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# Glossary

**benchmark  $2 \times \text{CO}_2$  warming.** Eventual equilibrium warming from a doubling of atmospheric concentration of carbon dioxide above preindustrial levels (280 parts per million by volume, or ppm, prior to the Industrial Revolution). The present concentration of  $\text{CO}_2$  is about 380 ppm. Equilibrium climate simulations commonly assume a radiative forcing equivalent to a doubling of preindustrial  $\text{CO}_2$  concentration.

**C3 and C4 crops.** Crops are generally divided into two groups—C3 and C4—depending on the number of carbon atoms in the first stable compound into which carbon dioxide is incorporated during photosynthesis (process by which plants use sunlight to make carbohydrates from  $\text{CO}_2$  and water, with oxygen as a waste product). Plants belonging to the C3 group include rice, wheat, soybeans, barley, oats, potatoes, fine grains, legumes, and most trees. Those in the C4 group include maize, millet, sorghum, and sugarcane. Because of differences in the photosynthesis process between the two groups, C3 crops benefit substantially more than C4 crops from “carbon fertilization” associated with higher atmospheric concentrations of  $\text{CO}_2$ .

**carbon dioxide equivalent.** Measure that expresses the amount of other greenhouse gases in terms of the amount of carbon dioxide that would have the same global warming potential.

**carbon fertilization.** Enhancement of the growth of plants as a result of increased atmospheric carbon dioxide concentration, resulting from the fact that  $\text{CO}_2$  is an input into the process of photosynthesis.

**crop process models.** Agronomic models that predict yields and other aspects of crop production as a function of temperature, precipitation, availability of irrigation, soil type, crop management, and other variables.

**equilibrium climate simulation.** Mode of running a global climate model in which greenhouse gas concentrations are suddenly changed (typically double the preindustrial values) and the model allowed to come into equilibrium with the new forcing (*see also* benchmark  $2 \times \text{CO}_2$  warming and ocean thermal lag).

**evapotranspiration.** Combined loss of moisture from soil through evaporation and from plants through stomatal transpiration.

**free air concentration enrichment (FACE).** Method whereby carbon dioxide levels can be elevated in a specified area of forest or other biomass. Unlike controlled environments such as growth chambers and greenhouses, this experiment enables scientists to study the response of plant growth to increased levels of  $\text{CO}_2$  under natural conditions.

**general circulation models (GCMs).** Computer models of the earth's climate system that simulate the physical processes whereby the atmosphere and oceans affect global climate. They have been developed over two decades and require extensive computations to run. They can be run to estimate current climates and the sensitivity of climate to different conditions such as different levels of greenhouse gases.

**greenhouse gas emissions.** Release of gases from the burning of fossil fuels for residential, commercial, and industrial purposes and to power transport vehicles (automobiles, trucks, airplanes, trains, and ships) and from other emissions-producing processes and activities. Globally these emissions are measured in gigatons (1 billion metric tons).

**greenhouse effect.** Warming of the earth attributable to the opacity of water vapor, carbon dioxide, and other greenhouse gases to outbound long-wave infrared radiation from the earth, relative to their transparency to inbound short-wave solar radiation. The result of this differential is that about half of the sun's radiation is permitted to enter through the atmosphere, but about 80 to 90 percent of the returning radiation from the earth is trapped. Natural greenhouse gases keep the earth's average surface temperature about  $33^\circ\text{C}$  warmer than it otherwise would be (at about  $+15^\circ\text{C}$  rather than  $-18^\circ\text{C}$ ). In its 2007 report, the Intergovernmental Panel on Climate Change judged that anthropogenic (manmade) emissions of greenhouse gases have been the main reason for the observed rise in average global surface temperatures by about  $0.8^\circ\text{C}$  from 1850–99 to 2001–05.

**Kyoto Protocol.** Agreement made under the United Nations Framework Convention on Climate Change. Industrial and transition-economy, but not developing, countries that ratify this protocol commit to reducing their emissions of carbon dioxide and five other greenhouse gases by at least 5 percent below 1990 levels in the commitment period 2008–2012 or engage in emissions trading if they maintain or increase emissions of these gases (*see* greenhouse gas emissions). The protocol was negotiated in Kyoto, Japan in December 1997 and came into force on February 16, 2005 following ratification by Russia in November 2004. As of October 2006, a total of 166 countries and other governmental entities have ratified the agreement (representing over 61.6 percent of emissions). Notable exceptions include the United States and Australia. Although India and China have ratified the protocol, as developing countries they are not required to reduce carbon emissions despite their large populations and (especially in the case of China) current emissions.

**MMSA.** Mendelsohn, Morrison, Schlesinger, and Andronova (2000).

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**ocean thermal lag.** Length of time (some three decades for benchmark  $2 \times \text{CO}_2$  warming) between increase in atmospheric concentration of greenhouse gases and the resulting eventual equilibrium warming, attributable to ocean thermal dynamics. During this period surface warming is slowed as the deep ocean is warmed to maintain an equilibrium differential from ocean surface temperatures.

**permanent crop land.** Land under crops that last many seasons and are not replanted after each harvest. Permanent crops include tea, coffee, rubber, flowering shrubs, fruit and nut trees, and vines.

**Ricardian models.** Family of Ricardian or cross-section (CS) models relating agricultural capacity to temperature and precipitation, usually in a nonlinear fashion, on the basis of statistical estimates from farm survey or county-level data across varying climatic zones. The classical economist David Ricardo developed the theory that the value of land depends on the difference between its fertility and that of the least fertile land just brought into cultivation at the margin. The seminal Ricardian agricultural impact model (Mendelsohn, Nordhaus, and Shaw 1994) argued that statistical regressions relating land values to climate differences could capture the impact of climate on agricultural productivity and thus be used to calculate prospective effects of global warming.

**SRES scenarios.** A suite of emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) in its Special Report on Emissions Scenarios (SRES) for the Third Assessment Report and also used in the Fourth Assessment Report. The six families of scenarios are A1FI, A1B, A1T, A2, B1, and B2. The central scenario set used in the present study is SRES A2, in which carbon dioxide emissions rise from about 7.3 GtC (gigatons of carbon) in 1990 to about 29 GtC by 2100.

**transient climate simulation.** Mode of running a global climate model in which a period of time is simulated with continuously varying concentrations of greenhouse gases so that the climate of the model represents prospective changes already realized by the time of each future date in question, rather than the higher long-run equilibrium warming eventually resulting from atmospheric concentrations at each such date. The difference stems from ocean thermal lag.

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*Sources:* The present study; Cline (1992); IPCC Data Distribution Center, [www.ipcc-data.org](http://www.ipcc-data.org); US Department of Agriculture, [www.usda.gov](http://www.usda.gov); Environmental Protection Agency, [www.epa.gov](http://www.epa.gov); United Nations Environment Program, [www.unep.org](http://www.unep.org); Pew Center on Global Climate Change, [www.pewclimate.org](http://www.pewclimate.org); and United Nations Framework Convention on Climate Change, <http://unfccc.int>. All Web sites accessed on June 8, 2007.