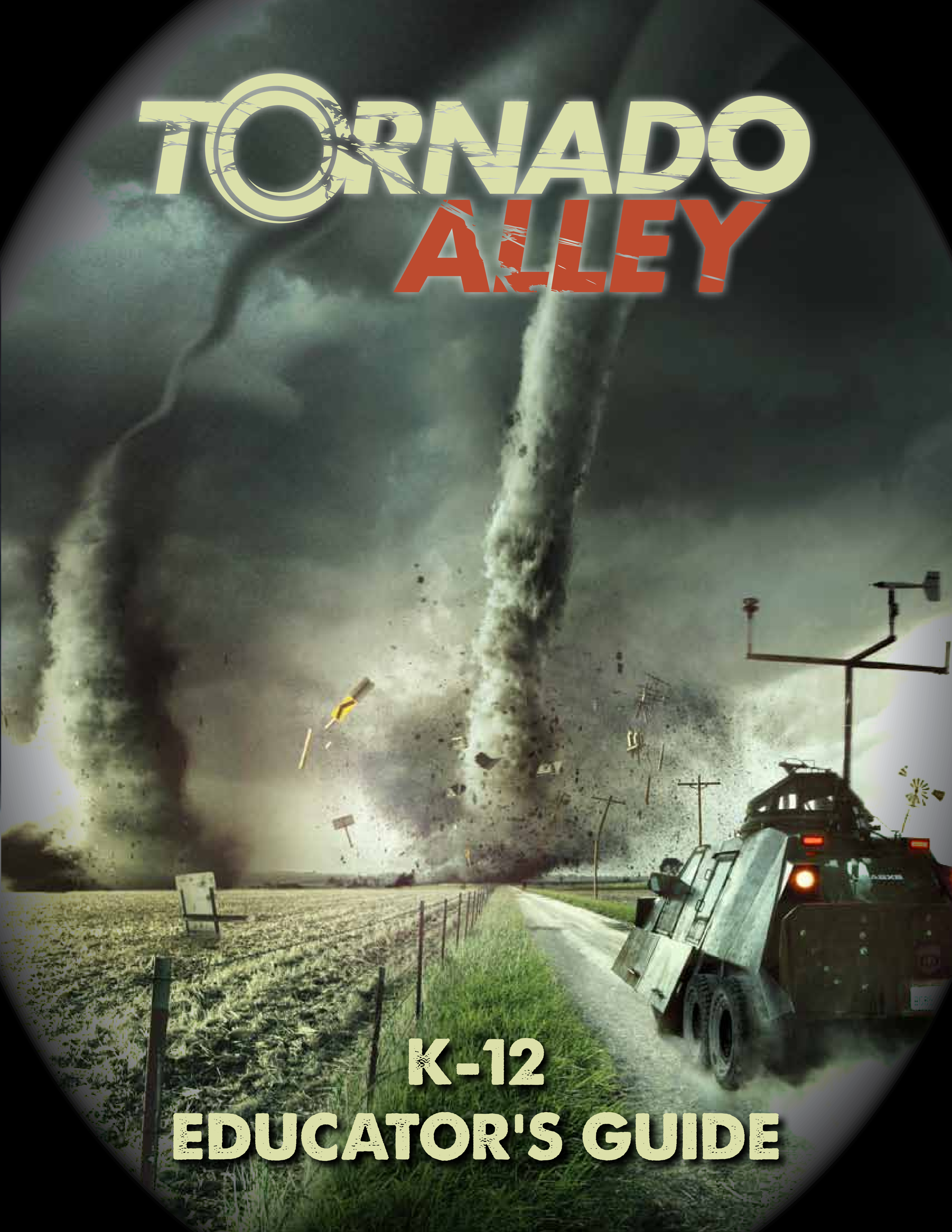
TORNADO ALLEY



K-12 EDUCATOR'S GUIDE

TORNADO ALLEY

Traversing the "severe weather capital of the world," "Tornado Alley" documents two unprecedented missions seeking to encounter one of Earth's most awe-inspiring events—the birth of a tornado. Filmmaker Sean Casey's personal quest to capture the birth of a tornado with a 70mm camera takes viewers on a breathtaking journey into the heart of the storm. A team of equally driven scientists, the VORTEX2 researchers, experience the relentless strength of nature's elemental forces as they literally surround tornadoes and the supercell storms that form them, gathering the most comprehensive severe weather data ever collected. This science adventure reveals the beauty and the power of some of our planet's most extreme—and least understood—weather phenomena.

"Tornado Alley" showcases the teamwork that makes scientific discovery and advancement possible. In this case, an international team of scientists have joined together to pool their resources and efforts in an attempt to understand tornadogenesis—the birth of a tornado from a supercell storm cloud. They converge on the area of the United States known as Tornado Alley during the prime tornado seasons of 2009 and 2010.

Learning Goals for K-12 Students:

- To understand where Tornado Alley is located.
- To understand the tools that scientists use to study tornadoes.
- To understand how scientists work together to gather data, make observations, and draw conclusions about severe weather events.

BACKGROUND INFORMATION

VORTEX2

"Tornado Alley" features the VORTEX2 scientific team as they work on their mission to capture information about how tornadoes form—the process called tornadogenesis. VORTEX2 was the largest and most ambitious effort ever made to understand tornadoes. Over 100 scientists and over 50 science and support vehicles participated in the unique, fully nomadic, field program during May and June of 2009 and 2010. The National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA) contributed over $10 million towards the effort. Participants came from over a dozen universities, and several government and private organizations.

The VORTEX2 team wanted to answer these important questions:

How, when, and why do tornadoes form? Why are some violent and long-lasting while others are weak and short-lived?

What is the structure of tornadoes? How strong are the winds near the ground? How exactly do they do damage?

How can we learn to forecast tornadoes better?

Currently, 70% of tornado warnings are false alarms. For the other 30% of warnings, people have only 13 minutes, on average, between hearing the warning and getting hit by the tornado.

Can we make warnings more accurate?

Can we increase the warning time so that people have 30, 45, or even 60 minutes to prepare?

Doppler Radar

Doppler Radar transmits and receives microwaves to calculate the speed and direction of moving objects, like raindrops in a thunderstorm. Doppler Radar allows meteorologists to calculate not only the location of storms, but the speed and direction of the winds within a storm as well. Doppler Radar has significantly improved the forecasting of severe weather events.

Tornado Season

Tornadoes can form at any time of the year, however there are certain times when conditions tend to be more favorable for the development of the supercell storms that generate tornadoes. For this reason, research scientists focus their efforts on tracking storms during the times when tornadoes are most likely to form. In "Tornado Alley," when the VORTEX2 scientists talk about tornado season, they are referring to the months of May and June.

The Enhanced Fujita Scale

The Enhanced Fujita (EF) scale is a six-level (EF0-EF5) scale for rating tornado intensity, based on the damage tornadoes inflict on human-built structures and vegetation. Though each damage level is associated with a wind speed, the Enhanced Fujita scale is a damage scale, and the wind speeds associated with the damage listed are unverified.

BACKGROUND INFORMATION

The Enhanced Fujita Scale

	Wind Speed	Damage Profile
EF0	40-72 MPH	Minor Damage - Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
EF1	73-112 MPH	Moderate Damage - The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
EF2	113-157 MPH	Considerable Damage - Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	158-206 MPH	Critical Damage - Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted and thrown.
EF4	207-260 MPH	Severe Damage - Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
EF5	261-318 MPH	Total Destruction - Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through the air; trees debarked; steel-reinforced concrete structures badly damaged.

SIGNIFICANT HISTORICAL TORNADOES

This is the oldest known photograph of a tornado. It was taken on August 28, 1884 approximately 22 miles southwest of Howard, South Dakota.

Tornadoes can be deadly. The scientists in “Tornado Alley” chase storms and gather data to study because they want to improve our ability to predict when and where a tornado might strike. When we have more time to prepare and get to safety, tornadoes become less deadly.Here is a timeline of some of the deadliest tornadoes ever to strike in the United States.

1896 *May 27 – 255 people died in the Great St. Louis Tornado which struck Missouri and Illinois.*

1899 *June 12 – 117 people died when a tornado struck New Richmond, Wisconsin.*

1902 *May 18 – 114 people died in Goliad, Texas.*

1925 *March 18 – 695 people died in the Tri-State Tornado that raced across Missouri, Indiana, and Illinois.*

1936 *April 5 – 216 people died when a tornado struck Tupelo, Mississippi.*

1936 *April 6 – 203 people died when a tornado struck Gainesville, Georgia.*

1947 *April 9 – 181 people died when a tornado raced across Texas, Oklahoma, and Kansas.*

1953 *May 11 – 114 people died in Waco, Texas.*

1953 *June 8 – 115 people died in Flint, Michigan.*

2011 *April 27 – at least 300 people died when tornadoes touched down across Alabama and Mississippi.*

SPOTLIGHT ON SCIENTISTS


Donald Burgess


Joshua Wurman


Karen Kosiba

Many people work together in “Tornado Alley” to capture data and information about tornadogenesis. Not everyone we see is a scientist, but many are. These three scientists have dedicated their careers to learning about severe storms in hopes of finding ways to provide more accurate warnings for people who may be in harm’s way.

Donald Burgess

Donald Burgess began studying the weather while growing up in the state of Oklahoma. His fascination with weather inspired him to become a meteorologist by earning science degrees at the University of Oklahoma. Today, he is a research scientist at the Cooperative Institute for Mesoscale Meteorological Studies and an Adjunct Professor of Meteorology, both at the University of Oklahoma. He also currently serves on the Steering Committee for the Verification of the Origins of Rotation in Tornadoes Experiment, Part 2 (VORTEX2). His research interests lie in the areas of severe weather and techniques for improving warnings of weather hazards, particularly techniques using Doppler radar for tornado detection and warnings. Because an important part of being a scientist is sharing information with others, he has also helped to write an award-winning book called “The Tornado: Its Structure, Dynamics, Prediction, and Hazards.”

Joshua Wurman

Joshua Wurman is an atmospheric scientist and inventor noted for tornado, hurricane, and weather radar research. After receiving science degrees from the Massachusetts Institute of Technology, he began working at the National Center for Atmospheric Research and was inspired to invent the Doppler on Wheels as well as other new technological tools used to track severe storms. He founded the Center for Severe Weather Research in Boulder, Colorado where he works today. He spends most of his time chasing severe storms around the country, especially during tornado season each year when he may travel 15,000 miles up and down Tornado Alley in search of the right conditions for his research.

Karen Kosiba

Karen Kosiba is a research meteorologist at the Center for Severe Weather Research in Boulder, Colorado. Her research mainly focuses on characterizing the low-level wind structure in tornadoes and in hurricanes. This is accomplished through the use of mobile radar observations and numerical modeling. She believes in studying weather, even severe weather, by experiencing it first-hand so she spends a lot of time doing field research and chasing storms. She prepared for her career by earning an advanced degree in science at Purdue University in Indiana.

SPOTLIGHT ON TECHNOLOGY

The VORTEX2 mission featured in "Tornado Alley" used an unprecedented fleet of cutting-edge instruments to surround tornadoes and the supercell thunderstorms that form them. By joining forces and combining their equipment, the scientists were able to capture the most complete picture of a tornado ever recorded.

The fleet included an armada of mobile radars, mobile mesonet instrumented vehicles, and deployable instruments including Stick-Nets, Tornado-Pods, disdrometers, weather balloon launching vans, and unmanned aircraft.

Mobile Radar Systems

Mobile radar systems are Doppler weather radar systems mounted on rugged, heavy-duty trucks that are able to get up close to severe storms, providing data about winds in tornadic storms, hurricane rain bands and eyewalls, and other structures inside severe storms.

Doppler On Wheels

SMART-Radar

NOX-P Radar

Mobile Mesonets

Mobile Mesonets

The mobile mesonet is a set of vehicle-borne weather sensors. The vehicles use global positioning satellites to determine the time and exact position of the instrument when it records conditions. The conditions include temperature, relative humidity, air pressure, and wind speeds.

Stick-Nets

Stick-Nets

A Stick-Net is a versatile, rapid-deployment meteorological observing station. Affectionately named for its resemblance to a stick figure, the Stick-Nets collect high resolution meteorological data, including temperature, relative humidity, air pressure, and wind speeds. The platforms are designed to be deployed in large numbers, in a short period of time (three minutes or less) by a small number of people.

Tornado Pods

Tornado Pods

Tornado Pods are instruments mounted onto 1 meter (3 foot) towers which measure wind velocity and direction in the center of the tornado.

SPOTLIGHT ON TECHNOLOGY


Disdrometers


Weather Balloon Launching Vans


Tempest Unmanned Aircraft

Disdrometers

Disdrometers are instruments used to measure the drop size distribution and velocity of falling precipitation. Some disdrometers can distinguish between rain, snow pellets, and hail.

Weather Balloon Launching Vans

These vans carry the equipment needed to launch high altitude weather balloons which carry instruments aloft to send back information on atmospheric pressure, temperature, humidity, and wind speed.

Tempest Unmanned Aircraft

The Tempest unmanned aircraft system is designed to fly into severe convective storms including supercell thunderstorms and record data from the inside.

SPOTLIGHT ON SAFETY

Tornado behavior is very hard to predict. VORTEX2 scientists are among those working to help find better ways to predict where they may strike.

Since prediction is a challenge, it is all the more important to be prepared and to know what to do if you find yourself in the path of a tornado. Below are safety tips for several different locations.

Small Buildings with Basements

Go to the basement. If there is a sturdy table or work bench, get beneath it. If not, look for something that would cushion you from any falling debris. Some families keep an old mattress in their basement for this purpose. Also, think about what is on the floor above you. Try not to be beneath the kitchen where heavy appliances might fall through to the basement.

Small Buildings without Basements

Go to a small room or closet at the center of the ground floor. If you don't have a room or closet, look for a space beneath a stairwell or at least an interior hallway. Crouch down as close to the ground as you can. Keep your face down and cover the back of your head with your hands. If you have something that might cushion you, get below it. If you have a bathroom in the center of the house which has a heavy bathtub, crouch inside it.

Multi-Story Buildings

Generally speaking, you should follow the same ideas as for small buildings. Get as close to the ground as possible. If the building has a basement, that is the best place to be. If not, get as close to the center of the ground floor as you can. If you are on a high floor and don't have time to get to the ground, find the smallest interior room near the center of the building as you can. Sometimes, there might be a central stairway to hide beneath. Never use the elevators!

Cars or Trucks

Vehicles are very dangerous during a tornado. If you can see a tornado far away in the distance, you may be able to drive to safety away from its path. However, if you see the tornado closely approaching, you should get out of your vehicle. Try to park safely at the side of a road so that you are not blocking the road for emergency vehicles. If at all possible, get inside a building. If that is not possible, though, your chance to survive is better out in the open than inside a vehicle.

SPOTLIGHT ON SAFETY

Mobile Homes

Get outside! Your chance to survive a tornado strike is better out in the open than inside a mobile home.

Out in the Open

If it's impossible to get to a safe place inside a sturdy building, lie flat and face-down on the ground out in the open and cover the back of your head with your arms. Pick a place that is away from trees, parked cars, or other objects that may topple over onto you. Do not seek shelter beneath a bridge or overpass.

In all cases, no matter where you are, avoid being near windows! The flying glass from breaking windows is always the cause of many injuries during tornado strikes. Also, no matter where you are, try not to panic! Stay calm, remember these safety tips, and follow leaders—like schoolteachers, security guards, or parents—who best know the shelter plans for the building where you are.

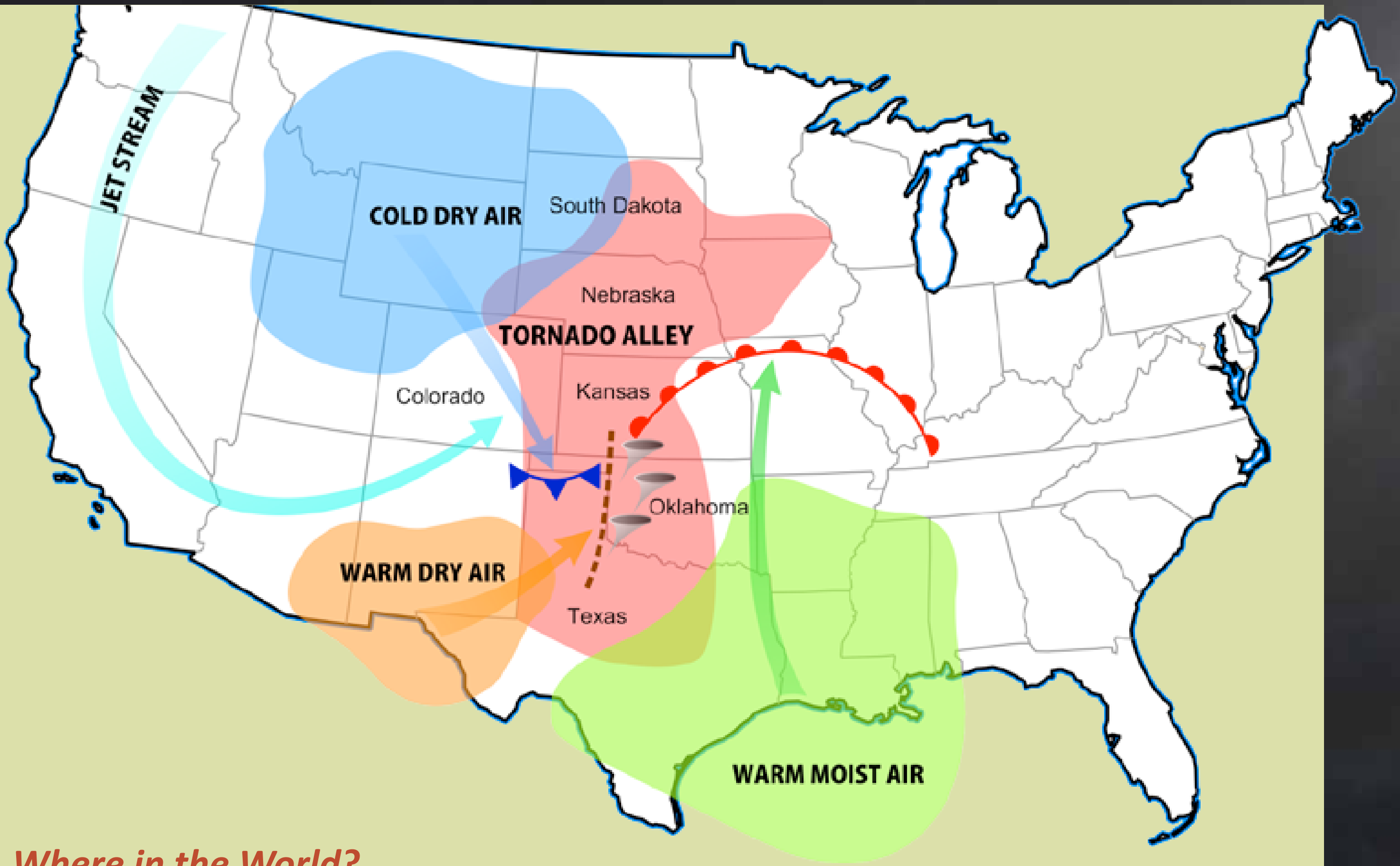
After the Tornado Passes

If you are inside a building that was struck, try to get outside, especially if the damage was severe and it may collapse. Stay with your group and wait for emergency workers to arrive. Beware of broken glass and other sharp objects. Stay away from power lines and other sources of electricity. Beware of puddles that may be covering wires—remember that water is a powerful conductor of electricity! Tornado damage may also have broken natural gas supply lines which makes open flame extremely dangerous. Do not use lighters or matches!

This information is derived from content provided by the National Oceanic and Atmospheric Administration's Storm Prediction Center.

TRY THIS!

Image courtesy Dan Craggs



Where in the World?

Tornado Alley is a nickname given to an area in the southern plains of the central United States that consistently experiences frequent tornadoes each year. Tornadoes in this region typically happen in late spring and occasionally the early fall. Although the actual boundaries of Tornado Alley are debatable and the National Weather Service does not consider it to be an official term, the core of Tornado Alley consists of the Texas Panhandle, Oklahoma, Kansas, Nebraska, eastern South Dakota, and the Colorado Eastern Plains. However, Tornado Alley can be also be defined as an area stretching from central Texas to the Canadian prairies and from eastern Colorado to western Pennsylvania. Meteorologically, the region known as Tornado Alley is ideally situated for the formation of supercell thunderstorms which are often the producers of violent tornadoes.

No matter where your school is located, students should know that tornadoes are possible at any time of year. The scientists in “Tornado Alley” spend the months of May and June chasing storms in the field, but only because that is the best time to do their research. They know that severe weather can happen at any time, in any location.

Discussion Questions

Younger students should be introduced to the map of Tornado Alley and asked to identify the states pictured in red. Is your school located in Tornado Alley?

Older students should be encouraged to think about the other factors on the map.

What is the source of the warm moist air pictured in green?

Where is the warm dry air pictured in orange coming from?

Why do many tornadoes form in the Alley during the late spring and early summer months?

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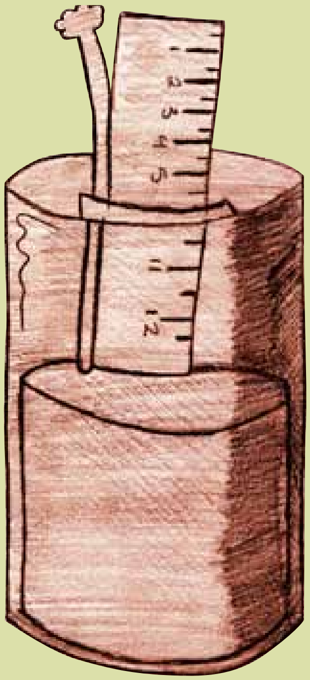

Under Pressure

Use these directions to make our own barometer in order to detect and observe changes in atmospheric pressure. Since barometers are very sensitive to minor changes in weather conditions, you'll want to keep the barometer indoors to get more accurate readings.

Things You Need:

glass or beaker with straight sides

ruler (12 inch)

tape

one foot of clear plastic tubing (could be a tall plastic drinking straw, but it must be clear)

stick of chewing gum

water

Begin by standing the ruler in the empty glass or beaker and holding it against the side. Tape the ruler to the inside of the glass. Make sure that the numbers on the ruler are visible.

Stand the plastic tube against the ruler in the glass. Make sure that the tube is not touching the bottom of the glass by positioning the tube up a half inch on the ruler. Secure the tube by taping it to the ruler.

Chew the stick of gum so that it is soft. While you're chewing, fill the glass about half way with water. Use the plastic tube like a straw and draw some water half way up the tube. Use your tongue to trap the water in the tube. Quickly move the gum onto the top of the tube to seal it.

Make a mark on the ruler to record where the water level is in the tube. Each time you notice a change in the water level, make another mark. You'll notice, over time, that the water level rises and falls. Pay attention to the change in weather as the water level changes.

The water in the tube rises and falls because of air pressure exerted on the water in the glass. As the air presses down (increased atmospheric pressure) on the water in the glass, more water is pushed into the tube, causing the water level to rise. When the air pressure decreases on the water in the glass, some of the water will move down out of the tube, causing the water level to fall. The change in barometric pressure will help you to forecast the weather. Decreasing air pressure often indicates the approach of a low pressure area, which often brings clouds and precipitation. Increasing air pressure often means that a high pressure area is approaching, bringing with it clearing or fair weather.

Tracking the Pressure

At all grade levels, students can use their barometer to collect data and keep a log of rising and falling air pressure.

K-3 students can simply observe the movement of water level in the tube and keep a classroom chart to see if they notice patterns. Students in grades 4-8 can keep individual charts and use the readings to create graphs. How high does the pressure get? How low? Which results in nicer weather? High school students can also access local online weather services to compare data and see if the local barometric pressure corresponds to the official readings for the area.

TRY THIS!

Tornado Math!

The VORTEX2 fleet covered 26,000 miles during its research mission.

1. There were 40 vehicles in the fleet.
   If each of those vehicles drove the entire mission, how many total miles did the mission log?

   ___________vehicles x _______________ miles = ________ total mission miles

2. On average, the fleet covered 10 miles per gallon of fuel. Keep in mind that the smaller, lighter vehicles in the fleet are more fuel efficient than the heavier vehicles, so they got more miles per gallon. But, the fleet-wide average was 10 miles per gallon of fuel.

   Use your answer from the question above to see how many gallons of fuel were used.

   ___________total mission miles ÷ 10 miles per gallon = ___________ gallons of fuel

3. During its total mission, VORTEX2 observed 25 tornadoes.
   How many miles of searching, on average, did it take to find a tornado?

   ___________total mission miles ÷ 25 tornadoes =_ miles of searching per tornado

4. When the entire VORTEX2 team stopped for a restroom break, how many minutes did they need?

   There were 150 people. Assume 1.5 minutes per person.

   How long would it take if there is…
   1 restroom =________________________
   2 restrooms =________________________
   3 restrooms =________________________

   If the team only has 45 minutes for their rest break, how many restrooms do they need to find?________________

5. The VORTEX2 mission collected 30 terabytes (TB) of data to analyze.

   1 terabyte (TB) = 1,000 gigabytes (GB)

   1 gigabyte (GB) = 1,000 megabytes (MB)

   1 megabyte (MB) = 1,000 kilobytes (KB)

   1 kilobyte (KB) = 1,000 bytes

   1 byte = 8 bits

   How many bits of data did VORTEX2 collect? ____________

Tornado Math Answer Key

1.) 1,040,000 total mission miles; 2.) 104,000 gallons of fuel;
3.) 41,600 miles per tornado; 4.) 225 minutes; 113 minutes; 75 minutes; 5 restrooms
5.) 240,000,000,000,000 bits

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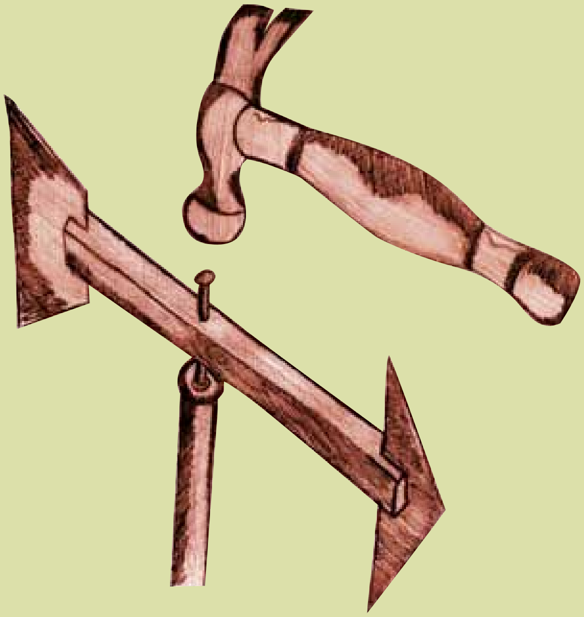


Which Way is the Wind Blowing?

Use these directions to make your own simple wind direction indicator.

Things You Need:

long wooden dowel (about the size of a broom stick)

aluminum pie plate

12-inch long piece of wood (a sturdy ruler would work)

nails

metal washer

hammer

glue

small saw (or serrated knife)

wire (for mounting)

scissors (strong enough to cut the aluminum plate)

Begin with the 12 inch piece of wood. Use the small saw (or serrated knife) to cut a vertical slit at each end of the stick. The slit should be about one half inch deep. At the midpoint (exactly halfway) of the top of the stick, hammer one nail all the way through the stick. Then turn the wood around the nail several times until the stick turns easily around the nail.

Refer to the pattern pictured and cut the head and tail from the aluminum plate. Glue the head into the slot at one end of the wooden stick. Glue the tail into the other end. Allow time for the glue to dry before you take the arrow-shaped vane outside.

Attach the vane to the long wooden dowel by placing the metal washer on the end of the dowel and then hammering the nail through the wooden stick and into the wooden dowel. (Refer to the picture.) Make sure that the vane moves freely and easily around the nail.

Now you are ready to mount your weather vane outside. Find a location where the vane will have room to move and catch the wind. The top of a wooden fence often works well. Attach the vane with wire. Try to get the vane as high as you can while still keeping the dowel steady and secure.

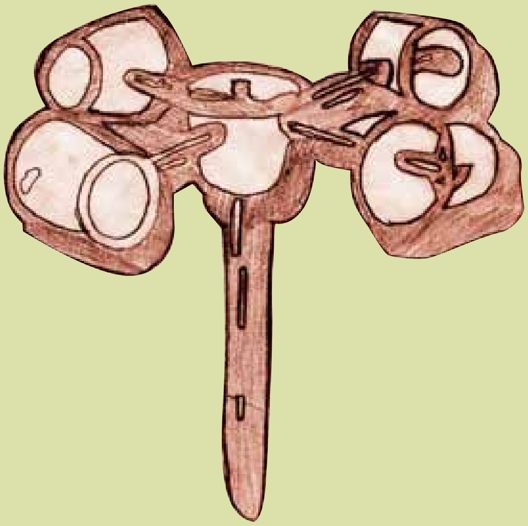
The head of the arrow/vane will always point to the direction from which the wind is blowing. For example, if the head points to the Northeast, then the wind is blowing from the Northeast. It's as simple as that.

Chasing the Wind

At all grade levels, students can use their wind direction indicator to collect data and keep a log of which way the wind is blowing.

K-3 students can simply observe the movement and keep a classroom chart to see if they notice patterns. Students in grades 4-8 can keep individual charts and use the readings to calculate averages. From which direction does the wind blow most often? Least often? High school students can also access local online weather services to compare data and see if the local conditions correspond to the official readings for the area.

TRY THIS!



How Fast is the Wind Blowing?

Use these directions to make your own simple anemometer. An anemometer helps you determine changes in wind speed. Use it with your wind direction indicator vane to see when the wind is blowing faster or slower.

Things You Need:

five 3 ounce paper Dixie cups

two straight plastic soda straws

a pin

scissors

paper punch

small stapler

sharp pencil with an eraser

Take four of the Dixie cups. Using the paper punch, punch one hole in each, about a half inch below the rim.

Take the fifth cup. Punch four equally spaced holes about a quarter inch below the rim. Then punch a hole in the center of the bottom of the cup.

Take one of the four cups and push a soda straw through the hole. Fold the end of the straw, and staple it to the side of the cup across from the hole. Repeat this procedure for another one-hole cup and the second straw.

Now slide one cup and straw assembly through two opposite holes in the cup with four holes. Push another one-hole cup onto the end of the straw just pushed through the four-hole cup. Bend the straw and staple it to the one-hole cup, making certain that the cup faces in the opposite direction from the first cup. Repeat this procedure using the other cup and straw assembly and the remaining one-hole cup.

Align the four cups so that their open ends face in the same direction (clockwise or counterclockwise) around the center cup. Push the straight pin through the two straws where they intersect. Push the eraser end of the pencil through the bottom hole in the center cup. Push the pin into the end of the pencil eraser as far as it will go. Your anemometer is ready to use.

Your anemometer is useful because it rotates with the wind. You can not use this elementary device to measure wind speed, but it will spin faster when the wind speed increases and slower when it decreases. Therefore it is useful for noticing changes and patterns.

Spinning with the Wind

At all grade levels, students can use their anemometer to observe changes in wind speed. The anemometer is an example of a vertical-axis wind collector. It need not be pointed into the wind to spin.

K-3 students can simply observe the movement and keep a classroom chart to see if they notice patterns. Students in grades 4-8 can keep individual charts and include both the readings from the anemometer and the wind direction indicator. How do direction and changes in speed correspond? Are there any patterns between the two? High school students can calculate the velocity at which the anemometer spins, by determining the number of revolutions per minute (RPM). Next calculate the circumference (in feet) of the circle made by the rotating paper cups. Multiply your RPM value by the circumference of the circle, and you will have an approximation of the velocity of at which your anemometer spins (in feet per minute). (Note: Other forces, including drag and friction, influence the calculation but are being ignored for this elementary illustration. The velocity at which your anemometer spins is not the same as wind speed.)

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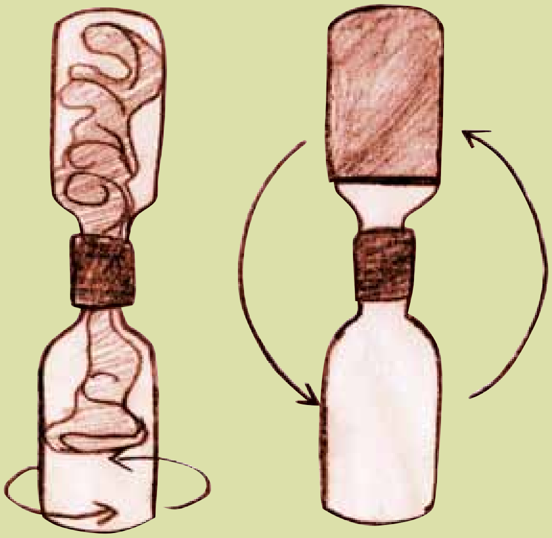


Make a Tornado!

Make a tornado in a plastic bottle to visualize tornado funnel formation.

This simple demonstration shows students how water spouts form as fluid rushes from one space to another.

Things You Need:

2 clear plastic bottles, two-liter size

1-inch metal washer

Waterproof tape, like duct tape

Water

Food coloring for enhanced visualization (optional)

Glitter to simulate debris (optional)

Remove all labels and plastic parts from the outside of the bottles. Make sure they are washed and clean inside.

Stand one of the two bottles on its base on a table and fill about 2/3 full with water. It is not necessary, but you can add a drop or two of food coloring to the water to enhance the visualization. Likewise, a little bit of glitter will simulate the movement of debris in a tornado's funnel cloud. Both of these enhancements are optional, but should be added now if desired.

Place the metal washer at the bottle's opening. Turn the second empty bottle upside down and align it with the washer. The hole in the washer will restrict the movement of water between the bottles during the demonstration. Have someone hold the bottles together firmly while you tape the two together securely. It is important that the bottles be perfectly aligned in order to prevent leakage. The empty bottle should stand straight up without any tilting.

Lift the bottles and give the water a firm swirl while flipping them so that the water is in the top bottle. The water will flow rapidly into the empty bottle, through the hole in the washer. As it does so, it will form a strong vortex that makes it easier to displace the air in the empty bottle that now suddenly has to compete with the water for space.

Once the water has settled in the bottom and the vortex has dissolved, you can repeat the process.

Teacher Tip: Many teacher supply stores sell a simple plastic device called a tornado tube connector. If you have one of those, it can be used to connect the two bottles instead of the washer and duct tape. It functions the same way by forcing the water to flow through a small hole between the two bottles.

MOBILE WEATHER INSTRUMENTS



The Tornado Intercept Vehicle

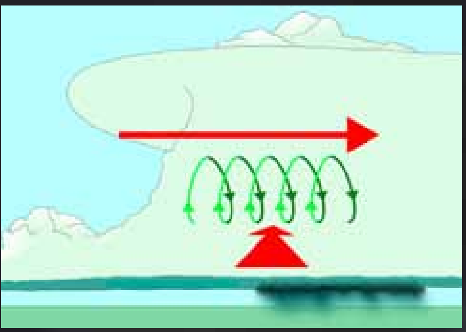
"Tornado Alley" tells the story of stormchaser Sean Casey's quest to film the inside of a tornado. In order to get safely into position to do so, he designed and built his Tornado Intercept Vehicle which he nicknamed TIV.

The TIV began its life as a standard Dodge 3500 pickup truck before being enhanced to withstand tornado-force storms. To protect the safety of the team inside, Sean added bulletproof glass and armored steel plates. The turret at the top was designed especially for the IMAX© film camera that he would use to film tornadoes.

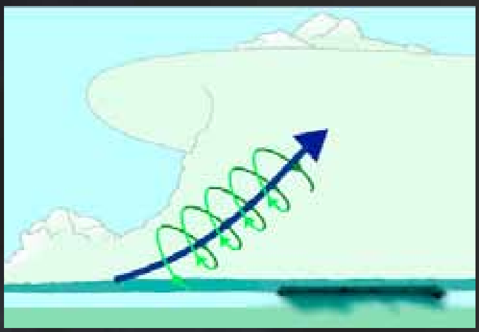
The TIV also has weather instruments mounted on it, including a wind direction vane, an anemometer, and barometer. Sean consulted with the VORTEX2 scientists to see which instruments would be most useful and to decide where best to mount them on the TIV. The instrument mast that sticks up from the top of the TIV holds the instruments which collect data including wind speed, temperature, relative humidity, and air pressure.

After you make your own weather instruments, you can begin to imagine someday making your own storm chasing vehicle!

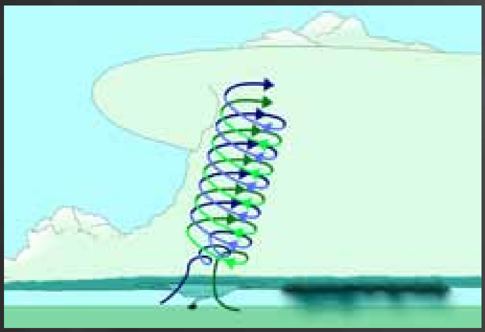
TORNADO FORMATION



The difference in speed and direction of high-level winds compared to low-level winds causes rotation or spin.



As warm moist air rises, it tilts the rotation into the vertical.



The rotation can be stretched or influenced by cool downdraft air forming a funnel cloud.

In "Tornado Alley," the scientists wait and watch for supercell thunderstorms to form. When they see one begin to form, they spring into action because they know that supercell storms often generate tornadoes. Not every supercell storm will produce a tornado, and not every tornado comes from a supercell. But, if you're a scientist looking for the best place to collect data about tornadoes, being near a supercell storm is a pretty good place to start.

During storm season in the region known as Tornado Alley, a unique combination of geography and converging air masses provide the perfect environment for these supercell storms to form and, ultimately, lead to tornadogenesis. With no southern mountain range to block the flow, warm moist air from the Gulf of Mexico moves northward, under the dry, cool, fast moving winds of the jet stream. If the warm air rises, it cools, and moisture condenses into clouds, reaching as high as ten miles into the atmosphere, and a storm is born.

The swirling in the clouds comes from the combination of winds that are blowing very fast in the cool high-altitude air and winds closer to the ground which are much warmer, moister, slower, and coming from a different direction. The difference in the wind speed and/or direction in layers is called wind shear. Wind shear is one source of vorticity, the amount of spin in the air.

Inside a storm, areas in which warm, moist air rises are called updrafts. Supercell thunderstorms have very strong updrafts. The updraft winds can tilt vorticity into a vertical direction. This is the source of rotation in supercell storms. Another key characteristic of a supercell is an area of cool, dry, descending air known as the Rear Flank Downdraft (RFD). The RFD wraps precipitation around the back of the rotation in the supercell and produces the classic hook shaped echo on Doppler radar. The convergence of the warm updraft air and the cool downdraft can cause a rotating wall cloud to form. For this reason, the RFD is critically important in tornadogenesis but scientists are still working to understand the exact conditions that cause tornadoes to form.

RECOMMENDED RESOURCES

Recommended Resources for Teachers

Websites

About the Doppler on Wheels
www.cswr.org/contents/aboutdows.html

National Doppler Radar Sites
radar.weather.gov

Web Weather for Kids – Thunderstorms and Tornadoes
www.eo.ucar.edu/webweather/thunderhome.html

National Severe Storms Laboratory – Education Resources
www.nssl.noaa.gov/edu

Tornado Handbook
dsc.discovery.com/tv/storm-chasers/handbook/handbook.html

Recommended Reading for Children and Young Adults

Grades K-3

"Tornado" by Catherine Chambers. ISBN 1403495904.

"Tornadoes!" by Gail Gibbons. ISBN 0823422747.

Grades 4-8

"Tornadoes" by Seymour Simon. ISBN 0064437914.

"Tornado Alert!" by Wendy Scavuzzo. ISBN 0778716031.

"Anatomy of a Tornado" by Terri Dougherty. ISBN 1429662816.

"Hurricane Hunters and Tornado Chasers" by Gary Jeffrey. ISBN 1404214593.

"Horror from the Sky: The 1924 Lorain, Ohio, Tornado" by Bonnie Highsmith Taylor. ISBN 078915837X.

Grades 9-12

"Adventures in Tornado Alley: The Storm Chasers" by Mike Hollingshead and Eric Nguyen. ISBN 0500287376.

"The Cambridge Guide to the Weather" by Ross Reynolds. ISBN 0521774896.

"The Tornado: Nature's Ultimate Windstorm" by Thomas P. Grazulis. ISBN 0806132582.

"The Tri-State Tornado: The Story of America's Greatest Tornado Disaster" by Peter S. Felknor. ISBN 0595311881.

"Tornado! The Story Behind These Twisting, Turning, Spinning, and Spiraling Storms" by Judy Fradin and Dennis Fradin. ISBN 1426307799.

"Tornado Hunter: Getting Inside the Most Violent Storms on Earth" by Stefan Bechtel, Tim Samaras, and Greg Forbes. ISBN 1426203020.

"Tornado Alley: Monster Storms of the Great Plains" by Howard B. Bluestein. ISBN 0195105524.

NATIONAL SCIENCE EDUCATION STANDARDS

"Tornado Alley" and the accompanying activities suggested in this guide can be used to support student learning as called for by the National Science Education Standards. The following presentation offers details of where the content aligns.

Unifying Concepts and Processes – K-12

STANDARD: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes:

SYSTEMS, ORDER, AND ORGANIZATION
The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation. The units of investigation can be referred to as ''systems.'' A system is an organized group of related objects or components that form a whole.

EVIDENCE, MODELS, AND EXPLANATION
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work.

CONSTANCY, CHANGE, AND MEASUREMENT
Although most things are in the process of becoming different—changing—some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles.

CONTENT STANDARD D – EARTH AND SPACE SCIENCE

GRADES K-4

CHANGES IN THE EARTH AND SKY

- The surface of the earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.
- Weather changes from day to day and over the seasons. Weather can be described by measurable quantities, such as temperature, wind direction and speed, and precipitation.

GRADES 5-8

STRUCTURE OF THE EARTH SYSTEM

- The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has different properties at different elevations.
- Clouds, formed by the condensation of water vapor, affect weather and climate.
- Global patterns of atmospheric movement influence local weather.

GRADES 9-12

ENERGY IN THE EARTH SYSTEM

- Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

NATIONAL SCIENCE EDUCATION STANDARDS

CONTENT STANDARD E – SCIENCE AND TECHNOLOGY

GRADES K-4

UNDERSTANDINGS ABOUT SCIENCE AND TECHNOLOGY

- People have always had questions about their world. Science is one way of answering questions and explaining the natural world.
- People have always had problems and invented tools and techniques (ways of doing something) to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.
- Scientists and engineers often work in teams with different individuals doing different things that contribute to the results. This understanding focuses primarily on teams working together and secondarily, on the combination of scientist and engineer teams.
- Women and men of all ages, backgrounds, and groups engage in a variety of scientific and technological work.
- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

GRADES 5-8

UNDERSTANDINGS ABOUT SCIENCE AND TECHNOLOGY

- Many different people in different cultures have made and continue to make contributions to science and technology.
- Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.

GRADES 9-12

UNDERSTANDINGS ABOUT SCIENCE AND TECHNOLOGY

- Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
- Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.
- Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people’s beliefs and practical explanations concerning various aspects of the world.

NATIONAL SCIENCE EDUCATION STANDARDS

CONTENT STANDARD F – SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

GRADES K-4

CHANGES IN ENVIRONMENTS

- Environments are the space, conditions, and factors that affect an individual's and a population's ability to survive and their quality of life.
- Changes in environments can be natural or influenced by humans. Some changes are good, some are bad, and some are neither good nor bad. Some environmental changes occur slowly, and others occur rapidly.

SCIENCE AND TECHNOLOGY IN LOCAL CHALLENGES

- People continue inventing new ways of doing things, solving problems, and getting work done. New ideas and inventions often affect other people; sometimes the effects are good and sometimes they are bad. It is helpful to try to determine in advance how ideas and inventions will affect other people.

GRADES 5-8

NATURAL HAZARDS

- Internal and external processes of the earth system cause natural hazards, events that change or destroy human and wildlife habitats, damage property, and harm or kill humans. Natural hazards include earthquakes, landslides, wildfires, volcanic eruptions, floods, storms, and even possible impacts of asteroids.

RISKS AND BENEFITS

- Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions).

SCIENCE AND TECHNOLOGY IN SOCIETY

- Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.
- Scientists and engineers work in many different settings, including colleges and universities, businesses and industries, specific research institutes, and government agencies.

GRADES 9-12

PERSONAL AND COMMUNITY HEALTH

- Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability, or death may be present. Humans have a variety of mechanisms—sensory, motor, emotional, social, and technological—that can reduce and modify hazards.

NATURAL AND HUMAN-INDUCED HAZARDS

- Some hazards, such as earthquakes, volcanic eruptions, and severe weather, are rapid and spectacular.
- Natural and human-induced hazards present the need for humans to assess potential danger and risk. The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations.

NATIONAL SCIENCE EDUCATION STANDARDS

CONTENT STANDARD G – HISTORY AND NATURE OF SCIENCE

GRADES K-4

SCIENCE AS A HUMAN ENDEAVOR

- Although men and women using scientific inquiry have learned much about the objects, events, and phenomena in nature, much more remains to be understood. Science will never be finished.
- Many people choose science as a career and devote their entire lives to studying it. Many people derive great pleasure from doing science.

GRADES 5-8

SCIENCE AS A HUMAN ENDEAVOR

- Women and men of various social and ethnic backgrounds—and with diverse interests, talents, qualities, and motivations—engage in the activities of science, engineering, and related fields such as the health professions. Some scientists work in teams, and some work alone, but all communicate extensively with others.

NATURE OF SCIENCE

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. Those ideas are not likely to change greatly in the future. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.

GRADES 9-12

SCIENCE AS A HUMAN ENDEAVOR

- Individuals and teams have contributed and will continue to contribute to the scientific enterprise. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question or technological problem. Pursuing science as a career or as a hobby can be both fascinating and intellectually rewarding.

NATURE OF SCIENTIFIC KNOWLEDGE

- Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public. Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific.

NATIONAL SCIENCE EDUCATION STANDARDS

	K-4	5-8	9-12
UNIFYING CONCEPTS & PROCESSES	*Systems, order, and organization* *Evidence, models, and explanation* *Constancy, change, and measurement*		
EARTH & SPACE SCIENCE	***CHANGES IN THE EARTH & SKY*** *Rapid changes, weather, measurement – temperature, wind direction*	***STRUCTURE OF THE EARTH SYSTEM*** *Atmosphere, clouds, atmospheric movement*	***ENERGY IN THE EARTH SYSTEM*** *Heating of atmosphere, air currents*
SCIENCE & TECHNOLOGY	*Questions about the world, tools to help answer questions, scientists work in teams*	*Reciprocity between science and technology, unintended consequences, constraints*	*Process of research, motivations, risk and reward*
SCIENCE IN PERSONAL & SOCIAL PERSPECTIVE	***CHANGES IN ENVIRONMENTS*** *Some are natural, Some are rapid* ***LOCAL CHALLENGES*** *Inventing new ways to address local challenges*	***NATURAL HAZARDS*** *Storms* ***RISKS & BENEFITS*** *Tornadoes* ***SCIENCE & TECHNOLOGY IN SOCIETY*** *Research funding, Settings, Ethics*	***PERSONAL & COMMUNITY HEALTH*** *Hazards* ***NATURAL AND HUMAN-INDUCED HAZARDS*** *Severe weather, Risk*
HISTORY & NATURE OF SCIENCE	***SCIENCE AS A HUMAN ENDEAVOR*** *Men & Women, Never be finished, Devote their lives, Great pleasure*	***SCIENCE AS A HUMAN ENDEAVOR*** *Diversity, Collaboration, Intellectual honesty, Tolerance, Skepticism* ***NATURE OF SCIENCE*** *Observation, Experimentation, Models, Debate*	***SCIENCE AS A HUMAN ENDEAVOR*** *Individuals & teams, Ethical traditions* ***NATURE OF SCIENTIFIC KNOWLEDGE*** *Criteria, Criticism*

TORNADO ALLEY

www.tornadoalleymovie.com

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GIANT SCREEN FILMS

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