Grade 6: Plants vs. Climate: Who Wins?

Stage 1 – Desired Results

Outcomes and Indicators:

Identify the role of scientific protocols in research by participating in a study of plant phenology within the school's geographic region.

Investigate weather patterns by comparing the results with historical records of the area.

Explore the meteorological implications of climate changes and plant life located within an area by initiating a long-term study of selected plants. [NOTE: This study will be continued by future students matriculating through this class and will also be continuing in grades 7 and 8.]

Share new learning by creating a presentation [media, oral, drama, musical] to present to others.

Understandings: *Students will understand that . . .*	**Essential Questions:** *Students will ask such questions as…*
Weather and climate are two related but different factors in determining which type of plants live within an ecosystem. Phenology is the study of periodic biological events (e.g., flowering) in relation to climatic conditions. Scientific protocols are used to maintain consistency and accuracy in reporting results of an investigation. Long-term scientific research can provide clues as to how plants might respond to a changing climate.	What is the difference between weather and climate? How are they related? How does weather affect plants? How does climate affect plants? What will this effect be over time? What plants are native to my area? Why are they important? Do they break bud/bloom/produce seeds at the same time every year? What is a protocol? Why is it used? How is a protocol made? What can I personally do to help scientists learn about my local climate?
Knowledge: *Students will know . . .*	**Skills:** *Students will be able to . . .*
Earth's atmosphere is comprised of layers. Weather occurs in the troposphere. Weather and climate are not the same. Both vary over time. Climate impacts our quality of life. A changing climate will mean that organisms need to adapt or move if they are to survive. Scientific investigations help researchers learn about the natural world via observations, questioning, and experimentation.	Identify factors that account for variations in the distribution of plant life. Make observations and analyze data collected personally and from historical sources. Make inferences based on scientific data. Communicate results of an investigation.

Key Vocabulary

Annual – a plant that flowers, produces seeds, and dies in one growing season

Biennial – a plant that lives for two years and produces flowers and fruits in the second year

Climate – the general pattern of weather in a particular part of the world over a long period of time

Meteorology –the study of earth's atmosphere (a.k.a., "weather")

Native plant – a plant that occurs naturally in a particular region, ecosystem, or habitat without direct or indirect human intervention (generally, plants living here before Europeans arrived). Native plants include all kinds of plants from mosses and ferns to wildflowers, shrubs, and trees. (The US National Arboretum)

Perennial – a plant that lasts for more than two growing seasons, either dying back after each season or growing continuously

Phenology – The study of key seasonal changes in plants and animals from year to year (such as flowering, emergence of insects and migration of birds) – especially their timing and relationship with weather and climate. [National Phenology Network]

Precipitation – water falling from clouds in any form: snow, ice, raindrops, etc.

Protocol – a standard set of procedures to follow when gathering data and communicating information about a scientific inquiry

Qualitative data – any data collected that deals with the description or qualities of a subject (e.g., color, texture, appearance, smell, etc.).

Quantitative data – any data collected that deals with measurable amounts in numbers (e.g., area, time, temperature, humidity, etc.).

Weather – daily atmospheric conditions (e.g., temperature, wind speed, humidity, precipitation, cloud cover, etc.)

Stage 2 – Assessment Evidence

Performance Tasks:

Student log/journals/graphs kept up to date with accurate data, organized so the student may readily extract information

Established protocols used consistently for gathering and recording data and evidence

Frequent *data collection* indicated within journal/log

Presentation to others (individual or group) reflects student initiative and academic growth

Other Evidence:

On-task with questions

Demonstrates enthusiasm for learning

Individual motivation and group cooperation

Stage 3 – Action Plan

Learning Activities:

Engage Guiding question: "What's above our heads?"

Study layers of the Earth's atmosphere, identify characteristics of each, and create a classroom chart to scale.

Explore Guiding question: "What makes weather different from climate?"

Using a Frayer model and descriptions about weather and climate from a variety of scientific websites, students use a jigsaw format to learn the differences between weather and climate.

Extension: Set up a basic weather station at your school for on-site data collection.

Explain Guiding question: "Is the weather always the same on my birthday?"

Research historic birthday records from the year of birth to the present, to see how weather data may have varied over one's lifetime. The Farmer's Almanac website allows you to view weather reports back to 1945 and you can select the closest zipcode to where students were born. http://farmersalmanac.com/weather-history/.

Questions to consider:

1. What weather conditions have I enjoyed on my birthdays?
2. What causes the weather to be different on the same date, from year to year?

Extension: Explore the RainLog website

Extension: Participate in RainLog data collection

Extension: Invite a guest speaker from the National Weather Service

Elaborate Guiding question: "How do weather and climate affect plant life in this area?"

Citizen Science: Participate in a long-term phenology project of native plants in your region. Begin long-term research project in cooperation with, and under the direction of, The Arboretum at Flagstaff.

Extension: Arrange a field trip to The Arboretum at Flagstaff

Evaluate Guiding question: "What does the future hold for plants and our changing climate?"

Students create products or presentations to demonstrate their new knowledge incorporating material from the previous lessons.

Plants vs. Climate: Who Wins?

Grade 6: Arizona Academic Standards, Framework for K-12 Science Education, and Climate Literacy Principles

Framework for K-12 Science Education

Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

5. Energy and matter: Flows, cycles, and conservation
7. Stability and change

Disciplinary Core Ideas

Life Sciences

LS2: Ecosystems: Interactions, energy, and dynamics

LS4: Biological evolution: Unity and diversity [adaptation]

Earth and Space Science

ESS2.D: Weather and Climate

ESS3.C: Human Impacts on Earth Systems

ESS3.D: Global Climate Change

Arizona Academic Standards

Science

Inquiry

S1C1PO3 Locate research information, not limited to a single source, for use in the design of a controlled investigation.

S1C2PO4 Perform measurements using appropriate scientific tools (e.g., balances, microscopes, probes, micrometers).

S1C2PO5 Keep a record of observations, notes, sketches, questions, and ideas using tools such as written and/or computer logs.

S1C3PO1 Analyze data obtained in a scientific investigation to identify trends.

S1C3PO3 Evaluate the observations and data reported by others.

S1C3PO4 Interpret simple tables and graphs produced by others.

S1C3PO6 Formulate new questions based on the results of a completed investigation.

S1C4PO2 Display data collected from a controlled investigation.

S1C4PO3 Communicate the results of an investigation with appropriate use of qualitative and quantitative information.

S1C4PO5 Communicate the results and conclusion of the investigation.

History and Nature of Science

S2C2PO3 Apply the following scientific processes to other problem solving or decision making situations:

- Observing
- Questioning
- Communicating
- Organizing data
- Inferring
- Identifying variables
- Predicting

NOTE: Classifying and generating hypothesis are a part of this PO but are not addressed in this lesson.

Climate Literacy: The Essential Principles of Climate Science

1. The sun is the primary source of energy for Earth's climate system.

3. Life on Earth depends on, is shaped by, and affects climate.
   A. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish.
   B. The presence of small amounts of heat-trapping greenhouse gases in the atmosphere warms Earth's surface, resulting in a planet that sustains liquid water and life.

4. Climate varies over space and time through both natural and man-made processes.
   A. Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location. Climate descriptions can refer to areas that are local, regional, or global in extent. Climate can be described for different time intervals, such as decades, years, seasons, months, or specific dates of the year.
   B. Climate is not the same thing as weather. Weather is the minute-by-minute variable condition of the atmosphere on a local scale. Climate is a conceptual description of an area's average weather conditions and the extent to which those conditions vary over long time intervals.

	Life Science S4C1PO1 Explain the importance of water to organisms. S4C3PO1 Explain that sunlight is the major source of energy for most ecosystems. S4C3PO2 Describe how the following environmental conditions affect the quality of life: • climate **NOTE**: Water quality, population density, and smog are a part of this PO but are not addressed in this lesson. **Earth and Space Science** S6C2PO1 Describe the properties and the composition of the layers of the atmosphere. S6C2PO5 Analyze the impact of large-scale weather systems on the local weather. **AZ College and Career Readiness Standards - ELA** Key Ideas and Details • Cite specific textual evidence to support analysis of science and technical texts. **(6-8.RST.1)** • Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. **(6-8.RST.3)** Craft and Structure • Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics.* **(6-8.RST.4)** Integration of Knowledge and Ideas Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). **(6-8.RST.7)** **Math: Ratios and Proportional Relationships (RP)** **Understand ratio concepts and use ratio reasoning to solve problems.** 6.RP.A.1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. [chart depicting the atmospheric layers] *Math: Statistics and Probability (SP)*	

	Develop understanding of statistical variability. 6.SP.A.1. Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. [In lesson: variability in weather on the date of one's birth] 6.SP.A.2. Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape. 6.SP.A.3. Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number. **Summarize and describe distributions.** 6.SP.B.5. Summarize numerical data sets in relation to their context, such as by: a. Reporting the number of observations. b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered. d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered. **Standards for Mathematical Practice (MP)** 6.MP.2. Reason abstractly and quantitatively. 6.MP.3. Construct viable arguments and critique the reasoning of others. 6.MP.5. Use appropriate tools strategically.	

Plants vs. Climate: Who Wins?

Materials Required – Grade 6

Websites*:*

- http://www.windows2universe.org/earth/Atmosphere/layers.html ("Windows to the Universe", National Earth Science Teachers Association)
- http://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.behttp://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.be (differences between weather and climate)
- http://www.srh.noaa.gov/jetstream/synoptic/wxmaps.htm#draw (surface weather maps)
- http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html (NOAA - weather "averages")
- www.rainlog.org (Citizen Science project for RainLog – precipitation records for AZ)
- https://www.usanpn.org/nn/species_search (National Phenology Network)
- http://www.sega.nau.edu (Southwest Experimental Garden Array at Northern Arizona University)
- http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff (SEGA weather data)

Books/media:

- How We Know What We Know about Our Changing Climate, Lynne Cherry and Gary Braasch, p. 10-11
- ScienceSaurus: A Student Handbook, Grade 6-8 by GREAT SOURCE, p. 212-230 (optional)

Photocopies:

- Frayer model – weather and climate (1 copy of each page/student)
- "Chain Reaction: Weather" (page 6) 1 copy/every 2-4 students)

For the following, *divide the class into six groups. The number of copies needed will be determined by the number of students. If you have 30 students, make 5 copies of each handout.* [See the "Weather-Climate" folder])

- Climate Impacts Group
- Diffen
- NSIDC (National Snow and Ice Data Center)
- NASA (National Atmospheric and Space Administration)
- UCAR (University Corporation for Atmospheric Research)
- NOAA (National Oceanic and Atmospheric Administration)

Art supplies:

- Butcher paper and art supplies (for atmospheric chart and for final presentation)

Science equipment:

- Weather station items (optional): thermometer, hygrometer, Beaufort scale

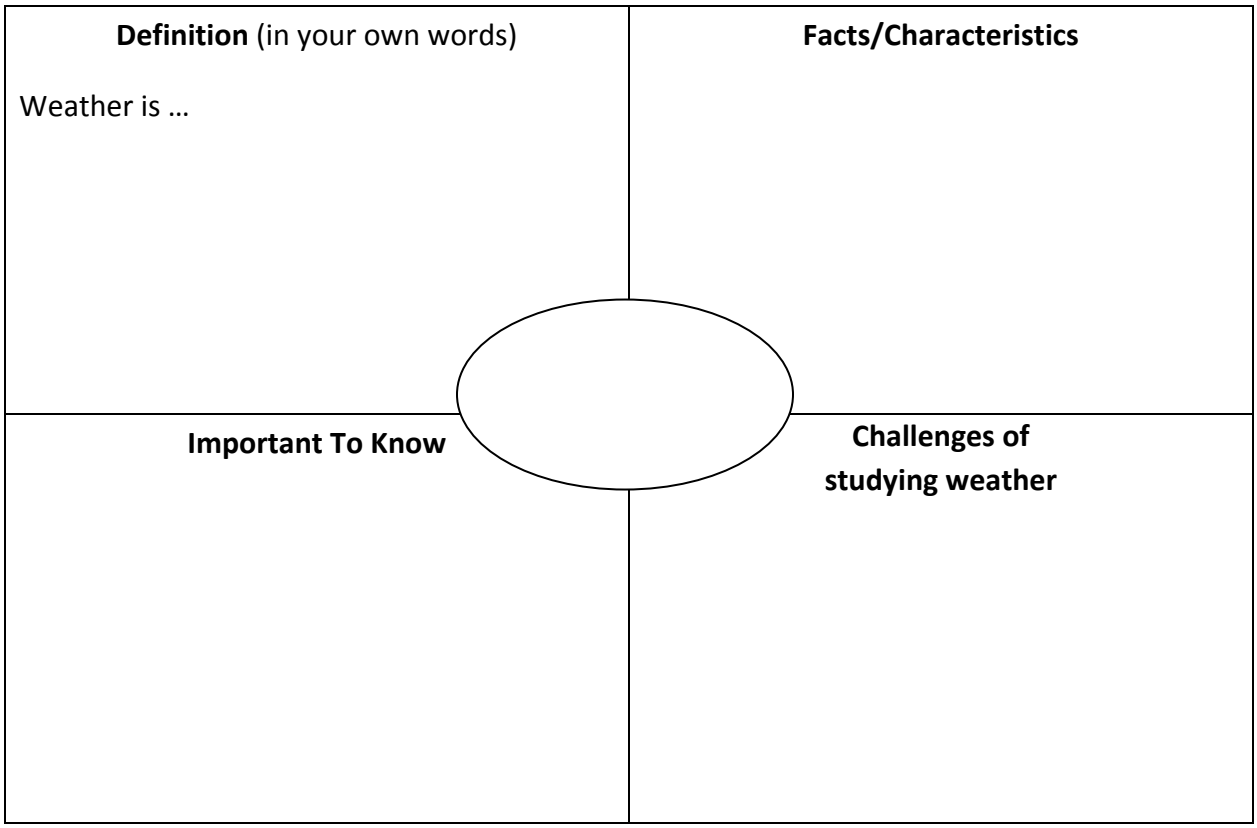
Miscellaneous:

- Journals for students [**or** add to science notebooks if already being used]
- Document camera, computer and media projector (if available)
- Adhesive tape and glue, markers/crayons

Rubric: Final Product or Presentation – Grade 6

Indicator	4: Exceeds expectations	3: Meets expectations	2: Approaches expectations	1: Falls short of expectations
Scientific Accuracy	All content is scientifically accurate, used in proper context, and supports the overall theme of the product or presentation. No obvious errors are evident.	Most content is scientifically accurate, used in proper context, and supports the overall theme of the product or presentation. Some errors may be present.	Little attention to scientific accuracy, with numerous factual errors and/or omissions.	No attention to scientific accuracy. Information presented is biased and lacks a scientific basis.
Understanding of Key Vocabulary	At least 5 key vocabulary words from the lesson are incorporated into the product or presentation and are used accurately. Students demonstrate a thorough understanding of each word.	4 key vocabulary words from the lesson are incorporated into the product or presentation and are used accurately. Students demonstrate a thorough understanding of each word.	2 or 3 key vocabulary words from the lesson are incorporated into the product or presentation and are used accurately. Students demonstrate a basic understanding of each word.	One or no key vocabulary words from the lesson are incorporated into the product or presentation but may be used inaccurately. Students demonstrate little understanding of each word.
Audience Appeal	Product/presentation is highly engaging to the audience: visually appealing, creative, and includes audience interaction when feasible.	Product/presentation is engaging to the audience: visually appealing, creative, and may include audience interaction when feasible.	Product/presentation does little to engage the audience. May lack visual appeal, creativity, and/or indicates a lack of preparation.	Product/presentation does not engage the audience. Lacks visual appeal and creativity. Demonstrates a lack of forethought and preparation.
Team Effort	All members of the group participate equally in designing, developing, and delivering the product or presentation.	Most members of the group participate equally in designing, developing, and delivering the product or presentation.	Few members of the group participate equally in designing, developing, and delivering the product or presentation.	One member of the group carries the assignment by designing, developing, and delivering the product or presentation without benefit of other group members.

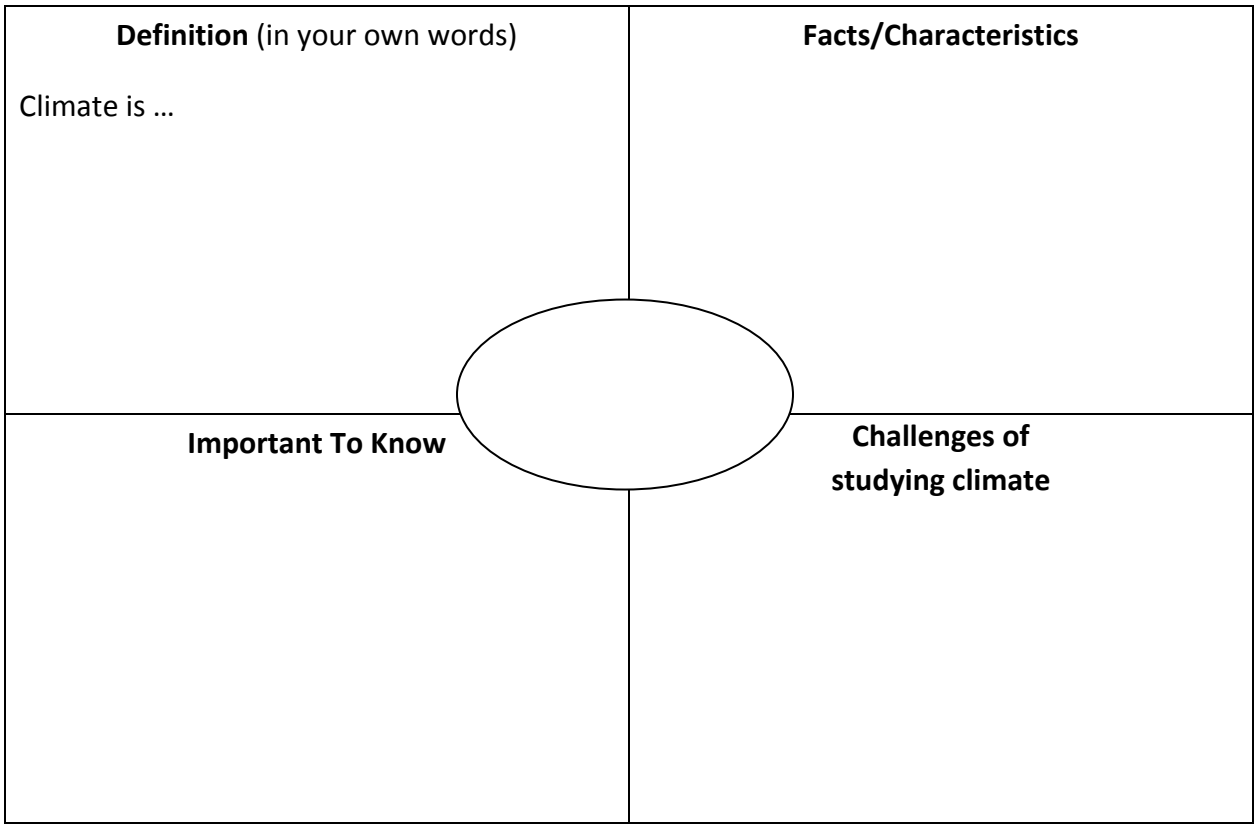
What is WEATHER?



Essential Questions

- How accurate was my original definition?
- What did I learn about weather?
- How important is weather to plants? To Flagstaff?
- What challenges are there in studying weather?

What is CLIMATE?



Essential Questions

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- What did I learn about climate?
- How important is climate to plants? To Flagstaff?
- What challenges are there in studying climate?

Grade 6: Plants vs. Climate: Who Wins?

Subject & Topics

Science, ACCR: layers of the atmosphere, weather and climate, phenology, scientific investigations, protocols

Arizona Academic Standards for Science are correlated to each segment of this lesson and may be found at the end of this document.

Framework for K-12 Science Education (from NGSS - http://nextgenscience.org/next-generation-science-standards)

This series of lessons for grade 6 correlaties to:

Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

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7. Stability and change

Disciplinary Core Ideas

Life Sciences

LS2: Ecosystems: Interactions, energy, and dynamics

LS4: Biological evolution: Unity and diversity [adaptation]

Earth and Space Science

ESS2.D: Weather and Climate

ESS3.C: Human Impacts on Earth Systems

ESS3.D: Global Climate Change

Objectives

1. Create a classroom chart of layers of the atmosphere and what happens within each, focusing special attention on the troposhere and the stratosphere.
2. Complete Frayer models of weather and climate and discuss, reflect, and clarify knowledge of both.
3. Research historic meteorological data for one's birthday, from year of birth to the present.
4. Begin a study of phenology of native plants on school grounds and/or at The Arboretum at Flagstaff and follow established scientific protocols while gathering data and recording observations. (**NOTE**: this project will initiate a long-term phenological research project in conjunction with The Arboretum at Flagstaff.)
5. Create presentations (oral, media, drama) to demonstrate new learning to the class or other audience.

Evidence of Mastery

Student log/journals/graphs kept up to date with accurate data, organized so the student may readily

extract information

Established protocols used consistently for gathering and recording data and evidence

Frequent *data collection* indicated within journal/log

Presentation to others (individual or group) reflecting student initiative and academic growth

Active *participation* in small-group assignments

Key vocabulary

Annual – a plant that flowers, produces seeds, and dies in one growing season

Biennial – a plant that lives for two years and produces flowers and fruits in the second year

Climate – the general pattern of weather in a particular part of the world over a long period of time.

Meteorology –the study of earth's atmosphere (a.k.a., "weather").

Native plant – a plant that occurs naturally in a particular region, ecosystem, or habitat without direct or indirect human intervention (generally, plants living here before Europeans arrived).

Perennial – a plant that lasts for more than two growing seasons, either dying back after each season or growing continuously

Phenology – The study of key seasonal changes in plants and animals from year to year (such as flowering, emergence of insects and migration of birds) – especially their timing and relationship with weather and climate. [National Phenology Network]

Precipitation – water falling from clouds in any form: snow, ice, raindrops, etc.

Protocol – a standard set of procedures to follow when gathering data and communicating information about a scientific inquiry.

Qualitative data – any data collected that deals with the description or qualities of a subject (e.g., color, texture, appearance, smell, etc.).

Quantitative data – any data collected that deals with measurable amounts in numbers (e.g., area, time, temperature, humidity, etc.).

Weather – daily atmospheric conditions (e.g., temperature, wind speed, humidity, precipitation, cloud cover, etc.)

Materials

Websites:

- http://www.windows2universe.org/earth/Atmosphere/layers.html ("Windows to the Universe", National Earth Science Teachers Association)
- http://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.behttp://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.be (differences between weather and climate)
- http://www.srh.noaa.gov/jetstream/synoptic/wxmaps.htm#draw (surface weather maps)
- http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html (NOAA - weather)
- www.rainlog.org (Citizen Science project for RainLog – precipitation records for AZ)
- https://www.usanpn.org/nn/species_search (National Phenology Network)
- http://www.sega.nau.edu
- http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff (SEGA weather data)

Books/media:

- How We Know What We Know about Our Changing Climate, Lynne Cherry and Gary Braasch, p. 10-11
- ScienceSaurus: A Student Handbook, Grade 6-8 by GREAT SOURCE, p. 212-230 (optional)

Photocopies:

- Frayer model – weather and climate (1 copy of each page/student)
- *Phenology in Your Backyard* Guide
- "Chain Reaction: Weather" (page 6) 1 copy/every 2-4 students)

For the following, *divide the class into six groups. The number of students will determine*

	the number of copies needed. If you have 30 students, make 5 copies of each handout. • Climate Impacts Group • Diffen NSIDC (National Snow and Ice Data Center) • NASA (National Atmospheric and Space Administration) • UCAR (University Corporation for Atmospheric Research) • NOAA (National Oceanic and Atmospheric Administration) • NSIDC (National Snow and Ice Data Center) **Art supplies:** • Butcher paper and art supplies (for atmospheric chart and for final presentation) **Science equipment:** • Weather station items (optional): min/max thermometer, anemometer, barometer **Miscellaneous**: • Journals for students [**or** add to science notebooks if already being used] • Document camera (if available) • Computer and media projector (if available) • Adhesive tape and glue

Engage

Guiding question*:* "What's above our heads?"

Prepare:

1. Use a document camera to present page 6 of the Chain Reaction "Weather" issue **OR** provide 1 copy of this page for small groups of students (2-4 per group).
2. Gather art supplies: butcher paper and markers for the atmospheric chart.
3. Review the "Windows to the Universe" and the weather-climate differences websites: http://www.windows2universe.org/earth/Atmosphere/layers.html and http://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.behttp://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.be

NOTE: *ScienceSaurus* 6-8 (p. 212-230) is also an excellent reference, but students may need to be introduced to the metric system if this resource is used.

Present:

Ask students the guiding question: "What's above our heads?" Allow them to share their responses, making note of all ideas presented.

Using page 6 (Chain Reaction) and the Windows to the Universe website, ask students to identify the

layers of the atmosphere, paying particular attention to the troposphere and the stratosphere. Ask:

1. Why do you think that one source cites four layers of the atmosphere while another cites five? [*Scientific observations are based upon clear evidence and are made by humans. They may not always agree on how that evidence and information should be presented*.]
2. Is this significant? Why or why not? [*In this case, it is generally accepted that there are five layers of atmosphere, but not all scientists agree. It is important to know that there are different ways of looking at the world*.]
3. Why might scientists sometimes disagree on such issues? [*Some prefer to separate evidence as much as possible, while others prefer to "lump" it together. Scientists themselves refer to the "lumpers" and the "splitters" – especially when it comes to classifying species*.]
4. Does that make one scientist's data less important than another's? [*No. It really depends on the question that is being asked by the investigator*.]

Student activity:

In their journals, students note key characteristics of each layer. Pay special attention to:

- Troposphere (weather happens here, the role of the sun to Earth and the hydrologic cycle)
- Stratosphere (the role of ozone)

By class consensus, students select criteria for each layer and create a classroom chart of these layers. (*The chart should be drawn to scale as much as possible*! Assign small groups to various parts of this chart: one group will determine the amount of space to devote to each layer, while other groups are assigned a specific layer.) Post chart for the duration of this lesson.

Explore

Guiding question: "What makes weather different from climate?"

Prepare:

1. Copy Frayer model worksheets for students.
2. Divide class into six working groups.

Present:

Distribute a copy of the Frayer models to each student. Students write "WEATHER" or "CLIMATE" in the appropriate ovals. (These will be cut out when completed and glued into the student's journal.)

Ask: What is *weather?* What is *climate?* As a class, discuss the respective models and ask students to complete what they *think* they know.

Student activity:

Divide the class into six groups and distribute copies of the six different "Weather-Climate" documents to each group, making sure that all students in the same group have the same sheet but **only** that sheet. (You may need to explain that "meteorology" is the scientific word for the study of weather.) Allow approximately 10-15 minutes for each group to read and discuss its information, and prepare to share key aspects of that information with others. Encourage students to use their Frayer models to make notes as each of them will be sharing their group's information with others.

Number off every student in each sub-group (numbers 1-6) and ask the class to rearrange themselves so that those with #1 are together, those with #2 are together, etc. In their new groups, students will share what they learned about the differences between weather and climate. Plan to spend 15 minutes for this segment. You may find it helpful to allocate 10 minutes for the sharing of information from each group, followed by 5 minutes of discussion within that group. [Any discrepancies will be resolved via a

class discussion later.]

When all groups have finished, revisit the Frayer models they initiated earlier.

Ask:

1. What is weather? What is climate?
2. What is the advantage of using more than one scientifically valid resource when studying an issue?

Students should make any corrections to their Frayer models at this time and glue their final pages into their journals. (Remind them that it is okay not to have a "perfect" paper in their journals: there will likely be some crossing out and erasing – and that is what science is all about! We learn as we go, refining our focus and revising our work as we uncover more information.)

As a class, watch the brief (1:04 minutes) video depicting the difference between weather and climate. http://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtube

Extension: Set up a basic weather station on your school campus and have students record daily temperatures (min/max thermometers are helpful for this), wind speed*, relative humidity, cloud cover. Compare their data with that of an established weather station. The Arboretum at Flagstaff has been an official NOAA weather station for over 30 years. Our station number is 023009, and our name is Flagstaff 4 SW,AZ US. You can search by station number or zip code. The website for the NOAA data is: http://www.ncdc.noaa.gov/cdo-web/. In 2015, the Southwest Experimental Garden Array (SEGA) will launch a state-of-the-art weather station at The Arboretum and nine other locations across northern Arizona. Data can be accessed here: http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff.

*Wind speed may be measured with an anemometer. If funding is not avialable, consider using the Beaufort Scale to enhance critical observations of the immediate environment. Visit http://www.spc.noaa.gov/faq/tornado/beaufort.html for a chart that is readily useable with students. Demonstrate how to convert "knots" to "miles per hour" at http://www.disastercenter.com/convert.htm which also includes the Beaufort Scale .

Explain

Guiding question: "Is the weather always the same on my birthday?"

Prepare:

- Computer with a media projector (or Smart Board) is preferable for this activity. (If unavailable, bring in sample weather forecasts from the daily newspaper – preferably ones that indicate isobars and/or other meteorological conditions.)

Present:

Ask the following questions to launch a class discussion:

1. What weather conditions have we each enjoyed on our birthdays?
2. What affects local weather? [See *ScienceSaurus: A student handbook*]

Use student responses to help them understand that weather is what's "happening above our heads", is variable from year to year, and is dependent upon many variables. Refer to the classroom atmospheric layers chart to identify where weather happens.

Display http://www.srh.noaa.gov/jetstream/synoptic/wxmaps.htm#draw to have students become aware of how meteorologists use surface weather maps to "plot" the weather for a specific place and

time.

Student activity:

Students will research historic records for their birth year to see what weather data they can find for that date in history. (They should look for meteorological records in their school area, whether or not this is where they were born). What other weather records can they find for their birth date? Encourage them to record the weather information for every year in a table, chart, or graph format. Share their information with the class by making a classroom graph of means, highlighting any major differences in their research. (**Note**: This is an excellent opportunity to incorporate the math standards for such concepts as range, mean, median. Include a variety of methods to represent their data. Refer to Math standards for guidance OR work with your math teacher to assist in reinforcing this learning.)

You can suggest the following website to students to help them find this information: http://farmersalmanac.com/weather/ (you can enter dates back to 1945 and search by location)

Questions to review/consider:

- What weather conditions have occurred on my birthdays?
- What causes the weather to be different in the same place, on the same date, from year to year? (Focus on the information gleaned during the Explore lesson.)
- Considering all the data collected by the class, do there appear to be any trends with the local weather? (CAUTION! It is important for students to understand that *geologic time* is vastly different from the time they mark with each passing day. Their collective data represent one very brief snapshot in time and should not be considered to be an indicator of whether or not climate change is occurring in your area. Nonetheless, this is a tool that scientists use to consider climate over geologic time.)

Fun fact: Do you know how the "average" daily temperature is computed? [NOAA updates this information every 30 years. This was last done at the end of 2010. See http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html for details.] When we see a TV weather person state the "average" temperature for today, they are referring to a 30-year window of time…far longer than any 6th grade student has been on the planet!

Extension*:* Visit the website for the RainLog project at www.rainlog.org and see where the nearest RainLogger might be. Explore that site to learn what precipitation is being recorded in AZ for the past few years and compare data from Flagstaff with that of other sites around the state.

Extension: Become a RainLogger! The RainLog site explains how to become a rain logger, describes the type of rain gauge needed, reviews protocols, and shows how you record your data. It also produces a summary of the weather patterns that have been monitored throughout the state for the previous month, as well as any long-term predictions (e.g., the development of El Niño or La Niña).

Extension: Invite a guest speaker from the National Weather Service (NWS) to come and give a presentation. Many NWS staff members are available year-round to provide this service.

Elaborate

Guiding question: "How do weather and climate affect plant life in this area?"

Initiate a research project [plant phenology in your area].

Prepare:

- Review the National Phenology Network (NPN) website: https://www.usanpn.org/nn/species_search
- Review "Phenology in Your Backyard", a guide to developing your own phenology garden, developed by The Arboretum at Flagstaff. This guide will include plant species lists for Flagstaff, AZ. Contact the Director of Research at The Arboretum for assistance with plant identification in your school environment.

Present:

Read *Inspired by Students 100 years ago, Today's Students Record the Seasons* (How We Know… pages 10-11) using a document camera. (If a camera is not available, read the information to the class.)

Initiate a class discussion on how they can participate as Citizen Scientists.

- What are some of the plants we might observe? (Use the list from The Arboretum at Flagstaff, extracted from the National Phenology Project.)
- What are some special adaptations of the plant(s) we will be researching? How do those help that plant survive in the local environment? How does the availability of water impact where a plant lives? How does the climate of our area impact what lives here?
- When scientists engage in research, what "rules" do they need to follow to ensure their data/evidence is correct? (Introduce the term "scientific protocol" and see if students can identify ways that their data will be accurate, consistent, able to be corroborated, and publishable.)

Student activity:

Launch your investigation! Participate in citizen science using established protocols for collecting and recording data. [*Reminder to teachers: this is intended to be a long-term project that will eventually help scientists discern long-term trends in weather patterns for your area. Students should not be encouraged to draw conclusions based upon observations created during one academic year. Nonetheless, they should remember that the observations made by Canadian students 100 years ago has provided evidence from which scientists today can make valid comparisons. Their work will be important!]*

The Arboretum staff will assist with helping you establish your research project, including working with protocols to use with your students, identifying the various stages of a plant's phenology (in addition to what is available on the National Phenology Network website), and how/where/when to post data.

Extension: Arrange a field trip to The Arboretum at Flagstaff to see the SEGA weather station, a phenology garden, and the I-STEM Learning Center.

Evaluate

Guiding question*:* "What might the future hold for plants and our changing climate?"

Prepare:

- Assemble any supplies students may need for creating visuals (if desired) for a final presentation.

Present:

(You may ask each individual student to create a final presentation OR may have them continue to work in their small groups.) Provide guidance as necessary for this culminating activity. Allow students the opportunity to be as creative as possible as they reflect on this guiding question and pull together what

they learned. The following questions may be helpful:

1. How do weather and climate impact the capacity of an organism to survive long-term?
2. What local plant adaptations help them survive in this area? What predictions might we make about their future if the area becomes warmer and drier?
3. How can I help contribute to scientific research? What will help ensure that my work is valid and reliable?
4. How might scientists 100 years from now use our research?

Student activity:

Students create presentations to demonstrate their new learning. Use the rubric to assess students' products.

Closure:

Revisit the question: "Plants vs. Climate: Who Wins?" Each small group of students creates a 12-18 word bumper sticker that summarizes their group's response. Post on classroom walls.

Standards Addressed in Each Lesson

(Refer to "Overview" for complete text of all standards cited. ACCR is the Arizona College and Career Readiness Standards, aka "Common Core".)

ENGAGE – Science	**ENGAGE – ACCR**	**ENGAGE – Math**	**ENGAGE – Technology**
S1C1PO3 S1C2PO5 S1C4PO3 and PO5 S2C2PO3 S4C3PO2 S6C2PO1	6-8.RST.1 6-8.RST.4 6-8.RST.7	6.RP.A.1	S1C1PO1
EXPLORE – Science	**EXPLORE – ACCR**	**EXPLORE – Math**	**EXPLORE – Technology**
S1C2PO5	6-8.RST.1 6-8.RST.4	None	S1C1PO1 S2C2PO1
EXPLAIN – Science	**EXPLAIN – ACCR**	**EXPLAIN – Math**	**EXPLAIN – Technology**
S1C1PO3 S1C3PO3, PO4, PO6 S1C4PO3 and PO5 S6C2PO5 (if using regional or national weather maps)	6-8.RST.1 6-8.RST.4 6-8.RST.7	6.SP.A.1 6.SP.A.2 6.SP.A.3 (aggregation of class data) 6.SP.B.5	S1C3PO1
ELABORATE – Science	**ELABORATE – ACCR**	**ELABORATE – Math**	**ELABORATE – Tech.**
S1C1PO3 S1C2PO4 and PO5 S1C3PO3, PO4, and PO6 S1C4PO2, PO3, and PO5 S2C2PO3	6-8.RST.3, RST.4, and RST.7	6.RP.A.1 6.SP.B.5 6.MP.2, 3, and 5	S1C1PO1 S1C3PO1 S1C4PO2 S2C2PO1 S5C2PO1

S4C1PO1 S4C3PO2			S5C3PO1 S6C1PO3
EVALUATE – Science S1C4PO5	**EVALUATE – ACCR** None	**EVALUATE – Math** None	**EVALUATE – Tech.** S1C4PO2 S2C2PO1 S5C2PO1 S6C1PO3

Standards

Science: Strand 1 - Inquiry

C1 **Observations, Questions, and Hypotheses:** Formulate predictions, questions, or hypotheses based on observations. Locate appropriate resources.

PO 3. Locate research information, not limited to a single source, for use in the design of a controlled investigation.

C2 **Scientific Testing (Investigating and Modeling):** Design and conduct controlled investigations.

PO 4. Perform measurements using appropriate scientific tools (e.g., balances, microscopes, probes, micrometers).

PO 5. Keep a record of observations, notes, sketches, questions, and ideas using tools such as written and/or computer logs.

C3 **Analysis and Conclusions:** Analyze and interpret data to explain correlations and results; formulate new questions.

PO 1. Analyze data obtained in a scientific investigation to identify trends.

PO 3. Evaluate the observations and data reported by others.

PO 4. Interpret simple tables and graphs produced by others.

PO 6. Formulate new questions based on the results of a completed investigation.

C4 **Communication**: Communicate results of investigations.

PO 2. Display data collected from a controlled investigation.

PO 3. Communicate the results of an investigation with appropriate use of qualitative and quantitative information.

PO 5. Communicate the results and conclusion of the investigation.

Science: Strand 2 - History and Nature of Science

C2 **Nature of Scientific Knowledge**: Understand how science is a process for generating knowledge.

PO3. Apply the following scientific processes to other problem solving or decision making situations:

- Observing
- Questioning
- Communicating
- Organizing data
- Inferring
- Identifying variables
- Predicting

NOTE: Classifying and generating hypothesis are a part of this PO but are not addressed in this lesson.

Science: Strand 4 - Life Science

C1 **Structure and Function in Living Systems:** Understand the relationships between structures and functions of organisms.

PO 1. Explain the importance of water to organisms.

C3 **Populations of Organisms in an Ecosystem:** Analyze the relationships among various organisms and their environment.

PO 2. Describe how the following environmental conditions affect the quality of life:

- climate

NOTE: Water quality, population density, and smog are a part of this PO but are not addressed in this lesson.

Science: Strand 6 - Earth and Space Science

C2 **Earth's Processes and Systems:** Understand the processes acting on the Earth and their interaction with the Earth systems.

PO 1. Describe the properties and the composition of the layers of the atmosphere.

PO 5. Analyze the impact of large-scale weather systems on the local weather.

AZ College and Career Readiness Standards

Key Ideas and Details

- Cite specific textual evidence to support analysis of science and technical texts. **(6-8.RST.1)**
- Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. **(6-8.RST.3)**

Craft and Structure

- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics.* **(6-8.RST.4)**

Integration of Knowledge and Ideas

- Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). **(6-8.RST.7)**

Math: Ratios and Proportional Relationships (RP)

Understand ratio concepts and use ratio reasoning to solve problems.

6.RP.A.1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. [chart depicting the atmospheric layers]

Math: Statistics and Probability (SP)

Develop understanding of statistical variability.

6.SP.A.1. Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. [In lesson: variability in weather on the date of one's birth]

6.SP.A.2. Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

6.SP.A.3. Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.

Summarize and describe distributions.

6.SP.B.5. Summarize numerical data sets in relation to their context, such as by:

a. Reporting the number of observations.
b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement
c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.
d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.

Standards for Mathematical Practice (MP)

6.MP.2. Reason abstractly and quantitatively.

6.MP.3. Construct viable arguments and critique the reasoning of others.

6.MP.5. Use appropriate tools strategically.

Technology

Creativity and Innovation

S1C1PO1 Analyze information to generate new ideas and products.

S1C3PO1 Identify patterns and trends to draw conclusions and forecast possibilities.

S1C4PO2 Use digital collaborative tools to analyze information to produce original works and express ideas.

Communication and Collaboration

S2C2PO1 Communicate and collaborate for the purpose of producing original works or solving problems.

Digital Citizenship

S5C2PO1 Promote digital citizenship by consistently leading by example and advocating social and civic responsibility to others.

S5C3PO1 Research a current technology and describe its potential use to solve an economic, environmental, health, political, scientific, or social problem.

Technology Operations and Concepts

S6C1PO3 Choose technology applications appropriate for the audience and task.

ChainReAction 6

Keep a watch on:

WEATHER

Stories of Science and Learning from Arizona State University

Starting a storm

Weigh the sky

Hot or not?

Freaky weather

ASU

BUBBLE, BUBBLE, TOIL AND TROUBLE (THAT'S SHAKESPEARE). EVERYWHERE AROUND US THE ATMOSPHERE IS STIRRING, BUBBLING, CHURNING AND FROTHING. WE CALL ALL THAT THRASHING…

WEATHER

ChainReaction

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Chain Reaction:
A series of chemical reactions in which the products of each reaction activate additional molecules of the reactants, thus causing new reactions…

http://chainreaction.asu.edu

Hot enough for you? How about that blizzard last week? We sure could use some rain. Do you think we will ever see the sun again? We've all heard those phrases or similar snippets of conversation. People love to discuss the weather. Talking about the weather is natural. Of course it is! The weather plays a role in how we respond to our environment, and how we live each and every day. Simply defined, weather describes conditions in the atmosphere over short periods of time, usually in terms of hours or days. The term "climate" refers to something much bigger. Climate is defined as the average of weather conditions over a longer period of time—months, years, or thousands of years. Weather and climate shape the world in which we live. Both will help define the future. Want to learn more? Turn the page and start your own personal chain reaction of learning.

Conrad J. Storad, Editor

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Columbus was Lucky
Freaky Weather

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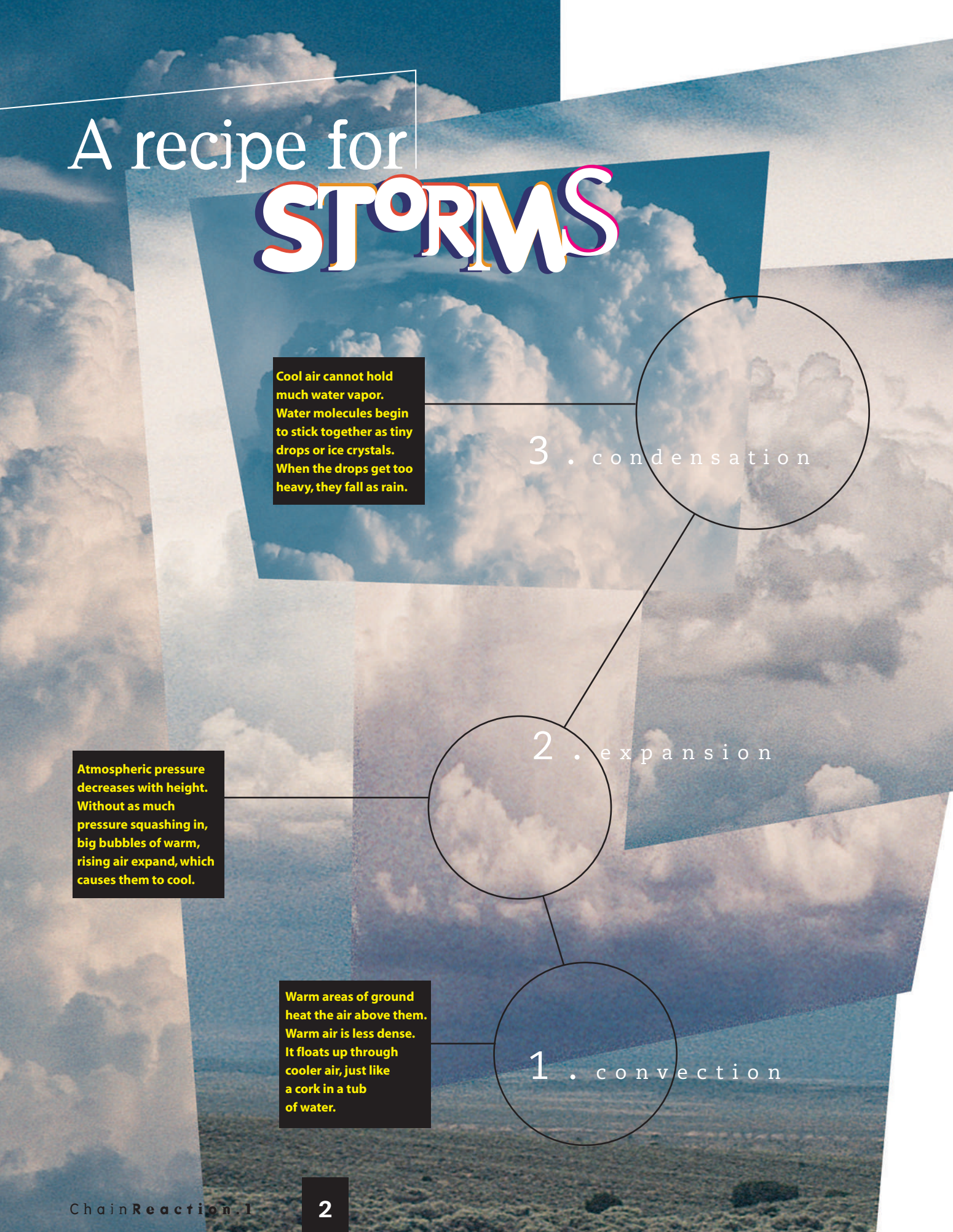
PHOTO: Summer monsoon lightning cracks over the Grand Canyon, seen from Point Sublime on the north rim. Michael Nichols photo.

A recipe for STORMS



Cool air cannot hold much water vapor. Water molecules begin to stick together as tiny drops or ice crystals. When the drops get too heavy, they fall as rain.

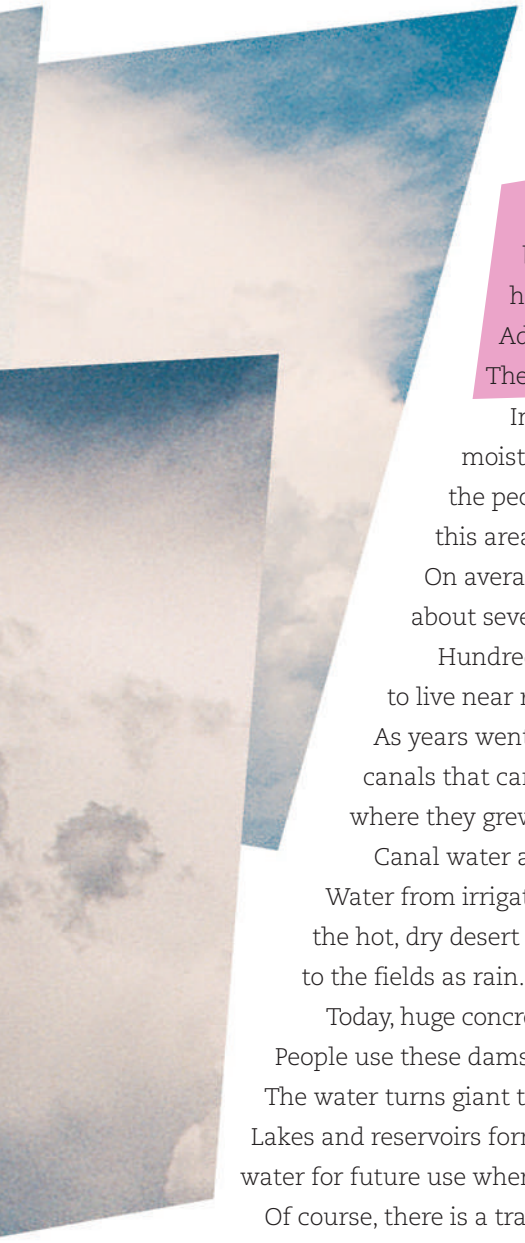
3. condensation

2. expansion

Atmospheric pressure decreases with height. Without as much pressure squashing in, big bubbles of warm, rising air expand, which causes them to cool.

Warm areas of ground heat the air above them. Warm air is less dense. It floats up through cooler air, just like a cork in a tub of water.

1. convection



Thunderstorms are like pots of boiling water. Combine water with heat in exactly the right proportions. Add something to stir the mixture. The result is a thunderstorm.

In Arizona's Salt River Valley, getting moisture used to be a real problem for the people who lived here. Today, we know this area as Phoenix and Maricopa County. On average, the entire Phoenix area gets only about seven inches of rain each year.

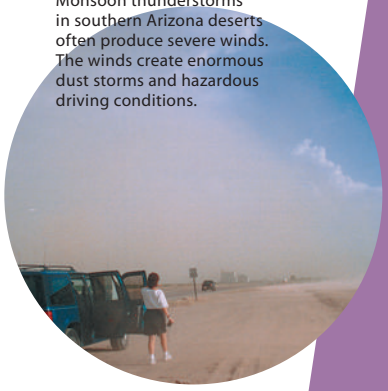
Hundreds of years ago, native people had to live near rivers if they wanted to survive. As years went by, they learned to design and build canals that carried water from the rivers to areas where they grew crops and built homes.

Canal water also helped new rainstorms to form. Water from irrigated fields evaporated quickly into the hot, dry desert air. Eventually, that moisture returned to the fields as rain.

Today, huge concrete dams block many of Arizona's rivers. People use these dams to harness the power of moving water. The water turns giant turbine blades to make electricity. Lakes and reservoirs form behind the dams. The lakes also store water for future use when there is little or no rainfall.

Of course, there is a trade-off. Water is not evenly spread throughout the Phoenix area as it was before the dams were built. Today, Arizona relies on moisture picked up over the Pacific Ocean and Gulf of Mexico to generate rainstorms. That moisture is carried to Arizona by strong wind currents.

Heat is the easiest storm ingredient to find. Arizona gets plenty of heat from a blazing sun that shines nearly every day. During the day, rocks, roads, buildings, and parking lots absorb the sun's heat. In fact, sometimes they absorb so much heat that it actually gets too hot to make a storm. Liquid moisture contained in the air changes to steam before winds can whip up a rainstorm. >>>



Monsoon thunderstorms in southern Arizona deserts often produce severe winds. The winds create enormous dust storms and hazardous driving conditions.

MONSOONS

A monsoon and a thunderstorm are not the same thing. The word monsoon actually comes from an Arabic word which means season—in this case, the summer season.

Arizona's monsoon winds blow from the south during the summer months, bringing air loaded with moisture from the Gulf of California and the Gulf of Mexico. Blend that moisture in exactly the right proportions with heat and wind, and the result is a thunderstorm almost every time.

During the rest of the year, winds blow in to Arizona from the west and northwest. Those winds cause different kinds of thunderstorms.

The longest monsoon season ever in Arizona was in 1984. That year, there were 72 consecutive monsoon days, lasting from June 25 to Sept. 4.

A monsoon requires hot weather and moist air. The dew point, which is the temperature to which air must be cooled for water vapor to condense into water, must be at least 55 degrees Fahrenheit for a true monsoon.

Before the days of television weather forecasters, members of Arizona's Native American tribes said that the monsoons would begin about a week after the cicadas began to sing at night.

Navajo weavers are influenced by the power of Arizona thunderstorms. This rug was made by Rebecca Tso. It is her interpretation of the "storm" pattern.

Dust Devils

Dust devils look like miniature tornadoes. They actually are very different. Tornado winds begin high up in the clouds. Dust devils begin directly on the ground. Dust devils occur when patches of ground get very hot. The hot ground causes air directly above to heat up rapidly as well. The heated air then rises, bangs together, and begins to spin. The result is a whirling column of hot air that sucks up dust and dirt. Dust devils can grow hundreds of feet tall. The fastest dust devils spin at about 40 miles per hour. Not even close to tornado speeds. Tornado winds spin at speeds up to 310 miles per hour.

TORNADOES

Monsoon storms can cause a great deal of wind and rain damage in Arizona. But the most destructive wind of all belongs to the tornado. Arizona rarely gets real tornadoes. Tornadoes usually occur under the jet stream. The jet stream is found high in the sky—at about 36,000 feet—which is where most jet planes fly. The jet stream is a powerful, fast-moving river of air that is similar to the air current that blasts from your portable hair dryer. Inside this stream air jets along at 150 to 200 miles per hour.

Air moving that fast can act like a big vacuum cleaner. It sucks up huge pockets of air from ground level. Combine that force with the right proportions of heat and moisture and tornadoes could result. Tornadoes are also called twisters. That's because air from different directions gets sucked up at the same time. When those currents bang together they can cause the air to twist at up to 310 miles per hour. That's faster than even the fastest Indianapolis 500 cars. No "Indy" car has yet reached speeds of 250 miles per hour.

Microbursts

Although Arizona rarely gets twisters, it does get some microbursts. Microbursts can be just as deadly as twisters. Think of microbursts as air bombs. They're blasts of air that begin high up in the clouds and explode straight down. Microbursts form when raindrops become so heavy that they force the air they are falling through to fall with them. That air can fall at speeds of 90 miles per hour. Air inside normal storms falls at about 10 miles per hour. When microbursts hit the ground, they pick up dust and shoot it out and up. The resulting blast pattern looks similar to that which would be caused by a nuclear bomb.

When water and heat are present in large enough quantities, wind can stir the pot to form a thunderstorm. Hot air rises. Certain structures can make normally gentle air rise fast enough to "stir" the thunder pot. Mountains are one such structure. Rocks and mountains store heat. As a result, mountains and the air around them are usually much hotter than non-rocky areas. Air glides across these non-rocky areas until it bumps into hot mountains. That bump starts the stirring process. Hot mountain air pushes cooler air upward at rapid rates. This is one reason that many Arizona thunderstorms begin in the mountainous Mogollon Rim area northeast of Phoenix.

Local parking lots and small hills can cause smaller rainstorms. During such a storm, for example, it might be raining at your house yet be perfectly sunny at a friend's house located just a half a mile away.

Photos: NOAA; iStock

Bolts from the Sky

Lightning is actually static electricity. Static electricity is very much like the sparks you get when you walk across a carpet and touch something. However, nature creates much more static electricity than all the rugs and carpets in the world combined.

Lightning forms when rain falls through clouds. As rain droplets fall, they tug electrons down through the clouds with them. Electrons are the tiny parts of an atom that have negative electrical charges. Nature likes to maintain a balance. So, when electrons get pulled out of place, nature wants to put them back. That is exactly what lightning does.

Raindrops pull down electrons. But their proton partners get left behind in the upper part of a cloud. Protons are the tiny parts of an atom with a positive electrical charge. Protons and electrons are attracted to one another, just like magnets.

Lightning Flashes

- **Every single second, a hundred bolts of lightning are striking towards the Earth. At any given moment, there are 1,800 thunderstorms in progress all over the world.**
- **The saying "lightning never strikes twice" is not really true. Lightning is very likely to strike the same place twice. Like all electric currents, lightning follows the path of least resistance.**
- **Lightning kills more people around the world than any other natural disaster. An average of 400 people die and 1,000 are injured by lightning every year.**
- **Arizona's mogollon rim area has one of the highest incidences of lightning strikes of any place in the world!**

Fact: A bolt of lightning is charged with about 1 billion volts of electricity. That is enough energy to light a 100-watt bulb for three months.

Photo: Jim Marshall

Lightning occurs when lonely electrons seek out nearby protons to recreate balance. Those protons might be resting at the top of another cloud. They can also form along the ground under the cloud. When protons are pulled from another cloud, the result you see is cloud-to-cloud lightning. But when the protons are pulled up from somewhere on the ground, the result is a lightning strike.

Well, not really. Lightning does not actually "strike" the ground. It stops about 50 feet above the ground. When downward flowing electrons meet upward flowing protons, they complete an electrical circuit. That circuit is much like the connection that forms when you plug in a CD player to an electric outlet and turn on the switch.

Lightning is actually a gigantic flow of electrons through the circuit that is completed in the air. On the ground, the protons closest to the downward flowing electrons will be pulled upward to complete the circuit. Those protons might be part of a tree, or part of a person standing in the middle of a golf course fairway.

Protons are drawn upward from the highest point closest to the electrons. That is why a person should never stand in a field or hide beneath a tree during a thunderstorm.

If you were the highest point closest to the flowing electrons in search of positive partners, the protons inside your body would begin to flow upward. Your hair, which contains protons, would stand straight up on end as those protons reach skyward. About 50 microseconds late—before you could even blink your eye—the circuit would be completed and you would be electrocuted.

LIGHTNING IN A JAR The Leyden Jar was one of the earliest electrical devices. It works in a similar way to the modern device called a capacitor. Early experimenters found they could build up a charge of static electricity in the jar—enough to cause a nasty shock!

Thunder above

If lightning is considered a completed electrical circuit, then what the heck is thunder? Thunder is caused when that electrical circuit—lightning—is formed. Air surrounding a lightning flash is superheated almost instantly. In fact, the air around a lightning bolt is five times hotter than the surface of the sun.

The superheated air expands so quickly that it explodes, just like a bomb. The blast, or shock wave, moves outward from the point of the explosion. That shock wave has a name. It is called thunder.

Because sound travels much more slowly than light, we hear the thunder after we see the lightning's flash.

Higher is hotter?

Temperature is different from heat. Molecules of any substance, like oxygen or nitrogen in the atmosphere, jostle around according to the energy they possess.

Higher temperature means more jostle—like shaking a box of ping-pong balls faster and faster. Temperature tells the speed of molecules as they shake.

Heat is energy. The amount of heat depends on temperature and density—a measure of how heavy the molecules are and how tightly they pack together. Think of the difference between shaking a box of ping-pong balls and a box of marbles.

The air of the thermosphere is thin. Although the temperature is very high in the thermosphere and the molecules are moving fast, there are very few molecules present. If you could stand outside in the thermosphere, 50 miles above the surface of the Earth, you would freeze rather than boil!

CATALYSTS make things happen. They speed up reactions and make some ingredients combine that could not without them.

What is atmosphere?

Atmosphere is the huge blanket of gas that circles the entire Earth. Without it, life as we know it could not exist.

This blanket of gas starts at ground level and stretches 600 miles into the sky. However, most of this life-supporting shell is squashed down into a layer only six miles thick. The top of Mount Everest barely peeks above the edge of this layer.

The remaining 594 miles cannot support life. However, these layers do protect us from the dangers of the sun's radiation. They also protect us from drifting rocks, big hunks of metal, and other bits and pieces of space junk that collide with our planet from time to time.

The atmosphere is made of four different layers. Layer number one is called the troposphere. People, plants, animals, and insects live in the troposphere. It is the layer where all weather occurs.

Scientists who study weather are called meteorologists. They refer to the troposphere as "The Weather Zone." The troposphere begins at ground level and extends six miles up into the sky where it meets with the second layer.

Layer number two is called the stratosphere. The stratosphere begins at the six-mile point and reaches nearly 31 miles into the sky.

A very important layer of atmosphere called ozone is located inside the stratosphere. The ozone layer is very important to all life on Earth. Ozone blocks large amounts of solar ultraviolet radiation from entering the troposphere. Too much solar radiation can harm living things, including people.

The third major layer is the mesosphere. The mesosphere begins 32 miles above the Earth's surface. Temperatures are warmest at the lowest level of the mesosphere and become colder at its highest level.

The thermosphere is the fourth layer and begins 50 miles above the Earth. Temperatures in the thermosphere become hotter and hotter when moving farther away from ground level.

Together, the troposphere, stratosphere, mesosphere, and thermosphere act as a giant safety blanket. They keep the temperature on the Earth's surface from dipping to extreme icy cold that would freeze everything solid, or from soaring to blazing heat that would burn up all life.

UP TO 600 MILES
THERMOSPHERE

UP TO 50 MILES
MESOSPHERE

UP TO 31 MILES
STRATOSPHERE

UP TO 6 MILES
TROPOSPHERE

Why is the sky blue?

White light is made up of all seven colors found in the rainbow. When pure sunlight shines through the weather zone, water droplets and other moisture refract, or bend, the light. The refraction of pure sunlight causes the sky to appear blue.

Scientists call this "weather zone" the troposphere. This important part of the atmosphere is made of mostly nitrogen and oxygen. About three-fourths of the troposphere is nitrogen. Less than one-fourth is oxygen, or just about 21 percent. The remaining 1 percent is made of a gas called argon, and tiny traces of other gases.

When pure sunlight shines through these gases, blue light is scattered in all directions, and some bounces toward your eyes. A deep blue sky means that there is very little moisture in the troposphere.

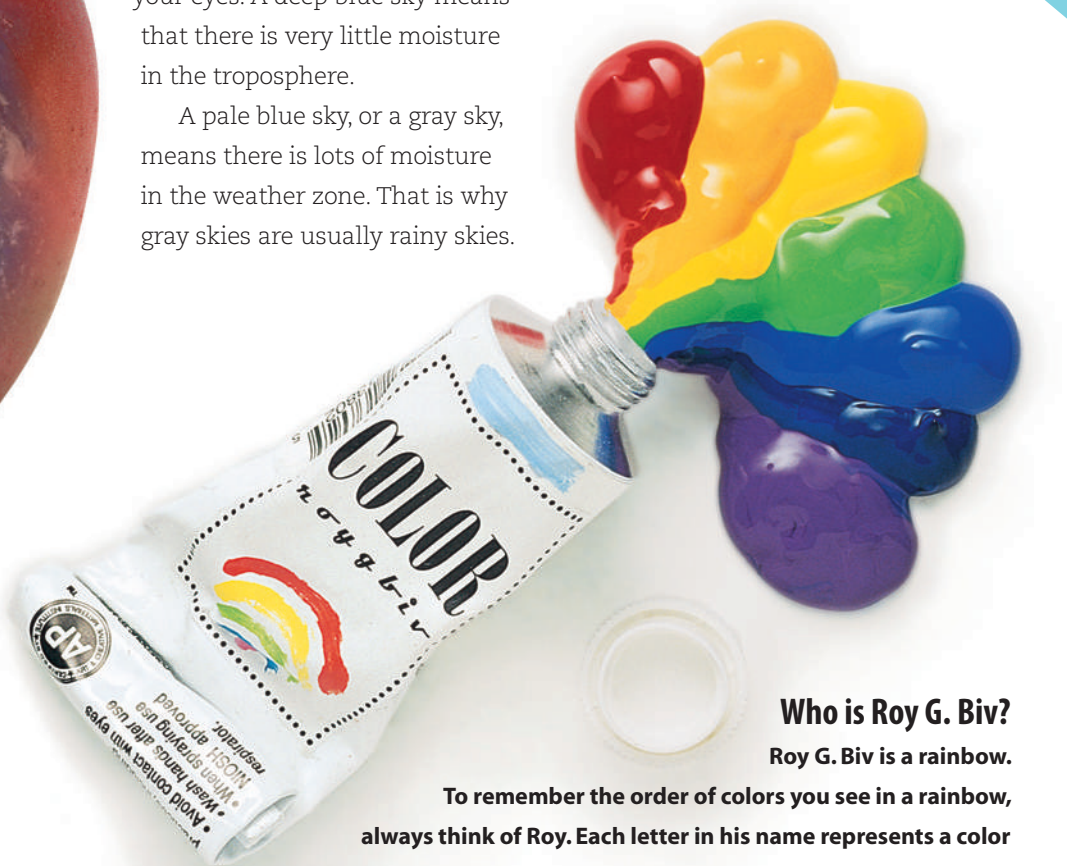
A pale blue sky, or a gray sky, means there is lots of moisture in the weather zone. That is why gray skies are usually rainy skies.

Refraction, reflection, scattering:

We see colors because light of that color enters our eyes. Things have color because they are made of material that reflects or transmits only certain colors of light. An opaque red material, for example, absorbs most light except red. Light reflects from the surface of opaque material, but refracts at the surface of transparent material. Refraction means light's direction of travel bends as it passes through the surface, depending on the material and color of the light. Blue light bends more than red.

Light of all colors is scattered by an irregular bunch of refractions and reflections. Clouds appear white because they are made of jumbled tiny water droplets and dust.

If the Earth was reduced to the size of an apple, the atmosphere would be only about as thick as the skin.



Who is Roy G. Biv?

Roy G. Biv is a rainbow. To remember the order of colors you see in a rainbow, always think of Roy. Each letter in his name represents a color of the rainbow. Use the first letter of each color and you spell his name: Red, Orange, Yellow, Green, Blue, Indigo, and Violet. These colors always occur in the same order. Red is always first. Violet is always last. Rainbows always occur in the sky on the side opposite the sun. If you are flying in an airplane and see a rainbow, you most probably will see it as a full circle, not just a bow.

Illustration: Michael Hagelberg

Meet clouds by name

Clouds can make us happy. Clouds can make us sad. Big puffy white clouds floating through a bright blue summer sky make us smile. But boiling black storm clouds slashed with jagged lightening and crashing thunder make us run for shelter. ✻ To be precise, a cloud is nothing more than a collection of water particles or ice crystals floating in the atmosphere. There are 10 different types of clouds. In 1803, English pharmacist Luke Howard identified these distinct cloud types. He then devised a system of cloud classification. ✻ Howard's cloud classification system uses Latin words that describe the placement (high) and appearance (spread out) of clouds. For example, using Howard's system, a high (alto), spread out (stratus) cloud is called an altostratus cloud. ✻ Meteorologists still use Howard's system today because it is so simple and effective.

HIGH Clouds forming in high-altitudes are called cirrus, cirrostratus, and cirrocumulus. It is so cold in the upper atmosphere that high altitude clouds contain ice crystals instead of water particles.

CIRROCUMULOUS clouds look like upside down waves rolling across the sky.

High, thin **CIRROSTRATUS** clouds look much like stratus clouds, but cirrostratus clouds contain ice crystals and are much higher.

CIRRUS clouds form when the wind blows these ice crystals into wispy streaks that look like thin horse tails.

MIDDLE Altocumulus and altostratus are middle-altitude clouds. Even though the word alto means "height" in Latin, these are not the highest clouds.

ALTOCUMULUS clouds look fleecy and have dark, shadowed sides.

ALTOSTRATUS clouds are flat and make the sun look as if it is being seen through a misty glass.

LOW Five of the 10 types of clouds can be found at low altitudes. The low-altitude clouds are called cumulonimbus, cumulus, stratus, stratocumulus, and nimbostratus.

CUMULONIMBUS clouds are piled up high like scoops of dark ice cream. These clouds usually bring rain showers.

CUMULUS clouds look like giant heads of cauliflower because they are white and fluffy.

STRATUS clouds are spread out, dull clouds usually found at ground level. Stratus clouds may so close to the ground they are identified as fog.

STRATOCUMULUS clouds are spread out heaps of dense cover that rise higher in the atmosphere.

Dark, flat **NIMBOSTRATUS** clouds often produce rain or snow.

Air and water

Relative humidity can be measured using two thermometers. Wrap one thermometer bulb with cotton gauze that is soaked with water. The other bulb is kept dry. The dry-bulb thermometer measures the temperature of the air. The wet-bulb thermometer is cooled by water evaporating from the wet gauze. If the air is dry, the water evaporates faster. This cools the wet-bulb more than the dry bulb. As a result, the temperature is lower on the wet bulb compared to the dry bulb temperature. The drier the air, the faster the evaporation. That means the cooler the wet-bulb temperature will be. If the air is humid, the water evaporates slowly, if at all. The wet-bulb cools slowly. The result is a temperature much closer to the dry-bulb temperature. The difference between the dry-bulb and wet-bulb temperatures indicates the relative humidity.

Wind Makes Weather Wind can be many things. A gentle breeze on a warm spring day is welcome and soothing. But the powerful swirling winds of a tornado or hurricane hold some of nature's most powerful destructive force. Breeze or gale, wind is really nothing more than hot and cold air in motion. The world's winds are part of a global system of air circulation that moves light hot air toward the poles and the heavy cold air toward the equator. When cold air meets hot air, the cold air is sucked under the rising hot air. A low pressure front is created. Low-pressure zones are characterized as wet and stormy weather. These zones come with gray skies and high winds. Winds blow wherever there is a difference in air temperature and pressure.

Cloud photographs courtesy
Mohan Ramamurthy, Ph.D.,
Dept. of Atmospheric Sciences,
University of Illinois at Urbana-Champaign,
and the National Center for Atmospheric Research,
Boulder, Colorado.

Meteorology and Climatology are not the same!

Scientists like facts. They use terms that mean specific things. When studying weather, you should know that meteorology and climatology are not the same thing.

Meteorology is the study of our atmosphere. The focus is on tracking and predicting weather patterns. Climatology is just one branch of meteorology. The focus is on the origin of atmospheric patterns observed over a period of time.

Meteorologists watch the development of storms and record daily temperatures. Meteorologists also provide the National Weather Service with warnings about severe weather and storms. Their job also is to inform the public about the same storms.

The climatologist's work is a bit different. A climatologist might compare modern hurricanes with hurricane activity that took place hundreds of years ago. He looks for similarities and differences. If there is a difference, the climatologist will try to discover reasons for the change and how it will affect future hurricanes.

POWERING THE WEATHER

The weather is powered by energy in many forms. Lightning is electrical energy. Thunder is sound energy. The wind involves kinetic energy. Gravity plays a role as well. Gravity causes cold air to fall and hot air to rise through a process called convection. Convection creates wind.

QUESTION: **Lots of people say that they can see shapes formed in the clouds. But exactly how do clouds form into shapes?**

PROFESSOR CERVENY: **The process of cloud formation is called "cloud physics." It's a pretty complex subject. But think about it this way. Clouds form as bubbles of moist air. Those bubble rise and then cool to the point that the water condenses out. In other words, the water changes from being a vapor, like steam, and becomes a liquid—water. Dry air sinks around the bubbles. That creates irregularly shaped bubbles that form different shapes. But those shapes are just accidental. They don't have any meaning other than being pretty to look at. A cloud is really just a big bubble of rain that hasn't fallen to the ground yet.**

Cloudy answers

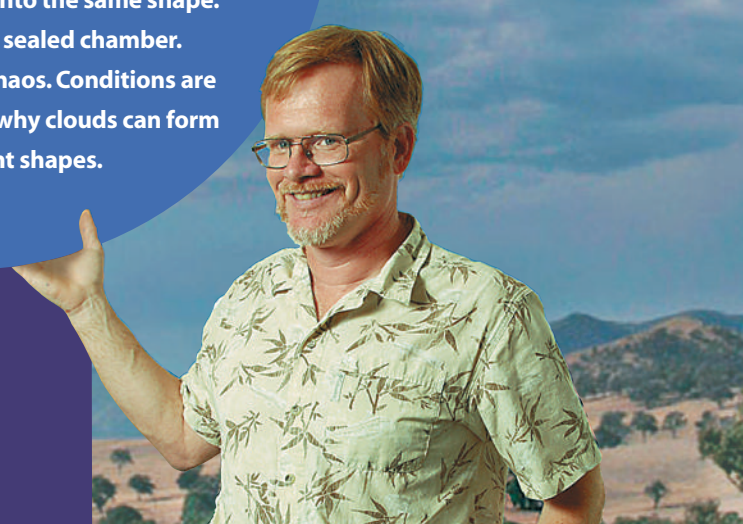
Randy Cerveny is a climatologist at Arizona Stataiversity. He is a President's Professor in the School of Geographical Sciences. That means he is a very smart guy. Cerveny knows all about clouds and lots of other interesting weather stuff. That's his job. He studies weather and climate and then teaches others about what he learns. Students always have lots of questions for the professor. Want to learn something about clouds? Keep reading:

QUESTION: **I know that clouds are formed by molecules of water that get all smooshed together. But why do they form different shapes?**

PROFESSOR CERVENY: **The answer is air. Air currents, to be exact. Air currents are constantly pushing clouds up and down. Different layers of the air have different amounts of water in them. Cloud shapes shift and change as the air pushes them in different directions.**

QUESTION: **But wouldn't all the molecules squeeze together? Then all the clouds would be one shape, and only one shape. Why don't clouds all look like a circle or an oval?**

PROFESSOR CERVENY: **If you were to form a cloud in a nice sealed chamber where you keep constant conditions (winds, temperature and humidity) inside, you would be right. Every cloud would form into the same shape. But our world is not a sealed chamber. Nature contains lots of chaos. Conditions are always changing. That is why clouds can form lots of different shapes.**



QUESTION: I notice that some clouds are thinner than others. That's because some clouds contain lots more water than others. But why don't the clouds break apart and become smaller?

PROFESSOR CERVENY: The key is how high up you push the clouds. All air contains water. But if you push some of that air up high enough (to where it is colder), that water condenses out from vapor (steam) to liquid (water). We see the liquid as a cloud. How high up a cloud gets pushed and how much water vapor it contains are the important factors that determine how thick a cloud will be.

QUESTION: How do clouds stick together? What holds the water molecules together?

PROFESSOR CERVENY: Sometimes they don't. When the water droplets get heavy enough, they fall out of the cloud. We call that rain.

QUESTION: How fast do clouds really move?

PROFESSOR CERVENY: That depends on how fast the winds are blowing around and above the clouds. On nice calm days, the puffy cumulus clouds we see are not moving at all. However, some storm clouds can move at 60 or 70 miles per hour.

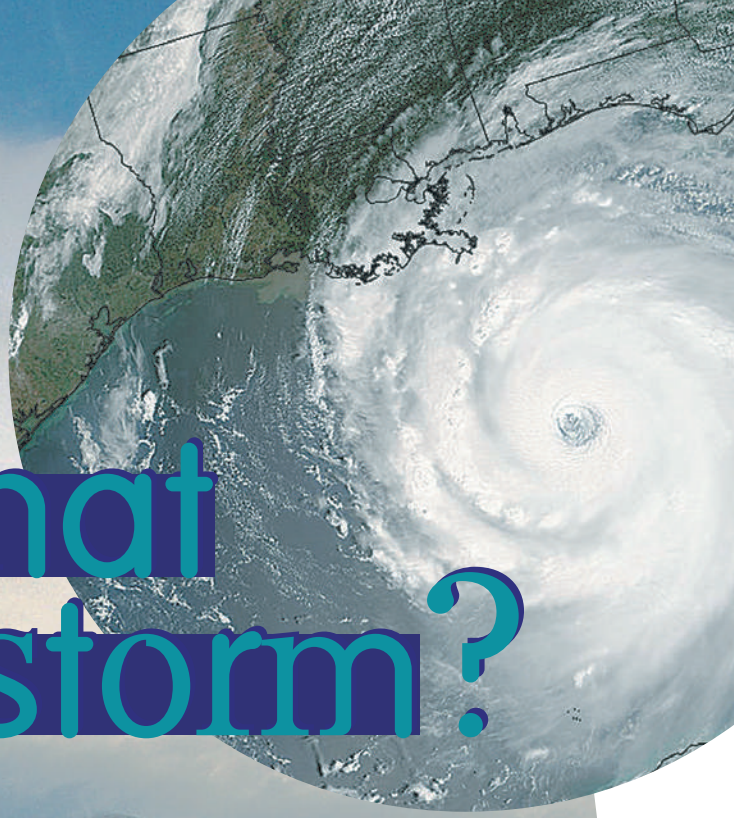
QUESTION: What would our weather be like if the Earth was shaped like a square instead of a round sphere?

PROFESSOR CERVENY: A square-shaped planet with an atmosphere would not exist for very long as a square. It would quickly become round-shaped. The power of weather plus time is very strong. It might take millions of years, but the power of wind, water, and heat would cause the "edges" of the cube to be rounded. Just like a square pebble or rock in a river gradually becomes rounded. Or think about mountains as an example. Mountains are built quickly (geologically-speaking). But over time, the power of weather erodes the even the tallest, sharpest mountains into smooth, round hills. Mother Nature prefers a nice smooth, rounded surface to blow across.

Who's that storm?

Exactly how do hurricanes get their names?

BY DIANE BOUDREAU



Hurricane Katrina's eyewall swirls in a photograph made by a National Oceanic and Atmospheric Administration P-3 hurricane hunter crewmember on August 28, 2005, a day before the powerful storm slammed into the United States Gulf Coast. (Photograph: NOAA)

Everyone talked about her in 2005. She's so famous she doesn't need a last name. Just mention her name and people stop to listen. Who is this celebrity? Is it Madonna? Is it Angelina? No, it's Katrina. But she's no singer or movie star.

Hurricane Katrina devastated New Orleans in August 2005, killing at least 1,300 people. Katrina caused about $75 billion in damage to the southeastern United States. No one who was alive during this storm will forget the name Katrina. But how exactly did this hurricane get that name to begin with?

Randy Cerveny is a climatologist at Arizona State University. He says the hurricane naming system began in the 1800s. An Australian man started naming storms after politicians he didn't like.

The U.S. Air Force began formally naming storms in the 1950s. They used the names of pilots' girlfriends. The World Meteorological Organization (WMO) later took over the process. Officials at the WMO created six lists of names for each region. Each list contains 21 names. The lists start with each letter of the alphabet except for Q, U, X, Y and Z. At first, the WMO only used female names. Public protest made them change the system in 1979. Since then, they have alternated male and female names.

The first storm of the season always starts with A. After that, the storm names follow the list in alphabetical order. If there are more than 21 storms in a season, any extra storms will be named using the Greek alphabet: Alpha, Beta, etc.

After going through all six lists the WMO goes back to the first list and starts over again. If a storm is particularly destructive, its name gets retired, just like a famous athlete's jersey number. For example, there will never again be another Hurricane Katrina.

The WMO naming system is not used everywhere on Earth. For example, on the east coast of Asia they use the names of flowers and old gods. But everywhere you go, people want to give storms some kind of name. "The reason we name hurricanes is because people pay more attention to a name than a number," explains Cerveny. When people are in danger and need to evacuate a town, getting their attention can be a matter of life and death.

Even the name "hurricane" isn't used everywhere. The general name for all hurricane-type storms is "tropical cyclones." In the Atlantic Ocean, they are called "hurricanes." In the Pacific Ocean they are called "typhoons." Off the coasts of Australia and India, the storms are called "cyclones."

But all these names describe the same weather process. "A hurricane is basically a big heat engine. It pumps hot water from the ocean and converts it to rain and heat," Cerveny says. "Almost all hurricanes start off as a dust storm.

WMO tropical storm names for Alantic and Carribean for 2010. Names are applied to each storm in order until 21 names are used. Additional storms are then named with Greek letters. Scientists like to use Greek letters to pay tribute to the society that produced some of the very first principles of scientific thought.

α ALEX

β BONNIE

γ COLIN

δ DANIELLE

ε EARL

ζ FIONA

η GASTON

θ HERMINE

ι IGOR

κ JULIA

λ

A country created by a storm

The worst tropical storm ever recorded struck a region that was known as East Pakistan in 1970. About 500,000 people died—more than died in the 2004 tsunami. The people of East Pakistan were angry that Pakistan did not send aid quickly enough, so they broke off and formed a new country. Today that country is called Bangladesh. It is the only country created as a result of a hurricane.

FAST FACTS ABOUT HURRICANES

Winds of more than 100 mph, a tidal surge of 25 feet above sea level and floodwaters from Lake Ponchatrane contributed to the devastation of

Usually they originate in Africa and work their way off the African coast into the Atlantic Ocean. Most fall apart without ever reaching the Americas. A few start to take on a form that causes more development," he adds.

Once a storm reaches 39 miles per hour, it becomes a tropical storm and gets a name. When it reaches 74 miles per hour it qualifies as a hurricane.

Scientists aren't sure why some storms become hurricanes while others die off, but they are trying to learn. As soon as a storm starts to spin, the National Weather Service sends some of the best pilots in the world to fly right through it. This is a risky business. Cerveny hasn't flown through a hurricane, but he has flown through an Arizona thunderstorm in a hurricane hunter plane. "They tell you not to eat breakfast and to take Dramamine (a drug for motion-sickness)," he says. "The plane is basically a modified commercial plane. The seats have been taken out and replaced with computer workstations. Instead of a seat belt you wear a harness. You go up to 50,000 feet and down to about 18 feet off the ground and up to 50,000 feet again. It beats any roller coaster hands down!"

Spin on The spin of a hurricane is caused by the coriolis effect. The Earth spins under the storm, making the storm spin. In the northern hemisphere, all tropical cyclones (the generic name for hurricanes) spin counter-clockwise. In the southern hemisphere, they spin clockwise. The coriolis effect only works on very big things like hurricanes. Some people think it affects the direction of the water flushing out of a toilet or a bathtub, but that spin is simply too small for the Earth's rotation to change.

This map shows all the major storm tracks from 1985 to 2005. The western Pacific Ocean sees more tropical cyclones than any other area. For more information about hurricane names, visit:

http://www.nhc.noaa.gov/aboutnames.shtml

The planes drop instruments into the storm to get information. Scientists also use satellite data for information. "But we still need people willing to risk their lives and fly through the middle of these things," Cerveny says. "Each time we do we learn new stuff and our forecasts get better."

Most damage from a hurricane comes from what is called the "storm surge." A hurricane's low pressure sucks up water from the ocean, lifting it above sea level. Then the water floods over the land. During hurricane Katrina, the worst of the storm surge was 25 feet high. "It's like a big bubble of water under the hurricane. It's kind of like a tsunami but it's not just one wave that comes in and recedes. It just keeps coming in underneath the hurricane," says Cerveny. "One foot of water moving at 10 miles per hour can move a Hummer."

Hurricanes generally don't affect Arizona, but in 1997, Hurricane Nora hit the Pacific coast and caused about 5 inches of rain in Yuma. "They were actually sandbagging and teaching people how to tape their windows," says Cerveny. "It dried out before it got to Phoenix. It was very odd."

Scientists at the National Oceanic and Atmospheric Administration were able to make accurate forcasts of the path of Hurricane Katrina. Unfortunately that path led almost directly to the city of New Orleans which suffered terrible floods as a result. This map shows the water depth covering the city. Green areas mark depths of 7 to 8 feet, yellow areas 4 to 5 feet.

An Island in the Sun

Is the whole world getting hot, or are we just making it hot in the places we live? How would you decide?

BY DIANE BOUDREAU

When you think about islands, you probably think about Hawaii or Jamaica. You probably don't think about Phoenix, Arizona. Phoenix has all the sand of a beachside resort, but it is not surrounded by water. Still, Phoenix is a type of island. Scientists call it an "urban heat island."

Phoenix is a city surrounded by desert and farmland. That's the "urban" part of the island. But the city is also hotter than the area around it. It is an island of heat.

How can this be so? Cities are made of buildings, roads, and parking lots. These structures absorb more heat from the sun than things like plants or dirt. They also hold onto the heat longer. When the desert cools down at night, the city stays pretty hot. You can often feel the heat radiating off of walls and pavement.

With summer temperatures well over 100 degrees Fahrenheit, people in Phoenix don't need more heat! Hotter weather means people use more energy and more water. These are two resources we need to conserve.

Tony Brazel is a climatologist at Arizona State University. He has been studying the Phoenix heat island for more than 20 years. He looks at the difference between city temperatures and rural temperatures.

This photo shows Phoenix as seen from the orbiting Space Shuttle. Can you see the difference between urban and rural areas?

[Thought question:]
Why would higher temperatures in Arizona make people use more electricity and more water?

This difference is called the "heat island magnitude." Brazel also studies what causes this difference, and how we can reduce it. "We've found it can be 12 to 15 degrees Fahrenheit higher in the city than in rural areas. On one night we measured a 22-degree difference between the Southeast Valley agricultural area and Sky Harbor Airport," Brazel says.

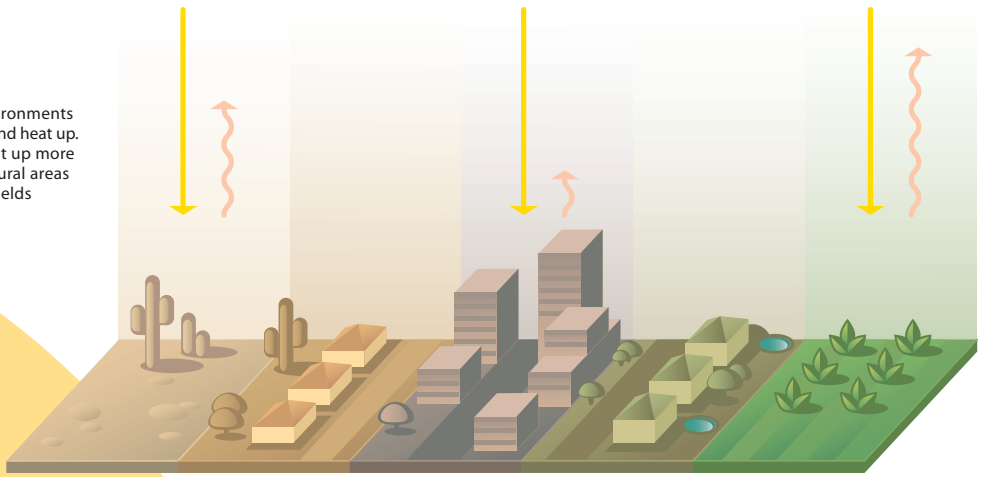
Agricultural areas are cooler than natural desert, Brazel says. This is because farms have a lot of water and plants. When water evaporates, it lowers the temperature of whatever is around it. For example, your body cools off when your sweat evaporates.

Some of the landscape water evaporates directly. Some of it evaporates through the leaves of plants in a process called transpiration. Plants also provide shade that further cools the ground. "You get a larger heat island magnitude if you compare the urban site to an agricultural area," says Brazel. "There's a smaller effect if you compare it to the natural desert."

Even within the city, there are temperature differences. Some neighborhoods are just plain hotter than others. Brazel and other ASU scientists are conducting a study to find out which neighborhoods and built-up areas are hottest, and why. Working with ASU's Decision Center for a Desert City, the scientists are looking at water use and nighttime temperatures. They are using a computer model and satellite surface temperatures of different neighborhoods—some quite dry, others with a lot of greenery. "The key is what we call impervious surfaces—roads, parking lots, buildings. Asphalt and concrete are heat-retaining materials that store energy and at night are still warm," says Brazel. >>>

Swamp cooler vs. air conditioner?

"Swamp cooler" is the popular name for a device known as an evaporative cooler. The device uses evaporation to cool a home. Evaporation also makes the air inside more humid. In an arid climate—such as Arizona's Sonoran Desert—added humidity can make for a more comfortable environment inside a home. However, when the summer rains begin, the air in the desert becomes very humid. Evaporation is no longer an efficient source of cooling. Swamp coolers no longer work well. To keep the inside environment comfortable, you need an air conditioner. This device uses a refrigeration cycle to cool the air inside a home. Hot humid air is blown over a chilled "condenser." This cools the air and also causes the humidity to condense, drying the air. The air that enters the home is cool and "dehumidified." In Arizona, the summer weather reports include the "evaporative cooling index." This is similar to the heat index. The evaporative cooling index measures how cold a swamp cooler will make your house depending on the relative humidity.



Sunlight beams down evenly on all the different environments of the desert. Some areas capture more of the energy and heat up. Urban areas with lots of pavement and buildings heat up more than suburban areas with houses and trees. Agricultural areas may heat up less than the open desert because the fields evaporate water, which carries off some heat.

Global warming or heat island?

Global warming and urban heat islands are both examples of how human beings can affect the weather. But they are not the same thing. Global warming is the average temperature change for the whole world. Urban heat islands are limited to individual cities.

In the 1990s, people used temperatures taken in cities to support the theory of global warming. Because of this, some scientists believed that global warming wasn't really happening. They said that the rising temperatures were actually an effect of urban heat islands, but weren't happening on a global level.

Now, scientists are looking at temperatures from all different kinds of environments. What have they found? The Earth is getting warmer—global climate change is real. But so are urban heat islands.

Human beings have an effect on both global warming and heat islands, but in different ways. Global warming is largely caused by greenhouse gases in the atmosphere. The most abundant greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, and ozone. People add greenhouse gases to the air by burning fossil fuels like gasoline and fuel oil.

The urban heat island is not caused by greenhouse gases. People affect heat islands mostly through the materials they use for building and paving.

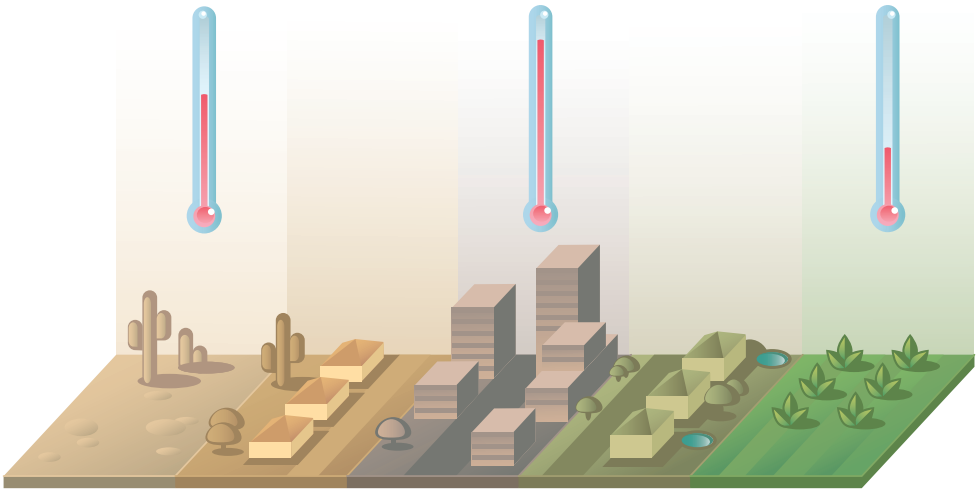
On the other end of the spectrum is vegetation—good old green plants. The sun's energy goes into evaporating the water that these plants receive, not into the ground. The researchers are finding out that neighborhoods with more plants and more water (such as swimming pools) are cooler than neighborhoods without these features. "This creates a dilemma," says Brazel. "On the one hand, we are a desert with limited water resources and we want to conserve water. On the other hand, we have a heat island problem, and using more water may create a cooler environment."

So far, the findings suggest that you can get significant cooling effects from adding a small amount of vegetation to areas that don't have much. But if you go into a neighborhood that already has a lot of vegetation and add even more, you don't get a very big boost in cooling. In fact, you can remove some of the plants from these areas without making them hotter.

Phoenix is not the only urban heat island in the world. Brazel says that all of the world's largest cities—such as Mexico City, Tokyo, and Los Angeles—have a major heat island effect. "What surprises people is that even small places can have heat islands. Even a shopping center can be substantive. When you change the surface, you change the temperature virtually overnight," says Brazel.

Adding plants is not the only way to lower temperatures in cities. There are other ways to cool the heat island. Choosing building materials that don't absorb a lot of heat is one way. For instance, buildings could use light-colored, cooling roof materials. And cities could pave streets and parking lots with less heat-absorbent paving materials.

Researchers with ASU's National Center for Excellence in SMART Innovations are studying how new paving materials can help the environment. They paved an ASU parking lot with pervious pavement. It allows water and air to pass through it. Pervious pavement absorbs less heat than regular pavement. It also reduces water pollution by eliminating runoff, and improves safety by preventing water from pooling on the surface.



The scientists have installed heat and moisture sensors on the parking lot. They are comparing the data with information from regular parking lots to find out how much effect the new pavement has.

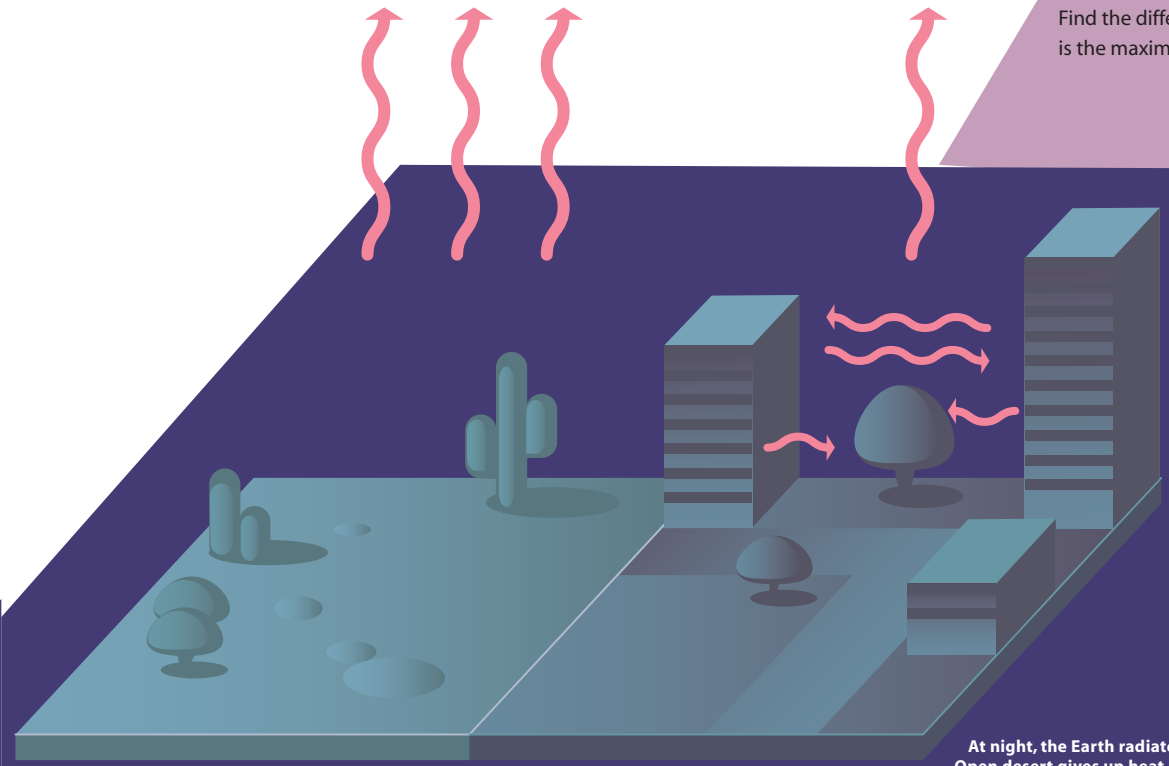
The way buildings are arranged can also have an effect on heat islands. Brazel talks about "urban canyons," created when you place tall buildings along narrow streets. The buildings provide shade and create cooling wind patterns. "The city of Phoenix was planned long ago," says Brazel. "It has wide streets with few trees. Now, ASU and the city are trying to make it pedestrian-friendly. We're trying to create a sustainable city."

Defining the heat island—two ways to do so

How do you know when a city is an urban heat island? ASU climatologist Tony Brazel says there are two general ways to define a heat island.

The average heat island: Find climate records for a weather station in the city and one outside the city. Write down the lowest and highest temperature from each station for each day in a month. Then find the average (mean) of all the high city temperatures, all the low city temperatures, all the high rural temperatures, and all the low rural temperatures. The difference between the city and rural temperatures is the average heat island.

The maximum heat island: Many things can affect a city's temperature besides the heat island effect. Wind, clouds, and rain all confuse the issue. When people want to know what effect the city alone has on temperature, they measure the maximum heat island. Choose a calm, sunny day with no wind, no clouds, and low humidity. Measure the temperature at a rural station and at the densest, hottest part of the city. Find the difference between the two. This is the maximum heat island.

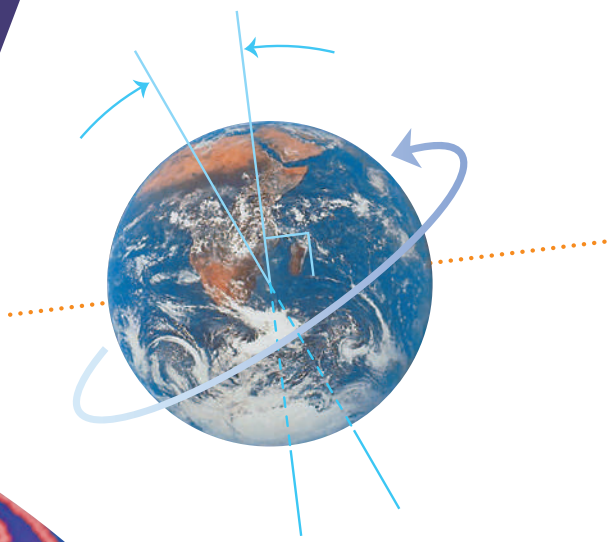


At night, the Earth radiates heat back into the atmosphere. Open desert gives up heat quickly. Buildings and pavements in the urban center give up less heat, because radiated heat given off by one structure is trapped by another.

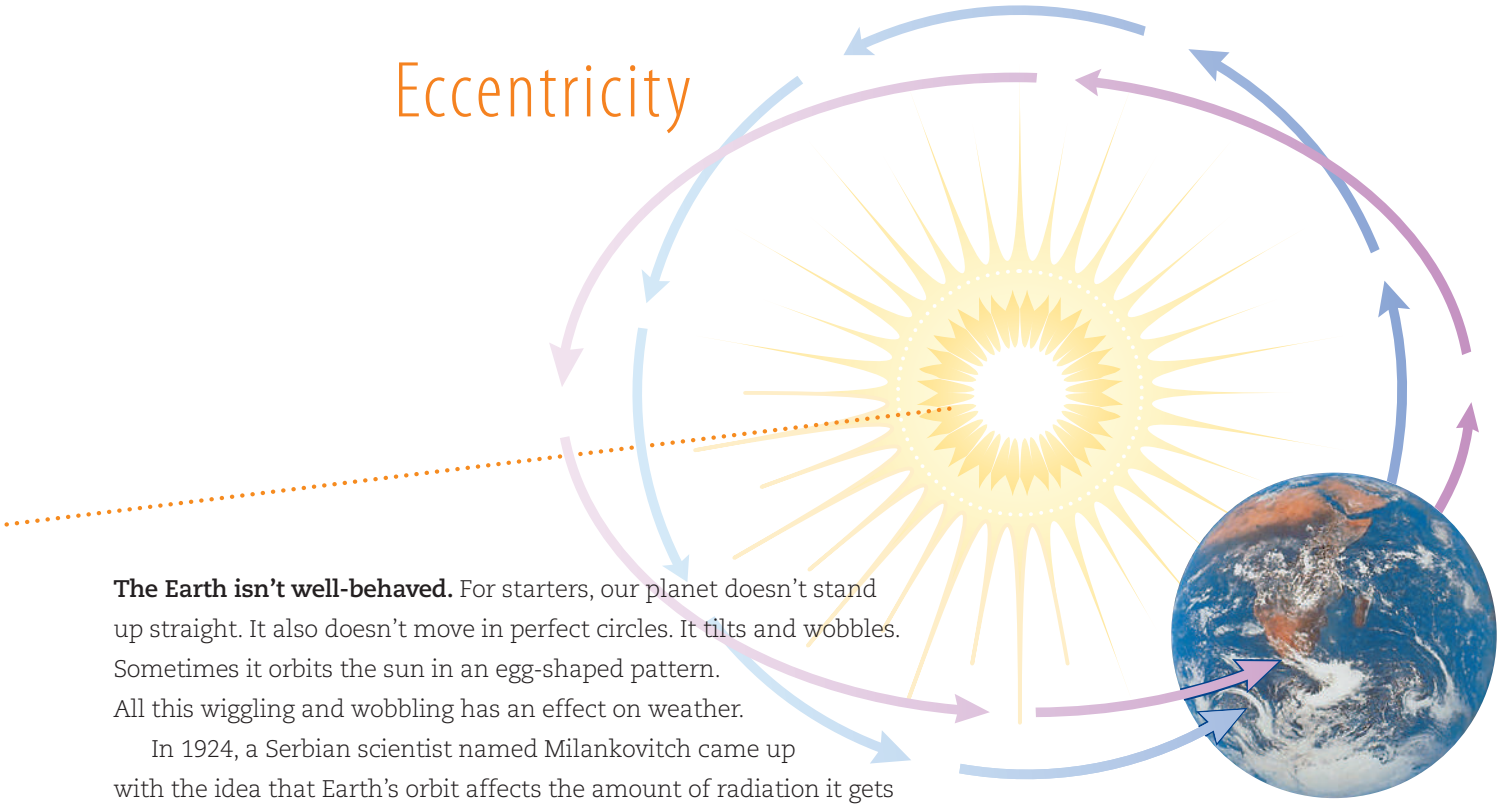
TOPSY TURVY EARTH

BY DIANE BOUDREAU

This is a computer model of the Earth created by former ASU graduate student John Shaffer. The model is based on how the Earth moves in space. It calculates and maps the amount of sunlight reaching the surface for separate zones of latitude. Results show how much sunlight arrived for any time thousands of years into the past.



Eccentricity



The Earth isn't well-behaved. For starters, our planet doesn't stand up straight. It also doesn't move in perfect circles. It tilts and wobbles. Sometimes it orbits the sun in an egg-shaped pattern. All this wiggling and wobbling has an effect on weather.

In 1924, a Serbian scientist named Milankovitch came up with the idea that Earth's orbit affects the amount of radiation it gets from the sun. The changes in radiation affect Earth's climate. In particular, they dramatically affect the big ice sheets we call glaciers.

The Milankovitch Theory uses three characteristics of Earth's orbit to find out how much solar radiation the planet receives. These three characteristics are eccentricity, axial tilt, and precession.

Eccentricity describes the shape of Earth's orbit. Earth revolves around the sun, but it doesn't always move in a perfect circle. Over a period of 100,000 years, Earth's orbit slowly changes from circular to egg-shaped and then back to circular.

The second characteristic is called axial tilt. Imagine a straw pushed through the center of an orange. When the straw is straight up, the orange doesn't tilt in any direction. But if you tilt the straw at an angle, the orange tilts in the same direction.

The same thing happens with the Earth. The "straw" is Earth's polar axis—an imaginary line that runs from the North Pole through the planet to the South Pole. As Earth orbits the sun, the axis is never straight up and down. It always tilts at a small angle.

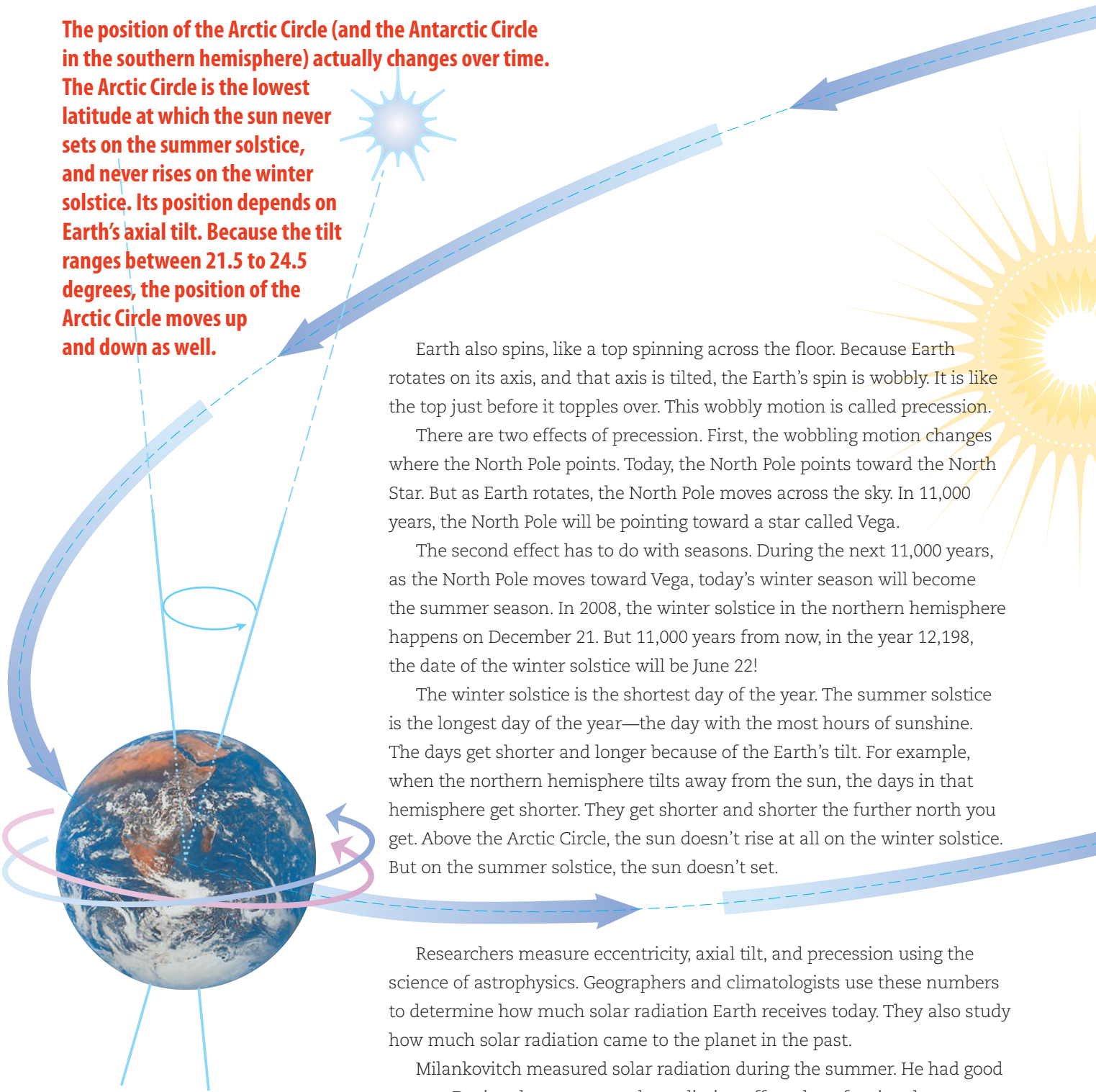
Picture a line drawn from the center of the sun to the center of Earth. The polar axis crosses this line. If the axis were straight up and down, these two lines would form a right angle (90 degrees). In reality, these two lines make an angle greater than 90 degrees because of the axial tilt. Currently, Earth's axis tilts about 23.5 degrees beyond the center. Over long periods of time, this angle ranges from 21.5 to 24.5 degrees.

Four hundred years ago, in 1609, Johannes Kepler worked out a theory to describe the motion of planets as they orbit. He discovered that the orbits of the planets follow ellipses—sort of football-shaped squashed circles. In fact, no planet can have a perfectly circular orbit, but Kepler did not know that. He did not understand that gravity holds planets in orbit around the sun, and propels them in their elliptcal orbits. Issac Newton figured out this connection by 1687, and said:

$$F = G\frac{m_1\, m_2}{d^2}$$

(IT MEANS THE FORCE OF GRAVITY BETWEEN ANY TWO OBJECTS IS PROPORTIONAL TO THEIR MASSES DIVIDED BY THE SQUARE OF THE DISTANCE BETWEEN THEM).

The position of the Arctic Circle (and the Antarctic Circle in the southern hemisphere) actually changes over time. The Arctic Circle is the lowest latitude at which the sun never sets on the summer solstice, and never rises on the winter solstice. Its position depends on Earth's axial tilt. Because the tilt ranges between 21.5 to 24.5 degrees, the position of the Arctic Circle moves up and down as well.



Precession

Earth also spins, like a top spinning across the floor. Because Earth rotates on its axis, and that axis is tilted, the Earth's spin is wobbly. It is like the top just before it topples over. This wobbly motion is called precession.

There are two effects of precession. First, the wobbling motion changes where the North Pole points. Today, the North Pole points toward the North Star. But as Earth rotates, the North Pole moves across the sky. In 11,000 years, the North Pole will be pointing toward a star called Vega.

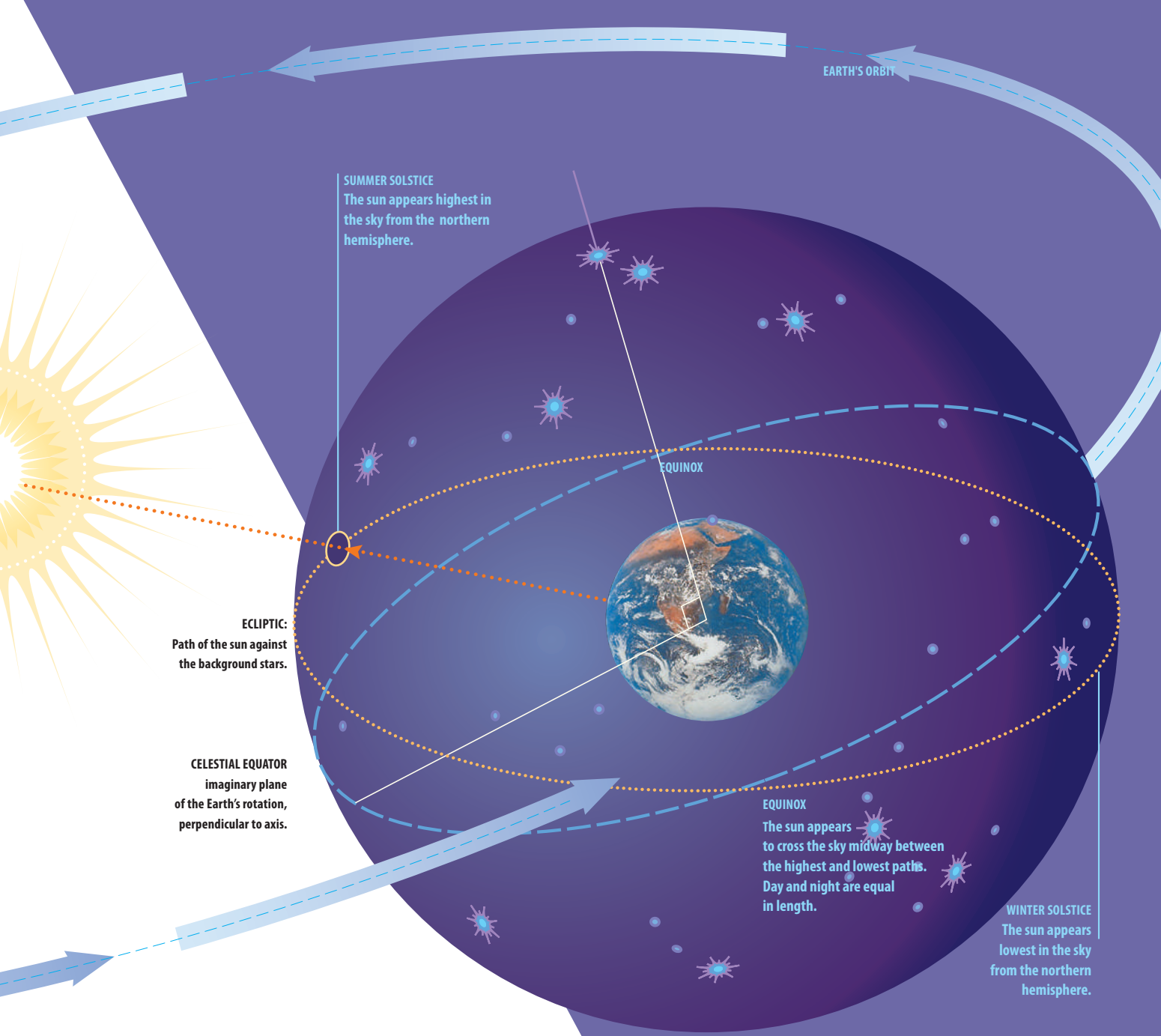
The second effect has to do with seasons. During the next 11,000 years, as the North Pole moves toward Vega, today's winter season will become the summer season. In 2008, the winter solstice in the northern hemisphere happens on December 21. But 11,000 years from now, in the year 12,198, the date of the winter solstice will be June 22!

The winter solstice is the shortest day of the year. The summer solstice is the longest day of the year—the day with the most hours of sunshine. The days get shorter and longer because of the Earth's tilt. For example, when the northern hemisphere tilts away from the sun, the days in that hemisphere get shorter. They get shorter and shorter the further north you get. Above the Arctic Circle, the sun doesn't rise at all on the winter solstice. But on the summer solstice, the sun doesn't set.

Researchers measure eccentricity, axial tilt, and precession using the science of astrophysics. Geographers and climatologists use these numbers to determine how much solar radiation Earth receives today. They also study how much solar radiation came to the planet in the past.

Milankovitch measured solar radiation during the summer. He had good reason. During the summer, solar radiation affects how fast ice sheets grow or melt. Low solar radiation during the summer keeps temperatures cool and helps glaciers to grow.

Of course, wet winters also are important to growing glaciers. Increased solar radiation during the winter causes rain and snow. The rain and snow fall on top of the ice sheet. When they freeze, the glaciers grow bigger.



Celestial sphere

The sun is about 93 million miles– 150 million kilometers– from the Earth. The next closest star is about 280 thousand times farther away. The Earth's orbit is so small compared to that distance that the stars are considered "fixed" in the sky. That is, the stars do not appear to move on the celestial sphere as the sun and planets do.

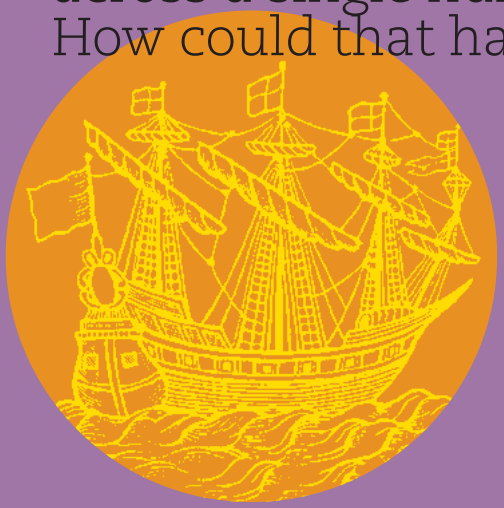
Illustration: Michael Hagelberg

The opposite conditions cause ice sheets to melt. No ice builds up on the glacier if it does not rain or snow during the winter. High solar radiation during the next summer means warmer weather. A warm summer makes ice melt off the glacier.

When Milankovitch thought up his theory in 1924, he had to do the math by hand. It took days to figure out the total amount of incoming solar radiation. Milankovitch didn't have time to study the entire planet.

Today's scientists have computers that can do the math much faster than people can. As a result, they can now study the entire planet.

In 1492, the Niña, Pinta, and the Santa Maria set sail during the peak of the hurricane season. Amazingly, Christopher Columbus and his small fleet did not come across a single hurricane. How could that happen?



Climatologist Randy Cerveny has answers. He compared the route Columbus sailed with historical hurricane data collected during this century. "Notorious modern hurricanes such as Gilbert and Hugo were spawned during September and October," says Cerveny, President's Professor of Geographical Sciences at Arizona State University. "Yet, according to Columbus' logbooks, he and his ships failed to meet with even nominally severe weather.

"Columbus' odds of meeting a big hurricane were less than one per century. He was a lucky sailor. He chose an incredibly favorable course—the best possible to avoid hurricanes," Cerveny says.

After discovering America, Columbus spent several years exploring Caribbean islands. It seems likely that a hurricane would have crossed the explorer's path at some point. More hurricane activity begins in the Caribbean than in the Atlantic Ocean. "For study purposes, we created what we call the 'Caribbean Box.' The Box includes an area where Columbus would most likely have been in 1492," Cerveny explains.

The ASU professor's computer model shows that no hurricanes have passed through the box during the last half of October in more than 100 years. "This is another remarkable statistic in Columbus' favor!" Cerveny adds. Although the admiral enjoyed favorable odds, the probability of coming across a hurricane was not zero. But would Columbus' fleet have survived if it did? Cerveny says "Yes," it would have. "After all, Columbus was a naturally gifted sailor. He used weather to the greatest advantage. He also was a skilled navigator."

Columbus did have a close call with bad weather during his fourth and final voyage in 1503. "Columbus saw clues that a major storm was brewing and predicted that it would hit Hispaniola," Cerveny says. "He didn't know the storm would be a hurricane because he had never seen one. But he recognized the signs of impending bad weather and warned the governor."

The governor ignored him and dispatched a fleet of 20 ships. The ships carried treasures of gold and jewels for the King of Spain. The valuable cargo never reached the Spanish crown. "That fleet went to the bottom of the Caribbean with all hands," Cerveny says.

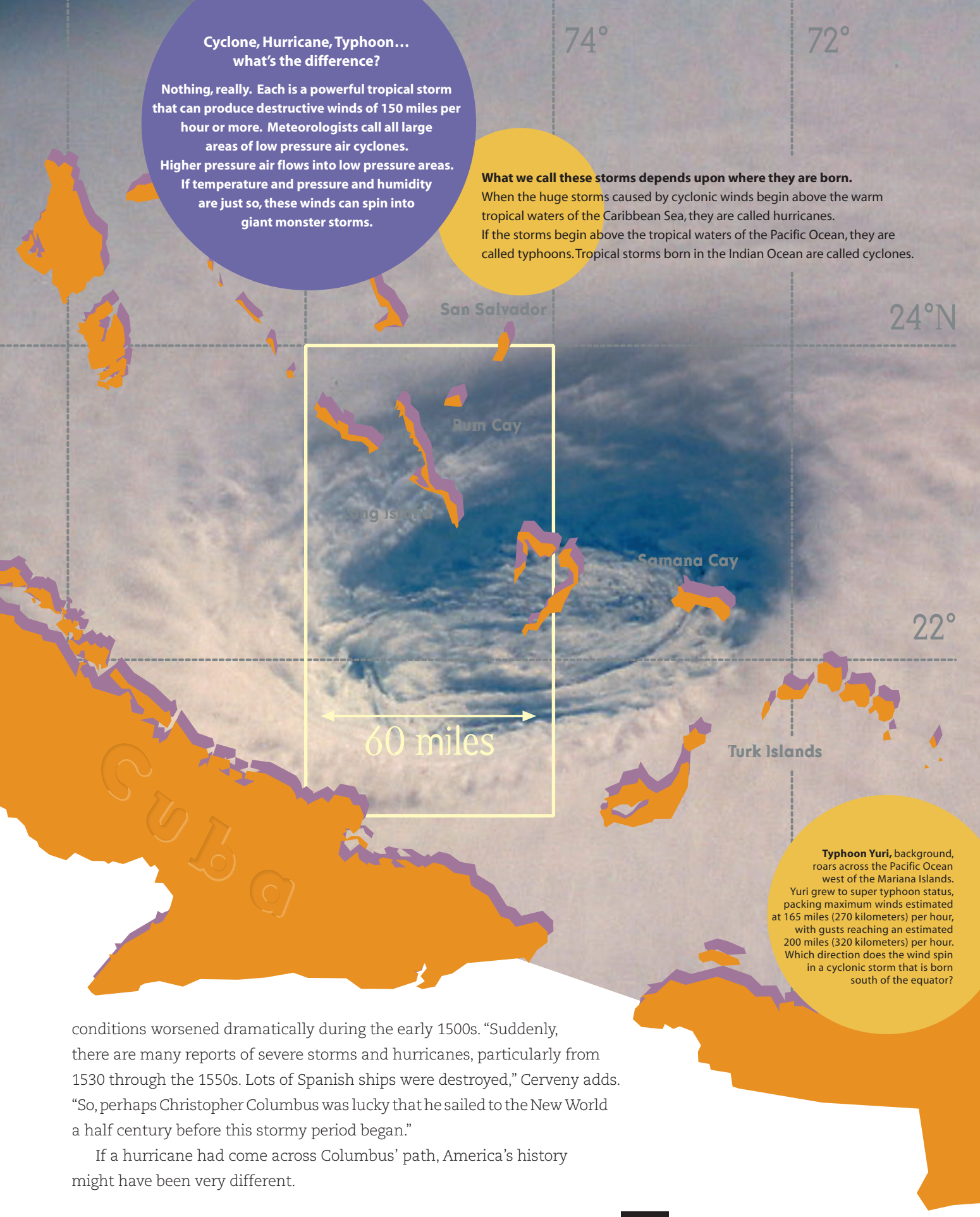
Columbus realized the danger and disobeyed the governor's orders. His ships stayed anchored safely in the harbor. The ships survived the powerful storm with only minor damage.

Historical records suggest that the 1490s were calm years in both the Old and New Worlds. Few major storms were recorded and harvests were good all across Europe. Other historical statistics reveal that climate

CrossLink

WEATHER AND HISTORY

Hold Onto Your Heads...
The fastest wind speed ever recorded was 231 miles per hour. This healthy little breeze took place at Mount Washington, New Hampshire on April 12, 1934.



Cyclone, Hurricane, Typhoon… what's the difference?

Nothing, really. Each is a powerful tropical storm that can produce destructive winds of 150 miles per hour or more. Meteorologists call all large areas of low pressure air cyclones. Higher pressure air flows into low pressure areas. If temperature and pressure and humidity are just so, these winds can spin into giant monster storms.

What we call these storms depends upon where they are born. When the huge storms caused by cyclonic winds begin above the warm tropical waters of the Caribbean Sea, they are called hurricanes. If the storms begin above the tropical waters of the Pacific Ocean, they are called typhoons. Tropical storms born in the Indian Ocean are called cyclones.

Typhoon Yuri, background, roars across the Pacific Ocean west of the Mariana Islands. Yuri grew to super typhoon status, packing maximum winds estimated at 165 miles (270 kilometers) per hour, with gusts reaching an estimated 200 miles (320 kilometers) per hour. Which direction does the wind spin in a cyclonic storm that is born south of the equator?

conditions worsened dramatically during the early 1500s. "Suddenly, there are many reports of severe storms and hurricanes, particularly from 1530 through the 1550s. Lots of Spanish ships were destroyed," Cerveny adds. "So, perhaps Christopher Columbus was lucky that he sailed to the New World a half century before this stormy period began."

If a hurricane had come across Columbus' path, America's history might have been very different.

freaky Weather...

Find the interactive extreme weather map at: wmo.asu.edu/maps/map.html

naKED CHICKENs ANd fALLiNG FiSH

BY DIANE BOUDREAU

It started out as a normal morning for A. D. Bajkov. He was eating breakfast with his wife in a restaurant in the small town of Marksville, Louisiana. Suddenly, a waitress hollered, "Quick, look! Fish are falling from the sky!" Bajkov, a wildlife biologist, ran outside to observe the strange event. The waitress was right—it was raining fishes.

This event happened in 1949. But it wasn't the first rain of fishes ever seen. People reported fish falling from the sky in India in 1830, Texas in 1886, Australia in 1906, and South Africa in 1909. The 1949 event was simply the first time a fishfall had ever been observed and recorded by a scientist.

Randy Cerveny loves weird weather stories. Over the past six years, he has collected more than 8,000 strange weather tales. Those tales include wacky stuff such as hailstones shaped like crosses. Or how about lightning strikes that cause your sweat to blow the clothes right off you. Even stranger: snow that turns blood-red when stepped on.

Cerveny is a climatologist at Arizona State University. He studies and teaches about weather and climate. He wrote a book describing some of the most interesting weather stories in his collection. The book is called *Freaks of the Storm*. "The title is a phrase that was used in the early part of the last century to describe strange phenomena that occurred during storms," Cerveny explains. "For example, when chickens would lose their feathers in a tornado, that would be called a freak of the storm."

Sometimes, the stories of how people try to figure out freaks of the storm are as interesting as the freaks themselves. For instance, tornadoes sometimes leave chickens completely plucked of their feathers, but otherwise healthy. People wanted to know how this happened. "At first people thought it was caused by wind speed. A scientist actually constructed a special gun and put a dead chicken in it and fired the gun to see if the force stripped it of its feathers," says Cerveny.

Mirage
In a hot arid desert, travelers often see what appears to be a shimmering lake in the distance. However, when they arrive at that location, there is only hot sand. The appearance of water was a mirage. A mirage is an optical effect produced by hot air rising from the ground during convection. Hot air acts like a lens that bends light in strange ways when hot and cold air are mixed.

wAteRSpOut ····→

The gun did strip the chicken, but scientists today do not believe wind speed is responsible for tornado pluckings. "Now we think chickens actually are doing something called 'panic molt.' This is common in flightless birds," Cerveny says. "When they are scared, they lose their feathers. If a predator is attacking and grabs them by the feathers, the feathers simply come out and the chicken escapes."

Not all freaks of the storm involve animals. In the mid-1800s, people in Swan's Quarter, N.C. decided to build a church. The congregation wanted to construct the church in the center of town, but the landowner wouldn't sell the land. Instead, the church was built on the edge of town.

Later, a hurricane flooded the city. Many buildings were destroyed, but the church wasn't harmed. Instead, it floated away! It floated down the street, turned a corner, and finally came to rest right on the plot of land where the congregation first wanted to build. "The owner decided that someone was sending him a message, and he sold the land to the church," Cerveny says. The church is still there today.

And what about those falling fish? Where did they come from? Scientists aren't completely sure. The most likely explanation is that the fish are picked up by waterspouts. Waterspouts are basically tornadoes that happen over water. The storm picks up the fish and drops them over land, often miles away. However, no one can explain why people only see fish falling. Why wouldn't the waterspouts pick up plants, shells, and other water creatures and drop them over the land, too?

Science is all about answering questions. But one answer often leads to lots more questions. That's what makes it fun. There is always more work to do.

Hot news, cold facts

Fried Eggs on the Sidewalk?
The highest temperature ever recorded in Arizona was 128 degrees Fahrenheit. The scorcher occurred in Lake Havasu City on June 29, 1994.

The highest temperature ever reached in the United States was 134 degrees Fahrenheit. This hellish high was recorded on July 10, 1913 in Death Valley, California.

In the same year (1913), Phoenix reached its all-time lowest temperature of 16 degrees Fahrenheit on Jan. 7.

Hawley Lake in the White Mountains holds the record for the lowest temperature ever recorded in Arizona—a bone-numbing minus–40 degrees Fahrenheit on Jan. 7, 1971.

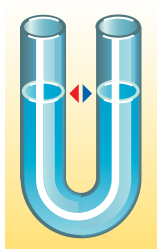
Quick-change
On January 22, 1943, the citizens of Spearfish, South Dakota got a big surprise. The temperature leaped from minus 4 degrees to 45 degrees Fahrenheit in only two minutes!

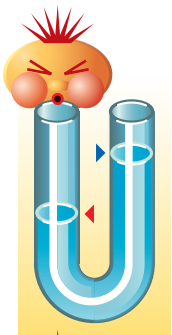
Sun tan lotion and parka please!
The Sahara Desert of North Africa can reach temperatures of more than 136 degrees Fahrenheit. Before you toss away your jackets, remember that the temperature has also gone down as low as 5 degrees in the mountains during the winter.

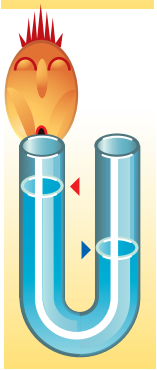
fiSH

HOW MUCH DOES THE SKY weigh?

BY DAVID WRIGHT







Air is all around you. It presses against your body all the time. That's why we call it air pressure. Usually, you don't notice air pressure because it presses against you evenly in all directions.

Anyone can measure air pressure using a tool called a barometer. When we use a barometer to measure the air pressure, the resulting number is called the barometric pressure.

Barometers work because air has weight. The air that surrounds us begins at the surface of the Earth and goes up to the top of the sky. All that air, the entire atmosphere, weighs about 5 million billion tons! We don't get crushed because all that weight is distributed evenly over the entire surface of the Earth. The average force you feel is about 15 pounds on every square inch of your body. Because air is fluid, that force is delivered evenly over your entire body, not just on the top of your head.

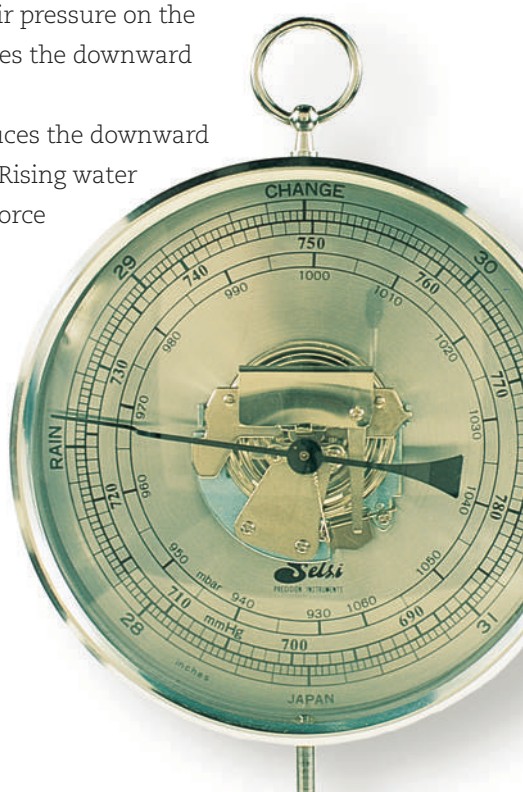
We can measure how much the air presses down on us with a simple but clever device. It's called a U-tube barometer and it works much like a teeter-totter. A teeter-totter can stay balanced as long as there is equal weight on both sides. If the weights are different, the teeter-totter tips to favor the heavy side. The same is true for a U-tube barometer.

Look at the tube at left. It contains some water. With both ends open to the air, the water levels in each side are the same. This is because the air pressure over each side is the same. The water is balanced between the downward forces on each side, just like a teeter-totter.

Blow some air into the left side. The water levels change because you have made the air press down more than the air on the right side. In other words, you have increased the air pressure on the left side. The water moves until it balances the downward forces on both sides.

The loss of water on the left side reduces the downward force from water weight on the left side. Rising water on the right side adds to the downward force from water weight on the right side. This balances the force from the air pressure you added on the left side.

On the other hand, when you suck air from the left side, the water levels change in a different way. By removing air from the left side, you have made the air press down less than the air on the right side. Again, the water moves until it balances the downward forces on both sides.



You read air pressure from a U-tube barometer by comparing the column of mercury to a built-in ruler. The sliding plate is a special measuring device called a vernier which allows very precise readings.

If you use a strong vacuum pump to remove all the air from the left side, the air pressure there will be zero. The only downward force on the left side would be from a tall column of water on that side. The force on the other side that balances all that water weight is the downward force from the normal air pressure on the right side. When this is done, the water level on the left side rises to a height of about 34 feet. This is not very practical, so U-tube barometers don't actually use water as the liquid.

Mercury is used instead, because it is a very dense liquid metal. Mercury is about 14 times more dense than water. Because mercury is so heavy, normal air pressure pushes it to a height of only about 30 inches, or 760 millimeters.

Meteorologists measure air pressure by counting the inches of mercury on a barometer. Other scientists who work with gas pressures prefer to use millimeters. One millimeter of mercury is known as a "Torr." The Torr unit is named in honor of Evangelista Torricelli, who invented the mercury barometer in 1643.

Torricelli filled a long glass tube with mercury and inverted the tube into a dish. He observed that some of the mercury did not flow out and that the space above the mercury in the tube was a vacuum.

Torricelli was the first person to create and sustain a vacuum. He concluded that the day to day changes in the height of the mercury were caused by changes in the atmospheric pressure.

At sea level, the barometric pressure is high because sea level is the lowest place you can go. More air above you creates more pressure. In the high mountains or in an airplane, the barometric pressure is less. Because you are higher in the atmosphere, there is less air on top of you, so the pressure it creates is less.

In any given location, when the barometric pressure drops, you can expect a storm. When it increases, you can expect sunny weather.

Pressure power

Pressure differences across the Earth's atmosphere drive large scale flows of wind. The wind can do useful work. People usually think of sailing ships and windmills as sucessful ways to capture the wind, but there are others.

Randall Cerveny holds a 1/8-scale model of a "wind wagon" that was made in 1860. A miller named Samuel Peppard built the wagon so he could go strike it rich in the Colorado gold rush. Peppard sailed his contraption from Kansas City almost all the way to Denver. About 50 miles out of Denver, a dust devil knocked over the wagon and destroyed it.

Cerveny, an ASU professor of climatology, is building a replica of the wagon with his students. They will try to sail it from Kansas City to Denver in 2010. "This is not going to be a pleasant ride. Back in the 1860s they didn't have shock absorbers!" says Cerveny. Still, the team is having a blast figuring out how to recreate the vehicle. "It's one of the first examples of an alternative energy mode of transportation. The students say this project is similar to a MythBusters type of thing," says Cerveny.

In any given location, when the barometric pressure drops, you can expect a storm. When it increases, you can expect sunny weather.

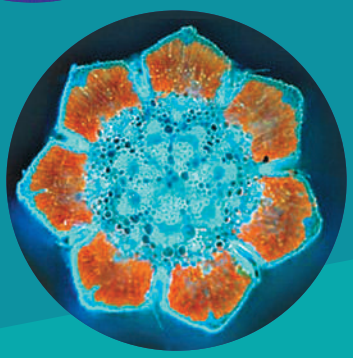
Aneroid barometers like this don't use liquid mercury to measure air pressure. Instead, they contain a small metal capsule. Air is pumped out of the capsule and it is sealed. A sensitive metal linkage is attached to the capsule. The capsule swells or shrinks as atmospheric pressure changes, and the movement is multiplied by the linkage to turn the pointer.

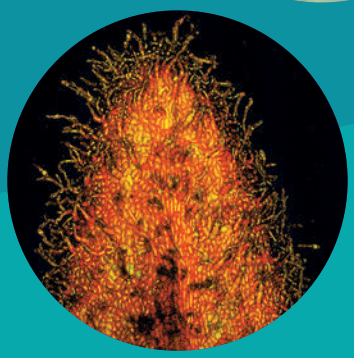
http://
chainreaction
.asu.edu

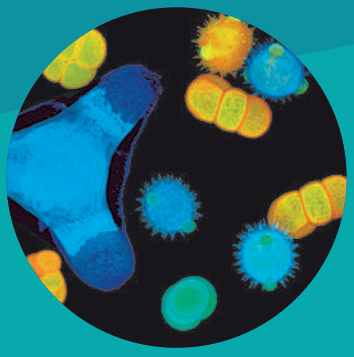
Ask a Biologist

http://askabiologist.asu.edu

Ask a Biologist is
an outreach program of
the Arizona State University
School of Life Sciences







Science is about curiosity. Science is about asking questions.

One answer often leads to a brand new set of questions. That is how science works. That is what learning is all about. Just think how great it would be if you could ask a real scientist for help with a tough question. Now you can. You can also hear the scientists themselves via podcasts from the site. Don't have a question? No problem. The site features backyard experiments you can do at home, coloring pages for young students, quizzes, and a new comic book science mystery with Dr. Biology. Check it all out at: http://askabiologist.asu.edu

Other resources at ASU:

ASU Mars Education Program
Make your own discoveries in space science.
http://marsed.asu.edu

Ecology Explorers
Work side by side with ASU scientists and investigate your schoolyard.
http://caplter.asu.edu/explorers

ASU in the Community
From photos of Mars to Sun Devil screensavers to tips for living green, Club ASU is your passport to everything cool online at ASU.
http://community.uui.asu.edu/

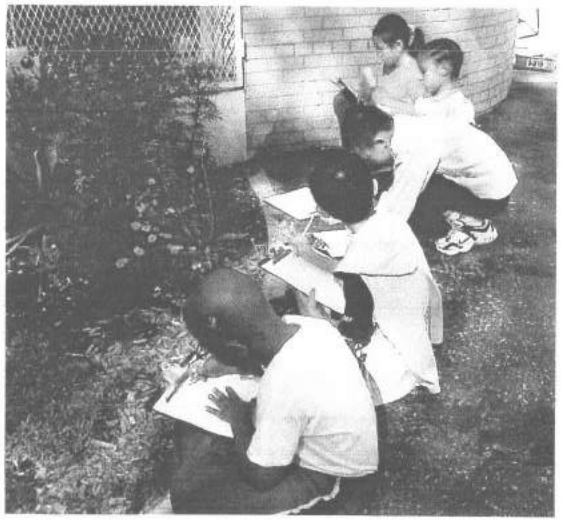
Inspired by Students 100 Years Ago, Today's Students Record the Seasons

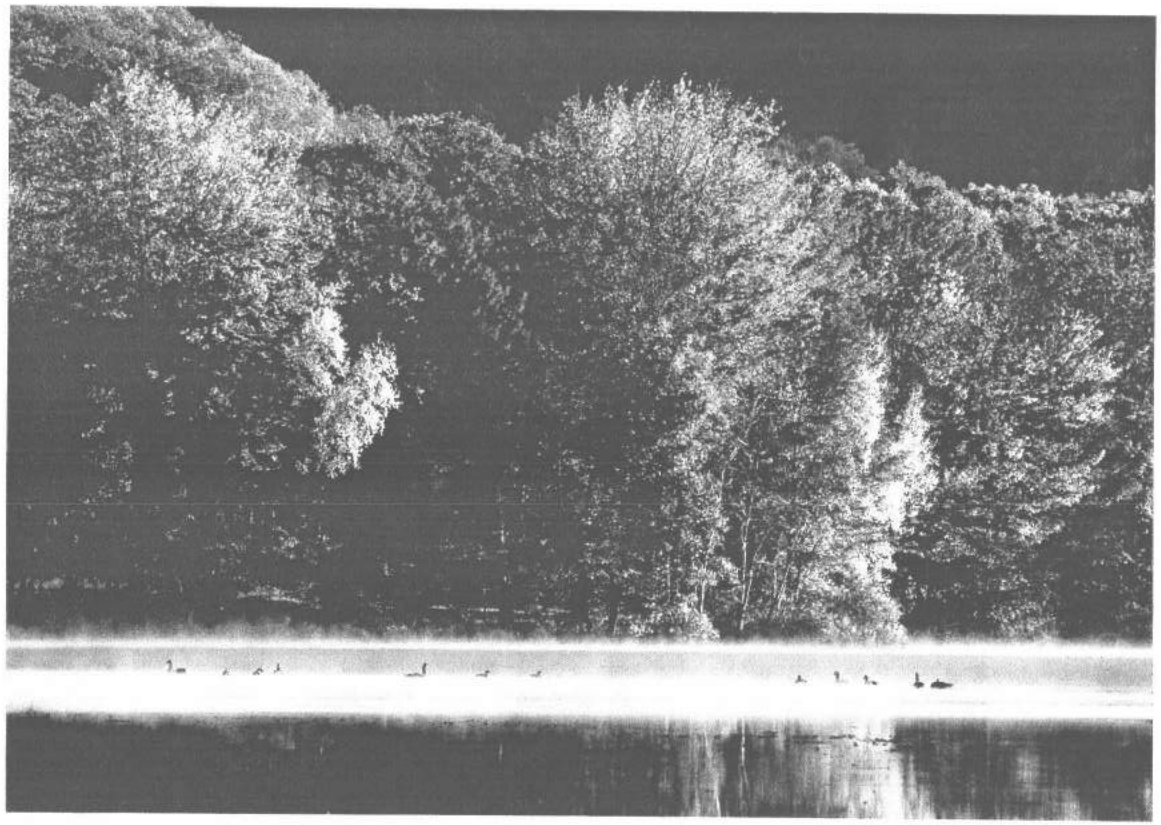
Over a hundred years ago, students in Nova Scotia, Canada collected data that can provide clues to scientists—and citizen scientists—today. From 1900 to 1923, the school superintendent there, Dr. Alexander MacKay, set up a program for observing nature in schools all around the province. Students and teachers recorded the first arrival of various bird species such as cedar waxwings and ruby-throated hummingbirds. They recorded the first fruiting of various trees, days when fields were ready to be hayed and the sheep shorn, the first autumn frost, the first appearance of snakes and of frogs calling, and the first thawing of the ice on rivers and lakes. Over 1,400 different schools participated in collecting this data, which MacKay recorded in large notebooks. They surely had no idea how valuable it could be to students and scientists in the future.

Now, a century later, the *Thousand Eyes Project* has posted MacKay's data on the internet. They are reviving his dream of having students follow seasonal changes to find out what is happening in nature. Students are again recording what birds they see and the first day they see buds on trees and blooms of flowers. With a thousand eyes observing natural events—the clues of seasonal change—scientists and citizen scientists can compare the data from 100 years ago with data collected today, and see nature's response to Nova Scotia's changing climate.

The study of how nature changes with the seasons is called *phenology*. The term comes from a Greek word meaning "to appear." Like the Canadian students one hundred years ago and today, many children are now helping scientists by collecting phenological data. You, too, can be a citizen scientist and observe changes in nature. But how can you get this information to scien-

tists who may be able to use it? There are many programs to help you connect with scientists, and more are being created all the time. Keep reading to see how you, too, can be a citizen scientist.





Previous Page: Many birds are changing their ranges in response to climate change. The Baltimore oriole, the state bird of Maryland, is living farther north than before and in the near future it may migrate to the north and not be found spending summers in Maryland any more.

Above: Fall in the northeastern part of North America is marked by the maples and oaks turning color. It is a regular event of the seasons that is happening later, while at the same time some of the maples are moving north following the warmer climate.

Top left: These students are recording when the first buds appear on various plants in their neighborhood as part of *Project Budburst*.

Bottom left: These students are in their schoolyard closely observing seasonal changes in plants.

Weather vs. Climate: What's the Difference?

People often talk about climate and weather as the same thing. However, they are quite different and these differences have important implications for how we predict changes in weather and climate.

Weather

Weather describes the atmospheric conditions at a specific place at a specific point in time. For example, the observed weather in Seattle, Washington, on Saturday, October 16, 2010 was sunny with a high of 57°F.

Weather is generally described in short time frames - minutes, hours, days, and weeks. Conditions associated with weather include (but are not limited to) sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, and thunderstorms (NASA 2010).

Climate

Climate refers to the statistics of weather. In other words, the average pattern for weather over a period of months, years, decades, or longer in a specific place. Going back to our earlier example from the weather discussion, the *average* high temperature for Seattle, Washington, on October 16 for 1971-2000 is 60°F. This value is determined by taking the average of all high temperatures recorded for the 30 October 16ths that have occurred between 1971-2000.

These examples of actual versus average conditions point to an important difference between weather and climate: while climate is what you expect, weather is what you get. Another easy way to remember the difference between weather and climate is the following statement:

"You pick your vacation destination based on the climate but pack your suitcase based on the weather."

Climate can vary seasonally or annually (e.g., because of El Niño or La Niña), over decades (e.g., because of the Pacific Decadal Oscillation), or over much long time scales (centuries or more). Climate has always varied because of natural causes. Increasingly, however, human increases in greenhouse gas emissions are beginning to cause changes in climate as well.

The following table summarizes some of the important differences between weather and climate.

	Weather	Climate
Definition	Describes the atmospheric conditions at a specific place at a specific point in time.	Describes the average conditions expected at a specific place at a given time.
Time frame	Short term: Minutes, hours, days, or weeks	Long term: Months, years, decades, or longer
Determined by:	Real-time measurements of atmospheric pressure, temperature, wind speed and direction, humidity, precipitation, could cover, and other variables	Aggregating weather statistics over periods of 30 years ("climate normals").
Study	Meteorology	Climatology

Table sources/modified from: NASA 2010, diffen.com

http://cses.washington.edu/cig/pnwc/weathervsclimate.shtml

Weather is the day-to-day state of the atmosphere in a region, and its short-term (minutes to weeks) variation whereas

Climate is defined as statistical weather information that describes the variation of weather at a given place for a specified interval. They are both used interchangeably sometimes but differ in their measure of time, and trends that affect them.

Weather is the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind. In popular usage, climate represents the synthesis of weather; more formally it is the weather of a locality averaged over some period (usually 30 years) plus statistics of weather extremes.

In a 2012 survey, a majority of Americans blamed global warming (or "climate change") for erratic weather patterns in the country, especially heat waves.

Comparison chart

	Climate	Weather
Definition	Describes the average conditions expected at a specific place at a given time. A region's climate is generated by the climate system, which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere.	Describes the atmospheric conditions at a specific place at a specific point in time. Weather generally refers to day-to-day temperature and precipitation activity
Components	Climate may include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms over a long period of time.	Weather includes sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains from a cold front or warm front, excessive heat, heat waves and more
Forecast	By aggregates of weather statistics over periods of 30 years	By collecting meteorological data, like air temperature, pressure, humidity, solar radiation, wind speeds and direction etc.
Determining factors	Aggregating weather statistics over periods of 30 years ("climate normals").	Real-time measurements of atmospheric pressure, temperature, wind speed and direction, humidity, precipitation, cloud cover, and other variables
About	Climate is defined as statistical weather	Weather is the day-to-day state of the

	Climate	Weather
	information that describes the variation of weather at a given place for a specified interval.	atmosphere, and its short-term (minutes to weeks) variation
Time period	Measured over a long period	Measured for short term
Study	Climatology	Meteorology

http://www.diffen.com/difference/Climate_vs_Weather

What's the Difference Between Weather and Climate?
02.01.05

The difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time.

In addition to long-term climate change, there are shorter term climate variations. This so-called climate variability can be represented by periodic or intermittent changes related to El Niño, La Niña, volcanic eruptions, or other changes in the Earth system.

What Weather Means

Weather is basically the way the atmosphere is behaving, mainly with respect to its effects upon life and human activities. The difference between weather and climate is that weather consists of the short-term (minutes to months) changes in the atmosphere. Most people think of weather in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure, as in high and low pressure.

In most places, weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Climate, however, is the average of weather over time and space. An easy way to remember the difference is that climate is what you expect, like a very hot summer, and weather is what you get, like a hot day with pop-up thunderstorms.

Things That Make Up Our Weather

There are really a lot of components to weather. Weather includes sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains from a cold front or warm front, excessive heat, heat waves and more.

In order to help people be prepared to face all of these, the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), the lead forecasting outlet for the nation's weather, has over 25 different types of warnings, statements or watches that they issue. Some of the reports NWS issues are: Flash Flood Watches and Warnings, Severe Thunderstorm Watches and Warnings, Blizzard Warnings, Snow Advisories, Winter Storm Watches and Warnings, Dense Fog Advisory, Fire Weather Watch, Tornado Watches and Warnings, Hurricane Watches and Warnings. They also provide Special Weather Statements and Short and Long Term Forecasts.

NWS also issues a lot of notices concerning marine weather for boaters and others who dwell or are staying near shorelines. They include: Coastal Flood Watches and Warnings, Flood Watches and Warnings, High Wind Warnings, Wind Advisories, Gale Warnings, High Surf Advisories, Heavy Freezing Spray Warnings, Small Craft Advisories, Marine Weather Statements, Freezing Fog Advisories, Coastal Flood Watches, Flood Statements, Coastal Flood Statement.

Who is the National Weather Service?
According to their mission statement, "The National Weather Service provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community."

To do their job, the NWS uses radar on the ground and images from orbiting satellites with a continual eye on Earth. They use reports from a large national network of weather reporting stations, and they launch balloons in the air to measure air temperature, air pressure, wind, and humidity. They put all this data into various computer models to give them weather forecasts. NWS also broadcasts all of their weather reports on special NOAA weather radio, and posts them immediately on their Interactive Weather Information Network website at: http://iwin.nws.noaa.gov/iwin/graphicsversion/bigmain.html.

What Climate Means
In short, climate is the description of the long-term pattern of weather in a particular area.

Some scientists define climate as the average weather for a particular region and time period, usually taken over 30-years. It's really an average pattern of weather for a particular region.

When scientists talk about climate, they're looking at averages of precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather that occur over a long period in a particular place.

For example, after looking at rain gauge data, lake and reservoir levels, and satellite data, scientists can tell if during a summer, an area was drier than average. If it continues to be drier than normal over the course of many summers, than it would likely indicate a change in the climate.

http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

We hear about weather and climate all of the time. Most of us check the local weather forecast to plan our days. And climate change is certainly a “hot” topic in the news. There is, however, still a lot of confusion over the difference between the two.

Think about it this way: Climate is what you expect, weather is what you get.

Weather is what you see outside on any particular day. So, for example, it may be 75 degrees and sunny or it could be 20 degrees with heavy snow. That’s the weather.

Climate is the average of that weather. For example, you can expect snow in the Northeast in January or for it to be hot and humid in the Southeast in July. This is climate. The climate record also includes extreme values such as record high temperatures or record amounts of rainfall. If you’ve ever heard your local weather person say “today we hit a record high for this day,” she is talking about climate records.

So when we are talking about climate change, we are talking about changes in *long-term* averages of daily weather. In most places, weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Climate, however, is the average of weather over time and space.

AZ Statewide: **National Weather Service (NWS) Automated Surface Observing Systems Arizona Stations**

The Automated Surface Observing Systems (ASOS) program is a joint effort of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD). ASOS serves as the Nation's primary surface weather observing network. ASOS is designed to support weather forecast activities and aviation operations and, at the same time, support the needs of the meteorological, hydrological, and climatological research communities. ASOS works non-stop, updating observations every minute, 24 hours a day, every day of the year observing basic weather elements, such as cloud cover, precipitation, wind, sea level pressure, and conditions, such as rain, snow, freezing rain, thunderstorms, and fog. There are 18 ASOS stations in Arizona.

National Weather Service (NWS) Cooperative Observer Program
Arizona Sites

The National Weather Service (NWS) Cooperative Observer Program (COOP) is truly the Nation's weather and climate observing network of, by and for the people. More than 10,000 volunteers take observations on farms, in urban and suburban areas, National Parks, seashores, and mountaintops. The data are representative of where people live, work and play. The COOP was formally created in 1890 under the NWS Organic Act to provide observational meteorological data, usually consisting of daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals, required to define the climate of the United States and to help measure long-term climate changes, and to provide observational meteorological data in near real-time to support forecast, warning and other public service programs of the NWS.

The data are also used by other federal (including the Department of Homeland Security), state and local entities, as well as private companies (such as the energy and insurance industries). In some cases, the data are used to make billions of dollars worth of decisions. There are 170 COOP sites in Arizona.

http://oceanservice.noaa.gov/facts/weather_climate.html

http://www.legislative.noaa.gov/NIYS/

National Snow and Ice Data Center

What is the difference between weather and climate?

Weather is the day-to-day state of the atmosphere, and its short-term variation in minutes to weeks. People generally think of weather as the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind. We talk about changes in weather in terms of the near future: "How hot is it right now?" "What will it be like today?" and "Will we get a snowstorm this week?"

Climate is the weather of a place averaged over a period of time, often 30 years. Climate information includes the statistical weather information that tells us about the normal weather, as well as the range of weather extremes for a location.

We talk about climate change in terms of years, decades, and centuries. Scientists study climate to look for trends or cycles of variability, such as the changes in wind patterns, ocean surface temperatures and precipitation over the equatorial Pacific that result in El Niño and La Niña, and also to place cycles or other phenomena into the bigger picture of possible longer term or more permanent climate changes.

Forecasting weather and predicting climate

Weather forecasters try to answer questions like: What will the temperature be tomorrow? Will it rain? How much rain will we have? Will there be thunderstorms? Today, most weather forecasts are based on models, which incorporate observations of air pressure, temperature, humidity and winds to produce the best estimate of current and future conditions in the atmosphere. A weather forecaster then looks at the model output to figure out the most likely scenario. The accuracy of weather forecasts depend on both the model and on the forecaster's skill. Short-term weather forecasts are accurate for up to a week. Long-term forecasts, for example seasonal forecasts, tend to use statistical relationships between large-scale climate signals such as El Niño and La Niña and precipitation and temperature to predict what the weather will be like in one to six months time.

Climate predictions take a much longer-term view. These predictions try to answer questions like how much warmer will the Earth be 50 to 100 years from now? How much more precipitation will there be? How much will sea level rise? Climate predictions are made using global climate models. Unlike weather forecast models, climate models cannot use observations because there are no observations in the future.

Arctic climate

Like other places on Earth, the weather in the Arctic varies from day to day, from month to month, and from place to place. But the Arctic is a unique place for weather and climate, because of the special factors that influence it. Sunlight is perhaps the most important of those

factors. Above the Arctic Circle, the sun disappears in the winter, leaving the region dark and cold. What light does reach the region in the winter comes in at a low angle. In summers, the sun shines around the clock, bringing warmth and light. The Arctic also experiences frequent **inversions**. Inversions occur when cold air settles close to the ground, with warm air on top of it. Inversions separate the air into two layers, like oil and water: this tends to slow down the winds close to the surface. Over cities, inversions can trap pollutants, creating smoggy conditions that last until the inversion clears.

Scientists separate the Arctic into two major climate types. Near the ocean, a **maritime** climate prevails. In Alaska, Iceland, and northern Russia and Scandinavia, the winters are stormy and wet, with snow and rainfall reaching 60 cm (24 inches) to 125 cm (49 inches) each year. Summers in the coastal regions tend to be cool and cloudy; average temperatures hover around 10 degrees Celsius (50 degrees Fahrenheit).

Away from the coasts, the interior regions of the Arctic lands have a continental climate. The weather is dryer, with less snow in the winter and sunny summer days. Winter weather can be severe, with frigid temperatures well below freezing. In some regions of Siberia, average January temperatures are lower than -40 degrees Celsius (-40 degrees Fahrenheit). In the summer, the long days of sunshine thaw the top layer of **permafrost** and bring average temperatures above 10 degrees Celsius (50 degrees Fahrenheit). At some weather stations in the interior, summer temperatures are warmer than 30 degrees Celsius (86 degrees Fahrenheit).

http://nsidc.org/cryosphere/arctic-meteorology/climate_vs_weather.html

WHAT'S THE DIFFERENCE BETWEEN CLIMATE AND WEATHER?

Weather is what's happening in the atmosphere on any given day, in a specific place. Local or regional weather forecasts include temperature, humidity, winds, cloudiness, and prospects for storms or other changes over the next few days.

Climate is the average of these weather ingredients over many years. Some meteorologists like the saying that "climate is what you expect; weather is what you get," memorable words variously attributed to Mark Twain, Robert Heinlein, and others.

In practical terms, the climate for a particular city, state, or region tells you whether to pack short-sleeved shirts and shorts or parkas and mittens before you visit, while the local weather forecast tells you if you'll want to wear the parka by itself or with an extra sweater today.

WHAT'S A NORMAL CLIMATE?

Climate varies across space and time, so climate is studied on a variety of spatial and time scales.

To interpret today's atmospheric conditions, we need a reference period of average, or "normal," climate to compare it against. How long is long enough to define the average climate **for a city, state, or region**? The National Oceanic and Atmospheric Administration's National Weather Service calculates a **30-year average** once a decade. The current "normals" (issued July 1, 2011) are based on data from 1981 to 2010.

When it comes to **climate on a global scale**, the "normal" reference period depends on which climate components scientists want to study. For example, many scientists compare average global temperatures, precipitation, and other variables for the 20th and 21st centuries with the 30-year averages for 1870 to 1899, before major industrialization produced large quantities of greenhouse gas.

You can see how recent observations and future projections of warming and cooling compare to conditions at the end of the 19th century by watching a visualization of data from the NCAR-based Community Climate System Model in our Climate Change Multimedia Gallery.

BEFORE THERMOMETERS

To understand how climate varies across time, scientists examine three kinds of climate data: observations, historical accounts, and environmental evidence locked up in fossils, ice cores, and other "proxy climate records."

Observations of temperature at Earth's surface date back as far as 350 years for some locations in England, but only about 100 to 150 years in most of the developed world. But even before

the thermometer was invented, **ancient civilizations kept records** of droughts, floods, unusual hot or cold weather, and other climate indicators, including planting and harvest times.

While human accounts can take us back hundreds or thousands of years, we need other tools to understand how Earth's climate has varied during its much longer lifetime of about 4.5 billion years.

Paleoclimatology delves into the deep history of past climate variation through what are called "proxy records." Air bubbles trapped in ice cores, the composition of lake sediments, changes in tree rings, pollen fossils, and other parts of Earth's ancient environment have given scientists many clues to past temperature, precipitation, wind patterns, and the chemical composition of the atmosphere through time.

Observations, historic accounts, and paleoclimate data are used to test the reliability of computer models that simulate Earth's climate on time scales from decades, to centuries, to millennia. Studying prehistoric variations can also provide important clues about what to expect in a warmer world.

https://www2.ucar.edu/climate/faq/whats-difference-between-climate-and-weather

Phenology in Your Backyard:
A Guide to Developing Your Own Phenology Garden

Developed by The Arboretum at Flagstaff
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Phenology in Your Backyard: A Guide to Developing Your Own Phenology Garden

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Appendix 1: Species Lists

I. What is Phenology?

"Phenology refers to key seasonal changes in plants and animals from year to—such as flowering, emergence of insects and migration of birds—especially their timing and relationship with weather and climate." – The USA National Phenology Network

The word phenology is derived from "phenomenon", meaning an occurrence or circumstance that can be observed. Combined with the suffix "-logy", meaning "to study," we arrive at our currently used term, which first dates back to the late 19th century. Using the power of observation and careful record keeping, scientists have been able to track changes in important biological events, like bird migration and bud burst, in association with changes in weather patterns. When a subject is studied over extended periods of time, and a long-term data set is developed, phenological events associated with a changing climate can be observed and tracked.

This guide focuses on plant-based phenology, but because plants cannot be separated from their animal symbionts, we also suggest observation of pollinators and pests of focal plants. Inclusion of animal associates of your focal plants is also a great way to reinforce the concepts of food chains and food webs.

II. Why Study Phenology?

Someone once said that "timing is everything," and for the study of important phenomena like bud burst and flowering this could not be more true. Perhaps it is easiest to visualize the importance of phenology by taking a closer look at what happens when a plant's timing is earlier or later than usual. A classic example which is frequently witnessed in Flagstaff, AZ, is the premature opening of leaf buds in the spring. Once the leaf bud breaks or bursts, the new leaf tissue is extremely vulnerable to freezing temperatures. A late frost can completely ruin a tree's flush of leaves, requiring the tree to send out a second flush of leaves, which costs the tree valuable resources in terms of energy use. Alternately, if a tree break its leaf buds later than usual, insects that would ordinarily feed on new leaves will go hungry, consequently causing their populations to decrease, which can then affect the ability of birds to feed their hungry young.

What triggers events like bud break and flowering? The answer to this question is not simple, but typically plant phenological traits are triggered by environmental cues, specifically temperatures and moisture levels. Both temperature and precipitation are critical components of climate, thus, as our climate changes, so will the timing of these events.

Over the past century, human activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. Greenhouse gases act like a blanket around Earth, trapping energy in the atmosphere and causing it to warm. This is a natural phenomenon called the "greenhouse effect" and it is necessary to support life on Earth. However, the buildup of too many greenhouse gases ("enhanced greenhouse effect") can change Earth's climate, resulting in negative effects on human health and welfare and

ecosystem function. Right now, the southwestern USA is experiencing one of the highest levels of climate change impacts in North America and has become a nexus for climate change research and study.

The study of phenology can provide important evidence that our climate is changing and reveal trends in how our environment is responding to the changing climate. For example, The U.S. Environmental Protection Agency (EPA, 2014) has identified a set of important indicators that describe trends related to the causes and effects of climate change. Among these are an index of leaf and bloom dates and documented observations in changes in the length of growing season. Anyone who has tried to grow a vegetable garden in northern Arizona knows how important length of growing season can be! Ecological studies, including phenology, often reveal disturbances in food webs.

III. USA National Phenology Network and Project BudBurst

The development of the USA National Phenology Network is credited to the U. S. Geological Survey, but many individuals and organizations have contributed to its continued growth and success, including The University of Arizona. So, what is the USA-NPN?

> "The Network is a consortium of organizations and individuals that collect, share, and use phenology data, models, and related information to enable scientists, resource managers, and the public to adapt in response to changing climates and environments." – U.S.G.S. Fact Sheet, 2011

The Network provides a very informative website (https://www.usanpn.org/node/35) that includes information on phenology indicators, educational and outreach materials, and how to become a participating Citizen Scientist. Through Nature's Notebook (https://www.usanpn.org/natures_notebook), participating members can provide data for a national database where it will be used to make important local, regional, and even global decisions regarding environmental management.

The information and resources provided by the USA-NPN are invaluable and we highly encourage you to explore these sites prior to developing your own phenology garden.

Project BudBurst began in 2007 by folks from the National Ecological Observatory Network and the Chicago Botanic Garden with funding from the National Science Foundation. Project BudBurst aims to "Engage people from all walks of life in ecological research by asking them to share their observations of changes in plants through the seasons." Project BudBurst operates within the broader scope of the USA-NPN, but caters to a slightly different audience. Similarly, you can find extremely helpful information on their website, http://budburst.org/home.

The websites offers species lists, from which you can choose (http://budburst.org/plantstoobserve) and also offers the option of selecting your own species to add to the database. Other features of this program are very similar to the USA-

NPN program in that they offer help with learning how to observe, provide datasheets and a database to which you can submit data, and data visualization tools, but Project BudBurst is primarily focused on plants.

IV. Planning Your Phenology Study: Design Options

The key to a successful garden, of any type, is having a plan! Prior to establishing your garden or trail, it is important to have a few concepts on paper. Begin by deciding **WHO** will be the garden coordinator. This person or group of people will be responsible for making sure that the plan is followed, the garden or trail is maintained, and that data are collected and stored appropriately. It is also a good idea to designate other duties, for example, who will be in charge of watering to establish the garden? Who will be in charge of weeding (if weeds are not the target organism)? And so on.

Next, decide **HOW** you will study phenology. Option A is to plan regular field trips to The Arboretum at Flagstaff to make observations using their established gardens. The pros of this option are that you do not need space for your own garden or resources to develop and maintain a garden, but the cons are that you need to expend resources in getting to and from The Arboretum at Flagstaff. Also, fewer observations will be made, but you might be able to examine more species. Option B is to develop a phenology garden trail. The USA-NPN website provides helpful information https://www.usanpn.org/node/21081 about this option. Typically, a phenology garden trail will fall along a walking path (loops work nicely), and will focus on species already growing there. The pros of this option are that you can likely find a path to use on your school property or nearby and that you will minimize expenses in establishing a new garden. The cons are that you may still need to use time to travel to the path and that you will have less choice in what you observe. Option C is to develop a phenology garden.. This option is the most resource intensive, but in the long run may be easier to maintain and utilize. For option C, the pros are that you will be able to walk outside your classroom and be at your study location. Your students can also take pride in helping with construction and ongoing maintenance of a school garden. The cons are that it will take some resources, including time, to develop and establish your school-based phenology garden.

If you decide to go with option B or C, then you need to decide **WHERE** the garden or trail will be placed. Keep the following things in mind: 1) Locate the site close as you will visit it frequently, 2) choose a uniform, representative habitat to minimize variation due to site location, 3) select a reasonable size to maintain within your available resources. Sites should not be bigger than 15 acres. And 4) make sure you have permission to establish the garden or trail. If you are establishing a garden (Option C), you want to be sure the garden area is near a water source and has good open natural light. Easy access by students and caretakers is also essential.

V. Focal Species Selection and Marking

Once you have developed a garden plan, the next step is to select the focal species for observation and mark these plants so that you know which ones to return to each

observation period. If you choose plants along a nature trail, the number of plants you select should be determined by the amount of time you want to spend making observations. For example, do you want to spend a week-long unit studying them or just a class period? If you have planted a garden, you will need to consider what species will grow well in your selected garden site and soil type. Staff at The Arboretum at Flagstaff can assist you with this process. Appendix 1 lists species taken from the USA-NPN website that can be found/grown in the Flagstaff area. For those who are outside of the Flagstaff area, we suggest looking at the species list on the USA-NPN website to choose your focal species https://www.usanpn.org/nn/species_search.

The key to any successful long-term monitoring project is making sure your plants are labeled clearly and that the labels do not come off! The Arboretum suggests using aluminum hang-tags that can wired onto a plant without hurting the plant. These tags hold up in the field environment very well, but will still need to be replaced periodically. The following website illustrates and provides pricing for the suggested tags, http://www.nationalband.com/nbtwrite.htm.

VI. Monitoring Protocols and Data Presentation

The USA-NPN website provides all of the tools that you will need to begin learning not only how to monitor but what to monitor in terms of different phenophases. We highly suggest joining Nature's Notebook and participating in the training videos found here: https://www.usanpn.org/nn/guidelines/shared-sites. Logging your class' data into Nature's Notebook will provide a sense of importance to the work that has been done, and make an important contribution to a citizen science database. The website can also assist you with visualizing datasets for classroom instruction and interpretation; see the following page, https://www.usanpn.org/nn/connect/visualizations for more information.

VII. References

U.S. Environmental Protection Agency. 2014. Climate change indicators in the United States, 2014. Third edition. EPA 430-R-14-004. www.epa.gov/climatechange/indicators.

U.S. Geological Survey. 2011. The USA National Phenology Network – Taking the Pulse of Our Planet. http://pubs.usgs.gov/fs/2011/3023.

Appendix 1: Species List
https://www.usanpn.org/nn/species_search

*Available from the USDA PLANTS database (http://plants.usda.gov/java/)

Common Name	Latin Name	Native or Exotic	Lifeform	Lifecycle	Fact Sheet-Plant Guide
alkali sacaton	*Sporobolus airoides*	Native	grass	perennial	Yes
Arizona fescue	*Festuca arizonica*	Native	grass	perennial	Yes
Blue grama	*Bouteloua gracilis*	Native	grass	perennial	Yes
cheatgrass	*Bromus tectorum*	Exotic	grass	annual	Plant Guide only
deergrass	*Muhlenbergia rigens*	Native	grass	perennial	Yes
needle and thread	*Hesperostipa comata*	Native	grass	perennial	Plant Guide only
sideoats grama	*Bouteloua curtipendula*	Native	grass	perennial	Yes
western wheatgrass	*Pascopyrum smithii*	Native	grass	perennial	Yes
butterfly milkweed	*Asclepias tuberosa*	Native	forbs/herbs	perennial	Yes
common dandelion	*Taraxacum officinale*	Exotic	forbs/herbs	perennial	No
common sunflower	*Helianthus annuus*	Native	forbs/herbs	perennial	Plant Guide only
common yarrow	*Achillea millefolium*	Native	forbs/herbs	perennial	Yes
scarlet gilia	*Ipomopsis aggregata*	Native	forbs/herbs	biennial	No
scarlet globemallow	*Sphaeralcea coccinea*	Native	forbs/herbs	biennial	Plant Guide only
yellow sweetclover	*Melilotus officinalis*	Exotic	forbs/herbs	all	Plant Guide only
arroyo willow	*Salix lasiolepis*	Native	shrub/tree	perennial	No
big sagebrush	*Artemisia tridentata*	Native	shrub/tree	perennial	Yes
blue elderberry	*Sambucus nigra ssp. Caerulea*	Native	shrub/tree	perennial	Plant Guide only
boxelder	*Acer negundo*	Native	shrub/tree	perennial	Plant Guide only
curl-leaf mountain mahogany	*Cercocarpus ledifolius*	Native	shrub/tree	perennial	No
Gambel's oak	*Quercus gambelii*	Native	shrub/tree	perennial	No

ponderosa pine	*Pinus ponderosa*	Native	shrub/tree	perennial	Yes
aspen	*Populus tremuloides*	Native	shrub/tree	perennial	Plant Guide only
Pinyon pine	*Pinus edulis*	Native	shrub/tree	perennial	Plant Guide only
redosier dogwood	*Cornus sericea*	Native	shrub/tree	perennial	Plant Guide only
Siberian elm	*Ulmus pumila*	Exotic	shrub/tree	perennial	Yes
rubber rabbitbrush	*Ericameria nauseosa*	Native	shrub/tree	perennial	Yes