Summary For Policymakers

The Third Assessment Report of Working Group I of the Intergovernmental Panel on Climate Change (IPCC) builds upon past assessments and incorporates new results from the past five years of research on climate change.[1] Many hundreds of scientists contributed to its preparation and review. This Summary for Policymakers describes the current state of understanding of the climate system and provides estimates of its projected future evolution.

An increasing body of observations gives a collective picture of a warming world and other changes in the climate system.

The observed changes in climate over time have been documented extensively by a variety of techniques. Many of these trends are now established with high confidence; others are far less certain.

The global-average surface air temperature has increased since the mid 19th century.

- The global-average surface air temperature has increased by 0.6 ± 0.2°C since about 1860, the earliest date for which sufficient data for global estimates are available (Figure 1a). This value is about 0.15°C larger than that estimated by the SAR[2] for the period up to 1994, mainly because of the relatively high temperatures of the additional years (1995 to 2000). The record shows a great deal of spatial and temporal variability; for example, most of the warming during the 20th century occurred during two periods (1910 to 1945 and since 1976).

- New analyses indicate that the magnitude of the warming in the 20th century is likely[3] to be the largest of any century during the past 1000 years for the Northern Hemisphere. It is likely that the 1990s was the warmest decade and 1998 the warmest year (Figure 1b).

- On average, night-time daily minimum temperatures over land have increased at about twice the rate of day-time daily maximum temperatures since about 1950 (approximately 0.2°C compared to 0.1°C per decade). This has lengthened the freeze-free season in many mid- and high-latitude regions.

[Insert Figure 1 here.]

Temperatures have risen during the past four decades in the lowest few kilometres of the atmosphere.

- Since the late 1950s (the period of adequate observations from weather balloons), the overall global temperature trends of the lower atmosphere and near-surface air temperature are similar (0.1°C per decade).

- Since the start of the satellite record in 1979, both satellite and weather balloon measurements show that the global average temperature of the lower atmosphere has increased by about 0.05°C per decade. This is less than the global average increase in surface air temperature of approximately 0.2°C per decade. The difference in the rates of warming occurs primarily over the tropical and subtropical oceans, and about half of the difference remains unaccounted for.

Snow cover and ice extent have decreased.

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[1] *Climate change* in IPCC Working Group I usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the Framework Convention on Climate Change, where *climate change* refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

[2] The IPCC Second Assessment Report is referred to in this Summary for Policymakers as the SAR.

[3] In this Summary for Policymakers and in the Technical Summary, the following words have been used to indicate approximate judgmental estimates of confidence: *virtually certain* (greater than 99% chance that a result is true); *very likely* (90-99% chance); *likely* (66-90% chance); *medium likelihood* (33-66% chance); *unlikely* (10-33% chance); *very unlikely* (1-10% chance); *exceptionally unlikely* (less than 1% chance).

- There have been decreases of about 10% in the extent of snow cover since the late 1960s and a reduction of about two weeks in the annual duration of lake- and river-ice cover in the mid- and high-latitudes of the Northern Hemisphere, over the 20th century.

- There has been a widespread retreat of mountain glaciers in non-polar regions during the 20th century.

- Northern Hemisphere spring and summer sea-ice extent has decreased by about 10 to 15% since the 1950s. It is likely that there has been about a 40% decline in Arctic sea-ice thickness during late summer to early autumn in recent decades and a considerably slower decline in winter sea-ice thickness.

Global average sea level has risen and ocean heat content has increased.

- Tide-gauge data show that global-average sea level rose between 0.1 and 0.2 meters during the 20th century. It is very likely that this is at least partly due to thermal expansion of sea water and widespread loss of land ice associated with 20th century warming.

- The rate of sea-level rise during the 20th century was about ten times larger than the average rate over the last 3000 years.

- Global-ocean heat content has increased since the late 1950s, the period for which adequate observations of sub-surface ocean temperatures have been available.

Changes have also occurred in other important aspects of climate.

- Precipitation has increased by 0.5 to 1% per decade in the 20th century over most mid- and high-latitudes of the Northern Hemisphere continents. Rainfall has decreased over much of the sub-tropical land areas during the 20th century (-0.3% per decade), although recovering during recent years. There are insufficient data to establish trends in precipitation over the oceans.

- It is likely that there has been an increase in heavy and extreme precipitation events, on average, in the mid- and high-latitudes of the Northern Hemisphere.

- Warm episodes of the El Niño/Southern Oscillation (ENSO) phenomenon have been more frequent, persistent, and intense since the mid-1970s. This recent behaviour of ENSO has been reflected in regional variations of precipitation and temperature over much of the tropics and subtropics.

Some important aspects of climate appear not to have changed.

- No significant trends of Antarctic sea-ice extent are apparent over the period of systematic satellite measurements (since the 1970s).

- The observed intensities and frequencies of tropical and extra-tropical cyclones, and severe local storms show no clear long-term trends, but data are often sparse and inadequate.

Emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that affect the climate system.

Changes in climate occur as a result of natural variability and as a result of external factors. The effects of external factors on climate can be broadly compared using the concept of radiative forcing[4]. A positive radiative forcing, such as produced by increasing concentrations of greenhouse gases, leads to a warming of the surface. A negative radiative forcing, which can arise from an increase in some types of aerosols (microscopic airborne particles or droplets), gives rise

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[4] *Radiative forcing* is a measure of the effect a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system, and is an index of the importance of the factor as a potential climate change mechanism.

to a cooling. Natural factors, such as changes in solar output or explosive volcanic activity, can also induce radiative forcing. Characterization of these climate forcing agents and their changes over time is required to understand past climate changes in the context of natural variations and to project what climate changes could lie ahead. Figure 2 shows current estimates of the radiative forcing due to increased concentrations of atmospheric constituents and other forcing mechanisms.

[Insert Figure 2 here.]

Concentrations of atmospheric greenhouse gases, with associated radiative forcing, have continued to increase due to human activities.

- Since 1750, the atmospheric concentration of carbon dioxide (CO_2) has increased by one-third. The present CO_2 concentration has not been exceeded during the past 420,000 years and likely not during the past 20 million years. The rate of increase is unprecedented during at least the past 20,000 years.

- Over two-thirds of the increase in atmospheric CO_2 during the past 20 years is due to fossil fuel burning. The rest is due to land-use change, especially deforestation, and, to a lesser extent, cement production.

- Both the ocean and the land are taking up anthropogenic CO_2. Ocean CO_2 uptake is governed by chemical processes. Causes of land CO_2 uptake include CO_2 and nitrogen fertilisation and changes in land management. On land, the uptake of CO_2 currently exceeds the release of CO_2 by deforestation.

- The rate of increase of atmospheric CO_2 concentration has been about 0.4%/yr over the past two decades. During the 1990's, the annual increase varied by a factor of three. A large part of this variability is due to the effect of climate variability on CO_2 uptake and release by land and oceans.

- Atmospheric methane (CH_4) concentrations have increased by a factor of 2.5 since 1750 and continue to increase. The annual increase in CH_4 atmospheric concentrations has become slower and more variable in the 1990s, compared to the 1980s.

- The atmospheric concentration of nitrous oxide (N_2O) has increased by 16% since 1750.

- The atmospheric concentrations of many of those halocarbon gases that are both ozone-depleting and greenhouse gases, are either decreasing or increasing more slowly in response to reduced emissions under the regulations of the Montreal Protocol and its Amendments. Their substitute compounds and some other synthetic compounds (e.g., perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)) are increasing rapidly in the atmosphere from recent near-zero concentrations.

- The radiative forcing of the well-mixed greenhouse gases is estimated to be 2.42 Wm^{-2}. The largest contribution is from CO_2 (1.46 Wm^{-2}), followed by CH_4 (0.48 Wm^{-2}), the halocarbons (0.33 Wm^{-2}), and N_2O (0.15 Wm^{-2}).

- The observed depletion of the stratospheric ozone layer over the past two decades has caused a negative radiative forcing (–0.15 Wm^{-2}). Assuming full compliance with current regulations, recovery of the ozone layer is expected over this century, thereby eliminating this negative forcing.

- The calculated one-third increase since 1750 in tropospheric ozone due to anthropogenic emissions of several ozone-forming gases is estimated to have caused a significant positive radiative forcing (0.35 Wm^{-2}). Ozone forcing varies considerably by region and responds much more quickly to changes in emissions than the long-lived greenhouse gases, such as CO_2.

Most anthropogenic aerosols are short lived and generally produce negative radiative forcing.

- Since the SAR, significant progress has been achieved in better characterising the direct radiative roles of types of aerosols other than sulphate, including black carbon (soot), organics, mineral dust, and sea salt. There is much less confidence in the ability to quantify the total aerosol effect, and its evolution over time, than that for the gases listed above. Aerosols also vary considerably by region and respond quickly to changes in emissions.

- There is now more evidence for the indirect effect of anthropogenic aerosols on the structure of clouds, but the estimates of radiative forcing remain very uncertain.

Natural agents have contributed small amounts to radiative forcing over the past century.

- The radiative forcing due to changes in the radiant energy emitted from the sun for the period since 1750 is estimated to be about one-fifth that due to CO_2, mainly due to an increase during the first half of the 20th century. Since the late 1970s, satellite instruments have observed small oscillations due to the 11-year solar cycle.

- Mechanisms for the amplification of solar effects on climate have been proposed, but lack a rigorous theoretical or observational basis.

- Stratospheric aerosols from large volcanic eruptions lead to significant negative forcing, which lasts a few years. Several major eruptions occurred in the periods 1880 to 1920 and 1960 to 1991, with weak volcanic activity in the interim and no major eruptions since 1991.

- The net radiative forcing effect of the two major natural factors (solar variation and volcanic aerosols) is estimated to be negative for the past two and possibly four decades, in contrast to the positive forcing for greenhouse gases.

Confidence in the ability of models to project future climates has increased.

Complex climate models are required to provide detailed estimates of feedbacks and of regional detail. Quantitative estimates of some globally averaged parameters can be made with simpler models calibrated against complex models.

- Understanding of climate processes and their representation in climate models has improved, including water vapour, sea-ice dynamics, and ocean heat transport.

- Some recent models produce satisfactory climate simulations without the need for non-physical adjustments of the heat and water fluxes at the ocean-atmosphere interface.

- Several models have reproduced the observed warming trend in surface air temperature during the 20th century, when forced with increases in greenhouse gases and sulphate aerosols. This general consistency provides an implicit constraint on model projections of global temperature for the next few decades.

- Some aspects of model simulations of ENSO, monsoons and the North Atlantic Oscillation have improved.

- The greatest uncertainty in modelling future climate still arises from clouds and their interactions with radiation and aerosols.

There is now stronger evidence for a human influence on global climate than at the time of the Second Assessment Report.

The SAR concluded: "The balance of evidence suggests a discernible human influence on global climate". That report also noted that the anthropogenic signal was still emerging from the background of natural climate variability. Further, it pointed out that there were uncertainties in a number of relevant factors, including internal variability and the magnitude and patterns of forcing and response, that prevented making a stronger conclusion at that time. New evidence allows for an updated assessment of this conclusion.

- *There is a longer and more closely scrutinised temperature record and new model estimates of variability.* Three of the years since the SAR (1995, 1997, and 1998) are the warmest in the instrumental record of global temperatures. Reconstructions of climate data for the past 1000 years and model estimates of natural climate variations suggest that the observed warming over the past 100 years is unlikely to be entirely natural in origin.

- *There are new estimates of the climate response to natural and anthropogenic forcing, and new detection techniques have been applied.* Detection and attribution studies consistently find evidence for an anthropogenic signal in the climate record of the last 35-50 years. Furthermore, model estimates of the rate of anthropogenic warming are consistent with observations in the majority of cases. Simulations of the response to natural forcings alone, including the response to solar variability and volcanic eruptions, indicate that natural forcings may play a role in the observed warming in the first half of the 20th century, but fail to explain the warming in the latter half of the century, (see Figure 3).

- *The effect of anthropogenic greenhouse gases over the last 50 years can be identified despite uncertainties in other forcings.* The sulphate forcing, while uncertain, is negative over this period and changes in natural forcing during most of this period are also estimated to be negative.

It is likely that increasing concentrations of anthropogenic greenhouse gases have contributed substantially to the observed warming over the last 50 years. Nevertheless, the accuracy of estimates of the magnitude of anthropogenic warming, and particularly of the influence of the individual external factors, continues to be limited by uncertainties in estimates of internal variability, natural and anthropogenic radiative factors, in particular the forcing by anthropogenic aerosols, and the climate response to those factors.

[Insert Figure 3]

Atmospheric composition will continue to change throughout the 21st century.

Climate models have been used to make projections of future climate based upon greenhouse gas and aerosol scenarios from the IPCC Special Report on Emission Scenarios (SRES). To enable a direct comparison with the SAR, the IS92a scenario is also shown in some cases.

Greenhouse gases

- Emissions of CO_2 due to fossil-fuel burning are virtually certain to be the dominant influence on the trends in atmospheric CO_2 concentration during the 21st century. As CO_2 concentration increases and climate changes, ocean and land will take up a progressively decreasing proportion of anthropogenic CO_2 emissions. By the end of the century, models project CO_2 concentrations of 540 to 970 ppm (compared to the pre-industrial concentration of 280ppm, and about 367ppm today). This range is due to differences among the SRES emissions scenarios; different model assumptions would add at least ±10% uncertainty to these projections.

- The sequestration of carbon by changing land use could influence atmospheric CO_2 concentration. However, even if all of the carbon so far released by land use changes could be restored to the terrestrial biosphere (e.g., by reforestation), CO_2 concentration would be reduced by only 40 to 70 ppm.

- Model calculations of the concentrations of the non-CO_2 greenhouse gases by 2100 vary considerably across the SRES scenarios. In some scenarios, tropospheric ozone would become as important a radiative forcing agent as CH_4 and would threaten the attainment of air quality targets over much of the Northern Hemisphere.

Aerosols

- The SRES scenarios include the possibilities of either increases or decreases in anthropogenic aerosols. In addition, natural aerosols (e.g. sea salt, dust, and emissions leading to the production of sulphate and carbon aerosols) may increase as a result of changes in climate and atmospheric chemistry.

Radiative forcing

- For the SRES scenarios, the global mean radiative forcing due to greenhouse gases will continue to increase up to 2100, with the fraction due to CO_2 becoming even greater than for the present day. The direct aerosol radiative forcing is estimated to be substantially smaller in magnitude than that of CO_2.

Global average temperature and sea level are projected to rise under all SRES scenarios.

In order to make projections of future climate, models incorporate past, as well as future, emissions of greenhouse gases and aerosols. Hence they include estimates of warming to date and the commitment to future warming from past emissions.

Temperature

- The globally averaged surface air temperature increase from 1990 to 2100 for the range of SRES scenarios is estimated to be about 1.5 to 6.0ºC, (Figure 4 (b)). This increase would be without precedent during the last ten thousand years. By comparison, the temperature range presented in the SAR was 1 to 3.5ºC, based on the IS92 scenarios. The difference is mainly due to the reduced future sulphur dioxide emissions in the SRES scenarios. The estimates are derived from a simple model adapted to yield a similar response to a range of complex models.[5]

- By 2100, the differences in the surface air temperature response across the group of complex models forced with a given scenario is as large as the range obtained from a single model forced with the different SRES scenarios.

- A coherent picture of regional climate change using regionalisation techniques, such as regional climate models, is not yet possible. However, based on recent global model simulations, it is likely that nearly all land areas will warm more rapidly than the global average, particularly those at high latitudes in the cold season. Most notable is the warming in the northern regions of North America, and northern and central Asia, which is in excess of 40% above the global-mean change. In contrast, the warming is less than the global-mean change in south and southeast Asia in summer and southern South America in winter.

[Insert Fig, 4 here]

Precipitation

- Globally averaged water vapour and precipitation are projected to increase. Based on recent global model simulations, it is likely that precipitation will increase over northern mid- and high-latitudes and Antarctica in winter. At low latitudes there are both regional increases and decreases, which are likely to be emissions scenario dependent.

Extreme Events

- Analyses of past data and improvements in climate models, since the SAR, have enabled changes in extreme events observed to date to be compared to similar changes in model simulations for future climate, see Table 1.

Table 1 – Observed and modelled changes in extremes of weather and climate.

	Observed (20th century, last 50 years)	**Projections from Models (end of 21st century, 2050-2100)#**
Higher maximum temperatures and more hot days	nearly all land areas	most models

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[5] These estimates are consistent with climate sensitivity in the range 1.5 to 4.5ºC. This estimate is unchanged from the time of the first and second assessment reports. The climate sensitivity is the equilibrium response of global surface temperature to a doubling of equivalent CO_2 concentration. The range of estimates arises from uncertainties in the climate models and their internal feedbacks, particularly those due to clouds and related processes. Factors that affect the time dependent response, e.g., ocean heat uptake, are not included in this concept.

Increase of heat index	many land areas	most models
More intense precipitation events	many northern hemisphere mid- to high-latitude land areas	most models
Higher minimum temperatures and fewer cold days	virtually all land areas	most models
Fewer frost days	virtually all land areas	physically plausible based on increased minimum teperatures
Reduced diurnal temperature range	most land areas	most models
Summer continental drying	few areas	most models
Increase in tropical cyclone peak wind intensities	not observed, but very few analyses	some models
Increase in tropical cyclone mean and peak precipitation intensities	insufficient data	some models

#In the models column, the phrase “most models” indicates that a number of models have been analysed for such a change, all those analysed show it in most regions, and it is physically plausible. No models have been analysed to show fewer frost days, but it is physically plausible since most models show an increase in night-time minimum temperatures, which would result in fewer frost days. The phrase “some models” indicates that theoretical studies and those models analysed show such a change, but only a few current climate models are configured in such a way to reasonably represent such changes. The assessment of model results represents very large scale changes, in some regions the changes of certain extremes may not agree with the larger scale changes.

- For some other extreme phenomena, many of which may have important impacts on the environment and society, there is currently insufficient information to assess recent trends, and the confidence in models and understanding is inadequate to make firm projections. The intensity of mid-latitude storms is a good example. Further, very small-scale phenomena, such as thunderstorms, tornadoes, hail and lightning, are not simulated in global models. Recent trends for conditions to become more El Niño-like in the tropical Pacific are projected to continue in many models, although confidence in such projections is tempered by some shortcomings in how well El Niño is simulated in global climate models.

Atmospheric and Oceanic Circulation

- Most models show weakening of the Northern Hemisphere thermohaline circulation (THC). Even in models where the THC weakens, there is still a warming over Europe due to increased greenhouse gases. It is not known whether irreversible collapse in the THC could occur or not, or at what threshold it might occur, although none of the current projections with climate models exhibits a complete shut down of the THC during the next 60 years.

Snow and Ice

- Northern Hemisphere snow cover and sea-ice extent are projected to decrease further.

- Glaciers and icecaps (excluding the ice sheets of Greenland and Antarctica) will continue their widespread retreat during the 21st century.

- The ice sheet over West Antarctica contains enough ice to raise sea level by 6 meters and, because it is grounded below sea level, rapid ice discharge may occur in response to ocean warming. Major loss of grounded ice and accelerated sea-level rise is now believed to be very unlikely during the 21st century.

Sea Level

- For the range of SRES scenarios, a sea-level rise of 0.14 to 0.80 metres is projected for 1990 to 2100, with a central value of 0.47 metres, which is about 2 to 4 times the rate over the 20th century, (Figure 4 (c)).

Climate change will persist for many centuries

- Stabilisation of atmospheric CO_2 concentrations at all levels considered in this report will entail substantial reductions in CO_2 emissions. To achieve any given equivalent CO_2 stabilisation target, continued emissions of other greenhouse gases would require even lower CO_2 emissions.

- Emissions of CO_2 have a lasting effect on atmospheric CO_2 concentrations. Even several centuries after emissions are eliminated, the amount remaining in the atmosphere is 20 to 30% of the total emitted.

- Global mean surface temperature will continue to increase and sea level will continue to rise due to thermal expansion for hundreds of years after concentrations of CO_2 have been stabilised, owing to the long timescales on which the deep ocean adjusts to climate change.

- Ice sheets will continue to react to climate change for thousands of years after climate has been stabilised. Models project that a local annual-average warming of larger than 3ºC, sustained for millennia, would lead to virtually a complete melting of the Greenland ice sheet. A local warming of 5.5°C, consistent with mid-range stabilisation scenarios, would result in a contribution from Greenland of 3 metres to sea-level rise in 1000 years. Current ice dynamic models project that the West Antarctic ice sheet will contribute no more than 3 metres to sea-level rise over the next 1000 years, but its dynamics are still inadequately understood, especially for projections on longer timescales.

Many gaps in information and understanding remain

Many factors continue to limit our ability to detect, attribute, and understand current climate change and to project what future climate changes may be. Further work is needed in eight broad areas:

- Arrest the decline of observational networks in many parts of the world.

- Expand the observational foundation for climate studies to provide accurate, long-term data with expanded temporal and spatial coverage.

- Improve estimates of future emissions and concentrations of greenhouse gases and aerosols, and their forcings.

- Understand and characterise more completely dominant processes (e.g., ocean mixing) and feedbacks (e.g., from clouds and sea ice) in and between the atmosphere, biota, land and ocean surfaces, and deep oceans.

- Address more completely patterns of long-term climate variability.

- Explore more fully the probabilistic character of future climate states by developing multiple ensembles of model calculations.

- Improve the integrated hierarchy of global and regional climate models with emphasis on improving the simulation of regional impacts and extreme weather events.

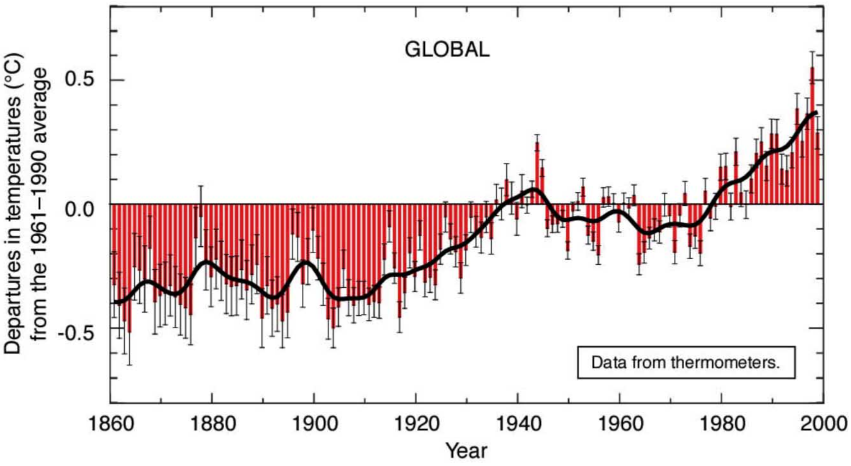
- Link more effectively, physical climate-biogeochemical models with models of the human system and thereby provide the basis for expanded exploration of possible cause-effect-cause patterns linking human and non-human components of the Earth system.

Cross-cutting these foci are crucial needs associated with strengthening the co-operation within the international research community, building research capacity in many regions, quantifying uncertainties and, as is the goal of this assessment, effectively and describing research advances in terms that are relevant to decision making.

Figures

Variations of the Earth's surface temperature for:

(a) the past 140 years



(b) the past 1000 years

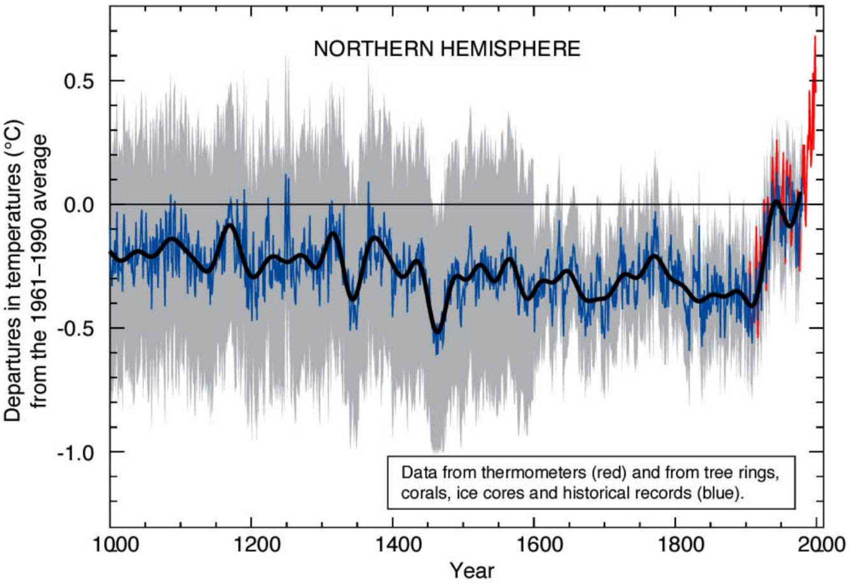


***Figure 1.* The Earth's surface temperatures vary year by year (bars) and decade by decade (smoothed curves).** Over the past 140 years, the global average surface temperature has increased by about 0.6°C (Panel a). Additionally, the year-by-year variations of the average surface temperature in the Northern Hemisphere for the past 1000 years have now been reconstructed from "proxy" data (Panel b). While the uncertainties (shaded area) in the millennial reconstruction are understandably larger than those of the more recent instrumental record, it is nevertheless clear that the overall warming of the 20th century has been atypical compared to the rest of the past 1,000 years in the Northern Hemisphere. Indeed, it is likely that the rate and duration of the warming of the 20th century is the largest of the millennium in the Northern Hemisphere. Similarly, it is likely that the 1990s have been the warmest decade in the millennium, and 1998 the warmest year. [Based upon (a) Figure 2.7c and (b) Figure 2.20]
(Note: Figure 1 (a) will be updated to include data for the year 2000 prior to the WGI Plenary)

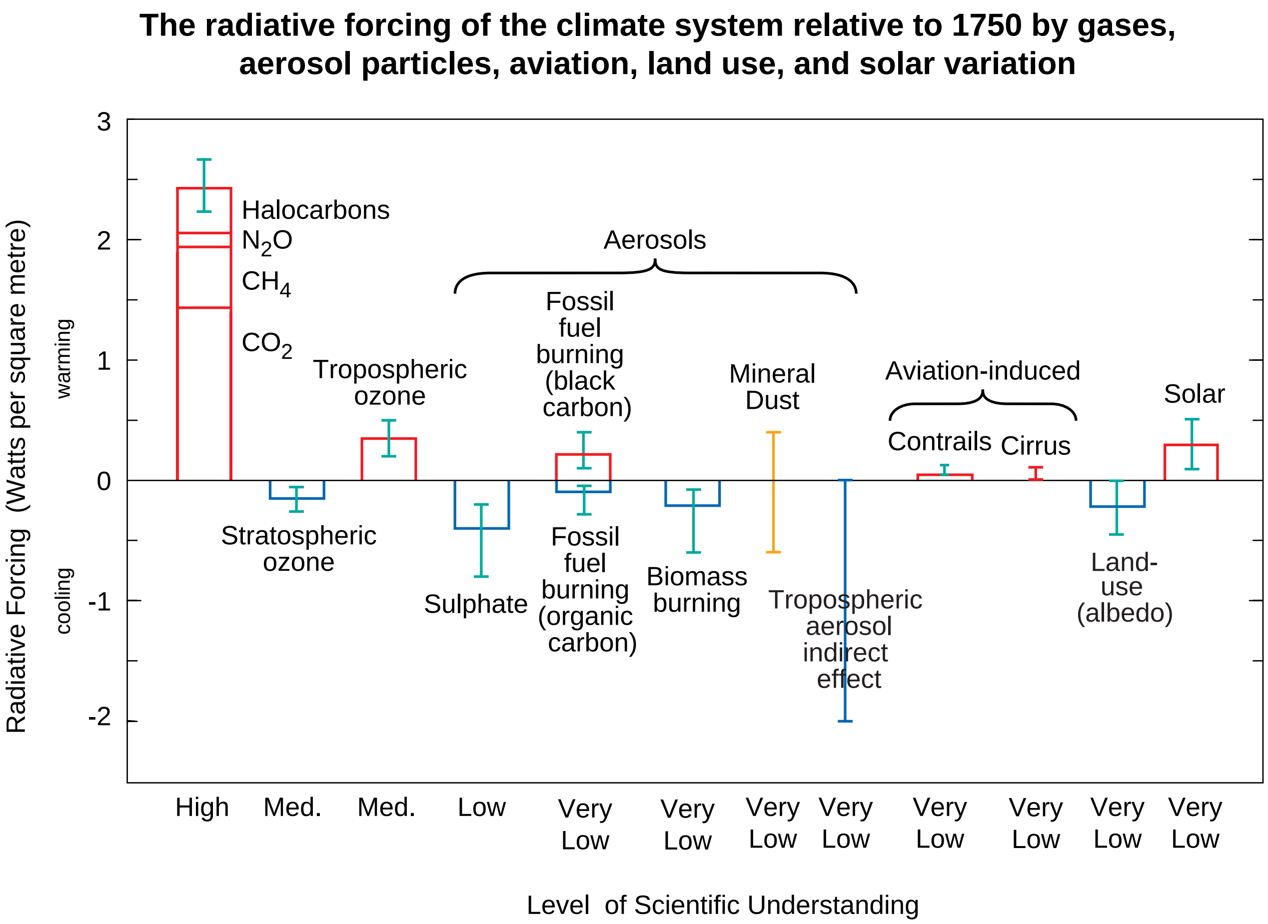


***Figure 2.* Many factors give rise to climate change.** These radiative forcings arise from changes in the atmospheric composition, alteration of surface reflectance by land use, and variation in the output of the sun. Except for solar variation, some form of human activity is linked to each. The rectangular bars represent estimates of the relative contributions of changes in these climate forcings - some yielding warming, some yielding cooling - from 1750 to the late 1990s. Forcing due to emissions from volcanoes, which lead to a negative forcing lasting for a few years, is not shown. The indirect effect of aerosols shown is their effect on the size and number of cloud droplets. A second indirect effect of aerosols on clouds, namely their effect on cloud lifetime, which would also lead to a negative forcing, is not shown. Some of the forcings possess a much greater degree of certainty than others. The vertical line about the rectangular bars indicates an estimate of the uncertainty range, for the most part guided by the spread in the published values of the forcings. A vertical line without a rectangular bar denotes a forcing for which no central estimate can be given owing to large uncertainties. The overall level of scientific understanding for each forcing varies considerably, as noted. Some of the radiative forcing agents are well mixed over the globe, such as CO_2, thereby perturbing the *global* heat balance. Others represent perturbations with stronger regional signatures because of their spatial distribution, such as aerosols. For this and other reasons, a simple sum of the positive and negative bar heights cannot yield the net effect on the climate system. Rather, the better-quantified forcings (such as well-mixed greenhouse gases, ozone, sulphate aerosols, and solar) have been included in climate models. The simulations of this assessment report (for example, Figure 3) indicate that the estimated net effect of these perturbations is to have warmed the global climate since 1750, with the most perturbation and hence the most warming being in the past century. [Based upon Figure 6.6]

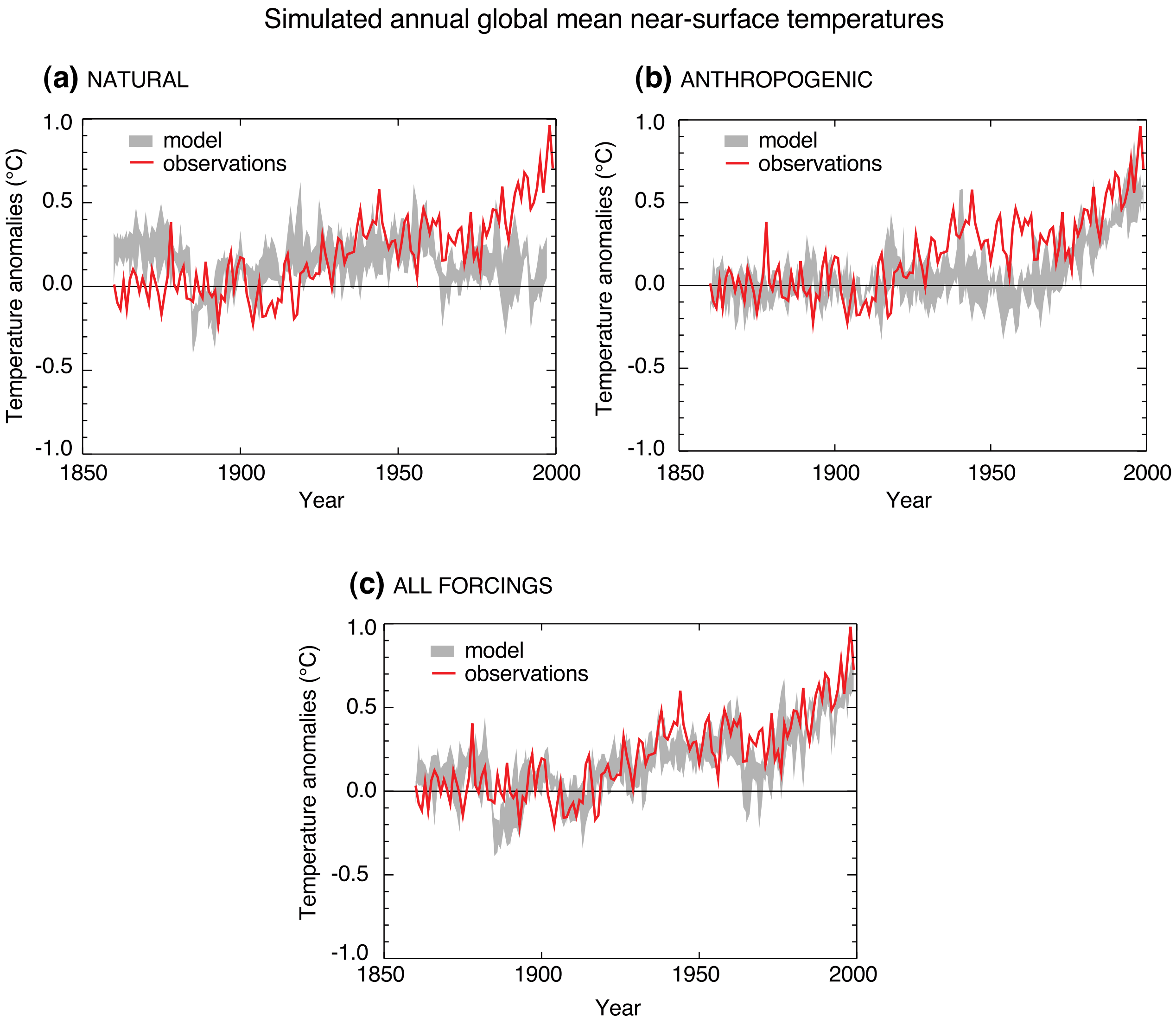


***Figure 3*. Simulating the Earth's temperature variations, and comparing the results to measured changes, can provide clues to the underlying causes of the major changes.** A climate model can be used to simulate the temperature changes that occur both from natural and anthropogenic causes. The simulations represented by the band in Figure 3 (a) were done with only natural forcings: solar variation and volcanic activity. Those encompassed by the band in Figure 3 (b) were done with anthropogenic forcings: greenhouse gases and an estimate of sulphate aerosols, and those encompassed by the band in Figure 3 (c) were done with both natural and anthropogenic forcings included. From Figure 3 (b), it can be seen that inclusion of anthropogenic forcings provides a plausible explanation for a substantial part of the observed temperature changes over the past century, but the best match with observations is obtained in Figure 3 (c) when both natural and anthropogenic factors are included. The bands of model results presented here are for four runs from the same model. Similar results are obtained with other models with anthropogenic forcing. [Based upon Figure 12.7].

***Figure* 4. The global climate of the 21st century** will depend on natural changes and the response of the climate system to human activities. Climate models can simulate the response of many climate variables - such as increases in global surface temperature and sea level - to various scenarios of greenhouse gas and other human-related emissions. Figure 4(a) shows the CO_2 emissions of the six illustrative SRES scenarios, which are summarized in the box below, along with IS92a for comparison purposes with the SAR. Emissions of other gases and aerosols were included in the model but are not shown in the figure. Figures 4 (b) and (c) show the simulated temperature and sea-level responses respectively from a simple model adapted to yield similar responses to several complex models. Estimates of the radiative forcings have been used in the model to make the projections. The "several models all SRES envelope" in Figures 4 (b) and 4 (c) shows the temperature and sea level rise respectively for the simple model when tuned to a number of complex models with a range of climate sensitivities. The "model average all SRES envelope" shows the average from these models for the range of scenarios. Note that the warming and sea level rise from these emissions would continue well beyond 2100. [Based upon (a) Figure 3.12, (b) Figure 9.14, (c) Figure 11.12].

The Emission Scenarios of the Special Report on Emission Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.