Climate Change: Summary Issues

Science News April 16 2016

Hurricanes

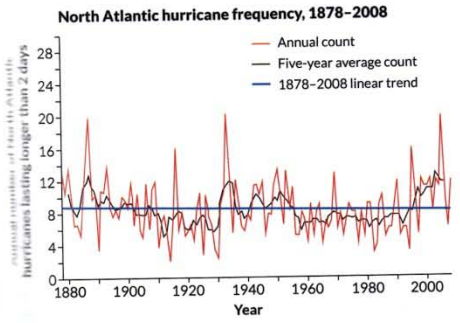
2006: The warming ocean could fuel more frequent and more intense Atlantic hurricanes.
2016: Hurricane frequency has dropped somewhat; hurricane intensities haven't changed much — yet.

In August 2005, Hurricane Katrina slammed into the Gulf Coast. Floodwaters covered roughly 80 percent of New Orleans, 1,836 people died, hundreds of thousands became homeless and the most active Atlantic hurricane season on record was far from over. As the last storm fizzled, damages had reached $160 billion, meteorologists had run through the alphabet of preselected storm names and many people, including Gore, were indicting global warming as a probable culprit.

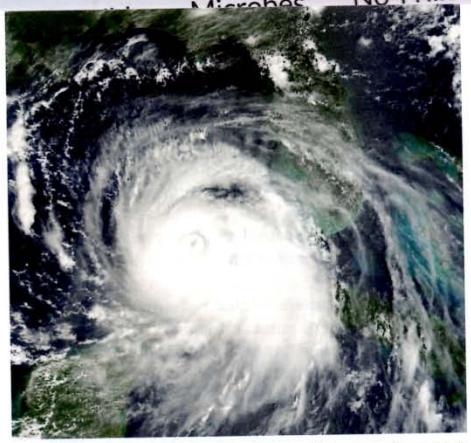
"Hurricanes were the poster child of global warming," says Christopher Landsea, a meteorologist at the National Oceanic and Atmospheric Administration's National Hurricane Center in Miami. "In reality, it's a lot more subtle than that."

Tropical cyclones, such as Atlantic hurricanes, are stirred up where seawater is warmer than the overlying air. Because climate change raises ocean temperatures, it made sense that such storms could strike more often and with more ferocity. A closer look at hurricanes past and future suggests, however, that the relationship between warming and hurricanes is less clear-cut.

Several studies in the mid-2000s examining the history of Atlantic hurricanes pointed to an overall rise in the number of 20th century storms in step with warming sea surface temperatures. Scrutinizing those numbers, Landsea uncovered a problem: Hurricane-spotting satellites date back only to 1961's Hurricane Esther. Before then, storm watchers probably missed many weaker, shorter-lived storms. Taking this into account, Landsea and colleagues reported in 2010 that the number of annual storms has actually decreased somewhat over the last century.



Steady storms The record-smashing 2005 hurricane season raised concerns that storms were becoming stronger and more frequent. Yet, closer look at the long-term trends revealed that Atlantic hurricane frequency has not significantly changed since 1878.
SOURCE: C. LANDSEA/NHC/NOAA



Hurricane Katrina strengthened to a Category 5 storm over the Gulf of Mexico's warm waters in 2005. Rising ocean temperatures have raised concerns that strong storms will strike more often in the future.

That decrease could be explained by climate factors other than rising sea surface temperatures. Changes in atmospheric heating can increase the variation in wind speed at different elevations, known as wind shear. The shearing winds rip apart burgeoning storms and decrease the number of fully formed hurricanes, researchers reported in 2007 in *Geophysical Research Letters*.

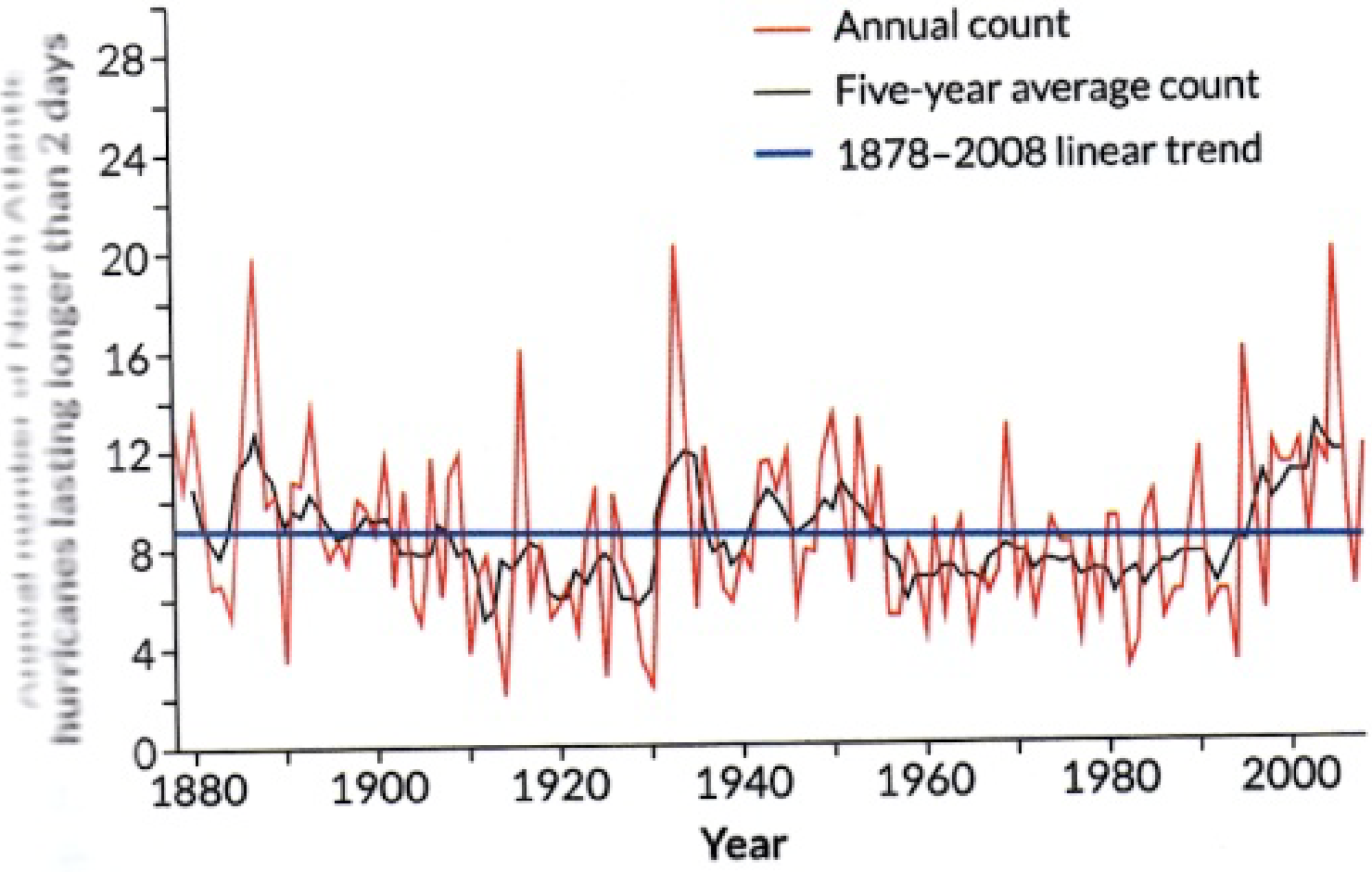
The overall frequency of storms, however, is less important than the number of Katrina-scale events, says Gabriel Vecchi, an oceanographer at NOAA's Geophysical Fluid Dynamics Laboratory in Princeton, N.J. Category 4 and 5 storms, the most violent, make up only 6 percent of U.S. hurricane landfalls, but they cause nearly half of all damage. Vecchi and colleagues used the latest understanding of how hurricanes form and intensify to forecast how the storms will behave under future climate conditions.

The work, published in 2010 in *Science*, predicted that the frequency of Category 4 and 5 storms could nearly double by 2100 due to ocean warming, even if the overall number of hurricanes doesn't rise. At present, however, climate change's influence on hurricanes is probably too small to detect, Vecchi says, adding that Katrina's wrath can't be blamed on global warming.

Future hurricanes will cause more damage, Landsea predicts, whether or not there's any change in storm intensity. Rising sea levels mean floodwaters will climb higher and reach farther inland. Hurricane Sandy, which stormed over New Jersey and New York in October 2012, had weakened by the time it reached the coast. But it drove a catastrophic storm surge into the coastline that caused about $50 billion in damages. If sea levels were higher, Sandy's surge would have reached even farther inland and damage could have been much worse.

Many vulnerable areas such as St. Petersburg, Fla., are woefully underprepared for threats posed by storms at current sea levels, Landsea warns. Higher sea levels won't help. "We don't need to invoke climate change decades down the line — we've got a big problem now," he says.

North Atlantic hurricane frequency, 1878–2008



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RCE: C. LANDSEA/NHC/NOAA

Ocean Circulation

2006: Freshwater flowing into the North Atlantic could shut down the ocean conveyor belt that shuttles warm water toward Western Europe.
2016: The ocean conveyor belt may already be slowing, but it's not much of a conveyor belt at that.

Last year may have been Earth's hottest on record (*SN: 2/20/16, p. 13*). But for one small corner of the globe, 2015 was one of the coldest. Surface temperatures in the subpolar North Atlantic have chilled in recent years and, oddly enough, some research suggests global warming is partly responsible.

An influx of freshwater from melting glaciers and increasing rainfall can slow — and possibly even shut down — the ocean currents that ferry warm water from the tropics to the North Atlantic. About 10 years ago, scientists warned of a possible abrupt shutdown of this "ocean conveyor belt." After years of closely monitoring Earth's flowing oceans, researchers say a sudden slowdown isn't in the cards. Some researchers report that they may now be seeing a more gradual slowing of the ocean currents. Others, meanwhile, have discovered that Earth's ocean conveyor belt may be less of a sea superhighway and more of a twisted network of side roads.

The consequences of a sea current slowdown won't be anywhere near as catastrophic as the over-the-top weather disasters envisioned in the 2004 film *The Day After Tomorrow*, says Stephen Griffies, a physical oceanographer at NOAA's Geophysical Fluid Dynamics Laboratory. "The doomsday scenario is overblown, but the possibility of a slowing down of the circulation is real and will have important impacts on Atlantic climates," Griffies says.

The Atlantic mixing that feeds the currents is powered by differences in the density of seawater. In the simple ocean conveyor-belt model, warm, less-dense surface water flows northward into the North Atlantic. Off Greenland, cold, denser water sinks into the deep ocean and flows southward. This heat exchange, known as the Atlantic overturning circulation, helps keep European cities warmer than their counterparts elsewhere in the world.

Ten years ago, scientists knew from past changes in Earth's climate that temperature shifts can disrupt this density balance. Freshwater from the shrinking Greenland ice sheet and increased rainfall make the North Atlantic waters less dense and therefore less likely to sink. Investigations into Earth's ancient climates show that the overturning circulation weakened around 12,800 years ago, probably causing cooling in Europe and sea level rise along North America's East Coast, as piled-up water in the north sloshed southward.

Tracking sea surface temperatures, researchers reported last year that the Atlantic overturning circulation significantly slowed during the 20th century, particularly after 1970. Comparing the recent slowdown with past events, the researchers reported in March in *Nature Climate Change* that the rapid weakening of the circulation is unprecedented in the last 1,000 years.

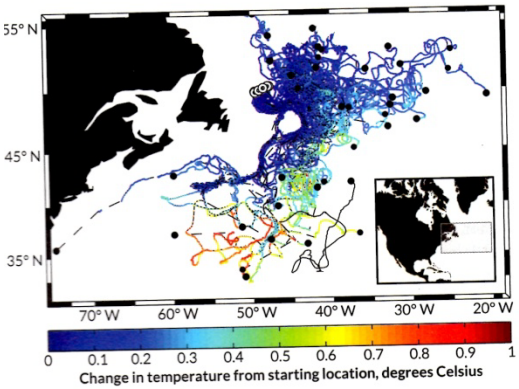
That result isn't the final word, though, says Duke University physical oceanographer Susan Lozier. Scientists have directly measured the speed of the ocean circulation only since the deployment of a network of ocean sensors in 2004. Earlier Atlantic circulation speed changes have to be gleaned from less reliable indirect sources such as sea surface temperature changes. "If you look at the most recent results, there's a decline, yes," she says. "But we can't say that's part of a long-term trend right now." And effects on Europe's climate could be masked by other factors.

Another challenge is that over the last 10 years, "the ocean conveyor-belt model broke," Lozier said in February at the American Geophysical Union's Ocean Sciences Meeting in New Orleans. From 2003 through 2005, she and colleagues tracked the movements of 76 floating markers dropped into the North Atlantic and pulled around by ocean waters. If the model was right, these markers should have traveled along the southward-flowing part of the conveyor belt. Instead, the markers moved every which way, the researchers reported in 2009 in *Nature*.

"We went from this simple ribbon of a conveyor belt to a complex flow field with multiple pathways," Lozier says. Determining past and possible future effects of climate change on ocean currents will require more measurements and a better understanding of how the ocean truly flows, she says.

Even if the overturning circulation cuts out completely, the resulting cooling effect will probably be short-lived, Griffies says. "At some point, even if the circulation collapses, it would only be 10 or 20 years before the global warming signal would overwhelm that cooling" in Europe, he says. "This is not going to save us from a warmer planet."

Every which way Tracking the motion of floating markers dropped into the northwest Atlantic (white-rimmed circles), researchers found that the idea of an ocean conveyor belt is overly simplistic. The markers quickly split up, ending up in many different destinations (solid circles).



AMY S. BOWER ET AL/NATURE 2009

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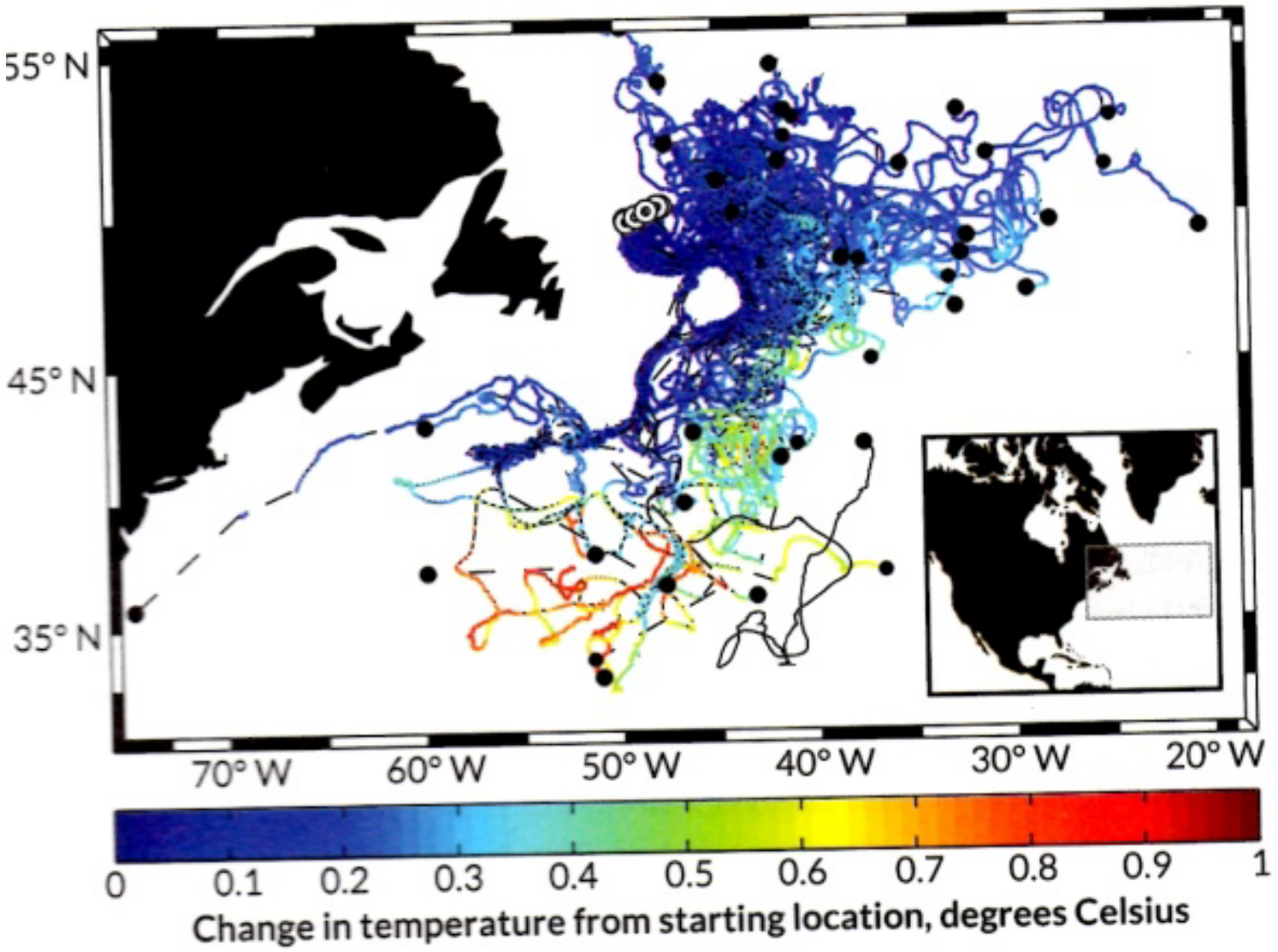


Drought conditions worsened by climate change helped fuel the civil unrest that led to 2011's Syrian civil war. Global security experts worry that continuing climate change will help spark more conflicts.

Drought, Climate and Conflict

2006: Climate change exacerbated droughts that contributed to regional conflicts, such as the war in Darfur.
2016: Drought conditions worsened by climate change helped spark the Syrian civil war.

Following escalating unrest and a wave of demonstrations across the Arab world, a bloody civil war broke out in Syria in 2011. The ongoing conflict sparked an international crisis and has left hundreds of thousands of people dead and millions more displaced. While the root cause of the conflict centered on clashes between the Syrian government and its people, multiple studies argue that climate change helped stoke the flames of rebellion.

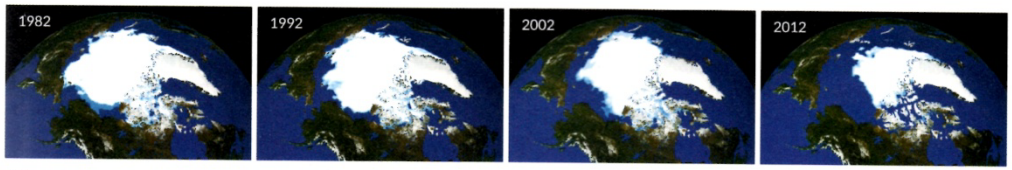
Mounting evidence from around the world has indicted climate change in several recent severe droughts from Syria to California. Computer simulations and direct measurements of weather patterns show that climate change can redirect the paths of rainstorms and cause higher temperatures that dry out soil.

In March 2015 in the *Proceedings of the National Academy of Sciences*, researchers estimated that decades-long shifts in Syria's rainfall and temperatures doubled or even tripled the severity of the three-year drought that preceded the Syrian civil war. Using tree rings, a separate group reported this March in the *Journal of Geophysical Research: Atmospheres* that 1998 through 2012 was the driest period in the Eastern Mediterranean since at least 1100.

The recent drought upset regional food security, prompted a mass migration into urban areas and emboldened anti-government forces, 11 retired U.S. admirals and generals wrote in a 2014 report published by CNA, a nonprofit research and analysis organization in Arlington, Va. The clash joins another conflict partly pinned on climate change: the war in Darfur, which broke out in 2003 following a decades-long drop in regional rainfall.

Since the 1970s, droughts have become longer and more severe across the globe, and scientists expect that trend to continue. Dwindling agricultural production in certain high-population areas such as parts of Africa could lead to food shortages that spark refugee crises, the report warned.

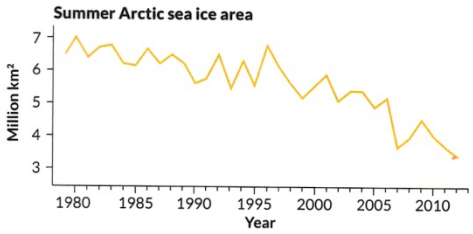
"We see more clearly now that while projected climate change should serve as a catalyst for change and cooperation, it can also be a catalyst for conflict," the retired admirals and generals wrote.



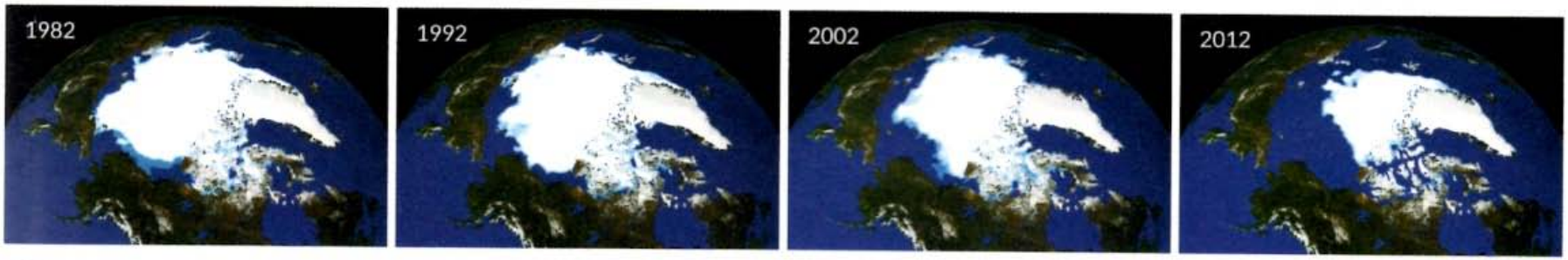
Arctic Ice

2006: The Arctic could see its first sea ice–free summers in the next 50 to 70 years.
2016: Arctic summer sea ice may disappear as early as 2052.

The top of the world could see its first iceless summer roughly a decade sooner than thought in 2006, according to a 2015 report (*SN Online: 8/3/15*). Simulating how sea ice interacts with the ocean using the latest understanding of how sea ice and climate interact, scientists estimated that the North Pole will be ice-free around 2052, nine years earlier than previous simulations suggested. Last year saw the fourth smallest footprint of summer sea ice in the Arctic on record. Ice-free Arctic summers would open the region to shipping and could affect climates elsewhere by redirecting the winds that circle the North Pole, the researchers wrote. The loss of reflective sea ice could also hasten warming as the dark ocean absorbs more sunlight. Newly open passages may also allow mingling of animals from formerly separated habitats (*SN: 1/23/16, p. 14*).



Open water Rising temperatures in the Arctic have dwindled the extent of summer sea ice. Since 1979, the minimum summer sea ice extent has decreased more than 7.5 percent per decade. An expanding Arctic Ocean could have major impacts for ecosystems and economies. SOURCE: NSDIC



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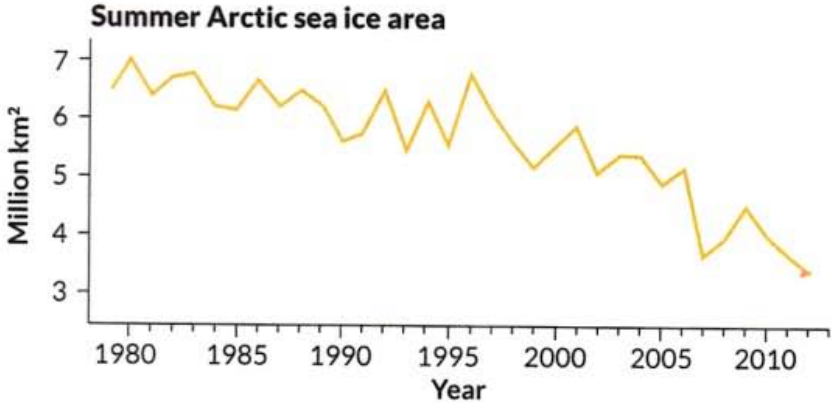

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Antarctica's Larsen B Ice Shelf collapsed into hundreds of icebergs in 2002, speeding the melt of its tributary glaciers.

Antarctic Ice Sheet

2006: Rising temperatures are warming the Antarctic and melting the West Antarctic Ice Sheet.
2016: The West Antarctic Ice Sheet could cross a point of no return.

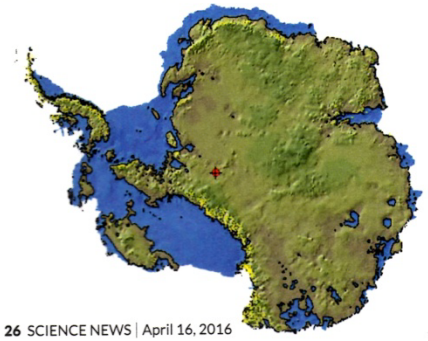
In 2002, an ice behemoth crumbled. Antarctica's Larsen B Ice Shelf, after 12,000 years of frozen stability, collapsed. The breakdown rapidly shattered 3,250 square kilometers of ice — an area about the size of Rhode Island (*SN: 10/18/14, p. 9*).

"Larsen B was a real wake-up call," says Maureen Raymo, a marine geologist at Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y. "It was like, 'whoa, this ice shelf didn't just slowly retreat on its edge — the whole thing just collapsed catastrophically over the course of two weeks.'"

Now with 10 years of on-the-ice research, scientists warn that the rest of the West Antarctic ice could share a shockingly swift fate unimaginable a decade ago. The ice sheet's collapse would raise global sea levels by about 3 meters (*SN: 6/14/14, p. 11*).

Ice shelves line about 45 percent of the Antarctic coast and help slow the flow of the continent's ice into the sea. For healthy ice shelves, the flow of ice from inland balances losses from melting and icebergs snapping off the shelf's seaward edge. Rising temperatures below and above the ice can fracture and thin the ice, upsetting this balance.

Farewell, ice As Antarctica's ice melts, warm seawater will flow through low-lying channels currently filled with ice and accelerate further melting. An ice-free Antarctica (beige area) would leave less land above sea level (blue shows footprint of current continent).



The loss of just a few ice shelves in the West Antarctic Ice Sheet could destabilize the whole region, according to new research by climate scientists Anders Levermann and Johannes Feldmann of the University of Potsdam in Germany. In a computer simulation, the researchers found that the loss of a few key ice shelves around Antarctica's Amundsen Sea would trigger a domino effect. Seawater would flow into the flanks of other ice and expedite melting. Such a collapse would annihilate the entire West Antarctic Ice Sheet within hundreds to thousands of years, they predict.

Once started, this chain reaction would be unstoppable, the researchers reported last November in the *Proceedings of the National Academy of Sciences*. Even if global temperatures return to normal, the ice sheet would still be doomed, according to the simulation. In 2014, researchers reported that one of those keystone ice shelves, the Thwaites Glacier, is on track to recede past an underwater ridge currently stalling its retreat and undergo catastrophic collapse in as few as two centuries.

Exactly what magnitude of warming will push the West Antarctic Ice Sheet past the point of no return remains uncertain, says Richard Alley, a glaciologist at Penn State. "It's hard to predict how the ice will fracture," he says. "That's why you don't want to tiptoe up on the disaster point. The edge between 'it's still there' and 'it's had a catastrophic failure' is something to be completely avoided."

The other half of the Antarctic continent has shown more resistance to climate change, and hasn't kept up with the global warming trend of the last few decades. That's good news, since the East Antarctic Ice Sheet holds more water than its sibling — enough to raise sea levels by about 60 meters if it fails.

Last year, however, researchers using radar to penetrate the Antarctic ice announced that East Antarctica's largest glacier, Totten Glacier, is still vulnerable. It may be at risk from encroaching ice-melting seawater. Radar maps revealed two seafloor troughs that could allow warm ocean water to melt the glacier's underside, the researchers reported in *Nature Geoscience*. The glacier alone holds enough water to raise global sea levels by at least 3.3 meters, though its collapse could take centuries, the researchers noted.

FROM TOP: TED SCAMBOS/NATIONAL SNOW AND ICE DATA CENTER; MARK HELPER/UNIV. OF TEXAS AT AUSTIN

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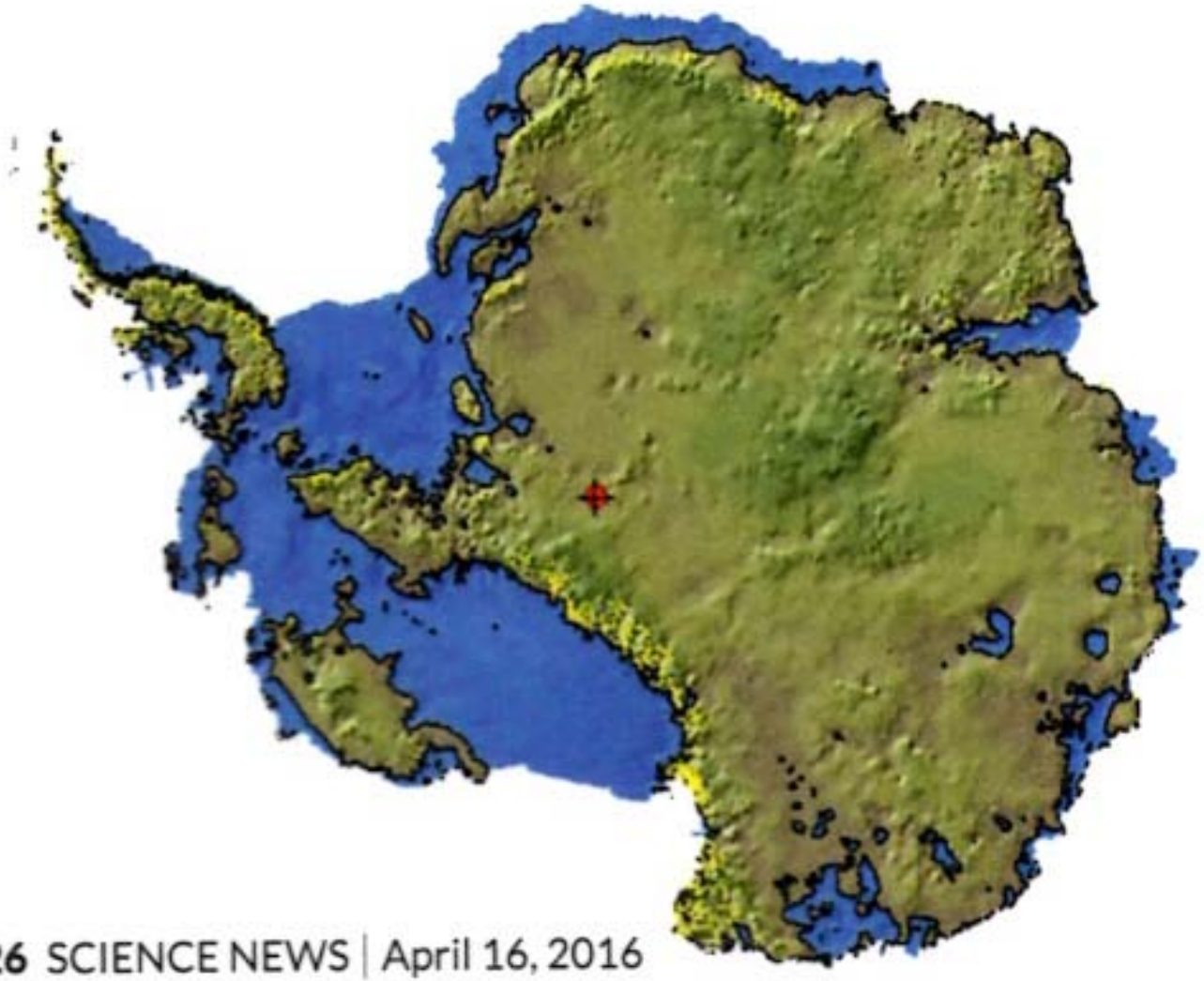


Sea Level Rise

2006: Melting ice and expanding seawater are raising global sea levels.

2016: Historical evidence suggests sea levels can rise more than 10 times as fast as they are now.

Expanding seawater and melting ice threaten the very existence of many island nations, including the Maldives. As climate change continues, rising sea levels could reshape Earth's coastlines.

In the Indian Ocean, a city seems to rise out of the waves. The island of Malé, the capital of the Maldives and home to more than 150,000 people, sits just two or three meters above sea level (*SN: 2/28/09, p. 24*). The residents of Malé are a small portion of the approximately 200 million people worldwide living along coastlines within five meters of sea level. By the end of the century, as sea levels reach inland and coastal communities grow, the population at risk of rising waters may balloon to as high as 500 million.

The global average sea level currently rises about three millimeters per year, with a meter of total sea level rise expected by 2100 if carbon emissions aren't curtailed. Some areas, such as the U.S. East Coast, are experiencing even faster sea level rise. In February, researchers reported in the *Proceedings of the National Academy of Sciences* that 20th century sea level rise was faster than any other century since Rome was founded (*SN: 4/2/16, p. 20*).

While sea levels are rising fast, they have the ability to climb even faster. Scientists are looking further into the future and investigating just how fast sea level rise could get, especially with a hypothetical collapse of the Antarctic ice sheets. Results gleaned from past warm periods suggest that sea levels can rise much faster than suggested just a few years ago — more than 10 times the present rate.

"Sea level is probably the biggest irreversible risk of global warming," Columbia's Raymo says. "I expect a hell of a lot more people are going to be personally impacted by a one-meter rise in sea level than by the extinction of the grand ladybug of something or other."

Most records of ancient climates provide only a snapshot of how high sea levels have reached at a given time, not how quickly they moved up or down. But on a 2005 expedition to Tahiti, a research team caught a break. Because coral reefs require plenty of light to thrive, they typically take root in waters shallower than 10 meters deep. As sea levels rose in the past, corals moved higher up the newly submerged coastline. Off the coast of Tahiti, the researchers sampled fossils of ancient corals from the last 150,000 years buried in layers of ocean sediment. Dating the corals using the known decay rate of radioactive uranium into other elements, the researchers created an accurate, long-term sea level record.

200
million
Approximate number of people worldwide living along coastlines within five meters of sea level

Around the end of Earth's last glacial period, about 14,650 years ago, sea levels rose about 14 to 18 meters, the researchers reported in 2012 in *Nature*. What surprised those researchers is how quickly this rise happened: Sea levels rose at least 46 millimeters per year during that period. The scientists concluded that at least half of the 14 meters of sea level rise during this bout of warming originated from melting Antarctic ice.

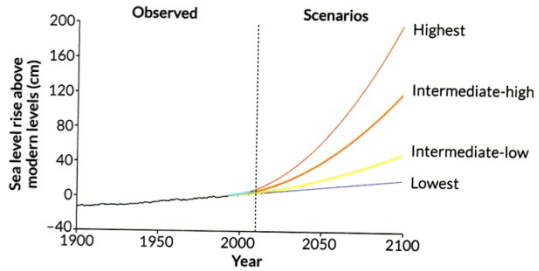
"The scary thing, and this is why it's kind of apocalyptic, is that once you start these things, they don't stop," Raymo says. "Everything we see shows that, if you look in the past, each increment of warmth seems to correlate with increasingly higher sea level."

Raising the stakes Projections of future sea level rise vary, but scientists warn that even a small increase in sea level can worsen flooding and change coastlines. Sea level rise primarily stems from two sources: the thermal expansion of seawater and meltwater from land-based ice.

SOURCE: NOAA, *GLOBAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES NATIONAL CLIMATE ASSESSMENT* 2012

Global average sea level rise by 2100: four scenarios

Scenario	Rise in meters	Influences
Highest	2.0	Increased rate caused by ocean warming combined with maximum potential glacier and ice sheet loss
Intermediate-high	1.2	Increased rate caused by ocean warming and limited ice sheet loss
Intermediate-low	0.5	Increased rate caused by ocean warming only
Lowest	0.2	Linear extrapolation of historical rate since 1900 (no increased rate)



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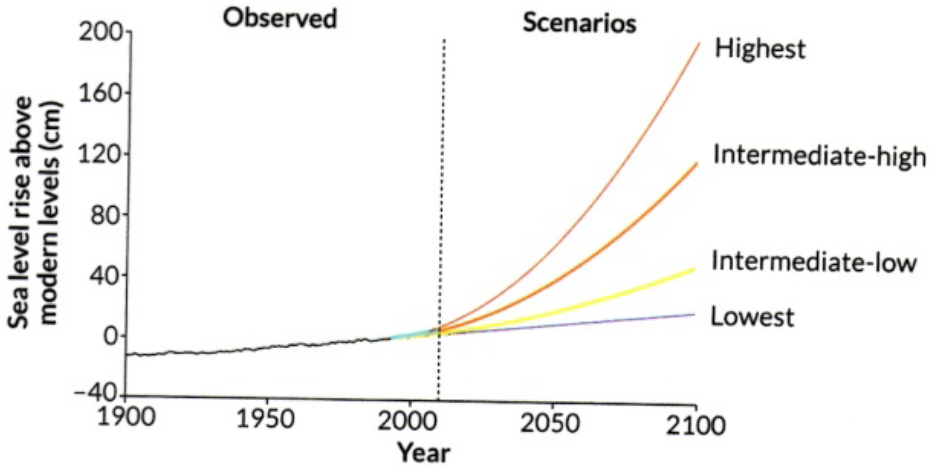


Scorching temperatures killed hundreds of people last year in Pakistan. Continued global warming will increase the risk of heat-related deaths, researchers warn.

Extreme Temperatures

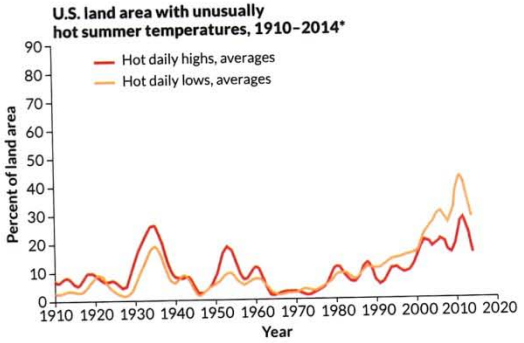
2006: Warming temperatures will cause more frequent and more deadly heat waves.
2016: Humidity may make future heat waves deadlier; cold snaps are on the decline.

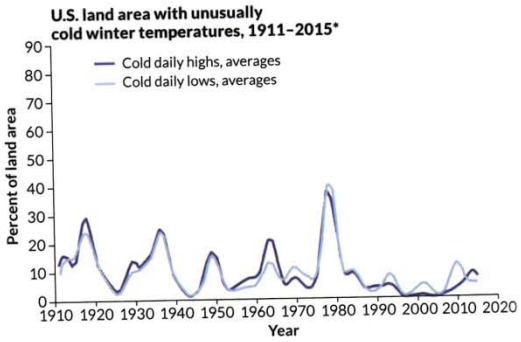
Last summer, sweltering heat waves scorched India and Pakistan. The extreme temperatures killed thousands of people and were two of the deadliest heat waves since 1900. Such lethal heat will become more common as the planet continues warming, climate scientist Ethan Coffel of Columbia University said last December at the American Geophysical Union's fall meeting.

The problem, Coffel said, is that climate change will raise humidity in many places alongside temperature as hot air wicks up more moisture. The evaporation of sweat keeps people cool when it's hot, but high humidity can slow or even shut off this skin-cooling evaporation. Rising humidity will make rising temperatures more deadly than previously feared, he said. By the 2060s, Coffel predicts, 250 million people worldwide could face deadly levels of heat and humidity at least once a year.

While heat waves worsen, researchers say that another killer weather phenomenon will become less common. The frequency of abnormally cold periods in North America will decrease by roughly 20 percent by the 2030s, researchers reported last year (*SN Online: 4/2/15*). The work overturned previous projections of a rise in cold snaps over the coming decades as climate change redirects frigid Arctic winds. From 2006 through 2010, about twice as many people in the United States died from cold-related causes, such as hypothermia, than from excessive heat.

Less extreme cold Since the early 1900s in the United States, climate change has increased the frequency of abnormally hot summer days. But an expected rise in cold snaps has not played out. Areas hit by unusually cold temperatures in winter are declining. SOURCE: NOAA 2015





Contiguous 48 states

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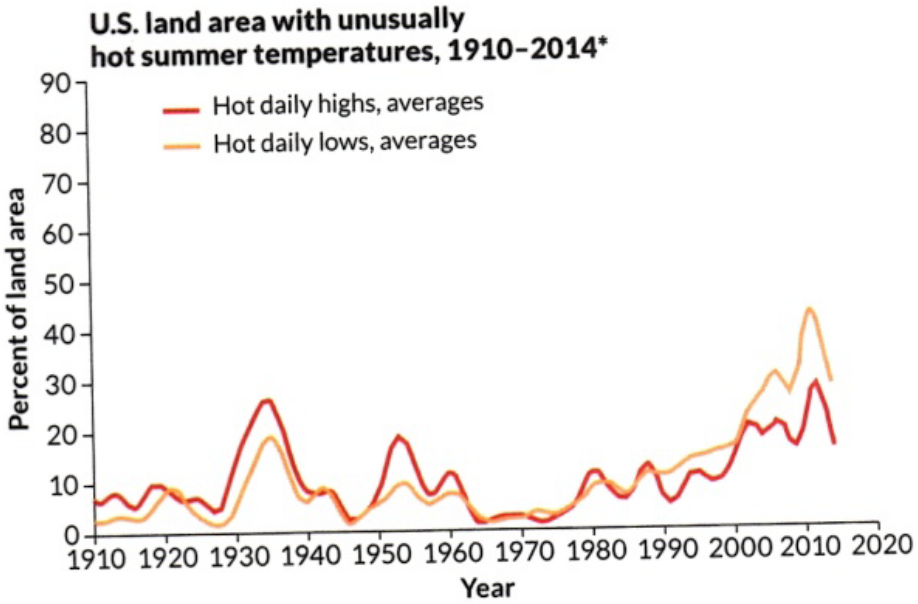
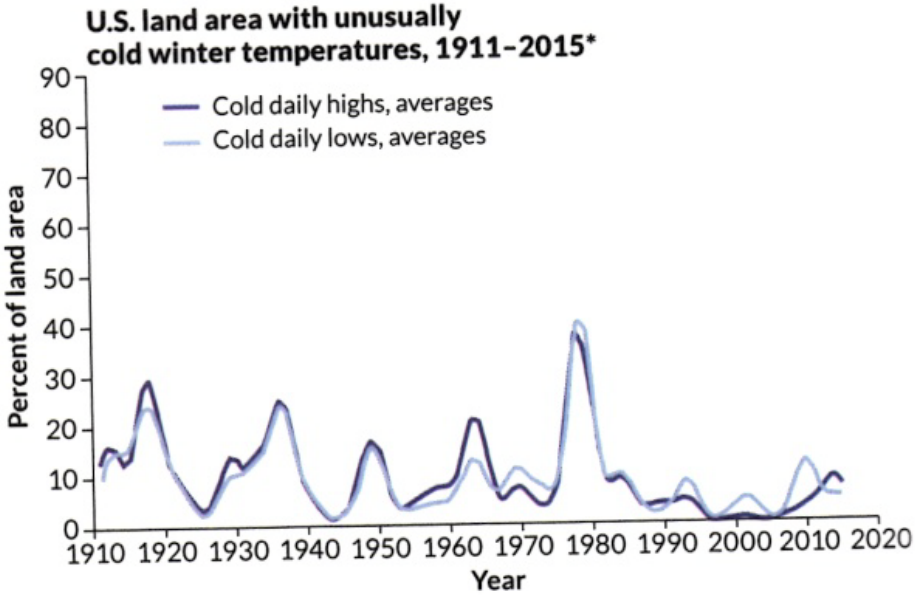
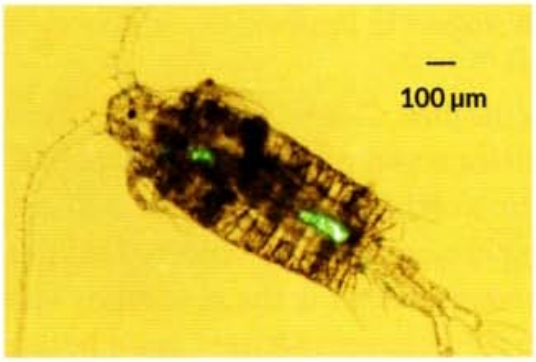


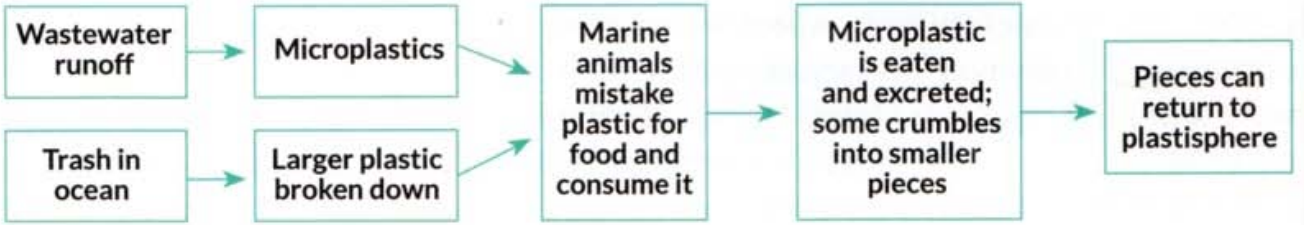


Plastic Pieces
In the Ocean

Science News
February 20, 2016



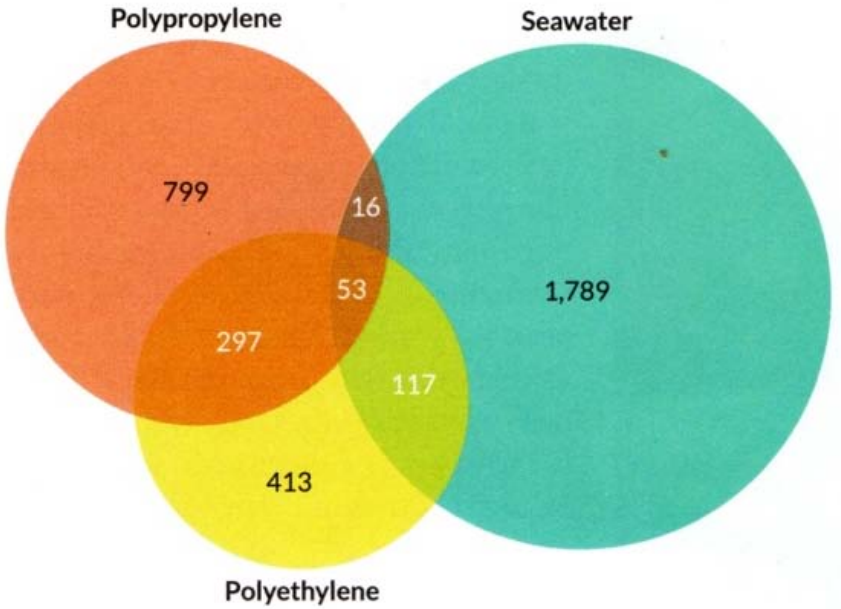
Land-to-sea journey Ocean plastic comes from wastewater and trash. Hungry ocean critters, like the copepod to the left, sometimes ingest the plastic (shown in green). After the plastic is pooped out, it can rejoin the plastisphere. SOURCE: M. COLE *ET AL/ENVIRON. SCI. TECHNOL.* 2013



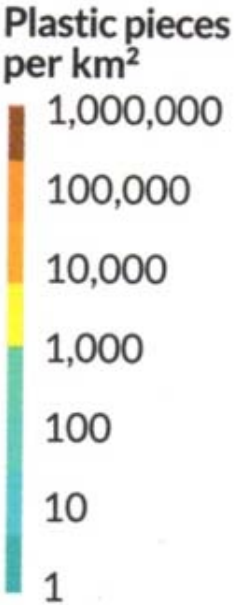
FEATURE | FLOATING FORTRESS OF MICROBES

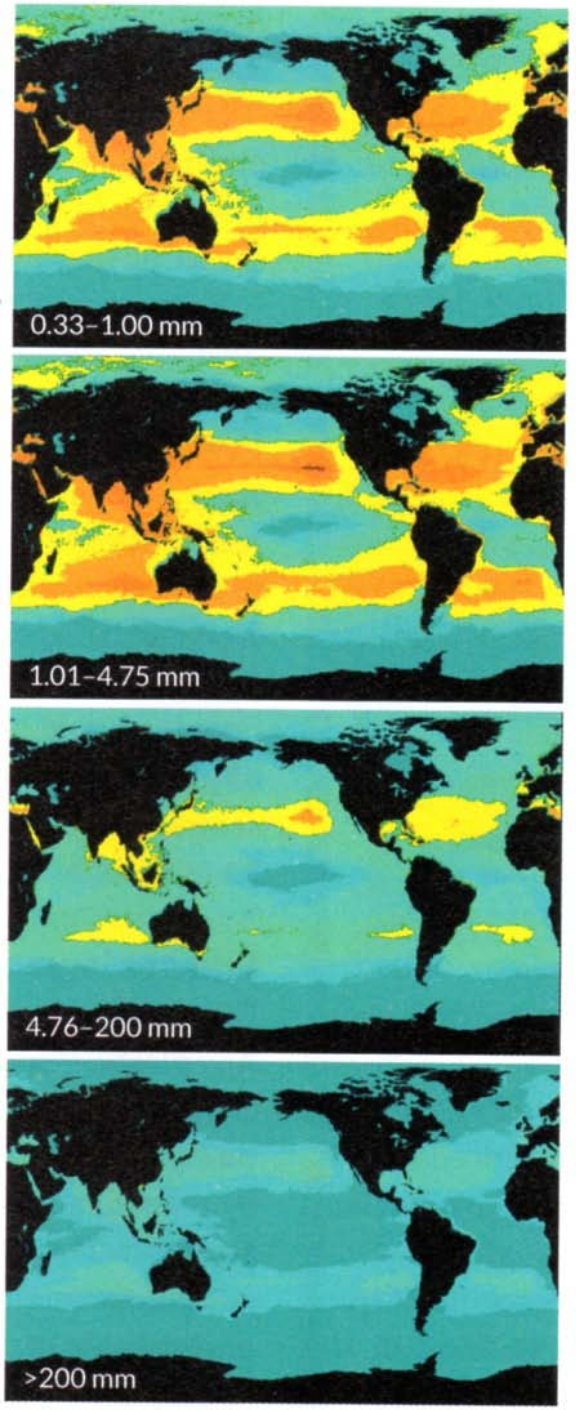
Different neighborhoods DNA fragments revealed that ocean plastic and seawater host their own kinds of microbes. Two common plastics, polypropylene and polyethylene, had hundreds of microbe species not common in seawater. Areas of overlap show microbes that occupy multiple habitats. SOURCE: E.R. ZETTLER *ET AL/ENVIRON. SCI. TECHNOL.* 2013

Number of microbe species found on plastics and in seawater



Plastic waves Oceans worldwide harbor lots of plastic, some places more than others. As seen in the top two maps, microplastics smaller than 5 millimeters in size make up most of the oceans' plastic. In some areas, concentrations reach 100,000 pieces per square kilometer.

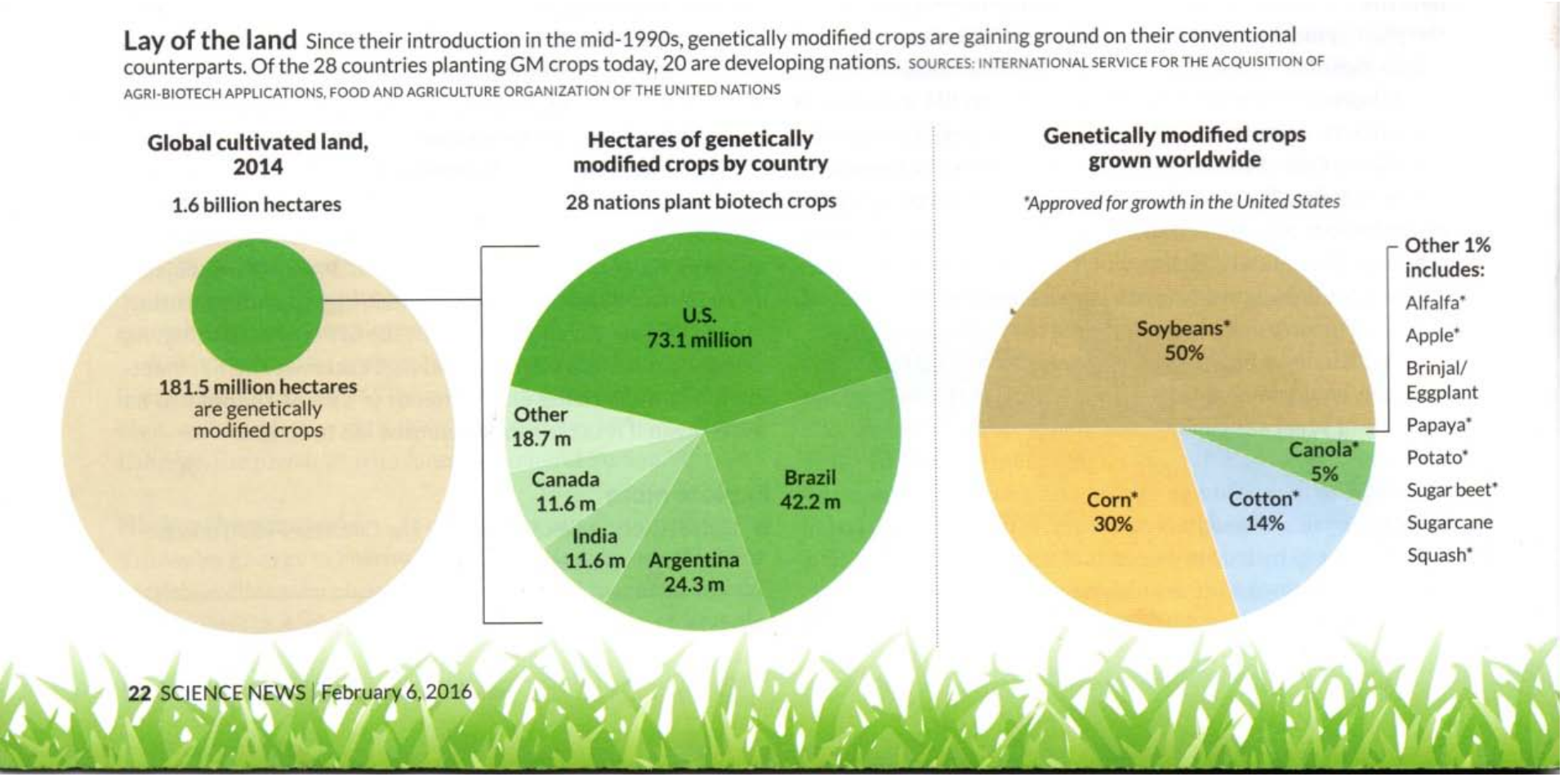




Are plastic bits in the ocean absorbing sunlight and heating the upper ocean?

GMOs Under Scrutiny
Science News February 6, 2016

Genetically Modified (GM) Crops



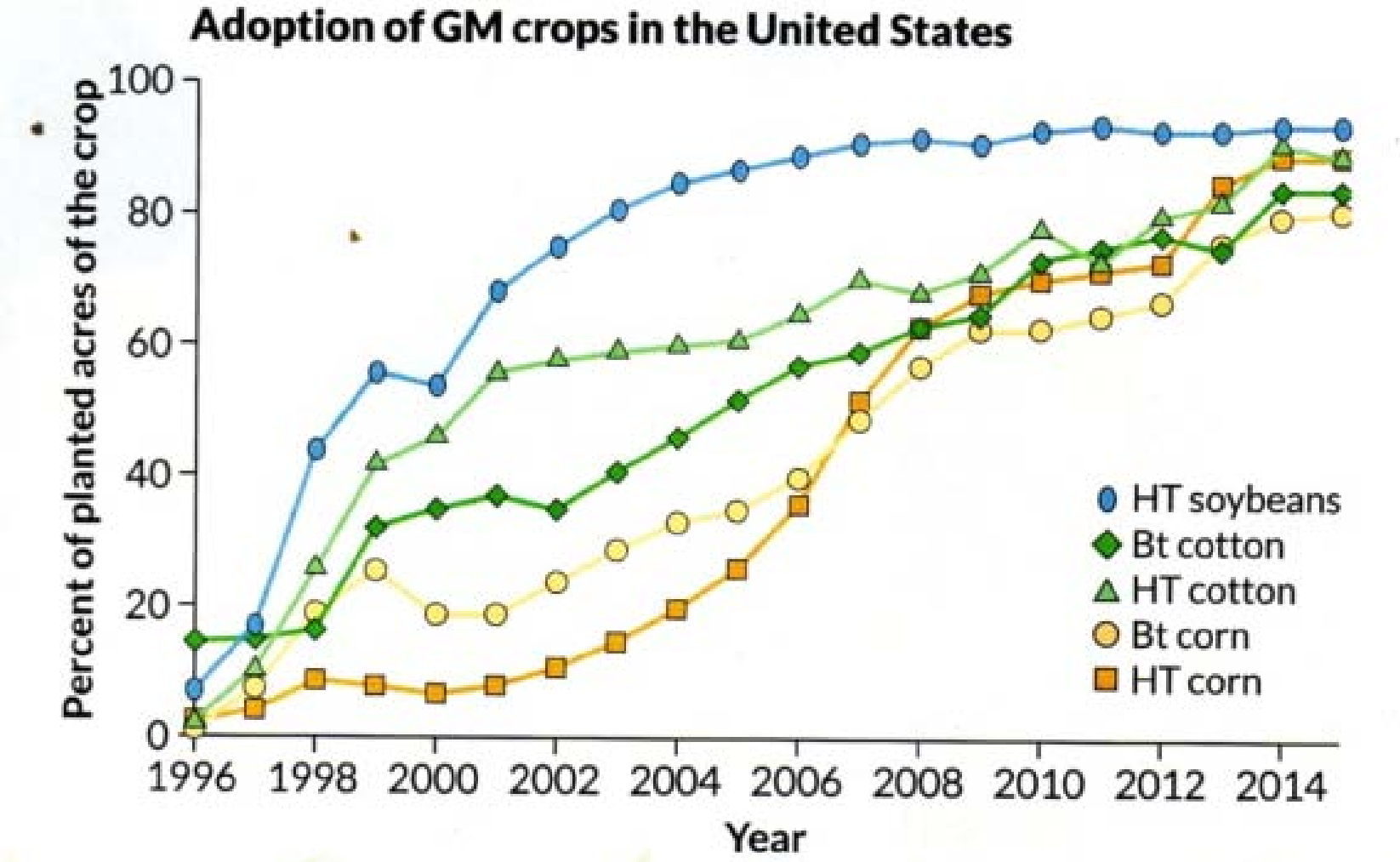
1 hectare = 100 m x 100 m = 10^4 m^2 = 2.5 acres

Good breeding Over time, plant breeding has gained speed and precision. Traditional crossbreeding mixes entire plant genomes and can take decades to yield a new variety. Transgenics and RNA interference breeding influence a handful of genes and can bring new products within a few years. SOURCES: FAO/IAEA MUTANT VARIETY DATABASE, A.E. RICROCH AND M.-C. HÉNARD-DAMAVE/*CRITICAL REVIEWS IN BIOTECH* 2015, ISAAA

Plant modifications throughout history

What?	Date developed	How?	Safety testing required?	Examples
Traditional crossbreeding	1700s	Cross closely related plants and select offspring with desirable traits	No	Myriad, including Burbank russet potato, Santa Rosa plum, sugar beets, corn, strawberries, peas, tobacco, peaches
Mutation breeding	1930s	Expose seeds or young plants to radiation or chemicals and select desirable mutants	No	Myriad, including Star Ruby grapefruit, Rio Red grapefruit, Golden Promise brewer's barley, varieties of cocoa, cotton, green pepper, sunflower, tomato, plum, peppermint, sugarcane, kale
Transgenics	1980s	Transfer specific genes by nonsexual means from one organism into another	Yes	Herbicide- and pest-resistant crops. In development: drought-tolerant peanut, wilt-resistant banana, bacteria-resistant orange, fungus-resistant chestnut, biofortified rice (includes Golden Rice), barley, corn and potato
RNA interference	1990s	Using RNA to turn off specific genes	Yes	Nonbrowning potato and apple. In development: decaffeinated coffee, tearless onion, higher-nutrition tomato, peanut and corn

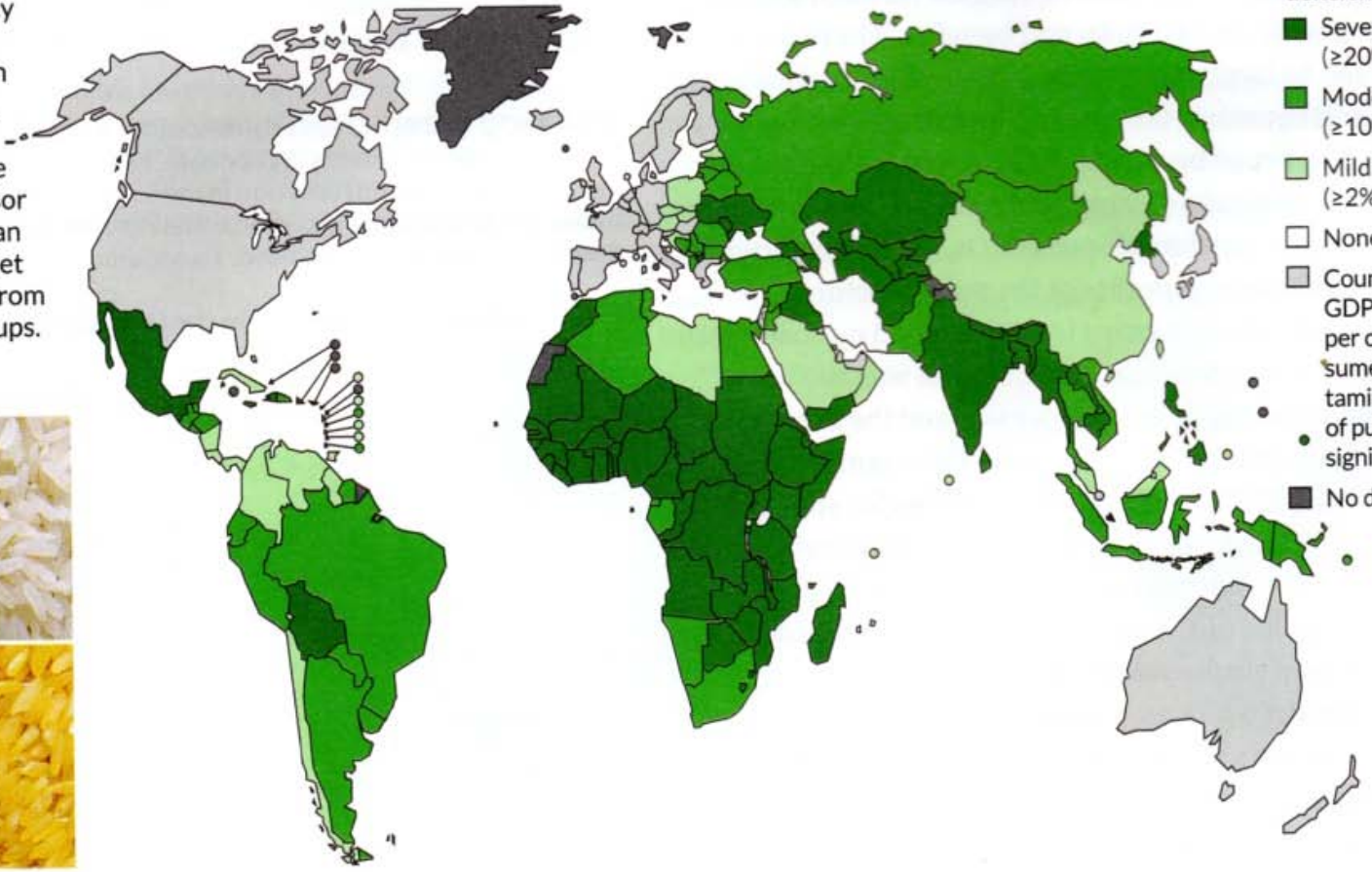
GM crop creep Crops engineered to be herbicide tolerant (HT) or toxic to specific insects (Bt), or both, have taken over U.S. farming acreage since their introduction in the 1990s. These modifications can reduce pesticide use and carbon emissions, but they can also lead to herbicide resistance if overused. SOURCE: USDA ECONOMIC RESEARCH SERVICE



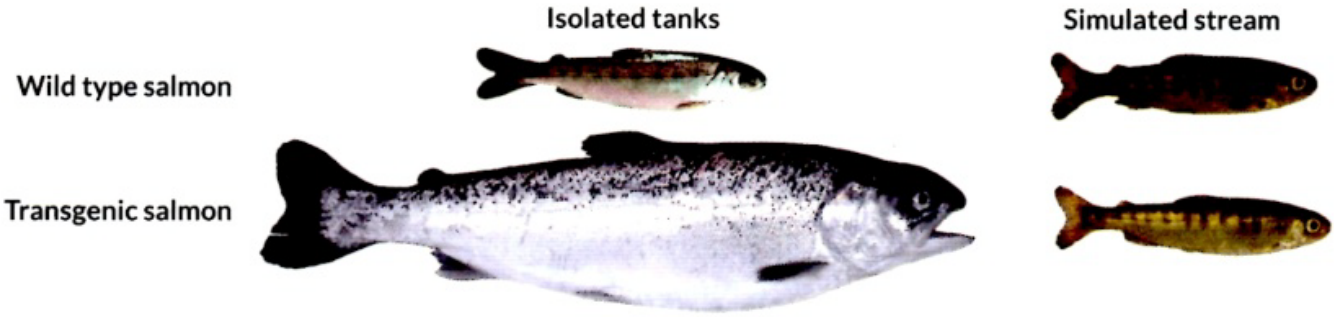
Against the grain

Vitamin A deficiency is a major cause of blindness and death in children. Golden Rice (bottom), engineered to make a vitamin A precursor in the grain, offers an antidote, but has met strong opposition from environmental groups.

Countries where vitamin A deficiency is a public health issue



Fish out of water What would happen if GM fish escaped and bred in the wild is a big question. In experiments with GM coho salmon, the transgenic fish grow rapidly in a hatchery tank, but not in a simulated natural stream. It's unknown if the same would happen for newly approved GM Atlantic salmon.



90

percent

Fraction of biotech crop farmers who are in resource-poor nations

2/3

Minimum fraction of foods sold in the United States that contain GMOs

SOURCE: GMA

80

percent

Estimated portion of hard cheeses sold in the U.S. that are made with enzymes created by genetically modified microbes

SOURCE: GMO COMPASS

Bye-bye butterflies

In 1999, a small study published in *Nature* found that monarch butterfly caterpillars that ate milkweed leaves dusted with Bt corn pollen died after a few days. But research reported in six studies published in the *Proceedings of the National Academy of Sciences* in 2001 found the pollen was toxic to the caterpillars only in the huge doses used in the study, which were much greater than what the insects would encounter in the field. Still, GM crops appear to pose a legitimate threat to the butterflies: Heavy use of the herbicide glyphosate, thanks to the widespread planting of crops engineered to resist it, has wiped out much of the milkweed the butterflies rely on for food. Farmland in the Midwest lost 80 percent of its milkweed from 1999 to 2010; the decline was mirrored in monarch populations, scientists reported in 2013 in *Insect Conservation and Diversity*. — *Rachel Ehrenberg*

Rising resistance Many herbicides interfere with a specific aspect of plant metabolism. Repeated use (across acres and time) leads to weeds resistant to the herbicides' action. A growing number of weeds are resistant to several herbicide classes (listed below), including glyphosate (black). SOURCE: IAN HEAP, WEEDSCIENCE.ORG 2015