

US EPA ARCHIVE DOCUMENT

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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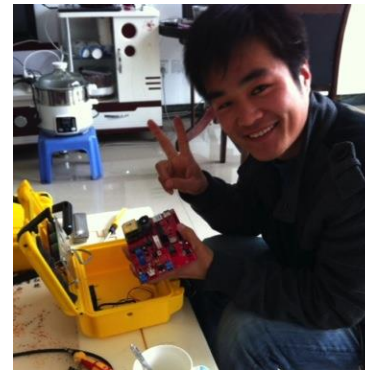
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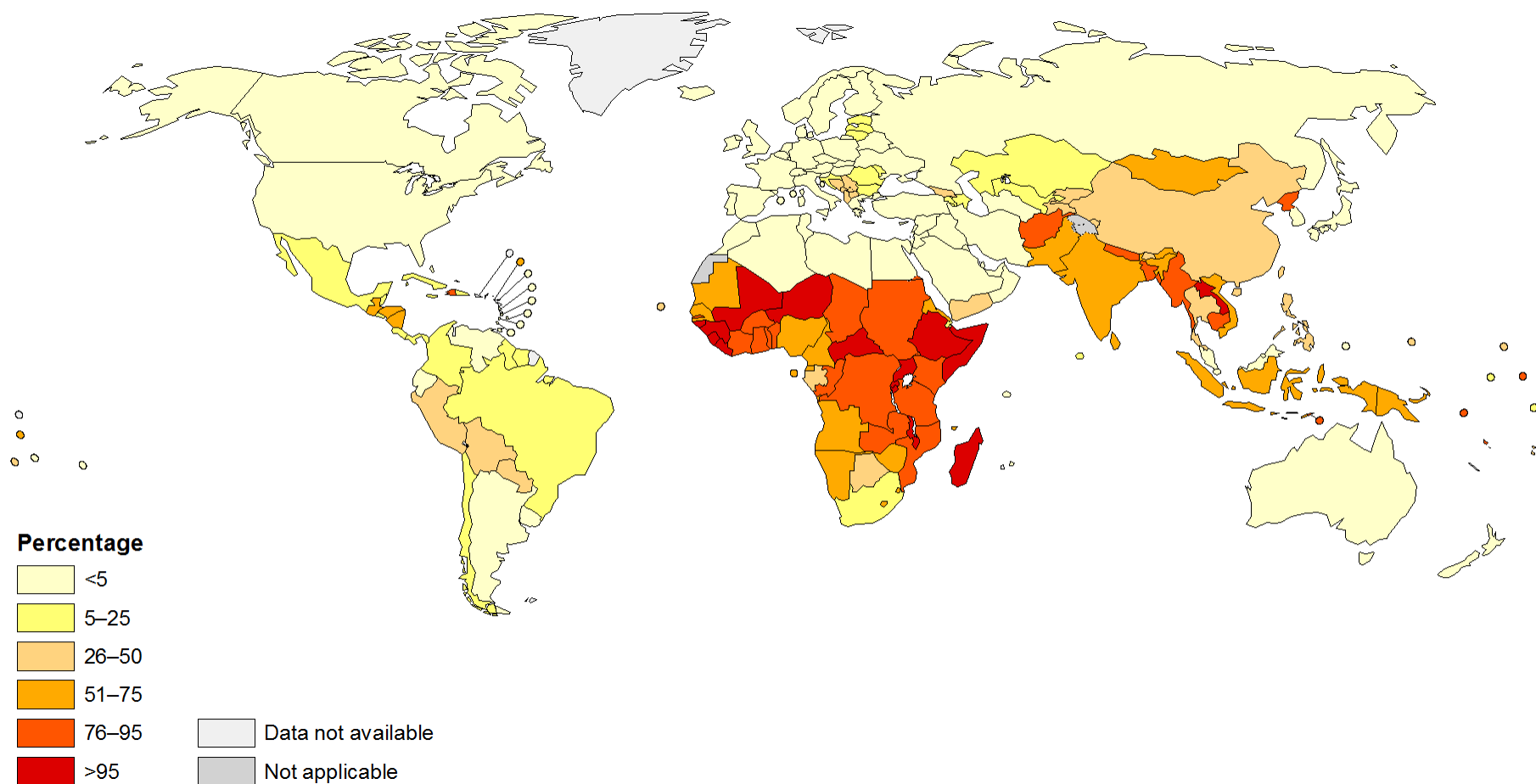
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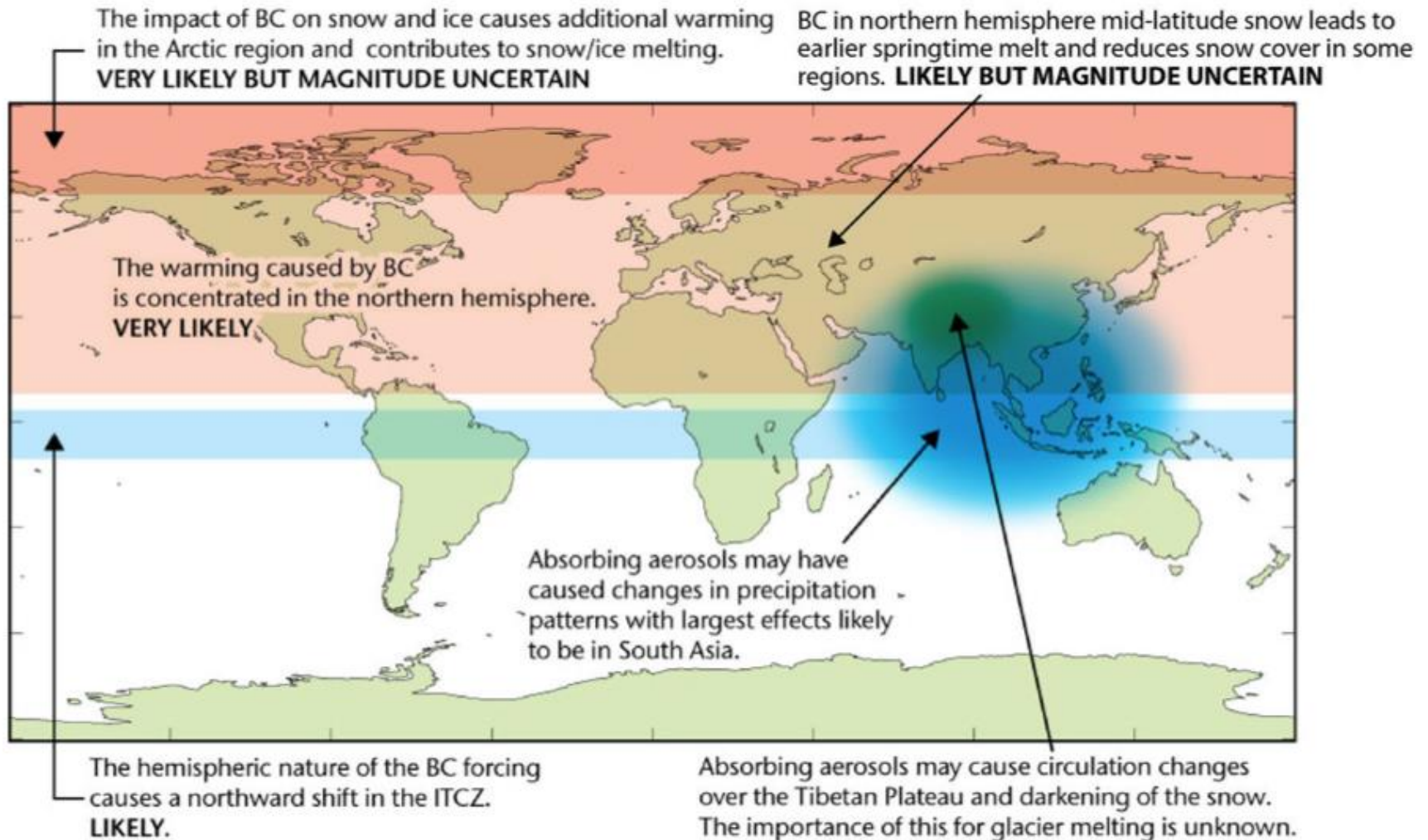


Population cooking with solid fuels (%), 2010

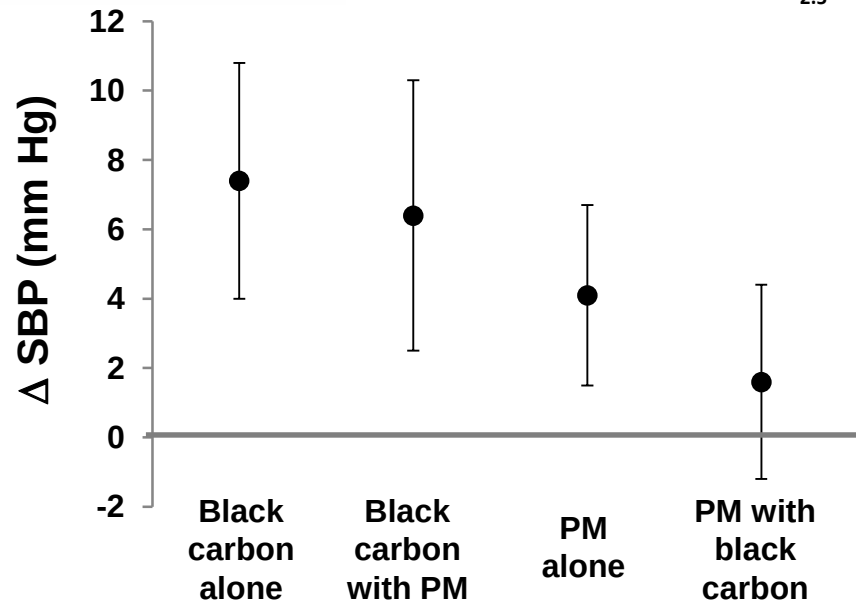
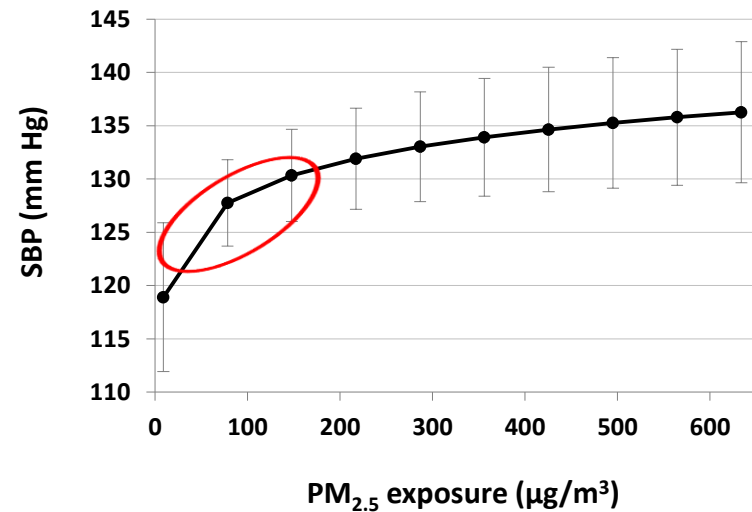




Climate effects of black carbon from solid fuel stoves in the Tibetan Plateau

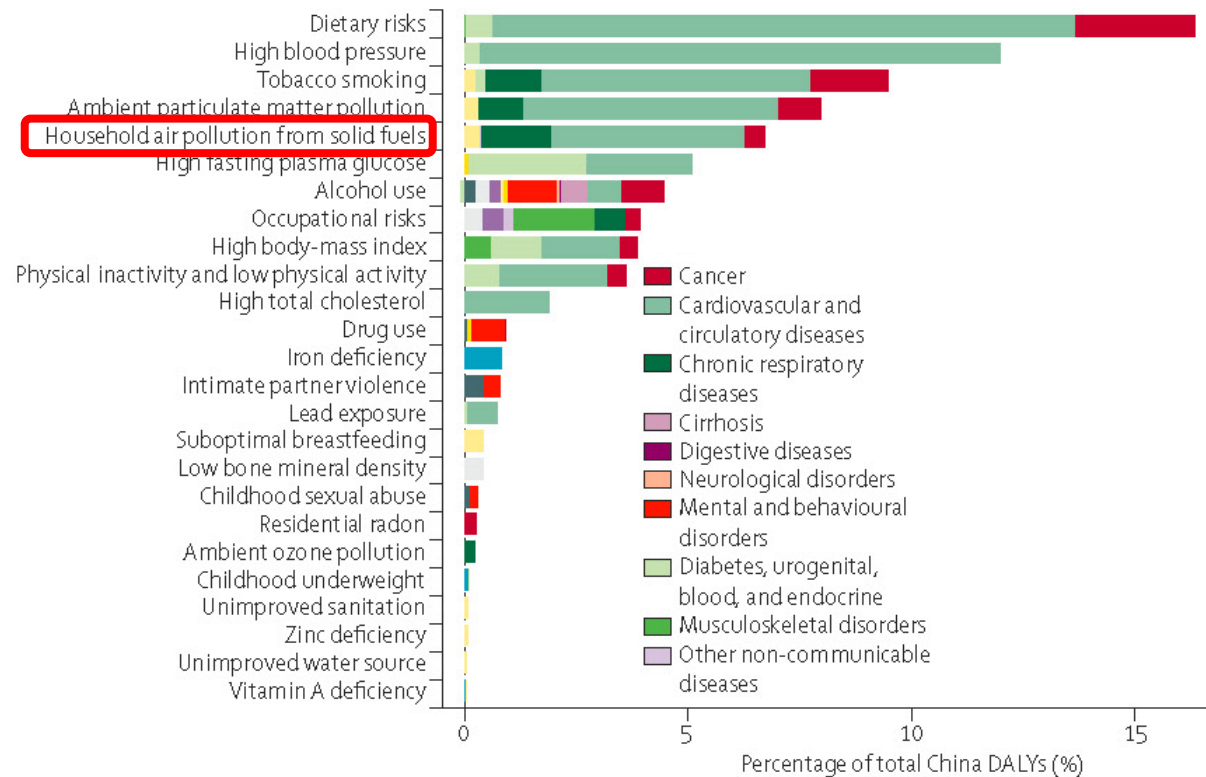


Household air pollution and blood pressure, China (n=280 women)

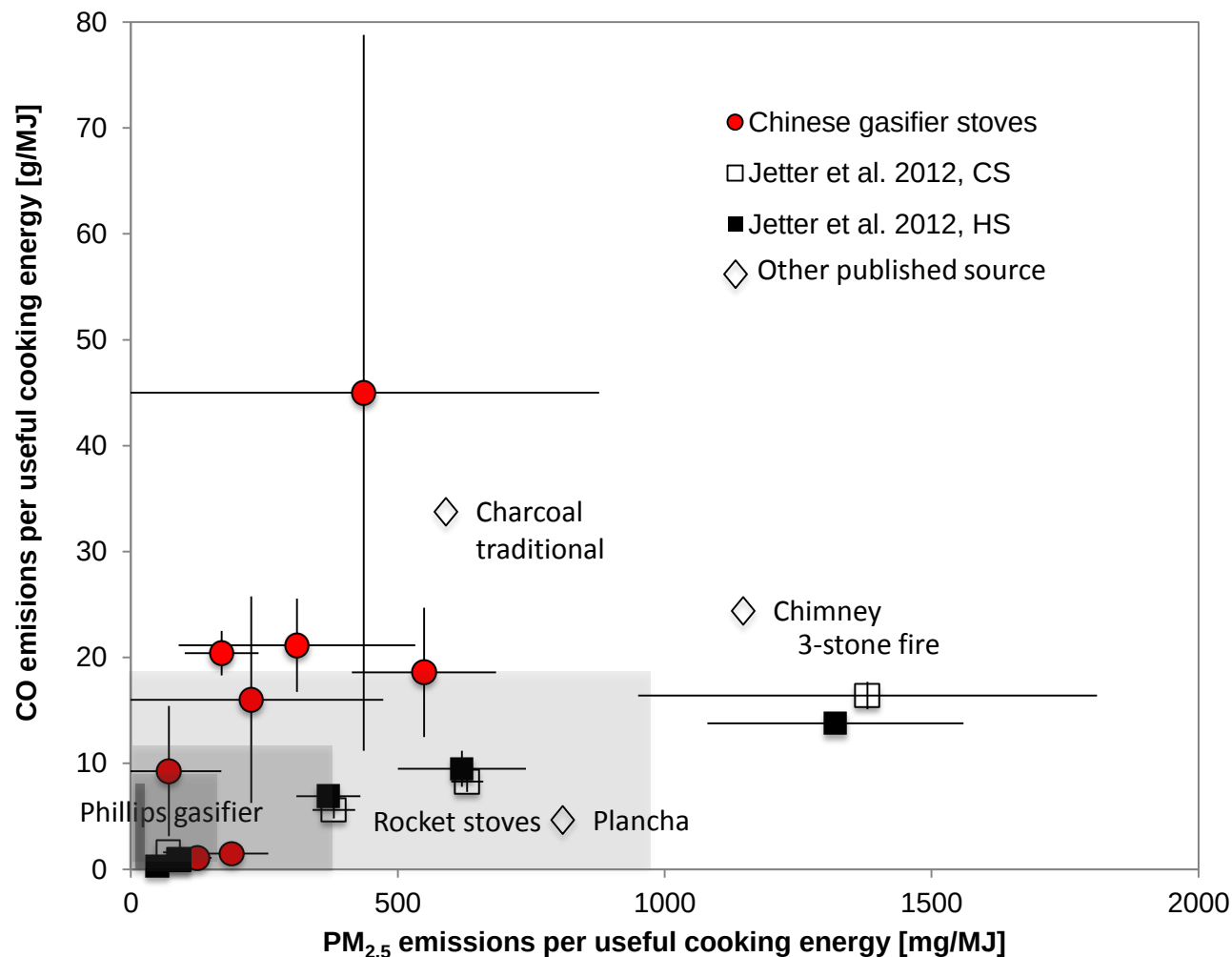


China's health transition: leading causes of death

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)



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



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



Adjustable
flame



Automatic
starter



Stand-
alone or
retrofit

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

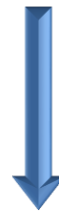
Design, development, and testing of improved energy packages



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



Laboratory analysis of air pollution & biomarker samples



Air pollution emissions and exposures

Aim 1

Climate forcing

Aim 2

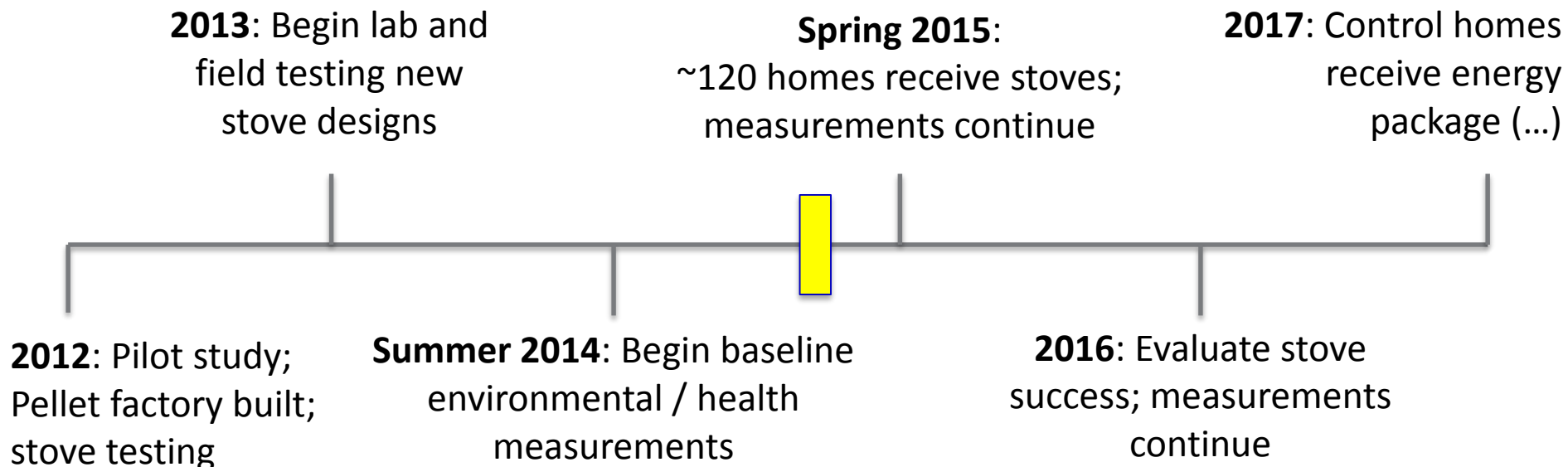
Cardiovascular impacts

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 $\pm$ 11.9	28 – 86
Household size [# occupants]	2.8 (1.1)	1 – 6
Socioeconomic status [land owned: mu]	20.6 $\pm$ 27.9	0 – 150
Socioeconomic status [assets] Motorcycle Car Computer	56% 21% 22%	
Secondhand smoking	60% live with $\geq$ 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, NO_x)
- 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 $\mu\text{g}/\text{m}^3$ (100, 123)
- Range: 35 - 1250 $\mu\text{g}/\text{m}^3$



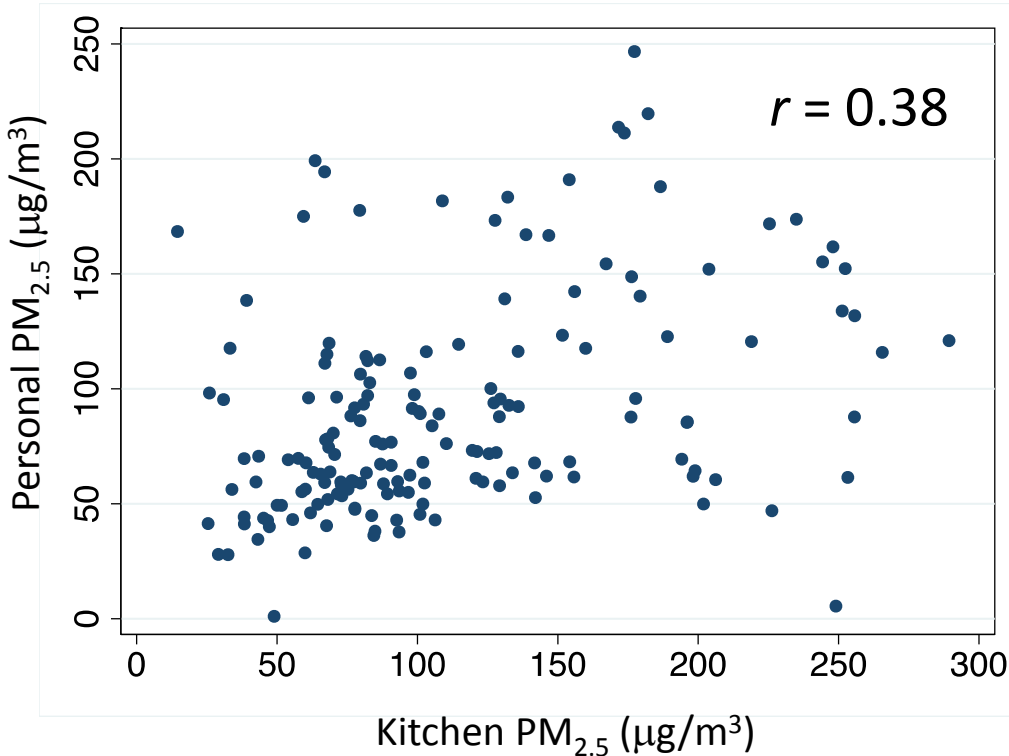
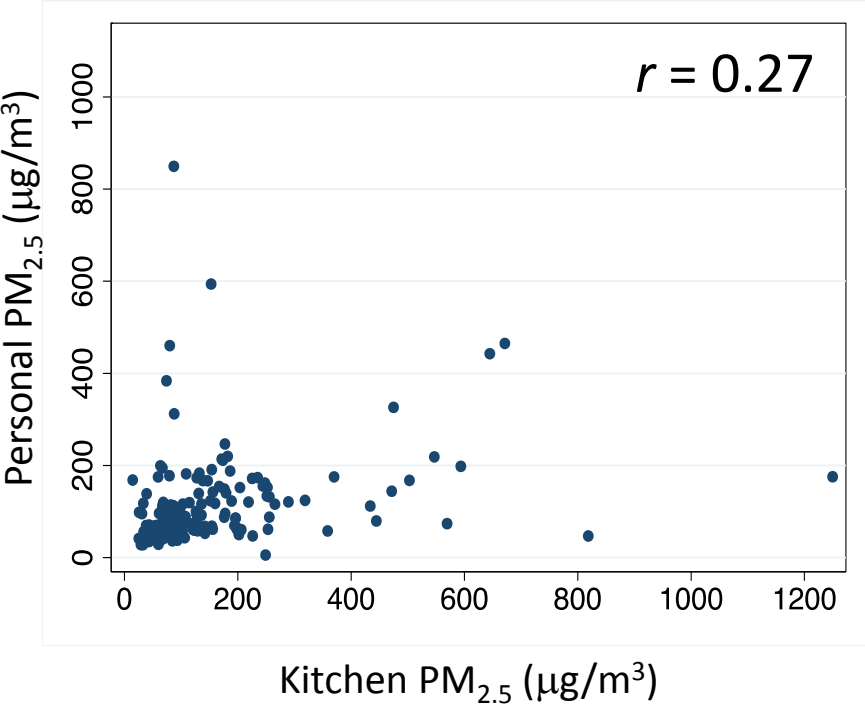
Women's average 48-hr PM_{2.5} exposure (summer; n=192):

- GM (95% CI): 90 $\mu\text{g}/\text{m}^3$ (81, 99)
- Range: 27 - 1129 $\mu\text{g}/\text{m}^3$



Personal exposure and kitchen PM_{2.5} concentrations, summer

	N	Geometric Mean (µg/m ³), 95% CI	Range
Personal PM _{2.5}	190	91 (83,99)	28-1129
Kitchen PM _{2.5}	187	111 (100,123)	14-1249



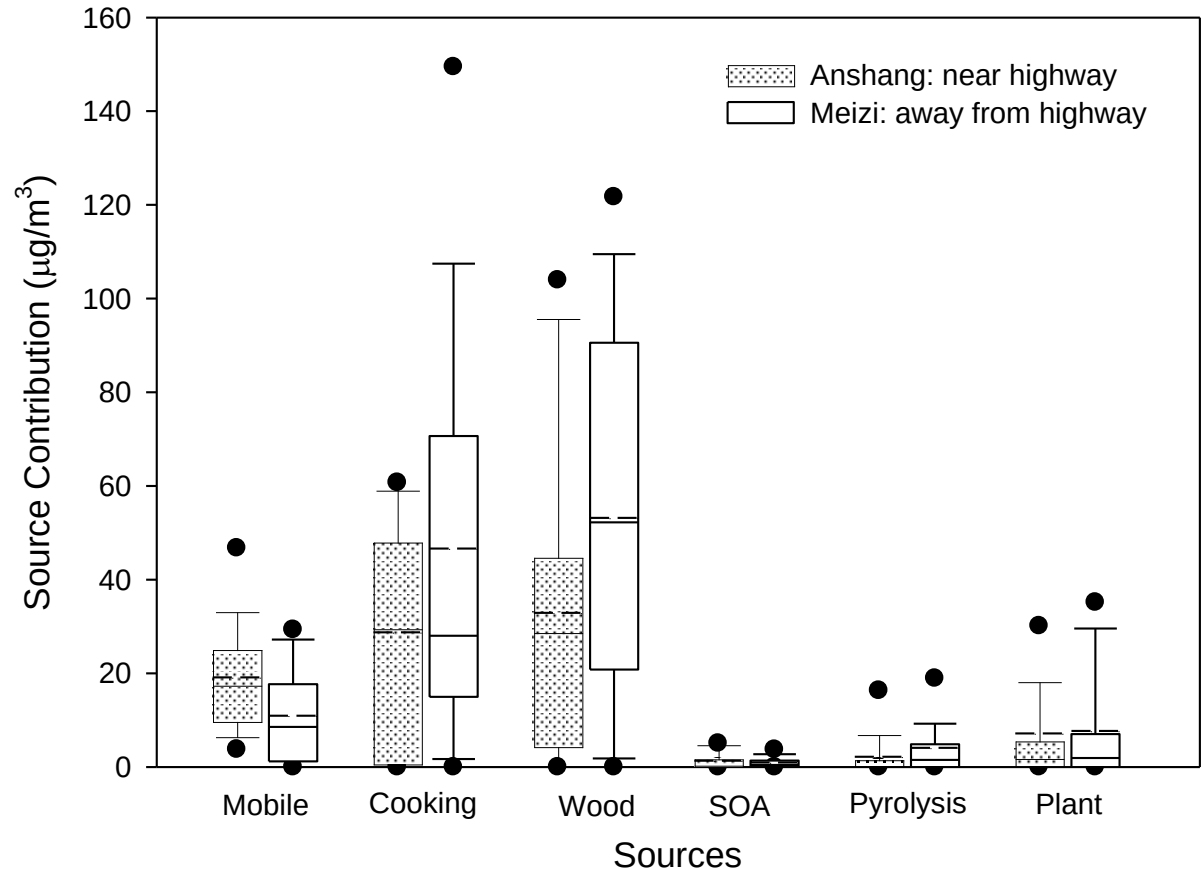
PM chemical analysis & source apportionment in women cooking with biomass, Yunnan

Chemical Analysis

Nominally 100 Samples
analyzed for WSOC, BC, and
Molecular Markers by GCMS

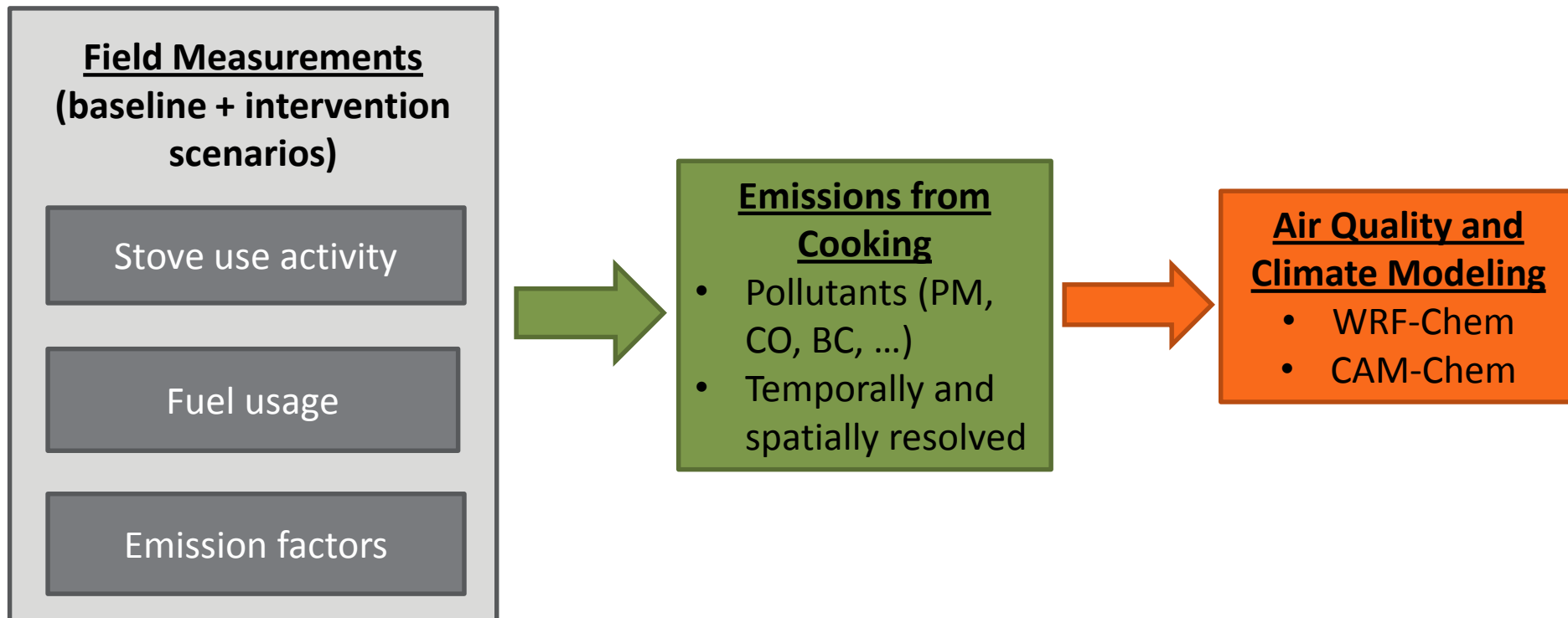
Data Analysis

Positive Matrix Factorization
(PMF) – US EPA Source
Apportionment Model



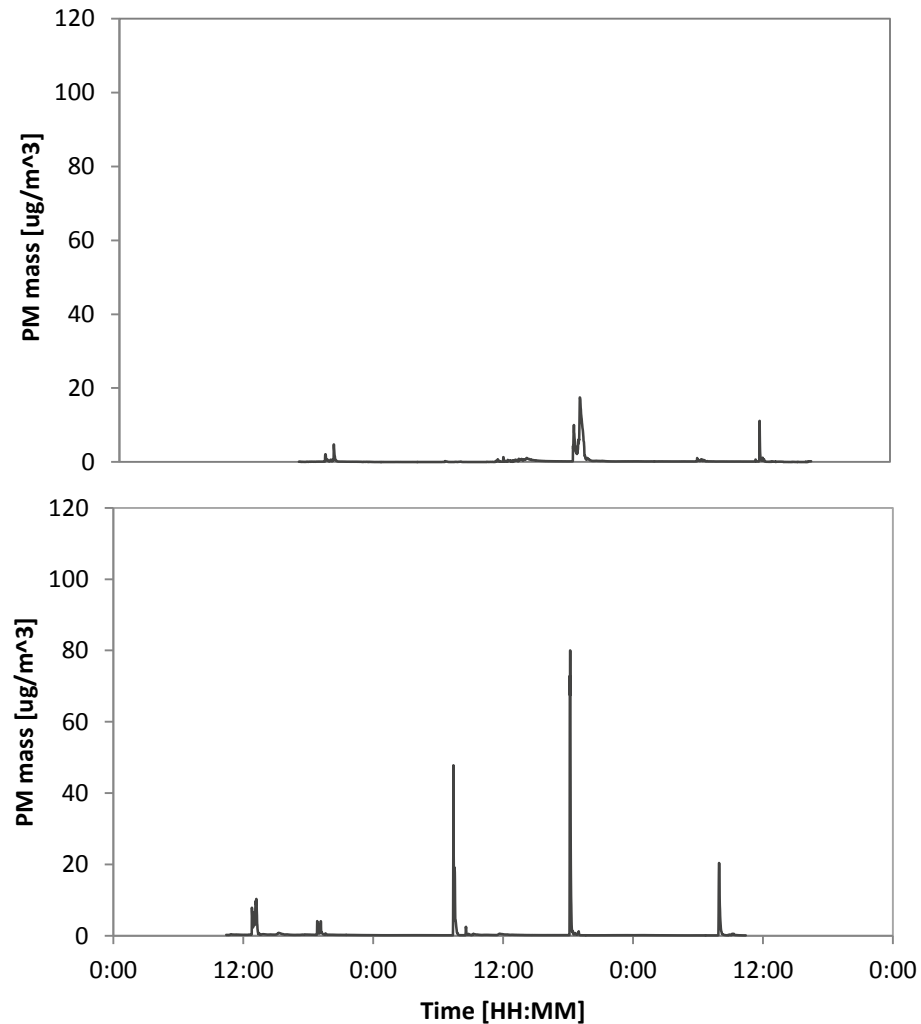
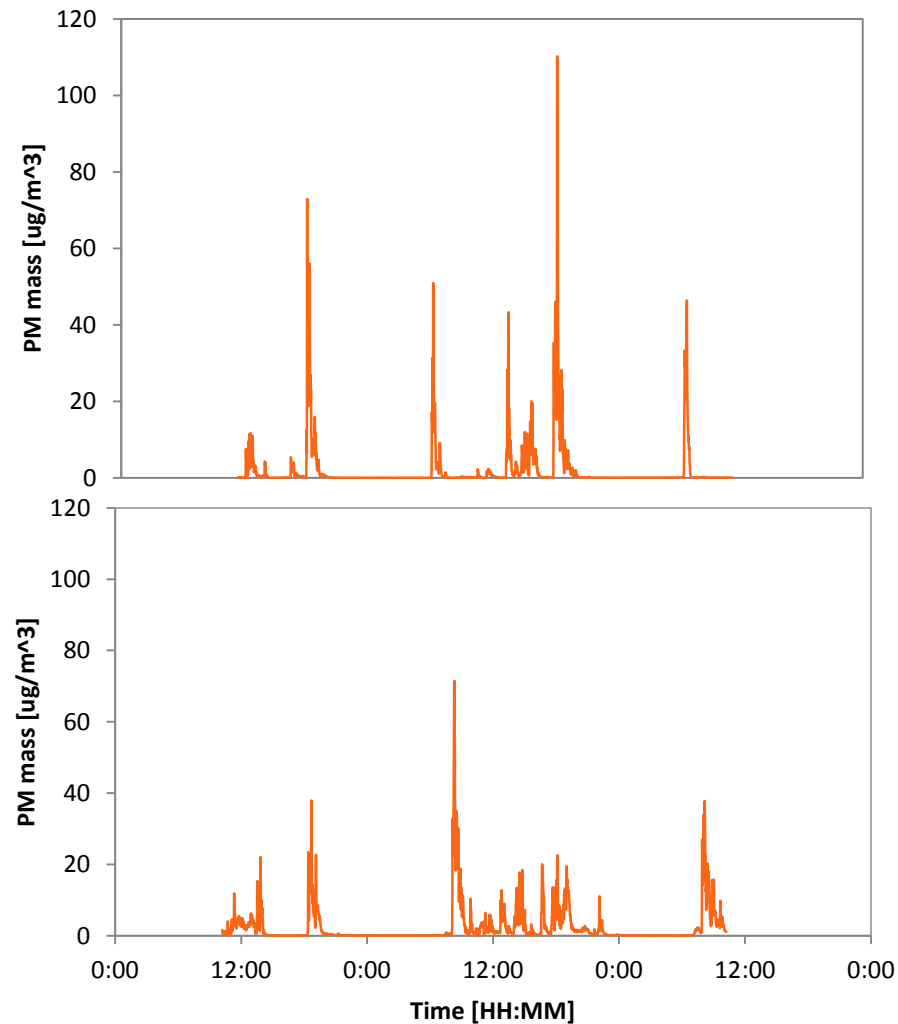
Aim 2: Model regional emissions, air quality, and climate under baseline & intervention scenarios

- 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:

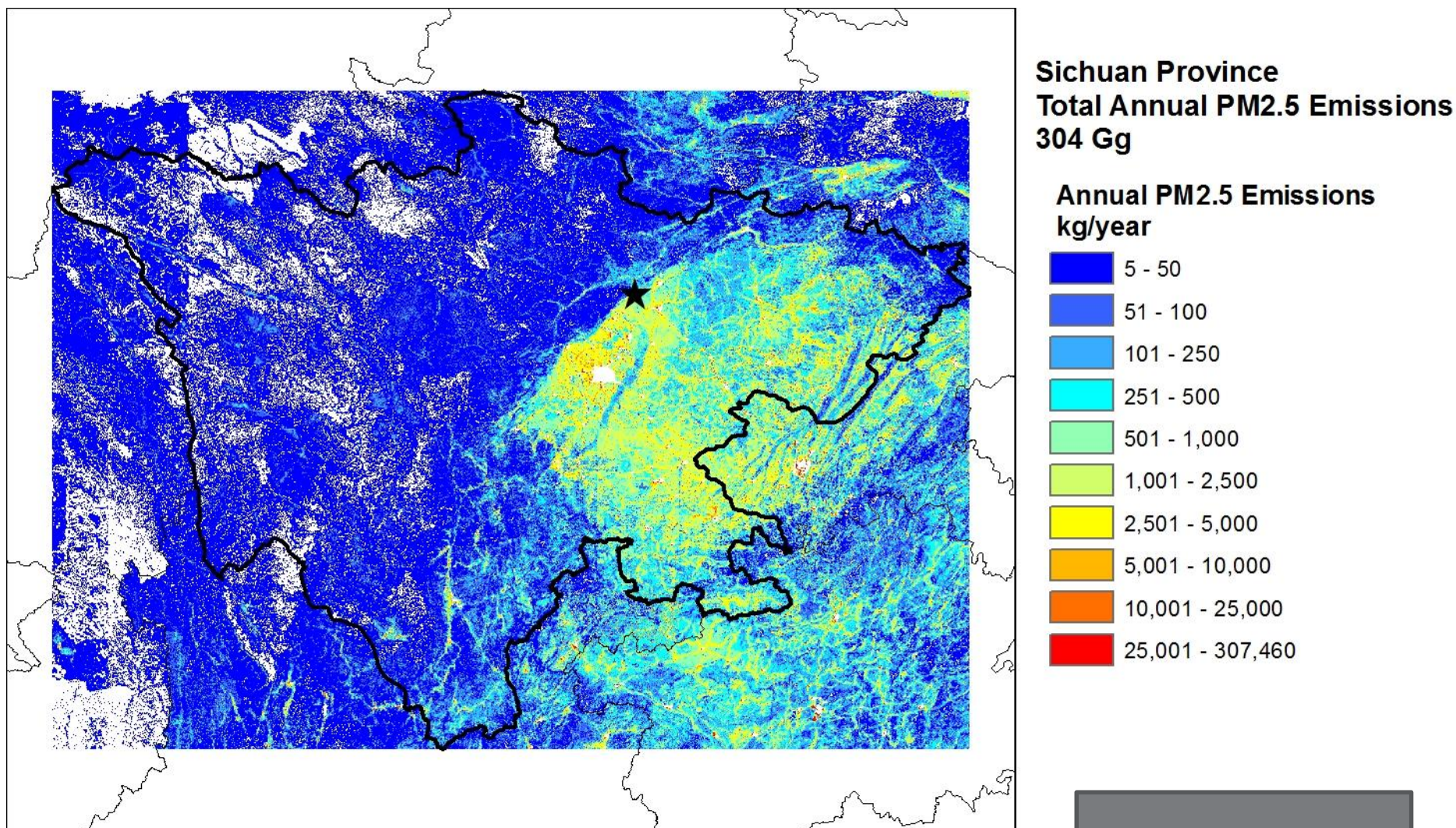
	SUMMER	WINTER
# Events	7	15
Stove usage time (hours)	4.2	7.5

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



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

REASv2.1
350 Gg

Example:

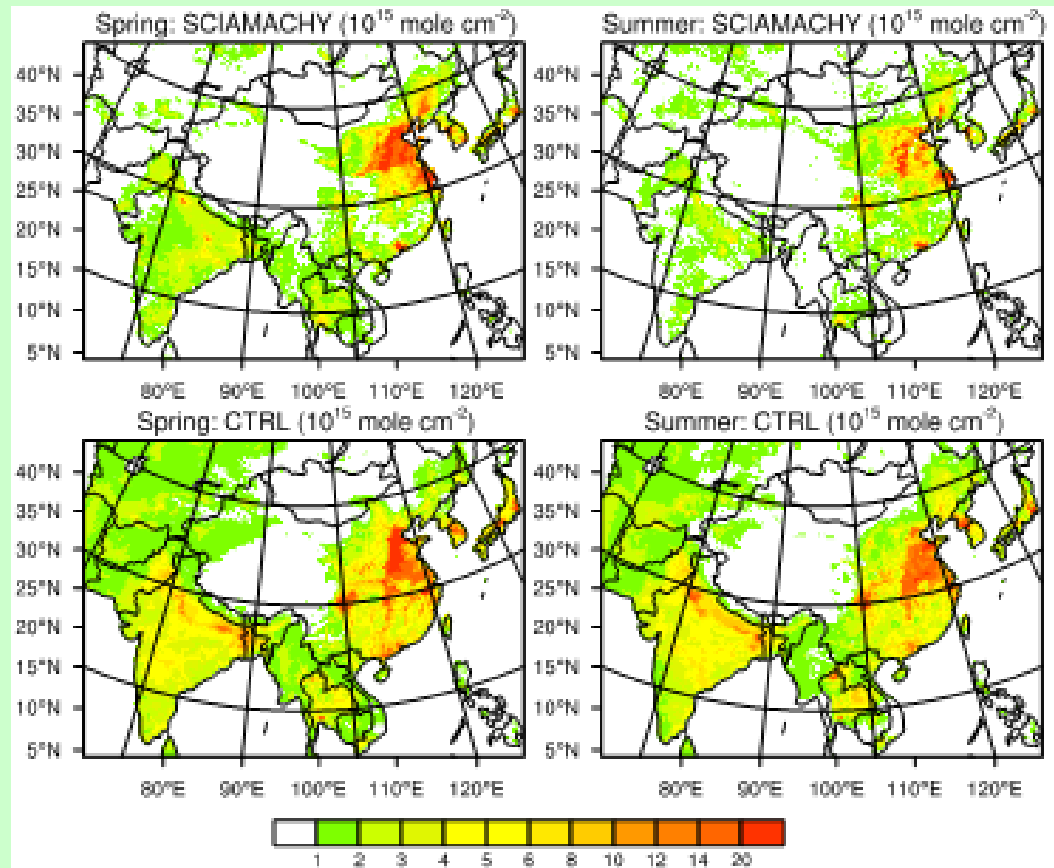
- Modeling
- Observations

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

SCIAMACHY
Satellite NO₂ column
(2008)

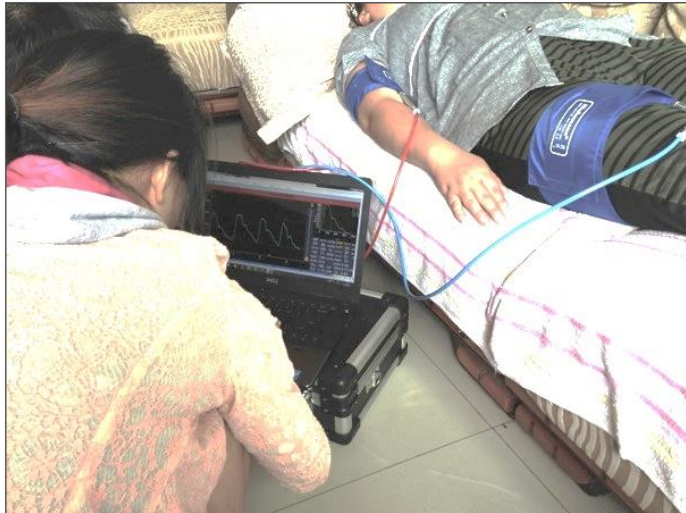
Model simulated
NO₂ column (2008)

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 $\pm$ 11.9	28 – 86
BMI [kg/m ²]	201	25.4 $\pm$ 3.3	19 – 37
Brachial SBP [mmHg]	162	116.9 (18.9)	93 – 181.3
Central (aortic) SBP [mmHg]	162	111.7 $\pm$ 17.9	86.1 – 174.4
Brachial DBP [mmHg]	162	71.4 (9.3)	52.6 - 107
Central (aortic) DBP [mmHg]	162	73.4 $\pm$ 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- $\log(\mu\text{g}/\text{m}^3)$ 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



Study concept

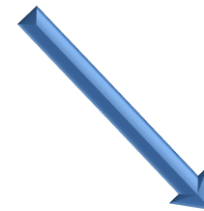
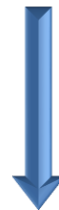
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Air pollution emissions and exposures

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Aim 2

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Aim 3



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Cookstove Research Meeting

Extra slides

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

