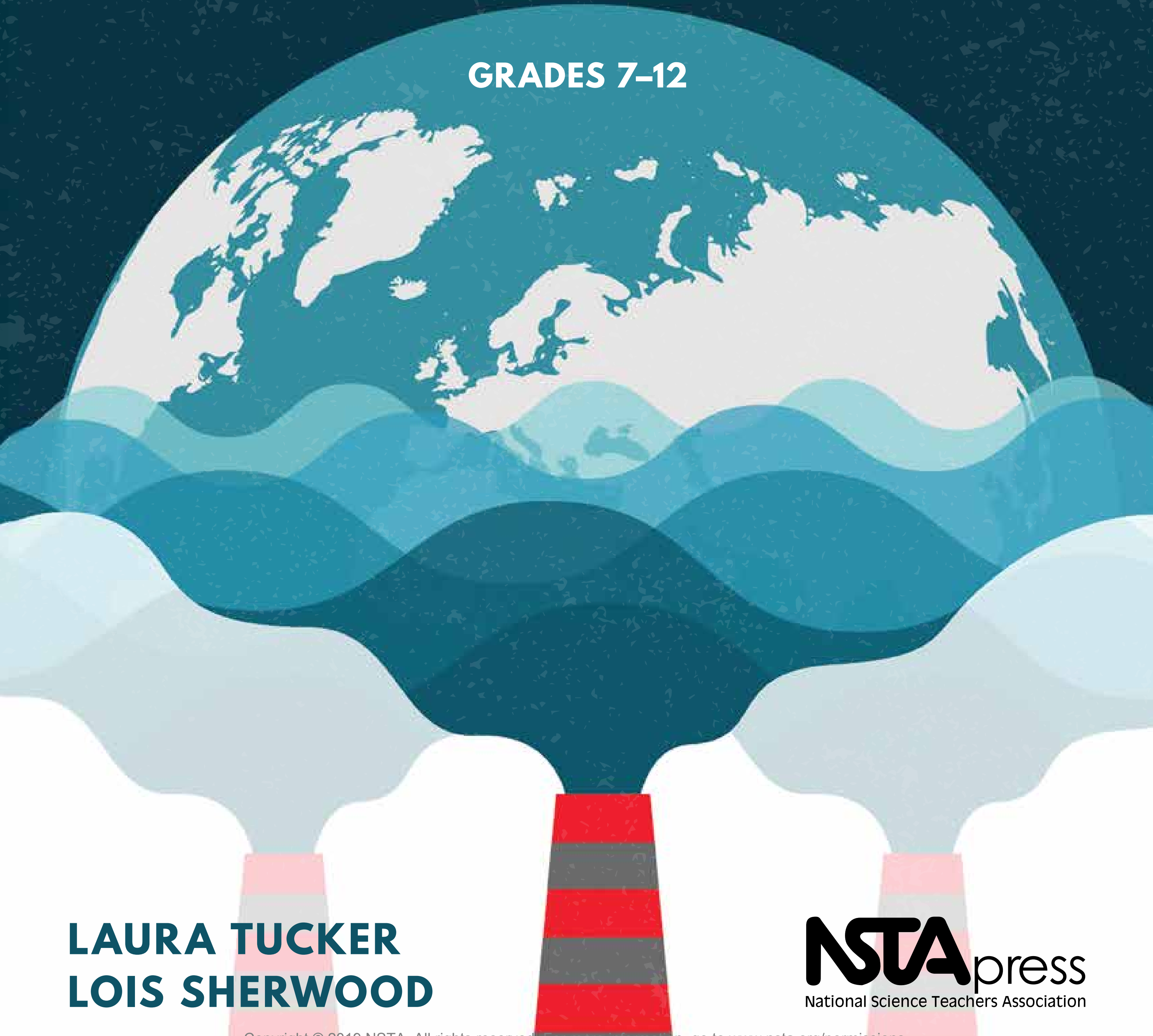
UNDERSTANDING CLIMATE CHANGE

GRADES 7–12



LAURA TUCKER
LOIS SHERWOOD

NSTA press
National Science Teachers Association

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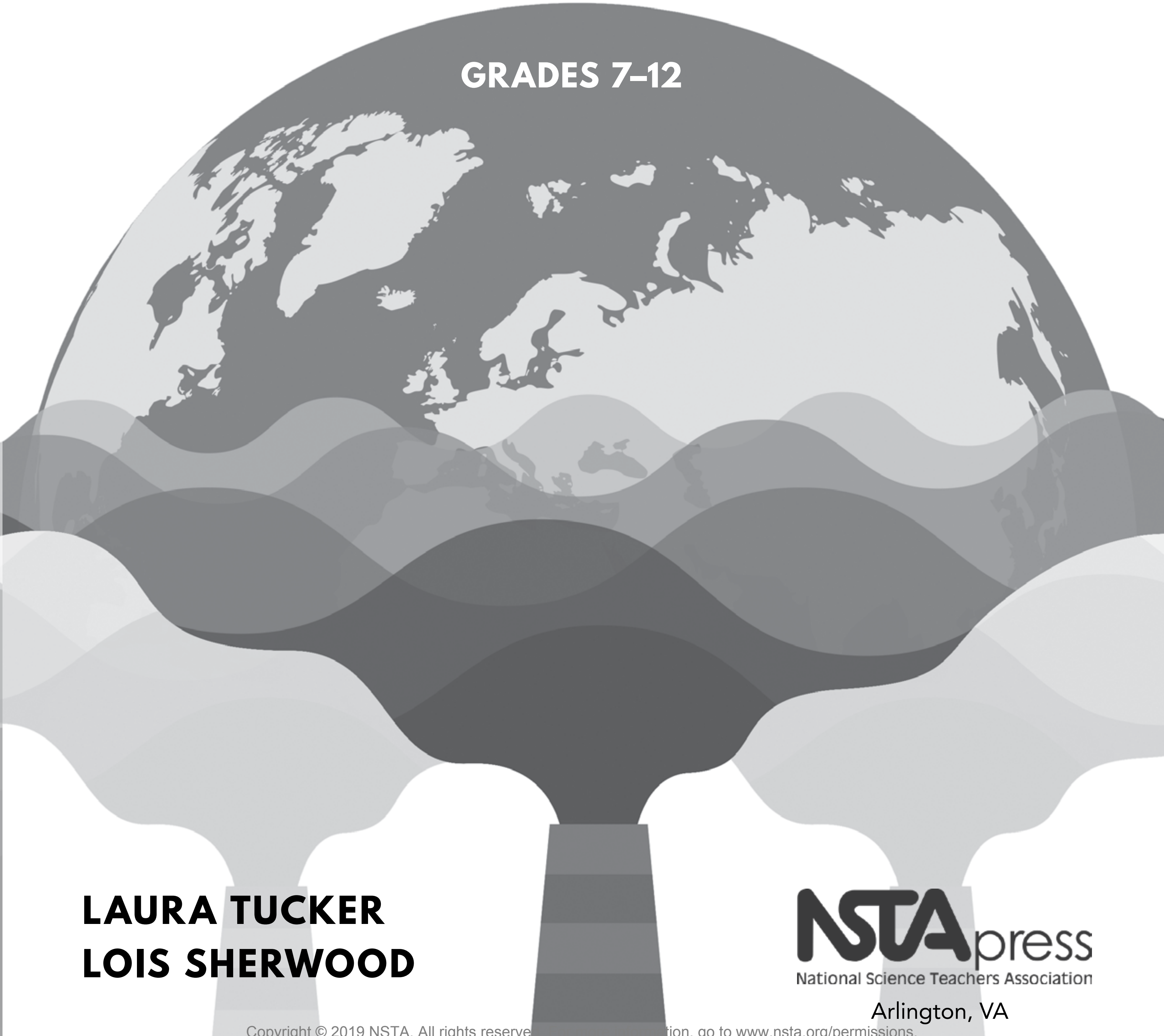

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About the Authors

Laura Tucker has been a science educator for more than 40 years. Initially educated as a wildlife biologist, she found her passion teaching students in the outdoors. In 1979, she founded a nonprofit educational organization called Exploring New Horizons. It was designed to provide a comprehensive outdoor environmental science program for K–8 grade students and a summer camp program for children ranging from age 9 to 18. During her tenure at the organization, she helped develop a variety of programs that combined environmental science curricula (redwood, coastal, and Sierra Nevada natural history and ecology, marine biology, botany, zoology, geology, and astronomy) with music, dance, drama, art, and team building. The programs blended the teaching skills and talents of staff naturalists with those of classroom teachers to facilitate the incorporation of the outdoor school experience into the classroom. Approximately 60,000 students attended the programs while Laura was the executive director. Exploring New Horizons continues to this day, serving about 6,000 students per year on three campuses in California's Santa Cruz Mountains.

In 1992, Laura became the professional development coordinator for Great Explorations in Math and Science (GEMS), a nationally acclaimed resource for activity-based science and mathematics at the Lawrence Hall of Science at the University of California, Berkeley. While at GEMS, she worked with a variety of educators, including preservice teachers; classroom teachers; district, regional, and state curriculum coordinators; university faculty; and nonformal educators from museums, zoos, and nature centers. She was a leader in establishing the GEMS Network, which included approximately 72 sites and centers around the United States and 11 international locations. Laura served as a curriculum developer and reviewer for many GEMS publications, including *Aquatic Habitats* (Barrett and Willard 1998), *Dry Ice Investigations* (Barber, Beals, and Bergman 1999), *River Cutters* (Sneider and Barrett 1999), and *Schoolyard Ecology* (Barrett and Willard 2001) teacher guides. She also worked on handbooks that support the implementation of GEMS units and other programs.

Laura has focused a great deal of her energy on climate education. In 2012, she was selected as a Climate Reality Project presenter and joined former vice president Al Gore and 1,000 other educators from 59 countries for three days of intensive training. She is an NOAA Climate Steward as well as a team member of the Climate Change Environmental Education Project-Based Online Learning Community Alliance in partnership with Cornell University, the North American Alliance for Environmental Education, and the EECapacity Project. She serves as a mentor with Students for Sustainability, a group from Port Townsend High School in Port Townsend, Washington, that is taking action to mitigate climate change at their school, in their community, in their state, and at the national level. Laura also serves on the Jefferson County/City of Port Townsend Climate Action Committee and chairs the L2020 Climate Action Outreach Group. In December 2015, she attended the 21st Conference of the Parties in Paris where she conducted live interviews between young climate scientists and activists and students in her community.

Currently, Laura wears two hats. She is the waste reduction education coordinator for Jefferson County, Washington, teaching the community to reduce, reuse, and recycle. She is also a consultant, providing custom professional development for formal and informal educational programs in standards-based environmental and STEM (science, technology, engineering, and mathematics) education.

When Laura is not working to address the climate crisis, she is recharging her batteries by hiking, swimming, sea kayaking, soaking in hot springs, and enjoying the beauty of our natural world with her husband and their English bulldog, Yogi.

Lois Sherwood originally trained in zoology at Washington State University and worked in the medical profession after graduating. But after a chance visit to a high school classroom, she realized that teaching was her calling.

Lois began her teaching career at the SEA Discovery Center (formerly the Poulsbo Marine Science Center) and then moved to Port Townsend High School. During her career, she has taught health, marine biology, oceanography, physical science, math, biology, and integrated science.

While teaching, she earned a master's degree in science, also through Washington State University. As she deepened her understanding of science, she became interested in constructivist teaching and allowing students to learn through engaging in science practices. She refined this skill through inquiry training with the Exploratorium museum in San Francisco, California. Her training later led to codeveloping inquiry workshops, which she taught for several summers through the Port Townsend Marine Science Center.

Lois also served as a district teacher leader and as a Teacher on Special Assignment (TOSA) with the North Cascade and Olympic Science Partnership, which was a five-year science leadership project sponsored by Western Washington University and funded by a National Science Foundation grant. Along with a cohort of five other TOSAs, she promoted teacher leadership and best teaching practices in a five-county region of northwestern Washington.

With the cohort of TOSAs, she designed and led monthly regional workshops in addition to working with partner teachers in their classrooms.

Lois received National Board Certification in Teaching in 2007 and was recertified in 2017. For her work in the classroom, she received the Amgen Excellence in Science Teaching award in 2011 and was a finalist for the Presidential Award for Excellence in Mathematics and Science Teaching in both 2013 and 2015.

Beyond the classroom, Lois served as a regional representative with the Washington Science Teachers Association (WSTA) from 2007 to 2016. In 2011, she cochaired a joint statewide teachers conference with WSTA and the Environmental Education Association of Washington. In 2016, she was appointed as professional development coordinator for WSTA. In this role, she has facilitated the design and presentation of professional development offerings for the organization.

Connecting science to student involvement motivated Lois to facilitate a variety of student-led environmental clubs over the course of her career. Although the focus of the clubs has evolved based on student interest, the goal has always been to promote environmental and social justice locally, regionally, and nationally.

Lois's passion for science education is driven by a personal passion to understand and experience the natural world. This also fuels her hobbies, which include bird watching, beach exploration, kayaking, hiking, biking, and running.

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My endless appreciation goes out to Lois Sherwood, my exceptional coauthor, who brings her years of high school classroom experience and extensive knowledge of the *Next Generation Science Standards* (*NGSS*) to take this revised edition to a new level of excellence and effectiveness.

I am also grateful to Lois for allowing me to use her four 10th-grade classes to field-test the first edition of this book in 2011. After completing this unit, a number of students formed their own group—Students for Sustainability—and went on to make huge changes in their school and in their community. They even took *public transportation* from Washington state to Washington, D.C., to lobby for climate action—6,000 miles round-trip. They are featured as Climate Change Agents in Session 8.

This book would not have been possible without spending 20 years working with the brilliant and talented curriculum developers and staff of GEMS (Great Explorations in Math and Science) at the University of California, Berkeley's Lawrence Hall of Science. Their years of experience and keen insight into creating effective, teacher-friendly curricula have taught me well. They were on the cutting edge of climate change curricula with the book *Global Warming and the Greenhouse Effect*, written in 1990.

GEMS was the inspiration for *Understanding Climate Change*. Sessions 2 and 3 are adapted and modified from *Global Warming and the Greenhouse Effect*, copyrighted by The Regents of the University of California and used here with permission. Other sessions are partly inspired by the activities in the GEMS guide but are substantially revised, rewritten, and updated by the authors.

The scientific discourse circle in Session 4 is inspired by similar student-group activities in the *Seeds of Science/Roots of Reading* curriculum by GEMS, copyrighted by The Regents of the University of California and used here with permission.

Special thanks to the Climate Reality Project. Their extraordinarily talented staff conducts trainings around the globe and provides support for more than 15,000 Climate Reality Leaders, ranging from 12 to 86 years in age. I was honored to be included in their 2012 training in San Francisco that brought more than 1,000 leaders from 59 countries together for three days of information, empowerment, and hope. We went out into our corners of the world to share the science of the climate crisis and provide a vision for how we can solve it.

I particularly want to thank all of the wonderful Climate Change Agents who so kindly agreed to be interviewed for this book and give a face to those working on the front lines for climate change solutions:

- James Balog
- Dr. Robert Bindschadler
- Dr. Shallin Busch
- Kate Chadwick
- Eliza Dawson
- Dr. Ziv Hameiri
- Dahr Jamail
- Rayan Krishnan
- Dr. Heidi Roop
- Ewan Shortess

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—Laura Tucker

SESSION 4

Fact or Phony? Scientifically Evaluating Data

Introduction

In a world where fictional information is often promoted as fact and cherry-picked data are offered as evidence, it can be very difficult for students to understand how to decide if information is accurate, verifiable, from a reputable source, and complete.

This session begins by looking at a purely fictional web page cleverly disguised as factual. Students are challenged to learn important information from this web page to help them decide if the Pacific Northwest tree octopus is, in fact, in danger of extinction due to the effects of climate change. In reality, this species doesn't exist. It was invented as an internet hoax in the late 1990s. After a bit of time exploring the web page, the teacher reveals that both the species and its plight are fictional and asks for student responses when they find they have been fooled.

Students are then asked to review two sets of data and evaluate their validity as well as interpret the information they are trying to convey. Through small-group discussions, students share their perceptions of the data sets and what they mean. They are challenged to decide if this information is valid and helpful in building an understanding of global warming and climate change.

The next step is for students to be given a series of common misconceptions about climate change and global warming. Using reputable sources of data, they dispel the misconceptions with accurate information and decide how people could be swayed into believing the misconception.

Objectives

1. To encourage students to think critically about data and carefully evaluate its relevance
2. To compare multiple sources of data, looking for concepts supported by verifiable evidence
3. To teach students how to participate in thoughtful, scientific discourse, backing up their statements with evidence that can be verified

What You Need

Gather the following materials.

For the class:

- ❑ Technology to project a web page for the class to view
- ❑ The current list of questions and statements on the wall OR access to the electronic documents with questions and statements
- ❑ Sentence strips for additional statements (if you're using the wall columns)
- ❑ Marking pens (if you're using the wall columns)

For each group of students:

- ❑ Laptop or electronic device with internet access

For each student:

- ❑ Science notebook
- ❑ Copy of Handout 4.1: How to Determine if Information Is Accurate
- ❑ Copy of Handout 4.2: Atmospheric CO_2 Levels in the Recent and Distant Past
- ❑ Copy of Handout 4.3: Looking Critically at Data

  Note: *Handouts 4.2 and 4.3 can be copied back-to-back.*
- ❑ Copy of Handout 4.4: Scientific Discourse Circle—Is Climate Change Caused by Human Activity?
- ❑ Copy of Handout 4.5: Lines of Evidence (3 pages)

- ❑ Copy of Handout 4.6: Explanations for Commonly Held Misconceptions About Climate Change and Global Warming
- ❑ Copy of Handout 4.7: Climate Change Agent Interview

Note: *All handouts are found on the Extras page: www.nsta.org/climatechange.*

Preparation

Before the Class

1. Make copies of the handouts, one for each student.
2. Preview the web page on the Pacific Northwest tree octopus (*https://zapatopi.net/treeoctopus*) as an example of a completely fictional web page designed to look factual. Decide how you will project the web page for students to view.
3. Set up a way to project or post these six commonly held misconceptions used in the Explaining Misconceptions About Climate Change section (pp. 72–73), so the whole class can see them:
   - It's been warmer before.
   - Increases in solar activity are causing the Earth to warm.
   - The Arctic is gaining ice.
   - It hasn't warmed since 1998.
   - Increasing CO_2 has little or no effect.
   - Scientists don't agree that humans are causing the Earth to get warmer.

Begin!

Can We Trust What We Read on the Internet?

1. Tell students that you want to show them an example of an animal that may be significantly affected by climate change. Direct their attention to the web page you have projected on the screen in front of the classroom, or have them look up the web page on their laptops or electronic devices.
2. Give students a few minutes to explore the web page. Ask students to find evidence that the tree octopus could be negatively affected by climate change. Have them explain their reasoning.

Note: *In 2006, the University of Connecticut Neag School of Education asked 25 seventh graders from middle schools across the state to review a website devoted to a fictitious endangered species, the Pacific Northwest tree octopus. The results troubled them:*

- *All 25 students fell for the internet hoax.*
- *All but one of the 25 students rated the site as "very credible."*
- *Most struggled when asked to produce proof—or even clues—that the website was false, even after the UConn researchers told them it was.*
- *Some of the students still insisted vehemently that the Pacific Northwest tree octopus really exists.*

The students, identified as their schools' most proficient online readers, were taking part in a federal research project funded by a $1.8 million grant from the U.S. Department of Education. For more information on this study, visit the web page: http://advance.uconn.edu/2006/061113/06111308.htm.

3. Ask students to determine if the web page is from a reputable source and, if so, how they determined its validity. Give them a few minutes to come up with answers. At this point, some students may notice oddities such as Sasquatch being listed as a predator to the tree octopus under the Why It's Endangered section on the About tab. The images and descriptions on the Sightings tab can be quite comical but potentially believable by students. The web page owner claims to be affiliated with the Kelvinic University branch of the Wild Haggis Conservation Society. That may or may not trigger a skeptical response.
4. Reveal to your students that this web page was created to show how easy it is to put completely false information on the internet and make it look believable. If students still maintain that the web page is true (as many of the students in the UConn study did), ask some volunteers to point out information that could be incorrect. Some quick internet searching may be necessary to sort out fact from fiction. You may want to direct students to fact-checking websites. (Snopes.com, for instance, has an interesting analysis of this false web page.)
5. Distribute Handout 4.1: How to Determine if Information Is Accurate, one for each student. Go over each item on the list to clarify its meaning. Then have students revisit the Pacific Northwest tree octopus web page and see how many examples they can find from the checklist. Depending on how many devices you have for students, they can work as individuals, in pairs, or in table groups.
6. After about 10 minutes, reconvene the class and ask students for examples of what they found. After a number of inaccuracies have been revealed, ask students what they have learned about checking for

accurate information on the internet. Tell them they will use this list to evaluate information they research in this unit.

Effective Data Analysis—CO_2 Levels From Our Recent and Distant Past

1. Explain that students will now evaluate two sets of data showing CO_2 measurements taken in two ways. Pass out copies of Handout 4.2: Atmospheric CO_2 Levels in the Recent and Distant Past and Handout 4.3: Looking Critically at Data (one page if copied back-to-back). Give students a few minutes to review the graphs on Handout 4.2. Then ask, "Which graph do you think has a more reliable source? Why?" In Graph 1, data were gathered by direct observation; in Graph 2, data were gathered by "proxy data collection." The direct-observation data was obtained at the Mauna Loa Observatory on the big island of Hawaii with instruments that directly measure the CO_2 content of the atmosphere. Dr. Charles David Keeling began taking observations in 1958, and conditions are monitored to this day. The proxy data was taken from two different ice cores, one in Greenland and one in Antarctica. The data from the oldest records came from a core that was drilled 2,803 meters (6,834 feet) into the Antarctic ice shelf. Bubbles of gas were trapped in the ice, allowing scientists to sample ancient air and determine the amount of CO_2 in the atmosphere over 400,000 years ago! Scientists correlate the CO_2 from ice core samples with other proxy data sources to ensure reliability.
2. Now direct students' attention to Graph 1 and ask a volunteer to identify what the scale on each axis represents. *(Answer: On the horizontal axis, the scale goes from the year 2005 to 2018; on the vertical axis, the scale represents the amount of CO_2 in parts per million.)*
3. Ask students to take a few minutes to look over the Graph 1 data and record their thinking on Handout 4.3: Looking Critically at Data. Students should note what the data tell them, what the data *does not* tell them, and what else they want to know to better understand what the graph reveals.
4. Next, have students look at Graph 2 and explain what the scale on each axis represents. Make sure that students recognize that the scale on the vertical axis of Graph 1 is different from the scale on Graph 2.

   *(Answer: On the horizontal axis, the scale goes from 400,000 years ago to the year 1950, represented by 0. The present [about 70 years after 1950] is represented just on the other side of 0. This is a small amount on a scale of 0 to 400,000. [**Note:** Since this graph goes in reverse of traditional measurements, with 0 being on the far right of the axis rather than at the beginning, make sure students understand this difference.] For the vertical axis, the scale represents the*

amount of CO_2 in parts per million, recorded in December 2017 as 407.62 parts per million, or 0.040762% of our atmosphere.)

5. Ask students to take a few minutes to look over the Graph 2 data and record their thinking in Handout 4.3 about what the data tell them, what the data *do not* tell them, and what else they want to know to better understand what the graph reveals.
6. If students do not know when we started burning fossil fuels (coal, oil, natural gas, etc.) to power vehicles and machinery, mention that it was during the Industrial Revolution, a period from 1750 to 1850. During this era, changes in agriculture, manufacturing, mining, transportation, and technology had a profound effect on the social, economic, and cultural conditions of the times. It began in the United Kingdom and then spread throughout Western Europe, North America, Japan, and eventually to the rest of the world.

Scientific Discourse Circle

1. Divide the class into teams of about four students each to begin the Scientific Discourse Circle[1]. Pass out Handout 4.4: Scientific Discourse Circle—Is Climate Change Caused by Human Activity?
2. Go over the sheet with the class and have each student jot down their own ideas about the statements in the space provided on the data sheet.
3. Once students have finished, tell them they are going to discuss the statements with their team. Each member should participate and contribute to the discussion. Like real scientists debating an issue, they may not agree on all points. Emphasize that this is OK!
4. Explain the procedure for the Scientific Discourse Circle:
   a. For each statement, one student states what they think and *provides specific evidence* to support this reasoning. No other members of the group may add their comments when a student is speaking. This is a listening activity first—not a group discussion.

      Note: *This part may be difficult for some students who are not used to supporting their statements with evidence.*
   b. Each student takes a turn either agreeing or disagreeing with the statement (*not* with their fellow students) and supporting this reasoning with evidence.

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[1]The Scientific Discourse Circle is inspired by similar group activities for students in the Seeds of Science/Roots of Reading curriculum, copyrighted by The Regents of the University of California and used here with permission.

c. After each student has had a chance to speak, the group tries to come to an agreement on the correct answer. All discourse needs to be respectful. It is not necessary for all students to agree. In fact, this is often how science moves forward, with one dissenting voice causing the scientific community to look again at the evidence and perhaps draw new conclusions. Good scientists are open to changing their minds based on evidence.

Note: *The main point of the Scientific Discourse Circle is for students to think about and discuss ideas and evidence in order to find the best explanation. Scientists are able to listen to the reasoning of others and change their minds if they think their viewpoint is no longer supported by the evidence or if another explanation is better supported by the evidence. At the same time, scientists are not easily swayed by arguments that are not based on evidence. They must decide for themselves if a particular bit of evidence supports or does not support a particular explanation or position.*

5. Let students know that scientists rely on evidence. They try to answer the question "What explanation best matches all of the available evidence?"
6. Once the groups have had a chance to discuss their views—first individually, then in a group—ask for volunteers to share how the process went for their groups. Some sample questions:
   - Did any group have all participants agree from the beginning?
   - Did any students change their minds? What evidence caused them to change their minds?
   - Did any groups remain divided? If so, what was the issue that kept them divided?
7. Some students may decide that there is not enough evidence in Graph 1 to draw scientific conclusions. Applaud their reasoning! Graph 1 is specifically included to provide students with short-term data that may not be sufficient for them to be able to fully answer the questions on the handout. This graph is designed to demonstrate what cherry-picked data look like, and it can be used as an example during the next activity in this session. Remind students that they learned in Session 1 that scientists agree the minimum number of years to collect data for evaluation of climate is 30 years. If that was not clear, share this definition:

   Climate: *Climate* is usually defined as the "average weather," based on collecting statistics over a period of time ranging from months to thousands or millions of years. The classical minimum period is 30 years, as defined by the World Meteorological Organization (WMO). These statistics are most often surface variables, such as temperature, precipitation, and wind. A simple way of remembering the difference is that climate is what you expect (e.g., cold winters) and weather is what you get (e.g., a blizzard).

Explaining Misconceptions About Climate Change

1. Tell students that they are going to look over some commonly held misconceptions about climate change and global warming. Pass out Handout 4.5: Lines of Evidence and Handout 4.6: Explanations for Commonly Held Misconceptions About Climate Change and Global Warming.
2. Project or post these six commonly held misconceptions so the whole class can see them:
   - It's been warmer before.
   - Increases in solar activity are causing the Earth to warm.
   - The Arctic is gaining ice.
   - It hasn't warmed since 1998.
   - Increasing CO_2 has little or no effect.
   - Scientists don't agree that humans are causing the Earth to get warmer.

   Give students a few moments to review the misconceptions. Ask if anyone has heard any of these misconceptions and where they might have heard them. Don't spend too much time on the discussion—just enough to get their curiosity going.
3. Tell students you have provided them with some data sets that may help them understand why someone might hold onto these misconceptions. Tell them the data are from reliable sources such as NASA and NOAA and are found in Handout 4.5: Lines of Evidence. Encourage students to check these sources against Handout 4.1 just to be sure. They can work with classmates at their tables to understand the graphs. They may also use information in their notebooks from previous sessions to help them explain the misconceptions. Have students identify the data by graph number so you know which they are referring to.
4. Explain that students will work at their tables in groups but should create a way to record their information as individuals. Provide them with three categories to complete:
   - List the misconceptions.
   - Provide scientific reasoning revealing inaccuracies in each misconception.

- Explain why someone might accept the misconception.

  Students need to record the evidence that reveals the inaccuracies of the misconception and add their reasoning. Once they have explained why the misconception is inaccurate, they will use Handout 4.6 to decide why someone could agree with the misconception. They may choose more than one reason from their handouts.

5. Have students begin their work. Circulate around the classroom to clarify any questions about the graphs. In some cases, students may need to use the information from more than one line of evidence to dispel the misconception. Encourage students to use information from previous sessions in this unit.

Debrief

1. After about 10–15 minutes, bring the class together for discussion. Ask, “Is there a misconception you used to think might be accurate but now have evidence to show that it is not?” Have students explain their reasoning. Ask, “Which misconception was the easiest to invalidate? Why?” Ask, “Which misconception was the most difficult to invalidate? Why?”
2. Have students at each table share one misconception, their evidence and reasoning for why it is a misconception, and reasons they chose for why someone might agree with it. Some possible answers are listed in Table 4.1 (pp. 74–75).
3. Ask students if they noticed any patterns in the data. Give students a few minutes to look over the data and write their ideas in their notebooks. Have them talk with other students at their tables to compare ideas of what patterns they notice in any of the data sets. Once conversations wane, regain the attention of the class and ask volunteers to share any “ah-ha moments” they had during their discussions.
4. To sum up the session, ask, “Can you find evidence that global warming is *not* directly related to the consumption of fossil fuels by human beings?” Have students record their answers in their notebooks. Take as many comments from the class as you have time for.
5. It is recommended that you do not provide an opportunity for students to debate whether human-caused climate change is real. This can give students the inaccurate impression that there are two equal sides to the debate. Please see additional information in the Pedagogy section at the end of the session (p. 78).

Table 4.1: Understanding Misconceptions About Climate Change and Global Warming (Sample Student Work)		
Common Misconception	Scientific Reasoning Revealing Inaccuracies in the Misconception	Explanation for the Misconception
It's been warmer before.	Graph 4 in Handout 4.5 shows that there were four temperature peaks when it was warmer than our current temperatures. It looks like we were starting a cooling trend after the Holocene period. Looking at Graph 1 in Handout 4.5, it clearly shows that we were in a cooling trend until 1910 and now are in a significant warming trend. It's true that it's been warmer before, but there weren't people around at those times. It looks like people are causing it to get warmer this time when it should be getting colder.	1. A logical fallacy could lead you to think that the warming we are seeing now is normal, since it's been warmer before. 2. The data could be used to misrepresent a conclusion that may not be true.
Increases in solar activity are causing the Earth to warm.	Graph 5 in Handout 4.5 shows a variation in solar radiation, but it looks fairly even since 1979. There are no data to support an increase in solar radiation that could cause the Earth to warm like it is now.	1. I think this is a red herring because it is information that misleads you. 2. It could also be a logical fallacy because it makes sense when you first hear the misconception.
The Arctic is gaining ice.	Graph 2 in Handout 4.5 shows that Arctic ice has been declining steadily since about 1968.	1. Maybe there are fake experts who are saying the Arctic ice is increasing. 2. It could also be a red herring since it's not true at all.

Continued

Table 4.1 *(continued)*

Common Misconception	Scientific Reasoning Revealing Inaccuracies in the Misconception	Explanation for the Misconception
It hasn't warmed since 1998.	Graph 1 in Handout 4.5 shows that it's been warmer than average every year since 1977. However, it was extra warm in 1998 and took another seven years for the temperature to get that warm again. So, if you just look at the data during those seven years, you could come to the conclusion that it hasn't warmed since 1998, because it doesn't look like the temperature got warmer during this small chunk of time.	This is an example of cherry-picked data. If you consider all of the data until now rather than just select data points, you'll see that it has warmed a lot since 1998.
Increasing CO_2 has little or no effect.	When you look at the CO_2 levels from Graph 2 in Handout 4.2, you can see that they are currently much higher than at any other time in the last 400,000 years. This sharp increase began after the Industrial Revolution, when we started burning fossil fuels. When you compare that increase to the temperature increase in Graph 1 in Handout 4.5, it seems to reinforce that increased CO_2 makes the temperature increase.	I think a fake expert must have said this, since I can find no evidence to show it could be true.
Scientists don't agree that humans are causing the Earth to get warmer.	Graph 3 in Handout 4.5 shows seven studies that have been done on climate change and how many scientists agree with them. The lowest one had 91% agreement, and the highest one had 100% agreement. I think that most scientists agree that climate change is real.	1. Maybe this misconception is a conspiracy theory by oil companies. 2. This could be an example of jumping to conclusions if you didn't have all of the data.

Climate Change Agent Interview

1. Pass out Handout 4.7: Climate Change Agent Interview. The interview is with Dahr Jamail, a journalist promoting the truth about climate change. Give students a few minutes to read the interview, and then have them jot their reflections in their notebooks.
2. Ask students for any impressions they had of this interview. Ask if any part of the interview was difficult to read due to its honesty. Take a few responses. Ask, “If you experienced some of the things that Dahr Jamail has seen firsthand, like the Iraq war and the BP oil spill, how would you feel?” Ask if anyone disagrees with Jamail’s opinions about our future world. Accept their disagreement. In this case, these are feelings, not facts. Therefore, they are not up for criticism or critique. Pose the question, “If you felt the same way as Dahr, what would you do?” This is meant to get students to reflect on the difficult nature of the truth about climate change and how difficult it might be to share this information with others.
3. Ask for any other comments before moving on to the statement review.

Reviewing Statements and Questions About Climate Change

1. Ask students to review the list they made in their notebooks about what they had heard about climate change. Ask if they now have enough evidence to determine the accuracy of any more of these ideas. If students have enough evidence to categorize a statement as accurate, they should record it on a sentence strip and post it in the Accepted as Accurate column. If they have enough evidence to categorize a statement as inaccurate, they should record it on a sentence strip and post it in the Accepted as Inaccurate column. If the evidence suggests that an idea on their list is accurate but not definitive, they may post it in the Needs More Information/Evidence/Research column. ***In each case, students need to support their decision with evidence.***
2. Now revisit the statements posted during the previous sessions. Ask if anyone thinks a statement should be moved to a different column based on new information they learned during the current session. Students may decide that they need more evidence for a statement that they had previously placed in the Accepted as Accurate category, or they may now have enough evidence to move a statement that had been placed in the Needs More Information/Evidence/Research column to

either the Accepted as Accurate or Accepted as Inaccurate column. ***In each case, they need to support their decision with evidence.***

3. Ask students if they can write new statements for any of the columns, based on new knowledge gained from this session. ***In each case, they need to support their decision with evidence.***
4. Ask students to review the questions that are posted. Are there any questions that they can now answer with their new knowledge? If so, remove the question, write out the answer on a sentence strip, and post this statement in the Accepted as Accurate column. ***In each case, they need to support their decision with evidence.***
5. Finally, ask students if they have any new questions to add to the Questions We Have About Climate Change column. Provide a few minutes for discussion and for posting questions.

Extending the Session

If you want students to meet the *NGSS* performance expectation HS-ESS2-4, include instruction on the natural variability of Earth's systems. One excellent resource for this is a tutorial at *www.sciencecourseware.org/eec/GlobalWarming/Tutorials/Milankovitch.*

You could follow this with a simulation where students manipulate individual factors in the Milankovitch cycles to see how each affects global temperature. Access the simulation here: *https://cimss.ssec.wisc.edu/wxfest/Milankovitch/earthorbit.html.*

Background for Teachers

Proxy Data

In Session 4, many of the data sets that students use are considered "proxy data." Proxy data do not come from direct measurement but rather from preserved physical characteristics of the environment that can stand in for direct measurements.

One example of proxy data is carbon dioxide bubbles trapped in ice cores over many thousands of years, which is studied during Session 4. Temperature values from thousands of years ago are determined by using proxy data. Paleoclimatologists extrapolate temperature from ratios of oxygen isotopes stored in sediments, tree rings, pollen, etc. The interview in Session 3 with Dr. Heidi Roop describes her work in this area.

A discussion of proxy data is appropriate if students ask how scientists know what the temperature was 300,000 years ago. You can get more information on proxy data here: *www.ncei.noaa.gov/news/what-are-proxy-data.*

Natural Cycles in Climate Change

Students may also raise questions about the role of natural cycles in climate change. The role of natural variation on climate variability was first described in 1920 by scientist Milutin Milankovitch. He is best known for developing one of the most significant theories about Earth's motion and long-term climate change.

He identified three factors and determined the relative influence of each:

1. **Eccentricity: The orbit of the Earth around the Sun varies from circular to slightly elliptical.** That means the Earth gets slightly closer to the Sun during peaks of eccentricity. These peaks occur every 95,000 years, but superimposed on those are larger peaks at 125,000 and 400,000 years.
2. **Obliquity: The tilt of the Earth's axis varies from 22.1° to 24.5°.** It is currently at 23.44°. The period of obliquity is 41,000 years.
3. **Precession: This is the Earth's slow wobble as it spins on its axis.** This toplike wobble, or precession, has a periodicity of 23,000 years.

Pedagogy

In Session 4, students will engage the science and engineering practice of argumentation. Argumentation is a key skill as it is the one practice that is consistent across all standards. This is a skill that overlaps with the *Common Core State Standards* and is developed heavily in both English language arts and mathematics.

For more depth in using scientific argumentation, these NSTA journal articles are excellent resources:

1. Blugren, J., and J. Ellis. 2015. Teacher's Toolkit: The argumentation and evaluation guide: Encouraging *NGSS*-based critical thinking. *Science Scope* 38 (7): 78–85.
2. Llewellyn, D. 2015. Teacher's Toolkit: Scaffolding students toward argumentation. *Science Scope* 39 (3): 76–81.

The "Debate" Over Climate Change

It is probable that discussion of the presumed controversy over human-caused climate change will arise in the classroom during this unit. It is important to remember that 97% of scientists worldwide agree that the causes of our rapidly warming planet are directly related to the burning of fossil fuels. To allow a debate by "both sides of the argument" is akin to having a debate about geocentric versus heliocentric models of the solar system. Although a geocentric model was widely accepted in its day, overwhelming scientific evidence has shown that model to be inaccurate, and it has not been accepted for more than 200 years.

The same is true for climate change. As of this printing in 2019, the United States is the only country to withdraw from the Paris climate accord, which was signed by 195 countries. At the 21st Conference of the Parties (COP21) in 2015, every "party" (each country, plus the European Union) came together to set limits that would ensure a sustainable future for humans on Earth. Of all the parties at the conference, only two did not sign the agreement. One was Nicaragua, which claimed the limits did not go far enough. The other was Syria, which was steeped in a civil war. Since then, both Nicaragua and Syria have signed the agreement. In 2017, the United States committed to withdraw, taking effect in 2020. This should make any skeptic ask, "Why?" Every other country in the world agrees that climate change is real, is primarily caused by burning fossil fuels, and if unchecked could make the Earth uninhabitable to most humans. They also agree there are solutions that need to be put in place as soon as possible.

Assessment Opportunities

Student notebooks are designed to be used as assessment tools throughout the entire unit. As students now begin their research and presentations, it would be a good time to check the notebooks in order to assess misconceptions and knowledge gained at this juncture.

Resources

1. Students may enjoy playing a game that tests whether they can discern fake news from real news. They read a short article and decide whether it is real or fake. At the end of each round, they are scored based on how well they did. You can access the game here: *http://factitious.augamestudio.com.*
2. Alfonso Gonzalez, an exceptional science teacher at Chimacum Middle School in Chimacum, Washington, has put together a considerable number of resources on fake news, which you can find here: *www.diigo.com/profile/educatoral_?query=fake-news.*
3. Skeptical Science (*www.skepticalscience.com*) is an excellent resource with commonly accepted misconceptions about global warming and climate change along with the corresponding scientific explanations.

You can choose different levels of scientific explanations, from basic to intermediate to advanced.

4. A graphic is available from NASA (*http://climate.nasa.gov/evidence*) to help students see that the level of CO_2 rose markedly after the Industrial Revolution in the 1800s, when fossil fuels (coal, oil, natural gas, etc.) began to be burned at an increasing rate.
5. Students may be curious about the tilt and wobble of the Earth and its effect on climate. This interactive web page allows students to explore the concept of the Milankovitch cycles, the cause of the major ice ages of the past 500,000 years: *http://profhorn.meteor.wisc.edu/wxwise/climate/milankovich.html.*

References

North Carolina Climate Office. Milankovitch cycles. *https://climate.ncsu.edu/edu/Milankovitch* (accessed October 31, 2018).

Sustainable Innovation Forum. Find out more about COP21. *www.cop21paris.org* (accessed November 3, 2018).

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Note: Page references in **boldface** indicate information contained in figures or tables.

UNDERSTANDING CLIMATE CHANGE

GRADES 7–12

What's the best way to approach the hot topic of climate change in your classroom? With the comprehensive curriculum in this book.

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- Scaffolding for students to research climate change and then present their findings to their peers in much the same way that scientists do
- A system to evaluate both the ripple effects of a warming climate and the actions the government, nonprofits, and corporations are taking to mitigate climate change

The module is easy to use even if you have no background in climate science or are new to the *Next Generation Science Standards*. Your classes can master the material in just three or four weeks. The module can also be used in part to supplement your existing middle or high school curriculum. *Understanding Climate Change* helps you empower students to conduct their own investigations, think for themselves, and plan positive actions in their homes, schools, and communities.

Grades 7–12

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