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Mr. Chairman and Members of the Committee, I am Dr. Thomas Peterson, a physical scientist with NOAA's National Climatic Data Center. I am pleased to present a summary of our understanding of the impacts of climate change on transportation infrastructure as well as a description of NOAA's role in creating and providing key information on climate change to transportation decision-makers. I am an author of a National Research Council (NRC) commissioned paper released this past March on *Climate Variability and Change with Implications for Transportation,* along with other colleagues from NOAA and the Department of Energy's Lawrence Berkeley National Laboratory.

My testimony will draw from the NRC paper as well as from three other timely reports of which I am an author of the report on climate extremes:

- *The Potential Impacts of Climate Change on U.S. Transportation* by the NRC Transportation Research Board (TRB) which was released March 11, 2008
- *Impacts of Climate Variability and Change on Transportation Systems and Infrastructure -- Gulf Coast Study*, US Climate Change Science Program (CCSP) Synthesis and Assessment Report 4.7, released March 12, 2008
- *Weather and Climate Extremes in a Changing Climate*, US Climate Change Science Program Synthesis and Assessment Report 3.3, released June 2008.

Climate Change and Its Impacts on Transportation Operation and Infrastructure

According to the NRC report, five aspects of climate change impact transportation operations and infrastructure: (1) increases in very hot days and heat waves, (2) increases in Arctic temperatures, (3) rising sea levels, (4) increases in intense precipitation events, and (5) increases in hurricane intensity.

<u>Increases in very hot days and heat waves</u>

It is highly likely (greater than 90 percent probability of occurrence) that heat extremes and heat waves will continue to become more intense, last longer, and be more frequent in most regions during the twenty-first century. In 2007, the probability of having five summer days at or above 43.3ºC (110ºF) in Dallas was about two percent. In 25 years the models indicate that this probability increases to five percent; in 50 years, to 25 percent; and by 2099, to 90 percent. Very hot days can have an impact on operations; for example, by limiting periods of outdoor railroad track maintenance activity due to health and safety concerns. High temperatures can have a big impact on aircraft by influencing the limits on payload and/or cancelling flights. This is due to the fact that, because warmer air is thinner (less dense), for any given take-off speed the wings of airplanes create less lift when temperatures are high. This causes lower lift-off load limits at high-altitude or hot-weather airports with insufficient runway lengths. Examples of impacts on infrastructure include rail-track deformities, thermal expansion on bridge joints and paved surfaces, and concerns regarding the integrity of pavement.

Increases in Arctic temperatures

Arctic warming is virtually certain (greater than 99 percent probability of occurrence), as temperature increases are expected to be greatest over land and at most high northern latitudes. As much as 90 percent of the upper layer of permafrost could thaw under higher emission scenarios. The greatest temperature increases in North America are projected to occur in the winter in northern parts of Alaska and Canada as a result of feedback effects of shortened periods of snow cover. By the end of the twenty-first century, termperatures could increase by as much as 10.0ºC (18.0ºF) in the winter and 2.0ºC (3.6ºF) in the summer in the northernmost areas. For the rest of North America, the projected annual mean temperature increase ranges from 3.0ºto 5.0ºC (5.4ºto 9.0ºF), with smaller increases expected near the coasts. Examples of impacts on operations include a longer ocean transport season and more ice-free ports in northern regions, as well as the possible availability of a northern sea route, or a northwest passage. Examples of impacts on infrastructure include a short season for ice on roads and thawing of permafrost, which causes subsidence of roads, rail beds, bridge supports, pipelines, and runway foundations.

Rising sea levels

It is virtually certain (greater than 99 percent probability of occurrence) that sea levels will continue to rise in the twenty-first century as a result of thermal expansion and loss of mass from ice sheets. The projected global range in sea level rise is from 0.18 m (7.1 in) to 0.59 m (23.2 in) by 2099. These estimates do not include subsidence in regions of the Gulf of Mexico and uplift along portions of the New England and Alaskan coasts. They also do not include the dynamics of land ice in frozen regions such as Greenland and Antarctica, which could increase the projection for sea level rise. The *Gulf Coast Study* estimates that a relative sea level rise of 0.5 to 4 feet is quite possible for parts of the Gulf Coast within 50 years, due primarily to land subsidence. With an increase of 4 feet in relative sea level, as much as 2,400 miles of major Gulf Coast roadways could be permanently flooded without adaptation measures. Other examples of the impacts of sea level rise on operations include more frequent interruptions in coastal and low-lying roadway travel and rail service due to storm surge. Sea level rise will cause storm water levels to be higher and flow further inland, exposing more infrastructure to destructive wave forces. Higher storm water levels will in turn require reassessment of evacuation routes, changes in infrastructure design, siting, and development patterns, and the potential for closure or restrictions at several of the top 50 airports, as well as key maritime ports that lie in coastal zones. With 50 percent of the population living in the coastal zone, these airports and ports provide service to the highest-density populations in the United States. Examples of impacts on infrastructure include reduced clearance under bridges; erosion of road base and bridge supports; inundation of roads, rail lines, subways, and airport runways in coastal areas; more frequent or severe flooding of underground tunnels and low-lying infrastructure; and changes in harbor and port facilities to accommodate higher tides and storm surges.

Increases in intense precipitation events

It is very likely (greater than 90 percent probability of occurrence) that intense precipitation events will continue to become more frequent in widespread areas of the United States. Examples of impacts on operations include increased flooding of evacuation routes, increases in weather-related delays and traffic disruptions, and increases in airline delays due to convective weather. Examples of impacts on infrastructure include increases in flooding of roadways, rail lines, subterranean tunnels, and runways; increases in scouring of pipeline roadbeds and damage to pipelines; and increases in road washout, damages to rail-bed support structures, and landslides and mudslides that damage roadways and tracks.

Increases in hurricane intensity

It is likely (greater than 66 percent probability of occurrence) that tropical storm *intensities*, with larger peak wind speeds and more intense precipitation, will increase. However, it is presently unknown how 21st century tropical storm frequency will change compared to the historical data. Increased storm intensity can lead to increased likelihood of negative impacts to operations and infrastructure, even though the number of storms may not be changing. Examples of impacts of increased storm intensity on operations include more frequent and potentially more extensive emergency evacuations; and more debris on roads and rail lines, interrupting travel and shipping. Examples of impacts on infrastructure include a greater probability of infrastructure failures, increased threat to stability of bridge decks, and harbor infrastructure damage due to waves and storm surges.

In addition to the five major aspects of climate change listed above, cold extremes are likely to decrease. This change should have mostly positive impacts on transportation, such as a decrease in ice build up on marine infrastructure. Also, if the snow season is shorter, roadway maintenance will be easier and highway safety will improve.

In summary, climate change will affect transportation operations and infrastructure in multiple ways. Transportation infrastructures have long lifetimes. For roadways it is typically 25 years, railroads 50 years, and bridges and underpasses 100 years. When planning a new bridge, for example, designers can take into consideration (among other things) current traffic, potential future traffic, current weather and climate, and potential future weather and climate. As illustration of such an adaptation measure, the design of the 8 mile long Confederation Bridge, which connects Prince Edward Island to the Canadian mainland, took into account the possibility of a 1-m (~3 feet) sea-level rise due to climate change. Many other adaptation measures can be adopted. For example, there are methods of laying railroad track that raise the temperature at which it will buckle, some pavement options are more resistant to rutting during hot weather than others and larger culverts can be placed under railroads and highways to accommodate heavier precipitation. To help the nation respond to this challenge, NOAA provides climate information to the transportation sector to aid in its efficient and safe operation, and to help design infrastructure to withstand future climate change.

NOAA's Role in Providing Climate Information

NOAA helps the nation's transportation industry identify and manage risks associated with climate variability and change. NOAA supports the transportation industry by serving as the centralized source of relevant and timely weather and climate information needed to support commerce. NOAA's contributions include historical and real-time data, monitoring and assessments, research and modeling, predictions and projections, decision-support tools.

For example:

- NOAA's Climate Prediction Center produces seasonal forecasts used for planning for transport on waterways and stockpiling supplies such as sandbags or salt for roadway (among other functions).
- NOAA's National Climatic Data Center (NCDC) develops national and global datasets that have been used to maximize climate resources and minimize the risks posed by climate variability and weather extremes.
- NOAA's Earth System Research Laboratory, working with the Federal Highway Administration, develops decision-support software applications that use weather forecasts to generate predictions about roadway conditions and recommendations for the frequency of snow plowing and de-icing. These efforts help to increase roadwaysafety and cost-savings due to reduced unnecessary roadway maintenance.
- NOAA's Geophysical Fluid Dynamics Laboratory develops climate models to prepare projections of future climate conditions.
- NOAA's Climate Program Office supports fundamental research aimed at fulfilling NOAA's goal to understand and describe climate variability and change to enhance society's ability to plan and respond.
- NOAA's National Weather Service and NCDC produce many publications that describe the weather and climate of the United States, participate in national and international climate research assessments, and fulfill millions of data customer requests each year.
- NOAA's National Ocean Service provides information on local vertical land movement and local relative mean sea level trends and provides coastal managers with coastal resilience tools and training.

Climate change presents a substantial challenge for future policy and business decision-making, and the demand for climate information from NOAA has increased over the past decade and continues to grow. Designers of transportation infrastructure can use NOAA's climate change information to help guide the design and construction of new infrastructure, so it will withstand climactic changes throughout its designed life time.

NOAA actively participates with other federal agencies and other organizations, and often takes a leadership role in collaborative climate change assessments and reports. NOAA has worked on both domestic efforts, such as the U.S. Climate Change Science Program (CCSP) report on changes in extremes in North America, and international efforts, including the Intergovernmental Panel on Climate Change (IPCC). These rigorous assessments synthesize the latest climate science to provide authoritative information on how the climate has changed in the past and is expected to change in the future. These reports are widely accessed by the transportation industry.

NOAA has taken a proactive role in understanding the emerging data and information needs facing a variety of data users and decision-makers. As climate services continue to evolve, NOAA recognizes that local, regional, state, and private entities require better information to understand how their localities are contributing to, will be affected by, and can adapt to a changing climate. It is NOAA's goal to provide relevant, user-specific climate information to meet this demand. NOAA has begun to address this through problem-focused initiatives developed collaboratively with users, such as the transportation industry.

For example, in 2007, NCDC hosted a specialized NOAA Data Users workshop to identify the climate data and information requirements of the energy, insurance, and transportation sectors, in the context of a changing climate. The workshop also explored how those emerging information needs might guide future products and services. The feedback gained from this workshop provided an understanding of the needs of each industry, enabling NOAA to maximize the value of the climate products and services it delivers. For instance, in addition to NOAA's role as provider of historical, current and modeled environmental data, these industries are interested in data about the probability of risk associated with a changing climate.

In summary, NOAA is striving to meet the rising demand for climate data and products, which support decision-making in a number of nationally significant industries including transportation. Government and industry leaders recognize the inherent value in planning for future climate change through an enhanced climate services partnership between the public and private sectors.

Mr. Chairman, thank you for inviting me to discuss the effects of climate change on our Nation's transportation operations and infrastructure. I look forward to working with the Committee on any further information you may require for your deliberations on this topic.

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