ENVIRONMENTAL AND ENERGY STUDY INSTITUTE
122 C STREET, N.W., SUITE 630 ■ WASHINGTON, D.C., 20001 ■ 202-628-1400 ■ www.eesi.org

CAROL WERNER
EXECUTIVE DIRECTOR

Climate Change Fact Sheet

Release: May 21, 2007

Contact:
Fredric Beck (202) 662-1892, fbeck@eesi.org

Annotated Bibliography of Important Climate Science Papers

The scientific community agrees that global climate change is occurring and that human activities are contributing to climate change. This fact sheet briefly summarizes a sample of major scientific papers documenting observed changes in the climate system indicative of a warming Earth, and provides links to a number of overview documents relevant to policymakers.

1. Overview Documents for Policymakers

Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) has been established by the World Meteorological Association (WMO) and UN Environment Program (UNEP) to assess scientific, technical and socioeconomic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.

Fourth Assessment Report--Summary for Policymakers:
The 2007 IPCC Fourth Assessment Report was developed with the participation of more than 2500 expert reviewers, 800 authors, 450 lead authors, and 130 countries. The Fourth Assessment Report is made up of three Working Group reports, each of which has a summary for policymakers as well as a technical report.

Working Group I: The Science of Climate Change
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_SPM.pdf (Summary for Policymakers)
http://ipcc-wg1.ucar.edu/wg1/wg1-report.html (Full report)

Working Group II: Impacts, adaptation and vulnerability
http://www.ipcc.ch/SPM13apr07.pdf (Summary for Policymakers)
http://www.ipcc-wg2.org/index.html (Full report)

Working Group III: Mitigation of climate change
http://www.mnp.nl/ipcc/docs/FAR/Approved_SPM_WGIII_0405.pdf (Summary for Policymakers)
http://www.ipcc-wg3.org/ (Full report)

Third Assessment Report
• Climate Change 2001: Synthesis Report
Summary for Policymakers
The 2001 Synthesis Report provides a policy-relevant, but not policy-prescriptive, synthesis and integration of information contained within the IPCC Third Assessment Report and also drawing upon all previously approved and accepted IPCC reports that would address a broad range of key policy-relevant, but not policy-prescriptive, questions.
http://www.ipcc.ch/pub/un/syreng/spm.pdf

Second Assessment Report--Summary for Policymakers:
The 1995 IPCC Second Assessment Report provides three different summary documents for policymakers, one for each of the three working groups of the Second Assessment:

• **Climate Change 1995: The Science of Climate Change**
http://www.ipcc.ch/pub/sarsum1.htm

• **Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses**
http://www.ipcc.ch/pub/sarsum2.htm

• **Climate Change 1995: Economic and Social Dimensions of Climate Change**
http://www.ipcc.ch/pub/sarsum3.htm

US National Assessment

In 1997, the U. S. Global Change Research Program initiated the "National Assessment of the Potential Consequences of Climate Variability and Change for the United States." This national level assessment included analyses of the importance of climate variability and change in twenty regions around the US, in five cross-cutting sectors focused around natural resources and public health, and for the US as a whole.

• **Climate Change Impacts on the United States**
The Potential Consequences of Climate Variability and Change
Overview Report (2000)
This document is the Assessment Overview, written by the National Assessment Synthesis Team (NAST). The NAST is a committee of experts drawn from governments, universities, industry, and non-governmental organizations. It has been responsible for broad over-sight of the Assessment, with the Federal agencies of the USGCRP. This Overview is based on a longer, referenced "Foundation" report, written by the NAST in cooperation with independent regional and sector assessment teams. These two national-level, peer-reviewed documents synthesize results from studies conducted by regional and sector teams, and from the broader scientific literature.
http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm

Arctic Climate Impact Assessment (ACIA) Summary

The Arctic Climate Impact Assessment (ACIA) is an international project of the Arctic Council and the International Arctic Science Committee (IASC), to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences. The results of the assessment were released at the ACIA International Scientific Symposium held in Reykjavik, Iceland in November 2004.

• **Impacts of a Warming Arctic – the 140-page synthesis report of the Arctic Climate Impact Assessment**
The Arctic is of special importance to the world and it is changing rapidly. It is thus essential that decision makers have the latest and best information available regarding ongoing changes in the Arctic. The Overview Report is a plain language synthesis of the key findings of the Arctic Climate Impact Assessment (ACIA), designed to make the scientific findings accessible to policymakers and the broader public. The ACIA is a comprehensively researched, fully referenced, and independently reviewed evaluation of arctic climate change and its impacts for the region and for the world. It has involved an international effort by hundreds of scientists over four years, and also includes the special knowledge of indigenous people.
http://www.acia.uaf.edu/pages/overview.html

2. The Basics: CO_2, Energy Balance, and Temperature

First Calculations of Temperature Variation Induced by Atmospheric CO_2

This 1896 paper was the first to predict the variation in Earth's temperature that would follow from various concentrations of "carbonic acid" (now known to be carbon dioxide, CO_2) in the atmosphere. The absorption of terrestrial radiation by CO_2 had been measured, and while it was unknown how much CO_2 the atmosphere contained, prominent chemist, and later 1903 Nobel Prize winner, Svante Arrhenius was able to calculate the effect of doubling or tripling atmospheric CO_2 at various latitudes and seasons on equilibrium temperature. He calculated that a doubling of CO_2 would result in an annual average 5°C warming at the equator and 6°C warming at the poles. This calculation is within the range of today's estimates of expected CO_2-induced warming.

• Arrhenius, S., "**On the influence of carbonic acid in the air upon the temperature of the ground**," *Philosophical Magazine* **41**, 237 (1896).
http://www.gps.caltech.edu/classes/ese148a/2003/Arrhenius.HTML *(transcribed)*

In 1938 Callender determined that higher content of CO_2 had caused warmer temperatures in America and Europe, and that Arrhenius had underestimated the rise of temperature. The warming event in the first part of the 20th century was considered at the time by some as the first sign of climate warming caused by increasing CO_2. Callender and Flohn discussed how the photosynthesis in trees and plants could take up some carbon dioxide and reduce the temperature rise.

• Callendar, G. S., "**The artificial production of carbon dioxide and its influence on temperatures.**" *Quart. J. Roy. Meteor. Soc*., **64**, 223-227 (1938).

By the late 1950s, American scientist Roger Revelle and Swiss scientist Hans Suess had clearly explained why the growing emissions of CO_2 from combustion of coal, oil, and natural gas (as well as from accelerated clearing of the land and oxidation of soil carbon) could not be taken up rapidly by the oceans, and so human influences on atmospheric composition and the climate would last for centuries, making clear that humans were undertaking a great "geophysical experiment" (Revelle and Suess, 1957). In 1965, a distinguished panel of American scientists convened by the President's Science Advisory Council (PSAC) summarized the science and reported that climate change was an issue that needed to be addressed (PSAC, 1965).

• Revelle, Roger, and Hans E. Suess. "**Carbon Dioxide Exchange between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO_2 During the Past Decades**." *Tellus* **9**: 18-27. (1957)
http://www.aip.org/history/climate/Revelle.htm
• President's Science Advisory Committee (PSAC), "**1965: Restoring the Quality of our Environment, Report of the Environmental Pollution Panel.**" The White House, Washington DC, November (1965).

Observation of Increasing Atmospheric CO_2 Concentrations

The classic Mauna Loa, Hawaii, record of atmospheric CO_2 concentration, showing an upward trend from 315 parts per million (ppm) in 1958 to 381 ppm in 2005, was begun by Charles Keeling. Keeling and colleagues at Scripps Institution of Oceanography established the connection between atmospheric CO_2 concentration and rates of industrial CO_2 emissions.

• Keeling, C.D., Bacastow, R.B., Bainbridge, A.E., Ekdahl, C.A., Guenther, P.R., Waterman, L.S., Chin, J.F.S., "**Atmospheric carbon-dioxide variations at Mauna Loa observatory, Hawaii**," *Tellus* **28**, 538 (1976).
• Keeling, C.D., Whorf, T.P., Wahlen, M., and van der Plicht, J., "**Interannual extremes in the rate of rise of atmospheric carbon dioxide since 1980**," *Nature* **375**, 666 (1995).
http://www.nature.com/nature/journal/v375/n6533/abs/375666a0.html

Increase in Surface Air Temperature Correlates with Greenhouse Gases

Hegerl, et al. used climate models and statistical analysis to detect greenhouse gas-induced climate change in the spatial pattern of observed near-surface temperature trends. The sophisticated atmosphere and ocean model included all known interactions and found that "a statistically significant externally induced warming has been observed."

They showed that "internal climate variability" remained an extremely uncertain parameter, and called for further study on climate responses to changes in solar radiation, and volcanic or anthropogenic sulfate aerosols.

• Hegerl, G.C., von Storch, H., Hasselmann, K., Santer, B.D., Cubasch, U., and Jones, P.D., "**Detecting greenhouse-gas-induced climate change with an optimal fingerprint method**," *Journal of Climate* **9**, 2281 (1996).
http://ams.allenpress.com/amsonline/?request=get-abstract&issn=1520-0442&volume=009&issue=10&page=2281

Earth's Energy Imbalance

According to a 2005 analysis, Earth is currently absorbing more energy from the Sun than it is emitting back into space due to the increasing concentration of human-made greenhouse gases and aerosols. This imbalance of 0.85 Watts per square meter (W/m^2) would result in an additional warming of 0.6 °C (1.1°F) without any further change in atmospheric composition. This "locked-in" commitment to future warming makes clear that the climate system exhibits a significant lag in responding to forcings, and the authors of this paper defined the degree of anticipatory actions that will be required to avoid a specified level of climate change.

• Hansen, J., Nazarenko, L., Ruedy, R., Sato, M., Willis, J., Del Genio, A., Koch, D., Lacis, A., Lo, K., Menon, S., Novakov, T., Perlwitz, J., Russell, G., Schmidt, G.A., and Tausnev, N., "**Earth's energy imbalance: Confirmation and implications**," *Science* **308**, 1431 (2005).
http://www.sciencemag.org/cgi/content/abstract/308/5727/1431

3. Warming Oceans and Melting Ice Sheets Cause Sea Level Rise

Warming Detected in the World's Oceans

Scientists from the Scripps Institution of Oceanography (Barnett et al.) recently made the first convincing (i.e., statistically significant) detection and attribution of human-induced increases in ocean heat content over the past 45 years. They found a complex warming signal that varied by ocean, and was clearly attributable to anthropogenic climate change. Another recent paper (Levitus, et al.) found a mean temperature increase of 0.037°C over the period 1955 to 1998, indicating a rate of ocean heat uptake of 0.20 Watts per square meter (W/m^2) (per unit area of Earth's total surface area).

• Levitus, S., Antonov, J., and Boyer, T., "**Warming of the world ocean, 1955-2003**," *Geophysical Research Letters* **32**, L02604 (2005).
http://www.agu.org/pubs/crossref/2005/2004GL021592.shtml
• Barnett, T.P., Pierce, D.W., AchutaRao, K.M., Gleckler, P.J., Santer, B.D., Gregory, J.M., Washington, W.M., "**Penetration of human-induced warming into the world's oceans**," *Science* **309**, 284 (2005).
http://www.sciencemag.org/cgi/content/abstract/309/5732/284
• Barnett, T.P., Pierce, D.W., Schnur, R., "**Detection of anthropogenic climate change in the world's oceans**," *Science* **292**, 270 (2001).
http://www.sciencemag.org/cgi/content/abstract/292/5515/270

Global Warming, Ice Sheet Melt, and Sea Level Rise

Complete melting of the Greenland and Antarctic ice sheets would raise sea level by about 70 meters (almost 250 feet) in coming centuries, starting a millennial-scale process. The Greenland and West Antarctic ice sheets, which total about 12 meters (roughly 40 feet) of rise, are most at risk. The freshwater melt from these ice sheets has the potential to affect oceanic circulation, which would further contribute to climate change. Meehl et al. describe how the greenhouse gases already in the atmosphere commit the Earth, over the next few decades, to roughly 0.5°C (1°F) increase in globally averaged surface air temperature and at least an 11 cm (4 inches) rise in global sea level by 2100. This projection of sea level rise accounts only for seawater expansion occurring because the world's oceans are absorbing heat; the contributions to sea level rise from the melting of glaciers and ice sheets appears to be changing very rapidly. The latter melts would contribute an additional sea level rise of at least 11 cm (4 inches). Overpeck, et al. studied the rate of ice-sheet melting leading up to the last interglacial period 125,000 years ago and concluded that future deterioration of the Greenland and West Antarctic ice sheets could be faster than previously included in the IPCC estimates; were this to occur, the rate of sea level rise could exceed 1 meter per century.

• Alley, R.B., Clark, P.U., Huybrechts, P., and Joughin, I., "**Ice-sheet and sea-level changes**," *Science* **310**, 456 (2005).
http://www.sciencemag.org/cgi/content/abstract/310/5747/456
• Meehl, G.A., Washington, W.M., Collins, W.D., Arblaster, J.M., Hu, A., Buja L.E., Strand W.G. and Teng, H., "**How much more global warming and sea level rise?**" *Science* **307**, 1769 (2005).
http://www.sciencemag.org/cgi/content/abstract/307/5716/1769
• Overpeck, J.T., Otto-Bliesner, B.L., Miller, G.H., Muhs, D.R., Alley, R.B., and Kiehl, J.T., "**Paleoclimatic evidence for future ice-sheet instability and rapid sea-level rise**," *Science* **311**, 1747 (2006).
http://www.sciencemag.org/cgi/content/abstract/311/5768/1747

4. Further Ocean Effects: Acidification and Slowing Circulation

Ocean Acidification due to Increasing Atmospheric CO_2

Almost half of the CO_2 released by burning fossil fuels is ultimately absorbed by the ocean, where it forms carbonic acid and lowers the ocean pH. This acidification (strictly, lowering ocean alkalinity) of the ocean makes it more difficult for marine life to build hard calcium carbonate shells and coral. Increasing acidification has likely already contributed to the decline of coral reefs, and analyses indicate that significant ecosystem damage is likely to occur within decades if a "business-as-usual" atmospheric CO_2 increase is assumed. (Initial impacts on marine organisms are likely to become evident in polar waters.)

• Doney, S.C., "**The dangers of ocean acidification**," *Scientific American* **294**, 58 (2006).
http://www.sciam.com/article.cfm?chanID=sa006&colID=1&articleID=00057536-E87F-13F5-A75F83414B7FFE9F
• Sabine, C.L., Feely, R.A., Gruber, N., Key, R.M., Lee, K., Bullister, J.L., Wanninkhof, R., Wong, C. S., Wallace, D.W.R., Tilbrook, B., Millero, F.J., Peng, T.-H., Kozyr, A., Ono, T., Rios, A.F., "**The oceanic sink for anthropogenic CO_2**," *Science* **305**, 367 (2004).
http://www.sciencemag.org/cgi/content/abstract/305/5682/367
• Caldeira, K., and Wickett, M.E., "**Oceanography: Anthropogenic carbon and ocean pH**," *Nature* **425**, 365 (2003).
http://www.nature.com/nature/journal/v425/n6956/abs/425365a.html

Slowing of Atlantic Ocean's Overturning Circulation

In 1985, Broecker, et al. first suggested a link between the "ocean conveyor belt" i.e., the global deep-ocean or meridional overturning circulation (MOC), generically called "thermohaline circulation", to climatic changes during past ice age cycling. In theory, northward heat transport could slow due to increasing temperature of surface waters resulting from greenhouse warming. This could make the water less dense and less likely to sink, which would diminish the driving force for the MOC at the northernmost part of the circulation loop. An unknown in predicting future scenarios for the MOC is an acceleration of the melting of the Greenland ice sheet. Rignot and Kanagaratnam recently observed a doubling in the rate of ice sheet mass loss in the past decade. Rahmstorf, et al. studied models looking at possible sudden changes in the MOC, and concluded that the current climate is not close to that point, but may approach it in the next 100 years. The MOC contributes to the moderate climate of maritime and continental Europe.

• Broecker, W.S., Peteet, D.M., and Rind, D., "**Does the ocean-atmosphere system have more than one stable mode of operation?**" *Nature* **315**, 21 (1985).
http://www.nature.com/nature/journal/v315/n6014/abs/315021a0.html
• Bryden, H.L., Longworth, H.R., and Cunningham, S.A., "**Slowing of the Atlantic meridional overturning circulation at 25°N**," *Nature* **438**, 655 (2005).
http://www.nature.com/nature/journal/v438/n7068/abs/nature04385.html
• Rignot, E., and Kanagaratnam, P., "**Changes in the velocity structure of the Greenland ice sheet**," *Science* **311**, 986 (2006).
http://www.sciencemag.org/cgi/content/abstract/311/5763/986
• Rahmstorf, S., Crucifix, M., Ganopolski, A., Goosse, H., Kamenkovich, I., Knutti, R., Lohmann, G., Marsh, R., Mysak, L.A., Wang, Z., and Weaver, A.J., "**Thermohaline circulation hysteresis: A model intercomparison**," *Geophysical Research Letters* **32**, L23605 (2005).
http://www.agu.org/pubs/crossref/2005/2005GL023655.shtml

5. Further Indicators of Warming: Storms and Extinctions

Increasing Destructiveness of Hurricanes in a Warming Climate

The scientific theory predicting greater hurricane intensity in a warmer climate was first proposed by Kerry Emanuel of MIT in 1987. He predicted a 40-50 percent increase in the destructive potential of hurricanes with doubling of the CO_2 concentration (from 1987 mixing ratio of 345 ppm to 690 ppm). Recently, the record of hurricane intensity expressed in terms of a power dissipation index (PDI) was analyzed, showing increasing hurricane destructiveness since the 1970s that correlates with rising tropical sea surface temperatures. In a separate study, Webster, et al. found a large increase in the number and proportion of hurricanes reaching categories 4 and 5 over the past 35 years, while the total number of cyclones had decreased. Emanuel (2005) suggested that future warming will lead to an upward trend in PDI which, combined with increasing coastal population and infrastructure, will lead to a continuing and substantial increase in hurricane-related losses in the 21st century.

• Emanuel, K., "**Increasing destructiveness of tropical cyclones over the past 30 years**," *Nature* **436**, 686 (2005).
http://www.nature.com/nature/journal/v436/n7051/abs/nature03906.html
• Emanuel, K., "**The dependence of hurricane intensity on climate**," *Nature*, **326**, 483 (1987).
http://www.nature.com/nature/journal/v326/n6112/abs/326483a0.html
• Webster, P.J., Holland, G.J., Curry, J.A., and Chang, H.-R., "**Changes in tropical cyclone number, duration, and intensity in a warming environment**," *Science* **309**, 1844 (2005).
http://www.sciencemag.org/cgi/content/abstract/309/5742/1844

Species Change and Extinction Connected to Anthropogenic Climate Change

Root, et al. found that 130 species, including diverse plants and animals, have responded to earlier spring temperatures since 1970. Their analysis statistically linked these springtime biological changes to greenhouse gas driven climate change using "joint attribution," ruling out the possibility that these species changes could be related to natural climate variability alone. A separate study by Pounds, et al. linked widespread extinctions in tropical amphibian species to climate change events of higher sea-surface and atmospheric temperatures. By accounting for the correlation between extinction and regional El Niño events, the authors again demonstrated that the driver was the global warming trend and not regional variability.

• Root, T.L., MacMynowski, D.P., Mastrandrea, M.D., and Schneider, S.H., "**Human-modified temperatures induce species changes: Joint attribution**," *Proceedings of the National Academy of Sciences* **102**, 7465 (2005).
http://www.pnas.org/cgi/content/short/102/21/7465
• Pounds, J.A., Bustamante, M.R., Coloma, L.A., Consuegra, J.A., Fogden, M.P.L., Foster, P.N., La Marca, E., Master, K.L., Merino-Viteri, A., Puschendorf, R., Ron, S.R., Sanchez-Azofeifa, G.A., Still, C.J., and Young, B.E., "**Widespread amphibian extinctions from epidemic disease driven by global warming**," *Nature* **439**, 161 (2006).
http://www.nature.com/nature/journal/v439/n7073/abs/nature04246.html

###

The Environmental and Energy Study Institute is a non-profit organization established in 1984 by a bipartisan, bicameral group of members of Congress to provide timely information on energy and environmental policy issues to policymakers and stakeholders and develop innovative policy solutions that set us on a cleaner, more secure and sustainable energy path.