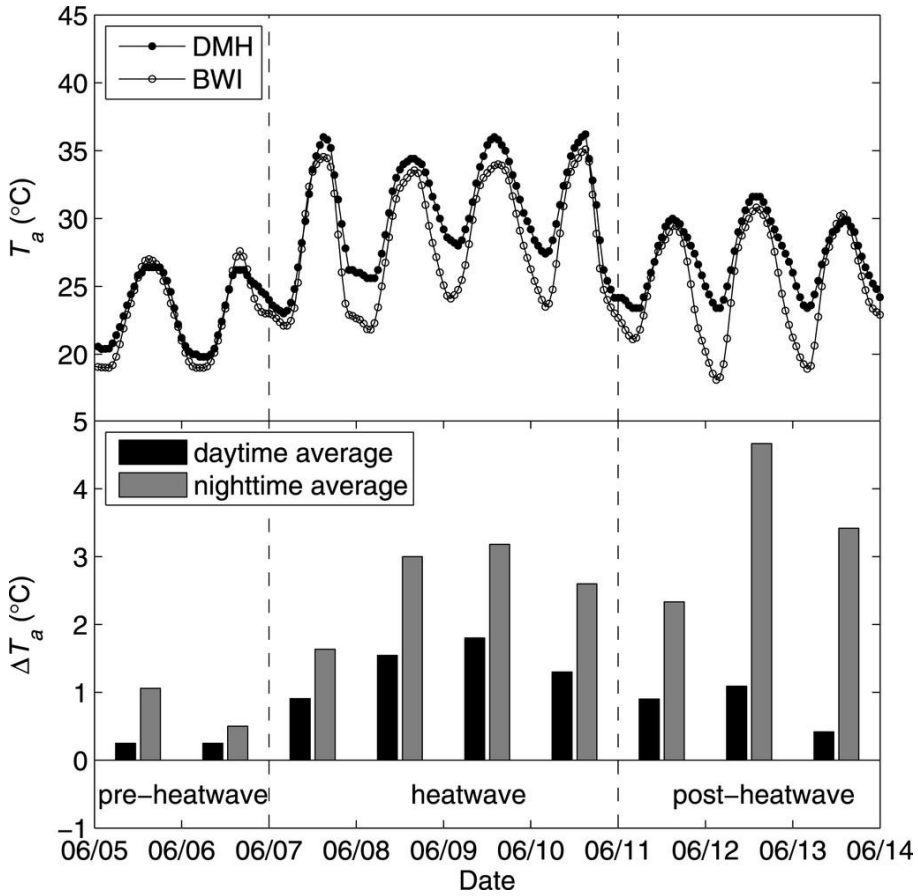
Integrating Chemistry & Earth Science

URBAN HEAT ISLAND MODULE

LESSON 7:

HEAT WAVES AND URBAN HEAT ISLANDS



The top panel is a direct comparison between the 2-meter air temperatures at DMH (downtown Baltimore) and BWI airport (located in the suburbs). As can be seen, the heat wave event lasts from 7 to 10 June: the maximum daytime air temperatures at the urban and suburban/rural sites are 5°–10°C larger during the heat wave period than before or after. *Source: Li, Dan and Elie Bou-Zeid. 2013. Synergistic Interactions between Urban heat Islands and Heat Waves: The Impact of Cities is Larger than the Sumer of Its Parts. Journal of Applied Meteorology and Climatology. 52:9, 2051-2054.* 10.1175/JAMC-D-13-02.1

THE GEORGE WASHINGTON UNIVERSITY WASHINGTON, DC

BALTIMORE CITY PUBLIC SCHOOLS

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The following lesson and associated materials are part of the Integrating Chemistry and Earth science (ICE) Urban Heat Island Module. The Module brings together important concepts from Earth science and chemistry to help students build an understanding of why urban areas have higher temperatures both during the day and at night, than their rural counterparts.

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Lesson 7: Heat Waves and Urban Heat Islands

Driving Question: *How does the temperature in Baltimore City compare to the temperature in Baltimore County?*

Summary: Over the next two lessons students will study the Urban Heat Island effect as it applies to Baltimore and its surrounding region and propose possible solutions for neighborhoods within Baltimore City.

Activity Description:

- **Opening Activity:** Introduce the concept of Urban Heat Island.
  - Choose one:
    - Show the Urban Heat Island Video (Science Museum of Virginia 2:11).
    - Show Why It's Usually Hotter in Cities (NPR 2:29)
    - Read Urban Heat Island Effect
- **Compare Temperature Data:** Students will compare surface temperatures.
  - The video we just watched was made about Richmond, VA, let's see if we can find evidence of the same effect happening in Baltimore.
  - Students examine land surface temperature and land development maps of Baltimore looking for an urban heat island effect.
    - These are infrared and standard satellite images of Baltimore City.
    - Students should notice that the developed areas of Baltimore are warmer than the undeveloped areas.
    - These images can be printed out for individual comparison or projected for class discussion.
    - Discussion Prompt: What is happening to energy in this system?
- **Measuring Heat Islands**
  - Have students wet the back of their hand. The wet location should feel cooler because evaporation is occurring. The same process explains why wet surfaces are cooler than dry surfaces. (Resource)
  - Students refer to the data they collected in Lesson 1 to identify the warmest and coolest locations in the schoolyard.
  - *A Baltimore Heat Wave-Student activity*
- **Urban vs Rural Energy Balance**
  - Provide students with blank copies of the UHI Modeling Template.
    - Have students create a revised Baltimore (Urban) thermal model and then create a Baltimore County (Rural/suburban) version of the same model.
    - **Teacher Note:** Remind students of the difference between reflected heat and heat radiated from buildings and the symbols they created to differentiate these two on their models. Remind them that their models should also include descriptions of

the process and mechanism represented in the model.

- Have students watch Baltimore neighborhood called a 'heat island' (WMAR-2 News 3:31)
- Students make a claim about how to reduce the Urban Heat Island Effect in Baltimore

- **Homework:** Jigsaw part 1:
  - Assign students to four groups. Each group reads one of four different articles for homework:
    - Trees EPA Trees reading
    - Cool Roofs EPA Cool Roofs reading
    - Cool Pavement EPA Cool Pavement reading
    - Green Roofs EPA Green Roofs reading

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 heat wave 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 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.

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) 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)

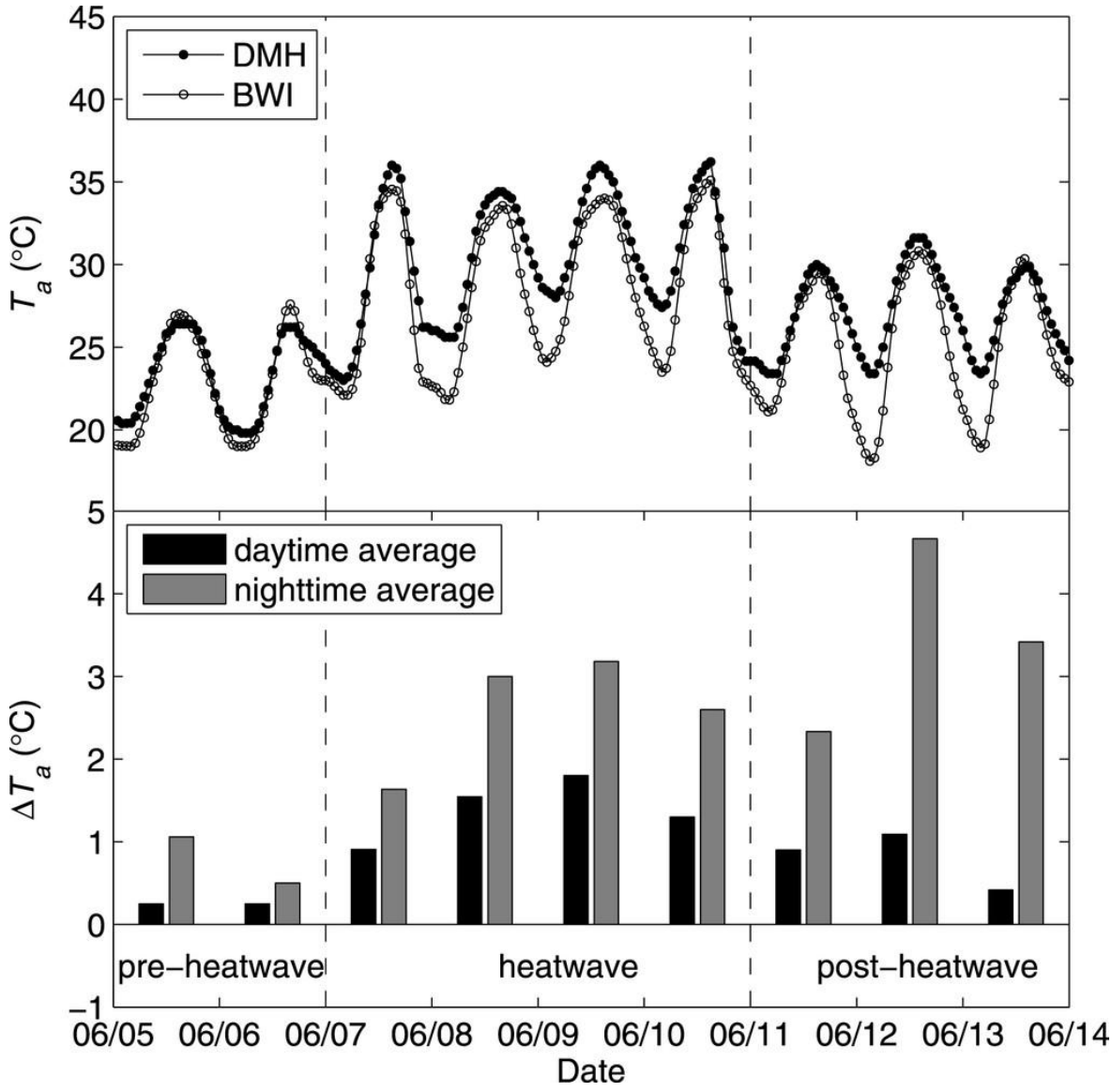

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Table 1: Daily Data:

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 (^{o} 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 (^{o}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, (^{o} 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 (^{o}F)	Maryland Science Center (MSC) data - downtown Baltimore. Data are maxima for either the entire day, or day and night, as indicated.
BWI max (^{o}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
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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
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10	4	n	81.3	74.3	7.0
10	5	n	81.7	74.7	7.0
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10	10	d	92.1	90.4	1.7
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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