Online Supplemental Materials for

Classroom-Scale Experiments in System-Scale Modeling

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Example Student Handouts

List of Documents

Name ____ Date _________ Period _______

Overview of Unit

Unit title: Water and Heat in the Atmosphere

Big idea: The movement of heat and moisture in the atmosphere causes weather to change and influences climate.

Driving questions

How can water evaporate when it's cold?

Where does the water come from that becomes our precipitation?

How can invisible water vapor be so important in the atmosphere and making storms?

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Does water evaporate when it's cold?

Making Observations and Asking Questions

Experiment you need to do at home:

1. Put 2 tablespoons of water into a small cup or glass. Mark the water level with an inked line or a piece of tape.
2. Place container upright in your family's freezer so that the water is LEVEL.
3. Let it be in the freezer for 2-4 weeks.
4. After each week, compare the ice level and original water level line. Are they the same? Draw a before and an after-1-week picture. Describe what you see.

5. After two weeks, compare the ice level and original water level line. Are they the same? Draw a before and an after-1-week picture. Describe what you see.

6. How long did it take for about 1 half of the water to evaporate? ________

7. What were some questions you wondered about as you made your observations?

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Video of Water Vapor Moving Through the Atmosphere
Making Observations and Asking Questions

Introduction to the movement of water in the atmosphere:

1. The video that you will be watching spans an entire year. The images show both the movement of water vapor and precipitation. Remember we can't see water vapor, so the folks who made this simulation put in false colors for the water vapor. So the white represents water vapor, not clouds, and the orange represents precipitation.

2. Find the video here: https://tinyurl.com/ydx64hpm, (or at his longer URL. https://prairiepublic.pbslearningmedia.org/resource/ess05.sci.ess.watcyc.cloudprecip/water-vapor-circulation-on-earth/#)

3. As you watch, what patterns do you see and what questions pop into your mind? The patterns might be general ones that are present the whole year. Or, they might be patterns that change over time. Your questions can be about the diagram itself, or about the natural processes you are seeing.

   a. ____

   ____

   b. ____

   ____

   c. ____

   ____

   d. ____

   ____

   e. ____

   ____

   f. ____

   ____

   g. ____

   ____

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For the teacher, (could be rewritten for various reading levels for student use)

The following essay can be found at *PBS LearningMedia* under the Support Materials link; it is titled Background Essay.
https://prairiepublic.pbslearningmedia.org/resource/ess05.sci.ess.watcyc.cloudprecip/water-vapor-circulation-on-earth/# Accessed March 30, 2018.

Water vapor -- the gaseous phase of water -- plays an important role in the water cycle and in regulating Earth's energy distribution. As oceans evaporate and plants transpire, liquid water from Earth's surface enters into the atmosphere as water vapor. When air cools, clouds form through water vapor condensation (forming liquid drops) or deposition (forming ice crystals); and clouds produce precipitation that returns liquid water back to Earth's surface.

Water vapor is also a greenhouse gas, absorbing infrared radiation from the Earth and trapping heat in the atmosphere. Without the greenhouse effect, Earth would be a much colder and unlivable world. In addition, the movement of water vapor through the atmosphere aids in the distribution of heat around the planet.

Water vapor is a critical component of Earth's atmosphere and, though it is invisible, it can be studied through the use of imaging that is sensitive to infrared wavelengths of about 6.5 to 7.4 micrometers in the electromagnetic spectrum. By assigning false colors to represent the infrared data, researchers are able to "see" water vapor in the atmosphere. In this simulation, water vapor is shown as white and precipitation is shown as orange. (Note: The white areas at the top and bottom of the simulation do not designate water vapor but instead represent the icy landscapes of the Arctic and Antarctic.)

When looking at water vapor in Earth's atmosphere, it is interesting to note its distribution. Because warmer air requires more water vapor in order to become saturated (the point at which water vapor condenses), the greatest concentration of water vapor is in the warmest climates. Thus, the equatorial region, which receives the most solar radiation, contains the most water vapor. The effects of Earth's tilt, solar heating, and the rotation of Earth are responsible for the global wind patterns.

The intense low-pressure areas created in the tropics are responsible for the formation of tropical cyclones called hurricanes -- damaging storms with very strong rotating winds. Tropical cyclones are fueled by the energy from warm tropical waters. When liquid water changes to water vapor, heat energy is stored in the atmosphere. This latent heat is released when water vapor condenses into clouds and precipitation. Thus, cyclones are like heat transport machines, taking heat from the warm ocean waters and transferring it to the atmosphere. The circulation of water vapor in the atmosphere, along with ocean circulatory patterns, is critical to the distribution of heat around the world.

Earth's rotation influences wind direction. For example, the winds of a tropical cyclone in the northern hemisphere spin in a counterclockwise direction while a storm in the southern hemisphere spins clockwise. In the simulation, note the swirling patterns of water vapor near Central America during July and August and the tropical cyclone east of Madagascar in early October.

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Latent Heat
Getting Ready for Lab

Today you will be getting familiar with the experimental set-up, remembering what the three states of matter are and what happens when water changes state, and you'll be imagining what might happen as we run our experiment.

1. Tape the drawing of the lab set-up into your journal. Label the following parts of the experimental setup:
    a. tubing
    b. beaker
    c. stopper
    d. flask
    e. thermometer
    f. hot plate

2. We will be heating the water in the flask so that it boils. Think about what you have already observed when water boils in a pot on your kitchen stove, like when you make mac 'n cheese.

    a. What do you suppose the bubbles in the boiling water are made of? Why do you think this?

    b. Water is made of molecules that are free to move past each other. What do you imagine happens to the molecules if you heat them up to make water boil?

    c. In the space below, devise a way to represent/draw your thinking that you described above.

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SPACE FOR NOTES ON STATES OF MATTER AND WHAT HAPPENS TO ATOMS OR MOLECULES DURING THOSE PHASE CHANGES.

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3. On the table below, describe what you think will happen when we heat the water in the flask. Think of a series of steps that might occur. Then explain what MIGHT cause each step to happen.

I think	______________________________	**will happen because**	______________________________
I think		will happen because	
I think		will happen because	
I think		will happen because	
I think		will happen because	
I think		will happen because	

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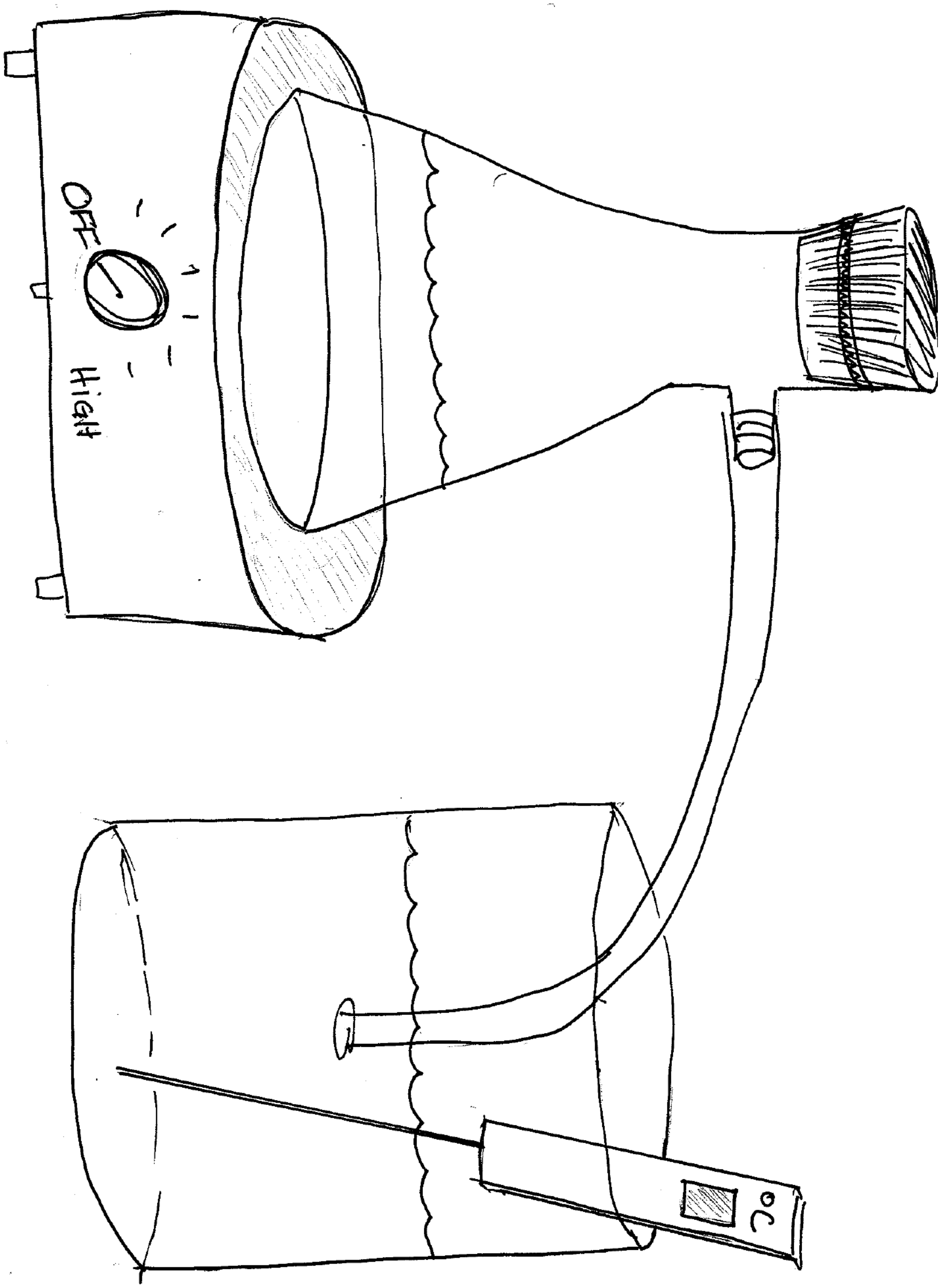
Lab Set Up—Label the different parts of lab equipment



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Lab Safety, Lab Procedure
Trying Out Our Experiment

Procedure

1. The hot plates are on and they are hot, so be careful.
2. Pour 400 ml of room temperature water into your beaker. The room temperature water is in the plastic jug on your lab station.
3. Put the tubing into the beaker.
4. Move the beaker so that the tubing extends halfway down through the 400 ml of water.
5. Put the digital thermometer into the beaker.
6. Situate the beaker and tubing so the tubing is not bumping the side of the beaker. You may have to prop it with the thermometer.
7. Place the stoppered flask with water on the hot plate and position the beaker so the tube is still about halfway into the 400 ml of water.
8. Turn the thermometer on.
9. Watch the flask and the beaker and the tubing as the water in the flask begins to heat up. What do you notice? Watch the thermometer too. Write these observations in your lab journal.
10. Let the water in the flask boil for _____ minutes, as directed by your teacher.
11. Continue to make observations and temperature measurements.
12. For clean up - a) remove the tubing from the beaker; b) dump the water from the beaker into the sink; c) your teacher will remove the hot flask from the hot plate.

Safety Contract

I have been told and I understand that:

1. I must wear my safety goggles at all times. Wearing my goggles means that I have them over my eyes and the elastic strap around my head and my hands are free.
2. I should not touch or bump the flask on the hot plate. If a situation arises that the hot flask needs to be moved, I'll call for <my teacher>. In the event I have to take action, I know how to use the silicone gripper pad provided for each lab station to handle the hot flask.
3. I will stay with my lab group.
4. I will not engage in any goofing around and fast movements.
5. Dangerous or unsafe behavior will not be tolerated, and <my teacher> may ask me to leave the classroom to insure the safety of my classmates.

My signature indicates that I have read and understand the above safety guidelines.

Signature: ____ Date ___________________

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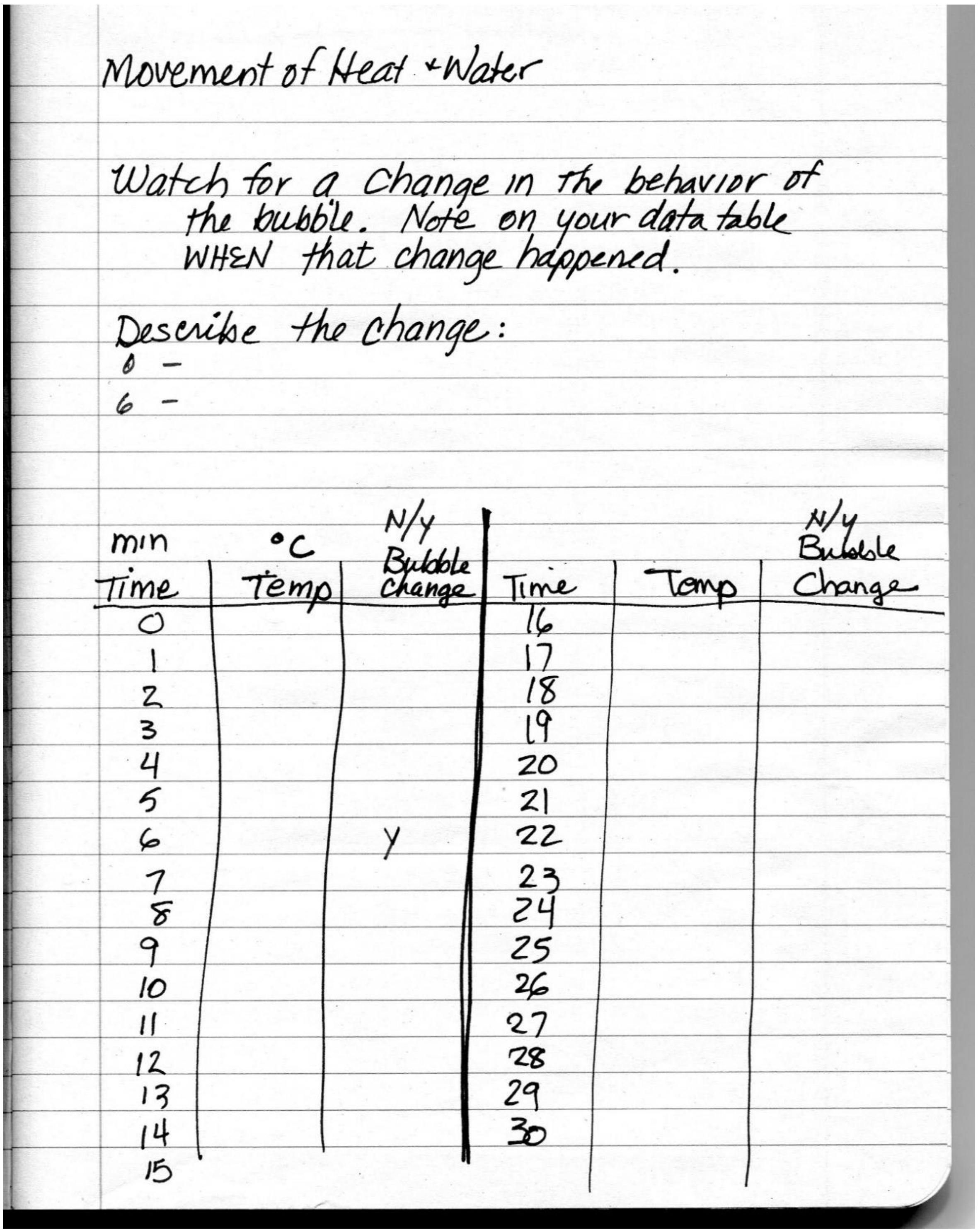
Data Recording

Example template for student lab journal entries

(This template is for recording temperature only—leaving the increase in water level to be discovered by students. Students kept their own lab notebooks even though they worked in groups of four.)



Movement of Heat + Water

Watch for a change in the behavior of the bubble. Note on your data table WHEN that change happened.

Describe the change:

0 –

6 –

min Time	°C Temp	N/Y Bubble change	Time	Temp	N/Y Bubble Change
0			16		
1			17		
2			18		
3			19		
4			20		
5			21		
6		Y	22		
7			23		
8			24		
9			25		
10			26		
11			27		
12			28		
13			29		
14			30		
15					

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Analyzing and Interpreting Our Data

Movement of Heat and Water in the Flask/Tube/Beaker Experiment

Analyze just means to look for patterns and connections in the data and observations. Interpret means to come up with possible ways to explain what is going on, based on empirical evidence and reasoning.

1. Graph your data (line graph) and at least one other group's data on the graph paper provided.

2. Patterns and connections
    a. Label the "slow T rise" part of your graph.
    b. Label the "fast T rise" part of your graph.
    c. Look at your lab journal for our observations about this change. Mark where you noticed the distinctive change in bubble behavior with a *. If you aren't sure at what temperature the bubble behavior changed, put a question mark here _____.
    d. At the highest T point on your line graph, write "The water level in the beaker increased to about ___ ml." If you didn't observe this, put a question mark here _____.

3. What are the similarities and differences between your graphed data and the other data you graphed?

4. In what ways might the change in bubble behavior be related to the abrupt change in slope of your line graph?

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Observations	Description of pattern of T change	Questions to Consider and Answer
The bubbles came out of the tube slowly. They were big and they rose to the top.	Rate of Temp rise = _____℃ in _____ minutes	Would you expect the bubbles to be made of air or water vapor? __________________ Explain your reasoning. Use your science ideas about the behavior of warm air.
The bubbles came out of the tube quickly, they were small and they didn't rise to the top.	Rate of Temp rise = _____℃ in _____ minutes	Would you expect the bubbles to be made of air or water vapor? __________________ Explain your reasoning. Use your science ideas about changes of state for water.

What may have caused the slow rise in T in the water of the beaker in the first part of your experiment? Explain why you think this.

What may have caused the fast rise in T in the water of the beaker in the second part? Explain why you think this.

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Where does the water come from that produces our precipitation?

Where do we get the energy to build towering thunderstorms?

1. Label the drawing of your experiment with the following words. Where matter and energy are moving draw in arrows to indicate the direction of movement and label the arrows with what is moving?

flask	beaker	tubing	hotplate
Water is evaporating	Water vapor is condensing	Heat energy added to the system	Hidden heat energy is given off
Hidden heat energy transported (arrow)	Water vapor transported (arrow)	Air transported (arrow)	

2. On the water cycle diagram provided: label the same parts and processes listed above.

3. Which part of the water cycle is absent from our desk-top water-cycle system? Why did it have to be absent?

4. How do we know from our experiment that heat is hidden in the water vapor that originated in the flask?

Claim	Evidence	Reasoning
The steep rise in temperature of water in our beaker was caused by the addition of heat hidden in the water vapor. That heat was released into the beaker when the water vapor condensed.		

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