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Introduction

My name is Dr. Jane Lubchenco and I am the Under Secretary of Commerce for Oceans and Atmosphere and the Administrator of the National Oceanic and Atmospheric Administration (NOAA). Thank you for the opportunity to testify before you today on the state of climate science. On behalf of the Administration, I thank the House Select Committee on Energy Independence and Global Warming for its interest in the state of climate science and the spectrum of climate science and services needed in this country and abroad to make critical decisions now and in the future. I am pleased to be joined today by Dr. John Holdren, an esteemed fellow scientist and Director of the White House Office of Science and Technology Policy.

In the short time that President Obama has been in office, he has made it clear that our choices will be informed by scientific knowledge and that he considers addressing climate change to be a high priority. As he said to the National Academy of Sciences, "Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before." The President has also made it clear that he believes that good government depends upon good science. As head of NOAA, one of the nation's premier science, service and stewardship agencies with responsibilities for the oceans and the atmosphere, I certainly support a focus on science-based decision-making. Science can help inform an understanding of the opportunities and challenges presented by climate change.

It was evident how relevant these topics are to the broader global community during our recent interactions with international colleagues at the World Climate Conference -3 in Geneva in early September. As head of the U.S. delegation, I had the opportunity to interact with numerous heads of state, ministers, and leaders of international organizations. The focus of the meeting was the need to develop a Global Framework for Climate Services. There was strong agreement that services must be informed by relevant and credible science and must engage the users at all steps in the process. Much of what we do as a Nation on climate services will undoubtedly be useful to the international community and vice versa.

Climate science encompasses an immense breadth of topics ranging from those that are well-understood and amply-documented (e.g., increases in greenhouse gases) to those on the cutting edge of knowledge (impacts of sea level rise, ocean acidification, melting of sea ice and ice sheets, role of aerosols, etc). The IPCC's periodic assessment of the state of climate science provides regular updates of changes in the level of scientific certainty with respect to different topics. The National Academy of Science (NAS) and the United States Global Change Research Program (USGCRP) provide international as well as national assessments that complement the international assessments.

Through sustained federal and extramural partnerships and collaboration, the nation has made significant progress in our understanding of climate change. The core capabilities needed to understand the state of the climate and make projections about the future and associated impacts include: observing systems (ecosystems, ocean, land, atmosphere, space); research of the biological, chemical and physical systems and their interconnectedness to human, ecological, and biogeochemical systems; modeling of global and regional climate changes from intra-seasonal to multi-decadal time scales; and a means to assess and communicate the climate information on current and future impacts.

More work lies ahead, however, to more fully understand the needs of society to address the challenge of a changing climate and to deliver useful climate-relevant information that can inform decision-making. In 2007, NAS released a report entitled "Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results," which highlighted existing gaps in federal programs ability to provide global climate change information. This report recognized that good progress has been made to determine many aspects of global climate change however, "progress in synthesizing research results or supporting decision-making and risk management has been inadequate."

State of the Science

I appreciate this opportunity to review and provide an update on the strong foundation of climate science – the very foundation upon which our nation and the world rely upon while deliberating about new directions to curb heat-trapping emissions and forge a clean energy to ensure a prosperous future for our children and generations to come. Two entities — the Intergovernmental Panel on Climate Change (IPCC) and the USGCRP — have published several peer-reviewed syntheses of the latest climate science findings and associated impacts. United States scientists, including those from or supported by the Departments of Agriculture, Energy (DOE), the Interior, Health and Human Services, and Transportation, as well as the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and NOAA, have played a significant role in both of these groups.

Since its inception about 20 years ago, the IPCC has produced assessments of the state of understanding of (i) the science of climate change, (ii) the impacts of climate change and climate change vulnerability, and (iii) mitigation of climate change. Each of these areas is the subject of a separate scientific assessment, and there is also a synthesis summarizing findings across all three. The IPCC's reports have become the gold standard for authoritative scientific information on climate change because of the rigorous way in which they are prepared, reviewed, and approved.

The USGCRP began as a presidential initiative in 1989 and was mandated by Congress in the Global Change Research Act of 1990 (P.L. 101-606), which called for "*a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change*." During the past two decades, the United States, through the USGCRP, has made the world's largest scientific investment in the areas of climate change and global change research. These advances have been documented in numerous assessments commissioned by the program and have played prominent roles in international assessments such as those of the IPCC.

Both the IPCC and the USGCRP have produced the two most recent assessments of climate science to date. The IPCC Fourth Assessment Report (IPCC 2007) is a climate science assessment prepared by 152 leading scientists from around the world who served as its authors. It was then reviewed and re-reviewed by more than 600 experts and dozens of governments.

In 2009, the U.S. government released a landmark report entitled *Global Climate Change Impacts in the United States* (GCCI 2009). It contains a comprehensive assessment of the state of knowledge about the impacts of climate change in the United States, region by region and sector by sector. This report provides concrete scientific evidence that demonstrates unequivocally that the climate is changing, and we are seeing its impacts in our own backyards in every region in the country.

Since the IPCC process began in the late 1980s, a wealth of global scientific effort has cumulatively provided stronger and stronger evidence that humans are primarily responsible for warming global temperatures. This has led to the latest key finding in the GCCI 2009 report: *Global warming is unequivocal and is primarily human-induced*.

This warming can be seen in increases in global-average surface air and surface and subsurface ocean temperatures, widespread melting of land snow and ice and sea ice, rising sea level, and changes in many other climate-related variables and impacts. Most of the observed increases in global temperatures since the mid-20th century are primarily due to human-induced increases in heat-trapping greenhouse gases (IPCC 2007, GCCI 2009).

At one time, we talked about what human-induced climate change *might* look like at some point in the future. The latest science says that it's happening now. We are now seeing the effects of human-induced climate changes on our landscape, our neighborhoods, schoolyards and farms, as well as our forests, beaches and mountains. We are able to measure this through significant advances in our observing systems over the last 20-30 years – many of which are NOAA's responsibility and innovation – and through collaborative global and national efforts to provide systematic and widespread monitoring of climate and associated environmental and social change; this has led to much better understanding of present and expected impacts of climate change: *Widespread climate-related impacts are occurring now and are expected to increase (GCCI 2009)*

In addition to observing the changes we have long anticipated, we are also seeing that some changes are happening faster than previous assessments have indicated (GCCI 2009). Our latest scientific assessments also tell us that our options for reducing overall climate change and avoiding the worst of the projected changes are likely to have more positive impact now than if we were to implement them later. For example, sizeable early cuts in emissions would significantly reduce the pace and overall amount of climate change (GCCI 2009).

Latest Key Findings

Highlights of the latest climate science findings at the global to regional scale and by sector, referencing peer-reviewed literature, are described below:

Highlights of climate change occurring globally -- Some details on magnitude of current and expected climate change, and greenhouse gas (GHG) emissions:

- Global average surface temperature has risen by about 1.5°F since 1900 and is projected to rise another 2°-11.5°F by 2100 (IPCC 2007 and GCCI 2009).
- The current atmospheric carbon dioxide concentration is estimated at around 385 ppm, which is higher than the highest point in at least the last 800,000 years[1] (GCCI 2009).
- Temperatures in the next couple of decades will be primarily determined by past emissions of greenhouse gases, but increases thereafter will also be primarily determined by future emissions (GCCI 2009).
- Current observed global emissions of carbon dioxide emissions are beginning to exceed even the upper range of IPCC past scenarios (IPCC 2007; GCCI 2009).
- There is significant evidence and agreement that under current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades (IPCC 2007).
- Longer ice-free season in the ocean and on lakes and rivers
    - End-of-summer Arctic Sea ice has fallen at a rate of 11percent per decade over the last 3 decades (GCCI 2009).
    - Arctic sea ice extent during the 2008 melt season (measured in September) dropped to the 2nd-lowest level (4.67 million km^2 / 1.80 million mi^2) since satellite measurements began in 1979. The record low was set in 2007 (4.28 million km^2 / 1.65 million mi^2) (NCDC Global State of the Climate, 2008*)*.
    - While the summer sea ice minimum in 2009 was not as low in 2007 or 2008, there is continued loss of older sea ice compared to five years ago (Arctic Report Card 2009).
    - Large scale wind patterns and high Arctic species, such as walrus and polar bears, are expected to be impacted by continuing loss of sea ice (Arctic Report Card 2009).
- Changes in snowmelt and snow cover
    - Runoff in snowmelt-dominated areas is occurring up to 20 days earlier in the West and up to 14 days earlier in the Northeast.

[1] Over the past 800,000 years, atmospheric carbon dioxide has varied within a range between 170 and 300 ppm.

        - Seven of the last ten Northern Hemisphere winters featured above-average snow cover, including two of the four largest winter snow cover extents since observations began in 1967. Nine of the last ten Northern Hemisphere springs have featured below-average snow cover, including two of the four smallest spring snow cover extents (NCDC Global State of the Climate, 2009*)*.
- The 2008 global combined land-and-ocean surface air temperature was tied (with 2001) for the 8th warmest on record (since 1880: 8th of 129). The ten warmest years have occurred within the last twelve years. The global combined land-and-ocean surface air temperature for 2008 was warmer than all years prior to 1998 in the dataset (i.e., warmer than each year from 1880-1997) (NCDC Global State of the Climate 2008*)*.
- The amount of sea level rise likely to be experienced during this century depends mainly on the expansion of ocean volume due to warming and the melting of glaciers and polar ice sheets. Complex processes control discharges from polar ices sheets and some are already contributing to sea level rise. In addition regional affects from changes in ocean circulation and geological and human processes that affect the elevation of the land above sea-level can either add to or subtract from the global mean sea level rise projected to be as high as 3.5 feet in some scenarios of increasing heat-trapping greenhouse gases (GCCI 2009).
- In addition to influencing global temperatures, increasing carbon dioxide is gradually acidifying the ocean. Approximately one third of carbon dioxide emitted into the atmosphere by human activities has been absorbed by the ocean. Further increases in ocean acidity are expected to continue to affect the ability organisms to calcify. Under these scenarios, coral calcification rates are likely to decline more than 30 percent under a doubling of atmospheric carbon dioxide concentrations (GCCI 2009).

Highlights of climate change impacts in the United States:

Climate changes are already underway in the United States (and elsewhere) and are expected to grow including (GCCI 2009):

- Temperature rise
    - U.S. average temperature has risen more than 2°F over the past 50 years and is projected to rise more in the future (GCCI 2009).
    - Under a higher emissions scenario, the U.S. as a whole is projected to warm 7-11°F by the end of this century, while under a lower emissions scenario, temperature increase would be approximately 4-6.5°F. Stabilizing emissions at still lower levels would yield lower temperatures – potentially limiting it to around 2°F higher than present (3.5 °F higher than pre-industrial) (GCCI 2009).
- Precipitation Patterns Changing
    - Precipitation has increased an average of about 5 percent over the past 50 years. Projections of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly the West, will become drier (GCCI 2009).
    - In the U.S., the amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the last century and this is expected to continue, with the largest increases in the wettest places (GCCI 2009).
    - Extreme events such as heavy downpours and droughts are likely to reduce crop yields because excesses or deficits of water have negative impacts on plant growth (GCCI 2009).

- Sea level rise
  - Global sea level has risen approximately 8 inches this century (IPCC 2007, GCCI 2009).
  - During the past 50 years, sea level has risen up to 8 inches or more in some locations along the U.S. coast (GCCI 2009).
  - Some recent estimates suggest that future global sea level rise may substantially exceed the IPCC estimates that do not include rapid ice flow and that sea level rise might be between 3-4 feet this century (GCCI 2009).
  - Sea level rise will not be uniform around the globe. Because of local differences in ocean circulation and in the amount of subsidence or uplift, a 2-ft global sea level rise would result in 2.3 ft at New York City, 3.5 ft in Galveston, TX, and only 1 ft in Neah Bay, Washington State (GCCI 2009).
- Increase in heavy downpours
  - In the U.S., the amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the last century and this is expected to continue, with the largest increases in the wettest places (GCCI 2009).
- Glaciers have been retreating worldwide for at least the last century and the rate of retreat has increased in the past decade (GCCI 2009).
- Thawing permafrost damages roads, runways, water and sewer systems, and other infrastructure (GCCI 2009).

Climate Change impacts critical resources and sectors of our economy:

- *Widespread climate-related impacts are occurring now and are expected to increase*. Climate changes are already affecting water resources; energy and transportation infrastructure; agriculture; ecosystems; and human health. These impacts vary from region to region and will grow under projected climate change (GCCI 2009).

  - *Climate change will stress water resources*. Water is an issue in every region but the nature of the potential impacts varies. Drought, related to reduced precipitation, increased evaporation, and increased water loss from plants, is an important issue in many regions especially in the West. Flood and water quality problems are likely to be amplified by climate change in most regions. Declines in mountain snowpack are important in the West and Alaska where snowpack provides vital natural water storage.

  - *Crop and livestock production will be increasingly challenged.* Agriculture is considered one of the sectors most adaptable to changes in climate. However, increased heat, pests, water availability, diseases and weather extremes will pose adaptation challenges for crop and livestock production.

  - *Coastal areas are at increasing risk from sea level rise and storm surge*. Sea level rise and storm surge place many U.S. coastal areas at increasing risk of erosion and flooding, especially along the Atlantic and Gulf coasts, Pacific Islands and parts of Alaska. Energy and transportation infrastructure and other property in coastal areas are very likely to be adversely affected.

- *Threats to human health will increase.* Health impacts of climate change are related to heat stress, water-borne diseases, air quality, extreme weather events, and diseases transmitted by insects and rodents. Robust public health infrastructure can reduce the potential for negative impacts.

- *Climate change will interact with many social and environmental stresses.* Climate change will combine with pollution, population growth, overuse of resources, urbanization, and other social, economic and environmental stresses to create larger impacts from any of these causes alone.

- *North Atlantic Fish Populations Shifting as Ocean Temperature Warm.* About half of 36 fish stocks in the Northwest Atlantic Ocean, many of them commercially valuable species, have been shifting northward over the last four decades, with some stocks nearly disappearing from U.S. waters as they move farther offshore, according to a new study by NOAA researchers. For example, Southern species like Atlantic Croaker may become common in New England waters. Fish species can respond to changes in ocean temperature in a variety of ways. The stock can move poleward to avoid warmer water temperatures, or move into deeper waters than they have previously been found. If fish cannot change their geographic or depth distribution, there may be changes in growth, reproduction and mortality rates. As a result, the size of the population may increase or decrease depending on the temperature preference of the species. Most species in the study were found to be responding to warming ocean temperatures in one of these ways (Nye et al., 2009).

The Earth's Changing Climate Necessitates Adaptation

The prospects of such climate changes have profound implications for a global society, underscoring the need for scientific information to aid decision-makers in developing and evaluating options for mitigating future human-induced climate change as well as alternatives for adapting to a changing climate.

Across the United States, decision-makers at all levels of government are considering options for how to best prepare their communities for the impacts of a changing climate. While climate change negotiations have primarily focused on mitigation of greenhouse gases, it is also critically important that we incorporate adaptation into our strategy. A bold strategy to reduce heat-trapping emissions is necessary to avoid the worst consequences of climate change, but even then some degree of future climate change will continue to occur despite mitigation efforts. We are already seeing the impacts of climate change on the ground and in our own backyards. In Alaska, for example, temperatures are warming at twice the rate of the rest of the United States, causing sea ice and permafrost melt, and threatening vulnerable infrastructure, ecosystems, and native communities (GCCI 2009). The Southwest is becoming drier, leading to user conflicts about water resource management (GCCI 2009). Sea level rise is occurring in the Gulf of Mexico, threatening the ports, 72 percent of which are at or below a 4-foot sea level (GCCI 2009). These impacts affect people, places, and natural resources and action is needed to protect our environment, economic livelihood, human health, and national security from the impacts of climate change.

Adaptation is not a new concept. Humans have adapted to changing conditions in the past. For example, farmers have to predict the optimum planting date for maximizing crop yield and profits. In the future, however, adaptation will be particularly challenging because the rate of change is escalating and is moving outside the range to which society has adapted in the past. The precise amounts and timing of these changes cannot be known with certainty. Because of this uncertainty and the high potential for surprises, adaptation plans will need to be robust, flexible, and able to evolve over time.

Climate scientists have developed a suite of global climate models to project climate change impacts on temperature, precipitation, sea level rise, and some aspects of extreme weather events (e.g., IPCC 2007). Long-term climate data have been collected through extensive monitoring and observing systems, and impacts such as changes in stream flow, snowpack, and urban heat islands are currently being studied. However, meeting the challenge of preparing for and responding to climate change will require an unprecedented level of coordination among federal agencies, along with our nongovernmental and international partners. We need to utilize our collective expertise to provide high-quality climate information and services that are user-friendly, responsive to management, and relevant to desired social, economic, and environmental outcomes. In addition, we need to translate global modeling projections to scales that are more meaningful to regional, state, and local decision makers. To best prepare their communities, decision-makers will need to be supported with access to the best climate information that science can provide and tools that can inform and guide their decisions. There are still gaps remaining in our scientific understanding of global climate change and its impacts, including strategies for building resilience of our people, places, and natural resources. For example, we need more climate information and projections at the local level where the impacts of climate affect each one of us. In addition, there are some impacts of climate change, such as ocean acidification on marine life, about which there are important knowledge gaps.

Despite these challenges, in many instances, decision-makers, resource managers, and urban planners throughout the United States are already beginning to develop and implement strategies for climate change adaptation. For example, Boston built one of its sewage treatment plants at higher ground to accommodate sea level projections over the next 50 years (GCCI 2009). Chicago is planting green roofs to cool its buildings and reduce the effects of urban heat waves (GCCI 2009). King County, Washington upgraded the specifications for a new regional wastewater treatment facility to include water reclamation capacity in response to the observed and projected declines in mountain snowpack (CCAP 2009). The State of California recently released a draft climate adaptation strategy that identified how state agencies can plan for climate impacts on multiple sectors, including public health, biodiversity and habitat, ocean and coastal resources, water management, agriculture, forestry, and transportation and energy infrastructure (CA Natural Resources Agency 2009). Several other cities, counties, and states have developed comprehensive plans that address adaptation, and in many cases, federal agencies such as NOAA, NASA, the U.S. Army Corps of Engineers, the U.S. Geological Survey (USGS), and the Environmental Protection Agency provided the data, sponsored the research, or enabled the services that supported their development.

The federal government can play an important role in building the institutional capacity to adapt to climate change. Climate change can and must be incorporated into our existing management, planning and decision-making frameworks as we look to the future. At the federal agency level, our science must be accessible, relevant, and timely. This will require two-way communication, which often begins with providing opportunities for decision-makers, resource managers, and planners to articulate their needs to the scientific community in order to ensure that the scientific community focuses on addressing the most relevant issues to decision-makers. The examples cited in the paragraph above show that this communication has already begun, but more is clearly needed. Through enhanced communication and cooperation, we will make effective steps towards preparing for climate change.

Conclusion

Thank you again, Mr. Chairman, for the opportunity to provide you with this review and update of climate change science. NOAA looks forward to continuing to provide national and international leadership, in collaboration with DOE, NASA, NSF, USGS and other federal agency partners. Contributions from all federal agencies and all countries are necessary to ensure the solid foundation of global climate science and service to inform critical decisions about our future as a nation and a global society.

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