Bluetooth Beacon technology for personal exposure and behavior assessment

Ricardo Piedrahita, Michael Johnson, Jiawen Liao

January 2019

ETHOS: Seattle, USA

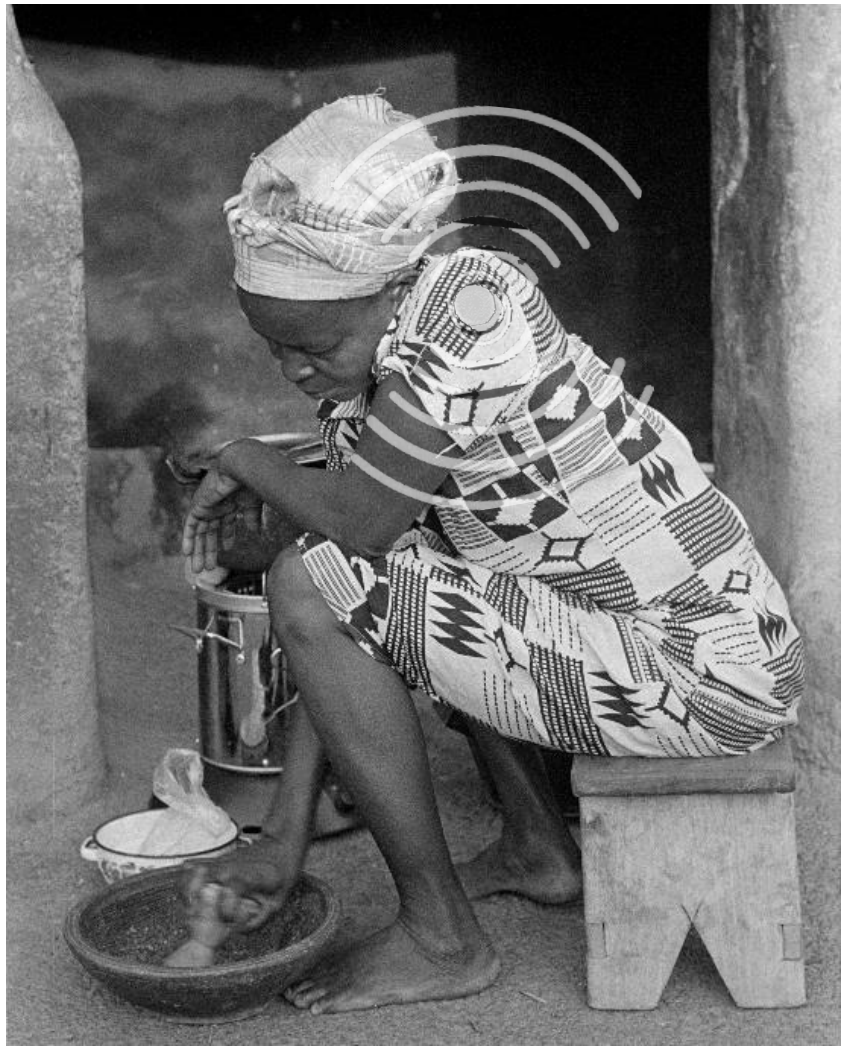
BERKELEY AIR
MONITORING GROUP

Proximity sensing with Bluetooth

Beacons constantly emit unique Bluetooth signal – the signal strength is inversely related to distance

A logger placed in a room records presence by recording Beacon signal strength. Beacon Loggers (an embedded system made by BA) or Android phones can be used for logging

Helpful in situations where specific indoor locations and/or proximity to exposure sources is important



BERKELEY AIR MONITORING GROUP

System components

Bluetooth beacons (emitters)

Phone or Bluetooth system logger

Ghana REACCTING Beacon Deployment

Beacons mounted on pollution monitors

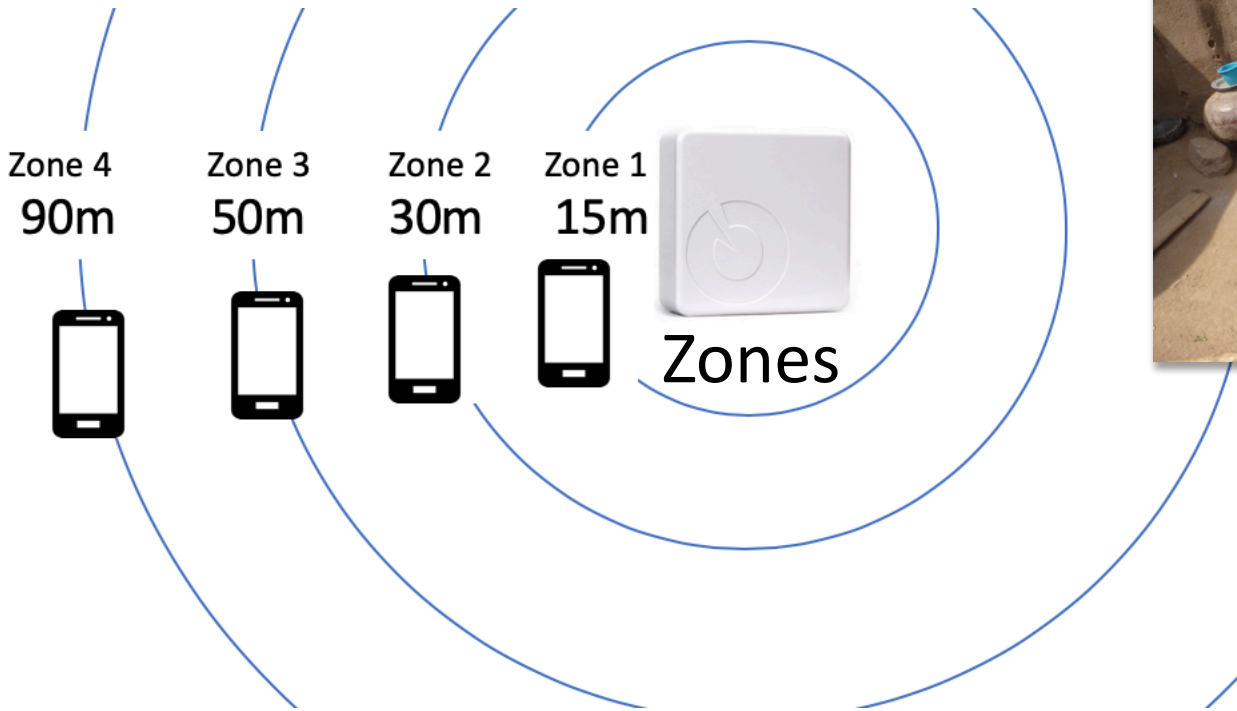
Participant wears a phone to log the data along with pollution sensors

BERKELEY AIR
MONITORING GROUP

Project: Ghana REACCTING

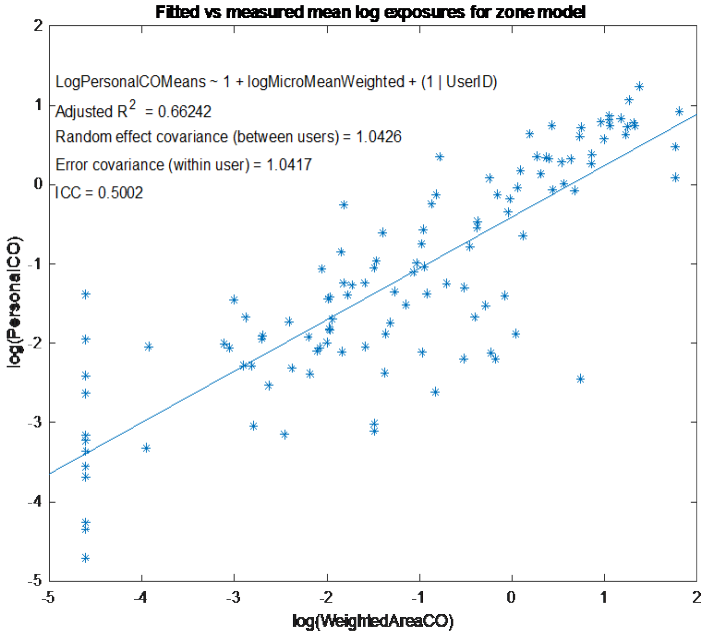
- How much exposure during cooking events?
  - Time-activity model related personal exposure of CO to time-activity categories derived from location and stove usage data
- Where are exposures are coming from (e.g. home vs. away)?

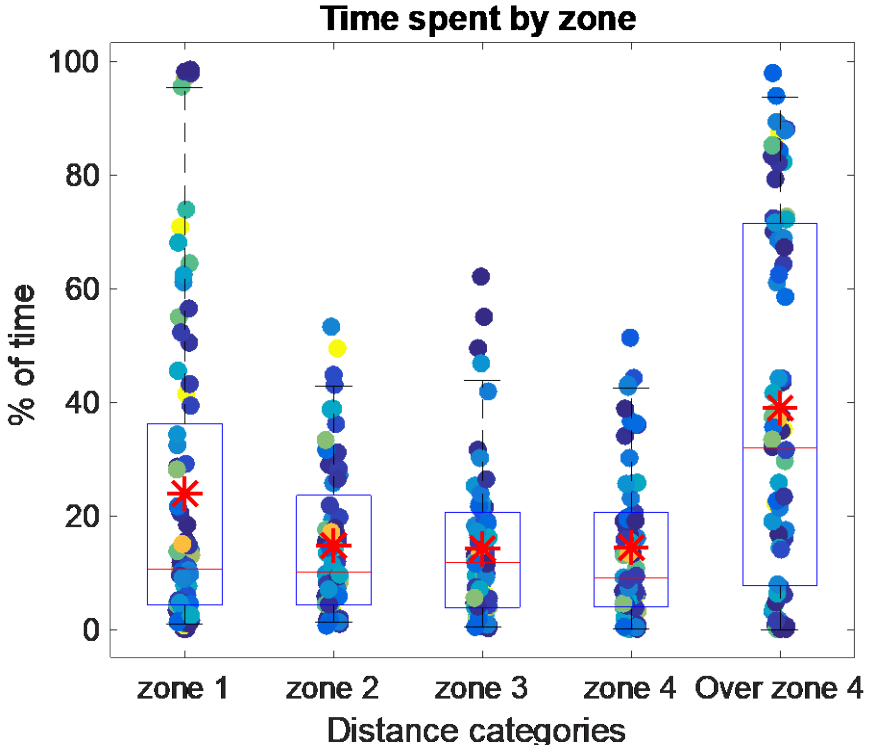
  Time-location model related personal exposure of CO to ‘zones’ and stove groups

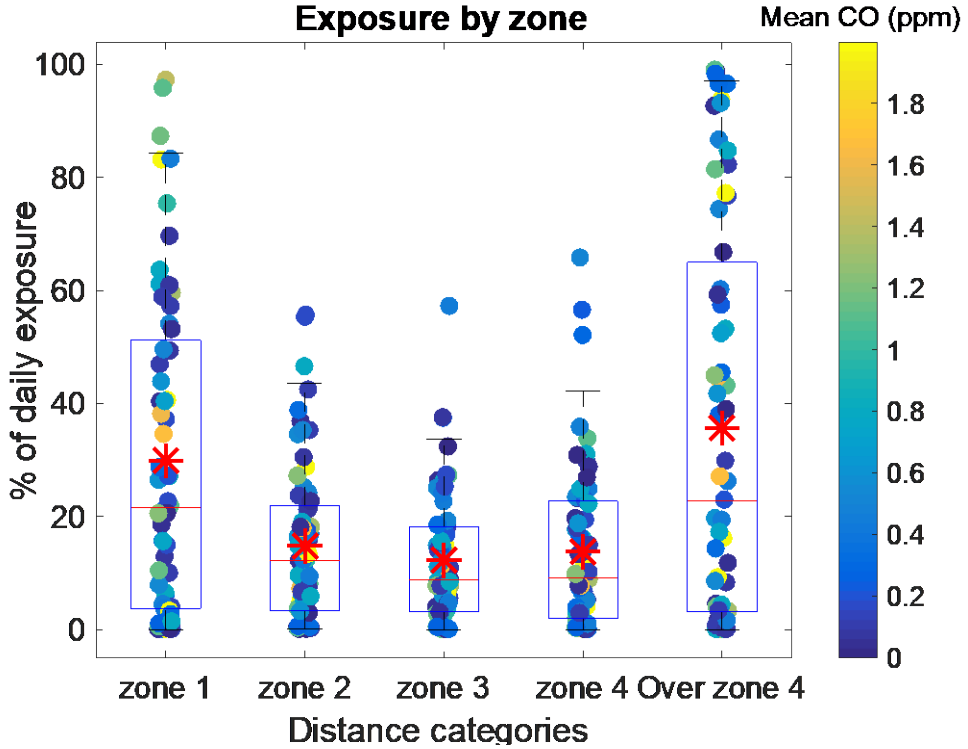


Ghana REACCTING Results

- *Log(Personal CO_{ijk}) = $ß_0 + ß_1$(weighted cooking area CO_{ijk}) + $\alpha_j + e_{ij}$*
- Adding beacon data improved explained variance from 33% to 66%

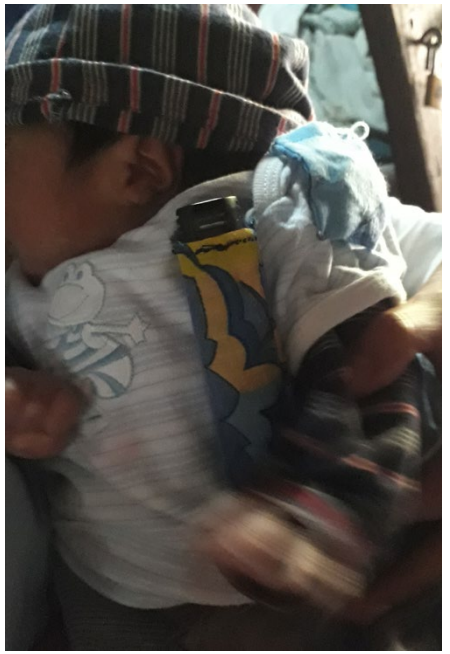


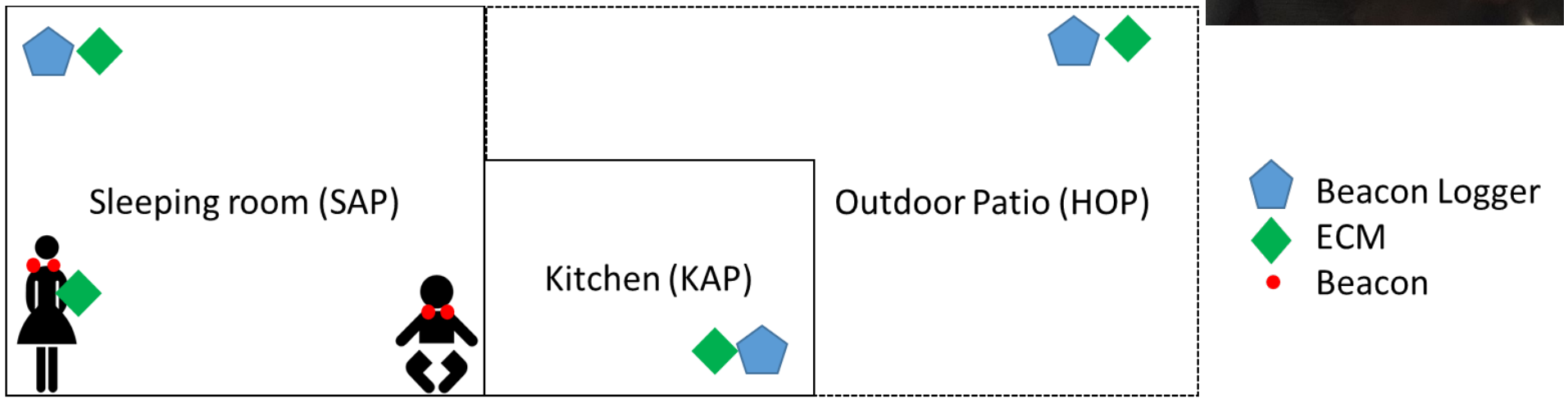




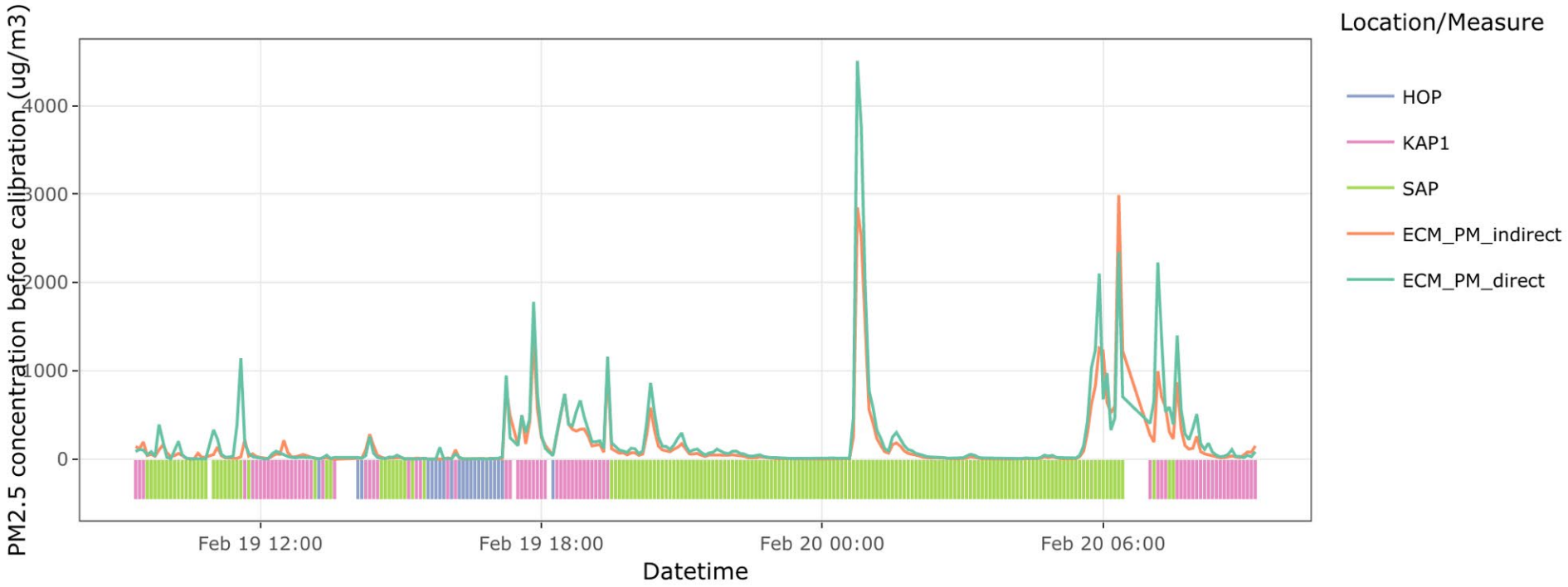
Projects: HAPIN (Household Air Pollution Intervention Network)

- Beacons worn by infants (and some mothers)
- Beacon Loggers placed with microenvironment pollution monitors in the kitchens, bedrooms, and another room where they spend time
- Used to generate indirect exposure estimates for the infants





HAPIN Guatemala Piloting Results



Spearman correlation between mothers' direct and indirect/kitchen measurement	
R between mothers' **direct and indirect** $PM_{2.5}$ measure	0.86
R between mothers' **direct and kitchen** $PM_{2.5}$ measure	0.64

Summary

- Reduces uncertainties/bias associated with time recall
- Small sensors allow for practical application with infants or small children
- Provides unique method for granular proximity data
- Has demonstrated good performance for estimating personal exposures based on location
- Best used for areas where indoor exposure is heterogenous
- Requires a fair amount of data processing

mjohnson@berkeleyair.com

rpiedrahita@berkeleyair.com

www.berkeleyair.com

BERKELEY AIR MONITORING GROUP

Thank you

BERKELEY AIR
MONITORING GROUP

Additional slides

BERKELEY AIR
MONITORING GROUP

Beacon Loggers

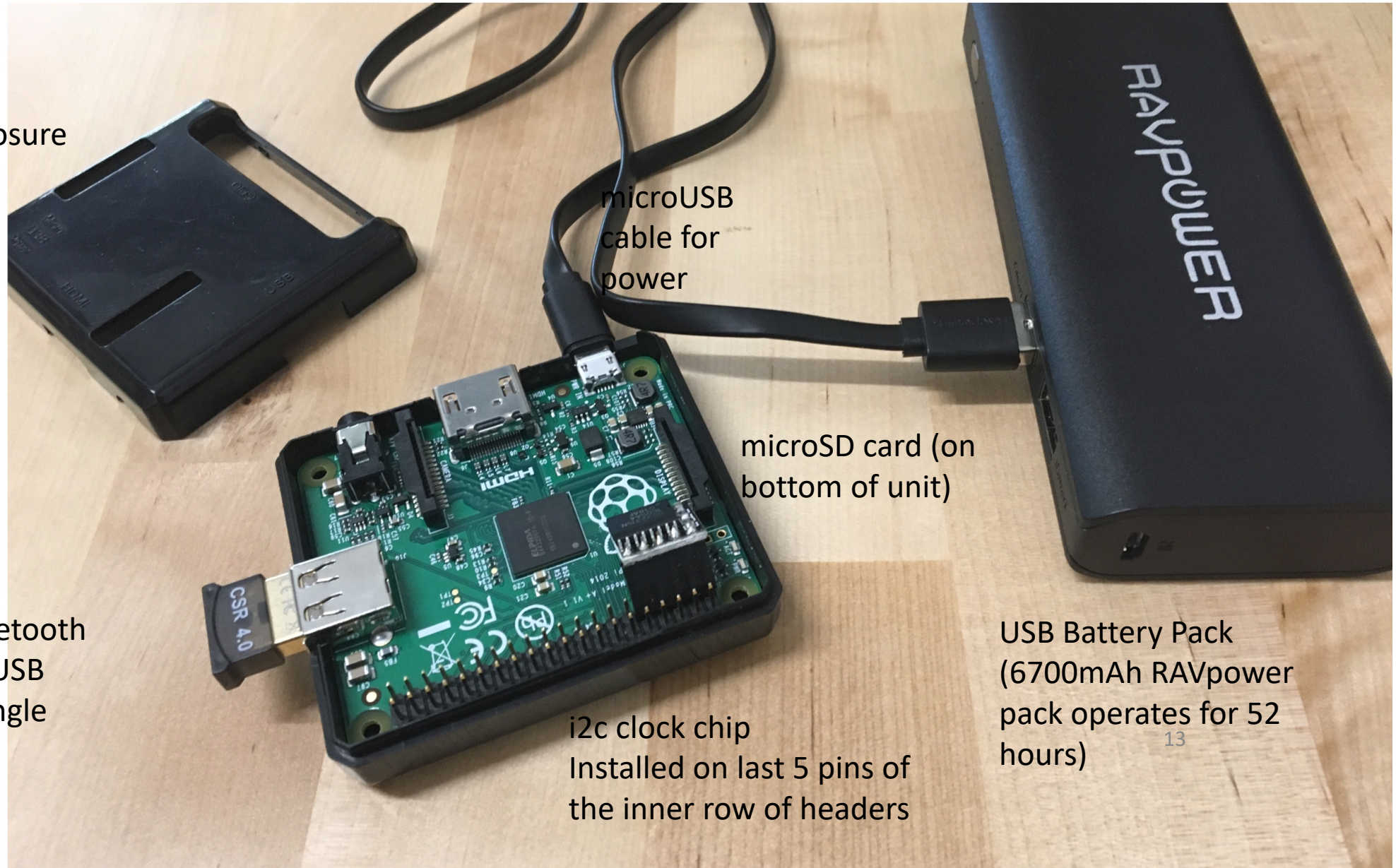
- Instead of using Android phones for Beacon logging, BA Beacon Loggers can be used

- They are programmed to log data upon connection to a USB power supply
  - The first sample is logged 70 seconds after power-on, and they log every 20 seconds

- The Berkeley Air Monitoring Group ID tag should be used as the Device ID. A different number appears in the file name, which is also labelled on the case for use in analysis.

BERKELEY AIR MONITORING GROUP

Beacon Logger Design



Enclosure

microUSB cable for power

microSD card (on bottom of unit)

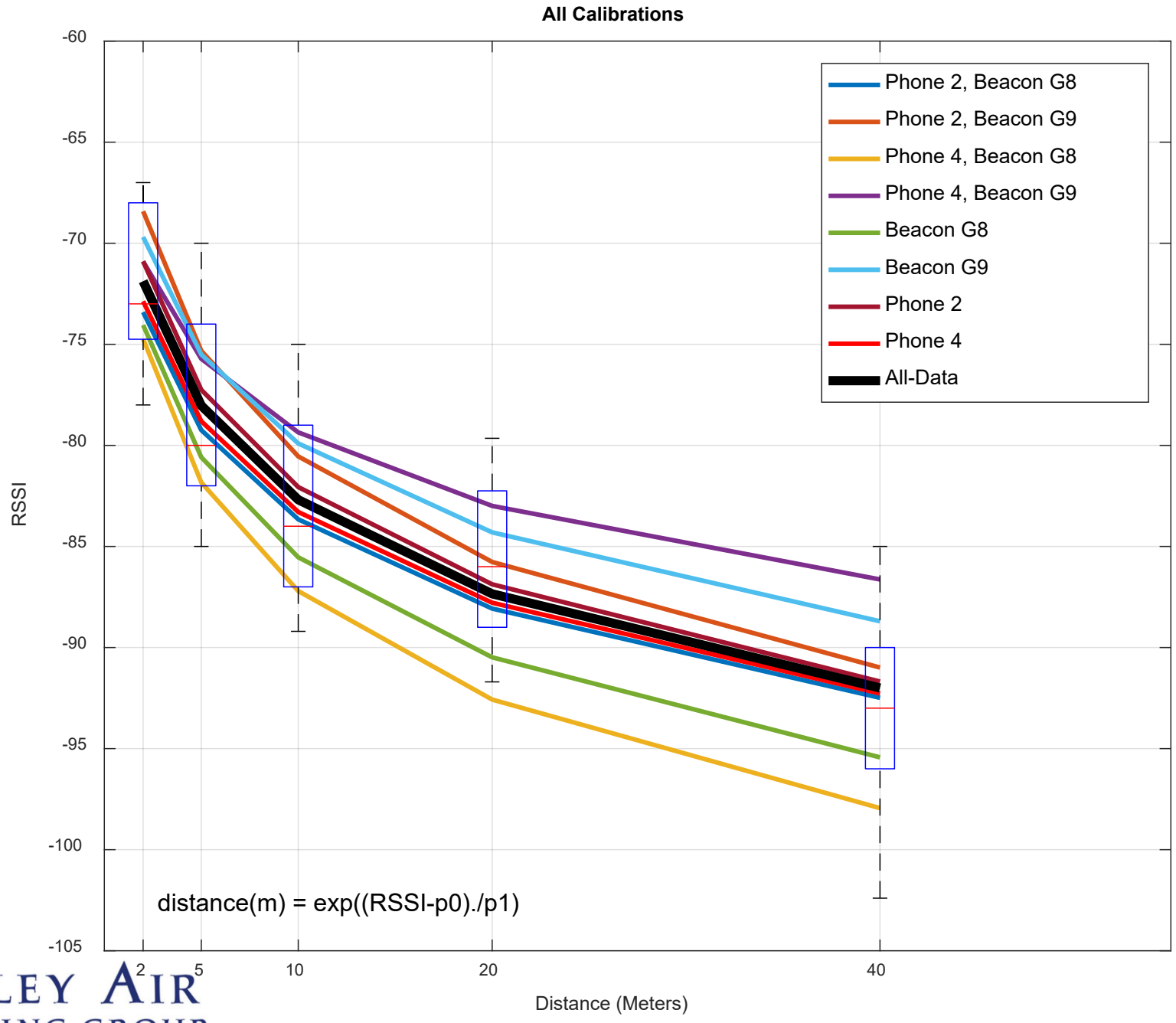
Bluetooth LE USB Dongle

i2c clock chip
Installed on last 5 pins of the inner row of headers

USB Battery Pack (6700mAh RAVpower pack operates for 52 hours)

Beacon Logger operation

- They run continuously for 48h with a USB battery sized 6700mAh or greater. We recommend 7000mAh+ batteries to account for capacity reduction over time
- Time stamps are logged in UTC-0 time
- Data is logged to the microSD card
- Light on USB dongle flashes blue when logging



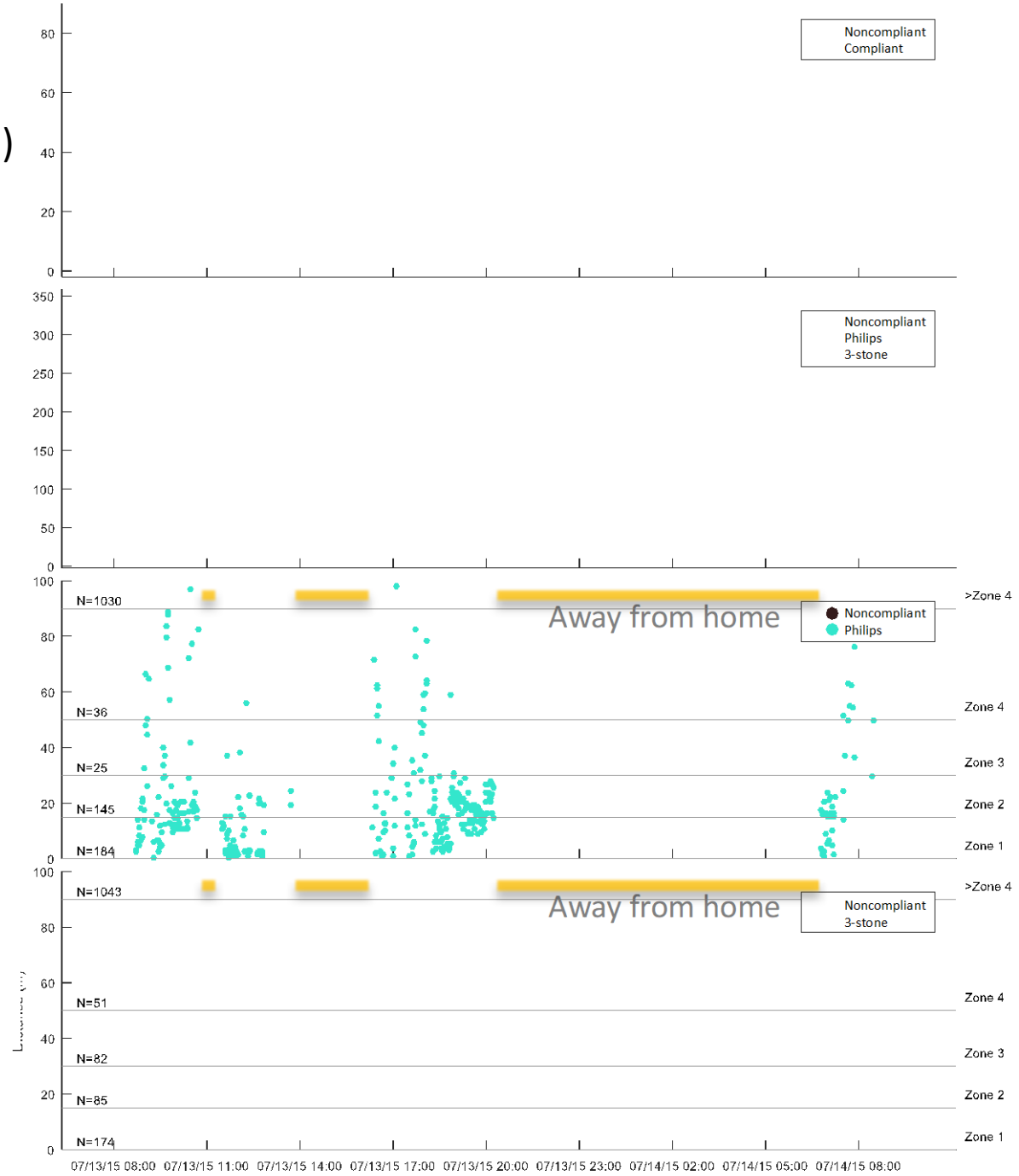
BERKELEY AIR MONITORING GROUP

Personal CO Exposure (ppm)

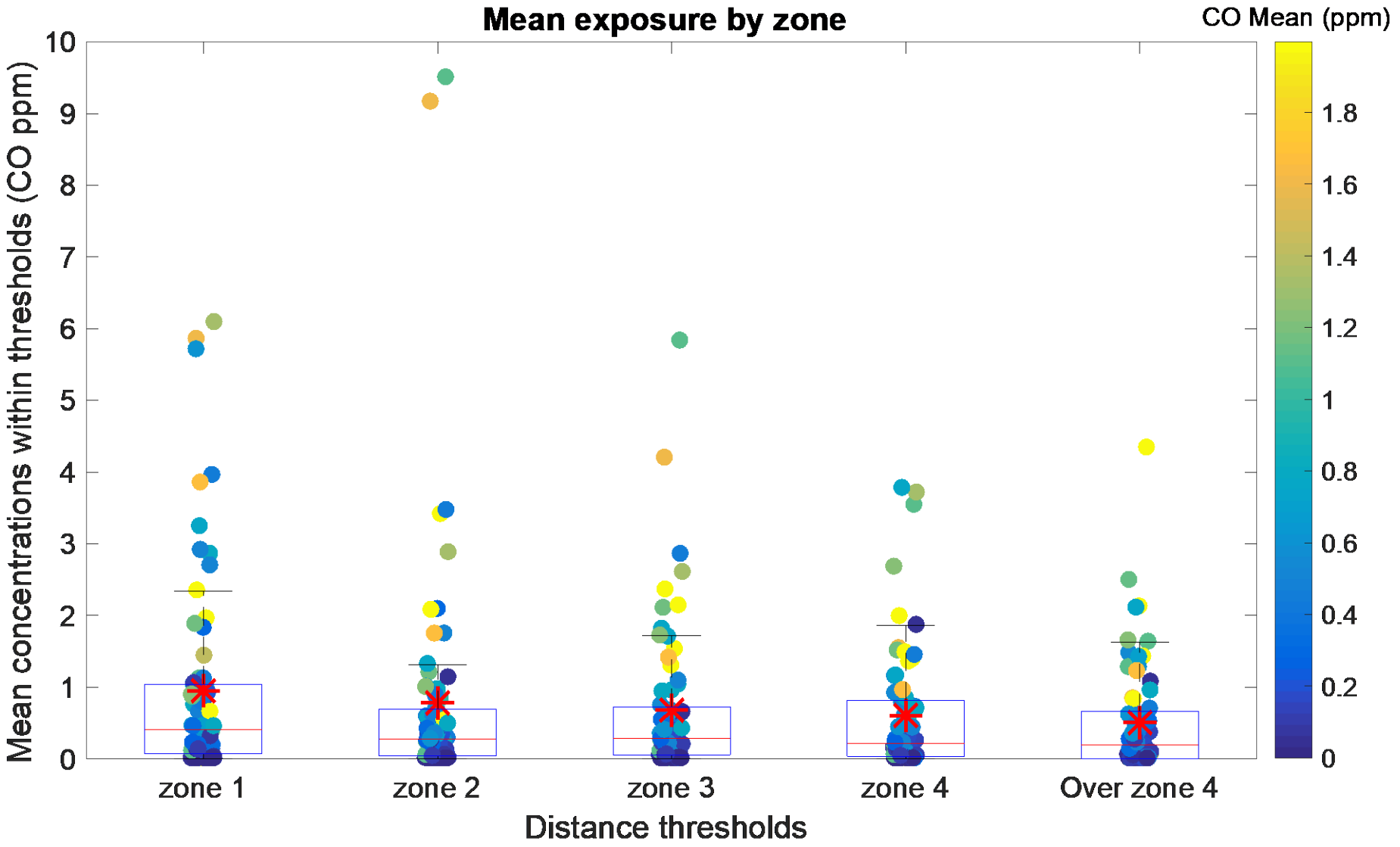
Cooking area CO (ppm)

Distance to Philips cooking area

Distance to 3-stone cooking area



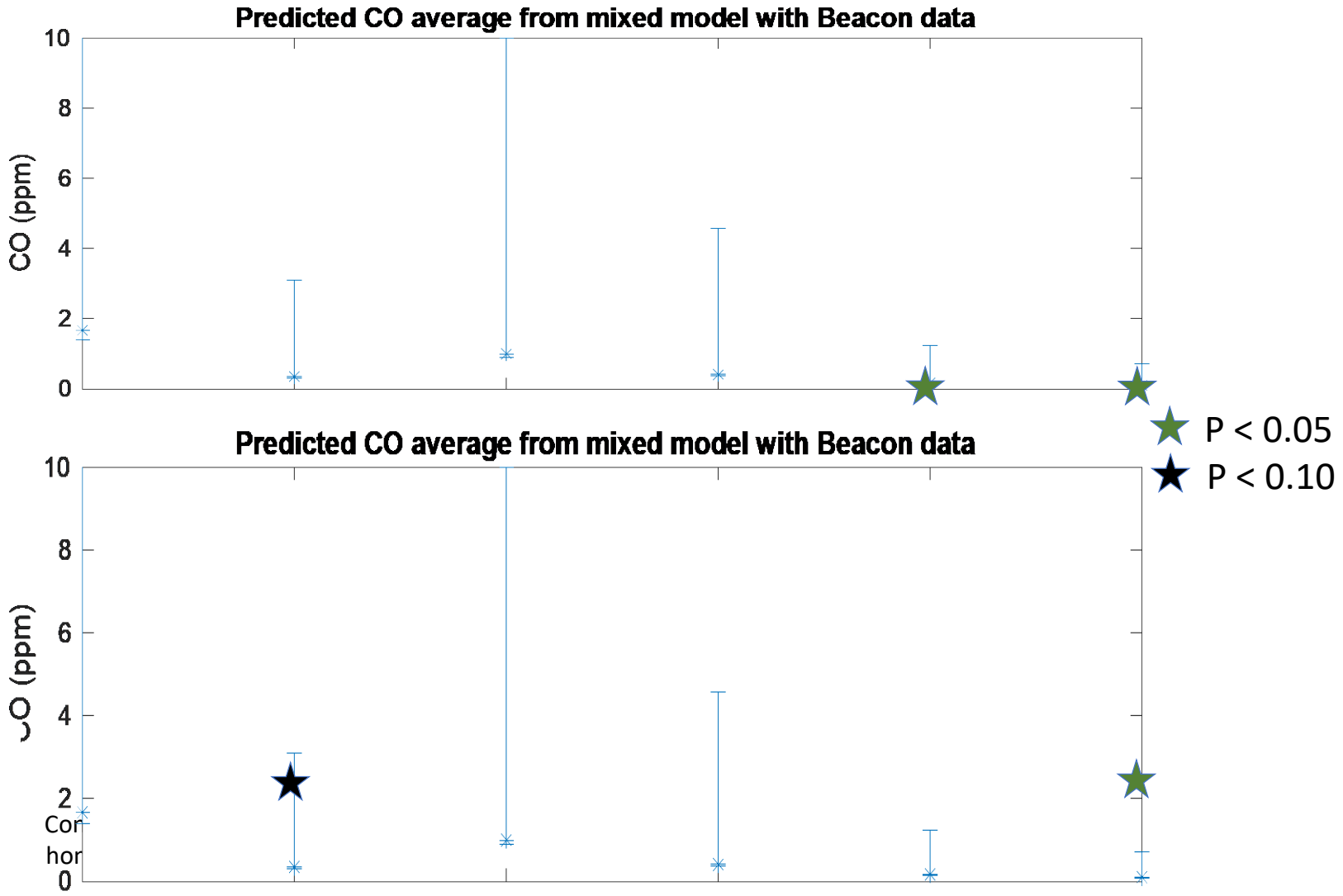
BERKELEY AIR MONITORING GROUP



BERKELEY AIR
MONITORING GROUP

Time-activity categorized model

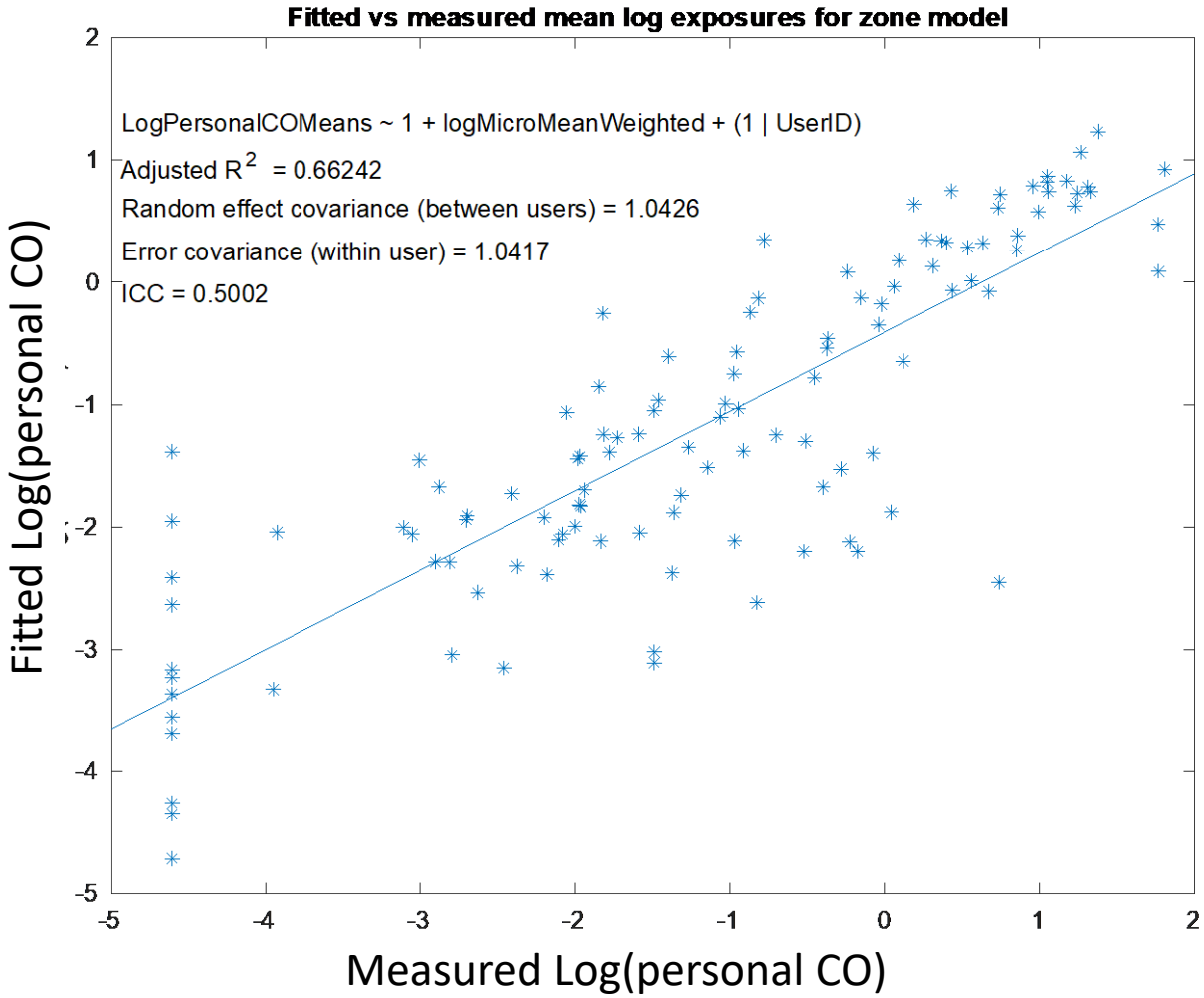
$$Log(Total\ personal\ CO_{ijk}) = \beta_0 + \beta_1(TimeActivity_k) + \alpha_j + e_{ij}$$



BERKELEY AIR MONITORING GROUP

Predicting personal CO from microenvironment CO and Beacon data

- $Log(Personal\ CO_{ijk}) = \beta_0 + \beta_1(weighted\ cooking\ area\ CO_{ijk}) + \alpha_j + e_{ij}$
- Adding beacon data improved explained variance from 33% to 66%

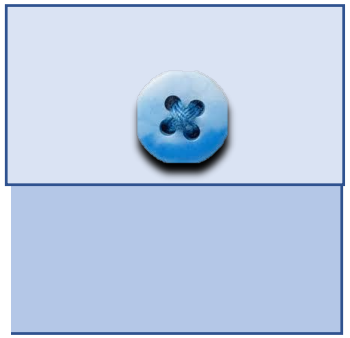


BERKELEY AIR MONITORING GROUP

Beacon placement

- Place on both shoulders, with the soft side of the Beacon facing up
- *One successful implementation of sampling shirts has been to provide the mother with two shirts for their child, in case the first gets dirty. They are then both collected from the mother, washed and reused in another deployment.*

Pockets are 5x5cm



BERKEL
MONITORI