Global Warming Is Here: The Scientific Evidence

EXTRAORDINARY HEAT WAVES, enormous drought-driven forest fires, raging storms, torrential downpours and massive floods—A rising wave of extreme weather events is sweeping the planet. In the first 11 months of 1998, the world saw almost $90 billion in weather-related damage, half-again more than the previous record set just two years before and more economic damage in a single year than in all the years of the 1980s combined.[1] The most destructive year in weather history was also the hottest since people began taking regular thermometer readings in 1860, and probably

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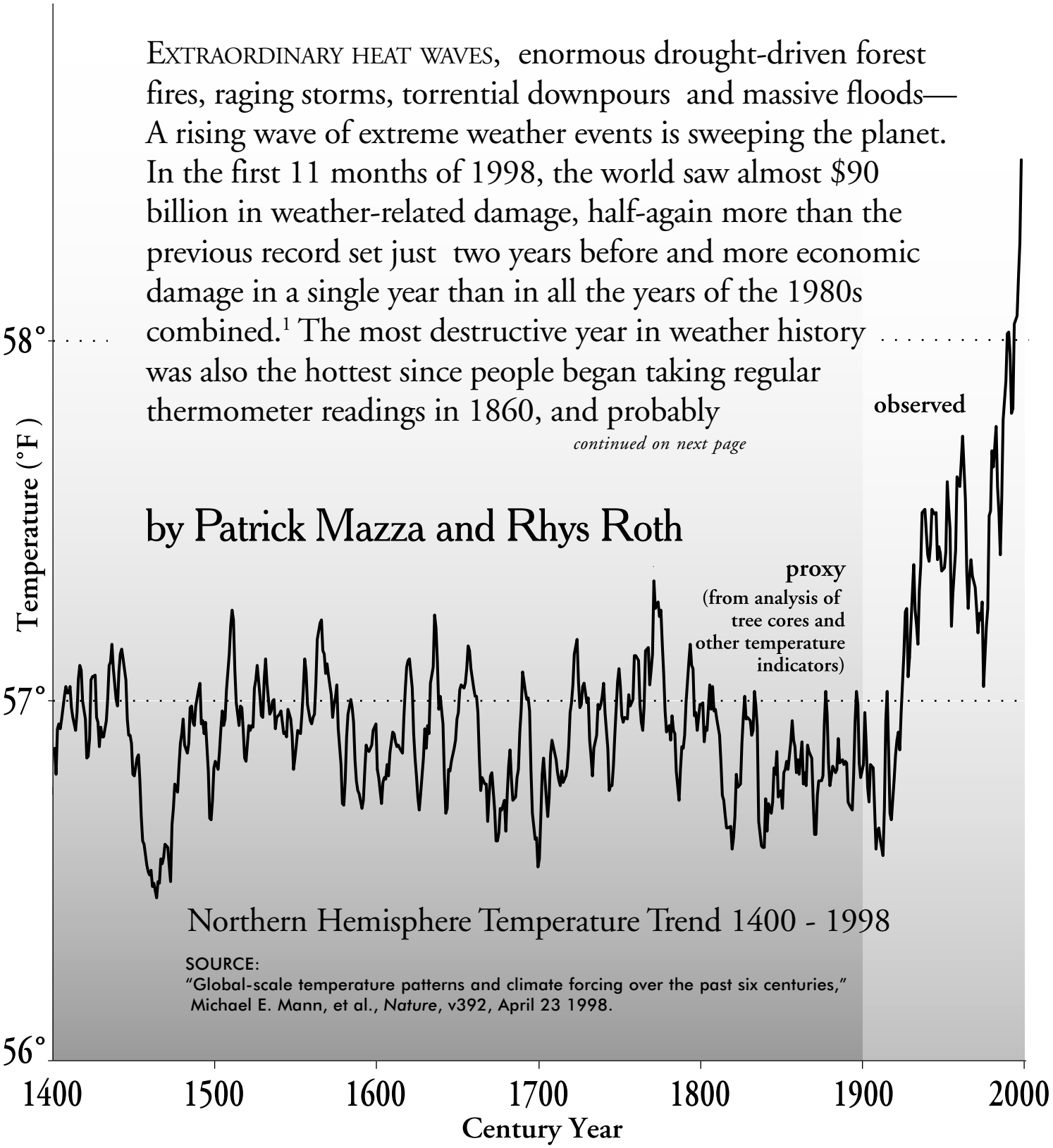
by Patrick Mazza and Rhys Roth



Northern Hemisphere Temperature Trend 1400 - 1998

SOURCE:
"Global-scale temperature patterns and climate forcing over the past six centuries," Michael E. Mann, et al., *Nature*, v392, April 23 1998.

the hottest in 1,200 years.

Has global warming finally caused the world's weather to go haywire? Some people continue to dismiss this notion, arguing that there is no real scientific evidence that the planet is heating up or that humans are causing it. Is scientific evidence really lacking or, like the debate over smoking and lung cancer, are opponents cloaking ideology and economic self-interest in outdated science?

These are questions of paramount importance for human well-being in the new century. The 1990s' upsurge in extreme weather is truly impressive. Pictures of human tragedies such as Hurricane Mitch move us. But underlying the record-breaking weather are long-term trends emerging from scientific data that point to a real global warming, and to heat-trapping pollutants from human activities as a primary cause.

If true, the situation is dire. The heating of the planet underway now cannot be reversed. In fact, scientists expect the worldwide heating-up to continue for decades or centuries after the point that heat-trapping pollutants level off.[2] How much more greenhouse gases will we accept in the atmosphere, keeping in mind that, if we could snap our fingers and stop the emissions now, 20-50 percent of the human-caused warming will still be "in the pipeline"?[3]

This report for public understanding summarizes the new findings of scientists, as reported in published scientific papers and official announcements, that shed light on the question of whether people have altered the global weather systems of our planet.

What We Know For Sure

Put aside this question of human impact on global climate for a moment. Three scientific facts are beyond debate:

1. Without the natural presence of heat-trapping greenhouse gases in the atmosphere the Earth would be a frozen planet unable to sustain life as we know it.

2. But greenhouse gases are accumulating beyond natural levels in the atmosphere and human activities, in particular fossil fuel burning, are responsible.

3. The amount of two of the most important greenhouse gases, carbon dioxide and methane, present in the atmosphere has swelled significantly higher than at any time in at least 220,000 years.[4]

These facts lead to two central questions. How will this remarkable buildup of heat-trapping gases alter the Earth's climate system over time? And, our question in this report, are we seeing the early effects on weather and ecosystems today?

Humanity's Fingerprint On The Planet

In 1990, over 2,000 of the world's top climate scientists working under the auspices of the United Nations-sponsored Intergovernmental Panel on Climate Change (IPCC) concluded that the surface of the Earth had warmed over the last century. The evidence was not clear enough, however, to conclude that this global warming was human-caused and not natural in origin.

The evidence for a human role grew stronger in the next five years, and in 1995 the IPCC issued its second state-of-the-science report[5], adopted by 157 national governments. It concluded that, "The balance of evidence suggests a discernible human influence on global climate." This is one reason why Dr. Jane Lubchenco, past president of the American Academy for the Advancement of Science, says, "In the last few decades, humans have become a force of nature."

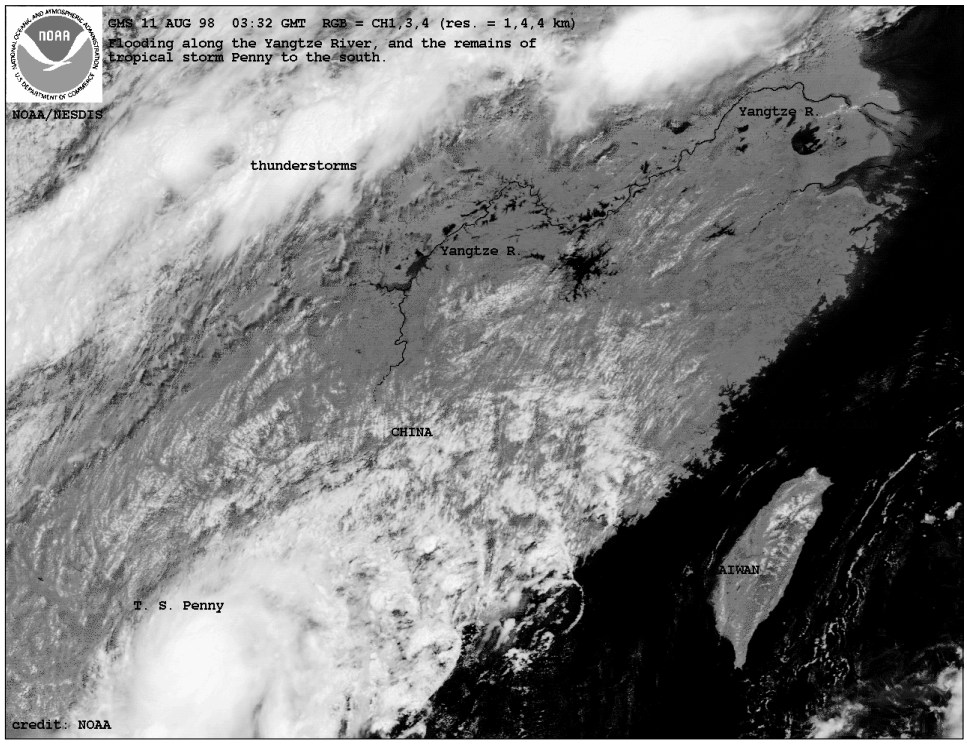
"The pattern, or fingerprint, of human-caused climate change is distinctly different from a natural warming pattern."

The breakthrough in scientific consensus was a product of improved scientific techniques, particularly "pattern-based" studies. This kind of research dusts the climate for human fingerprints by tracking temperature trends regionally, seasonally, and at different levels of the atmosphere. The pattern, or fingerprint, of human-caused climate change is distinctly different from a natural warming pattern. For example, when the planet warms naturally due to changes in the Sun's intensity the entire atmosphere warms. But a buildup of greenhouse gases will warm the lower atmosphere while cooling the upper layers.

The IPCC carefully compared real-world observations with the expected pattern of human-caused global warming. The scientists found a close enough match to conclude that the "probability is very low" that this is a coincidence.[6]

Since 1995 respected scientists have announced a stunning series of new findings that dramatically strengthen the IPCC's conclusion that humans are probably changing the climate.

One important piece of evidence came even as government delegates gathered in Geneva to officially adopt the IPCC 1995 report. Another pattern-based study was published by 13 co-authors, including several of the most respected scientists in the field. Employing an even wider set of observations than the IPCC, the study made a yet stronger case that global warming due



Extreme flooding along China's Yangtze River was one of many weather disasters spawned in the record-breaking global heat of 1998.

to greenhouse pollution is already gripping the planet.[7] Neville Nicholls, the convening lead author of the 1995 IPCC report, said the new study "provides the clearest evidence yet that humans may have affected global climate."[8] Jerry Mahlman, director of NOAA's Geophysical Fluid Dynamics Laboratory described it as "by far the closest (we've gotten) to a smoking gun."[9]

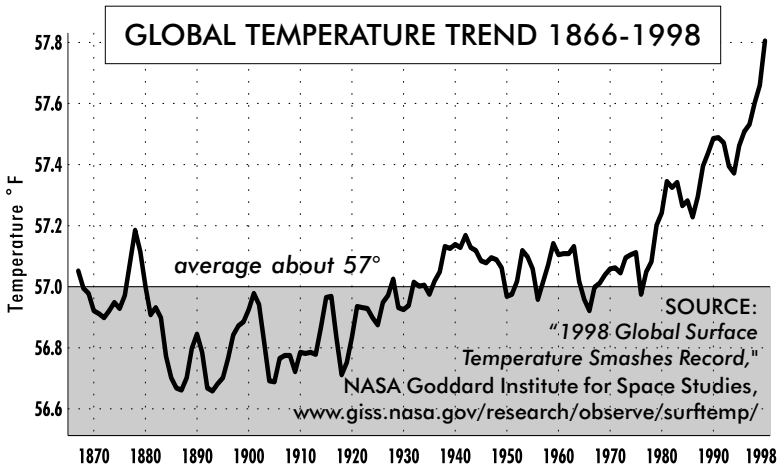
Hot And Getting Hotter

Certainly, something is warming up the globe. 1998 goes down as the hottest year on the books by far, breaking the record set only in 1997. Every one of the 18 months leading up to October 1998 was the warmest on record, a feat so statistically improbable that John Topping, president of the Climate Institute, likens the odds to that of bowling 18 consecutive perfect games. Each of the last 20 years has been warmer than the long-term global average and, with 1998 breaking the record, the century's 10 warmest years have all occurred since 1983, seven of those in this decade.[10]

Temperatures are up about 1.25 degrees Fahrenheit (deg F) at the end of the century compared to the beginning.[11] While that increase might not seem like much, distributed across the planet it represents a tremendous amount of energy. It is also a huge spike in temperature. While temperatures vary greatly place to place, day to day and hour to hour, the average temperature across the whole surface of the planet remains remarkably stable year to year. When it goes up just a small fraction of a degree, as it has in many recent years, it sets a record. That is why the warm surge measured in 1998 - about a full degree F above the 1961-90 average - both impresses and worries scientists - "This number's amazing," said climatologist Philip Jones of the University of East Anglia in England, one of the world's leading climate data centers.[12]

The startling 1998 record punctuates a compelling long-term trend. "The rapid warming of the past 25 years undercuts the argument of greenhouse skeptics, who have maintained that most of the global warming occurred early this century while greenhouse gases were increasing more slowly - In fact, the fastest warming is occurring just when it is expected," according to NASA Goddard Institute of Space Studies Director James E. Hansen.[13]

Late in 1998, scientist Thomas Wigley of the National Center for Atmospheric Research and two colleagues, published results of rigorous statistical testing of the last 115 years of temperature data. They tested the observed record against computer models of the climate system to examine if a cyclic increase in the Sun's intensity could have caused the global warming,



The last century's 10 warmest years have all occurred since 1983, each of the past 20 years has been warmer than the global average, and 1998 was probably the hottest single year in at least 1200 years.

rather than greenhouse gases from humans. They found that the climate would have to be six times more sensitive to solar changes than is believed realistic to account for the warming trend. "These results provide another important piece in the jigsaw puzzle of climate change, strengthening further our confidence that there has been a discernible human influence on climate."[14]

Hottest In Centuries

Worldwide thermometer readings go back to around 1860. But how does the warming this century fit a longer-term picture? A recent National Science Foundation (NSF) study reconstructs a 600-year temperature history using natural records such as tree rings, ice-cores and corals. The study finds that 1990, 1995, and 1997 were hotter than "any other year back to 1400... (at) roughly a 99.7% level of certainty."[15] NSF scientists found that small temperatures swings in earlier centuries were linked to changes in solar brightness and, to a lesser degree, major volcanic explosions. When it comes to the rising temperatures in the 20th century, the correlation with these natural phenomena is weak. Instead, scientists said, the warming strongly correlates to growing greenhouse gases.

"Each of the last 20 years has been warmer than the long-term global average"

Says Herman Zimmerman, program director of the National Science Foundation's Division of Atmospheric Sciences: "This study adds solid information to the growing base of data which points to the warming of our planet by human-related activities. The balance of evidence now firmly supports an important human influence on the global climate system. This is a serious problem for people everywhere, and it needs to be addressed at all levels of government."[16]

A climate record for the Northern Hemisphere that stretches back twice as long has been pieced together by a team led by NOAA chief paleoclimatologist Jonathan Overpeck, using a variety of natural records and historical documents. Their study concludes that the 20th century is the hottest in 12 centuries, and that 1998 is probably the Warmest year in the last 1200.

Significantly, Overpeck's research shows that the "Medieval Warm Period" extending from around 1,000 to 600 years ago, was not a period of global warmth as previously thought. The warmth was limited to northern Europe and North America. "Our study of the Medieval Warm Period supports the likelihood that no known natural phenomenon can explain the record 20th century warmth," Overpeck said. "Twentieth Century global warming is a reality and should be taken seriously."[17]

This conclusion is reinforced by a completely independent line of evidence in which scientists looked at temperature readings gleaned from the soil at 358 sites in eastern North America, central Europe, southern Africa and Australia. Temperature changes at the Earth's surface migrate down into the soil, providing a record of long-term temperature trends that scientists recover and analyze. The soil record on these four continents show temperatures have climbed about 1.8 deg F in the last 500 years - with nearly 1 deg F of that in the 20th century alone. That rate of warming is "well in excess of temperature trends of earlier centuries," according to the scientists.[18]

Satellite Data Now Shows Significant Warming

A primary argument of those skeptical that global warming is underway has been that, while surface-based and balloon-borne instruments show clear warming trends, satellite readings with better global coverage contradict them,

showing instead slight cooling from 1979 to 1995 at about 5.5 miles in altitude. Satellite experts corrected a critical discrepancy in 1998, however. They found that drag from the atmosphere has caused satellites to drop into lower orbits since they were launched in 1979, distorting their readings. When corrected, the satellite data actually show a warming trend of .13 deg F per decade, which is consistent with surface-based measurements.[19]

"The world's mountain glaciers have lost on average at least 60 feet since 1961, and the rate at which they are melting is increasing."

"The supposed tropospheric cooling derived from satellites was the strongest argument of the greenhouse skeptics," said study lead author Frank Wentz of Remote Sensing Systems in Santa Rosa, Calif. "Now that we understand the orbit decay correction, there is an even stronger consensus that global warming is indeed a reality."[20]

Looking At The Layers

Greenhouse gases raise the temperature at the surface and lower atmosphere of the planet by trapping some of the heat absorbed and reradiated toward space by the Earth. In contrast, in its upper reaches the atmosphere is expected to cool as greenhouse gases slow the flow of outgoing heat.

Temperate and tropical mountain glaciers are in rapid retreat around the world.

Again, observations are reinforcing the global warming predictions. The IPCC reported in 1995 that the stratosphere cooled rapidly in the 15 years previous, by about 1.1 deg F.[21] Further up, in the upper stratosphere and mesosphere (18-37 miles up), a new study found "significant cooling" of 3 deg F per decade between 1962 and 1991.[22] Further still, researchers recently found cooling throughout the mesosphere and thermosphere regions (30-280 miles up), even greater than predicted by greenhouse models.[23]

Deep in the ocean, there is also ominous evidence that suggests that excess heat may be filling the deep ocean, which will continue to warm the atmosphere for decades or centuries after greenhouse gas levels stabilize. Measurements taken in 1957, 1981 and 1992 on trans-Atlantic voyages along 24 degrees N latitude show "the waters between 800 and 2,500 meters in depth have consistently warmed over the past 35 years and...(the warming) is remarkably uniform across the east-west extent of the North Atlantic."[24]

Planet Warms, Glaciers Shrink

In 1992, the IPCC was already reporting a worldwide mountain glacier retreat that "...is among the clearest and best evidence for a change in energy balance at the Earth's surface since the end of the last century. It provides sufficient support...to show that global warming has indeed occurred over the last century."[25]

In 1998, glaciologists at the University of Colorado at Boulder reported that the world's mountain glaciers have lost on average at least 60 feet since 1961, and the rate at which they are melting is increasing. "In the last century, there has been a significant decrease in the area and volume of glaciers, especially at middle and low latitudes," said Professor Emeritus Mark Meier of the geological sciences department. "The disappearance of glacier ice is more pronounced than we previously had thought."[26]

The University of Colorado survey shows smaller, low-latitude glaciers seem to be taking the biggest hit. The largest glacier on Africa's Mount Kenya lost 92 percent of its mass in the last century and Mount Kilimanjaro glaciers have shrunk by 73 percent in that time period. Spain had 27 glaciers in 1980. That number has dropped to 13.

The retreat of mountain ice in tropical and subtropical latitudes is proceeding at "a phenomenal rate," confirm scientists at Ohio State University's Byrd Polar Research Center, providing "some of the most compelling evidence yet for recent global warming." For example, the Qori Kalis glacier in the Peruvian Andes retreated 13 feet each year between 1963 and 1978. By 1995, the annual rate of retreat was 99 feet.[27] Since 1970 the freezing level in the Earth's atmosphere has been rising nearly 15 feet each year.[28]

One of the scientists, Ellen Mosley Thompson, told the 1997 annual meeting of the Association of American Geographers that the changes to tropical and subtropical glaciers "are taking place in water stressed areas already having problems feeding their people, and where large population increases are expected."[29]

Middle latitude glaciers are also showing significant shrinking. Both the European Alps and Caucasus Mountains have lost half their ice in the past century. New Zealand glaciers have shrunk about 26 percent since 1890. In the Tien Shan Mountain Range bordering China and Russia, 22 percent of the ice volume from the thousands of glaciers there has disappeared in the past 40 years.[30]

"The rate of warming is unprecedented in the last 600 years and the retreat of glaciers is probably unprecedented, too, although we do not have the figures to prove it," Mark Meier said . "But I'm convinced there is a detectable human influence in the pattern of climate change we are seeing." [31]

The Sea Is Rising, Ice Shelves Are Melting

Global warming causes the level of the ocean to rise in two ways: by unlocking vast amounts of water from melting glaciers around the world, and because warmer waters expand. Records of sea level drawn from around the world show that the sea has risen by between 4 and 10 inches in the last century, according to the IPCC, and "it is likely that much of the rise in sea level has been related to the concurrent rise in global temperature."[32]

Scientists also predict that global warming will be greatest in the polar regions. A study of the Arctic shows that temperatures in the far North have climbed 2.7 deg F in the 20th century, significantly more than the planet as a whole, to levels warmer than any other time in at least the past 400 years. The effects are being seen in "the widespread retreat of glaciers throughout the Arctic in the last century," the melting of permafrost and sea ice, and alteration of ecosystems, according to the report authored by a team of 18 scientists.[33]

At the opposite end of the world, warming around Antarctica is showing up in the decreasing amount of sea ice - This is ice that forms seasonally in the open ocean near the conti-

nent. In the middle of the century, extensive ice formed around the Antarctic Peninsula 4 winters out of every 5. Since the 1970s that has dropped to 1 or 2 winters out of 5.[34] Scientists with the British Antarctic Survey have uncovered another piece of evidence. They found that with temperatures up about 4.5 deg F since 1945 several of the Peninsula's ice shelves, giant year-round lips of ice attached to the continent but stretching into the sea, have been in dramatic retreat.[35]

What takes place on this Peninsula is particularly significant - as the northernmost point of the South Polar continent, it is most vulnerable to any warming trends. With the warming now taking place, its ice shelves are increasingly prone to sudden disintegration. The Larsen A ice shelf, after years of slowly melting away, suddenly broke apart during a January 1995 storm. "The speed of the final breakup was unprecedented, and followed several of the warmest summers on record for this portion of the Antarctic," said Ted Scambos of the Cooperative Institute for Research in Environmental Sciences, a joint institute of NOAA and the University of Colorado.

A chunk of ice three times larger than Manhattan Island broke off the Larsen B ice shelf in February 1998. Two-thirds of Larsen B now threatens to dissolve. Scambos points out that, "The total size of the Larsen B Ice Shelf is more than all the previous ice that has been lost from Antarctic ice sheets in the past two decades."[36] A new study of ice shelf stability concluded that for Larsen B, "unless the situation changes dramatically and ice-front retreat ceases almost immediately, it seems fairly certain that another ice shelf will disappear, perhaps even this century."[37]

Thawing Permafrost

Alaska, most of which is covered by permafrost - permanently frozen soil - is watching roads and other human structures collapse as permafrost melts. Studies at the Bonanza Long-Term Ecological Research Site show that the layer of soil that thaws each warm season is penetrating deeper in recent years. The permafrost that remains is warming to within a few-tenths of a degree of the melting point.[38]

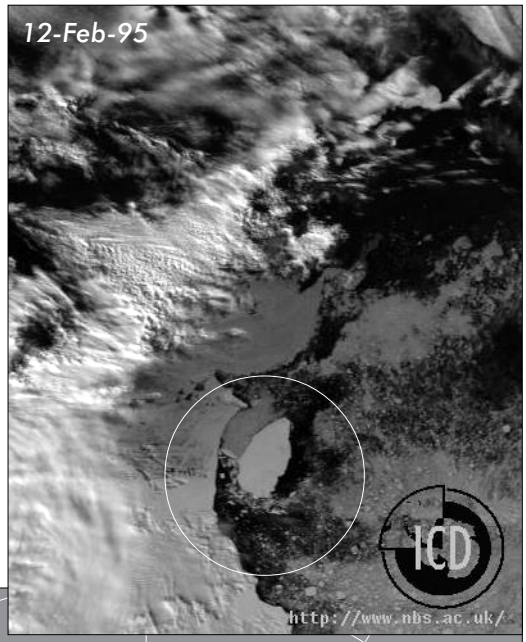
Thawing of permafrost also raises concerns about releases of greenhouse gases that had been locked safely away in permanently frozen soil. Measurements from northern Alaska in the early 1970s showed tundra soils absorbing more CO_2 than they released. Twenty years later, measurements from the same region show tundra soils releasing more CO_2 than they absorbed.[39]

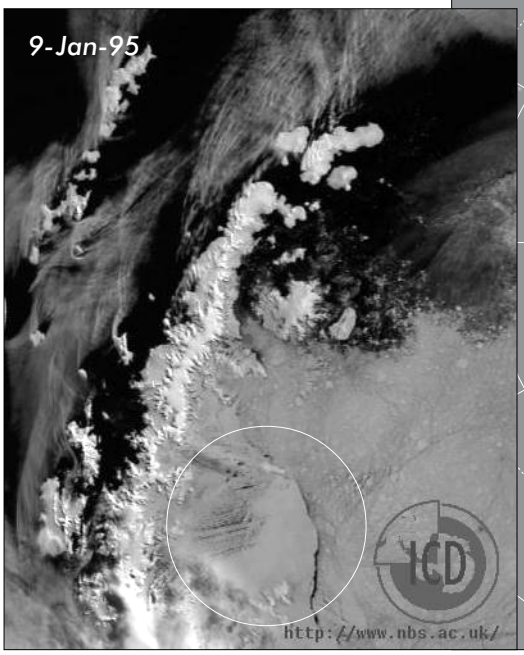
This is a crucial issue: the carbon now held in the permafrost of the northern tundra equals around one-third of the total carbon floating in the atmosphere, according to University of Michigan biologist George W. Kling, who is working on a National Science Foundation study of an 8,100-square-kilometer tundra on Alaska's North Slope. "Our latest data show that the Arctic is no longer a strong sink for carbon. In some years, the tundra is adding as much or more carbon to the atmosphere than it removes. The concern is what will happen in the future as global warming increases and melting permafrost exposes more of this buried carbon to be respired and released into the atmosphere."[40] The frightening prospect is that the buildup of heat-trapping gases could accelerate even if human emissions are stabilized.

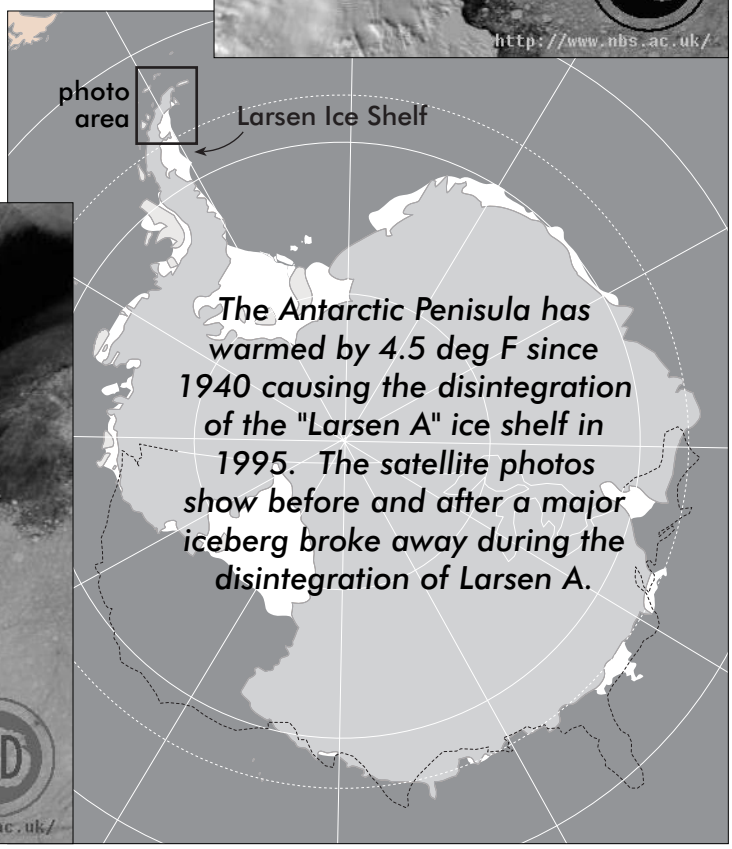
Water Cycle "Intensification"

The IPCC states that global warming "will lead to an intensification of the global hydrological cycle."[41] This means that a warmer atmosphere will cause more evaporation globally (over 2/3rds of the Earth's surface is ocean). More water and energy in the air could translate into more deluges and flooding, while drier continental interiors see summertime soil evaporation intensify, worsening droughts.

More water in the air may also mean an overall increase in the cloudiness of the world. How global warming will affect cloudiness and how cloudiness will in turn affect global warming remains one of the key areas of uncertainty in climate science. A 1997 study, however, does report strong evidence that cumulonimbus, nimbostratus and cirriform clouds increased significantly over Australia, Europe and the United States between 1951 and 1981. The researchers conclude that the increase in thick, precipitation-prone clouds is "likely to be related" to the human-caused increase in greenhouse gases.[42]







The Antarctic Penisula has warmed by 4.5 deg F since 1940 causing the disintegration of the "Larsen A" ice shelf in 1995. The satellite photos show before and after a major iceberg broke away during the disintegration of Larsen A.

If the world is heating up *and* getting cloudier, nighttime temperatures should rise faster than daytime temperatures. That is because cloud cover holds in heat after the sun goes down. Heat that normally escapes to space at night is contained, raising overnight temperatures. Nighttime warming then is a significant indicator of global warming.

"Thawing of permafrost also raises concerns about releases of greenhouse gases that had been locked safely away in permanently frozen soils."

Nighttime temperatures are in fact going up more than twice as fast as daytime temperatures, according to the largest study ever of surface temperatures. In it, a team of researchers led by David Easterling of NOAA' s National Climatic Data Center surveyed 5,400 stations that monitor 54 percent of the planet's land area. Between 1950 and 1993, daytime temperatures climbed at a rate of about 1.5 deg F per century, while nights warmed at about 3.2 deg F per century.[43]

Another recent study found that extreme summer heatwaves are up sharply in the U.S., with the biggest increases coming at night. And humidity, increasing several percent a decade, is making a growing contribution. NOAA scientists Dian Gaffen and Rebecca Ross used the heat threshold at which, according to earlier studies, deaths increase sharply. The two scientists examined temperature and humidity records from 113 weather stations and found three-day-or-longer stretches of such killer heat increased 88 percent in the U.S. between 1949 and 1995. "Extremes of summertime heat have a greater impact on human health than any other severe weather in the United States," they noted.

More Extremes

In 1996, the National Climatic Data Center, a division of NOAA, published findings of a new analysis technique that showed weather in the U.S. has been growing more extreme.[44] They scrutinized records for the last 80 years to track summer droughts, drenching rainstorms, wet winters and other types of wild weather events that are expected to increase in a greenhouse-heated world. They discovered that since the late 1970s, the climate has been stuck in greenhouse-mode, with more weather extremes. Statistical analysis showed only a 5% probability, in other words 1-in-20 odds, that the surge in extreme weather is a natural fluctuation within a stable climate. NCDC researcher Tom Karl told the *New York Times*, "I would say the climate is responding to greenhouse gases."

A new study[45] looks at the percentage of the globe that experienced severe drought or extreme rainfall from 1900 to 1995. The numbers vary quite a bit through time, but the researchers identified "a distinctive change in character" beginning around 1980. Droughts are coming more frequently in sections of the United States, Europe, Africa and Asia, while parts of the U.S. and Europe have become much wetter.

Particularly implicated in drying or drenching more parts of the planet is El Niño. The Pacific Ocean warming changes the pattern of the jet stream as it curls around the Earth. This reshapes the flow of clouds and moisture. Over the past 20 years, El Niño has come more often, and with record intensity. A statistical analysis of the data by Kevin Trenberth and Timothy Hoar, veteran El Niño researchers with the National Center for Atmospheric Research, concluded that the odds against this happening solely due to natural causes are 2,000 to one.[46] "The main thing we can point to is global warming," Trenberth says. "I think El Niños are being changed by global warming."[47]

A computer modeling study by NOAA/Geophysical Fluid Dynamics Laboratory adds weight to that conclusion. Scientists determined that warming in the tropical Pacific Ocean is unlikely to be purely a product of natural cycles. "Instead, it is likely that a sustained thermal forcing, such as the increase in greenhouse gases in the atmosphere, has been at least partly responsible for the observed warming."[48] Climate is one of the basic factors that shape how well plants and animals can survive in particular locations. Scientists are beginning to document some profound effects that the changing climate is apparently causing in plant and animal populations.

Plants Affected Over "Huge Spatial Scale"

A study of the Earth's annual carbon cycle may be the first evidence climate change is affecting "the growth of plants on a huge spatial scale," Pieter Tans of NOAA said. "This is quite significant."

Every spring plants across the northern hemisphere soak up CO_2 from the atmosphere as they grow, enough to cause CO_2 levels to drop measurably. In winter, decaying plants and soils release CO_2 back into the atmosphere, so CO_2 levels "see-saw" back up. Charles D. Keeling of the Scripps Institution of Oceanography and keeper of the world's most important records of atmospheric carbon dioxide levels, found that since 1964 the see-saw has been swinging more wildly in each direction - 20 percent more over Hawaii and 40 percent more over the Arctic. And spring is arriving earlier. The yearly drop in CO_2 as plants start spring growth is now a week earlier than it was 30 years ago.[49]

"Off the California coast, populations of zooplankton, the tiny plant-eaters at the base of the marine food chain, dropped 70 percent after a dramatic shift to warmer waters suppressed the upwelling of cool, nutrient-rich waters."

Keeling's data show the Earth is, in a sense, breathing harder, like a person does when they become physically stressed. "I think we should focus on the fact that the plants are being influenced by the climate in a way that might be unprecedented," Keeling told the *San Francisco Chronicle*.[50]

Plant Species Climb Warming Alps

Plant species are migrating to higher elevations in the Swiss and Austrian Alps, where temperatures have climbed 1.25 degrees F this century. University of Vienna scientists collected data on vascular plant species at high elevations in the middle Alps and compared the modern data with detailed historical records from early in the century. They concluded that "there is no doubt that even moderate warming induces migration processes, and that this process is under way...global warming is already having a significant impact on plant ecology."[51]

Alaska's Dying Forests

In forests on Alaska's south central coast, cool summers and cold winters normally keep the spruce bark beetle under control. But temperatures there are up 3 deg F this century. And spruce bark beetles have been running wild, killing most trees over a three-million-acre area. This is one of the largest insect-caused forest deaths in North American history. Over in Southeast Alaska forests have also experienced insect infestations, and are endangered by blowdown from the doubling in days with gale-force winds since 1950.[52]

Migratory Range Shifts For Entire Species

Camille Parmesan, a scientist at the University of California at Santa Barbara, surveyed the range of the Edith's checkerspot butterfly and found, "the clearest indication to date that global climate warming is already influencing species' distributions." The butterfly, which inhabits North America's West Coast, has shifted noticeably northward in response to warmer temperatures. Parmesan's study was a breakthrough because it was the first to look at the entire migratory

Over its huge range, from Mexico to Canada, the Edith's checkerspot butterfly has responded to warming temperatures by shifting its habitat northward.

Species Devastated By Coastal Warming

Using temperature records kept since 1916, Scripps Institution of Oceanography scientists detected a dramatic shift in 1977 to warmer, lower-nutrient waters along North America's west coast. This warming has continued to the present. Simultaneously, populations of zooplankton, the microscopic plant-eaters that are at the base of the marine food chain, dropped 70 percent because warmer waters suppressed the upwelling of colder, nutrient-rich currents. The effect on higher animals has been catastrophic. Ocean seabirds in the Southern California Bight have declined 90% since counts began in 1987. The long-term decline in commercial catch of ocean fish accelerated after the shift in ocean conditions. The health of kelp forests, critical habitat in coastal ecosystems has also been badly affected: they "are now systematically smaller and depauperate", biologically impoverished in other words, according to the scientists.[54]

"Profound Change" In Monterey Bay

Scientists at the Monterey Bay Aquarium Research Institute in the mid-90s returned to one stretch of the bay's rocky intertidal beach that was surveyed in the 1930s. They wanted to see what had happened to populations of 45 species of limpets, barnacles, anemones, chitons and sea stars. They found "profound change in community structure". Over the past 60 years shoreline water has grown an average of 1 deg F warmer, with summertime highs up by 4 deg F. Eight out of nine species that favor warmer waters to the south grew more abundant at the site. Five out of eight that favor cooler habitat to the north declined. In all, the habitat of 32 species was altered.[55]

Conclusion

A sober and dispassionate assessment of the evidence emerging from a wide range of scientific disciplines leads to a compelling conclusion: Global warming is here now and humanity is driving the warming. The reality of global warming is a clear and present danger to global security and the well-being of billions of people across the planet. The accelerated extinction of species and the obliteration by the rising sea of entire low-lying nations, as well as immense social and economic disruption to the lives of virtually all nations, are in prospect.

The global climate crisis is as grave as any military threat we have ever faced, and must draw a similar response. As we typically do when drawn into military battle, we must mobilize a massive outpouring of resources against global warming - money, technology and human energy - and strategically deploy them for maximum effect. Only through a rapid transition from fossil fuels to clean energy sources, and preservation and restoration of the world's forests, can we stop the buildup of greenhouse gases that imperils us all.

Writing recently in the esteemed science journal *Nature*[56], 11 scientists examined the rate at which carbon-free energy sources must come on line to stabilize the atmosphere in the 21st century at various carbon dioxide (CO_2) concentrations. For stabilization to happen, they note, fossil fuels must be reduced at the same time world energy use expands rapidly as rich economies grow and developing countries industrialize. Total primary energy use is expected to double from about 10 terawatts (TW) in 1990 to 20 TW by around 2020.

Stabilizing the CO_2 level in the atmosphere at current levels or less seems a prudent objective, given that economic damages from global warming appear to be quite serious already, and the heat will continue climbing after greenhouse pollution levels off. To do so, the scientists estimate that we will need to supply about half of our energy from carbon-free sources in 20 years, the equivalent of total world energy use in 1990, and virtually the entire 30 TW energy use expected by 2050.

"This past century," the scientists wrote, "accelerated technology development from wartime and postwar research produced commercial aviation, radar, computer chips, lasers and the Internet, among other things. Researching, developing and commercializing carbon-free primary power technologies capable of 10-30 terrawatts by the mid-21st century could require efforts, perhaps international, pursued with the urgency of the Manhattan Project or the Apollo space program... the potentially adverse effect of humanity on the Earth's climate could well stimulate new industries in the 21st century, as did the Second World War and the 'cold war' in this century."

All people stand to benefit from putting our societies and economies on an ecologically sound footing. All stand to lose if we do not. Perhaps the greatest challenge in the history of civilization, the global climate crisis calls upon us to act—decisively and without delay. ■

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