

2009

# The State of the Climate

HIGHLIGHTS



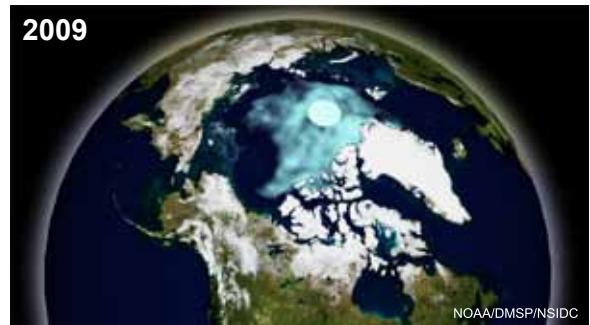
# How we know the world has warmed

A comprehensive review of key climate indicators confirms the world is warming and the past decade was the warmest on record. More than 300 scientists from 48 countries analyzed data on 37 climate indicators, including sea ice, glaciers and air temperatures. A more detailed review of 10 of these indicators, selected because they are clearly and directly related to surface temperatures, all tell the same story: global warming is undeniable.

For example, the surface air temperature record is compiled from weather stations around the world, and analyses of those temperatures from four different institutions show an unmistakable upward trend across the globe. But even without those measurements, nine other major indicators of climate change agree: the earth is growing warmer and has been for more than three decades.

A warmer climate means higher sea level, humidity and temperatures in the air and ocean. A warmer climate also means less snow cover, melting Arctic sea ice and shrinking glaciers.

## Arctic Sea Ice Annual Minimum



Arctic sea ice reaches its annual minimum in September. The satellite images above show September Arctic sea ice in 1979, the first year these data were available, and 2009. The areas of ice coverage range from 15 percent coverage (darker shades of medium blue) to complete coverage (lightest blue). The light circles over the pole indicate areas where there are no data from this satellite instrument. Dark blue is open ocean. September Arctic sea ice is the last of the 10 indicators shown on the facing page.

## Ten Indicators of a Warming World

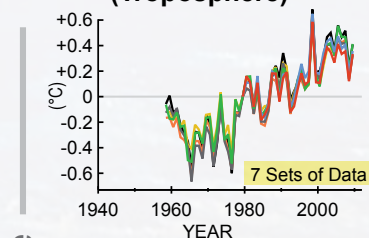


Seven of these indicators would be expected to increase in a warming world and observations show that they are, in fact, increasing. Three would be expected to decrease and they are, in fact, decreasing.



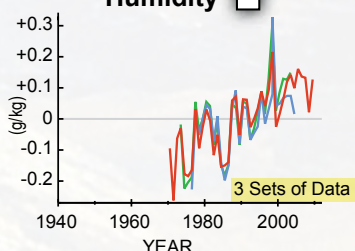
# These indicators all increase in a warming world

**Air Temperature Near Surface (Troposphere)** ↑

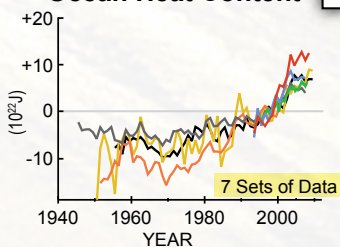


Change from Average

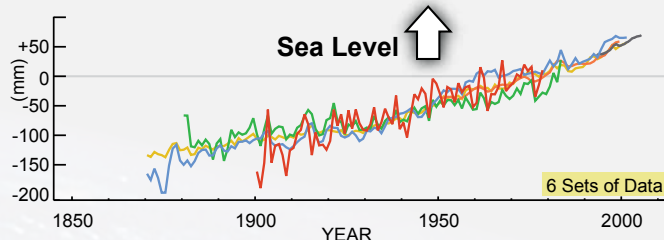
**Specific Humidity** ↑



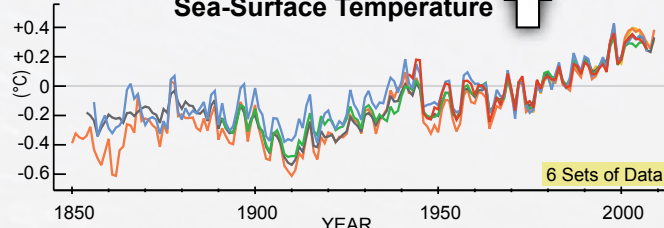
**Ocean Heat Content** ↑



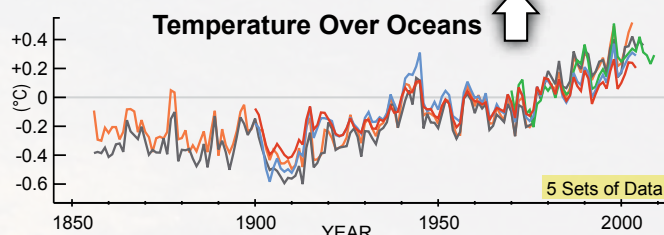
**Sea Level** ↑



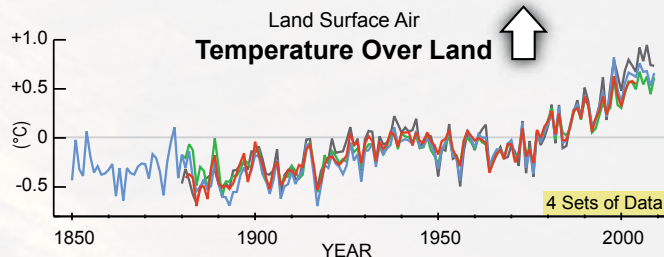
**Sea-Surface Temperature** ↑



**Temperature Over Oceans** ↑



**Land Surface Air Temperature Over Land** ↑

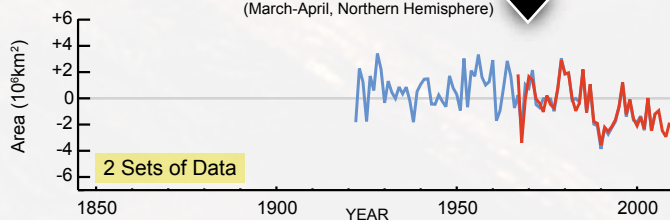


The panels on this page show changes in climate indicators over several decades. Each of the different colored lines in each panel represents an independently analyzed set of data. The data come from many different technologies including weather stations, satellites, weather balloons, ships and buoys.

## These indicators all decrease in a warming world

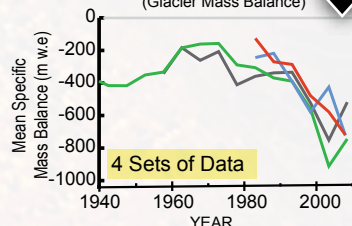
**Snow Cover** ↓

(March-April, Northern Hemisphere)



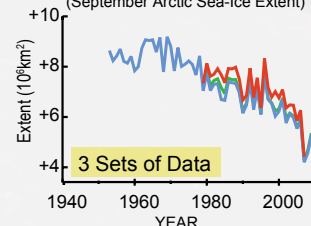
**Glaciers** ↓

(Glacier Mass Balance)



**Sea-Ice** ↓

(September Arctic Sea-Ice Extent)

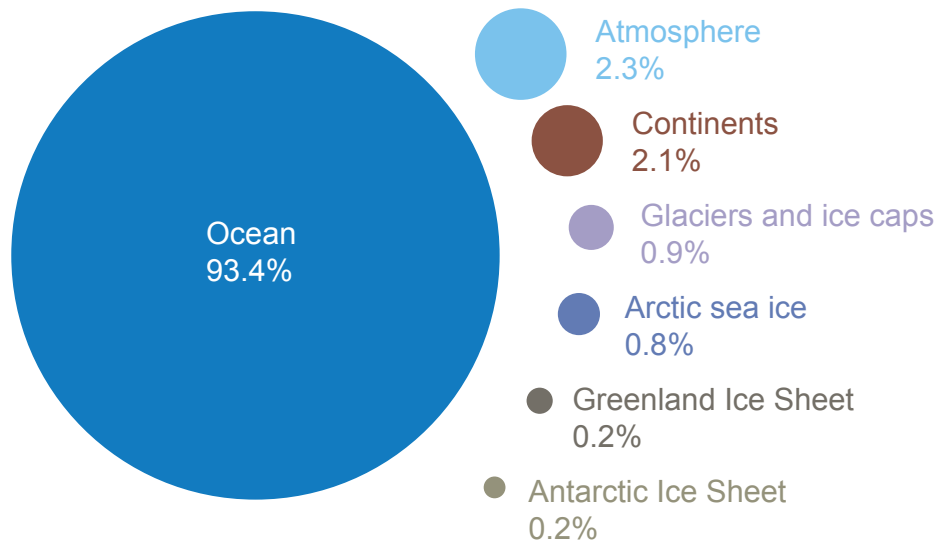


# New Evidence on Warming Oceans

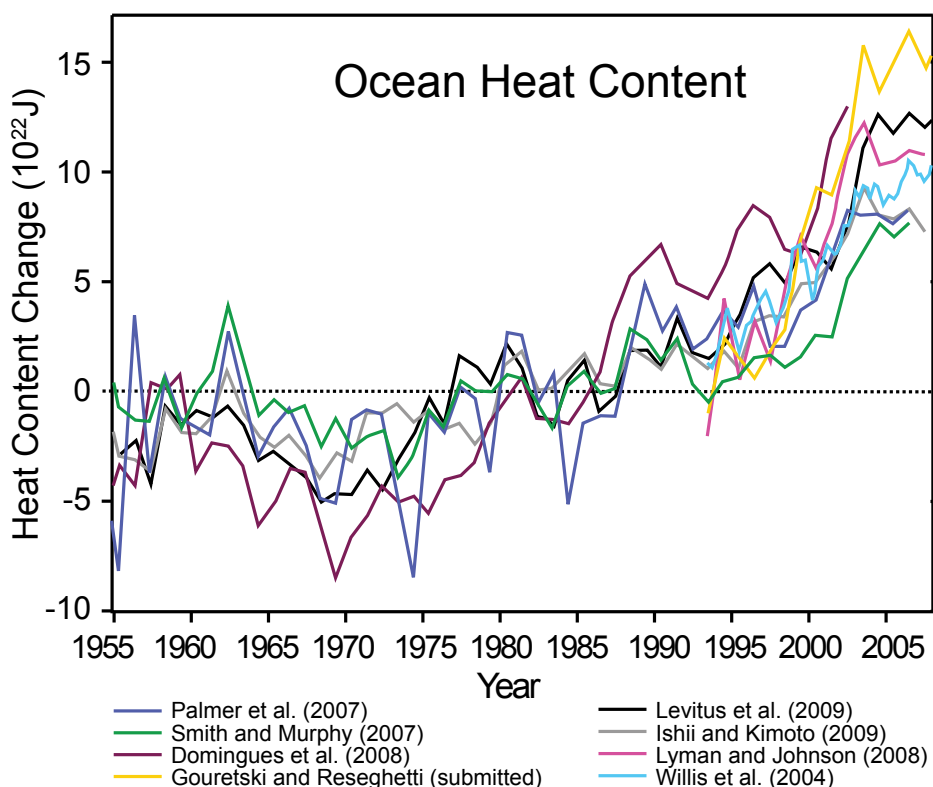
Recent studies show the world's oceans are heating up as they absorb most of the extra heat being added to the climate system from the build-up of heat-trapping gases. In fact, more than 90 percent of the warming that's happened on earth during the past 50 years has gone into the oceans. Warming has been observed as far as 6,000 feet below the surface, but most of the heat is accumulating in the oceans' near-surface layers.

The implications are considerable. First, because water expands as it warms, ocean heating is responsible for much of the sea-level rise we've observed. Melting of land-based ice is responsible for the rest. Further, the oceans will hold the heat they've accumulated because they warm and cool much more slowly than air. This makes sense if you've ever noticed how much quicker it is to heat the air in a room than the water in a swimming pool – and how much longer the pool holds its heat.

## Where is global warming going?



Data from IPCC 2007



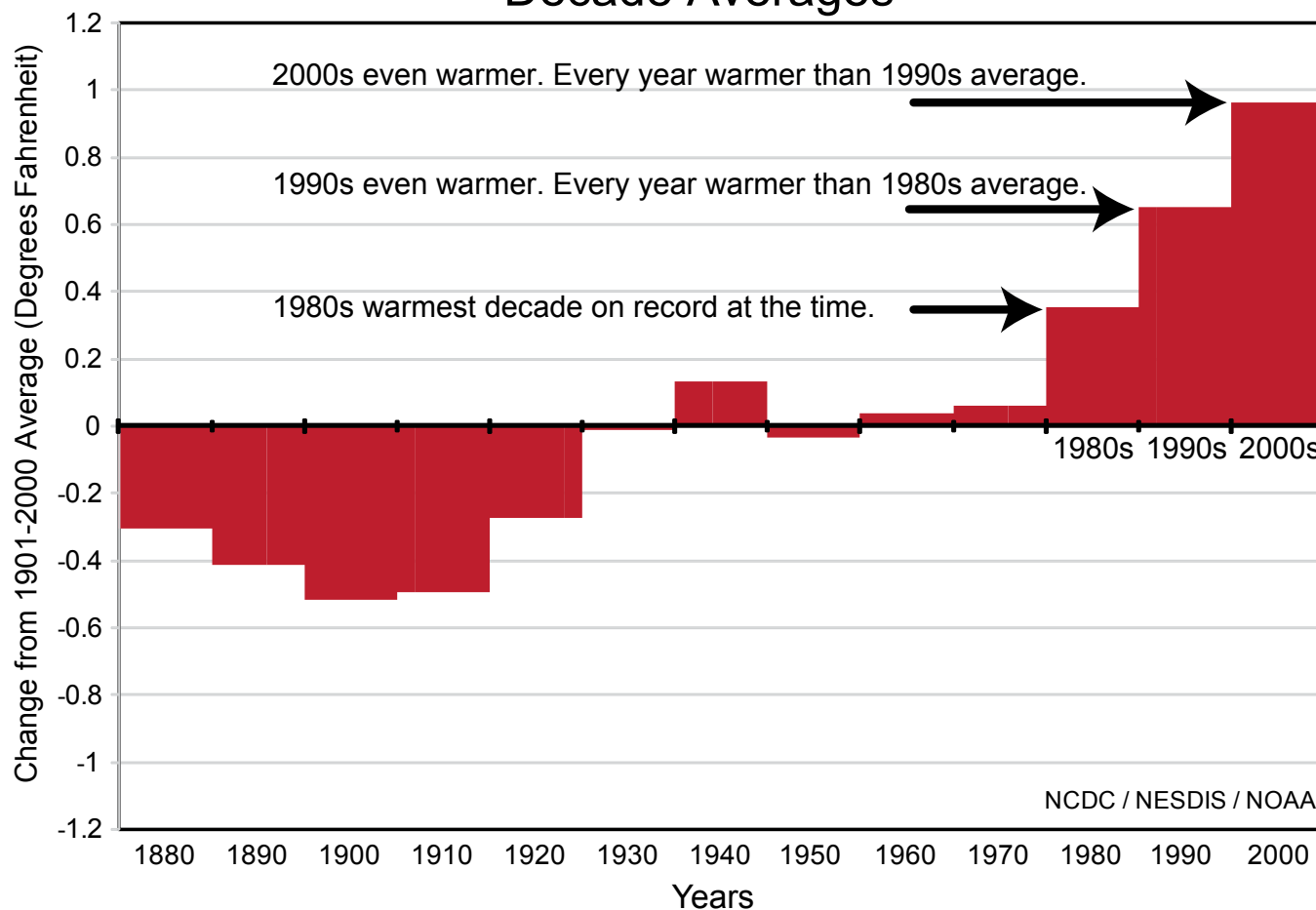
The graph shows changes in ocean heat content in joules (a measure of energy) compared to the 1955-2002 average. The different colored lines represent various independently produced analyses of ocean heat content data. The most recent studies, in which recently discovered data errors have been corrected, show the strongest warming.

# Decade-to-Decade Warming

While year-to-year changes in temperature often reflect natural climatic variations such as El Niño/La Niña events, changes in average temperature from decade to decade reveal a long-term warming. Each of the last three decades has been much warmer than the decade before it, with each one setting a new and significant record for the highest global temperature. At the time, the 1980s was the hottest decade on record. But in the 1990s, every year was warmer than the average of the previous decade, and the 2000s were warmer still.

At first glance, the amount of increase each decade — about a fifth of a degree Fahrenheit — may seem small. But the temperature increase of about 1 degree Fahrenheit experienced during the past 50 years has already altered the planet. Glaciers and sea ice are melting, heavy rainfall is intensifying and heat waves are becoming more common and more intense. Continued temperature increases will threaten many aspects of our society, including coastal cities and infrastructure, water supply and agriculture. People have spent thousands of years building society for one climate and now a new one is being created — one that's warmer and more extreme.

## Global Temperature Change Decade Averages





# Weather and Climate

Mark Twain said it well: "Climate is what we expect; weather is what we get."

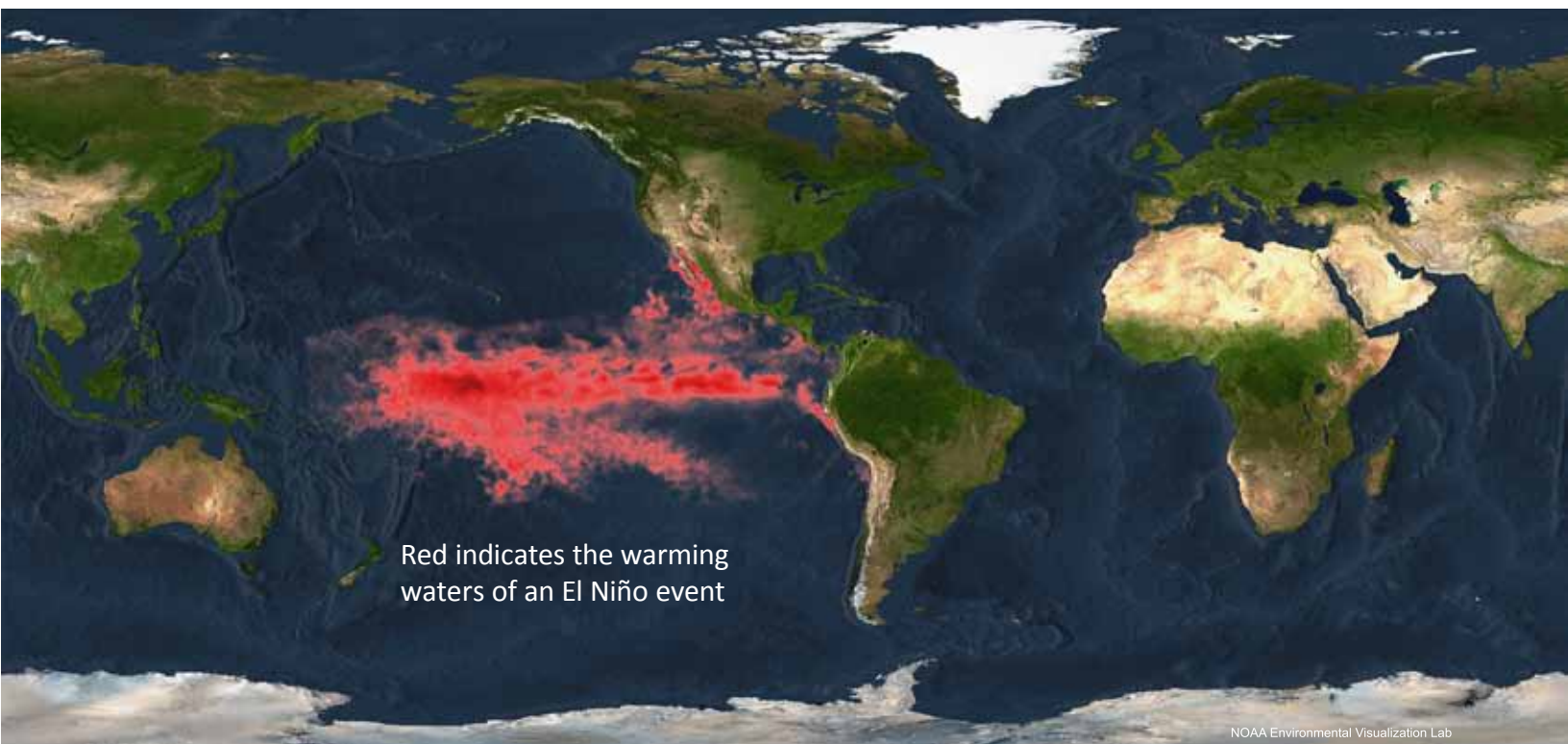
Climate is the long-term average of weather patterns.

Weather can vary dramatically from year to year partly because it is influenced by short-term natural variations.

One of the natural variations that affects weather is the El Niño/La Niña phenomenon. Every few years, El Niño brings a vast swath of warmer water to the Pacific Ocean along the equator; at other times, La Niña brings cooler water. Both events have conditions that disturb normal patterns and affect the location of ocean currents, winds and weather systems around the globe.

A warming climate will still have cold spells, though they will become less frequent and less intense. For example, in the winter of 2009-2010, a warm air mass moved into Canada and pushed cold air south. Canadians experienced a mild winter, but the mid-Atlantic coast of the United States was extremely cold and snowy. At the same time, other regions were unusually warm and the globe as a whole had one of the warmest winters on record. A particular year can experience record-breaking highs and lows in any given location, but, as a whole, global climate continues to warm, following a 30-year trend.

Scientists have learned a great deal about these phenomena, but cannot yet reliably predict beyond a few seasons how an El Niño or a La Niña will behave. The existence of El Niño or La Niña is a well-accepted fact. Farmers, sailors, insurance companies and commodity traders know the impacts of an El Niño or La Niña, and take steps to prepare for its occurrence. They don't need exact forecasts of a climate event to prepare for its consequences.



# Extreme Weather in 2009

Extreme weather events around the world in 2009 included the following:

- In Brazil, extreme rainfall in the Amazon basin caused the worst flood in a century. Forty people were killed and 376,000 were left homeless.
- In southeastern South America, the wettest November in 30 years displaced thousands of people.
- In northwest England, heavy rainfall flooded the Lake District, setting new records for river flows and damaging 1,500 properties.
- In northern Iberia and southern France, a North Atlantic storm raked the land with record winds, downed power lines, closed airports and blocked railroads.
- Three intense heat waves broke temperature records in Australia. One of them was accompanied by high winds that fanned bushfires, killing 173 people.
- The central north Pacific, which includes Hawaii, experienced several tropical cyclones after years of relative calm.

Extreme weather events are unavoidable. But a warmer climate means that many of these events will be more frequent and more severe.



Flooding in Brazil



Heat waves and drought in Australia



Flooding in the Lake District of England

# Tools for Tracking Climate

For generations, climate scientists have used weather stations, weather balloons, ships and buoys to track the weather. In the digital age, instruments for these devices have steadily improved, taking advantage of computer technology, high-speed data communications and global positioning systems. The result is a wealth of information scientists can use to track local weather patterns and the larger trends of global climate.

Today, more than 7,000 weather stations provide data to track global climate. This flow of information helps scientists see big-picture trends, even when local or short-term patterns vary.



Weather station

## Measuring Sea Level

As water warms, it expands. Warming also melts ice on land (glaciers and ice sheets), adding new water to the oceans. For these two reasons, climate warming is increasing global sea level. Rising sea levels threaten coastal communities and infrastructure such as roads and utilities.

Water level gauges and instruments on satellites measure sea-level changes with great precision. For the past 15 years, sea level has been rising a little more than one-eighth of an inch per year. This is double the rate of sea-level rise during the past century, which followed 2,000 years of little change. During the next few decades, if it continues at current or greater rates, sea-level rise will have serious effects on our coasts. It's already affecting some areas, including New Orleans and the surrounding Gulf Coast, which is especially vulnerable because its land is sinking as sea level is rising.



Doppler radar



Weather balloon



Weather satellite



Coastal inundation in California



# About the State of the Climate Report

The State of the Climate in 2009 is the latest installment of a series led by NOAA and published every year in the Bulletin of the American Meteorological Society (BAMS). Its purpose is simple: to annually document the status of the climate system and our capacity to observe it.

## What makes this report different from others?

Some climate assessments compile research from around the world and others compile climate model projections. The State of the Climate compiles observed data – it is the climate system's annual scorecard. It provides a comprehensive look at what is actually occurring around the world. This helps advance the understanding of the climate system, which, in turn, boosts confidence in climate projections.

## What kind of information goes into the report?

Our climate system is large and complex. To perform its annual check-up, the State of the Climate report analyzes more than 30 different climate indicators. Some are obvious: temperature, sea ice, glaciers, precipitation, greenhouse gas amounts. Others are not so obvious: humidity, cloud cover and type, temperature of the stratosphere and saltiness of the ocean. Each of these is placed into historical context – just how do this year's observations fit with other recent years? How do they fit with known trends?

The report also documents important weather and climate events, like El Niño or the amount of activity during a hurricane season. Because the trend in extreme events is another important climate indicator,

the report tries to capture extreme weather specifics, like the strength of a storm or the amount of rain it delivers.

## Who writes the State of the Climate?

Each section of the report is written by experts in observing that aspect of the climate system. As you might expect, such a diverse array of experts – those observing land, sea, sky and ice – cannot come from a single laboratory or even one country. More than 300 authors from 48 countries contributed to the 2009 edition of the report.

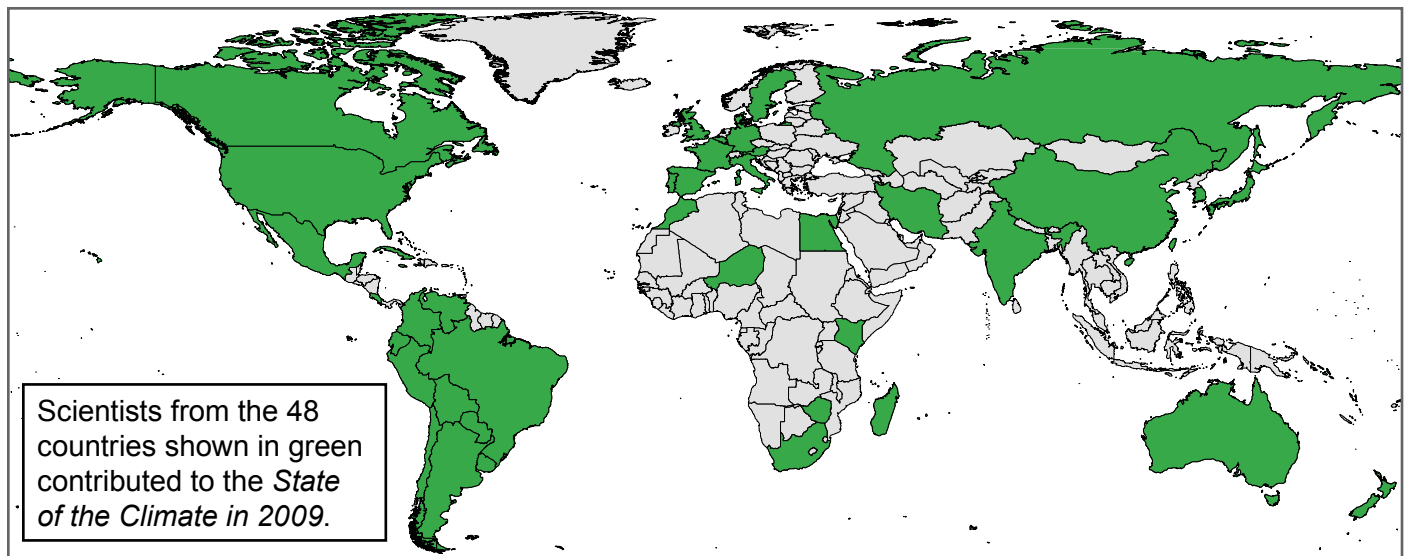
## Who leads the State of the Climate?

The State of the Climate report has been coordinated by NOAA for 20 years, incorporating editorial leadership from many American and international institutions. It was first developed at the Climate Prediction Center and is now led each year by the National Climatic Data Center. The Bulletin of the American Meteorological Society provides scientific reviewers for each chapter and publishes the report.

## Where can I go to get this and similar reports?

NOAA's National Climatic Data Center maintains a library of annual State of the Climate reports at: <http://www.ncdc.noaa.gov/bams-state-of-the-climate>.

This site also provides access to the annual data for key global climate indicators. A monthly State of the Climate report, which focuses on just a few indicators available in real-time, is available at: <http://www.ncdc.noaa.gov/sotc>.



***This annual report provides a broad look at Earth's climate from the top of the atmosphere to the depths of the ocean, providing insight and perspective that helps us better understand what is happening to our climate.***