



Climate Change 2007: The Physical Science Basis

Summary for Policymakers

Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

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Note:

Text, tables and figures given here are final but subject to copy-editing.

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Drafting Authors:

Richard Alley, Terje Berntsen, Nathaniel L. Bindoff, Zhenlin Chen, Amnat Chidthaisong, Pierre Friedlingstein, Jonathan Gregory, Gabriele Hegerl, Martin Heimann, Bruce Hewitson, Brian Hoskins, Fortunat Joos, Jean Jouzel, Vladimir Kattsov, Ulrike Lohmann, Martin Manning, Taroh Matsuno, Mario Molina, Neville Nicholls, Jonathan Overpeck, Dahe Qin, Graciela Raga, Venkatachalam Ramaswamy, Jiawen Ren, Matilde Rusticucci, Susan Solomon, Richard Somerville, Thomas F. Stocker, Peter Stott, Ronald J. Stouffer, Penny Whetton, Richard A. Wood, David Wratt

Draft Contributing Authors:

Julie Arblaster, Guy Brasseur, Jens Hesselbjerg Christensen, Kenneth Denman, David W. Fahey, Piers Forster, Eystein Jansen, Philip D. Jones, Reto Knutti, Hervé Le Treut, Peter Lemke, Gerald Meehl, Philip Mote, David Randall, Dáithí A. Stone, Kevin E. Trenberth, Jürgen Willebrand, Francis Zwiers

INTRODUCTION

The Working Group I contribution to the IPCC Fourth Assessment Report describes progress in understanding of the human and natural drivers of climate change¹, observed climate change, climate processes and attribution, and estimates of projected future climate change. It builds upon past IPCC assessments and incorporates new findings from the past six years of research. Scientific progress since the TAR is based upon large amounts of new and more comprehensive data, more sophisticated analyses of data, improvements in understanding of processes and their simulation in models, and more extensive exploration of uncertainty ranges.

The basis for substantive paragraphs in this Summary for Policymakers can be found in the chapter sections specified in curly brackets.

HUMAN AND NATURAL DRIVERS OF CLIMATE CHANGE

Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing², which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate. Since the Third Assessment Report (TAR), new observations and related modelling of greenhouse gases, solar activity, land surface properties and some aspects of aerosols have led to improvements in the quantitative estimates of radiative forcing.

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years (see Figure SPM-1). The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture. {2.3, 6.4, 7.3}

- Carbon dioxide is the most important anthropogenic greenhouse gas (see Figure SPM-2). The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm³ in 2005. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. The annual carbon dioxide concentration growth-rate was larger during the last 10 years (1995 – 2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960 – 2005 average: 1.4 ppm per year) although there is year-to-year variability in growth rates. {2.3, 7.3}
- The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use, with land use change providing another significant but smaller contribution. Annual fossil carbon dioxide emissions⁴ increased from an average of 6.4 [6.0 to 6.8]⁵ GtC

¹ *Climate change* in IPCC 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 *Radiative forcing* is a measure of the influence that 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. Positive forcing tends to warm the surface while negative forcing tends to cool it. In this report radiative forcing values are for 2005 relative to pre-industrial conditions defined at 1750 and are expressed in watts per square metre ($W m^{-2}$). See Glossary and Section 2.2 for further details.

³ ppm (parts per million) or ppb (parts per billion, 1 billion = 1,000 million) is the ratio of the number of greenhouse gas molecules to the total number of molecules of dry air. For example: 300 ppm means 300 molecules of a greenhouse gas per million molecules of dry air.

⁴ Fossil carbon dioxide emissions include those from the production, distribution and consumption of fossil fuels and as a by-product from cement production. An emission of 1 GtC corresponds to 3.67 GtCO₂.

⁵ In general, uncertainty ranges for results given in this Summary for Policymakers are 90% uncertainty intervals unless stated otherwise, i.e., there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range. Best estimates are given where available. Assessed uncertainty intervals are not always symmetric about the corresponding best estimate. Note that a number of uncertainty ranges in the Working Group I TAR corresponded to 2-sigma (95%), often using expert judgement.

(23.5 [22.0 to 25.0] GtCO₂) per year in the 1990s, to 7.2 [6.9 to 7.5] GtC (26.4 [25.3 to 27.5] GtCO₂) per year in 2000–2005 (2004 and 2005 data are interim estimates). Carbon dioxide emissions associated with land-use change are estimated to be 1.6 [0.5 to 2.7] GtC (5.9 [1.8 to 9.9] GtCO₂) per year over the 1990s, although these estimates have a large uncertainty. {7.3}

Changes in Greenhouse Gases from ice-Core and Modern Data

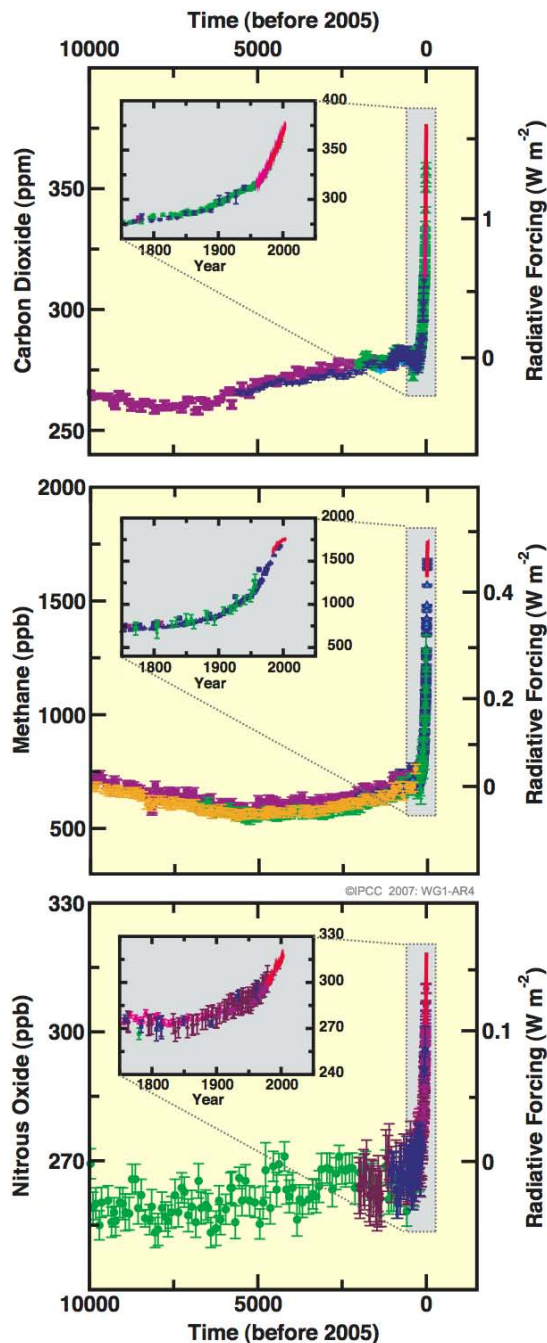


FIGURE SPM-1. Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels. {Figure 6.4}

- The global atmospheric concentration of methane has increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s, and is 1774 ppb in 2005. The atmospheric concentration of methane in 2005 exceeds by far the natural range of the last 650,000 years (320 to 790 ppb) as determined from ice cores. Growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. It is *very likely*⁶ that the observed increase in methane concentration is due to anthropogenic activities, predominantly agriculture and fossil fuel use, but relative contributions from different source types are not well determined. {2.3, 7.4}
- The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 319 ppb in 2005. The growth rate has been approximately constant since 1980. More than a third of all nitrous oxide emissions are anthropogenic and are primarily due to agriculture. {2.3, 7.4}

Radiative Forcing Components

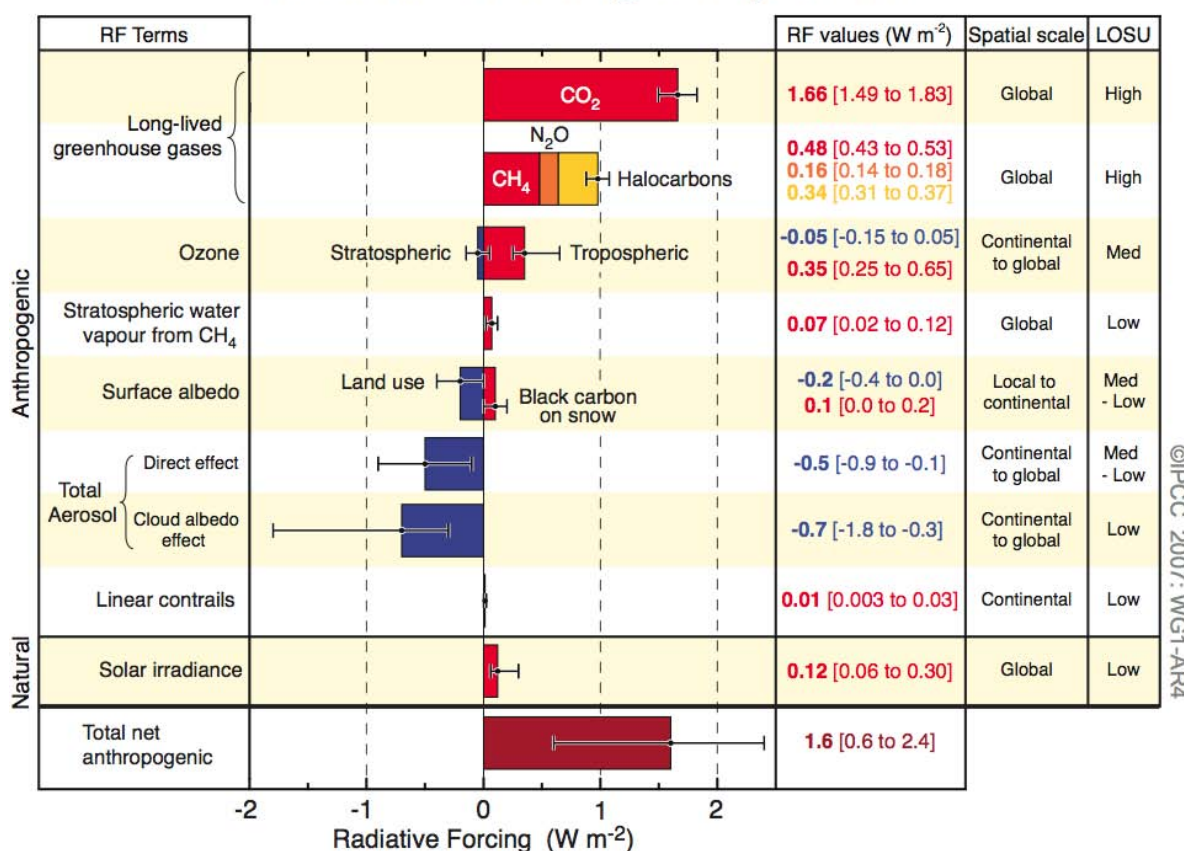


FIGURE SPM-2. Global-average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. Range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}

⁶ In this Summary for Policymakers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5%. (See Box TS.1.1 for more details).

The understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Report (TAR), leading to *very high confidence*⁷ that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m⁻². (see Figure SPM-2). {2.3, 6.5, 2.9}

- The combined radiative forcing due to increases in carbon dioxide, methane, and nitrous oxide is +2.30 [+2.07 to +2.53] W m⁻², and its rate of increase during the industrial era is *very likely* to have been unprecedented in more than 10,000 years (see Figures SPM-1 and SPM-2). The carbon dioxide radiative forcing increased by 20% from 1995 to 2005, the largest change for any decade in at least the last 200 years. {2.3, 6.4}
- Anthropogenic contributions to aerosols (primarily sulphate, organic carbon, black carbon, nitrate and dust) together produce a cooling effect, with a total direct radiative forcing of -0.5 [-0.9 to -0.1] W m⁻² and an indirect cloud albedo forcing of -0.7 [-1.8 to -0.3] W m⁻². These forcings are now better understood than at the time of the TAR due to improved *in situ*, satellite and ground-based measurements and more comprehensive modelling, but remain the dominant uncertainty in radiative forcing. Aerosols also influence cloud lifetime and precipitation. {2.4, 2.9, 7.5}
- Significant anthropogenic contributions to radiative forcing come from several other sources. Tropospheric ozone changes due to emissions of ozone-forming chemicals (nitrogen oxides, carbon monoxide, and hydrocarbons) contribute +0.35 [+0.25 to +0.65] W m⁻². The direct radiative forcing due to changes in halocarbons⁸ is +0.34 [+0.31 to +0.37] W m⁻². Changes in surface albedo, due to land-cover changes and deposition of black carbon aerosols on snow, exert respective forcings of -0.2 [-0.4 to 0.0] and +0.1 [0.0 to +0.2] W m⁻². Additional terms smaller than ±0.1 W m⁻² are shown in Figure SPM-2. {2.3, 2.5, 7.2}
- Changes in solar irradiance since 1750 are estimated to cause a radiative forcing of +0.12 [+0.06 to +0.30] W m⁻², which is less than half the estimate given in the TAR. {2.7}

DIRECT OBSERVATIONS OF RECENT CLIMATE CHANGE

Since the TAR, progress in understanding how climate is changing in space and in time has been gained through improvements and extensions of numerous datasets and data analyses, broader geographical coverage, better understanding of uncertainties, and a wider variety of measurements. Increasingly comprehensive observations are available for glaciers and snow cover since the 1960s, and for sea level and ice sheets since about the past decade. However, data coverage remains limited in some regions.

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (see Figure SPM-3). {3.2, 4.2, 5.5}

- Eleven of the last twelve years (1995 -2006) rank among the 12 warmest years in the instrumental record of global surface temperature⁹ (since 1850). The updated 100-year linear trend (1906–2005) of 0.74 [0.56 to 0.92]°C is therefore larger than the corresponding trend for 1901-2000 given in the TAR of 0.6 [0.4 to 0.8]°C. The linear warming trend over the last 50 years (0.13 [0.10 to 0.16]°C per decade) is nearly twice that for the last 100 years. The total temperature increase from 1850 – 1899 to 2001 – 2005 is 0.76 [0.57 to 0.95]°C. Urban heat island effects are real but local, and have a negligible influence (less than 0.006°C per decade over land and zero over the oceans) on these values. {3.2}

⁷ In this Summary for Policymakers the following levels of confidence have been used to express expert judgments on the correctness of the underlying science: *very high confidence* at least a 9 out of 10 chance of being correct; *high confidence* about an 8 out of 10 chance of being correct. (See Box TS.1.1)

⁸ Halocarbon radiative forcing has been recently assessed in detail in IPCC's Special Report on Safeguarding the Ozone Layer and the Global Climate System (2005).

⁹ The average of near surface air temperature over land, and sea surface temperature.