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Analysis of Stack Temperature Data to Identify Real-Life Use Pattern of Wood Burning Devices

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NESCAUM

Using wood and wood waste in the U.S.

- Wood is used in homes throughout the United States for heating as cord wood in fireplaces and wood-burning appliances, and as pellets in pellet stoves.

- In 2017, wood energy accounted for about 2% of total residential energy consumption, 16% of which consumed in the residential sector

- In 2015, about 12.5 million U.S. households, or 11% of all households, used wood as an energy source, mainly for space heating, and

- 3.5 million of those households used wood as the main heating fuel

Source: U.S. Energy Information Administration https://www.eia.gov/energyexplained/index.php?page=biomass_wood

Test Methods of Residential Wood Heaters

ASTM E2779-10 Standard Test Method for Determining Particulate Matter Emissions from Pellet Heaters	**Fueling & Operating Protocol -** This method covers the fueling and operating procedures for determining PM emissions from pellet or other granular or particulate biomass burning room heaters and fireplace inserts. An integrated hot-to-hot (no cold start) test run is conducted including 3 burn rate segments ranging from low to maximum. A separate test run is required for each fuel type specified by the manufacturer. If more than one grade of pellets is listed for the heater, the lowest recommended grade is used as test fuel.

Three burn rate segments

Test Methods of Residential Wood Heaters

EPA Method 28R for Certification and Auditing of Wood Heaters	**Fueling & Operating Protocol** - This method covers the fueling and operating procedures for measuring PM emissions from wood-fired room heaters and fireplace inserts. Four burn rate categories (kg/hr of wood fuel burned) are used to calculate the weighted average emission rate, based on a hot-to-hot (no cold start) test cycle. The method incorporates the provisions of ASTM E2780-10 except that the startup, burn rate categories, low burn rate requirement and weightings of Method 28 must be used. Knowledge of EPA Methods 1, 2, 3, 4, 5, 5G, 5H, 6, 6C and 16A is assumed. ASTM E871-82 may be used as an alternative to the moisture content determination procedures in Method 5H and Method 28 for particulate wood fuel.

Four burn rate categories

Weighting factors used to calculate annual average values

Research Question

- Fueling and operating pattern has great influence on emissions

- Fueling and operating protocol should represent real-life use pattern of the wood heaters

- Different method to quantify real-life use patterns:
  - In situ measurements
  - Assessment of typical real life user behavior by a survey

- What can we learn from stack temperature data about real-life use pattern on wood burning devices?

Methodology

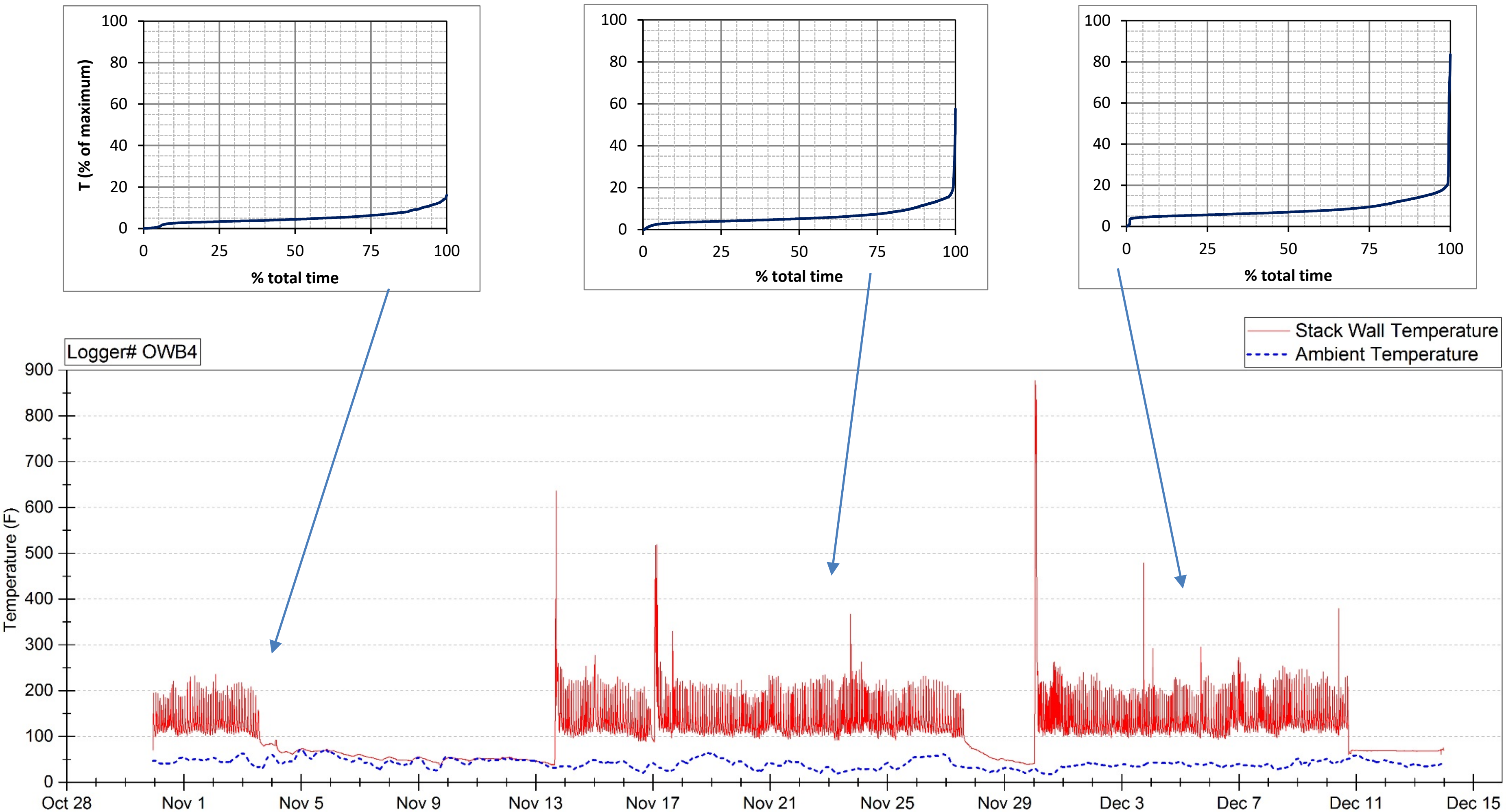
- Stack wall temperature measurement
- Type K thermocouples with ±1°C accuracy
- Four Outdoor Wood Boilers (OWB)
- 11 Indoor Wood Stoves (IWS)
- All in New York State
- Meteorological data was obtained from the nearest station, Massena Airport (WBAN ID: 94725),

Data Logging

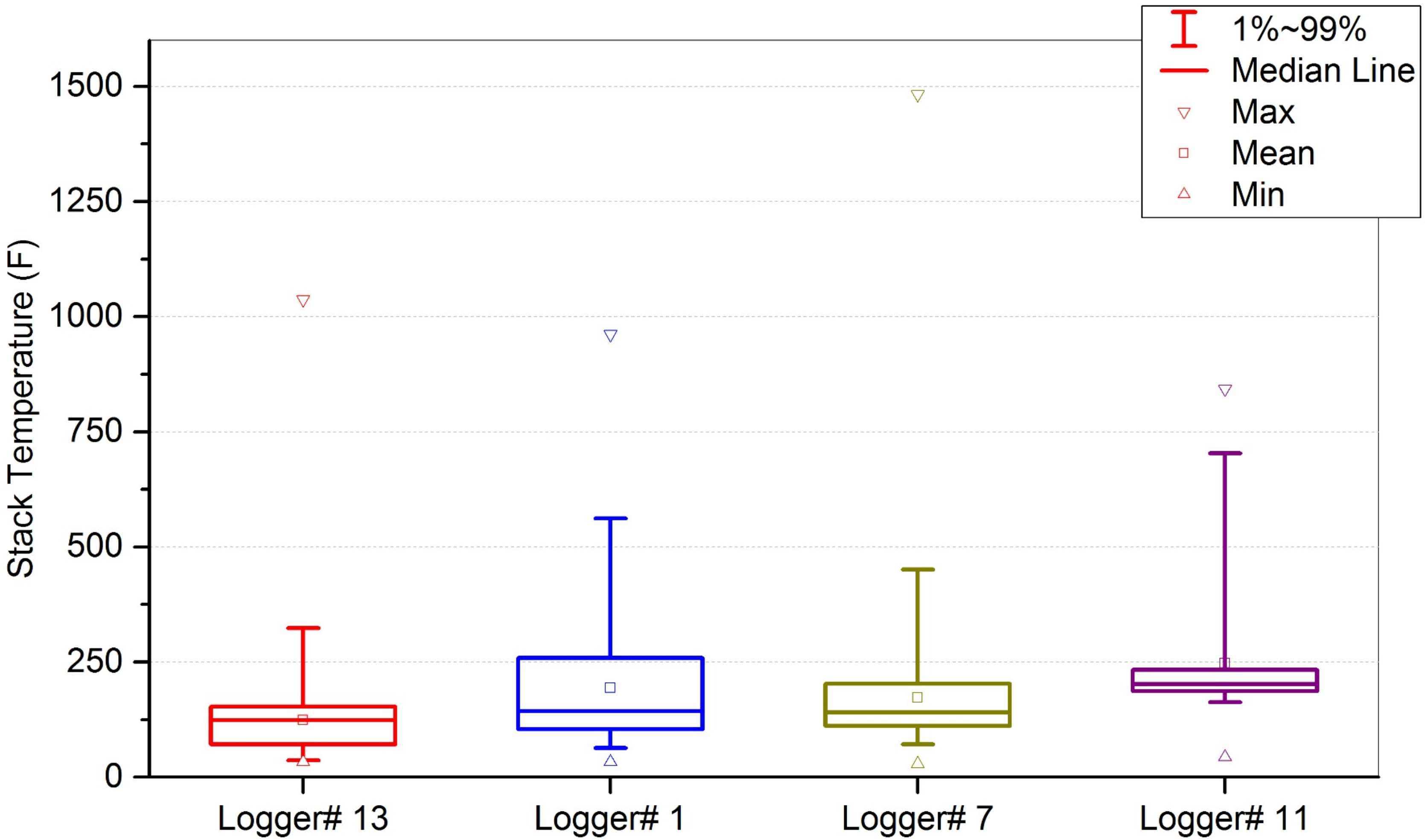
Logger ID	Village/City	Data logging period
OWB1	Potsdam	10-31-15 to 2-14-16
OWB2	Morristown	11-17-15 to 2-13-16
OWB3	Dickinson Center	11-08-15 to 12-11-15
OWB4	Potsdam	10-31-15 to 2-11-16

Logger ID	City/Village	Data logging period
IWS_N1	Canton	1-19-15 to 3-2-15 12-16-15 to 4-7-16
IWS_N2	Potsdam	1-17-15 to 2-16-15
IWS_N3	Potsdam	1-22-15 to 2-27-15
IWS_N4	Canton	1-17-15 to 2-26-15
IWS_N5	Potsdam	1-17-15 to 2-27-15 12-15-15 to 3-22-16
IWS_N6	Hermon	1-14-15 to 2-26-15
IWS_N7	Colton	1-18-15 to 2-26-15
IWS_N8	Potsdam	1-18-15 to 2-26-15 9-17-15 to 4-5-16
IWS_N9	Potsdam	1-17-15 to 2-26-15 12-19-15 to 3-19-16
IWS_N10	Potsdam	1-17-15 to 2-27-15 12-15-15 to 3-22-16
IWS_N11	Ogdensburg	1-17-15 to 2-26-15

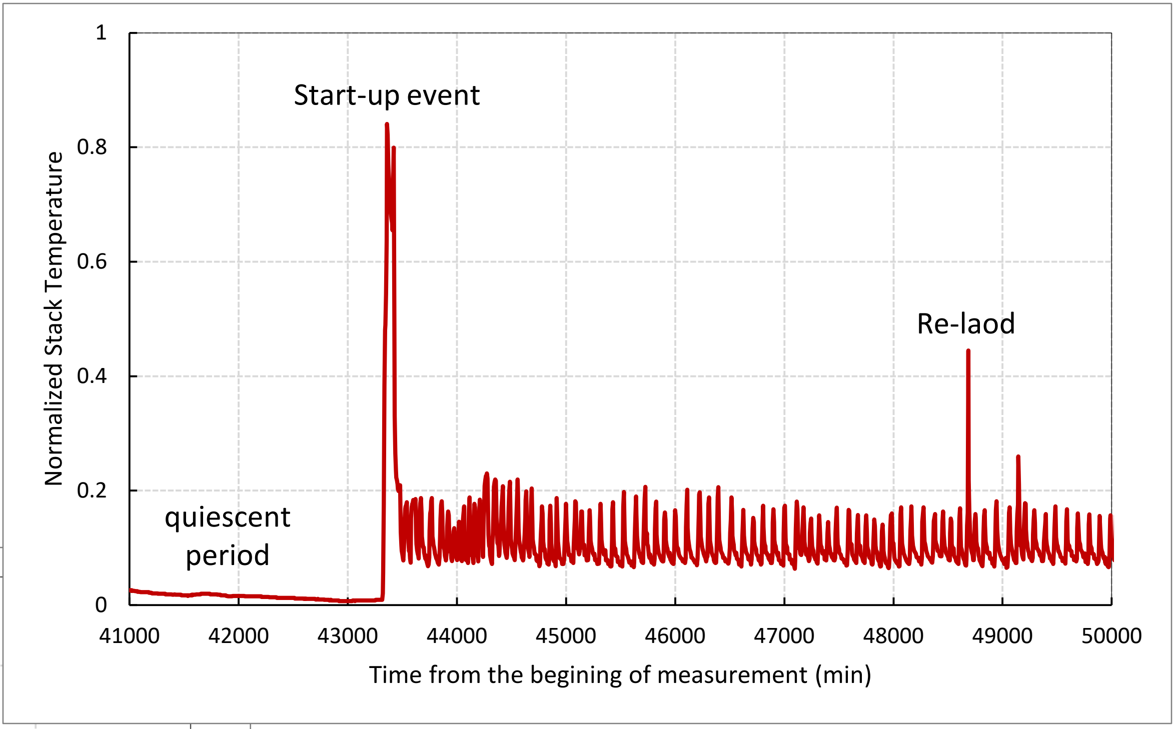
OWB Stack Wall Temperature Time Series

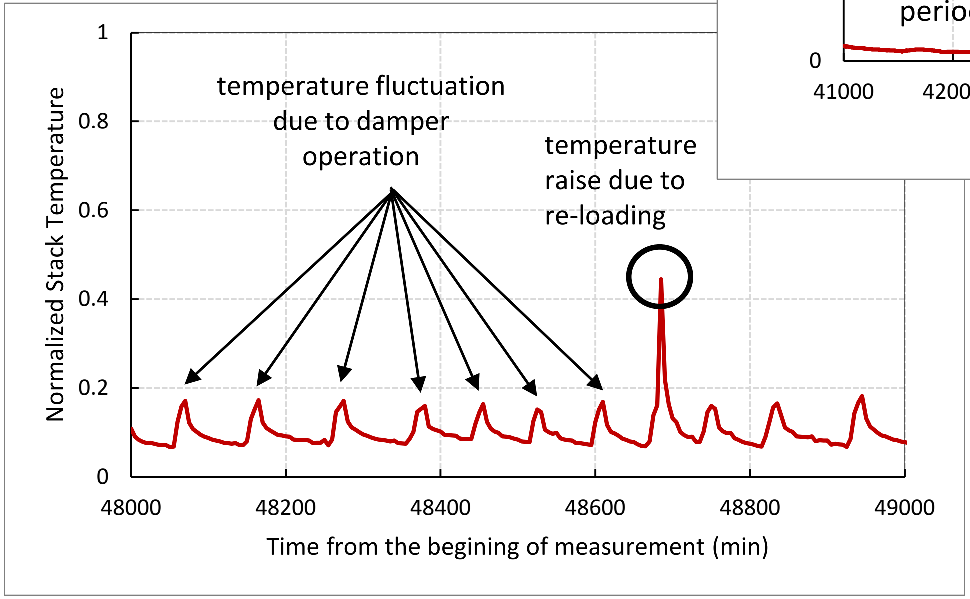


OWB Temperature Range

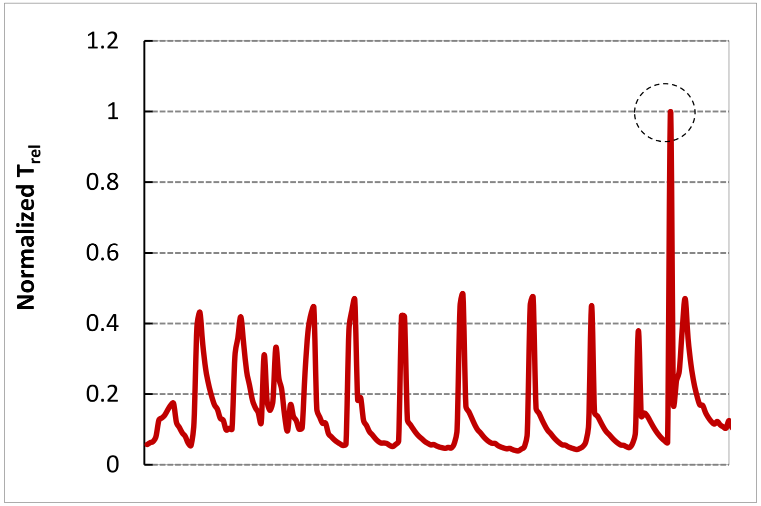


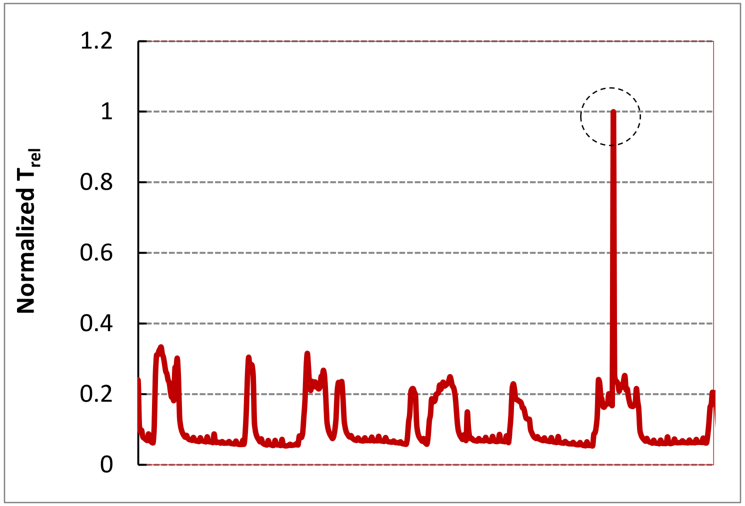
OWB Temperature Profile

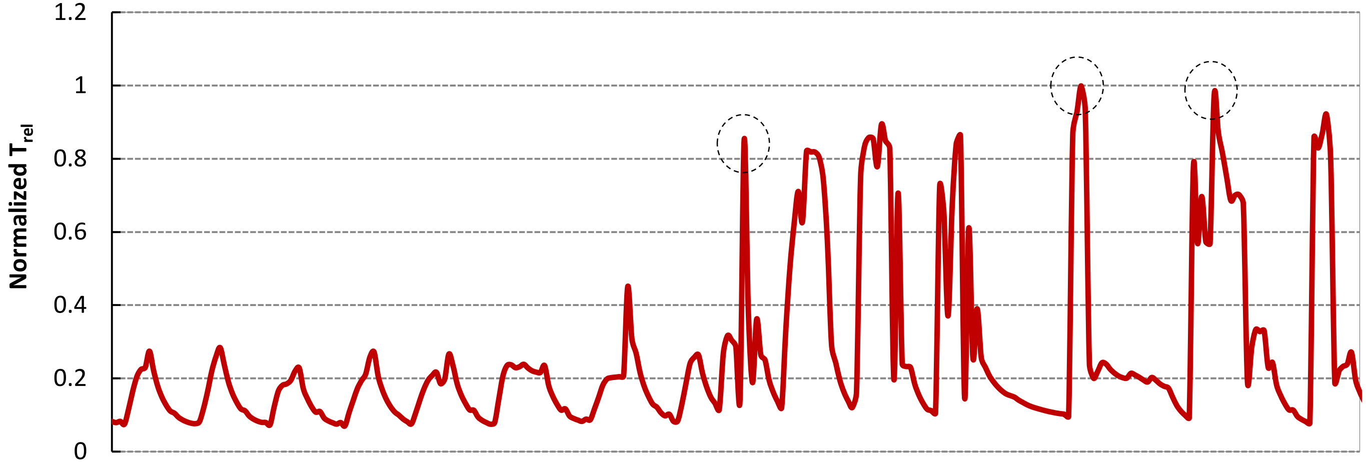




Different Forms of OWB Re-load Events





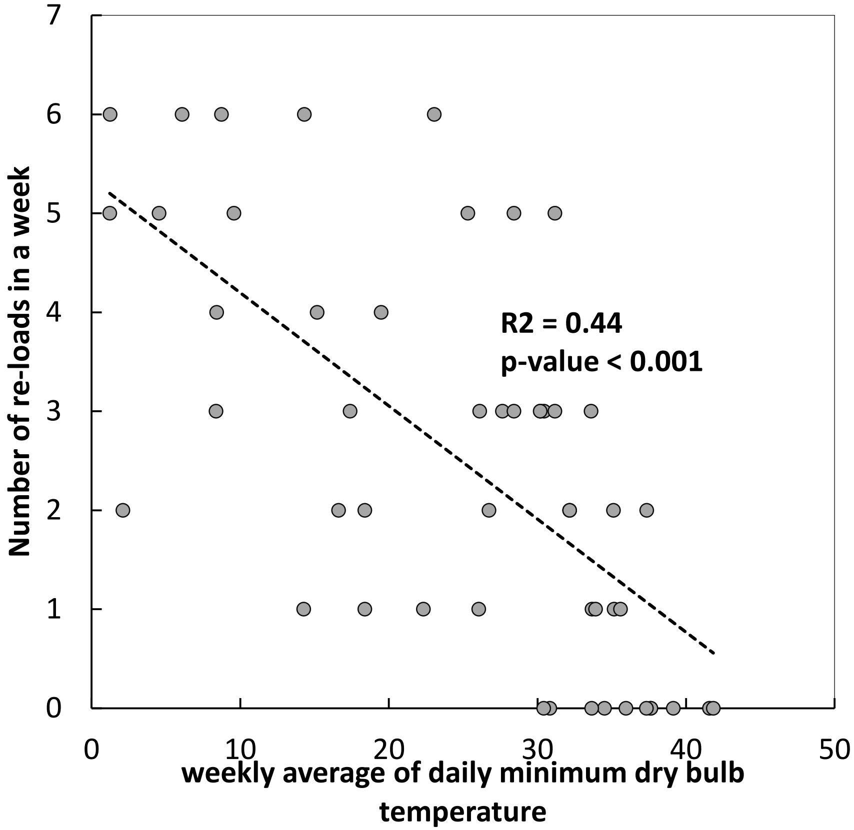


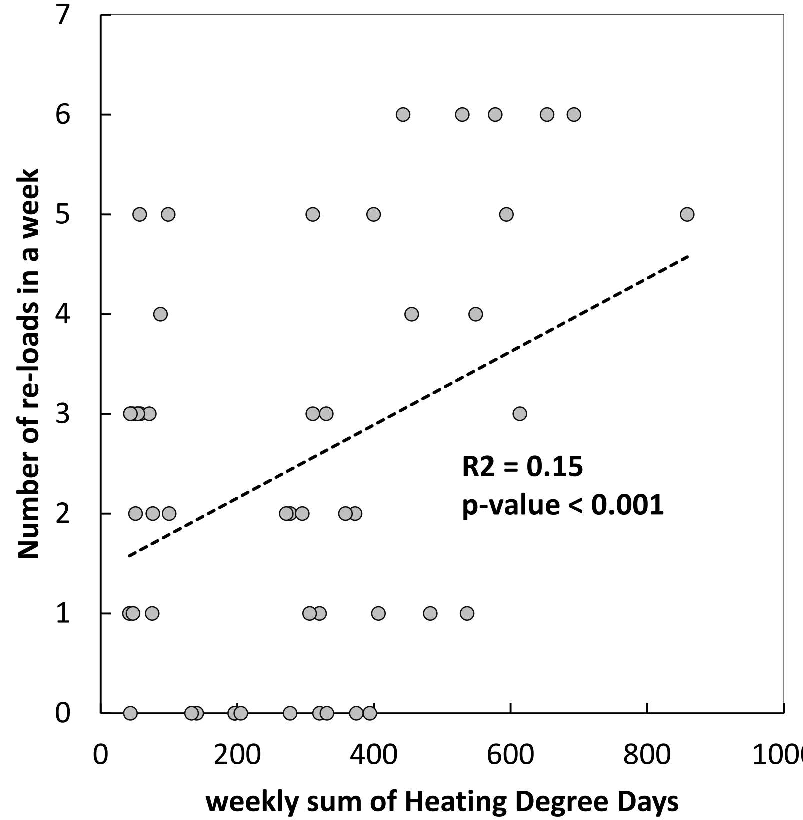
Event Identification Results - OWB

Logger ID	Season	Number of Data Logging Days	% of Time Active	Number of Start-ups	Reload events per week
OWB1	winter	83	0.99	2	3.4
OWB2	fall	45	0.99	1	2.2
OWB2	winter	35	1.00	1	3.2
OWB3	winter	33	0.99	1	3.0
OWB4	fall	62	0.50	4	1.0
OWB4	winter	42	0.95	2	4.7

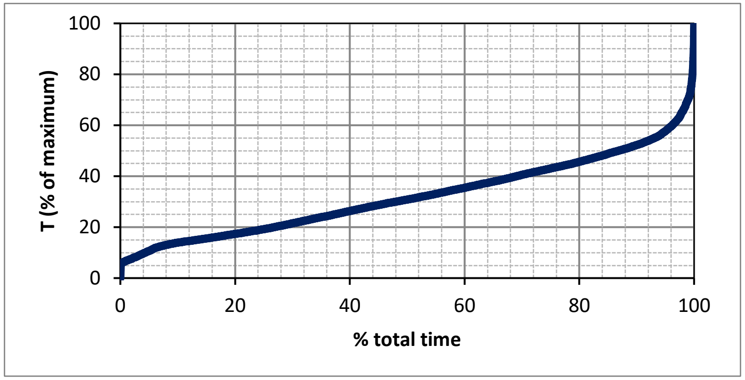
		weekly sum of the Heating Degree Days		**Weekly average of daily minimum dry bulb temperature**	
Logger ID	Number of data points	Pearson Correlation Coefficient	p-value	Pearson Correlation Coefficient	p-value
OWB1	14	-0.82	<0.001	0.75	0.0019
OWB2	12	-0.50	0.01	0.47	0.012
OWB3	5	-0.83	0.071	0.67	0.097
OWB4	20	-0.71	<0.001	0.64	0.0026

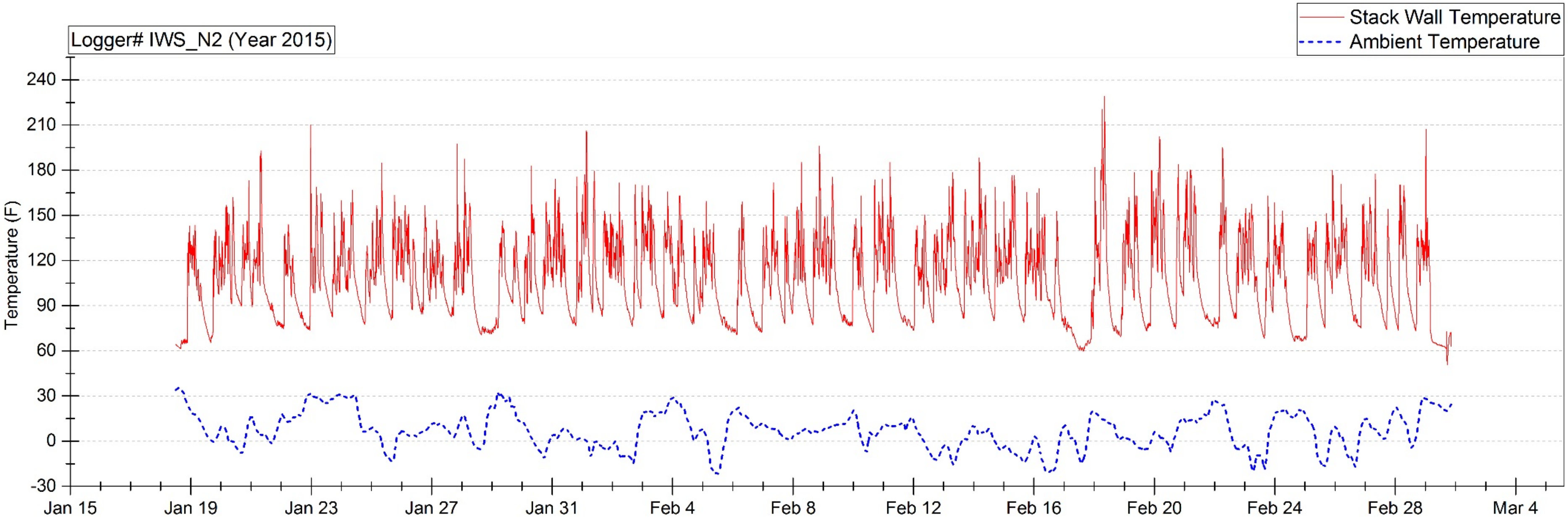
Correlation Between Environmental Parameters and Number of OWB Reload Events



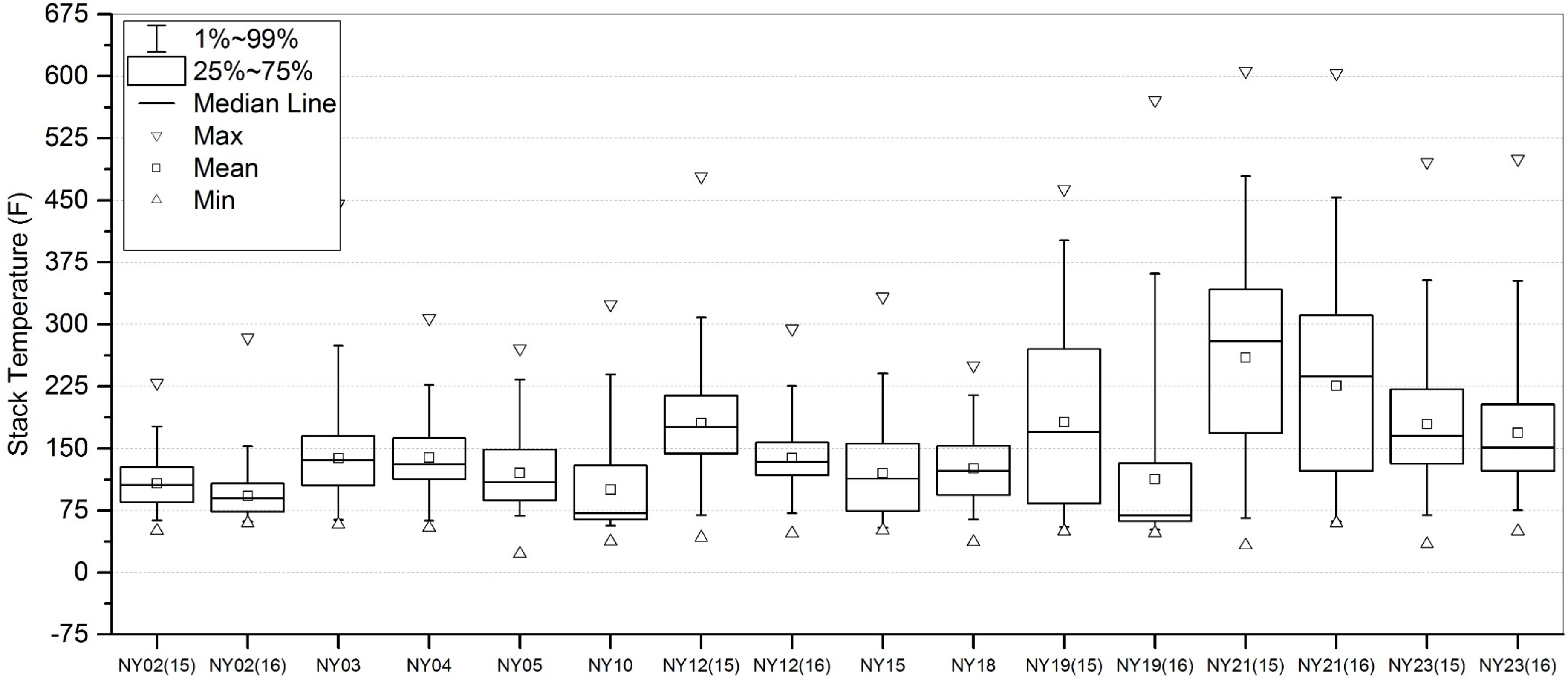


IWS Stack Wall Temperature Time Series

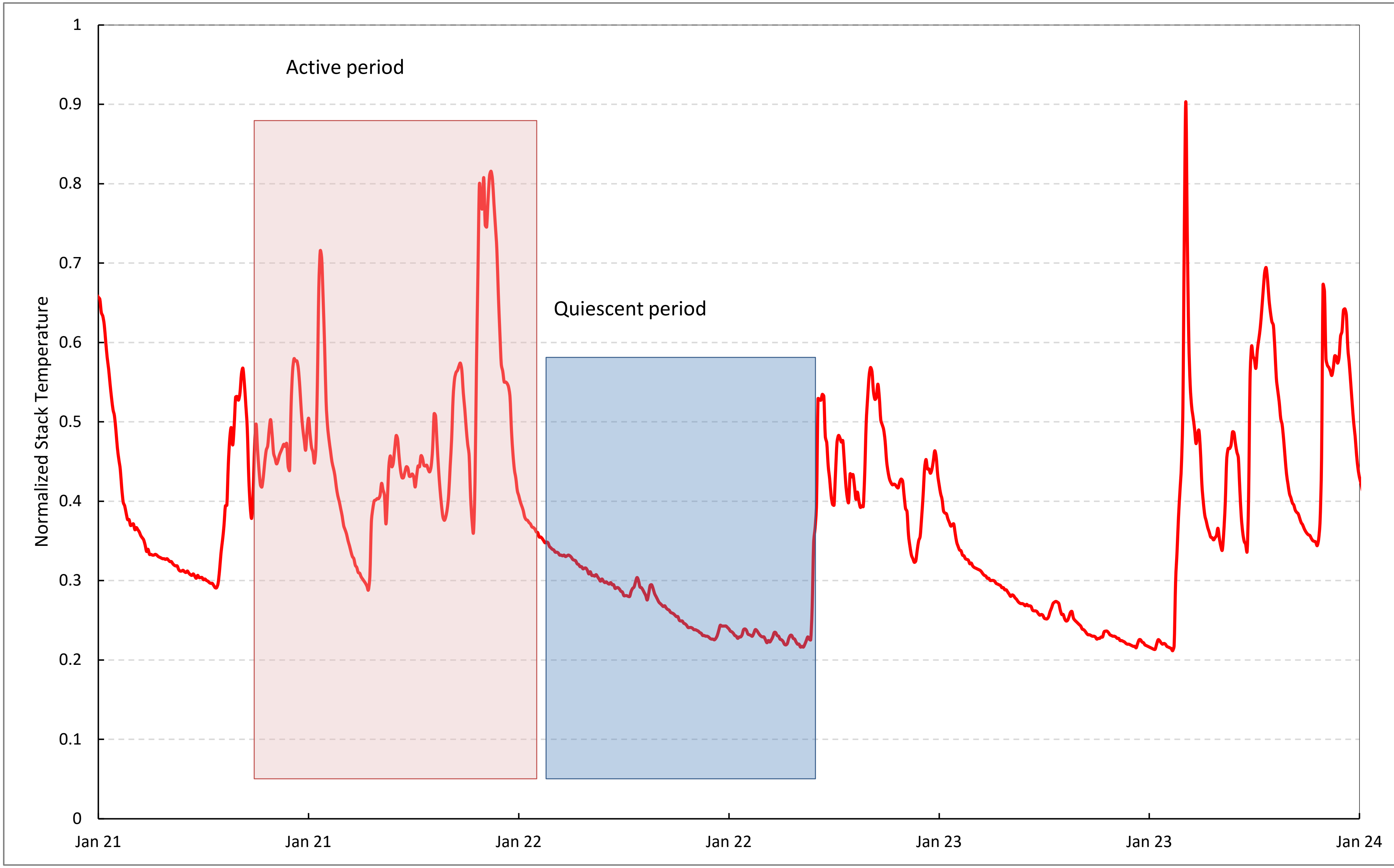




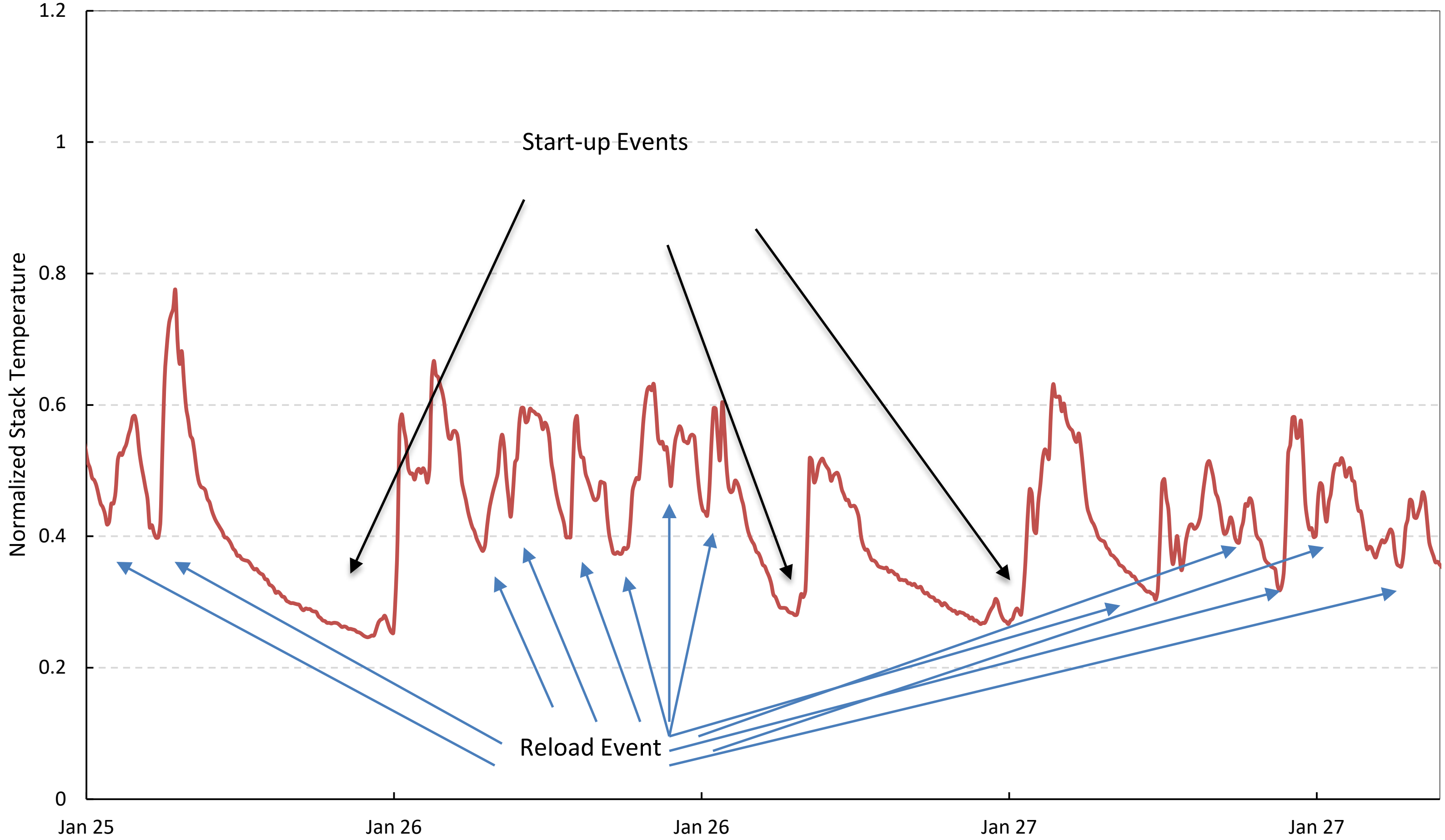
IWS Temperature Range



IWS Re-load Events



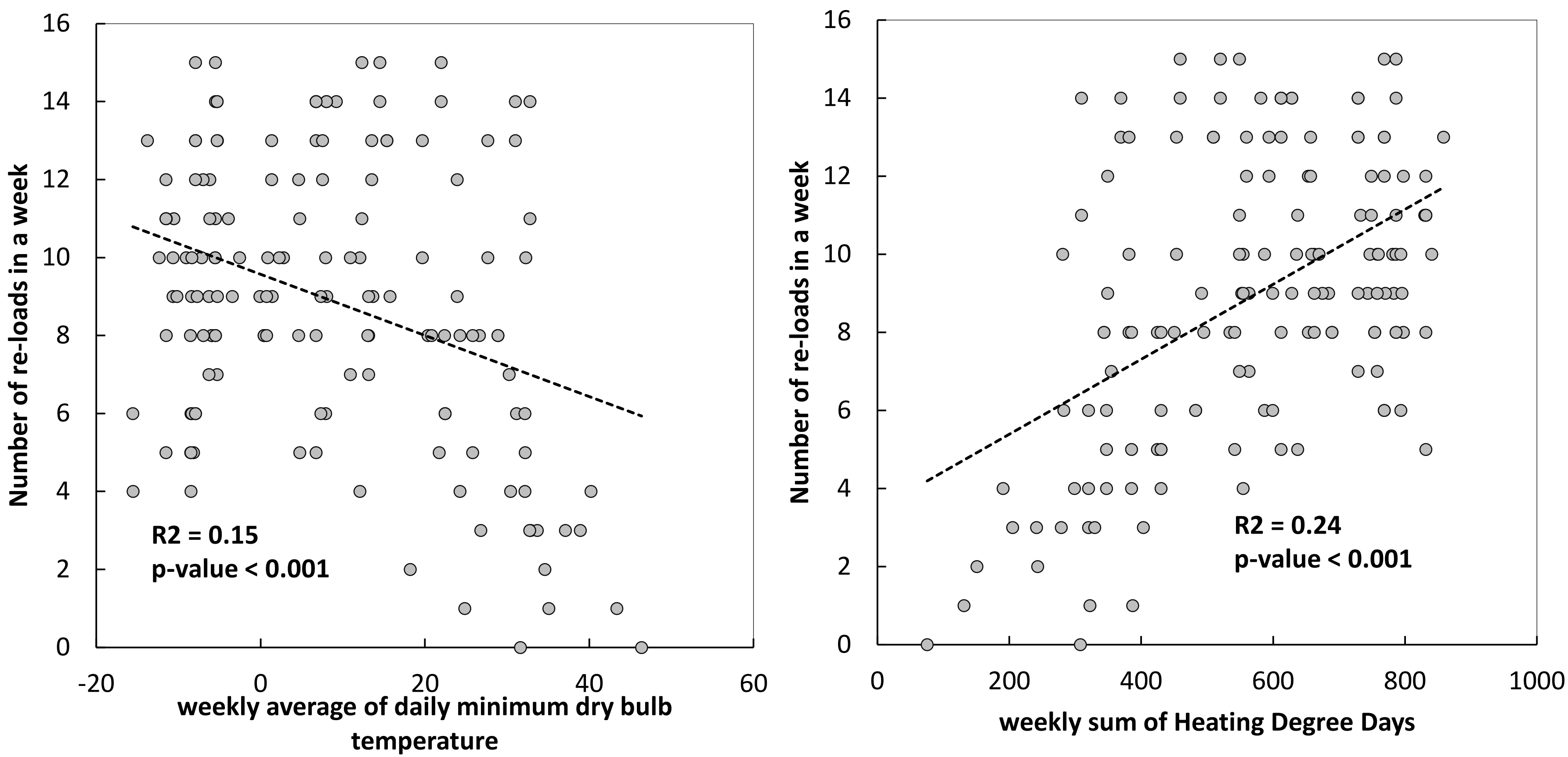
IWS Start-up and Re-load Events



Event Identification Results - OWB

Logger ID	Year	Season	Active	Inactive	Reload events per-day
IWS_N1	2015	winter	54%	46%	1.5
IWS_N1 (16)	2016	fall	39%	61%	0.9
IWS_N1 (16)	2016	winter	54%	46%	1.2
IWS_N2	2016	winter	56%	44%	1.8
IWS_N3	2016	winter	54%	46%	1.5
IWS_N4	2016	winter	51%	49%	0.9
IWS_N5	2015	winter	64%	36%	1.7
IWS_N5	2016	fall	72%	28%	1.7
IWS_N5	2016	winter	56%	44%	1.8
IWS_N6	2016	winter	56%	44%	1.3
IWS_N7	2016	winter	54%	46%	1.5
IWS_N8	2015	winter	52%	48%	1.0
IWS_N8	2016	fall	27%	73%	0.3
IWS_N8	2016	winter	76%	24%	1.1
IWS_N9	2015	winter	57%	43%	1.1
IWS_N9	2016	fall	53%	47%	0.8
IWS_N9	2016	winter	54%	46%	1.2
IWS_N10	2015	winter	62%	38%	1.8
IWS_N10	2016	fall	49%	51%	2.0
IWS_N10	2016	winter	62%	38%	1.9
IWS_N11	2016	winter	57%	43%	1.9

Correlation Between Environmental Parameters and Number of IWS Reloads



Summary

- Stack temperature is representative of changes in combustion modes inside the unit, and therefore can be used to understand variations in emission rates.
- In this study, we developed two numerical algorithms to analyze stack wall temperature time series of 4 OWB and 11 IWS units over two fall and winter seasons.
- Events such as re-load and start-up were defined and identified in the data.
- Relationship between the frequency of reload events and environmental factors were examined (weekly average of daily minimum dry bulb temperature and weekly sum of the heating degree days)
- The developed algorithms are useful for identification and classification of combustion events in boilers and stoves.
- The results of this study can be used to design better test procedures that are more representative of typical in-use wood burning device operation.

Acknowledgments

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THANK YOU

Questions?

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