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Data Analysis Teaching Activity (DATA)

Can't Take the Heat?

Exploring Heat Capacity with Ocean Observing System Data

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Sea Grant

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http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive0909.html

written by Christopher Petrone

Summary

Why does coffee take so long to cool down? Why is ocean water sometimes the warmest when the average daily air temperature starts to drop? How can buoys help us explore these questions? In this hands-on introduction to heat capacity by the Bridge and COSEE-NOW, students explore the concept and its effects on our daily lives. Students use ocean observing system data to investigate why water acts as a thermal buffer and the practical applications this has.

Objectives

After completing this activity, students will be able to:

- Analyze graphs of air and water temperature
- Create graphs of temperature range
- Describe the difference in the heat capacities of air and water
- Explain the practical applications of water's high heat capacity

Vocabulary

Heat capacity, Specific heat, Thermal buffer

Introduction

Imagine it's the beginning of October. School has been back in session for a few weeks and the temperature is beginning to cool as autumn quickly approaches. At dinner one night, your parents surprise you with a trip to the beach for the weekend. Normally, if it were July or August, this would be great news—hot sun and the refreshing ocean water! Unfortunately, the beach is not located in one of those areas that stay warm year-round. So how much fun will this weekend be if you cannot swim in the ocean!?

The weekend finally arrives and you find yourself in your bathing suit standing inches from the breaking waves. The air temperature is in the mid-70s, but you're at the beach, so you must brave the coldest of water temperatures to get your money's-worth out of the trip. Finally, you take a deep breath, grit your teeth and run full speed into the water expecting it to feel like the Arctic the instant it touches your skin.

Once submerged, you come up for air and are ready to run out just as fast as you ran in, and curl up in your beach towel. But wait! You soon realize that the water is not cold at all, but instead, actually warmer than the air all around you. As you continue to splash around, riding waves and swimming, you start to ponder how this is even possible. How could the water actually be warmer than the air after it's been so cool out the past few days? The difference has everything to do with the heat capacities of the two substances.

Heat capacity is the amount of heat required to raise the temperature of an object by 1˚C without changing the state of matter. It is measured in Joules/˚C and its value is proportional to the amount of material in the object; for example, a lake has a greater heat capacity than a puddle.

NATIONAL SCIENCE EDUCATION STANDARDS CORRELATIONS

Science as Inquiry
- Abilities necessary to do scientific inquiry (5-8, 9-12)
- Understanding about scientific inquiry (5-8, 9-12)

Physical Science
- Transfer of energy (5-8)
- Interactions of energy and matter (9-12)

Earth and Space Science
- Energy in the earth system (9-12)

Science & Technology
- Abilities of technological design (5-8, 9-12)
- Understandings about science and technology (5-8, 9-12)

Science in Personal and Social Perspectives
- Science and technology in society (5-8)
- Science and technology in local, national and global challenges (9-12)

History and Nature of Science
- Science as human endeavor (5-8, 9-12)
- Nature of science knowledge (5-8, 9-12)

OCEAN LITERACY PRINCIPLES & FUNDAMENTAL CONCEPTS

1 – A, F
3 – A, F
6 – A
7 – B, D, E

The *specific heat* is the actual quantity of heat energy required to raise 1 gram of a substance 1˚ C and it is typically measured in J/g˚C. Water has a much higher heat capacity, and specific heat, than air, meaning it takes more energy to heat water than it does to heat air. Water has a specific heat of 4.186 J/g˚C, versus air, which has a specific heat of 1.005 J/g˚C.

In the beach scenario above, the water was actually warmer than the air, despite the recent lower air temperatures. This is because of water's much higher heat capacity than air; and because of its higher heat capacity, it takes longer for water to gain and lose heat (cool), than it does for air. In both cases, either heating or cooling, there will be a lag between the air and water temperatures. Because of this, you may also find chilly water temperatures in June, even though the air temperature has been in the 80s and 90s for weeks.

The heat capacity of water has tremendous effects on the climate of the surrounding area. Because the water buffers the air temperature, the range of air temperature near water bodies is often smaller than the air temperature range further from large bodies of water. On a greater scale, because the ocean occupies over 70% of the Earth's surface, it buffers the atmospheric temperature, providing a livable climate (link to http://www.oco.noaa.gov/index.jsp?show_page=page_roc.jsp&nav=universal).

In addition to keeping the Earth's atmospheric temperature in check, water's high heat capacity has numerous practical applications for humans. We use water to prevent engines from overheating in automobiles, boats and power plants. This is also why water is used in fire fighting (link to http://www.ffti.com.au/product_detail/36/); it absorbs the heat of the material it comes in contact with, dissipates the heat as it changes from liquid to gas, and actually lowers the temperature of the fire. At the same time, the water increases the heat capacity of the material, making it harder for the fire to burn the material. The human body even utilizes water's high heat capacity when we sweat!

You often come in contact with materials that have different heat capacities. Perhaps you have walked home from the beach on a hot, sunny day without wearing shoes. The sand is scorching, so you quickly walk to the street, which you find is also hot, so you move to the sidewalk, which may be only slightly cooler, so you end up on the grass, which is the coolest. These materials each have very different heat capacities (http://www.engineeringtoolbox.com/specific-heat-capacity-d_391.html). Although they are all subject to the same sun exposure, they all store the thermal energy at different rates and thus radiate different temperatures to your bare feet.

The heat capacity of a material is very carefully considered in the construction of houses and other buildings (http://en.wikipedia.org/wiki/Heat_capacity#Thermal_mass_in_buildings). The ability of a material to collect and tolerate heat and then effectively dissipate it is critical to ensuring the durability and safety of a structure, and the comfort of its inhabitants.

Data Activity

Using the information learned above, students will now explore air and water temperature data from four monitoring stations in Virginia along an inland-to-offshore gradient. Two of the stations are NOAA National Climate Data Center (http://www.ncdc.noaa.gov) monitoring stations. These are located in Amelia and Petersburg, VA and students will use only air temperature data from these stations. The other two stations are ocean observing system buoys; one is located in the James River, VA and is a part of the Chesapeake Bay Interpretive Buoy System (http://www.buoybay.org), which is a part of the NOAA Chesapeake Bay Office. The second buoy is a NOAA National Data Buoy Center (http://www.ndbc.noaa.gov) entity. From the two buoys, students will use both air and water temperatures.

A. General Analysis

1. Using the scale in Figure 1—a map of the four monitoring stations—and a ruler, measure the distance between each station and Virginia Beach, VA. Enter the distance (in miles) into column 4 in Table 1. The first one has been done for you.
2. In column 5, convert the distance measured from miles to kilometers using the following conversion:

   1 mile = 1.609 kilometers

3. In column 6, indicate the direction the station is in relation to Virginia Beach, VA (N, S, E, W, etc.). The first one has been done for you.
4. Calculate the 2008 temperature range for each parameter. To calculate, subtract the minimum temperature from the maximum temperature. Record the range in column 9.

B. Graphing and Graph Analysis

Using the Figure 2, a blank graph, graph the temperature range data (Table 1, column 9) by hand and then discuss trends as a class or in small groups.

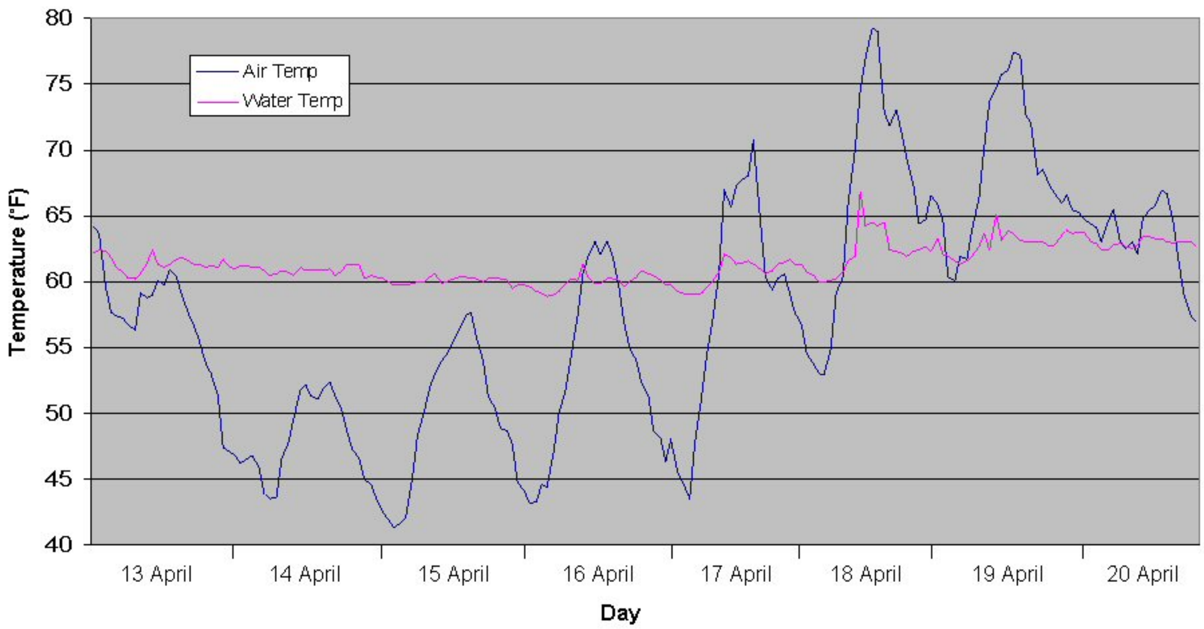
**Note to teachers:* If students are graphing by hand, instructions on how to create a floating, stacked column graph, as seen in Figure 2a, may need to be given. If students do not need graphing practice, use the completed graph found here (link to Figure 2a-floating column graph) to discuss trends as a class or in small groups.

C. Additional Analysis

Answer the following questions after viewing Figure 3 (below), air and water temperature from the Chesapeake Bay Interpretive Buoy System (CBIBS) buoy at Jamestown, VA from April 13-20, 2008.

5. What is the range of the air temperature during this time period? __________
6. What is the range of the water temperature? __________

Figure 3. Air & Water Temperature 13-20 April, 2008 from CBIBS Buoy: Jamestown



D. Real Time Data Analysis: www.buoybay.org

Visit the CBIBS website and click on any of the yellow buoys

7. Which buoy was selected? ____________________
8. What are the air and water temperatures at this buoy? ____________________

Click on "Get more data" and find your buoy site in the list.

9. Record the date and time of the most recent data. ____________________
10. What else is measured by this buoy?

Now click on the *Air Temperature* data for the past seven days at this buoy (yellow "7" circle at far right).

11. What are the dates these data were recorded? ____________________
12. What is the air temperature range over the past 7 days? __________

Now change the Y-axis to *Water Temperature* data and click on "Create Graph."

13. What is the water temperature range over the past 7 days? __________
14. Are the two temperature ranges (question #12 and #13) comparable or is there a large difference between them?

View other parameters on the X-axis that may be related to the water temperature data on the Y-axis.

15. Do any other relationships between the parameters measured exist? Explain.

Discussion and Application Questions

1. From Table 1 and either the graph students created (Figure 2) or the pre-filled graph (Figure 2a), what is the trend in air temperatures moving from west to east?
2. From Table 1, Figure 2/Figure 2a, and Figure 3, what is the trend in air temperature range versus water temperature range?
3. In addition to the applications discussed in the introduction, how else can water's high heat capacity be utilized?
4. Describe advantages and disadvantages of buoy sensor technology.

Extensions

A. Using the NOAA National Data Buoy Center buoys (www.ndbc.noaa.gov), explore archived air and water temperature data from a monitoring station near you, or at your favorite vacation spot. What trends exist in the data?

B. Complete heat capacity lab activities:
   a. http://tinyurl.com/ok8ttu (forwards to a www.teachengineering.org lesson plan)
   b. http://www.bigelow.org/virtual/handson/coastvsinland.html
   c. http://sccoos-weather.ucsd.edu/temp_weather_5/temperature/index.html

C. Use various statistical measures to further explore the air and water temperature, or other data that are available to determine if the trends are significant.

Other Resources

– Bridge Ocean Observing System Depot – Observing system primer, links, and activities
http://www.marine-ed.org/bridge/index_oos.html

– COSEE-Networked Ocean World – Observing system resources, blogs, forums and resources
http://www.coseenow.net

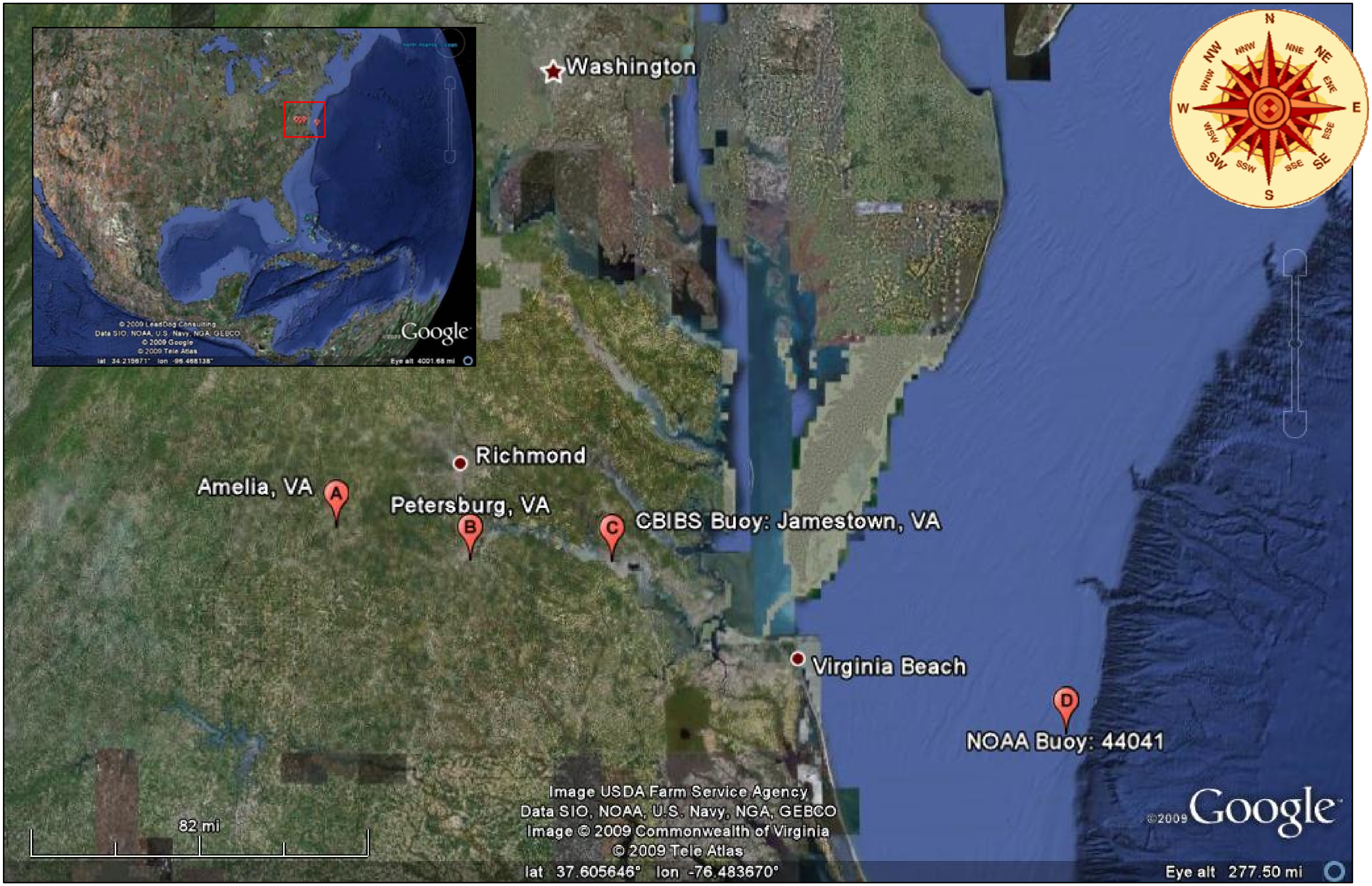


Figure 1. Map of 4 monitoring stations. *From Google Earth*

Bridge DATA: Can't Take the Heat

www.marine-ed.org/bridge

Table 1

1	2	3	4	5	6	7	8	9
Station	**Station Letter on Map**	**Parameter**	**Distance from Virginia Beach, VA (miles)**	**Distance in km** miles*1.609	**Direction, in relation to Virginia Beach (N, NE, E...)**	**2008 Maximum Temp. (˚F)**	**2008 Minimum Temp. (˚F)**	**2008 Temp. Range (˚F)**
NCDC #440188: Amelia, VA	A	Air Temp	*225*		*WNW*	100	2	
NCDC #446656: Petersburg, VA	B	Air Temp				100	12	
CBIBS Buoy: Jamestown, VA	C	Air Temp				97	18	
CBIBS Buoy: Jamestown, VA	C	Water Temp				88	40	
NDBC #44014: Offshore VA Beach, VA	D	Air Temp				83	29	
NDBC #44014: Offshore VA Beach, VA	D	Water Temp				86	47	

NCDC – NOAA National Climate Data Center – www.ncdc.noaa.gov
CBIBS – Chesapeake Bay Interpretive Buoy System – www.buoybay.org
NDBC – NOAA National Data Buoy Center – www.ndbc.noaa.gov

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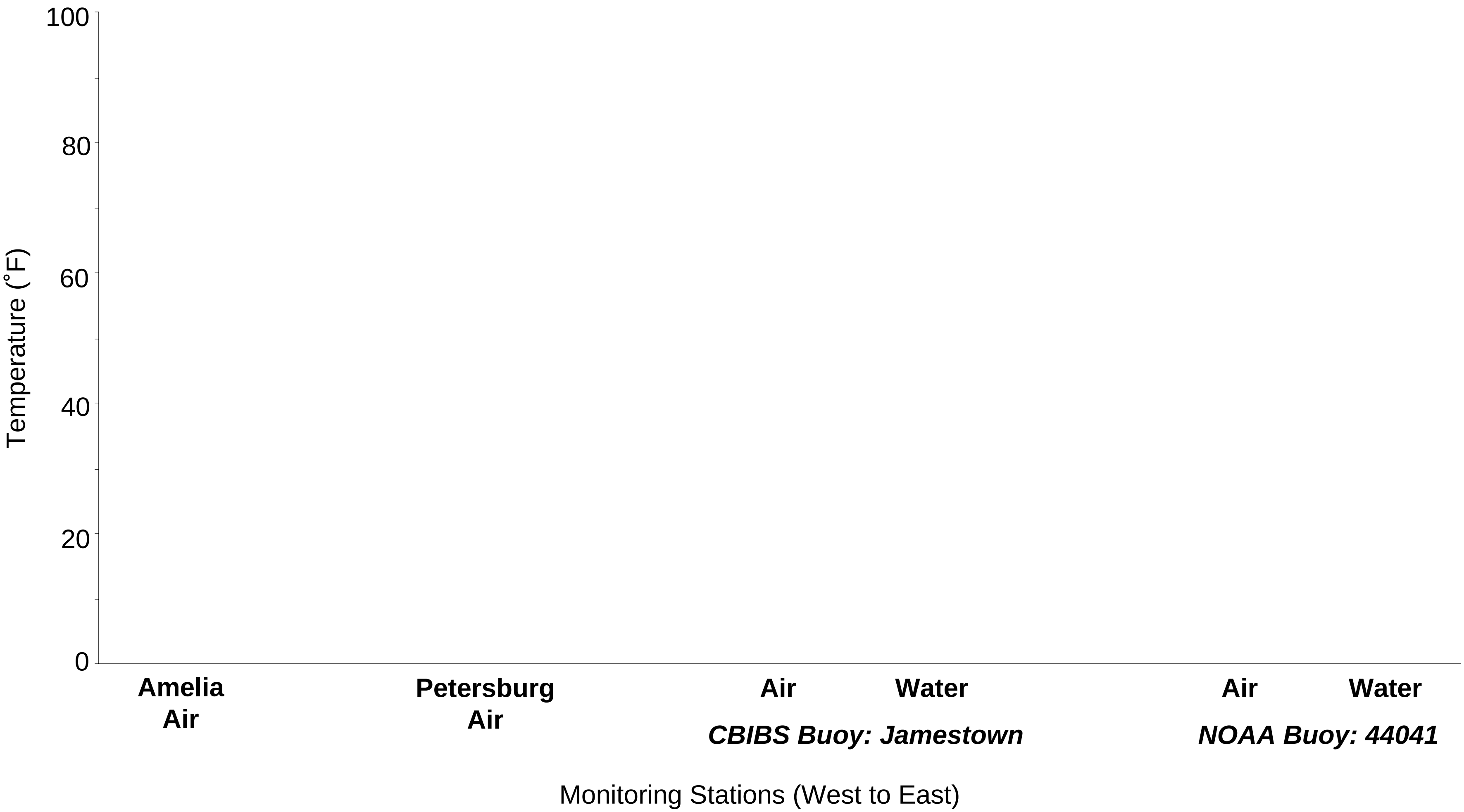
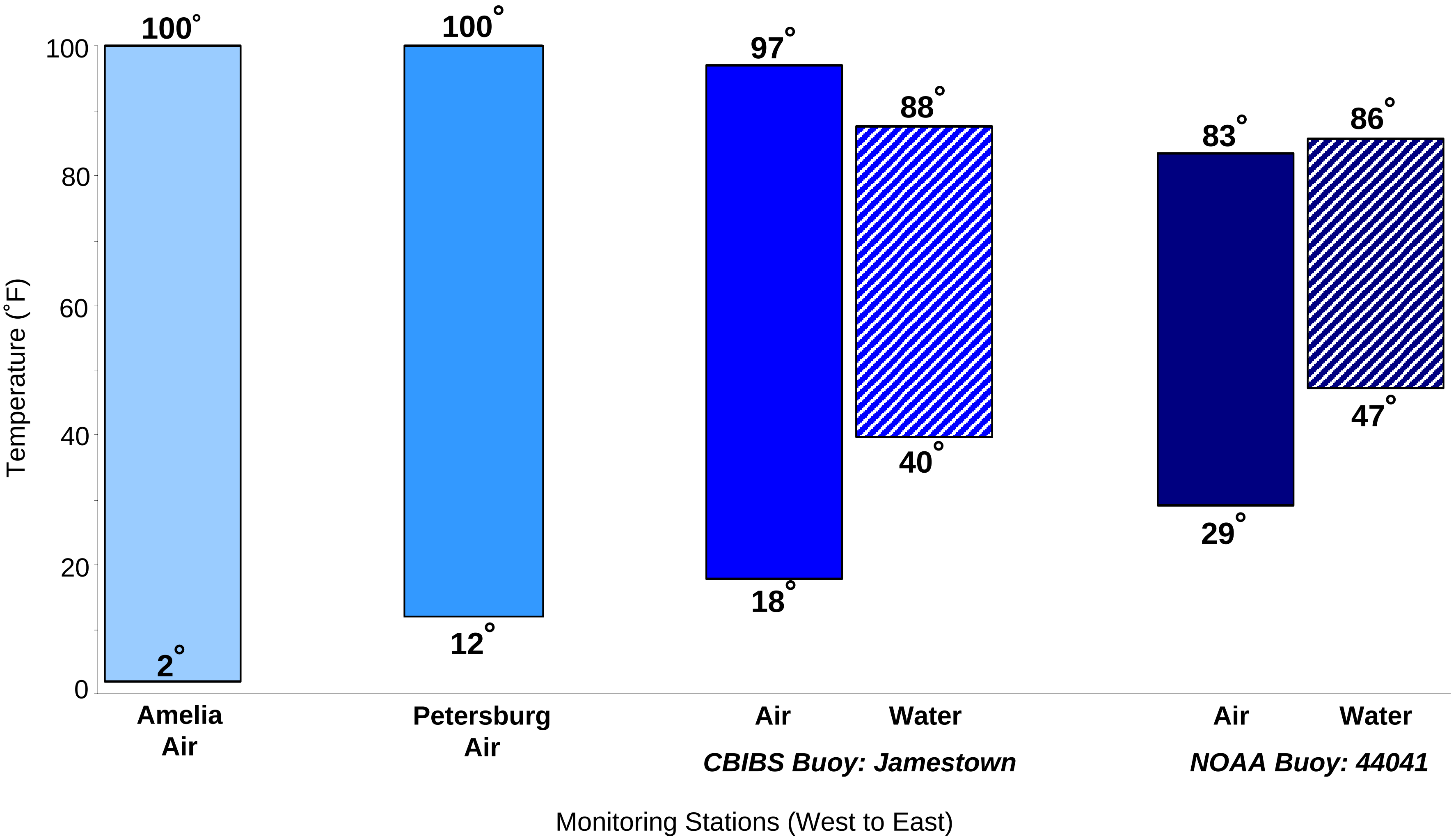
Figure 2. 2008 Temperature Range Data from Four Monitoring Stations in Southern Virginia, USA



Air and water temperature from 4 monitoring stations in Southern Virginia, USA. The Amelia and Petersburg sites are NOAA National Climate Data Center data are measured on land. The Jamestown and 44041 air data are measured over water.

Figure 2a. 2008 Temperature Range Data from Four Monitoring Stations in Southern Virginia, USA



Air and water temperature from 4 monitoring stations in Southern Virginia, USA. The Amelia and Petersburg sites are NOAA National Climate Data Center data are measured on land. The Jamestown and 44041 air data are measured over water.

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