**Climate Change**

**Climate change, once considered an issue for a distant future, has moved firmly into the present. This report of the National Climate Assessment and Development Advisory Committee concludes that the evidence for a changing climate has strengthened considerably since the last National Climate Assessment report, written in 2009. Many more impacts of human-caused climate change have now been observed.**

**Americans are noticing changes all around them. Summers are longer and hotter, and periods of extreme heat last longer than any living American has ever experienced. Winters are generally shorter and warmer. Rain comes in heavier downpours, though in many regions there are longer dry spells in between.**

**Other changes are even more dramatic. Residents of some coastal cities see their streets flood more regularly during storms and high tides. Inland cities near large rivers also experience more flooding.**

**Scientists studying climate change confirm that these observations are consistent with Earth’s climatic trends. Long-term, independent records from weather stations, satellites, ocean buoys, tide gauges, and many other data sources all confirm the fact that our nation, like the rest of the world, is warming, precipitation patterns are changing, sea level is rising, and some types of extreme weather events are increasing. These and other observed climatic changes are having wide-ranging impacts in every region of our country and most sectors of our economy.**

**Transportation systems influence future climate characteristics and are also affected by changes in the climate. In 2010, the U.S. transportation sector accounted for 27% of U.S. greenhouse gas emissions (also called heat-trapping gas emissions) (Source: EPA 2011). Petroleum accounts for 93% of the nation’s transportation energy use (EIA 2011), while cars and trucks account for 65% of transportation emissions (EPA 2011). 5**

**Past emissions of heat-trapping gases have already committed the world to a certain amount of future climate change. How much more the climate will change depends on** **future emissions and the sensitivity of the climate system to those emissions.**

**A certain amount of climate change is already inevitable due to the build-up of CO2 in the atmosphere from human activities over the past few centuries. Even if the net CO2 emissions could be reduced to zero today, the human-induced perturbation to the global carbon cycle would persist for thousands of years (NRC 2011). Because global emissions of CO2 and other heat trapping gases continue to rise, exactly how much climate will change over this century and beyond depends primarily on two factors: 1) the amount of human activities and resulting emissions; and 2) how sensitive the climate is to those changes (the responsiveness of temperature to a change in radiative forcing). However, a series of plausible projections of what might happen, under a given set of assumptions, can and have been developed. These scenarios describe the future in terms of population, energy sources, technology, heat-trapping gas emissions, atmospheric levels of carbon dioxide, and/or global temperature change.**

**1. Although climate changes in the past have been caused by natural factors, human** **activities are now the dominant agents of change. Human activities are affecting** **climate through increasing atmospheric levels of heat-trapping gases and other** **substances, including particles.**

**2. Global trends in temperature and many other climate variables provide consistent evidence of a warming planet. These trends are based on a wide range of observations, analyzed by many independent research groups around the world.**

**3. Natural variability, including El Niño events and other recurring patterns of ocean-** **atmosphere interactions, influences global and regional temperature and** **precipitation over timescales ranging from months up to a decade or more.**

**4. Human-induced increases in atmospheric levels of heat-trapping gases are the main cause of observed climate change over the past 50 years. The “fingerprints” of** **human-induced change also have been identified in many other aspects of the** **climate system, including changes in ocean heat content, precipitation, atmospheric** **moisture, and Arctic sea ice.**

**5. Past emissions of heat-trapping gases have already committed the world to a certain amount of future climate change. How much more the climate will change depends** **on future emissions and the sensitivity of the climate system to those emissions.**

**6. Different kinds of physical and statistical models are used to study aspects of past** **climate and develop projections of future change. No model is perfect, but many of** **them provide useful information. By combining and averaging many models, many clear trends emerge.**

**7. Scientific understanding of observed temperature changes in the U.S. has greatly** **improved, confirming that the U.S. is warming as expected in response to global** **climate change. This warming is expected to continue.**

**8. Many other indicators of rising temperatures have been observed in the U.S. These include reduced lake ice, glacier retreat, earlier melting of snowpack, reduced lake** **levels, and a longer growing season. These and other indicators are expected to continue to reflect higher temperatures.**

**9. There have been observed trends in some types of extreme weather events, and these are consistent with rising temperatures. These include increases in: heavy precipitation nationwide, especially in the Midwest and Northeast; heat waves, especially in the West; and the intensity of Atlantic hurricanes. These trends are** **expected to continue. Research on climate changes’ effects on other types of extreme events continues.**

**10. Drought and fire risk are increasing in many regions as temperatures and evaporation rates rise. The greater the future warming, the more these risks will increase, potentially affecting the entire U.S.**

**11. Summer Arctic sea ice extent, volume, and thickness have declined rapidly, especially north of Alaska. Permafrost temperatures are rising and the overall amount of permafrost is shrinking. Melting of land and sea-based ice is expected to** **continue with further warming.**

**12. Sea level is already rising at the global scale and at individual locations along the U.S. coast. Future sea level rise depends on the amount of temperature change and on the ice melt around the world as well as local processes like changes in ocean currents and local land subsidence or uplift.**

1. **The impacts from sea level rise and storm surge, extreme weather events, higher** **temperatures and heat waves, precipitation changes, Arctic warming, and other** **climatic conditions are reducing the reliability and capacity of the U.S. transportation system in many ways.**
2. **Sea level rise, coupled with storm surge, will continue to increase the risk of major coastal impacts, including both temporary and permanent flooding of airports,** **ports and harbors, roads, rail lines, tunnels, and bridges.**
3. **Extreme weather events currently disrupt transportation networks in all areas of the country; projections indicate that such disruptions will increase.**

**Past observations, including both recent measurements as well as studies that look at climate changes in the distant past, can’t tell us precisely how sensitive the climate system will be to increasing emissions of heat-trapping gases if we are starting from today’s conditions. They can tell us, however, that the net effect of these feedbacks will be to increase, not diminish, the direct warming effect. In other words, the climate system will warm by more than would be predicted from the greenhouse effect alone.**

**From a large number of independent datasets and analyses, it appears that the best estimate of climate sensitivity is about 5.4ºF (3ºC), with a likely range from 3.5ºF to 8ºF (for a doubling of the CO2 concentration from preindustrial levels). This sensitivity includes feedbacks that respond to global temperature change over timescales of years to decades. These “fast” feedbacks include increases in atmospheric water vapor, reduction of ice and snow, warming of surface ocean temperature, and changes in cloud characteristics. The entire response of the climate system will not be seen until the deep ocean comes into balance with the atmosphere, a process that can take thousands of years.**

**Combining the uncertainty due to climate sensitivity with the uncertainty due to human activities produces a range of future temperature changes that overlap over the first half of this century, but begins to separate over the second half of the century as atmospheric CO2 levels diverge.**

**As discussed previously in Key Message 3, interactions among various components of the Earth’s system produce patterns of natural variability that can be chaotic, meaning that they are sensitive to the initial conditions of the climate system. These patterns can affect global and regional climate on time scales ranging from years to a decade or more. Over climatological time.**