IBHS Roof Aging Program

2016 Data, Climate, and Roof Condition Summary

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Executive Summary

In 2013, the Insurance Institute for Business & Home Safety (IBHS) began a long-term roof aging program. This measurement and testing program seeks to understand and report how the wind, impact, and fire performance of various roof cover materials change with age and exposure to the natural environment.

This document, which is the third in a series of annual reports, provides:

- A brief description of the program, which currently includes asphalt shingle products at three project sites.
- Summary tables of maximum and minimum shingle temperatures experienced by roof specimens in 2016.
- Summary of the accumulated time spent above specific temperature thresholds during 2016.
- Weather observations from each site in 2016 and comparisons of them to climate averages.
- Notable weather events that occurred at the three sites during 2016.
- Summary of visual inspections of all specimens.

1. Program Description

The IBHS roof aging program collects data on the conditions that asphalt shingles experience in the natural environment and seeks to relate those data to product performance. The program currently has a total of 76 roofs at three different locations, as outlined in Tables 1-1 and 1-2. The first set of roofs was installed at the IBHS Research Center in 2013, and additional roofs were installed in 2014 at IBHS and partner locations in Madison, Wisconsin, and Amelia, Ohio. In 2015, another set of roofs was installed at IBHS. Roofs will be tested at four-year intervals beginning in 2018, such that performance differences can be evaluated for 4-, 8-, 12-, and 16-year exposures. Roof temperature data (Figure 1-1), and meteorological data such as the environmental temperature, humidity, precipitation, and solar radiation are collected. Each roof is also inspected on an annual basis to determine if there are any changes in appearance or condition.

Table 1-1. Types of products currently deployed on the IBHS roof aging farm site.

Specimen Identification	Product Class
2013-IBHS-A	Architectural
2013-IBHS-B	Polymer Modified Impact Resistant Architectural
2013-IBHS-C	Architectural
2013-IBHS-D	Architectural
2013-IBHS-E	3-Tab
2013-IBHS-F	3-Tab
2014-IBHS-A	Polymer Modified Impact Resistant Architectural
2014-IBHS-B	Traditional Impact Resistant Architectural
2014-IBHS-C	Traditional Impact Resistant Architectural
2015-IBHS-A	Architectural
2015-IBHS-B	Architectural
2015-IBHS-C	Traditional Impact Resistant Architectural
2015-IBHS-D	3-Tab
2015-IBHS-E	Traditional Impact Resistant Architectural
2015-IBHS-F	Polymer Modified Impact Resistant Architectural

Table 1-2. Types of products currently deployed on the Madison and Amelia roof aging farm sites. The matching specimens on the IBHS aging farm site are the A–D products installed in 2013.

Specimen Identification	IBHS Match	Product Class
2014-AmFam-A	2013-IBHS-A	Architectural
2014-AmFam-B	2013-IBHS-B	Polymer Modified Impact Resistant Architectural
2014-AmFam-C	2013-IBHS-C	Architectural
2014-AmMod-D	2013-IBHS-D	Architectural

Figure 1-1. Diagram of a roof specimen showing temperature probe measurement locations. Note that for specimens at the Madison, Wisconsin, and Amelia, Ohio, sites, temperature probes are located on the center panel of each roof face only.

All roofs included in this program are identical in construction, oriented in the same direction (north-south exposure), and similar in color. The variables—including product type, length of exposure, and climate—will be examined to understand how they contribute to performance differences.

For additional information on the roof specimen construction and instrumentation, please see the 2014 and 2015 data and climate summaries (IBHS Roof Aging Farms: 2014 Measurement Summary; IBHS Roof Aging Program: Data and Condition Summary for 2015).

2. Data

The data collected on the 16-year specimens from each of the three roof aging farm sites were used to produce summary statistics for yearly maximum and minimum temperature for each roof face; total hours above specified temperature thresholds; and number of temperature fluctuation events experienced during the year. For maximum and minimum temperatures, the values represent the observation from the center panel shingle thermocouple sensor on the north and south roof faces for all three sites. A spatial average across each roof face was used for the IBHS specimens and the accumulated hours above different temperature thresholds to show approximate time that the entire roof face was above the specified thresholds. In February, the hard-drive on the IBHS roof farm data acquisition failed, leading to a data outage for a large portion of February. A lightning strike at the IBHS Research Center campus on the evening of August 2, 2016 caused extensive electrical damage to the aging farm data acquisition infrastructure. The failure of several internal instrument components within the data collection system resulted in intermittent data for some specimens during August and September. Hardware repairs were completed, and data flow was restored by September 20, 2016. No physical damage resulting from the lightning strike was observed on any specimens.

2.1 Maximum and Minimum Shingle Temperatures

The absolute maximum shingle temperatures during a year are primarily driven by the amount of incoming solar radiation reaching and being absorbed by the roof specimens. Differences in peak roof temperatures are also related to the color of individual products and its influence on radiative absorption. Roofs at different slopes, different orientations, and of different color variations than those in the aging farms would exhibit differences compared to the observations presented here.

Observations of peak shingle temperatures are summarized in Table 2-1. The observations of peak temperatures were made using data collected in 2016.

North-Facing Roof Slopes

- In general, maximum shingle temperatures of 170°-195°F were observed for the IBHS site (one specimen reached 198.5°F) and lower maximum temperatures were observed at the Madison and Amelia locations due to higher latitude.
- Maximum temperatures occurred in June at the IBHS site and in July at the higher latitude sites in Madison and Amelia (Table 2-1A).

South-Facing Roof Slopes

- Maximum temperatures did not exceed 200°F for any specimens in 2016, despite IBHS specimens exceeding this threshold in 2015.
- Maximum shingle temperatures generally occurred in May or June for IBHS specimens (one occurred in April) and in August for the Madison and Amelia specimens.

General Observations

- In general, daily minimum shingle temperatures converge toward the overnight low environmental temperature.
- Minimum temperatures at the IBHS site occurred in January. It is noted that the February data records were incomplete; however, data from the IBHS weather monitoring station suggested that February would not have produced colder roof temperatures.
- Polymer modified asphalt products typically deviate some from the oxidized asphalt products. In general, their minimum temperatures are higher than conventional asphalt products.

Table 2-1. (A) North face and (B) south face maximum and minimum shingle temperatures at the center panel shingle-mounted thermocouple probe for 20-year specimens during 2015.

A.

Specimen	Location	Roof Face Orientation	Maximum Temperature (°F)	Maximum Temperature Month	Minimum Temperature (°F)	Minimum Temperature Month
2013-A-IBHS	Richburg, SC	North	173.6	June	6.7	January
2013-B-IBHS	Richburg, SC	North	169.7	June	8.4	January
2013-C-IBHS	Richburg, SC	North	174.0	May	8.4	January
2013-D-IBHS	Richburg, SC	North	168.6	June	9.4	January
2013-E-IBHS	Richburg, SC	North	178.9	July	10.1	January
2013-F-IBHS	Richburg, SC	North	173.7	June	9.3	January
2014-A-IBHS	Richburg, SC	North	187.7	June	23.3	January
2014-B-IBHS	Richburg, SC	North	184.6	June	24.4	January
2014-C-IBHS	Richburg, SC	North	173.0	June	17.9	January
†2015-A-IBHS	Richburg, SC	North	180.8	June	NA	NA
†2015-B-IBHS	Richburg, SC	North	181.0	June	NA	NA
†2015-C-IBHS	Richburg, SC	North	177.4	June	NA	NA
†2015-D-IBHS	Richburg, SC	North	175.4	June	NA	NA
†2015-E-IBHS	Richburg, SC	North	174.9	May	NA	NA
†2015-F-IBHS	Richburg, SC	North	159.7	July	NA	NA
2014-A-AmFam	Madison, WI	North	138.6	July	-8.2	January
2014-B-AmFam	Madison, WI	North	131.4	July	-7.4	January
2014-C-AmFam	Madison, WI	North	145.3	July	-9.0	January
2014-D-AmMod	Amelia, OH	North	153.6	July	4.9	January

B.

Specimen	Location	Roof Face Orientation	Maximum Temperature (°F)	Maximum Temperature Month	Minimum Temperature (°F)	Minimum Temperature Month
2013-A-IBHS	Richburg, SC	South	184.1	June	7.0	January
2013-B-IBHS	Richburg, SC	South	180.5	May	11.8	January
2013-C-IBHS	Richburg, SC	South	186.3	June	9.5	January
2013-D-IBHS	Richburg, SC	South	182.8	May	9.0	January
2013-E-IBHS	Richburg, SC	South	189.4	June	10.5	January
2013-F-IBHS	Richburg, SC	South	180.7	June	9.7	January
2014-A-IBHS	Richburg, SC	South	198.5	April	24.9	January
2014-B-IBHS	Richburg, SC	South	192.9	June	24.3	January
2014-C-IBHS	Richburg, SC	South	184.4	May	16.7	January
†2015-A-IBHS	Richburg, SC	South	196.0	June	NA	NA
†2015-B-IBHS	Richburg, SC	South	194.2	June	NA	NA
†2015-C-IBHS	Richburg, SC	South	192.3	June	NA	NA
†2015-D-IBHS	Richburg, SC	South	192.7	June	NA	NA
†2015-E-IBHS	Richburg, SC	South	185.6	June	NA	NA
†2015-F-IBHS	Richburg, SC	South	174.0	June	NA	NA
2014-A-AmFam	Madison, WI	South	188.2	July	-8.5	January
2014-B-AmFam	Madison, WI	South	183.5	July	-9.3	January
2014-C-AmFam	Madison, WI	South	186.1	July	-6.8	January
2014-D-AmMod	Amelia, OH	South	194.6	July	5.9	January

†2015 IBHS Specimen data flow began March 2016

2.2 Temperature Thresholds

Shingle temperatures at the three sites were compared to different thresholds to examine the accumulated time the roof faces spent above these values. Five high-temperature thresholds were selected to guide research efforts focused on simulating and accelerating the effects of natural weathering on roofing products: 100°F, 120°F, 140°F, 160°F, and 180°F. The accumulated time that the north and south faces of each 16-year specimen spent above these values is shown in Table 2-2.

Observations included:

- The IBHS specimens accumulated more time above each temperature threshold than the higher latitude sites.
- North-facing roof slopes at Madison (one specimen) and Amelia did exceed 140°F but only by a few degrees. In 2015, north-facing roof slopes did not exceed this value at these two sites.
- South-facing roof slopes readily exceeded 140°F during much of the year and exceeded 180°F at times.

Table 2-2. (A) North face and (B) south face total duration above the specified temperatures in 2016. For IBHS specimens, duration was determined using a spatial average of temperatures from all thermocouple probes on each roof face. Due to the data acquisition hardware issues in 2016, IBHS specimen records are not fully complete, and the hours presented here may be lower than actual hours. Durations are rounded to the nearest hour.

A.

Specimen	Location	Roof Face Orientation	> 100°F (hr)	> 120°F (hr)	> 140°F (hr)	> 160°F (hr)	> 180°F (hr)
*†2013-A-IBHS	Richburg, SC	North	2356	1906	433	32	0
*†2013-B-IBHS	Richburg, SC	North	1607	996	358	10	0
*†2013-C-IBHS	Richburg, SC	North	2374	1921	472	41	0
*†2013-D-IBHS	Richburg, SC	North	2337	1863	408	25	0
*†2013-E-IBHS	Richburg, SC	North	2147	1239	507	157	0
*†2013-F-IBHS	Richburg, SC	North	2339	1854	496	91	0
*†2014-A-IBHS	Richburg, SC	North	2067	1463	862	328	17
*†2014-B-IBHS	Richburg, SC	North	1974	1370	757	230	3
*†2014-C-IBHS	Richburg, SC	North	1501	953	372	27	0
°†2015-A-IBHS	Richburg, SC	North	837	493	201	43	0
°†2015-B-IBHS	Richburg, SC	North	1634	1092	462	64	0
°†2015-C-IBHS	Richburg, SC	North	826	504	174	26	0
°†2015-D-IBHS	Richburg, SC	North	1508	983	434	51	25
°†2015-E-IBHS	Richburg, SC	North	1455	921	362	19	0
°†2015-F-IBHS	Richburg, SC	North	2036	1664	855	60	0
2014-A-AmFam	Madison, WI	North	663	110	93	1	0
2014-B-AmFam	Madison, WI	North	601	119	88	0	0
2014-C-AmFam	Madison, WI	North	527	98	84	0	0
2014-D-AmMod	Amelia, OH	North	1032	864	198	5	0

B.

Specimen	Location	Roof Face Orientation	> 100°F (hr)	> 120°F (hr)	> 140°F (hr)	> 160°F (hr)	> 180°F (hr)
*†2013-A-IBHS	Richburg, SC	South	2486	2093	593	111	4
*†2013-B-IBHS	Richburg, SC	South	1729	1180	488	65	0
*†2013-C-IBHS	Richburg, SC	South	2505	2110	673	140	8
*†2013-D-IBHS	Richburg, SC	South	2470	2069	591	106	2
*†2013-E-IBHS	Richburg, SC	South	2237	1289	738	294	14
*†2013-F-IBHS	Richburg, SC	South	2494	2083	1165	157	0
*†2014-A-IBHS	Richburg, SC	South	2216	1631	1099	494	70
*†2014-B-IBHS	Richburg, SC	South	2132	1560	990	375	32
*†2014-C-IBHS	Richburg, SC	South	1617	1214	532	107	4
°†2015-A-IBHS	Richburg, SC	South	860	594	402	191	31
°†2015-B-IBHS	Richburg, SC	South	1659	1203	661	194	21
°†2015-C-IBHS	Richburg, SC	South	849	616	370	159	20
°†2015-D-IBHS	Richburg, SC	South	1537	1135	647	197	47
°†2015-E-IBHS	Richburg, SC	South	1486	1059	536	110	6
°†2015-F-IBHS	Richburg, SC	South	2328	1909	821	31	4
2014-A-AmFam	Madison, WI	South	2006	1211	388	79	1
2014-B-AmFam	Madison, WI	South	1475	1009	299	68	0
2014-C-AmFam	Madison, WI	South	1398	986	287	62	0
2014-D-AmMod	Amelia, OH	South	2006	1621	433	109	5

**Partial February data record*
†Partial data record for August and September
°Data flow began March 2016

2.3 Temperature Fluctuations

Data collected from the IBHS aging specimens in 2014 revealed that shingle material temperatures can fluctuate by 10°-20°F between two five-minute observation periods as a result of passing cloud cover. Precipitation, especially during the warm season (April–September), was found to produce larger temperature variations. In the most extreme cases, the shingle temperature fell more than 50°F between consecutive five-minute observations. The specimen temperature data from 2016 were used to evaluate the occurrence of these rapid temperature decreases between two five-minute observations, using thresholds of 10°F, 25°F, 45°F, and 60°F. For IBHS specimens, a spatial average across each roof face was calculated for each five-minute observation. Thus, more localized temperature departures may have exceeded the thresholds used here.

Table 2-3 provides the total number of large fluctuation events observed during 2016, and the results from data showed:

- Product-to-product variability was most evident in fluctuation events of less than 25°F.
- Large shock events due to thunderstorms (> 45°F) showed consistency across specimens in the magnitude of their fluctuations.
- The south-facing roof slopes generally experienced more fluctuation events due to the generally higher mean shingle temperatures.
- Little correlation to product class (i.e., 3-tab, architectural, impact rated, etc.).

Table 2-3: (A) North face and (B) south face total number of identified temperature fluctuation events in 2015. Events are defined as a temperature decrease of 10°F, 25°F, 45°F, or 60°F between two consecutive five-minute observations. For IBHS specimens, the temperature decrease is determined from the spatial average across each roof face for each five-minute observation. Values presented here are likely below what occurred for IBHS specimens, due to data acquisition problems encountered in 2016.

A.

Specimen	Location	Roof Face Orientation	ΔT > 10°F	ΔT > 25°F	ΔT > 45°F	ΔT > 60°F
*†2013-A-IBHS	Richburg, SC	North	833	136	8	2
*†2013-B-IBHS	Richburg, SC	North	519	47	9	1
*†2013-C-IBHS	Richburg, SC	North	784	111	5	1
*†2013-D-IBHS	Richburg, SC	North	715	122	5	1
*†2013-E-IBHS	Richburg, SC	North	1244	235	7	1
*†2013-F-IBHS	Richburg, SC	North	823	101	5	2
*†2014-A-IBHS	Richburg, SC	North	1141	160	6	0
*†2014-B-IBHS	Richburg, SC	North	1213	196	8	4
*†2014-C-IBHS	Richburg, SC	North	794	117	22	6
°†2015-A-IBHS	Richburg, SC	North	465	79	12	5
°†2015-B-IBHS	Richburg, SC	North	1190	190	6	2
°†2015-C-IBHS	Richburg, SC	North	360	47	6	1
°†2015-D-IBHS	Richburg, SC	North	623	49	6	1
°†2015-E-IBHS	Richburg, SC	North	724	80	6	0
°†2015-F-IBHS	Richburg, SC	North	530	39	7	2
2014-A-AmFam	Madison, WI	North	1321	201	26	2
2014-B-AmFam	Madison, WI	North	1013	196	22	2
2014-C-AmFam	Madison, WI	North	997	199	23	2
2014-D-AmMod	Amelia, OH	North	1165	166	9	0

B.

Specimen	Location	Roof Face Orientation	ΔT > 10°F	ΔT > 25°F	ΔT > 45°F	ΔT > 60°F
*†2013-A-IBHS	Richburg, SC	South	931	132	9	2
*†2013-B-IBHS	Richburg, SC	South	690	74	11	2
*†2013-C-IBHS	Richburg, SC	South	1117	206	25	11
*†2013-D-IBHS	Richburg, SC	South	1169	233	8	3
*†2013-E-IBHS	Richburg, SC	South	1263	427	200	112
*†2013-F-IBHS	Richburg, SC	South	1085	161	9	2
*†2014-A-IBHS	Richburg, SC	South	1670	293	11	2
*†2014-B-IBHS	Richburg, SC	South	1491	249	11	5
*†2014-C-IBHS	Richburg, SC	South	1254	244	23	8
°†2015-A-IBHS	Richburg, SC	South	768	198	19	5
°†2015-B-IBHS	Richburg, SC	South	1144	283	9	2
°†2015-C-IBHS	Richburg, SC	South	614	139	11	3
°†2015-D-IBHS	Richburg, SC	South	1032	190	11	0
°†2015-E-IBHS	Richburg, SC	South	776	82	6	0
°†2015-F-IBHS	Richburg, SC	South	1133	623	482	34
2014-A-AmFam	Madison, WI	South	1456	561	41	5
2014-B-AmFam	Madison, WI	South	1403	489	38	4
2014-C-AmFam	Madison, WI	South	1445	511	38	4
2014-D-AmMod	Amelia, OH	South	1235	301	15	1

**Partial February data record*
†Partial data record for August and September
°Data flow began in March

3. Climate and Weather

Instrumentation at each roof aging farm site collects meteorological data. Each site logs temperature, relative humidity, solar radiation, and precipitation (the IBHS research center weather observing station also collects: wind speed/direction and barometric pressure). In addition to the standard meteorological variables, a hail impact disdrometer was installed at each site in early 2017. Weather observations from 2016 are compared to climatic averages from the closest long-term observation site operated by the National Oceanic and Atmospheric Administration (NOAA). Notable weather events during 2016 are also provided for each site.

3.1 IBHS Research Center - Richburg, South Carolina

Climate Summary

The observations collected at the IBHS Research Center in South Carolina are compared to the Lancaster, South Carolina, (KLKR) climatic record. Average daily maximum and minimum temperatures at the IBHS Research Center were well above average for much of 2016 (Figure 3-1). Only May exhibited a daily average high temperature that was below average. The November average minimum temperature was near the long-term KLKR average. Despite the warmer than average year, the site only experienced one day with the temperature exceeding 100°F (July 25). The minimum temperature for the year was 13.6°F, which occurred on January 19. The minimum roof temperatures also occurred on this day. The light winds and dry air on the morning of January 19 allowed some roof specimens to cool a few degrees below the ambient air temperature (measured at 2.5 m). The IBHS Research Center experienced approximately 570 hours of sub-freezing temperatures during 2016, which was the fewest observed at the site since the first full annual record was collected in 2011. Precipitation for the year also fell below average for each month during 2016 (Figure 3-2). The southeast United States suffered from a significant drought during much of the year.

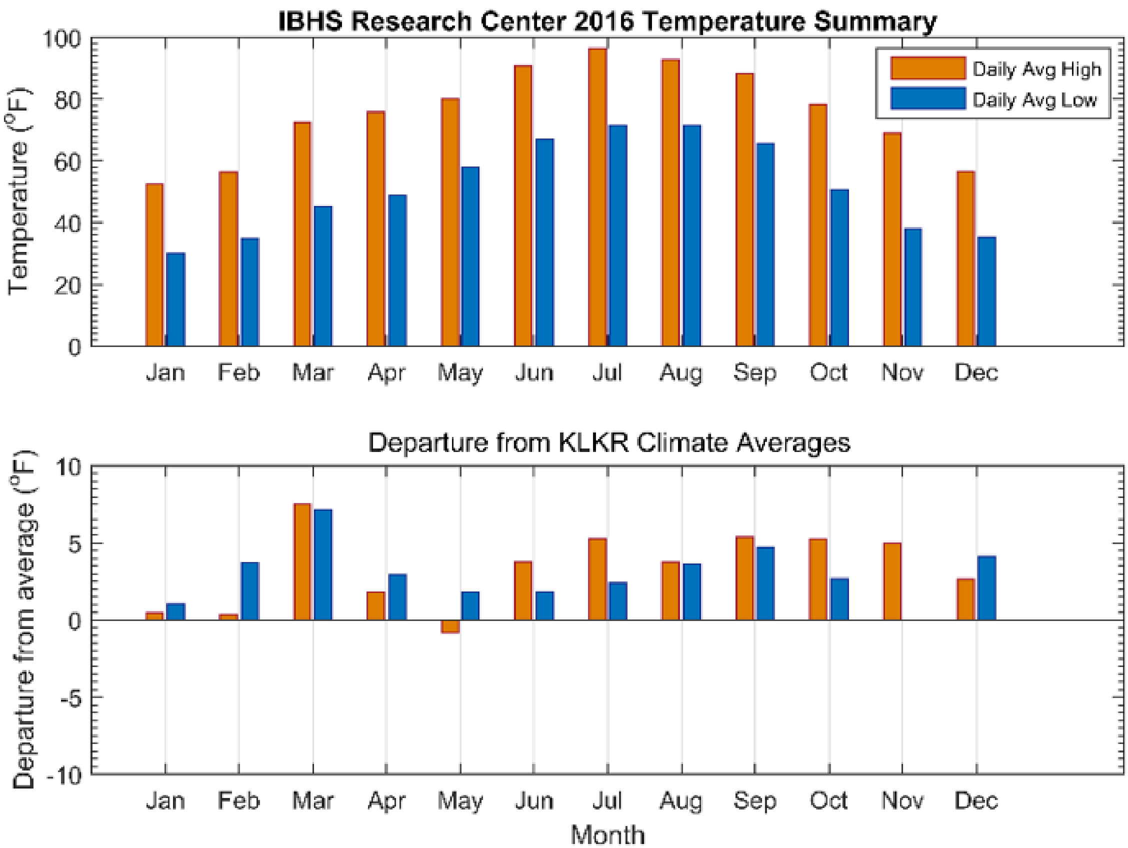

Figure 3-1. Diagram of a roof specimen showing temperature probe measurement locations. Note that for specimens at the Madison, Wisconsin, and Amelia, Ohio, sites, temperature probes are located on the center panel of each roof face only.

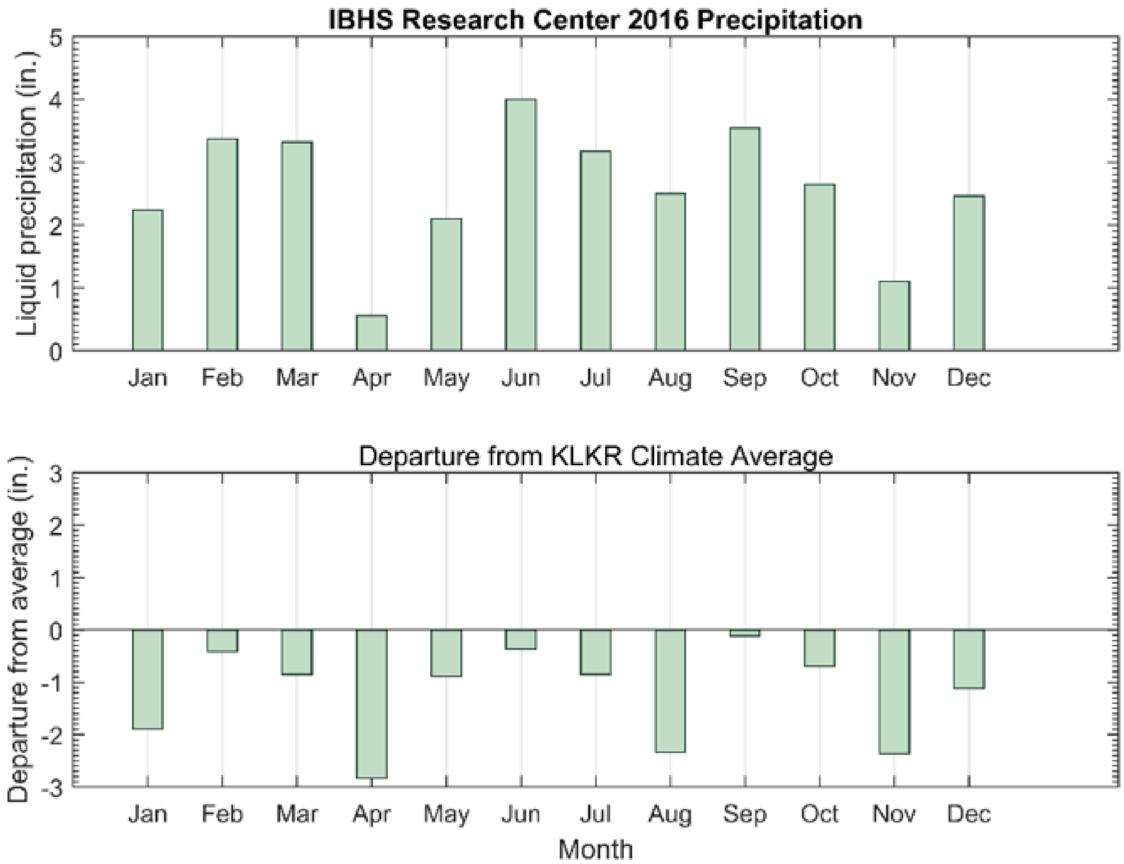

Figure 3-2. IBHS Research Center (top) monthly total precipitation and (bottom) departure from KLKR (Lancaster, South Carolina) long-term climate average.

Notable Weather Events

- **January 21-22, 2016–Ice Storm**
  A winter storm impacted the Piedmont of North Carolina and the Upstate of South Carolina during the evening of January 21 through mid-day on January 22. Across York and Chester Counties in South Carolina, precipitation began as freezing rain with a shallow cold airmass in place. The precipitation eventually changed to a mix of snow and sleet on the morning of January 22, with approximately 0.5 inches of accumulation at the IBHS Research Center in Chester County.

- **February 24, 2016–Severe Thunderstorms**
  A significant outbreak of severe weather occurred across the mid-Atlantic region of the United States on February 24. The large-scale weather system spawned thunderstorms across a large portion of the eastern U.S. One particular storm produced the highest wind gust recorded at the IBHS Research Center since weather data collection began in December of 2010. A peak three-second wind gust of 45 mph was recorded by the IBHS weather observing station. No damage was observed on any roof specimens or on the Research Center campus; however, tree damage was reported further east near Lancaster, South Carolina, as this cell passed by.

- **May 2, 2016–Severe Thunderstorms**
  While not a significant outbreak, a number of severe wind and hail reports occurred from thunderstorms across the upstate region of South Carolina. One cell did produce pea-size hail and a peak wind gust of 32 mph as it passed over the IBHS Research Center. Hail was observed by IBHS staff and captured by the impact disdrometer on-site. Peak total hail concentrations approached four impacts per second, per square foot, with the event lasting approximately five minutes. Hail sizes did not exceed 0.5 inches at the IBHS Research Center, which is less than the severe hail criteria and no visible damage was caused to any roof specimens. This was the first hail event the roof aging farm has experienced since the first group of specimens was constructed.

3.2 Madison, Wisconsin

Climate Summary

Observations collected at the Madison, Wisconsin, roof aging farm site are compared to long-term records collected at the Dane County Regional Airport (KMSN). Snowfall measurements were measured at KMSN. The average temperatures observed for 2016 were above average for much of the year (Figure 3-3). Average temperatures were well above normal in the late winter and early spring, as well as the late fall (i.e., November). April was the only month with below-average daily high and low temperatures. In December, only the daily average maximum temperature was below average. The coldest temperature observed in 2016 occurred on January 19, with a minimum of -9.1°F at the roof aging farm site (KMSN minimum was -8.9°F). The warmest temperature recorded in 2016 was 90.2°F on July 11, and only six 90°F days were observed during the year. Summer maximum temperatures were 1°–3°F above normal, while the other times of the year exhibited larger departures from normal.

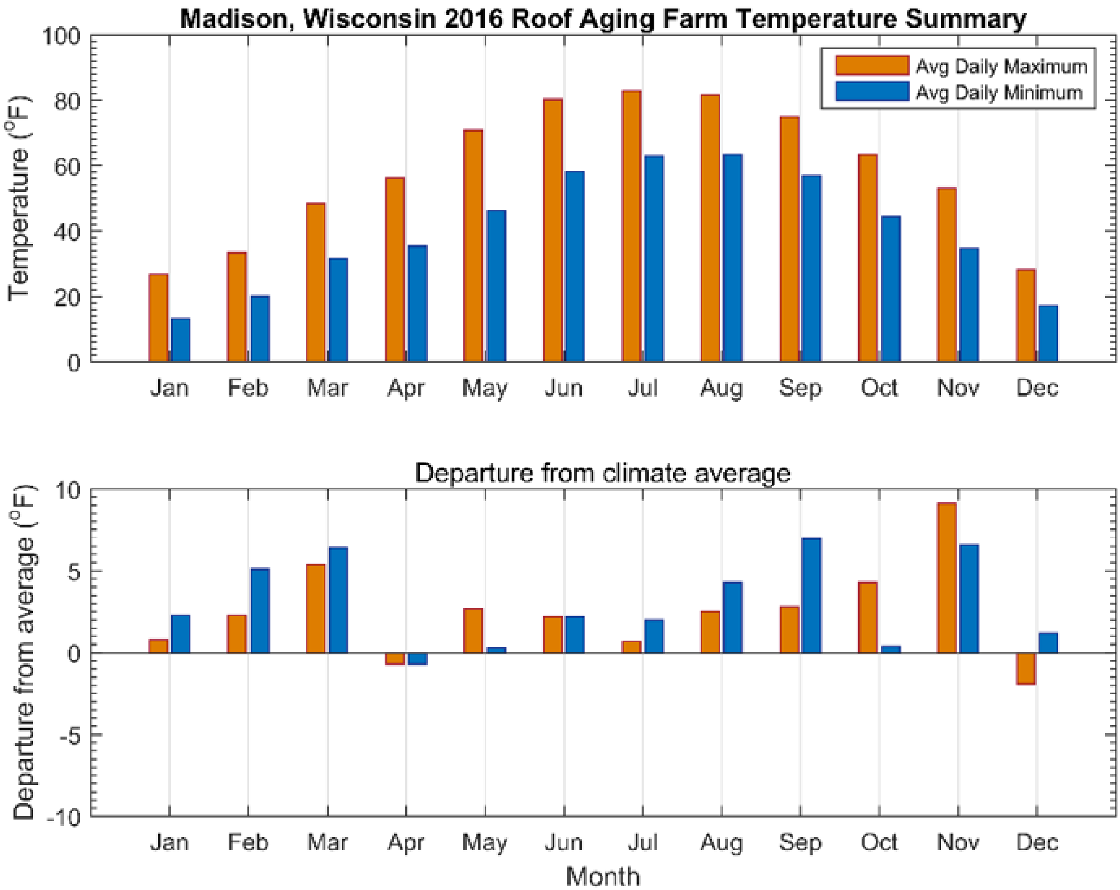

Figure 3-3. Madison, Wisconsin, roof aging farm site (top) average daily maximum and minimum temperatures and (bottom) their departure from KMSN (Dane County Regional Airport) long-term climate averages for each month.

For the first half of 2016, precipitation exhibited variability and was only slightly above or below normal from January through July before a wetter pattern became established (Figure 3-4). The June–August period was the 8th wettest for this monthly range at KMSN. August through October were also wetter than normal by several inches of rainfall. While liquid precipitation in December was near normal, over 22 inches of snow were recorded at KMSN during the month, which ranked as the 18th snowiest December on record.

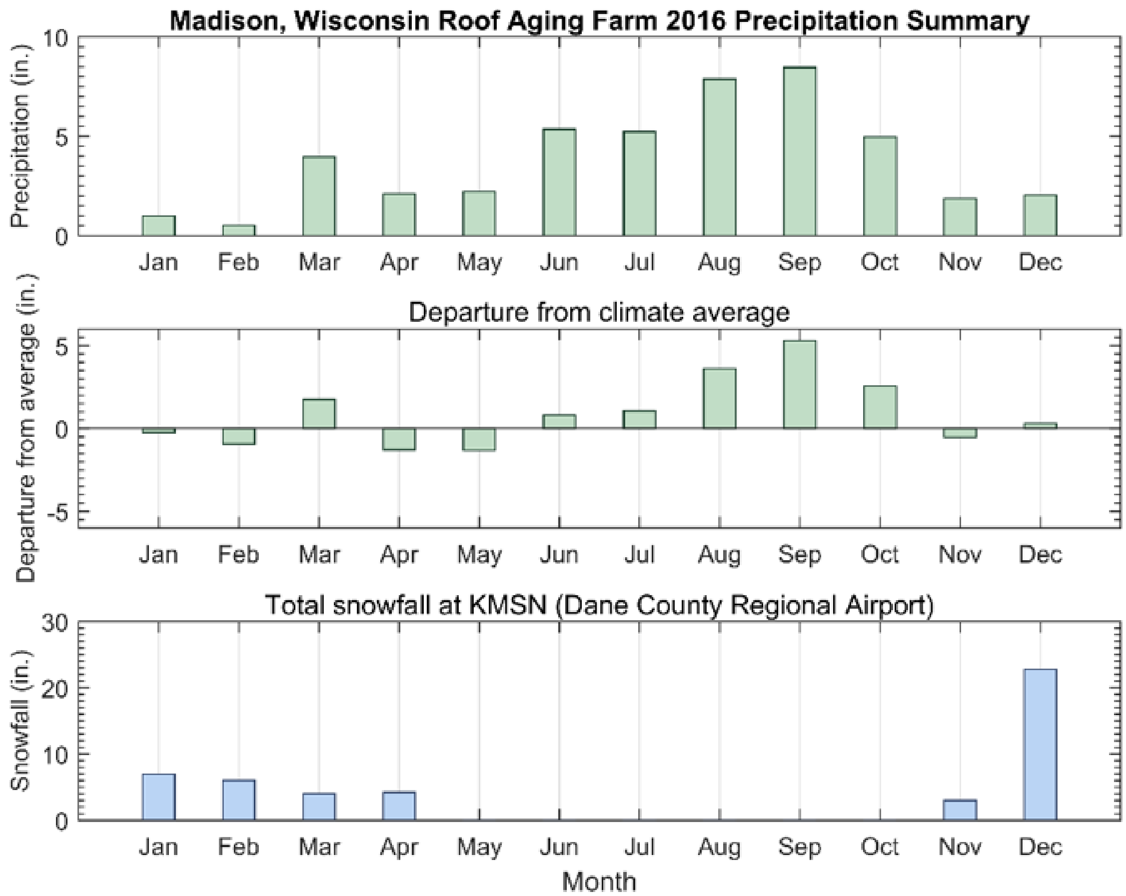

Figure 3-4. Madison, Wisconsin, roof aging farm (top) monthly total liquid precipitation, (middle) departure from KMSN (Dane County Regional Airport) long-term climate average, and (bottom) monthly total measured snowfall at KMSN.

Notable Weather Events

- **March 23-24, 2016–Ice Storm**
  Southern Wisconsin experienced a late-season winter storm in late March 2016. The event brought freezing rain and snow to much of the southern half of Wisconsin. Precipitation across Madison began as rain during the evening of March 23, before transitioning to freezing rain overnight. Ice accumulations ranged between 0.15–0.25 inches. The precipitation transitioned to sleet then snow during the day on March 24, leaving total sleet/snow accumulations in the Madison area of approximately 1 inch. Significant snow accumulations occurred further north.

- **December 10-11, 2016–Winter Storm**
  The winter storm, which began December 10, started a 10-day period of significant snow across much of southern Wisconsin. A strong low-pressure system exited the Central Plains and tracked south of southern Wisconsin, placing the region in a favored location for heavy snowfall. Snow began during the afternoon of December 10 and continued through the evening on December 11. Total snow accumulations ranged from 6–10 inches across much of southern Wisconsin. Observations across Dane County were typically 5–7 inches. Further east near Milwaukee, snow totals approached 8–10 inches. During this period, snow cover on the roof aging specimens helped to keep the roof temperatures from falling to the ambient nighttime low values. While still below freezing, roof temperatures underneath the snow cover were typically 5°–7°F warmer than the ambient air temperature.

- **December 16-18, 2016—Winter Storm**
  The second in the series of December winter storms brought accumulating snow to nearly all of Wisconsin. Snowfall began during the afternoon of December 16 and continued through the early morning hours on December 18, with two pulses of heavier snow. Much of southern Wisconsin received 8–11 inches of snow. Observations in Dane County ranged from 5–8 inches. The system also ushered in a very cold airmass. The low temperature on the morning of December 19 at the roof aging farm site was -8.2°F (not the lowest temperature observed during 2016). With snow cover on the roof specimens, shingle temperatures remained above 0°F. It has been observed that snow cover can help insulate the roof cover such that it cannot cool to the ambient daily low temperature. Figure 3-5 shows snowfall from the Madison area during this event.

Figure 3-5. Madison, Wisconsin, on the morning of December 18, 2016. Photograph courtesy of Bill Eberle.

3.3 Amelia, Ohio

Climate Summary

Observations collected at the Amelia, Ohio, roof aging farm site are compared to long-term records collected at the Cincinnati-Northern Kentucky international Airport (KCVG). Temperature data collected at the roof aging farm site showed a general cyclic pattern throughout the year when compared with the long-term KCVG climate averages (Figure 3-6). Due to a data logger hardware issue, the weather station data beginning in early December were corrupted.

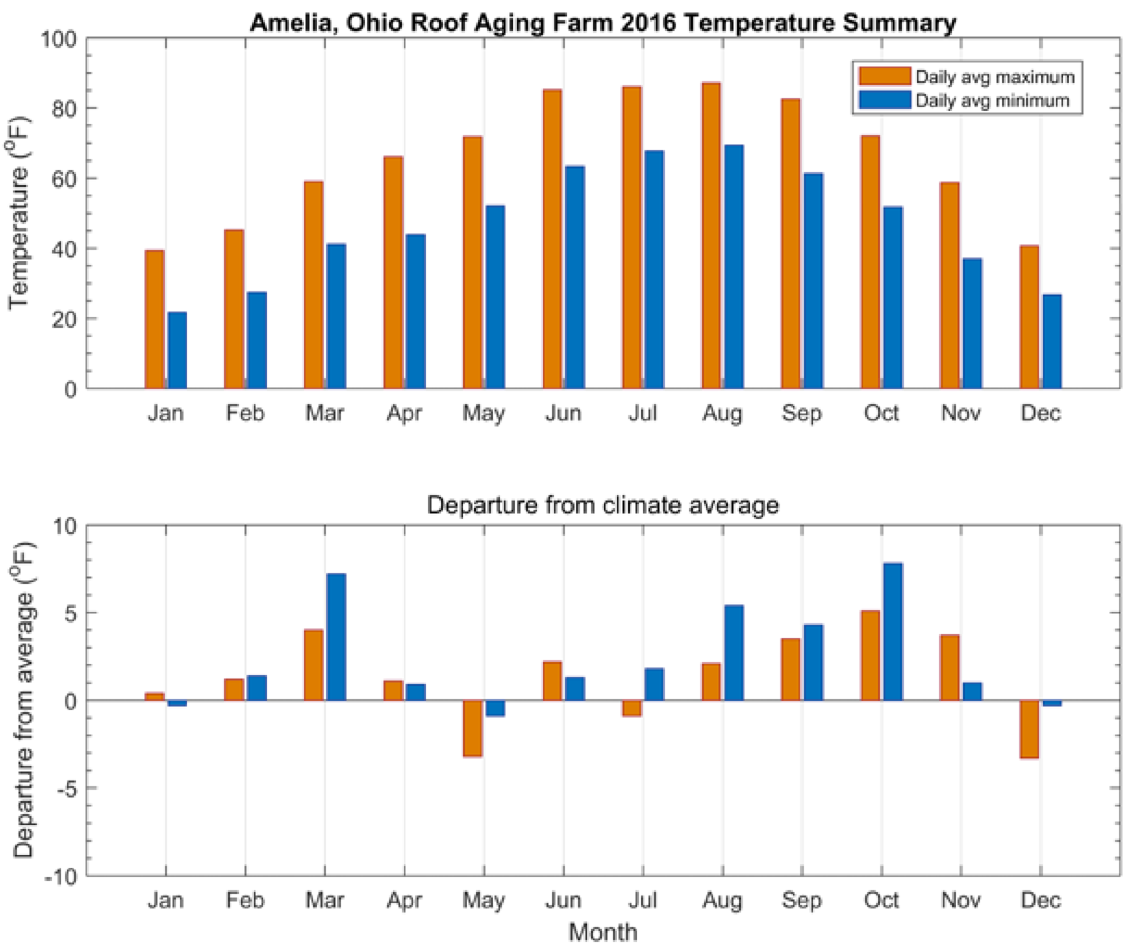

Figure 3-6. Amelia, Ohio, roof aging farm site (top) average daily maximum and minimum temperatures, and (bottom) their departure from KCVG (Cincinnati-Northern Kentucky International Airport) long-term climate averages for each month.

Observations from the nearest automated weather observing station in Clermont, Ohio, were used to supplement the record for December 2016. Roof temperature observations were unaffected. The year began near normal, but temperatures warmed to above average for the late winter. The minimum temperature for 2016, 4.3°F, occurred on the morning of January 18. With the onset of spring, temperatures increased above average in April, were cooler than normal in May, and climbed back to above normal in June. The peak temperature in 2016, 91.4°F, was observed on August 28. The air temperature did not fall below 65°F for the first twenty-one days of August. The stretch of warmer-than-average temperatures was due to a humid and stagnant airmass. The region was located underneath a stubborn upper-level ridge, which was not displaced until a cold front moved through the region during the last two days of the month. After June, average temperatures began a steady climb above normal until dropping below average for December. Average temperatures across much of the Midwest in December of 2016 were below normal.

Monthly precipitation totals also exhibited a cyclic pattern alternating between above and below normal (Figure 3-7). The late winter and late summer were generally wetter than normal with dry periods in between. Snow totals approached 10 inches for both January and February; however, snowfall was spread over several low-impact events. Daily snowfall totals did not exceed 3 inches for any day during 2016 at KCVG.

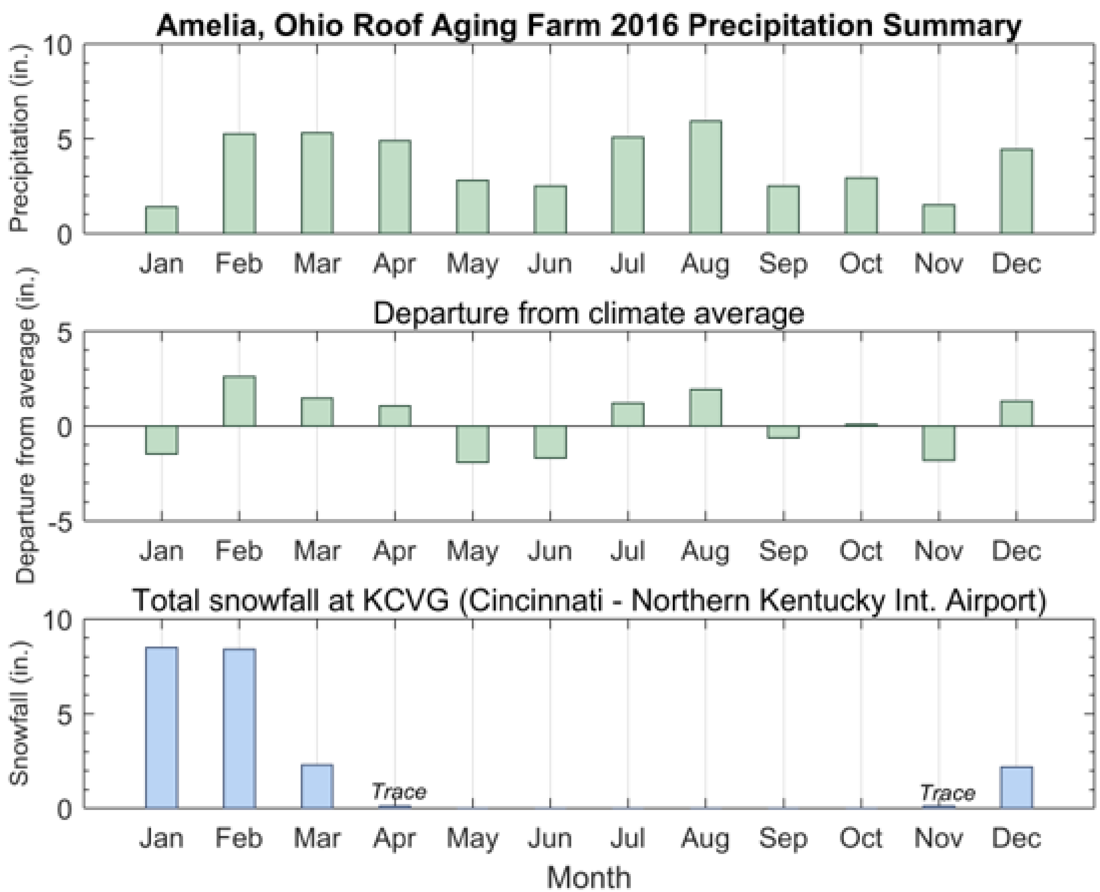

Figure 3-7. American Modern Insurance Group roof aging farm (top) monthly total liquid precipitation, (middle) departure from KCVG (Cincinnati-Northern Kentucky International Airport) long-term climate average and (bottom) monthly total measured snowfall at KCVG.

Notable Weather Events

- **April 2, 2016–Non-Thunderstorm Winds**
  A strong area of surface low pressure resulted in a prolonged high-wind event on April 2. The large-scale system produced a widespread area of wind gusts of 40–50 mph across much of southern Ohio and northern Kentucky. A peak wind gust of 48 mph at 5:35 p.m. EST was measured by the automated weather observing station (AWOS) at the Clermont County Airport near Batavia, Ohio. The station is the closest official observing station to the roof aging farm site; it monitors wind, but has not operated long enough to be used for climate comparisons.

- **April 26, 2016–Severe Thunderstorms**
  A stalled frontal boundary provided the general focus for thunderstorm development on April 26. Daytime heating allowed for strong instability to develop and, coupled with adequate deep-layer wind shear, provided the necessary ingredients for organized thunderstorms. By late afternoon, a relatively widespread region of thunderstorms had developed, some exhibiting supercell characteristics. While there were no tornado reports in the immediate Cincinnati metropolitan area, these thunderstorms did produce severe wind and hail as shown in Figure 3-8. As a supercell thunderstorm passed, several trees were blown down to the west of the roof aging farm site. The same cell produced severe hail to the east of the site. It is unclear if the thunderstorm produced strong winds or any hail at the roof aging farm site; there were no reports in the immediate vicinity. Later in 2016, roof specimen condition surveys by IBHS personnel did not reveal any visible damage due to wind or hail.

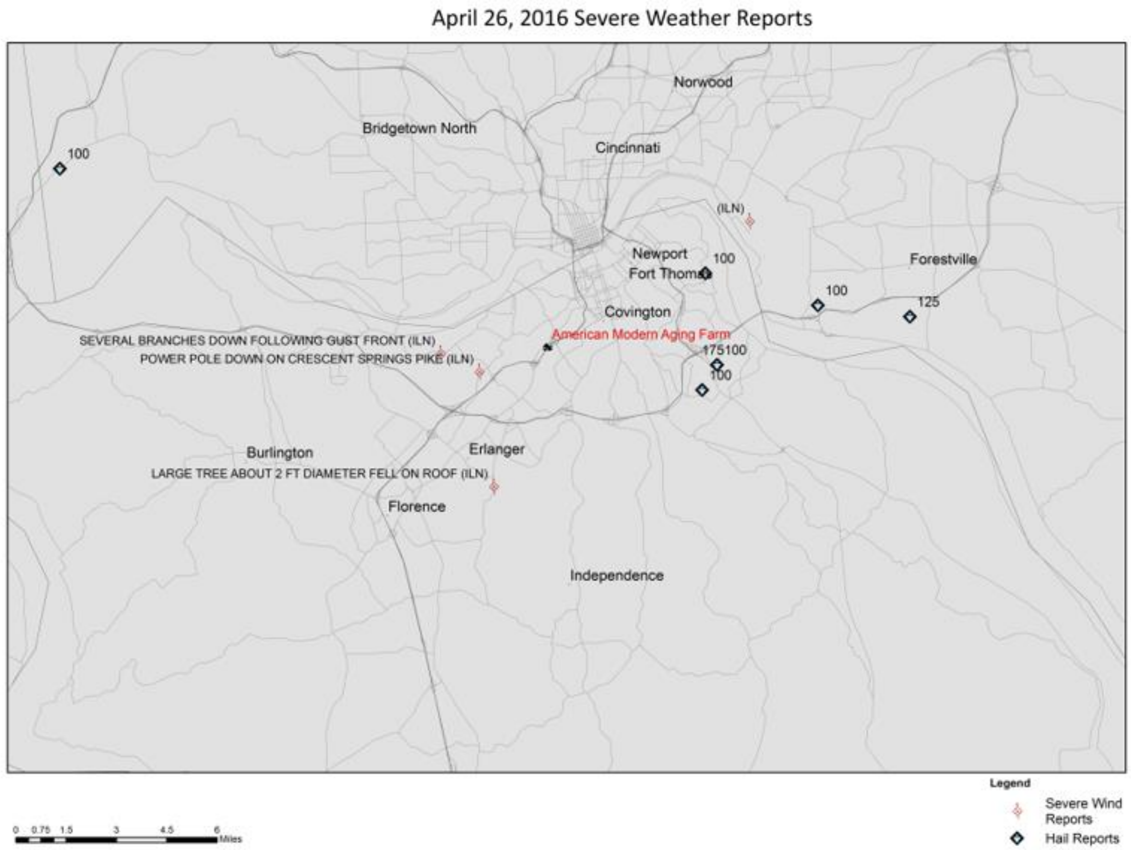

Figure 3-8. Severe weather reports from April 26, 2016.

- **June 23, 2016–Severe Thunderstorms**
  During the morning of June 23, a line of thunderstorms passed the roof aging farm site. The complex was part of a larger-scale system that produced severe weather across much of southern Ohio on June 22 and 23. The complex produced sporadic high-wind reports across the Cincinnati metropolitan area. While there were no severe wind reports in the immediate vicinity of the roof aging farm site, Doppler radar velocity data did show strong winds above the surface. As the line of thunderstorms passed, the closest observing station with wind capability was located approximately 5 miles to the northeast (Clermont County Airport AWOS) and did not measure any surface winds above 40 mph.

- **September 10, 2016–Severe Thunderstorms**
  An intense line of thunderstorms moved through the Cincinnati area during the evening of September 10 (Figure 3-9). The organized line of storms produced widespread severe-wind reports across the area. The event caused significant tree damage and power outages across the region. Tree damage was reported approximately two miles west of the roof aging farm site. In addition to the strong winds, flash flooding was reported across the Cincinnati area as rainfall totals exceeded 1.25 inches within a short time.

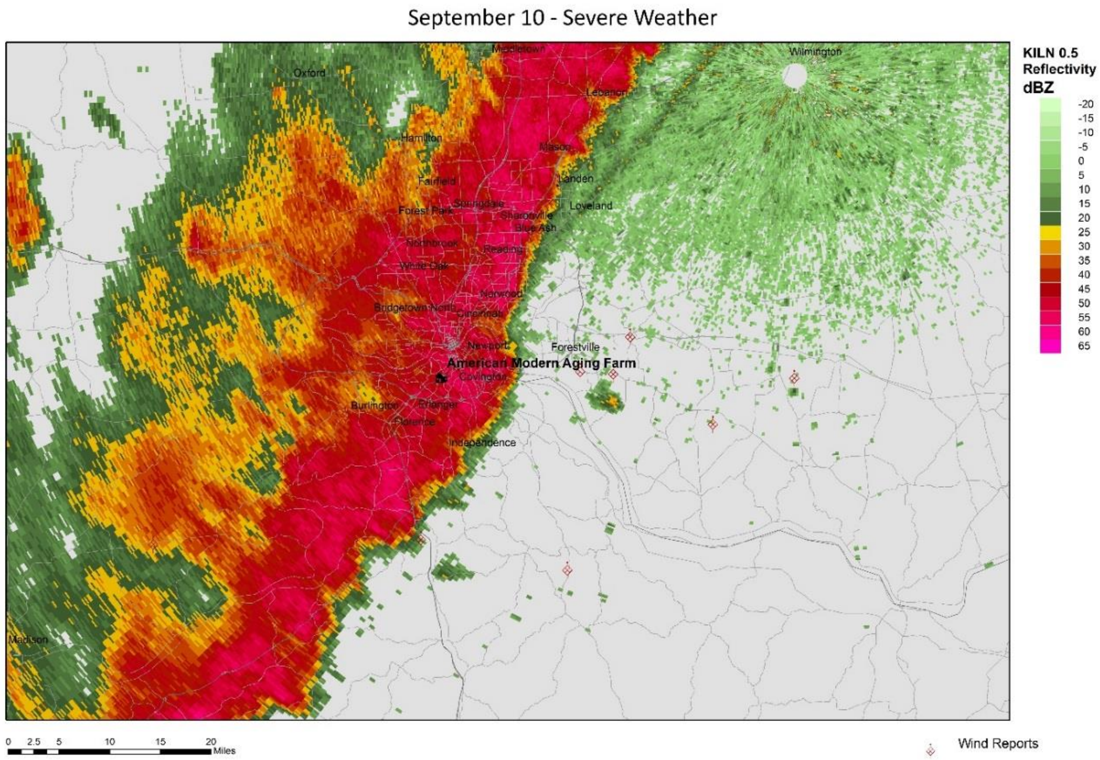

Figure 3-9. KILN 0.5° reflectivity at 20:22 UTC on September 10, 2016. Local storm reports are also provided.

Annual surveys by IBHS personnel did not indicate any visible damage from the notable weather events that impacted the site in 2016. Hail detection instrumentation was installed in late 2016.

4. Roof Condition

Visual inspections of each roof were conducted at the IBHS site in October and November 2016, and at Amelia and Madison sites in late September. All roof faces were visually examined, and locations of unsealing, nail pops or exposed fasteners, granule loss, blistering, foot traffic scuffs, uneven substrates, and other types of vulnerabilities were documented and will be monitored each year. These conditions may have been wide spread across entire roof faces, or limited to small areas on an individual roof face. New areas of interest will be added to the database each year as they appear, and trends will be monitored. Some general patterns observed on the IBHS site, by product, are listed in Table 4-1. The general patterns observed in Madison and Amelia are listed by product in Table 4-2.

Table 4-1: Roof condition visual evaluation patterns observed at the IBHS Research Center by personnel in 2016. Observation modes are color-coded to allow for quick comparisons between products. These represent common patterns observed on each roof set, but other conditions may be present on individual roof faces.

Roof Set	Condition Description	North Faces Affected	South Faces Affected
2013-A-IBHS	Loss of granules generally around edges of shingles	4/4	4/4
	Loss of granules exposing mat	4/4	3/4
	Loss of granules due to blistering	4/4	4/4
2013-B-IBHS	Loss of granules generally around edges of shingles	4/4	4/4
	Loss of granules exposing mat	2/4	1/4
	Loss of granules due to blistering	3/4	3/4
	Lumps and unevenness of substrate	1/4	2/4
	Holes in shingles that do not extend to underlayment	1/4	2/4
2013-C-IBHS	Loss of granules not exposing mat	2/4	3/4
	Loss of granules generally around edges of shingles	4/4	4/4
	Scuff marks	2/4	2/4
	Loss of granules exposing mat	1/4	2/4
	Loss of granules due to blistering	4/4	2/4
	Lumps and unevenness of shingles	2/4	4/4
	Lumps and unevenness of substrate	1/4	2/4
	Fasteners beginning to back out		3/4

Roof Set	Condition Description	North Faces Affected	South Faces Affected
2013-D-IBHS	Loss of granules not exposing mat	2/4	2/4
	Loss of granules generally around edges of shingles	4/4	4/4
	Loss of granules exposing mat		2/4
	Loss of granules due to blistering	4/4	4/4
	Lumps and unevenness of shingles	1/4	2/4
	Lumps and unevenness of substrate		2/4
	Holes in shingles that do not extend to underlayment		2/4
	Fasteners beginning to back out	2/4	2/4
2013-E-IBHS	Loss of granules not exposing mat	4/4	4/4
	Loss of granules generally around edges of shingles	4/4	3/4
	Loss of granules due to blistering	4/4	3/4
	Fasteners beginning to back out		2/4
2013-F-IBHS	Loss of granules generally around edges of shingles	1/4	4/4
	Loss of granules due to blistering	4/4	4/4
	Lumps and unevenness of substrate	2/4	1/4
	Fasteners beginning to back out	2/4	3/4
2014-A-IBHS	Loss of granules generally around edges of shingles	2/4	4/4
	Scuff marks	1/4	2/4
	Loss of granules due to blistering	4/4	4/4
	Lumps and unevenness of shingles	2/4	1/4
	Lumps and unevenness of substrate		2/4
	Holes in shingles that do not extend to underlayment	3/4	1/4
	Fasteners beginning to back out	1/4	2/4

Roof Set	Condition Description	North Faces Affected	South Faces Affected
2014-B-IBHS	Loss of granules not exposing mat	4/4	4/4
	Loss of granules generally around edges of shingles	3/4	4/4
	Loss of granules exposing mat	4/4	2/4
	Loss of granules due to blistering	4/4	4/4
	Lumps and unevenness of substrate		2/4
2014-C-IBHS	Loss of granules not exposing mat	3/4	3/4
	Loss of granules generally around edges of shingles	2/4	4/4
	Scuff marks		3/4
	Loss of granules exposing mat		2/4
	Loss of granules due to blistering	3/4	4/4
	Lumps and unevenness of shingles	3/4	1/4
	Fasteners beginning to back out	1/4	2/4
2015-A-IBHS	Loss of granules generally around edges of shingles	3/4	4/4
	Loss of granules due to blistering	4/4	4/4
	Lumps and unevenness of shingles	2/4	
2015-B-IBHS	Loss of granules generally around edges of shingles	4/4	4/4
	Scuff marks		2/4
	Loss of granules due to blistering	3/4	4/4
	Lumps and unevenness of substrate	2/4	1/4

Roof Set	Condition Description	North Faces Affected	South Faces Affected
2015-C-IBHS	Loss of granules generally around edges of shingles	4/4	4/4
	Scuff marks		2/4
	Loss of granules due to blistering	4/4	2/4
	Lumps and unevenness of shingles	2/4	1/4
	Lumps and unevenness of substrate		3/4
	Fasteners beginning to back out		2/4
2015-D-IBHS	Loss of granules not exposing mat	1/4	3/4
	Loss of granules generally around edges of shingles	4/4	3/4
	Loss of granules due to blistering	4/4	4/4
	Holes in shingles that do not extend to underlayment	2/4	
	Fasteners beginning to back out	2/4	2/4
2015-E-IBHS	Loss of granules not exposing mat	2/4	3/4
	Loss of granules generally around edges of shingles	4/4	4/4
	Loss of granules due to blistering	4/4	4/4
	Lumps and unevenness of shingles	2/4	2/4
2015-F-IBHS	Loss of granules generally around edges of shingles	4/4	4/4
	Loss of granules due to blistering	4/4	4/4
	Lumps and unevenness of substrate		3/4
	Fasteners beginning to back out	4/4	3/4

Table 4-2: Roof condition visual evaluation patterns observed at the Madison and Amelia aging farm sites by IBHS personnel in 2016. Observation modes are color-coded to allow for quick comparisons between products. These represent common patterns observed on each roof set, but other conditions may be present on individual roof faces.

Roof Set	Condition Description	North Faces Affected	South Faces Affected
2014-A-AmFam	Loss of granules not exposing mat	2/4	2/4
	Loss of granules generally around edges of shingles	4/4	4/4
	Loss of granules due to blistering	2/4	
	Lumps and unevenness of shingles	2/4	2/4
2014-B-AmFam	Loss of granules not exposing mat	2/4	2/4
	Loss of granules generally around edges of shingles	4/4	4/4
	Loss of granules due to blistering		2/4
	Lumps and unevenness of shingles		2/4
	Holes in shingles that do not extend to underlayment	2/4	
	Grease, solvent drippings	1/4	2/4
2014-C-AmFam	Loss of granules generally around edges of shingles	3/4	4/4
	Loss of granules due to blistering	2/4	1/4
	Loss of granules exposing mat	1/4	3/4
	Lumps and unevenness of shingles	2/4	1/4
2014-D-AmMod	Loss of granules not exposing mat	2/4	2/4
	Loss of granules generally around edges of shingles	4/4	4/4
	Loss of granules due to blistering	2/4	1/4
	Fasteners beginning to back out	2/4	3/4
	Lumps and unevenness of shingles	1/4	2/4

Loss of granules in various zones and of various severities were the most common conditions observed and were more frequent with additional loss modes present. In some cases, these conditions were more severe compared to the 2015 observations. Lumps and unevenness, and fasteners beginning to back out were seen across multiple roof sets, but occurred less frequently than granule loss. Based on these observations, granule loss patterns will be important to monitor over the long-term life of the project to determine if shingle manufacturer, color, location, and/or roof direction have a larger role. It is believed that granule loss due to natural weathering and exposure may often be mistaken for hail damage, particularly for high-severity and large-coverage instances. These annual inspections clearly show that granule loss can be problematic, even without a hail event, since the roof farm weather data show that no substantial hail occurred at any of the sites. Some initial trends indicate that some shingle brands may have more widespread granule loss and increased likelihood of lumps and unevenness in the shingles.

5. Summary

The in-situ instrumentation deployed on specimens at the three roof aging sites has enabled an in-depth look at conditions experienced by the asphalt shingles. This information will continue to guide ongoing IBHS research for simulating these conditions in a laboratory environment. Data and site climate summaries will be compiled each year, providing an overview of the conditions experienced by the roof specimens. Roof condition inspections will be conducted annually. A more detailed analysis study will be conducted when the first group of specimens are ready for testing in 2018, and it will examine the annual variability in the conditions experienced during the previous exposure time period. The data and visual inspection information will be compared to performance test results to determine trends.