APPENDIX B: ADDITIONAL INFORMATION ON FIGURES

Figure 1. Ocean Warming Since the 1950s

Decadal values of anomalous heat content (10^{22} J) in various ocean basins. The heavy dashed line is from observations, and the solid line is the average from five realizations of the Parallel Climate Model (PCM) forced by observed and estimated anthropogenic forcing. (The PCM was developed primarily by the National Center for Atmospheric Research, with the ocean and sea-ice components contributed by the DOE Los Alamos National Laboratory.) Both curves show significant warming in all basins since the 1950s. The shaded bands denote one (heavy shading) and two (light shading) standard deviations about the model mean signal estimated from the standard deviation in the scatter of the five-member ensemble. The heat content is computed over the upper 3000 m of the water column. The space/time sampling was identical for both model and observations. Basin averages for the northern oceans are defined between 60°N and the equator. The southern ocean averages are between the equator and 77°S.

Large-scale increases in the heat content of the world's oceans have been observed to occur over the last 45 years. The horizontal and temporal character of these changes has been closely replicated by the state-of-the-art PCM forced by observed and estimated anthropogenic greenhouse gases and aerosols. Application of optimal detection methodology shows that the model-produced signals are indistinguishable from the observations at the 0.05 confidence level. Further, the chances of either the anthropogenic or observed signals being produced by the PCM as a result of natural, internal forcing alone are less than 5%. This suggests that the observed ocean heat-content changes are consistent with those expected from anthropogenic forcing, which broadens the basis for claims that an anthropogenic signal has been detected in the global climate system. Additionally, the requirement that modeled ocean heat uptakes match observations puts a strong, new constraint on anthropogenically forced climate models. It is unknown if the current generation of climate models, other than the PCM, meet this constraint.

Tim P. Barnett*, David W. Pierce, Reiner Schnur, "Detection of Anthropogenic Climate Change in the World's Oceans," *Science*, 292 (5515): 270, 13 April 2001.

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Figure 2. Observed Effects of Climate Variability on Salmon

Abundances of many salmon stocks have closely tracked interdecadal climate variation since 1940. Upper Columbia bright spring Chinook are abundant when the Pacific Northwest Index (one measure of decadal climate variation) is negative. Both curves are 5-year moving averages.

Northwest salmon stocks have been highly stressed for decades by intense fishing pressure and threats to their stream habitats. Salmon are sensitive to various climate-related conditions, both inshore and offshore, at various times of their life cycle. Although the relative contributions of and interactions between climate and non-climate factors, and inshore and offshore conditions, are highly uncertain, salmon stocks throughout the North Pacific show a strong association with the Pacific Decadal Oscillation. Salmon in the Northwest are more abundant in the cool PDO phase, while Alaska salmon show the opposite pattern. The mechanisms for this observed climate effect on stocks are poorly known, and probably include some effects of both freshwater and marine changes.

National Assessment Synthesis Team, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change,* Overview report, p. 70, and Foundation report, pp. 262-263.

Figure 3. Large-Scale Atmospheric Pollution in Southeast Asia During the Last El Niño Event

The Total Ozone Mapping Spectrometer (TOMS) shows a heavily polluted air mass covering much of Southeast Asia during the last El Niño event (October 1997), an illustration of how short-term variations in climate and changes in land-use practices can lead to unhealthy levels of large-scale pollution. The color scale represents the integrated column abundance of ozone in the lower-most region of the atmosphere (the troposphere) in Dobson units. The scale runs from blue, representing about 20 Dobson units or less, to red, representing about 70 Dobson units. Column abundances of 30 Dobson units and greater indicate polluted regions, with ozone concentrations in some layers of the atmosphere as high as 100 parts per billion. The grey scale represents the aerosol index, a relative scale of aerosol abundance that indicates the location of high levels of smoke from the fires. The data show that the smoke and ozone, both products of the biomass burning, moved in different ways through the atmosphere. The fires and smoke were doused by rainfall at the end of 1997, but higher than normal ozone lasted another seven months.

This research, sponsored by NASA's Earth Science Enterprise, may soon help scientists do a better job of tracking pollution plumes around the world and help provide more advance warning of unhealthy air. Since 1996, with the launch of the TOMS Earth Probe satellite, scientists have been able to measure tropical smoke aerosols and tropospheric ozone, major components of air pollution and hazardous to health, on a daily basis. During the 1997 El Niño event, when Indonesian fires caused unhealthy air throughout the Southeast Asia region, TOMS was able to observe pollution spreading out from Kalimantan in southern Borneo (Indonesia). This image clearly demonstrates that air pollution is more than a local problem. Pollution from both biomass burning and industrial activity can travel great distances and affect regions far from the source.

TOMS was designed to monitor the health of the stratospheric ozone layer, which protects life on Earth from exposure to higher levels of ultraviolet radiation. The ability of TOMS to measure tropospheric ozone, a source of pollution, is an outgrowth of the increased precision of TOMS observations over time, coupled with increased knowledge of atmospheric composition and its variability.

For a more detailed account of this research, See A.M. Thompson, et al., "Tropical Tropospheric Ozone and Biomass Burning," *Science*, 16 March 2001, p. 2128.

Source: NASA

Figure 4. Plant Life on Earth as Observed From Space

False-color image of plant life on Earth as observed from space with the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). On land, greens indicate abundant vegetation, and tans show relatively sparse plant cover. In the oceans, blue areas are the least biologically productive, whereas green, yellow, and red areas represent progressively greater productivity. Since September 1997, SeaWiFS has measured light absorption by land plants and phytoplankton chlorophyll biomass in the oceans, providing a basis for quantifying biospheric photosynthesis.

Phytoplankton process carbon in the upper ocean, transforming it from dissolved form to particulate, and are therefore essential components of the ocean carbon cycle. Without phytoplankton living in the ocean's surface layer, atmospheric carbon dioxide levels would be many times higher than they are today.

SeaWifs image from the cover of Science, 30 March 2001. *Science OnLine* subscribers see: http://www.sciencemag.org/content/vol291/issue5513/cover.shtml.

Source: SeaWiFS Project, NASA Goddard Space Flight Center, and ORBIMAGE

Figure 5. Modeling Clouds

Predicted vs. observed time-height (surface to 16 km above the surface) cloud fraction at the Atmospheric Radiation Measurement Program (ARM) Southern Great Plains site from 19 June to 17 July 1997. Top panel: Shows the cloud fraction observed by cloud radar (3-hour averages). Center panel: cloud fraction predicted by UCLA-CSU cloud resolving model (1-hour averages). Bottom panel: cloud fraction predicted by National Centers for Environmental Prediction (NCEP) single column model (3-hour averages). Color indicates cloud fraction, which ranges from 0 (violet) to 1 (red).

ARM focuses on acquiring the data for understanding the role of clouds in climate and on seeing this understanding reflected in the improvement of the appropriate components of General Circulation Models (GCMs). The ARM data provide the testbed data sets for the process models representing the cloud-climate feedbacks in the currently available GCMs as well as in the future climate-change-prediction models of regional-scale resolution. Developing the capability to account for cloud water distribution determined from observations at ARM sites will lead to improved cloud parameterization in climate simulation models and will support efforts to predict precipitation.

Source: DOE Atmospheric Radiation Measurement Program

Figure 6. Trends in Annual Greenness 1989 – 2000

Changes in annual greenness during the period 1989-2000 as measured by the normalized difference vegetation index (NDVI) derived from the advanced very high resolution radiometer (AVHRR) satellite sensor. NDVI values for each year are integrated over the growing season to produce the seasonal integrated NDVI (annual greenness). The number of runs statistical test is then run for each pixel to identify those areas that show an increasing or decreasing trend that is stronger than would be expected by random chance.

Source: U.S. Geological Survey

Figure 7. Land Use and Land Cover Change in the Chicago Metropolitan Region between 1972 and 1997.

Land cover maps of the Chicago Metropolitan Region document changes in several categories of land cover and land use during a 25-year period using LANDSAT imagery from 1972, 1985, and 1997. This data set was developed as part of a NASA-funded project entitled "Tracking Natural Community Fragmentation and Changes in Land Use and Land Cover: A Case Study of *Chicago Wilderness* with Dr. Yeqiao Wang and Dr. Debra Moskovits serving as the Principal Investigators. Chicago Wilderness is an alliance of more than 90 organizations, including local, state, and Federal agencies, research and nongovernmental institutions, and landowners in the Greater Chicago area. It is also a regional nature reserve of 81,000 hectares extending in a crescent around Lake Michigan, from southeastern Wisconsin, through Illinois, into northwestern Indiana. Its goal is to maintain existing natural areas and restore others in a network of protected lands and waters connected by greenways and wildlife corridors.

This study reveals that dramatic increases in urban land dominate the land-cover changes in the past twenty-five years. Between 1972 and 1985, urban land increased by 14.5 percent. The rate of urban and suburban expansion accelerated to increase by nearly 30 percent between 1985 and 1997. Between 1972 and 1997, the total area of developed land increased by 49 percent. Most of the suburban land expansion came at the expense of agricultural lands, with a total decrease of 37 percent over the 25 years. In addition, more than one-fifth of natural area (21 percent), including forest, woodland, prairie, and wetland, was converted to urban use during that period. Urban sprawl results not only in wholesale loss of natural lands, but also in extreme fragmentation and isolation of the remaining natural areas within the suburban matrix. Another significant change in land cover is the increase in unassociated vegetation over time. Unassociated vegetation includes a mixture of shrubs, trees, and abandoned agricultural fields. This increase reflects the degradation of natural lands in the absence of appropriate management and ecological restoration.

Through a series of pilot projects demonstrating the utility of NASA imagery for conservation biology, NASA has supported efforts by Chicago Wilderness to use remote sensing, particularly with imagery from the LANDSAT spacecraft, to complete a current vegetation map of the area in the reserve and examine changes in land use and land cover. This figure depicts changes in land cover during that time period. The information is a vital tool for use by those developing a Biodiversity Recovery Plan for the region.

Source: NASA and Y.Q. Wang, University of Rhode Island. The data set was developed as part of a NASA-funded project, *Tracking Natural Community Fragmentation and Changes in Land Use and Land Cover; A Case Study of Chicago Wilderness*, with Dr. Wang serving as a Principal Investigator.

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Abstract

Our Changing Planet: The FY 2002 Global Change Research Program is a report to Congress supplementing the President's FY 2002 budget, pursuant to the Global Change Research Act of 1990. The report describes the U.S. Global Change Research Program (USGCRP); summarizes scientific insights from global change research, discusses the six Research Program Elements and FY 2002 plans in each of these research areas; and includes an appendix that details the FY 2002 budget, including program components and program highlights for each of the departments and agencies that comprise the USGCRP. Achieving the goals of this program will require continued strong support for the scientific research needed to improve understanding of how human activities are affecting the global environment, and of how natural and human-induced global change is affecting society and ecosystems.