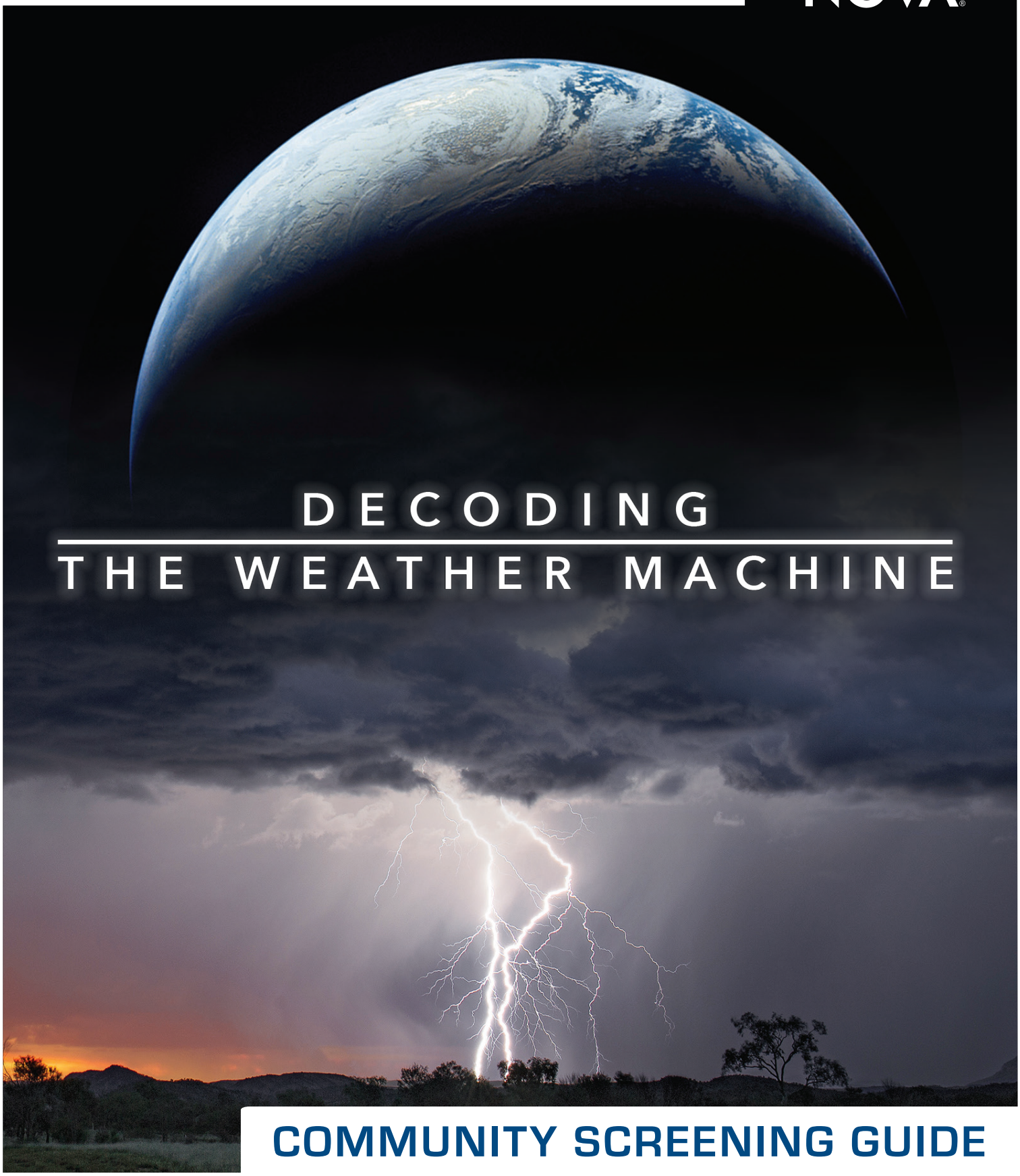
NOVA



DECODING THE WEATHER MACHINE

COMMUNITY SCREENING GUIDE

PBS WGBH

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DECODING THE WEATHER MACHINE

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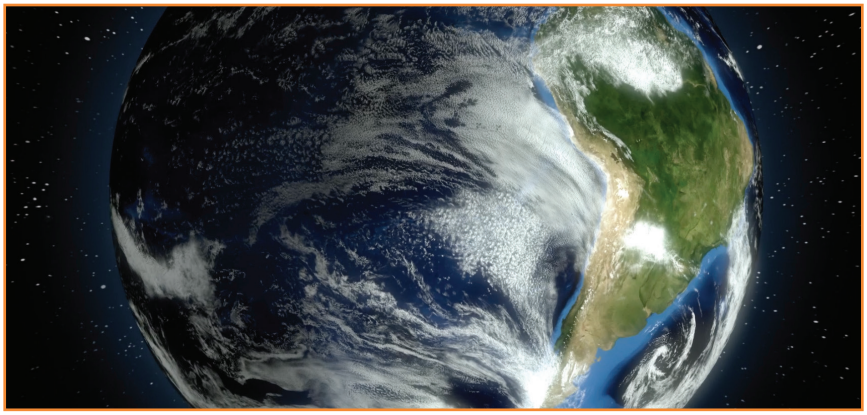


Disastrous hurricanes. Widespread droughts and wildfires. Pervasive heat. Extreme rainfall.

It's hard not to conclude that something's up with the weather. And the vast majority of scientists agree that this trend toward unusual and extreme weather is not just a coincidence. It's the result of the weather machine itself—our climate—changing, becoming hotter, more erratic. Climate change is arguably the defining challenge of our time, yet widespread misunderstanding and misinformation have hampered the public's ability to understand the science and address the issue. In this two-hour documentary, NOVA will cut through the confusion and help define the way forward. Why do scientists overwhelmingly agree that our climate is changing and that human activity is the cause? How will climate change affect us through the weather we experience, and when? And what will it take to bend the trajectory of planetary warming toward more benign outcomes? Join scientists around the globe on a quest to better understand the workings of the weather and climate machine we call Earth, and discover how they are finding that we can be resilient—even thrive—in the face of enormous change.

For more information about the film, visit **bit.ly/weathermachine**.

HOW TO USE THIS SCREENING GUIDE

The purpose of this guide is to help schools, nonprofits, community groups, government organizations, and student groups plan and facilitate a *Decoding the Weather Machine* screening and community discussion around climate change.

OUR GOALS FOR COMMUNITY SCREENINGS ARE:

- **Educating the public:** There's a lot of misinformation about climate change online and on TV. Screening participants should come away with a greater understanding of the science and skills to identify misinformation.
- **Discussing local impacts:** Climate change is global; however, its effects are, and will continue to be, felt locally. The screenings will help participants connect with their community to discuss how daily life could be impacted by climate change.
- **Brainstorming community solutions:** How will your community adapt to climate change? This screening will help participants start a conversation with other community members to identify local adaptation strategies—such as rezoning neighborhoods and increasing growing seasons—to curve the impacts of climate change.

SIGN UP TO HOST A COMMUNITY SCREENING

Thank you for your interest in hosting a community screening of NOVA's *Decoding the Weather Machine*. Please go to **www.pbs.org/weathermachinescreening** to complete the form so that your request can be processed. You will receive an email from WGBH with instructions for your screening.

Questions? Contact NOVA Education at NOVAEducation@wgbh.org

BACKGROUND SCIENCE: WHY CLIMATE CHANGE?

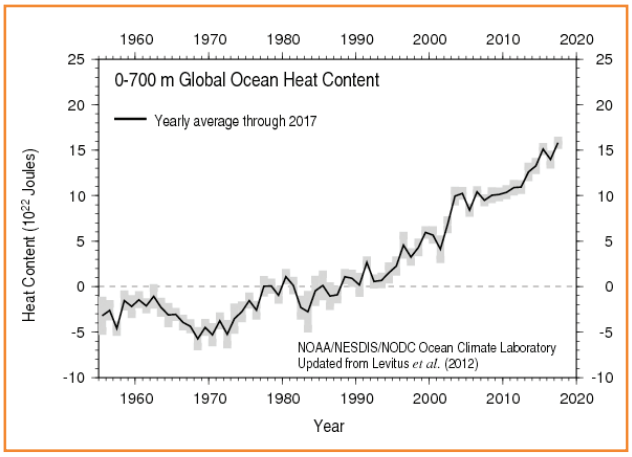
From Puerto Rico to South Africa to Virginia, communities around the world are already starting to feel the impacts of climate change. Whether it happens in two months or two decades, Earth's changing climate will impact everyone on our planet. But how do scientists know this is a question of "when," and not "if"?

Like all science, climate science relies on empirical evidence—evidence that is collected by careful observation of the world around us. Climate scientists can observe some aspects of the climate directly by taking measurements of temperature, rainfall, and ice volume. They can also make observations indirectly by analyzing plant structures in the fossil record or the content of ancient gas bubbles trapped in ice. There is an absolutely stunning amount of data available to researchers, spanning millions of years and coming from dozens of independent sources, and it all points to the same conclusions. More than 97 percent of climate scientists agree that human-caused climate change is occurring; however, only about two thirds of Americans accept the scientific consensus about climate change.

So how do we talk to the public about climate change? We start by explaining where our data comes from. NOAA (National Oceanographic and Atmospheric Administration) has categorized evidence of climate change into 10 indicators:

- **Land surface temperature:** This is the same measurement you rely on daily to decide whether to take a jacket when you go outside. It's simply the temperature at Earth's surface as measured by thermometers at weather stations around the world.
- **Sea surface temperature:** This is the measurement you'd use to decide whether to take a jacket when you went outside... if you were living on a boat in the middle of the ocean. The data are recorded by thermometers on ocean buoys and ships.
- **Air temperatures over land:** These data are taken by satellites continually scanning Earth's lower atmosphere from about 10 kilometers above its surface. The satellites use microwaves to measure the radiation emitted by oxygen molecules in the atmosphere.

- **Air temperature over oceans:** This temperature is collected by the same satellites as above. Temperatures above land and ocean are considered two different lines of evidence because of how differently land and ocean react to increased temperatures.
- **Ocean heat content:** Water can store a tremendous amount of heat without making much of a difference in its overall temperature. So, to monitor how much heat the oceans are absorbing is not as simple as taking its temperature. Instead, scientists constantly compare data from satellites and probes and calculate an estimate for global average ocean heat content every three months.



Yearly average global ocean heat content (0–700 meters deep) from 1955–present.

- **Sea level:** Climate scientists monitor sea levels in two ways. Satellites send laser pulses to the ocean's surface and record how long it takes for the pulse to be reflected back to the satellite (the faster the return signal, the higher the sea's surface). In addition, instruments attached to buoys around the world precisely measure high and low tides.
- **Specific humidity:** Weather stations around the world, over land and oceans, record how much moisture is in the air. This is the same measurement that indicates how sticky and "thick" the air feels in summer, or how dry and "thin" it feels in winter. Generally, warm air holds more moisture than cool air.
- **Glaciers:** To monitor the overall mass of glaciers, researchers measure their overall area and thickness at different points of the year in addition to making other observations such as whether and how often cracks form or pieces break off.
- **Northern hemisphere snow cover:** Satellites monitor when the first snow comes, how much of the northern hemisphere is snow covered during the winter months, and when the last snow melts in spring.
- **Arctic sea ice:** Satellites can monitor the extent of sea ice in the Arctic each year. Sea ice forms over the open ocean—unlike glaciers and most of the ice in the Antarctic, which form over land.

Scientists collect data to test hypotheses. "Global temperatures are increasing" is a hypothesis. For each set of data laid out above, you can make a prediction along these lines: If global temperatures were increasing, then...

Land surface temperatures would be ***increasing***.

Sea surface temperatures would be ***increasing***.

Air temperatures over land would be ***increasing***.

Air temperatures over the ocean would be ***increasing***.

Ocean heat content would be ***increasing***.

Sea levels would be ***rising***.

Specific humidity would be ***increasing***.

Glacial mass would be ***decreasing***.

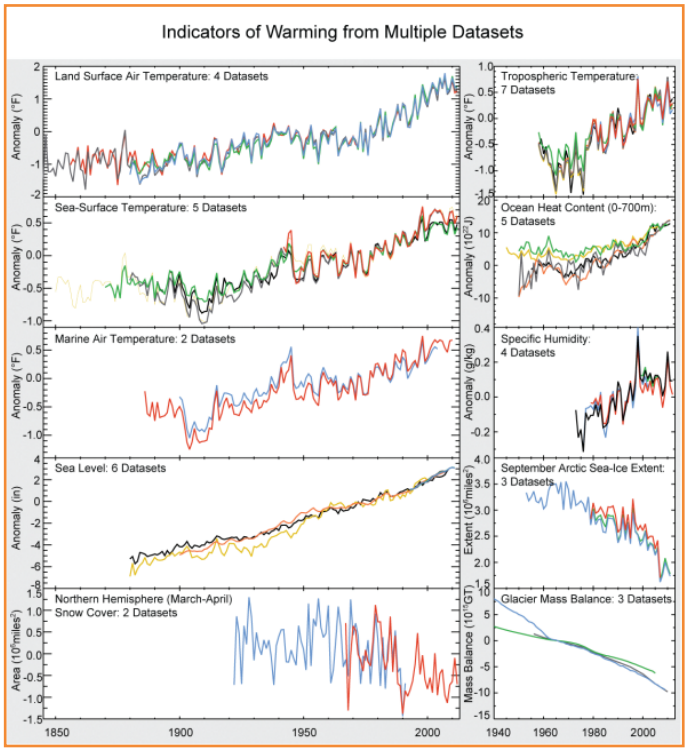
Northern hemisphere snow cover would be ***decreasing***.

Arctic sea ice would be ***decreasing***.

All of those predictions are supported by the data. And there isn't just one set of data for each of these indicators; there are many. There are six independent groups monitoring sea level, for example, and they all show the same trends. Our Earth is clearly getting warmer.

But how do we know it's getting warmer because of us? We know from fossil and geological evidence and ice cores that the climate has warmed before. Couldn't this be natural? The answer is, sadly, no. Yes, Earth has gone through extreme warming periods before, long before humans evolved; however, our current period of warming is a human-caused phenomenon. Every global warming event is tied to greenhouse gases, primarily carbon dioxide. There are natural sources of carbon dioxide, such as volcanic activity, but these natural sources don't come close to accounting for the 30 billion tons of carbon dioxide poured into the atmosphere every year by human activity. Globally, oxygen levels are actually decreasing, just as you'd predict if it were being consumed in combustion reactions that form carbon dioxide. The carbon atoms in the carbon dioxide molecules in our atmosphere and in the calcium carbonate of corals in our oceans have the chemical signatures of having come from fossil fuels. In other words: it's not the volcanoes, it's our cars and factories.

So, what do you say the next time someone asks you how we know that climate is changing and that our activities are the cause? Reflect the question back: If climate were changing, what would you expect? Have you noticed any changes in when flowers first bloom, or how often the snow melts during the middle of winter, or how many "one-in-a-thousand-years" floods are occurring? So have scientists. That'll open the door to a conversation. All of the data are available in a variety of formats to the public. You can access the raw data and process it yourself or obtain processed data sets with accompanying activities. Engaging with the evidence is a powerful experience—much more so than just being told the facts. No matter who you are, don't squander the opportunity of being asked these questions. Our planet's future depends on what we do next, and we need to do all we can to increase climate literacy. Start a dialogue. Listen, ask questions, and be respectful. The data is incontrovertible, but it's useless unless we can get people to trust it and to understand what it's telling us.



Observed changes, as analyzed by many independent groups in different ways, of a range of climate indicators. All of these are changing as expected in a warming world. (Figure source: updated from Kennedy et al. 2010)

EVENT FORMATS

There are a variety of ways in which you can format your event. Here are a few suggestions:

- **Film Screening:** Invite community members to watch the full two-hour documentary with you. Offer popcorn, candy, and soft drinks to give a real movie theater experience! Encourage attendees to discuss themes informally (without a formal speaking portion).
- **Film Screening with Expert Panel:** Choose 30 to 40 minutes of the film that you find the most interesting. After screening the excerpts, moderate a panel discussion among local scientists, policymakers, and activists to discuss climate change and its implications for your community. Questions such as "Is your community feeling the effects of climate change now, or will you not be impacted for another 20 years?," "What initiatives are currently being taken to combat climate change?," and "How can community members get involved?" are a great place to start. Additional question ideas are provided on page 8; frequently asked questions and their answers are on page 9.
- **Film Screening with Community Discussion:** Choose 30 to 40 minutes of the film that you find the most interesting and prepare three to five discussion topics or questions based on the selected film segments. Invite attendees to form small groups; provide each group with one question. After giving the groups 10 to 15 minutes to discuss the question, invite each group to share their answers with the full audience to start a larger dialogue. Additional question ideas are provided on page 8; frequently asked questions and their answers are on page 9.
- **Film Screening with Community Activity:** Pair the screening with a fun outdoor activity. Invite community members to join you for a hike, trash pick-up, or gardening session and watch 30 to 45 minutes of the film that you find most interesting. Feel free to watch the film before your activity to get your group excited about being outdoors and making a difference!

We want to hear about your event! After the screening, please ask attendees to fill out the paper or online survey below:

- The printable NOVA screening viewer survey can be downloaded at: **bit.ly/weathermachineaudiencesurveyprint**. Please send completed surveys to:
  WGBH
  c/o NOVA Education
  1 Guest Street
  Boston, MA 02135
- Attendees can also complete viewer surveys online at this link: **bit.ly/weathermachineaudiencesurvey**.
- We're also interested in hearing from those who host screenings. Please complete NOVA's online survey for screening hosts at: **bit.ly/weathermachinehostsurvey**.

EVENT TIMELINE & TO-DO LIST

Planning a community event can be overwhelming. Below we have a checklist to ensure you have all bases covered before and after your event. Not all of these steps will be applicable for each event; pick and choose which are right for your event objectives.

SIX WEEKS BEFORE...

- ◯ Identify your audience and goals.
- ◯ Reach out to possible partners.
- ◯ Reserve the venue and set the date and time.
  - — Make sure the audiovisual equipment is adequate and available.
  - — Calculate any costs (utilities, custodial, etc.)
- ◯ Contact and confirm possible post-screening activities.

FOUR WEEKS BEFORE...

- ◯ Create a Facebook or Eventbrite page to publicize the screening.
  - — Ask other organizations to join and invite their members.
  - — Link to the NOVA site.
- ◯ Promote the event.
  - — Connect with social media influencers and bloggers.
  - — Contact community calendars and media with the event listing.

TWO WEEKS BEFORE...

- ◯ Post flyers in the community (local businesses, libraries, etc.) and hand them out at related events.
- ◯ E-mail news organizations, government officials, and community organizers.
  - — Explain details and goals of the event.
  - — Include contact information.

THREE TO SEVEN DAYS BEFORE...

- ◯ Send out final reminders via e-mail and social media.
- ◯ Print out event materials.
- ◯ Finalize the program schedule.
- ◯ Confirm plans for post-screening event.

DAY OF THE EVENT...

- ◯ Go to the venue early to set up seating, refreshments, materials, microphones, etc.
- ◯ Make nametags for organizers, volunteers, panelists, and the facilitator.
- ◯ Assign a photographer/videographer to capture the event for social media and websites.
- ◯ Create a sign-up sheet to collect names and contact information for future events.

AFTER THE SCREENING...

- ◯ Encourage attendees to connect with NOVA on Facebook, Twitter, and Instagram **@NOVAEducation**.
- ◯ Complete the post-event screener survey and ask attendees to fill out the attendee survey; mail all back to WGBH.
- ◯ Follow up on ideas expressed in your discussion.

FILM CHAPTER SUMMARIES

CHAPTER 1: THE CASE FOR CLIMATE CHANGE

- Discovery of greenhouse gases and the greenhouse effect
- The Keeling Curve: measuring carbon dioxide in our atmosphere
- Increased levels of carbon dioxide in the atmosphere from fossil fuels

CHAPTER 2: THE CLIMATE MACHINE

- Land's role in absorbing carbon
- Ocean's role in absorbing heat
- Melting ice at the poles
- Sea level rise
- Climate refugees and impacts of climate change

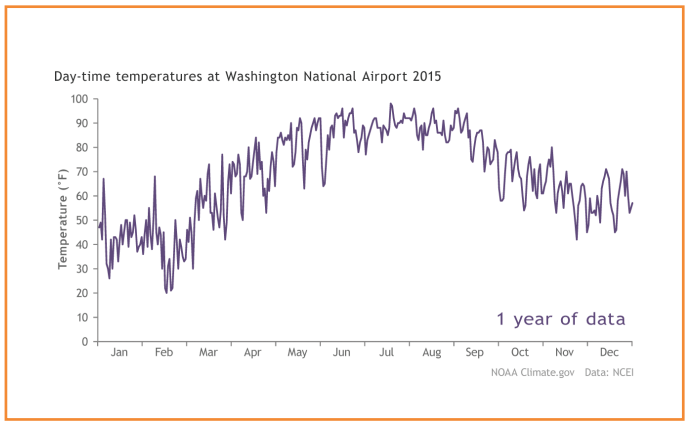
CHAPTER 3: CLIMATE CHANGE SOLUTIONS

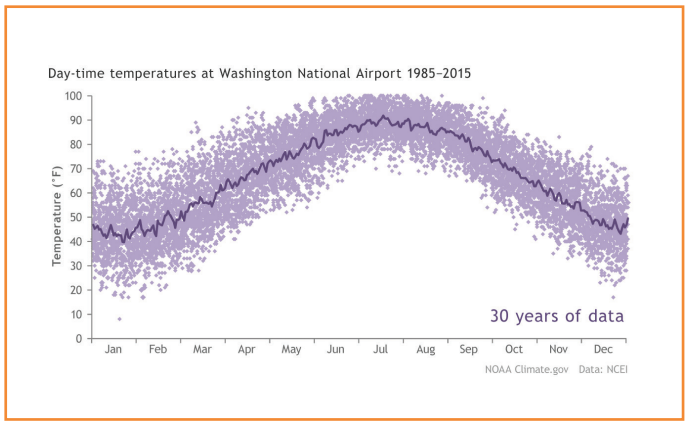
- Creating climate models
- Adapting to climate change effects
- Mitigating climate change effects

SCREENING DISCUSSION QUESTIONS

- How can one person's actions make a difference in something as large as global climate change? What can I do to help?
- How will climate change impact the economy? Will food, energy, water, etc., be more or less expensive as the climate changes?
- What are the big questions about climate change that are still unanswered?
- What are some of the biggest challenges that humans will face because of climate change?
- What is our community doing to combat climate change? What role can businesses and governments play in mitigating the impact of climate change?
- How will climate change impact my daily life? Will I see the impacts in weeks, months, or years?
- Is it too late to prevent climate change? Can we reverse the changes that are occurring right now?
- How can we adapt to weather and landscapes that are changing because of climate change?
- Is there any scientific research or new technology that we should prioritize in the next 5, 10, or 15 years in order to mitigate the effects of climate change?
- What are the challenges and benefits of adding more renewable energy resources into the power grid? Can we realistically make the switch to 100 percent renewable energy?
- How did we get to this point? Why was nothing done sooner if we knew the temperature was rising?
- There's a lot of misinformation about climate change. Where can I find up-to-date, reliable news about climate change?

CLIMATE CHANGE FAQS





Graphs showing maximum daily temperature ("daytime high") at Washington National Airport for 1 year and 30 years. By the time 30 years of observations have been collected, the scattering of individual dots (weather) becomes a broad swath that marks our range of normal daytime high temperatures (climate).

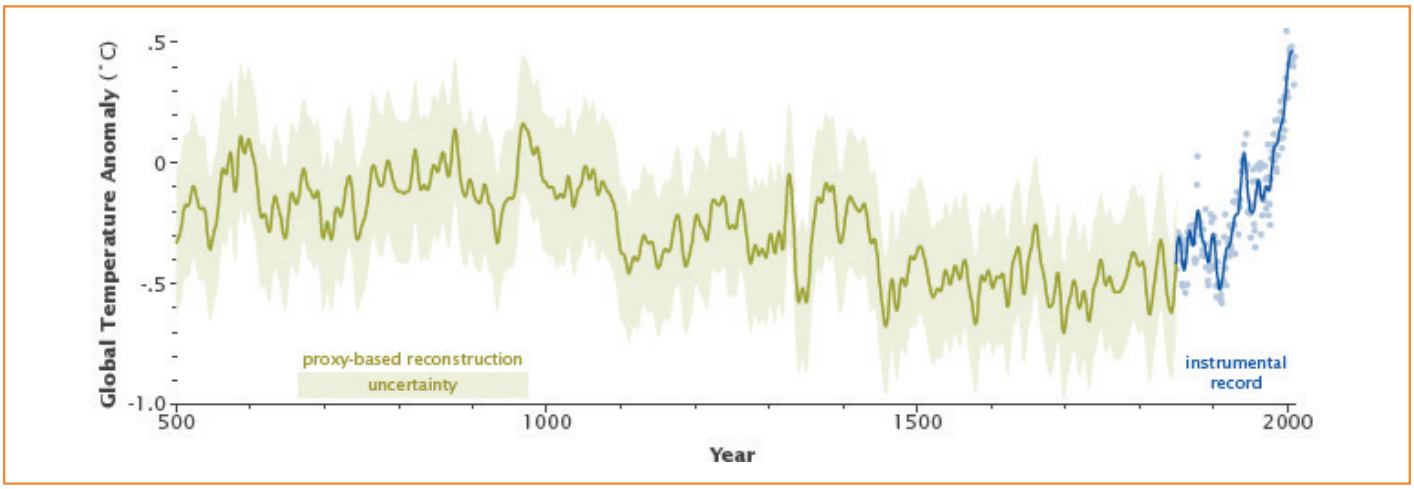
1. What's the difference between weather and climate? What's the difference between climate change and global warming?

The difference between weather and climate is a matter of timescale. *Weather* refers to the conditions we experience daily. "It's warm and humid in Houston today," and "There was a nor'easter in New England over the weekend," are statements about the weather. *Climate* encompasses the average weather conditions in an area over a long period of time, usually at least a few decades. "The American Southwest is hot and dry," and "Boston gets about 11 inches of snow in February every year," are statements about climate. In other words, climate tells us what weather we can expect, and weather tells us what is actually happening.

Similar to weather and climate, climate change and global warming are different, but related. *Global warming* refers to the documented increase in global average temperature that has been occurring over the last 100+ years. The primary cause of global warming is increased greenhouse gases in the atmosphere. *Climate change* encompasses all of the changes that have resulted from global warming, including such things as the increased frequency of floods, droughts, and strong storms.

2. Isn't this natural, normal climate fluctuation we've seen throughout history?

It's true that there have been many periods of global warming in Earth's past, and these periods of warming have caused global climate changes. It's also true that these past periods of warming were caused by an increase in greenhouse gas concentration in our atmosphere, and that sometimes the increase occurred at a rate just as rapid as what is happening today. But there is a key difference between all of these past periods of warming and change and the one we are experiencing at present: the source of the greenhouse gases. Past periods of global warming were brought on by an increased production of natural sources of greenhouse gases, such as volcanoes. Our current period of global warming is fueled by human activities, such as fossil fuel use and the widespread burning of forests. And an important warning is worth mentioning: the fossil and geologic records show us that past times of rapid climate change were accompanied by widespread mass extinctions.



Temperature histories from paleoclimate data (green line) compared to the history based on modern instruments (blue line) suggest that global temperature is warmer now than it has been during the past 1000 years, and possibly longer. (Graph adapted from Mann et al., 2008).

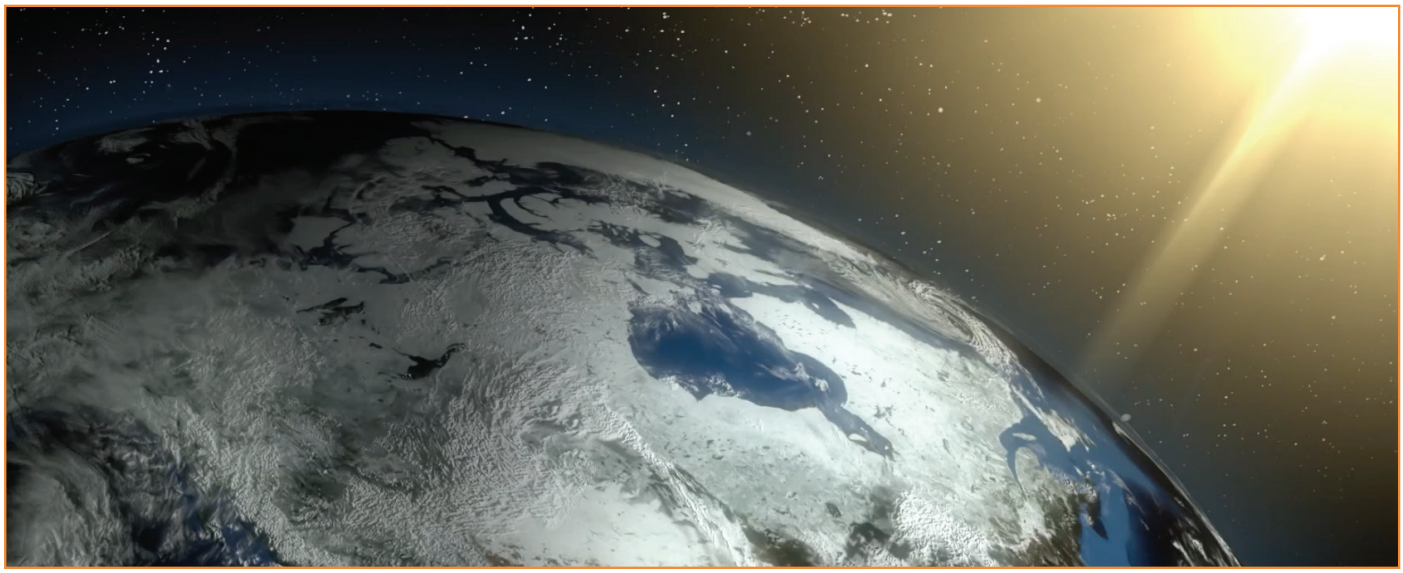
3. If the globe is warming, why was it so snowy and cold this winter?

"It was snowy and cold this winter" is a statement about weather, and "the globe is warming" is a statement about climate. While weather and climate are absolutely related, they are not the same thing. The weather in a particular place has little to nothing to do with the long-term trends of global climate. One, or even several, cold winters in one location does not disprove global warming; in fact, one of the consequences of increasing global temperatures is more extreme weather, including colder and, yes, snowier winters in the northern hemisphere. Global climate models do not predict that every season in all locations will be warmer each year. What it does predict is that when averaged out across all locations and looked at across decades, temperatures will continue to climb unless we do something to curb greenhouse gas emissions.

4. How can we predict climate change if we can't correctly predict the weather for tomorrow?

Modeling Earth's climate is not easy. The climate machine is incredibly complicated, with numerous inputs, outputs, and feedback interactions. But climate models do *not* predict weather, they predict climate. Said differently, climate models focus on trends by looking at weather conditions over decades. In this way, climate models eliminate some of the "noise" caused by daily weather fluctuations to more accurately describe how things have changed over decades and to make predictions about how things are likely to be, in general, in the future.

A climate model will predict that summer will be warmer than average; however, it will not predict what the temperature on any given day will be—that's the kind of thing that weather forecasting models predict. And while meteorologists (the scientists who study and predict weather) sometimes get things wrong, they are right far more often. In fact, the increased precision and accuracy of weather prediction has perhaps ironically made it seem like their data are unreliable. It's relatively easy to be "wrong" when you make predictions down to the minute, city block, and tenth of a degree.



ADDITIONAL RESOURCES

NASA:
Climate Change & Global Warming
www.climate.nasa.gov

NOAA:
Climate
www.noaa.gov/climate

The Intergovernmental Panel on Climate Change
www.ipcc.ch

Climate Central
www.climatecentral.org

World Health Organization: Climate and Health
www.who.int/globalchange/en

Grist
www.grist.org

US Global Change Research Program
www.GlobalChange.gov

NOAA Climate.gov
www.climate.gov

Climate Literacy and Energy Awareness Network
www.cleanet.org

Yale Program on Climate Change Communication
www.climatecommunication.yale.edu

Climate Data Online: National Centers for Environmental Information
www.ncdc.noaa.gov

NOVA Earth Systems Collection
www.pbslearningmedia.org/collection/earth-system-science/

NOVA Energy Lab
www.pbs.org/wgbh/nova/labs/lab/energy/

NOVA Cloud Lab
www.pbs.org/wgbh/nova/labs/lab/cloud/

GLOSSARY OF TERMS

ATMOSPHERE
the envelope of gases surrounding Earth

CARBON CAPTURE
a technology that captures carbon dioxide emissions to prevent them from entering the atmosphere when burning fossil fuels

CARBON FOOTPRINT
the amount of greenhouse gases emitted by someone or something during a certain amount of time

CLIMATE
the average course or condition of weather at a specific location over a long period of time

CLIMATE CHANGE
the change of Earth's global and regional climate patterns

EMISSION
a substance discharged into the air

FOSSIL FUELS
natural gas, coal and oil; fuel sources that were created from ancient plant and animal remains

GLACIER
a mass of ice formed by mass accumulation of snow that moves slowly down a slope or valley

GLACIER RETREAT
when the end of a glacier does not extend as far down the slope/valley as it once did

GLOBAL WARMING
a gradual increase in the average atmospheric and oceanic temperatures on Earth

GREENHOUSE EFFECT
the process by which the Earth's atmosphere traps the sun's radiation that in turn warms the surface and lower atmosphere of Earth

GREENHOUSE GASES
a gas that contributes to the greenhouse effect by trapping radiation from the sun; examples include water vapor, carbon dioxide, and methane

ICE SHEET
a permanent layer of ice covering a large amount of land, particularly in the poles

KEELING CURVE
a graph created by Charles David Keeling that maps the change of carbon dioxide concentrations in Earth's atmosphere since the 1950s

NEGATIVE EMISSIONS
removing existing carbon dioxide from the atmosphere while simultaneously not creating new carbon dioxide emissions to create a deficit

RENEWABLE ENERGY
a source of energy that can be replenished on a human timescale, such as wind, solar, geothermal, and tidal

WEATHER
The current state of the atmosphere in respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness

NOTES

CREDITS

Writers: Stephanie Keep, Gina Varamo **Copy Editor:** Cindy Bond **Designer:** Anna-Rose Schenerman

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Written, produced, and directed by DOUG HAMILTON. Co-produced by CAITLIN SAKS. Deputy Executive Director is JULIA CORT. Senior Executive Producer for NOVA is PAULA S. APSELL.

About NOVA
Now in its 45th season, NOVA is the most-watched prime time science series on American television, reaching an average of four million viewers weekly. The series remains committed to producing in-depth science programming in the form of hour-long (and occasionally longer) documentaries, from the latest breakthroughs in technology to the deepest mysteries of the natural world. NOVA is a production of WGBH Boston. NOVA airs Wednesdays at 9pm ET/PT on WGBH Boston and most PBS stations. The director of the WGBH Science Unit and Senior Executive Producer of NOVA is PAULA S. APSELL.

About PBS
PBS, with 350 member stations, offers all Americans the opportunity to explore new ideas and new worlds through television and online content. Each month, PBS reaches nearly 100 million people through television and nearly 33 million people online, inviting them to experience the worlds of science, history, nature and public affairs; to hear diverse viewpoints; and to take front row seats to world-class drama and performances. PBS' broad array of programs has been consistently honored by the industry's most coveted award competitions. Teachers of children from pre-K through 12th grade turn to PBS for digital content and services that help bring classroom lessons to life. PBS' premier children's TV programming and its website, pbskids.org, are parents' and teachers' most trusted partners in inspiring and nurturing curiosity and love of learning in children. More information about PBS is available at www.pbs.org, one of the leading dot-org websites on the Internet, or by following PBS on Twitter, Facebook or through our apps for mobile devices.

THE IVES FAMILY FUND

THE KENDEDA FUND

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DRAPER

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