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The El Nino Factor.(El Nino weather pattern may be beginning of new weather patterns)(Abstract)

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With the latest El Nino now gone and its twin, La Nina, set to take over, scientists wonder if what we've just seen is a taste of the weird weather to come.

WHEN 1998 BEGAN, East Africa should have been at its most beautiful. Normally the short rainy season ends in December, the rivers subside, and the country sparklers; farmers raise crops, animals graze, tourists go on safaris. But this year was different. The rains were heavy and long. The water spread out for miles in places in Kenya and Somalia, cutting off villages and forcing herders to crowd with their livestock onto a few patches of dry land. Things quickly turned ugly. Camels, cows, sheep, and goats all started dying of violent fevers. Soon people, too, began to get sick. Some went temporarily blind; others began bleeding uncontrollably.

The disease was Rift Valley fever, caused by an obscure mosquito-borne virus. It pops up every few years in Africa when standing water encourages mosquito eggs to hatch. This year's huge flood brought a spectacular outbreak: according to official (albeit rough) estimates, at least 89,000 people caught the disease. Two hundred died, but then the disease is not usually fatal to humans. Animal losses, however, were almost certainly vast--owners reported losing up to 90 percent of their herds. "This is probably the worst outbreak of Rift Valley fever in recorded history," says Ali Khan, a medical epidemiologist at the Centers for Disease Control and Prevention in Atlanta.

Yet catastrophic as the East African floods were, they had to jostle for the world's attention with other cases of strange weather--with unusual occurrences of droughts, fires, rains, cold snaps, and heat waves. Every year brings its own grab bag of such anomalies, but this year many of them could be linked to a phenomenon in the empty expanses of the equatorial Pacific--a change in the ocean currents and winds that began in the early months of 1997 and that altered weather patterns around the world. The change in the weather was, of course, the work of El Nino.

By the end of 1997, El Nino had already become a celebrity of sorts--in storm-battered California, television news programs offered a tabloid flurry of El Nino updates. In 1998, however, El Nino's effects on the world came into full flower. It helped make the year the hottest ever recorded. In addition to Rift Valley fever, El Nino has been linked to an upsurge in diseases ranging from cholera to malaria to dengue fever, in Kenya, Cambodia, Peru, and other countries scattered around the globe.

Scientists are now trying to figure out how they can use this year's experiences to predict what the future will bring--both in the next few months and in future decades. The good news is that they can now forecast an El Nino with some precision, and during El Nino years predict its effect on the world's weather months in advance. The bad news is that according to some research this latest El Nino might be a preview of the weather to come in the next century.

El Nino is caused by an erratically swinging pendulum made of air and water. Under typical conditions a giant pool of warm water sits in the tropical western Pacific. The heat makes the seawater evaporate and build massive thunderclouds. As rain falls from the clouds, the air both dries out and is pulled upward by the storm's violent updrafts; when the air reaches higher altitudes, it gets blown eastward, until it sinks back down off the coast of South America. This dry air is now blown back west over the Pacific by trade winds, replacing the air carried up and away by the thunderstorms. This cycle is similar to ones found all along the equator, all powered by thunderstorms rising over warm water or on the edges of mountain ranges, and all rotating side by side like a set of interlocking cogs.

In the Pacific the atmosphere and the ocean normally reinforce this circulation pattern. As the trade winds travel west, they push the warm surface water of the ocean ahead of them toward the warm pool, making the pool even warmer. As a result of the winds, sea level in the warm pool is actually a few inches higher than in the eastern Pacific. Meanwhile, off the coast of South America, cold water from the deep ocean wells up to replace the surface water pushed west by the trade winds, creating an even bigger temperature difference between the two ends of the ocean. Loaded with nutrients, these upwelling waters support the healthy stocks of fish that Peruvians have depended on for centuries.

El Nino arrives when the pendulum begins to swing away from this arrangement. Every three to seven years or so, the easterly winds die down. The warm pool is no longer penned in its western Pacific corral and can spread east along the equator. Less cold water rises from the deep along South America; without it, the ocean surface warms even more. With less of a temperature difference between the eastern and western Pacific, the trade winds decrease yet further. That lets the warm pool push farther east. Eventually this collapse of the old arrangement looses a colossal underwater wave of warm water, which races across the ocean until it slams into South America.

As the ocean shifts, so does the atmosphere. With warm water now distributed along the equator, big thunderstorms can form as far east as the Andes. The old cycle of air circulation collapses and is replaced by a new one, or rather two new ones. Now the thunderstorms over the Andes pump dry air east over the Amazon and the western Atlantic. Meanwhile, thunderstorms that form in the central Pacific pump dry air west to Southeast Asia.

This new circulation pattern brings changes to the weather of lands bordering the tropical Pacific. In Peru rain comes when dry weather is expected. (This is how El Nino, which means "the Christ child," got its name: unexpected rains around Christmastime made the arid South American coast bloom.) In normally rainy Indonesia, drought hits. Because of the interaction between the cycles of air over the Pacific and similar cycles elsewhere, southwestern Africa turns dry as well.

The new circulation set up by El Nino also shifts the jet streams--those high rivers of wind that herd the weather around the world--and invigorates them with the energy released from the warm Pacific. A now powerful jet stream rips across the southern United States, bringing rain with it. When the high winds reach the Atlantic, however, they shear off the northern edges of hurricanes, destroying the storms and sparing the East Coast.

Yet even as El Nino's effects are raging, the pendulum of the Pacific has already started to swing back. The wave of warm water that slammed against South America has bounced back to the west. The westward trade winds pick up again, pushing warm water back from the eastern Pacific. The warm pool warms up again, forming storms that restore the old cycle of air circulation to the Pacific. Stronger trade winds now blow westward, pushing even more warm water back with them. The Pacific now returns to average conditions--sometimes. But on some occasions the pendulum can overshoot and enter a sort of anti-El Nino, known as La Nina.

The western Pacific gets so much warmer than the cool eastern ocean that droughts come where heavy rains once fell and vice versa.

Peruvian scientists had taken notice of El Nino's visits by the late 1800s, but they had no way of predicting just when the next one would arrive. Even as late as 1983, when a huge El Nino hit, few guessed that it was on its way. But in the years since, researchers have become better prepared, thanks to the work of ocean modelers like Mark Cane and Stephen Zebiak of Columbia University's Lamont-Doherty Earth Observatory. In the mid-1980s Cane and Zebiak wanted a miniature Pacific they could play with, a simulation in which they could shut off this wind or that current to see which factors were most important to El Nino's existence. They built a simple computer model, and almost as an afterthought they tried to use it to predict real El Ninos. They gave the computer a pattern of winds that were moving around the Pacific up to January 1986 and let the simulated ocean respond. "The model wasn't started to make predictions but to see how El Nino works," says Cane, "but it seemed to do the right things, so we tried it out." It accurately predicted the onset of the next El Nino, in 1986; then, in the early 1990s, months in advance of each one, it predicted the onset of a string of El Nino.

Other scientists began building more sophisticated computer models. These simulated the entire world's atmosphere, in addition to the Pacific Ocean, and allowed sea and air to interact in much more complex ways. By late 1996 the new models had outperformed their predecessor. At that time Cane and Zebiak's model predicted no great change in the Pacific, while other programs--notably the one that runs at the National Oceanic and Atmospheric Administration's Climate Prediction Center in Camp Springs, Maryland--correctly saw an El Nino coming.

Then came the challenge of predicting what an El Nino would do to the world's weather. Researchers at places like the Scripps Institution of Oceanography in La Jolla, California, ran simulations of their own, using as their guide the historical patterns seen in El Ninos of the past. These predictions were on target in some places, but in others they fell short. Australia, for example, missed the late 1997 droughts that had been predicted, as did southern Africa in the early part of 1998.

As powerful as it may be, El Nino shares the world with other weather patterns, and it can only influence, not over ride, them. Some researchers suspect, for example, that southern Africa defied expectations because the modelers didn't take into account something known as the Quasi-Biennial Oscillation, a switch in the direction of stratospheric winds that occurs every two years or so; it happened to switch this year. Also, some pretty spectacular weather in 1998 probably had little to do with El Nino. The summer floods on the Yangtze River in China, for instance-although it was suggested that they were partly the result of El Nino, no link has been scientifically demonstrated.

Still, from late 1997 into the spring of 1998, this El Nino proved itself to be a global powerhouse, perhaps the biggest of the century. Thanks to the induced dryness, fires set by farmers and loggers raged out of control in Indonesia last winter; in February and March the spark hit Brazil. Some places in Canada had February weather more than 15 degrees above average. Tampa, had three times more rain than average between November and April; the Caroline Islands had a sixth as much. Seabirds and marine mammals died in droves as the fisheries of the western Pacific collapsed. Late in the life of an El Nino, it typically intensifies the jet stream over the United States in such a way that it keeps it from drifting south over the Gulf States. This year was no exception, and as a result Texas withered under a brutal drought in spring and early summer.

By the time the next El Nino arrives, scientists hope to be able to give much better forecasts. To that end, Lamont-Doherty and Scripps have joined forces to create the International Research Institute for Climate Prediction. At the moment, the institute is nothing more than a few stakes in the ground on Lamont-Doherty's property along the Hudson River in New York. But by this October it will take the form of a sleek low building housing 80 scientists, all dedicated to making climate predictions up to a year in advance.

Much of their effort will have to go into making better computer models. Rather than relying on the historical averages of El Ninos behavior, they will be trying to simulate the whole shebang, from the initial slosh of the Pacific to the downpours in Kenya. Ultimately, the researchers hope to take what they learn about El Nino and use it to understand trickier oscillations in other parts of the world's ocean, such as the rise and fall of sea surface temperatures in the North Atlantic. That might make it possible to reliably predict climate many months in advance even in years without a big El Nino. "As exciting as it is, El Nino is a small part of the whole show," says Chet Ropelewski, a meteorologist at the institute.

The institute's stated purpose is to help people better survive the extremes of weather through climate prediction, but there are many pitfalls to long-range forecasting. For instance, researchers talk of the likelihood that a given year will fall into the top, middle, or bottom third of the historical ranges of rainfall or temperature. From January to March, Zimbabwe was forecast to have a 50 percent chance of having rainfall in the bottom third, a 35 percent chance of having it in the middle third, and a 15 percent chance of having it in the top third.

That's a carefully hedged prediction, but the word on the street in Zimbabwe last fall was much simpler: a big drought was coming. Banks tightened credit for fear that farmers wouldn't be able to pay their loans, and farmers were forced to plant fewer crops. Northern Zimbabwe, where most of the farming is done, actually received normal rainfall, but because of the worry, crop production dropped by 20 percent. As their powers of prediction improve, meteorologists are discovering a Hippocratic challenge to their work: First, do no harm.

In May, El Nino took a tumble. The waters off western South America chilled as much as 12 degrees in a matter of 20 days. This was a very dramatic event, since water has a tremendous heat capacity. The top few yards of the ocean can hold the same amount of heat as the entire atmosphere. The cooling of the eastern Pacific in May thus meant the sudden disappearance of a vast amount of energy. "We've never seen anything like that," says Tony Busalacchi, an oceanographer at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Much of the warm water was headed back west. It was lurching so far back, in fact, that in June the Climate Prediction Center forecast that conditions would swing over into a La Nina. The eastern Pacific continued to cool as 1998 progressed, and the emerging La Nina made itself known with a string of hurricanes that began hammering the southeastern United States. After 1997's El Nino-induced reprieve, the hurricane business was returning to normal.

In the next few months, if climate models are on target, La Nina will reach adulthood. A giant warm pool in the western Pacific will trigger lots of thunderstorms in Southeast Asia and northern Australia, places that were dry last year. By bending the jet streams, La Nina will create dry conditions in southern California and the southeastern United States as well, while western Canada and the northern United States will have a cold, wet winter. La Nina will probably disappear in the spring, and by summer its effects may have subsided, allowing the world to return, finally, to some semblance of normal weather.

The models still disagree, though, on the intensity of the coming La Nina. "A lot of us are looking to see how large this La Nina becomes," says Busalacchi. Their interest isn't simply in tinkering with their simulations. The way La Nina plays out in the next few months--relatively quiet and brief or long and intense--may offer a clue to what the world's weather is going to be like in the next century.

There are signs, for example, that the power and the frequency of El Ninos and La Ninas may rise and fall according to vast cycles of the Pacific Ocean. It's clear that from decade to decade the nature of El Ninos does change. From 1885 to 1915, for example, El Ninos were powerful, but from 1915 to 1950 they were minuscule. After 1960 they picked up again, and since the late 1970s they've been very big. The variation of El Ninos before the late 1800s is harder to figure out because weather data are so sparse. Some clues can be found in the way El Nino's heavy rains and dry spells affect the growth rates of trees and corals, and studies of them suggest that its rise and fall also extends back many centuries.

Researchers still have only the dimmest ideas of what might be driving these variations. Busalacchi and his colleagues may have found a clue recently when they looked at the changes that El Nino underwent in the late 1970s. Combing through ocean temperature readings, they found signs of a "tongue" of warm water flowing hundreds of feet below the surface of the Pacific. In the early 1970s it was in the northern ocean; by the end of the decade it had reached the tropics.

They suggest that this tongue might be making a full circuit through the ocean every few decades or so. Currents carry warm tropical surface water northward, and the water becomes salty as it evaporates. Salt makes water dense, so at some point this water sinks below the surface. Swept along by underwater currents, this parcel of water moves back to the equator. The equatorial Pacific thus gets an infusion of heat, which may act as a jolt to the El Nino pendulum. More intense El Ninos might be the result, and perhaps fewer of the cooler La Ninas. "If you change the background state of El Nino, you're going to get a change in the character of El Nino" says Busalacchi. "But the studies haven't been done yet to really quantify what that means."

If some slow dance of the Pacific is indeed responsible for the character of El Nino, then the powerful El Ninos of recent years should be coming to an end. "We've been in this prolonged warming state for the 1990s, and the work we do would tend to show that we're overdue to go into the cold phase," says Busalacchi.

In the opinion of researchers such as Kevin Trenberth, however, we may have moved beyond a natural timetable. Trenberth, an atmospheric scientist at the National Center for Atmospheric Research in Boulder, Colorado, was so struck by the recent spate of El Ninos that he decided to analyze them statistically. He reviewed the most reliable, continuous measure of El Nino's effects, a series of air-pressure readings at Darwin, Australia, that reaches back to 1882. He found that statistically speaking, the past 20 years have been decidedly strange compared with the past century. "There were about 24 El Ninos and 24 La Ninas in the first hundred years of the record," says Trenberth, "and then in the last 20 years of the record there have been 7 El Ninos and 3 La Ninas. If you assume the climate is not changing, then the odds of this actually happening are once in 2,000 years, which is fairly rare. The odds are that something else is influencing it."

That something else might, according to Trenberth, be global warming. Carbon dioxide, released into the atmosphere through activities such as burning coal, traps heat and may be able to raise the temperature of the planet. In the past century the amount of carbon dioxide has increased by 30 percent, and the global climate has warmed by a little over 1 degree.

A warming world, Trenberth thinks, could change the pattern of El Nino, given the role that it plays for the Pacific. "There's a build-up of heat in the Pacific," he says, "and El Nino is a mechanism for getting the heat out. First, all of the heat moves eastward across the Pacific, and then it moves out of the Pacific in the course of heating up the atmosphere. If you have extra heat going into the Pacific, then the recovery stage should be quicker, and so the La Ninas don't last as long before you are back to a stage where you've got surplus heat."

Trenberth's suggestion is quite controversial, given that he's using only a century's worth of data to decide how unusual 20 years' worth of weather has been. "What we're all talking about when we're looking at these last few decades is, after all, a very short period of time," says Mark Cane. "There's a lot of natural variability in the climate system, so it's hard to know it isn't a statistical accident when you see something like that. Maybe it just happens, or maybe it has something to do with global warming."

How this La Nina and future ones play out will help show whether Trenberth is right. His case would certainly be strengthened by another small La Nina in the next few months, followed not very long afterward by another big El Nino.

If global warming has indeed taken off, and if it continues in decades to come, some climatologists think that a general rise in temperatures may make El Ninos still more dramatic. Gerald Meehl, a climatologist at the National Center for Atmospheric Research, has been running simulations of the atmosphere and oceans with his colleagues in which they gradually increased the level of carbon dioxide. The planet grew warmer, but not uniformly. One of the biggest imbalances could be found in the Pacific, where the eastern ocean became up to 4 degrees hotter than the ocean in the west.

"We figured it had something to do with cloud feedbacks and we've confirmed that," says Meehl. The system involves relative degrees of evaporation, cloud formation, and reflection of solar radiation away from the surface in the eastern and western Pacific. The ultimate effect, though, is a set of events similar to those that characterize the onset of an El Nino. "Once you kick into one direction," says Meehl, "toward an El Nino type of response, it keeps going in that direction due to these feedbacks."

In other words, global warming might create a sort of permanent El Nino. But according to Meehl, the oscillations we experience every few years might still take place in this new world. "As time went on, the trend would be toward greater warming in the east as opposed to the west, but superimposed on that you'd still have El Nino and La Nina events. If the base state is already altering to look more like El Nino, and then you put an El Nino on top of that, the juxtaposition of them would give you a whopping impact."

The work of these researchers, combined with El Nino's power this year, has made clear that it is far more than a matter of the occasional bad fish catch. El Nino represents the fickleness of a powerful ocean that can focus its energy on the world's weather with stunning swiftness. Cane and Zebiak have recently been studying the quirkiness of the Pacific on the scale of hundreds of thousands of years. One of the most startling things they've found is the ability of the ocean--even without the push of extra carbon dioxide--to sometimes shift abruptly into an El Nino-like pattern and then stay that way for thousands of years.

Cane speculates that by behaving this way, the Pacific may go so far as to kick the planet in and out of ice ages. Researchers have been studying the past few hundred thousand years of the planet's climate with newly dug-up ice cores, and they've been stumped by drastic, sudden swings between cold and hot, swings that happen in a few decades and leave the climate altered for millennia. Cane thinks something akin to today's El Ninos might have been at work. If the Pacific should switch to an El Nino pattern, a combination of global weather patterns--a warming of the planet, a melting of some of the ice sheets, an increase in heat-trapping water vapor in the atmosphere--could all combine to throw the global climate into a new state.

Cane himself admits that his extrapolating from today's El Nino to the past may be "outrageous." Extrapolating into the future is even more hazardous. Yet it's possible, and certainly worth contemplating, that someday El Nino will stop making the occasional visits we're now used to and settle in for a long, long stay.

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Add a new accomplishment to the long resume of this year's El Nino: it slowed down the planet. As westward trade winds slackened and eastward jet streams sped up, El Nino made the atmosphere move faster in the direction of Earth's rotation. The total momentum of Earth and its atmosphere is fixed, so in compensation for the strong winds, the planet's rotation had to slow down. At its strongest, El Nino added .7 millisecond to each day in February. What El Nino giveth, La Nina taketh away: as of November, it was shaving .2 millisecond off each day.

CARL ZIMMER ("The El Nino Factor," page 98) is a senior editor of DISCOVER, the winner of the 1997 American Institute of Biological Sciences Media Award, and the author of *At the Water's Edge*.

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