

## Climate Change

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The Testimony of  
**The Honorable John McCain**  
United States Senator, (R-AZ)

Welcome. Today, we continue with our series of hearings on the very critical topic of global climate change—an issue, obviously, of world wide importance.

- The National Academy of Sciences (NAS) has reported that, “Greenhouse gases are accumulating in the Earth’s atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising. The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability.”

- The National Academy of Science recently completed its review of the Administration’s Strategic Plan for the U.S. Climate Change Science Program. The National Academy called for urgent action and an increase in funding to implement the plan.

- Unfortunately, the Congressional Research Service has indicated that the funding for climate change research in the fiscal year 2005 budget request is down 2 percent. Needless to say, this is not the direction that the National Academy was recommending.

- There is a strong scientific consensus about the fact that global climate change is occurring, and occurring as a result of human activity. Those few scientists, and those in industry to claim otherwise do so despite their lying eyes. The dramatic and devastating changes wrought by climate change can be seen all around us.

- To raise awareness of the impact of climate change in Arctic communities, Will Steger, an American explorer who gained international fame in the 1980s for making the first unsupported dogsled expedition to the North Pole, is currently leading a 4,800 kilometer trek across the Arctic region. His progress is being watched by more than a million American schoolchildren, who are serving as regular observers of the expedition via e-mails and digital photographs made possible by satellite connections. They are seeing in real time the environmental destruction caused by climate change.

- There has been and continues to be a series of major climate-related events around the world. We have seen increased melting of the polar ice caps, the shifting and destruction of many species, the destruction of coral reefs, unprecedented heat waves and other extreme weather events, and new “outbreaks” of health problems linked to climate change. The devastation will only get worse until we begin to address this very serious issue.

- The witnesses here today will discuss some of the consequences of climate change, and I look forward to their testimony.
- Dr. Antonio Busalacchi of the National Academy of Science stated in one of our previous hearings on climate change, "...we have a problem, this planet has a fever, and it is time to be taking action." Indeed, it is time to take action.
- Let me also thank those members of the Committee who supported S. 139, the Climate Stewardship Act of 2003, last year as the Senate conducted its first vote on legislation that would reduce the emission of greenhouse gases. To those who did not support it, I hope to give you another opportunity to do so later this spring. I hope that today's hearing will help convince you to do so.

The Testimony of  
**Honorable Joseph Lieberman**  
United States Senator, (D-CT)

Thank you, Mr. Chairman, and members of the committee, for inviting me to testify.

Mr. Chairman, I feel that we are within reach of finally taking action to combat this global warming. The bill that I have sponsored with you would provide a moderate first step in reducing our nation's greenhouse gas emissions, with little or no adverse economic impact. It would achieve this goal by capping emissions at 2000 levels by 2010 and creating a market for trading pollution credits. Last fall, we garnered the support of 44 Senators. Before this Spring turns to Summer, I pledge to work with you to bring our bill to the floor again for a vote, and I know we can do even better this time.

As we have pushed our legislation, I believe that the debate has changed with us. Since we embarked on this venture together, Mr. Chairman, old notions of fear and denial have given way to a new sense of confidence that we are up to the challenge of balancing environmental protections and economic health. And that gives me hope for the Spring.

The witnesses at this hearing will provide the Committee with the latest scientific research on the impacts of global warming. This is a debate that should be over. In my view, there really is no longer any question that human-caused global warming is a very real scientific problem. Last October 1, you heard it yourself, Mr. Chairman, from the Chair of the National Research Council's Committee on Climate Research, who testified bluntly, "The evidence is there. The time is now to take action."

He is right. You will hear dire warnings today, of scenarios in which global warming changes the world around us irreparably. I want to say clearly: It does not have to be that way.

To me, our problem of global warming is much like another of the serious problems facing us today – our national debt. We can ignore it for a while, but the more we continue emitting greenhouse gases unabated, the more we are buying ourselves a bigger

debt to pay off down the road. Just like a dollar borrowed today will eventually have to be paid back, a ton of greenhouse gases emitted today will have to be offset by emissions reductions in the future. By avoiding modest emissions reductions today, opponents of our bill would not evade the cost of greenhouse gas reductions – they would only ensure that they would have to pay even more in the future.

Our inaction also will cost us in terms of the competitiveness of U.S. businesses abroad. The rest of the world is already capping their emissions, and providing the incentive for the development of the next generation of energy technologies. The European Union and other governments will place limits on greenhouse gases as early as next year. U.S. companies are supposed to be competing in those markets, yet we are giving no direction and no incentives here at home.

The solution we offer here is incentives now for private sector innovation that will enable us to cut emissions more substantially in the future. And the way to unleash such private sector involvement is to make reductions greenhouse gas emissions worth something to businesspeople – which that is exactly what our legislation would do. I am very encouraged by the increasingly broad support that we have garnered for these policies in recent days.

Our coalition has broadened to include the religious organizations that help form the moral compass of this nation. It is a central premise of all major religions that we must be good stewards of God's creation, and maintain the Earth's splendor for the generations that will follow us. Leaders of these religious faiths do not believe we are upholding these responsibilities when it comes to global warming.

We also now hear the voices of Wall Street investors, demanding action. Last November, fund managers who manage more than one trillion dollars in capital, convened at the United Nations to raise concerns about the risks which climate change poses to long-term investments. The meeting resulted in a call for mandatory climate action.

We also are hearing from an ever-broadening set of industry voices. For years, utilities have called for a specific regulatory requirement for greenhouse gases so they can plan for future investment decisions, but now leaders from other business sectors are speaking out because they have concluded that they have a lot to lose if the globe warms. For example, over 40 ski areas just announced their endorsement of our legislation through their campaign to "Keep Winter Cool." During last October's debate, we also received letters from investors representing more than \$20 billion in capital, requesting that we provide the economic stimulus that our legislation would give to the growing market in new advanced energy technologies. Finally, there has been increasing concern about global warming among the nation's national security experts. Last week, the Pentagon produced a report describing the risk of global destabilization that would result from abrupt climate change. For example, what would the effect of an extended drought be on the precarious political situation in nuclear-armed Pakistan? It is a question I hope we will never need to answer, but it is a real question.

In sum, Mr. Chairman, a growing chorus of voices is demanding that we act to address global warming. With such a groundswell, the day of action is coming. Together, we can take another big step toward that action this Spring.

The Testimony of

**Dr. Robert Corell**

Chairman, Arctic Climate Impact Assessment, and Senior Fellow, American Meteorological Society

Mr. Chairman, Members of the Committee, thank you for the opportunity to participate in today's Full Committee hearing on Climate Change Impacts. I am honored to testify before you today on behalf of an international team of 300 scientists, other experts, and elders and other insightful indigenous residents of the Arctic region who are preparing a comprehensive analysis of the impacts and consequences of climate variability and changes across the Arctic region, including the impacts induced by increases in UV radiation arising from depletion of stratospheric ozone in the region. I am Dr. Robert W. Corell, Chair of the Arctic Climate Impact Assessment (ACIA), which was established and charged to conduct the assessment by the Arctic Council<sup>1</sup> and the International Arctic Sciences Committee<sup>2</sup>. The Arctic Council is composed of senior officials from the eight Arctic countries (U.S. is represented by senior officials of the Department of State) and the leadership from six international indigenous peoples organizations of the Arctic region. The International Arctic Sciences Committee (IASC) was founded to encourage and facilitate cooperation in all aspects of Arctic research; the US is represented by an appointment made by the National Academy of Science. <sup>1</sup> The Arctic Council was established on September 19th, 1996 in Ottawa, Canada. A high level intergovernmental forum, the Council provides a mechanism to address the common concerns and challenges faced by the Arctic governments and the people of the Arctic. The members of the Council are Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden, and the United States of America. The Association of Indigenous Minorities of the North, Siberia and the Far East of the Russian Federation, the Inuit Circumpolar Conference, the Saami Council, the Aleutian International Association, Arctic Athabaskan Council and Gwich'in Council International are Permanent Participants in the Council. There is provision for non-arctic states, inter-governmental and inter-parliamentary organizations and non-governmental organizations to become involved as Official Observers. The Arctic Council is a high-level intergovernmental forum that provides a mechanism to address the common concerns and challenges faced by the Arctic governments and the people of the Arctic as a means of improving the economic, social and cultural well being of the north. <sup>2</sup> The International Arctic Sciences Committee was founded 28 August 1990 by national science organizations in all the arctic countries. It provides the major venue for national science organizations, mostly academies of science, to facilitate and foster cooperation in all fields of arctic research. It currently brings together scientists from Canada, China, Denmark, Finland, France, Germany, Iceland, Italy, Japan, The Netherlands, Norway, Poland, Republic of Korea, Russia, Sweden, Switzerland, United Kingdom, and the United States of America. <sup>2</sup> Assessing the Impacts induced by Climate Change across the Arctic Region: The Arctic Climate Impact Assessment (ACIA) is a four-year comprehensive scientific assessment

that was established and charged at the Ministerial meeting of the Arctic Council in Barrow, Alaska in the fall of 2000. The ministers called for the ACIA to (i) evaluate and synthesize knowledge on the impacts and consequences of climate variability and change and increased ultraviolet radiation across the Arctic region, and (ii) support decision and policy making processes for the eight Arctic countries and their residents. ACIA is charged with assessing environmental, human health, social, cultural and economic impacts and consequences, including recommendations, by assessing how climate and UV radiation have been changing in the Arctic, how they are projected to change in the future, and the likely impacts of those changes. Most importantly, the assessment is charged with the responsibility of providing useful information to the governments, organizations, and peoples of the Arctic and the world to help them respond to the challenges and opportunities presented by climate change. Arctic Council sponsors ACIA through its Arctic Monitoring and Assessment Program (AMAP) and its Conservation of Arctic Flora and Fauna (CAFF) program and jointly sponsors the assessment with the International Arctic Sciences Committee (IASC). The ACIA teams of authors, including substantial expert contributions by indigenous and other residents of the Arctic, will submit their final reports, including their scientific and technical findings to the Arctic Council and the International Arctic Sciences Committee during the Ministerial meeting of the Arctic Council in Reykjavik, Iceland in November of this year. The Scientific Report, which is expected to total over 1800 pages is organized into 17 chapters of the Assessment and has already been revised after being subjected to a comprehensive external review by an independent group of over 225 international scientists and other experts from over a dozen countries. The Overview Report (about 100 pages) is in its final phases for preparation. It is designed for a broad non-scientific readership. It, too, will be externally reviewed. Because the Assessment is still in its final phases, my testimony will be in the form of a progress report that provides a preliminary “snapshot” of the knowledge and insights gleaned from the analysis, synthesis and documentation concerning the impacts and consequences of climate variability and change across the Arctic region. Preliminary Findings Regarding the Key Impacts of Climate Change across the Arctic Region: The IPCC’s Third Assessment Report summarized the evidence that the Earth’s, and more particularly the Arctic’s, climate is changing more rapidly and persistently than at any time since the beginning of civilization. While some climate changes reflect natural variability, careful investigations of the strength and patterns of change indicate human influences are responsible for most of the changes since the mid-20th century. As projected both by this Assessment and the IPCC3, these climatic changes are the largest and are being experienced most intensely in the Arctic region. For example, over the past 50 years, the average temperatures across the Arctic have risen by nearly twice as much as the global average with some parts of the Arctic region experiencing much greater increases. That unusual changes are underway is indicated by increases in surface and oceanic temperatures, an overall increase in precipitation that is more evident in some sub-regions of the Arctic than in others, large reductions in sea ice and glacier volume, increases in river runoff and sea level, the thawing of permafrost, and shifts in the 3 The IPCC Summary for Policymakers from the Third Assessment Report (2001) states, “Climate change in polar regions is expected to be among the largest and most rapid of any regions on the Earth, and will cause major physical, ecological, sociological, and economic impacts, especially in the Arctic, Antarctic Peninsula, and

Southern Ocean”. 3 engage experts from indigenous and other resident communities across the Arctic region, drawing upon their insights as a companion to the scientific and technical findings. As an example of what is being experienced by those in the region, let me quote from an indigenous person’s experiences. This 2002 observation by Larisa Avdeyeva, an elder from Lovozero, Russia, summarizes many of the insights emerging from both the scientific analyses and the insights of indigenous peoples across the Arctic. With this perspective as a backdrop, I would like to outline some of the findings that are likely to highlight the Assessment when it is released this fall: 1. Arctic Climate is Warming Rapidly and Much Larger Changes are Projected: Records of increasing temperatures, melting glaciers, reductions in extent and thickness of sea ice, thawing permafrost, and rising sea level all provide strong evidence of recent “Nowadays snows melt earlier in the springtime. Lakes, rivers, and bogs freeze much later in the autumn. Reindeer herding becomes more difficult as the ice is weak and may give way... All sorts of unusual events have taken place. Nowadays the winters are much warmer than they used to be. Occasionally during winter time it rains. We never expected this; we could not be ready for this. It is very strange... The cycle of the yearly calendar has been disturbed greatly and this affects the reindeer herding negatively for sure...” ranges of plant and animal species. Overall, the Assessment details significant disruptive impacts while identifying a number of potential opportunities for indigenous and other residents, communities, economic sectors, and governments of the region. Because we are still in the final stages of completing the scientific and technical aspects of the assessment, I am only able to outline some of the most important findings that I believe are likely to be among those that will be included in the Assessment when we complete the process this fall. The ACIA’s reports have been prepared by teams of scientists and other experts who have conducted their work in the tradition of an independent process of research, analysis, and assessment based on published data and information. In addition, this assessment has undertaken substantial efforts to 4 warming in the Arctic (e.g., the plot below indicates the overall increase in Northern Hemisphere temperatures over the past 1000 years). There are regional variations due to circulation patterns in the atmosphere and oceans, with some areas experiencing more warming than others and a few areas even show a slight cooling; but for the Arctic as a whole, there is a clear warming trend. There are also patterns within this overall trend; for example, in most places, temperatures in winter are rising more rapidly than in summer. In Alaska and western Canada, the average winter temperatures have increased by as much as 3 to 4°C over the past 60 years, which is a significant increase given that the global average increase over the past 100 years has been only about  $0.6 \pm 0.2^\circ\text{C}$ . With respect to future changes, all of the models, regardless of the emissions scenario or computer model selected, project very significant warming for the Arctic over the next 100 years. Although these models do not agree on the regional and temporal details of the projected warming, there is little doubt that the world will warm significantly during the decades ahead and that the Arctic region will experience more warming than the rest of the world. On average, the models project that the Arctic is very likely to warm by more than twice the global average over the 21st century. One of the changes that is of particular importance is the rate at which Arctic sea ice is melting and the projection by models that there is likely to be an even more rapid reduction in the extent and seasonal duration of sea ice in the future. Not only will the melting back of the sea ice lead to seasonal opening of potentially important marine

transportation routes, but the reduced sea ice extent and duration will lead to significant changes in the surface reflectivity, cloudiness, humidity, exchanges of heat and moisture, and ocean circulation, particularly along coastlines and near ice margins. Over the past 30 years, Arctic sea ice extent has decreased, on average, by about 10%, and this change has been 20% faster over the past two decades than over the past three decades. The average of the five ACIA model simulations project that there will be substantial reductions in summertime sea ice around the entire Arctic Basin, with one model projecting an ice free Arctic in the summer by the middle of this century (see graphic below). On average, the climate models project an acceleration of in sea ice retreat, with periods of extensive melting spreading progressively further into spring and fall. As a result of the sea ice melt back, there will be a longer navigation season in the Northern Sea Route that extends on the Asia side of the Arctic from the Atlantic to the Bering Straits. For purposes of our study, the navigation season is defined as the number of days per year in which there are easily navigable conditions, often defined as less than 50% sea ice concentration. The average of the five ACIA models projects that the current navigation season of 20-30 days per year will increase to 90-100 days by 2080, with one model indicating it is likely to open to this degree by mid-century. Passage is presently feasible for ice-breaking capable ships in seas with about 75% sea ice concentration, suggesting a navigation season for ice-breaking vessels of around 150 days a year by 2080. Opening new shipping routes and extending the navigation season could have very important economic implications because there will very likely be increased access to the region's oceanic and near coastal resources. However, potentially important issues regarding sovereignty, safety, and environmental preservation will also arise as more nations enter the region. While easing access to oceanic and coastal resources, the longer melt season on land may also make access to inland resources more difficult.

## 2. Warming Across the Arctic and its Consequences are likely to have Major Implications for the Entire World:

The likelihood of continued melting of glaciers including the Greenland Ice Sheet have significant implications for the entire planet as the total land-based ice in the Arctic has been estimated to be about 3,100,000 cubic kilometers which, if melted, would correspond to a sea-level equivalent of about 8 meters. The Greenland Ice Sheet dominates land ice in the Arctic. Over the past two decades, the melt area on the Greenland ice sheet has increased on average by about 0.7%/year (or about 16% from 1979 to 2002), with considerable variation from year to year (See graphic on the next page). The total area of surface melt on the Greenland Ice Sheet broke all past records in 2002. IPCC estimated that a sustained increase in Arctic temperatures of 3°C would lead to the melting of the Greenland Ice Sheet over a period of 1000 years – the ACIA models suggest that regional warming will be much higher than this by the end of the 21st century, putting us past the threshold for the long-term disintegration of that ice sheet. Recent studies of glaciers in Alaska already indicate an accelerated rate of melting. This rapid retreat of Alaskan glaciers represents about half of the estimated loss of mass by glaciers worldwide; the largest contribution by glacial melt to rising sea level identified for any region. The Arctic exerts a special influence over global climate. There are three major mechanisms by which Arctic processes can influence climate change on global scales. The first of these involves the snow and ice that reflect most of the incoming solar energy upward from the surface back into space. The melting back of snow and ice reveals the land and water surfaces beneath, which are much darker. These

darker surfaces tend to absorb rather than reflect back the Sun's energy. This warms the surface further, causing faster melting, which in turn causes more warming, and so on, creating a self-reinforcing cycle, amplifying and accelerating warming trends. A second mechanism by which Arctic processes can induce changes in global climate is through alterations in ocean circulation patterns. One of the ways the energy from the Sun absorbed by the oceans is transported from the equator toward the poles is through the globally interconnected circulation of ocean waters. As these oceanic waters move northward, the uniquely very cold, dense, and highly saline (salty) waters in the North Atlantic sink. This sinking drives an overturning process called the thermohaline circulation, the process that drives the global oceanic circulation (depicted in the graphic on the next page). However, as more fresh and less dense waters enter the North Atlantic as a result of the melting of sea ice and glaciers, and increased river outflows into the Arctic oceanic basin, this freshwater then mixes with the saltier water producing a less density sea water that weakens the sinking process and has the potential to weaken or even shut down thermohaline circulation. There is increasing scientific evidence derived from ocean sediments, ice cores, and oceanic current measurements that indicated that this weakening process has already begun and virtually all the climate models indicate a continuation of the weakening during this century. It is not likely that there will be complete shutdown in this century, but as IPCC and studies from this Assessment indicate, this is a process which must be more fully understood as the consequences affect both the timing and magnitude of the warming trends, including the potential for local cooling in Europe even in a globally warming planet. A third way that Arctic warming could potentially amplify global change in the climate is by stimulating the release of greenhouse gases trapped in Arctic soils and coastal ocean sediments. For example, methane and CO<sub>2</sub> are currently trapped in permafrost (frozen soil) that underlies much of the Arctic region. Permafrost is already thawing in many areas and thawing is expected to accelerate as warming intensifies. Such thawing has the potential for accelerating the release to the atmosphere of methane and CO<sub>2</sub>. In addition, the soils and vegetation of the boreal forests now serve as a major global storehouse for carbon. Boreal (northern) forests contain 40% of the world's reactive soil carbon, an amount similar to all the carbon that is stored in the atmosphere. Available studies do not yet indicate whether the net effect of the projected changes will be to take up or release more carbon overall as climate change proceeds, but recent studies suggest that over the Arctic as a whole, more productive vegetation will probably increase carbon storage in ecosystems over this century. There are other mechanisms that could lead to the release of methane, including the vast amounts of methane currently trapped at shallow depths in Arctic oceanic sediments (stored in a solid icy form called methane hydrates). If the temperature of the water at the seabed rises a few degrees, these hydrates could ultimately be released as methane and enter the atmosphere. Because each molecule of methane is about 30 times as potent (60 times as potent over a 100 year timeframe) at trapping heat in Earth's atmosphere as a molecule of CO<sub>2</sub>, it is essential that we advance our understanding of this long-term potential effect on global climatic processes.

3. Impacts from the Projected Shifts in Arctic Vegetation and Changes in the Biosphere: Climate-induced changes in Arctic landscapes are important to people and animals in terms of habitat, food, fuel, and

culture. The major Arctic vegetation zones include the polar deserts, tundra, and northern part of the boreal forest. Climate warming is projected to cause vegetation shifts because rising temperatures favor taller, denser vegetation, and will thus promote the expansion of forests into the Arctic tundra, and tundra into the polar deserts. This change, along with rising sea levels, is projected to shrink tundra area to its lowest extent in at least the past 21,000 years, potentially reducing the breeding area for many migratory bird species and the grazing areas for land animals that depend on the open landscape of tundra and polar desert habitats. Half the current tundra area is projected to disappear in this century.

Arctic agriculture is a relatively small industry in global terms. Agriculture in the north consists mostly of cool season forage crops, cool-season vegetables, small grains, and the raising of cattle, sheep, goats, pigs, and poultry, and reindeer. While agriculture in the Arctic is presently limited by climatic factors, especially in the cooler parts, it is also limited by the lack of infrastructure, the small population base, the remoteness from markets, and land ownership issues. Warming is projected to advance the potential for commercial crop production northward throughout this century, with some crops now suitable only for the warmer parts of the boreal region becoming suitable as far north as the Arctic Circle. Average annual yield potential will likely increase because of an increase in the suitability for higher yielding varieties and lowering the probabilities of low temperatures limiting growth. Longer and warmer growing seasons are thus very likely to increase the potential number of harvests and hence seasonal yields for perennial forage crops.

#### 4. Animal Species' Diversity, Ranges, and Distribution are Likely to Change:

Arctic marine fisheries provide an important food source globally, and are a vital part of the economy of virtually every Arctic country. Because they are largely controlled by factors such as local weather conditions, ecosystem dynamics, and management decisions, projecting the impacts of climate change on marine fish stocks has been and will likely continue to be difficult. Based on available information, however, projected warming is likely to improve conditions for some important fish stocks such as cod and herring, because higher temperatures and reduced ice cover could possibly increase productivity of their prey and provide more extensive habitat. Although projected conditions are likely to benefit some species, they are likely to negatively affect others. For example, the extent of northern shrimp will probably contract, decreasing its abundance and reducing the large catch (about 100,000 tons a year) currently taken from Greenlandic waters. The total effect of climate change impacts, however, will likely be less important than decisions regarding fisheries management. While it is unlikely that climate change effects on fisheries will have longterm Arctic-wide social and economic impacts, certain areas of the region that are heavily dependent on fisheries may be dramatically affected, particularly indigenous communities and other residents of the region. Climate also has a profound influence on marine mammals. Years with little or no ice in the Gulf of St. Lawrence (1967, 1981, 2000, 2001, 2002) resulted in years with almost zero production of seal pups, whereas in other years, these numbered in the hundreds of thousands. Polar bears are dependent on the presence of sea ice where they hunt ringed seals and other ice-associated seals, and use ice corridors to move from one area to another. Their seal hunting success, which depends on good spring ice conditions, is essential for their survival. Changes in ice extent and stability are thus of critical importance and similarly for many other species. The earliest impacts of warming are likely to occur near James and Hudson Bays, which are at the southern limits of the polar

bears' range, and, such impacts have already been documented. As the loss of sea ice continues, the increasing loss of habitat for polar bear is likely to have significant and rapid consequences for their populations and for the indigenous people whose culture is tied to the polar bears and who depend on the polar bear for food, clothing, and other needs. Indigenous people are already reporting that the thinning and depletion of sea-ice in the Arctic will "push to extinction" key marine mammals, including polar bear, walrus, and some species of seal that are hunted by Inuit in Alaska, northern Canada, Greenland, and Chukotka in the Federation of Russia. As such, climate change in the Arctic is a human and cultural, as well as an environmental issue, which they report will in the long-term threaten the very existence of Inuit as a hunting culture. Caribou (North American forms of *Rangifer tarandus*) and reindeer (Eurasian forms of the same species) are of primary importance to inland peoples throughout the Arctic for food, clothing, shelter, fuel, tools, and other cultural items. Caribou and reindeer herds depend on the availability of abundant tundra vegetation and good foraging conditions, especially during the calving season. Climate-induced changes to arctic tundra are projected to cause vegetation zones to shift significantly northward, reducing the area of tundra and the traditional pastures for these herds. Freeze-thaw cycles and freezing rain are also projected to increase. Further, data suggest that migrations of other animal species (moose, red deer, etc into Fennoscandia) into the traditional pasturelands of reindeer herders will have significant implications for the ability of the reindeer populations to forage for food and raise healthy calves. Much of the redistribution of species is climate induced, though it is important to note that the development of roadways, pipelines, and other civilian infrastructure also impact the abilities of herders to maintain their tradition ways of herding and, hence the culture that is endemic to these peoples. Future climate change could thus mean a potential decline in caribou and reindeer populations, threatening human nutrition and the cultural base of indigenous households and a way of life for those Arctic communities that have existed for as long as 9,000 years.

5. Thawing Ground Will Disrupt Transportation, Buildings, and other Infrastructure: Much important transportation on land in the Arctic is over frozen tundra and across ice roads and bridges. Rising temperatures are already creating increasing challenges on these routes and the problems are projected to increase as temperatures continue to rise. In addition, the incidence of mud and rockslides and avalanches are sensitive to the kinds of changes in weather that are anticipated to accompany warming. The number of days per year in which travel on the tundra is approved by the Alaska Department of Natural Resources has dropped from over 200 to about 100 in the past 30 years, causing a 50% reduction in days that oil and gas exploration and extraction equipment can be used. Forestry is another industry that requires frozen ground and rivers. Higher temperatures mean a longer period during which the ground is thawed and thinner ice on rivers. This leads to a shortened period 10 during which timber can be moved from forests to sawmills and increasing problems associated with transporting wood. Permafrost, the foundation for these transportation pathways, is soil, rock, or sediment that has remained below 0°C for two or more years. Permafrost presently underlies most of the land surfaces in the Arctic region. "Continuous" permafrost thickness varies from a few meters to hundreds of meters. Permafrost temperatures over most of the sub-Arctic land areas have increased by from several tenths of a degree C up to 2°C during the past few decades, and the depth of the layer that thaws each year is increasing in many areas (see graphic below). Over the

coming hundred years, these changes are projected to continue and their rate to increase, with permafrost degradation projected to occur over 10-20% of the present permafrost area, and the southern limit of permafrost is projected to shift northward by several hundred kilometers. 11 6. Indigenous Peoples and other Residents of the Arctic are likely to Face Major Impacts Due To Climate and other Environmental Changes: The Arctic is home to thousands of indigenous communities whose cultures and activities are shaped by the Arctic environment. They have interacted with their environment for many generations through careful observations and skillful adjustments in subsistence activities and lifestyles. Through ways of life closely linked to their surroundings, these peoples have developed uniquely insightful ways of observing, interpreting, and responding to the impacts of environmental changes. Indigenous observations and perspectives are therefore of special value in understanding the processes and impacts of Arctic climate change. There is a rich body of knowledge based on their careful observations of and interactions with the world. Holders of this knowledge will be able to use it to make decisions and set priorities. The ACIA has attempted to incorporate knowledge and insights from indigenous peoples with data from scientific research, bringing together these complementary perspectives on Arctic climate change. Across the Arctic, indigenous peoples are already reporting the effects of climate change. In Canada's Nunavut Territory, Inuit hunters have noticed the thinning of sea ice, a reduction in ringed seals in some areas, and the appearance of insects and birds not usually found in their region. Inupiat hunters in Alaska report that ice cellars are too warm to keep food frozen. Inuvialuit in the western Canadian Arctic are observing an increase in thunderstorms and lightning, previously a very rare occurrence in the region. Athabaskan people in Alaska and Canada have witnessed dramatic changes in weather, vegetation, and animal distribution patterns over the last half-century. Sámi reindeer herders in Norway observe that prevailing winds relied on for navigation have shifted and that snow can no longer be relied on to travel over on trails that people have always used and considered safe. Indigenous peoples who are accustomed to the wide range of natural climate variations are now noticing changes that are unique in the long experience of their peoples. Climate change will affect human health in the Arctic. The impacts will differ from place to place due to regional differences in climate change as well as variations in health status and adaptive capacity of different populations. Rural Arctic residents in small, isolated communities with a fragile system of support, little infrastructure, and marginal or nonexistent public health systems appear to be most vulnerable. People who depend on subsistence hunting and fishing, especially those who rely on just a few species, will be vulnerable to changes that heavily impact those species (for example, reduced sea ice impacts on ringed seals and polar bears). Age, lifestyle, gender, access to resources, and other factors affect individual and collective adaptive capacity. 7. Climate in the Context of other Changes across the Arctic Region: Climate change is occurring in the context of many other changes taking place in the Arctic. Environmental changes include chemical pollution, increased ultraviolet radiation, habitat destruction, and over-fishing. Social and economic changes include technological innovations, trade liberalization, urbanization, self-determination movements, and increasing tourism. All of these changes are interrelated and the consequences of these phenomena will depend largely on their interactions. Some of these changes will exacerbate impacts due to climate change while others alleviate impacts. Some changes

will improve peoples' ability to adapt to climate change while others hinder adaptive capacity. The degree to which people are resilient or vulnerable to climate change depends on the cumulative stresses to which they are subjected as well as their capacity to adapt to these changes. Adaptive capacity is greatly affected by political, legal, economic, social, and other factors. Responses to environmental changes are multi-dimensional. They include adjustments in hunting, herding, and fishing practices as well as alterations in the political, cultural, and spiritual aspects of life. Adaptation can involve changes in knowledge and how it is used, for example, using new weather prediction techniques. Arctic people have historically altered their hunting and herding grounds and the species they pursue in response to changing conditions; however, they are increasingly indicating that the rapid rate of climate changes is limiting their capacities to adapt.

**Concluding Thoughts** The ACIA represents the first effort to comprehensively examine climate change and its impacts in the Arctic region. As such, it represents the initiation of a process, rather than simply a set of reports. The ACIA brought together hundreds of scientists from around the world whose research focuses on the Arctic. It has also incorporated the insights of indigenous peoples who have a long history of gathering knowledge in this region. Linking these different perspectives is an exciting process for both the science community and the indigenous and other residents of the Arctic and it clearly has great potential to continue to improve our knowledge of climate change and its impacts. A great deal has been learned from this process and these interactions, though much remains to be studied and better understood. This Assessment is illustrating that climate change presents major and growing concerns to the Arctic region and the entire world. While these concerns are important now, they are even more important for the future generations that will inherit the legacy of our current stewardship. Climate change thus deserves and requires urgent attention by policymakers and the public worldwide. The assessment process should continue, and expand to more comprehensively include all issues of importance to Arctic residents as well as to the wider world.

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- ACIA International Scientific Symposium: The ACIA in cooperation with the Environment and Food Agency of Iceland, the Icelandic Institute of Natural History, and the Icelandic Meteorological Office will host a scientific symposium November 9-12, 2004 in Reykjavik, Iceland. This Symposium will address a variety of issues connected to climate change in the circumpolar Arctic and its environmental and society consequences. In addition to an overview of the Assessment by the many of the authors of the Assessment, other potential authors of papers are invited to submit abstracts that extend the insights of the Assessment. Such submission should be sent by April 1, 2004 to the Program Committee Chair at Pål Prestrud ([pal.prestrud@cicero.uio.no](mailto:pal.prestrud@cicero.uio.no)). Updates on the Symposium will be posted on [www.acia.uaf.edu](http://www.acia.uaf.edu), [www.amap.no](http://www.amap.no), [www.iasc.no](http://www.iasc.no), and [www.caff.is](http://www.caff.is).

The Testimony of  
**Dr. Marvin Geller**

Professor, Institute for Terrestrial and Planetary Atmospheres, State University of New York, Stony Brook, Marine Science Research Center

Good morning. Thank you very much for this opportunity to testify. I am Dr. Marvin Geller, Professor at the Institute for Terrestrial and Planetary Atmospheres, Stony Brook University. I am also a past-President of the American Geophysical Union's Atmospheric Sciences Section, and I was the chair of the AGU panel that drafted the AGU position statement, "Human Impacts on Climate," which the AGU Council adopted unanimously on December 12, 2003. AGU President Robert Dickinson, several members of the panel, and I released the statement at the National Press Club on December 16.

This morning, I plan to talk about why AGU believes it important to make this statement. As part of my full written testimony, I submit the rationale for the statement, the process leading up to the statement, and the text of the statement itself.

Before proceeding though, I should say a few words about AGU. AGU is the largest scientific society in the world for researchers in the Earth and space sciences. Its membership currently exceeds 41,000. It publishes 13 peer-reviewed scientific journals, and it is estimated that more than one-quarter of the papers in them deal in one way or another with issues related to the Earth's climate. I believe that the AGU statement is a conservative one, in that it only addresses issues where the weight of scientific evidence is extremely strong. This is appropriate when representing the views of a scientific society whose membership is so large and diverse.

Governments face a number of issues for which science is an important factor in decision-making. Usually, there are a number of other factors that also must be considered. The AGU considers it important that the scientific understanding on such topics be accurately portrayed, so on areas in which the AGU membership is particularly well qualified, it issues position statements to convey its best assessment of the science on that topic. AGU considers the subject of humans' impacts on climate to be one such case. I will now quickly go through some of the major points in this AGU statement.

- Human activities (greenhouse gas emissions, ozone depletion, changes in land use, etc.) have reached the point where they significantly add to the physical processes that have produced a changing climate over the Earth's history. State-of-the-art climate models cannot reproduce the rapid warming of global temperatures that have been observed from about 1970 onward at, and near, the Earth's surface without including the influence of human activities (see Figure 1, which is Figure 4-2 from the Strategic Plan for the U.S. Climate Change Science Program).

- A particular concern is that atmospheric carbon dioxide (CO<sub>2</sub>) levels have increased from 280 ppmv (parts per million by volume) in 1900 to 373 ppmv in 2002. It took 21,000 years for atmospheric CO<sub>2</sub> to increase by approximately the same amount, from 200 ppmv during the last Glacial Maximum to 280 ppmv in 1900 (see Figure 2, which is Figure 2-2 from the Strategic Plan for the U.S. Climate Change Science Program).

· This rapid increase in atmospheric CO<sub>2</sub> concentrations is predominantly attributed to fossil fuel burning (see Figure 3, which is Figure 7-3 from the Strategic Plan for the U.S. Climate Change Science Program). This increased CO<sub>2</sub> in the atmosphere will persist for a very long time (100s to 1,000s of years).

· The physics of the radiation forcing from increasing concentrations of greenhouse gases is very straightforward. The climate system feedbacks (those processes that either amplify or counteract the response to a climate forcing) are what make for the complexities of predicting the exact nature of the climate response. It is very unlikely that these feedbacks will cancel all of, or reverse the sense of, the forcing toward a warmer climate by the increasing atmospheric concentrations of greenhouse gases.

· Some predictions of changes in the climate system are quite certain. These include warmer mid-continent climates than over the oceans; greater warming at high latitudes; melting of some polar and glacial ice, which will lead to higher sea levels; and changes and intensification of the hydrologic cycle, which will lead to changes in water supply as well as flood and drought patterns. There will be considerable regional variations in the resulting impacts.

· The concept of a “dangerous level of greenhouse gas concentrations.” has been inferred by some from the wording of the 1992 United Nations Framework on Climate Change. Scientifically speaking, there is no single “dangerous level of greenhouse gas concentrations” below which the climate system is “safe” and above which the system is in danger. Rather, there is a continuum of effects that will occur as global warming becomes greater. Some scientists say that dangerous effects are already occurring at present levels of enhanced greenhouse gas concentrations. Others disagree.

· Science provides society with information useful in dealing with natural hazards such as earthquakes, hurricanes, and drought. Science improves our ability to predict and prepare for their adverse effects. While human-induced climate change is unique in its global scale and long lifetime, AGU believes that science should play the same role in dealing with climate change. AGU is committed to improving the communication of scientific information to governments and private organizations so that their decisions on climate issues will be based on the best science.

Thank you very much for the opportunity to talk about the AGU statement, “Human Impacts on Climate.” I hope that you will take it as an objective assessment of the science. I fully expect that the AGU will continue to update its statement on this important subject as the science evolves.

Figure 1 (Figure 4-2 from the Strategic Plan for the U.S. Climate Change Science Program)

Figure 2 (Figure 2-2 from the Strategic Plan for the U.S. Climate Change Science Program)

Figure 3 (Figure 7-3 from the Strategic Plan for the U.S. Climate Change Science Program)

### The AGU Position Statement, “Human Impacts on Climate” – Rationale and Process

In December 2002 AGU Council voted to extend the lifetime of AGU’s position statement, “Climate Change and Greenhouse Gases” for one year until a new statement was prepared. A year later Council voted unanimously to adopt a new statement, “Human Impacts on Climate”, that reflected advances in the relevant science since 1998 when the original statement was adopted (see Eos, 23 December 2003). The purposes of this article are to give the rationale for this revision and to explain the process for formulating and approving this new statement. Background material for this new AGU statement can be found in several sources. These include Ledley et al. (1999), IPCC (2001), NRC (2001), and CSSP (2003). The statement itself is available at [http://www.agu.org/sci\\_soc/policy/climate\\_change\\_position.html](http://www.agu.org/sci_soc/policy/climate_change_position.html).

The AGU Global Environmental Change Focus Group requested that AGU consider updating its climate change statement under the rationale that the relevant science was advancing rapidly. The Focus Group asked that AGU consider broadening the statement beyond its focus on greenhouse gases, and posed several other questions. In accord with AGU policy and procedures, AGU President Robert Dickinson appointed a panel from the AGU membership to draft a new statement.

In appointing this panel (see Box 1), President Dickinson consulted with many AGU Council members and panel chair Geller to achieve representation that spanned the relevant AGU disciplines, and included some members who were involved in developing the previous AGU statement, who were active researchers on climate change, and who had the diversity of views that was representative of the AGU membership.

The policy on AGU’s role in advocacy of public issues guides a decision to write a position statement (see Box 2). Once that decision is made, a set of procedures lays out a course for producing the statement for Council consideration and a vote. AGU members are notified about the process and their comments are solicited via Eos (see [http://www.agu.org/sci\\_soc/policy/policy\\_advocacy.html](http://www.agu.org/sci_soc/policy/policy_advocacy.html)).

About forty inputs were received in response to the Eos announcement that a panel was appointed to revise the AGU statement, “Climate Change and Greenhouse Gases” (see Eos, 22 July 2003). These comments spanned the views on this issue; some believing that the AGU position on human actions affecting the earth’s climate should be strengthened and others stating they believed that no human effects on climate have been satisfactorily demonstrated.

The following quotes are indicative of the diversity of the views that were expressed in these comments from AGU members.

“... it seems that the case for anthropogenic warming has weakened considerably: ... Satellite data and independent balloon data still show no appreciable atmospheric warming.”

“Several recent studies appearing in peer-reviewed literature now suggest that the recent warming of the earth’s surface may not be linked to increasing concentration of greenhouse gases (GHG) but could be explained as a result of urbanization and land-use change and landscape dynamics.”

“It appears that the presence of a significant link between solar activity and climate variations is backed by credible evidence, ...”

“In the public non-scientific discussion, there is far too much emphasis on the uncertainties of the model PREDICTIONS... What IS certain is that we are at risk of major climate change due to our activities.”

“This statement (that of 1998) does not accurately reflect the IPCC (2001) assessment conclusions ‘There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities’ and ‘In the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations.’”

“I believe that there is enough evidence now to make a somewhat stronger statement about the fact that models are converging on the notion that there will likely be large disparities between regions that experience beneficial versus damaging changes. Evidence now points to the likely consequence that the poorest nations (particularly in Africa) will experience the more damaging changes than richer nations in the Northern Hemisphere (damage inversely proportional to per capita emissions of greenhouse gases).”

“I think that part of moving forward on the climate change problem as a society, both at the national and at the global levels, is getting away from the sense of exoticism that colors the debate (‘Is this for real or not?’) and moving it onto a hazard-management basis. ... A natural hazards management approach allows them to factor in our uncertainty as a form of knowledge, rather than as a form of ignorance ...”

The panel considered all of these statements in the context of the peer-reviewed scientific literature on the issue.

The panel then proceeded to review the existing statement, “Climate Change and Greenhouse Gases,” together with the more detailed Eos article by Ledley et al. (1999) giving the science background for this previous statement. It examined the various comments received from the AGU membership, the relevant research on the topic with which panel members were familiar, and various assessments of research on the topic (this included IPCC, 2001, and NRC, 2001).

Taking all of this into account, several inputs to the new statement were discussed via telephone conference calls and e-mails. This culminated in two candidate versions for the statement that were discussed during a two-day (24-25 October 2003) meeting at AGU Headquarters in Washington, DC. During this meeting, successive drafts were circulated among those present and sent via e-mail to those not attending. Several conference phone calls took place to discuss the drafts. Every effort was made to keep all panel members informed of progress on the statement, and at the end of the meeting, a consensus candidate statement was adopted.

This candidate statement was then circulated to all panel members and to all members of AGU Council for comment. As a result, small changes were made, and Council discussed the revised version at the Council Forum on 7 December 2003. The Forum discussion resulted in additional small changes to the statement. Finally, Council approved the AGU statement, "Human Impacts on Climate" on 12 December 2003. All of the panel members and all AGU Council members endorsed the final statement.

## References

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Ledley, T. S., E. T. Sundquist, S. E. Schwartz, D. K. Hall, J. D. Fellows, and T. L. Killeen, 1999: Climate Change and Greenhouse Gases, EOS, 80, 453.

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## Box 1. Human Impacts on Climate Panel Members

André Berger, Université Catholique de Louvain, Louvain-la-Neuve, Belgium  
Anny Cazenave, Observatoire Midi-Pyrénées, Toulouse, France (Member of AGU Council)  
John Christy, University of Alabama, Huntsville, AL  
Ellen Druffel, University of California, Irvine, CA  
Jack Fellows, University Consortium for Atmospheric Research, Boulder, CO (Member of AGU's Committee on Public Affairs)  
Marvin Geller, Stony Brook University, Stony Brook, NY (Panel Chair)  
Hiroshi Kanzawa, Nagoya University, Japan  
William Schlesinger, Duke University, Durham, NC  
William (Jim) Shuttleworth, University of Arizona, Tucson, AZ  
Eric Sundquist, U. S. Geological Survey, Woods Hole, MA (Chair of the Global Environmental Change Focus Group)  
Richard Turco, University of California, Los Angeles, CA  
Ilana Wainer, Universidade de Sao Paulo, Brazil

## Box 2. Policy on AGU's Role in Advocacy of Public Issues

The American Geophysical Union is an association of scientists, scholars, and interested lay public for the purpose of advancing geophysical science. The Union shares a collateral sense of responsibility to assure that the results of geophysical research are made available to benefit all mankind. The Union encourages its members to exercise their individual sense of responsibility in addressing political and social issues. Should they choose to act collectively on such issues, other organizations exist for such purposes. The American Geophysical Union, as a society, should preserve its unique position as an objective source of analysis and commentary for the full spectrum of geophysical science. Accordingly, the following policies should guide the AGU's role as an advocate.

- The American Geophysical Union has a responsibility to its members to adopt a position of advocacy on geophysical science issues based on their intrinsic merits and needs.
- To the extent that the understanding and application of geophysical science is relevant to public policy, AGU as a responsible scientific association should make relevant information available to all parties interested in the issue.
- As a scientific society, AGU should not take or advocate public positions on judgmental issues that extend beyond the range of available geophysical data or recognized norms of legitimate scientific debate. Public positions adopted by AGU and statements issued on its behalf must be based on sound scientific issues and should reflect the interests of the Union as a whole. Human Impacts on Climate AGU position statement

Human activities are increasingly altering the Earth's climate. These effects add to natural influences that have been present over Earth's history. Scientific evidence strongly indicates that natural influences cannot explain the rapid increase in global near-surface temperatures observed during the second half of the 20th century.

Human impacts on the climate system include increasing concentrations of atmospheric greenhouse gases (e.g., carbon dioxide, chlorofluorocarbons and their substitutes, methane, nitrous oxide, etc.), air pollution, increasing concentrations of airborne particles, and land alteration. A particular concern is that atmospheric levels of carbon dioxide may be rising faster than at any time in Earth's history, except possibly following rare events like impacts from large extraterrestrial objects.

Atmospheric carbon dioxide concentrations have increased since the mid-1700s through fossil fuel burning and changes in land use, with more than 80% of this increase occurring since 1900. Moreover, research indicates that increased levels of carbon dioxide will remain in the atmosphere for hundreds to thousands of years. It is virtually certain that increasing atmospheric concentrations of carbon dioxide and other greenhouse gases will cause global surface climate to be warmer.

The complexity of the climate system makes it difficult to predict some aspects of human-induced climate change: exactly how fast it will occur, exactly how much it will change, and exactly where those changes will take place. In contrast, scientists are confident in other predictions. Mid-continent warming will be greater than over the oceans, and there will be greater warming at higher latitudes. Some polar and glacial ice will melt, and the oceans will warm; both effects will contribute to higher sea levels. The hydrologic cycle will change and intensify, leading to changes in water supply as well as flood and drought patterns. There will be considerable regional variations in the resulting impacts.

Scientists' understanding of the fundamental processes responsible for global climate change has greatly improved during the last decade, including better representation of carbon, water, and other biogeochemical cycles in climate models. Yet, model projections of future global warming vary, because of differing estimates of population growth, economic activity, greenhouse gas emission rates, changes in atmospheric particulate concentrations and their effects, and also because of uncertainties in climate models. Actions that decrease emissions of some air pollutants will reduce their climate effects in the short term. Even so, the impacts of increasing greenhouse gas concentrations would remain.

The 1992 United Nations Framework Convention on Climate Change states as an objective the "...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." AGU believes that no single threshold level of greenhouse gas concentrations in the atmosphere exists at which the beginning of dangerous anthropogenic interference with the climate system can be defined. Some impacts have already occurred, and for increasing concentrations there will be increasing impacts. The unprecedented increases in greenhouse gas concentrations, together with other human influences on climate over the past century and those anticipated for the future, constitute a real basis for concern.

Enhanced national and international research and other efforts are needed to support climate related policy decisions. These include fundamental climate research, improved observations and modeling, increased computational capability, and very importantly, education of the next generation of climate scientists. AGU encourages scientists worldwide to participate in climate research, education, scientific assessments, and policy discussions. AGU also urges that the scientific basis for policy discussions and decision-making be based upon objective assessment of peer-reviewed research results.

Science provides society with information useful in dealing with natural hazards such as earthquakes, hurricanes, and drought, which improves our ability to predict and prepare for their adverse effects. While human-induced climate change is unique in its global scale and long lifetime, AGU believes that science should play the same role in dealing with climate change. AGU is committed to improving the communication of scientific information to governments and private organizations so that their decisions on climate issues will be based on the best science.

The global climate is changing and human activities are contributing to that change. Scientific research is required to improve our ability to predict climate change and its impacts on countries and regions around the globe. Scientific research provides a basis for mitigating the harmful effects of global climate change through decreased human influences (e.g., slowing greenhouse gas emissions, improving land management practices), technological advancement (e.g., removing carbon from the atmosphere), and finding ways for communities to adapt and become resilient to extreme events.

Adopted by AGU Council, December, 2003

## AMERICAN GEOPHYSICAL UNION

### Who We Are

The American Geophysical Union (AGU) is an international scientific society open to those professionally engaged in or associated with the Earth and space sciences. Membership currently exceeds 41,000 members, of which about 20% are students.

### What We Do

AGU's mission is: \$ to promote the scientific study of Earth and its environment in space and to disseminate the results to the public, \$ to promote cooperation among scientific organizations involved in geophysics and related disciplines, \$ to initiate and participate in geophysical research programs, \$ to advance the various geophysical disciplines through scientific discussion, publication, and dissemination of information.

AGU members conduct scientific research over a wide range of subjects from ground water to interplanetary space. This research provides critical information about natural hazards, Earth's climate and its record of past climate change, and other natural processes that directly affect quality of life, prosperity, and economic development.

### What We Create

AGU sponsors several scientific meetings each year that include sessions on how AGU research relates to public policy. AGU publishes 13 peer-reviewed scientific journals, nine book series and a weekly newspaper, Eos, which includes news on current research, legislative and policy developments, and opinion articles.

Dr. Marvin Geller Professor, Institute for Terrestrial and Planetary Atmospheres, Stony Brook University. Major areas of interest are all types of atmospheric wave motions, including tides, gravity waves, extratropical planetary waves, and equatorial waves, how those waves interact with mean flows to effect constituent transport, particularly in the stratosphere. B.S., 1964, applied mathematics, Ph.D., 1969, meteorology, Massachusetts Institute of Technology. Professor, University of Illinois, 1969-1977; Professor, University of Miami, 1977-1980; NASA Goddard Space Flight Center, 1980-1989, Chief, Laboratory for Atmospheres, 1985-1989. National Associate, U.S. National

Academy of Science; President, Atmospheric Sciences Section, AGU, 2000-2002. Councilor, American Meteorological Society (AMS), 2001-2003. AMS and AGU Fellow.

The Testimony of

**Dr. Lee Hannah**

Research Fellow, Climate Change Biology, Center for Biodiversity Science, Conservation International

Mr. Chairman, distinguished committee members, committee and senate staff, visitors, ladies and gentlemen, good morning. My name is Lee Hannah and I work for the Center for Applied Biodiversity Science at Conservation International. Conservation International is a non-profit conservation group that focuses on finding solutions that allow people and biodiversity to coexist in some of the most species-rich areas of the world. My job is to examine possible impacts of climate change in the areas in which we work.

What does climate change mean for wild animals and plants?

No one thinks climate change will be good for biodiversity. My job is to figure out just how bad it might be. My co-workers and I focus on priority regions called hotspots. We are studying these areas in detail to help avoid impacts in these critical areas and to generate lessons for other regions of the world.

All plants and animals depend on a suitable climate to survive. As climate changes, species will move to maintain their preferred climate. Climate change can impact species either when suitable climate shrinks or disappears, or when movement to track preferred climate is impossible. I study these changes in biodiversity hotspots, and therefore I am most familiar with impacts expected in these areas.

Hotspots are regions that have high numbers of plants and animals found nowhere else in the world, that also have already had more than 70% of their natural habitat destroyed. 24 such areas have been identified in the literature, and some estimates indicate that more than half of all species on earth are found in these areas. The last thing these species-rich, high habitat loss areas need is another threat, but that is just what climate change presents.

We expect serious climate change impacts even in the tropics. Most of the hotspots, and the greatest number of the Earth's species, are in the tropics. While we expect climate change to be most pronounced near the poles, this doesn't mean the tropics are immune from its impacts. A growing body of literature indicates possible major impacts of climate change on wild plants and animals in the tropics, and this is one major reason that we are racing to put research programs in place to understand these effects.

Climate change is the major new threat to biodiversity this century.

Habitat loss is the greatest threat to biodiversity worldwide. In the past century, more than one quarter of all remaining natural areas in the world were lost. Recent analyses show that most habitable areas of the planet are now dominated by human activities. In addition to direct losses of habitat, the increasing dominance of human land uses has facilitated the acceleration of related threats, such as invasions of weedy, alien species.

In this century, climate change threatens to compound these losses. As the century progresses, habitat loss will have run its course, or be diminishing as human population stabilizes later in the century. In contrast, climate change will start slowly over the next few decades, gathering in intensity and becoming much more extreme toward the end of the century. So, while the magnitudes and timing are still to be resolved, it seems certain that climate change will surpass habitat loss as the number one threat to wild plant and animal species (biodiversity) sometime this century.

The most severe threat is the “double whammy” of habitat loss and climate change.

The rise of climate change will expose species to a new and deadly combination - habitat loss and climate change. Species move to maintain their preferred climate, but this may be impossible where a cornfield or superhighway or other human land use lies in the way. Since many parts of the world have already lost most of their natural habitat, such obstructions are the rule, rather than the exception. When a species can't move to find its suitable climate, its range shrinks, its population dwindles and its risk of extinction rises.

Species extinctions will result as movements required by climate change run into existing habitat loss. Climate change will be much more deadly in today's heavily transformed landscapes than it would be in a fully natural world.

Conservation responses can help plants and animals adapt to climate change.

One way to reduce the species losses associated with climate change is to create conservation systems that allow species to move. This is a novel concept, as most of our conservation efforts currently focus on parks, which are fixed in one place. We are used to thinking that a park of adequate size placed where a species currently exists will protect it. However, when a species starts to move due to climate change, we need a park not only where it is today, but where it will be in the future, AND connections that allow it to get it from point A to point B. This is a new challenge for conservation, one that requires us to create new parks and to develop new conservation mechanisms that will allow species to move naturally between parks.

Extinction estimates

Recent work has attracted attention to the large numbers of species extinctions that may result from climate change. The article that created that attention appeared in the journal *Nature*, and I was a co-author of that work. We estimated extinction risks in six widely diverse regions of the world. My work focused on the protea family of South Africa, where we modeled the response of over 300 species to climate change. We used a mid-

range climate change scenario and found that over one-fourth of the plants we studied would be placed at high risk of extinction. Other researchers in the study found similar risks in other parts of the world.

How was the study done?

A team of 19 international scientists looked at 6 regions around the world. My part of the team modeled species range shifts in over 300 species in the protea plant family in the Cape region of South Africa. The results showed about one-fourth of the species studied at high risk of extinction, which turned out to be in good agreement with the other regions and species studied.

Is one million species a realistic number?

The press coverage of the study often focused on the figure of over 1 million species at risk of extinction due to climate change. That estimate was not part of the Nature paper; it was produced by the lead author of the study (Chris Thomas of Leeds University) to give journalists and the public a sense of the magnitude of the losses that might be involved. While it is a very rough extrapolation from the more detailed results of the research, as an index for the general public, it seems a fair number. Some systems, such as freshwater, may be at even higher risk.

The number itself is just a simple sum of a mid-range percentage risk calculated in the six regions (for a mid-range climate scenario), times the number of species in the world. It assumes that the six regions in the study are representative, and there is no strong reason to believe that they are not. The estimate of the number of species in the world is on the low side. Most scientists believe that there are a minimum of 10-15 million species in the world, about half of which are marine species. The estimate assumes that there are 5 million terrestrial species.

The study focused on climate change expected by 2050, but these rough numbers are probably more useful as an index of what's at stake taking the whole century in perspective. Climate change will be accelerating in the second half of the century, so whether or not the risk estimate is high or low for the climate change expected by 2050, it is likely to be low for the century as a whole. It is important to emphasize that these numbers are risks, they don't say anything about which particular species will go extinct or when (most certainly not by 2050) and that they assume nothing is done about climate change or to improve conservation strategies. The best way to avoid these extinctions is to work to make sure that both of those assumptions are wrong.

These extinctions are not inevitable

It is very important to emphasize that the extinctions referred to in our study are not inevitable. We have two very important tools at our disposal to avoid these extinctions - strengthened conservation efforts and reduction of greenhouse gas emissions.

The last ice age has no comparison to this.

One might ask why species that survived a large climate change in the last ice age are vulnerable now. There are two reasons. First, the past 11,000 years has been a period of very warm, very stable climate compared to the past two million years in which the ice ages and many rapid climate swings occurred. We are now adding warming to an already warm climate, and many species are thus facing conditions unlike any they have faced during the ice ages. Second, past changes occurred in a totally natural landscape. We have now altered most natural habitat on the planet. Species no longer have natural pathways between their current locations and future suitable climates. When climate changes, they will be cut off from their preferred climates.

A two-pronged response is required - better conservation and control of greenhouse gases.

Our two solutions - strengthened conservation efforts and reduction of greenhouse gas levels - are at hand and well understood. We need to use them. We need to create parks to protect the areas to which species will move in the future, and use flexible landscape conservation to help them get there.

We also need to reduce global greenhouse gas concentrations. Even a perfect conservation effort, working in today's heavily modified habitats, cannot save species from extinction in the face of unchecked climate change. The less climate change there is, the less species movement there will be, and the more species can be saved from extinction.

We can get a head start by ramping up conservation efforts now.

One of the best things we can do to get ready for climate change is to strengthen existing conservation efforts. Adjusting to climate change will be much easier in a well-conserved landscape than in one in which habitat destruction is ongoing.

Major cost savings can result by avoiding climate change.

Creating new parks when land is increasingly scarce entails major new costs. The cost of land is rising around the world, making creating new parks adequate to deal with climate change a substantial expense.

For this reason, limiting the amount of species movements will result in major cost savings. The less climate change takes place, the less species will have to move and the less new parks and connections will be needed to cope. As climate change becomes more and more severe, parks will be less and less effective at accommodating the larger species movements required. Thus, limiting climate change can also help make the investments in new parks that are made more cost-effective.

Early reductions in greenhouse gases can have major benefits

Ultimately, no system of parks can compensate for uncontrolled climate change. The greatest cost will be in species extinctions. No park system or corridor can conserve a species that loses all suitable climate, or one that moves towards areas in which there is no remaining habitat. Restraining climate change must be a major complement to heightened conservation if major species extinctions are to be avoided.

Instituting reductions sooner can mean substantially lower impacts on wildlife in the long run. Early reductions can help stabilize global greenhouse gas concentrations at lower levels, meaning less climate change and less rearrangement of natural systems. In the end, lowering greenhouse gas levels can reduce the risk of extinctions for hundreds of thousands of species.

The time to act is now.

There are long lead times associated with reducing greenhouse gas concentrations. It is unrealistic to think that last-minute efforts will save the day or that wholesale changes in the way we fuel our cars or generate our electricity can be made overnight. Such major changes take time, and starting early is the best way to ensure that they take place in an orderly and cost-effective manner.

The Testimony of  
**Dr. Jerry Mahlman**  
, National Center for Atmospheric Research

Mr. Chairman and Members of the Committee: My name is Jerry Mahlman, I am a scientist at the National Center for Atmospheric Research, a world leader in global warming research. I was a NOAA scientist in the Department of Commerce for thirty years. Much of the pioneering research on global warming was done at NOAA's Geophysical Fluid Dynamics Laboratory, which I directed for 16 years. I have just finished service as a member of the National Research Council's Committee to Evaluate the U.S. Climate Change Science Plan. However, this testimony, and the opinions I present here today, are solely my own. Today, I will be speaking bluntly and simply about what we know about global warming, and its implications for society. Global warming is real and is a phenomenon that humans have created. Climate scientists worldwide have understood its essence since the so-called "Charney Report" of the National Research Council 25 years ago. Our burning of fossil fuels (coal, oil, and natural gas) is the undisputably direct cause of the ever-increasing concentrations of carbon dioxide in the atmosphere. This added carbon dioxide acts directly to warm the planet. There is no scientific controversy about these facts. The eventual warming amounts for Earth are expected to be substantial, but with some remaining uncertainty concerning how much warming we will receive for given scenarios of future amounts of carbon dioxide, and other "greenhouse" gases. We do have strong information that provides a sharper perspective on the policy-relevant impacts of global warming. For example: \* A doubling of atmospheric carbon dioxide amounts is expected to occur within this century, almost independent of expected progress in emissions mitigation measures. \* Another 3-6 degrees Fahrenheit global warming is expected to occur this century, with continued

warming thereafter. \* Global sea level is expected to rise steadily over the next 1000 years, with ominous very long-term consequences. \* Summer Arctic sea ice is expected to disappear by the middle of this century. \* Semi-arid continental areas are expected to have substantially less soil moisture in summer, with daunting implications for agriculture. \* Humid subtropical climates such as in the southeast U.S. are expected to have summertime heat index increases that will exceed the temperature increases. \* Tropical storms are expected on average to have stronger winds, and much more rain. Other projected changes are more uncertain than this "very probable" list, but could also have daunting consequences. I am not here today, or on any day, to advocate a specific public policy choice on this very important, but widely evaded, global problem. I do, however, believe that it is scientists' obligation to communicate the science of global warming, including its remaining uncertainties, to leaders and stakeholders, worldwide. I would also argue that it is our responsibility to offer our science-based perspectives on the available policy options, as well as their strengths and weaknesses. Clearly, improvements in this two-way communication are necessary. The viable policy options to deal with this problem meaningfully are very straightforward, but dauntingly difficult in their application. The basic major options are: \* Mitigation of Greenhouse Gas Emissions: A world-wide effort to reduce the emissions of carbon dioxide and other greenhouse gases substantially over the next half century, and likely much longer \* Adaptation: Altering society and earth's life systems, in many ways, to be more resilient to global warming, in the U.S. and globally. \* Coping: Proceed with "business as usual", and let the detrimental consequences be dealt with by future generations. This appears to be the unstated current national, and international, global warming "strategy". My opinion is that our descendants are likely to judge us harshly for our not yet having begun to address this problem meaningfully. Even though some significant uncertainties remain, important advances have already been achieved in observing, understanding, and modeling the climate. Today's climate models can simulate most large-scale aspects of climate and its changes. Although major progress has been made, today's world is now demanding more precise information. More efforts are needed to repair, and enhance, the long-term climate observing system. Focussed research into climate processes must be maintained. Climate modeling efforts must receive funding that is consistent with the demands that are now being placed upon them. Sharply enhanced research to evaluate the expected detrimental societal and environmental impacts of global warming must receive new resources to build the capability to address these critical challenges. Currently, the Administration's Climate Change Science Plan does speak to the importance of these critical needs. Unfortunately, no real new budget resources are yet being committed to address these compelling current and accelerated priorities. I look forward to the day when I might see the public policy process responding within the U.S., and the world, to address these serious challenges to the future of our planet. Thank you. I would be pleased to address any questions that you may have.

The Testimony of

**Dr. Lara Hansen**

Senior Scientist, Climate Change Program, World Wildlife Fund

Climate change is arguably the greatest threat to the world's biodiversity. Carbon dioxide and other greenhouse gases, generated by the anthropogenic burning of fossil fuels, have resulted in global warming, increasing the global average temperature by 0.6 degrees Celsius over the past century. While this warming continues, we are already seeing the effects of global warming on the Earth's biodiversity. WWF has a broad range of efforts focussed on protecting this biodiversity from the threat of climate change. This includes the projects that I oversee which document the impacts of climate change and redesign conservation to buy systems time, while we secure the actions urgently needed to reduce the greenhouse gas emissions that cause global warming.

Climate change is affecting life around the globe, from the poles to tops of mountains, from forests to the tropical oceans. WWF is working throughout these varied habitats. Our work in the Arctic has highlighted how shrinking sea ice is adversely impacting polar bears (*Ursa marinus*) and the ecosystems on which they rely. WWF supports scientists in the field and attempts to raise awareness through materials such as our polar bear tracker, an Internet tool that allows people to monitor the relationship between two polar bears (Lena and Yana) and the shifting sea ice. Research indicates that as sea ice in the Arctic melts earlier and forms later each year, polar bears are left with less time on the sea ice to hunt for seals and other food to build up their fat stores, and increased time on land where they must fast. As their ice habitat disappears, the survival of the polar bear is at risk. If global warming continues unabated, modeling suggests that by 2050 there will be no arctic sea ice during summer months. Such a rapid and dramatic change in habitat will have serious consequences for polar bears and all species adapted to current arctic conditions.

In the Western United States, WWF is supporting and highlighting research on the American pika (*Ochotona princeps*). This species lives at higher elevations due to factors including heat intolerance. Over the past few decades, historic populations of pika have disappeared; the hypothesis best supported by the pattern of loss is climate change. These local extinctions of pikas may very well be the first disappearances of a North American mammal due to climate change.

The impact of climate change on fisheries is also an important concern for WWF. Not only are fish important parts of aquatic ecosystems, they are also an important food source and were worth \$55.2 billion in international trade in 2000 according to the Food and Agriculture Organization of the United Nations (FAO). We are currently studying the effects of climate change on Chinook salmon (*Oncorhynchus tshawytscha*) in the Pacific Northwest. Lastly, I am the principle investigator on a set of projects evaluating the effects of climate change on coral reefs. In fact, I provide this testimony having just returned from my field sites in the U.S. Territory of American Samoa where we are observing the lasting effects of last year's bleaching event and additional damage from Cyclone Heta. We are also watching the mercury in the thermometer rise at our field sites, monitoring for signs of yet another year's bleaching.

One of the most visually dramatic effects of climate change has been coral bleaching. Coral reefs are the most biologically diverse ecosystems of the ocean--rivalled only by the

tropical rainforests on land. As snorkelers and divers know, thousands of beautiful fish, mollusks and urchins are among the amazing marine life that populates coral reefs. Almost a thousand coral species currently exist in fantastic shapes ranging from mushrooms to elk antlers, cabbages, tabletops, wire strands, fluted pillars, and wrinkled brains.

With the majority of human population living in coastal regions, many people depend on living coral reefs for food and protection from storm surges and erosion, as well as the additional benefits of tourism, medical research and aesthetic beauty. Coral reefs contribute an average of 25 percent of the total fish catch in developing countries, providing food for one billion people in Asia alone. The calmer area behind a reef can shelter sea grass beds and mangrove forests that serve as important nurseries for the young of fish and shellfish. As a result of this rich habitat, six million metric tons of fish are caught annually in and around coral reefs.

Coral bleaching is defined by the loss of colorful symbiotic single-cell algae (dinoflagellates known as zooxanthellae) by the host coral animal. When this symbiotic relationship is intact, dinoflagellates provide the coral host with additional energy from their photosynthetic activity which is vital to the survival of the coral. Long-term loss of the dinoflagellates can result in the death of the affected coral. Bleaching is considered to be a stress response caused primarily by increased water temperature and synergistically enhanced by increased irradiance levels. In historic, localized bleaching events, other stresses such as salinity, sedimentation and pollution have been implicated.

The El Niño-Southern Oscillation (ENSO) event of 1982-83 marked the first contemporary broad scale reef coral bleaching and mortality event. Since then there have been subsequent bleaching events including the 1997-98 ENSO event. The rate of occurrence (annually in some cases) and almost global scale since the early 1980's is in stark contrast to the trend of the first half of the century in which bleaching events were small in scale and linked to local factors. From 1876-1979, only three bleaching events were recorded, whereas 60 are on record from 1980 until 1993. The 1997-98 ENSO event is estimated to have removed 16 percent of the world's coral, with some regional estimates as high as 46 percent. The increase in bleaching occurrence and scale indicates that anthropogenic alterations of the environment are responsible, notably global climate change related increases in annual sea surface temperature and occurrence of ENSO events.

The 1997-98 bleaching event affected corals in all of the world's coral oceans. In the Indian Ocean off the coast of Africa, for example, bleaching reached 80 percent on some reefs in 1998. On the Mesoamerican Reef in Belize, coral bleaching and Hurricane Mitch caused a 50 percent reduction in live coral cover. Corals in U.S. waters have not been unscathed by climate change.

Coral reefs in Florida were estimated to have generated \$3.9 billion in 2001 for Broward, Miami-Dade, Monroe and Palm Beach counties. According to the ReefBase coral bleaching database, coral bleaching occurred in the Florida Keys every year between

1997 and 2001. Permanent loss or substantial degradation of coral reefs by bleaching due to climate change would be not only devastating to marine biodiversity in the region, but would have serious economic ramifications as well.

Corals in Hawaiian waters have perhaps had less bleaching than other U.S. corals, however they also have suffered dramatic bleaching events. For example, in 1996, an extensive bleaching event occurred on several islands and included bleaching in Kanoeh Bay, Oahu. This event was particularly well documented as it occurred in the bay surrounding the laboratory of the Hawaiian Institute of Marine Biology on Coconut Island. In some portions of the bay, 100 percent of corals were bleached. The economy of Hawaii is closely tied to its marine resources, especially through tourism. In 2001, for example, approximately half of the millions of US visitors (4,224,321) to Hawaii participated in snorkeling and/or scuba diving activities. It is estimated that coral reefs provide \$364 million of added value to the state economy.

The Northwest Hawaiian Islands were believed to be less susceptible to the affects of the increasing sea temperatures associated with climate change. Being farther from the tropics and surrounded by deep water and strong currents, there had not been any extensive bleaching events until 2002. In September of that year, bleaching was seen at Midway Island, as well as Kure, Pearl and Hermes Atolls. Mortality rates of 50 percent to 75 percent were reported in some parts of all of these reefs. It is important to note that in the case of the Northwest Hawaiian Islands, the damaging non-climate stresses that can harm reefs are largely absent. These remote, largely protected systems are the “canaries in the coal mine” of climate change. At sites in the U.S. Virgin Islands, including some within the National Park and the Buck Island Reef National Monument, corals experienced up to 50 percent bleaching in 1998 during the ENSO event.

In the U.S. Territory of American Samoa, my research group is working with local stakeholders to assess the effects of climate change on territorial reefs in U.S. waters. Collaborating with local communities and agencies, we are evaluating how reefs respond to warming ocean waters and what this means for effective conservation strategies. In February 2003, bleaching occurred at all seven of our field sites around the American Samoa island of Tutuila, including sites in the U.S. National Park of American Samoa and Fagatele Bay National Marine Sanctuary. In Fagatele Bay National Marine Sanctuary, follow-up surveys six months later revealed that bleached corals had died and were now covered with epiphytic macroalgae, or seaweed. As the corals die and are replaced by seaweed, the larger composition of the ecosystem also will change. The purpose of the National Marine Sanctuary program is to protect and preserve "natural and cultural resources in areas of special significance in the oceans and Great Lakes of the United States" and the U.S. National Park Service aims to protect areas that "possess nationally significant natural, cultural, or recreational resources." Yet, clearly climate change is already threatening all of these valued resources despite the boundaries of sanctuaries and parks.

WWF work on coral bleaching is not limited to U.S. waters. We are currently undertaking studies to monitor coral bleaching and its conservation implications

throughout our tropical marine ecoregions. This includes coral reefs in Indonesia, Philippines, Solomon Islands, Fiji, Belize, Tanzania and Australia.

Clearly coral reefs are sources of vast natural and economic resources for the communities associated with them. To better assess this dependence, WWF endeavored to explore the implications of further climate change induced damage to the world's most prominent coral reef system, the Great Barrier Reef. Our recent report, "Implications of Climate Change for Australia's Great Barrier Reef" (available at [http://www.wwf.org.au/News\\_and\\_information/News\\_room/viewnews.php?news\\_id=65](http://www.wwf.org.au/News_and_information/News_room/viewnews.php?news_id=65)), provides an analysis of the projected biological and economic effects of climate change on that reef. Discussion of this important topic could not be more timely. As this committee meets, reports from the Great Barrier Marine Park Authority state that "the threat of widespread coral bleaching for the Great Barrier Reef region is currently rated as moderate-high."

According to the recent WWF report, following current climate trajectories, by 2050, water temperatures will exceed bleaching thresholds every year at all sites along the Great Barrier Reef. This will result in the biodiversity of the region changing dramatically. For example, coral cover could decrease to less than 5 percent on most reefs in the region. This loss of coral cover would have major consequences for the whole reef ecosystem. Coral dependent species, such as some fish and shrimp, will become rare. Reef systems will become dominated by algae, which will change the species found within the system. Additionally, cyanobacteria species abundance may increase with implications for ciguatera poisoning and harmful algal blooms.

These changes will also have implications for human systems due to loss of tourism, changing environmental quality, commercial and recreational fisheries, subsistence gathering and coastal protection. The report goes on to estimate the cost of the loss of some of these sectors. For example, tourism and fishing both have substantial economic value for the region. Tourism to the Great Barrier Reef was worth \$2 billion (Australian), 7 percent of Australia's total tourism gross domestic product. Fishing in the Great Barrier Reef Marine Park was estimated to be worth \$145 million (Australian) in 2000. Large industries like these resulted in estimates that climate change could cost Australia between \$3.5 and 8 billion (Australian, in terms of 2001 prices) by 2020. This range is based upon comparison of four of the Intergovernmental Panel on Climate Change scenarios.

While the Great Barrier Reef is widely considered to be one of the best managed reef systems in the world, WWF's report and current conditions on the reef, as well as past bleaching events, indicate that local conservation actions will not be sufficient to protect coral reefs from the effects of climate change. We must take action to limit the rate and extent of climate change if we are serious about conserving corals, coral reef ecosystems, or the rest of the world's biodiversity. Research in corals reefs and other ecosystems indicates that climate change must be limited as much as possible. To date, studies indicate that the best chance for successful conservation in the face of climate change is

to limit the temperature increase by the end of this century to less than 2 degree Celsius (3.6 degrees Fahrenheit).

Because human activities that contribute to global warming are at the root cause of the almost epidemic coral bleaching and other environmental damage currently underway, we have a window of opportunity now to prevent further and more catastrophic damage if elected officials act quickly.

Significant reductions in CO<sub>2</sub> and other greenhouse gas emissions are urgently needed to slow global warming. Such reductions can be achieved by setting mandatory caps on greenhouse gas emissions, including CO<sub>2</sub>, and supporting a switch towards clean energy—increased energy efficiency, and use of renewable energy resources such as wind, solar and biomass.

WWF's work with businesses and the power sector show that such steps are feasible, good for the environment, and good for business. Just last month, five electric power companies from across the United States joined WWF in stating their support for binding limits on CO<sub>2</sub> emissions while also preparing for these CO<sub>2</sub> limits by committing to increase energy efficiency and availability of renewable energy. WWF also works with companies from various industries, including Johnson & Johnson, Nike, and IBM, to show that businesses can significantly reduce their CO<sub>2</sub> emissions while still meeting business goals. Multiple analyses show there are clear benefits to taking action now to reduce greenhouse gas emissions and little risk. On the other hand, there is great risk to life on earth and high costs in terms of wildlife and critical ecosystems by delaying action in the face of global warming.

In conclusion Mr. Chairman, to prevent further and more catastrophic damage to wildlife like corals and critical ecosystems like coral reefs, mounting scientific evidence clearly indicates that the United States and other countries must act responsibly and enact laws that will significantly reduce CO<sub>2</sub> and other greenhouse gas emissions now before it is too late.