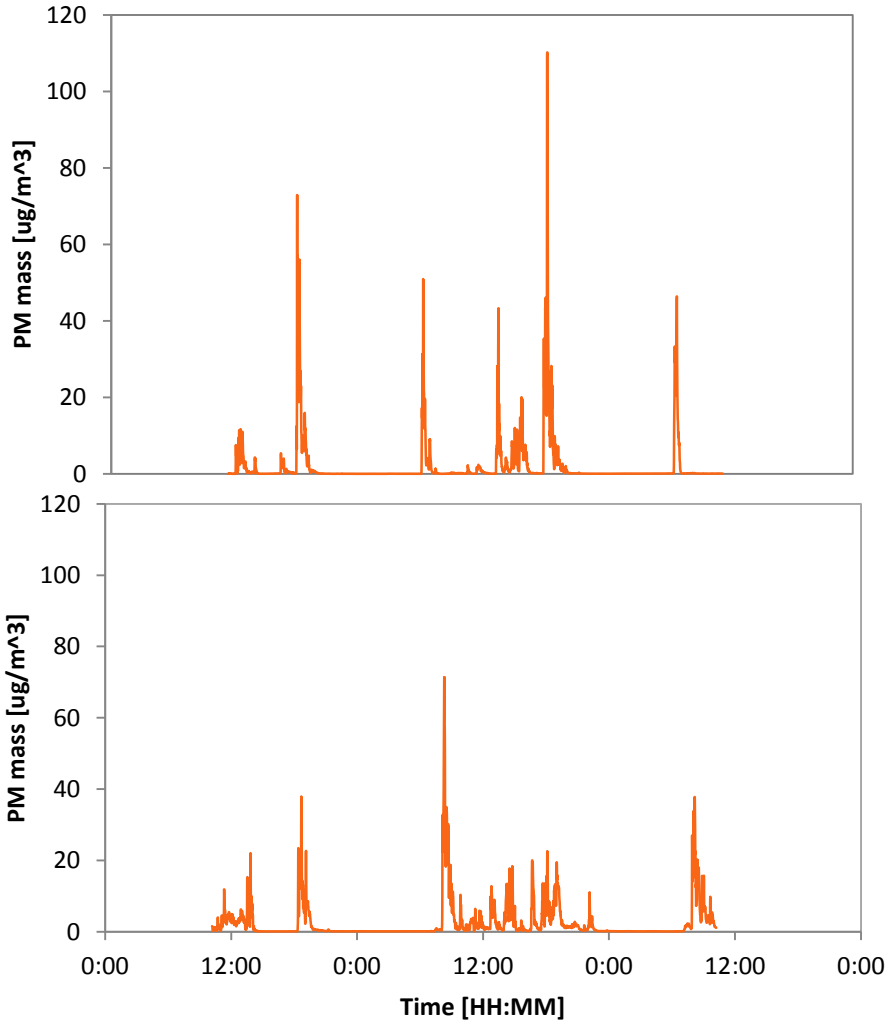
Aim 2: Model regional emissions, air quality, and climate under baseline & intervention scenarios

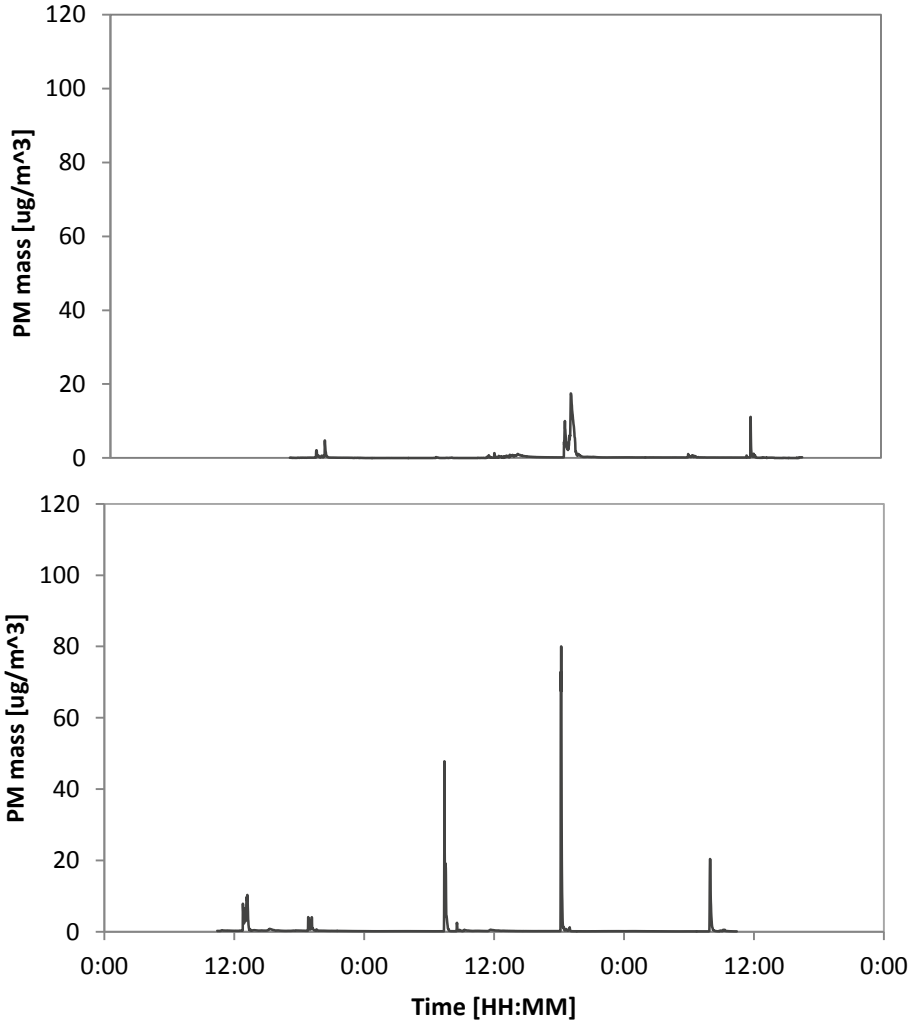
- Apply baseline and seasonal / intervention changes in chemical-specific emissions, fuel use, and cooking frequency to regional emission estimates
- Develop regional chemistry-climate models for emissions scenarios



Exploratory analysis for real-time 48-hr kitchen PM concentrations

	Study home #65		Study home #83	
	Summer	Winter	Summer	Winter
Number of Peaks	49	67	18	18
Hours of combustion	16.7	25	10	17.7





Estimating cooking activity

Preliminary Results from real-time PM (DustTrak) measurements in kitchens

Cooking Activity per day:

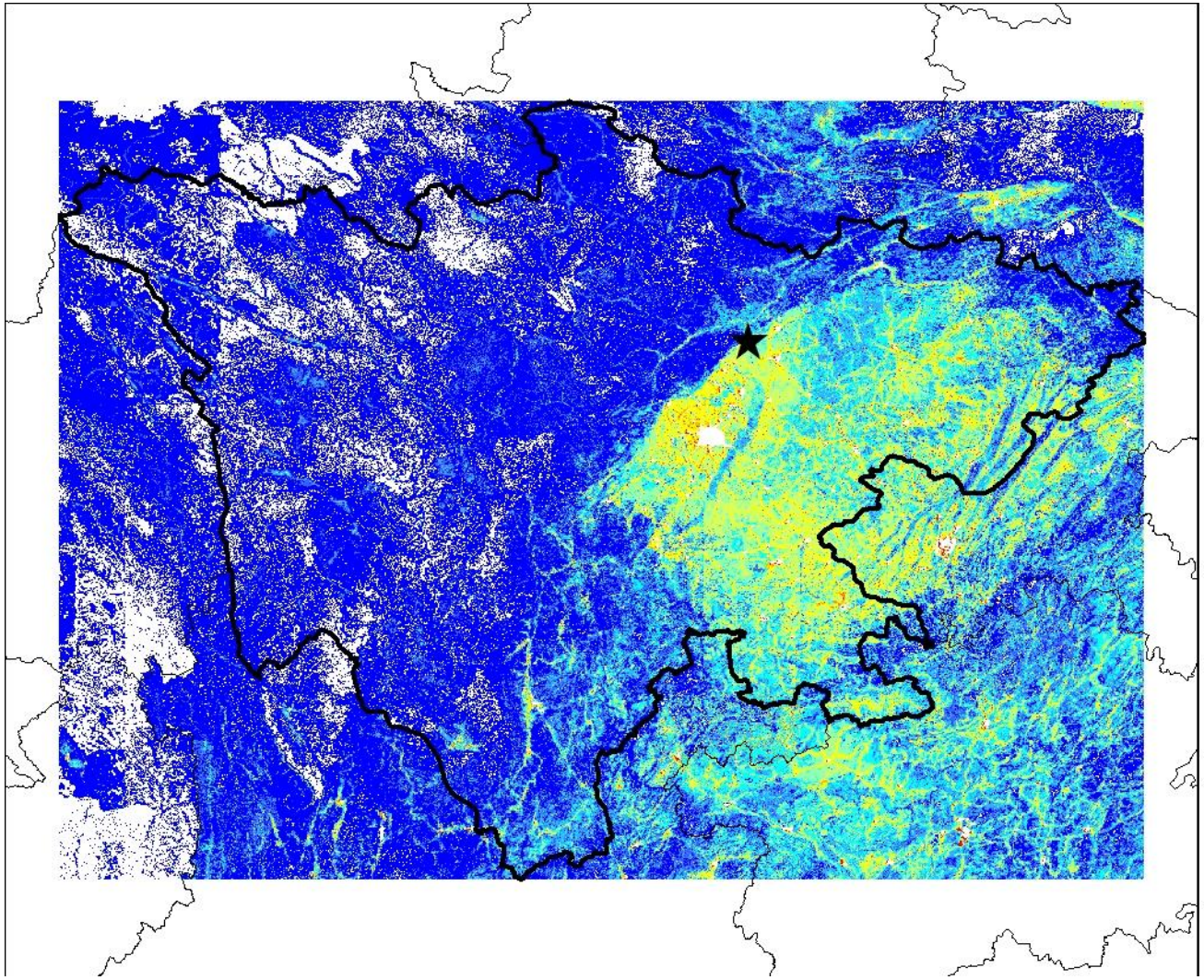
	SUMMER	WINTER
# Events	7	15
Stove usage time (hours)	4.2	7.5

Streets et al. (2003) provides recommended hourly cookstove usage for the emissions inventory. For our study region:

- 3 hours per day (summer)
- 6 hours per day (winter)

Initial results suggest that models currently underestimate daily cookstove emissions in this region

Preliminary estimates of **domestic biofuel use emissions** in Sichuan Province



Sichuan Province
Total Annual PM2.5 Emissions
304 Gg

Annual PM2.5 Emissions
kg/year

- 5 - 50
- 51 - 100
- 101 - 250
- 251 - 500
- 501 - 1,000
- 1,001 - 2,500
- 2,501 - 5,000
- 5,001 - 10,000
- 10,001 - 25,000
- 25,001 - 307,460

Using fuel loadings collected in Sichuan (summer, 2014), published emission factors, ESA Urban Extent, 2013 Landscan population

REASv2.1
350 Gg

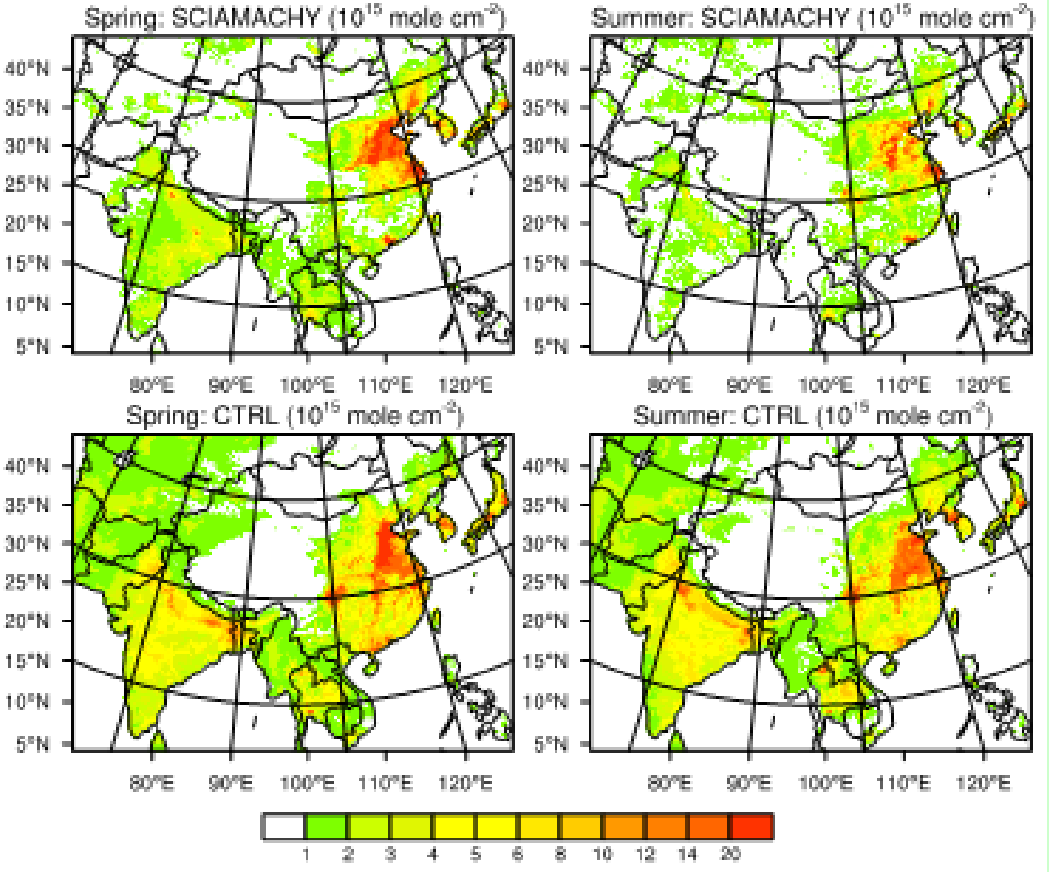
Example:

- Modeling
- Observations

All simulations are performed using WRF-Chem at 42kmx42km spatial resolution and are integrated for 6 months.

SCIIAMACHY Satellite NO_2 column (2008)

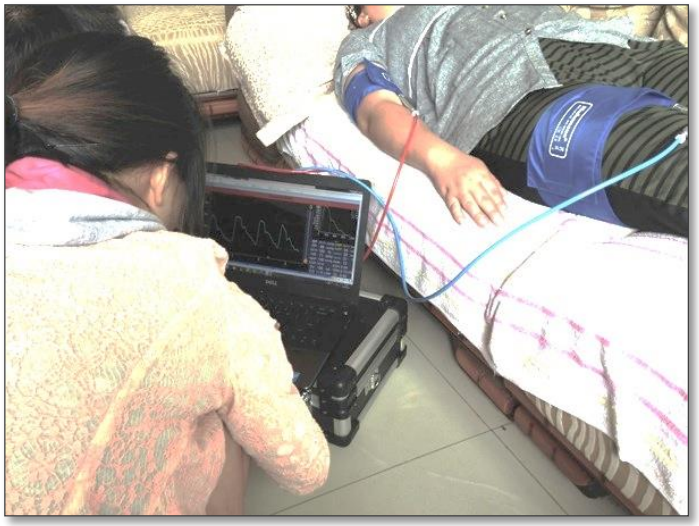
Model simulated NO_2 column (2008)



Jiang et al.

Aim 3: Measure the impact of an energy package on cardiovascular disease risk

- Central and brachial blood pressure
- Arterial stiffness (pulse wave velocity & augmentation index)
- Collection of biological markers: urine, buccal cells, blood spots
- Measure nutritional, behavioral, and physiological covariates
- Self-reported health, co-morbidities, medication use



Baseline (summer) health characteristics of the study population

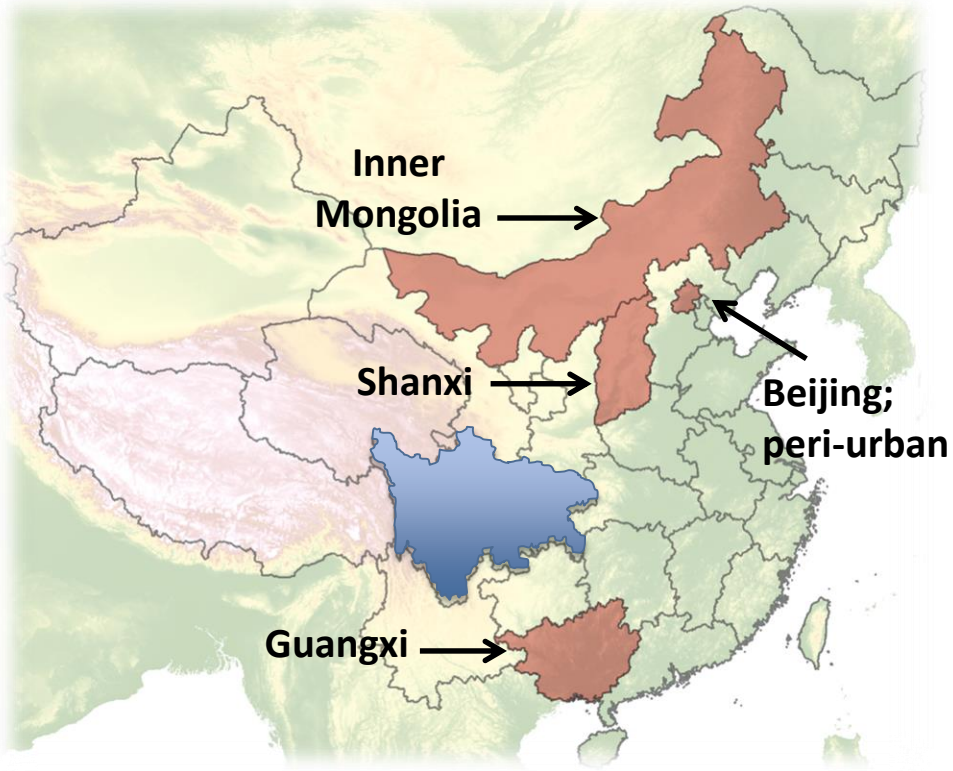
	N	Mean (Std Dev);	Range
Age [years]	201	52.2 ± 11.9	28 – 86
BMI [kg/m^2]	201	25.4 ± 3.3	19 – 37
Brachial SBP [mmHg]	162	116.9 (18.9)	93 – 181.3
Central (aortic) SBP [mmHg]	162	111.7 ± 17.9	86.1 – 174.4
Brachial DBP [mmHg]	162	71.4 (9.3)	52.6 - 107
Central (aortic) DBP [mmHg]	162	73.4 ± 9.6	54.6 – 111.2
% Hypertensive % Treated for hypertension	200	20% physician diagnosed; 26% of whom treat	

Preliminary associations between $PM_{2.5}$ exposure & brachial / central blood pressure (n=135)

- Difference in blood pressure associated with 1-log($\mu g/m^3$) higher 48-hr $PM_{2.5}$ exposure, adjusted for age, body mass index, socioeconomic status, and sodium intake:
  - Brachial SBP: 0.6 mmHg (-0.4, 1.6); p=0.18
  - Central SBP: 3.1 mmHg (1.2, 5.0); p=0.008
  - Brachial DBP: 0.6 mmHg (-0.1, 1.2); p= 0.08
  - Central DBP: 1.9 mmHg (1.6, 2.1); p<0.001

Leveraging of the EPA-STAR project

- Feasibility studies of biomarker collection and analysis (CIHR)
- Biomarker discovery for biomass/coal smoke exposure and health (Wellcome Trust)
- Stove acceptability & usage patterns (MITACS, McGill Global Health)
- Collaborations with other STAR projects
- Several proposals under review



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Aim 1

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Aim 2

Cardiovascular impacts

Aim 3

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Extra slides

Design and development of a high-efficiency semi-gasifier cookstove for Chinese homes