Name: Date: Period:

A Baltimore Heat Wave

Temperature Analysis of an Urban Heat Island

Introduction

An Urban Heat Island (UHI) is an urban/metropolitan area that is significantly warmer than its surrounding rural areas due to human activities.

In this activity you will be given access to the data from the heatwave of 2008 in Baltimore. You will generate/choose research questions, choose the data you will need to analyze, organize and graph the data you need to address your question, and make an argument (CER: a claim supported by evidence and reasoning) that responds to your original question.

Objective:

The students will use authentic data to develop a research question that the data can be used to answer, analyze and graph the data, and make a claim with evidence and reasoning about the original question.

Student Instructions:

1. Obtain data, from your teacher, about a four-day heat wave that took place in Baltimore in June, 2008.
    - The data set is for a nine-day period around (before, during and after) the heat wave in June 2008.
    - The data points were collected on an hourly basis at two sites: the Maryland Science Center (MSC) in downtown Baltimore (urban location), and Baltimore Washington International Airport (BWI) just outside of Baltimore (suburban location).
2. Look over the data sets.
    - What variables are included?

    - Describe how it is organized.

3. Considering what you've already learned about Urban Heat Islands, brainstorm questions you might be able to answer about differences you might find in these data.

4. Choose a question you would like to address using these data and record it on the worksheet. (Answer Question 1)

5. Decide on what data you will need to address your question and write this on the worksheet. (Answer Question 2 and 3)

6. Organize, calculate and plot or chart the data so you can address your question.
    - Be sure to include your key, axis labels, title, etc. on your graph.
    - Attach your graph to this form once it is complete.

7. Now, make an argument (CER: a claim supported by evidence and reasoning) that addresses your question and complete the next part of the worksheet. (Complete Question 4 Before you write your paragraph)

You will be sharing your results – your argument and summarized data – with your teacher and the rest of the class.

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Analysis Questions:

1. What Question are you addressing?

2. What data will you need to address your question?

3. Why is this an interesting question, and why will these data help you address it?

4. Once you've done your analysis, summarize your findings
    a. Restate your question (modified as needed)

    b. What claim are you making about your question?

    c. Present the evidence that supports your claim (and reference the graph or table that summarizes your data)

    d. Explain why the evidence supports the claim, and how it is consistent with basic principles about the phenomena.

Now address these follow-up, reflection questions:

5. What would be a stronger argument?
    a. Would you ask a different question or make a different claim?

    b. Better evidence?

6. What are the strengths and limitations of using data for the heat wave from MSC and BWI to address questions about the Urban Heat Island? Can you propose better locations to study?

Teacher Notes:

Summary:
Students are given data for a 9 day period before, during and after a 4 day heat wave in June 2008. Data were collected on an hourly basis at two sites: the Maryland Science Center (MSC) in downtown (urban) Baltimore, and Baltimore Washington International Airport (BWI) just outside of Baltimore (suburban). Students generate questions about differences they might find, decide on the data they would need to address their questions, organize and then plot the data and make an argument (CER: a claim supported by evidence and reasoning) that addresses their question.

Preparation and Materials Needed:

- Choose between two datasets to present to students:
    1. Hourly mean temperatures (5 pages of data printed, or 216 lines of data in the spreadsheet).
    2. Averages and maxima by day, and by day vs. night for each date (1 page of data printed, or 28 lines of data in the spreadsheet).
- Decide whether students will access the data as printouts or excel spreadsheets. If as printouts, make the appropriate number of copies of the data you choose to provide.
- Make copies of the Worksheet.

Background for Teacher:

- Possible questions students might address:
    1. Is there evidence of an Urban Heat Island (UHI) in during this time period?
    2. Is the UHI greatest during the day or night?
    3. Is the UHI greatest before, during or after the heat wave?
    4. Is the UHI more evident from daily means, daily maxima, day vs. night means, or some other way of looking at the data?
    5. Is the UHI consistent every hour of every day?
- For more information, refer to the paper by Li and Bou-Zeid.
- A graph is available presenting their way of visualizing these data. (See below)

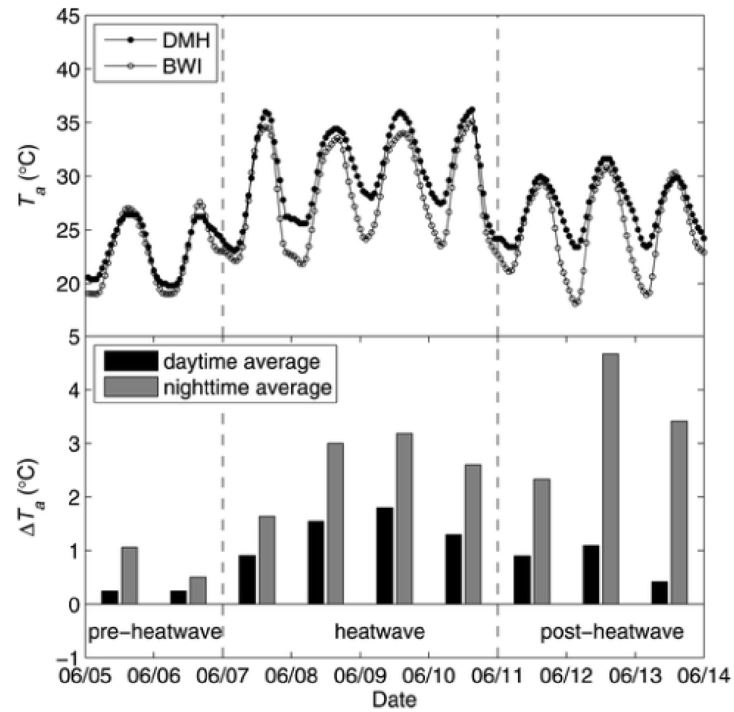

Fig. 5. (top) The 2-m air temperatures measured at DMH (Maryland Science Center) and at BWI in Baltimore MD. (bottom) The difference between the urban and rural air temperatures, i.e., the UHI index ΔT_a, for daytime and nighttime. The heat wave event lasts from 7 to 10 Jun.

Li, D. and E. Bou-Zeid, 2013: Synergistic Interactions between Urban Heat Islands and Heat Waves: The Impact in Cities Is Larger than the Sum of Its Parts. *J. Appl. Meteor. Climatol.*, **52**, 2051–2064, https://doi.org/10.1175/JAMC-D-13-02.1

Name: Date: Period:

Table 1: Daily Data:

June 2008 date day (d) / night (n)	MSC mean (degrees F)	BWI mean (degrees F)	UHI: MSC-BWI, (degrees F)	MSC max (degrees F)	BWI max (degrees F)	
5	74.6	73.4	1.1	79.5	80.6	
d	76.9	76.3	0.6	79.5	80.6	
n	70.7	68.6	2.1	76.3	74.7	
6	73.2	72.5	0.7	79.2	81.7	
d	74.4	74.3	0.1	79.2	81.7	
n	71.2	69.4	1.7	77.0	74.2	
7	83.8	81.3	2.5	96.8	94.2	
d	88.4	86.3	2.0	96.8	94.2	
n	76.1	72.9	3.2	82.0	74.7	
8	86.7	82.3	4.4	93.9	92.4	
d	89.9	86.8	3.1	93.9	92.4	
n	81.4	75.0	6.4	88.9	82.8	
9	89.5	85.3	4.2	96.8	93.2	
d	92.6	89.4	3.1	96.8	93.2	
n	84.5	78.4	6.0	88.5	84.4	
10	86.6	83.0	3.6	97.2	95.2	
d	90.2	87.4	2.9	97.2	95.2	
n	80.5	75.6	4.9	84.6	79.3	
11	79.9	76.9	3.0	86.0	85.0	
d	81.9	80.3	1.7	86.0	85.0	
n	76.5	71.3	5.2	81.3	73.9	
12	82.2	77.4	4.9	88.9	87.4	
d	85.2	82.5	2.7	88.9	87.4	
n	77.2	68.7	8.5	82.4	76.0	
13	80.1	76.7	3.4	85.6	86.6	
d	82.4	80.7	1.6	85.6	86.6	
n	76.3	69.8	6.5	78.8	74.9	
Grand Total	81.8	78.8	3.1	97.2	95.2	
Explanation of Data:						
June 2008 date; day (d)/night (n)	Day of the month, June 2008. Day includes hourly readings between 06:00 and 20:00. Night includes hourly readings between 21:00 and 05:00.					

MSC mean (° F)	Maryland Science Center (MSC) data - downtown Baltimore. Data are means for either the entire day (numbered), or day (d) and night (n), as indicated.
BWI mean (°F)	Baltimore Washington International airport (BWI) data - suburban Baltimore. Data are means for either the entire day, or day and night, as indicated.
UHI: MSC-BWI, (° F)	Urban Heat Index, calculated as urban minus suburban. Data are means for either the entire day, or day and night, as indicated.
MSC max (°F)	Maryland Science Center (MSC) data - downtown Baltimore. Data are maxima for either the entire day, or day and night, as indicated.
BWI max (°F)	Baltimore Washington International airport (BWI) data - suburban Baltimore. Data are maxima for either the entire day, or day and night, as indicated.

Table 2: Hourly data:

Day	Hour (local)	Day (d) / Night (n)	MSC (DMH, degrees F)	BWI (degrees F)	UHI (MSC-BWI, degrees F)
5	0	n	69.3	66.4	2.9
5	1	n	69.0	66.3	2.7
5	2	n	68.7	66.3	2.4
5	3	n	68.7	66.2	2.5
5	4	n	68.7	66.2	2.5
5	5	n	69.4	66.6	2.9
5	6	d	70.5	67.7	2.9
5	7	d	71.6	69.3	2.3
5	8	d	73.0	71.4	1.6
5	9	d	74.5	73.2	1.3
5	10	d	75.9	74.7	1.2
5	11	d	77.0	76.5	0.5
5	12	d	78.4	78.2	0.3
5	13	d	78.8	79.6	-0.8
5	14	d	79.5	80.4	-0.9
5	15	d	79.5	80.6	-1.1
5	16	d	79.5	80.4	-0.9
5	17	d	79.5	80.0	-0.4
5	18	d	79.5	79.1	0.4
5	19	d	78.8	77.7	1.1
5	20	d	77.7	76.3	1.4
5	21	n	76.3	74.7	1.5
5	22	n	74.1	73.2	0.9
5	23	n	72.0	71.6	0.4
6	0	n	70.2	69.8	0.4
6	1	n	69.1	68.2	0.9
6	2	n	68.4	67.0	1.3
6	3	n	68.0	66.4	1.6
6	4	n	68.0	66.2	1.8
6	5	n	67.6	66.2	1.4
6	6	d	67.6	66.2	1.4
6	7	d	67.6	66.4	1.3
6	8	d	68.0	67.0	1.0
6	9	d	68.7	68.2	0.5
6	10	d	70.5	69.8	0.7

6	11	d	72.3	71.8	0.5
6	12	d	74.5	74.0	0.4
6	13	d	76.6	76.5	0.1
6	14	d	78.4	79.1	-0.6
6	15	d	79.2	80.9	-1.8
6	16	d	79.2	81.7	-2.5
6	17	d	79.2	80.9	-1.8
6	18	d	78.4	79.3	-0.8
6	19	d	77.7	77.2	0.5
6	20	d	77.4	75.4	2.0
6	21	n	77.0	74.2	2.8
6	22	n	76.3	73.6	2.7
6	23	n	75.9	73.4	2.5
7	0	n	75.2	73.4	1.8
7	1	n	74.5	73.2	1.3
7	2	n	74.1	72.8	1.4
7	3	n	73.8	72.2	1.5
7	4	n	73.4	71.8	1.6
7	5	n	73.8	71.8	2.0
7	6	d	74.8	72.4	2.4
7	7	d	76.6	74.1	2.5
7	8	d	79.5	77.5	2.0
7	9	d	82.8	81.9	0.8
7	10	d	85.6	86.6	-1.0
7	11	d	89.2	90.2	-1.0
7	12	d	92.5	92.2	0.3
7	13	d	94.3	93.2	1.1
7	14	d	95.7	93.8	1.9
7	15	d	96.8	94.2	2.6
7	16	d	96.4	94.0	2.4
7	17	d	95.4	92.8	2.5
7	18	d	91.8	89.3	2.4
7	19	d	88.5	83.8	4.7
7	20	d	85.3	78.8	6.4
7	21	n	82.0	74.7	7.3
7	22	n	79.2	73.2	5.9
7	23	n	79.2	73.1	6.1
8	0	n	78.8	72.8	6.0
8	1	n	78.8	72.6	6.2

8	2	n	78.4	72.1	6.4
8	3	n	78.1	71.3	6.8
8	4	n	78.1	71.3	6.8
8	5	n	78.1	72.1	5.9
8	6	d	79.2	74.2	4.9
8	7	d	81.3	77.0	4.3
8	8	d	83.8	80.1	3.7
8	9	d	86.7	83.5	3.2
8	10	d	89.6	86.3	3.3
8	11	d	91.4	88.6	2.8
8	12	d	92.5	90.1	2.4
8	13	d	93.2	90.8	2.4
8	14	d	93.6	91.4	2.2
8	15	d	93.9	92.0	1.9
8	16	d	93.9	92.4	1.5
8	17	d	93.6	92.0	1.5
8	18	d	93.2	90.4	2.8
8	19	d	92.1	87.8	4.3
8	20	d	90.7	85.0	5.7
8	21	n	88.9	82.8	6.1
8	22	n	87.4	80.9	6.6
8	23	n	86.0	78.9	7.1
9	0	n	84.6	77.1	7.4
9	1	n	83.5	75.7	7.7
9	2	n	83.1	75.4	7.7
9	3	n	82.8	75.8	6.9
9	4	n	82.4	76.5	5.9
9	5	n	83.1	77.8	5.3
9	6	d	84.6	79.8	4.8
9	7	d	86.0	82.6	3.4
9	8	d	88.2	85.8	2.3
9	9	d	90.7	88.6	2.1
9	10	d	92.8	90.4	2.4
9	11	d	94.3	91.4	2.9
9	12	d	95.7	92.0	3.7
9	13	d	96.4	92.6	3.9
9	14	d	96.8	93.0	3.8
9	15	d	96.4	93.2	3.2
9	16	d	95.7	93.0	2.7

9	17	d	95.0	92.4	2.6
9	18	d	93.6	91.0	2.5
9	19	d	91.8	89.0	2.8
9	20	d	90.3	86.6	3.7
9	21	n	88.5	84.4	4.1
9	22	n	86.7	82.4	4.3
9	23	n	85.6	80.8	4.9
10	0	n	84.6	79.3	5.3
10	1	n	83.1	77.7	5.4
10	2	n	82.4	76.5	5.9
10	3	n	81.7	75.2	6.5
10	4	n	81.3	74.3	7.0
10	5	n	81.7	74.7	7.0
10	6	d	83.1	76.6	6.6
10	7	d	85.3	80.0	5.3
10	8	d	87.8	84.0	3.8
10	9	d	90.3	87.6	2.7
10	10	d	92.1	90.4	1.7
10	11	d	94.3	92.2	2.1
10	12	d	95.4	93.2	2.2
10	13	d	96.1	94.0	2.1
10	14	d	96.8	94.8	2.0
10	15	d	97.2	95.2	2.0
10	16	d	93.9	93.6	0.4
10	17	d	91.0	89.2	1.9
10	18	d	87.8	84.0	3.8
10	19	d	83.1	79.4	3.8
10	20	d	79.2	76.5	2.6
10	21	n	77.7	75.2	2.5
10	22	n	76.6	74.2	2.3
10	23	n	75.5	73.4	2.1
11	0	n	75.5	72.8	2.7
11	1	n	75.5	72.1	3.3
11	2	n	75.1	71.2	3.9
11	3	n	74.5	70.5	4.0
11	4	n	74.1	70.0	4.1
11	5	n	74.1	70.2	4.0
11	6	d	74.1	71.3	2.9
11	7	d	75.6	73.1	2.4

11	8	d	77.0	75.7	1.3
11	9	d	78.8	78.2	0.6
11	10	d	80.2	80.2	0.0
11	11	d	82.4	81.6	0.8
11	12	d	83.5	82.4	1.1
11	13	d	84.9	83.2	1.7
11	14	d	85.6	84.2	1.4
11	15	d	86.0	85.0	1.0
11	16	d	85.6	85.0	0.6
11	17	d	85.3	84.2	1.1
11	18	d	84.2	82.7	1.5
11	19	d	83.5	80.3	3.2
11	20	d	82.4	77.3	5.1
11	21	n	81.3	73.9	7.4
11	22	n	79.9	71.4	8.4
11	23	n	78.4	69.8	8.6
12	0	n	77.0	68.3	8.7
12	1	n	75.9	66.8	9.1
12	2	n	74.8	65.4	9.4
12	3	n	74.1	64.6	9.5
12	4	n	74.1	64.9	9.2
12	5	n	75.2	66.7	8.5
12	6	d	77.0	70.1	6.9
12	7	d	79.2	74.8	4.4
12	8	d	81.7	79.0	2.7
12	9	d	84.2	82.1	2.1
12	10	d	85.6	83.7	1.9
12	11	d	87.1	84.8	2.2
12	12	d	88.2	86.0	2.2
12	13	d	88.9	87.0	1.9
12	14	d	88.9	87.4	1.4
12	15	d	88.9	87.2	1.7
12	16	d	88.2	86.5	1.7
12	17	d	87.1	85.4	1.7
12	18	d	85.6	83.8	1.8
12	19	d	84.6	81.6	3.0
12	20	d	83.5	78.8	4.7
12	21	n	82.4	76.0	6.4
12	22	n	81.3	73.8	7.6

12	23	n	80.2	71.9	8.4
13	0	n	78.8	70.2	8.6
13	1	n	77.0	69.0	8.0
13	2	n	75.6	67.6	8.0
13	3	n	74.5	66.7	7.8
13	4	n	74.1	66.0	8.1
13	5	n	74.5	66.5	8.0
13	6	d	75.9	69.1	6.8
13	7	d	77.7	72.9	4.8
13	8	d	79.9	77.0	2.9
13	9	d	81.7	80.2	1.4
13	10	d	83.1	82.2	0.9
13	11	d	84.2	83.7	0.5
13	12	d	84.6	85.3	-0.7
13	13	d	85.3	86.3	-1.1
13	14	d	85.6	86.6	-1.0
13	15	d	85.6	85.8	-0.2
13	16	d	84.9	84.2	0.7
13	17	d	84.2	82.4	1.8
13	18	d	82.4	80.4	2.0
13	19	d	81.0	78.3	2.6
13	20	d	79.5	76.5	3.0
13	21	n	78.4	74.9	3.5
13	22	n	77.4	74.0	3.3
13	23	n	76.6	73.6	3.1

Data for 9 days Description	
Day	Day of the month, June 2008
Hour (local)	Time is in 24 hour or military time units.
Day (d) / Night (n)	Day was assigned to hours 6 to 20 each day, assuming sunrises 5:40 AM and sets 20:32 (times for June 10). Night was assigned to hours between 21 and 5.
MSC (DMH, degrees F)	Maryland Science Center (MSC) data - downtown Baltimore
BWI (degrees F)	Baltimore Washington International airport (BWI) data - suburban Baltimore
UHI (MSC-BWI, degrees F)	Urban Heat Index, calculated as urban minus suburban