

A summary of current climate change findings and figures

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1) There is a strong scientific consensus that the global climate is changing and that human activity contributes significantly. This consensus is attested to by a joint statement signed in 2005 by 11 of the world's leading national science academies representing Brazil, Canada, China, France, Germany, Italy, India, Japan, Russia, the United Kingdom and the United States. Their statement confirmed the likelihood of human-induced climate change.¹ Many other science bodies have issued similar statements.²

Most of the scientific debate on climate change takes place through articles that climate scientists publish in peer-reviewed scientific journals. Peer review, while not perfect, is a highly effective system for ensuring that journals only accept articles that meet a good standard of scientific rigor and objectivity. Several surveys of the refereed literature on climate change science have confirmed that virtually all published papers accept the fundamentals of human-induced climate change. The peer-reviewed literature is assessed every few years by the WMO/UNEP Intergovernmental Panel on Climate Change.³

A 2010 paper in the Proceedings of the National Academy of Sciences of the United States reviewed publication and citation data for 1,372 climate researchers. It concluded that 97–98% of the most active climate researchers support the reality of human-caused climate change.⁴ Yet another survey reviewed articles published between 1993 and 2003 with the keyword phrase “global climate change” and found that not one of the 928 articles identified rejected human-caused global warming.⁵ A 2009 survey by the American Geophysical Union found that 82% of the 3,000 responding Earth scientists – and 97.4% of those who were climate scientists – believe that human activity contributes to climate change.⁶

While the fact that humanity's emissions of greenhouse gases (GHGs) contribute to climate change is not in dispute, scientists continue to investigate just how the climate will respond to these emissions over time and in the various regions of the world.

2) Human-induced climate change is caused by greenhouse gas emissions from industry, transport, agriculture and other vital economic sectors. Carbon dioxide makes the largest

¹ www.nationalacademies.org/onpi/06072005.pdf

² For example: www.ametsoc.org/policy/2012climatechange.html; www.aps.org/policy/statements/07_1.cfm; www.interacademies.net/File.aspx?id=4825; www.ucsusa.org/assets/documents/ssi/climate-change-statement-from.pdf.

³ www.ipcc.ch

⁴ www.pnas.org/content/early/2010/06/04/1003187107.full.pdf+html

⁵ www.ametsoc.org/atmospolicy/documents/Chapter4.pdf

⁶ http://tigger.uic.edu/~pdoran/012009_Doran_final.pdf

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contribution to enhanced climate change. Fossil fuels (coal, oil and gas) are the greatest source of humanity's carbon dioxide (and of black carbon, which is soot resulting from incomplete combustion) as well as significant quantities of methane and nitrous oxide. Deforestation and other land-use changes also release large amounts of carbon dioxide. Methane is produced by domesticated animals, rice paddies and the disposal and treatment of garbage and human waste. Fertilizer use releases nitrous oxide. Industry has created a number of long-lived and potent greenhouse gases for specialized uses, such as CFCs, HCFCs and sulphur hexafluoride.

Thanks to greenhouse gases from natural sources, the planet is some 30°C (54°F) warmer than it would be otherwise. Most energy from the sun reaches the Earth in the form of visible light, which either scatters back out to space or penetrates the atmosphere to warm the surface. Because the Earth is much cooler than the sun, it emits energy as infrared, or thermal, radiation. Infrared radiation cannot pass straight through the air like visible light, but most of the Earth's infrared radiation does eventually escape to space, while some of it is blocked by greenhouse gases. As these gases increase, more infrared energy is trapped in the lower atmosphere, further warming the Earth's surface. The correlation between carbon dioxide concentrations and global temperature over the past 800,000 years has been well demonstrated.

It is sometimes claimed that global warming results from changes in energy from the sun. Since 1750, the average amount of energy coming from the sun has either remained constant or increased slightly. However, if warming had been caused by a more active sun, then scientists would expect to see warmer temperatures in all layers of the atmosphere. Instead, they have observed a cooling in the upper atmosphere, and a warming at the surface and in the lower parts of the atmosphere. This is because greenhouse gases are trapping heat in the lower atmosphere before it can reach the stratosphere. Climate models that include only changes in solar irradiance are unable to reproduce the observed temperature trend over the past century or more without including a rise in greenhouse gases.⁷

3) The consensus view on climate change and greenhouse gases is based on multiple lines of evidence. They include basic physics, many different kinds of observations of both past and present climate conditions, and models that project future climate conditions. This is a major reason why researchers have good confidence in their assessment that humanity's greenhouse gas emissions are contributing to climate change.

- **The laws of physics and chemistry.** Scientists have understood since the 19th century that the chemical composition of the atmosphere influences the temperature of the Earth. Carbon dioxide and other greenhouse gases, which together constitute less than one per cent of the atmosphere, act like a blanket to keep the Earth warmer than it would otherwise be. The broad outlines of how the circulation patterns of the atmosphere and the oceans redistribute the sun's energy over the planet's surface are also well understood.
- **Observations of today's climate.** The climate is directly observed by thousands of weather stations; measuring instruments carried into the upper atmosphere by balloons, kites, airplanes and rockets; merchant ships that take measurements of the atmosphere and the oceans; wind profilers, radar systems and other specialized sensors; a globally coordinated fleet of Argo buoys that monitor sea temperatures and currents; and remote-sensing satellites that measure cloud cover, temperature, water vapour, atmospheric chemistry, sea level, ice caps, forest cover, and other global climate variables. High-speed telecommunications systems and the Internet distribute vast amounts of data from these instruments to data processing and research centres. These climate observations show a clear warming signal that is greater than what can be attributed to non-human causes (such as volcanoes). They are gathered by agencies and networks that cooperate through the Global Climate Observing System (GCOS)⁸ and WMO's Global Atmosphere Watch (GAW) programme⁹.

⁷ www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-7-1-2.html; <http://climate.nasa.gov/causes>

⁸ www.wmo.int/pages/prog/gcos/. GCOS is co-sponsored by WMO, UNEP, UNESCO/IOC and ICSU.

⁹ http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html

- **Studies of past climates.** The Earth's climate has changed naturally over billions of years in response to variations in the sun's energy, the Earth's orbit, the atmosphere's chemical composition, the shape of continents and mountain ranges, plant and animal life, and so forth. Paleoclimatologists study these past climates using a variety of evidence. Indirect evidence of ancient climates comes from tree rings, corals, ice cores drilled from ice caps, ocean and lake sediment, and changing lake and ocean levels. The more recent past can be studied through systematic global temperature records that started around 1850. These records and studies confirm that the speed at which modern climate change is occurring – the rate of change – is now much greater than in past periods that scientists have investigated. Understanding past climates and how they changed allows scientists to improve and test their models and understanding of today's climate.
- **Models of the climate system.** The climate system is extremely complex. The atmosphere responds to additional greenhouse gases by warming up, which leads in turn to changes in clouds, water vapour, snow and ice cover, and the oceans. Additional variables include pollution, deforestation, urbanization and other human activities. These diverse effects influence one another, and the resulting interactions can amplify or reduce climate change. Computer models allow scientists to model interactions between different components of the climate system using equations of the physical laws governing the behaviour of the atmosphere, the oceans, land vegetation, ice caps, and so forth. While these abstract representations of the enormously complex climate system inevitably contain uncertainties, they are the best tool we have for projecting the future climate. The modelling community cooperates through the World Climate Research Programme (WCRP) to compare and improve models to ensure the best possible future projections.¹⁰

4) Atmospheric concentrations of the greenhouse gases that cause climate change continue to rise. The amount of greenhouse gases in the atmosphere reached a new record high in 2011 (2012 data will be available later this year). The period 1990 to 2011 saw a 30% increase in radiative forcing – a measure of the warming effect on the climate – because of increased atmospheric concentrations of greenhouse gases.

Carbon dioxide (CO₂), the single most important greenhouse gas emitted by human activities, is responsible for 85% of the increase in radiative forcing over the past decade (water vapour is also a powerful GHG but human activities affect its levels indirectly). The amount of CO₂ in the atmosphere reached 390.9 parts per million in 2011, or 140% of the pre-industrial level of 280 parts per million.

Methane (CH₄) is the second most important long-lived greenhouse gas. Atmospheric methane reached a new high of about 1813 parts per billion (ppb) in 2011, or 259% of the pre-industrial level, due to increased emissions from man-made sources. Since 2007, atmospheric methane has been increasing again after a period of levelling-off, with a nearly constant rate during the last three years.

Nitrous oxide (N₂O) is emitted into the atmosphere by both natural (about 60%) and man-made sources (approximately 40%), including oceans, soil, biomass burning, fertilizer use, and various industrial processes. Its atmospheric concentration in 2011 was about 324.2 parts per billion, which is 1.0 ppb above the previous year and 120% of the pre-industrial level. Nitrous oxide also plays an important role in the destruction of the stratospheric ozone layer which protects us from the harmful ultraviolet rays of the sun.

In addition to greenhouse gases, other emissions, such as black carbon (which recent research suggests has a greater warming effect than previously understood) and dust (which has a cooling effect) also influence the climate.

The chemical composition of the atmosphere is monitored by over 50 countries participating in the WMO Global Atmosphere Watch network.¹¹

¹⁰ www.wcrp-climate.org/. WCRP is co-sponsored by WMO, UNESCO/IOC and ICSU.

¹¹ www.wmo.int/pages/prog/arep/gaw/ghg/documents/GHG_Bulletin_No.8_en.pdf

Table: Global abundances (relative number of molecules)* of key greenhouse gases averaged over the twelve months of 2011 as well as changes relative to 2010 and 1750, and contributions to radiative forcing (a measure of how much a gas contributes to “global warming”), from the WMO Global Atmosphere Watch global greenhouse gas monitoring network. Source: WMO Greenhouse Gas Bulletin, no. 8, November 2012

	Carbon dioxide (CO ₂)	Methane (CH ₄)	Nitrous oxide (N ₂ O)
Pre-industrial levels (1750)	280	700	270
Global abundance in 2011	390.9± 0.1 ppm	1813± 2 ppb	324.2± 0.1 ppb
2011 abundance relative to year 1750	140%	259%	120%
2010-11 absolute increase	2.0 ppm	5 ppb	1.0 ppb
2010-11 relative increase	0.51%	0.28%	0.31%
Mean annual absolute increase during last 10 years	2.0 ppm/yr	3.2 ppb/yr	0.78 ppb/yr
Contribution to radiative forcing relative to 1750**	+1.8 W m ⁻²	+0.51 W m ⁻²	+0.18 W m ⁻²

* ppm = parts per million and ppb = parts per billion

** Measured as watts per meter squared as calculated by NOAA (<http://www.esrl.noaa.gov/gmd/aggi>)

5) Global temperatures continue to climb. The global average temperature is estimated to have risen by 0.6°C (1.1°F) over the course of the 20th century. Although the rate of warming varies from year to year due to natural variability such as the El Niño cycle, volcanic eruptions, and solar variations, the human-induced warming trend has clearly continued (see diagram).

2001-2010 was the warmest decade on record since modern temperature monitoring began around 160 years ago. The global combined land-air surface and sea-surface mean temperature for the decade is estimated at 0.47°C (0.8°F) above the 1961-1990 average of 14.0°C (57.2°F). Globally, 2010 is estimated to be the warmest year ever recorded since modern measurement began, closely followed by 2005. No single year since 1985 has recorded a below-average mean.

The 2001-2010 decade was also the warmest ever recorded for each continent. Average temperatures above the 1961-1990 level dominated every continent in every year of the decade, with the exception of Australia in 2001. Europe and Asia recorded the largest average temperature anomaly for the decade (+0.97°C), while South America recorded the lowest decadal temperature anomaly among the continents (+0.41°C).

2011 was an estimated 0.40°C (0.72°F) above the 1961-1990 average and the warmest-ever year that featured a cooling La Niña event. 2012 was the ninth warmest year since records began in 1850. The global land and ocean surface temperature for the year was about 0.46°C (0.83°F) above the corresponding 1961–1990 average of 14.0°C. After the end of the La Niña in April 2012, the global land and ocean temperatures rose increasingly above the long-term average with each consecutive month.¹² In January 2013, NOAA and NASA announced that 2012 was the warmest year on record for the United States.¹³

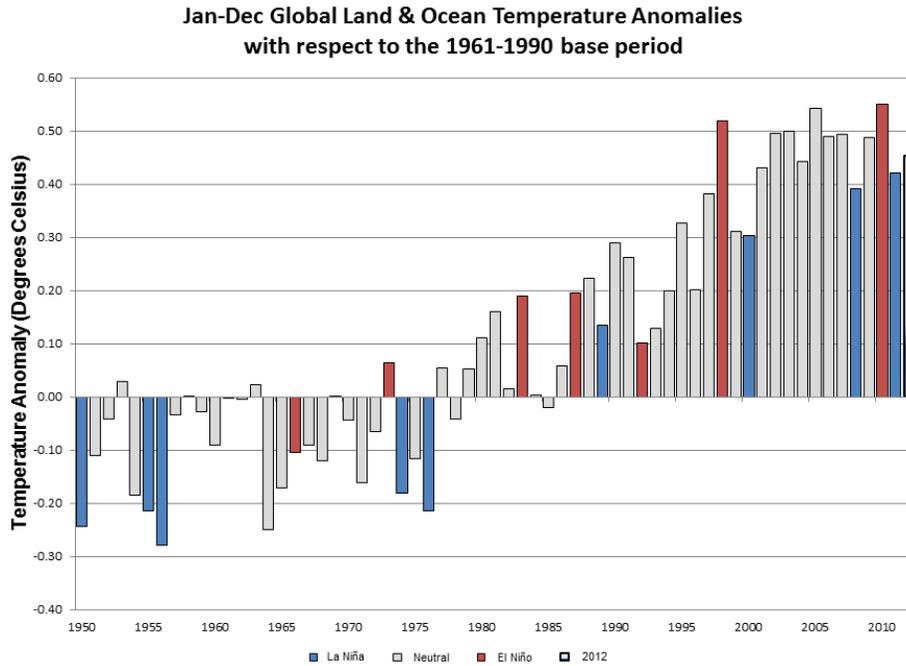
Although the global average temperature is clearly rising, some regions of the planet have nevertheless experienced unusual cold. This can result from natural variability, but also, paradoxically, it may sometimes be caused by global warming itself. For example, researchers are

¹² These WMO figures are averages of the global temperature records maintained by the world’s leading climate monitoring centres: the Met Office Hadley Center, Climate Research Unit (Had-CRU); the National Climatic Data Center – National Oceanic and Atmospheric Administration (NCDC-NOAA); and the National Aeronautics and Space Administration – Goddard Institute for Space Studies (NASA-GISS). Additional information is drawn from the ERA-Interim reanalysis-based data set maintained by the European Centre for Medium-Range Weather Forecasts (ECMWF). See www.wmo.int/pages/publications/showcase/documents/WMO_1085_en.pdf,

¹³ www.ncdc.noaa.gov/sotc/national/2012/13

exploring whether today's warming of the Arctic may actually be contributing to recent cold winters in North America and northern Eurasia by altering weather and pressure patterns.¹⁴

A temperature difference of a half degree Centigrade may not seem like much when it comes to the daily weather. However, it can be highly significant for the global average climate. Over at least the past one thousand years, the global temperature has varied by less than one degree C. Global average temperatures fluctuated by 4 to 7°C (7.2-12.6°F) over the past one million years as ice ages and warm interglacial periods alternated.¹⁵ The last ice age was marked by 3-4 km (1.9-2.5 miles) thick ice sheets and sea levels that were 120m (393 feet) lower than those of today.



Source: WMO

6) The Arctic is changing rapidly. The state of sea-ice cover in the 20th century is relatively well documented, largely because of intensive exploration of the Arctic and the existence of routine monitoring services using ship observations, aerial reconnaissance and (since the 1970s) remote-sensing satellites.

Until the 1960s, Arctic sea ice covered 14-16 million km² (5.4-6.2 million mi²) in late winter and 7-9 million km² (2.7-3.5 million mi²) at the end of the summer. Since the end of the 1960s, sea-ice cover in the Arctic has been showing systematic and marked declines in both extent and thickness. The period 2005 to 2010 included five years with the lowest September extents ever recorded, with 2007 reaching a then-record minimum extent of 4.28 million km² (1.65 million mi²), or 39% below the long term average. By the end of the decade, the rate of Arctic sea ice decline at summer's end was estimated at 700,000-800,000 km² per decade.¹⁶

The Arctic summer of 2012 witnessed even more dramatic changes, with a record low Northern Hemisphere snow extent in June, a record low sea-ice extent in September, record high permafrost temperatures in northernmost Alaska, and the longest duration of melting on the Greenland ice sheet ever observed in modern times, with a rare, nearly ice sheet-wide surface melt in July. The Arctic reached its lowest annual sea ice extent since the start of satellite records

¹⁴ www.arctic.noaa.gov/future/warm_arctic_cold_continent.html

¹⁵ www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-6-2.html,

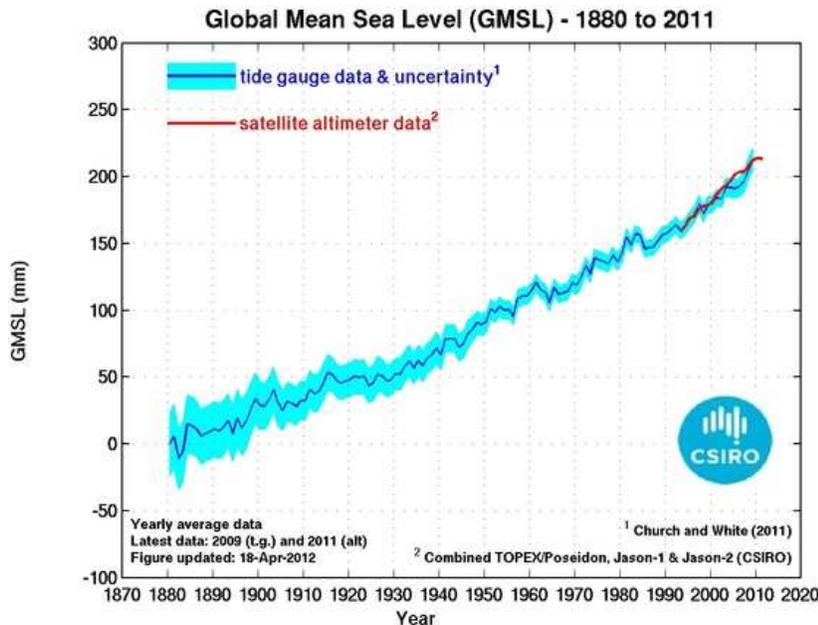
¹⁶ <http://nsidc.org/>

on 16 September at 3.41 million square kilometers. This was 18% less than the previous record low of 18 September 2007. The 2012 minimum extent was 49 percent or almost 3.3 million square kilometers (nearly the size of India) below the 1979–2000 average minimum. Some 11.83 million square kilometers of Arctic ice melted between March and September 2012.¹⁷

In assessing these changes, the Arctic Report Card 2012 produced by NOAA and other international partners states that “[M]ultiple observations provide strong evidence of widespread, sustained changes driving the Arctic environmental system into a new state ... Changes in the sea ice cover, snow cover, glaciers and Greenland ice sheet are reducing the overall surface reflectivity, with bright, white surfaces that reflect summer sunlight being replaced by darker surfaces, e.g., ocean and land, which absorb sunlight. These conditions increase the capacity to store heat within the Arctic system, which enables more melting – a positive feedback ... Thus, we arrive at the conclusion that it is very likely that major changes will continue to occur in the Arctic in years to come, particularly in the face of projections that indicate continued global warming.”¹⁸

Meanwhile, trends in Antarctica are less clear. Few continuous observations of the Antarctic climate are available from before the International Geophysical Year of 1957-58. Since then, surface temperatures have remained fairly stable over much of the continent, in particular in East Antarctica. The Antarctic Peninsula, on the other hand, is warming; temperatures on the west coast have risen by nearly 3°C (5.4°F), making it one of the fastest warming areas in the world and causing many glaciers to retreat and ice shelves to collapse. Significant warming of more than 1°C (1.8°F) has also occurred over the past 50 years in the Southern Ocean that surrounds Antarctica. The Antarctic atmosphere has warmed below an altitude of 8 km and cooled above this level, consistent with the expected signature of human-induced climate change. Satellite observations since the 1970s show a small increase in the overall extent of Antarctic sea ice.¹⁹

7) Sea levels are changing globally. The upper layers of the oceans expand as they heat up, while water from melting glaciers and ice caps add to the volume of the sea. Local variations in currents and in land movement mean that the rise in sea levels is not uniform, so some coastal regions are more affected than others. As warming penetrates deeper into the oceans and ice continues to melt, sea levels will continue to rise long after atmospheric temperatures have levelled off.



¹⁷ www.arctic.noaa.gov/reportcard/index.html

¹⁸ www.arctic.noaa.gov/reportcard/index.html

¹⁹ www.antarctica.ac.uk/bas_research/science/climate/climate_change.php;
<http://arctic.atmos.uiuc.edu/cryosphere/>

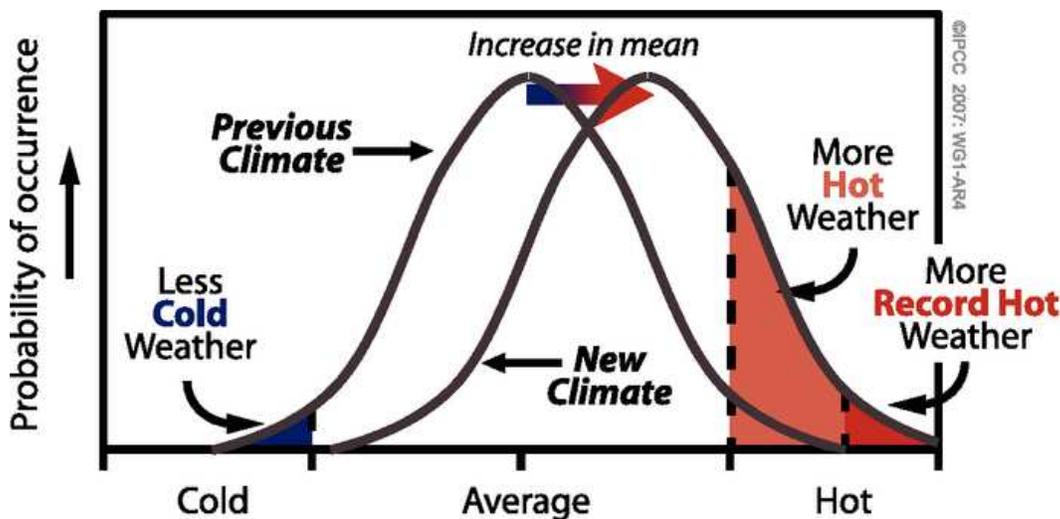
The rate of increase of global mean sea levels over the 2001-2010 decade, as observed by satellites, ocean buoys and land gauges, was some 3.2 mm per year, double the observed 20th century trend of 1.6 mm per year. As a result, global sea levels averaged over the decade were about 20 cm (8 inches) higher than those of 1880.²⁰ Sea levels are projected to rise by a further 28-58 cm (11-23 inches) (compared to 1989-1999 levels) over the course of the 21st century; the higher end of this range would cause enormous damage to cities and other coastal settlements, infrastructure and ecosystems. Even higher levels could occur if the ice caps melt at a more rapid pace.²¹ Estimates of future sea-level rise continue to be assessed and will be updated by the next IPCC report in September 2013.

8) Recent trends in extreme events are consistent with the expected impacts of climate change. Human influences have likely increased temperatures of the most extreme hot nights, cold nights, and cold days, and it is more likely than not that human-induced climate change has increased the risk of heat waves. There have been statistically significant trends in the number of heavy precipitation events in some regions. A lack of longer term data makes it difficult to evaluate trends in the intensity, frequency and duration of cyclones, hurricanes and typhoons.

The first 12 years of the 21st century have seen record temperatures, Arctic ice melt, exceptional heat waves in Western Europe (2003) and Russia (2010), the most costly ever Atlantic hurricane (Katrina in 2005), and major floods in many parts of the world, including Pakistan in 2010, which affected more than twenty million people. Many other extremes were also experienced elsewhere in the world. Early 2013 was marked by extreme heat in Australia and drought in Brazil and the United States.

As illustrated by the diagram below, higher average temperatures increase the chance of hot weather. Because warm air can hold more water vapour – itself a greenhouse gas – there is a greater chance of extreme events and floods. More warmth speeds up the hydrological cycle and contributes to both heavier rainfall and increased evaporation. Higher sea levels increase the potential for coastal flooding and storm surges.²²

While climate scientists believe that it is not yet possible to attribute individual events to climate change, they increasingly conclude that many recent events would have occurred in a different way or would not have occurred at all in the absence of climate change. Studies are currently ongoing to determine what percentage of various types of extreme event can be attributed to climate change, and how climate change affects the probability of such events occurring.²³



²⁰ www.cmar.csiro.au/sealevel/

²¹ www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

²² www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html; www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

²³ www.cgd.ucar.edu/cas/ace/

9) Climate science can support practical actions for adapting to climate change impacts.

Over past 10 or 20 years climate science has become sufficiently robust to guide governments, organizations and individuals in managing climate risks and opportunities. For example, improved observations combined with a better understanding of how the oceans and the atmosphere interact have led to better predictions of seasonal patterns, particularly in the tropics. The most important such pattern is the El Niño/Southern Oscillation (ENSO), which is linked via “teleconnections” to major climate fluctuations around the world.

Depending on the user’s needs, climate data and information products may be combined with non-climate data, such as agricultural production, health trends, population distributions in high-risk areas, road and infrastructure maps for the delivery of goods, and other socio-economic variables. These integrated data sets can support efforts to prepare for new climate conditions and adapt to their impact on water supplies, health risks, extreme events, farm productivity, infrastructure placement, and so forth.

A growing number of governments are providing science-based climate information and prediction for the specific needs of a broad array of public and private sector users. The world’s governments are collaborating through the Global Framework for Climate Services (GFCS) to build greater capacity for using these climate services.²⁴

10) The Fifth Assessment Report (AR5) of the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) will provide a rigorous and updated assessment of the state of knowledge about climate change.

The Working Group I contribution to the AR5, The Physical Science Basis, will be released in Stockholm in September 2013. Work on this volume is being guided by 258 authors and review editors from 44 countries. The early drafts have received tens of thousands of comments from hundreds of expert reviewers.²⁵ The writing and review teams are following a transparent and detailed set of procedures designed to ensure the credibility and rigour of the assessment. The report’s other three volumes – Impacts, Adaptation and Vulnerability; Mitigation of Climate Change; and the Synthesis Report – will be released in 2014.

The IPCC’s previous four assessment reports have demonstrated the important advances made over the past 25 years in understanding climate change and the climate system. They have also confirmed our growing confidence in the scientific findings and models and in the role that human activities play. While the findings of the earlier assessments (1990, 1995, and 2001) are broadly consistent with the most recent one (2007), new and increased observations and research have ensured a steady trend towards greater detail and confidence.

The IPCC does not conduct new research. Instead, its mandate is to make policy-relevant (as opposed to policy-prescriptive) assessments of the worldwide, peer-reviewed literature on the scientific, technical and socio-economic aspects of climate change. Many thousands of articles based on research as well as data provided by virtually all countries are critically reviewed for each volume of each assessment.

²⁴ www.wmo.int/pages/gfcs/index_en.php

²⁵ www.ipcc-wg1.unibe.ch/