Climate Models

Excerpts from:

Climate Models and Their Evaluation, In: Climate Change 2007: The Physical Science Basis, Chapters 8 and 10

Ch 8 http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf

Ch 10 http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter10.pdf

Climatic Research Unit (CRU) website: http://www.cru.uea.ac.uk/

What are climate models?

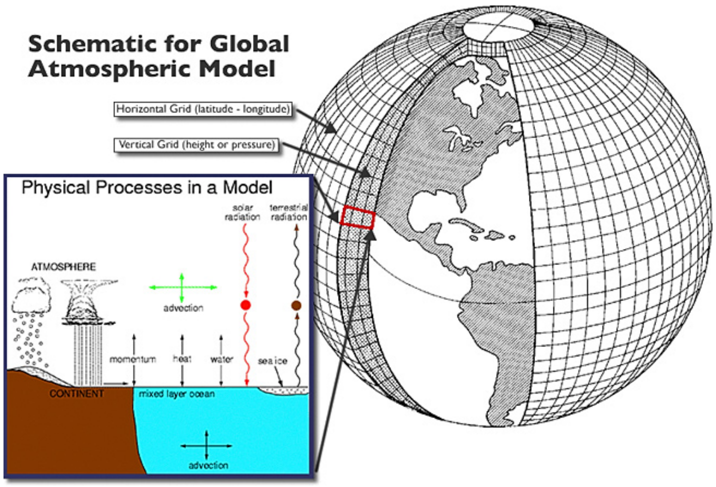
Climate models use quantitative methods to simulate the interactions of the atmosphere, oceans, land surface, and ice. They are used for a variety of purposes from study of the dynamics of the weather and climate system to projections of future climate. All climate models balance, or very nearly balance, incoming energy as short wave electromagnetic radiation (visible and ultraviolet) to the earth with outgoing energy as long wave (infrared) electromagnetic radiation from the earth. Any imbalance results in a change in the average temperature of the earth.

There have been major advances in the development and use of models over the last 20 years and the current models give us a reliable guide to the direction of future climate change. Computer models cannot predict the future exactly, due to the large number of uncertainties involved. The models are based mainly on the laws of physics, but also empirical techniques which use, for example, studies of detailed processes involved in cloud formation. The most sophisticated computer models simulate the entire climate system. As well as linking the atmosphere and ocean, they also capture the interactions between the various elements, such as ice and land (CRU).

Climate models have been used successfully to reproduce the main features of the current climate; the temperature changes over the last hundred years, and the main features of the Holocene (6,000 years ago) and Last Glacial Maximum (21,000) years ago. Current models enable us to attribute the causes of past climate change, and predict the main features of the future climate, with a high degree of confidence (CRU).

The most talked-about models of recent years have been those relating temperature to emissions of carbon dioxide (and other greenhouse gases). These models project an upward trend in the surface temperature record, as well as a more rapid increase in temperature at higher altitudes.

Coupled atmosphere-ocean general circulation models (AOGCMs)
(e.g. MIROC3.2(medres), CSIRO-MK3.0, UKMO-HadCM3)



Climate models are systems of differential equations based on the basic laws of physics, fluid motion, and chemistry. To "run" a model, scientists divide the planet into a 3-dimensional grid, apply the basic equations, and evaluate the results. Atmospheric models calculate winds, heat transfer, radiation, relative humidity, and surface hydrology within each grid and evaluate interactions with neighboring points.
From: NOAA http://celebrating200years.noaa.gov/breakthroughs/climate_model/welcome.html

AOGCMs combine the two general circulation models, atmospheric and ocean. They thus have the advantage of removing the need to specify fluxes across the interface of the ocean surface. These models are the basis for sophisticated model predictions of future climate, such as are discussed by the IPCC. AOGCMs represent the pinnacle of complexity in climate models and internalize as many processes as possible. They are the only tools that could provide detailed regional predictions of future climate change. However, they are still under development. The simpler models are generally susceptible to simple analysis and their results are generally easy to understand. AOGCMs, by contrast, are often nearly as hard to analyze as the real climate system (Randall, 2007).

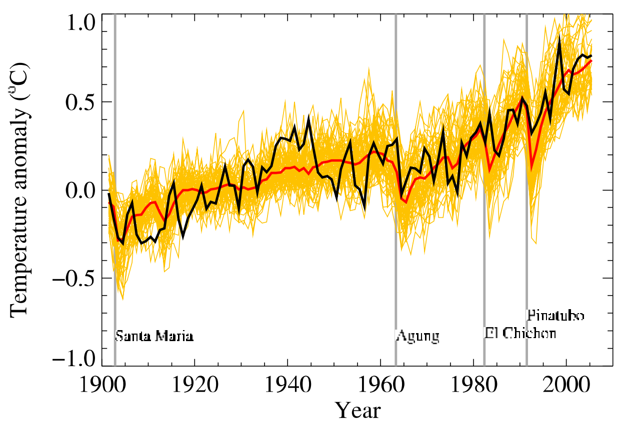
Atmosphere-Ocean General Circulation Models are able to simulate extreme warm temperatures, cold air outbreaks and frost days reasonably well. Models used in Fourth Assessment Report (AR4 2007) for projecting tropical cyclone changes are able to simulate present day frequency and distribution of cyclones, but intensity is less well simulated. Simulation of extreme precipitation is dependent on resolution, parameterization, and the thresholds chosen. In general, models tend to produce too many days with weak precipitation (<10 mm day–1) and too little precipitation overall in intense events (>10 mm day–1) (Randall, 2007).

The large-scale patterns of seasonal variation in several important atmospheric fields are now better simulated by AOGCMs than they were at the time of the Third Assessment Report (TAR 2001). Notably, errors in simulating the monthly mean, global distribution of precipitation, sea level pressure and surface air temperature have all decreased. In some models, simulation of marine low-level clouds, which are important for correctly simulating sea surface temperature and cloud feedback in a changing climate, has also improved. Nevertheless, important deficiencies remain in the simulation of clouds and tropical precipitation (with their important regional and global impacts) (Randall, 2007). Since the TAR, developments in AOGCM formulation have improved the representation of large-scale variability over a wide range of time scales. The models capture the dominant extratropical patterns of variability including the Northern and Southern Annular Modes, the Pacific Decadal Oscillation, the Pacific-North American and Cold Ocean-Warm Land Patterns. AOGCMs simulate Atlantic multi-decadal variability, although the relative roles of high- and low-latitude processes appear to differ between models. In the tropics, there has been an overall improvement in the AOGCM simulation of the spatial pattern and frequency of ENSO, but problems remain in simulating its seasonal phase locking and the asymmetry between El Niño and La Niña episodes (Randall, 2007).

How Reliable Are the Models Used to Make Projections of Future Climate Change?

Excerpt from: Frequently Asked Question 8.1.Climate Models and Their Evaluation, In: Climate Change 2007: The Physical Science Basis, Chapter 8, pages 600-601.

There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes. Confidence in model estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). Over several decades of development, models have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases (Randall, 2007).



Global mean near-surface temperatures over the 20th century from observations (black) and as obtained from 58 simulations produced by 14 different climate models driven by both natural and human-caused factors that influence climate (yellow). The mean of all these runs is also shown (thick red line). Temperature anomalies are shown relative to the 1901 to 1950 mean. Vertical grey lines indicate the timing of major volcanic eruptions. (Figure adapted from Chapter 9, Figure 9.5, IPCC 2007: Climate Change 2007: The Physical Science Basis. Refer to corresponding caption for further details.)

Supporting Documentation

Randall, D.A., R.A. Wood, S. Bony, R. Colman, T. Fichefet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla, J. Srinivasan, R.J. Stouffer, A. Sumi and K.E. Taylor, 2007: Climate Models and Their Evaluation. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter10.pdf

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.
http://www.ipcc.ch/ipccreports/ar4-wg1.htm

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf

IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.
http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

IPCC, 2000: Emissions Scenarios. Nebojsa Nakicenovic and Rob Swart (Eds.), Cambridge University Press, UK. pp 570. Available from Cambridge University Press, The Edinburgh Building Shaftesbury Road, Cambridge CB2 2RU ENGLAND
http://www.ipcc.ch/ipccreports/sres/emission/index.htm