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STATEMENT TO THE HOUSE OF REPRESENTATIVES COMMITTEE ON FOREIGN
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Dr. Anthony C. Janetos
Director, Joint Global Change Research Institute
Pacific Northwest National Laboratory/University of Maryland

Mr. Chairman and Members of the Committee and Subcommittee, thank you for the opportunity to talk with you today about climate changes, their consequences and impacts for natural resources and communities, our understanding of the vulnerabilities of different parts of the world, and how this understanding might inform the ongoing policy process.

I am the Director of the Joint Global Change Research Institute, a joint venture between the Pacific Northwest National Laboratory and the University of Maryland. I was originally trained as an ecologist. Our Institute has an interdisciplinary approach to understanding climate change and the potential responses to it – we do research and modeling on the energy economy and greenhouse gas emissions, on climate impacts to agricultural productivity and ecosystems, and increasingly on potential adaptation responses and regional vulnerabilities to climate impacts, in addition to our ongoing work on the importance of technology development and emissions scenarios for the important greenhouse gases. I have also been fortunate to be an author in several IPCC reports dealing with climate impacts, adaptation, and vulnerability, as a leader in national assessments of climate change impacts, and as an author in the recently released report from the US Global Change Research Program, *Global Climate Change Impacts on the United States*.

In each topic below, I will try to characterize some of the differences between the concerns we have in our own country with those in the developing world.

I would like to cover four areas briefly in my testimony:

- What do we now know about the impacts of climate change?
- What are the factors that determine the vulnerabilities of natural resources and societies to changes in climate?
- How are people beginning to respond to climate impacts?
- What are some of the challenges that still face us?

What do we now know about the impacts of climate change?

The IPCC Fourth Assessment Report was a milestone in terms of presenting our evolving knowledge of climate impacts. It provided documentation of literally thousands of impacts of climate change on natural resources, on coastal regions, on health status, on animal and plant species, and on agricultural productivity. Out of the IPCC report emerged a clear consensus that not only are we beginning to see the impacts of longer-term changes in the climate system, but also that we expect such manifestations to continue to grow in future decades, especially if greenhouse gas concentrations in the atmosphere continue to rise as they have been doing.

But our scientific knowledge has continued to evolve. Studies and findings since the IPCC report was published indicate, for example, that IPCC's projections of sea-level rise may have been conservative, raising additional concerns for low-lying island nations, for coastal barrier islands in such parts of the world as our own Southeast coast and Gulf regions. We now have a better appreciation of the

challenges to marine and coastal resources presented by the acidification of the oceans, which inhibits the abilities of many organisms, including many species of corals, to form their calcium carbonate exoskeletons. In addition, such reports as the US Government's assessment of the impacts of climate change on agriculture, land resources, water resources, and biodiversity indicate widespread current impacts on US natural resources, with the prospect of accelerated levels and rates of impacts in coming decades.

The recent publication of the new US Global Change Research Program's report, *Global Climate Change Impacts on the United States*, demonstrates that concerns over both observed and projected impacts extends to the transportation sector, to human health and nutrition, to agricultural productivity, and to the energy sector, as well as to natural resources and the living world. That report also begins to outline how some sectors and regions are beginning to respond to climate change, as they develop adaptation strategies.

Finally, the IPCC and subsequent reports have convincingly demonstrated that while no nation or region of the world is immune from the impacts of changes in the climate system, there are systematic additional vulnerabilities that exist in the developing world. In many, although not all, parts of the tropics and sub-tropics, the impact of even modest climate changes on agricultural productivity are expected to far outweigh those in the productive regions of the US and western Europe, for example. The influences of sea-level rise on island nations are clearly more problematic than they are for us, nationally (although different regions of the US clearly have different vulnerabilities than the overall national picture). Moreover, the supply of fresh water on many islands is clearly affected by rising sea level, and the consequent reduction of the size of the freshwater "lens" that often supplies drinking water.

What are the factors that determine the vulnerabilities of natural resources and societies to changes in climate?

There are many factors that determine the overall vulnerability of natural resources and societies to changes in climate. For example, different crops have different responses both to the increased concentrations of carbon dioxide in the atmosphere, and increase their growth rates at different levels depending on the specific biochemical pathway of photosynthesis in the plants. At the same time, they also have characteristically different responses to extremes of temperature and rainfall, which in many cases inhibit the growth response to CO₂. For example, even a crop as common as maize goes through a period in its lifecycle where heat waves can significantly reduce pollination success, and therefore the ultimate production of kernels for consumption. The major temperate cereal crops are significantly better understood in these respects than most tropical crops, although the responses of different varieties of rice are also well understood. Different species of trees, of animal wildlife, and of marine species all have characteristic responses to the combination of changes in climate, CO₂ concentrations in the atmosphere (or acidity in the oceans), and to other sorts of disturbances from both natural and human sources.

Societal vulnerabilities, though, are more complicated. Our current scientific understanding indicates that they are a combination of both physical sensitivities (what happens to forest and ecosystem processes), economic well-being, and distribution of resources, human capital and knowledge, and access to resources that can be mobilized when impacts are beginning to be felt. Perhaps the simplest way to think about this is that the overall response to agricultural impacts depends not only on what happens to crops in a particular part of the world, but also what resources are available to import food from other places, whether the institutions to manage those transfers are in place, and whether the knowledge exists to make use of appropriate mechanisms for response. Under one set of conditions, regions and societies could successfully adapt – under another, one has the conditions for famine.

In the IPCC, we began to analyze some of these factors and how they might change over time, as climate itself changes, using research published by our own Institute and that from other colleagues.

Elizabeth Malone and other collaborators at our Institute have derived, for example, a set of indicators known as the Vulnerability and Resilience Indicator Model (VRIM), which is a first attempt to systematize indicators of vulnerability that combine ecological, economic, and social factors at a country level. We use VRIM to provide insights into how different countries' capacity for adaptation could change over time in different climate change scenarios, compared to today and to reference baselines.

What we find in such analyses are some general principles – poorer countries are in general more vulnerable than richer, although within every country, there are poorer regions and populations of people that are more vulnerable than the average. Countries in the tropics and subtropics have more apparent vulnerabilities than those in the northern temperate latitudes. Coastal regions, islands, and mountainous regions will suffer from more immediate impacts than other places. But perhaps the most important insight from the IPCC evaluation of this literature was the realization that the adaptive capacity of many countries, including our own, is not unlimited, and under more scenarios of rapid and large climate change, the physical changes in climate can overwhelm adaptive capacity, leading to potential displacement of agriculture, natural resources, damages to the built environment, and the potential displacement of very large numbers of people from sensitive countries and regions around the world.

In more recent research, some of it focusing specifically on Southeast Asia, while we find that the potential for rapid economic growth may ameliorate some of these impacts, it is very unlikely to eliminate them all. Rice agriculture, for example, is extremely sensitive to changes in the hydrologic cycle and the timing of the Asian Monsoon, and while those changes cannot be predicted easily, the consequences of even small reductions in the productivity of this major crop would be extremely severe. Most immediate, however, are the potential vulnerabilities to storm surge and sea-level rise, with the combination of very large, and often very poor populations of people in harm's way. Their options for responding are limited, and this has the potential to significantly affect standards of living and the distribution of large numbers of people.

How are people beginning to respond to climate impacts?

There is an emerging literature on adaptation to climate change, based on the fact that we are already beginning to see climate impacts around the world, and therefore, people are beginning to respond in practice. The scientific and policy communities are also attempting to understand the phenomenon of adaptation better than we currently do, in order to provide our best evaluation of practices that work and those that do not.

In some cases, regions, cities, and even some countries have begun to implement specific programs of adaptation to climate change. For example, several cities in the US have instituted early warning systems for heatwaves in order to ameliorate the human suffering that can be the result of such episodes. There is agricultural research on trying to breed crops that are more resilient to drought and heat waves, or on management techniques for dealing with the impact of heat waves on domestic animals. There has also been the beginnings of applied research on how we might increase the resilience of transportation systems, of reducing the vulnerability of coastal regions to storm surge and sea level rise, and so forth. Some cities in the US, for example New York, have created entire programs devoted to long-term planning of their critical infrastructure and operations, with an eye towards increasing their own adaptive capacity to climate change. The UK has instituted its own national program of adaptation, with a national catalogue of practices that are being tried on all levels.

In other cases, for example, how we choose to deal with vulnerable natural ecosystems, such as coastal marshes, coral reefs, and many aspects of wildlife, it is less clear exactly how to respond, and what actions might be successful for adaptation. This is an important area for research, and the scientific community has called many times over the past decade for more focus on the costs and effectiveness of potential adaptation actions.

In developing countries, however, the situations we face here in the US or in Europe, are magnified. There are many more people at risk, many more are already under severe environmental stress, with insufficient access to drinking water, insufficient security for food, and without easy access to social resources and capital that might be deployed to protect them.

What are some of the challenges that still face us?

In my view, it is critically important to begin to develop adaptation strategies that take into account known sensitivities to climate change of natural resources and of such sectors as transportation, energy, and health, and begin to institute programs to build resiliency in particularly vulnerable parts of the world. There are many aspects of this challenge where scientific research will prove to be invaluable – we need to know much better than we currently do how the combination of climate and other stresses affect crop production, for example, in the most important crops in the developing world. It is equally critical to continue to get a much better handle on the actual regional changes in climate that we might expect over the next several decades, as well as over the century, because there are many investments in infrastructure – water projects, transportation projects and the like – whose design life will coincide with near-term changes in climate and not just century-long projections.

At the same time, it is crucial to begin collecting information on the costs and effectiveness of different adaptation strategies. What is the right balance, for example, of rebuilding coastlines with a combination of hard defenses, like seawalls, levees, and dikes, and softer defenses, like re-constituted coastal marshlands, wetlands, and mangroves? What other ecological services might be provided by ecosystem reconstruction? What are the interactions between adaptation strategies and greenhouse gas mitigation – the sequestration of carbon in agricultural systems and forests, for example? And how might the answers to these questions vary in different countries and under a continually varying and changing climate system?

As we need to begin to understand both the fundamental science and economics of adaption for our own resources, our own society and our own purposes, it is equally important that we begin to understand and assist countries less fortunate than our own. Several studies of the national security implications of climate change for the US have concluded that severe climate impacts in the developing world could reduce our own security, for many reasons that I will not go into here. It has also been argued that countries such as the US could dramatically improve our collective understanding of climate impacts, adaptation, and vulnerability, and that this knowledge could serve the developing world as well as ourselves, if applied appropriately.

I will not pretend to offer prescriptions for success. It is clear that the policy process will have to wrestle with these observations about climate impacts, vulnerability, and adaptation, and will need to find an acceptable balance in discussions among many different countries. But it is equally clear that adapting to changes in climate that cannot be avoided is an essential part of an overall strategy of response to climate change, and that the most vulnerable parts of the world, in general, are those countries that are less fortunate than our own.

Thank you, and I will be happy to address any questions you might have.

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