Climate Change Science and Modeling: What You Need to Know Narration Script

1. Title Slide
   a. Climate Change Science and Modeling: What You Need to Know
2. Introduction
   a. In recent decades, many changes in the climate and in forest ecosystems have been observed in the United States.
   b. Temperature is increasing. In the last 50 years, temperature has risen 1 to 2 degrees Fahrenheit in most of the United States, but temperature in Alaska has increased twice as much as the rest of the country. Minimum temperatures are increasing faster than maximum temperatures, and minimum temperatures in urban areas are increasing about 25 percent faster than in rural areas.
   c. Precipitation patterns are changing. Snowfall is decreasing on both the west and east coasts. Snowpack is decreasing in the northern Rocky Mountains and elsewhere in the United States. Many glaciers in the Northwest and Alaska are losing mass and receding. Across the Midwest, the frequency of heavy precipitation events has more than doubled from 1961 to 2011.
   d. Dry episodes are increasing in the West, Southwest, and Southeast. Particularly in the West and Southwest, droughts are longer, more severe, and more frequent, leading to water stress, low soil moisture, and low river flows.
   e. Invasives, pests, and diseases are increasing. Close to 10 million acres of forest have been killed in the United States by epidemics of bark beetles. The growing season is increasing across the country, which may actually benefit forest and grassland ecosystems and croplands. But longer growing seasons are beneficial for invasives and pests too.
   f. Wildfire activity is also changing. Annual area burned in the West has increased since the 1980s, and the length of fire season is increasing.
   g. These changes are actually only a few examples of what is occurring across the United States. To better understand how and why these changes are important, and to begin planning how to cope with them in ecosystem management, we need to understand some basic information on climate, climate change, and future climate projections.
3. Weather Versus Climate

a. Weather and climate are two different things, although they are related. Weather is a short-term trend, such as daily or monthly changes. Climate is a long-term trend, generally occurring over 30 years or more. Weather can be described as your daily outfit, while climate is your entire wardrobe.

4. Climate Change/Increasing Temperature

a. The global climate is changing. The Intergovernmental Panel on Climate Change, or the IPCC, is a partnership of thousands of scientists from around the globe that reviews and assesses the most recent scientific, technical, and socio-economic information produced worldwide on climate change. The IPCC has stated that there is no doubt that global temperatures have been rising over the last 50 years. The average global temperature has increased by 1.4 degrees Fahrenheit, although specific regions may vary from the average.

b. For example, the average temperature in the United States has risen more than 2 degrees Fahrenheit during that same time period.

5. Milankovitch Cycle

a. In the past hundreds of thousands of years, major fluctuations in climate have been driven by changes in the Earth's movements, called Milankovitch Cycles. The way the Earth moves and tilts on its axis as it orbits the sun affects the angle at which sunlight travels through our atmosphere, ultimately affecting our climate.

b. Natural climate cycles, like the Milankovitch Cycles, repeatedly cause global surface temperature changes, leading to changes in ocean temperature and the amount of carbon dioxide released into the atmosphere. When these cycles cause increased temperatures, additional carbon dioxide is released into the atmosphere from the land and oceans, which amplifies the temperature increases. These natural climate cycles last tens of thousands of years and generally shift slowly from the perspective of humans.

c. This graph shows temperature in blue and atmospheric carbon dioxide in yellow. The temperatures increase first in these natural cycles, and carbon dioxide follows with a lag of several hundred years. At the right edge of the graph there is a recent large spike in the yellow carbon dioxide data. This is where the carbon dioxide increase now precedes the temperature change. This recent atmospheric carbon dioxide spike is primarily caused by humans and is outside of the pattern of natural cycles over the last 400,000 years. This means that humans are now effectively overriding the natural climate cycle, and the resulting climate shifts are happening very rapidly.

6. Greenhouse Gas Causes
    a. The current changes in our climate are caused by increases in greenhouse gases in the atmosphere. These increases come primarily from our use of fossil fuels and deforestation, which is often considered a part of land-use change.
7. Main Greenhouse Gases
    a. Increases in greenhouse gases, from human-caused sources or otherwise, add to the natural greenhouse gas effect. Carbon dioxide, halocarbons, methane, nitrous oxide, and water vapor are all important greenhouse gases, but carbon dioxide, methane, and water vapor are talked about most often. The generation of electricity from fossil fuels is a large source of carbon dioxide emissions. The use of fossil fuels also releases methane, as do livestock, farming, and landfills. It surprises many people that water vapor is also an important greenhouse gas. The primary sources of atmospheric water vapor are oceans and other large bodies of water, and water vapor from these sources increases when temperatures rise.
    b. Greenhouse gas emissions from fossil fuels are effectively an addition to the climate system and can persist for many years or decades. Water vapor, however, is transitory, mostly driven by temperature, and leaves the atmosphere quickly. Atmospheric lifetime is the average time a gas molecule spends in the atmosphere. The atmospheric lifetime of carbon dioxide is on the timescale of decades. The lifetime of methane is on the timescale of years, and lifetime of water vapor is days. As these greenhouse gases have increased in the atmosphere, the amount of energy and heat in the atmosphere has increased, disrupting the global climate system.
8. Greenhouse Effect – 1
    a. The greenhouse effect is a natural process involving the interaction of sunlight and certain gases. Sunlight is high-energy, short-wave radiation. About 30 percent of this energy is reflected back into space by the atmosphere, clouds, and surface of the Earth. The remaining energy is absorbed by the Earth.
9. Greenhouse Effect – 2
    a. The Earth emits long-wave, infrared radiation into the atmosphere. Some of the radiation passes through the atmosphere into space, but most of the long-wave

radiation is absorbed by greenhouse gases. The greenhouse gases then re-emit the energy in all directions, which causes warming at the Earth's surface and lower atmosphere. Without the greenhouse effect the average temperature on Earth would be about 0 degrees Fahrenheit. The increase in atmospheric concentration of greenhouse gases through human activities amplifies the natural effect by absorbing and re-emitting more energy, causing global surface temperatures to increase.

10. Carbon Dioxide Measurements
    a. Carbon dioxide has been monitored at the Mauna Loa Observatory in Hawaii since the late 1950s. During this time, atmospheric carbon dioxide has steadily increased. The high-low pattern of observations shows the seasonal influence of vegetation in the Northern Hemisphere, which you can also see in this video from NASA. During the spring and summer in the Northern Hemisphere, vegetation grows and photosynthesis occurs, slightly lowering the amount of carbon dioxide in the atmosphere. During the fall and winter, growth stalls, and the carbon dioxide levels rise again.
    b. This graph shows greenhouse gas levels over the past 2,000 years for carbon dioxide, in green; methane, in yellow; and nitrous oxide, in dark blue. Increases in concentrations since 1750 are primarily caused by human activities.

11. Carbon Cycle
    a. The carbon cycle is the flow of carbon through the atmosphere, ocean, vegetation, soil, and the Earth's rocky crust and upper mantle known as the lithosphere. In this graphic, down arrows indicate carbon sinks—this is where carbon is absorbed from the atmosphere. The up arrows represent sources—this is where carbon is released into the atmosphere. Vegetation acts as both a source and a sink through natural processes of respiration and photosynthesis, and wildfire can also be a significant source of carbon. Human-caused changes in land use add carbon to the atmosphere, often through vegetation clearing and burning, as well as soil disruption. Soils store large amounts of carbon, but also release some of that carbon through organic matter decomposition. Fossil fuels, such as oil and coal, are pools of carbon that were stored for millions of years, and humans are now extracting and burning these carbon pools, releasing them to the atmosphere. Carbon is readily transferred between the surface of the ocean and the atmosphere, and the deep ocean acts as a sink for carbon.

b. Carbon cycling between the atmosphere and land, and atmosphere and ocean, is nearly balanced. The numbers next to the carbon cycle source and sink arrows show the gigatons—1 gigaton equals 1 billion tons—of carbon per year flowing through that part of the cycle. The numbers in parentheses show the total size of the carbon pool in gigatons. The large bold numbers indicate the size of net sources or sinks. Both land and ocean are net sinks for carbon, meaning that slightly more carbon enters those pools than leaves. Photosynthesis absorbs about 122 gigatons of carbon, and plant respiration and decomposition almost counter that by releasing about 60 gigatons of carbon each. Surface mixing between the ocean and atmosphere is nearly balanced, but the ocean takes up about 2 gigatons more carbon than it releases.

c. U.S. forests are an important carbon sink, providing the largest annual offset of carbon dioxide emissions of any other land use in the country. In fact, 15.8 percent of U.S. carbon dioxide emissions were sequestered in forests and long-lasting wood products in 2011, according to the USDA Forest Service Forest Inventory Analysis. In spite of the important annual carbon sinks into the land and ocean, fossil fuel combustion and landuse change still result in a net addition to the atmosphere of about 5 gigatons of carbon every year.

12. Regional Observed Changes in Climate

a. A number of effects from climate change are being observed nationally and globally. Here are a few examples of the trends observed around the country. The Northeast is experiencing a rise in sea level and increases in heavy precipitation. Ocean surface temperatures are rising in the Southeast, which interacts with the severity of hurricane events. The Midwest is experiencing a decrease in lake ice. Temperatures and water stress are increasing in the Great Plains. The Northwest is experiencing changes in snowpack levels and the proportion of precipitation falling as snow. The severity of drought is increasing in the Southwest, resulting in low river flows. The Islands region is experiencing a rise in sea level. Finally, the size and frequency of wildfire is increasing in Alaska.

13. General Circulation Models

a. General circulation models, often called GCMs, are used to simulate the global climate system and its response to increasing greenhouse gas concentrations. These models are also known as global climate models, and they contain components from the ocean, atmosphere, land surface, and solid water surfaces, known as the cryosphere. General circulation models are global models that simulate global climate over very large areas. For information specific to smaller regions, other models may need to be used or outputs from the global models may need to be downscaled. If some of the general circulation model components, like albedo or radiation, are unfamiliar to you, click on the bullets to learn more.

14. General Circulation Model Uncertainty
    a. General circulation models are just that: models. They are not 100 percent accurate at reproducing the climate system because the climate system is so complex. Most of the uncertainty in the models comes from the complexities of cloud dynamics, forcings, extremes, and feedbacks – all of which vary through space and time. If you are uncertain about some of these terms, like forcings, which are factors that force the climate system and energy balance of the Earth, then click on the circles to learn more.
    b. Although there is uncertainty in the general circulation models, the models still do a good job of replicating past climate and projecting ranges of reasonable future climates. There is scientific consensus that the global climate is changing and causing wide-ranging effects, and in spite of uncertainties, we know enough about the climate system to engage in responsible planning for a plausible range of climate futures.
15. Uncertainty With Climate Change
    a. Climate change adds uncertainty to the future, because we can't rely on climate conditions in the future to be the same as those in the past.
    b. For example, every decade since the 1980s has been the warmest decade on record. Each individual year in the 1990s was warmer than the average for the 1980s, and the same thing occurred in the 2000s, with each year of the 2000s warmer than the 1990s average.
    c. For these reasons, it's important to consider a range of potential future conditions.
16. Emissions Scenarios
    a. Emissions scenarios provide a range of possible future greenhouse gas emissions based on expectations about future demographics, economics, and technology. They are used as inputs into general circulation models. The IPCC fourth assessment report used four scenario families, each with differing projections and expectations. The fifth IPCC assessment report did not use these same emissions scenarios. Instead, the IPCC used

representative concentration pathways, known as RCPs, which are specific emissions trajectories leading to a set radiative forcing.

17. Emissions Scenarios Continued
    a. All climate models project there will be further warming in the future, but the extent of projected warming depends on the different emissions scenarios or representative concentration pathways. Higher emissions scenarios would result in larger temperature increases than lower emissions scenarios.
    b. This graph shows temperature increases across the United States. As each pathway leads to a higher radiative forcing, the United States is getting warmer and the colors transition into red.
18. Projected Changes in Climate
    a. The average global temperature is projected to rise another 2 to 11.5 degrees Fahrenheit by 2100, depending upon future greenhouse gas emissions and sensitivity of the climate system to those increases.
    b. Many of the effects currently observed are expected to continue, and often intensify. Besides warmer temperatures, these include rising sea levels, increases in extreme events, retreat of glaciers, and changing precipitation patterns.
    c. These projected future impacts will vary by region.