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No single cause, no simple answer

Most Mainers have heard of global warming, but the truth of Earth's changing climate is far more complex than a simple equation of pollution equals warmer weather.

"The Earth's climate is not a black-and-white system. It's many shades of gray," said Greg Zielinski, Maine's state climatologist and a member of the Climate Change Institute.

The vast majority of the world's scientists don't doubt that there is an out-of-control greenhouse effect occurring, in which pollutants such as carbon dioxide and methane build up in the atmosphere, trapping unnatural amounts of heat from the sun near Earth's surface.

"It's very clear that the greenhouse gases are part of this story," said Robert Kates of Trenton, a member of the National Academy of Sciences who has helped craft international reports on climate change.

But answering the question of just how large a part human activities such as burning fossil fuels and cutting down forests play in determining Earth's climate will require solving one of the most staggering problems ever considered by humankind: How does the world work?

Just as an orchestra needs dozens of different instruments, each playing its role, to perform all the dips and swells of a symphony, climate is more complicated than it first appears.

Solar flares — often cited by detractors as evidence to discount the theory that climate change is caused by humans — play an important role, perhaps prompting climate cycles on a time scale of tens of thousands or even hundreds of thousands of years. But also playing a part are the "wobbles" in Earth's rotation around the sun and the shifting locations of the continents.

Over shorter periods, dramatic natural events such as volcanic eruptions and changing ocean currents can transform the climate, both locally and worldwide. Hundreds of factors, some of which scientists are just beginning to observe, have influenced the melody of climate over the eons.

"Discounting that anything else happens, there would be that nice, simple relationship [between atmospheric carbon dioxide concentrations and global temperatures]. But other things do happen," said Kirk Maasch, a climatologist at the University of Maine.

That makes linking the pollution coming out the tailpipe of your neighbor's sport util-



Kirk Maasch (above) is a climatologist at the University of Maine's Climate Change Institute. National Academy of Sciences member Robert Kates (left) of Trenton has helped craft international reports on climate change.

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Kirk Maasch, climatologist, University of Maine

ity vehicle to your earlier-blooming lilacs virtually impossible.

"We can never say that a single event, a hurricane or a flood or a warm season, is caused by greenhouse gases," said University of Maine paleobotanist George Jacobson.

Climatologists graph out the cycles they recognize, each line atop the last like hundreds of echocardiograms, until clear peaks and valleys emerge.

"All of it comes into play," Maasch said. "You've got to keep [all the factors] in and let the cards fall where they may," he said.

A jumbo of disciplines

But even the best climate records from Arctic ice cores go back only about 100,000 years, while most scientists today believe that Earth was formed at least 4.6 billion years ago.

As science essayist John McPhee once wrote, imagine a man standing with both

arms outstretched as a timeline. If the tip of the left middle finger represents the birth of the planet, then the whole of human civilization — just 10,000 years — is encompassed in the fingernail of the right middle finger.

While the concept of a warming climate caused by excess carbon dioxide and other greenhouse gases in the atmosphere dates back to the 19th century, it wasn't until the environmental movement of the 1960s that the idea captured people's imaginations. Talk of mass pesticide poisonings and potential nuclear winter brought home the possibility that humans could change the entire world, Kates said.

For thousands of years, the El Nino cycle in the Pacific and the devastating storms that marked the start of a cold period called the Little Ice Age nearly 700 years ago were attributed to the supernatural, a punishment from above.

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Over 128 years, lake watchers chart 'ice out' changes

The Staples family has been watching climate change happen just a "stone's throw" from their front door for 128 years.

Since 1878, this Washington County family has volunteered to keep the official record of when the ice recedes from West Grand Lake, data scientists now are using to find the "footprint" of global climate change in Maine.

"It seems as if the climate here in the winter isn't as extreme as it used to be," Marion Staples said. "We're seeing warmer winters ... nowhere near as much snow."

A hundred years ago, Staples' grandmother kept careful records of the ice-out date for the fishermen who frequented her sporting camp. Today, a warden pilot helps the third generation keep track of the ice's progress.

The date that the ice finally disappears from the lake is a matter of local gossip, hashed over at the streamside Pine Tree

Store where locals make their guesses of the magic number.

Scientists also look to lakes and rivers for more precise signals of a shifting climate. In fact, ice-out dates, ice thickness measurements and the timing of the spring snowmelt indicate that Maine's winters have undergone significant changes over the past hundred years, said Glen Hodgkins, a hydrologist with the United States Geological Survey in Augusta.

The past four or five decades, in particular, have brought shorter, milder winters to northern New England. Averaged data from all three climate indicators show spring arriving one to two weeks earlier than it did in the 1950s and '60s, Hodgkins said.

A USGS analysis of ice-out dates at 29 New England lakes revealed that the event is occurring an average of nine days earlier in northern and mountainous regions and 16

days earlier in southern New England.

Hodgkins and his colleagues also studied the thickness of the ice on the Piscataquis River, noting that the ice thinned by about 9 inches between 1912 and 2001, helping to prompt the earlier ice-out date.

At 13 sites statewide, heavy spring stream flows from melting snow have occurred as much as two weeks earlier, according to a recent USGS study.

The evidence that Maine's climate is shifting just keeps mounting, and every study done in New England echoes the findings of research being conducted worldwide, Hodgkins said.

"We're looking at some pretty dramatic changes," he said.

Marion Staples has continued a century-plus-long family tradition of recording the ice-out dates at Grand Lake Stream.



Shifts in avian patterns serve as portent

The first biological "footprints" of climate change have begun to appear. Lilacs are blooming earlier. Snow is melting sooner. Bird-watchers say that migratory birds, the heralds of spring in New England, could be among the first to be affected by an altered climate.

A 1999 study of 14 songbirds in Great Plains states supports the theory. After analyzing statistics from the National Audubon Society's Christmas Bird Count, researchers found that birds begin to change their behavior after just a few winters that are unusually warm or cold.

Throughout Europe and North America, biologists have published studies demonstrating that species of songbirds that travel only short distances are adjusting the timing of their migration to account for an earlier spring.

But birds and butterflies that spend the winter in tropical climes and migrate greater distances don't see the seasonal changes and continue to migrate on their old schedule — averaging about 13 days late. That puts them on a different schedule than the blooms and insects their chicks depend upon for survival.

"It's as though they served dinner at 5 and nobody told you, so you showed up at 6," said Jeff Wells, an ornithologist who lives in Hallowell.

Long-distance migrants may eventually adjust to the changing climate, but scientists have not found evidence for that yet.

Using data from upstate New York, collected since the early 1900s, biologists have demonstrated that tree swallows, which migrate short distances, are laying their eggs 10 to 12 days earlier than they did 50 years ago.

There is not yet any similar evidence of early nesting here in Maine.

W. Herbert Wilson, a biology professor at Colby College in Waterville, worked with several of his students to compare data about bird migrations from the periods of 1899-1911 and 1994-97 and found that nine of the 80 species they studied showed significantly earlier spring migrations. The study did not distinguish between long- and short-distance migratory birds.

Wilson concluded that because so few species had changed their pattern, it's too soon to cite any signal of climate change here in Maine.

Yet bird-watchers throughout the state insist they're watching climate change happen through their binoculars.

Carolina wrens, for instance, have become a common sight in southern Maine in the past 15 years.

"I remember driving to Falmouth to see the only nest in Maine," Wells said. "There are literally just hundreds of them now."

Tom Hodgman, a biologist with the Maine Department of Inland Fisheries and Wildlife, points to the Northern cardinal — a bird that used to be rare in northern Maine but has slowly built up a substantial breeding population statewide over the past few decades.

Red-bellied woodpeckers have appeared in Maine by the hundreds in the past year or two, said Wells, who believes the sightings could be evidence that the species is pushing its range north in response to climate pressure.

Birds can be difficult indicators, as their migrations are affected by so many other factors. Some scientists argue that the woodpecker "invasion" is related to habitat destruction or that the gradual cardinal and wren



Birdwatchers look for various species along the Penobscot River in the Orono and Old Town area in 2004.

boom is in response to backyard bird feeders.

However, the shifts that birders have noticed correspond to many of the forecasts made by scientists, including a wildlife ecologist from the University of Maine, who used data from several climate models to predict how birds' ranges might change.

If climate change progresses as

expected, birds such as the yellow-bellied flycatcher, Philadelphia vireo, evening grosbeak and Tennessee warbler could disappear from Maine altogether, instead breeding in cooler Canada.

Maine's state bird, the black-capped chickadee, will vanish from southern regions of the state, the study predicts.

"The state bird could be something that [most Mainers] would have to take a trip to see," Wells said.

75,000 years ago
Toba erupts in Sumatra, the largest volcanic event of the past half-million years. Its crater measures 60 miles across, and enough dust is thrown into the atmosphere to cool Earth for nearly 200 years. One model estimates that high noon on a day after the eruption would have been about as bright as a night with a full moon.



40,000 years ago
Neanderthals, an early hominid species, disappear from Europe, after coexisting with early humans and living for nearly 200,000 years. Some scientists have theorized that Neanderthals were unable to adapt to climate change as the ice age began and large game animals such as mammoths fled south.

35,000 to 30,000 years ago
Glaciers advance from the poles as the most recent ice age begins.

28,000 to 20,000 years ago
The Laurentide Ice Sheet, which blanketed New England during the most recent ice age, reaches its peak, stretching as far south as Long Island.

17,000 to 12,000 years ago
The last glaciers disappear from Maine.