Delaware Sea Grant Data Activity

Can't Take the Heat?

Grade Level: 6-12

Lesson Time: 45 minutes

Required Materials:

- Ruler
- Maps of monitoring stations
- Blank graphs
- Graphs of air and water temp from monitoring stations
- Graph of Newbold air vs. water temperature
- Computer with internet access or print outs of real-time data
- Student worksheet

STEM Connections

Science – Density; Meteorology; Climatology; Human impact; Interpreting graphs
Technology – Archived and real-time data from environmental observing systems
Engineering – Land use; Coastal development
Math – Creating graphs

Delaware Science Content Standards

Grades 6-8		*Grades 9-12*
1.1.A	3.3.G	1.1.A
1.1.C	5.1.B	1.1.D
1.2.A	5.2.F	1.2.A
2.1.D	5.2.H	5.3.A
2.1.E	5.2.I	
3.1.D	5.2.M	
3.2.F	5.3.A	

Related Topics

weather, climate, properties of water, land use, sustainable development, human impact, heat island effect

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This activity has been modified from the original *Can't Take the Heat?* to include data from Delaware. For the Virginia version, please visit www.marine-ed.org/bridge/heatcapacity.htm

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 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.

Activity Use

This activity can be used as part of a:

- Properties of water unit
- Human impacts and/or weather & climate unit in Environmental Science
- Density unit

Objectives

After completing this activity, students will be able to:

- Analyze graphs of air and water temperature
- Create graphs of temperature range
- Describe 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, trend

Invitation

Imagine it's the beginning of fall. 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 summer, 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 co me 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 be warmer than the air after it's been so cool out the past few days? How can we investigate this phenomenon?

Introduction

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.

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 early summer, 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 (http://www.oco.noaa.gov/roleofOcean.html).

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 firefighting (http://www.education.com/reference/article/firefighter-exam-study-guide-extinguishing-agents/); 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 benefits from 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 Analysis

Using the information learned above, students will now explore air and water temperature data from a series of monitoring stations in Delaware along an inland-to-offshore gradient.

Four of the stations are Delaware Environmental Observing System stations (http://www.deos.org). These are located in Seaford, Georgetown, Stockley, and at Indian River Inlet, DE. Students will use only air temperature data from these four stations. The eastward-most station is operated by the NOAA National Data Buoy Center (http://www.ndbc.noaa.gov) and is located offshore of Fenwick Island, DE in the Atlantic Ocean. This station monitors air and water quality.

I. Land-based Stations

A. General Analysis

1. Using the scale in Figure 1—a map of the four land-based monitoring stations and Buoy 44009—and a ruler, measure the distance between each station and Station D: Indian River Inlet. Enter the distance (in miles) into column 4 in Table 1.
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 Indian River Inlet, DE (N, S, E, W, etc.).
4. In column 7 and 8, record the maximum and minimum temperatures for each parameter.
5. In column 9, calculate the 2010-2011 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

1. Air Temperature across an inland-to-coast land transect
   Using Figure 2, a blank graph, graph the temperature range data (Table 1, columns 7 and 8) 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.

II. Water-based Stations

A. General Analysis

1. Similar to the mapping activity completed above using Figure 1 and Table 1, complete the same analysis using Figure 3 and Table 2.

B. Graphing and Graph Analysis

1. Air Temperature across an inland-to-coast water transect.
   Using Figure 4, a blank graph, graph the temperature range data (Table 2, columns 7 and 8) by hand and then discuss trends as a class or in small groups. The completed graph can be seen in Figure 4a.

2. Water Temperature across an inland-to-open water transect
   After viewing Figure 5—a graph of water temperature ranges—infer the temperature ranges for the three mid-river stations, Delaware City, Reedy Point, and Ship John Shoal. Explain your inferences. Once you are finished, view Figure 5a, the completed graph of water temperatures. Were your inferences correct? Hypothesize why these stations have the ranges that they do (hint: be sure to review where these stations are on the map).

   Is there a trend in the water temperature ranges moving from North to South? Explain.

3. Air vs. Water Temperature over time
   Answer the following questions after viewing Figure 6, air and water temperature from the National Ocean Service buoy at Newbold, PA from April 1-7, 2011.
   7. What is the range of the air temperature during this time period? __________
   8. What is the range of the water temperature? __________
   9. Do these data confirm or refute what you would expect? Explain.

C. Real Time Data Analysis: www.deos.org

Visit the DEOS website and click on the DEOS GeoBrowser button. Now click on any of the orange "D" stations.

10. Which station was selected? ____________________
11. What is the air temperature at this buoy? ____________________

Click on "View Last 24 Hours."

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

Click on the Air Temperature chart icon to bring up air temperature from the last 24 hours.

14. What is the temperature range over the last 24 hours? _____________________

Close the graph window and the Observations window; and in the GeoBrowser's dialogue bubble, click on "View Yesterday's Daily Summary."

15. What is the date that these data were recorded? ____________________
16. What is the difference in air temperature between midnight (Hour 0) and 11:00pm (Hour 23)? *Be sure to note whether it was cooler or warmer* ____________________

Go back to the GeoBrowser and click on "View Current Monthly Summary."

17. What trend do you notice in the daily average temperature? (choose one)
    A. Higher in the beginning of the month and lower at the end of the month
    B. Lower in the beginning of the month and higher at the end of the month
    C. Higher at the beginning and the end of the month, but a lower in the middle
    D. Lower at the beginning and the end of the month, but a higher in the middle
    E. Up and down throughout the month (roller-coaster)

Discussion 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 2, Figure 4a, and Figure 5a, what is the trend in air temperature range versus water temperature range?
3. In addition to the applications discussed above, how else can water's high heat capacity be used?
4. Discuss the implications of global climate change as it affects ocean water temperatures. How will ocean warming affect land?
5. Describe advantages and disadvantages of using buoys to record data.
6. Using the DEOS GeoBrowser, click on the yellow station marker at Cambridge, MD. Note the current and recent-past air temperatures. This station is further inland from the ocean, but is located very close to the Chesapeake Bay. Do you expect this station to have a larger or smaller air temperature range than the four DEOS stations examined above. Defend your answer.

Assessment

Performance: Did the student actively participate in the discussion portions of the activity, clearly demonstrating a grasp of the material? Was the student engaged during the activity?
Product: Did the student answer the data analysis questions coherently and provide evidence for their answers?

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.

Additional Resources

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

National Science Standards

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

#1. The Earth has one big ocean with many features.
- **a.** The ocean is the dominant physical feature on our planet Earth
- f. The ocean is an integral part of the water cycle and is connected to all of the earth's water reservoirs.

#3. The ocean is a major influence on weather and climate.
- **a.** The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.
- f. The ocean dominates the Earth's carbon cycle.

#6. The oceans and human are inextricably interconnected.
- **a.** The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and over half of Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

#7. The ocean is largely unexplored.
- **b.** Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- **d.** New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- **e.** Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

Can't Take the Heat

Table 1

1	2	3	4	5	6	7	8	9
Station	**Station Letter on Map (Fig. 1)**	**Parameter**	**Distance from Indian River Inlet, DE (miles)**	**Distance in km** miles*1.609	**Direction, in relation to Indian River Inlet (N, NE, E...)**	**2010-2011 Maximum Temp. (˚F)**	**2010-2011 Minimum Temp. (˚F)**	**2010-2011 Temp. Range (˚F)**
DEOS: Seaford, DE	A	Air Temp				101	5	
DEOS: Georgetown, DE	B	Air Temp				101	7	
DEOS: Shockley, DE	C	Air Temp				104	7	
DEOS: Indian River Inlet, DE	D	Air Temp	*0*		--	100	17	
Buoy #44009: Offshore Delaware	E	Air Temp				83	22	

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Table 2

1	2	3	4	5	6	7	8	9
Station	**Station Letter on Map (Fig. 3)**	**Parameter**	**Distance from the mouth of Delaware Bay (miles)**	**Distance in km** miles*1.609	**Direction, in relation to Delaware Bay mouth (N, NE, E...)**	**2010-2011 Maximum Temp. (˚F)**	**2010-2011 Minimum Temp. (˚F)**	**2010-2011 Temp. Range (˚F)**
Newbold, PA	F	Air Temp				101	11	
Burlington, NJ	G	Air Temp				100	11	
Philadelphia, PA	H	Air Temp				106	13	
Delaware City, DE	I	Air Temp				99	13	
Reedy Point, DE	J	Air Temp				103	14	
Ship John Shoal	K	Air Temp				96	17	
Brandywine Shoal	L	Air Temp				90	16	
Buoy #44009	M	Air Temp				83	22	

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

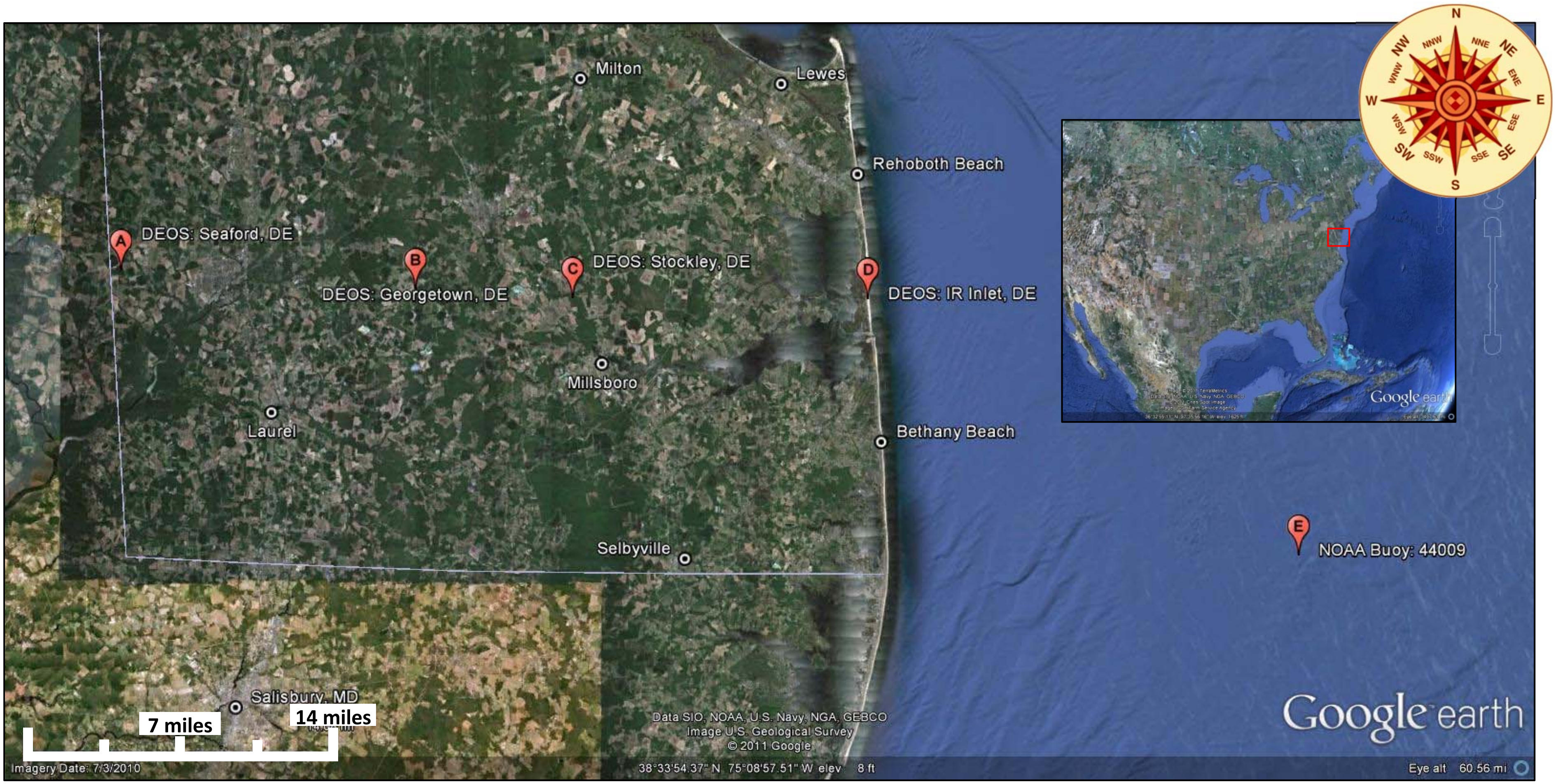
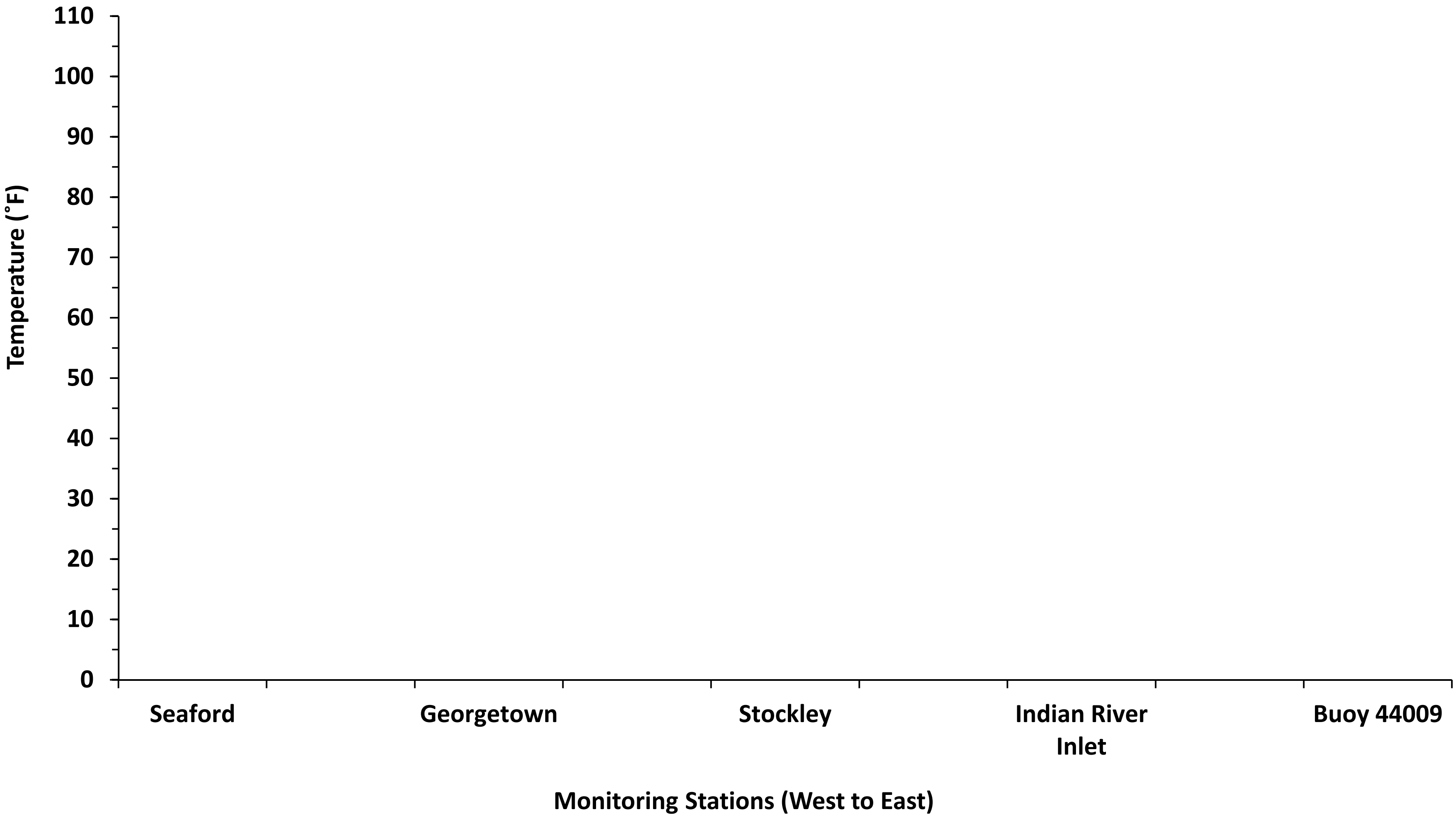


Figure 2. 2010-2011 Average Air Temperature Range Data from Five Monitoring Stations in Southern Delaware, USA



Air temperature from five monitoring stations in Southern Delaware, USA. The Seaford, Georgetown, Shockley, and Indian River stations are Delaware Environmental Observing System data and were measured on land. The Buoy 44009 are NOAA National Data Buoy Center data were measured over water.

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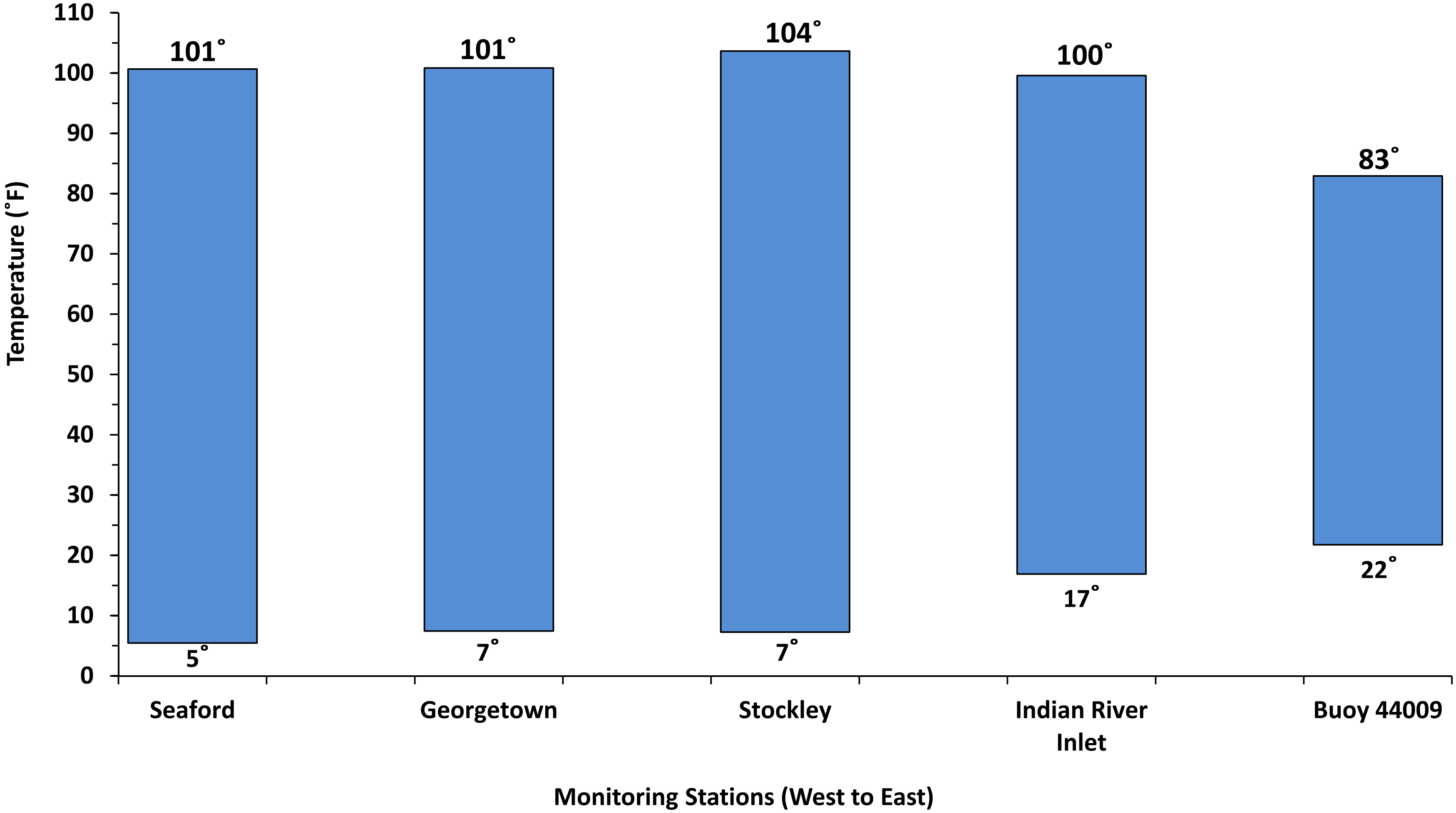
Figure 2a. 2010-2011 Average Air Temperature Range Data from Five Monitoring Stations in Southern Delaware, USA



Air temperature from five monitoring stations in Southern Delaware, USA. The Seaford, Georgetown, Shockley, and Indian River stations are Delaware Environmental Observing System data and were measured on land. The Buoy 44009 are NOAA National Data Buoy Center data were measured over water.

Figure 3. Map of eight water monitoring stations. From *Google Earth*

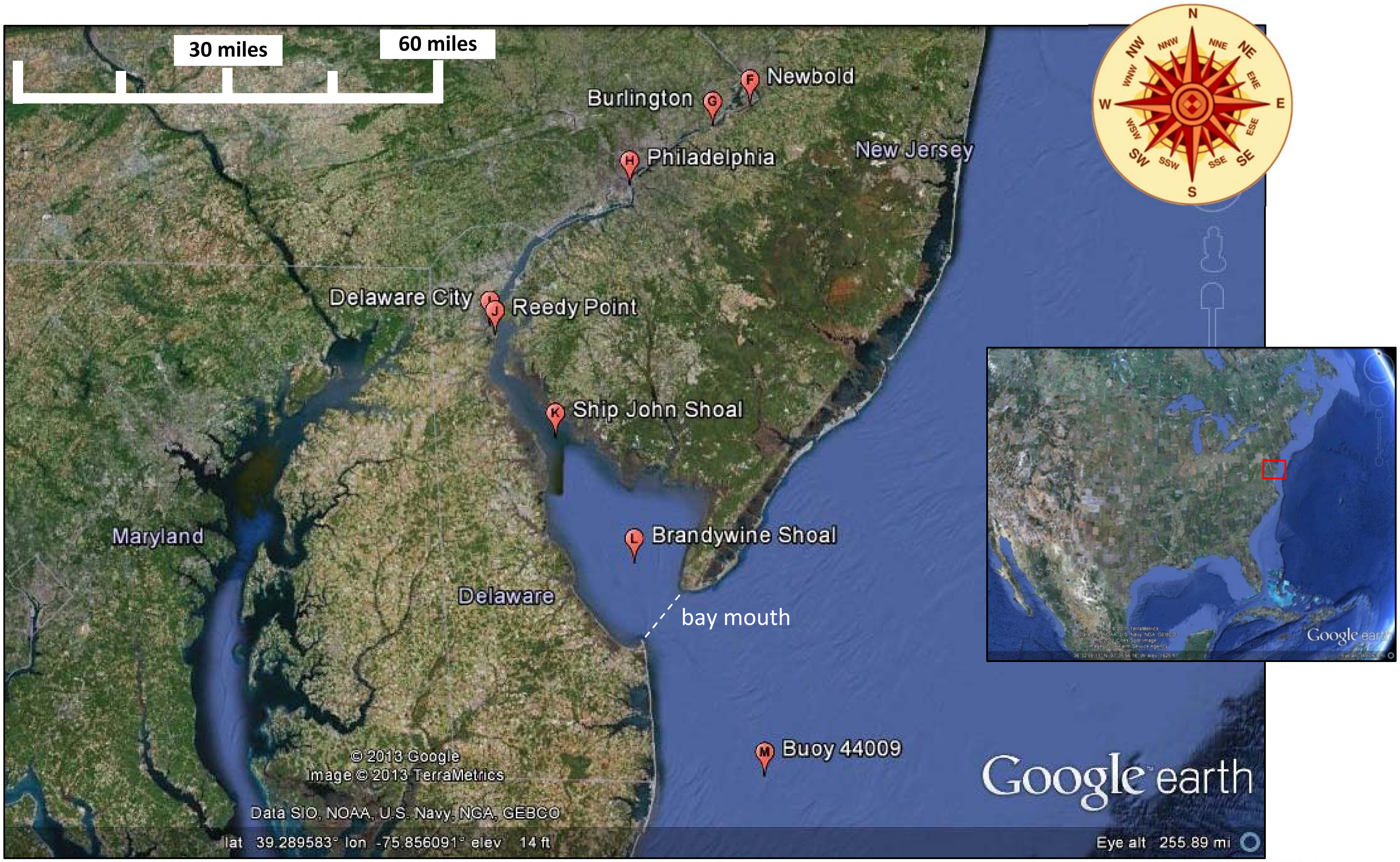


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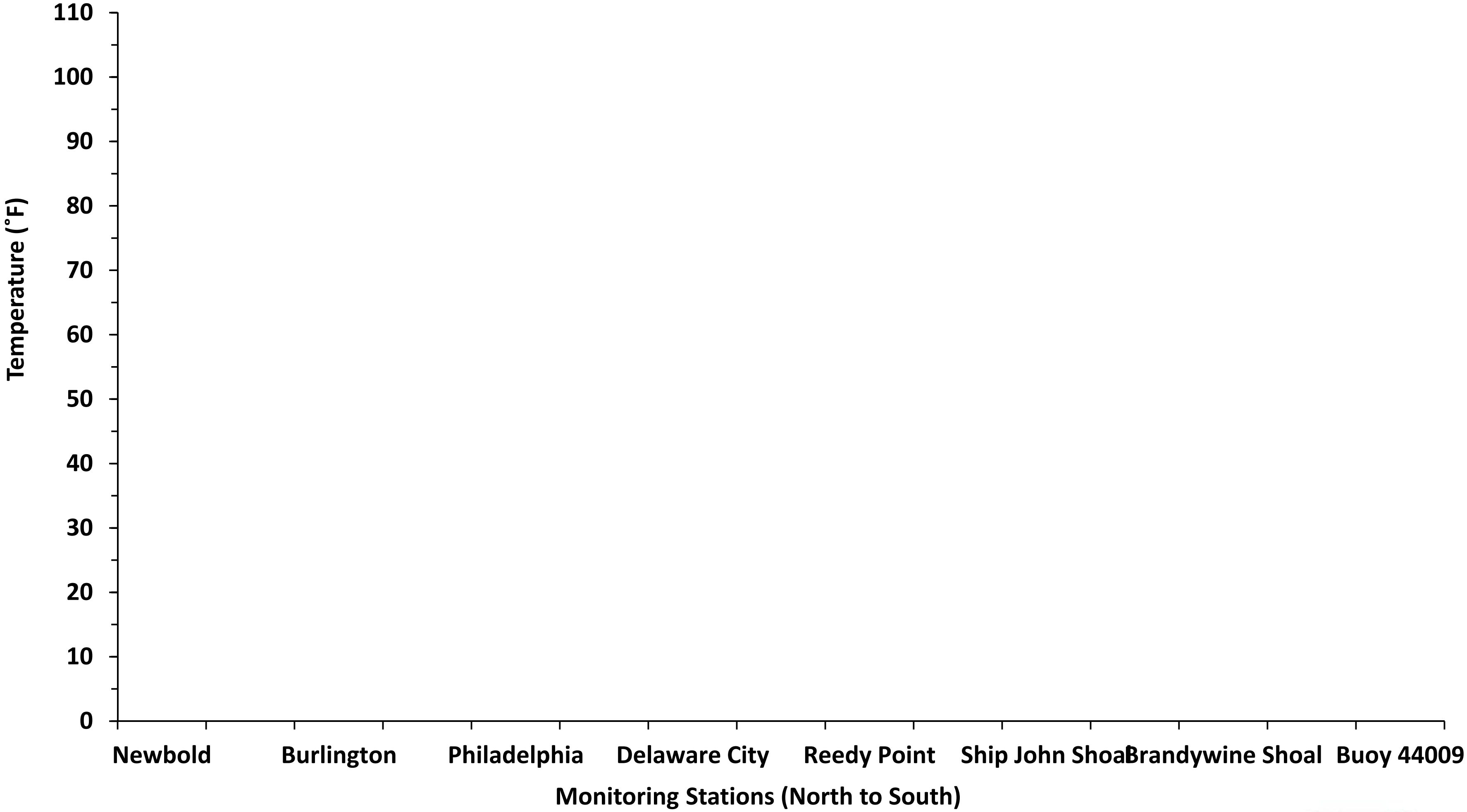
Figure 4. 2010-2011 Average Air Temperature Range Data from Eight Monitoring Stations in Southern Delaware, USA



Air temperature from eight NOAA monitoring stations in Delaware River and Bay, USA. All data were measured over water.

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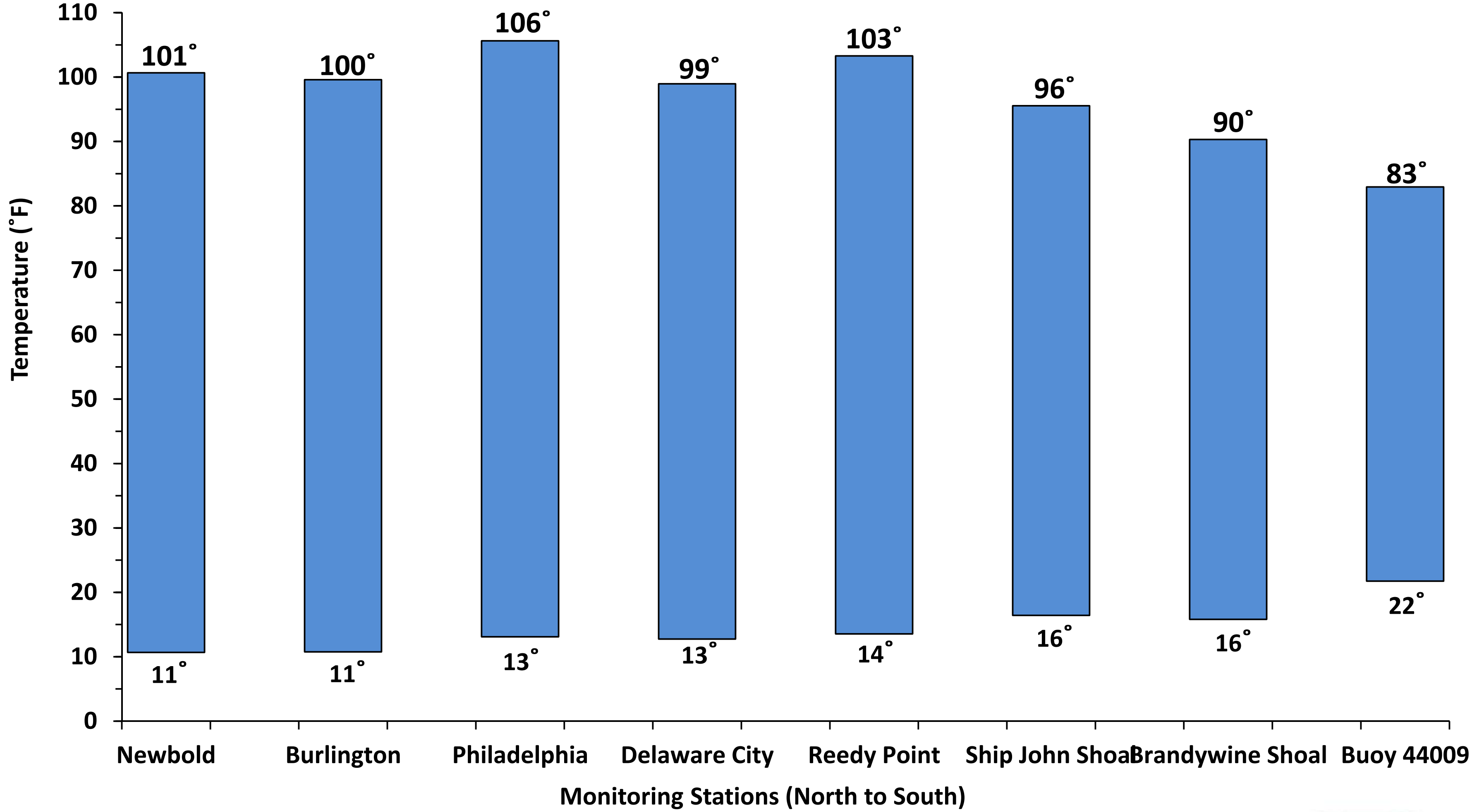
Figure 4a. 2010-2011 Average Air Temperature Range Data from Eight Monitoring Stations in Southern Delaware, USA



Air temperature from eight NOAA monitoring stations in Delaware River and Bay, USA. All data were measured over water.

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Figure 5. 2010-2011 Average Water Temperature Range Data from Eight NOAA Monitoring Stations in Southern Delaware, USA

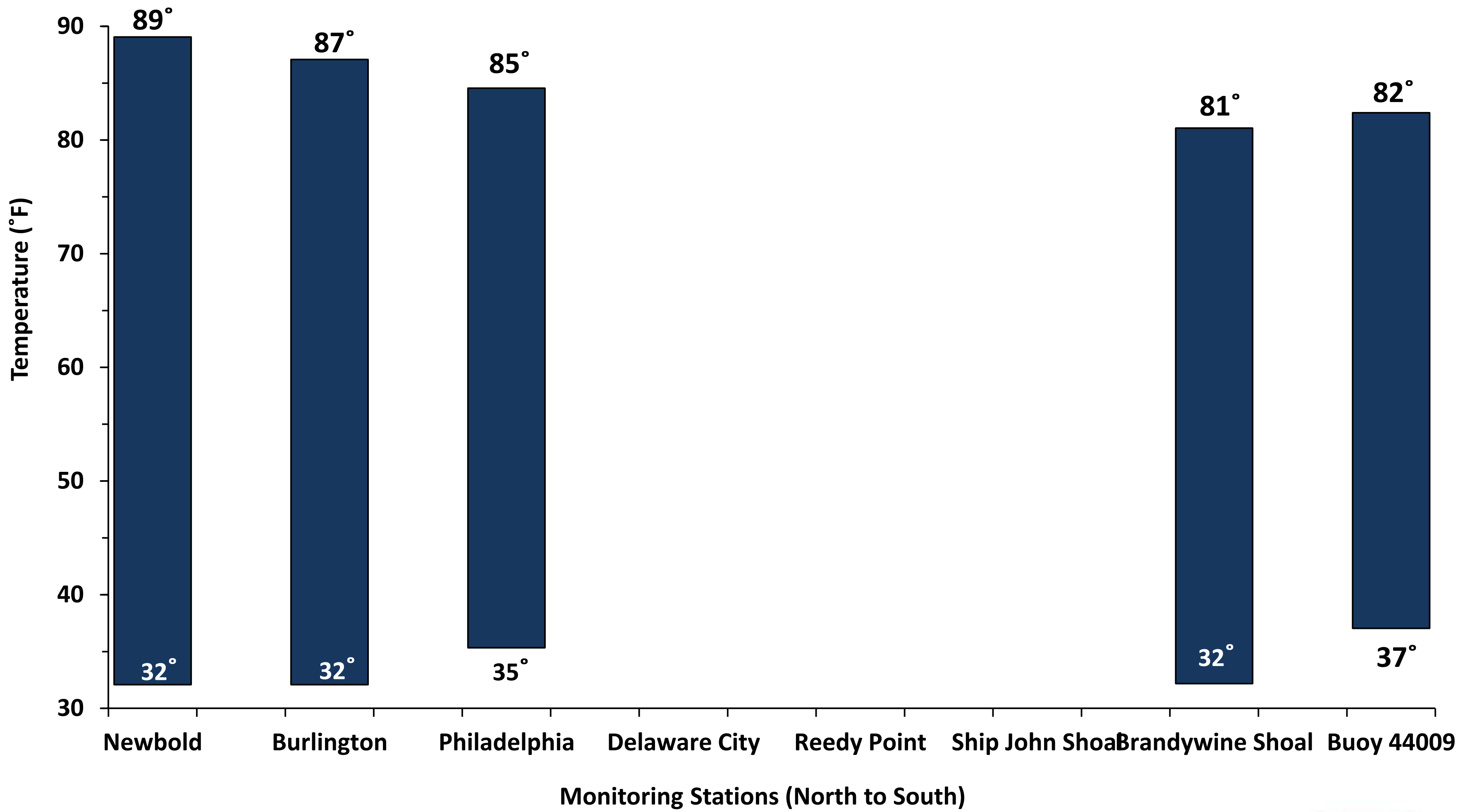

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Figure 5a. 2010-2011 Average Water Temperature Range Data from Eight NOAA Monitoring Stations in Southern Delaware, USA

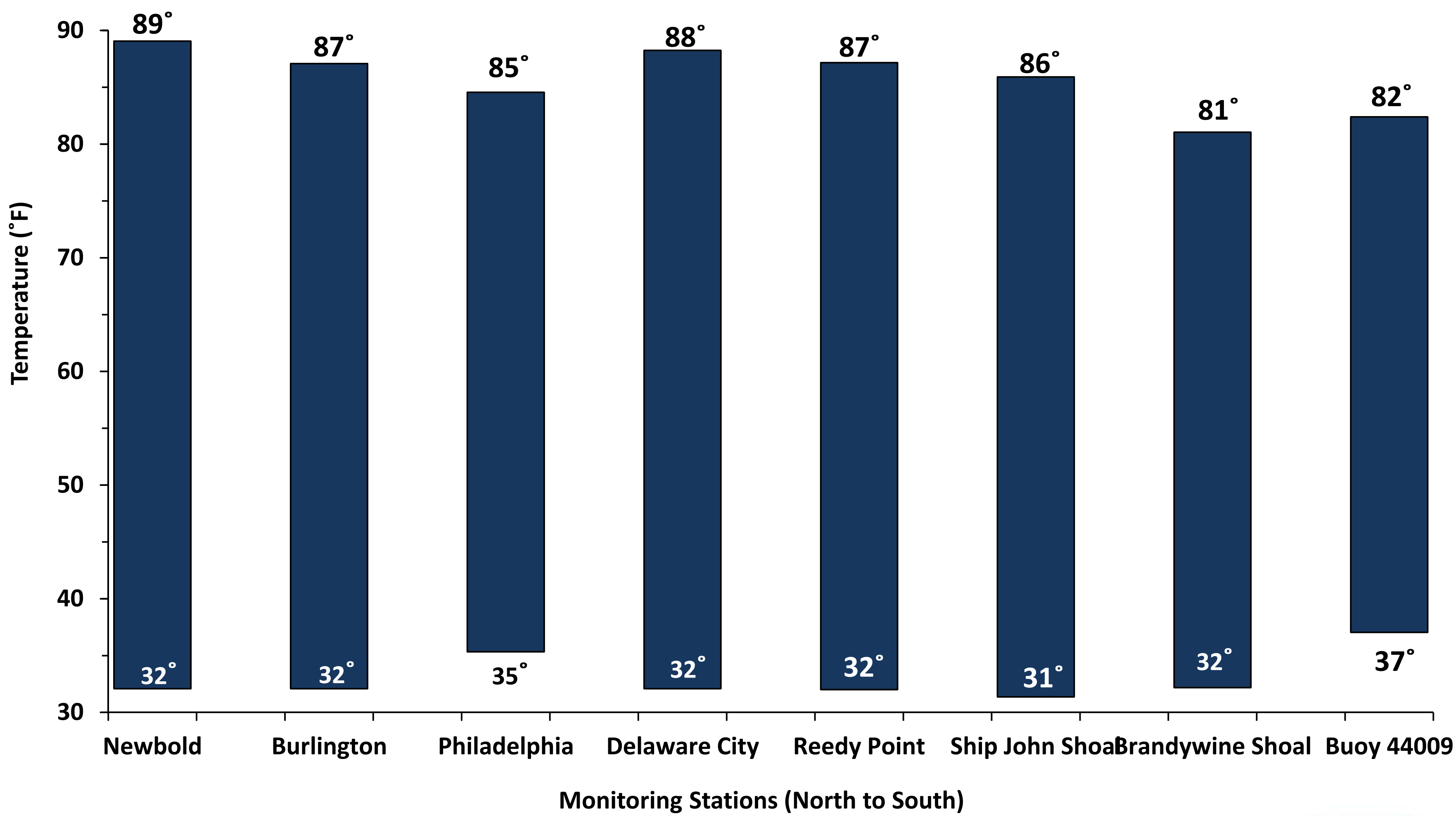

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Figure 6. Air and Water Temperature 1-7 April, 2011 from NOAA Station: Newbold.