PASSPORT TO WEATHER AND CLIMATE
Implementation Guide

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PASSPORT TO WEATHER AND CLIMATE
Introduction and Overview

> Will it rain today... will it be sunny? Is there snow in the forecast? Will a hurricane close school? *Weather* affects the way we live each and every day.
>
> Will this winter be dry or wet? Will farmers face drought and years of hardship? Will fishermen off South America find feast or famine in the seas? Global *climatic* events like El Niño and La Niña shape the seasons and the decades in which we live.

PASSPORT TO WEATHER AND CLIMATE uses students' natural fascination with thunder, lightning, and extreme weather events such as tornadoes and winter storms to bring to life fundamental science concepts central to all science curricula for students in grades 5-9. Eight (8) fifteen minute student programs use dramatic footage, taped on location in America and around the world, to show the forces which shape Earth's weather and climate: Sun and the seasons; radiation, convection and conduction; the differential heating and cooling of land and ocean; terrain and topography; pressure and altitude, and the greenhouse effect. Two (2) thirty minute Teacher Orientation Videos show educators, step-by-step, how to implement the Module, using hands-on and on-line resources.

PASSPORT TO WEATHER AND CLIMATE was produced with the cooperation of the nation's leading research agencies on weather and climate—NOAA (the National Oceanic and Atmospheric Administration), NASA (the National Aeronautics and Space Administration) and NCAR (the National Center for Atmospheric Research, funded primarily by NSF.) Through the videos and on-line your students will meet a diverse group of researchers working for these agencies and universities across the United States: we hope your students catch the scientists' enthusiasm for their subject and that the on-camera researchers, engineers and technicians will serve as role models for the benefits of applying your self at school in order to develop the skills to have a satisfying career as an adult.

As the hip, young meteorologist Mark Croxford says (students see him in programs 1, 2, and 8)

> *"It is so exciting to learn (weather and climate) in the classroom… You're learning principles, and then the very next hour you can go outside and see those principles in action… I've been in other sciences, where you're learning more abstract notions: meteorology is just so "applied," it's the most applied science there is… I mean, what other science do you have where you have a report about them, every single night on the news. Every night people want to know about the weather. It's the most applicable science, it's the most exciting thing going."*

Throughout the Module students will also see the technology, and the engineers and technicians, without which weather scientists would be flying blind. They'll see why balloons and specially armored planes, satellites and Doppler radar are also part of studying weather and climate. And they'll see that software designers like Deborah Miller (program 8) are just as enthusiastic—idealistic, even—about their jobs. Deb helps develop computer programs to bring near-real time data to firefighters and emergency managers:

> *"Hopefully, we can say that we played a role in saving some lives because weather unlike any other science, is interrelated with human activity. Here we are actually a humanitarian science, and that's why I love my job."*

PASSPORT TO WEATHER AND CLIMATE also allows you to demonstrate the relevance of math, physics, communication skills and teamwork. Understanding still mysterious phenomena such as lightning and tornadoes requires minds open to new ways of thinking.

Unlike some other "instructional television" which is merely adult or general interest programming re-purposed into shorter segments, **PASSPORT TO WEATHER AND CLIMATE** has been created specifically to speak to students, literally as well as figuratively. The scientists appearing to camera directly address student-viewers, looking into the camera. When Daphne Zaras from NOAA's National Severe Storms Lab shows students the instruments carried on board one of the cars of the mobile mesonet used in VORTEX and STEPS (see programs 3 and 4), we want students to feel as if they're VIPs, taken behind the scenes to get a briefing from the researchers who know the science and technology best. In program 1, when NASA's Marshall Shepherd and NOAA's Patrice Kucera introduce basic concepts, they use hand gestures and dynamic graphics, as well engaging viewers with clear and accessible language. On location at a Miami, FL beach as a storm rolls in, Mark Croxford uses the unfolding scene to describe the characteristic behavior of cumulonimbus clouds. In program 3, Daphne gestures behind her to a huge "mothership" cloud, describing how its rotation may come to ground as a tornado. Through **PASSPORT TO WEATHER AND CLIMATE** the living world outside your classroom becomes the "text," and you—the teacher—working with the researchers and these multiple media materials replace the dry and dated "book."

Some of the ideas you and your students will encounter in **PASSPORT TO WEATHER AND CLIMATE** are new: in program 8 you'll see why scientists now think soot from forest fires reduces rainfall (it increases the number of condensation nuclei so water drops don't grow large enough to fall as rain); in program 7 they'll hear climate data updated through the year 2000. In every program, however, some of the world's best scientists, some senior, some up and coming—like JPL's Bill Patzert, Paul Markowski from Penn State, Cynthia Rosenzweig from NASA's Goddard Institute for Space Science, or Warren Washington from NCAR—bring the topic to life in clear and expressive language. NASA animations show our world in dynamic motion, and the processes that shape our lives.

Most middle and upper elementary schools already have "weather units" so we think you'll find this Module fits easily into the curriculum. But weather and climate, like P2K's other Modules on Antarctica, the rainforest and the solar system, also connects with otherwise context-less topics from "physical" or general science. Lightning (program 5) allows you to explore insulation and conduction. A hands-on Activity like 1.2, *Differential Heating and Cooling of Land and Ocean* (TG, page 11) introduces issues of energy and heat in a natural context. We think you'll find many more connections allowing you to enrich topics you already teach with these fresh, new programs and activities.

PASSPORT TO WEATHER AND CLIMATE (PTW&C) builds, in part, on resources originally gathered to support a series of live, interactive "electronic field trips" plus new footage specifically taped for this instructional use. These materials have now been completely re-edited and reformatted into an evergreen package of materials that can be implemented *anytime* during the school year, and *anywhere* there's a teacher dedicated to turning young minds on to the wonders of the natural world. Watching the programs on videotape frees you from difficulties with live satellite downlinks, and the PTW&C website allows you to time-shift interaction with weather and climate researchers to whenever it works best for you and your schedule.

The original project was made possible, in part, by support from NOAA (the nation's lead agency in forecasting weather and climate) and NASA (responsible for researching and prototyping new space-based technologies to help us monitor weather and climate). Thanks, also, to the NASA Education Division, Code FE, Goddard TV and the individual researchers who spoke with us on-camera or behind the scenes, during the research and production process.

But **PASSPORT TO WEATHER AND CLIMATE** is far more than a set of TV programs, no matter how lively and informative. For students, the availability of the Hands-On Activities makes watching the videos just the beginning of the learning experience. The PTW&C Teacher's Guide co-packaged with this Implementation Guide (IG) offers 31 Hands-On Activities—far more than any teacher would ever have time to implement, even if you dedicated 1/3 of the year just to this Module. This IG suggests a short sub-set of specific Activities which P2K thinks best complement and enhance each of the videos.

Here's how we hope the integrated multiple media materials might work effectively for your and your students: after seeing the dramatic, destructive force of tornadoes (program 3), a hands-on Activity like "Twister in a Bottle" (TG p32) helps students understand the shape and force of a tornado's vortex. After seeing how severe storms produce lightning, and how lightning produces thunder (program 4), Activity 2.3 (TG p30) enables students to make lightning safely for themselves, and literally get their hands on simple insulators and conductors. The on-line resources available at the PTW&C website and the extensive links suggested in the TG and IG then allow students to go further to both meet the researchers whose work they have been seeing, and also find out more information. It's a 1-2-3 punch which utilizes the unique P2K learning model in which "100% video + 100% hands-on + 100% on-line" makes *Real Science*, *Real Scientists* and *Real Locations* into *Real Learning*. (See the chart that follows on page 15 for a summary of some the most important scientific principles which each video and set of Activities will help you cover. In this IG, each video also has a specific set of NSES/"Benchmarks" associated with it. On-line you will find a state-by-state listing of standards met.)

This Module is designed to be a powerful but integrated and easy-to-use package of materials and resources. It has been shaped by educational designers and multimedia producers, working collaboratively with classroom teachers, over several years. It provides more than enough information and activities to function as a 6-8 week replacement unit for segments of your current Earth and Physical science curriculum. Or it can be used to supplement your existing texts with current and engaging experiences. (See Teacher Handout A.1 for "Three Scheduling and Implementation Options.")

There are many variables that will influence a teacher's decisions in planning how to use this Module, from the grade level of the students, to scheduling limitations, to access to technology. Will PTW&C be entirely implemented within a science class at the middle school level or in the more fluid dynamics of an upper elementary school setting? Will other teachers be involved? The possibilities are both varied and numerous. And the rewards, for teachers and students alike, should be significant, from measurable new cognitive learnings to less easily-measurable, but no less important, changes in affective areas, such as an increased awareness of real world science, the diversity of jobs and people involved in meteorology, the changing seasons, and the daily drama we can read in the skies above our heads.

This Implementation Guide is your roadmap to the entire project, showing how to get the most from the integrated, multiple media resources at your disposal. These are the components of **PASSPORT TO WEATHER AND CLIMATE**:

VIDEO

Eight 15 minute Classroom videos, enlivened with documentary sequences taped on location across America and in exotic locations such as the Ivory Coast show students weather and climate phenomena close-up and in detail. Animations and satellite imagery from NASA and others present the planetary processes that shape Earth's weather and climate, and help explain many physical science principles. Two 30 minute Educator programs introduce weather and climate, preview the series and key science concepts, and show master teachers demonstrating some important Hands-On Activities. Each program (apart from #4 which has 2 segments) includes three 4-5 minute segments, indicated by "chapter-heads", which can be used to help you pace the class period.

Program 1 introduces some of the key principles which power all weather and climate phenomena: it's full of information, and you may choose to re-use it as a wrap-up, allowing students to appreciate how much they've learned since the beginning of the Unit. Programs 2, 3, 4, 5 and 6 then explore some of the most dramatic weather and climate phenomena: hurricanes, tornadoes, winter storms, thunder and lighting, and El Niño/La Niña. Program 7 looks at Earth's climate over time, and introduces issues such as the Greenhouse Effect and global climate change, which students will recognize from the headlines. Program 8 focuses on the technology used to make forecasts, and how weather and climate science can be used to help society.

HANDS-ON

The **PASSPORT TO WEATHER AND CLIMATE** Teacher's Guide which accompanies this Implementation Guide provides 31 field-tested Hands-On Activities to help you put essential science content in exciting real world context. Teacher Backgrounders provide additional factual information to help you introduce the Activities, and extend topics covered in the videos. The Module provides you, the educator, with a broad menu of choices through which to connect the science principles students can see at work in the real-world scenes captured on video to project-based discovery activities. Students can then experience those principles for themselves in your classroom—without fear of being hit by lightning, or chasing too close to a twister!

ON-LINE

The **PASSPORT TO WEATHER AND CLIMATE** website provides essential background on this Module both for you and your students. It also serves as a portal to the best on-line resources available elsewhere on the Web—reviewed by fellow teachers—and offers learning opportunities unique to PTW&C, such as:

- BIOgraphies telling how many of the featured researchers began their careers
- Behind the scenes JOURNALS describing first-hand and in memorable anecdotes what it's like to have a career studying weather and climate
- DISCUSS, a moderated forum delivered via e-mail, specifically for teachers, and
- RESEARCHER Q&A, a way for students to interact directly with leading scientists and others. (From here on in the Implementation Guide, when you see words in bold, Courier font, such as **`BIOgraphies`** or **`RESEARCH/ers`**, this special formatting indicates a specific section of the website.)

THE IMPLEMENTATION GUIDE

This Implementation Guide (IG) is organized to complement the 2 "Educator" and 8 "Classroom" or student videos. Each section provides:

- 3-4 achievable student learning objectives aligned with the NAS/NRC *National Science Education Standards* and AAAS/Project 2061 *Benchmarks*
- Background on the content of the videos
- Vocabulary words (many found in the Glossary of the printed Teacher's Guide and all defined on-line, in student-friendly, interactive "WordSearch" puzzles)
- Pre-Viewing Questions to help you manage students' anticipatory set
- Post-Viewing / Quiz Questions and Discussion Starters to use after the programs
- Specific Hands-On Activities (cited by page numbers in the companion Teacher's Guide)
- Science standards met by each program and set of Hands-On Activities and on-line resources.

While the IG suggests what we believe are the most appropriate Activities for each video, you'll likely find others that may better suit your own particular instructional goals and local circumstances. Feel free to pick and choose—and let us know what works best for you, via **`discuss-storm`**.

GETTING STARTED (for Teachers)

- **Step 1** Preview the eight 15:00 minute **PASSPORT TO WEATHER AND CLIMATE** classroom videos. Will you use all eight? Will you show them in the suggested sequence?
- **Step 2** Examine the specific learning objectives suggested for each of eight videos. Which student outcomes are most appropriate for your group of students? Which Activities best meet these objectives? Some Activities will fit into one 40-50 minute class period; others may require 2-3 class periods. Some Activities are hands-on labs requiring specific equipment and science supplies, and therefore advance teacher prep.
- **Step 3** Make decisions about assessing student progress. Teachers might consider including students in this aspect of decision-making. Certainly, at the very least, students need to be aware from the beginning of the expectations and requirements you have for this Module.

Please use the **PASSPORT TO WEATHER AND CLIMATE** website for the latest and most accurate URLs: as you already know, the World Wide Web evolves as rapidly as the world itself. Some addresses may have changed since the printing of the IG and the TG.

If you have questions, submit them to **`ptkinfo@passporttoknowledge.com`** or subscribe, via the website, to the **`discuss-storm`** mail list. An experienced classroom educator will get right back to you with answers.

Good luck with implementing **PASSPORT TO WEATHER AND CLIMATE**. We hope to hear of your success in exciting students about science concepts that will help them academically *and* also inspire them with a new understanding of and appreciation for the world around them. As Mark Croxford says in program 8, weather is perhaps the most accessible of all sciences, and certainly the only one where every day on the TV news you'll find a bulletin about its consequences. Weather matters to all of us, and we hope that this gives you a powerful hook to make the science come to life for your students. Perhaps one day some of them will follow in the footsteps of the adventurous researchers they'll encounter in the videos, and discover important new things about storms which may save lives while giving us new understanding of weather and climate.

PASSPORT TO WEATHER AND CLIMATE
Geoff Haines-Stiles, Project Director
Erna Akuginow, Executive in Charge
Eileen Bendixsen, P2K On-line Moderator
Summer / Fall 2001

NOTE ON THE VIDEOS
If your local public television station or educational network has not broadcast the programs, you may obtain videocassettes of individual programs, or the entire 10 program series. To inquire about educational audiovisual rights (which can include school- and/or district-wide broadcast, video-streaming or broadband hosting via "video jukebox" etc.) please contact PASSPORT TO KNOWLEDGE via e-mail, or by calling (800) 267-2977.

The Teacher's Guide referred to in this IG, together with an oversize, full-color poster are also available: please contact P2K as above for availability and pricing.

Educator Program A
Weather and Climate: A Primer for Teachers (29:03)

The two Educator programs, A and B, are designed to:

1) provide brief introductions to the *people* and *places* seen in the Classroom videos
2) familiarize teachers with some of the key scientific *principles* which can be addressed through **PASSPORT TO WEATHER AND CLIMATE**
3) complement the IG in suggesting how best to connect Hands-On Activities to fundamental scientific principles and specific videos, and provide a few exemplary demonstrations by master teachers

Please note that while these programs are specifically structured to serve as a kind of mini "in-service" for teachers, some segments may also be of interest to students. For example, the overviews of NOAA's and NASA's research provide a quick roundup of interesting locations and processes. You may also find that some of Marshall Shepherd's metaphors ("wind is a little like what you feel when you open your freezer door") or Jeff Halverson's comments about angular momentum at different scales help introduce important concepts.

Educator program A has 4 main sections following Program titles and a visual Table of Contents:

1) **WHAT IS P2K?**
2) **HOW TO IMPLEMENT "PASSPORT TO WEATHER AND CLIMATE"**
3) **NOAA'S AND NASA'S RESEARCH**
4) **THE SCIENCE BEHIND WEATHER AND CLIMATE**

WHAT IS P2K?
This segment is designed to familiarize you with the power of using multiple media materials to engage students with key science concepts. Scenes from previous P2K projects are intercut with comments from a variety of classroom teachers who've participated. You'll see how each element—video, hands-on, and on-line—contributes to a powerful learning experience, and what each contributes. You'll see how the hands-on Activities all relate to real-world content, and how on-line resources provide opportunities for accessing information, but still more importantly facilitate interaction and collaboration. We also cite some headlines from the 3-year evaluation of P2K which was supported by NSF: you can find a full report on-line. If you (or your Administration) have any doubts about the educational value of implementing P2K instead of more traditional materials, this is the place to go for statistics, case studies, and encouraging comments from fellow teachers.

HOW TO IMPLEMENT "PASSPORT TO WEATHER AND CLIMATE"
The second section describes the specific components of this Module. There's a quick overview of the Classroom videos, using the introductions of each of the 8 programs. You'll preview the 2-3 sections, each 3-5 minutes long, which make up each video. Chapter heads give you a place to start and stop to facilitate student discussion, or to break to shift to hands-on or on-line work. But

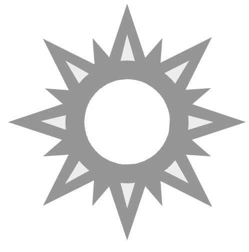
a hallmark of P2K is that we integrate direct-to-camera comments from working researchers with the science and documentary footage. On-line resources enable students to find out how the on-camera researchers got started on their careers, and what they like, and even dis-like, about their jobs. Next we describe the **PASSPORT TO WEATHER AND CLIMATE** website. While it already provides a great deal of background as well as useful links to the extensive information available elsewhere on the Web, it's also a "Continuing Construction" site. It will grow to support new science, new interactive opportunities and, we hope, also to house examples of your students' work. Be sure to check out the interactive animations of hurricanes and tornadoes, El Niño and winter weather. The website provides a way for students to review what they've seen in the videos, as well as to dig deeper in content if they, or you, so wish.

NOAA'S AND NASA'S RESEARCH

Another unique aspect of P2K projects is that rather than staging one-time-only expeditions for video or the Web, instead we look over the shoulders of real scientists doing real science. This is only possible because of the exceptional collaboration of research agencies and the researchers themselves. In this segment you'll see an introduction to NOAA's weather and climate research, and a preview of some of NASA's contribution to meteorology and Earth System Science. You and your students will readily see how "relevant" weather and climate science is to society: new understanding of storms helps save lives and protect property.

THE SCIENCE BEHIND WEATHER AND CLIMATE

In the final segment of Educator Program A, two of our on-camera presenters introduce a few of the key concepts that help make weather and climate understandable. Marshall Shepherd compares Earth's temperature and pressure gradients to what happens when you open your refrigerator. There's a rush of cold air out into the warmer air. Then he introduces the idea of weather "fronts" and traces its derivation to the battles of World War I. In nature, it's cold and warm air which are in conflict, producing the changeable weather we experience. Jeff Halverson, also a NASA researcher and educator, describes angular momentum as what shapes a hurricane, a tornado, or the rotation of an ice-skater pulling in his or her arms. It's these kinds of synthesizing ideas that we try to present throughout the series, to help students both understand the central concepts, and to connect "classroom learning" to what they can see in the real world.



Educator Program B
"Connecting Weather and Climate to the Curriculum" (29:49)

Educator program B has 3 sections, each presenting a Master Teacher (and member of the PTW&C Materials Development team) implementing one of the hands-on Activities in class. These are real teachers and real students, and we present them at some length and with "teacher tips" comments to encourage you to use these and the other Activities with your own students.

1) **Activity 4.2 "Hurricane Houses"**
2) **Activities 2.1-2.6, "Making Weather in Class"**
3) **Activity 3.5, "Doppler Radar in a Shoebox"**

1) Activity 4.2 "Hurricane Houses"

At Leon High School in Tallahassee, FL, 9th grade science teacher Kathy McQuone shows how to implement one of the noisier and more ambitious Activities. Though it does require some teacher preparation, recruiting some additional adult assistance (or parent volunteer) and using a leaf-blower in class, you can see how positively students and their Principal respond. As Kathy explains, this Activity involves math as well as science, wrestling with issues of design and technology as well as hurricane-force winds, and teamwork as well as individual learning.

> "When I see the excitement of the students, when I see the interaction of the students, when I see them cheering when they accomplish a task, I certainly see the benefit of that over just handing back a test grade. And that motivates me, even more, to want to bring in these kinds of activities into my classroom because I clearly see the difference in the excitement of the students when they say, 'Mrs. McQuone, I really like science this year,' it makes it all worth it."
> Kathy McQuone, 9th grade science teacher
>
> Student (excitedly) "Hey, the roof stays on!!!"

2) Activities 2.1-2.6, "Making Weather in Class"

In this section, we see details of how to make lightning, measure the dew point, and create a twister in a bottle. P2K on-line moderator and veteran middle school science teacher Eileen Bendixsen shows how to set up the 6 "making weather" activities at a set of experiment stations, allowing students to experience each in turn. She emphasizes the simplicity and inexpensiveness of the materials, and describes how she integrates the different media by starting with a segment of the video, then undertaking the hands-on Activities, and then suggesting students go on-line. Like Kathy, she argues that not only does this kind of learning excite students, but also allows her to cover the core science concepts even more effectively than more traditional instruction.

> "One of the things this Unit allows us to do, just like all the other Passport to Knowledge Modules, is to integrate other topics. It's not just about weather, it's about heat, energy, pressure…" Eileen Bendixsen, 7th grade science teacher

3) **Activity 3.5, "Doppler Radar in a Shoebox"**

Some of the most dramatic imagery in **PASSPORT TO WEATHER AND CLIMATE** shows tornadoes, and the efforts of forecasters to understand where they are going, and how large they will be. Tim McCollum, whose school is in Charleston, IL, at the top of Tornado Alley, shows how to simulate the operation of Doppler Radar using a simple shoebox. This Activity connects to the Standards that relate to how the changing wavelength of light provides clues to the motion of an object. Exploring the Doppler shift this way also makes one of astronomy's main tools more understandable. This section of the Educator Program integrates actuality footage of NWS forecasters at work, and may also be used to introduce Activity 3.5 to your students in order to reinforce their sense that they are paralleling in class what real scientists do in the real world.

Tim also shows how the "Doppler data" can be presented using colored pencils and paper, or on a computer, using a simple software package such as NIH Image. In the **`Teacher Tips`** section of the PTW&C website, you'll find the URL where you can see the results obtained by Tim's students. As you'll see, this simple Activity really does generate images that resemble real Doppler data.

> "I think this is really fun because it's sort of like we're scientists and we're recording data and making images, so it makes you kind of feel like a meteorologist. And I think we've gotten a lot out of this." Female student
>
> "Feedback from the parents has been great. The kids come home excited, they're not tied to a textbook; we go well beyond what any textbook could offer. We're simulating real science in the classroom, so they're actively involved. I'd like to think that science for them becomes a verb and not just a noun. It's a way of doing things, and not just something that they studied. What I'm hoping is that when they go home and they turn the TV on and they see a radar image on the TV screen, the kids say, 'hey, I know how that works, I did that in class, we modeled that in class.' Tim McCollum, 8th grade science teacher

In addition to the specific content Standards and Benchmarks listed for each video, PASSPORT TO WEATHER AND CLIMATE also touches on process and "habits of mind" throughout. The following important standards can therefore also be covered.

16.3.3 Knows various settings in which scientists and engineers may work (e.g., colleges and universities, businesses and industries, research institutes, government agencies)
16.4.2 Understands that individuals and teams contribute to science and engineering at different levels of complexity (e.g., an individual may conduct basic field studies; hundreds of people may work together on a major scientific question or technological problem)
16.4.5 Understands that science involves different types of work in many different disciplines…
16.4.6 Knows that creativity, imagination, and a good knowledge base are all required in the work of science and engineering

Opening Activities

Once you've reviewed the student and educator videos, this IG and sampled the co-packaged printed Teacher's Guide, we hope you'll be anxious to begin. Teacher Reference Sheet A.1 suggests a varying menu of options if you have 2, 4 or 6 weeks to spend on this Module. Just as in any tour book that suggests how to "do" New York, Rome or Paris in a day or two, you'll obviously be able to cover more topics in more depth the longer you have available to you.

PASSPORT TO KNOWLEDGE has found there are several excellent ways to help students reflect on what they learn as they participate in the Module, and which will also help you, the teacher, assess that learning.

Getting Students Started

The Opening Activities found in the Teacher's Guide (pp. 4-6) are designed to familiarize your students with the kinds of topics they'll be encountering during the Module, to introduce key concepts and vocabulary, and also to enable you to establish a baseline of pre-existing knowledge—conceptions and *mis*conceptions alike—for assessment and evaluation purposes.

1) Activity A.1 Weather and Climate Facts, Fictions and Questions

As described on Teacher's Guide, p4 this Activity gives you a window on the mis/conceptions about weather and climate which students bring to school. Reviewing their answers will give you an inventory of their pre-existing ideas. Sharing them in class at the beginning of the Module will stimulate students. Still more, revisiting their ideas both during and at the end of the Module will show you and them how far they've come. (There are answer keys for both this Activity and the more formal Pre- / Post-test in the package of copy masters and handouts.)

2) Activity A.2 The KWL (Know-Want to know-Learned) Chart

The KWL process is likely already well known to you. This can be used instead of, or as a supplement to Activity A.1. Each student should create a three-column chart with the headings: KNOW, WANT TO KNOW, and LEARNED. In the first column, the student should list all the facts they already know about weather and climate. (Misconceptions—e.g. "Summer is warmer than winter because Earth is closer to the Sun in summer"—are acceptable at the beginning since they can be addressed and corrected during the Module) The following questions might help to focus their thoughts:

- What is weather? What is climate? Why do we use 2 different words?
- What makes a thunderstorm? (Or clouds, or lightning, or a tornado…?)
- Why is my home state's climate the way it is?
- What kinds of people study weather and climate, why, and with what tools?

See TG, p5 for more suggestions about how to get the most from KWL. Throughout the Module, students should be encouraged to assess and record in their WEATHERlogs (see below) how their ideas have changed, note what questions have been answered, and keep an ongoing list of new learnings.

A.3) Pre-test / Post-test

Just what you'd expect, with a mix of True/False, Multiple Choice, Fill in the Blank, Size and Sequence, Mix and Match items.

A.4) WEATHERlogs (or Weather Journals)

TG, p5 suggests ways to create and use student journals or portfolios. Copy master A.4 gives you a Rubric to assess this aspect of their work if it forms part of your formal Module assessment. Share with students *your* expectations for how their work during the Module will be graded. We hope that **PASSPORT TO WEATHER AND CLIMATE** will be fun for your students, but we also want you, them—and your Administration—to know that this Module should also be a powerful and effective learning experience.

The **PASSPORT TO WEATHER AND CLIMATE** Hands-On Activities relate to a significant number of the National Science Education Standards but, of course, this IG can only present *national* standards, not 50 different sets of state guidelines. (A 4-sided Correlation of PTW&C Activities with the NSES and Benchmarks is part of the package of worksheets.) On-line at the PTW&C website, however, (select `EDUCATORS` in the bottom navigation bar, and then `STANDARDS` / `State-by-State` in the side panel) you'll find state-by-state correlations that show you more clearly how this P2K Module can function effectively as a substantive curriculum replacement unit. These are the Standards/Benchmarks you will most easily be able to address through PTW&C:

Science Standard: 1 Understands basic features of the Earth [Project 2061: Benchmarks for Science Literacy, p. 66 (Explicitly stated)]
Science Standard: 2 Understands basic Earth processes [Project 2061: Benchmarks for Science Literacy, p. 71 (Explicitly stated)]
Science Standard: 10 Understands basic concepts about the structure and properties of matter [Project 2061: Benchmarks for Science Literacy, p. 75 (Explicitly stated)]
Science Standard: 11 Understands energy types, sources, and conversions, and their relationship to heat and temperature [Project 2061: Benchmarks for Science Literacy, p. 81 (Implied)]
Science Standard: 12 Understands motion and the principles that explain it [Project 2061: Benchmarks for Science Literacy, p. 87 (Explicitly stated)]
Science Standard: 13 Knows the kinds of forces that exist between objects and within atoms [Project 2061: Benchmarks for Science Literacy, p. 93 (Explicitly stated)]
Science Standard:14 Understands the nature of scientific knowledge Project 2061: Benchmarks for Science Literacy, p. 5 (Explicitly stated)
Science Standard:15 Understands the nature of scientific inquiry Project 2061: Benchmarks for Science Literacy, p. 9 (Explicitly stated)
Science Standard: 16 Understands the scientific enterprise Project 2061: Benchmarks for Science Literacy, p. 14 (Explicitly stated)

WHAT ELSE CAN YOU FIND IN THE TEACHER'S GUIDE?

Complementing the PTW&C Guide, all necessary Student Worksheets and handouts are included as copy masters for easy duplication. If you are team-teaching, there are also social studies, language arts, mathematics, and technology extensions for some of the Activities. "Suggested URLs" have been reviewed by our educator team and the best ones are listed with brief descriptions.

Closing Activities (discussed on IG page 52, TG page 61) allow you and your students to review concepts, procedures and experimental outcomes to assess what's been learned and to evaluate how well the learning goals stated at the outset have been accomplished.

TIPS FOR USING THE VIDEOS

In this Guide we suggest and assume the programs are used to begin each mini-unit and set of Activities. But since the programs are packed with information and (we hope) also fun to watch, you may find students enjoy and benefit from repeating the program(s) or segments of them *after* you have completed the correlated Activities. With each viewing students will pick up additional facts and concepts. What they've learned will be powerfully reinforced. Be sure to show the programs with the classroom lights *on* to emphasize to students that this is a genuine learning experience. (A number of additional suggestions are made by educational consultant Faith Rogow in the "Don't Turn Off the Lights" double-sided handout provided.) You'll find leaving lights on will help your students pay closer attention to what's happening on screen and not view this set of videos as free time.

ON-LINE RESOURCES

The on-line components of the Module allow you to extend student learning. The website provides additional information, links to other resources, and much more. The **`WHAT'S NEW`** section includes links to new material on the PTW&C website as well as to some of the latest information to be found elsewhere on the WWW. Students are also able to find out more about the researchers they've seen on camera through the **`BIOgraphies`** and **`JOURNALS`** found in the **`WHO`** section. If your school is subscribed to the interactive section of the website, your students will have the opportunity to interact with weather and climate researchers at any time of the year through **`INTERACT / RESEARCHER Q&A`** by submitting individual questions. They will receive back—within 1-2 weeks—individual responses. Each Q&A pair is then archived to form a growing and evolving resource that other students can search and access. As noted above, the **`EDUCATORS`** section provides you with some of the state standards you can cover using this Module and links directly to the Activities through which you can cover each standard. There are also areas to post student work and additional tips and resources for this Module. **`MENTORS`** are available to answer any questions you have about how to use the Module with your students.

There's lots of talk about "virtual communities" but PASSPORT TO KNOWLEDGE has seen it happen. Look at the archives of discussion groups from previous projects for examples of the kind of teacher-to-teacher support that's possible. Then sign on, take a **`TOUR`**, subscribe to the mail lists and share your ideas and your questions with a community of teachers. Remember with the world seen through your classroom window a constant reminder of the relevance of weather and climate, we're sure this should be a fun and informative Module. Every day will bring new "subject matter." So, let's get started…

Summary of key Science Concepts covered through the PASSPORT TO WEATHER AND CLIMATE Videos, Hands-On Activities and On-line Resources

Program 1 **What Makes Earth's Weather and Climate?**	The Sun as Earth's primary source of energy Sun-Earth position as cause of seasons Differential heating and cooling of land and ocean
Program 2 **In and Out of a Hurricane!**	The Water Cycle: latent heat of water vapor as fuel for extreme weather How networks of sensors and teams of observers work together to create forecasts
Program 3 **Tornado Detectives**	Convection and circulation in storm clouds Angular momentum and high speed of tornadic winds The Doppler Effect applied as research and forecasting tool: uses of the electromagnetic spectrum
Program 4 **Winter Storms—White Hurricanes**	Changes of state of water from gas to liquid to solid Terrain as driver of regional and local weather Organization of a scientific field campaign
Program 5 **Thunder and Lightning**	Differences between light and sound waves Static electricity, insulators and conductors Rainbows and optical phenomena Nature of electrical charge
Program 6 **El Niño and La Niña: the "Boy" and the Buoys**	Effect of ocean currents and upwelling on regional and global climate Transfer of heat energy Technologies for climate forecasting
Program 7 **Earth's Variable Climate**	Fossils as way to retrieve past climate The Greenhouse Effect Scientific evidence for, and debate about, global climate change Science and social policy
Program 8 **Tracking and Recording Weather and Climate**	Application of physical principles (e.g. heated liquids expand) to construct simple weather instruments Practice in data collection and analysis through experiments Contributions of other times and cultures to the study of weather and climate

Please note: GPN and some participating public television stations may refer to Educator Programs A and B as programs 9 and 10 respectively. A = 9, and B= 10. They are identical.

Program 1 WHAT MAKES EARTH'S WEATHER AND CLIMATE?

Temperature, Pressure and Air in Motion (14:50)

Objectives

After viewing the video, participating in one or more of the Hands-On Activities, and using on-line resources, students will be able to:

- discuss why the Sun is the primary force driving Earth's weather, through the differential heating of land and ocean
- describe how Earth's tilt on its polar axis is the reason for the seasons
- demonstrate that land and ocean, and light and dark colors, heat and cool at different rates
- identify and describe the main changes of state of water, and relate this to weather and climate

Program Description

This program has 3 sections: "**Sun and Seasons**" Uses satellite images showing day and night, as well as footage from the Equator and the Poles, deserts and mountains, to show the Sun-Earth relationship, and why we have seasons on our planet. "**Ocean, Atmosphere and Land**" How sea and land both heat and cool at different rates, and how this differential heating results in changes in pressure and temperature in the air above. "**Water—Solid, Liquid, Gas**" Water as the primary fuel of Earth's weather, carrying heat from region to region, and in its vertical motions as water vapor in convective clouds, producing storms and other severe weather.

- "**Sun and Seasons**" (Video segment running time: 04:34) After simple definitions of weather and climate, we see Earth as a planet: Marshall Shepherd describes how Earth's tilt of 23.5 degrees relative to its orbit round the Sun (illustrated in a video graphic) brings summer and winter. Patrice Kucera introduces the concept that violent weather results from the meeting of hot and cold air masses, resulting in "chaos." We see a large convective cloud, exhibiting circulation: it resembles a special effects "mothership" from the movies. Marshall explains the global circulation of the atmosphere and Earth's and weather-generating machine as the result of heating of air by Sun near the Tropics. Satellite and NCAR computer models show clouds circulating round the globe, and how rising warm air is replaced by colder air from Pole. Marshall says the gas law means temperature differences become pressure differences (temperature and pressure *gradients*) which result in wind, and circulation pattern such as the jet streams.
- "**Ocean, Atmosphere and Land**" (03:55) We see how terrain affects local, regional and global weather. The El Niño/La Niña phenomenon in explained as the result of unusually warm waters off the coast of South America, but having consequences for wind, rainfall and drought around the planet. A strong El Niño tends to reduce the number of East Coast hurricanes. (For more detail, see program 6.) Marshall describes "mountain weather" as dropping more rain on the windward (the side the wind blows from) than on the leeward side. We see the Atacama Desert in Chile, the driest place on Earth, which results from this effect (plus a strong off-shore cold current.) The example of land- and sea-breezes, which students may have experienced at lake or shore, is explained with graphics. Marshall says that Florida has so many thunderstorms as the result of sea-breezes from both coasts colliding head-on, like trains on a track. Patrice shows how the Rockies shape the Polar Jet Stream as if flows down across the USA.

- "**Water—Solid, Liquid, Gas**" (04:02) Marshall introduces the idea of water vapor as the "fuel" which powers Earth's weather "engine." Graphics show evaporation from the ocean, and condensation into clouds. Strong updrafts result in hail, and the interaction of solid and liquid water in severe storms results in lightning and thunder. In contrast to the numerous satellite views of clouds and storms seen throughout the program, Mark Croxford (an avid surfer) describes conditions on a Miami beach as a storm approaches. Animatedly, he describes how hot and humid air is flowing into "that beast", the storm. He points out the typical cauliflower shape of developing cumulonimbus clouds, pulling together concepts and terms ("convection" "convergence", etc.) previously used by Patrice and Marshall. Mark also quotes one of his instructors: there is so much weather data out there as a result of contemporary research, that we "need more students!" At the first lightning strike, he prudently leaves the beach for shelter.

Vocabulary

climate, weather, temperature, jet stream, warm front, cold front, temperature (and pressure) gradient

Pre-Viewing Questions

Before viewing each program, you may wish to write the Pre-Viewing Questions (PVQs) on the chalkboard, or pass out a copy of the questions to each student or team of students. At the end of the program have students answer the PVQs in their WEATHERlogs, or write a summary of the program that includes the answers to the questions. Alternatively you can use the Quiz Questions or Discussion Topics (below) to help students assimilate what they've seen.

- ✓ Is the Sun closer to or farther away from the Sun when we experience summer in the Northern hemisphere? (It's actually *closer* in the Northern winter than in the Northern summer: the difference in seasonal temperatures, as Marshall makes clear in the video, comes from Earth's tilt/angle to the Sun.)
- ✓ What makes Earth's winds? (Temperature differences create pressure differences, resulting in air flowing from higher to lower pressure regions.)
- ✓ Does warm air or cold air bring storms? (Trick question: Both! It's where warm and cold meet that storms tend to occur.)
- ✓ What is the "fuel" for Earth's weather? (Answers can include the heat of the Sun, or water vapor changing state or "phase.")
- ✓ Do different forces shape different kinds of weather, such as summer heat and winter cold, tornadoes and hurricanes? (The same physical principles underlie all types of weather.)

Post-Viewing / Quiz Questions (see also the Pre-and Post-test questions to be found on the copy masters, which can be used here or elsewhere in the Module.)

- ❑ What are the "reasons for the seasons"? (Earth's tilt on its axis relative to its orbit around the Sun.)
- ❑ Does Earth rotate or revolve about its polar axis? Does it rotate round the Sun, or revolve around it? (Earth *rotates* about its polar axis, and *revolves* around the Sun)
- ❑ What phenomenon does the program (based on its consultants' comments) say is the second most powerful influence on Earth's weather, after the seasons? (El Niño and La Niña, referred to collectively as ENSO—the El Niño/Southern Oscillation.)

- Where does Marshall Shepherd say air colliding like head-on locomotives make thunderstorms? (Florida: as you'll see in program 4, Florida has more thunder and lightning than anywhere else in the USA.)
- Is the warm air over a beach in summer at a HIGHER or LOWER pressure than the cooler air over water? (Lower. Air at lower pressure tends to rise. Air at higher pressure tends to fall.)
- Does the daytime "sea-breeze" flow toward, or away from the shore? (Towards the shore, away from the sea.
- Why does the United States experience some of the wildest weather on Earth? (Its position between 2 oceans—which bring lots of humidity—and two air masses, the Tropical and Polar, creates different temperatures and pressure which are sometimes in conflict.)

Discussion Topics

- What are the reasons for the seasons? (Students answers will be richer if they have both watched the video and undertaken Activity 1.1, *Sun and Seasons*.)
- What role does "weather" play in your life? What role does "climate" play?
- How many different kinds of weather are seen in the video? (Hurricanes, tornadoes, thunder and lightning, floods, drought, ENSO, hail, and more.) How many of them have you personally experienced? Which one had most impact on your life? (Cue for writing activity?)
- Marshall speaks about the "weather engine": do you think this is a good metaphor? Why or why not? Is this a familiar concept to you?
- Mark Croxford says we "need more students" of the weather: why would you like to study weather for a career, or not?

Hands-On Activities

The Activities suggested for this and the following programs provide a context for the images, information and concepts seen and heard in the video. Each program and set of suggested Hands-On Activities is designed to offer, *in class*, specific, concrete and memorable parallels to the *real world* phenomena seen on camera, or read about on-line. Each section of this IG offers several Activities—more than any one teacher is likely to have time to use—from which you are encouraged to choose those which best fit your instructional goals and local resources. Each Activity has its own "Teacher Background" introduction. In this IG, therefore, we headline the most immediate connection of the Activity to the videos and on-line resources.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 8, Activity 1.1 *Sun and Seasons* (1 class period)
This Activity, whether done as a teacher demo or by student groups, allows them to replicate for themselves the "tilt" demonstrated by Marshall Shepherd in the video. The 2-sided copy master provides a reference diagram for the Activity and for the flashlight extension which enables them to see how much more intense direct light is than more angled light.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 11, Activity 1.2 *Differential Heating and Cooling* (1 class period—2 if you use the "Sports Shirt")
Relates to Marshall's comments, and to the on-screen graphic showing why sea- and land-breezes are found by day or night respectively. One 2-sided student worksheet allows for data collection and analysis. The "Cool" Sports Shirt Design Contest provides a "light" (sic) extension for a substantive and important concept.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 16, Activity 1.4.1 *The Interaction of Temperature and Pressure* (1 class period)
During the video, Marshall refers to the gas law: this Activity allows students to experiment with principles associated with the gas law, and to see for themselves how temperature and pressure are related. (See Teacher Background for a brief discussion of the gas law itself.)

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 19, Activity 1.4.2 *Highs, Lows, Winds and Jet Streams* (1 class period)
Connects temperature and pressure to weather maps, and helps students understand the typical directions of air flow in the Northern and Southern hemispheres.

On-line

At the PASSPORT TO WEATHER AND CLIMATE website, read some of the **BIOgraphies** and **JOURNALs** to be found in the **WHO** section, such as those from Marshall Shepherd, Patrice Kucera, Paul Markowski and others.

If you're subscribed to the interactive component of the website, students with questions that are not answered by the programs or other on-line resources can submit them to **RESEARCHER Q&A**. Please check out the **TIPS FOR USING RESEARCHER Q&A** before submitting questions. If you do not have easy classroom access have the students write their questions on index cards, and discuss them as a group, selecting the most interesting topics. Questions could then be submitted later from a connected computer at school, or by using your home computer and bringing in printed copies of the answers.

Suggested URLs (providing background for a teacher and resources for student use)

http://www.noaa.gov
http://www.education.noaa.gov/
NOAA's main page, and its main education page, with links to the National Severe Storms Lab (NSSL) which has its own extensive education resources. Also links to the NOAA Library, with great, public domain photos and intriguing historical connections, resources, and much more.

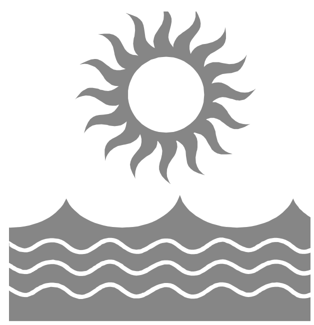
http://www.earth.nasa.gov
http://earthobservatory.nasa.gov/science
NASA's Earth Science Enterprise main page, and its excellent on-line newsletter, with links to graphics, animations and background information. You can sign up on-line for regular bulletins.

http://www.usatoday.com/weather/wworks0.htm
"How Weather Works" Basic information on air masses, pressure, El Niño, fronts and more.

http://ww2010.atmos.uiuc.edu/(Gh)/home.rxml
WW2010 (University of Illinois): On-line Guides on air masses and fronts, clouds and precipitation, weather forecasting, severe storms and more. Excellent background and graphics.

Selected “NSES/2061 Benchmarks” met by the video, hands-on and on-line resources

1.2.4 Knows that air is a substance that surrounds us, takes up space, and moves around us as wind
1.2.5 Knows that night and day are caused by the Earth’s rotation on its axis
1.2.6 Knows that the Sun provides the light and heat necessary to maintain the temperature of the Earth
1.3.5 Knows how the tilt of the Earth’s axis and the Earth’s revolution around the Sun affect seasons and weather patterns (i.e., heat falls more intensely on one part or another of the Earth’s surface during its revolution around the Sun)
1.3.9 Knows that the Sun is the principle energy source for phenomena on the Earth’s surface (e.g., winds, ocean currents, the water cycle, plant growth)
3.3.6 Knows how the regular and predictable motions of the Sun and Moon explain phenomena on Earth (e.g., the day, the year, phases of the Moon, eclipses, tides, shadows)
11.3.3 Knows how the Sun acts as a major source of energy for changes on the Earth’s surface (i.e., the Sun loses energy by emitting light; some of this light is transferred to the Earth in a range of wavelengths including visible light, infrared radiation, and ultraviolet radiation)



Program 2 In and Out of a Hurricane! (14:50)

Latent Heat and the Water Cycle

Objectives

After viewing the video, participating in one or more of the Hands-On Activities, and using on-line resources, students will be able to:

- model the water cycle and compare their simulations to real world phenomena
- discuss complex weather *systems*, and interactions between parts of such a system, such as temperature, pressure and wind speed
- track the development of hurricanes on weather maps using appropriate symbols and mathematics
- build model structures from simple materials and test them for endurance in the face of simulated hurricane force winds
- discuss how the design of structures can make them more or less vulnerable to hurricane force winds, and how more accurate and timely hurricane forecasts benefit society

Program Description

Fly through a hurricane with NOAA researchers, and track storms the size of Texas with NASA's satellite eyes. See how hurricanes are literally "heat engines," transforming latent energy into ferocious winds. "**What's the Water Cycle?**" NASA's TRMM satellite (Tropical Rainfall Measuring Mission) measures precipitation close to the Equator. TRMM researcher Marshall Shepherd describes how global circulation and the water cycle spawn hurricanes. "**The Eye of the Storm**" How and why NOAA researchers fly through severe storms in order to capture pressure, temperature and wind speed data essential for accurate predictions of a hurricane's direction and intensity. "**Hurricanes as 'Heat Engines'** " NASA's Jeff Halverson uses a regular automobile engine to explain how latent heat fuels storms, and drives their vertical and horizontal motion.

- "**What's the Water Cycle?**" (Video segment running time: 03:57) The program introduces the wind speeds typical of "tropical storms" (winds +39mph) and hurricanes (+74mph.) Hurricanes, in contrast to tropical storms, also have an eye and deep convection. Flying out towards Hurricane Dennis, during the 1999 season, NOAA researchers Neal Dorst and Stan Goldenberg explain that hurricanes are really a collection of 100s or 1000s of thunderstorm clouds organized into bands. Marshall Shepherd describes (using NASA animation showing a cutaway view through a hurricane) how water evaporating from the ocean and then condensing into clouds powers these storms, which are—he says—a perfect example of the water cycle in action. As warm air rises, pressure drops and the hurricane gains power. Flying towards it we find out why NOAA needs this kind of data for hurricane forecasting, and how NASA's TRMM research satellite can give hurricanes a kind of cat-scan, looking down from high above (Red in the graphics indicates the most violent portion of the storm.)
- "**The Eye of the Storm**" (05:18) This segment shows the extensive network of people and research tools (airplanes, satellites and instruments dropped down through storms—dropwinsondes—BTW, there's no "d" in the word) it takes to track hurricanes and make accurate forecasts. We fly aboard two NOAA research aircraft, a newer Gulfstream IV jet, and a 30-year old but still sturdy P-3 turboprop nicknamed "Kermit". (In program 4 we fly aboard its sister craft, "Miss Piggy.") We go behind the scenes at the National Weather Service (NWS) National Hurricane Center, a heavily fortified building in Miami. Air Force Reserve Captain John Gordon introduces the chain of data collection and dissemination devices involving planes, ground stations and computers, and a series of quick comments from Stan Goldenberg up in the P-3, Shirley Murillo at NOAA's AOML (Atlantic Oceanographic and Meteorological Laboratory) and others shows how NOAA puts all the time-critical data together and sends it out as bulletins via the Internet and live TV. NHC director Max Mayfield (then NHC deputy director) appears on camera during a live broadcast update. Mark Croxford and Shirley Murillo describe why they like to fly through hurricanes and HRD director Hugh Willoughby talks about turbulence and the dangers of this kind of research. (See on-line, Frank Marks **BIO**, for more on this.) The researchers and forecasters use the latest temperature, pressure, wind speed and direction data to try to figure out where the storm is going, and how strong it will become. Flying into the eye of the storm, wind speeds drop, and they get a "center fix." During Dennis, they note that the water still ahead of the storm is very warm.

- “**Hurricanes as Heat Engines**” (03:25) Close to NASA’s Goddard Space Flight Center, TRMM researcher Jeff Halverson takes us to Reidy’s Exxon, where—in a repair bay—we peer under the hood of a car. Using cutaway graphics of an auto engine and a hurricane, and actuality footage, Halverson compares a hurricane’s storm clouds to a car’s cylinders, the combustion of gasoline (resulting in the release of energy) to condensation of water vapor (releasing latent heat energy), and the car’s gas tank to the ocean, full of warm water. Halverson pulls together many of the words and concepts used by the (many) other researchers seen during the program to synthesize an explanation of how hurricanes begin, develop and travel. Back up in the storm, aboard the P-3, we discover that too little water (to drink) is a typical condition, but also hear, in the words of John Gordon, about the exhilaration and job satisfaction felt by all the researchers, flight crews and engineers as they collaborate to improve our understanding of hurricanes and so improve forecasts. This kind of hurricane research is a combination of science and high adventure.

Vocabulary

tropical depression, tropical storm, hurricane, mesoscale weather processes, water cycle, humidity, pressure, GPS dropwinsonde, dew point, eye (of the storm), storm track, turbulence

Pre-Viewing Questions

- ✓ Which kind of storm is larger, a hurricane or a tornado? (Hurricanes can be as large as Texas: a tornado may be just a few hundred meters wide.)
- ✓ Do hurricanes have a season? (East Coast hurricanes only happen in late Summer and early Fall when ocean temperatures have grown warm enough.) Do tornadoes? (Trick question: tornadoes can happen at any time of year, but are relatively more frequent in Spring and Summer.)
- ✓ If hurricanes are “heat engines” what’s their fuel? (Hot water, as explained by Jeff Halverson in the 3rd segment of the video.)

Post-Viewing / Quiz Questions (see also the Pre-and Post-test questions to be found on the copy masters, which can be used here or elsewhere in the Module.)

- ❑ Is there a scientific reason for flying through hurricanes, or do NOAA pilots just want to show they have the “right stuff”? (As yet, satellites cannot obtain as much data as planes flying through storms. Since needless evacuations very costly and late evacuations cost lives, NOAA and the Air Force both think it’s necessary to fly through storms.)
- ❑ What has stronger winds, a tropical storm or a hurricane? (Hurricane winds are 74+ mph, tropical storms +39 mph.)
- ❑ Where and how do hurricanes begin? (As thunderstorms, off the coast of Africa)
- ❑ What are some of the weather data NOAA researchers collect as they fly through a hurricane? (Temperature, pressure, humidity, wind speed and direction.)

Discussion Topics

- ❖ Who’s more in the “eye of the storm”? The researchers aboard the P-3, or the forecasters down on the ground in Miami?
- ❖ Would you want to fly through a hurricane? Why or why not?

- ❖ Have you ever been affected by a hurricane? What happened? How did your family respond? (See also Activity 4.1, *Writing Up a Storm* [TG p52])
- ❖ Should state or national governments control who moves into coastal areas where hurricanes are possible? Why or why not?) (See also Activity Z.2, [TG p61])

Hands-On Activities

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 14, Activity 1.3 *The Water Cycle* (1 class period)
Allows students to create and diagram the water cycle Marshall describes in the video.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 54, Activity 4.2 *Hurricane Houses* (2-3 class periods)
Excellent and dynamic way to relate hurricane science to social issues: see the demonstration (with student and Principal comments) in Educator program B. Don't be put off by noise concerns! Plan ahead and borrow a leaf-blower and a parent volunteer, or two. Based on very positive student responses we think this could be a "repeat" activity for many years.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 44, Activity 3.3 *Interpreting Weather Symbols: the visual language of weather* (1 class period)
Also relevant for program 8: invites students to become critical viewers of weathercasts on TV, and to deconstruct weather symbols in the newspaper. "Media lit." alongside weather science!

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 46, Activity 3.4 *Plotting Temperatures on a Weather Map* (1 class period)
Another activity in which students actively put the data available in newspapers or on-line to work for them. If you are able to implement this activity for portions of classes over several days as a hurricane or tropical storm moves slowly up the East Coast, your students will be able to grasp the correlation of pressure and wind speeds with emergency preparedness and evacuations in specific and concrete ways.

Teacher Tip: Eileen Bendixsen
I would begin this segment either by having the students review the water cycle and either complete Activity 1.3 "Water Cycle", or draw the diagram and then use the video. From there I would go to the PTW&C website and in the `WHAT` section click on `WEATHER` and then on `HURRICANES` and begin a discussion on how hurricanes form and what happens as they go from tropical depressions to tropical storms to full fledged hurricanes and then how they are downsized once they lose their energy over land.

Students can also use this site for background information and class discussion: **National Hurricane Center Hurricane Awareness** `http://www.nhc.noaa.gov/HAW/index.htm`
I would spend three class periods on this beginning section. It would include the video, class discussion using the two websites, and also plotting the path of a hurricane. If this can be done during the actual hurricane season then they could track a hurricane in real time. They will find the archived data from past hurricanes at: `http://www.nhc.noaa.gov/pastall.html`

I would then begin the scenario that I have used with my own students and say that they are going to move to the Eastern coast of North Carolina. They need to find a house that will withstand a hurricane and have a class discussion about what they would need to have in this house. I would then use this site to develop a family hurricane safety plan. If they live in Florida, North Carolina or one of the other states that is subject to hurricanes they should develop a family hurricane safety plan for where they live. This could lead to talking to someone in town and also bringing in speakers who can provide knowledge about what safety procedures have been set up in their town. They can use these two sites for their family hurricane safety plan: **National Weather Service Hurricane Awareness** `http://www.nws.noaa.gov/om/hurricane/index.shtml` or the **FEMA Hurricane Fact Sheet**: `http://www.fema.gov/library/hurricaf.htm` After they have completed this I would then have them complete the "Hurricane Houses" Activity using all of the background information they've received from the segment.

Interdisciplinary connections The family hurricane safety plan is basically a interdisciplinary activity. It would probably come under health. They could also create safety awareness posters which would be art and health. The "Hurricane Houses" Activity also has math connections.

On-line

At the PTW&C website, read **`BIOgraphies`** and **`JOURNALs`** (found in the **`WHO`** section) of some of the NOAA hurricane researchers, to be found in the **`WHO`** section, such as those from Sim Aberson (also **`JOURNAL`**), Chris Landsea, Shirley Murillo and Frank Marks. Follow links from the latter to a hair-raising account of flying the kinds of severe turbulence Hugh Willoughby describes during the video.

Suggested URLs (providing background for a teacher and resources for student use)

`http://www.nhc.noaa.gov/`
National Hurricane Center: Tropical Prediction Center *The* site for the latest information on active tropical storms in the Atlantic & Caribbean and Eastern Pacific.

`http://www.nhc.noaa.gov/HAW/index.htm`
Hurricane Awareness: Excellent background information on hurricanes including hurricane preparedness and how to set up a family plan.

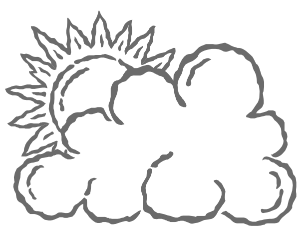
`http://cimss.ssec.wisc.edu/tropic/tropic.html`
Tropical Cyclones (University of Wisconsin-Madison) with the latest warnings and information for every part of the world.

`http://www.wunderground.com/tropical/`
The ever-popular and invaluable "Weather Underground" site, with an extensive set of links to maps, explanations and more.

`http://www.nws.noaa.gov/om/raob.htm`
Radiosonde Measurement of the Weather: explains the radiosonde instrument in detail from pre-launch to scientific results.

Selected "NSES/2061 Benchmarks" met by the video, hands-on and on-line resources

1.3.7 Knows the processes involved in the water cycle (e.g., evaporation, condensation, precipitation, surface run-off, percolation) and their effects on climatic patterns
1.3.8 Knows the properties that make water an essential component of the Earth system (e.g., its ability to act as a solvent, its ability to remain a liquid at most Earth temperatures)
11.3.1 Knows that energy is a property of many substances (e.g., heat energy is in the disorderly motion of molecules and in radiation; chemical energy is in the arrangement of atoms; mechanical energy is in moving bodies or in elastically distorted shapes; electrical energy is in the attraction or repulsion between charges)
11.3.2 Understands that energy cannot be created or destroyed but only changed from one form to another
12.2.3 Knows that an object's motion can be described by tracing and measuring its position over time
12.2.4 Knows that when a force is applied to an object, the object either speeds up, slows down, or goes in a different direction
16.3.1 Knows that people of all backgrounds and with diverse interests, talents, qualities, and motivations engage in fields of science and engineering; some of these people work in teams and others work alone, but all communicate extensively with others



Program 3 Tornado Detectives (14:29)
Up, Down and Round and Round

Objectives
After viewing the video, participating in one or more of the Hands-On Activities, and using on-line resources, students will be able to:

- simulate the rotation and funnel cloud of a tornado
- understand how warm and cold air, and dry and moist air, interact at frontal boundaries
- discuss how researchers track, record and analyze key data about weather systems leading to tornadoes
- simulate how Doppler radar is used to track the position of storms and the nature of the precipitation found in them

Program Description

Tornadoes spin out of supercell thunderstorms, but researchers still don't know exactly how and why. We go on location with NOAA's "VORTEX" project as they use Doppler radar and mobile mesonets to venture close to nature's fastest winds in search of answers. "**Destruction from the Sky**" Tornadoes are Nature's most violent storm, though they usually only last for minutes and travel just a few miles. This segment explains why twisters most often happen in spring and summer, and most frequently in "Tornado Alley." "**Convection and Circulation**" How winds moving in different directions, and the meeting of moist and drier air masses results in the development of a rotating column of air (a "mesocyclone") and sometimes—when conditions are right—in a tornado. "**Researchers on the Road**" How NOAA and other researchers hit the highway to get their instruments up close to twisters, in search of the clues we need to enable more timely and more accurate forecasts.

- "**Destruction from the Sky**" (Video segment running time: 03:31) Amazing video footage shot on May 3, 1999 close to Oklahoma City (OKC) by KWTV shows one of the most deadly and destructive recent outbreaks of tornadoes. Behind-the-scenes images taped in December 1999 at the local, Norman, OK, NWS office when less violent twisters threatened, show how NOAA forecasters react and work to get warnings out to the public. One of the key tools is Doppler radar: on the computer screen, green indicates winds moving *towards* the radar, and red *moving* away. When both colors are seen side-by-side there's *circulation*, a condition which may lead to a twister. May 3rd 1999 saw a category F-5 tornado, the strongest kind. In all 60 tornadoes hit that day, killing 42 people close to OKC. But thanks to advance warning from NOAA, aggressive media coverage, and safety education in schools and homes, experts were surprised and pleased, that there were not more fatalities. Saving more lives will take understanding twisters better.
- "**Convection and Circulation**" (04:02) This section reviews what we now know about what makes tornadoes. They can happen just about anywhere on Earth, at any time of day or night, though they are more frequent in spring and summer, and in the area of the USA known as "Tornado Alley." The U.S., in fact, experiences on average some 900 tornadoes per year, more than anywhere else on Earth. Graphics show that this is caused by the interaction of warm wet air from the Gulf with hot, dry air from the West at what's called the "dryline." Severe thunderstorms with violent up- and downdrafts result. Especially strong storms occur late in the afternoon or early evening when an "inversion" has capped the warm, wet air all day. Penn State meteorologist Paul Markowski, NSSL researcher Daphne Zaras, and NSSL field coordinator Al Pietrycha define a supercell thunderstorm as one with a strong, persistent updraft. This kind of storm can be so violent that large hail results. As we hear hailstones bouncing on the car's roof, Daphne explains that this is because the updraft pushes heavy hailstones back up repeatedly to colder regions of the cloud, coating them again and again with more ice. Graphics show how *circulation* added to *convection* may lead to a tornado. In front of a massive and very impressive circular storm cloud (the "mothership") Daphne explains that if this circulation extends all the way to the ground there may be a twister
- "**Researchers on the Road**" (05:29) In this program segment, NOAA and other researchers hit the highway to get their instruments up close to twisters, in search of the clues we need to enable more timely and more accurate forecasts. Archival black and white footage recalls the very first official tornado forecast, made by 2 Air Force

meteorologists in 1948. Before that time, forecasts were so unreliable that they weren't even issued for fear of causing unnecessary panic. Here in Norman, World War II radars were converted into the first Doppler units, which improved forecast reliability. The nearby University of Oklahoma, working with NOAA, developed "Dopplers On Wheels" (DOW), research radars carried on trucks out close to tornadoes. We see scenes from VORTEX, a mid-90s "Verification of the Origin of Rotation in Tornadoes Experiment" and hear from its leader, Erik Rasmussen. On May 3rd, 1999, the VORTEX team was once again on the road, and we see and hear some of what they saw that day. Footage taped during the summer 2000 "STEPS" project ("Severe Thunderstorm Electrification and Precipitation Study") shows contemporary research instruments and logistics used in field research on supercells and tornadoes. Daphne Zaras explains the weather instruments aboard cars of NOAA's "mobile mesonet." Veteran torndado chaser Paul Markowski grumbles that most TV programs only show the action footage, not the long hours of hard work tracking storms. Daphne explains the safety precautions responsible, professional storm-chasers must take. Paul explains how he uses the very same subjects students cover in school in his attempt to understand twisters better and save lives: *"I think the least I can do is to try to use my math and science and physics talents to try to learn something about tornadoes so that maybe if there is something good that can come out of a terrible outbreak like May 3rd., maybe it's that someday in the not too distant future, we can actually learn why some of these storms can rotate for hours and hours and not produce tornadoes while others, like on May 3, produce one tornado after another in succession, and they're all very large and very intense."* The program ends with some of the latest findings about what spawns tornadoes, based largely on the work of Paul and Erik. When the downdraft at the back of a mesocyclone is warm, it seems to feed the warm, frontal updraft and tornadoes are more likely. Daphne concludes with a comment that any of the researchers seen in any of the programs might echo: *"I find it really interesting to chase storms because it's a chance to take the things I've learned in a textbook and in the classroom and graduate school down into real life, and try to look for things that I learned about. All these theoretical processes with equations and things, to actually see that happening, is absolutely fascinating. So I like that aspect of being able to see my science."*

Vocabulary

circulation, convection, vortex, Doppler radar, supercell, updraft, downdraft, accretion, dryline, mesocyclone, persistent, pulse thunderstorm, anemometer

Pre-Viewing Questions

- ✓ Which has the fastest speeds of any storm on Earth? Hurricanes, tornadoes or winter storms (Tornadoes)
- ✓ What's a supercell thunderstorm? (One with a strong, persistent updraft.)
- ✓ Do tornadoes tend to happen early in the day, or late? (Late in the day when the atmosphere has had time to warm up—however they can happen at any time, even in the middle of the night.)
- ✓ What comes first: a supercell thunderstorm, or a tornado? (Supercell thunderstorms spawn tornadoes, not vice versa.)

Post-Viewing / Quiz Questions (see also the Pre-and Post-test questions to be found on the copy masters, which can be used here or elsewhere in the Module.)

- What three factors, according to NOAA, helped limit fatalities during the violent May 3, 1999, Oklahoma City outbreak? (Early warnings from NOAA, media outlets broadcasting news and alerts, and good education about tornado safety precautions to take in school or at home. Kids in school were part of the solution.)
- Why does “Tornado Alley” exist? (It’s a region of the country where warm wet air from the Gulf collides with dry air from the west. Once formed, supercell thunderstorms tend to move north and east, up into places such as Illinois, at the top of Tornado Alley.)
- Why is large hail an indicator of a severe thunderstorm? (Because it takes a very strong updraft to keep the growing hailstone from falling to Earth.)
- Why did the researchers replace plastic pressure sensors with metal? (Because plastic broke during severe hail.)

Discussion Topics

- Would you like to be a professional storm-chaser, like Paul or Daphne? Why or why not?
- If tornadoes can happen anywhere, at any time of year, should your school have a tornado safety plan? Why or why not? (In simplest form, such a plan would include: get away from windows; congregate in the lowest, most enclosed section of the school. Have students use the URLs below to find out more.)
- Is it safe to take shelter beneath an overpass if you’re out on the road when a tornado approaches? (No. Despite what students may have seen on so-called “reality TV shows, NOAA’s current advice is that winds beneath an overpass are more deadly than taking cover in a ditch or gully beside the road. The overpass acts as a wind tunnel and accelerates debris to deadly speeds.)

Hands-On Activities

PASSPORT TO WEATHER AND CLIMATE Teacher’s Guide, page 32, Activity 2.4 *Twister in a Bottle* (1 class period)
While the physical processes that make a tornado (warm air spiraling up) and a “twister in a bottle” (water rushing down) are fundamentally different, the visual similarities provide an excellent connection to the video and on-line resources. See Educator Program B to see how much serious fun students can have.

PASSPORT TO WEATHER AND CLIMATE Teacher’s Guide, page 48, Activity 3.5 *Doppler Radar in a Shoebox* (2-3 class periods)
This adaptation of a classic marine science Activity connects science and technology in a powerful way: whether it’s an orbiting laser altimeter on a spacecraft, or Doppler radar used by NOAA or traffic cops, the principle of turning the *travel time* of radiation traveling at the speed of light into *distance data* is well worth implementing. Again, see Educator Program B for suggestions from PTW&C materials development team member, Tim McCollum, about how to implement this Activity. The video also shows several scenes where students can see NOAA forecasters intently relying on Doppler radar in order to issue tornado warnings.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 37, Activity 2.6 *Warm Front, Cold Front* (1 class period)
Warm fronts and cold fronts are the classic phenomena charted on weather maps, and as Patrice Kucera says in program 1, and as video graphics make clear in program 3, where warm and cold collide is where "interesting" weather happens. Handout 2.6.1 gives students a visual reference similar to that used in the program. Activity 2.6.2 enables them to experiment with physical materials in order to develop a visceral sense of what a scientific principle means.

On-line

At the PTW&C website, read **`BIOgraphies`** and **`JOURNALs`** (found in the **`WHO`** section) of some of the researchers who study tornadoes (such as Kevin Kloesel, with a dramatic account of a chase), Daphne Zaras (who describes the mobile mesonets) and Doug Speheger, one of the NWS forecasters seen during the video. The website (**`WHY`**, **`ANIMATIONS`**) also provides an interactive description of the forces which make a tornado.

Suggested URLs (providing background for a teacher and resources for student use)
`http://www.nssl.noaa.gov/NWSTornado/`
`http://www.nssl.noaa.gov/researchitems/tornadoes.shtml`
"Nature's Most Violent Storms", from the NSSL, home base for many of the researchers seen during the videos.

`http://www.nssl.noaa.gov/faq/outbreak.shtml`
NSSL Frequently Asked Questions: Information about the May 3, 1999 Oklahoma tornado outbreak, amazing footage of which appears in program 3.

`http://mrd3.nssl.ucar.edu/%7Eeras/www/SSR/index.htm`
`http://mrd3.nssl.ucar.edu/%7Evortex/`
Website for VORTEX scientist Erik Rasmussen, and background on VORTEX

`http://www.nssl.noaa.gov/noaastory/`
The science of VORTEX in storybook format, written on a student level.

Selected "NSES/2061 Benchmarks" met by the video, hands-on and on-line resources

11.3.4 Knows that heat can be transferred through conduction, convection, and radiation; heat flows from warmer objects to cooler ones until both objects reach the same temperature
12.3.4 Knows that an object's motion can be described and represented graphically according to its position, direction of motion, and speed
12.4.3 Knows that apparent changes in wavelength can provide information about changes in motion because the observed wavelength of a wave depends upon the relative motion of the source and the observer; if either the source or observer is moving toward the other, the observed wavelength is shorter; if either is moving away, the wavelength is longer
14.3.3 Understands that questioning, response to criticism, and open communication are integral to the process of science…
15.2.5 Knows that good scientific explanations are based on evidence (observations) and scientific knowledge

Program 4 Winter Storms—White Hurricanes (14:34)

Precipitation, Temperature and Terrain

Objectives

After viewing the video, participating in one or more of the Hands-On Activities, and using on-line resources, students will be able to:

- explain how temperature at different levels in the atmosphere results in snow, sleet, hail and rain
- discuss the role of mountain ranges, plains, lakes and other types of terrain in determining the severity of winter storms, and other weather systems
- model cloud formation and dew point in class, and compare results with real world data
- research, write up and compare experiences of severe winter weather with classmates and—optionally—via the Internet, with remote sites

Program Description

Winter storms can pack as much energy as hurricanes, and NOAA calls them "silent killers." In this Unit, students find out how temperature and humidity determine whether snow, sleet or freezing rain will fall, and how snowstorms affect daily life and the economy. "**Nature's Battle Fronts**" How jet streams and different masses of air shape the weather found in different regions of the United States, and the "Nor'easters" of the Appalachians. "**Operation MOUNTAIN STORM**" A case study of winter weather in the mountains of Utah: how terrain shapes snowfall, and a discussion of "lake effect snow". (Please note, this is the only one of the 8 classroom programs to have only 2, and therefore somewhat longer, video segments.)

- "**Nature's Battle Fronts**" (Video segment running time: 06:37) The program begins with a reminder of what makes Earth, the blue planet, unique in the solar system: abundant liquid water on its surface. But water can change state depending on temperature, changing from a *liquid* to a *gas* or to a *solid*. These changes of state add or remove heat from atmosphere and serve as the main fuel for weather, summer or winter. (See also program 2, "Hurricanes as Heat Engines.") On a snowy field in mid-winter, close to NASA's Goddard in Greenbelt, MD, TRMM researcher Jeff Halverson introduces the idea of winter storms (called "Nor'easters" in this part of the country) as "white hurricanes." (The second segment of the program looks at winter weather in the West and, briefly, at "lake effect" snow.) Though little understood, these storms can be very powerful and impact the entire East Coast, hitting major cities such as Washington, DC, New York and Boston, bringing 1-2 feet of snow and high winds. Halverson adds detail to what students have heard in earlier videos, by describing, with explanatory graphics, the Tropical, Mid-latitude, and Polar air masses, each with characteristic temperatures and pressures. Each zone comprises approximately 30 degrees of latitude from the Equator (zero degrees) up to the Poles (90 degrees south or north latitude.) Where the air masses meet, severe weather may result. When they jockey for position, moving north and south, they bring warmer or colder weather, respectively, to the United States. *"It's this constant tug-of-war back and forth through the mid latitudes that creates our weather."* Jeff explains that the snow crystals he holds in his hand began as sea-water. The segment ends with scenes of the PTW&C website where students can experiment with air and ground temperatures to make rain, sleet, freezing rain or snow.

- "**Operation MOUNTAIN STORM**" (06:47) Out west, winds of over 100 mph howl over the Rockies, higher and more complex than the East Coast's Appalachian chain. We go on location with NOAA's "weather warriors" during a field experiment called "IPEX", the Intermountain Precipitation Experiment. Students see that there are many undergraduates and recent graduates involved, along with professional meteorologists from NOAA and the University of Utah (UU.) IPEX works out of NWS office in Salt Lake City, in one of the fastest growing regions of the country. What makes winter weather hard to forecast in the mountain west is the presence of the Great Salt Lake, whose warm waters sometimes produce "lake effect" snows, when warm air above the lake rises and snow falls downwind, and the intricacy of the mountain ridges and valleys. Weather forecasting here is important for saving lives in backcountry accidents, and to support the ski industry. James Steenburgh from the University of Utah describes the great variations in local conditions. We see the teams of researchers involved in IPEX, which include NOAA's P-3 hurricane research plane, "Miss Piggy" (we saw "Kermit" in program 2), DOWs (see program 3) from the University of Oklahoma, and balloons and support vehicles from NSSL. At a weather station high in the mountains, NSSL's Steve Vasiloff explains that poorly understood atmospheric conditions mean that sometimes 1" of liquid water results in up to 20" of snow, but in other conditions, only 6". We see IPEX researchers planning the complex logistics of their experiment, both on the ground, and being briefed by the NOAA aircrew. NOAA pilot Dave Tenneson, tongue a little in cheek, dramatizes the upcoming flight by talking to the student interns about ditching in the Great Salt Lake. In flight the PhD scientists function like captains in a military campaign, coordinating the army of instruments in the air and on the ground. Research Meteorologist Dave Shultz from NSSL (along with Steenburgh one of the IPEX leaders) draws a diagram on a scrap of paper showing what he's intrigued by: it seems as if snow is not falling on the windward side of the mountains as every textbook says it should (see also program 1.) In an example of what excites researchers he says: *"This is totally unexpected, and hopefully when we get back and have some time to analyze this case we may discover something new about the way the atmosphere works."* It turns out that it was just unusually strong winds that blew the snow across the ridges. But IPEX still ended up with lots of good new data about winter storms out West, and also introduced a whole new generation of younger researchers to the excitement and challenge of field research. James Steenburgh concludes, *"Basically I live for skiing and meteorology, so for me this is a blast. After our first, or second Intensive Observing Period I got home at 3:30 in the morning and I couldn't get to sleep I was so excited about the data we collected. So this is not a "job." Meteorology is… for people who really love the weather. If you like it, it's very exciting to be involved in it. Constantly having to forecast and having to put yourself out on the line is a fun and challenging field to be in."*

Vocabulary

jet stream, warm front, cold front, terrain, Gulf Stream, Nor'easters, radiosonde, relative humidity, dew point, pressure, temperature

Pre-Viewing Questions

- ✓ Why do we sometimes get snow, and sometimes freezing rain and sleet? (The combination of air temperatures high above Earth, and closer to its surface. See the PTW&C website for an interactive explanation.)
- ✓ Does the same amount of liquid water also result in equal amounts of snow when it falls to Earth? (No. Local conditions mean that the same amount of water sometimes brings a lot, and sometimes a lesser amount, of snow.)
- ✓ Do researchers know everything about winter weather? Do any mysteries remain? (Out west, at least, winter weather is very unpredictable, because of terrain, and also because there are few weather stations out over the Pacific to show in detail what's coming. But even on the East Coast, forecasters can still be surprised at the timing and amount of snowfall.)
- ✓ Where does snow begin? (According to Jeff Halverson, on the East Coast it starts as warm ocean water.)

Post-Viewing / Quiz Questions

- ❑ What are the zones that Jeff Halverson describes in the video? (Tropical, Mid-latitude, Polar.)
- ❑ Why does the United States experience such a wide variety of wild weather? (Its position between 2 mighty oceans, bringing lots of humidity to the continent, and between the warm tropical zone, and the colder polar air mass.)
- ❑ Where do researchers expect the stronger snow to fall, on the windward, or the leeward side of a mountain range? (On the windward side: that's why David Schultz got so excited when he thought they were seeing something different.)

Discussion Topics

- ❖ In what ways is the IPEX experiment similar to or different from your idea of a typical scientific project? (As opposed to a classic "hypothesis-data collection-analysis-results" experiment found in the textbooks, IPEX has hunches but basically is looking to collect information, and then develop new ways to understand it. It also involves very complex logistics and a large team of diverse researchers and research platforms. But as David Schultz and James Steenburgh both say and show us, it's a whole lot of fun to explore nature in this way.)
- ❖ Would you rather study hurricanes, tornadoes, or winter weather? Present your thoughts based on the inherent interest of the topic, plus what you think might benefit more people.

Hands-On Activities

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 26, Activity 2.1 *Creating Clouds* (1 class period)

Whether you set up the "Making Weather in Class" Activities in one larger "Experiment Station" undertaking (as Eileen Bendixsen suggests and demonstrates in Educator Program B, and writes about on TG p25), or use individual activities to complement various of the programs, we urge you to let students literally make some of the different types of weather they see in the programs, or can observe in reality outside their windows. It's this kind of hands-on experience that lives on after all the listing and definition of specific cloud types have faded.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 28, Activity 2.2 *"Dew-ing the Dew Point"* (1 class period)
This Activity, also demonstrated in Educator Program B, connects local data collection and analysis, using SI measurements, to real-world phenomena, and then encourages students to use on-line resources to check their findings. Also note how the various balloon and dropwinsondes collect similar kinds of data as part of NOAA's regular forecast operations. Students will be making their own small-scale experiments directly paralleling real-world data collection.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 52, Activity 4.1 *Writing Up a Storm* (1 class period)
Whether here or as a cumulative activity, it's good to have students connect weather and/or climate phenomena to their own lives and past experiences, especially if you have students of diverse national origins. Please share the best of the student stories on-line. (See the PTW&C website, under **`EDUCATORS`** and **`STUDENTS' CORNER`** for how to submit.)

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 37, Activity 2.6 *Warm Front, Cold Front* (1 class period)
(see program 3 for comments on this Activity.)

On-line

At the PTW&C website, read **`BIOgraphies`** and **`JOURNALs`** (found in the **`WHO`** section) of some of the researchers involved in IPEX, such as those from avid mountaineer, David Schultz, and DOW scientist, Jeff Trapp (also author of three **`JOURNALs`**).

> Teacher Tip: Eileen Bendixsen
> After the video I would take them to the PTW&C site—**WHAT / WEATHER / WINTER STORMS** and also use this site for more information:
> **`http://www.nws.noaa.gov/om/winter/index.shtml`**

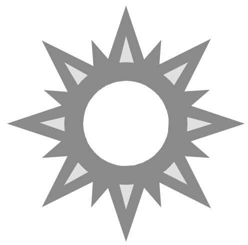
Suggested URLs (providing background for a teacher and resources for student use)
`http://www.nssl.noaa.gov/researchitems/winter.shtml`
Winter Weather: The National Severe Storms Laboratory website with information on winter safety and the "Intermountain Precipitation Experiment" (IPEX.)

`http://www.usatoday.com/weather/wwater0.htm`
`http://www.usatoday.com/weather/wwinter0.htm`
Understanding Water in the Atmosphere: Information on the basics of water including changes of state and understanding snow and ice, and Understanding Winter Weather.

Selected "NSES/2061 Benchmarks" met by the video, hands-on and on-line resources

1.2.1 Knows that water can change from one state to another (solid, liquid, gas) through various processes (e.g., freezing, condensation, precipitation, evaporation)
10.2.4 Knows that materials have different states (solid, liquid, gas), and some common materials such as water can be changed from one state to another by heating or cooling

15.3.1 Knows that there is no fixed procedure called "the scientific method," but that investigations involve systematic observations, carefully collected, relevant evidence, logical reasoning, and some imagination in developing hypotheses and explanations
15.4.6 Knows that scientists conduct investigations for a variety of reasons (e.g., to discover new aspects of the natural world, to explain recently observed phenomena, to test the conclusions of prior investigations, to test the predictions of current theories)


Program 5 Thunder and Lightning (14:58)
Light, Sound and Electrical Charge

Objectives
After viewing the video, participating in one or more of the Hands-On Activities, and using on-line resources, students will be able to:

- simulate and explain how charges build up, resulting in static electricity
- compare and contrast materials serving as *conductors* and *insulators* of small amounts of static electricity
- describe changes in how lightning is studied between the time of Ben Franklin and contemporary research campaigns
- research and report on safety procedures recommended by NOAA and the American Red Cross for severe thunderstorms

Program Description
This program explores how static electricity gets generated and discharged in towering cumulus clouds, and why we see lightning before we hear the thunder. Safety tips and basic science should benefit students both on playing fields and in tests. "**Flash and Crash!**" How light and sound differ in character and travel time, and why we both see and hear the effects of severe thunderstorms. Graphics show how positive and negative charges accumulate in different parts of storm clouds, and then discharge to trees and other tall objects on the surface of the Earth. "**From Ben Franklin to 'STEPS'** " Research old—and unsafe!—and how today's NOAA researchers, from the National Severe Storms Laboratory and elsewhere, use balloons, computers and other high-tech tools to study lightning, as safely as possible. "**Storm Safety**" Tips from NOAA experts and others about how students can apply their new knowledge of what makes thunder and lightning to keeping themselves and their families safe in severe weather.

- "**Flash and Crash**!" (Video segment running time: 05:30) Humans have always trembled at the sight of lightning and the sound of thunder. The program refers to the Norse god of thunder, Thor, and to stories of the Thunderbird, told by Native Americans. Today's researchers can study storms from above, from the Space Shuttle, and from satellites. Images from NASA's TRMM satellite (boosted in mid-summer 2001 to a higher orbit to prolong its highly productive research life) show lightning strikes around the globe. We now know that at any one time there are some 2,000 thunderstorms happening somewhere at any moment: there are more storms over land than sea. The most thunderstorms anywhere on Earth happen near Kampala, in Uganda, East Africa, with on average some 280 thunderstorm days a year. In the USA, Central Florida is the record holder with 80 days per year. Lightning is #2 in causing weather related deaths, surpassed only by floods. David Rust, one of America's leading lightning researchers, says there's still much we don't know about lightning. The program reviews what we do know with some certainty. Thunderstorms begin with warm, moist air near the ground, and cooler air up above, conditions which are more common in spring and summer. Images from the PTW&C website show how when warm air rises it expands and cools, and, at the top of the clouds, produces raindrops which create a cooler downdraft. Location footage shows a dramatic, dark, tornado-like rainshaft. In such severs storms, hail results (See program 3.) When conditions are right, different electrical charges build up in different portions of the cloud as the result of the interaction of solid and liquid water, hail and raindrops. When charges grow large enough, there's a "discharge," and cloud-to-cloud or cloud-to-ground lightning results. A "stepped leader" comes down from the (usually) negatively charged lower portions of the cloud. Under the cloud the Earth is positively charged. Opposites attract, and a streamer rises up from ground through a tall object such as a tree, current flows in a "return stroke", and lightning results. (Students can use the website to "step" [sic] through the process for themselves.) Each flash lasts less than a second, but can have temperatures more than 30,000 degrees, 5 times hotter than the outer layers of the Sun. This sudden heat causes air molecules to vibrate, like the stereo loudspeaker we see in the video, producing the sound of thunder. We see lightning before we hear thunder since the flash travels at the speed of light, 186,000 miles per second, whereas thunder only travels a mile in 5 seconds. Graphics show students that if they hear a crash 15 seconds after they see a flash, that means the storm is 3 miles away (flash to crash ratio, 15/5 = 3 miles away) close enough to take precautions. (In fact current NOAA suggestions often rely on what's called the "30/30" rule: if a storm is closer than "30 seconds" or 6 miles away, take shelter, and don't emerge for 30 more minutes after it has passed. Other researchers argue that since the majority of lighting deaths in fact occur when the storm is approaching or has already passed—and that lightning strikes may occur as much as 10 miles from a storm—that you should take cover if you can see *any* lightning or hear *any* thunder rather than counting and calculating.)
- "**From Ben Franklin to 'STEPS'** " (06:39) Ben Franklin (seen in an original oil painting by Benjamin West, now in the collection of the Philadelphia Museum of Art) was fascinated by weather and lightning (as were many others of the Founding Fathers. Jefferson, for example, kept a daily, detailed log of weather conditions.) We see Ben's famous experiment with the kite. (Take this opportunity to re-emphasize to students NOT to attempt this or anything like it at home.) A French researcher doing pretty much the same experiment was killed just a few weeks after Franklin's lucky strike. Today we use

satellites, balloons, and specially armored planes to study lighting much more safely. We go on the road with David Rust and his team during STEPS, the "Severe Thunderstorm Electrification and Precipitation Study." Supported by NSF as well as NOAA, we see the research process in and around Goodland, KS, and as far west as Colorado and as far south as Texas. A specially equipped T-28 trainer from the South Dakota School of Mines and Technology was part of STEPS. One of its pilots, Tom Root (who also flies for Continental Airlines) describes what it's like to fly through a severe thunderstorm protected by an insulated Faraday cage. The plane carries special instruments to detect and record the size and electrical charge of raindrops. Says Tom, *"…what they're trying to do is figure out why thunderstorms work the way they do, and if I can facilitate that research by having an opportunity to do that with my thirty years of experience at flying, I'd like to think that I can do it as safely as anybody. If the wing comes off, I've got a parachute; so I can open the canopy and step over the side… although I'd be floating down through a thunderstorm!"* Down on the ground, we see how Dave Rust's team deploys the balloons that carry radio-linked detectors up through storms. They use a huge bag, invented by Dave, as a "high-wind launch tube." Rust is also concerned for safety (note the dramatic cloud-to-ground strike which hits just over his shoulder during one scene.) *"Safety is always foremost in our minds, and we worry very much about that. When we launch these balloons, we try to minimize the time that we're out in the field. One does have to be conscious about the proximity of lightning, and we are always evaluating whether we think it's safe to continue or not. We have aborted some balloon flights and gotten people into safety without making a flight because the lightning gets too close."* One of the members of his team, however, says something that any serious meteorologist might echo*: "Severe storms is what meteorology is all about. That's a lot of the reason why we're all out here. 'Cause this is Mother Nature at her best, with everything she has to work with this."* Interviewer*: "And you like this?" "Yes."* Rust says that this kind of research is important because lightning in especially severe storms may have a distinctive signature that can help improve the accuracy and timeliness of short-term warnings and forecasts.

- "**Storm Safety**"(01:41) This short segment is crammed with important information and advice. Summer, with its outdoor sports like golf or baseball, or time spent on the beach, is also lightning season. We see PGA golf pro, Rocco Mediate, who stars in a NOAA lightning awareness campaign. Mike Utley, an amateur golfer struck by lightning, is still recovering, with nerve damage, more than a year later. Talking about students and sports he asks, *"If you look at that recreation area, what's the tallest thing out there? Our kids…"* Tying science to safety, we reprise the animation showing lightning striking a tall tree. Mary Ann Cooper, a medical doctor from the University of Illinois at Chicago who specializes in lightning injuries, introduces her pithy and practical advice: *"If you see it, flee it. If you hear it, clear it."* Jack Kelly, Jr., Director, NWS, NOAA, adds his suggestion that youngsters be aware of the sky at all times. "Lightning kills, play it safe", as the NOAA public service announcement ends. With our scientific knowledge of thunder and lightning we need no longer fear storms, but even so we should respect their awesome power and take seriously NOAA's safety recommendations.

Vocabulary

downdraft, rainshaft, updraft, radar, positive, negative, charge, insulator, conductor, stepped leader, return stroke

Pre-Viewing Questions

- ✓ Does light travel faster than sound? (Yes) What do you sense first, lightning or thunder? (Lightning before thunder.)
- ✓ How fast does light travel? (186,000 miles, or 300,000 kms per second) How fast does sound travel? (1 mile in 5 seconds.)
- ✓ How close should a thunderstorm be for you to take cover? (NOAA now recommends that if you see lightning or hear thunder, that's close enough for you to take shelter.)

Post-Viewing / Quiz Questions

- ❑ What short rhyme summarizes NOAA's current safety advice about thunder and lightning? ("If you see it, flee it. If you hear it, clear it." Or, "Lightning kills: Play it safe." [the latter is the slogan of the PGA-NOAA safety campaign seen during the program.])
- ❑ What place on Earth has the most thunderstorms? (Kampala, Uganda.) Where in the USA has the most thunderstorms? (Florida.)
- ❑ How many thunderstorms are happening somewhere on Earth at any one time? (2,000)

Discussion Topics

- ❖ You're out on the playing field, and one run behind, and you see a lightning strike and hear thunder: what do you do? Call the game, or play on in the hope of making up the loss?
- ❖ What's the scariest weather experience you've ever had? Was thunder and lightning the first weather phenomenon you recall?
- ❖ Does your school have a lightning safety plan, and do all coaches follow it? (See Teacher Tips box below for more resources if you choose to explore this topic.)

Hands-On Activities

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 30, Activity 2.3 *Making Lightning* (1 class period)
Featured in Educator Program B, this Activity connects lightning to several of the topics you'll likely already cover as part of physical science, e.g. conductors, insulators, etc.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 35, Activity 2.5 *Rainbows and the Spectrum of Visible Light* (1 class period)
At the end of a thunderstorm, what else? A rainbow. Jumping off from the obvious weather connection, this simple but memorable activity illuminates both the spectrum and optics and, like several of the other Activities, empowers students to politely inform parents and caregivers of the science behind a real-world phenomenon when they next experience one.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 26, Activity 2.1 *Creating Clouds* (1 class period)
If you've not implemented this Activity to accompany a previous program, consider using it here.

On-line

There are some excellent on-line resources providing both information and stories from lightning survivors, both young people and adults. In addition to the informational URLs which follow, P2K suggests:

National Weather Service Lightning Safety
http://www.lightningsafety.noaa.gov/factsheet.htm

"Lightning is the #2 storm killer in the U.S., killing more than hurricanes or tornadoes. Only floods kill more. But the real story of lightning isn't the deaths, it's the injuries. Only about 10% of those struck are killed; 90% survive. But of the survivors, the large majority suffers life-long severe injury. These injuries are primarily neurological, with a wide range of symptoms, and are very difficult to diagnose. Lightning also causes about $5 billion of economic loss each year in the U.S."

http://www.azstarnet.com/~anubis/sabintro.htm
Lightning Safety for Kids: Introduction, and stories of young people who were hit:

The following link relates to the baseball game seen during the video: after calling the game one of the adults was asked why he chose to end it with his team losing: "Better to be 3 runs down than 6 feet under" was his memorable reply.
http://www.lightningsafety.noaa.gov/success.htm#bunting

> **Teacher Tips: Eileen Bendixsen**
> I would use the following story to lead into the class finding out what lightning safety policies and procedures have been adopted in their town. This could lead to student and town officials working together to establish a policy if one is not in place.
> **http://www.lightningsafety.noaa.gov/success.htm#brody** I would end this segment with the students planning a "lightning-safe" camping trip and presenting their plans to the class.

Suggested URLs (providing background for a teacher and resources for student use)
http://www.lightningsafety.noaa.gov/
Lightning Safety: The slogan for NOAA's lightning safety program is "Lightning Kills, Play It Safe". The latest information on lightning including facts, success stories, and survivor stories.

http://www.noaanews.noaa.gov/stories/images/lightningsafety.pdf
Preparedness booklet provides information on how lightning works, warning signs, safety precautions, an action plan for outside events, first aid for lightning victims, and fast facts.

http://www.nssl.noaa.gov/
Information on thunderstorms and lightning including FAQs on thunderstorms and lightning and safety information.

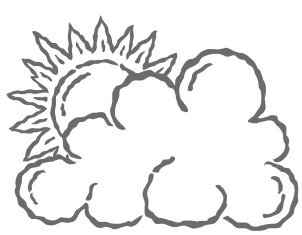
http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/svr/home.rxml
Severe Storms: On-line Meteorology Guide (University of Illinois): Information on the dangers, types and components of thunderstorms.

http://www.nws.noaa.gov/om/trw.htm
Background information on thunderstorms and lightning including myths about lightning.

http://www.redcrosslv.org/news/thunderstorm.html
American Red Cross: Safety Tips Regarding Thunderstorms and Lightning

Selected "NSES/2061 Benchmarks" met by the video, hands-on and on-line resources

1.2.3 Knows that clouds and fog are made of tiny droplets of water
11.2.1 Knows that heat is often produced as a by-product when one form of energy is converted to another form (e.g., heat is produced by mechanical and electrical machines)
11.3.5 Knows that electrical circuits provide a means of transferring electrical energy to produce heat, light, sound, and chemical changes
12.1.2 Knows that light travels in a straight line until it strikes an object
12.3.1 Knows that vibrations (e.g., sounds, earthquakes) move at different speeds in different materials, have different wavelengths, and set up wave-like disturbances that spread away from the source
12.4.1 Knows that waves (e.g., sound, seismic, water, light) have energy and can transfer energy when they interact with matter
12.3.3 Knows that only a narrow range of wavelengths of electromagnetic radiation can be seen by the human eye; differences of wavelength within that range of visible light are perceived as differences in color
13.4.1 Knows how different kinds of materials respond to electric forces (e.g., as insulators, semiconductors, conductors, superconductors)
13.4.7 Knows that the strength of the electric force between two charged objects is proportional to the charges (opposite charges attract whereas like charges repel…)
15.2.2 Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer



Program 6 El Niño and La Niña: the "Boy" and the Buoys (14:51)

The World in Hot Water

Objectives

After viewing the video, participating in one or more of the Hands-On Activities, and using on-line resources, students will be able to:

- model the interaction of jet streams and ocean currents
- simulate the effect of El Niño in choking off the upwelling of nutrient rich bottom waters
- use on-line and other resources to explain the global effects of El Niño and La Niña
- describe the technologies used by NOAA and NASA to track and predict future El Niño and La Niña events

Program Description

The second most powerful influence on global weather and climate, after Sun and the seasons, are the phenomena known as El Niño and La Niña: a network of buoys in the Pacific meant the 1997-98 ENSO event was the world's first-ever climate forecast. "**Second only to the Seasons**" Describes how ocean currents and the cycling of warm and cold water leads to characteristic temperatures and nutrient productivity in the waters off South America—and what happens during El Niño, named for the Christ child and appearing around December 25. "**Wiring the World**" We're out in the middle of the Pacific, and setting sail from Africa's Ivory Coast with NOAA researchers deploying buoys to satellite back detailed and continuous measurements of ocean temperatures: key to understanding and predicting Pacific, Atlantic and other marine-based climatic oscillations. "**Climate Forecasting**" How NASA and NOAA satellites, ocean sensors, advanced computers and sophisticated software are used to create models of Earth's future climate, allowing pre-emptive measures by farmers, fisherman and emergency managers around the world.

- "**Second only to the Seasons**" (Video segment running time: 04:17) JPL (NASA/Caltech) satellite oceanographer, Bill Patzert, introduces what he calls the largest "disturbance in the force" (in terms of Earth's weather and climate) after the seasons: El Niño and La Niña. An explanation of how El Niño and La Niña got their names. Patzert comments that nobody on planet is left untouched by a large El Niño. El Niños tend to arrive every 2-7 years when the usual trade winds relax or reverse, and a pool of warm water washes back eastward across the Pacific to cut off the normal upwelling of nutrient rich cold waters off the coasts of Ecuador and Peru. Since fish feast on the nutrients, fishermen recognize the arrival of El Niño by reductions in their catch. After an especially large El Niño you tend to get a large La Niña (the "little girl," in Spanish.) Through graphics, students see that El Niños tend (i.e. this is not always and inevitably the case) to bring warmer weather to Northern United States, floods to California, and colder and wetter weather than usual to the south. La Niña winters, on the other hand, may (same caveat as for El Niño) be colder in the West, dry in California, wet in the Northwest and warmer and wetter in the South East. As noted in program 2, El Niños also reduce the number and intensity of East Coast hurricanes. But the El Niño/La Niña cycle is not the only such oscillation in Earth's seas. Researchers now think other oceans also have similar periodic cycles.

- "**Wiring the World**" (04:57) The 1982 El Niño was the largest of the 20th Century, until that of 1997-8. But the 1982 event was not even detected until at its height. This segment describes the TAO (Tropical Ocean Atmosphere) array of autonomous data buoys. Footage from NOAA shows them being placed across what Michael McPhaden, Director TAO Project Office, says is about 1/3 of circumference of the world at the Equator. The USA, Japan, France, Taiwan, and Korea are partners in TAO. These buoys (plus satellite data) proved so effective that a similar set is now being placed across the tropical Atlantic. Operating out of Abidjan, Ivory Coast, we see how NOAA/USA, France and Brazil are collaborating on PIRATA, the "Pilot Research Moored Array in the Tropical Atlantic." Ocean temperatures in the Atlantic affect rainfall in both Africa and South America, and may even have an impact on the origin of North American East Coast hurricanes. NOAA's buoy expert, Andy Shepard, describes the capabilities of the ATLAS buoys. John Kermond, from NOAA's Office of Global Programs, emphasizes the power of international cooperation and notes the PIRATA effort is "*historic because the scientific community has now learned where to put the stethoscope to get a better handle on the role of the ocean and its linkage with the atmosphere, which collectively give us climate."* Jacques Servain, head of PIRATA speaks (in French with subtitles) of the connection between sub-surface ocean temperatures and rainfall, and gives the URL for finding out more about this project. PLEASE NOTE THAT YOU MUST USE THE URL AS IT APPEARS ON SCREEN, NOT AS HE SAYS IT. THERE IS AN EXTRA "FR" IN THE ACTUAL ADDRESS.
- "**Climate Forecasting**" (04:10) NASA's Patzert reinforces and extends what Marshall Shepherd said in program 1: Earth's oceans and atmosphere redistribute heat from the Equator towards the Poles. Because the oceans retain heat more than land or air (see program 1 and the "Differential Heating" hands-on Activity suggested for that program) knowing the temperature of the oceans enables you to see father ahead into the future, and make more accurate predictions. With graphics showing the US/French TOPEX-Poseidon satellite at work, Patzert notes that a simple principle of nature—when you warm something up it takes up more room—enables a satellite 1300 kms up in space to assess ocean temperatures, to an accuracy of 3-4 cms! He indicates that the great white and red spots seen in the accompanying graphics are higher (in elevation) and therefore warmer in temperature. The segment ends by saying that as buoys and satellites advance, and as we understand ocean and atmosphere interactions better, it should be more possible to make more accurate "climate predictions" to save billions of dollars and thousands of lives.

Vocabulary

Autonomous, oscillations, El Niño, La Niña, jet stream, buoys

Pre-Viewing Questions

- ✓ Is El Niño unique, or do all oceans have periodic cycles of heating and cooling? (Researchers now think many of Earth's ocean, including the Atlantic, Indian and South—or Antarctic—ocean may have similar cycles.)
- ✓ In which ocean does ENSO happen? (In the Pacific.)
- ✓ Do El Niño events only impact South America, or are they felt around the world? (They have global impacts.)

- ✓ What scientific principle does a satellite high above Earth use to tell the temperature of the ocean? (Hot things expand: warm water is higher than cold water.)
- ✓ How small a change in ocean temperature does John Kermond say has an impact on climate? (As little as one degree C: during El Niños there have in fact been changes of as much as 5 degrees.)

Post-Viewing / Quiz Questions

- ❑ How did El Niño get its name? (The warmer water appeared around Christmas, which made people in predominantly Catholic countries name it for the "Christ child.")
- ❑ What physical process causes reduced catches for the South American fishermen? (El Niño's warmer waters cut off the upwelling of nutrient rich colder waters from deep in the ocean.)
- ❑ How many nations other than the United States are part of TAO and PIRATA? (The US and Japan lead TAO, with participation also by France, Taiwan, and Korea. On PIRATA, France takes the lead, with Brazil and the USA participating.)
- ❑ Why do ocean temperatures have an affect on Africa and South America? (They affect rainfall on both sides of the ocean.)

Discussion Topics

- ❖ The program says that El Niños tend to bring warmer weather to Northern United States, floods to California, and colder and wetter weather than usual to the south. Do you think that means every El Niño winter will be like this? Why, or why not? (This topic introduces the idea that average conditions do not predict actual conditions in any one year.)
- ❖ Why do El Niños have an affect on East Coast hurricanes?

Hands-On Activities

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 21, Activity 1.5.1 *Ocean Current and Jet Streams* (1 class period)
Program 6 uses some amazing NASA images to show students El Niño from space: but there's always the risk that students will lack a more concrete understanding of the phenomenon as other than a 2-dimensional reality. That's the value of one or both of these hands-on Activities. (Please note that some similar activities use hair-driers to power the winds: we prefer mouth power via straws for the obvious reason of student safety.)

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 23, Activity 1.5.2 *A Hands-On El Niño* (1 class period)
The combination of the TOPEX-Poseidon data, animation from NASA's Goddard Space Flight Center Science Visualization Studio and this activity should give students a sense of a phenomenon more talked about than understood.

> **Teacher Tips: Eileen Bendixsen**
> Before showing the video I think there are several places that need to be pointed out on a map (or you could use student worksheet 1.5.1.1 or 2.) This will give students some geography/social studies correlations. Places, regions or phenomena that could be located are: "trade winds," Ecuador, Peru and the waters off their coast, Indonesia, Australia, California, Texas, and Florida, Abidjan in the Ivory Coast.) I think it is better before and to have the teacher explain that in the video they will see how the temperature of the waters off the coast of Ecuador and Peru impact the weather in countries around the world. If they know where the places are they can absorb and apply the information better than having no or a weak idea of where these places are located.

On-line

Follow the voyages of the NOAA research fleet (**http://www.pmel.noaa.gov/tao/kaimi/**) via some of the links which follow. See Brian Igelman's Abidjan **JOURNAL**.

Suggested URLs (providing background for a teacher and resources for student use)
http://www.pmel.noaa.gov/tao/elNiño/el-Niño-story.html
Excellent background information on El Niño including how to recognize it, and animations.

http://www.pmel.noaa.gov/tao/elNiño/la-Niña-story.html
What is La Niña? Background information on La Niña including the origin of the name, the impact on global climate, animations and recent events.

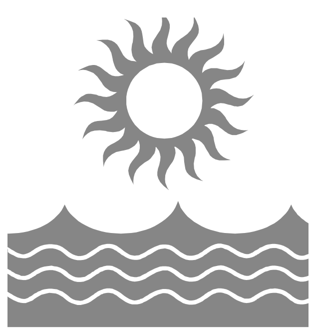
http://www.pmel.noaa.gov/tao/elNiño/faq.html
http://www.pmel.noaa.gov/%7Ekessler/occasionally-asked-questions.html
Frequently asked questions about El Niño and La Niña.

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/enso_cycle.html
Graphics and text explanation of the ENSO Cycle

http://topex-www.jpl.nasa.gov/
NASA JPL's TOPEX site, with great animations, information and news of follow-on missions.

Selected "NSES/2061 Benchmarks" met by the video, hands-on and on-line resources

1.1.3 Knows that short-term weather conditions (e.g., temperature, rain, snow) can change daily, and weather patterns change over the seasons
1.2.2 Knows the major differences between fresh and ocean waters
1.4.3 Knows how winds and ocean currents are produced on the Earth's surface (e.g., effects of unequal heating of the Earth's land masses, oceans, and air by the Sun; effects of gravitational forces acting on layers of different temperatures and densities in the oceans and air; effects of the rotation of the Earth)
1.3.6 Knows factors that can impact the Earth's climate (e.g., changes in the composition of the atmosphere; changes in ocean temperature; geological shifts such as meteor impacts, the advance or retreat of glaciers, or a series of volcanic eruptions)
11.2.2 Knows that heat can move from one object to another by conduction and that some materials conduct heat better than others


Program 7 Earth's Variable Climate (14:59)
Weather, Climate and Society

Objectives
After viewing the video, participating in one or more of the Hands-On Activities, and using on-line resources, students will be able to:
- discuss techniques used to obtain evidence of Earth's past climate
- model and observe the physical effects of a simplified Greenhouse Effect
- research and discuss the potential impact of global climate change on their own and other communities

Program Description
Are we living in a time of unprecedented climate change? Is the "Greenhouse Effect" caused by humans? How has Earth's weather varied in the past? "**Detecting Past Climates**" How tree rings and fossils from creatures long dead, plus ice coring and other techniques, allow researchers to infer weather and climate from the distant past. "**The Greenhouse Effect**" Relates the familiar greenhouse used to raise plants or vegetables to a planetary greenhouse effect: the sequence explains how Earth's greenhouse effect has—in the past—made our world habitable. "**Human Induced Change?**" Evidence for man-made changes in the climate is reviewed, using data on carbon dioxide, ozone and other components of the atmosphere. On-line sources are cited as the place to find current data and discussion of evidence for and against anthropogenic climate change.

- "**Detecting Past Climates**" (Video segment running time: 04:26) 1998 was the hottest of the 1990s, which was the hottest decade of the 20th Century. 1998 may even have been the hottest year for past 1,000 years. This segment introduces the evidence which scientists use to read the "book" of Earth's climate from epochs long before humans were around to record what was going on: trees rings, ice cores, fossils, and rocks. The segment re-introduces definitions of weather, and of climate (the average of weather conditions over years and decades.) Ice expert Richard Alley (Penn State) says that a fat tree ring is an indicator of a "happy tree," and a small ring an "unhappy tree." In a dry place, a wet tree is happy. We see glaciologist Paul Berkman collecting ancient clam shells in the Antarctic: a thick shell indicates warmer conditions, a thinner shell, colder waters. Alley indicates that the longest annual climate record comes from ice cores. Once again, their thickness tells you how much it snowed, but ice also traps bubbles of the atmosphere. So you can "ask of the air, how much methane…" was in the atmosphere at the time, etc. etc. Still farther back in the Climate Book we can "read" the rocks. We find fossils of crocodiles up North, and dinosaurs down South, indicating the Poles were not always the cold places they are today: there have been large changes in Earth's past climate. Alley says the evidence suggests that sometimes things changed a lot, quite quickly: *"changes of 10 degrees Celsius in something around 10 years, 2-fold (changes) in snow, 10-fold in dust, and 50% in methane. Remarkably fast changes."*
- "**Greenhouse Effect**" (03:26) Beginning with images of a regular greenhouse used to grow plants and vegetables, this segment describes the planetary greenhouse effect. Animation shows how Earth's atmosphere becomes the "glass" of the planetary greenhouse. The most important greenhouse gases are methane, carbon dioxide, and

water vapor: without them Earth would be 34 degrees Celsius colder, and life as we know it could not exist. Now *"We are enhancing the natural greenhouse effect,"* says climate expert, Cynthia Rosensweig, of NASA's Goddard Institute for Space Science. *"We are applying a slow but steady change in the forcing,"* and eventually on average the planet will warm. Average global temperatures rose 0.6 degree C. in the 20th century, says Warren Washington, Senior Scientist at NCAR, America's leading weather and climate research center. Graphics updated through the end of the 1990s show how levels of carbon dioxide and temperature have risen in step through the last century. Alley, Washington and Rosenzweig agree that much of this change is due to increasing greenhouse gases, and that we can forecast that this will continue into the future.

- "**Human Induced Change**?" (05:27) NASA satellite imagery shows the local and regional effects of humans on weather: we see how urbanization around Atlanta, GA, has increased temperatures, the so-called "heat island effect." More warm air, in turn, means more thunderstorms. We can also see human impacts in rural areas. Soot from burning fields or forests results in less precipitation. The presence of more condensation nuclei means that condensing drops of water don't grow large enough to fall as rain. Other evidence for human-induced changes in the climate is reviewed, using data on carbon dioxide emissions: 80% of the excess carbon dioxide (i.e. beyond that which would be balanced out by natural processes) comes from industrial emissions, power generation or automobile sources. In a spectacular example of the consequences of climate change, we see how the Larsen Ice Shelf off the Antarctic Peninsula has crumbled. Here there have been 5 degree F. changes in temperature since the 1950s. Based on accepted international and US panels, global warming will affect everyone. Extreme weather events, of hot, and cold, or wet and dry, will be more frequent. Exactly how, no-one knows. According to Alley, the climate is not predictable: *"When you push the climate, it does not change smoothly, it staggers. Like a light switch. Suddenly, it flips."* What can we do? Rosenzweig argues that Earth's response to the ozone hole (banning CFCs through the Montreal Protocol) was a success: *"so if we could do it with Montreal Protocol on ozone, we will be able to do it with carbon dioxide and greenhouse gases."* Warren Washington says he knows there are still uncertainties in our knowledge of climate and climate change, such as our understanding of the role of clouds. He urges us to consider what he calls the "Precautionary Principle": *"if you invoke this principle it means that even though you don't have all of the data and all of the uncertainty nailed down, that you start to take steps. And this is very important because we have to worry about whether we are changing this planet and its climate in a way that will be harmful to future generations."*

Vocabulary

Forcing, fossil, weather, climate, pressure, temperature, greenhouse effect, radiation

Pre-Viewing Questions

- ✓ Can Earth's temperature change by more than a degree or so in less than a century? (Richard Alley says there's evidence of 10 degree changes in less than a decade!)
- ✓ Is Earth warming? (Most researchers now say yes. There is, it must be said, still uncertainty about how much of this change is human-generated and how much natural.)
- ✓ Can humans impact Earth's weather and climate? (Yes.)

- ✓ What evidence is there that the Poles were once warmer? (Crocodile fossils near the North Pole and dinosaur fossils in Antarctica.)

Post-Viewing / Quiz Questions

- ❑ What are some of the impacts humans have already had on weather and climate? (Increased urbanization has increased city temperatures. Deforestation and forest fires reduce rainfall. Industrial and auto emissions have increased carbon dioxide levels in the atmosphere. Until banned in 1987 through the Montreal Protocol CFCs amplified the ozone hole.)
- ❑ How much change in temperature we do know has happened in the Antarctic Peninsula in recent decades? (A 5 degree F rise since the 1950s.)
- ❑ Why are tree rings fat or thin? (It depends on how much water and/or heat exist as they grow each year.) Why are Antarctic clam shells thick or thin? (When waters are cold, shells are thin. When warmer, thicker.)

Discussion Topics

- ❖ Do you think humans are causing Earth's weather and climate to change? Referring to the program, and to what you've read or hear about, why or why not?
- ❖ Do you agree with Warren Washington's "Precautionary Principle" (quoted verbatim in the program description.) Why or why not?
- ❖ Do you believe humanity is smart enough to tackle global climate change? Why or why not?

Hands-On Activities

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 59, Activity 4.4 *The Greenhouse Effect and Global Warming* (1 class period)
Just as with El Niño, the Greenhouse Effect is much discussed but little understood. This simple hands-on Activity, using soda bottles, helps make it real.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 57, Activity 4.3 *Making a Weather and Climate Timeline* (2-3 class period)
Just like Richard Alley's provocative remarks in the video, this Activity helps expand students' conception of the scale of human thinking about, and experimenting with, weather and climate, and can help counteract the "now"-centrism of the Information Age. The requirement to have at least 10 of the 50 cited events be from outside Europe and North America will also spur student research into lesser-known weather history.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 61, Activity Z.2 "*Weather Wise 2000"* (1 class period)
Either here or as a cumulative Activity, "Weather Wise 2000" (update the year as necessary!) invites students to deploy scientific learning in a social context. Alert all students to double check each others facts and arguments.

On-line

Check out the interactive animation with additional background on the Greenhouse Effect at the PTW&C website. Also, under **WHAT** / **CLIMATE**, see additional information.

Suggested URLs (providing background for a teacher and resources for student use)
`http://www.usatoday.com/weather/wozone0.htm`
Understanding Ozone: A guide to the science of ozone depletion.

`http://www.worldbook.com/fun/atw/climates/index.htm`
Provides information on the climate in each of the fifty states and the provinces in Canada plus general information about other countries around the world.

`http://www.usatoday.com/weather/clisci/wclisci0.htm`
Information on the basic science of climate change, its causes and its potential effects.

`http://www.epa.gov/globalwarming/`
US government site discusses global warming, including what is the problem, what do we know, how serious is the problem and what is being done.

`http://www.ozonelayer.noaa.gov/`
NOAA's monitoring and research site for stratospheric ozone with good background information including the discovery of the Antarctic Ozone Hole.

`http://www.giss.nasa.gov/edu/gwdebate/`
Comments by Goddard Institute head, James Hansen, on a "scientific" approach to sometimes controversial questions of global climate change.

Selected "NSES/2061 Benchmarks" met by the video, hands-on and on-line resources

1.3.3 Knows the composition and structure of the Earth's atmosphere (e.g., temperature and pressure in different layers… circulation of..)
1.3.4 Knows ways in which clouds affect weather and climate (e.g., precipitation, reflection of light from the Sun, retention of heat energy emitted from the Earth's surface)
2.3.7 Knows that fossils provide important evidence of how life and environmental conditions have changed on the Earth over time (e.g., changes in atmospheric composition…)
10.3.1 Knows that matter is made up of tiny particles called atoms, and different arrangements of atoms into groups compose all substances
14.3.2 Knows that all scientific ideas are tentative and subject to change and improvement in principle, but for most core ideas in science, there is much experimental and observational confirmation
15.3.6 Understands the nature of scientific explanations (e.g., emphasis on evidence; use of logically consistent arguments; use of scientific principles, models, and theories; acceptance or displacement based on new scientific evidence)
16.3.2 Knows that the work of science requires a variety of human abilities, qualities, and habits of mind (e.g., reasoning, insight, energy, skill, creativity, intellectual honesty, tolerance of ambiguity, skepticism, openness to new ideas)
16.4.4 Knows that science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen
16.3.6 Knows ways in which science and society influence one another…

Program 8 Tracking and Recording Weather and Climate (14:38)

Technology to Understand the Weather

Objectives

After viewing the video, participating in one or more of the Hands-On Activities, and using on-line resources, students will be able to:

- predict future weather through the identification of cloud types and experiment to compare their forecasts to the actual weather
- construct simple weather instruments, and explain the physical principles by which they work
- create a "Weather and Climate Timeline" showing the development of new ideas and instruments by which to understand and measure weather in different times and cultures
- discuss the importance of accurate information about weather and climate in terms of personal safety and economic well-being

Program Description

"Make weather" and build simple weather instruments in class: see how NOAA and NASA study weather and climate with super-computers and satellites. "**Reading the Sky**" On the beach with a young NOAA researcher, we read the signs of an approaching storm—and are reminded why you must take cover when it comes close! "**Making Weather**" A student oriented review of the types of weather they can make in class, designed to motivate participation—and to show how the hands-on Activities simulate key science principles behind real world weather. "**Research to the Rescue**" Examples of how new technologies can be used to make weather forecasts more accurate, timely and localized, and so help to manage fire and floods, as well as hurricanes and tornadoes.

- "**Reading the Sky**" (Video segment running time: 04:42) How to read the sky with unaided eyes. Once more we're on the Miami beach with NOAA meteorologist Mark Croxford, whom we met in program 1. He shows viewers how the shape of the "cauliflower" clouds indicates strong vertical motion. Using graphics we see how and why an approaching warm front is indicated by high cirrus clouds. Croxford comments that watching the weather is exciting and important, and is of interest to everyone. It's the most "applicable science" he knows of: there's a report about it every night on the news. NOAA's Daniel McCarthy, Warning Coordination Meteorologist at the NWS's Storm Prediction Center, and Patrice Kucera (also seen in program 1) provide an overview of how NOAA makes the weather forecasts we later see on the TV news or in newspapers. The two GOES (Geostationary Operational Environmental Satellites) satellites sit some 22,000 miles up in space, beaming back an image every minute if it's needed. This gives us, says Patrice, a "thermal" picture, where the purples and red are cold, and whites and grays are warm, and thereby shows us where clouds and storms are. Down on the surface there is also a network of automated weather instruments. From the ground, sounding balloons are launched twice a day here in the U.S., and around the world. Using sophisticated computers and models of how weather and climate behave, today's data is extrapolated out into the future. The forecasts are based on both getting accurate date and doing the math right: *"The more complex the math, the more detailed we can become in* *our forecasts. What we're looking at back (behind me) is the answer to mathematical equations of the current state of the atmosphere, then projected through time."*

- "**Making Weather**" (01:34) This short segment (a companion to the more extensive teacher demonstration to be seen in Educator Program B) is intended to motivate students' interest in participating in the set of 6 "Making Weather in Class" hands-on Activities (TG, p25 and accompanying worksheets.) We see students making lightning, a "Twister in a Bottle", "Dew-ing the Dew Point" and having messy but serious fun. Simple materials but substantive insights should result.
- "**Research to the Rescue**" (07:04) The real-world example of the practical benefit of more accurate and timely weather forecasts featured in this segment is "fire weather". (The same information would also be of use for emergency managers confronting floods.) Deborah Miller develops software at NOAA's Forecast Systems Lab in Boulder, CO. She and her husband also volunteer as medic and firefighter for the Boulder Mountain Fire Authority. We travel with them on a simulated wildland fire, modeled on an actual event. We see how a laptop providing the latest humidity, temperature and wind data could help fight fires and keep the firefighters themselves more safe. Says Deb, *"Hopefully, we can say that we played a role in saving some lives because weather unlike any other science, is interrelated with human activity. Here we are actually a humanitarian science, and that's why I love my job."* The segment, program and series concludes by showing some of the latest instruments which NOAA and NASA use to monitor weather and climate worldwide, including biomass burning, deforestation, tracking land use practices, monitoring the ozone hole, and even tracking conditions leading to disease from space. (Above normal rainfall associated with El Niño and warmer than usual waters in the Indian Ocean result in a greater incidence of Rift Valley fever in southern and eastern Africa.) But satellites are just machines, says NASA oceanographer, Bill Patzert: *"Space technology, super computers; these are not the most critical tools to the next leap we need in understanding the climate system. Really, the most fundamental tool is right between the ears. What we need is bright young people with new ideas…"* Marshall Shepherd argues that weather and climate science has profound and important benefits to society. The last word belongs to Mark Croxford who ties the dedication, spirit and intellectual commitment of all the researchers we've met during the series directly to students' experiences in school: *"I'm telling you, kids, you gotta start, like, you can be studying this stuff. I actually get to fly in a hurricane because of school. I sat in a monsoon for 6 weeks because of school. I get to live where I can surf because I studied meteorology. People go, 'school's kinda lame.' If you put your hours in you can get yourself into good positions like this…"*

Vocabulary

CFCs, climate, weather, temperature, jet stream, warm front, cold front, temperature gradient

Pre-Viewing Questions

- ✓ How does a weather forecast end up in a TV newscast or in the newspaper? (See the description in the program summary for prompts on this.)
- ✓ Can satellites track disease from up in space? (Yes, amazingly enough. Rift Valley fever in Africa, which is caused by mosquitoes, is tied to El Niño and warmer than usual ocean water in the Indian Ocean, both of which can easily be tracked form space.)

- ✓ Can you predict the future just by watching the sky? (Yes, if you know how to "read" the clouds you can have a fair idea of both short and mid-term weather—e.g. 2-3 days ahead.)
- ✓ Is there such a thing as "fire weather"? (Yes, there are conditions that promote or retard the spread of fire.)

Post-Viewing / Quiz Questions (see also the Pre-and Post-test questions to be found on the copy masters, which can be used here or elsewhere in the Module.)

- ❑ What are four of the instruments involved in creating weather forecasts? (Satellites, balloons, computers, surface weather stations—human brains!)
- ❑ Are balloons still useful in an epoch of satellites and supercomputers? (Yes, as seen in the video, balloons are still able to provide a vertical profile of weather conditions that satellites cannot.)
- ❑ What 3 factors affect "fire weather"? (According to Boulder Mountain Fire Chief, temperature, relative humidity, and the wind—both speed and direction.)

Discussion Topics

- ❖ Mark Croxford says we "need more students" of the weather: why would you like to study weather for a career, or not?
- ❖ What are some of the most intriguing things you learned during the series?
- ❖ What are some of the things still not known about weather and climate which you think would be most important to work on?
- ❖ Do you agree with Bill Patzert that the most important thing to help us understand weather and climate is not supercomputers and satellites but human brains? Why or why not?
- ❖ Which of the researchers you've seen during the series seems to be having the most fun, and why? ("Answers will vary…")

Hands-On Activities

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 40, Activity 3.1 *Making Simple Weather Instruments in Class* (2-3 class periods)
This set of 5 hands-on Activities not only enables students to build simple instruments to make weather phenomenon more visible, but also—perhaps more importantly—exposes them to some of the scientific principles also seen in the satellites and professional meteorological tools seen in the videos. A thermometer, for example, (Activity 3.1.3) works on the same principle (hot fluids expand) which enables TOPEX-Poseidon to track temperatures from space (Program 6.) Building an anemometer (Activity 3.1.2) helps students understand why NOAA replaced its plastic wind gauges with metal ones, less apt to be damaged during hail storms! (Program 3.) We think that by implementing these classic Activities juxtaposed to the videos and on-line resources you will engage and direct student interest in a powerful new way.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 42, Activity 3.2 *Reading the Sky: Using Cloud Types to Predict the Weather* (1-2 class period)
Twice in the series we see Mark Croxford on the beach in Miami "reading" the sky. This Activity with its student worksheet providing simplified cloud diagrams (you may already have the useful GLOBE cloud chart, or other color versions of the same) invites students to educate their own eyes and to record and then analyze cloud data. While not as powerful as NOAA and

NASA's satellite eyes in the sky, students' eyes on the sky should enable them to make some relatively good predictions about the kind of weather that's imminent, and when it might arrive.

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 57, Activity 4.3 *Making a Weather and Climate Timeline* (1-2 class periods, with home work)
(See discussion following program 7. This Activity can be assigned appropriately there, here, or as a cumulative and concluding project.)

PASSPORT TO WEATHER AND CLIMATE Teacher's Guide, page 61, one of more of the "Z" or Closing Activities.
(see IG page 52 for an overview of the post-Module assessment options.)

On-line

At the PTW&C website, read any of the **`BIOgraphies`** and **`JOURNALs`** (found in the **`WHO`** section) of researchers you've not previously explored. Check out sections of **`WHY`** and **`WHERE`** for more seasonal or geographic information.

If you're subscribed to the interactive component of the website, students with questions that are not answered by the programs or other on-line resources can submit them to **`RESEARCHER Q&A`**. Please check out the **`TIPS FOR USING RESEARCHER Q&A`** before submitting questions. If you do not have easy classroom access have the students write their questions on index cards, and discuss them as a group, selecting the most interesting topics. Questions could then be submitted later from a connected computer at school, or by using your home computer and bringing in printed copies of the answers.

Suggested URLs (providing background for a teacher and resources for student use)
`http://www.usatoday.com/weather/wworks0.htm`
How Weather Works: Basic information on air masses, pressure, El Niño, fronts and more.

`http://www.ncdc.noaa.gov/ol/climate/severeweather/extremes.html`
Climate Extremes and Weather Events: Information on worldwide weather and climate events, satellite images, historical global extremes and more.

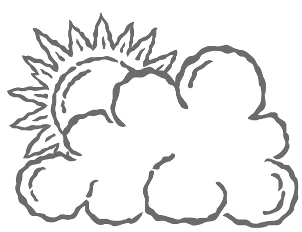
`http://www.usatoday.com/weather/wforcst0.htm`
Understanding Weather Forecasting: This site explains the basics of weather forecasting and why it's often difficult to be completely accurate.

`http://ww2010.atmos.uiuc.edu/(Gh)/guides/maps/home.rxml`
Reading Weather Maps: Learn how to read maps containing weather observation information for the surface and above the surface.

`http://www.nytimes.com/learning/teachers/lessons/990713tuesday.html?searchpv=learning_lessons`
The Heat is On! Students research severe weather in their area and then write safety guides for the types of severe weather found locally.

Selected "NSES/2061 Benchmarks" met by the video, hands-on and on-line resources

10.2.3 Knows that properties such as length, weight, temperature, and volume can be measured using appropriate tools (e.g., rulers, balances, thermometers, graduated cylinders)
10.3.9 Knows factors that influence reaction rates (e.g., types of substances involved, temperature, concentration, surface area)
14.3.1 Knows that an experiment must be repeated many times and yield consistent results before the results are accepted as correct
15.3.2 Designs and conducts a scientific investigation (e.g., formulates questions, designs and executes investigations, interprets data, synthesizes evidence into explanations, proposes alternative explanations for observations, critiques explanations and procedures)
15.2.4 Uses simple equipment and tools to gather scientific data and extend the senses (e.g., rulers, thermometers, magnifiers, microscopes, calculators)
15.3.4 Uses appropriate tools (including computer hardware and software) and techniques to gather, analyze, and interpret scientific data
15.3.5 Establishes relationships based on evidence and logical argument (e.g., provides causes for effects)
16.2.1 Knows that people of all ages, backgrounds, and groups have made contributions to science and technology throughout history



Closing Activities

> *"Better Earth science can have an immediate impact on many parts of our lives …There are now questions related to 'is the Earth getting warmer,' 'is there climate change,' is there global warming?' Our ability to answer these questions and hopefully preserve our standard of living on this planet depends on better science and better Earth science."*
> Marshall Shepherd, Research Meteorologist, NASA Goddard

We hope that the dramatic footage of weather and climate down here on Earth and from space, and comments from the engaging and committed researchers, will have interested and informed your students and presented substantive science concepts in real world context. To help you assess what they've learned you can use one or more of the Closing Activities beginning on page 61 of the **PASSPORT TO WEATHER AND CLIMATE** Teacher's Guide.

Revisiting KWL

If your students began by making a KWL chart, now is the time to update and complete it—with, we hope, many of the Want to Know items now Learned. Have students finalize their *WEATHERlogs* by checking to make sure all of the Activities done in class are included and complete. Suggest they use the Logbooks to help them update their KWL charts, and to make sure they have listed everything they've learned in the Module. By sharing individual KWL charts with the whole class, you'll help students recall the videos and what they experienced.

Activity A.1 and/or A.3 Weather and Climate Facts and Fictions, or Pre-test/Post-test If you used either of these Activities as an Opener or Pre-test, you and your students might find it worthwhile to repeat it now as a Post-test. We hope you and they alike find they've learned a great deal of factual information about weather and climate, along with key science concepts.

Other Activities

After they complete these Closing Activities have students also provide feedback about what they liked, what they *didn't* like, and what changes *they* would make if they were implementing the Module. Their answers might surprise you and provide additional input for next year, when we hope you'll be motivated to implement PTW&C once again.

We hope both you and your classes enjoy this Module. Please share examples of your students' work created in the course of **PASSPORT TO WEATHER AND CLIMATE** by submitting it as suggested in the **STUDENTS' CORNER** section of the website.

And "You're Invited…" to share your responses, ideas, challenges (and, OK, problems too!) by conversing with your fellow teachers in the **DISCUSS-STORM** e-mail forum. Use the **PASSPORT TO WEATHER AND CLIMATE** website to check out new opportunities for interaction and collaboration, and to find out how your classes can look over the shoulders of NOAA and NASA researchers and other scientists studying Earth's weather and climate. Check out the archive of **UPDATES-STORM** and subscribe to keep up with all that's new with PASSPORT TO KNOWLEDGE and this Module.

Thanks for participating, and Onward and Upward in your continuing exploration of the some of the most relevant and exciting science which students and their families encounter every day. We hope they will never look at a cloud, or a rainstorm, or even a TV weather report, in quite the same way again!

PASSPORT TO WEATHER AND CLIMATE

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Summer/Fall 2001

PASSPORT TO WEATHER AND CLIMATE website
http://passporttoknowledge.com/storm

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