Effectiveness of RWIS Bridge Temperature Simulators Appendices

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

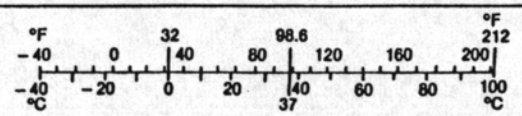
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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Ohio University
Athens, Ohio 45701-2979

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May 2007

TABLE OF CONTENTS

LIST OF FIGURES

Appendix A: Time series graphs

Stark County (Site 9):

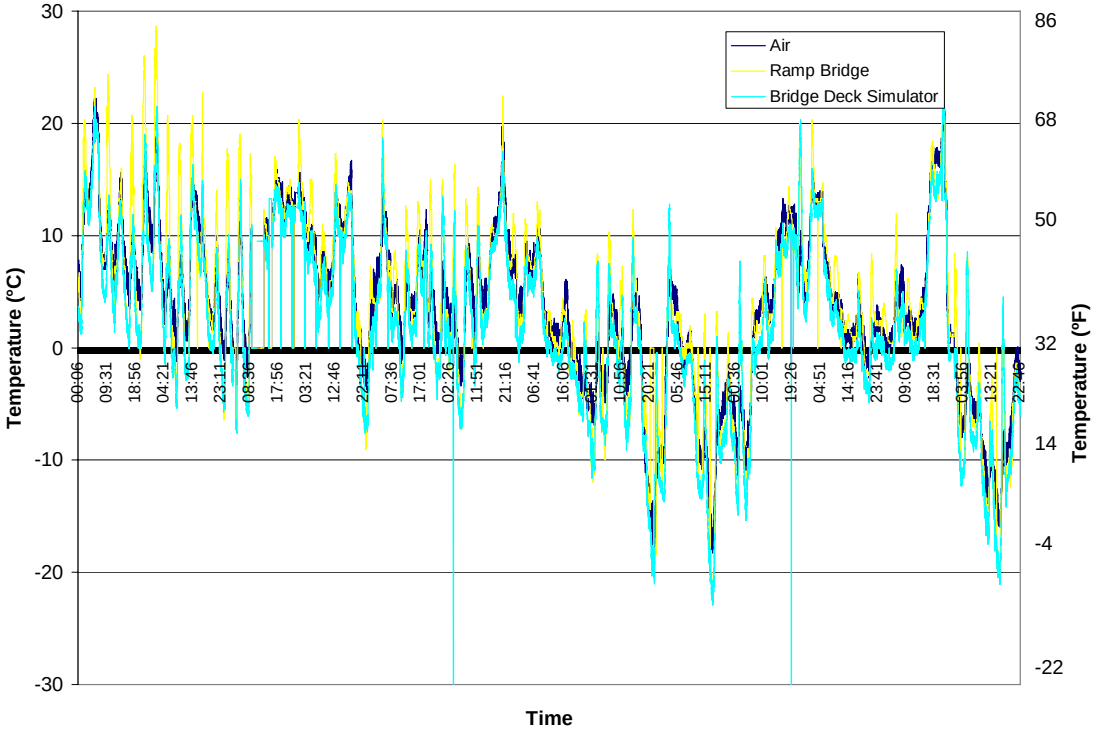


Figure 1: Time series graph raw for full day data for Site 9 I-77 Stark County bridge sensor November 1, 2004-January 19, 2005.

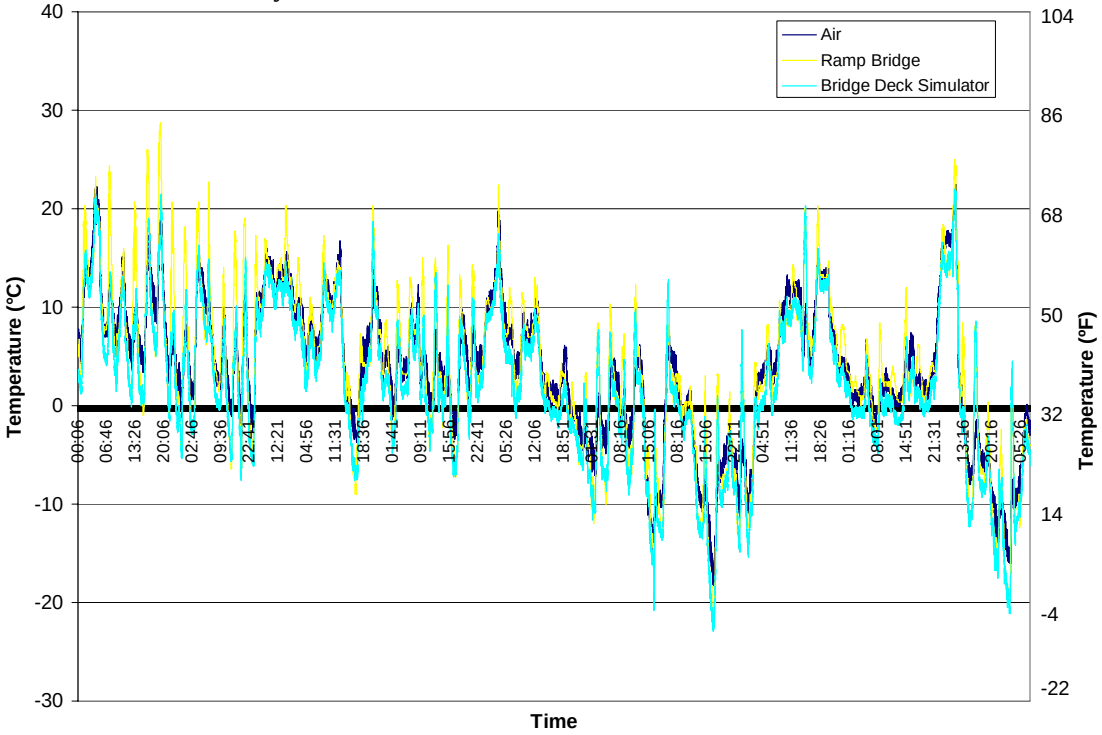


Figure 2: Time series graph modified for full day data for Site 9 I-77 Stark County bridge sensor November 1, 2004-January 19, 2005.

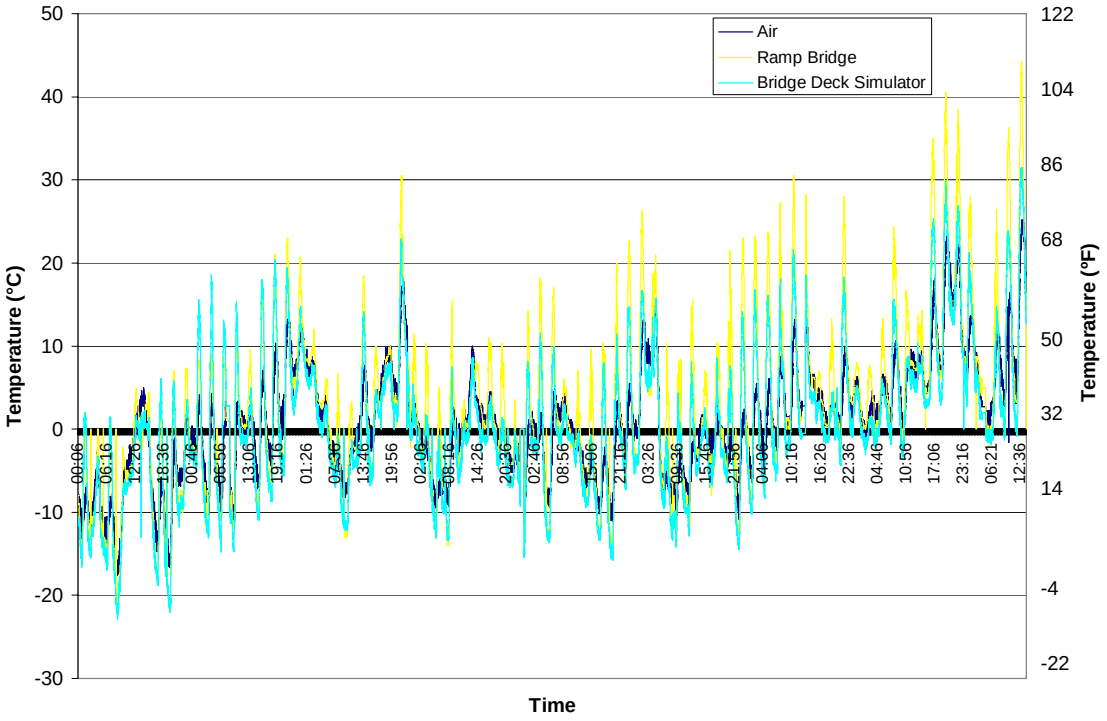


Figure 3: Time series graph raw for full day data for Site 9 I-77 Stark County bridge sensor January 21-April 5, 2005.

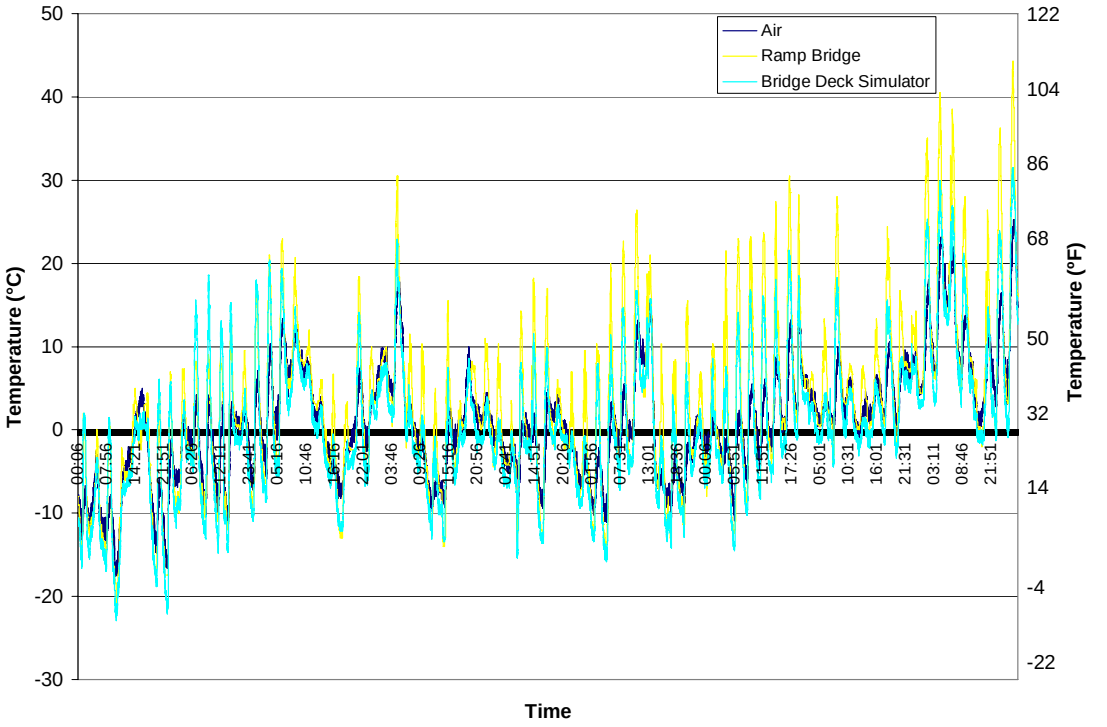


Figure 4: Time series graph modified for full day data for Site 9 I-77 Stark County bridge sensor January 21-April 5, 2005.

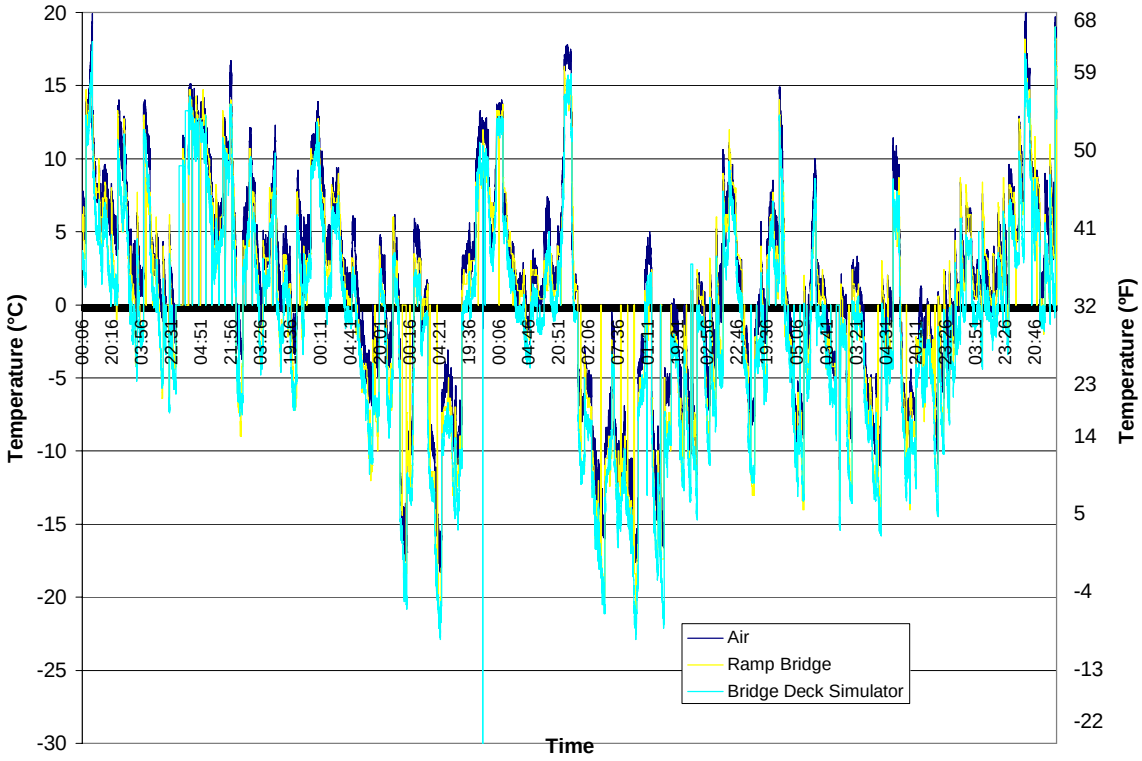


Figure 5: Time series graph complete raw nighttime data for Site 9 I-77 Stark County bridge sensor November 1, 2004- April 5, 2005.

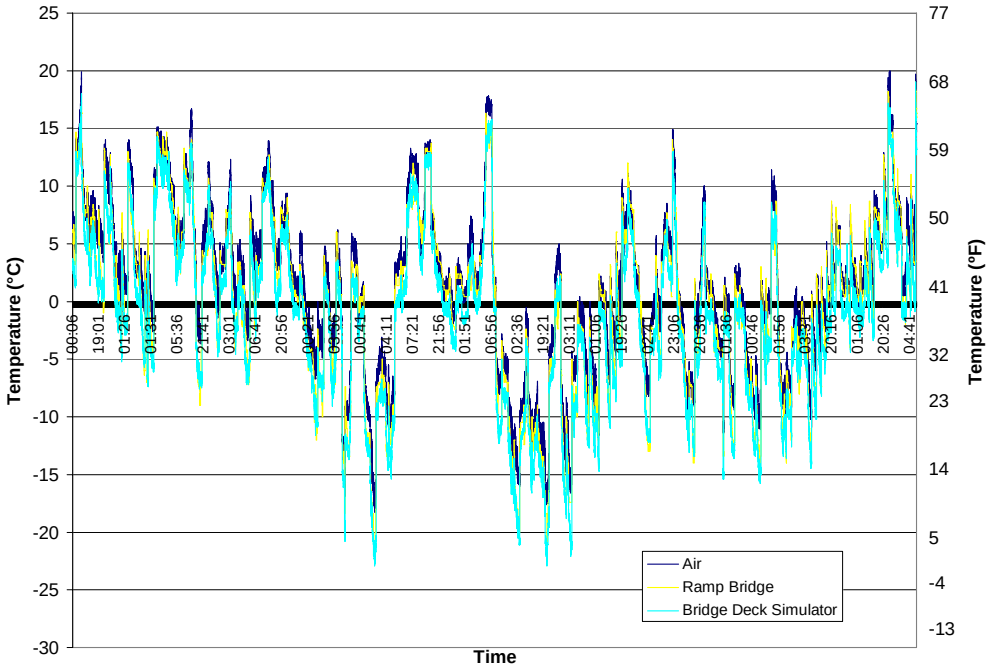


Figure 6: Time series graph complete modified nighttime data for Site 9 I-77 Stark County bridge sensor November 1, 2004- April 5, 2005.

Warren County (Site 59):

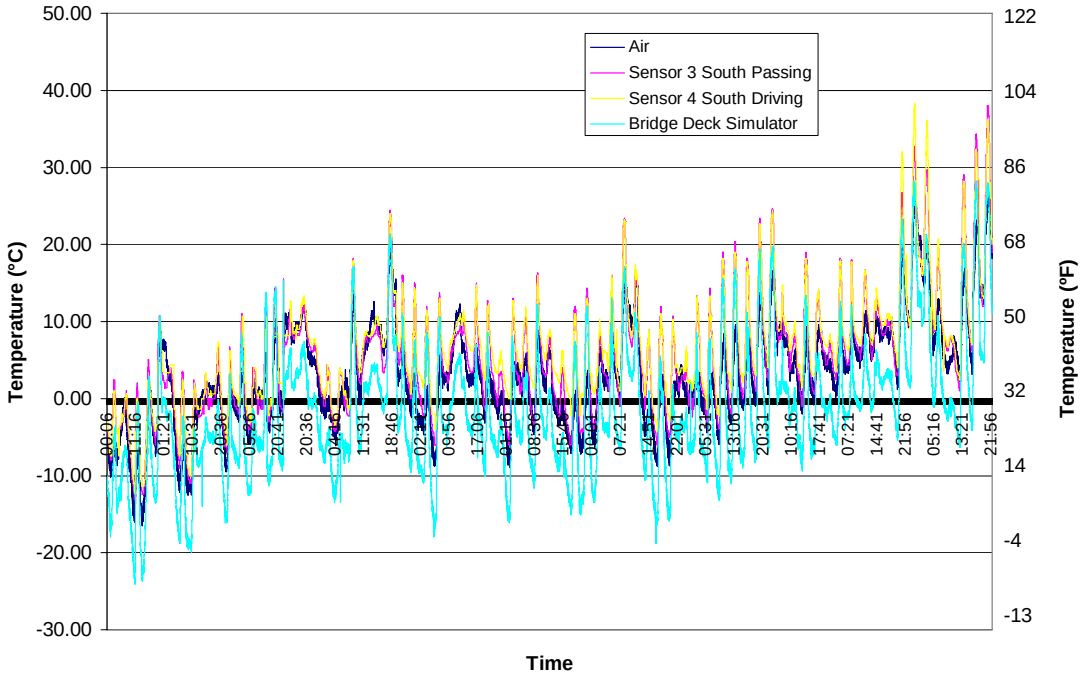


Figure 7: Time series graph for full day data for Site 59 I-71 Warren County road sensor January 21- April 5, 2005.

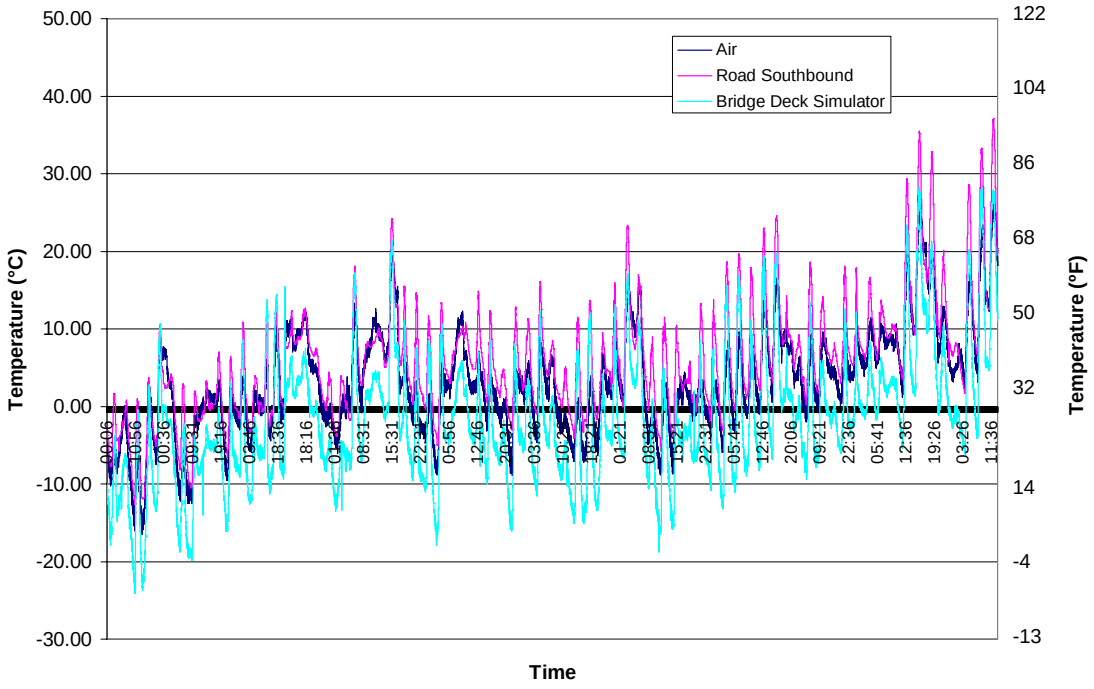


Figure 8: Average time series graph for full day data for Site 59 I-71 Warren County road sensor January 21- April 5, 2005.

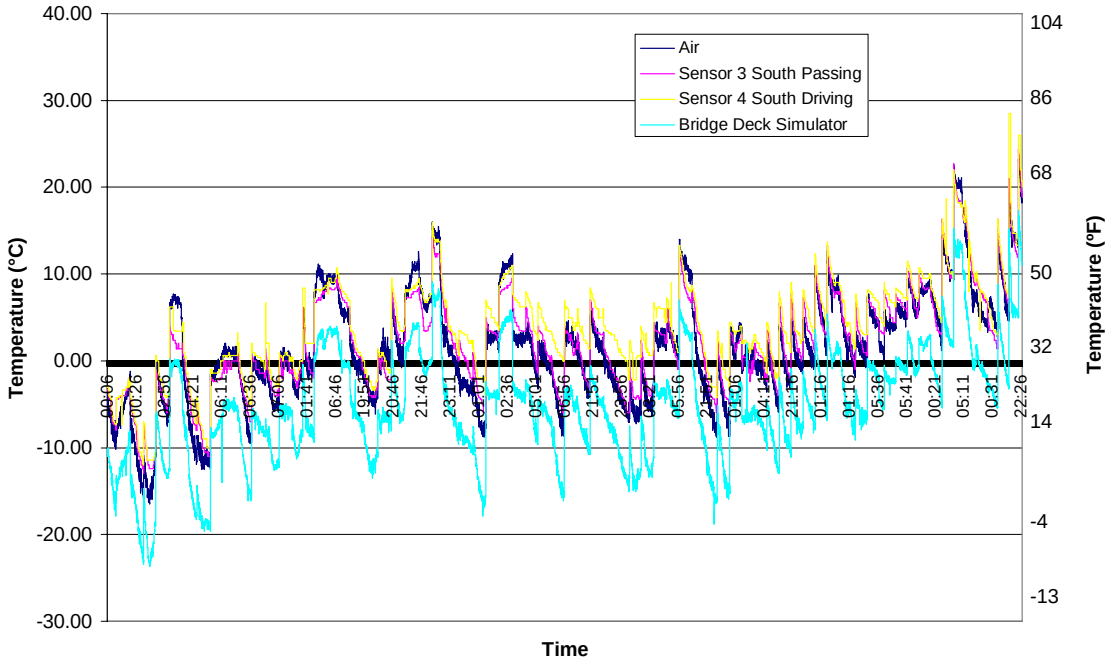


Figure 9: Time series graph for night time data for Site 59 I-71 Warren County road sensor January 21- April 5, 2005.

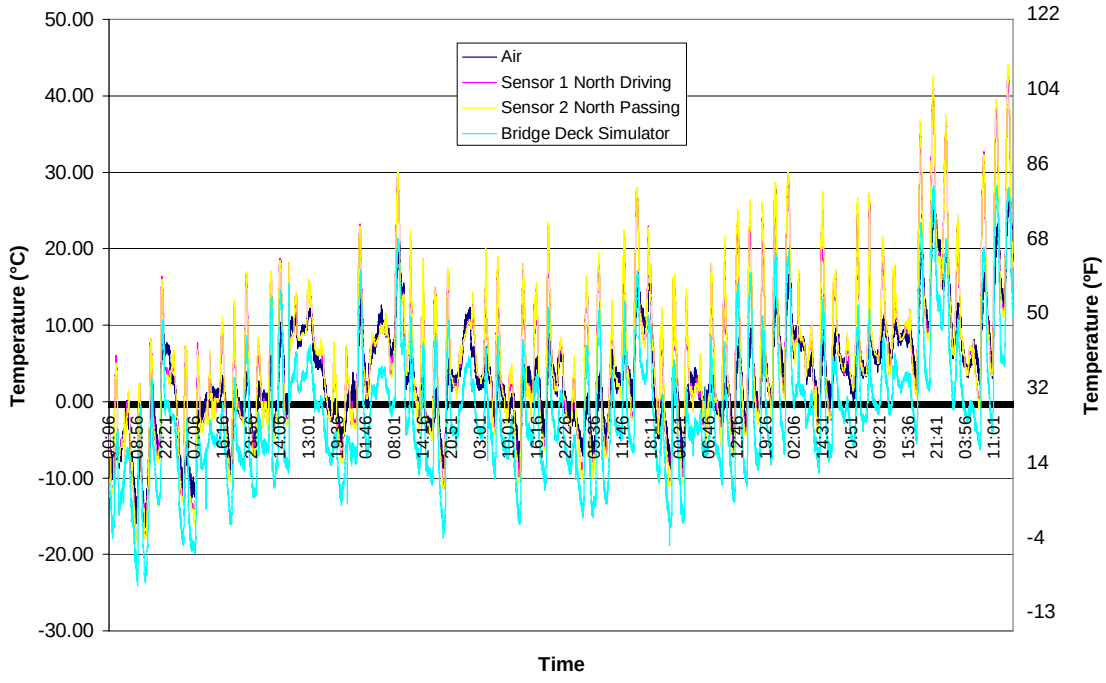


Figure 10: Time series graph for full day data for Site 59 I-71 Warren County bridge sensor January 21- April 5, 2005.

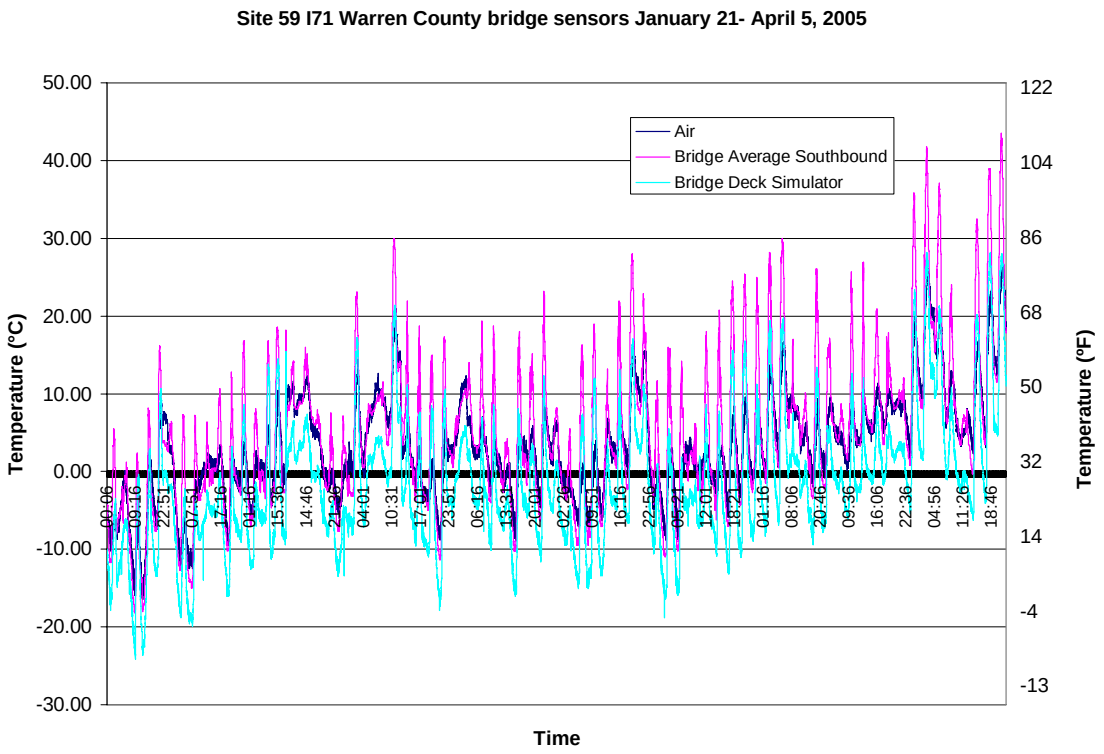


Figure 11: Average time series graph for full day data for Site 59 I-71 Warren County bridge sensor January 21- April 5, 2005.

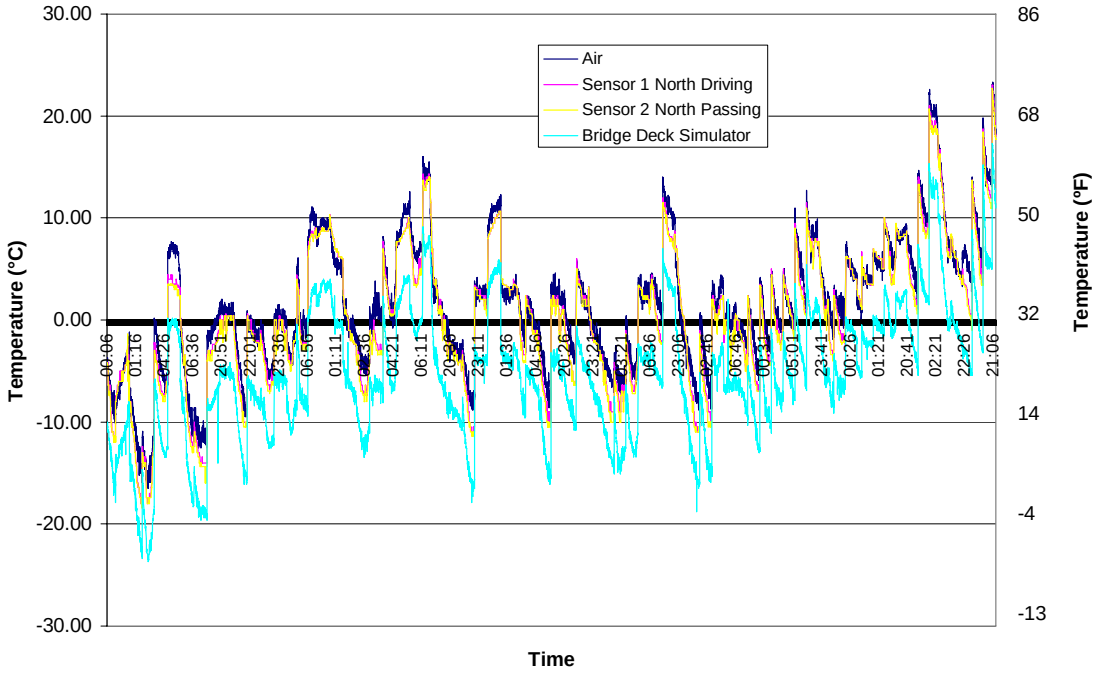


Figure 12: Time series graph for night time data for Site 59 I-71 Warren County bridge sensor January 21- April 5, 2005.

Summit County (Site 68):

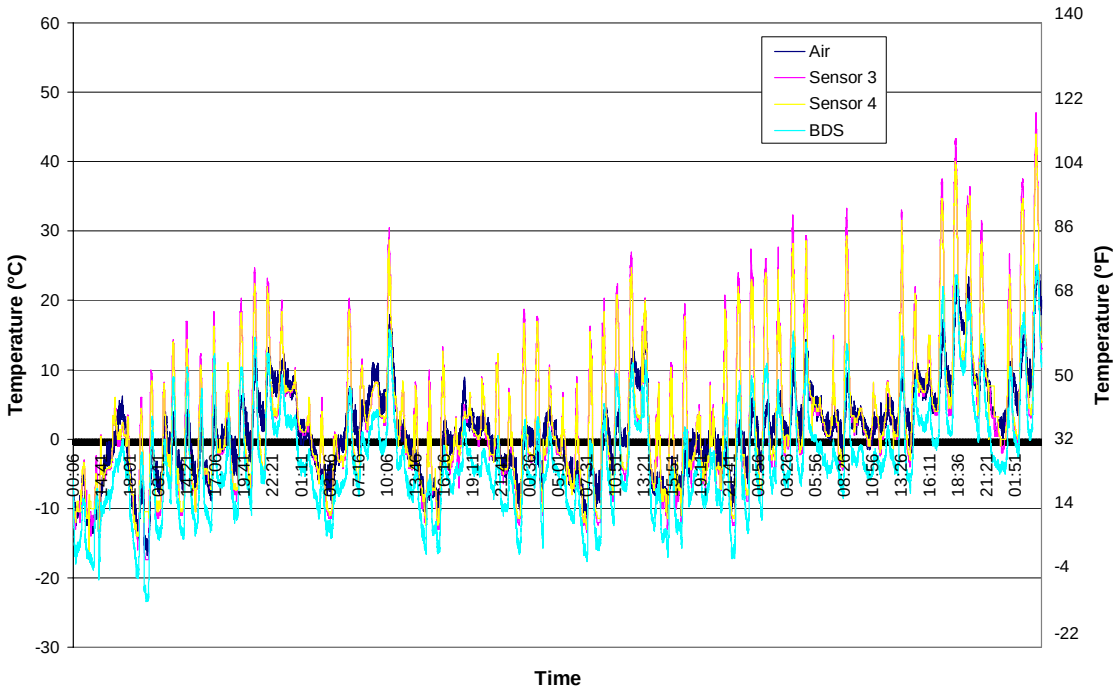


Figure 13: Time series graph for full day data for Site 68 I-271 Summit County road sensor January 21- April 5, 2005.

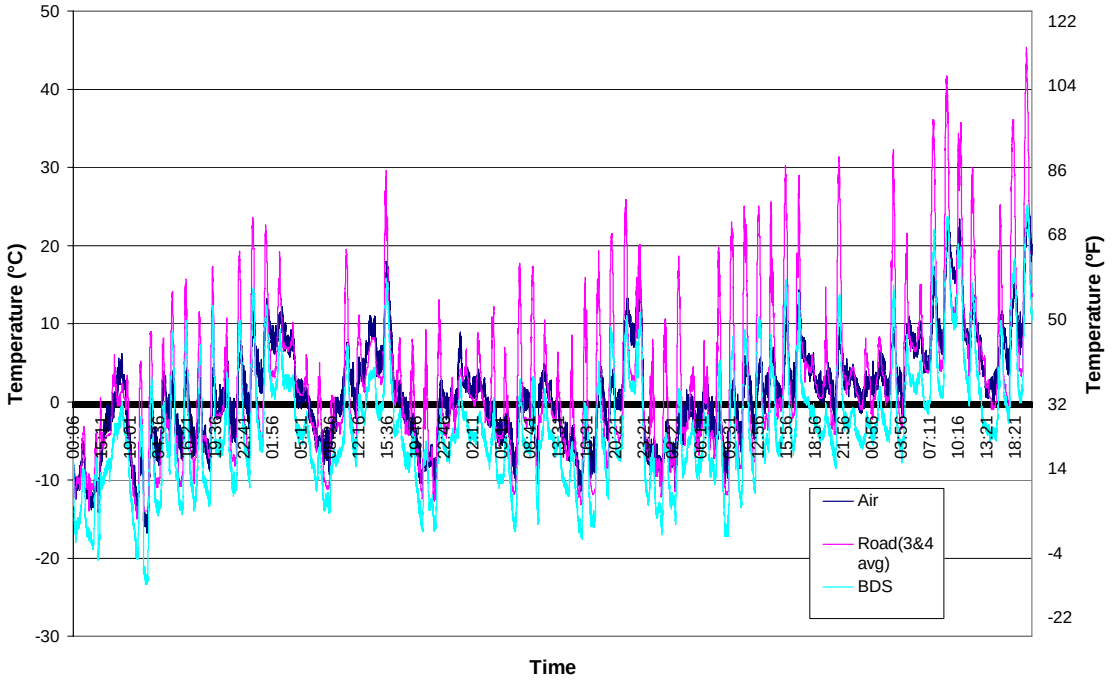


Figure 14: Average time series graph for full day data for Site 68 I-271 Summit County road sensor January 21- April 5, 2005.

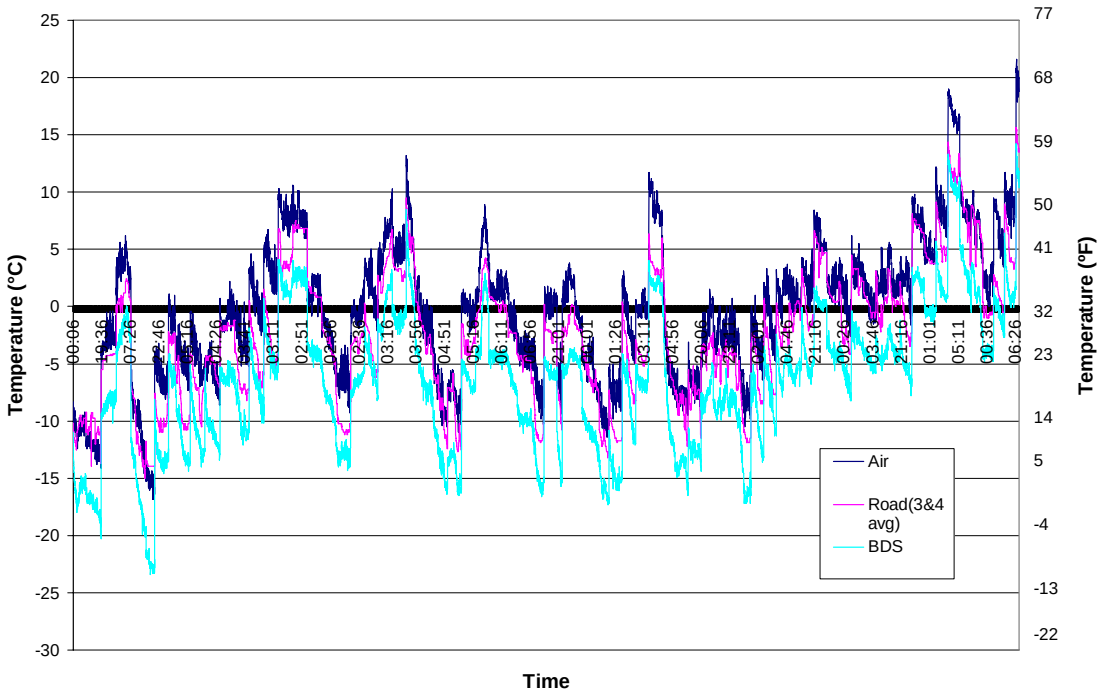


Figure 15: Time series graph for night time data for Site 68 I-271 Summit County road sensor January 21- April 5, 2005.

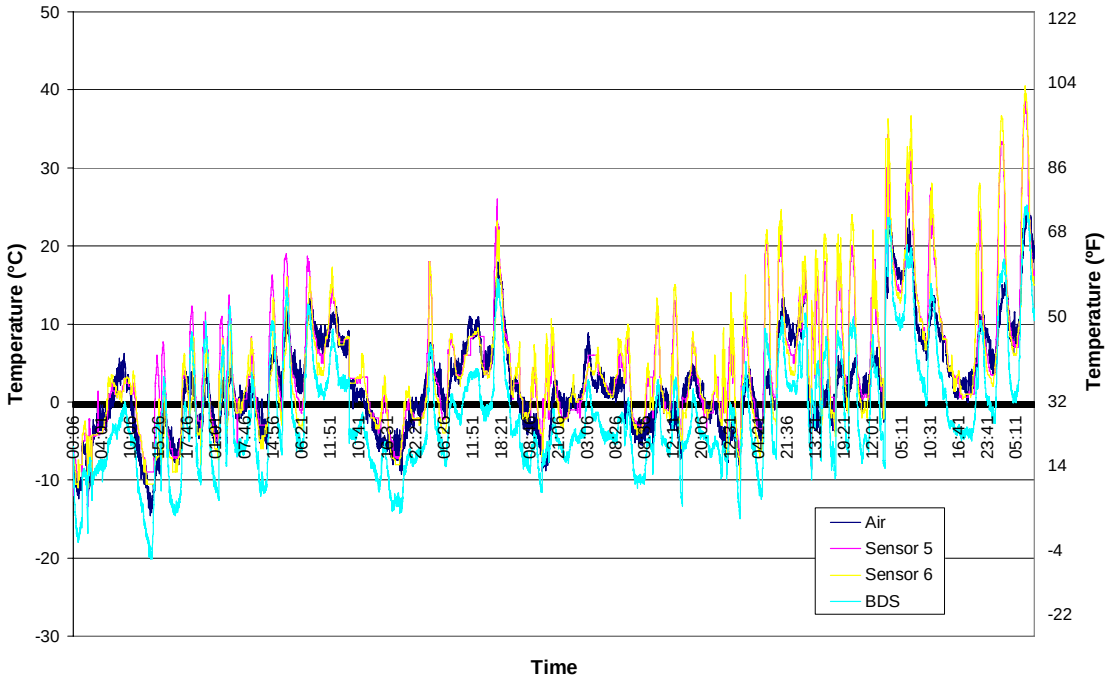


Figure 16: Time series graph for full day data for Site 68 I-77 Summit County road sensor January 21- April 5, 2005.

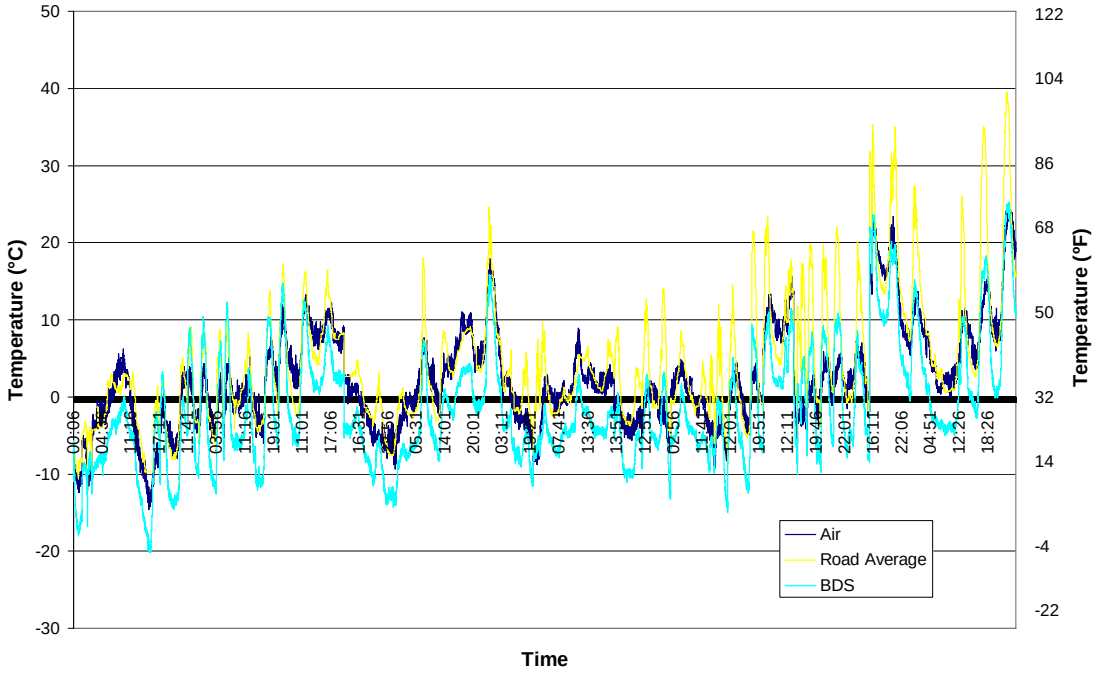


Figure 17: Average time series graph for full day data for Site 68 I-77 Summit County road sensor January 21- April 5, 2005.

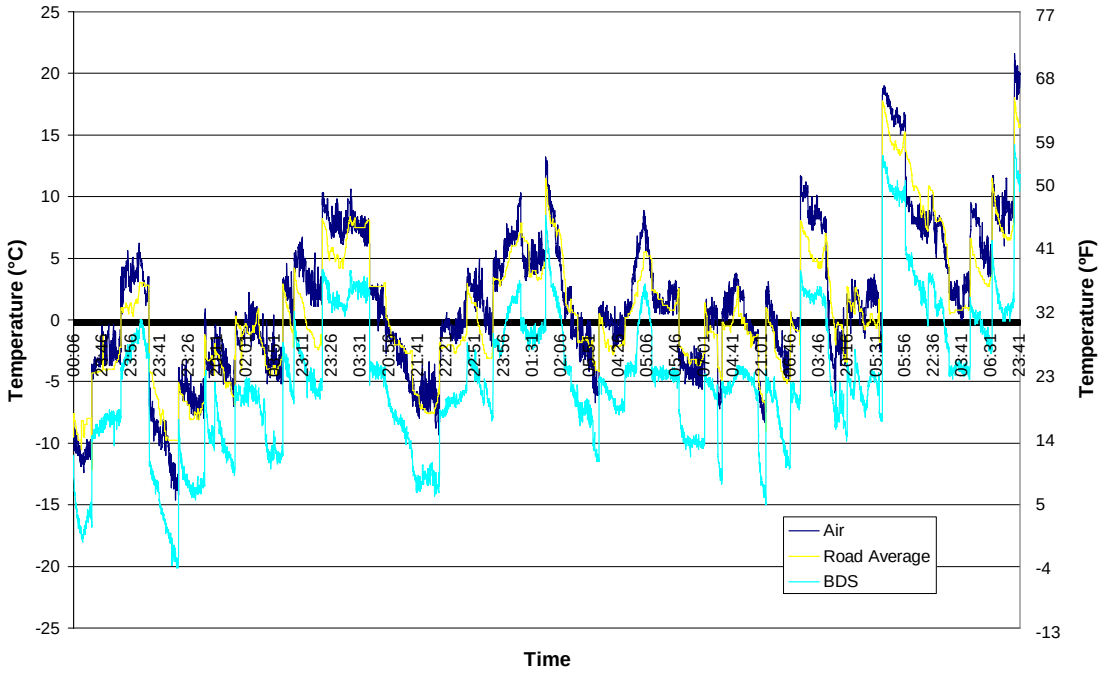


Figure 18: Time series graph for night time data for Site 68 I-77 Summit County road sensor January 21- April 5, 2005.

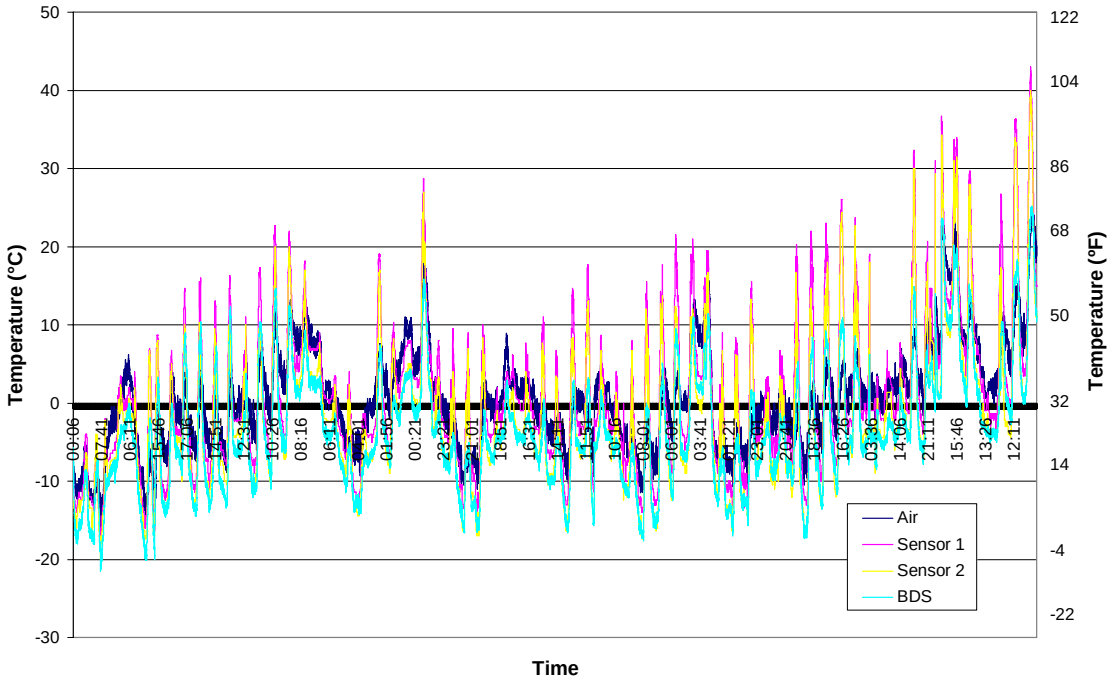


Figure 19: Time series graph for full day data for Site 68 I-271 Summit County bridge sensor January 21- April 5, 2005.

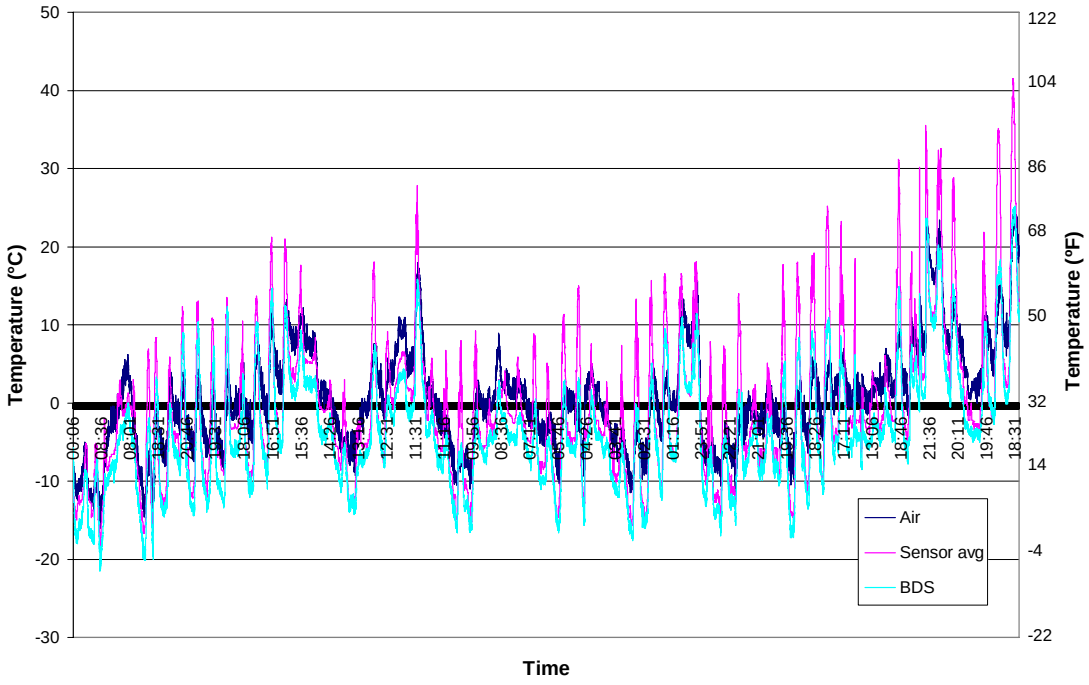


Figure 20: Average time series graph for full day data for Site 68 I-271 Summit County bridge sensor January 21- April 5, 2005.

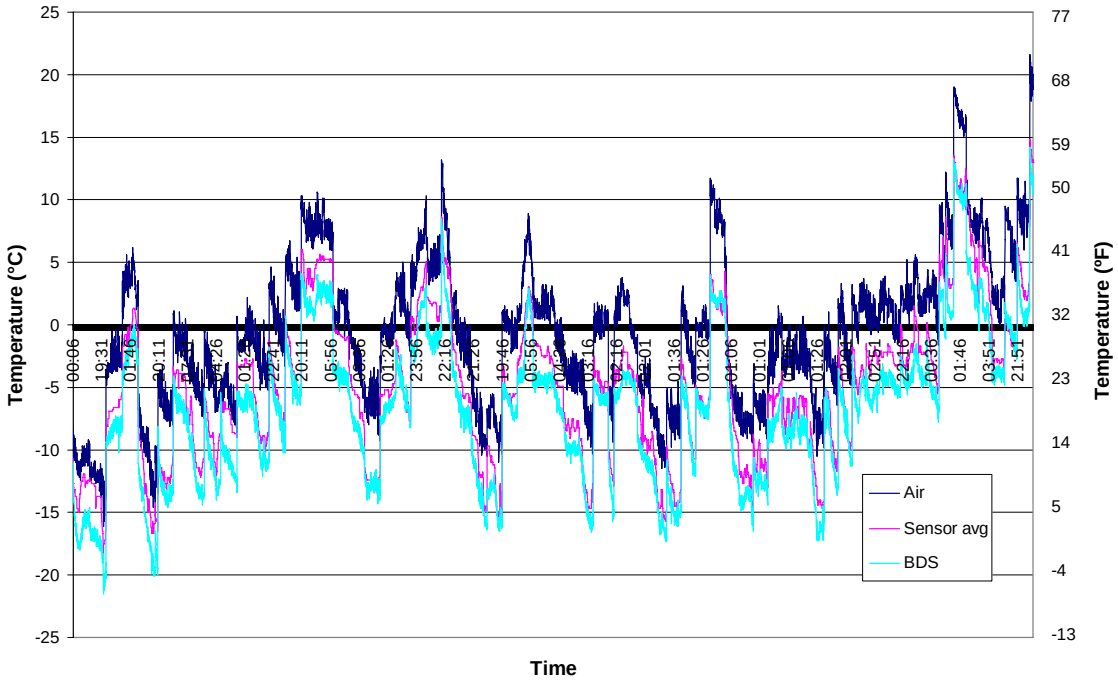


Figure 21: Time series graph for night time data for Site 68 I-271 Summit County bridge sensor January 21- April 5, 2005.

Hamilton County (Site 69):

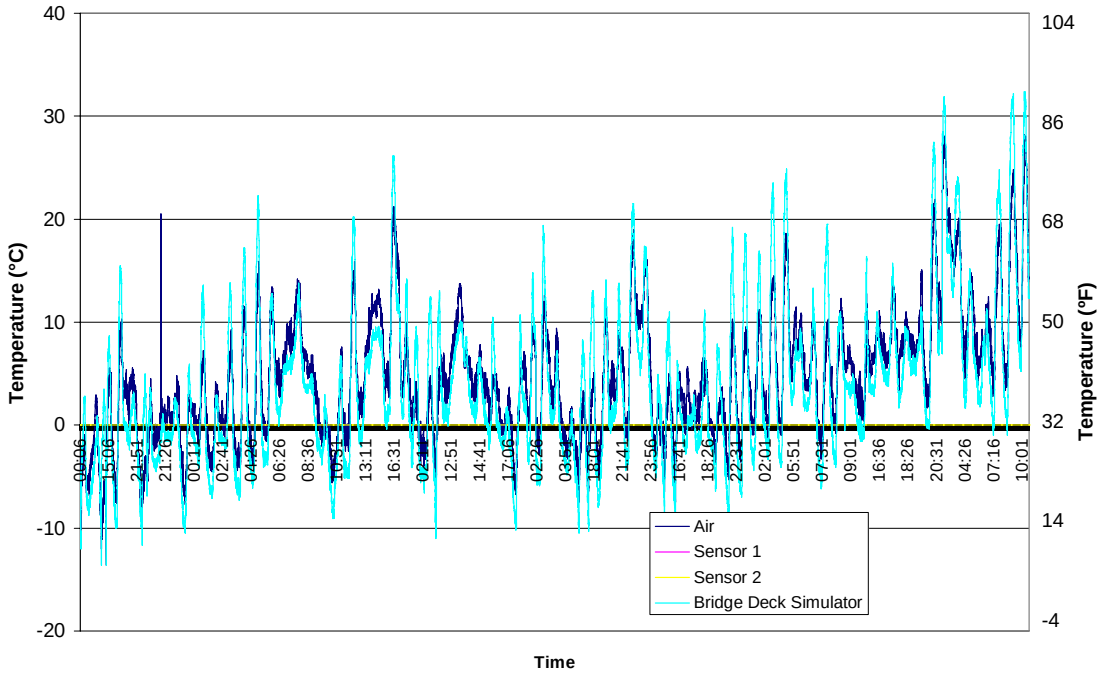


Figure 22: Time series graph for full day data for Site 69 I-275 Hamilton County road sensor January 21- April 5, 2005.

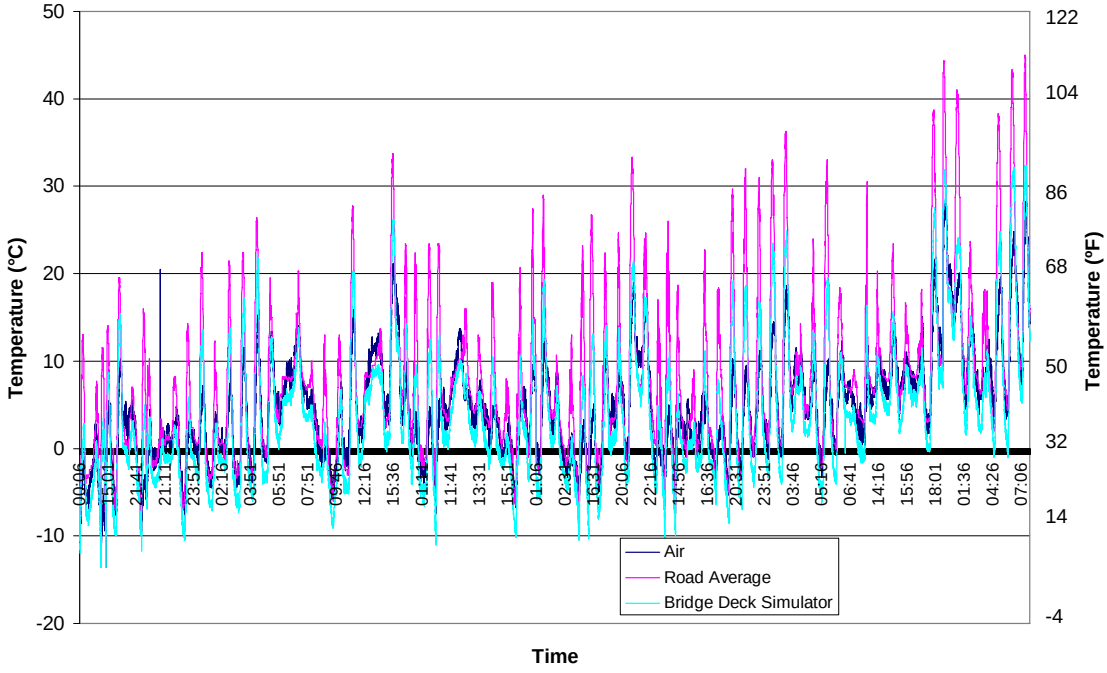


Figure 23: Average time series graph for full day data for Site 69 I-275 Hamilton County road sensor January 21- April 5, 2005.

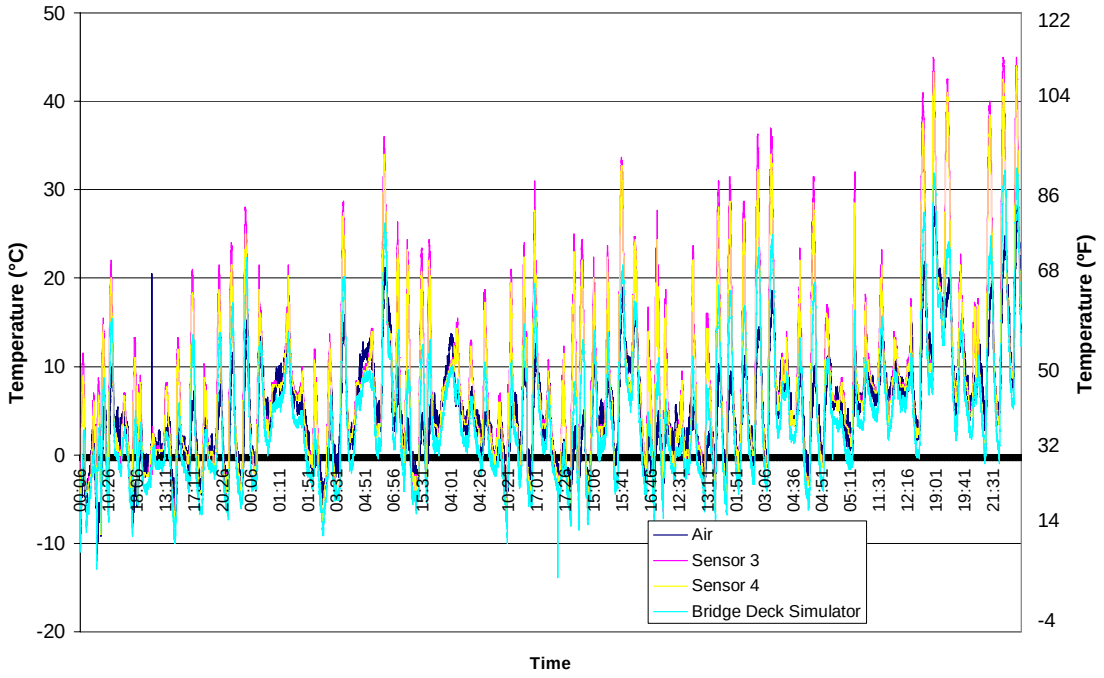


Figure 24: Time series graph for full day data for Site 69 I-275 Hamilton County bridge sensor January 21- April 5, 2005.

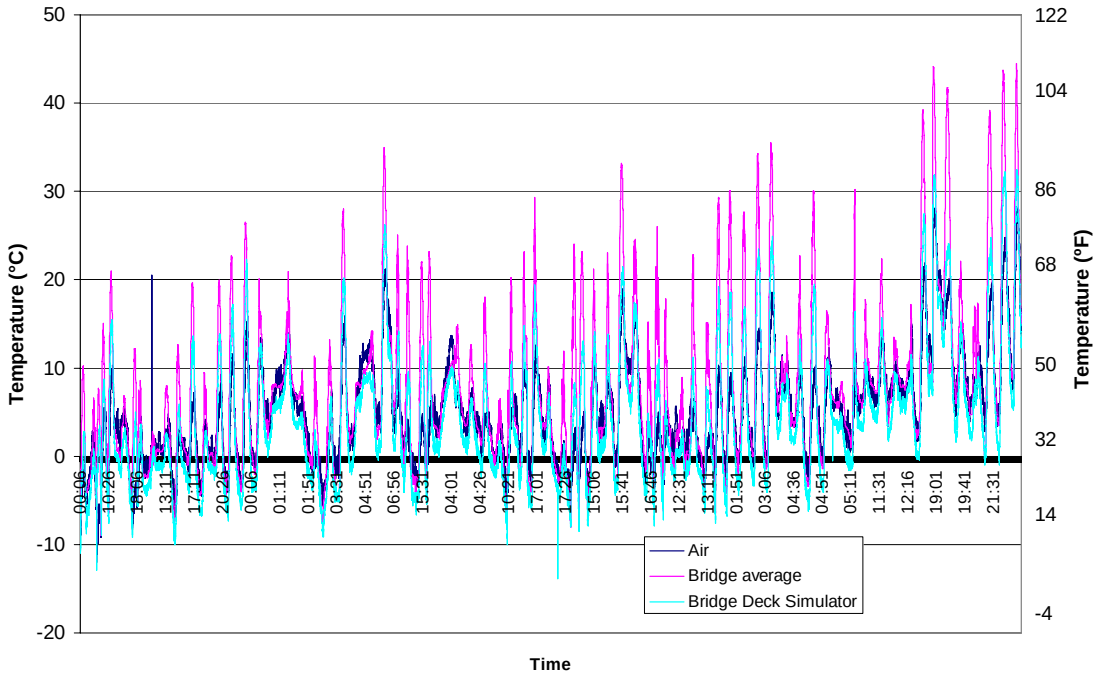


Figure 25: Average time series graph for full day data for Site 69 I-275 Hamilton County bridge sensor January 21- April 5, 2005.

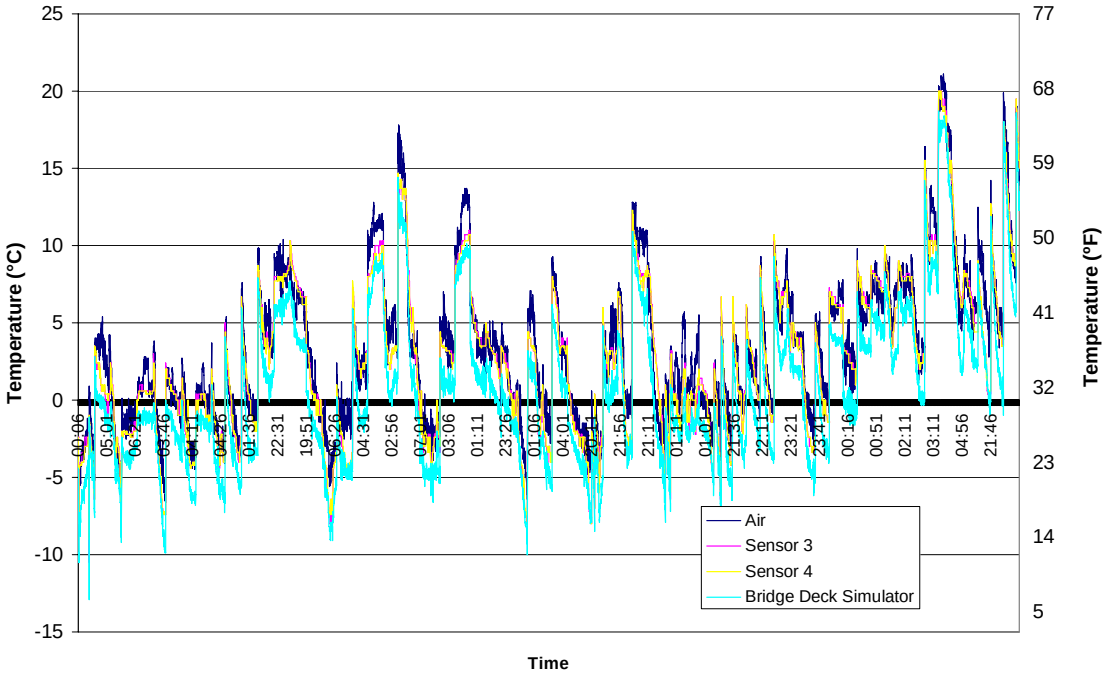


Figure 26: Time series graph for night time data for Site 69 I-275 Hamilton County bridge sensor January 21- April 5, 2005.

Hamilton/Clermont County (Site 70):

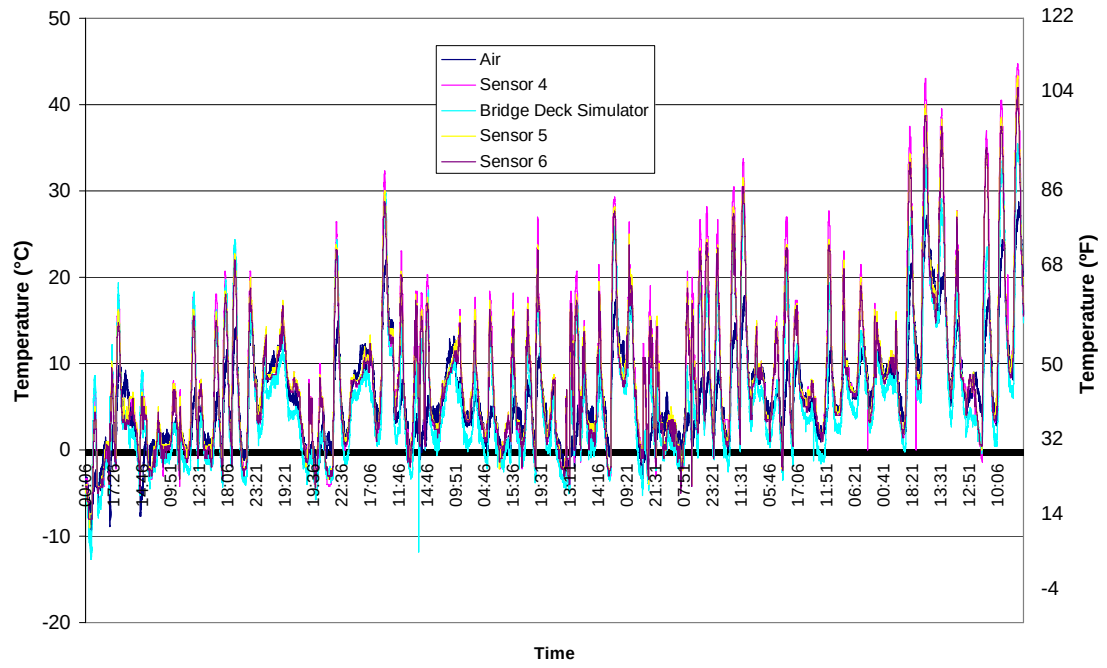


Figure 27: Time series graph for full day data for Site 70 I-275 Hamilton/Clermont County road sensor January 21- April 5, 2005.

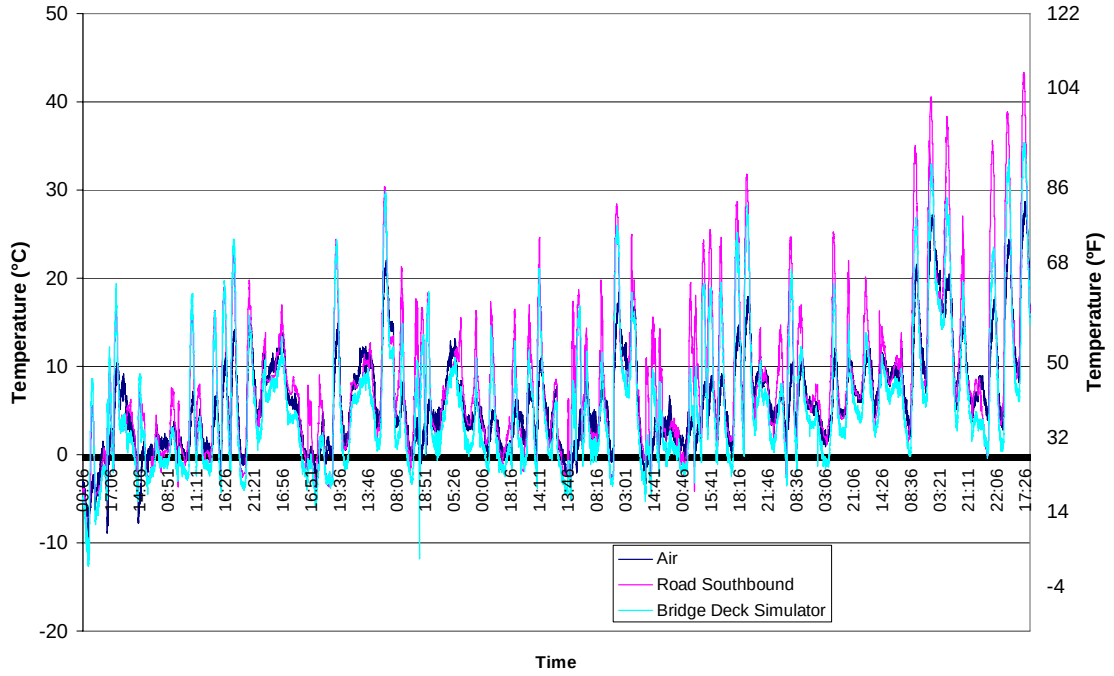


Figure 28: Average time series graph for full day data for Site 70 I-275 Hamilton/Clermont County road sensor January 21- April 5, 2005.

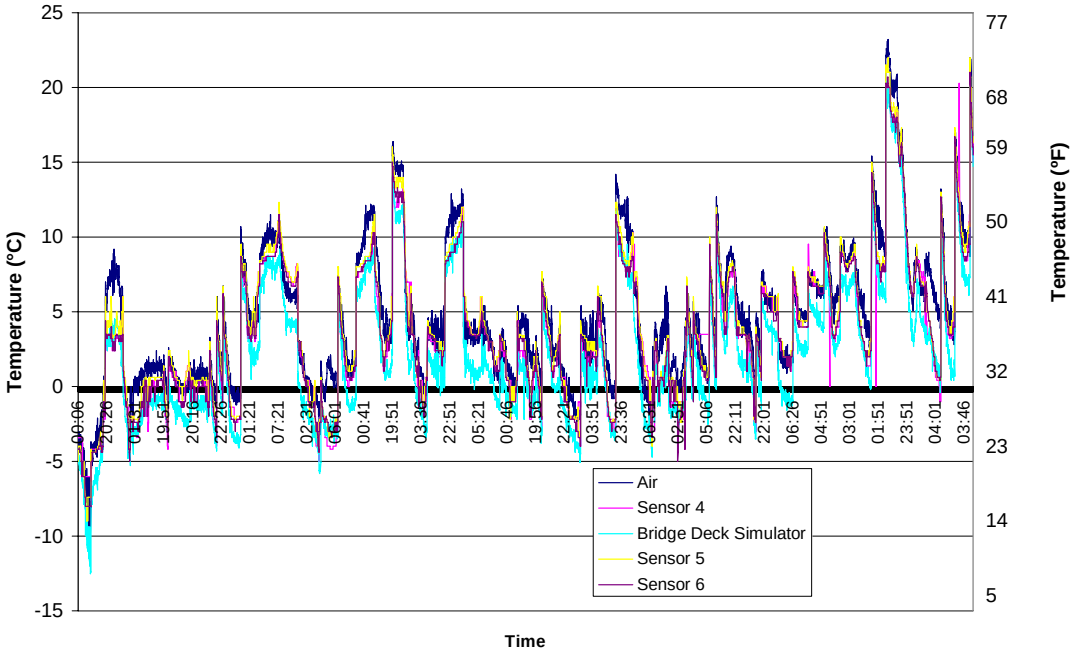


Figure 29: Time series graph for night time data for Site 70 I-275 Hamilton/Clermont County road sensor January 21- April 5, 2005.

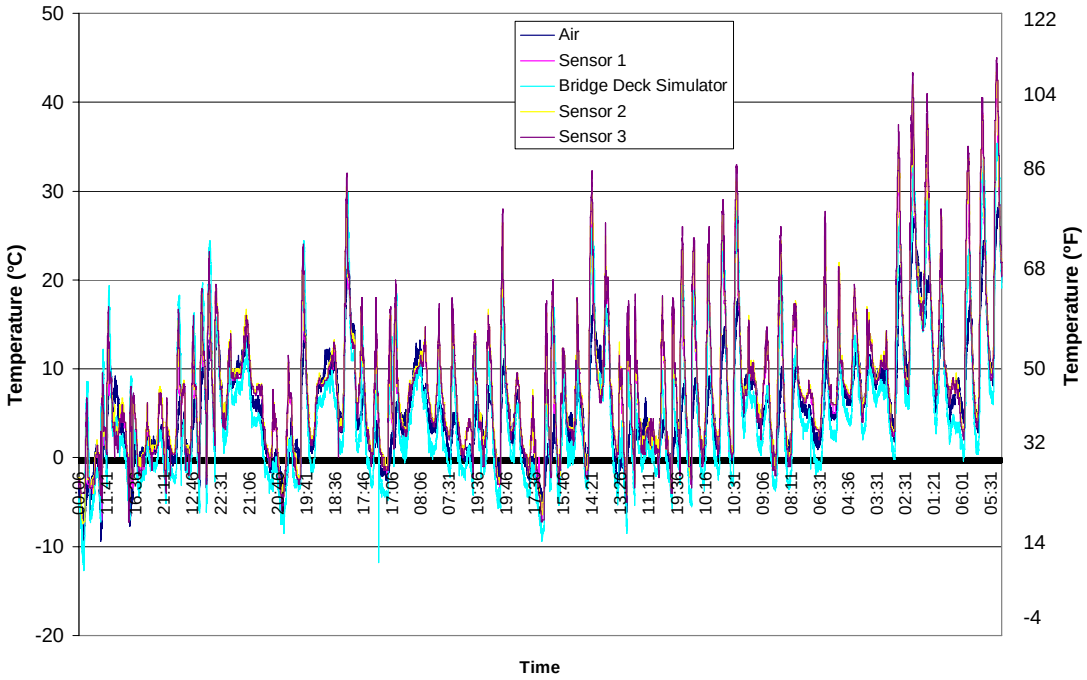


Figure 30: Time series graph for full day data for Site 70 I-275 Hamilton/Clermont County bridge sensor January 21- April 5, 2005.

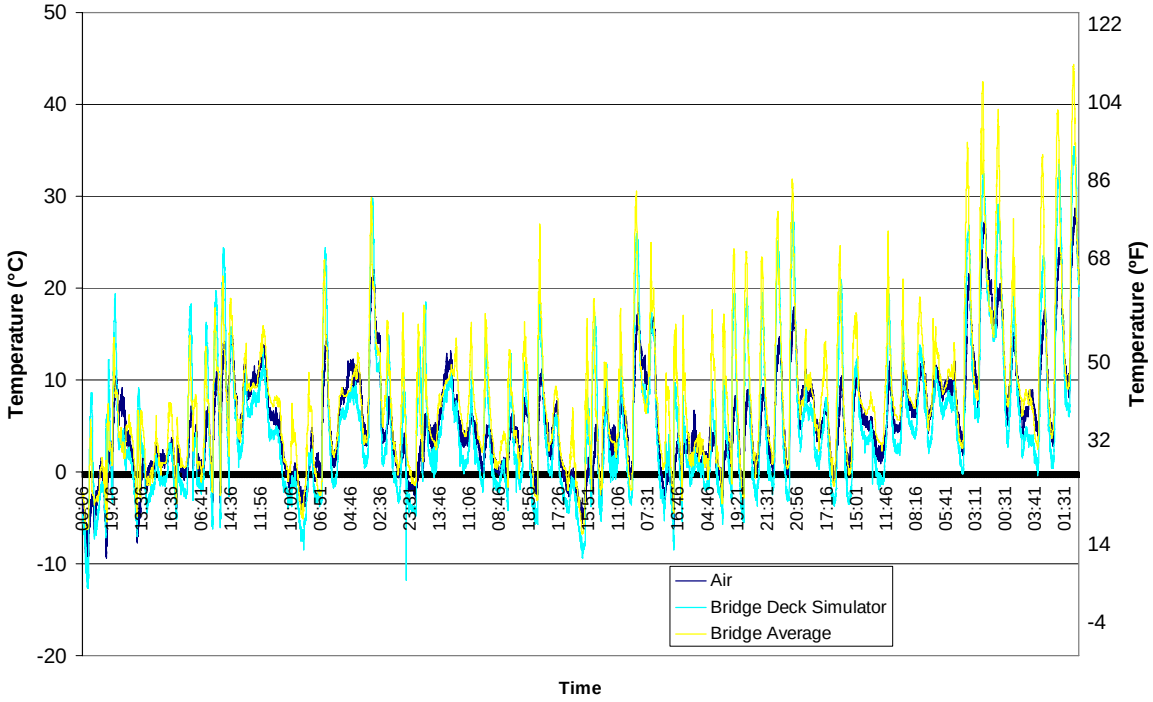


Figure 31: Average time series graph for full day data for Site 70 I-275 Hamilton/Clermont County bridge sensor January 21- April 5, 2005.

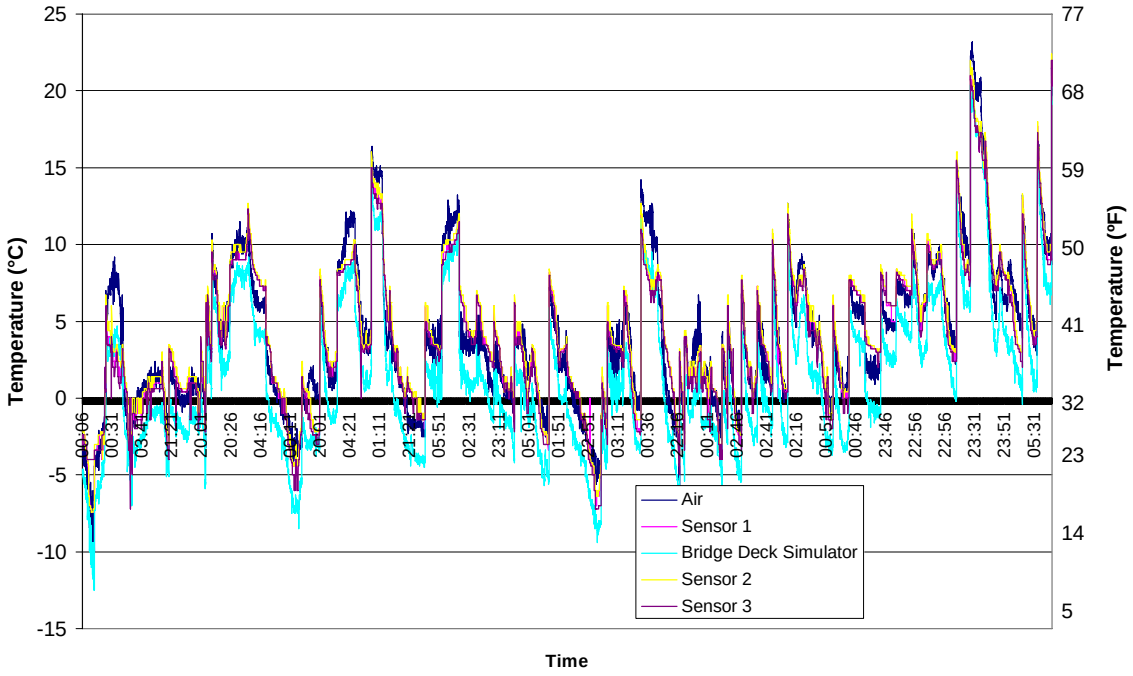


Figure 32: Time series graph for night time data for Site 70 I-275 Hamilton/Clermont County road sensor January 21- April 5, 2005.

Lorain County (Site 86):

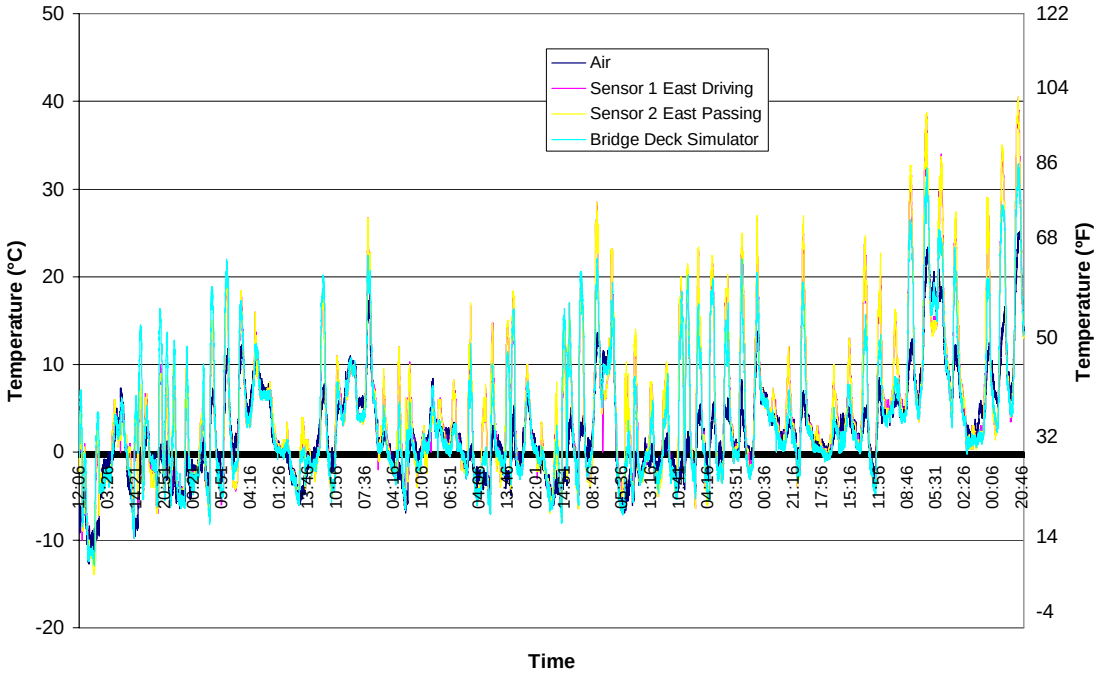


Figure 33: Time series graph for modified full day data for Site 86 I-90 Lorain County road sensor January 21- April 5, 2005.

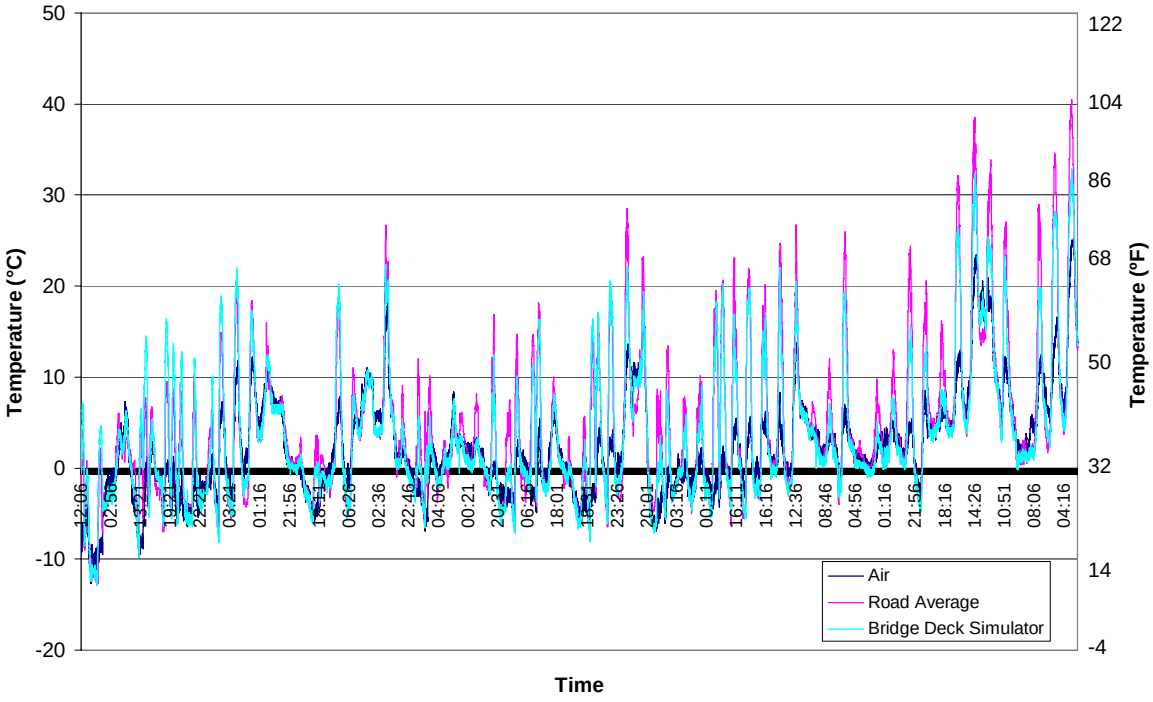


Figure 34: Average time series graph for modified full day data for Site 86 I-90 Lorain County road sensor January 21- April 5, 2005.

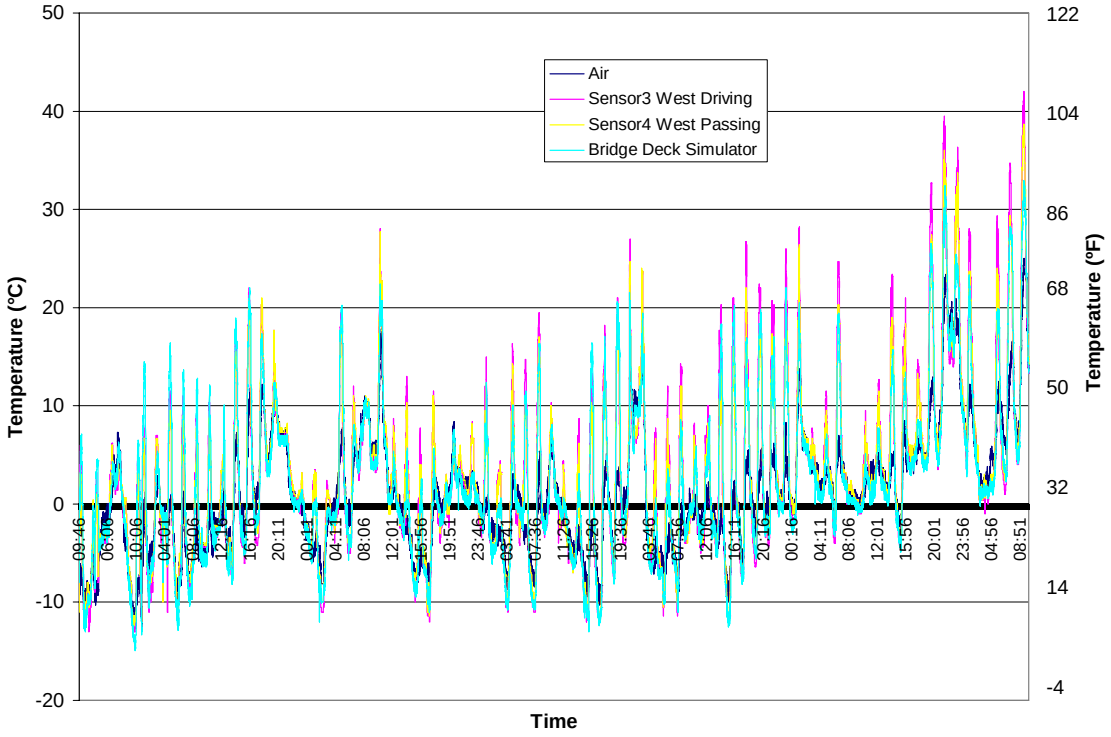


Figure 35: Time series graph for modified full day data for Site 86 I-90 Lorain County bridge sensor January 21- April 5, 2005.

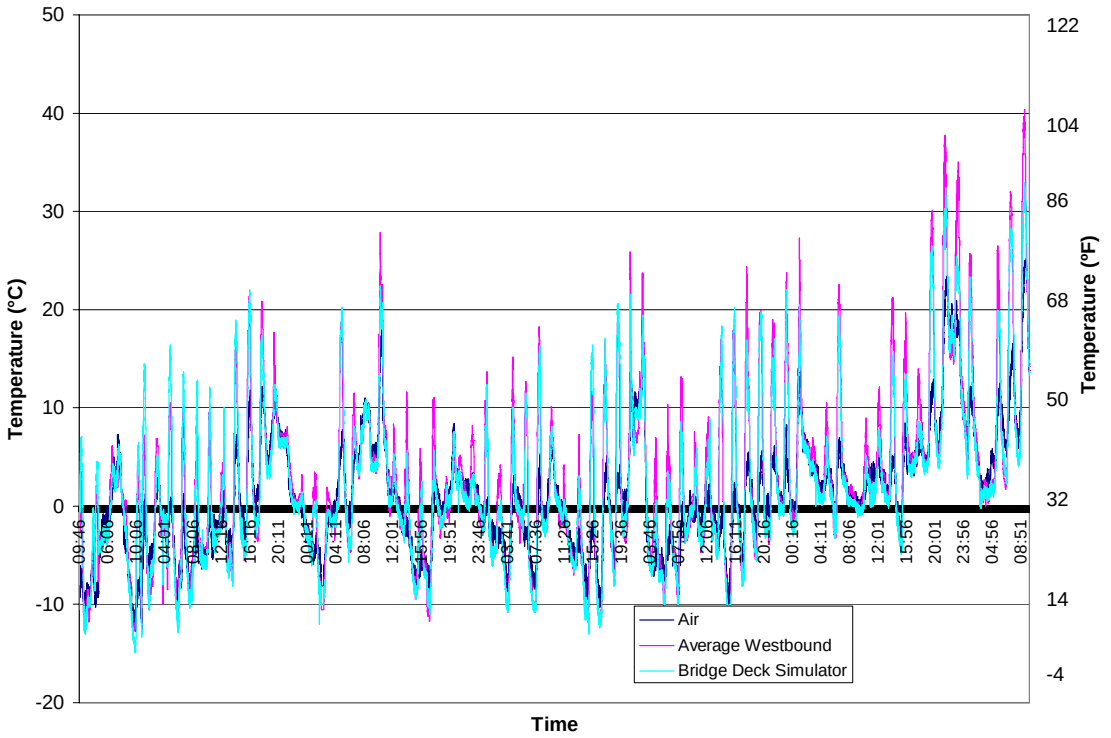


Figure 36: Average time series graph for modified full day data for Site 86 I-90 Lorain County bridge sensor January 21- April 5, 2005.

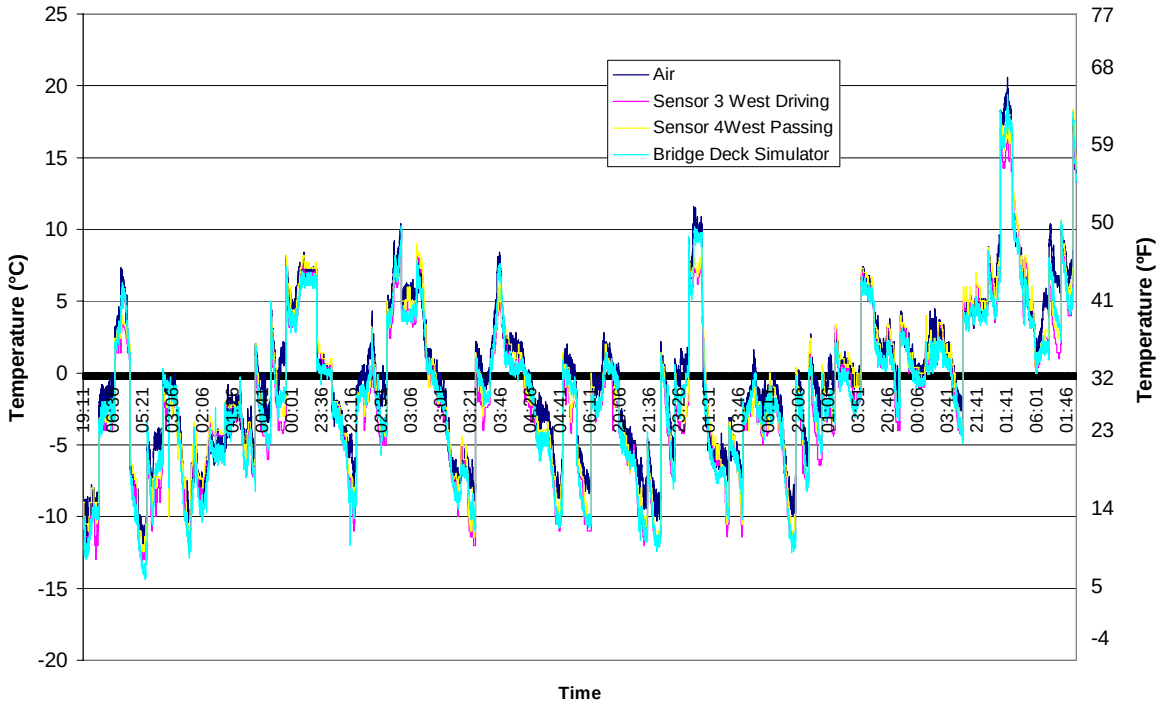


Figure 37: Time series graph for modified night time data for Site 86 I-90 Lorain County bridge sensor January 21- April 5, 2005.

Ashtabula County (Site 88):

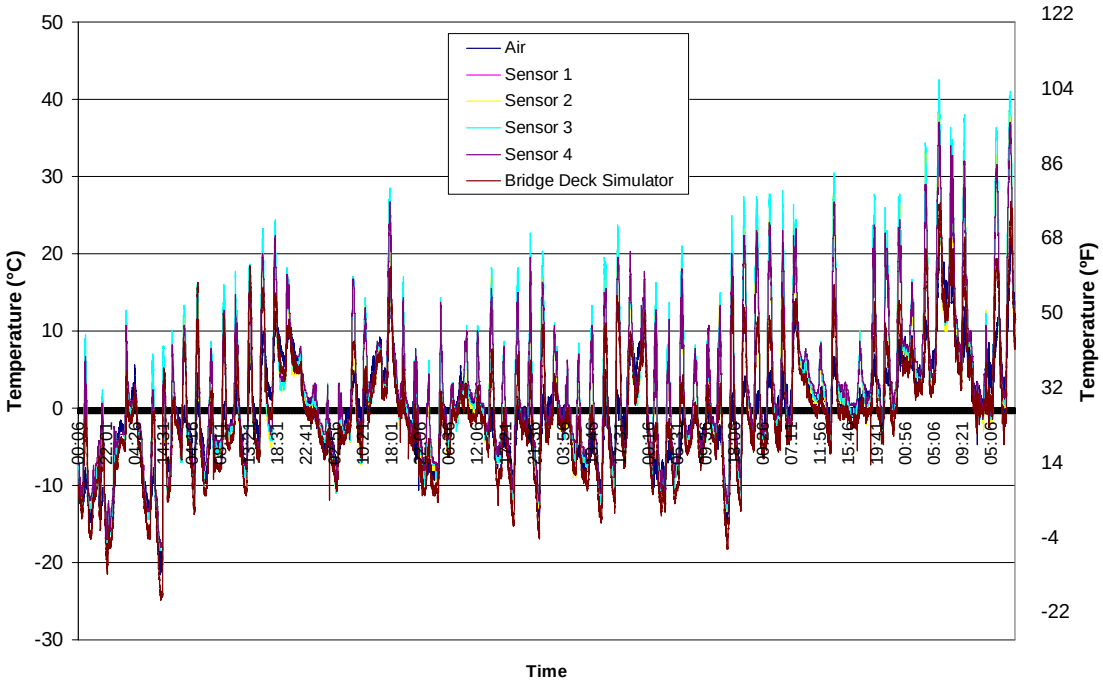


Figure 38: Time series graph for full day data for Site 88 I-90 Ashtabula County road sensor January 21- April 5, 2005.

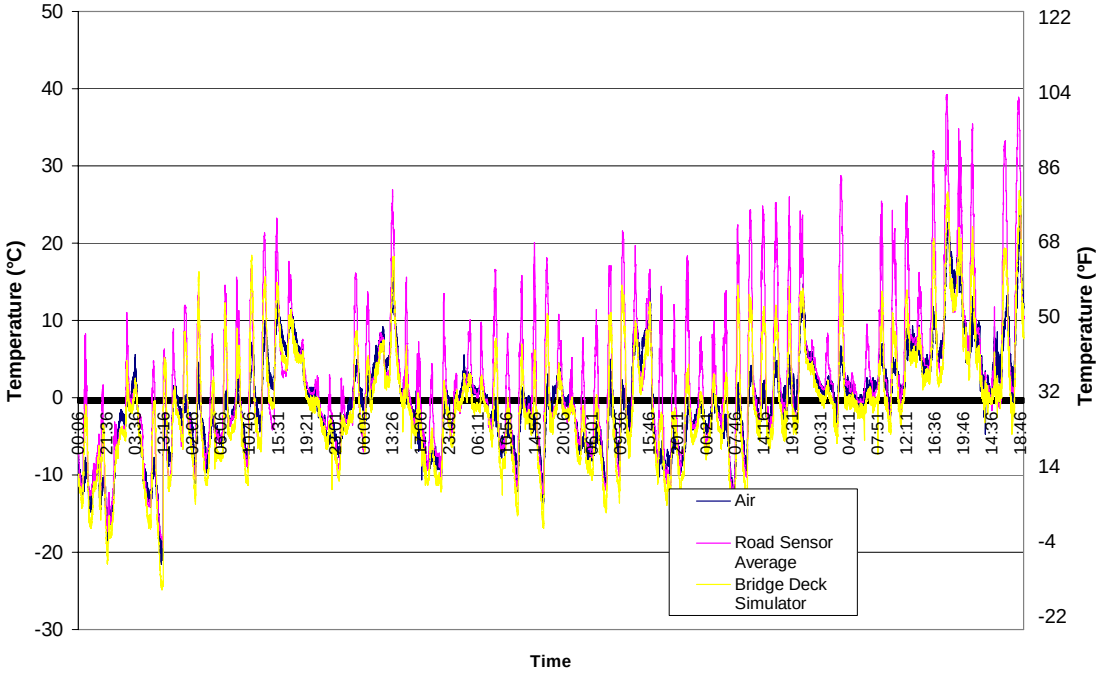


Figure 39: Average time series graph for full day data for Site 88 I-90 Ashtabula County road sensor January 21- April 5, 2005.

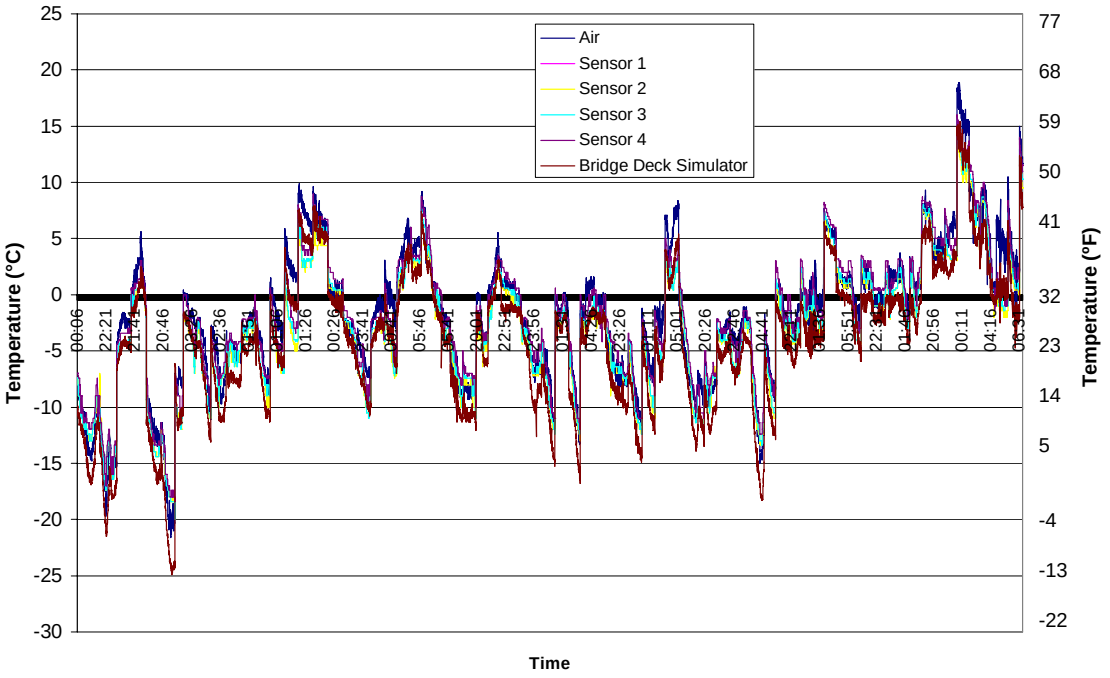


Figure 40: Time series graph for night time data for Site 88 I-90 Ashtabula County road sensor January 21- April 5, 2005.

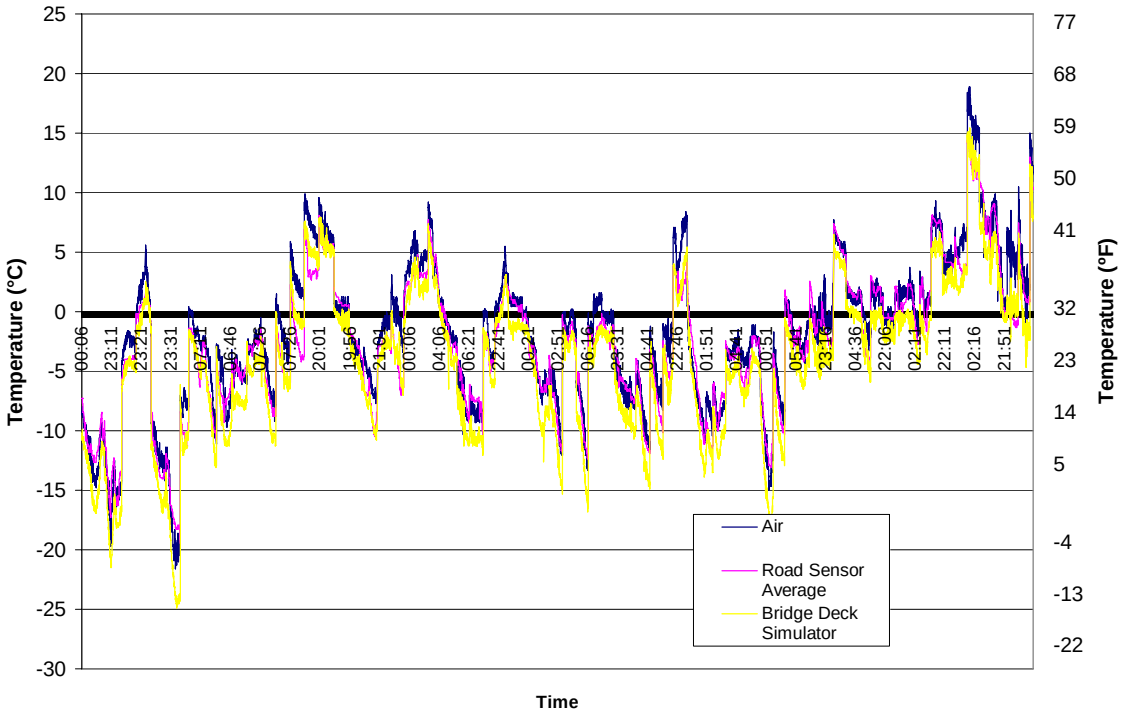


Figure 41: Average time series graph for night time data for Site 88 I-90 Ashtabula County road sensor January 21- April 5, 2005.

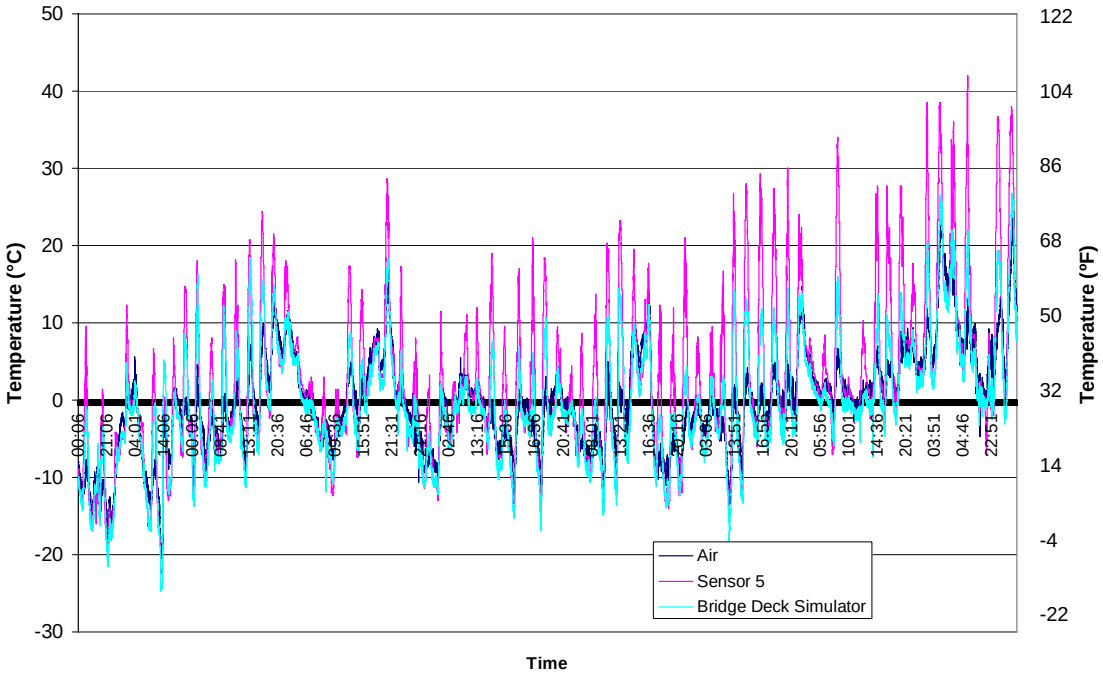


Figure 42: Time series graph for full day data for Site 88 I-90 Ashtabula County bridge sensor January 21- April 5, 2005.

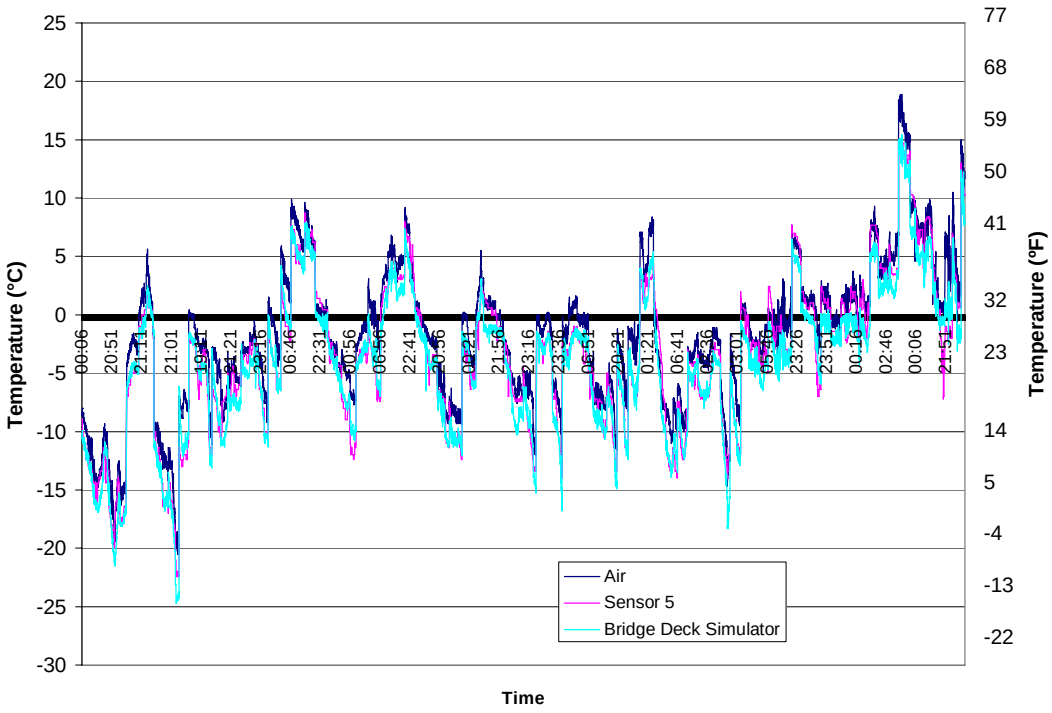


Figure 43: Time series graph for night time data for Site 88 I-90 Ashtabula County bridge sensor January 21- April 5, 2005.

Portage/Mahoning County (Site 91):

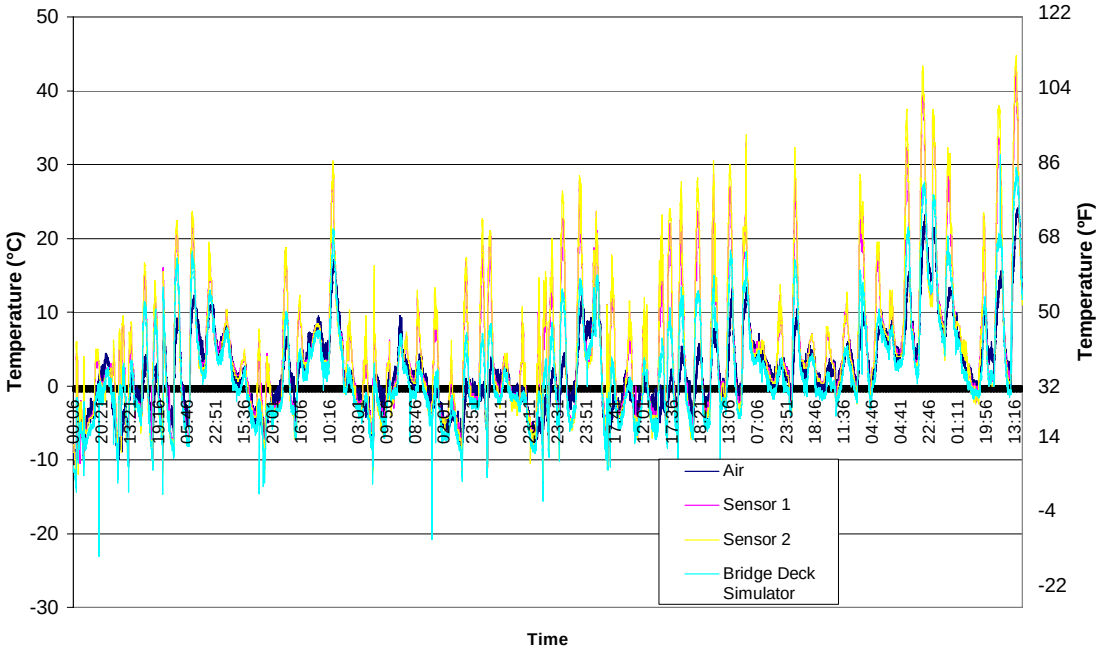


Figure 44: Time series graph for full day data for Site 91 I-76 Portage/Mahoning County road sensor January 21- April 5, 2005.

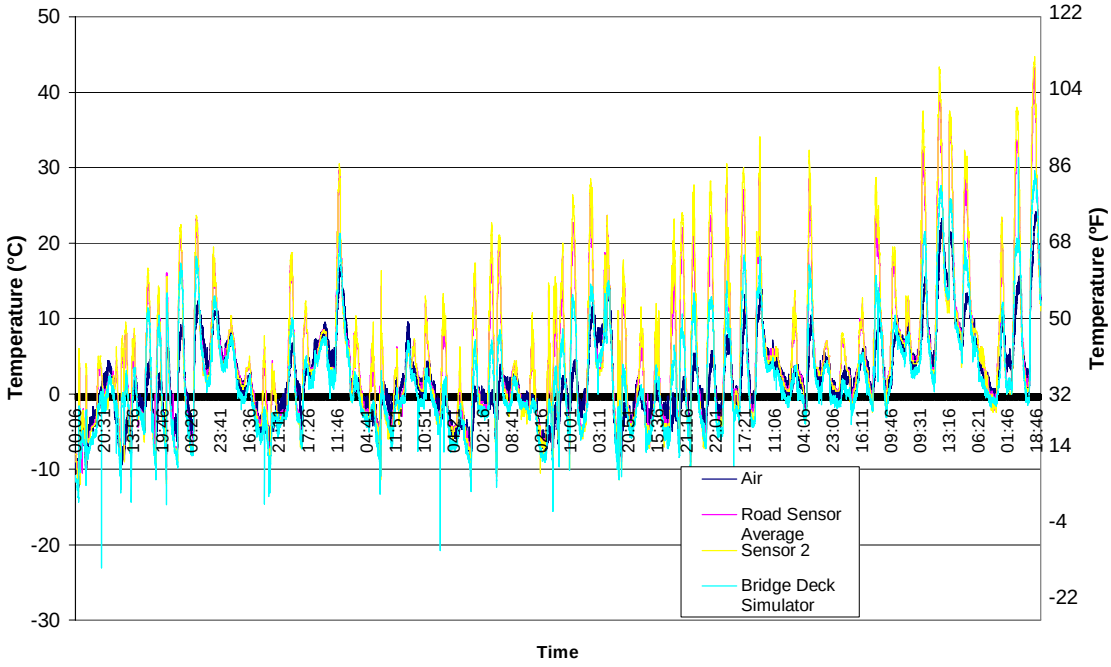


Figure 45: Average time series graph for full day data for Site 91 I-76 Portage/Mahoning County road sensor January 21- April 5, 2005.

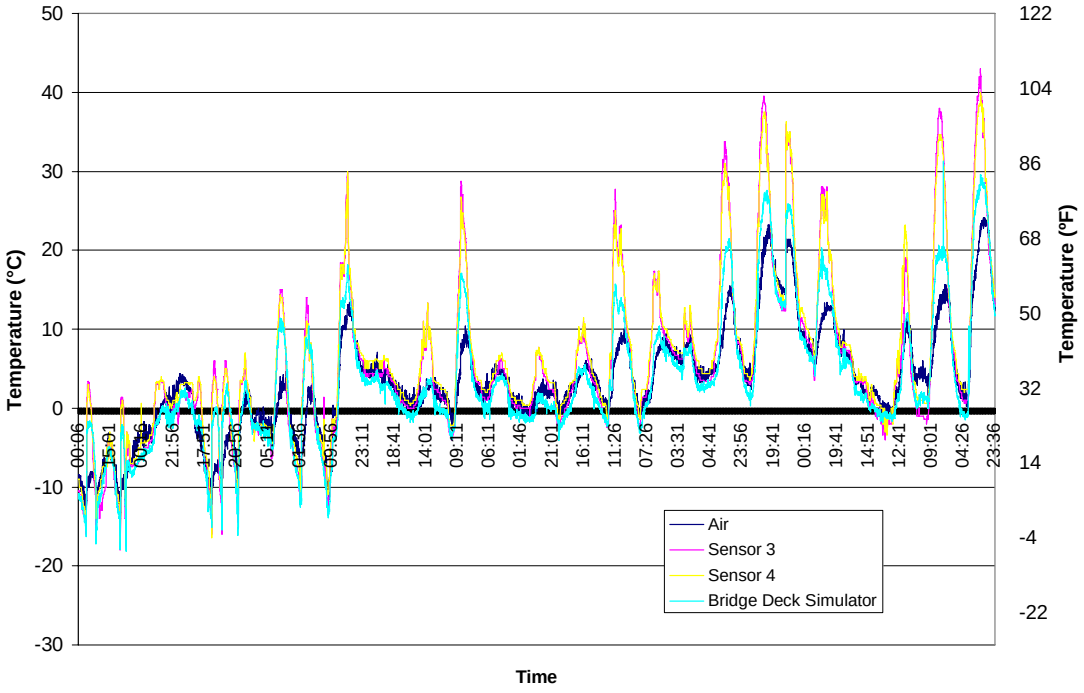


Figure 46: Time series graph for full day data for Site 91 I-76 Portage/Mahoning County bridge sensor January 21- April 5, 2005.

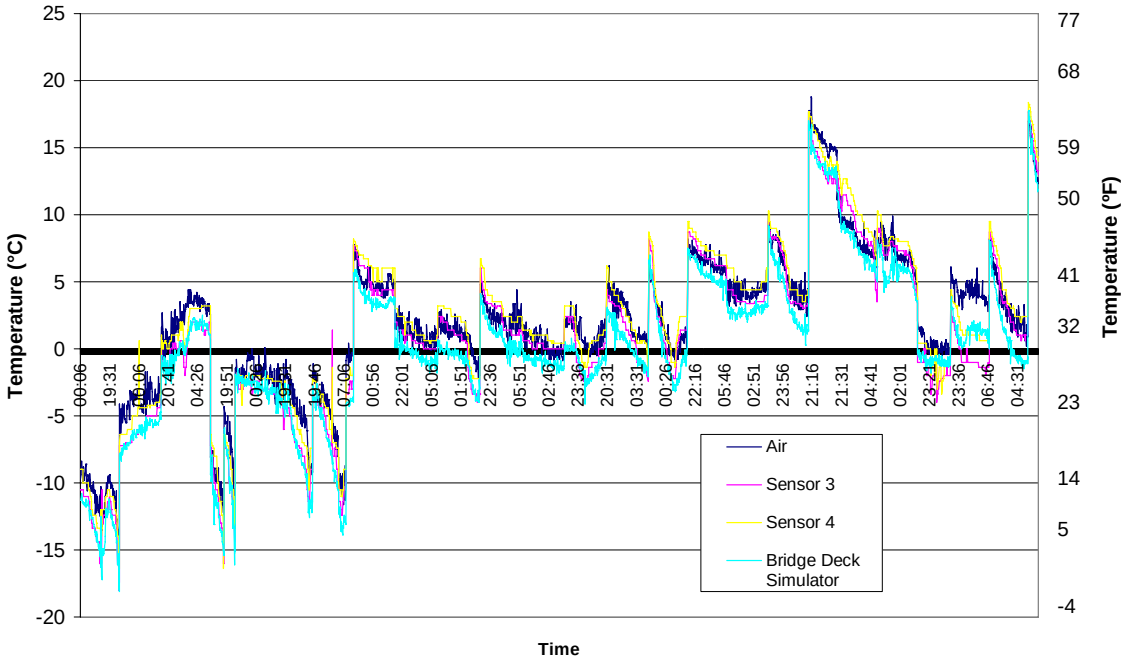


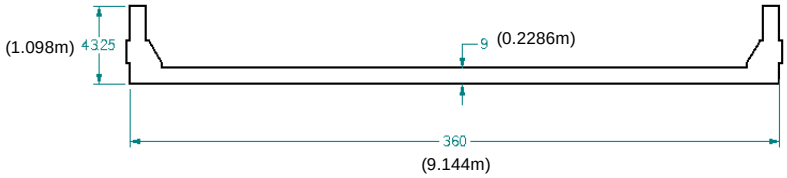
Figure 47: Time series graph for night time data for Site 91 I-76 Portage/Mahoning County bridge sensor January 21- April 5, 2005.

Appendix B: Finite element analysis – bridge drawings and temperature difference graphs

Stark County (Site 9):

BRIDGE NO: STA-77-1433

Average Wind Speed: Max Cooling Gradient = 4.78 mph - 7.69 kmph (84.128 in/sec)
Max Warming Gradient = 2.12 mph - 3.41 kmph (37.31 in/sec)
Maximum Wind Speed :Max Cooling Gradient =8 mph - 12.87 kmph (140.8 in/sec)
Direction :2° (N)
Maximum Wind Speed :Max Warming gradient = 3.6 mph - 5.79 kmph (63.36 in/sec)
Direction :190° (S)



ALL DIMENSIONS ARE IN INCHES

Length of bridge = 311.26' (94.87 m)
Orientation:81°0'6"(NE)

Figure 48: Cross-Section view of Stark County Bridge (Site 9).

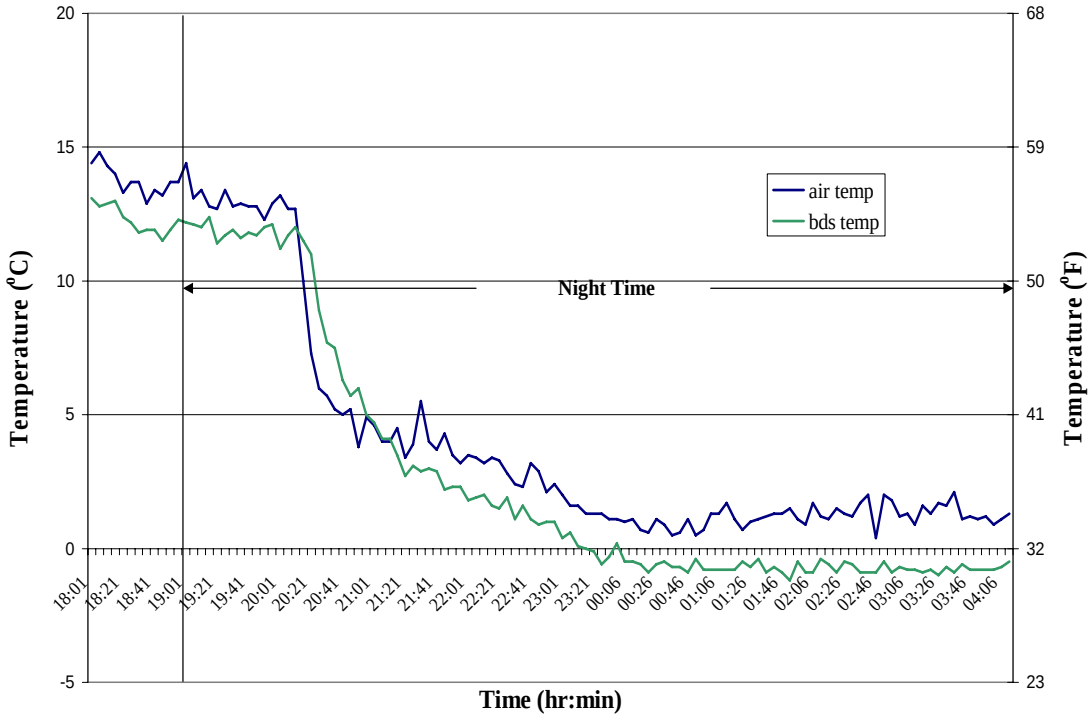


Figure 49: Data containing the -8.6°C/hr (-15.48°F/hr) temperature gradient for Stark County (Site 9) from 1/13/05 18:01 – 1/14/05 04:16.

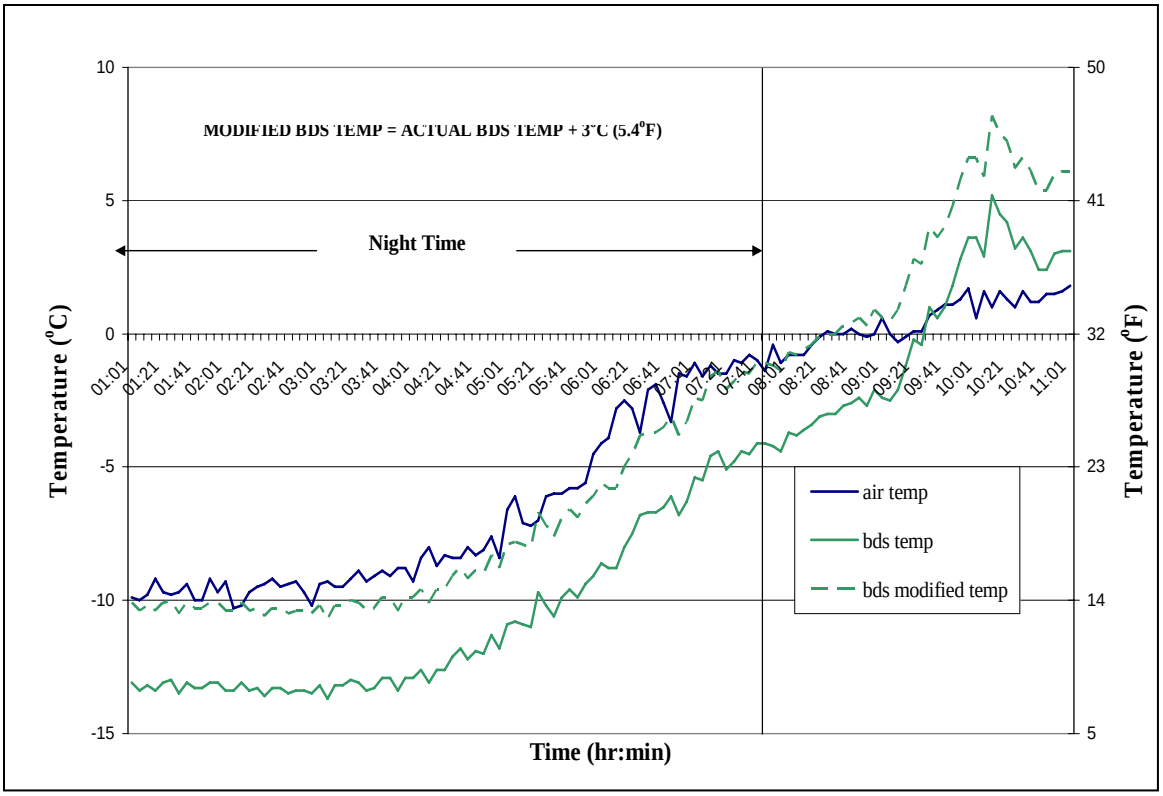


Figure 50: Data containing the 4.3°C/hr (7.74 °F/hr) temperature gradient for Stark County (Site 9) from 12/21/05 01:01 – 12/21/05 11:01.

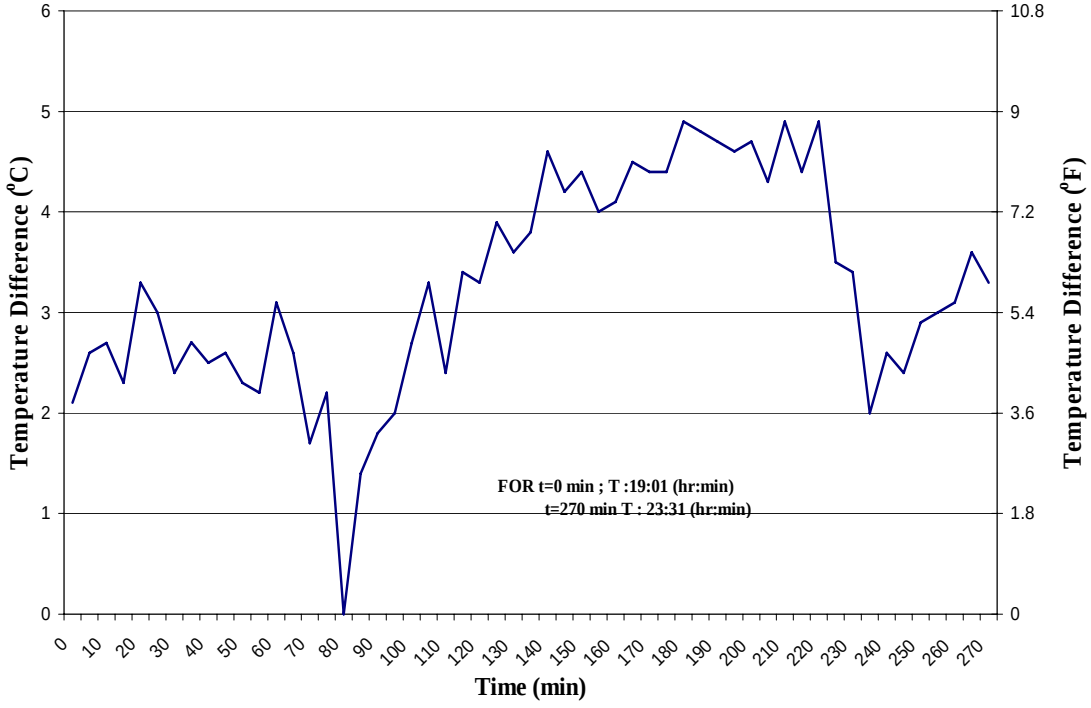


Figure 51: Temperature difference between actual values for bridge and block for Site 9 – Stark County for delta = 8.6°C/hr (-15.48°F/hr) from 1/13/05 19:01 – 1/13/05 23:31.

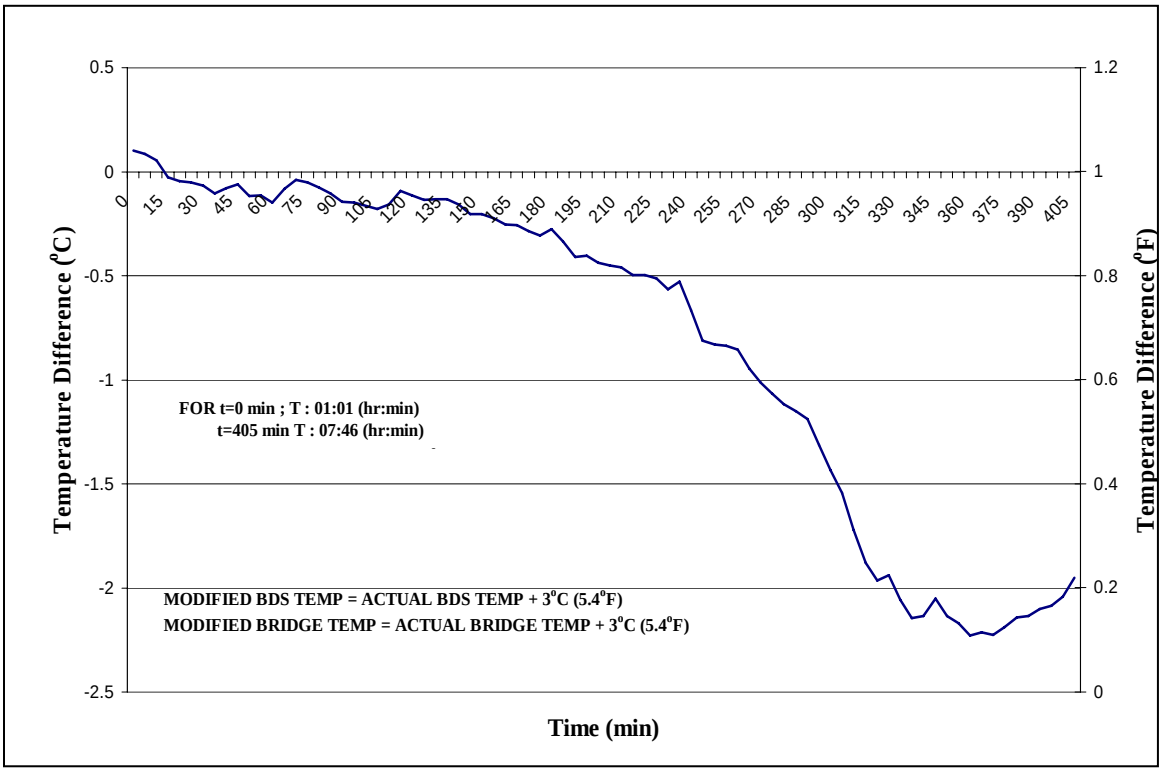


Figure 52: Temperature difference between simulated values for bridge and block for Site 9 – Stark County for delta = 4.3°C/hr (7.74 °F/hr) from 12/21/05 01:01 – 12/21/05 07:46.

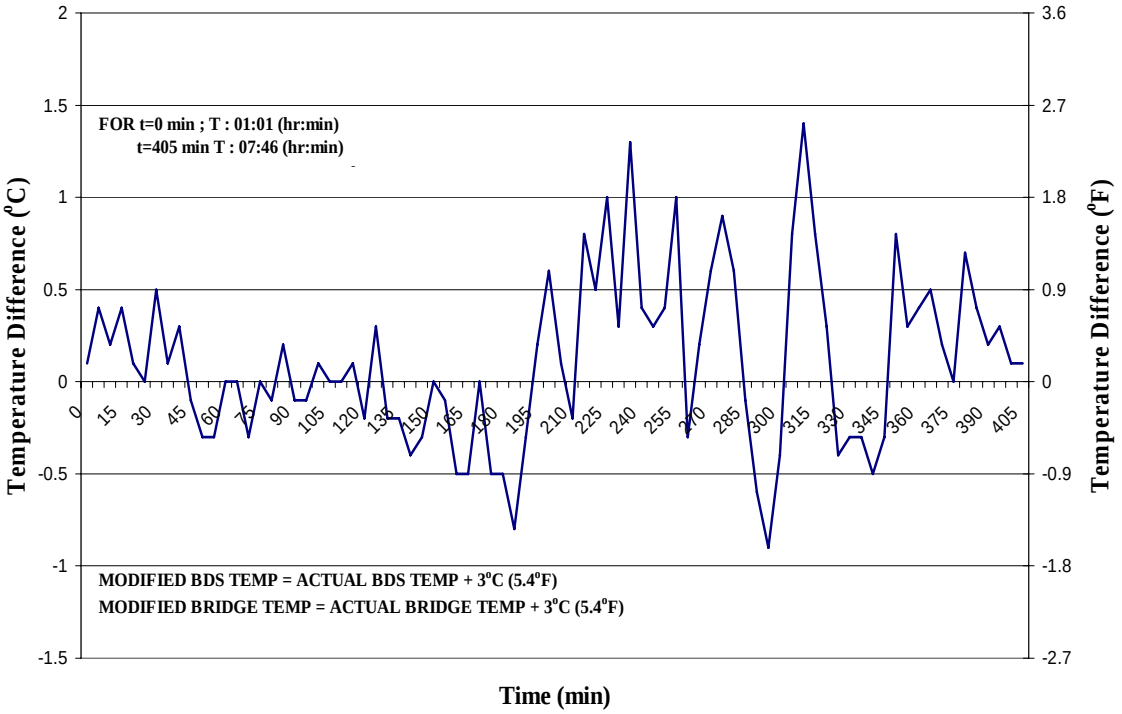
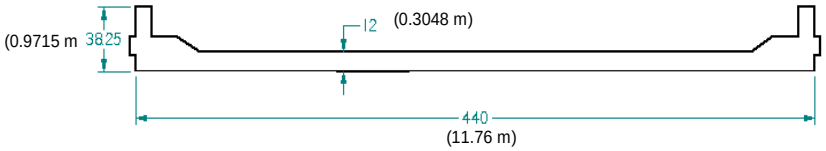


Figure 53: Temperature difference between actual values for bridge and block for Site 9 – Stark County for delta = 4.3°C/hr (7.74 °F/hr) from 12/21/05 01:01 – 12/21/05 07:46.

Warren County (Site 59):

BRIDGE NO: WAR-1-1514

Average Wind Speed: Max Cooling Gradient = 2.32 mph - 3.73 kmph (40.83 in/sec)
Max Warming Gradient = 0.178 mph - 0.286 kmph (3.13 in/sec)
Maximum Wind Speed :Max Cooling Gradient =5.1 mph - 8.2 kmph (89.76 in/sec)
Direction : 254° (WSW)
Maximum Wind Speed :Max Warming gradient = 0.6 mph - 0.965 kmph (10.56 in/sec)
Direction : 313° (NW)



ALL DIMENSIONS ARE IN INCHES

Length of bridge = 2330' (679 m)
Orientation : 69°29'15" (ENE)

Figure 54: Cross-Section view of Warren County Bridge (Site 59).

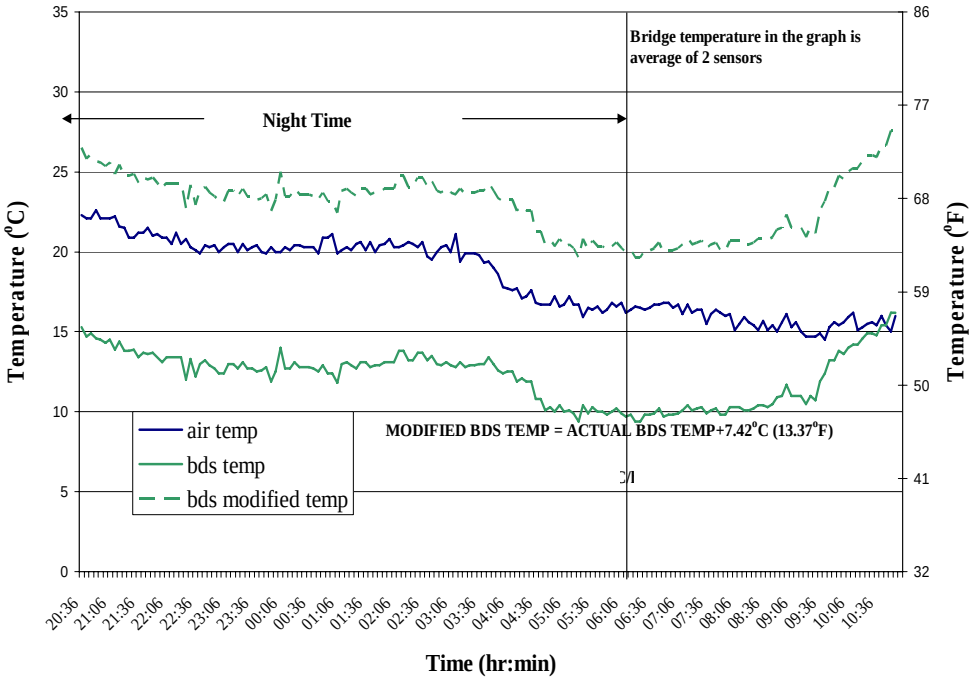


Figure 55: Data containing the -3°C/hr (-5.4°F/hr) temperature gradient for Warren County (Site 59) from 3/30/05 20:36 – 3/31/05 11:01.

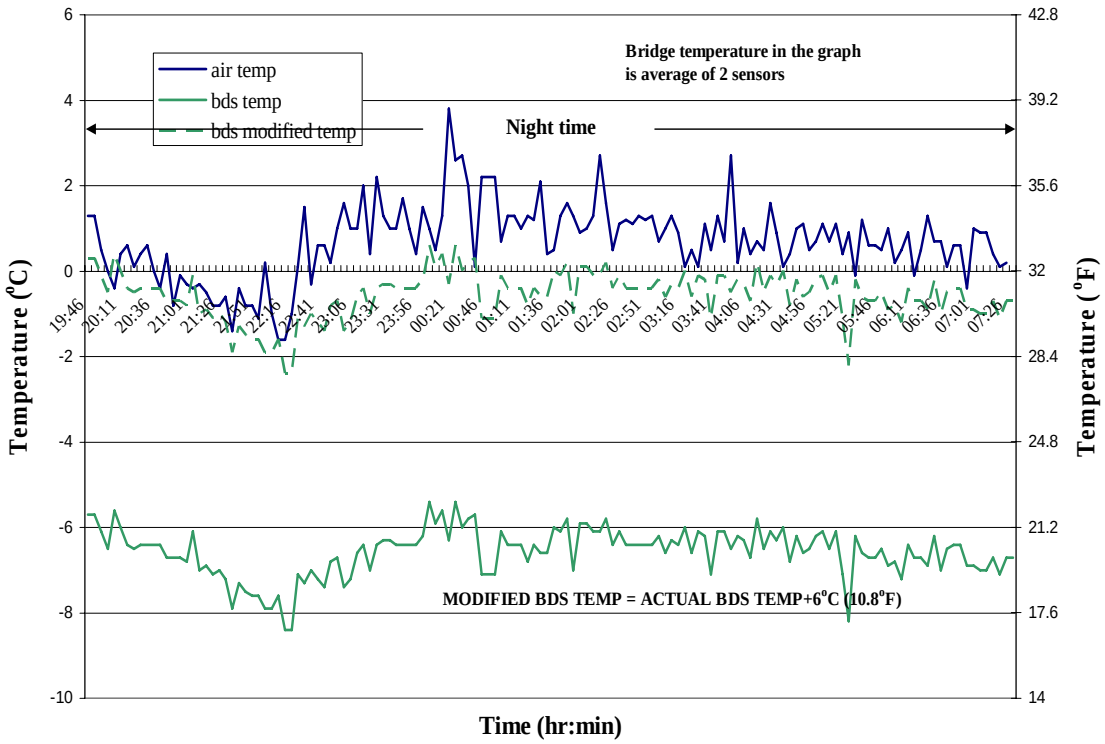


Figure 56: Data containing the 1.4°C/hr (2.52 °F/hr) temperature gradient for Warren County (Site 59) from 2/11/05 19:46 – 2/12/05 07:36.

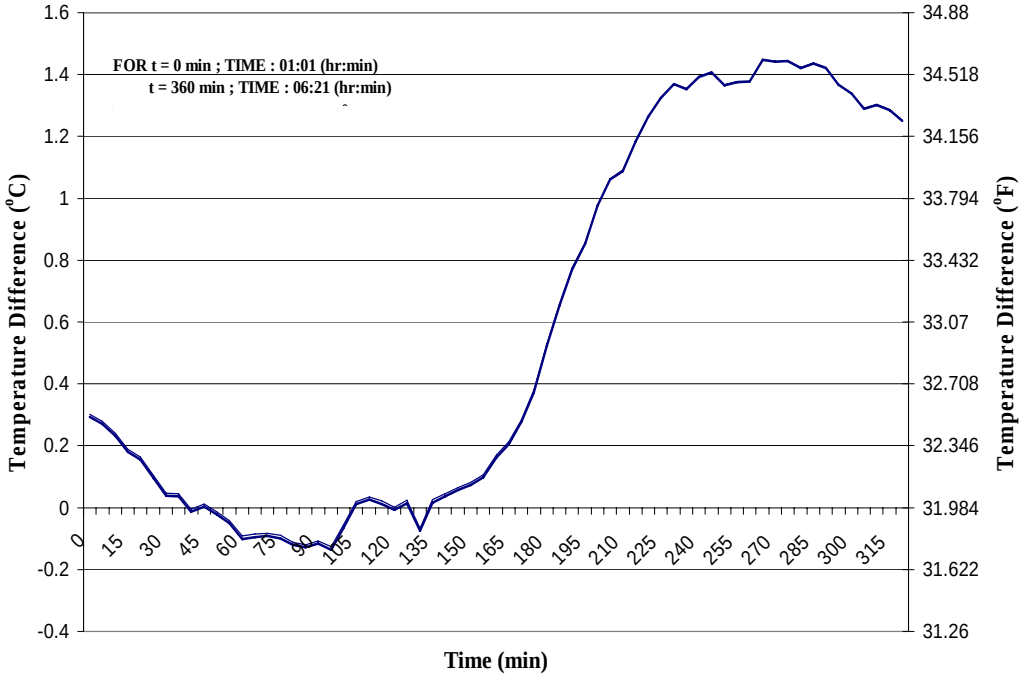


Figure 57: Temperature difference between simulated values for bridge and block for Site 59 – Warren County for delta = -3°C/hr (-5.4°F/hr) from 3/31/05 01:01 – 3/31/05 06:21.

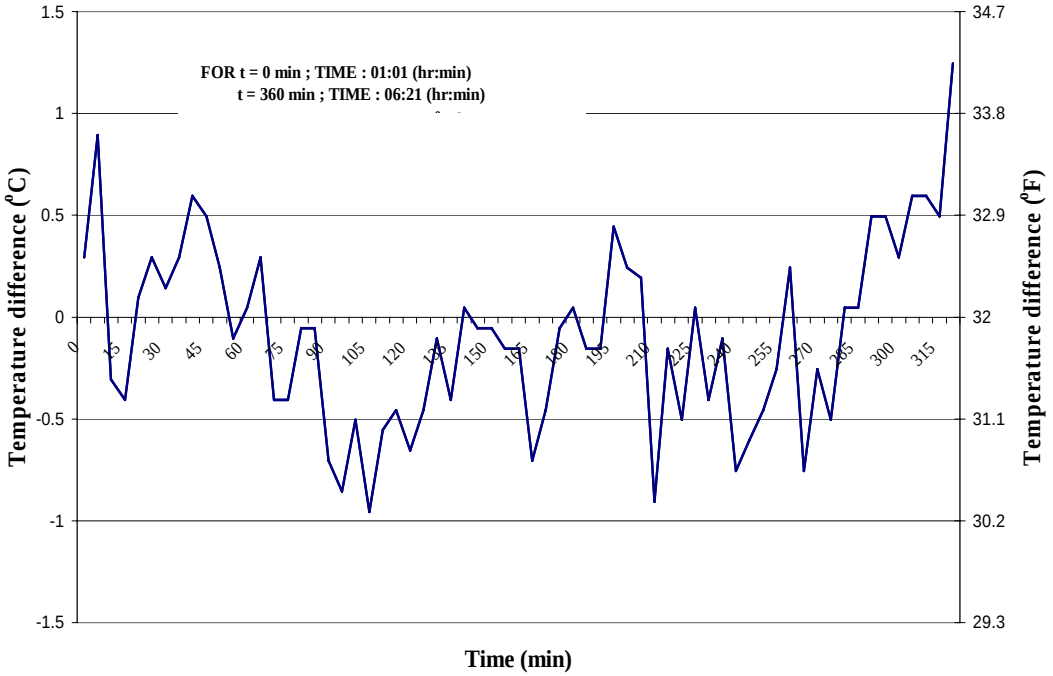


Figure 58: Temperature difference between actual values for bridge and block for Site 59 – Warren County for delta = -3°C/hr (-5.4°F/hr) from 3/31/05 01:01 – 3/31/05 06:21.

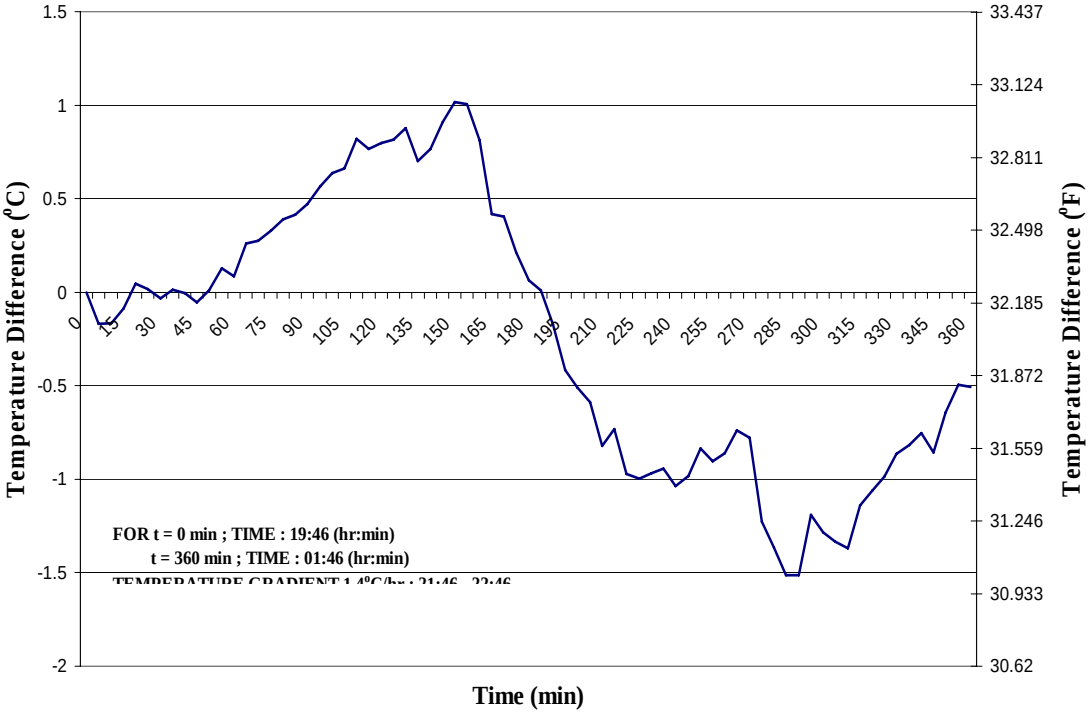


Figure 59: Temperature difference between simulated values for bridge and block for Site 59 – Warren County for delta = 1.4°C/hr (2.52 °F/hr) from 2/11/05 19:46 – 2/12/05 01:46.

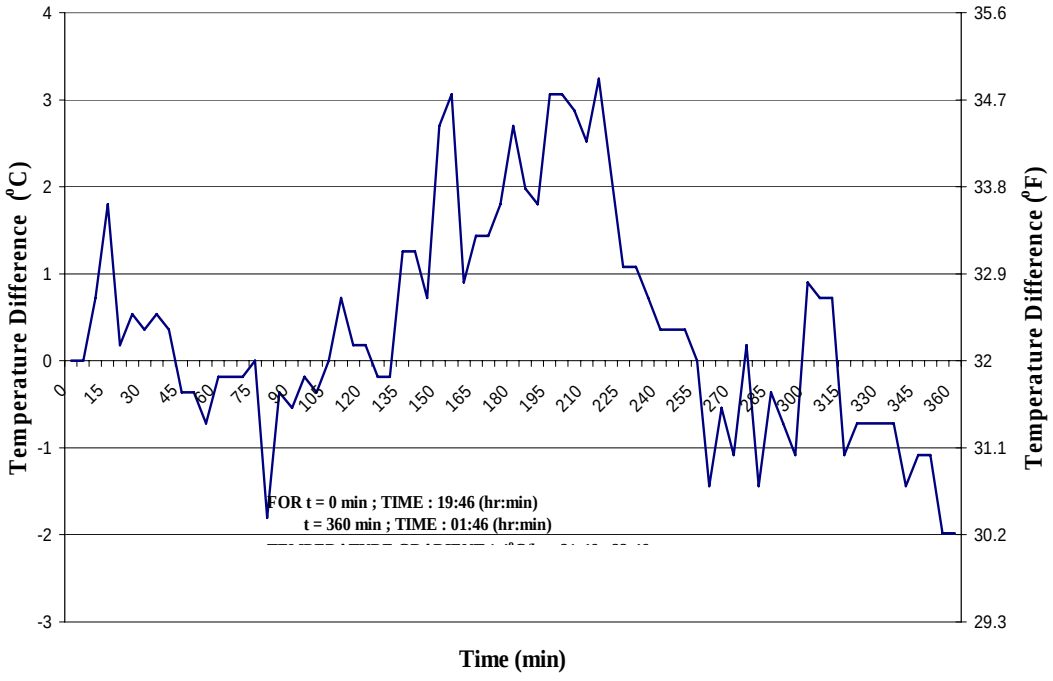
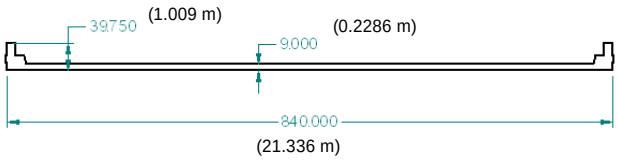


Figure 60: Temperature difference between actual values for bridge and block for Site 59 – Warren County for delta = 1.4°C/hr (2.52 °F/hr) from 2/11/05 19:46 – 2/12/05 1:46.

Summit County (Site 68):

BRIDGE NO: SUM-271-0358

Average Wind Speed: Max Cooling Gradient = 4.81 mph - 7.74 kmph (84.65 in/sec)
Max Warming Gradient = 1.75 mph - 2.815 kmph (30.8 in/sec)
Maximum Wind Speed :Max Cooling Gradient =8 mph - 12.87 kmph (140.8 in/sec)
Direction :314° (NW)
Maximum Wind Speed :Max Warming gradient = 3.7 mph - 5.95 kmph (65.12 in/sec)
Direction: 211° (SSW)



ALL DIMENSIONS ARE IN INCHES

Length of bridge = 319.25 feet (97.3 m)
Orientation: 65°4'(ENE)

Figure 61: Cross-Section view of Summit County Bridge (Site 68).

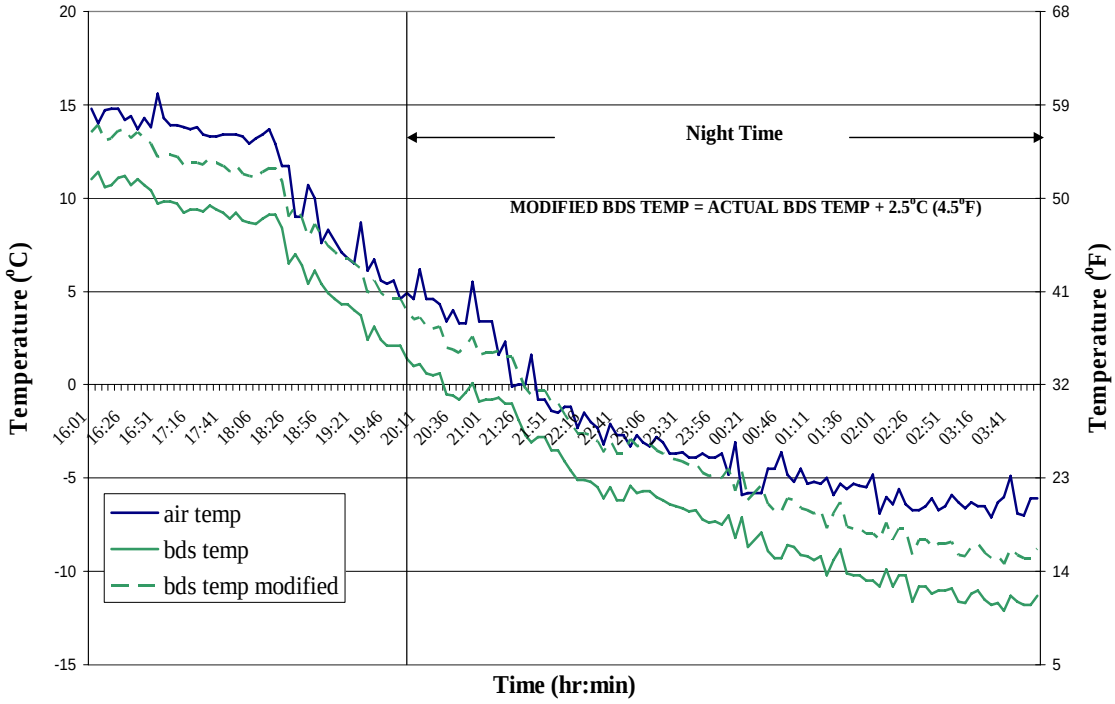


Figure 62: Data containing the -4.9°C/hr (-8.82 °F/hr) temperature gradient for Summit County (Site 68) from 3/7/05 16:01 – 3/8/05 04:01.

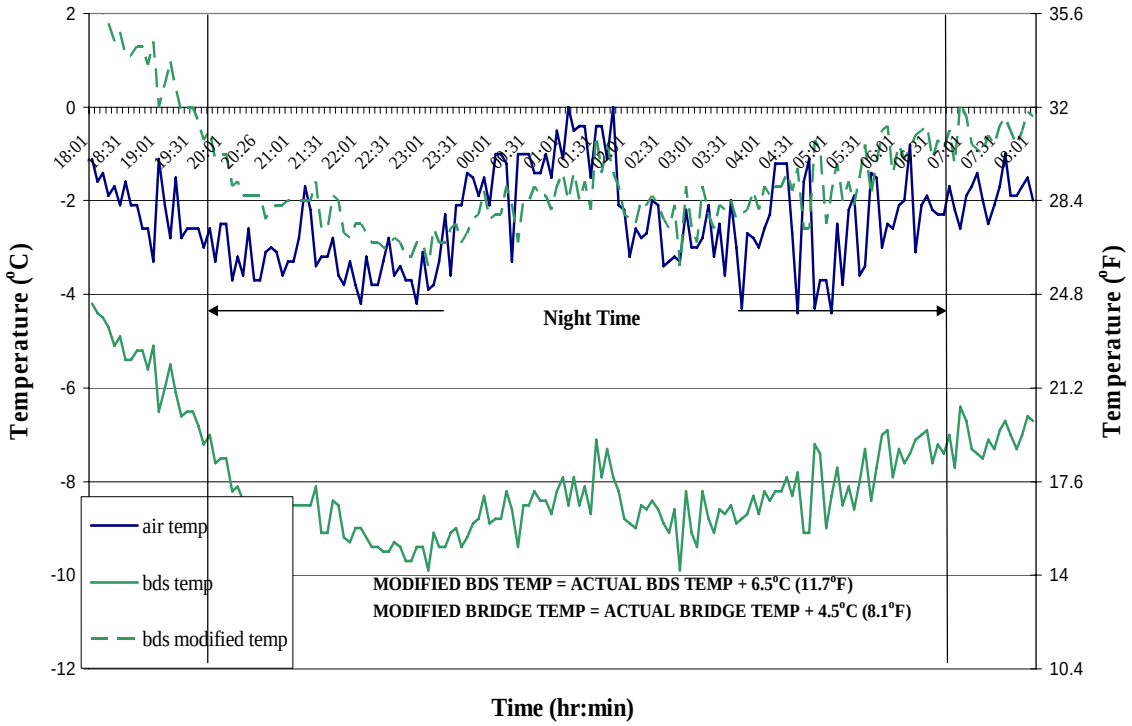


Figure 63: Data containing the 2.9°C/hr (5.22 °F/hr) temperature gradient for Summit County (Site 68) from 3/11/05 18:01 – 3/12/05 08:01.

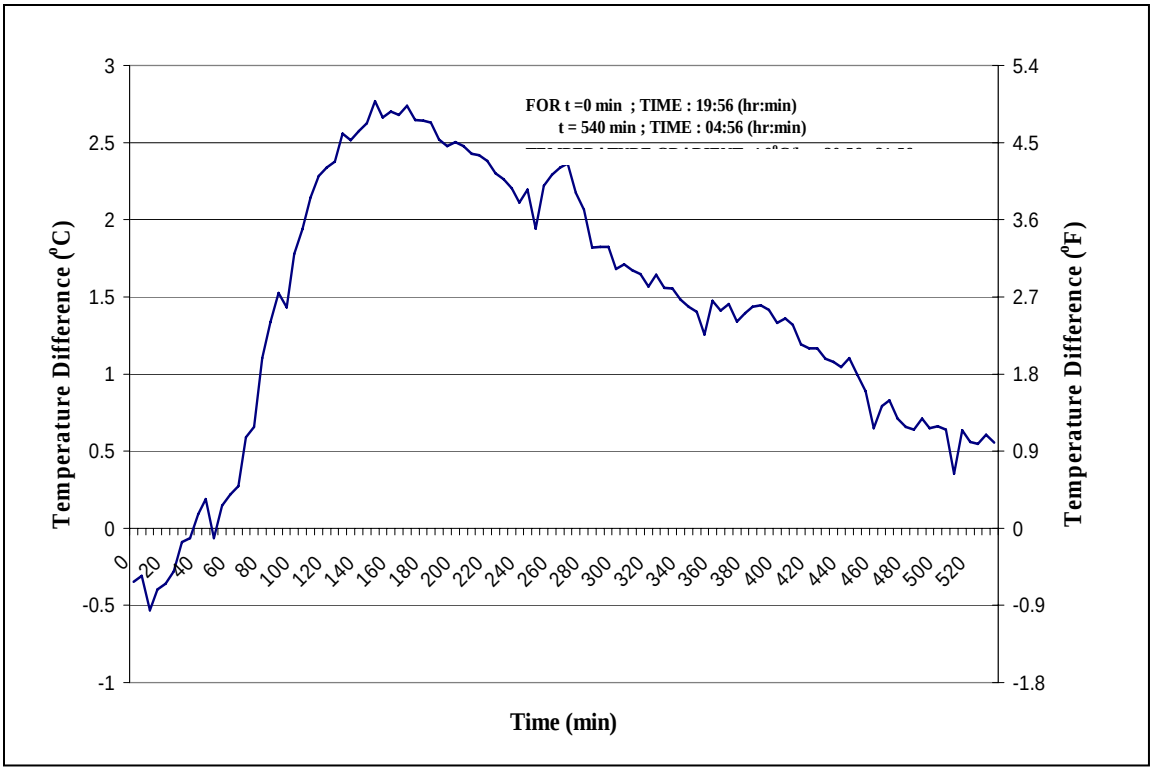


Figure 64: Temperature difference between simulated values for bridge and block for Site 68 – Summit County for delta = -4.9°C/hr (-8.82 °F/hr) from 3/7/05 19:56 – 3/8/05 04:56.

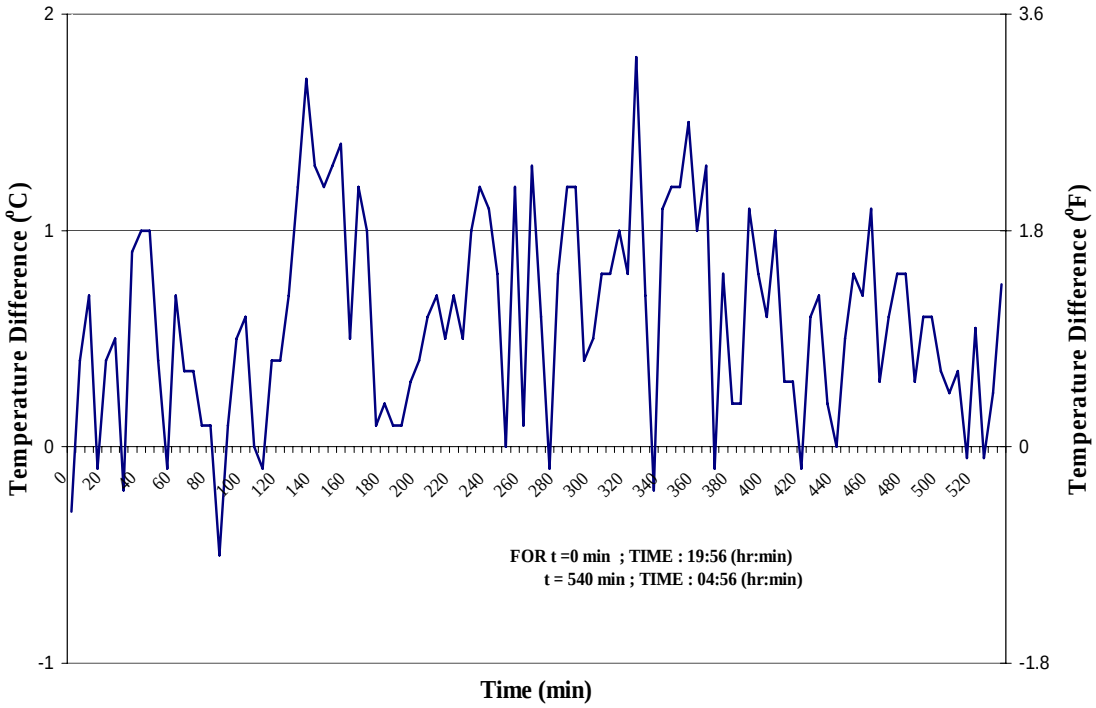


Figure 65: Temperature difference between actual values for bridge and block for Site 68 – Summit County for delta = -4.9°C/hr (-8.82 °F/hr) from 3/7/05 19:56 – 3/8/05 04:56.

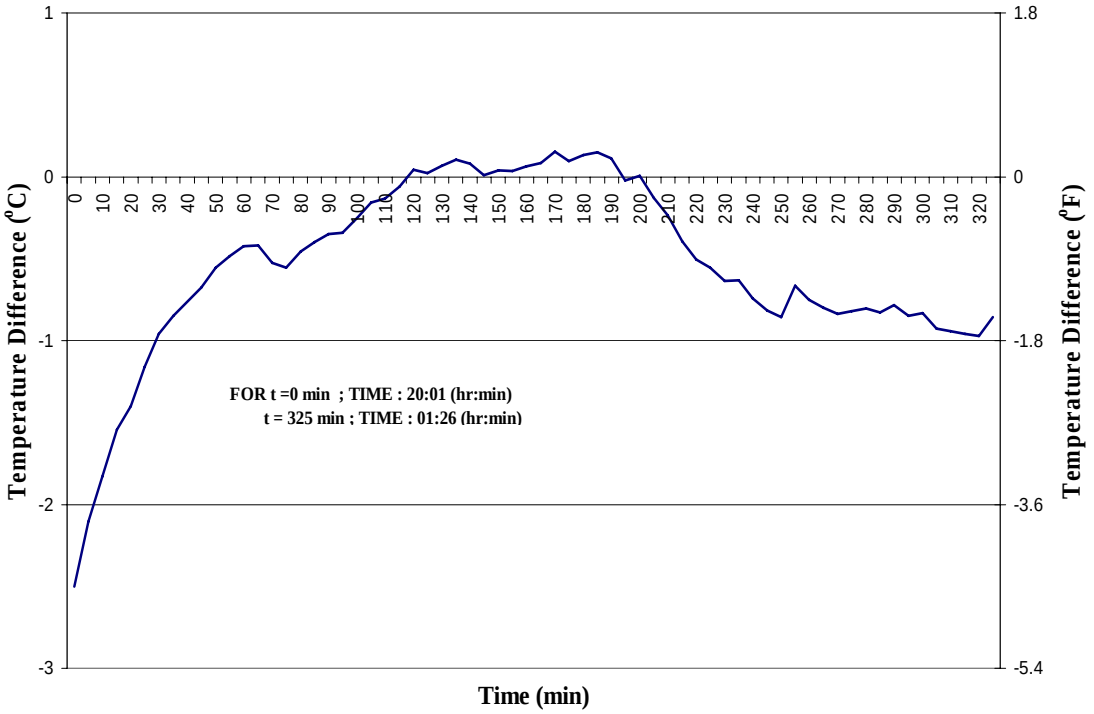


Figure 66: Temperature difference between simulated values for bridge and block for Site 68 – Summit County for delta = 2.9°C/hr (5.22 °F/hr) from 3/11/05 20:01 – 3/12/05 01:26.

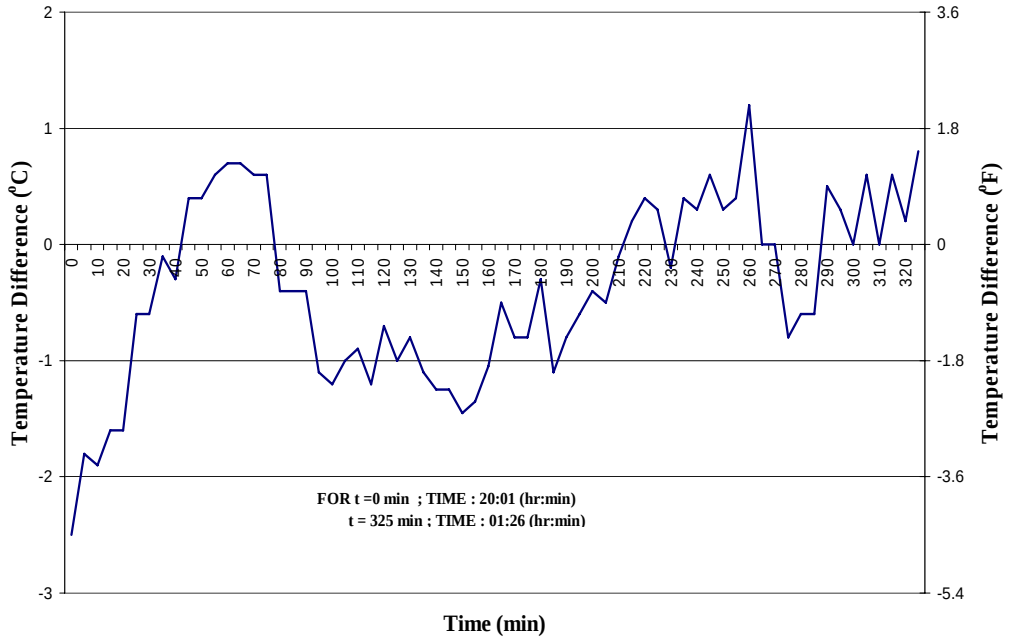
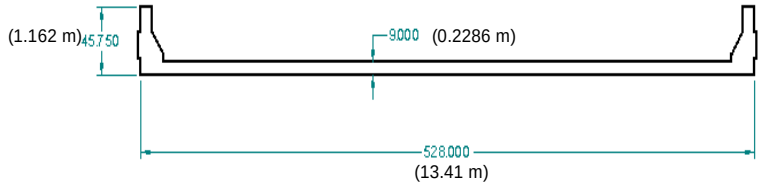


Figure 67: Temperature difference between actual values for bridge and block for Site 68 – Summit County for delta = 2.9°C/hr (5.22 °F/hr) from 3/11/05 20:01 – 3/12/05 01:26.

Hamilton County (Site 69):

BRIDGE NO: HAM-275-0314

Average Wind Speed: Max Cooling Gradient = 2.5 mph - 4.022 kmph (44 in/sec)
Max Warming Gradient = 0.552 mph - 0.888 kmph (9.71 in/sec)
Maximum Wind Speed :Max Cooling Gradient = 4 mph - 6.436 kmph(70.41 in/sec)
Direction :179° (S)
Maximum Wind Speed :Max Warming gradient = 3.3 mph - 5.30 kmph (58.08 in/sec)
Direction :234° (SE)



ALL DIMENSIONS ARE IN INCHES

Length of bridge = 572' (174.3 m)
Orientation:88°35'29"(E)

Figure 68: Cross-Section view of Site 69 – Hamilton County Bridge.

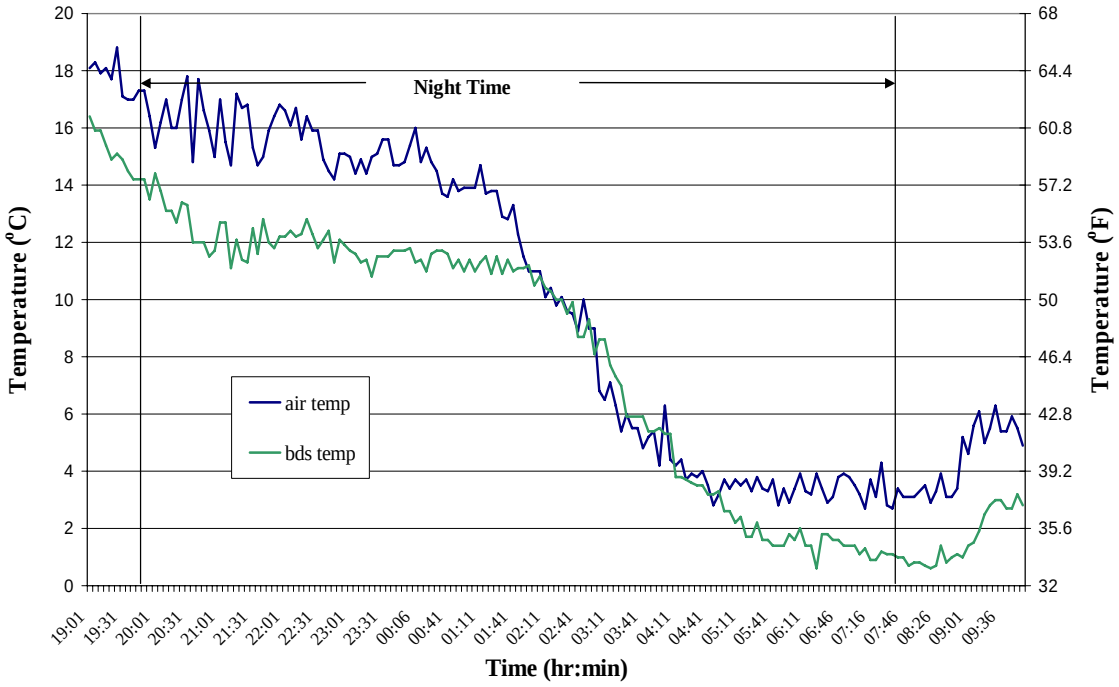


Figure 69: Data containing the -4.8°C/hr (-8.64 °F/hr) temperature gradient for Hamilton County (Site 69) from 2/15/05 19:01 – 2/16/05 09:56.

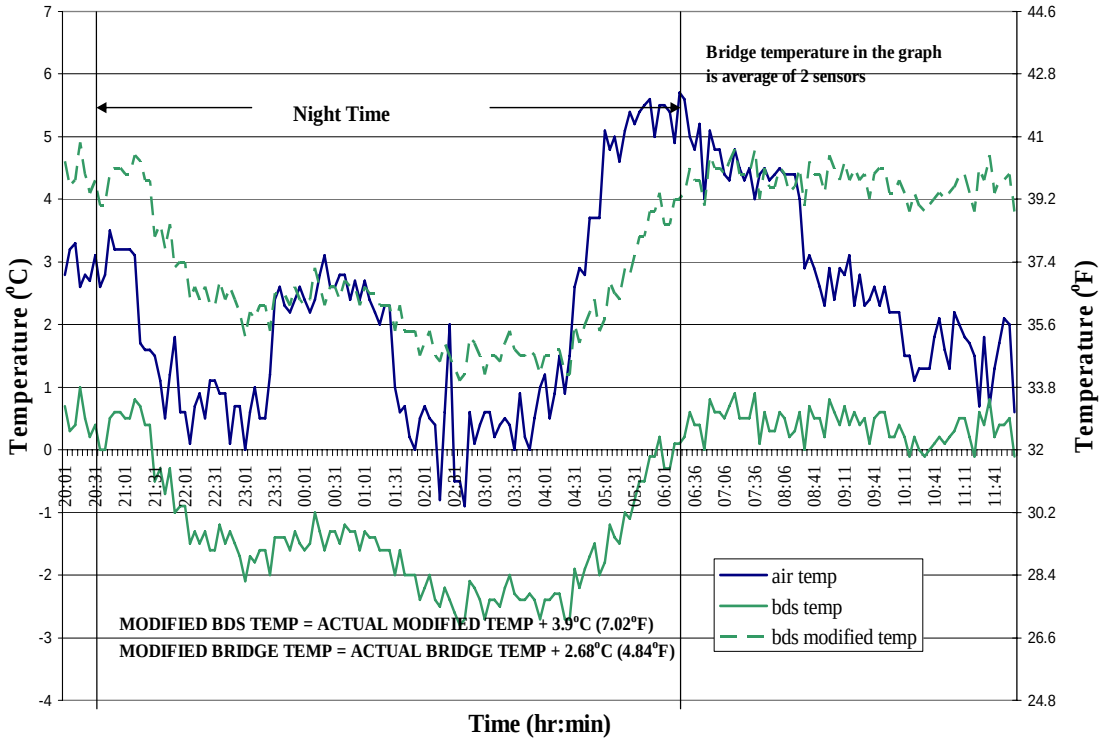


Figure 70: Data containing the 4.1°C/hr (7.38 °F/hr) temperature gradient for Hamilton County (Site 69) from 3/10/05 20:01 – 3/11/05 12:01.

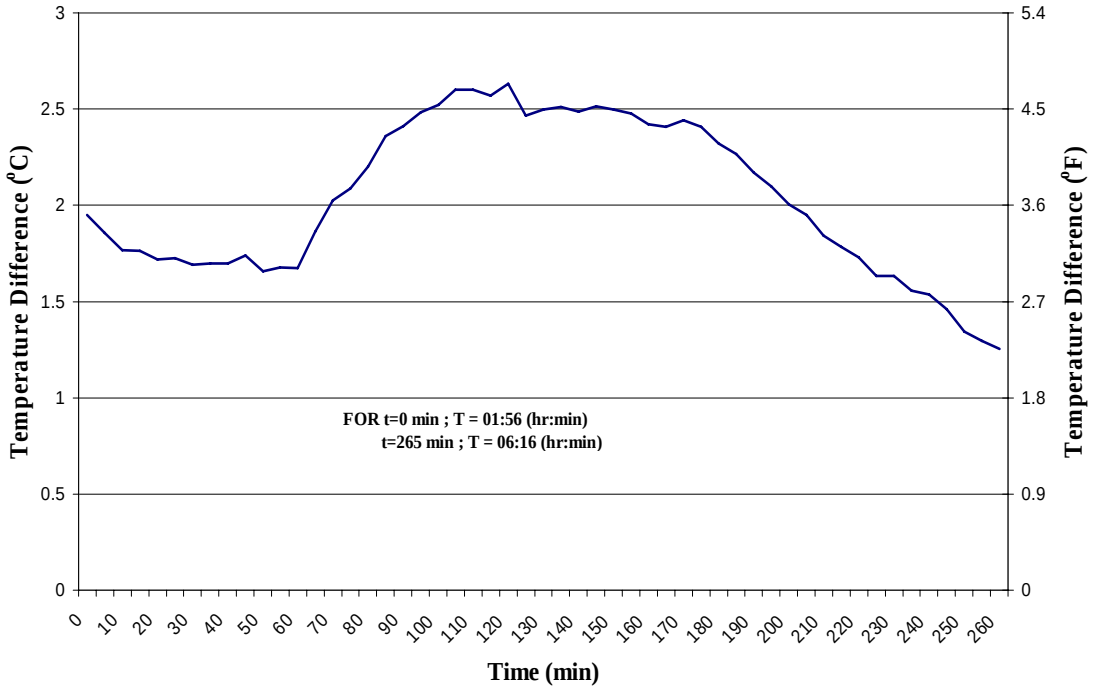


Figure 71: Temperature difference between simulated values for bridge and block for Site 69 – Hamilton County for delta = -4.8°C/hr (-8.64 °F/hr) from 2/16/05 01:56 – 2/16/05 06:26.

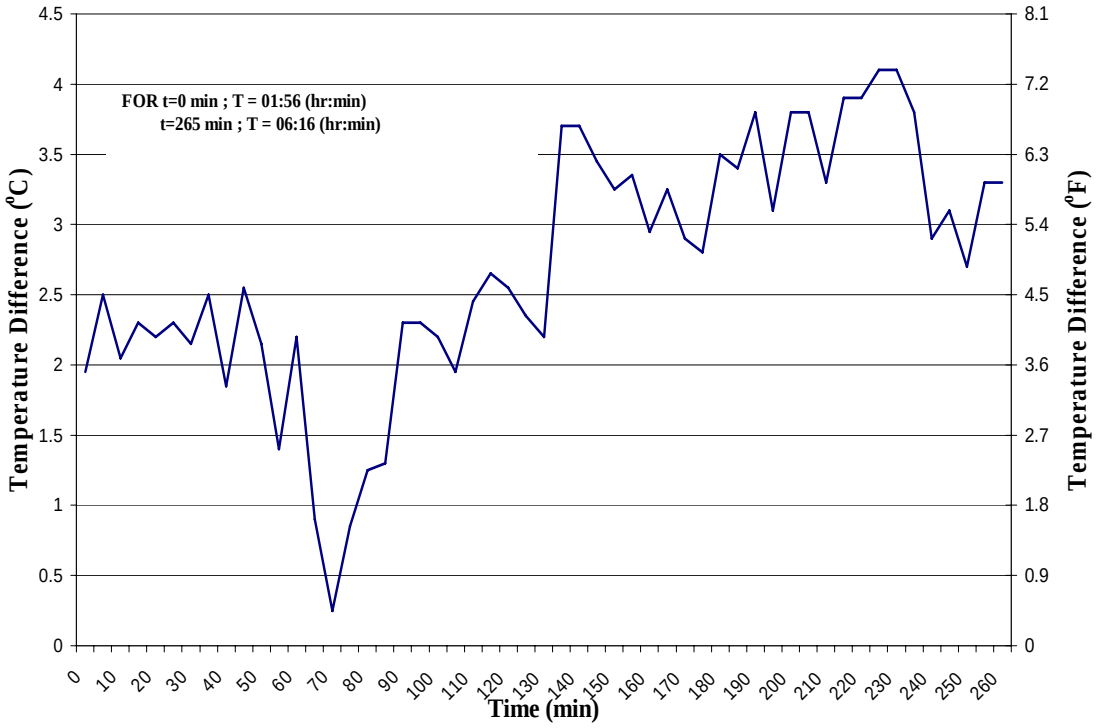


Figure 72: Temperature difference between actual values for bridge and block for Site 69 – Hamilton County for delta = -4.8°C/hr (-8.64 °F/hr) from 2/16/05 01:56 – 2/16/05 06:16.

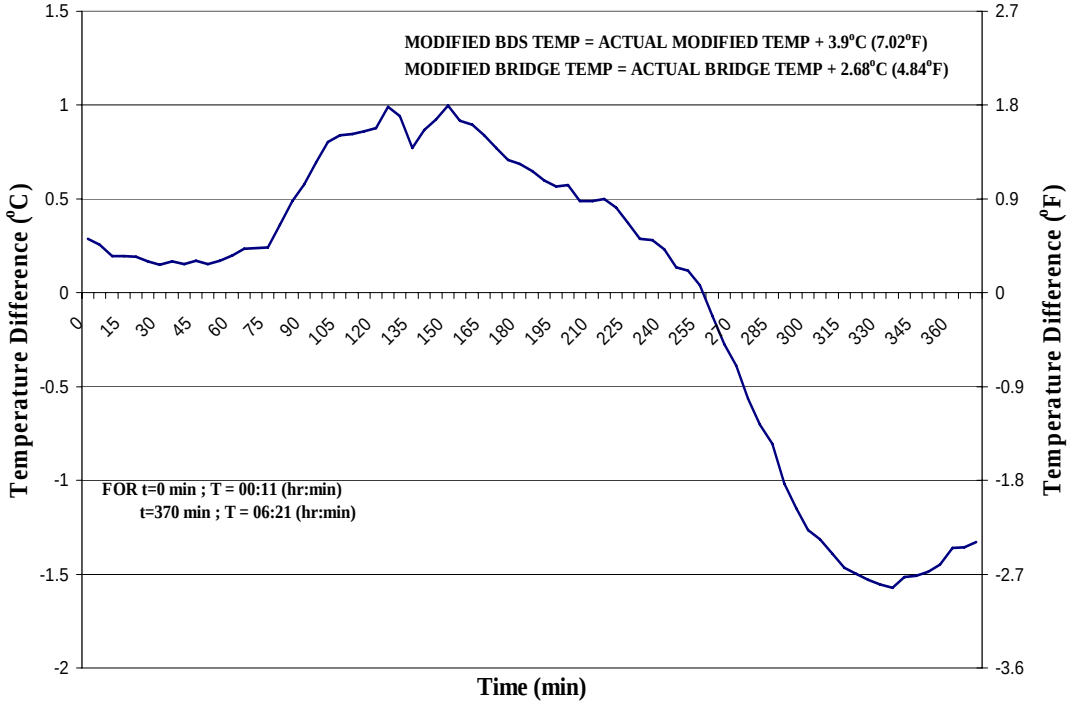


Figure 73: Temperature difference between simulated values for bridge and block for Site 69 – Hamilton County for delta = 4.1°C/hr (7.38 °F/hr) from 3/11/05 00:11 – 3/11/05 06:26.

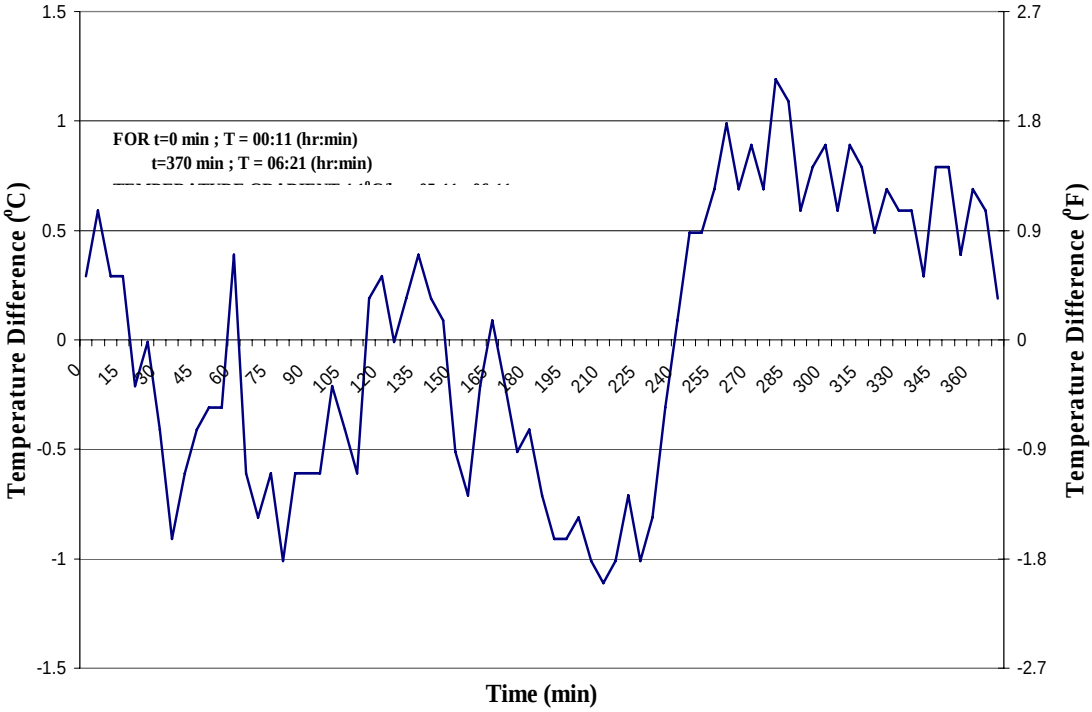
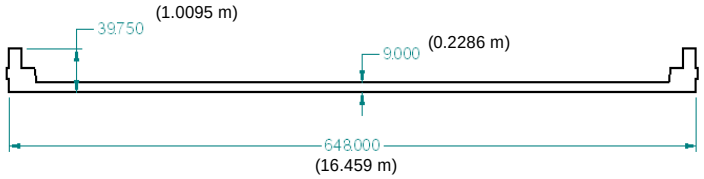


Figure 74: Temperature difference between actual values for bridge and block for Site 69 – Hamilton County for delta = 4.1°C/hr (7.38 °F/hr) from 3/11/05 00:11 – 3/11/05 06:26.

Hamilton County (Site 70):

BRIDGE NO: HAM-275-3200

Average Wind Speed: Max Cooling Gradient = 3.09 mph - 4.97 kmph (54.38 in/sec)
Max Warming Gradient = 0.564 mph - 0.907 kmph (9.92 in/sec)
Maximum Wind Speed :Max Cooling Gradient =5.9 mph - 9.49 kmph (103.84 in/sec)
Direction :304° (NW)
Maximum Wind Speed :Max Warming gradient = 2.1 mph - 3.378 kmph (36.96 in/sec)
Direction :131° (SE)



ALL DIMENSIONS ARE IN INCHES

Length of bridge = 860.75' (262.35 m)
Orientation:50°17'37"(SE)

Figure 75: Cross-Section view of Site 70 – Hamilton County Bridge.

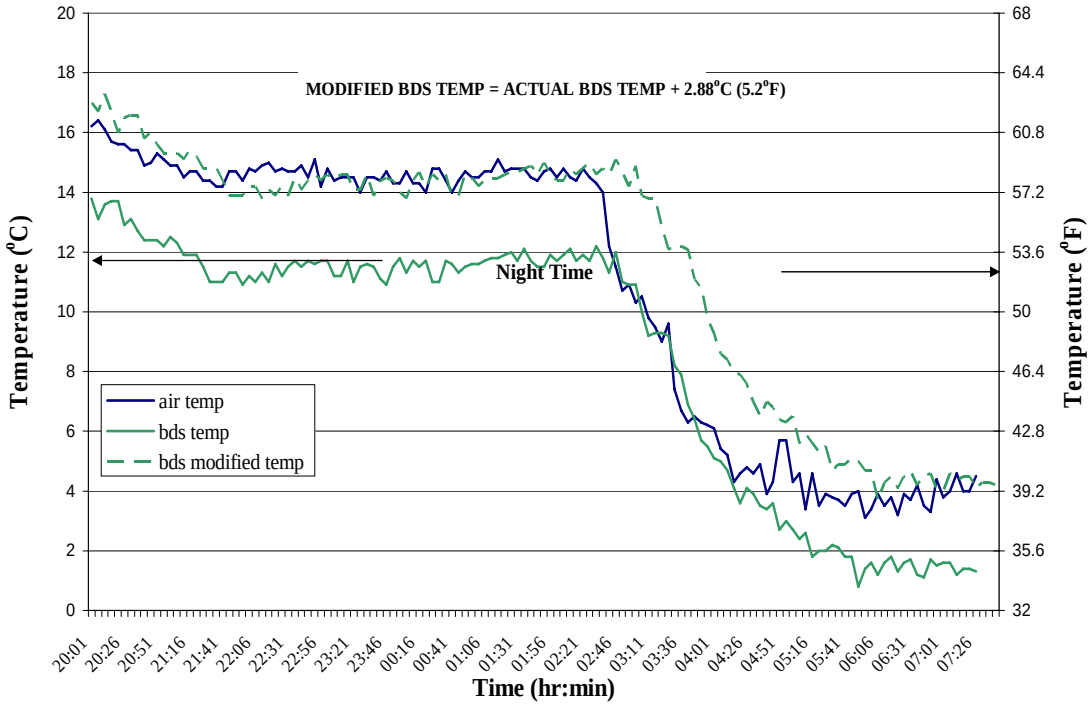


Figure 76: Data containing the -5°C/hr (-9 °F/hr) temperature gradient for Hamilton County (Site 70) from 2/15/05 19:46 – 2/16/05 07:26.

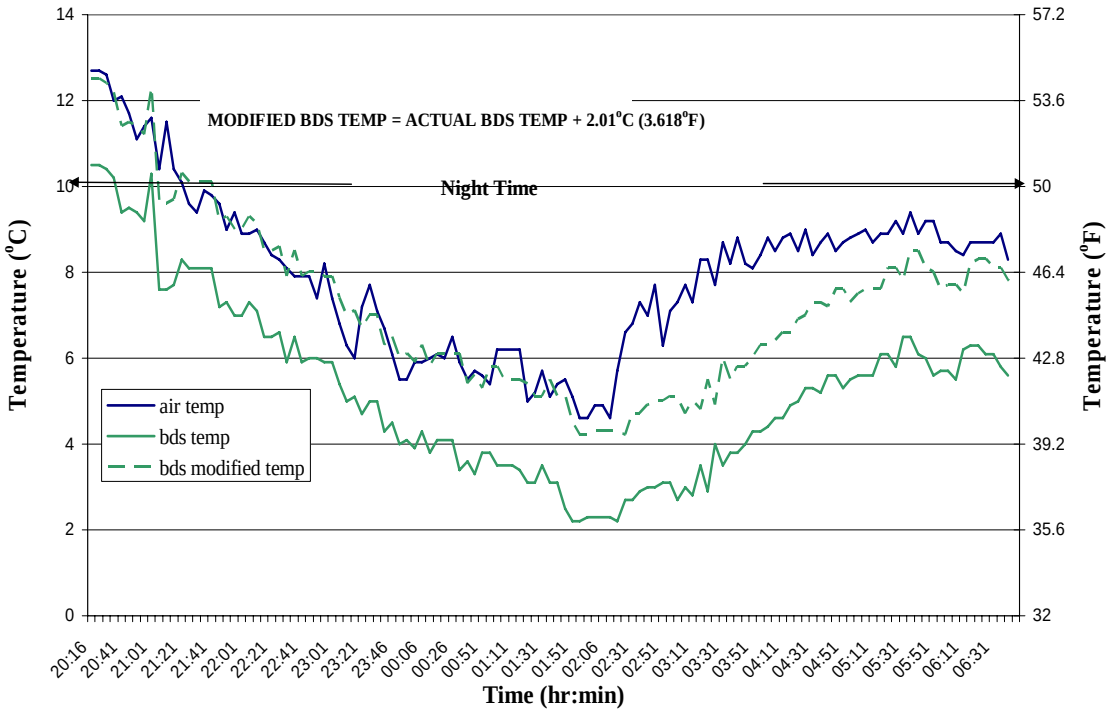


Figure 77: Data containing the 3.7°C/hr (6.66 °F/hr) temperature gradient for Hamilton County (Site 70) from 3/18/05 20:16 – 3/19/05 07:26.

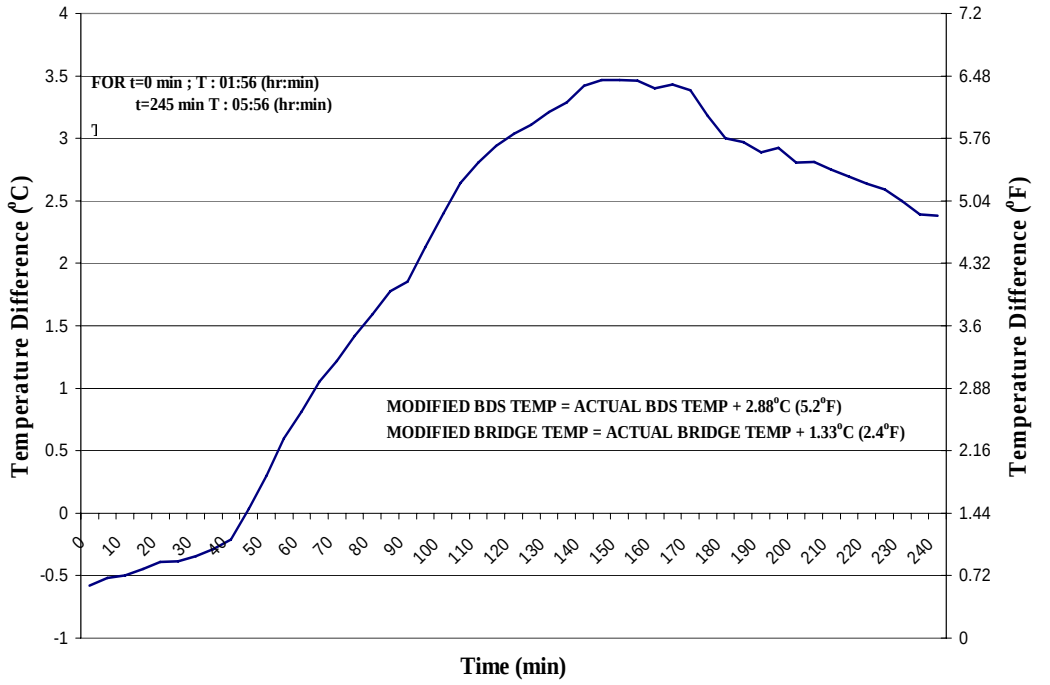


Figure 78: Temperature difference between simulated values for bridge and block for Site 70 – Hamilton County for delta = -5°C/hr (-9 °F/hr) from 2/16/05 01:56 – 2/16/05 05:56.

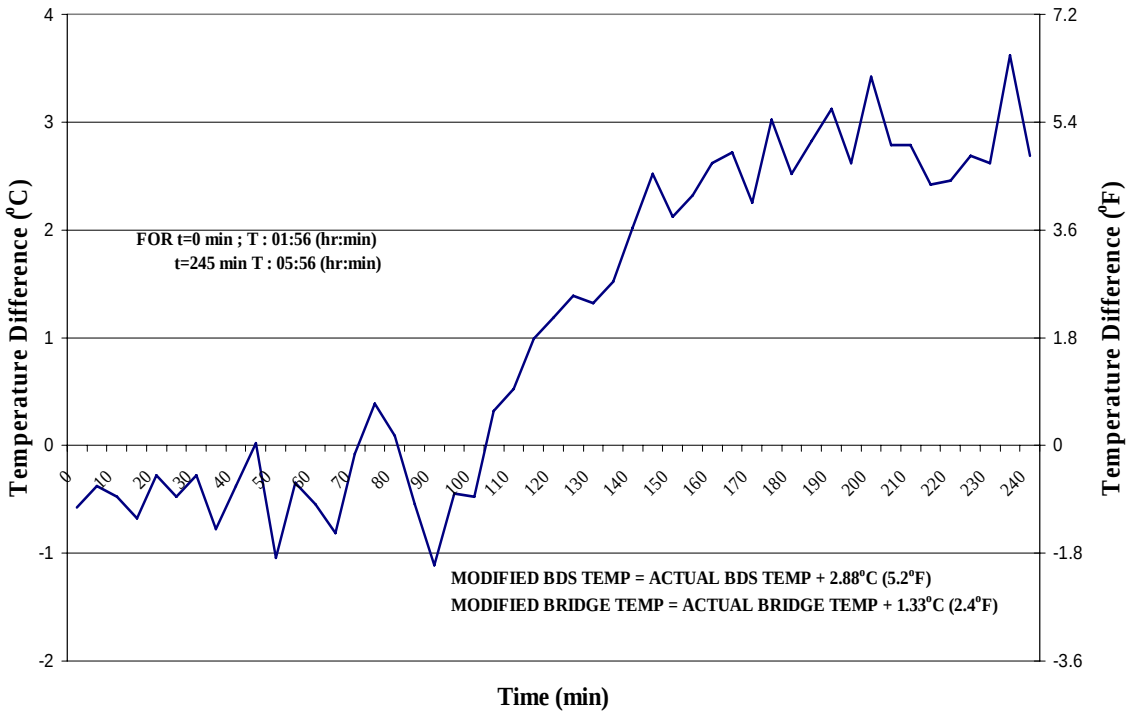


Figure 79: Temperature difference between actual values for bridge and block for Site 70 – Hamilton County for delta = -5°C/hr (-9 °F/hr) from 2/16/05 01:56 – 2/16/05 05:56.

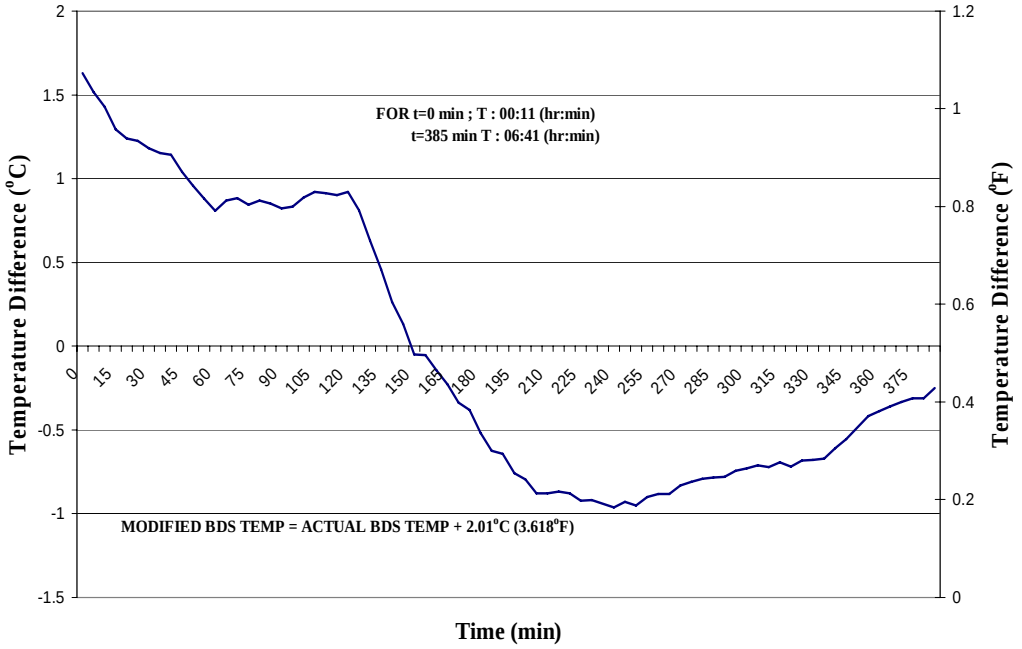


Figure 80: Temperature difference between simulated values for bridge and block for Site 70 – Hamilton County for delta = 3.7°C/hr (6.66 °F/hr) from 3/19/05 00:11 – 3/19/05 06:41.

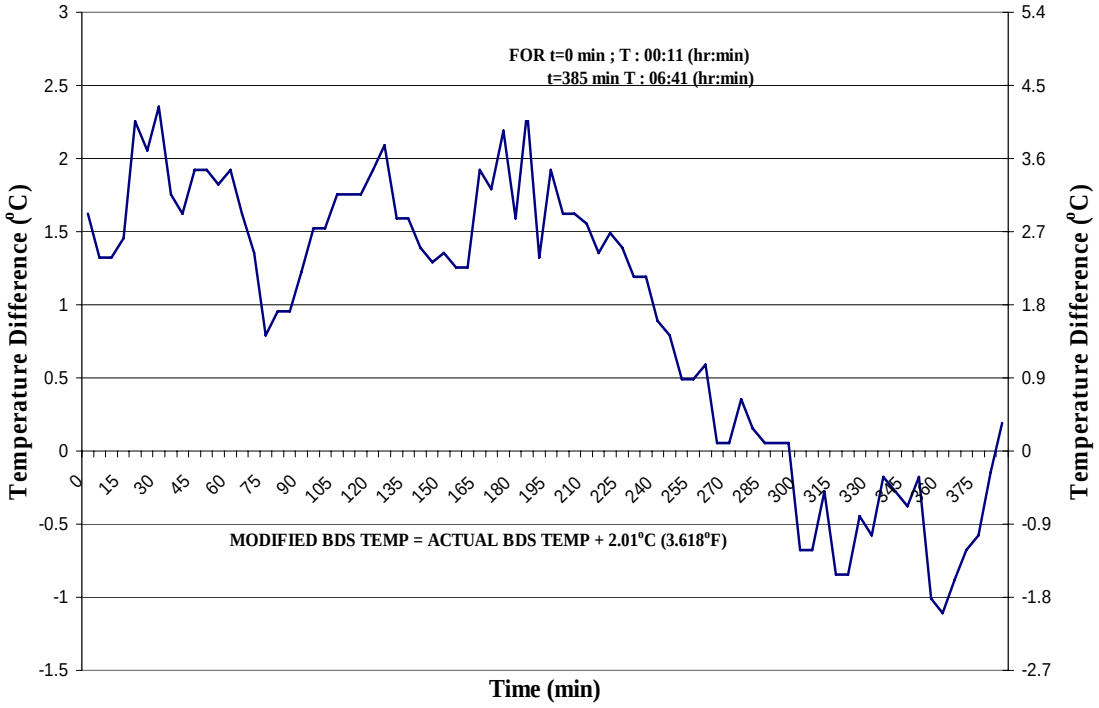
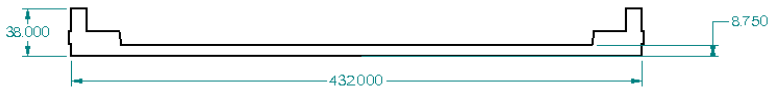


Figure 81: Temperature difference between actual values for bridge and block for Site 70 – Hamilton County for delta = 3.7°C/hr (6.66 °F/hr) from 3/19/05 00:11 – 3/19/05 06:41.

Lorain County (Site 86):

BRIDGE NO: LOR-90-1426

Average Wind Speed: Max Cooling Gradient = 3.30mph - 5.30 kmph (58.06 in/sec)
Max Warming Gradient = 0.3 mph - 0.53 kmph (5.8 in/sec)
Maximum Wind Speed :Max Cooling Gradient = 5.6 mph - 9.01 kmph (98.56 in/sec)
Direction : 351° (N)
Maximum Wind Speed :Max Warming gradient = 1.2 mph - 1.93 kmph (21.12 in/sec)
Direction : 24° (NNE)



ALL DIMENSIONS ARE IN INCHES

Length of bridge = 368.5' (112.38 m)
Orientation: 62°30' (NE)

Figure 82: Cross-Section view of Lorain County Bridge (Site 86).

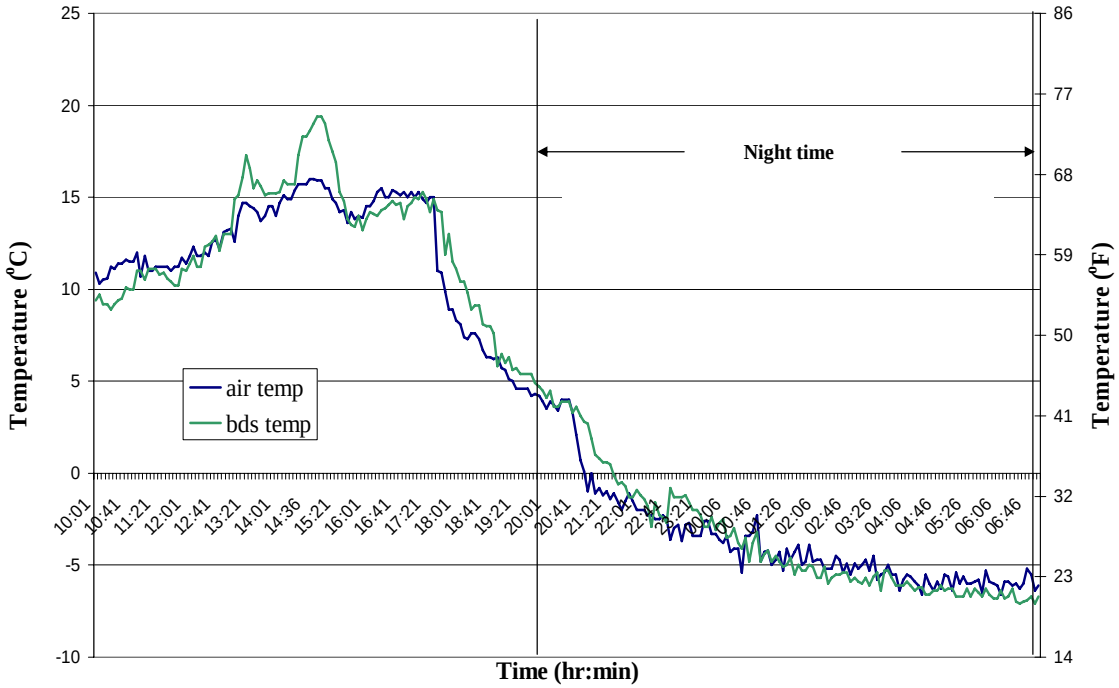


Figure 83: Data containing the -3.5°C/hr (-6.3 °F/hr) temperature gradient for Lorain County (Site 86) from 3/7/05 10:01 – 3/8/05 07:01.

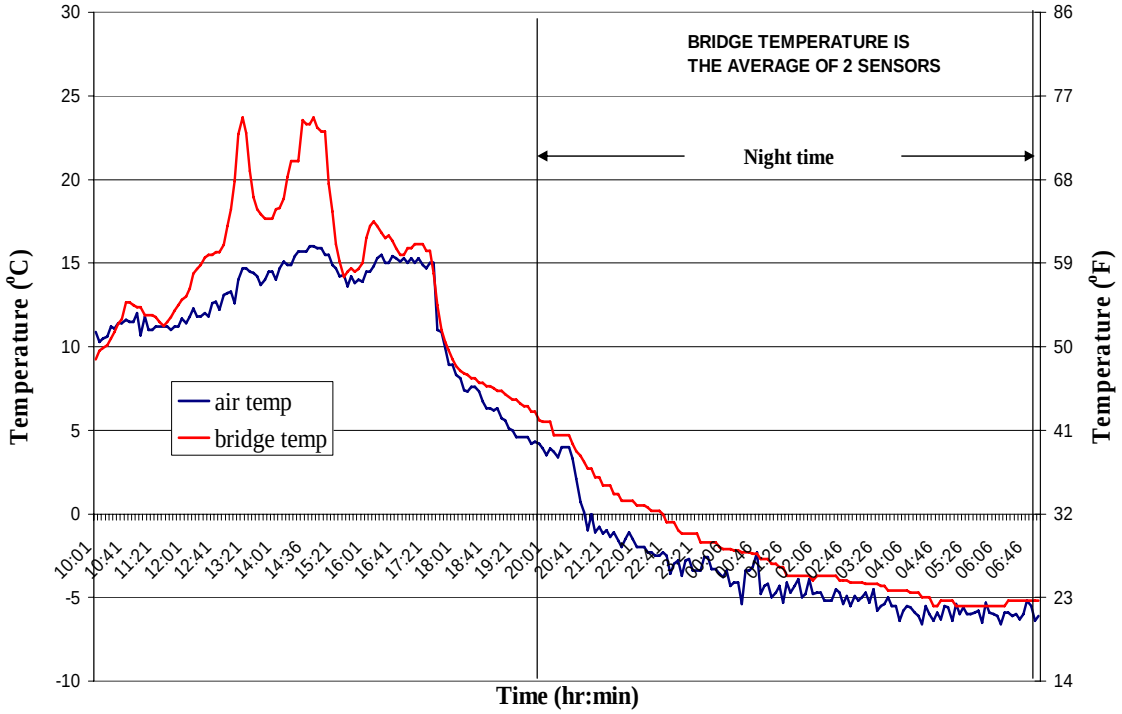


Figure 84: Data containing the -3.5°C/hr (-6.3 °F/hr) temperature gradient for Lorain County (Site 86) from 3/7/05 10:01 – 3/8/05 07:01.

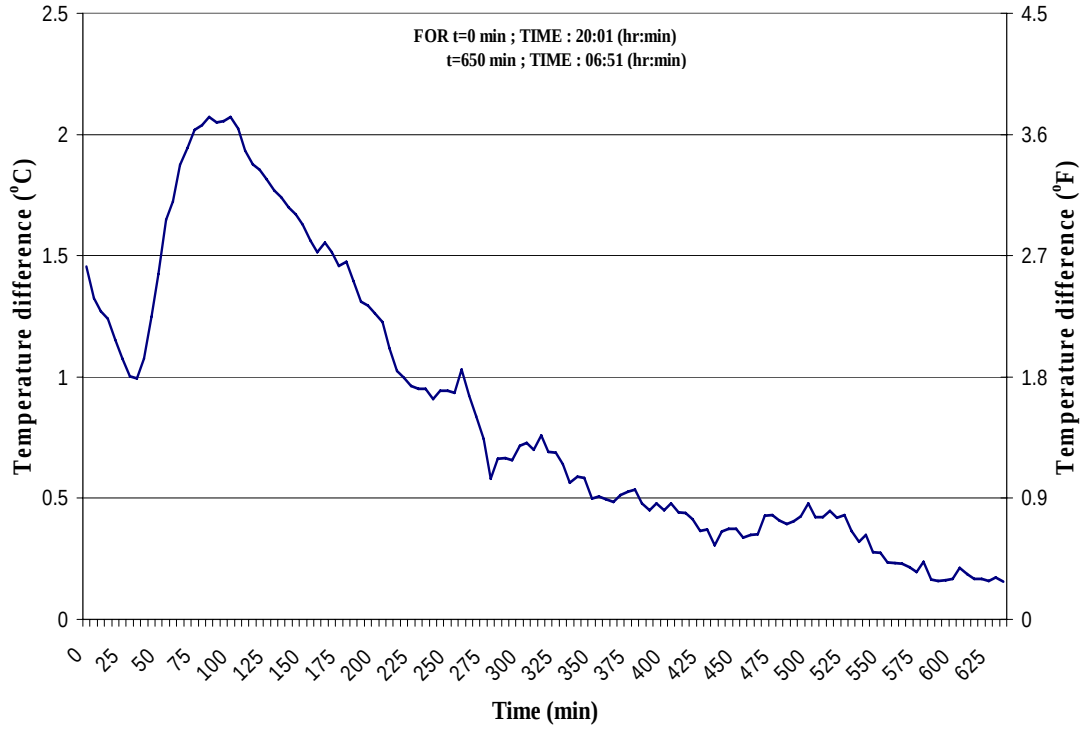


Figure 85: Temperature difference between simulated values for bridge and block for Site 86 – Lorain County for delta = -3.5°C/hr (-6.3 °F/hr) from 3/7/05 20:01 – 3/8/05 06:51.

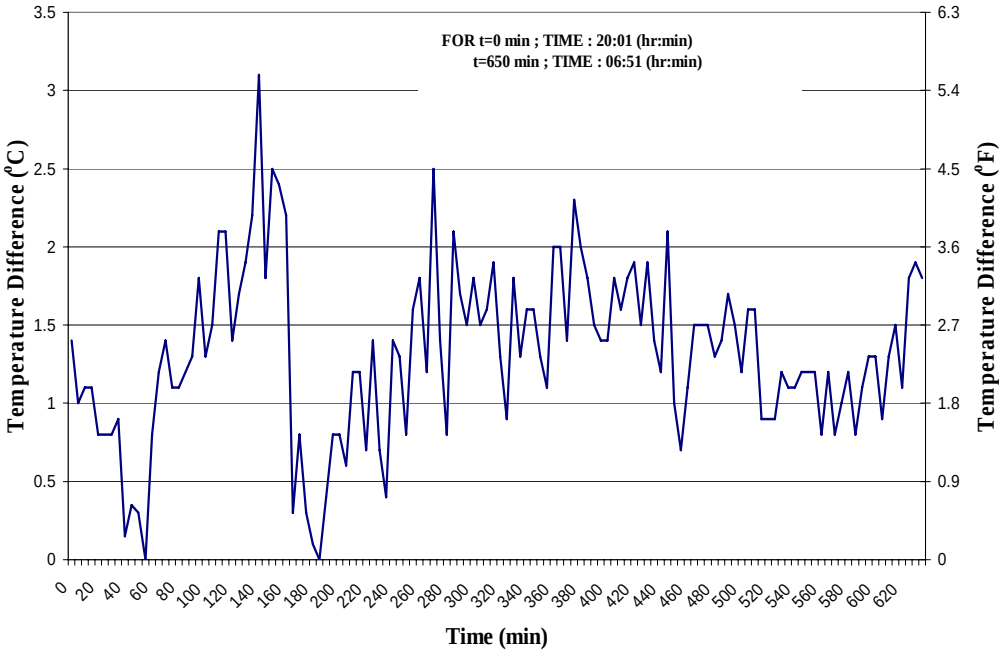


Figure 86: Temperature difference between actual values for bridge and block for Site 86 – Lorain County for delta = -3.5°C/hr (-6.3 °F/hr) from 3/7/05 20:01 – 3/8/05 06:51.

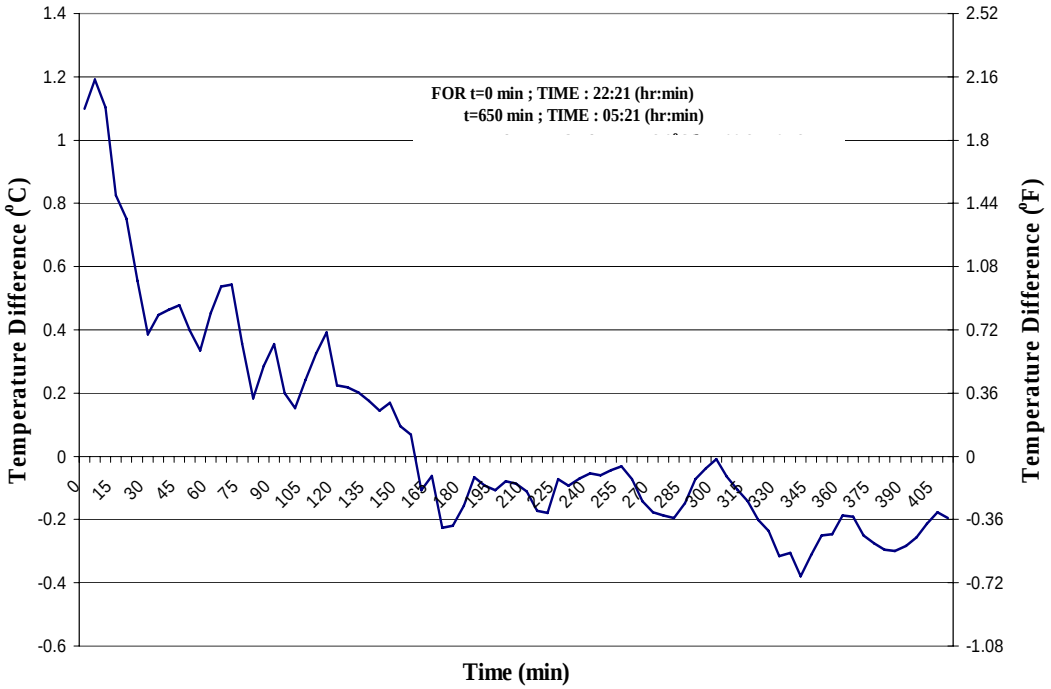


Figure 87: Temperature difference between simulated values for bridge and block for Site 86 – Lorain County for delta = 2.9°C/hr (5.22 °F/hr) from 2/2/05 22:21 – 2/3/05 05:21.

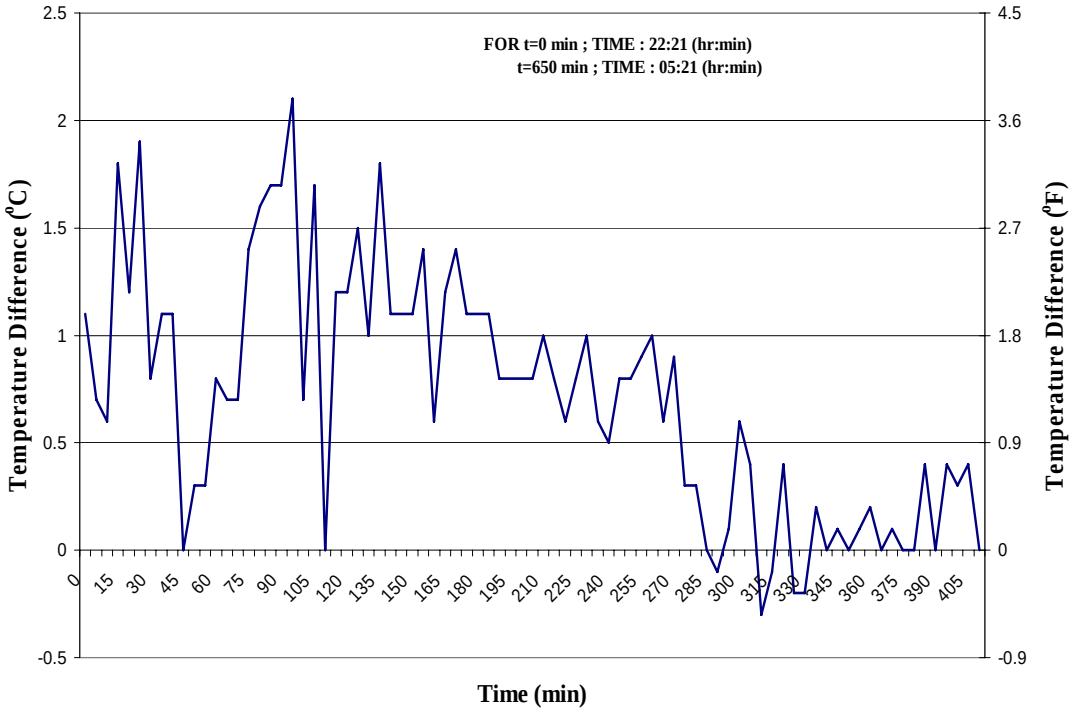
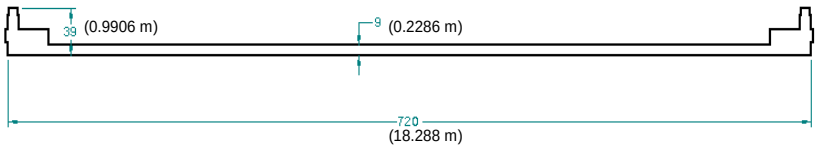


Figure 88: Temperature difference between actual values for bridge and block for Site 86 – Lorain County for delta = 2.9°C/hr (5.22 °F/hr) from 2/2/05 22:21 – 2/3/05 05:21.

Ashtabula County (Site 88):

BRIDGE NO: ATB - 1 -1362

Average Wind Speed: Max Cooling Gradient = 4.06 mph - 6.54 kmph (71.45 in/sec)
Max Warming Gradient = 3.85 mph - 6.19 kmph (67.76 in/sec)
Maximum Wind Speed : Max Cooling Gradient =6.4 mph (112.64 in/sec)
Direction : 334° (NNW)
Maximum Wind Speed : Max Warming gradient = 5.2 mph (91.52 in/sec)
Direction : 74° (ENE)



ALL DIMENSIONS ARE IN INCHES

Length of bridge = 336' (102.4 m)
Orientation : 89° 36' 9" (SE)

Figure 89: Cross-Section view of Ashtabula County Bridge (Site 88).

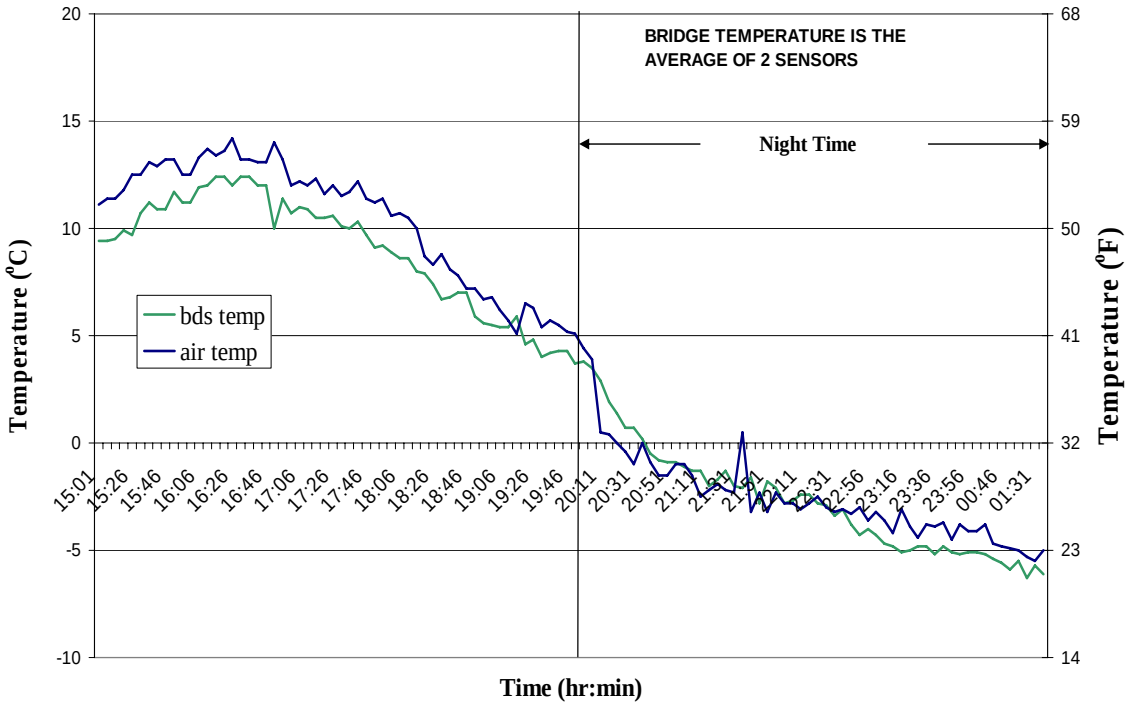


Figure 90: Data containing the -4.5°C/hr (-8.1 °F/hr) temperature gradient for Ashtabula County (Site 88) from 3/7/05 15:01 – 3/8/05 01:36.

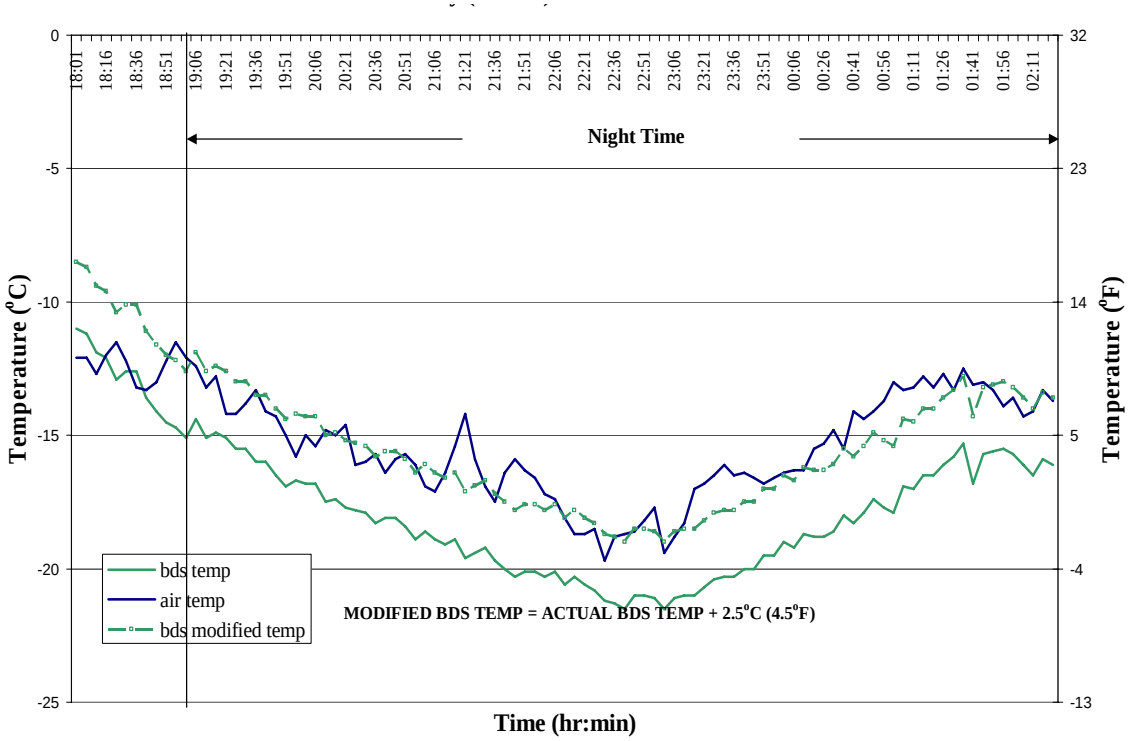


Figure 91: Data containing the 3°C/hr (5.4 °F/hr) temperature gradient for Ashtabula County (Site 88) from 1/23/05 18:01 – 1/24/05 02:21.

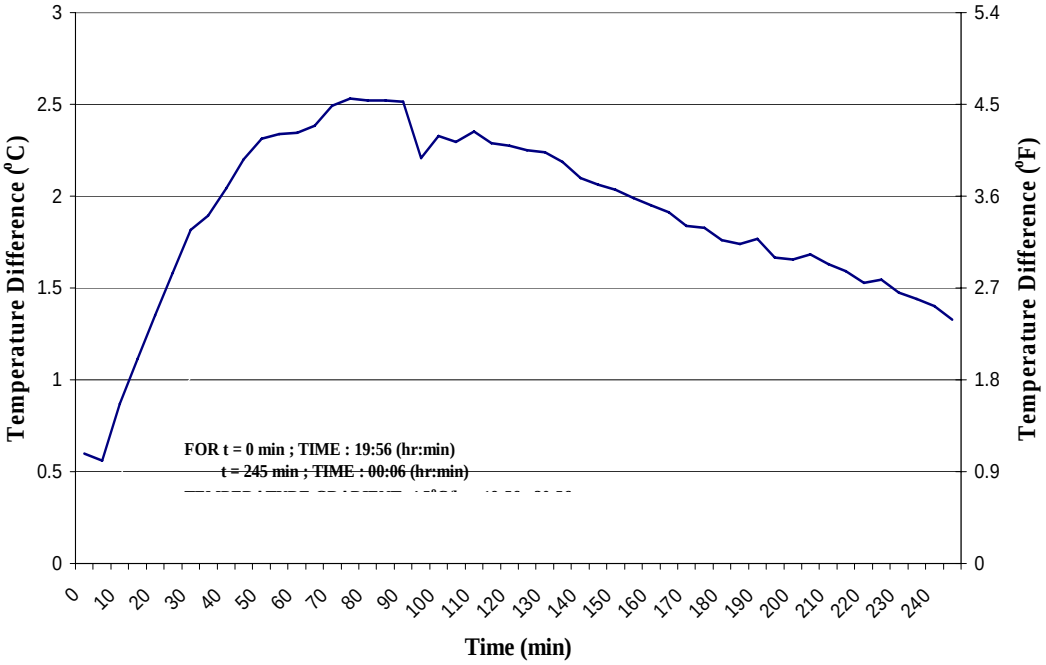


Figure 92: Temperature difference between simulated values for bridge and block for Site 88 – Ashtabula County for delta = -4.5°C/hr (-8.1 °F/hr) from 3/7/05 19:56 – 3/8/05 00:06.

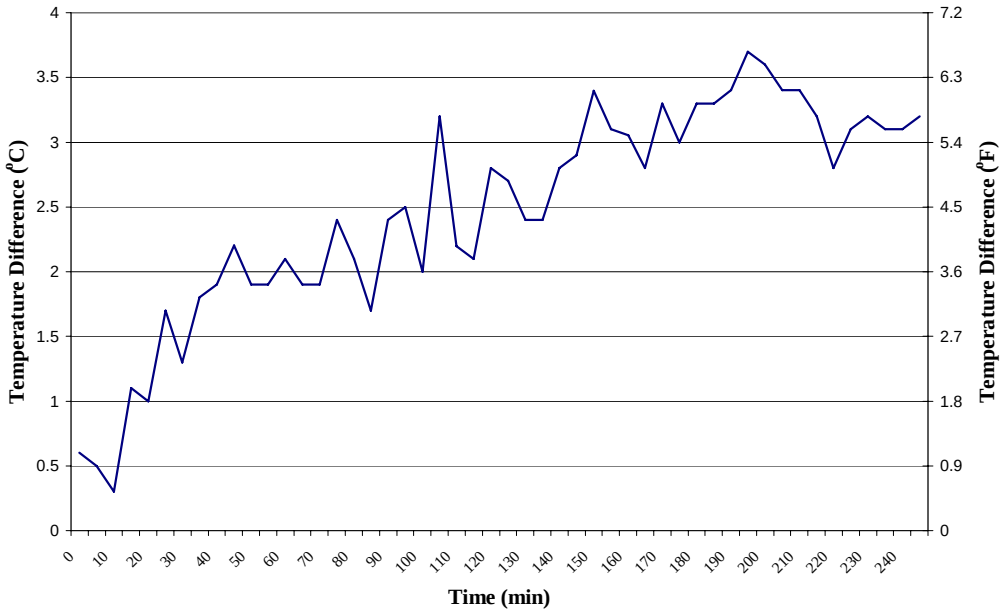


Figure 93: Temperature difference between actual values for bridge and block for Site 88 – Ashtabula County for delta = -4.5°C/hr (-8.1 °F/hr) from 3/7/05 19:56 – 3/8/05 00:06.

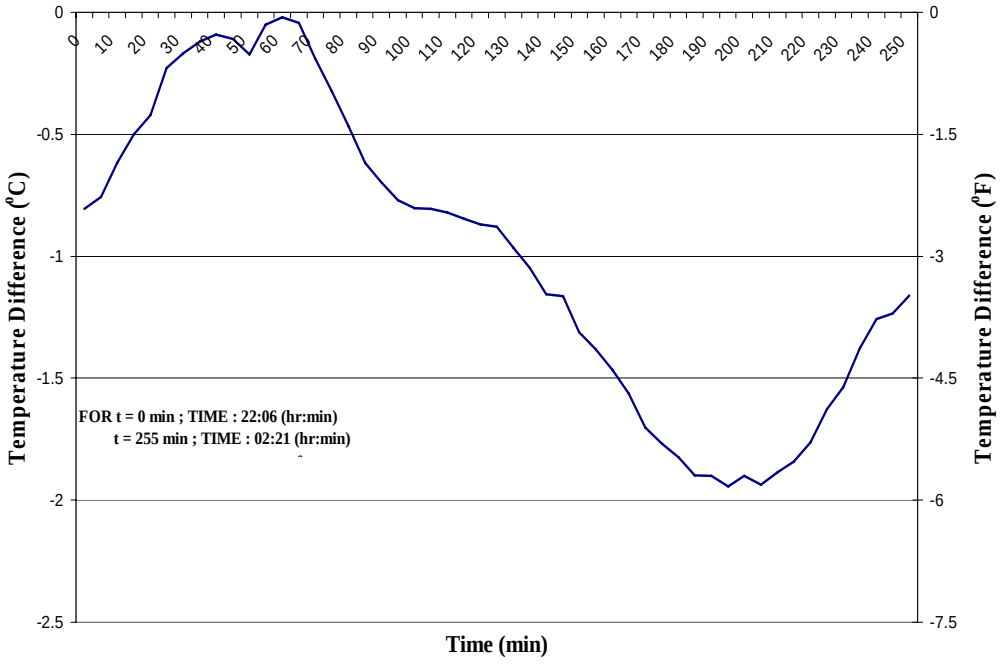


Figure 94: Temperature difference between simulated values for bridge and block for Site 88 – Ashtabula County for delta = 3°C/hr (5.4 °F/hr) from 1/23/05 22:06 – 1/24/05 02:21.

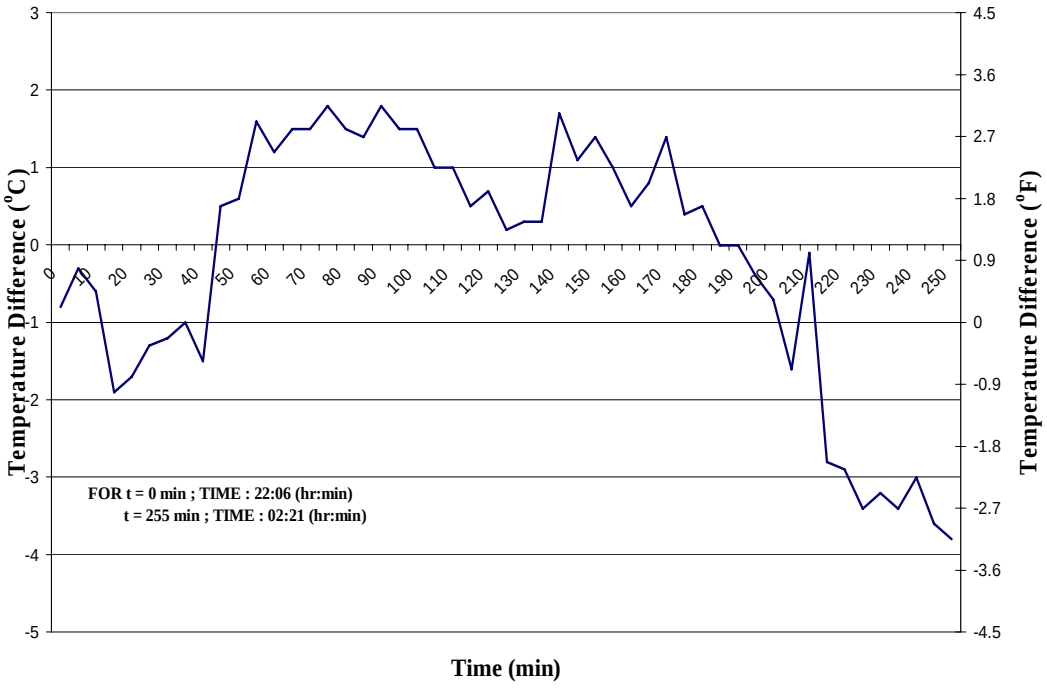
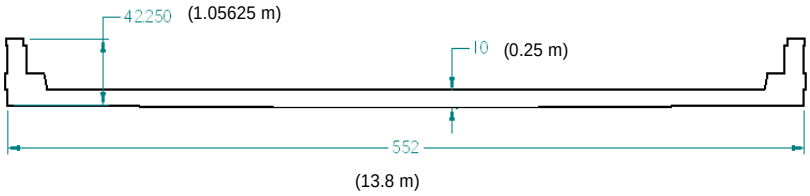


Figure 95: Temperature difference between actual values for bridge and block for Site 88 – Ashtabula County for delta = 3°C/hr (5.4 °F/hr) from 1/23/05 22:06 – 1/24/05 02:21.

Portage County (Site 91):

BRIDGE NO: POR-18-2010

Average Wind Speed :Max Cooling Gradient = 0.422 mph - 0.678 kmph (7.42 in/sec)
Max Warming Gradient = 0.228 mph - 0.366 kmph(4.01 in/sec)
Maximum Wind Speed :Max Cooling Gradient =2.2 mph - 3.53 kmph (38.72 in/sec)
Direction :33° (NE)
Maximum Wind Speed :Max Warming gradient = 0.8 mph - 1.28 kmph (14.08 in/sec)
Direction :175° (S)



ALL DIMENSIONS ARE IN INCHES

Length of bridge = 195.94' (59.72 m)
Orientation:90° E

Figure 96: Cross-Section view of Portage County Bridge (Site 91).

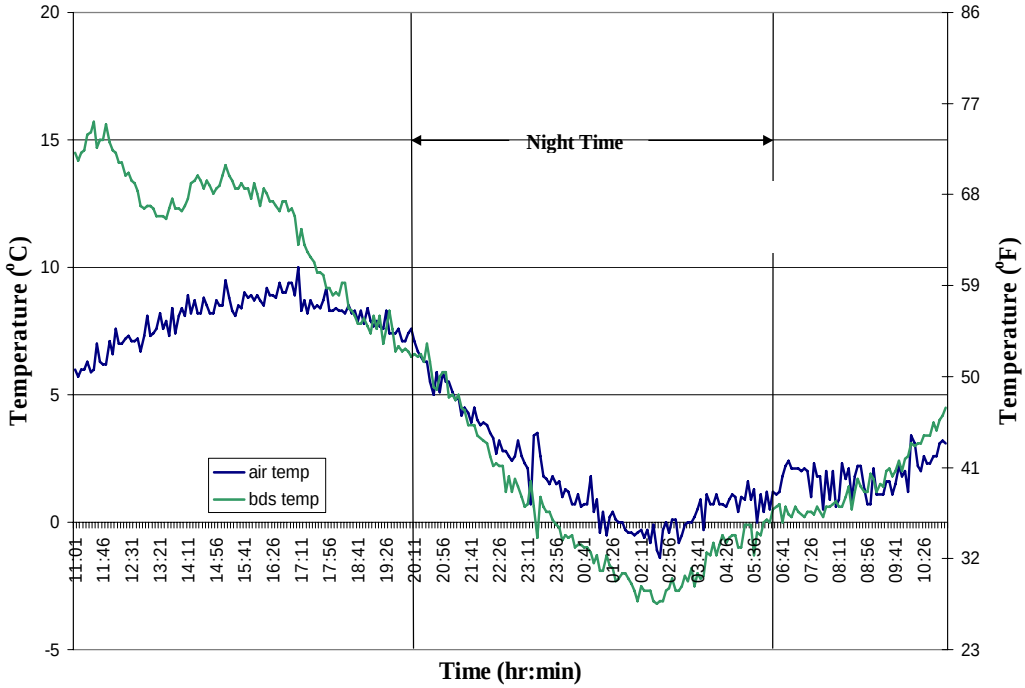


Figure 97: Data containing the -2.7°C/hr (-4.86 °F/hr) temperature gradient for Portage County (Site 91) from 3/26/05 11:01 – 3/27/05 11:01.

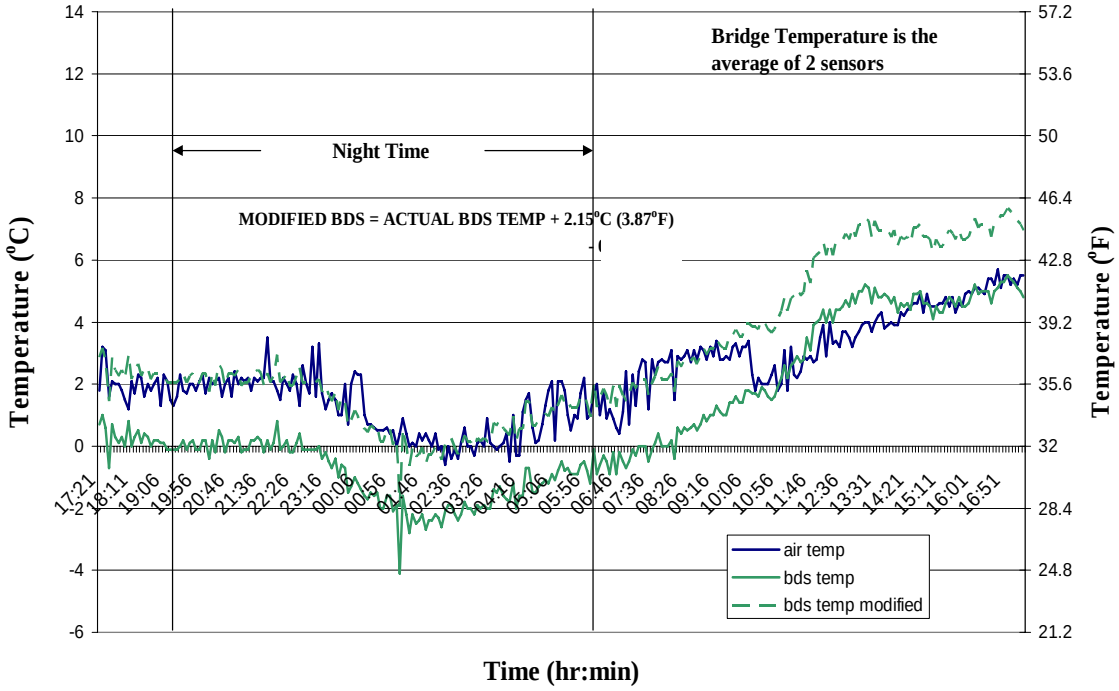


Figure 98: Data containing the 2.4°C/hr (4.32 °F/hr) temperature gradient for Portage County (Site 91) from 3/24/05 17:21 – 3/25/05 17:21.

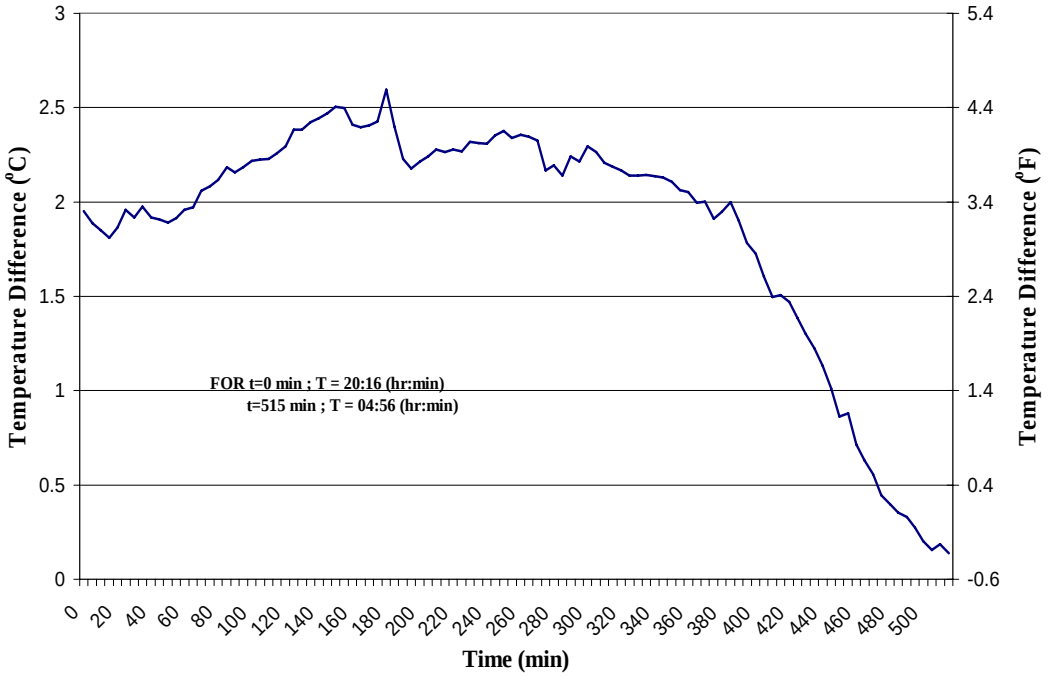


Figure 99: Temperature difference between simulated values for bridge and block for Site 91 – Portage County for delta = -2.7°C/hr (-4.86 °F/hr) from 3/26/05 20:16 – 3/27/05 04:56.

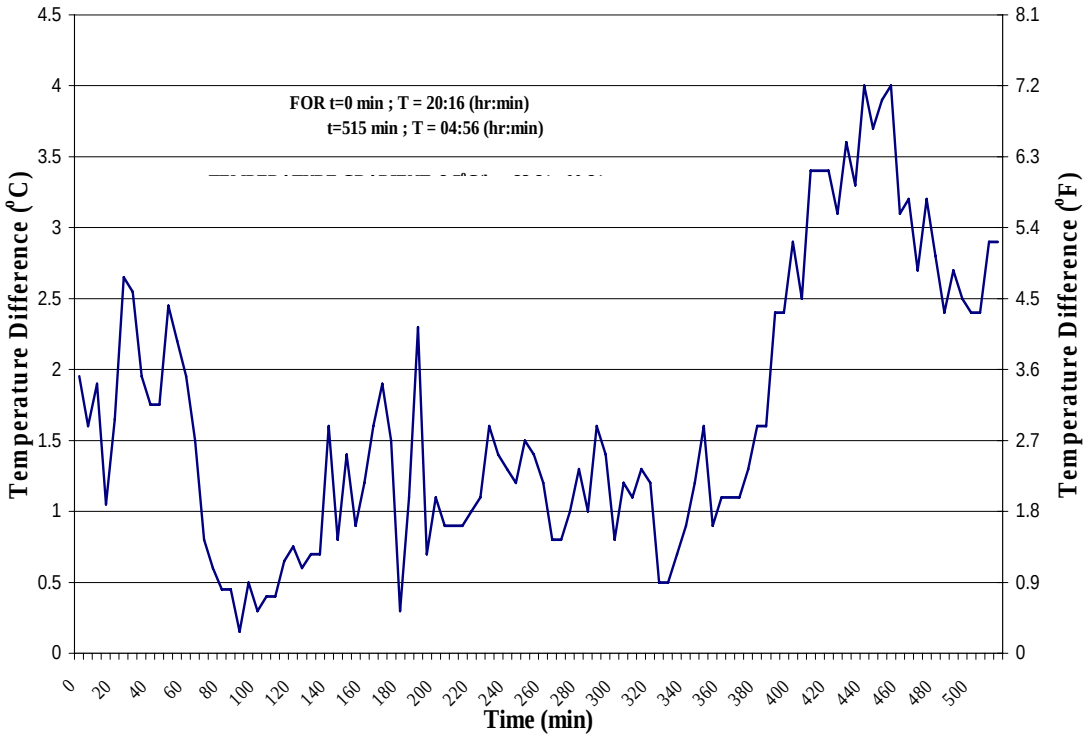


Figure 100: Temperature difference between actual values for bridge and block for Site 91 – Portage County for delta = -2.7°C/hr (-4.86 °F/hr) from 3/26/05 20:16 – 3/27/05 04:56.

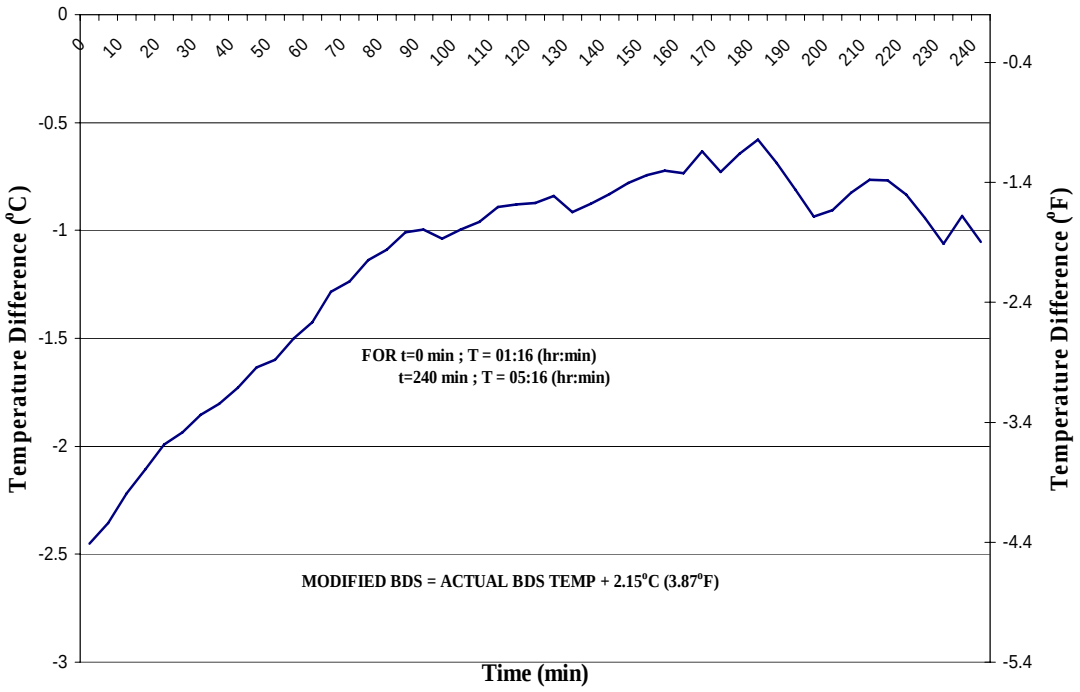


Figure 101: Temperature difference between simulated values for bridge and block for Site 91 – Portage County for delta = 2.4°C/hr (4.32 °F/hr) from 3/25/05 01:16 – 3/25/05 05:16.

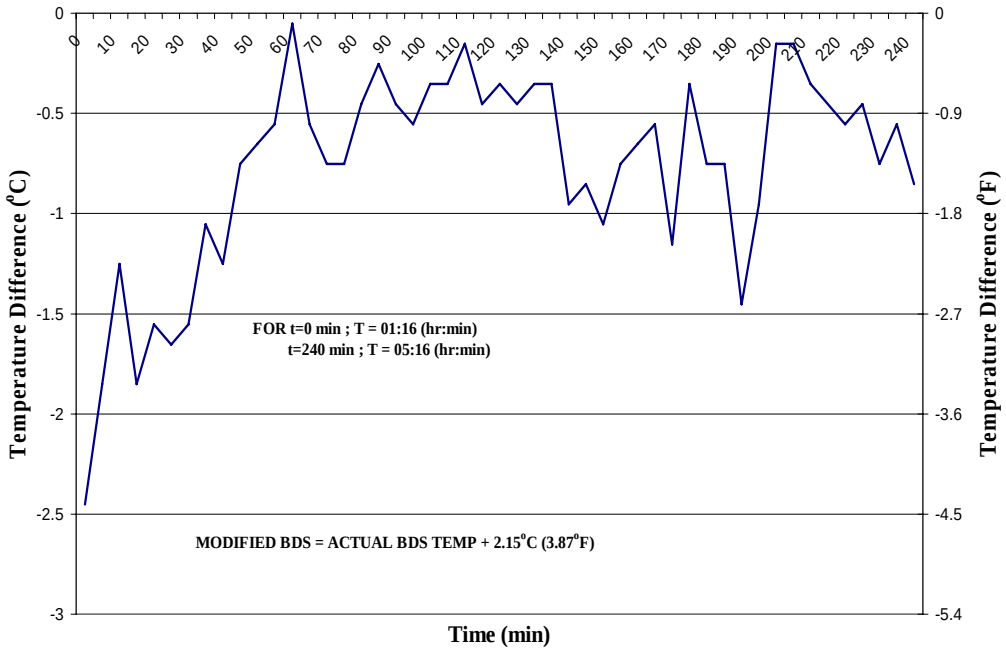


Figure 102: Temperature difference between actual values for bridge and block for Site 91 – Portage County for delta = 2.4°C/hr (4.32 °F/hr) from 3/25/05 01:16 – 3/25/05 05:16.

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