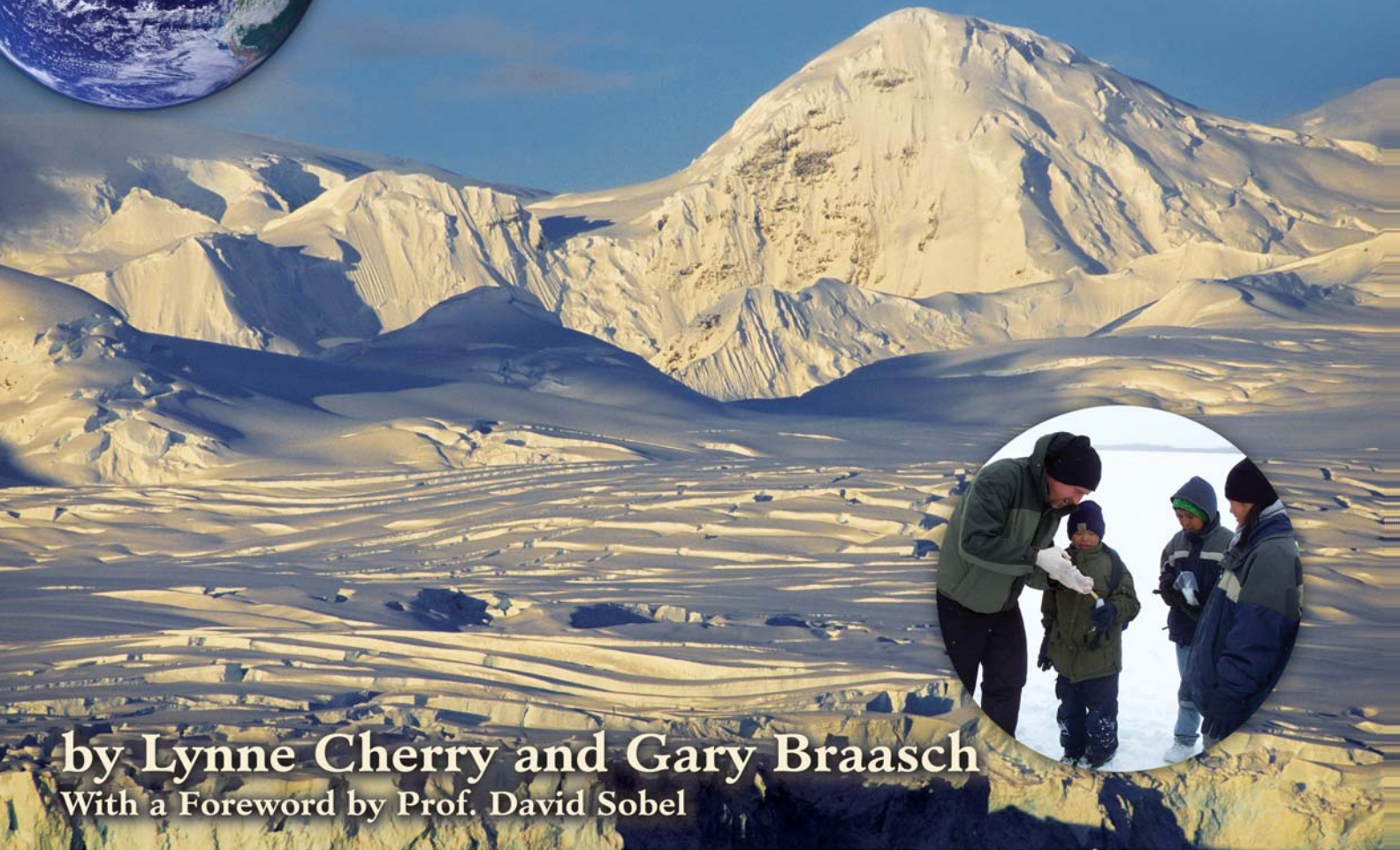




How We Know What We Know About Our Changing Climate

Scientists and Kids Explore Global Warming



by **Lynne Cherry and Gary Braasch**

With a Foreword by Prof. David Sobel



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Students Help Scientists Collect Data on Butterflies



Above: The monarch butterfly has a truly amazing migration between Mexico and North America that involves three or four generations of butterflies for each full cycle in the migration. The butterflies require flower nectar to fuel their amazing migration each spring and fall.

Next page top and bottom right: These students in Minnesota and Mexico are participating in *Journey North*, tagging butterflies and collecting data on their migration.

Next page, bottom left: This Journey North map shows the weekly progression of monarchs during their spring migration.

Data collection by amateur naturalists was essential to Dr. Camille Parmesan's research. And information from thousands of citizen scientist students through several butterfly-monitoring programs is helping other scientists—and young people—understand more about wildlife migration. Volunteers for the *Monarch Larval Monitoring Project* and *Monarch Watch* program study how monarchs use their habitat throughout the breeding season, while *Journey North* tracks monarchs as they move north.

Until 1975, butterfly scientists did not know where monarchs went on their fall migration south. People had seen them in Texas and along the Gulf Coast, but nobody knew where they went next. Canadian Lepidopterist Dr. Fred Urquhart was the first to mark the butterflies with tiny tags to track them across the continent. Thousands of citizen scientists helped.

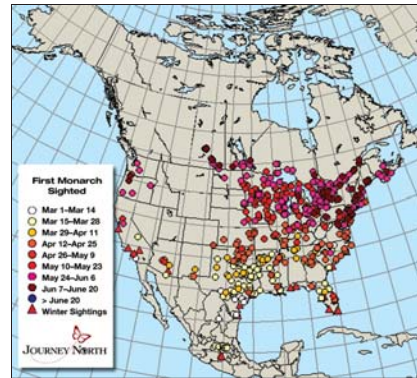
On January 2, 1975, two of Urquhart's volunteers reported the location of the monarchs' winter home in Mexico. They had discovered millions of monarch butterflies hanging from trees in a high mountain forest deep in central Mexico. When Urquhart went there the following year, he found a butterfly that had been tagged by one of his volunteers. This confirmed that monarchs from Canada and the United States fly all the way to Mexico. Urquhart announced the discovery of the monarch's winter home in a *National Geographic* article in August, 1976. Today, people continue to tag tens of thousands of monarchs and help scientists learn new information about monarch migration through the *Monarch Watch* program.

Dr. Lincoln Brower has studied monarchs for over fifty years and has published hundreds of papers about them. Brower has spent much of his career studying the *microclimate* of the forest in

Mexico where the monarchs spend the winter. A microclimate is the unique climate of a small area, sometimes as small as a patch of moss growing on the north, cool sides of trees. The monarch's survival in Mexico depends on a very delicate balance. If temperatures are too cold, the butterflies can freeze to death. If temperatures are too warm, they can burn their fat reserves too quickly and starve. "The forests serve as a blanket and an umbrella which keep the monarchs warm and dry, and are a key to their survival," says Brower. He is concerned about how a changing global climate could change the microclimate of the monarch's forest.

Brower discovered that the monarch's spring migration involves two or more generations of butterflies. The monarchs that leave Mexico in the spring travel only as far as the southern U.S. states. There they lay eggs on milkweed, then die. These eggs hatch into caterpillars that *metamorphose*—change and transform—into new butterflies. And it is those *new* butterflies that continue the journey north. Brower and his colleagues figured this out by looking at the chemicals in the different milkweed plants that the butterflies ate as caterpillars.

Today, students and scientists continue to learn more about the monarch's migration by tagging butterflies and tracking the migration live each spring and fall, and on the internet through the *Journey North* program. They continue to observe butterflies and learn more about how they use their habitat throughout the breeding season through the



Monarch Larval Monitoring Program and *Monarch Watch*. Their observations support Brower's original research and also help answer complex questions about the timing of the migration and monarch survival.

Elizabeth Howard, the founder and director of *Journey North*, explains why this work is important: "By observing individual butterflies and the habitats in which they are found, the participants in these monarch monitoring programs understand how closely monarchs are adapted to the existing climate, and how climate change could affect them." To see how you can help track monarchs—and birds, too—see *Journey North* in the Resources section.



In the North, Evidence that the Forest is Changing



Above: Meteorologist Dr. Scott Chambers inspects instruments on a 50-foot tower overlooking the boreal forest near Fairbanks, Alaska. In addition to weather readings, these instruments also measure the energy coming from the sun and the flow of carbon dioxide into the plants of the forest.

Top Right: Many white spruce trees in the boreal forests cannot cope with warmer weather.

In the far north there is a point beyond which no trees can grow—the *tree line*. It is where the *boreal forest* meets the *tundra*. The tundra is a vast landscape of bushes, grasses and *permafrost*—permanently frozen ground. The boreal forest, south of the tundra, is adapted to cold, moist climates and dominated by *conifers*—cone-bearing trees—that keep their needles all year round. The climate in Alaska has been warming, and some scientists hypothesized that the tree line would move north and up the mountains. Botanist Glenn Juday hypothesized that as recent temperatures became even warmer, all the trees in the forest would increase in growth.

In one of many studies of Alaskan trees, Juday and Dr. Martin Wilmsking took tree cores from 2400 trees in 15 stands in the Brooks and Alaska mountain ranges.

This was such a massive amount of data that it was very robust, so they could be very sure of their results.

To get local high school students interested in understanding their local environment, Juday helped with the Bonanza Creek Schoolyard LTER (Long-Term Ecological Research) Tree-Ring Study Program near his university in Fairbanks, Alaska. He involved the students in his quest to figure out how boreal forests are responding to climate change. Some of the students recorded the location of trees in their schoolyard. They extracted tree cores just like scientists do. Another group of high school students



helped with some of Juday's fieldwork, measuring the height of trees and how much they had grown since the year before.

What Juday discovered from all his research came as a surprise. It seemed that his hypothesis—that entire forests would grow better with warming—was wrong. At first, with a small bit of warming, most of his white spruce trees did grow a bit better. But when the daily temperature got too high, half of them just shut down completely. During this time they did not take up nutrients or water from the soil to grow. Juday says that this is the natural reaction of a cold-climate tree to excessive heat in the place where it grows. Some of the trees are going to suffer and stop growing after a certain temperature. “If temperatures continue to increase we are not going to have a smooth movement of the tree line north and up the mountains,” he says. “The forest area will break apart. White spruce today define this forest—but this species won't be so common in the future. We may still have a forest but we will have a different kind of boreal forest.”



Above: High school students in Alaska provided data in the study of white spruce trees. They reported “the strenuous work of measuring trees,” including the following:

- “We measured from last year's ‘node’ to the end of this year's ‘node.’
- “If it is over 50 cm tall we take the base diameter. If it is over 137 cm we take the diameter at breast height.
- “We measured 2,188 seedlings, two measurements each, which makes 4,376 measurements.
- “We measured 1,504 seedlings at the base or ground level and 674 seedlings at breast height.
- “We made 1,071 comments about the trees.
- “That is 7,175 comments and measurements altogether.”

The Weather RATS Learn to Observe and Record Climate Data



Above: Using drinking straws and paper cups, these students constructed simple *anemometers*—wind measuring devices. They are collecting data and calculating wind speed.

Next page, bottom left: students locate the Jet Stream by observing a water vapor map on the internet showing current satellite images.

Next page, top right: These *Weather RATS* at a school in Oklahoma ham it up for the camera. They compare information with partner RATS in Arizona, Massachusetts, and Puerto Rico. The program is named for “Weather Research and Tracking Systems.”

Next page, middle right: Students learn the principles of science by making a simple thermometer out of a drinking bottle. They partially fill the bottle with colored water, insert a straw, and seal the straw in place with modeling clay. They alternately cool and heat the bottle and observe the level of the water in the straw.

At Soule Road School in Wilbraham, Massachusetts, students are learning about weather by taking measurements from their own weather station and sharing weather information with partner schools in Oklahoma, Puerto Rico, Arizona and seven other Massachusetts schools. These *Weather RATS* (Weather Research and Tracking Systems) learn that in North America, weather generally moves with the jet stream from west to east. That means that weather passing over Tuba City, Arizona may be heading their way. They take measurements of humidity, rainfall, temperature, wind speed and wind direction.

Weather RATS sometimes track hurricanes and severe weather events with partner schools. By tracking the weather, they see that the world—including the atmosphere—is interconnected. When their teacher, Mary Taft, takes jet stream data and enters it into the computer and animates it, they can actually see the weather moving. Now the students have conversations with each other about how the jet stream’s ridges and troughs might impact their local weather.

At first the students had a hard time understanding the difference between weather and climate, but by taking daily weather readings they saw that climate is the average of many weather readings over a long period of time in a certain place.

The Monroe School in Enid, Oklahoma has been studying weather since 1992, when Dr. Kenneth Crawford began putting weather data into the hands of middle school students. They have been fascinated with *meteorology*—the study of the weather—ever since. Through *Oklahoma Mesonet*, students have access to the data collected by an extensive network of meteorological towers that are used by the weather service, the Severe Storm Laboratory

and professional meteorologists. The students can analyze real-time data.

Like the other *Weather RATS* schools, they have their own weather station and monitor current weather at their own school. They communicate with *Weather RATS* in Puerto Rico, for example, when there's a hurricane there, and take a personal interest, asking the Puerto Rican students questions via the internet. Oklahoma gets some wild weather too, including tornados. They have come to realize that weather is very different from place to place.

Their teacher Lori Camp Painter described how her students might see a bank of clouds coming in. They view the Mesonet data, go outside and do observations, and then make predictions about when the front might arrive. The students predict tornado-watch areas and then, on the news, often see that the meteorologist has targeted the same area.

The Monroe students have also delved into weather and climate history. They research things in Oklahoma's past such as dust storms and floods. "The kids learn the importance of looking at long-term data," says Ms. Painter. "Now they can see how some of the agricultural problems that caused the dust bowl are being addressed. It gets them thinking about what has happened in the past, what will happen in the future and what they can do to

make a better, safer world."



The Power of Friends and Community



Above: Healthy rainforests like this one in the Children's Eternal Rainforest in Monteverde, Costa Rica, "eat," or absorb, large amounts of carbon dioxide.

Although the middle school students near Montpelier, Vermont did not set out to reduce their climate footprint, they did something that will keep lots of carbon from entering the atmosphere each year. They noticed that sometimes breathing the air in school made them feel sick, especially if they had asthma. Mornings and afternoons, school buses sat outside waiting, with their motors idling. The students wanted to know: Were the exhaust fumes coming into the school? What was in the fumes? How could they find out?

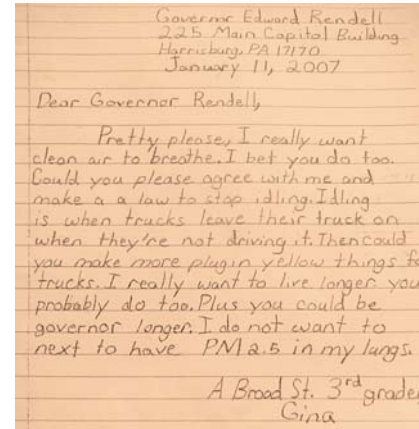
They found that a group called Air Vermont had equipment to help them. With ACCESS (A Computerized Community-Based Environmental Sampling System), students tested the indoor air before and after the buses idled in front of the school. The tests showed that unhealthy fumes from the buses were invading the school. There were 12 different pollutants. The students petitioned the school board for a "no-idling" policy to require buses and cars to turn off their engines when parked in front of the school. The school board agreed. The students went further: they testified before the state legislature, and in February, 2007, Vermont passed a no-idling law. Now the students realize that the carbon dioxide in the fumes is also a global warming gas and that while protecting their health, they are also reducing Vermont's carbon footprint.

By stopping school bus idling, students can save 20 gallons of gasoline per bus—and 400 pounds of carbon dioxide per year—from going into the atmosphere. If 100,000 schools did this for all their school buses, it would prevent 97,000 tons of CO₂ from going into the air each year. *Clean School Bus USA* is an organization that can assist in stopping idling in your school and state. (See Resources.)

All around the world young people are planting trees, which is a good thing. But nothing can take the place of existing forests, which provide many essential life-support functions. A mature tree can absorb 48 lbs. of carbon dioxide a year and release enough oxygen back into the atmosphere to support 2 human beings. Tropical forests are even more important. “Tropical forests are good for climate, so we should be particularly careful to preserve them,” says Ken Caldeira of Carnegie Institute’s Department of Global Ecology. A wonderful example of a rain forest that would otherwise have been cut for farming is the *Bosque Eterno de los Niños*—the “Children’s Eternal Forest” in Monteverde, Costa Rica. That spectacular forest of over 50,000 acres of rain forest was saved by contributions from children all over the world.

In the upper peninsula of Michigan young people wrote letters to their local newspaper and did radio and TV interviews to educate their community and raised \$200,000 to buy a threatened forest. When young people in Maryland heard that a 600 acre forest that was owned by the Episcopal church was going to be cut down, they wrote letters to the bishop. They read their letters on “Sunday Morning With Charles Osgood,” a national news program, and the church was so deluged with letters of protest that the forest was saved.

Young people can make a difference by asking others to put the next generation—and the planet—at the top of their list of priorities. There is a saying: “We do not inherit the Earth from our ancestors, we borrow it from our children.”



Two photos, top right: Around Carlisle, Pennsylvania, children have been writing to their governor and other elected officials asking for a no-idling law. They are citing data collected from the Clean Air Board’s air monitor in their town. Most of the students in Carlisle couldn’t see or smell the pollution, but those who suffered from asthma could feel its effects.

Bottom right: These children in a Mexican village worked with *Journey North* to track the migration patterns of the monarch butterfly that winters over in that part of Mexico.

What You—and a Million Kids—Can Do



These students are planting pumpkins in their school garden in California. In the autumn, some pumpkins became jack-o'-lanterns. The seeds were dried and eaten. Others became pumpkin pies and spicy cookies.

The things you do every day use energy and release greenhouse gases into the air. From sunrise to sunset, and even through the night as your house keeps you comfortable, you are using energy—and leaving a climate footprint. When you flip a switch to turn on a light, a power plant somewhere burns fossil fuels. Gasoline powers cars, trucks, SUVs, lawnmowers, leaf-blowers, and boats, and sends up clouds of *anthropogenic*—human generated—CO₂. One gallon of gas gives off nearly 20 pounds of carbon dioxide.

The actions below will reduce your climate footprint. They are easy changes that will make a difference right away. And it is better to prevent your own CO₂ from going skyward than to pay someone else to “carbon offset” your emissions!

- **Walk or ride your bike to school**, if it's safe. Use public transportation. Shop near your home and make one trip instead of many. Vacation by train rather than airplane.
- **Ask your parents to turn off the engine**. Idling the car 10 minutes less a day will save 550 pounds of CO₂ per year.
- **Stop school bus idling** and save 20 gallons of gasoline per bus—and 400 pounds of carbon dioxide per year—from going into the atmosphere!
- **Drive an energy-efficient car**—a hybrid if possible. Driving a car that gets at least 32 miles per gallon saves 5,200 pounds of CO₂ per year. Some hybrids can get 50 miles per gallon!
- **Re-use, recycle and reduce** paper, glass and plastic. Start or improve a recycling program in your community and school.
- **Replace** incandescent light bulbs with compact fluorescents.
- **Unplug your house**. Heat and electricity in your house make up one-third of the average family's greenhouse emissions. Turn things off, unplug them, and use appliances less.

■ **Drink filtered tap water** rather than buying water in plastic bottles. Carry your own reusable travel-cup for drinks, rather than throwing away bottles and cups each day.

■ **Help to preserve old trees in forests**, especially rain forests, which soak up a lot of CO₂. If a million kids each raise \$100 which is used to protect a million acres of tropical forest, those forests will continue to absorb and store 286,000,000 tons of CO₂/yr!

■ **Eat less meat.** Cows and sheep produce *methane*, a greenhouse gas. Raising and processing livestock creates more greenhouse emissions than all the gases from cars and SUVs combined.

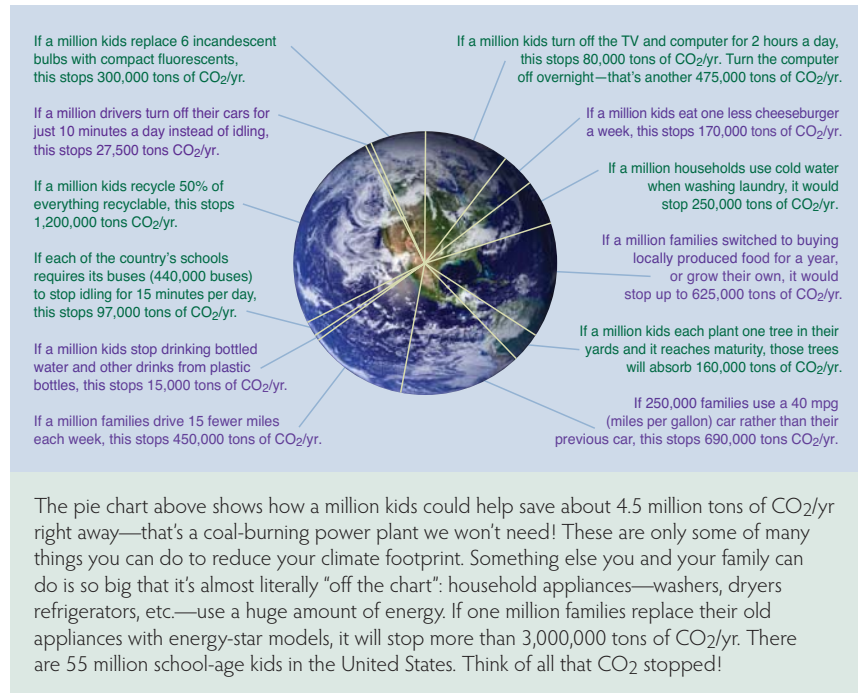
■ **Buy mindfully and buy less.** Think: Where did it come from? What was it made from? Buy locally grown, in-season food, which takes less fuel to transport, or grow some of your own.

Buy un-packaged products. Think about thneeds. A thneed, as Dr. Seuss said in *The Lorax*, is something you think you need but don't really need.

■ **Share what you've learned with your school.** Help your school to be smarter about climate change. Encourage your school to recycle, reduce throw-aways, encourage car-pooling, stop school bus idling, and install a green roof and solar panels.

■ **Get involved in your community.** Write a letter to the newspaper editor suggesting that the town reduce its CO₂ emissions. Ask elected officials to sign the Step It Up pledge. Volunteer to help town leaders who are already doing something. Let companies know that you care about using less energy.

■ **Check out** the Resources in this book to find out much more you can do. Thank you for showing how much you care about planet Earth.





When the **weather** changes daily, how do we really know that Earth's **climate** is changing?

HERE IS THE SCIENCE behind the headlines—evidence from flowers, butterflies, birds, frogs, trees and much more, gathered by scientists from all over the world, sometimes with assistance from young “citizen-scientists.” And here is what both scientists and young people are doing that makes a difference.

Climate change is an important and timely topic of deep concern, here told in an age-appropriate manner, with clarity and hope. Kids *can* make a difference!

This book combines the talents of two uniquely qualified authors: **Lynne Cherry**, the leading children’s environmental writer/illustrator and author of *The Great Kapok Tree*, and **Gary Braasch**, award-winning photojournalist and author of *Earth Under Fire: How Global Warming is Changing the World*.



Parents today have the toughest and most important job in the world—passing the torch of knowledge and environmental stewardship on to their children. This magical book provides an invaluable service to parents by blasting open the doors to the world of climate science. A world that our children will be required to know well to solve the problem of global warming.

—Dr. Heidi Cullen, climate expert at
The Weather Channel

This is a necessary book. It treats kids with respect—they deserve to know what’s going on. But they also deserve to know that there’s much that can be done, and much that is being done. In a word, it’s empowering!

—Bill McKibben, author, *The End of Nature*

This book explains the fundamentals of climate change so well—wonderfully written for children, although adults will find it factual and interesting too. And, it is fun to read!

—Dr. Warren Washington, UCAR Senior Scientist
Advisor to Pres. Carter, Reagan, Bush, and Clinton



This beautiful and informative book fills a major gap in environmental writing for children. It covers a wide range of research, defining technical terms gracefully and naturally as they arise. The overall tone—urgent without being shrill, hopeful without being complacent—strikes me as just right. I happily recommend it.

—Robert Coontz, deputy news editor, *Science Magazine*

Children of all ages will delight in this introduction to the science of climate change—a thrilling inspiration for one and all to get outdoors and experience the adventure of citizen science.

—Thomas Lovejoy, tropical biologist and
President of the Heinz Center



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Lessons, Resources, and Guidelines for Teaching About Global Warming*

By Carol L. Malnor

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