RIGHT HERE, RIGHT NOW

A Communications Guide
to Climate Change Impacts

Right Here, Right Now

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climatenexus

Cover photo: Reeve Jolliffe. Traffic and street lights in New York City disabled by Hurricane Sandy.

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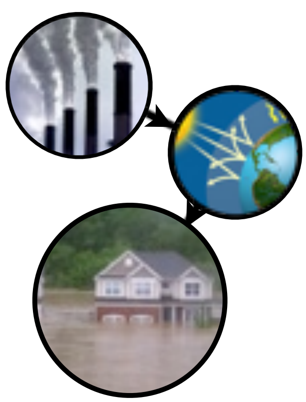
Executive Summary

We are no longer discussing the threat of climate change. We are living with the reality of it, right here and right now. Today the impact of climate disruption in the United States is clear, costly and widespread.[1,2,3,4] Importantly, these changes are teachable moments that can help galvanize public will for climate protection.

The fingerprint of global warming is found on disasters ranging from raging wildfires and flooded coastlines to extreme heat waves and the growing threat of asthma.[5] Weather catastrophes have tripled in North America over the last 30 years, incurring over $1 trillion in damages.[6,7] Climate disruption has driven up food prices,[8] increased the risk of West Nile outbreaks across the U.S.,[9] and helped fuel wildfires that caused over $1 billion in damages in 2012.[10] Our seas are now 30 percent more acidic due to the carbon pollution taken up by the oceans.[11] Global warming drives up sea levels, increasing the reach of storm surge[12] and dramatically amplifying disasters such as Superstorm Sandy.[13] Half of the summer sea ice in the Arctic has been lost due to warming,[14] a change that has altered global weather patterns, and brought harsh winter storms south to the United States.[15]



The science of fingerprinting has developed significantly in the last several years, and we can connect the dots with confidence. The news media are increasingly recognizing the links to climate change and the massive scientific evidence supporting them. And perhaps most importantly, a majority of Americans now connect the dots themselves and are changing their attitudes as a result. Taken together, these trends make climate change impacts, right here and right now, a powerful focus in the fight for climate protection.

The links between climate change on one hand and damage and disaster on the other are complex and can be tricky to talk about in the sound-bite vernacular of mainstream media. Helping Americans understand the link between climate change and disaster requires a well-crafted and disciplined approach. As the public increasingly recognizes the changing weather they are living through, the broader changes to other facets of society must also be recognized and understood. This presents challenges to scientists, elected leaders, health care providers, policymakers and communicators. The threats are myriad and complex, but they are rooted in climate disruption and unfold within the context of the communities, governments and economies that must adapt to such changes. By their nature, disasters can open eyes and drive political will. To help meet this communication challenge, this guide offers tools and strategies for making current climate change impacts clear and understandable.

Impacts

As science has long predicted, climate change is bringing damage and disruption to ecosystems, infrastructure and society across the United States:

Infrastructure: Through heat waves that cripple utilities' cooling systems, western fires that destroy neighborhoods, storm surges that devastate public transportation systems and road networks, and much more, climate disruption is damaging the physical foundations of modern society. The range of systems threatened by climate disruption encompasses transit and transportation, the electric grid, the public health network, emergency response and water and sewage systems.

Food: Droughts, heat waves and extreme precipitation are impacting crop production, leading to spikes in food prices and disruptions in food supply. Recent drought in the southern Plains accounts for losses in the billions. Damage to transportation systems is another source of disruption for food supplies, as reflected in the challenges for grain production and distribution posed by the recent record-low water levels in the Mississippi River.

Health: The stress on human health is already apparent in climate change-links to recent illness and increased exposure risk. Outbreaks of West Nile virus correlate with higher temperatures, for instance, and heat waves are the no. 1 weather-related cause of death.

Extreme Weather: Extreme weather offers perhaps the most tangible fingerprint of climate change. As more people experience unprecedented heat waves, extreme precipitation and drought, they are better able to wrap their minds around the scale of the threat. Weather is the foundation for many of the impacts happening here and now so for the full scope of the problem to be seen clearly, the links to disruption must be made explicit.

Seasons: Season creep has been increasing for years. Although it poses immediate risk to farmers and food supply, the impacts extend to damaged ecosystems and other repercussions that are only now being grasped. Bark beetle infestations across the West that decimated old-growth forests are one vivid example, but others, such as a ski industry crippled by low snow pack, illustrate how climate change threatens the businesses and activities that anchor the U.S. economy.

Geophysical changes: The unprecedented changes to the Arctic sea ice, Greenland ice sheet and glaciers in Antarctica and beyond pose a series of threats that cross boundaries of all other impacts. These changes help drive sea level rise, play critical roles in global weather formation, are fundamental to water supply and crop production, and are a pivotal force in determining ocean currents. The links between these ongoing and record-breaking changes and our daily lives must be made as explicit as possible, even as science seeks to understand all the potential ramifications.

Ocean Acidification: The swift and unprecedented changes to ocean chemistry stress sea life and coral reefs that are critical to ecosystems. The changes have already been witnessed and tallied, as in oyster production, and their impacts are on track to get much worse.

Science

Science has advanced dramatically in the last several years, and the ability to fingerprint (or attribute) many events, disasters, and trends to climate change now exists.[16] Climate disruption has greatly amplified and fueled many disasters, such as Superstorm Sandy[17,18] and western wildfires.[19] In other disasters, climate change has so dramatically increased the odds of the underlying event (such as in the case of the recent record-breaking heat wave in Texas) it can be said that climate disruption is the primary cause.[20]

Climate change impacts run far ahead of projections offered by climate models. Past predictions have turned out to be overly cautious, often underestimating the rate of change.[21,22,23]

Just as slow-moving impacts, such as sea level rise, are constant and observable, the fast-moving impacts, such as extreme weather and wildfires, now also show clear, constant trends extending over decades.[24,25,26,27,28,29] There will be no returning to the old normal when it comes to extreme weather or other fast-moving impacts.

Jim Cantore, an on-camera meteorologist for The Weather Channel, reports on Hurricane Irene from Battery Park in New York City.
Photo: The Weather Channel via Getty Images

Media

Domestic disasters are widely reported by the news media, fill social media channels, and are a mainstay of kitchen table conversation. Americans are particularly good listeners when the story is unfolding in their own backyard. Because news focuses the public on damage and disaster, it offers a tremendous opportunity to put climate change in the spotlight.

While media coverage linking climate change to disasters still often falls short, the situation has improved significantly over the last two years. Most analyses show coverage rising, and all show a striking upturn in attention to current climate change impacts.[30,31,32] Stories linking climate change to sea-rise, unusual weather and other events reached an all-time high in 2012. A recent analysis found 5,800 stories on impacts published in 2012, 37 percent more than 2011 and 25 percent more than during the 2009 peak.[33]

Although media coverage can still improve, these trends highlight the opportunity to work with the news media in highlighting climate change right here, right now.

Public Opinion

One of the great challenges in mobilizing action on climate disruption is that despite Americans' clear concern about global warming, most see the matter primarily as a problem for the future.[34] This helps explain the low priority Americans assign the issue when ranking it against other pressing national concerns for immediate national action.[35]

However, over the last three years there has been a steady and significant rebound in Americans' recognition of global warming, particularly among Republicans.[36,37,38]

This sea change was driven largely by personal experience and media coverage of warmer temperatures, extreme weather, and the loss of iconic Arctic sea ice.[39,40,41,42,43]

Majorities of Americans are now connecting the dots between global warming and extreme weather. This gives advocates a platform for highlighting climate disruption and damage across the U.S. It also underscores the value in doubling down, as political science suggests, to focus on current climate impacts.

Strategies

For a variety of reasons, climate change discussion typically focuses on the future. Unfortunately this approach reinforces the perception that climate change is not an immediate concern. Switching the focus to highlight current climate impacts means talking about the here and now.

The link between climate disruption and current impacts is parallel to the link between cancer and smoking. Much like the Surgeon General needed a simple message to convey the risks of smoking, speakers on global warming need to lead, continue, and end with the simple overarching statement that climate change is here and now.

When it comes to cigarettes, public health advocates have figured it out. Keep it simple, strong, and relevant, like this warning label. Photo: Collectiva/Alamy

One way to connect climate change to current events is to link events and impacts to the ongoing trends, and then link the trends to climate change. These trends are the middle link between individual events and global warming. Unprecedented events or events for which there are no long-term records can be linked to climate change by explaining how they are consistent with the physical changes global warming drives.

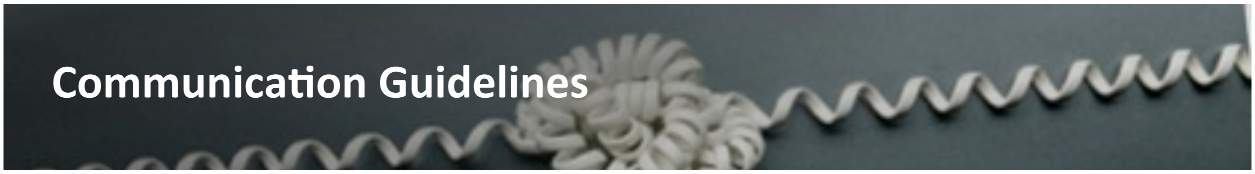
Throughout this guide, the terms global warming, climate change and climate disruption are used interchangeably to describe the often complex changes to global climate driven by human-caused warming of the planet.

Climate disruption can evoke the destructive impacts that change alone fails to fully convey and avoids the counter-intuitive assumption that warming could not also bring other impacts, such as intense winter storms.

It is useful to link climate disruption to the damage incurred in a disaster rather than to the underlying event. In some instances, climate change magnifies the scope of a disaster. Because explaining causality can be distracting, it is more effective to frame climate change as amplifying disaster — as opposed to contributing to the underlying event.

Disaster usually strikes when a threshold is crossed, and climate change is often the straw that breaks the camel's back. It is important to point out the role of climate disruption in driving disaster. Even when climate change may have only amplified the events underlying any particular disaster, it may have been primarily responsible for most of the damage. Climate disruption turns events into disasters.

How far you go in connecting the dots depends on your audience. When discussing disaster and extreme events, introduce climate disruption as appropriate. Talking about choices can help move a discussion about preparation (adaptation) to a conversation about prevention (mitigation). How far we go in preparing for global warming depends upon how much climate change we prevent. We know an ounce of prevention is worth a pound of cure, and we need to act now to prevent climate disruption from becoming much worse.



Talk About the Here and Now

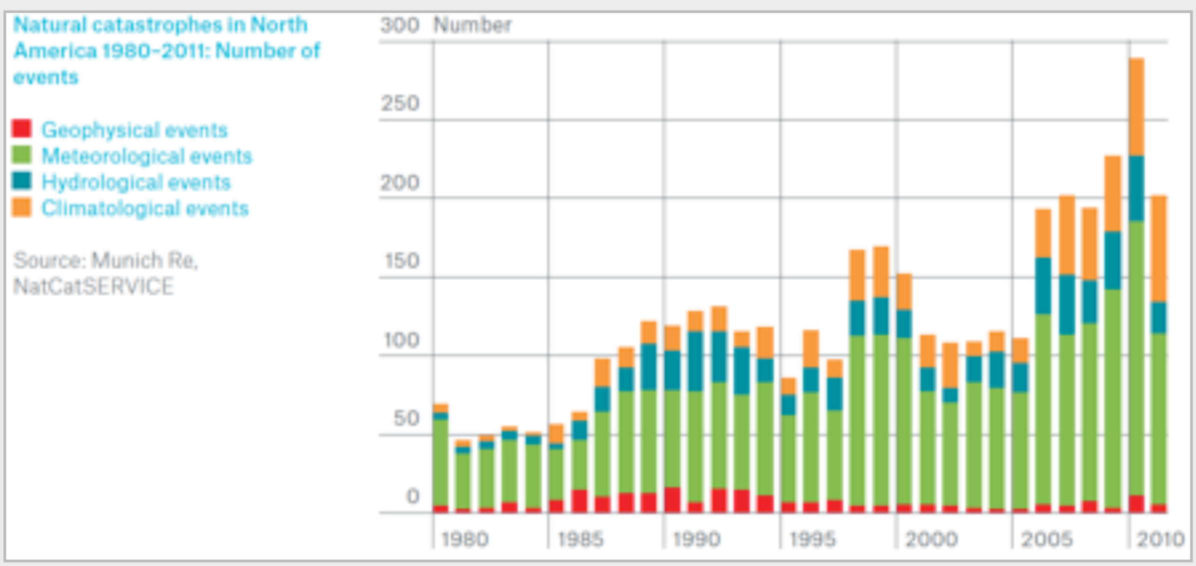
Focus first on the here and now, not on what might come later. Too often speakers focus solely on the potential of future climate change impacts to warn against inaction in controlling carbon pollution. This approach reinforces the perception of many Americans that climate change is primarily an issue of the future.[44] Unfortunately, this frame undermines any sense of urgency.

Paint the Big Picture

It is important to frame conversations, including discussions about individual events and disasters, by making the fundamental connection: climate change is happening right here, right now. Much like the Surgeon General needed a simple statement to convey the risks of smoking, speakers on global warming need to lead, continue, and end with the simple overarching statement that climate change is here.

Link Damage and Disasters to the Larger Trends

These trends are the middle link between individual events and global warming. Connect the dots by starting with the current event, explain how it is consistent with the ongoing trend, and then link that trend to climate change. Consider, for example, these trends and impacts: Increasing drought and interruptions in food supply; increasing extreme precipitation, flooding and disruption in transit and transportation; increasing heat waves and mortality among the ill and elderly.



Climate-related natural disasters have already increased in the U.S.
Source: Munich Re, NatCatSERVICE

Highlight the Strongest Link
When linking climate disruption to individual events with multiple climate change connections, start with the links where the science is strongest. For example, in the disaster brought on by Superstorm Sandy, the strongest link to climate change is found in the elevated sea levels that increased the reach of the storm's sea surge, significantly amplifying the cost of the disaster.

Focus on Climate Disruption
Talk about climate disruption, rather than climate change or global warming. This helps avoid counter-intuitive framing, such as warming causing extreme winter storms in the U.S., which can be confusing though factual. It also helps your audience understand how a small change in the average global temperature can have a major impact on extreme events. The average temperature during the last Ice Age was only 9˚ F cooler than recent conditions.

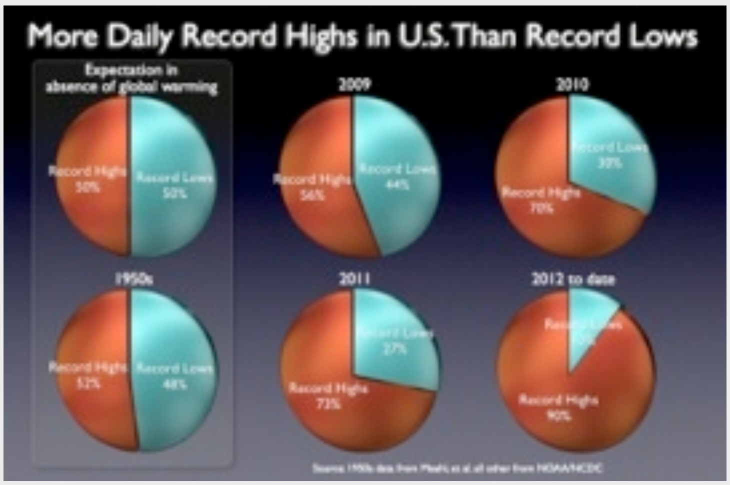
Connect Climate Disruption to the Disaster
Link climate disruption to the collateral and direct damage incurred by the event, rather than just to the event itself. In some instances, climate change magnifies the scope of a disaster, such as the rising sea levels that pushed up the surge from Superstorm Sandy. At other times, global warming contributes directly to the event itself, such as in the case of heat waves. But even then, explaining causality can be distracting, and there are other instances where the connections are very complex. In general, frame climate change as amplifying the disaster as opposed to contributing to the underlying event. This can help avoid an overly narrow conversation focused on whether climate change "caused" an event.

> "*When we see records being broken and unprecedented events such as this, the onus is on those who deny any connection to climate change to prove their case. Global warming has fundamentally altered the background conditions that give rise to all weather. In the strictest sense, all weather is now connected to climate change*."
>
> – Dr. Kevin Trenberth, National Center for Atmospheric Research

Invoke Thresholds for Assessing Damage and Disaster
Disaster usually strikes when a threshold is crossed, and climate change is often the straw that breaks the camel's back. Human infrastructure and natural systems have developed to cope with historical extremes such as 100-year events. New, more intense extremes can overwhelm and collapse existing human systems and structures.[45] Although climate change may have only contributed to or amplified the events underlying any particular disaster, it may have been primarily responsible for most of the damages. Climate disruption turns an extreme event into a disaster.

Talk About What You Know
Don't start with what you don't know. Don't lead, for instance, by saying you can't blame a particular disaster on climate change. Conversations in the media are extremely short and often framed by the very first thing we say. In this context, explaining that we cannot blame individual events on climate change is confusing at best and misleading at worst. Instead, start with what you do know, and build from there.

Highlight Broken Records
Record setting events are a signal of climate change. They grab attention and offer an intuitive understanding of climate change. Records tend to be broken when natural variability runs in the same direction as a trend driven by global warming.



New record high temperatures have consistently outnumbered record lows. Source: Meehl et al. and NOAA

Focus on Frequency and Severity
A small change in average global temperature leads to a very large change in the frequency of the most extreme events.[46] Extreme events are rare. However, a small shift in temperatures bumps these events toward the middle range where events are much more commonplace. For instance, NOAA found that the intensity of a heat wave in Texas equal to the state's recent record-breaking heat wave is now 20 times more likely due to climate disruption.[47] The most severe events are exactly the kind of events that are the most likely to have become much more frequent due to climate change.

Emphasize Unprecedented Events
Don't shy away from linking climate disruption to unprecedented events, particularly when the event is consistent with the basic physical changes driven by global warming. By definition, there are no long-term trends for unprecedented events, so that method for assessing the link to climate change is not available. Climate models tend to be poor at simulating the kinds of atmospheric circulation changes, such as "blocking," that foster many unprecedented weather events, making that kind of analysis less than reliable. However, unprecedented events are exactly what climate change produces. Any particular event could represent the wild cards introduced by climate disruption. In the strictest sense, all weather events are now affected by climate change, so the burden of proof becomes showing that something *other than* climate change is fully responsible.[48]

Know the Signatures of Climate Change
The signatures of climate change vary for different kinds of impacts and for different regions. Learn the signatures of climate change for your region. Get the language right. The relationship between impacts and climate change is complex, and opponents will jump on mistakes. Learn the science and the right phrasing to link current impacts and disasters to climate change (see sections below).

Don't Debate the Science
Spending too much time rehashing denier talking points can reinforce the idea that the science is controversial. Instead, it is better to simply point to trusted authorities who have validated the reality of climate change and its current impacts, such as NOAA, NASA and the U.S. National Academy of Sciences, as well as the insurance industry and the U.S. military.

Don't Debate the Consensus
Explain the existence of deniers by comparing them to those who denied the consensus on smoking for many years after the Surgeon General's warning.

Push Back
Questioning the link between climate change and extreme events is no different than questioning the link between smoking and cancer. It is important to assert that the science is extremely strong.

Preempt Alternate Explanations
Sometimes natural variation, El Niño, blocking events and other circulation changes are invoked as the cause of unprecedented or record-breaking extreme weather. You can preempt these arguments by accounting for them in your communication. These kinds of "explanations" amount to nothing more than a description of the larger event. They do not identify the ultimate drivers of the event, among which climate change should be counted. Invoking a circulation change as the cause of an extraordinary and unprecedented extreme weather event is like saying the engine was responsible for accelerating the car. The real question remains: where did the extra fuel come from? One contributing factor is climate change.[49]

While global warming is now a contributing factor to all weather events, natural variation has always been, and will continue to be, a major determining factor for day-to-day weather. It is important to start conversations about extreme weather events by spotlighting and explaining their connection to global warming. Nevertheless, as the conversation deepens and gains nuance, you can preempt arguments about natural variation by explaining how climate disruption dramatically changes the frequency and intensity of the weather delivered by natural variation. However, remember the goal is not to deliver a science lesson, but to answer the question that Americans want to know: are current extreme events related somehow to global warming?

Know Your Audience
Consider your audience when deciding how explicitly to connect the dots. When discussing disaster and extreme events, introduce the role of carbon pollution in driving climate disruption as appropriate. Sometimes you may not be the best spokesperson for your audience. Use the messengers most trusted by those who you are trying to reach.

Signatures of Climate Change

Extreme Weather

The effects of climate change differ across regions and in relation to sectors of society and its systems, so it is important to know and highlight the signatures of global warming according to individual impacts.

Heat Waves

For heat waves, focus on the intensity, duration and frequency of events, as climate change amplifies each of these characteristics. Strikingly, a small change in average global temperature leads to a dramatic change in the frequency of extreme events such as heat waves.[50,51]

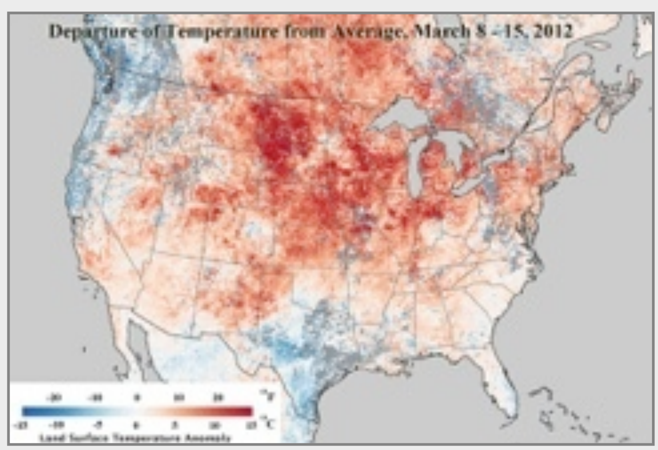
Since 1950, the number and duration of heat waves worldwide has increased.[52] The hottest days and nights have become hotter and more frequent.[53,54] And in the past several years, the global area hit by extremely hot summertime temperatures has increased 50-fold.[55]

The fingerprint of global warming has been firmly identified in these trends.[56,57,58] The signal of climate change can be seen in the trend toward hot nights, hot days, and high humidity.[59,60,61]

In the United States, new record high temperatures now regularly outnumber new record lows by a ratio of 2:1.[62] And for the U.S., the rise in heat-trapping gases in the atmosphere has increased the probability of record-breaking temperatures 15-fold.[63] The signal of climate change is reflected in record-breaking heat waves, as records are more likely to be broken when climate change runs in the same direction as natural variation.[64]

Cold Spells

Cold spells can be driven by disruption of regional circulation patterns such as the jet stream. While average global temperatures rise with global warming, individual regions can experience unusually cold weather if they are in the path of changing weather patterns circulating cold air from places such as the arctic.[65] Natural variation will continue to bring cold weather. Look for cold spells associated with unusual weather patterns linked to climate change, such as increased "waviness" in the jet stream.



Temperatures were over 20 degrees F (dark red areas) above average during the heat wave of spring 2012. Source: NASA

Rain and Snow

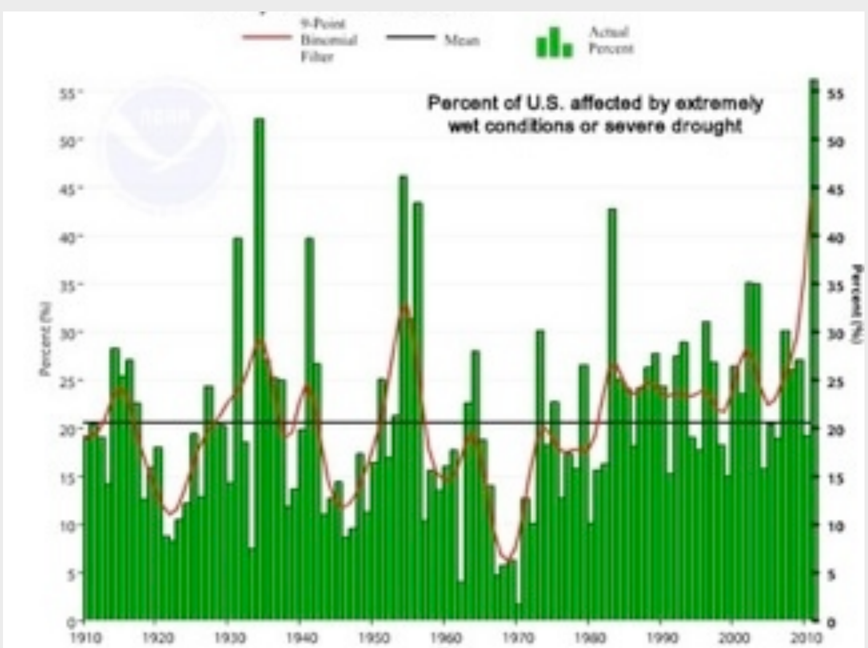
For rain and snowfall, it is important to focus on the trends driven by climate change specific to each region. Global warming has changed the geographic pattern of precipitation; some areas are getting drier while others are getting wetter. At the same time, climate change has increased the intensity of precipitation across the world. When it rains now, it really does pour.

Even areas that see less precipitation overall now experience this trend of concentrated downpours. Focusing on intense rainfall events, then, is a powerful way to highlight the impact of climate change regardless of region.[66,67,68,69]

One of the clearest changes in the weather across the U.S. is the increasing frequency and intensity of heavy rain and snow. For example, in the past century we have witnessed a 20 percent increase in the amount of precipitation falling in the heaviest downpours. In the Northeast, the amount of precipitation falling in the heaviest 1 percent of events has increased 67 percent over the last 50 years.[70]

Storms supplied by climate change with increasing moisture are widely observed to produce heavier rain and snow.[71] NOAA reports that the record-breaking rainfall dumped by Hurricane Irene was the primary impact of the storm in the United States, with flooding and other damage totaling more than $15 billion.[72]

In addition to concentrating rain and snowfall into heavier events, climate change also has dramatically reworked the pattern of wet and dry areas around the world. While total global precipitation has remained flat or increased slightly, dry areas are becoming drier and wet areas wetter.



The percentage of the country affected by either extreme drought or extreme rainfall has increased. Source: NOAA

Mid-latitude areas, such as the U.S. Midwest and Northeast, have experienced an increase in total precipitation. Sub-tropical areas, such as the U.S. Southeast and Southwest, on the other hand, have experienced a sharp decrease. As a result, the risk of both drought and flooding in the U.S is increasing.[73,74]

Some sub-tropical areas, such as Texas, have not witnessed clear changes in long-term precipitation trends, but recent shortfalls in precipitation are consistent with the global changes driven by climate change.[75]

Heavier snowfalls are also consistent with climate change. A warmer atmosphere holds more water, which will continue to fall as snow as long as winter temperatures don't rise above freezing.[76] The U.S. Northeast, for example, has experienced a dramatic increase in one-day precipitation extremes during the October to March cold season.[77]

Drought

Global warming drives drought through changes in both precipitation and temperatures that vary by region, so it is important to focus on the climate change-driven trends specific to the local region. Watch, too, for large swings between drought and flood, a pattern consistent with global warming.

Depending on a region's latitude, climate change can reduce or increase the total annual precipitation. It can also concentrate the year's precipitation into fewer but heavier downpours. This can lead to more run-off and, in turn, contribute to drought.

Global warming can also raise local temperatures and drive more frequent and intense heat waves, all of which can dry out land and prompt the early melt of snow pack, another contributor to drought.

Drought has become more frequent and intense in some regions of the U.S. The drought over the last decade in the western U.S. represents the driest conditions in 800 years.[78]

Farmer Steve Niedbalski of Nashville, IL shows the effects of drought on his corn. The drought of 2012 has been devastating to farmers.
Photo: Seth Perlman, AP

Worldwide, climate change tends to cause dry areas to become drier. Moreover, areas around the world are seeing increasingly wide swings between wet and dry extremes, another hallmark of climate change.[79,80]

The different ways climate change can drive drought can be observed across the United States. The U.S. Southwest has experienced climate change-amplified drought through higher temperatures and loss of snow pack.[81] Texas has experienced climate change-fueled drought through recent record heat waves, which dry out soils.[82,83,84] And dramatic swings between drought and flooding in the Southeast U.S. have been linked to changes in the North Atlantic Subtropical High, another result of global warming.[85]

Flooding

Flooding can be particularly tricky to discuss. In addition to changes in extreme weather (which vary regionally), flooding is affected by factors such as land development, deforestation, levee placement and local topography.[86]

Focus on floods consistent with regional climate change trends, such as an increase in heavy rain and snow, early snowmelt, and increased seasonal precipitation. All of these trends may be linked back to climate change depending on the region.[87,88] Watch, too, for large swings between drought and flood, a pattern consistent with global warming.[89]

Heavy precipitation is contributing to increased flooding around the world.[90,91] Very heavy precipitation has increased over the past century in many parts of the U.S. The largest increases have occurred in the Northeast, Midwest, and Great Plains, where heavy downpours have exceeded the capacity of infrastructure such as storm drains and have led to flooding events.[92] The extreme precipitation during both the Nashville flood of 2010[93] and Hurricane Irene[94] illustrate this trend.

In contrast to flooding driven by short-term extreme precipitation, flooding in large river basins, such as the Mississippi, is caused by seasonal precipitation persisting for weeks or even months. The frequency of great floods (100-year floods in large basins) around the world has increased over the course of the 20th century.[95] Recent periods of sustained rain in the U.S. Midwest and Northeast are consistent with the shift of the mid-latitude rain belt, which has been pushed northward by changes in atmospheric circulation driven by global warming.[96]

Flooding in the northern half of the eastern Great Plains and much of the Midwest has been increasing, especially over the last several decades. In the areas of greater flooding, increases in both total precipitation and extreme precipitation contribute.[97] Very heavy, sustained rains drove record-breaking Mississippi River flooding in 2011. Such long-term heavy precipitation events are becoming more common. In the U.S., 90-day periods of heavy rainfall were 20 percent more common from 1981 to 2005 than in any 25-year period on record.[98]

Superstorm Sandy caused unprecedented flooding in the subways of New York City, with massive costs.
Photo: Timothy A. Cleary, Getty Images

Storms

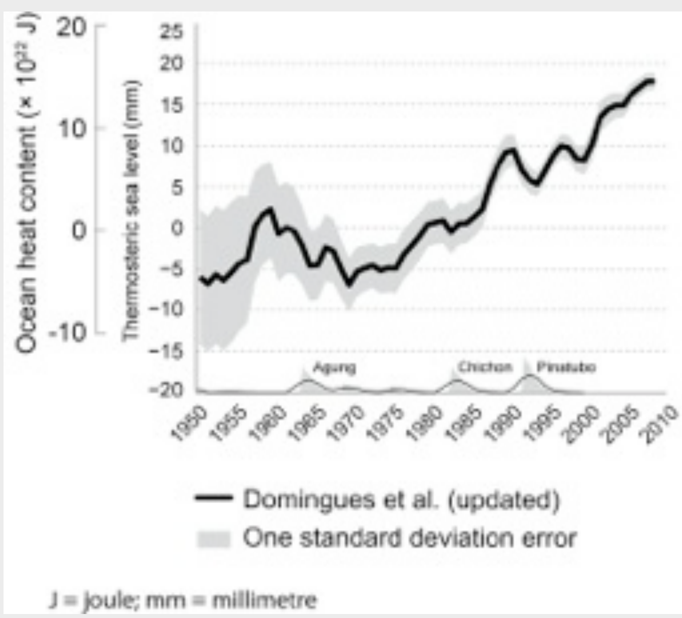
For storms generally, focus on their intensity and heavy rainfall. [Note: see specific guidelines for hurricanes and tornadoes below.] Climate change loads storms with more energy, thus increasing intensity. All storms, including thunderstorms, snow storms, and tropical cyclones, are now developing in a warmer, moister environment.[99] General storminess around the world, as measured by winds speeds and ocean wave heights, has increased in recent years, particularly during winter months.[100]

Consistent with a warming climate, a 4 percent increase in atmospheric moisture has been observed.[101] Storms reach out to gather water vapor over regions that are 10 to 25 times as large as the precipitation area, thus multiplying the effect of increased atmospheric moisture. As water vapor condenses to form clouds and rain, it releases heat energy that adds buoyancy to the air and fuels the storm. This increases the gathering of moisture into storm clouds and further intensifies precipitation.[102]

For winter storms, use the term climate disruption to help explain the link to winter storms instead of counter-intuitive terms such as global warming. Climate disruption in the Arctic occasionally lets loose severe winter storms that sweep down and over the United States.[103]

Hurricanes

For hurricanes, focus on the role global warming plays in increasing heavy rains and on the contribution of global warming to higher storm surge through rising sea levels. The science is strongest on these links, and for many storms, the damages wrought by heavy rain and storm surge are often much worse than the damage from heavy winds.



Ocean heat content has greatly increased since 1950, and more heat in the ocean means more energy for storms and hurricanes. Source: Center for Australian Weather and Climate Research

Global warming is already loading hurricanes with additional moisture that makes rainfall more intense. Global warming meant Hurricanes Katrina and Ivan, for example, carried significantly more rainfall. In the case of Katrina, that increase may have contributed to the breach of the levees in New Orleans.[104,105]

At the same time, hurricane storm surge now rides higher on seas that have risen over the last century, much of which is attributable to melting ice sheets and a warmer, expanding ocean. Rising sea levels give storm surge a higher platform for jumping onto land.[106] Over the last century sea level has risen nearly a foot in the New York harbor, for instance, one of the locations damaged worst by the storm surge thrown up by Superstorm Sandy.[107]

There has been a substantial increase in virtually every measure of hurricane activity in the Atlantic since the 1970s. These increases are linked, in part, to higher sea surface temperatures in the region that Atlantic hurricanes form in and move through. Numerous factors influence these local sea surface temperatures, including human-induced emissions of heat-trapping gases and particulate pollution and natural variability.[108]

Substantial evidence indicates that global warming also may be responsible for the recent increasing intensity of Atlantic hurricanes,[109, 110,111,112,113,114] for the increasing size of hurricanes[115] and a lengthening hurricane season.[116] Out of the 11 most intense North Atlantic hurricanes ever recorded, five have occurred in the last eight years (Wilma, Rita, Katrina, Dean and Ivan).[117] There is some debate, however, over whether one can confidently attribute these recent trends to global warming due to the incomplete historical record over the last 150 years[118] and the complex interaction of the factors that govern hurricane formation.[119]

Looking forward, there is a consensus among experts that global warming will create stronger hurricanes.[120,121] Although the global tropical cyclone count may decline slightly, the science projects a dramatic increase in the number of very strong hurricanes in the Atlantic.[122] Unfortunately, these two trends may not balance out, as the damage caused by stronger hurricanes is exponentially greater than the damage wrought by lesser storms. As such, one can say that as global warming becomes locked in, the damage brought on by particularly strong hurricanes will grow.

Tornadoes

Due to poor quality records, the long-term trends in tornadoes over the last century are unclear.[123,124] Be careful with the science connecting tornadoes to climate disruption. While there is considerable evidence, the full story is not yet known and important pieces are still missing. To connect the dots, it is best to simply note that an increase in tornadoes is consistent with the warmer, wetter world created by climate change, and that particularly large and unprecedented tornado events MAY represent the results of climate disruption. Focus in particular on intense February tornadoes and tornadoes appearing well north of usual.

Note that 2011 was the second-most active year in the tornado record, and 2004 ranked as the all-time most active year.[125] Meteorologists report that in recent years tornadoes have appeared well north of usual latitudes and have been unusually intense early in the calendar year.[126] February 2008 was the most active February in the modern record; February 2010 the fourth most-active and February 2012 the fifth-most active. The five largest early- season two-day outbreaks have all occurred since 1997, and three of the top five outbreaks occurred in the last four years.[127]

Is global warming influencing tornadoes? According to the National Oceanic and Atmospheric Administration (NOAA), the best answer is: “We don't know.”[128] However, tornado spikes, particularly early season tornadoes and tornadoes further north than usual, are consistent with the warmer, wetter world brought on by climate change. The computer models that illustrate our best understanding of climate in a warming planet indicate that the conditions that foster the thunderstorms that spawn tornadoes may increase in some regions and stronger tornadoes will become more frequent.[129,130]

Wildfires

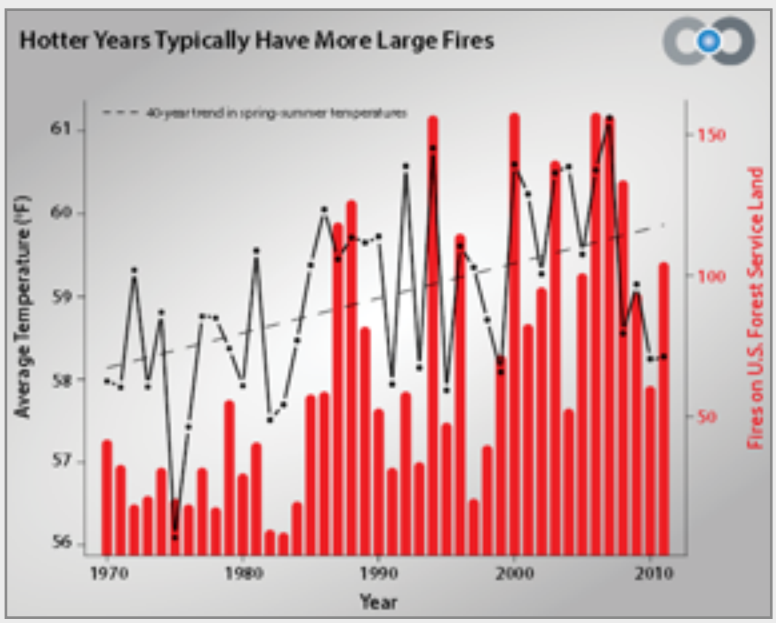
Climate disruption has amplified the threat of wildfires. This is particularly true for the western United States. To make climate connections, focus on the length of the fire season and the size of fires. Watch for new fires burning in regions where fires were not witnessed before.

In the western United States, both the frequency of large wildfires and the length of the fire season have increased substantially in recent decades. Earlier spring snowmelt and higher spring and summer temperatures drive this change.[131,132] Climate change has increased the threat of "mega-fires" – large fires unprecedented in their impacts.[133] Warming has also led to wildfires present in regions where they have been absent in recent history.[134]

Climate change is also promoting bark beetle outbreaks: these pests breed more frequently and successfully in warmer winter conditions. And the dead trees left behind by bark beetles make crown fires more likely.[135]

Average fire size in 2012 was largest on record. More than nine million acres burned in 2012, the 3rd highest total on record behind 2006 and 2007, and damages topped $1 billion dollars.[136] More than 740,000 homes in 13 western states— with an estimated value of $136 billion — are located in areas deemed at high risk of wildfire.[137]

In the midst of severe drought in the summer of 2011, Arizona and New Mexico suffered the largest recorded wildfires in their recorded history, vividly illustrating how different elements of climate change can interact to escalate events into a disaster. Following the fire, heavy rainstorms led to major flooding and erosion, including at least 10 debris flows that caused costly damage to drinking supplies. Sediment and ash eroded by the floods were washed downstream into the Rio Grande, which supplies 50 percent of drinking water for Albuquerque, the largest city in New Mexico. The city stopped water withdrawals for a week and reduced them for six months due to the increased cost of treatment.[138]



Higher average spring and summer temperatures correspond with more forest fires on U.S. Forest Service land.
Source: Climate Central

Season Creep

As climate change continues to advance, spring is arriving much sooner, while winters are becoming shorter and milder. This phenomenon has been documented around the world and informally dubbed "season creep."[139,140]

Global warming drives season creep.[141] Natural variability can, at best, explain only one-third of the rate of "creep" in the arrival of spring.[142]

Season creep is an example of how small changes can have a big impact; climate change disrupts the critically important timing of events, such as snow melt and spring bloom, upon which ecosystems and agricultural industries depend. Focus on these disruptions to highlight climate change here and now.

In the United States, spring now arrives an average of 10 days to two weeks earlier than it did 20 years ago.[143] Growing seasons have lengthened by 10-20 days.[144] Many migratory bird species are arriving earlier. For example, northeastern birds that winter in the southern United States now return to the Northeast an average of 13 days earlier.[145] Spring snowmelts have shifted so that peak melt flow now arrives 1-4 weeks earlier.[146] Flowers are blooming earlier, including a week earlier on average for Washington D.C's famous cherry blossoms.[147] Hardwood forests are holding their green leaves 10 days longer.[148]

Season creep is impacting a wide range of industries. For example, warmer winters can lead to early bud-burst or bloom of some perennial plants, resulting in frost damage when cold conditions occur in late spring, as was the case with Michigan cherries in 2012.[149] Maple syrup production requires cold temperatures for strong sap flow and good flavor, and the brevity of recent winters has cost producers.[150]

Rick Hardy of the Brookdale Fruit Farm shows peach blossoms that opened early due to warm weather, but then were damaged by frost. They will bear no peaches, causing him financial loss. Photo: Bob Hammerstrom

Finally, season creep is impacting biodiversity, with cascading effects on agriculture, tourism, hunting, and fishing. All species do not respond to the change of seasonal cues in the same way. This can lead to mismatches between the availability of flowers and their pollinators or predators and their prey.[151,152] For example, the pied flycatcher now migrates at the wrong time relative to its prey and has experienced a 90 percent population decline.[153] In some cases, these disruptions can enable takeover by invasive species, as witnessed at Thoreau's Walden Pond.[154]

Arctic Sea Ice

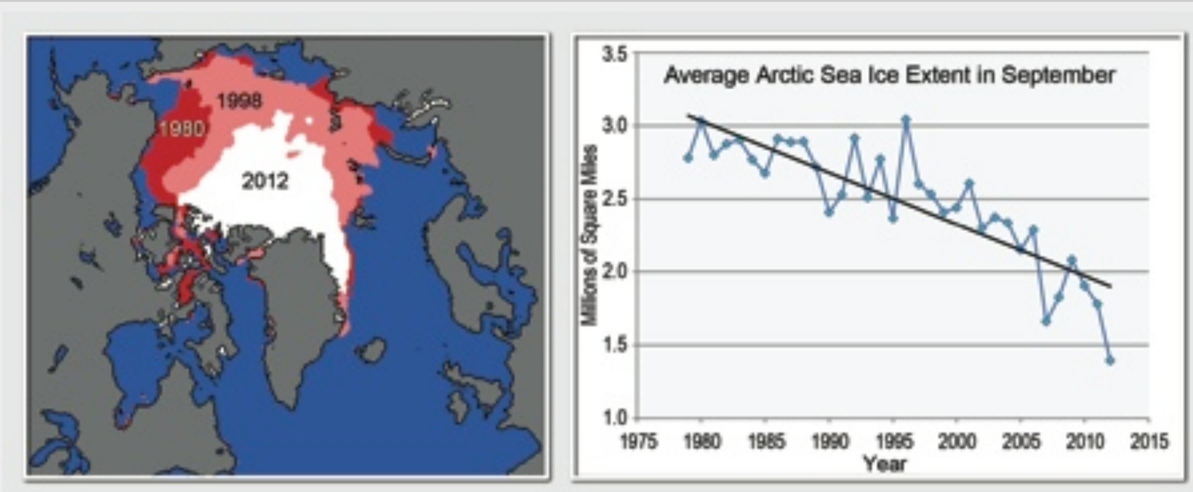
The massive loss of iconic sea ice in the Arctic is one of the most powerful indicators of climate change and resonates strongly with the American public. When public opinion surveys ask respondents to explain why they recognize global warming, sea-ice loss is one of the primary factors cited.[155,156]

To discuss the impact of global warming in the Arctic, highlight the 50 percent summer sea ice loss and the Arctic's diminished capacity to work as the planet's air conditioner in moderating global temperatures. Additionally, link to disruptions in Arctic weather patterns that have recently surfaced and are driving extreme weather (in particular, harsh winter storms) down to the lower 48 states.

Due to a combination of greenhouse gasses and its unique climate feedbacks, the Arctic has been warming at double the rate of the rest of the globe. This is causing an unprecedented and rapid retreat of thick Arctic sea ice. The signature of climate change has been firmly documented in the recent record-breaking melt seasons. The summer melt of 2012 reached an all-time record low, with sea ice extent falling to 50 percent of the historic average. The record low of 2012 was 18 percent below the prior record low set in 2007. And the total amount lost was equivalent in size to 43 percent of the contiguous United States.[157,158]

Currently, Arctic sea ice serves as the planet's air conditioner, moderating solar heating by increasing the reflectivity of Earth's surface and decreasing the amount of heat that would otherwise be absorbed by ice-free Arctic seas. The loss of the air-conditioner effect, as sea ice disappears, creates a feedback loop that accelerates global warming.[159]

Arctic sea ice has been retreating over the past 30 years, and the rate of retreat is accelerating at a pace that exceeds most models' forecasts.[160] Research shows that before the 20th century's influx of greenhouse gasses and subsequent period of Arctic sea ice retreat, the Arctic was in a 2,000-year cooling trend.[161]



Arctic sea ice has shrunk dramatically. Source: Melillo et al. 2013

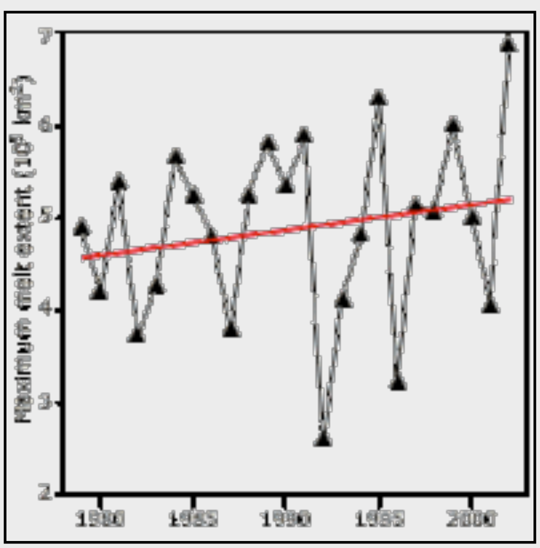
Changes in the Arctic, especially sea ice loss, are affecting weather patterns in the lower United States. The loss of Arctic summer sea ice and the rapid warming of the area alter the jet stream — and thus weather patterns — over North America, Europe and Russia. These changes increase the likelihood of extreme weather and drive winter storms south.[162,163]

If heat-trapping pollution continues, summer sea ice will be lost entirely. The climate models that most accurately simulate past sea ice trends suggest this will probably happen in 22 years, possibly as soon as eight years.[164]

Ice Sheets and Glaciers

Greenland

The melting of ice sheets and glaciers around the world is accelerating and contributing to rising sea levels. Glaciers are retreating and/or thinning in Alaska and in the lower 48 states. Some well-known glaciers, such as those in Glacier National Park, are on the verge of disappearing altogether. Melting in Greenland is particularly dramatic and has the potential to become as powerful a climate change signal as Arctic sea ice loss.



Greenland melt extent has been steadily increasing over time.
Source: NASA Earth Observatory

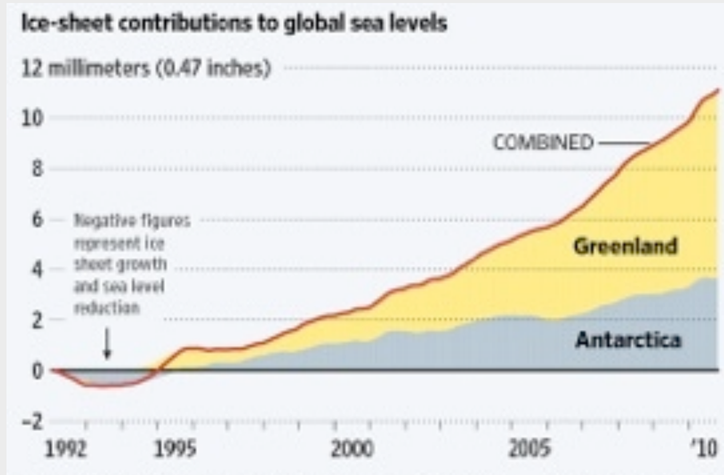
The glaciers and ice sheets of Greenland are among the largest bodies of fresh water on the planet. The surface of the Greenland ice sheet has been experiencing summer melting over increasingly large areas during the past several decades. In the decade of the 2000s, the daily melt area was double the corresponding amount of the 1970s, culminating in summer melt that was far greater in 2012 (97 percent of the Greenland ice sheet area) than in any year since satellite records began in 1979. More importantly, the rate of mass loss has accelerated in recent decades. This increases Greenland's contribution to sea level rise.[165]

The key issue in predicting future rates of global sea level rise is to understand and predict how ice sheets in Greenland and Antarctica will react to a warming climate. Current projections of global sea level rise do not account for the complicated behavior of these giant ice slabs as they interact with the atmosphere, the ocean and the land. Lack of knowledge about the ice sheets and their behavior is the primary reason that projections of global sea level rise include such a wide range of plausible future conditions that include more than 6 feet of sea level rise in the coming decades.

The massive weight of Greenland's ice sheet physically pushes the island down into the ocean. As the ice sheet melts and the weight decreases, the island rises in response. In recent years, so much ice has melted so quickly that the rate of Greenland's rising has been accelerating since 1990s.[166]

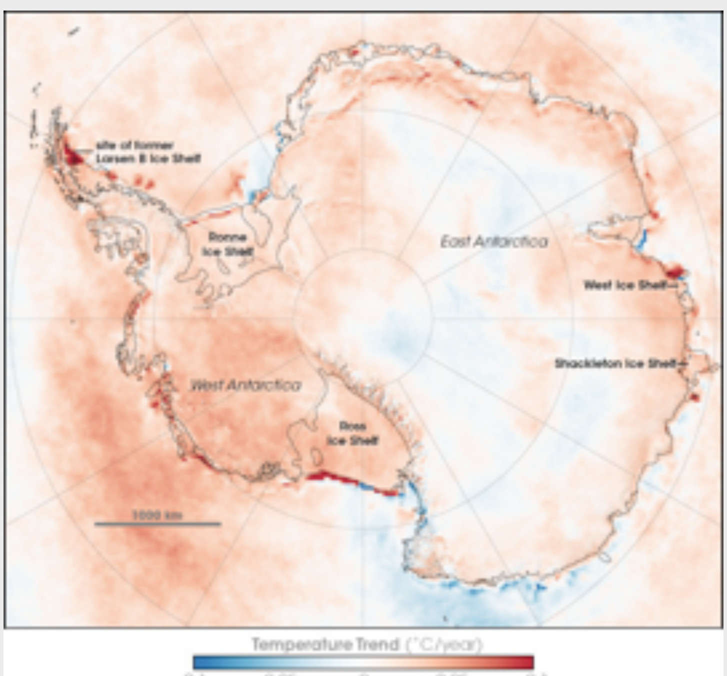
Antarctica

In the face of climate change, Antarctica presents a more complex picture than its counterpart in the Arctic. Continent-wide, Antarctica has shown a positive warming trend over the last 50 years.[167] However, not every region has responded in the same way. The Antarctic Peninsula has shown the strongest warming, followed by West Antarctica, while East Antarctica and the continental interior have at times shown cooling trends.[168] To explain these trends, researchers note that ocean currents deliver heat to the Antarctic Peninsula and coastal regions. In the interior and eastern regions, on the other hand, reduced ozone coverage alters air currents, increases winds, and thereby diverts warm air.[169,170,171]



Over the past two decades, warmer temperatures have caused the permanent ice sheets of greenland and antarctica to melt at an accelerating rate and contribute to rising sea levels. Source: The Ice Sheet Mass Balance Inter-comparison Exercise (IMBIE)

When it comes to ice, the story is similarly complicated. In spite of warming temperatures, sea ice extent in some areas of Antarctica has increased.[172] Research suggests this is due to reduced mixing between warm and cool layers in the ocean that ordinarily speeds the melting of ice.[173] The previously mentioned wind patterns induced by ozone depletion may also play a role.[174]



The coastlines and west of Antarctica are warming, while the central and eastern parts are cooling.
Source: NASA

In other, more important ways, though, Antarctica is losing ice. Independent of any changes to the extent, or surface area, of sea ice, new research shows that melting from below is causing most of the continent's ice shelves to grow thinner, some at a rate of up to seven meters per year.[175] Land ice sheets are melting too, at an accelerating rate of over 246 billion tons per year.[176,177,178] Unlike sea ice, land ice melt contributes to sea level rise. Melting of the Antarctic and Greenland ice sheets alone was responsible for about a half inch of sea level rise since 1992.[179]

In summary, Antarctica is both warming in temperature and contributing significantly to sea level rise. While some localized areas may be cooling and/or gaining ice, these examples are not enough to reverse the trend.

Sea Level Rise

Sea levels have increased by about 10 inches since they began rising in the middle of the 19th century.[180] Recently, the rise has accelerated, with the rate of rise doubling since 1992.[181] These changes stand in stark contrast to the prior 2,000 years, when there was little change.[182] This rise is primarily due to global warming.[183]

Sea level rise is already impacting coastal communities in the United States.[184] Focus on the impact of sea level rise in storm surge, tidal flooding and saltwater intrusion into fresh water aquifers. Also watch for local flooding compounded by intense rainfall, another impact of climate disruption.

While sea level rise may be modest relative to the total height of storm surge or high tides, it can be the straw that breaks the camel's back. Disaster usually strikes when a threshold is crossed. Human infrastructure and natural systems have developed to cope with a range of historical extremes, such as 100-year events. New, more intense extremes can overwhelm and collapse existing human systems and structures.[185] When sea level rides on top of storm surge

The impact of sea level rise is particularly visible in coastal flooding events such as this Annapolis scene from January 2010 in which sea level rise furthered the reach of an unusual high tide compound by a strong onshore wind. Photo: Chesbayprogram on Flickr

and high tides, it can be responsible for a disproportionate amount of damage.
Sea level rise, combined with coastal storms, has increased the risk of erosion, storm-surge damage, and flooding for coastal communities, especially along the Gulf of Mexico, the Atlantic seaboard, and Alaska. Rising sea levels give storm surge a higher platform for jumping onto land.[186] Over the last century, sea level has risen nearly a foot in the New York harbor, one of the locations worst hit by the storm surge driven by Superstorm Sandy.[187] Coastal infrastructure including roads, rail lines, energy infrastructure, and port facilities including naval bases, are at risk from storm surge that is exacerbated by rising sea levels.[188]

Higher sea levels also destroy the marshes and wetlands that provide coastal areas an essential buffer from storms and flooding. Higher sea levels cause more frequent flooding from higher tidal surges as well as saltwater intrusion into aquifers and estuaries. In regions where precipitation increases, coastal areas will see heavier runoff from inland areas, with the already observed trend toward more intense rainfall events continuing to increase the risk of extreme runoff and flooding.[189]

Climate change drives sea level rise in two major ways. Warming expands the volume of water in the oceans, which pushes up sea levels. Warming also melts glaciers and ice sheets on land, with the run-off adding to sea levels. Melting sea ice is *not* a significant factor, as melted water mostly fills the empty volume left behind by melted ice. Regional sea levels vary based on regional and local changes in land movement and long-term changes in coastal circulation patterns.[190] Looking forward, the consensus science suggests an upper limit of 6.6 feet of global rise by 2100 should be used for risk analysis.[191]

Ocean Acidification

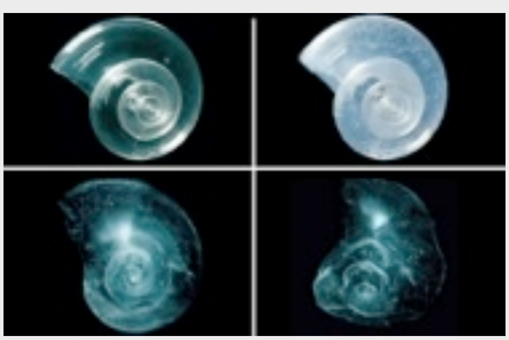
Ocean acidification, driven directly by rising carbon dioxide levels in the atmosphere, is progressing steadily and measurably and is already taking a toll on sea life. Ocean acidification is the evil twin to global warming. Both stem from carbon pollution, and the production of CO2 emissions from power plants, factories, cars and buildings has already tipped the balance in the oceans around the world.

Focus on the link between acidification and carbon pollution and the parallel link between carbon pollution and global warming. Highlight the current impacts of acidification and the risks it poses to food resources, related industries and the broad web of relationships between ecosystems. Acidification currently threatens sea life, primarily by making it harder for animals with hard shells and skeletons to access material to build them. Weaker and thinner shells

Ocean acidification impairs the development of shellfish like this Pacific oyster. Many hatcheries in the Pacific Northwest have already experienced declines in production. Photo: NOAA make sea life more vulnerable to predators, disease and death. Scientists believe acidification may worsen corrosion of marine animal shells and skeletons in the future.

The increase in ocean acidity is indisputable, and the rate and magnitude of the change is unprecedented, with a 30 percent jump since the beginning of the industrial revolution, as reported by the National Academy of Sciences. The rate of change is one of the main reasons scientists are concerned that marine life cannot adapt quickly enough to acidification.[192,193]

The impact of acidification is already happening and illustrates the risks to ocean life and resources that both ecological and economic systems rely upon. Damage from acidification to oyster larvae in the Pacific Northwest has been documented,[194,195] as well as poor shell development in sea snails that many whales depend upon as feedstock.[196,197] Both observations confirm scientific expectations of threats from acidification.[198] In addition, scientists have discovered damage to coral reefs consistent with acidification.[199]



In an experiment simulating water conditions in 2100, a snail shell slowly dissolves over 45 days. Current levels of acidity are enough to impair shell development. Source: NSF/NOAA

Human Health

Climate disruption is already affecting health risks and disease vectors.[200] The interaction between climate change and health is extremely complex. Focus on the current health impacts that are consistent with the trends in the way climate change is affecting the underlying risks and vectors.

Heat-Related Illness

Exposure to extreme heat is already the primary cause of weather-related mortality in the U.S.[201] As climate change drives more frequent and longer-lasting heat waves, the associated illness and death multiply, especially in metropolitan areas and communities at higher latitudes, which are not used to such extreme temperatures.[202] There is a marked difference in the rate of deaths resulting from hot and cold temperatures. Researchers have found that on average, cold snaps in U.S. cities increase death rates by 1.6 percent, whereas heat waves trigger a 5.7 percent increase in death rates.[203]

Asthma, Allergies and Lung Disease

Global warming is amplifying some of the factors that drive asthma and lung disease.[204]

While the Clean Air Act is helping to lower emissions of traditional pollutants that drive the formation of ozone and smog, rising temperatures due to carbon pollution are working in the opposite direction and promoting their formation.[205] Hotter temperatures accelerate the processes that create surface ozone, a key lung irritant that exacerbates lung diseases and can cause breathing difficulties even in healthy individuals.[206]

Climate disruption has also prompted earlier onset for the spring pollen season in the United States, and pollen allergies have shifted earlier in parallel.[207]

West Nile, Rocky Mountain Spotted Fever, and Insect Vector Diseases

Climate change affects the life cycle and distribution of the mosquitoes, ticks, and rodents that carry West Nile virus, equine encephalitis, Lyme disease, Rocky Mountain Spotted Fever and hantavirus.[208]

West Nile virus outbreaks have exploded across the U.S. over the last 14 years, with more than 5,000 cases recorded in 2012.[209] The risk of West Nile outbreak rises with more frequent heat waves, and the epicenters of recent outbreaks have been locations marked by drought or above-average temperatures.[210]

Warmer temperatures contribute to the expansion of mosquitoes and the West Nile virus. Photo: Center for Disease Control and Prevention.

Waterborne Diseases

Heavy rains can lead to flooding that can increase the incidence of waterborne diseases due to pathogens. Contaminated drinking water after a heavy rain has already been linked to illness from organisms such as *Cryptosporidium* and *Giardia*.[211] Downpours can trigger sewage overflows that contaminate drinking water and endanger beachgoers. During heavy rains, these systems often cannot handle the volume, and raw sewage spills into lakes or waterways, including into drinking-water supplies and places where people swim.[212]

Heavy rain and flooding can contaminate certain food crops with feces from nearby livestock or wild animals. This increases the likelihood of food-borne disease associated with fresh produce.[213]

Cases of food poisoning due to *Salmonella* and other bacteria peak within one to six weeks of the highest reported ambient temperatures.[214]

Shellfish Poisoning

Vibrio sp. (shellfish poisoning) accounts for 20 percent of the illnesses and 95 percent of deaths associated with eating infected shellfish. There is a close association between temperature, *Vibrio* sp. abundance and clinical illness. Concurrent with rising temperatures, the U.S. infection rate increased 41 percent from 1996 to 2006.[215]

Society and Systems

The combination of interlocking systems, such as transportation, food, fuel and energy, raise the risk of "cascading system failures" that pose urgent risks to economies, communities and local health systems, with commensurate costs.[216]

The impact of climate disruption on U.S. infrastructure is becoming increasingly apparent from both the growing number of climate-related disasters[217] to the spectacular damage incurred in individual climate-related disasters.[218]

Focus on disasters and infrastructure damage in events consistent with the trends driven by climate change. Highlight the role that climate change may have played in amplifying the disaster and pushing the infrastructure past the point of collapse. Disaster usually strikes when a threshold is crossed.

Sea level rise, extreme weather, heat waves and droughts – all stress infrastructure, from drinking and wastewater systems to the transportation that drives our economy and the energy system that powers the national grid.[219]

The National Oceanic and Atmospheric Administration reports an increase in billion-dollar weather disasters across the U.S. in recent years, with an astonishing 25 such billion-dollar disasters with damages totaling more than $120 billion occurring in just the last two years.[220] Four out of five Americans live in counties where natural disasters have been declared since 2006.[221] The insurance giant Munich RE reports that the number of weather catastrophes across the world has tripled since 1980, with the greatest increases in North America. Climate change is helping drive this trend.[222,223]

This nuclear power plant, the Millstone Power Station in CT, had to shut down a reactor due to the warmth of the Long Island Sound. This is one of many ways climate change disrupts necessary systems. Image: Associated Press

Storm surges from Superstorm Sandy swamped New York City's subway system and disrupted the gasoline delivery system for a three-state area.[224] Hurricane Irene washed out scores of roads and bridges across New England.[225] A nuclear reactor in Connecticut shut down in August 2012 because the water in the Long Island Sound was, for the first time, too hot to effectively cool the equipment.[226] A record-breaking heat wave in July 2012 melted the asphalt at Reagan National Airport in Washington DC, trapping a jet liner on the tarmac.[227] Aquifers that supply drinking water along the heavily populated coast of south Florida are threatened by saltwater intrusion caused by sea level rise.[228]

Transportation and infrastructure are built and designed to cope with historical extremes. New, more intense extremes can overwhelm and collapse existing infrastructure.[229] The flooding of New York City subways during Sandy's storm surge and the topping of the levee in New Orleans during Katrina are just two examples where thresholds marked the transition to disaster. Although climate change may only contribute to the event underlying any particular disaster, it can be primarily responsible for most of the damages. Climate disruption turns events into disasters.

Food Price and Supply

Climate disruption is already affecting prices for food and crops through changes in growing seasons, increasing extreme weather, rising sea levels, and warming oceans. Focus on rising prices consistent with shortfalls in production that align with climate change trends.

Climate disruptions to agricultural production have increased in the recent past and are projected to increase further over the next 25 years. The rising incidence of weather extremes will have increasingly negative impacts on crop and livestock productivity because critical thresholds are already being exceeded.[230]

The effect of higher temperatures has already begun to occur; corn yields were affected by high nighttime temperatures in 2010 and 2012 across the Corn Belt.[231] The 2012 drought, the United States' most extensive drought in decades, destroyed large areas of cropland and led to increased prices that are expected to continue through 2013.[232]

Rising food prices are dependent on many factors, including population, income, and availability of supply.[233] This last factor is particularly affected by climate change.[234] From 1980 to 2008, growing seasons changed in most parts of the world. These changes had a significant effect on global corn and wheat production, leading to a roughly 20 percent increase in global prices for these commodities. During this time period, climate change resulted in a 5 percent increase in prices.[235]

Rising sea levels driven by global warming can affect food production. Higher seas make flooding in rice fields in vulnerable areas more likely, reducing yields and leading to higher prices.[236] Climate change is also changing the distribution of marine species, affecting production from fisheries as well.[237]

The connections of U.S. agriculture and food security to global conditions are clearly illustrated by the recent food price spikes in 2008 and 2011 that highlighted the complex connections of climate, land use, demand, and markets. The doubling of the FAO food price index over just three months was caused partly by weather conditions in food-exporting countries such as Australia, Russia, and the U.S., but was also driven by increased demand for meat and dairy in Asia, increased energy costs and demand for biofuels, and commodity speculation in financial markets.[238]

"How Do We Know?"

The connections between climate disruption and impacts in the United States are numerous, strong and well documented. Authoritative science institutions including NASA,[239] NOAA,[240] the U.S. National Climate Assessment,[241,242] and the U.S. National Academy of Sciences[243] have each assessed and validated these changes. And the rising cost of these impacts has been clearly tied to climate change.[244,245,246]

Several types of scientific query/investigation show us how climate change is already affecting the United States.

The first line of proof is by direct scientific measurement. Many impacts such as extreme weather, drought, ocean acidification and sea level rise have been rigorously measured. The changes are long-term, dramatic and unequivocal. And the measurements have been widely assessed and validated.

Basic physical principals offer the second proof. For example, we know that a warmer atmosphere holds more energy and more heat. Thus, global warming accounts for why the hottest days are now hotter in the United States. Or, in another example, we know that a warmer atmosphere holds more moisture, which is why the heaviest rainstorms in the United States now dump more water than before.

The computer models that simulate the climate offer the third line of proof. These models can only replicate current climate impacts when carbon pollution is put into the models. Although the models are built to simulate natural variability, the models can't produce the trends we observe in the real world based on natural variability alone. The strength and length of the trends, as well as the incidence of unprecedented events, go far beyond what natural variation could possibly explain. In some cases, trends have actually gotten worse despite the counter-acting direction of natural variation. For instance, prior to global warming, the long-term trend in global temperatures was toward cooling. If all other factors that affect global temperatures had remained unchanged, the recent decline in the sun cycle should have driven a slight dip in global temperatures. Instead, global temperatures rose.

The rising cost of the disasters related to these impacts is also clearly tied to climate change. The rise in costs goes far beyond what can be explained by population growth or increased exposure of buildings and communities due to increased wealth.[247,248,249] Climate change turns events into disasters. While climate-related catastrophes around the world have surged, rates of geophysical disasters, such as earthquakes, have remained largely level.

Example Language

This early outbreak of allergy season is consistent with global warming that has already moved up the spring start date by 20 days.

This disaster is what climate disruption looks like.

Extreme weather, which is fueled by climate change, drove this spike in food prices.

Asthma sufferers are among those hit hardest as air quality worsens with warming and climate change.

Climate change amplified this disaster and was the straw that broke the camel's back.

Global warming is feeding this heat wave.

Global disruption is driving extreme storms and flooding like this.

The storm surge in this hurricane rode on sea levels that have risen due to global warming. Global warming raises sea levels, so storm surge in hurricanes like this now reaches further inland.

Ocean acidification is creating hostile conditions for sea life, such as the problems for oyster farms in the Northwest.

Global warming is driving up sea levels, increasing the reach of high-tide flooding in our region.

Climate disruption in the Arctic is bringing harsh winter storms like this one down into the U.S.

Climate change is amplifying this drought through higher temperatures that dry out soils.

Water supplies are low due to early snow melt driven by global warming.

The feast or famine swings between flood and drought on the Mississippi River are consistent with climate disruption.

Unprecedented events like this super swarm of tornadoes may represent the wildcards that global warming has introduced into the climate.

Global warming is the climate on steroids. Like a player hitting more home runs on steroids, heat-trapping gases from smokestacks and tailpipes are fueling more extreme weather like this.

This heat wave is just one event in the larger trend toward longer, hotter and more frequent heat waves, driven by global warming.

Global warming has stacked the deck with extra aces, making events like this both more frequent and more severe.

Climate change has loaded the dice, making events like this more frequent.

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