Seasonal Indoor Air Quality of Homes in Colorado Supplemental Information

Table S1. Summary statistics of particulate matter mass concentrations (24-hour time-integrated samples for $PM_{2.5}$, 24-hour averages for PM_{10}) and $PM_{2.5}$ indoor/outdoor ratios by season.

Metric	Season	N Samples	Mean	St. Dev.	Median	IQR	Min	Max	25th Per.	75th Per.
Indoor PM_{10}	Winter	30	12.1	11.2	7.8	9.6	1.5	48.4	5.2	14.7
	Spring	30	18.9	31.1	9.7	5.6	3.0	156.2	6.6	12.2
	Summer	28	18.3	11.2	16.7	8.3	3.5	56.4	12.0	20.3
	Fall	26	12.3	8.5	10.5	7.7	3.9	39.0	6.2	13.8
	All Data	114	15.4	18.3	11.4	11.1	1.5	156.2	6.5	17.6
Indoor $PM_{2.5}$	Winter	29	6.1	5.7	3.9	5.1	0.6	19.7	2.1	7.2
	Spring	30	8.1	11.2	4.7	3.4	0.6	53.3	3.5	7.0
	Summer	28	10.6	7.4	8.3	9.1	0.6	30.0	5.9	15.0
	Fall	28	7.6	6.4	5.8	5.9	2.0	29.9	3.3	9.2
	All Data	115	8.1	8.1	5.8	6.6	0.6	53.3	3.4	9.9
Outdoor $PM_{2.5}$	Winter	29	7.5	5.4	5.7	5.6	0.5	22.7	3.8	9.4
	Spring	30	5.3	3.4	4.9	2.2	1.7	20.3	3.7	5.9
	Summer	28	9.2	4.6	7.7	4.9	4.8	23.7	6.0	11.0
	Fall	28	5.1	3.1	4.7	4.7	0.7	14.8	2.7	7.4
	All Data	115	6.8	4.5	5.6	4.1	0.5	23.7	4.0	8.1
$PM_{2.5}$ In/Out Ratio	Winter	29	1.2	1.3	0.7	1.0	0.03	6.0	0.4	1.3
	Spring	30	2.0	3.7	1.1	0.8	0.2	18.9	0.7	1.4
	Summer	28	1.2	0.7	1.0	0.6	0.1	2.7	0.8	1.4
	Fall	28	2.2	2.5	1.2	1.5	0.3	11.4	0.9	2.4
	All Data	115	1.6	2.4	1.0	1.0	0.03	18.9	0.6	1.6

Table S2. Summary statistics of particulate matter mass concentrations (24-hour time-integrated samples for $PM_{2.5}$, 24-hour averages for PM_{10}) and $PM_{2.5}$ indoor/outdoor ratios by home.

	Indoor $PM_{2.5}$					**Outdoor $PM_{2.5}$**				
	Mean	**St. Dev.**	**Median**	**Min**	**Max**	**Mean**	**St. Dev.**	**Median**	**Min**	**Max**
A	14.4	13.2	8.2	4.1	42.2	5.6	3.6	5.2	1.2	12.1
B	9.0	4.1	7.8	4.7	16.7	11.2	6.5	8.6	4.7	23.7
C	5.8	3.6	5.4	2.1	11.1	7.4	5.2	5.6	2.5	17.3
D	7.9	6.6	6.5	0.6	19.7	8.1	6.1	6.2	4.0	20.3
E	6.1	1.9	6.1	3.5	8.8	9.7	4.5	8.6	5.1	17.6
F	6.9	2.2	6.8	4.3	11.1	4.9	2.1	4.7	2.7	9.5
G	8.2	12.1	2.0	0.6	30.0	7.4	5.2	5.5	2.3	16.7
H	4.0	1.9	3.2	1.5	6.2	3.0	1.6	2.9	0.7	5.4
J	2.9	1.9	2.7	0.6	5.8	10.1	6.0	8.6	4.6	22.7
K	9.3	6.3	8.8	0.6	17.8	4.1	2.5	4.7	0.5	8.5
M	7.3	5.2	5.3	2.3	15.6	5.0	3.3	3.8	0.6	11.8
N	9.0	10.2	3.9	2.8	29.9	5.5	2.0	5.4	2.6	8.1
P	6.6	7.5	3.9	1.0	23.4	5.0	2.5	4.6	2.1	9.5
Q	6.6	2.1	6.5	4.2	11.2	7.3	1.4	7.2	5.6	10.2
R	18.7	15.7	17.1	2.9	53.3	6.8	4.0	6.4	2.2	14.9
	Indoor PM_{10}					**$PM_{2.5}$ I/O Ratio**				
	Mean	**St. Dev.**	**Median**	**Min**	**Max**	**Mean**	**St. Dev.**	**Median**	**Min**	**Max**
A	29.8	29.7	18.2	4.7	95.8	4.6	6.5	1.6	0.7	18.9
B	13.8	7.5	11.4	8.4	31.1	0.9	0.4	0.9	0.4	1.7
C	10.7	6.8	9.1	2.5	20.4	0.9	0.3	0.9	0.4	1.3
D	18.4	9.2	15.9	9.8	32.2	1.1	0.9	1.1	0.1	2.8
E	13.4	7.6	10.1	7.0	27.6	0.7	0.3	0.7	0.3	1.0
F	13.4	4.3	13.9	6.5	19.1	1.5	0.7	1.3	0.9	2.7
G	7.5	5.4	5.7	2.1	18.0	0.8	0.7	0.6	0.1	1.8
H	9.5	4.2	8.2	5.0	18.1	1.7	1.2	1.2	0.5	4.2
J	6.7	4.5	3.9	3.0	13.5	0.4	0.3	0.3	0.0	0.7
K	14.9	10.7	13.6	2.4	36.0	2.0	0.7	2.2	1.1	3.3
M	12.5	9.7	9.0	1.5	30.3	1.9	1.7	1.3	0.6	6.0
N	14.6	13.6	8.4	4.0	39.0	2.6	4.1	0.6	0.5	11.4
P	9.7	6.6	5.9	4.4	22.3	1.3	0.8	1.1	0.1	2.5
Q	13.7	4.1	13.4	8.8	21.8	0.9	0.3	0.9	0.6	1.7
R	46.9	51.6	29.9	6.3	156.2	3.8	3.8	2.6	0.3	11.3

Table S3. Hypothesis test results for comparing seasonal differences (significant p-values less than 0.05 are highlighted in green bold text).

p-values for Kruskal-Wallis Test One-Way ANOVA by Ranks						
	PM_{10} In	**$PM_{2.5}$ In**	**$PM_{2.5}$ Out**	**$PM_{2.5}$ I/O Ratio**	**qPCR In**	**qPCR Out**
All Seasons	**0.003**	**0.014**	**0.0001**	0.12	0.29	0.33
p-values for Nonparametric Multiple Comparison Tests						
	PM_{10} In	**$PM_{2.5}$ In**	**$PM_{2.5}$ Out**	**$PM_{2.5}$ I/O Ratio**	**qPCR In**	**qPCR Out**
Overall	**0.009**	**0.02**	**3.2E-07**	0.10	0.39	0.10
Spring - Fall	0.94	0.68	0.99	0.69	0.87	0.99
Summer - Fall	**0.04**	0.33	**0.0008**	0.71	0.76	0.85
Winter - Fall	0.74	0.52	0.41	0.10	0.82	0.81
Spring - Summer	**0.009**	**0.02**	**3.2E-07**	0.99	0.38	0.86
Winter - Spring	0.93	0.96	0.24	0.41	0.49	0.99
Winter - Summer	**0.01**	**0.04**	0.40	0.58	0.93	0.10

Detailed Cluster Analysis:

There were five clusters for indoor $PM_{2.5}$, with homes A and R clustering individually due to elevated concentrations throughout the year from elevated outdoor $PM_{2.5}$ or high PM emissions during cooking (see Figures 2, 4, 6 and S21). Clusters 2 and 3 had time series that peaked in the summer., but Cluster 3 $PM_{2.5}$ levels were much lower during winter and fall compared to Cluster 2. Cluster 4 (D, M, N) homes had indoor $PM_{2.5}$ that peaked during the winter and fall sampling periods.

Four clusters were determined for indoor PM_{10} concentrations and were similar to the clusters for indoor $PM_{2.5}$ indicating that most of the PM_{10} was $PM_{2.5}$. Home R clustered by itself once again, with high concentrations and peaking during the third home visit due to a cooking event. Cluster 2 (homes B, D, M, N) contained homes that had increased levels during winter and fall. Cluster 3 for indoor PM_{10} (C, E, F, G, H, J, P, Q) peaked in summer. Homes C, E, F, G, P from Cluster 3 also clustered according to home size (large) and had similar house characteristics.

Three clusters were determined for outdoor $PM_{2.5}$ concentrations. Cluster 1 contained ten homes (A, F, H, K, M, N, P, R, C, G) located nearest to Boulder city with concentrations that peaked during the summer (samples 5 and 6, Figure S3). Homes in clusters 2 (B, E, J, Q) and 3 (D) experienced higher average outdoor $PM_{2.5}$ concentrations (especially winter and summer) than those in cluster 1. All homes in clusters 2 and 3 except home J were located north of Boulder in the cities of Longmont, Lyons, and Fort Collins. Median outdoor $PM_{2.5}$ concentrations plotted in Figure 1 show a similar spatial variability. These results suggest that spatial variability in outdoor $PM_{2.5}$ concentrations along the Front Range cities of Colorado must be considered in this analysis, as homes in cities north of Boulder were exposed to different (usually higher) outdoor $PM_{2.5}$ compared to most homes in Boulder city. Cluster 2 and 3 for both the indoor and outdoor $PM_{2.5}$ have homes B, D, E and Q, which are located in Longmont, Lyons, and Fort Collins, showing that the outdoor $PM_{2.5}$ influenced the indoor $PM_{2.5}$ more strongly than other homes and indoor levels were similarly elevated during the summer.

Four clusters were found for the indoor and outdoor qPCR data, with home Q clustering individually due to extreme high and low mean values (Figure S7). Indoor and outdoor qPCR clusters had overlapping homes showing the influence of outdoor qPCR on indoor values. The clusters had similarities with the outdoor $PM_{2.5}$ clusters (but not indoor $PM_{2.5}$) showing more dependence on location of the home. Homes A, F, P, G, J, K were all located within Boulder and Niwot (Cluster 1 for outdoor $PM_{2.5}$; Cluster 1 and 3 for indoor qPCR; Cluster 1 and 4 for outdoor qPCR)

Table S4. Results for clustering analysis in home and inhabitant characteristics.

Data set	Variables	Cluster	Homes	Cluster Description
Home Size	Volume # Rooms # Floors Basement Type # Operable Windows Year Built Time in Residence Neighborhood	1	A, D, N, Q	Small homes w/ basement, fewer operable windows, built in 1960-1973, lived in 1-10 years
		2	B, C, E, F, R	Large homes w/ finished basement (B unfinished), many operable windows, mostly built in 1995-2006
		3	G, P	Largest homes, partially finished basement, lived in 11-20 years
		4	H, M	Small rural homes, no basement, few operable windows, lived in > 20 years
		5	J, K	Medium size homes, many operable windows, finished basement, lived in > 20 years
Inhabitants	# Male # Female Inhabitant Age(s) # Dogs # Cats # Other Pets	1	A, E, N	Adults 35-44, kids < 8 years old
		2	B, R	Adults 35-64, kids 9-16 years old, w/ multiple other pets
		3	C, D, F	Adults 45-54, kids <8-21 years old
		4	G, H, K, P	Two adults (1 male, 1 female) 55->65 years old
		5	J, M, Q	Older adults (55->65 years old) and young adults (22-34 years old)
HVAC System	Stove Type Furnace Type Fireplace Type Heating Type AC Type Electrostatic Filter VPS ACH_{50}	1	A, D, F	Gas stove and furnace, wood fireplace, VPS 5-6, high ACH_{50} (9-16)
		2	B, C, E, N, P	Gas stove (not B), gas furnace, forced air heating, central AC, low ACH_{50} (4-6)
		3	G, J, K	Gas stove, wood fireplace, forced air heating, central AC w/ electrostatic filter, moderate ACH_{50} (7-9)
		4	H, M	Wood furnace, wood fireplace, fireplace heating, no AC, VPS of 5, moderate ACH_{50} (7-10)
		5	Q	Electric stove, gas furnace, no fireplace, radiator heating, wind AC, high ACH_{50} (16)
		6	R	Gas stove, no furnace, radiant heating, evaporative AC, low ACH_{50} (4)

Table S5. Clustering results and summary statistics for particulate matter data sets.

Metric	Cluster	Homes	Mean	St. Dev.	Min	Max
Indoor $PM_{2.5}$ (μg/m^3)	1	A	14.4	13.2	4.1	42.2
	2	B,E,F,Q,K	7.4	3.6	0.6	17.8
	3	C,G,H,J,P	5.5	6.7	0.6	30.0
	4	D,M,N	8.3	7.2	0.6	29.9
	5	R	18.7	15.7	2.9	53.3
Outdoor $PM_{2.5}$ (μg/m^3)	1	A,F,H,K,M,N,P,R,C,G	5.5	3.5	0.5	17.3
	2	B,E,J,Q	9.6	5.0	4.6	23.7
	3	D	8.1	6.1	4.0	20.3
$PM_{2.5}$ I/O Ratio	1	A	4.6	6.5	0.7	18.9
	2	B,C,E,G,H,J,P,Q	0.9	0.7	0.0	4.2
	3	D,F,N	1.8	2.4	0.1	11.4
	4	K,M	2.0	1.4	0.6	6.0
	5	R	3.8	3.8	0.3	11.3
Indoor PM_{10} (μg/m^3)	1	A,K	22.9	23.6	2.4	95.8
	2	B,D,M,N	14.7	10.0	1.5	39.0
	3	C,E,F,G,H,J,P,Q	10.6	5.8	2.1	27.6
	4	R	46.9	51.6	6.3	156.2
Indoor qPCR (gen eq/m^3)	1	A,F,H,N,P,R	372	387	6.20	1610
	2	B,D	599	539	20.8	1520
	3	C,E,G,J,K,M	239	242	2.70	1010
	4	Q	1260	1490	56.4	4130
Outdoor qPCR (gen eq/m^3)	1	A,C,F,P	749	995	430	4080
	2	B,D,M	992	1810	8.61	8100
	3	E	231	282	32.4	754
	4	G,H,J,K,N,Q,R	562	930	1.23	5530

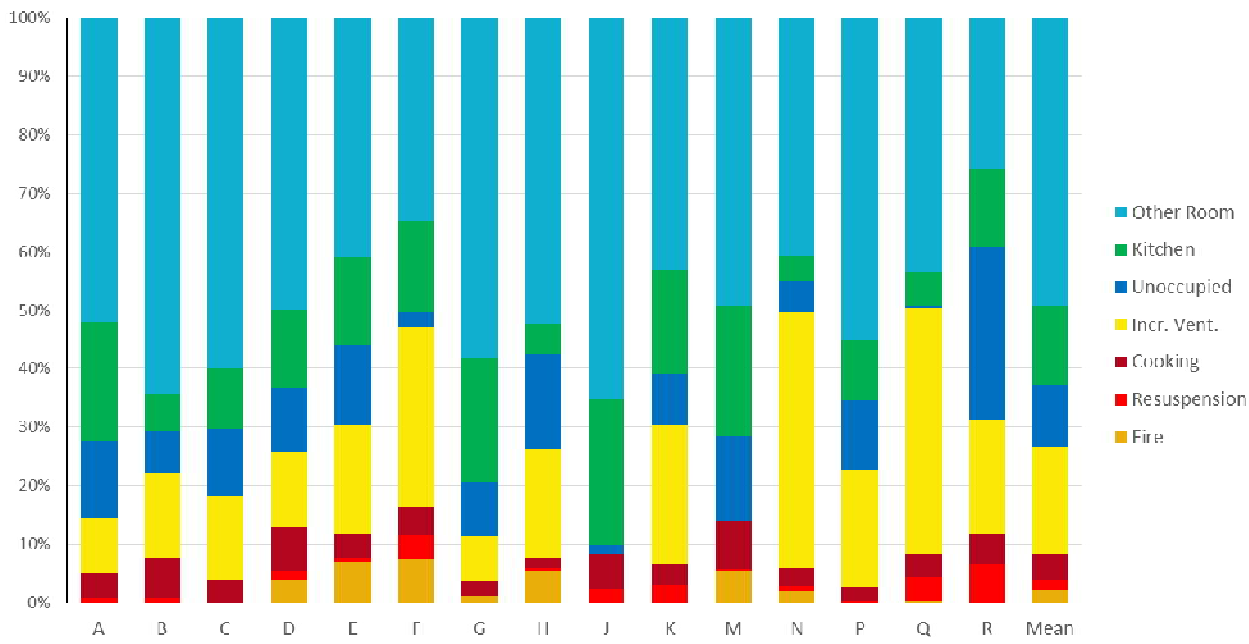

Figure S1. Average activity-hours relative to total reported activity-hours by home.

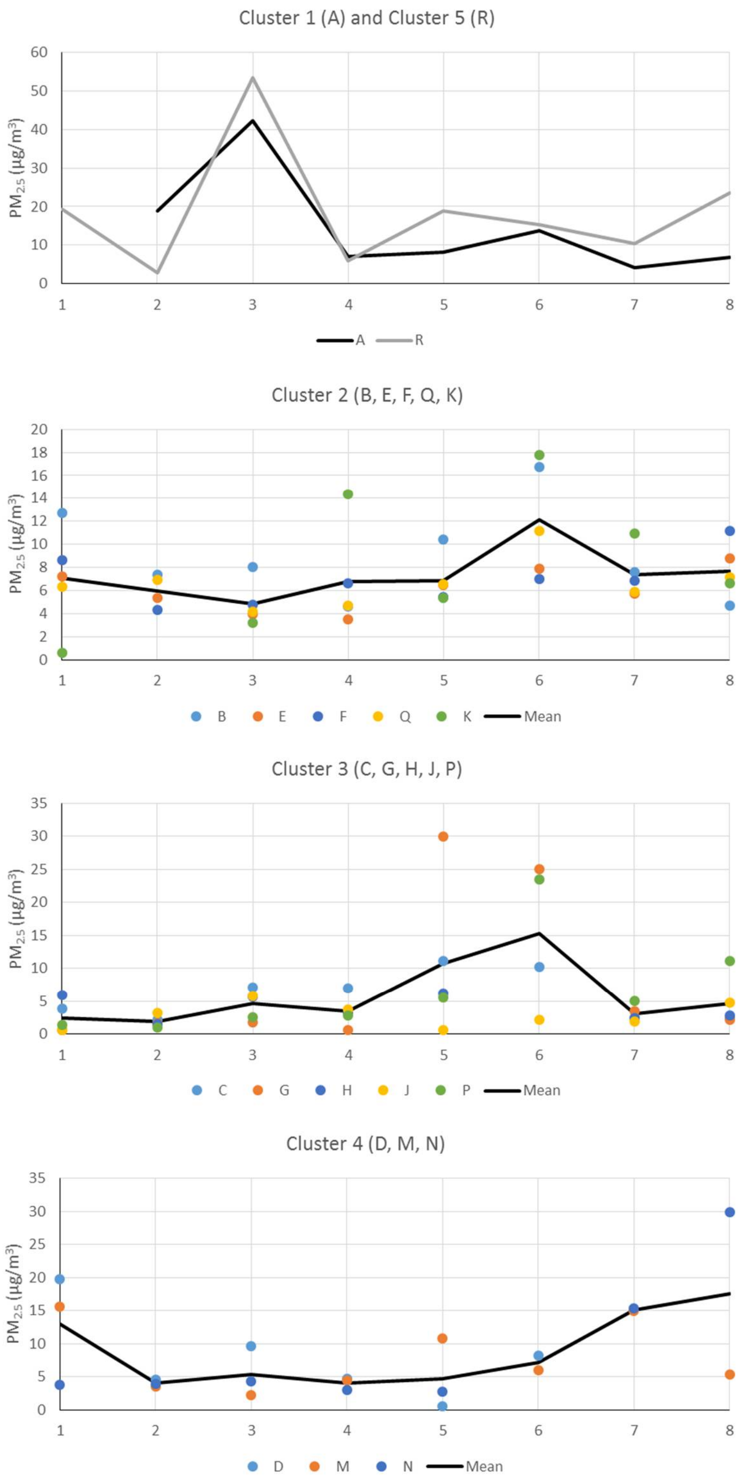

Figure S2. Time series of indoor $PM_{2.5}$ clusters. Numbers 1-8 on x axis indicate the home sampling number. Each home was visited eight times, two times per season with sample 1 starting in December. Roughly samples 1-2 are winter, 3-4 are spring, 5-6 are summer, and 7-8 are fall.

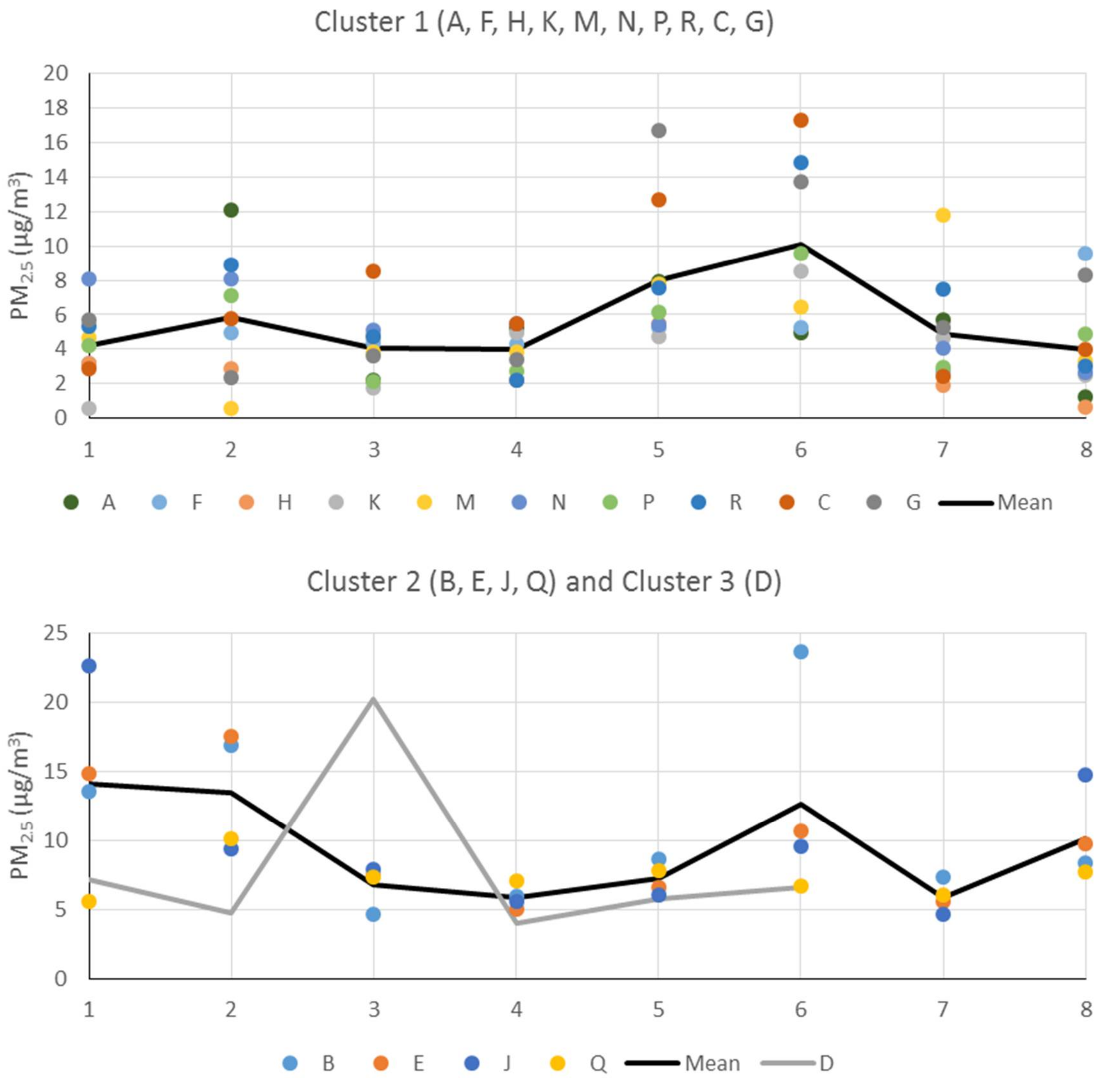

Figure S3. Time series of outdoor $PM_{2.5}$ clusters. Numbers 1-8 on x axis indicate the home sampling number. Each home was visited eight times, two times per season with sample 1 starting in December. Roughly samples 1-2 are winter, 3-4 are spring, 5-6 are summer, and 7-8 are fall.

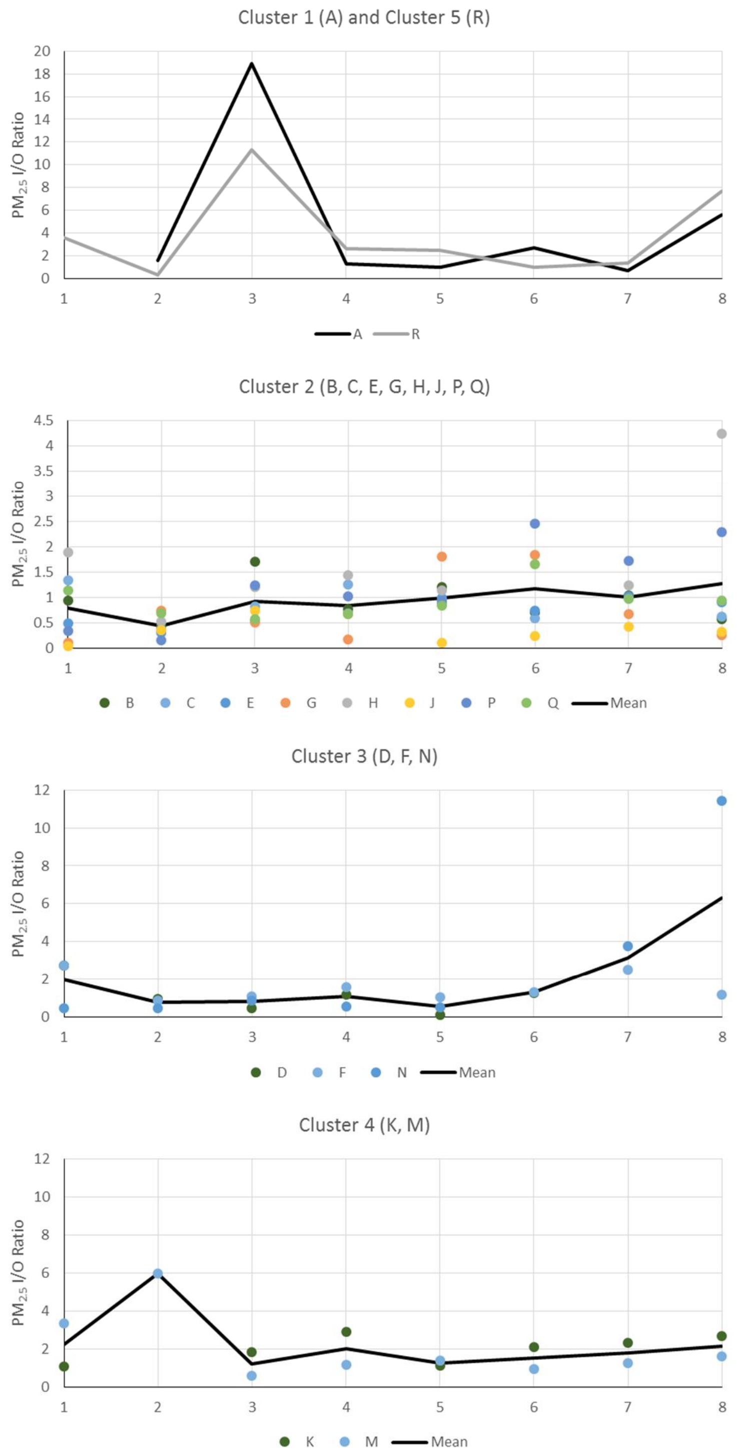

Figure S4. Time series of $PM_{2.5}$ I/O ratio clusters. Numbers 1-8 on x axis indicate the home sampling number. Each home was visited eight times, two times per season with sample 1 starting in December. Roughly samples 1-2 are winter, 3-4 are spring, 5-6 are summer, and 7-8 are fall.

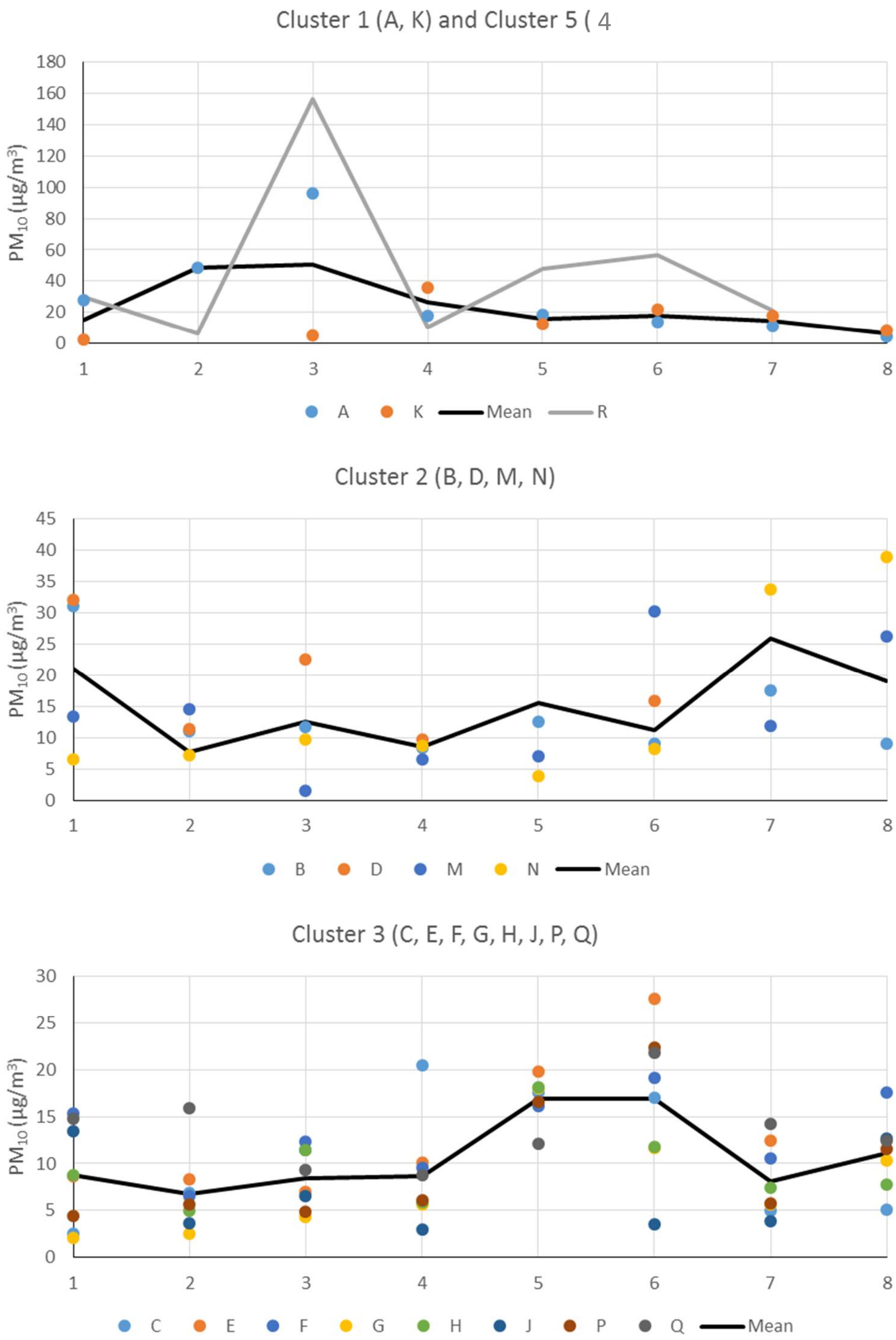

Figure S5. Time series of indoor PM_{10} clusters. Numbers 1-8 on x axis indicate the home sampling number. Each home was visited eight times, two times per season with sample 1 starting in December. Roughly samples 1-2 are winter, 3-4 are spring, 5-6 are summer, and 7-8 are fall.

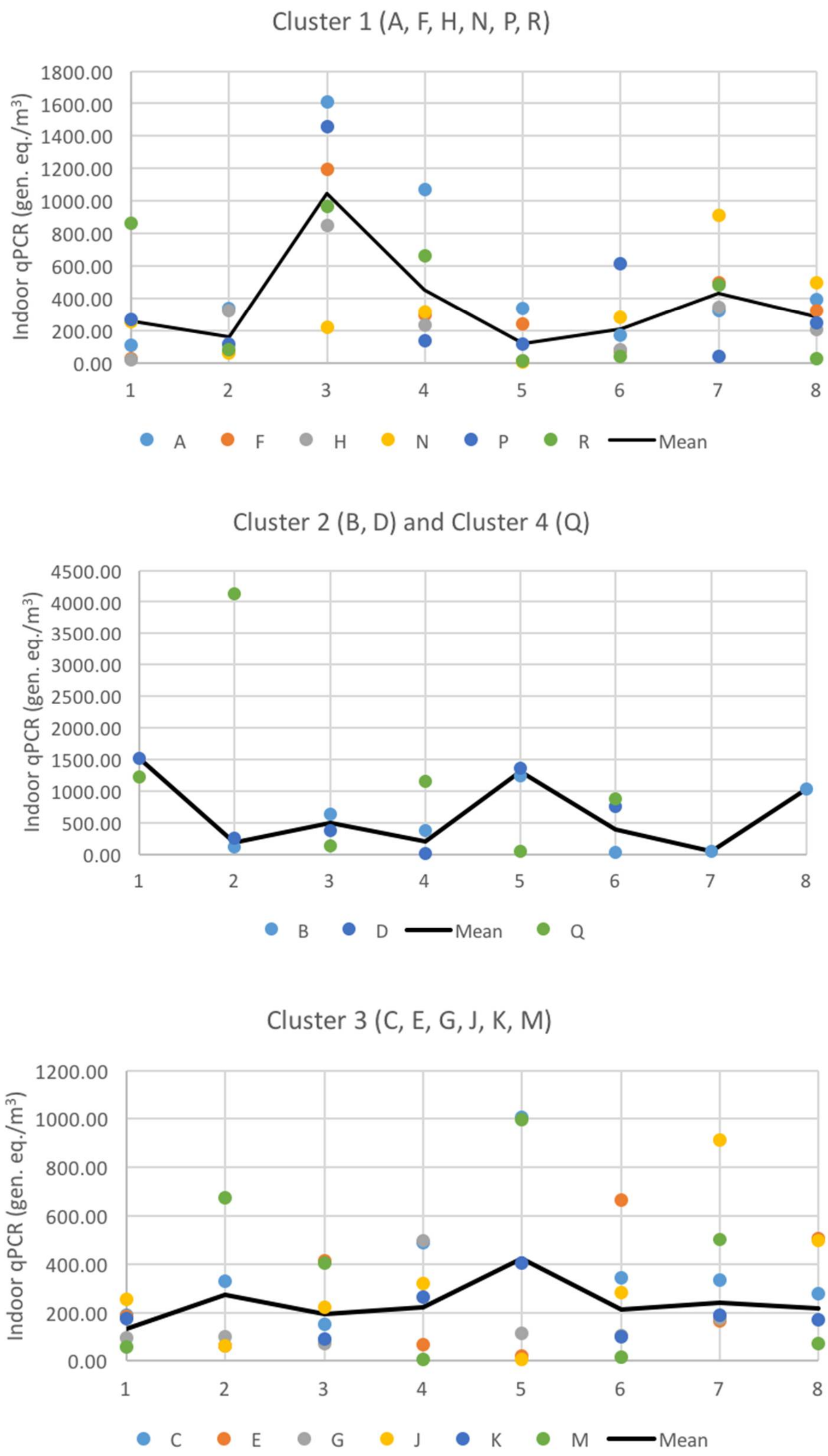

Figure S6. Time series of indoor qPCR clusters. Numbers 1-8 on x axis indicate the home sampling number. Each home was visited eight times, two times per season with sample 1 starting in December. Roughly samples 1-2 are winter, 3-4 are spring, 5-6 are summer, and 7-8 are fall.

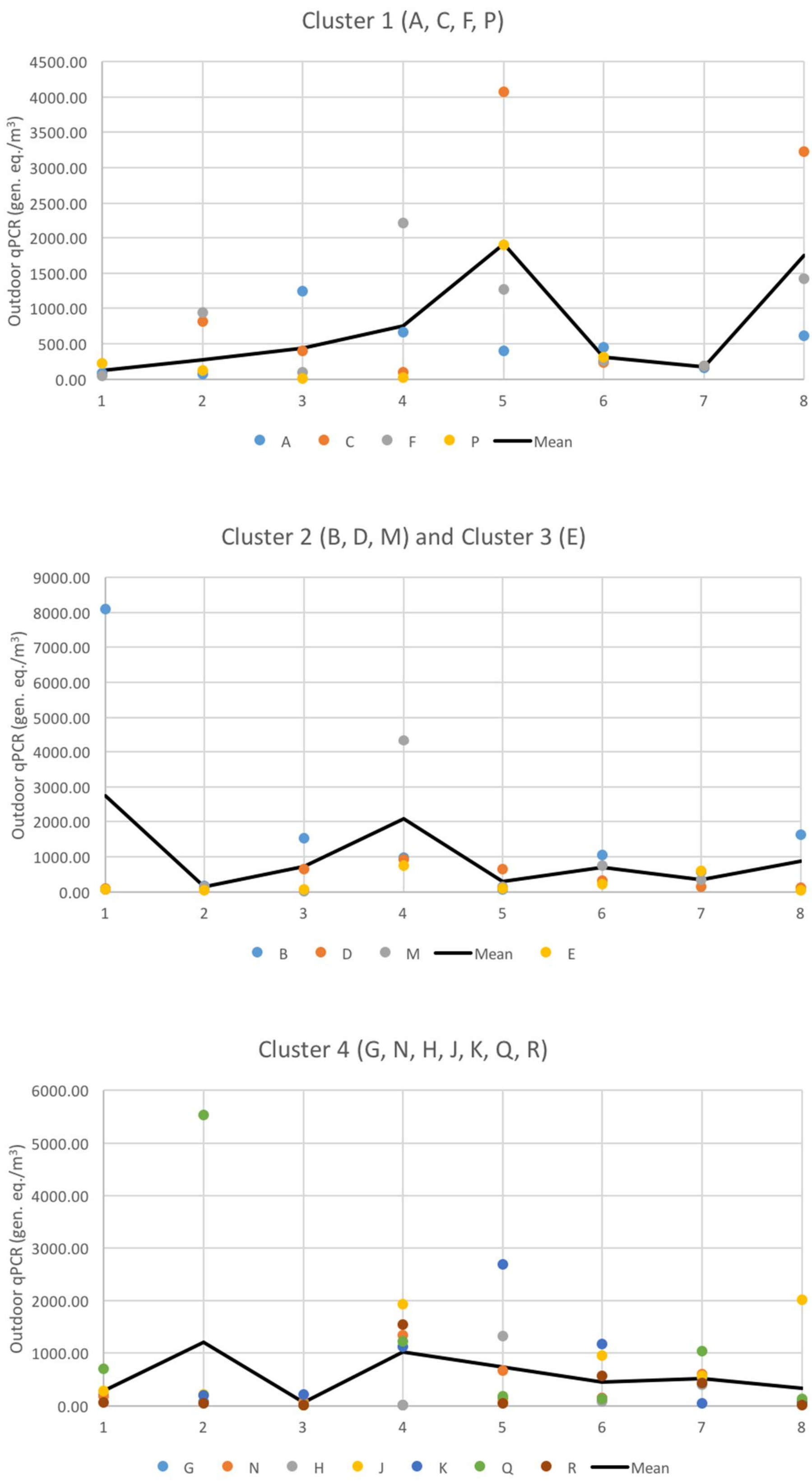

Figure S7. Time series of outdoor qPCR clusters. Numbers 1-8 on x axis indicate the home sampling number. Each home was visited eight times, two times per season with sample 1 starting in December. Roughly samples 1-2 are winter, 3-4 are spring, 5-6 are summer, and 7-8 are fall.

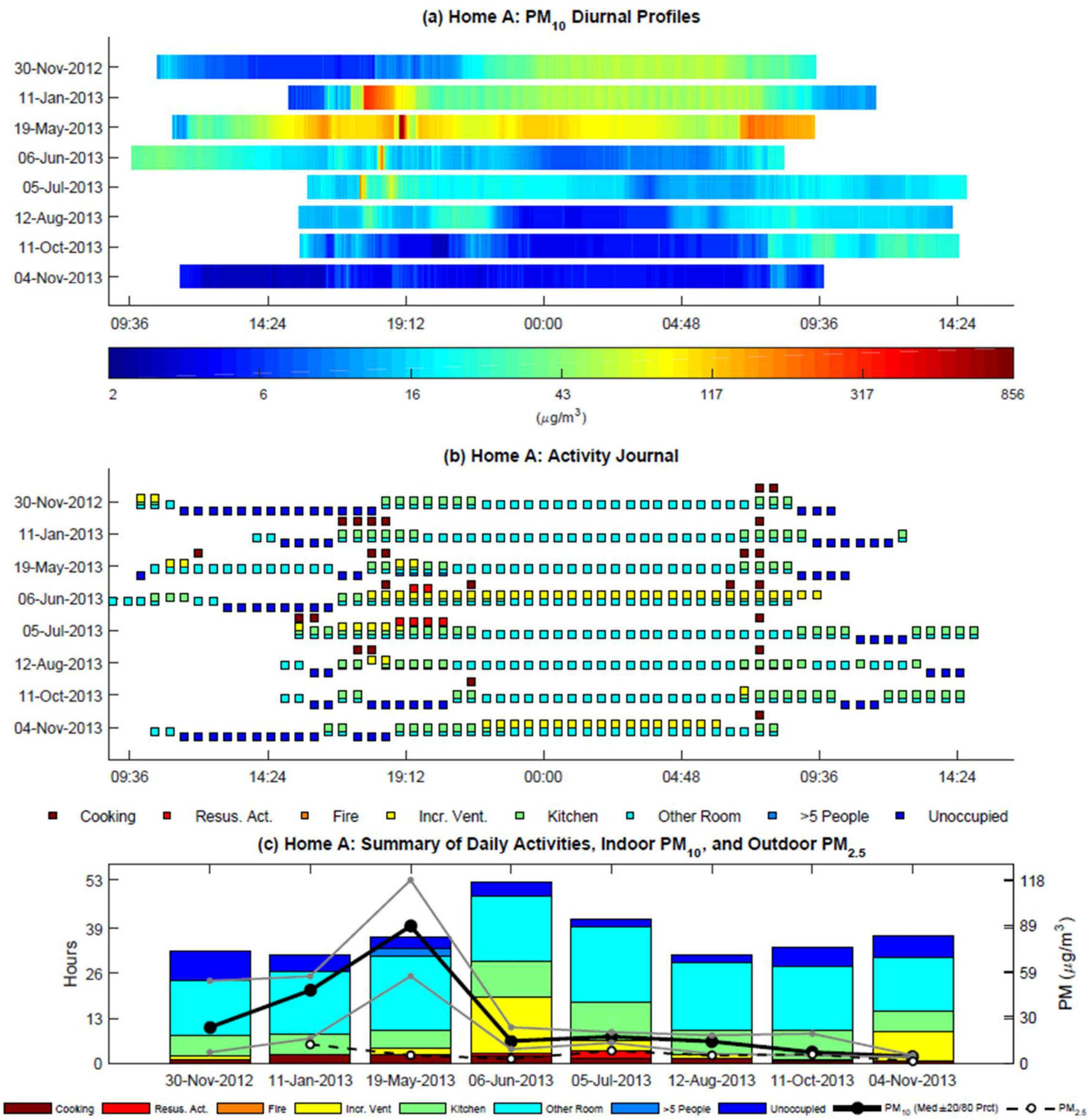

Figure S8. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home A.

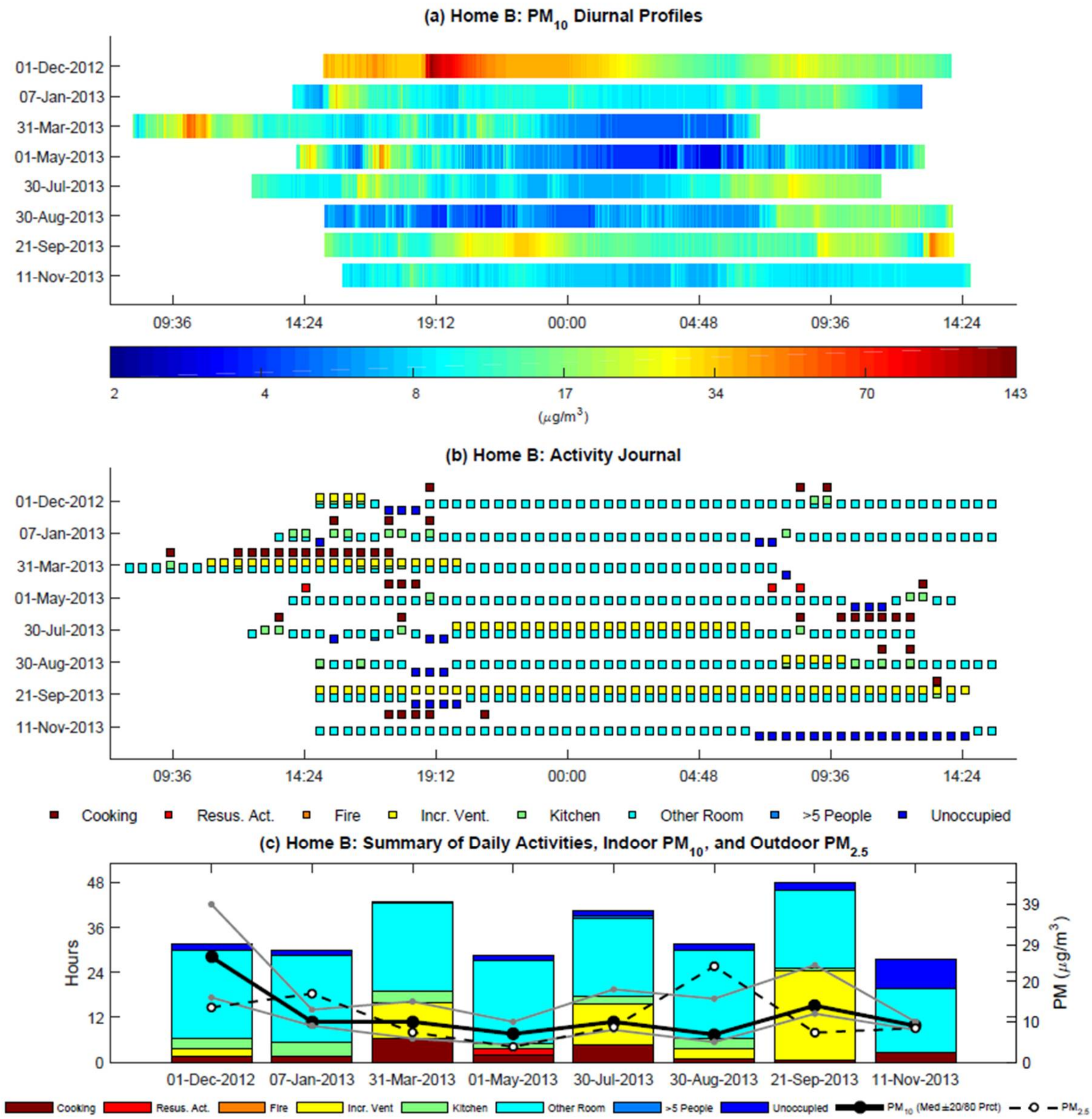

Figure S9. (a) Indoor PM10 diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM10, and outdoor PM2.5 concentrations for Home B.

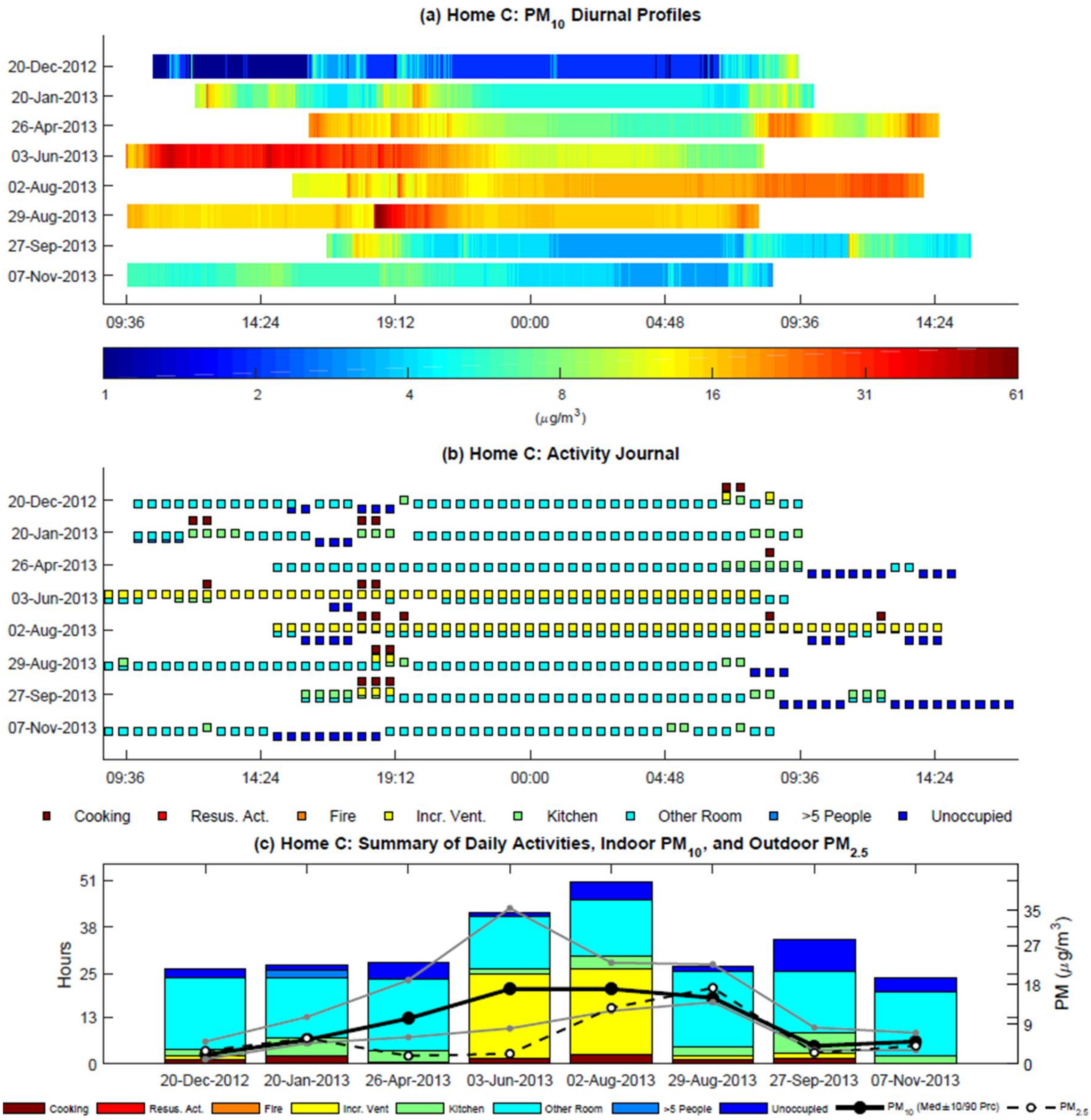

Figure S10. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home C.

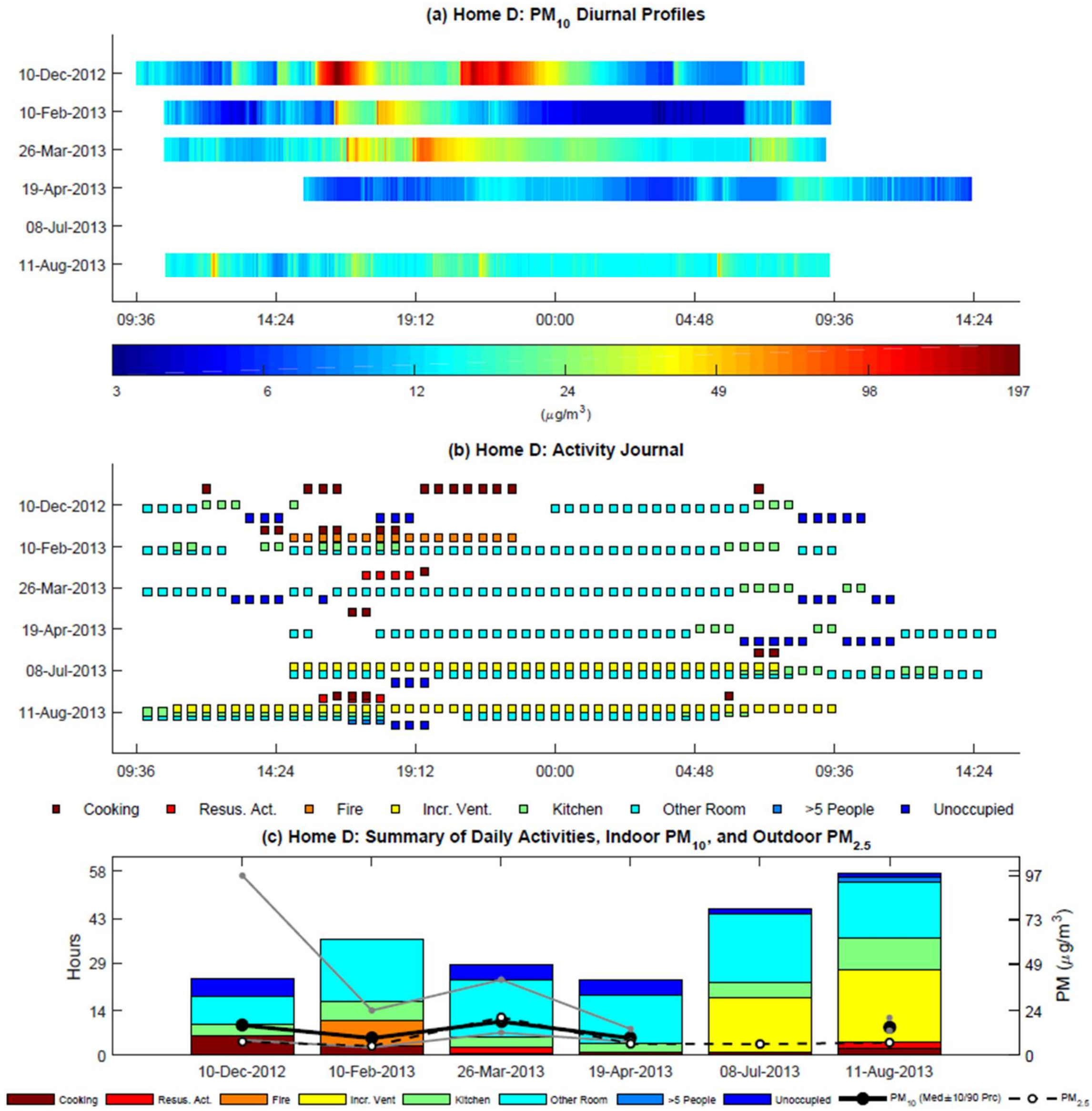

Figure S11. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home D.

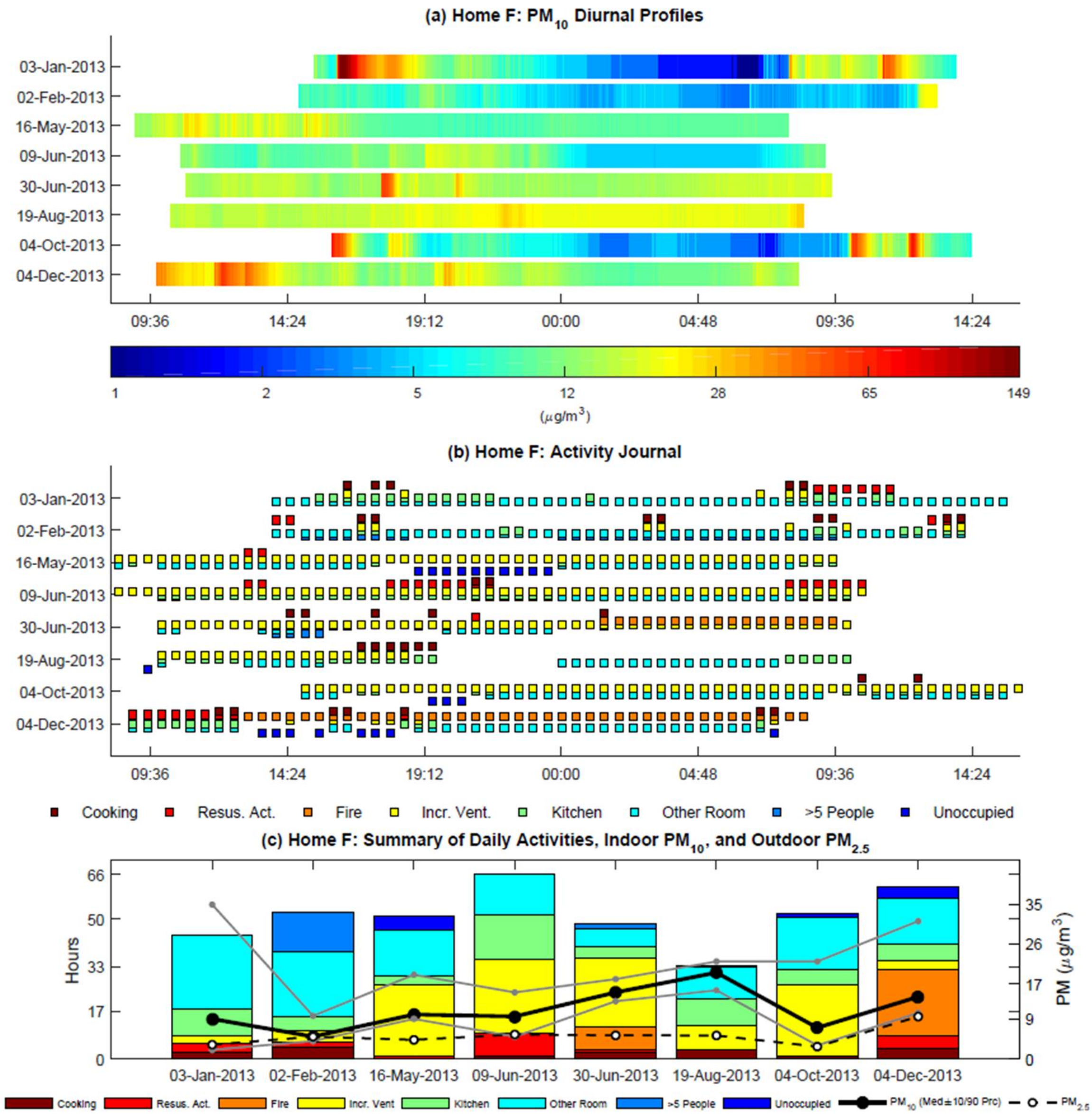

Figure S12. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home F.

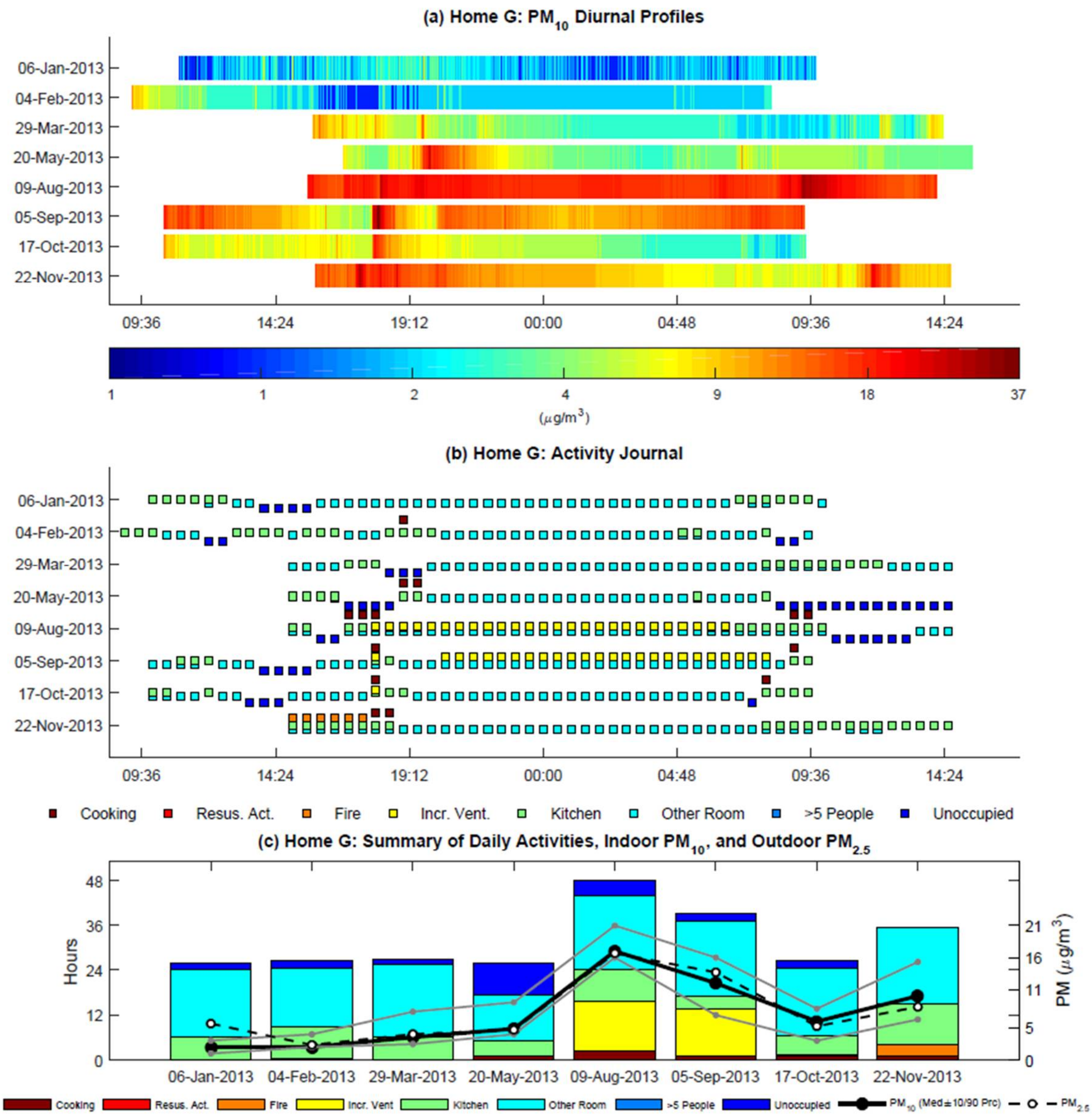

Figure S13. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home G.

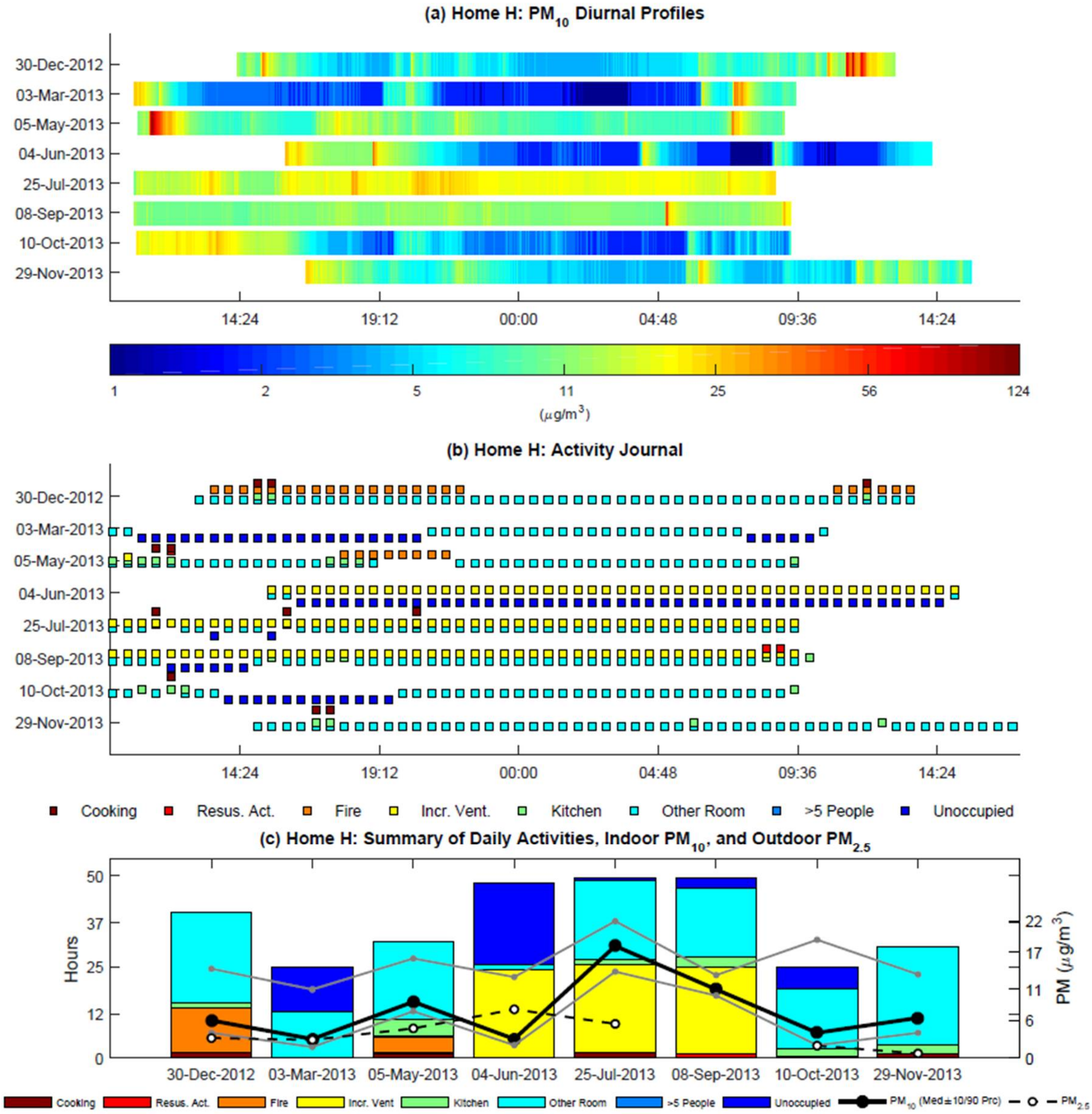

Figure S14. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home H.

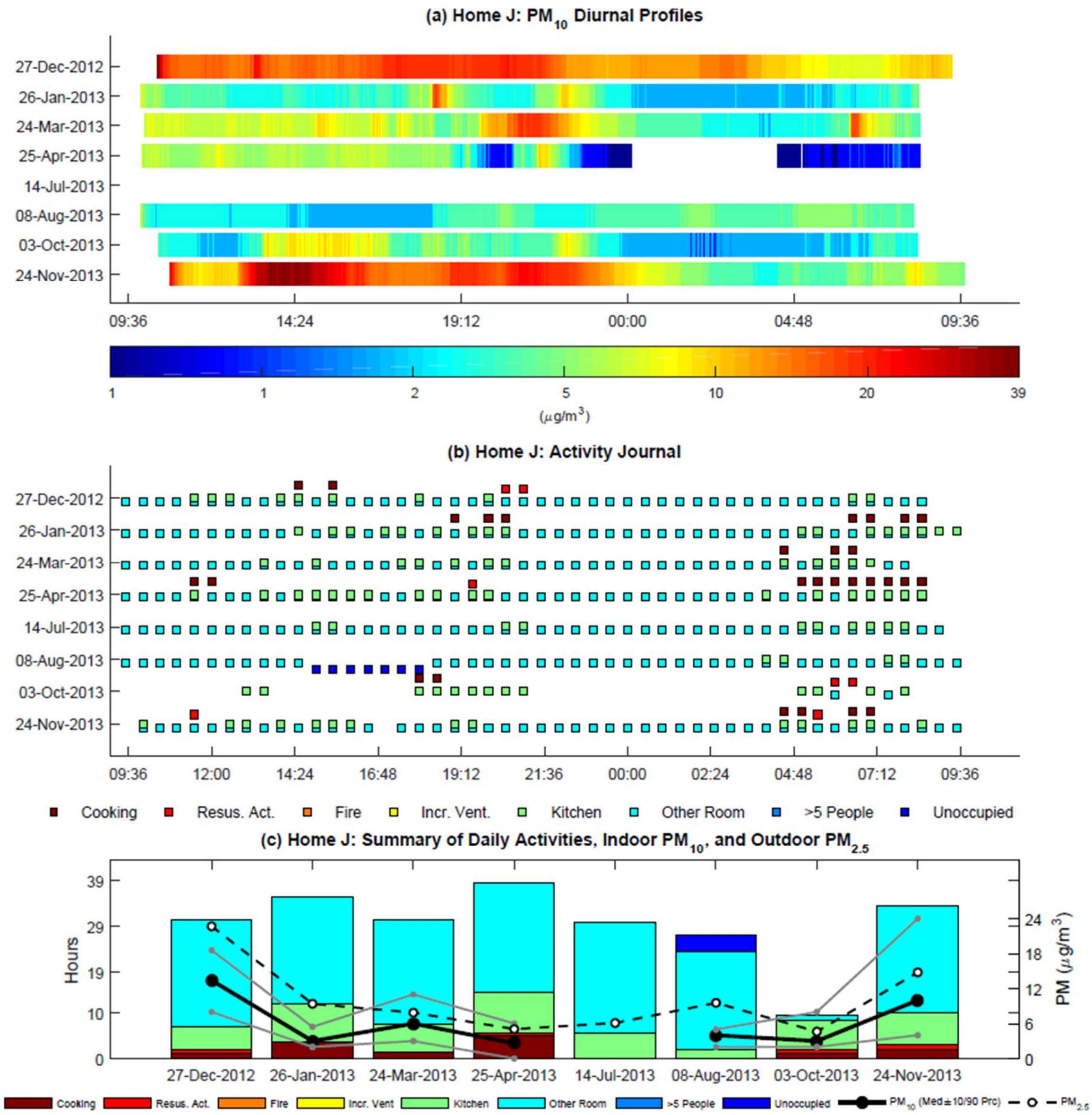

Figure S15. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home J.

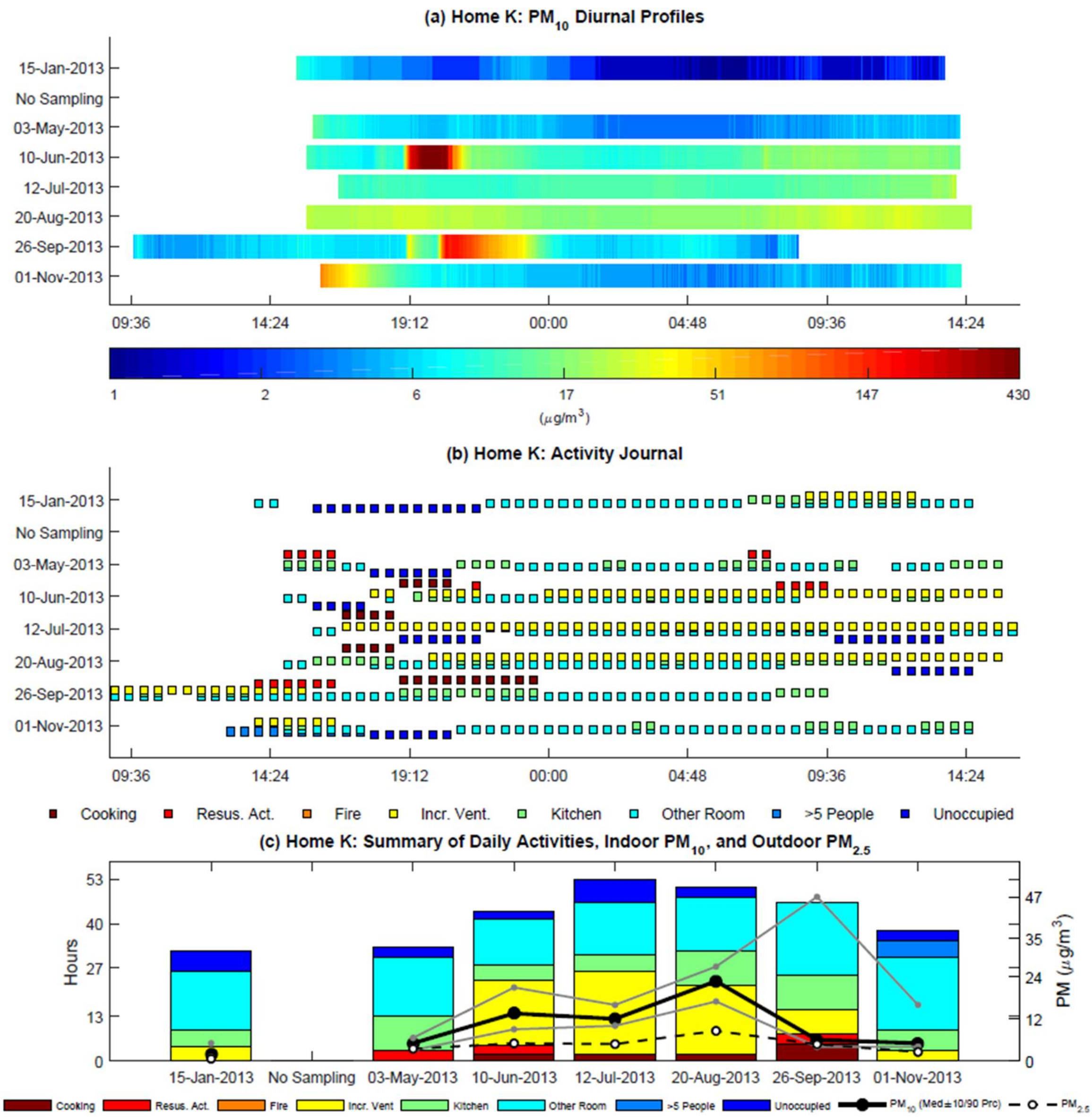

Figure S16. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home K.

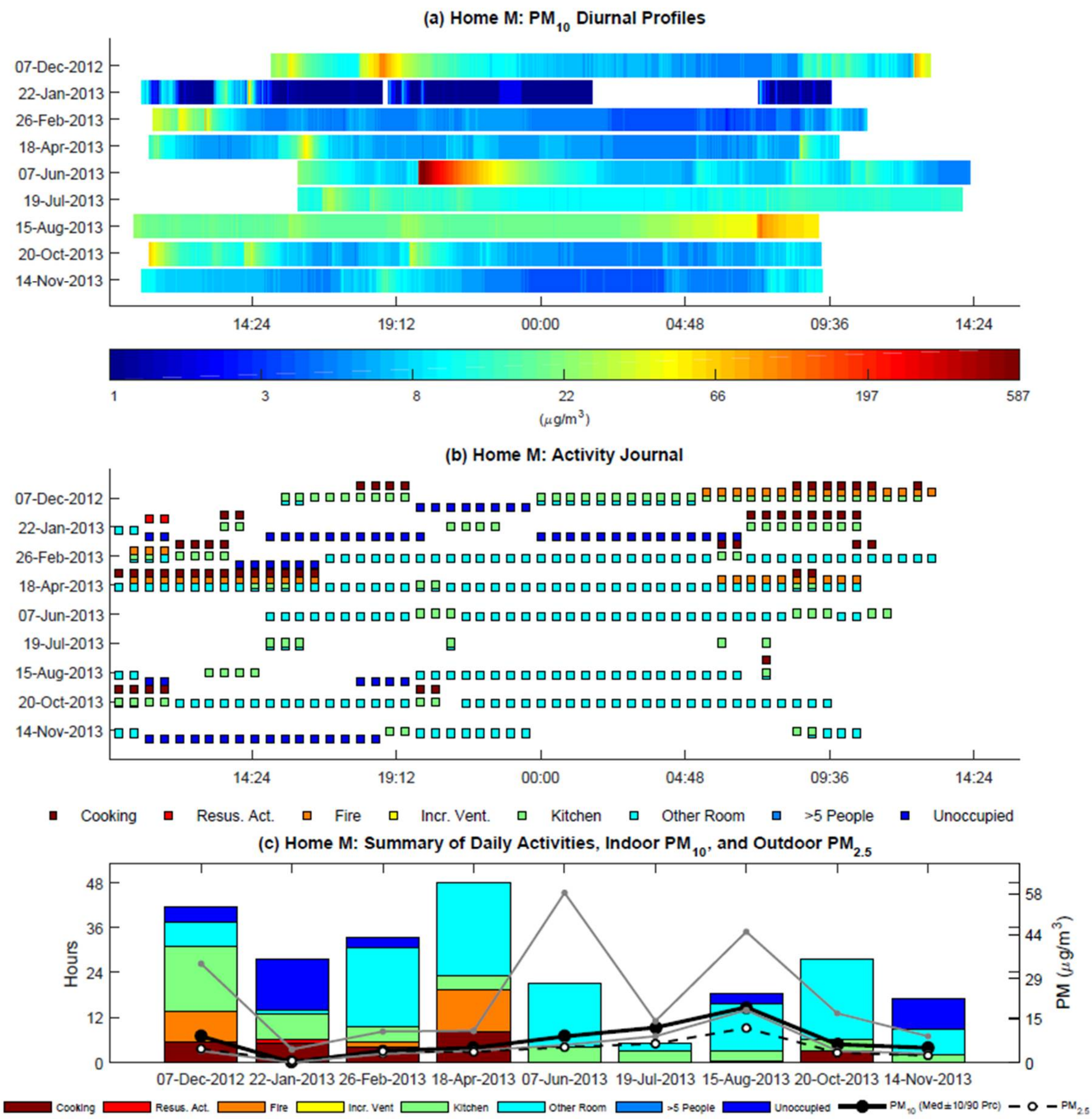

Figure S17. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home M.

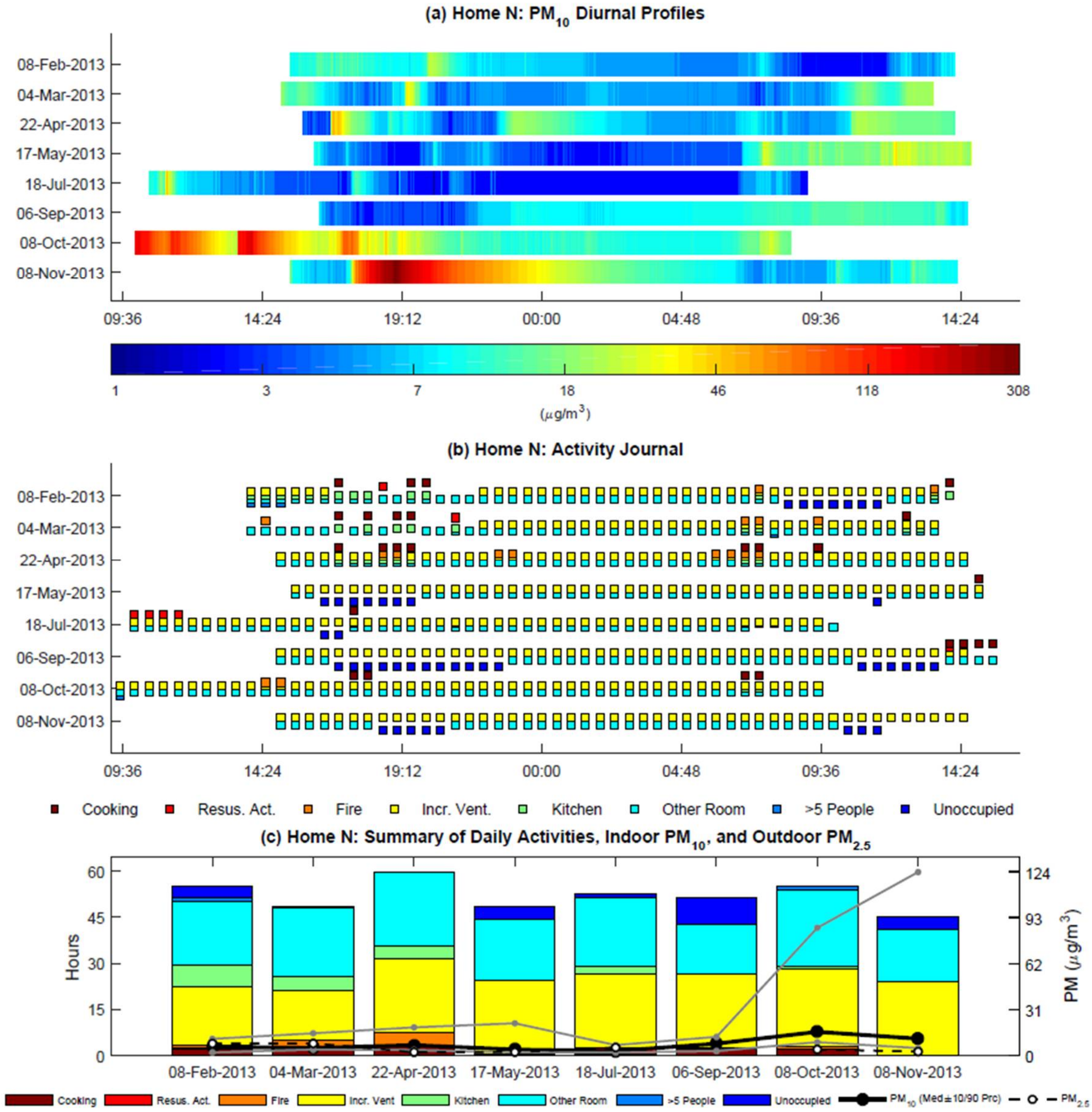

Figure S18. (a) Indoor PM10 diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM10, and outdoor PM2.5 concentrations for Home N.

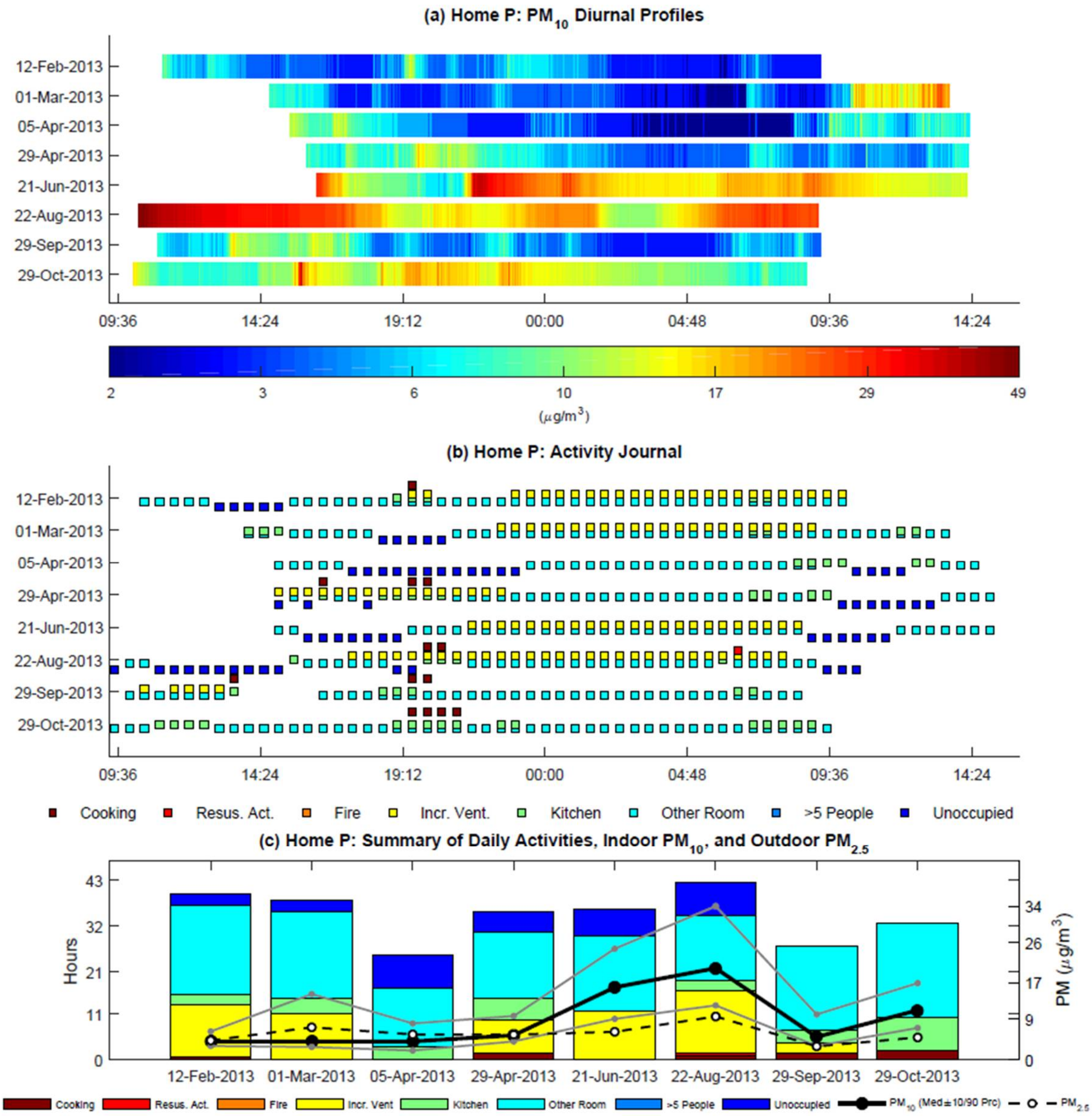

Figure S19. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home P.

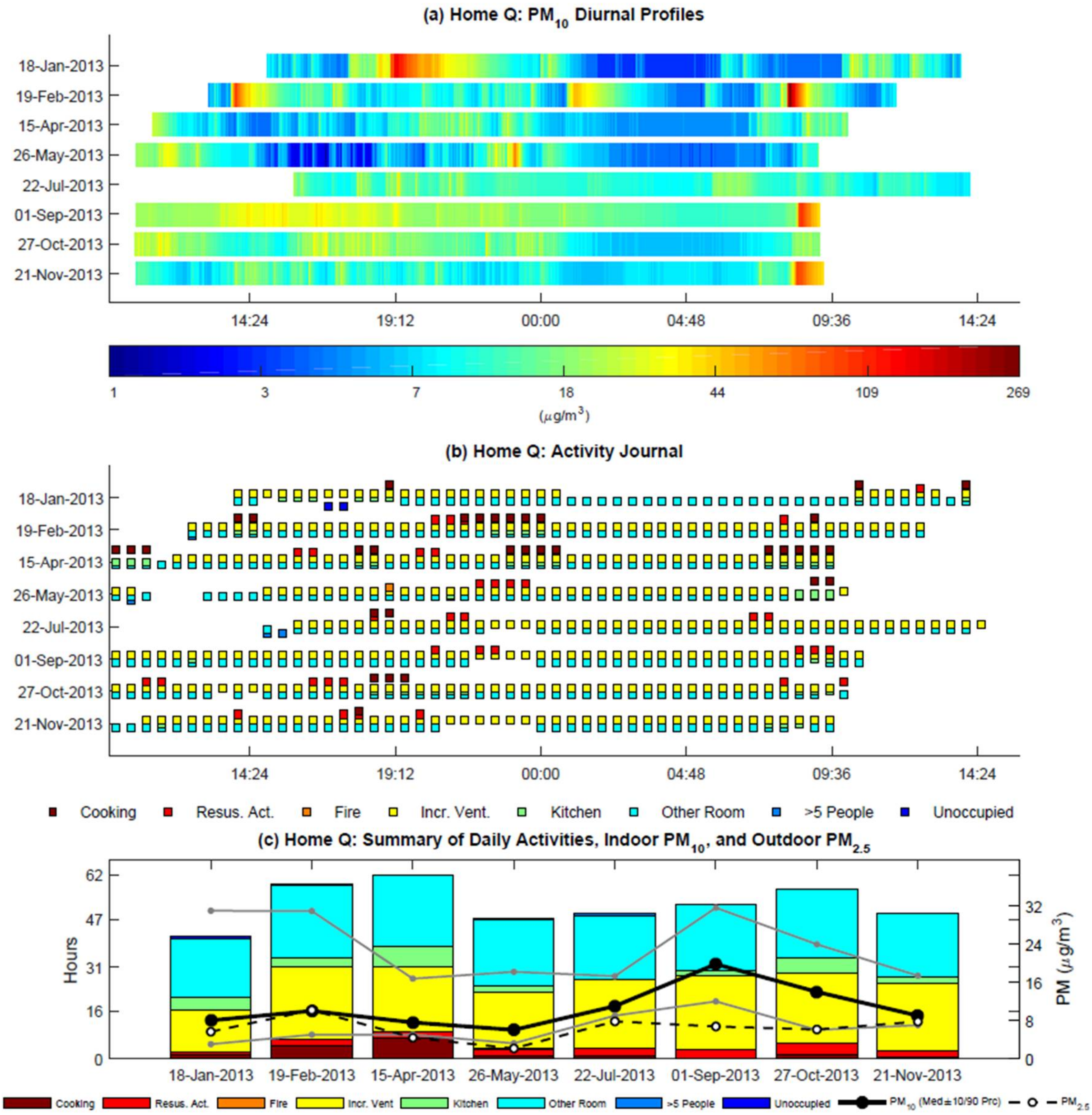

Figure S20. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home Q.

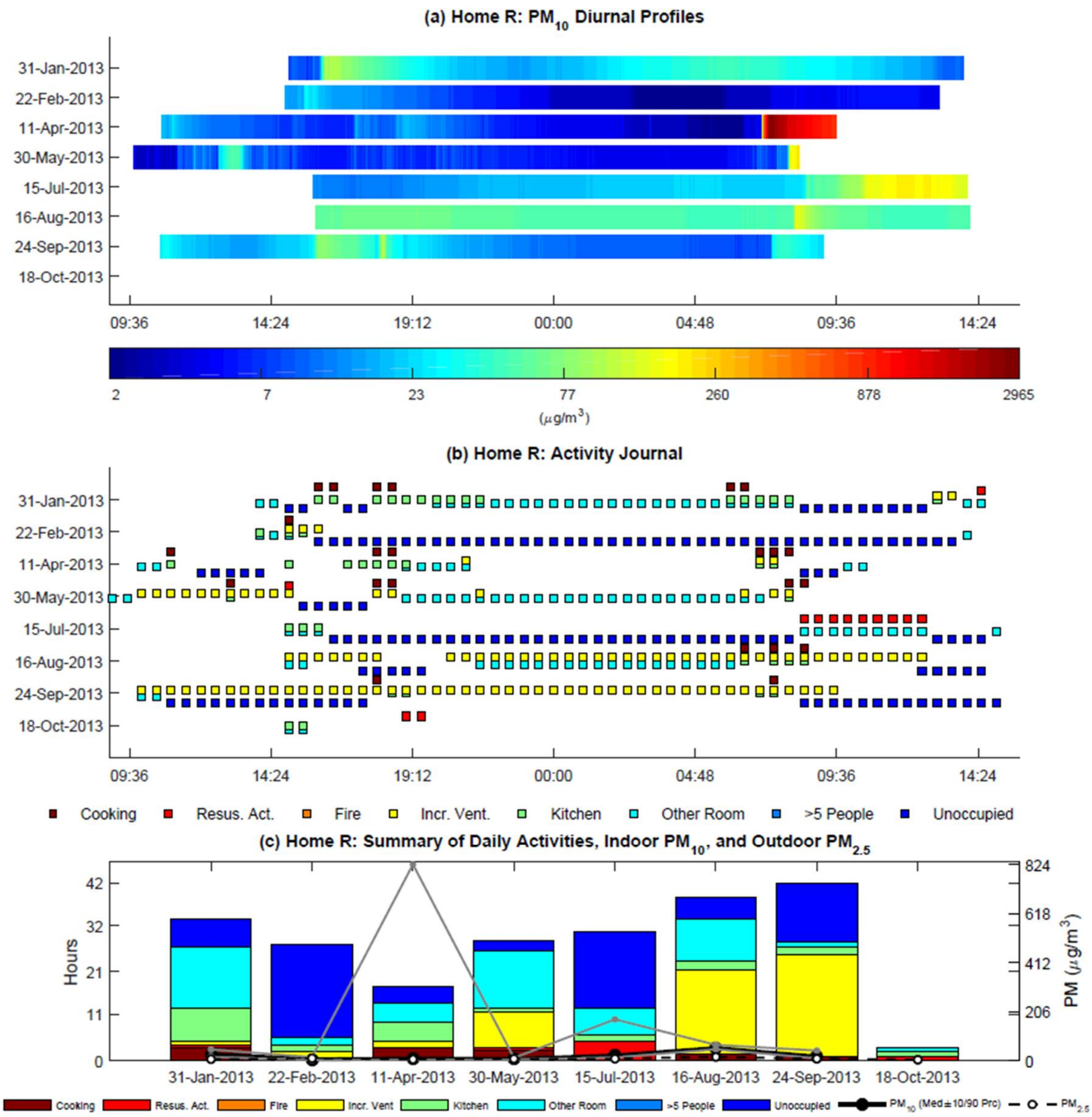

Figure S21. (a) Indoor PM_{10} diurnal profiles, (b) activity journal on half-hour intervals, and (c) summed activity-hours per day, indoor PM_{10}, and outdoor $PM_{2.5}$ concentrations for Home R.