VORTEX: TEACHER GUIDE

Subject: Earth & physical sciences
Grade Level: Middle School
Last Updated: May 25, 2006

Case Summary

Strange greenish light, a change in the wind, and sudden hail give Margarite a clue to head inside for cover. She witnesses lightning strike her neighbor's tree and a swirl of air pick up a car and other things from the yard. In the aftermath, Margarite and her neighbors are amazed by where they find things, and they plan future safety procedures.

Keywords: vortex, convection, updraft, supercell, safety skills, air mass

Credits

This case was written by Molly Embree (PhD student, Psychology, Emory University, Atlanta, GA) with input from Amy Webb (PhD student, School of Public Health, Emory University, Atlanta, GA), Kevin McMahon and Carly Price (teachers, Renfroe Middle School, Decatur, GA) fellows of the Emory University PRISM program (http://www.prism.emory.edu). Author may be contacted at membree@emory.edu.

Learning Objectives

1. Diagram the stages of tornado formation, detailing the changes of state that occur in the supercell and how forces act to create a vortex of air. (final project)
2. Create a safety plan for your own home in the event of a severe thunderstorm or tornado.
3. Quantify the distances (in m & km) of objects thrown from a tornado.
4. Estimate the relative differences in mass of the objects
5. Calculate the differences in distance thrown among the objects
6. Hypothesize about why a skateboard, bike, and car, picked up by the tornado from the same spot, end up at different distances away.
7. After research, write a paragraph explaining the forces involved in tornadoes picking up objects, and how those objects are expelled from the vortex.
8. Conduct research using textbooks, dictionaries, online encyclopedias and web sources to investigate:
    - What is wind? and what causes wind?
    - How does rain change to hail?
    - What is a hurricane?
    - What is a tornado?
    - What is a thunderstorm?
    - supercell
    - humid (air)
    - updraft, convection current

 This material is based upon work supported by the GK-12 program of the National Science Foundation, under Award #DGE0231900. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. *CASES Online* is brought to you by the Emory College Center for Science Education, Emory University, Atlanta, GA. This document and other resources are available from the *CASES Online* Web site, http://www.cse.emory.edu/cases

- vortex
- tornado warning, tornado watch
- How does an air mass take on or lose humidity and/or heat?
- safety precautions for tornado

9. Prepare research reports on the above learning issues giving complete definitions, citing sources of information, and explaining concepts in your own words.

Georgia Performance Standards

SCS1. Students will explore the importance of curiosity, honesty, openness, and skepticism in science. (NSES Content Standard A)

SCS3. Students will use computation and estimation skills necessary for analyzing data and following scientific explanations. (NSES Content Standard A)

b. Use metric input units of scientific calculations to determine the proper unit for expressing the answer.

SCS4. Students will use instruments for observing, measuring, and manipulating equipment and materials in scientific activities. (NSES Content Standard A)

c. Make direct measurements of length, volume, weight, elapsed time, rates, and temperature, and choose appropriate units forward porting various quantities.

SCS6. Students will communicate scientific ideas and activities clearly. (NSES Content Standard A)

SCS10. Students will enhance reading and all curriculum areas.

S6E4. Students will understand how the distribution of land and oceans affects climate and weather. (NSES Content Standard D) (NSES Content Standard E)

b. Relate unequal heating of land and water surfaces to form large global wind systems and weather events such as tornadoes and thunderstorms.

S8P1. Students will examine the scientific view of the nature of matter. (NSES Content Standard B)

c. Describe the movement of particles in solids, liquids, gases, and plasma states.

e. Distinguish between changes in matter as physical or chemical.

S8P2. Students will be familiar with the forms and transformations of energy. (NSES Content Standard B)

a. Explain energy transformation in terms of the Law of Conservation of Energy.

d. Describe how he can be transferred through matter by the collisions of atoms (conduction) or through space (radiation). In a liquid or gas, currents will facilitate the transfer of heat (convection).

S8P3. Students will investigate relationships between force, mass, and the motion of objects.

b. Demonstrate the effect of balance and unbalanced forces on an object in terms of gravity, inertia, and friction. (NSES Content Standard B)

S8P5. Students will recognize characteristics of gravity, electricity, and magnetism as major kinds of forces acting in nature. (NSES Content Standard B)

a. Recognize that every object exerts gravitational force on every other object and that the force exerted depends on how much mass the objects have and how far apart they are.

Assessment

- Boxcharts (i.e., piece of paper divided into 4 quadrants: data (or facts), questions, hypotheses, learning issues (group assessment)
- **Learning Issue Reports** (*see Student Materials document*) with proper citation (individual assessment)
- Paragraph explaining forces in tornadoes & how objects are picked up & expelled (individual assessment)
- Tornado Home Safety Plan (individual assessment)
- Diagram of tornado formation (individual assessment)

Implementation Strategy

This is a Problem-Based Learning (PBL) case, designed for use in standard public school classrooms of about 30 students. Subgroups of about 4-5 students were ideal for small group (team) work, such as reading the scenes, breaking down the data, questions, hypotheses, and learning issues, and assuming research responsibilities. Small groups were facilitated by at least one adult (teacher, parent, graduate or undergraduate student). Students researched learning issues individually and in pairs (duplicate assignment of learning issues so that a single issue is researched by more than one person/pair) and reported findings to the small group. Learning issues were assigned using the **Summary of Learning Issues** sheet (*see Student Materials document*). Small groups reconvened with the whole class and their teacher frequently to review separate findings and summarize data and new directions.

Implementation Schedule (see Facilitator Guide below for more detail)

Day 1 (facilitated small groups)	
Brief announcement about case	5 min
Move into small groups; student-facilitator introductions	5 min
Read Scene 1 (first silently, then aloud, as a rule)	5 min
Brainstorm Data/Questions/Hypotheses/Learning Issues (DQHL)	10 min
Read Scene 2 (first silently, then aloud) + DQHL	10 min
Assign Learning Issues (individual and duplicate responsibility)	5 min
Self and small-group evaluations	10 min
Day 2 (small groups)	
Individuals & pairs research with laptops, & discuss with group	50 min
Day 3 (small groups)	
Individuals & pairs research with laptops, & discuss with group	40 min
Whole class reconvenes, discusses group findings	10 min
Day 4 (facilitated small groups)	
Review initial hypotheses; brief facilitator on research findings	25 min
Read Final scene & Epilogue	10 min
Review and discuss case objectives & group's performance	10 min
Self and group evaluations	5 min

Day 5 (large group→small groups)	
Class demonstrations (vortex in a bottle, mist vortex)	15 min
Final Project worktime (remainder for homework)	35 min

Case Notes

This Problem-Based Learning (PBL) case, entitled *Vortex*, was designed to be the first in a series of four cases addressing physical science concepts (*see Resources below for other case titles*) in sixth-grade classes at Renfroe Middle School, in Decatur, GA. In brief, the case uses a character's experience of a tornado to address concepts such as (but not limited to) force and movement of mass, circular vs. linear particle movement, convection, and changes of state.

Two points of background influenced the design of this case:
1) In the previous year, Renfroe Middle School began a 3-year transition from a more traditional science curriculum to one anchored in the PBL method.
2) The state-mandated science curricula for sixth and eighth grades are scheduled to swap after this academic year, such that sixth graders will study Earth science while eighth graders will study physical science.

Goals

At Renfroe Middle School, the PRISM team for sixth grade (two science teachers and two Emory graduate students) had several goals for this first case of the year. First, we wanted to introduce students to the PBL method, and this case would be the first exposure to PBL for almost all of them. Second, we planned to gauge from the results of this case how complex to make subsequent cases throughout the year. Third, and very challenging, we wanted to address physical science concepts within an Earth science context. This way, when the sixth-grade science curriculum shifts to Earth science in the next year, the cases could be modified only slightly to focus on the appropriate Earth science concepts. Additionally, we wanted to invite parents to participate as PBL facilitators for the students' small group teamwork.

Results

As we expected, students varied widely in their hypothesis-generating and research skills. The fact that PBL cases generally introduce many more concepts and threads of investigation than can possibly be addressed allows high achieving and highly motivated students an opportunity to perform, either for themselves or for the team. At the same time, PBL requires each team member to contribute in different roles and to be accountable for different information in order for the team to succeed. Thus, less motivated or lower achieving students cannot ride the coattails of their team members, and in fact, often become motivated to participate when given a role that plays to their particular strength (e.g. reading aloud, organizing information, checking facts, managing group dynamics, designing graphics, etc.). Even if students do not become motivated by the particular topic of investigation, they often become motivated by peer pressure; they are accountable to their team for research on one or two manageable questions.

The students' performance overall on this case indicated to us the need for more structured supports to their research. They did well at generating hypotheses, but many had difficulty defining *learning issues*, or the topics they would need to research in order to solve a piece of the case. We decided that one of the broad goals of our PBL cases for the sixth-grade would be to start them off with some research questions and guides for investigation, and then gradually wean them off the structure, case-by-case, until they are proficient at pinpointing their own learning issues. They should enter the seventh grade fully familiar with the PBL process and able to generate hypotheses and follow-up with pertinent research questions.

Our hybrid physical/Earth science case was challenging to steer toward the physical science objectives, mostly because these concepts are more abstract than the Earth science concepts more familiar to the students. (This is, of course, the reason that the physical science curriculum is being moved to the eighth grade, where the students are developmentally more mature and have more math and science background). But the students enjoyed the drama of the tornado in the story, and this context made the concepts of air mass, particle movement, forces of motion, and changes of state more meaningful to them.

Our open invitation for parents to participate as PBL facilitators for the student teams was quite successful. Ten parents participated, some of them for all four classes in one of the two classrooms running the case. The parents were a diverse group, including stay-at-home moms, a racecar driver, a government official, and medical and education professionals. Most were not professionals in the sciences. We emphasized to the parents that the facilitator's role is not to teach content, to confirm correct information, or to dispute incorrect information; rather, it is to stimulate thinking, challenge any and all "answers," and ask the team whether its information is sufficient and reliable. Parents appreciated the opportunity to participate in the classroom, and most of them commented that the PBL case engaged the students and themselves in potentially dry subject matter. In fact, parent facilitators increased from 10 to 16 (not including several more volunteers who had scheduling conflicts) for the second case we ran, and participation continues to increase. We hope to build a strong corps of parent facilitators, who will join our PBL program as their child enters the sixth-grade and continue through the eighth grade.

Case Synopsis

Scene 1
Margarite has a crush on Marc, and starts to take him a note after school. Walking over, she observes a strange greenish light, feels the still air turn to strong wind, and sees rain turn to hail. She runs home and turns on the weather report.

Scene 2
Margarite's TV flickers in and out; she gets some clues about the severe weather in her area. She hears an enormous explosion with a flash of light. She sees a tree in Marc's yard catch fire while hail continues to fall. She observes a skateboard, bicycle, and car in Marc's yard

get sucked up into a swirl of air. Margarite runs to the bathroom, grabs some safety equipment, and gets in the bathtub.

[End of Session One. Students research learning issues next two days.]

Scene 3
Margarite, Marc, and their families are uninjured and reunited. They examine and discuss property damage. Marc hypothesizes that the lightning which struck his tree caused an updraft, which spawned the tornado, which, in turn, picked up and threw the skateboard, bicycle, and car. Marc and Margarite find the skateboard, bike, and car at different distances from Marc's house. Margarite remembers the note she was carrying to Marc's house; she hopes that it won't be found and cause her embarrassment.

Epilogue
Marc and Margarite help their families and neighbors repair property damage and reestablish tornado safety kits. Marc may be developing a crush on Margarite, and he decides to give her skate boarding lessons. Meanwhile, in Lawrenceville, a Mr. Marc Johnson finds Margarite's note in his driveway fence one morning on his way to work and reads it . . .

[End of Session Two. End of facilitated portion of case.]

Facilitator Guide:

Day 1 Facilitation Strategy

[15 min, Scene 1 & boxchart]
Allow students to read Scene 1 silently.
Suggest that they
- circle words they don't know (these become learning issues)
- underline facts/data
- jot down hypotheses & learning issues if they finish reading before others

Read Scene 1 aloud. Encourage each student to read a part of the scene.

Students organize information in boxcharts (facts/data, hypotheses, and learning issues). Accept a wide range of hypotheses from them.
They may need help identifying learning issues until they get the hang of it:
"It sounds like we need to find out exactly what a hurricane is and what a tornado is in order to evaluate our hypotheses. So let's make those into learning issues . . . "

The tricky part is getting them to apply the physical science concepts they have learned (mass, forces, particle movement, energy transfer, changes of state) to the earth science context of the story.

[10 min for Scene 2 & boxchart]
Read Scene 2 silently, using the same techniques above, then read aloud as a group.
Do boxchart procedure again, adding to their learning issues and hypotheses. You can discuss whether new facts reinforce or weaken any of their hypotheses.

[10 min for Learning Issue (LI) distribution]
Hand out a **Learning Issue Summary Sheet** and a **Learning Issue Report** *(see Student Materials document)* sheet to each student. Write students' initials next to their LI's on the master copy. Emphasize the importance of each person finding correct information to bring back to the group.

[10 min for self & group evaluations]
Allow at least 5 minutes at the end for self and group evaluations. Provide each student with a **Self & Group Evaluation** sheet *(see Student Materials document)*. Ask them to reflect on their own strengths and weaknesses within the group. Then have them consider their group members' strengths (or problems that the group should address). Discuss what they did well and what they can improve for next time.

Reflection for self & peer evaluation are important parts of problem-based learning. This is a chance for them to realize their own strengths and how others (especially *peers*) perceive their strengths. It is also an opportunity to pinpoint what they can improve. Of course, the focus should be on behavior, both academic and social, and personal attacks cannot be allowed. We want them to learn how to give and receive constructive feedback.

"Vortex" Facilitator Guide: Scene 1

Margarite couldn't wait to see Marc after school. He was so cute! She wanted to give him a note she had written, but she was nervous. From her front porch, she could see his skateboard and BMX bike in the yard next to his mom's yellow VW bug. She took a deep breath and started over to his house.

Walking across the street, Margarite looked at the sky. The afternoon light seemed to be a strange greenish color. She did not hear birds singing or feel any breeze.

Before she got far, she felt a change in the air. A powerful wind came rushing past, and big, fat raindrops plopped down all around her. Margarite turned back to her house to get an umbrella.

"Ow!" she said, as something hard hit her in the head and arm. The rain had turned to hail; marble-sized white hail was dropping all around and bouncing off the ground at her feet. She ran the last few steps up to the porch and into her house.

"Oh, this is not good," she thought to herself. By now, Margarite had a hypothesis about the strange weather outside.

She turned on the TV, and looked for her local news channel.

FACTS	HYPOTHESES
• Still air, followed by strong wind • Big raindrops, followed by hail • Greenish light	• Margarite's hypothesis is that: - Aliens are landing - A hurricane is coming - A severe thunderstorm is coming - A tornado is coming • Margarite has a crush on Marc • [students' own hypotheses]
INTERVIEW QUESTIONS • What does she (Margarite) think is happening? • What will she do to prepare? • Has she experienced this kind of weather before?	**LEARNING ISSUES** **1. vortex (title)** **2. What is *wind*? (in physical sci terms)** **3. what causes wind?** **4. how does rain change to hail?** **5. describe a hurricane** **6. describe a tornado** **7. describe a thunderstorm**

Discussion Questions

*(Note: the weather topics provide the context, but keep the focus on the **physical science** issues of temp change, change of state, forces, particle movement, etc)*

How does rain change to hail? What happens to the water droplets to make them freeze? Where does this happen? How are air currents involved in this? Is exchange of energy involved?

What was happening when Margarite felt the air go from very still to a powerful wind? Is pressure involved in that? How does the temperature of an air mass affect its movement?

"Vortex" Facilitator Guide: Scene 2

Margarite clicked on the TV and Channel 5 WAGA's Ken Cook stood in front of a weather map showing metro Atlanta. The TV picture and sound crackled in and out:

" – as you can see, Dekalb and Fulton counties lie directly in the path of this supercell. Warm, humid air ---- [static]---- slamming into the cold, dry air coming east over the Rockies. Updrafts of the warm air can cause the two air masses to start spinning in a vortex. ------ [static] -------

"Come on, TV!" Margarite whacked the TV a few times to try to get a better picture. It didn't help.

"--- Lightning increases the risk of tornadoes, because of the updrafts, or convection currents, that they cause ----[static]---- -. . . tornado warning in effect for Dekalb County so please take precautions for your safety . . ."

sssssBAM!!!

Light filled the air as she heard a crackling explosion. She looked out the front window and saw a tree in Marc's yard flaming in the midst of the hail falling from the sky.

In the instant before she turned, Margarite saw her neighbors' skateboard, red bike, and yellow VW bug get sucked up into a twisting swirl of air. She ran to the bathroom, grabbed the safety supplies she had prepared last year for a school assignment, and got into the bathtub.

FACTS	HYPOTHESES
• Dekalb in path of "supercell" • Tornado warning in effect for Dekalb • Warm & cold air masses are colliding • Updrafts cause air masses to spin in a vortex • Updrafts = convection currents • Lightning in storms increases risk of updrafts & tornado formation • tree caught fire in the middle of the hail • bike, skateboard, and VW bug were lifted into a "twisting swirl of air" • M ran to bathroom, got in tub	• A tornado may hit Margarite's house • Lightning struck Marc's tree • A tornado picked up the skateboard, bike, and VW bug. • Margarite knows what to do in a tornado • Margarite will . . . [kids name various safety precautions]
INTERVIEW QUESTIONS • Has she been in a similar storm before? • What are the safety supplies she had prepared? • Does she have family at home with her? • Does she have pets to take care of?	**LEARNING ISSUES** **1. supercell** **2. humid (air)** **3. updraft, convection current** **4. vortex** **5. tornado warning (vs. watch)** **6. how does an air mass get to be warm or cold, humid or dry?** **7. what are the best safety precautions to take before and during a tornado?**

Discussion Questions

*(Note: the weather topics provide the context, but keep the focus on the **physical science** issues of temp change, change of state, forces, particle movement, etc)*

Do air masses have substance or are they just nothing?
Why don't air masses from opposite directions just go around each other instead of colliding?
How does a vortex get started? What factors make a vortex more likely? Why?
Is it possible for a tree to burn during a hailstorm?
How does a tornado form? What do lightning and hail have to do with tornado formation?

Day 4 Facilitation Strategy

[< 5 min]
Quick review of plot from Scenes 1 & 2
Review hypotheses

- had they discarded any?
- which were they leaning toward? based on what evidence?

[20-25 minutes for reports & re-eval of hypotheses]
What information did they find from their research?

Allow them to volunteer in any order. (don't need LI's in order, just need good info)
Each LI report should

- have correct content
- be phrased in the kid's own words
- cite the source(s) consulted

Note: Above all, it is **not** the facilitator's job to provide answers to content, though they will want you to do that. It is your job to help them identify learning issues and to work together as a group to decide whether they have the information they need.
Allow them to "fail" at any of these tasks, but address this with the group.

- is the group missing important information?
- Will that impede their ability to evaluate their hypotheses and solve the case?

This is their first case, so they will discover what they can improve for next time. Don't spend too much time on this before getting to Scene 3 & the Epilogue – you'll have a chance to come back to evaluations at the end of the hour.

Quickly re-evaluate their hypotheses given the new information.

[10 minutes for Scene 3 & Epilogue]
Read Scene 3 silently and then aloud together. Briefly discuss the new information with regard to their hypotheses and their research findings.

- How confident are they in their main hypotheses?
- Can they use evidence from the text to bolster their claims?
- Do they understand and can they explain in physical science terms how a tornado is formed?

Use the discussion questions included in the facilitation guide if they need some help focusing.

Read the Epilogue together. Discuss whether it confirms their hypotheses.

[10 minutes for evaluations]
Hand out the **Self & Group Evaluation** sheets *(see Student Materials document)* and do as described above. Return to the issue of each person contributing vital information to the group and how this impacts the group's ability to solve the case.

"Vortex" Facilitator Guide: Scene 3

An hour after Margarite climbed out of the bathtub, she was standing outside with her family and neighbors. The sun was shining down on mud, fallen tree branches, and litter blown into their yards.

"Looks like we have a few shattered windows and some damage to the rain gutters, but the house is in pretty good shape," said Margarite's mom. "The main thing is that no one got hurt."

"That's the truth!" said Marc's mom. "I'm so glad these kids prepared tornado safety kits last year in school! Marc knew just what to do."

"Dude! look at our tree!" Marc said. "It is completely torched! I'll bet the lightning that struck it is what caused the updraft that carried off the car and my bike!"

Following the line of destruction caused by the tornado, they found the little yellow bug flipped on its back and smashed into a neighbor's tool shed about 100 meters away. Marc's bike was caught in the branches of a tree about a half a kilometer further along. Margarite found Marc's skateboard about 2 km from his house and brought it to him.

Just then Margarite remembered the note she had been taking to Marc when the storm hit. She had no idea where it was. "Man, I hope *that* doesn't turn up somewhere," she thought. "That would be *sooo* embarrassing!"

Discussion Questions

*(Note: the weather topics provide the context, but keep the focus on the **physical science** issues of temp change, change of state, forces, particle movement, etc)*

What is Marc's hypothesis about how the bike and car got lifted away from his house? Is his hypothesis possible?

"Vortex" Facilitator Guide: Epilogue

In the days after the tornado, everyone in the neighborhood was busy cleaning up their yards and fixing the damage to their houses. Margarite put the tornado kit back together for her own family and made a list of things they could do to make their house even safer in the future.

Margarite and Marc decided to see if their neighbors had a tornado safety plan and kit ready to use in their houses. They got to know everyone in their community and helped several of their neighbors write up tornado safety plans. In a short time, the buildings and houses were repaired, and people felt more prepared in case of another emergency.

Marc's mom was able to get another VW bug with her insurance money – this time she got a blue one. Since Margarite had found his skateboard after the tornado, Marc decided to give her a few lessons on it. "Besides which," he thought, "she *is* pretty cute . . ."

Meanwhile, in Lawrenceville, Mr. Marc Johnson was on his way to work one morning when something caught his eye. It was a piece of paper caught in the fence of his driveway. He opened it up. It said:

"*Dear Marc,*

I think you are so cute. You are the coolest guy I know. I am so glad that we live near each other. Do you have a girlfriend? Maybe we can walk home together sometime. Or we could both ride on your skateboard, if you teach me how.

-Margarite"

Extra Facilitation Tips: How to Manage Group Dynamics

- Encourage all students to contribute.
- Try to get the group members to speak to each other, not so much to you the facilitator.
- Allow students to do what they excel at (for some: reading, others: recording notes, others: generating ideas)
- Allow the group to address problematic behavior (without personalizing attacks).
- Allow some tangents related to hypotheses or learning issues, but bring them back to solving the case: what do they need to know more about in order to say definitively what is going on?
- Use a sense of humor.
- *When one or two students dominate:*
  Ask them to write down their ideas and then allow each person a turn to share their idea.
  Shift your gaze from the dominating student to another student, and ask, "what do *you* think?"
  Say that you'd like to hear one idea/hypothesis/question from each member of the group.
  "Does anyone other than X have thoughts/suggestions?"
  "Let's hear from some folks who haven't had a chance to speak yet."
  "I wonder what Y thinks about that point."
  "What does the group think about that – agree? disagree?"
- *When you want to draw out quiet students:*
  Allow sufficient "wait-time" before asking another question or changing to another student. Silence and encouraging eye-contact can be powerful tools.
  Sometimes allowing time for them to write an answer first, before asking for volunteers helps students participate.
  Ask them how they would like to contribute (reading? writing for the group? etc)

Resources

Weather in general

USA Today. (2005, September 18). *Atmospheric Science Resources*. Retrieved March 20, 2006, from http://www.usatoday.com/weather/resources/basics/wworks0.htm

USA Today. (2005, May 24). *Resources: Thunderstorms*. Retrieved March 20, 2006, from http://www.usatoday.com/weather/resources/basics/thunderstorms.htm#more

Tornadoes *– several links feed off of these – a link to a really cool graphic on the anatomy of a tornadic thunderstorm is in the first one.*

Brain, M. (n.d.). *How tornadoes work*. Retrieved March 20, 2006, from How Stuff Works Web site: http://www.howstuffworks.com/tornado2.htm

Cappella, C. (2005, May 17). *Tornadoes are Earth's most violent storms*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/resources/basics/twist0.htm

Palmer, C. (2005, May 20). *Caps often aid tornado development*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/wconvcap.htm

Palmer, C. (2001, May 3). *More about torndaoes*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/wtorwhat/wtorwha1.htm

Rose, C. (2005, May 20). *Only simple mateials needed to see 'twisters.'* Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/wchamb/wchamb.htm

The Tornado Project. (2000). *The tornado project online*. Retrieved March 20, 2006, from http://www.tornadoproject.com/

Web Weather for Kids. (n.d.). Retrieved March 20, 2006, from the University Corporation for Atmospheric Research Web site: http://www.ucar.edu/40th/webweather/tornado/tornadoes.htm

Williams, J. (2003, May 5). *Basics: How tornadoes work, what they are*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/resources/basics/2003-05-05-basics-tornadoes_x.htm

Tornado safety

Edwards, R. (2006, January 31). *The online tornado FAQ*. Retrieved March 20, 2006, from Storm Prediction Center Web site: http://www.spc.noaa.gov/faq/tornado/index.html#Safety

How to make a tornado

Web Weather for Kids. (n.d.). *Make a tornado!* Retrieved March 20, 2006, from the University Corporation for Atmospheric Research Web site: http://www.ucar.edu/40th/webweather/tornado/tornadoes.htm

detailed instructions on building a tornado box –

Beaty, W. (2006). *Tornado generator box*. Retrieved March 20, 2006, from http://www.eskimo.com/~billb/amateur/tornbox.html

Hurricanes

Palmer, C. (2005, May 20). *What makes a storm a hurricane*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/whurwhat/whurwhat.htm

Sheets, B., & Williams, J. (2005, May 20). *Hurricanes form and grow in stages*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/whurlife/whurlife.htm

Sheets, B., & Williams, J. (2005, May 20). *Why hurricanes form over warm oceans*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/whur7.htm

Williams, J. (2005, May 17). *Why hurricanes hit in summer, early fall*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/whur5.htm

Thunderstorms

Palmer, C. (2005, May 20). A look inside a thunderstorm. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/wtsmwhat/wtsmwhat.htm

What turns skies green?

Cappella, C. (2005, May 17). *What turns thunderstorms green isn't clear*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/resources/basics/green-thunderstorms.htm

What causes rain / hail? Why is hail associated with bad storms?

Palmer, C. (2001, May 3). *More about tornadoes*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/wtorwhat/wtorwha1.htm

Palmer, C. (2005, May 20). *Rising air creates summer ice*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/whail/whail.htm

Williams, J. (2005, May 20). *Molecular motion determines water's state*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/wevapcon/wevapcon.htm

Williams, J. (2005, May 20). *Water's three phases are a key to the weather*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/wwatphse.htm

What is wind and how does it form?

Williams, J. (2005, May 20). *Pressure differences get the wind going*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/wpress.htm

Williams, J. (2005, August 23). *Understanding winds and jet streams*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/wwind0.htm

Coriolis effect:

Williams, J. (2005, May 17). *Understanding the Coriolis force*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/resources/basics/coriolis-understanding.htm

What is a supercell and how do they differ from regular storm cells?

Williams, J. (2005, May 20). *Supercells are the kings of thunderstorms*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/wtsm2.htm

What causes wind / wind shear?

Williams, J. (2005, May 20). *Wind shear can make plane rides bumpy*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/wshear/wshear.htm

What is a tornado vortex? How and why do they form?

Palmer, C. (2005, May 20). *Intense tornadoes can have more than one vortex*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/wmltivor.htm

What creates a tornado? (1997, August 13). In Lansing State Journal. Retrieved March 20, 2006, from Michigan State University, Ask Science Theatre Web site: http://www.pa.msu.edu/~sciencet/ask_st/081397.html

Building a vortex

How Stuff Works. (n.d.). Retrieve March 20, 2006, from How Stuff Works Web site: http://science.howstuffworks.com/framed.htm?parent=tornado.htm&url=http://www.nationalgeographic.com/world/trythis/try4.html

How Stuff Works. (n.d.). *Whirling water creates a tornado in a bottle*! Retrieved March 20, 2006, from How Stuff Works Web site: http://science.howstuffworks.com/framed.htm?parent=tornado.htm&url=http://www.exploratorium.edu/learning_studio/vortex/

What are warm and cold air masses and what happens when they meet?

Palmer, C. (2005, May 20). *Cold fronts not always all that cold*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/wcfront/wcfront.htm

Palmer, C. (2005, May 20). *Warm fronts not as nice as they sound*. Retrieved March 20, 2006, from USA Today Web site: http://www.usatoday.com/weather/tg/wwfront/wwfront.htm

What are convection currents?

Mackenzie, G. (n.d.). Retrieved March 20, 2006, from http://www.mec.edu/gltech/library/htmlaps/mackenzie/mackenzie.htm

WeatherStreet. (2004). *What is convection?* Retrieved March 20, 2006, from http://www.weatherquestions.com/What_is_convection.htm

For teachers to look at

Project Atmosphere Australia Online. (n.d.). Retrieved March 20, 2006, from http://www.schools.ash.org.au/paa2/deliver/content.asp?pid=628

Safety Issues – What are tornado watches vs warnings? What safety precautions should be taken for each?

The Tornado Project. (1999). Retrieved March 20, 2006, from How Stuff Works Web site: http://science.howstuffworks.com/framed.htm?parent=tornado.htm&url=http://www.tornadoproject.com/safety/safety.htm

Others

Forces and winds: online meteorology guide. (1999). Retrieved March 20, 2006, from University of Illinois at Urbana-Champaign Web site: http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/fw/home.rxml

Meteorology Guide. (1999). Retrieved March 20, 2006, from University of Illinois at Urbana-Champaign Web site: http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/home.rxml

Other Marc & Margarite Cases

1. **Vortex**
   Embree, M., & McMahon, K. M., Price, C. J., & Webb, A. L. (2005). Vortex. Retrieved May 25, 2006 from Emory University, CASES Online Web site: http://www.cse.emory.edu/cases/casedisplay.cfm?case_id=243

2. **The Day After Tomorrow**
   Webb, A. L., & McMahon, K. M. (2005). *The day after tomorrow*. Retrieved May 25, 2006 from Emory University, CASES Online Web site: http://www.cse.emory.edu/cases/casedisplay.cfm?case_id=245

3. **Liftoff!**
   Price, C. J., & Webb, A. L., McMahon, K. M., & Embree, M. (2005). *Liftoff!* Retrieved May 25, 2006 from Emory University, CASES Online Web site: http://www.cse.emory.edu/cases/casedisplay.cfm?case_id=244

4. **Mars**
   Embree, M., & McMahon, K. M., Price, C. J., & Webb, A. L. (2005). *Mars*. Retrieved May 25, 2006 from Emory University, CASES Online Web site: http://www.cse.emory.edu/cases/casedisplay.cfm?case_id=246