OLR RESEARCH REPORT

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IPCC REPORT ON THE PHYSICAL SCIENCE OF CLIMATE CHANGE

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You asked for a summary of the recent Intergovernmental Panel on Climate Change (IPCC) report on the physical science basis of climate change. This memo is based on the report's Summary for Policymakers and Technical Summary, which are both available at http://www.ipcc.ch/. The report was accepted, but not approved in detail, by the IPCC's Working Group I on September 26, 2013. As a result, it should be considered a draft, rather than final, product.

This memo focuses on the aspects of the report that are most relevant to Connecticut, global warming and changes in sea level and precipitation patterns. Other issues addressed in the report include climate modeling and changes in ocean chemistry, glaciers and Arctic and Antarctic ice sheets, and climate phenomena such as monsoons.

SUMMARY

Among the report's key findings are:

1. Climate warming is unequivocal. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of carbon dioxide (CO_2) and other greenhouse gases have increased.

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2. Each of the last three decades has been successively warmer at the earth's surface than any preceding decade since 1850. In the northern hemisphere, 1983–2012 was very likely the warmest 30-year period of the last 800 years.

3. It is extremely likely that human influence has been the dominant cause of the warming observed since the mid-20th century.

4. Continued emissions of greenhouse gases will cause further warming. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

5. Global surface warming for the end of the 21st century is likely to exceed 1.5°C relative to the 1850 to 1900 baseline and will continue beyond 2100.

6. More than 90% of the energy accumulated between 1971 and 2010 has been stored in the oceans.

7. The oceans' volume has increased due to this warming and this, combined with melting of glaciers and ice sheets, has caused sea levels to rise.

8. The rate of sea level rise since the mid-19th century has been larger than the mean (average) rate during the previous two thousand years. From 1901 to 2010, global mean sea level rose by 0.19 meters (7.4 inches).

9. Global mean sea level will continue to rise during the 21st century at a rate that will very likely exceed that observed during 1971–2010.

10. Extreme precipitation events (e.g., downpours) over most of the mid-latitudes (e.g., Connecticut) will very likely become more intense and more frequent by the end of this century.

According to the report, most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped.

On the other hand, there are variables where the data are not clear. For example, the report notes that there are no clear trends in annual numbers of tropical storms, hurricanes, and major hurricanes over the past 100 years in the North Atlantic basin. It expresses low confidence, on a global scale, that climate change will increase the intensity or

duration of droughts. In addition, warming has varied and, according to the report, will continue to vary from year to year and decade to decade and will not be uniform across regions.

The report's findings and projections are generally similar to those in IPCC's last assessment of the climate. This report is more confident that climate change is largely due to anthropogenic (human-made) forces. On the other hand, it projects that a doubling of CO_2 concentrations may have less impact on temperature than IPCC previously projected.

PROCESS

The report will become part of the fifth IPCC assessment on climate change. Each assessment consists of three reports compiled by separate working groups. This memo describes the first report, which covers the basic science of climate change. The subsequent reports will address (1) climate change impacts, adaptation, and vulnerability (to be issued in mid-March 2014) and (2) mitigation of climate change (to be issued in early April 2014). IPCC will release a synthesis of these reports in October 2014.

This initial report discusses new evidence of climate change based on scientific analyses from observations of the climate system, paleoclimate archives, theoretical studies of climate processes, and simulations using climate models. Observations of the climate are based on instrument measurements and remote sensing from satellites and other platforms. Since the mid-19th century instruments have been used globally to measure temperature and other variables, with more comprehensive and diverse sets of observations available from 1950 onwards. Paleoclimate reconstructions extend some records back hundreds to millions of years.

The IPCC itself does not carry out research or monitor climate related data. Instead, the authors of IPCC reports assess available information about climate change, drawn mainly from the peer reviewed and published scientific and technical literature. Authors are chosen from a list of researchers prepared by governments and participating scientific organizations, as well as other experts known through their published work. Authors are chosen to represent a range of views and areas of expertise, as well as geographical representation.

TERMINOLOGY

Table 1 describes the terms the report primarily uses to describe the probability of only future events. It also uses the terms extremely likely (95–100% probability), more likely than not (>50–100% probability), and extremely unlikely (0–5% probability).

Table 1: Terms Used to Describe Probability

Term	*Probability*
Virtually certain	99–100%
Very likely	90–100%
Likely	66–100%
About as likely as not	33–66%
Unlikely	0–33%
Very unlikely	0–10%
Exceptionally unlikely	0–1%

GLOBAL WARMING

Historical Data

The report states that it is "certain" that the global mean surface temperature has increased since the late 19th century. Each of the past three decades has been warmer than all the previous decades since instruments have recorded temperatures, and the 2000-2010 decade was the warmest since records have been kept. The global combined land and ocean temperature data showed an increase of about 0.89°C from 1901 to 2012. About 80% of this increase occurred since 1951. It is also virtually certain that both high and low temperature extremes have warmed over most land areas since the mid-20th century.

Despite these clear trends, temperatures vary substantially from year to year and decade to decade. The rate of warming from 1998 to 2012 was 0.05°C per decade, somewhat less than half the 0.12°C per decade trend since 1951. There are also variations in where the warming occurs. For example, warming has slowed in the past 15 years in the upper layers of the ocean, while it has continued at a generally constant pace in the lower levels of the ocean.

Causes

According to the report, human influence on climate has been detected in (1) warming of the atmosphere and oceans, (2) reductions in snow and ice, (3) global sea level rise, and (4) changes in some climate extremes. This evidence for human influence has grown since the last IPCC assessment. The current assessment finds that it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.

According to the report, human influence is clear from the increasing greenhouse gas concentrations in the atmosphere and positive radiative forcing, as well as observed warming. The atmospheric concentrations of CO_2, methane, and nitrous oxide are at levels not seen in at least the last 800,000 years. CO_2 concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from emissions associated with changes in land use, e.g., deforestation.

The report uses the term "radiative forcings" (RF) to describe the impact of anthropogenic (human-made) and natural phenomena on temperatures. Radiative forcings are measured in watts per square meter; positive numbers reflect warming, while negative numbers reflect cooling.

The report states that the largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2. The increase in RF from emissions of CO_2 and other greenhouse gases was 3.0 watts per square meter from 1750 to 2011. These warming trends were partially offset by increases in aerosol emissions (e.g., soot), which reduced RF by 0.9 watts per square meter during this period.

The report states that the total RF from natural forces, such as changes in energy coming from the sun and volcanic eruptions, made only a small contribution to the increase in radiative forcing throughout the last century, except for brief periods after large volcanic eruptions.

Projections

The report projects future changes to the climate using a set of scenarios with varying levels of CO_2 concentration in the atmosphere. The concentrations range from 421 parts per million (ppm) to 936 ppm by the year 2100. In all of these scenarios, atmospheric CO_2 concentrations are higher in 2100 than today (the September 2013 level

was 393 ppm) due to a further increase of cumulative CO_2 emissions during the 21st century. Projected climate change under all of these scenarios is similar to those made in the last IPCC assessment in both patterns and magnitude.

Under these scenarios, the global mean surface temperature for the period 2016–2035 will likely be 0.3°C to 0.7°C higher than the average for the period 1986-2005, assuming there are no major volcanic eruptions or long-term changes in the amount of energy coming from the sun. In all but the lowest concentration scenario, the global surface temperature change by 2100 is likely to exceed 1.5°C relative to the 1850 to 1900 baseline.

SEA LEVEL RISE

Historic Data

The report finds that, based on instrumental and proxy data, it is virtually certain that the average rate of global sea level rise has accelerated during the last two centuries. It is very likely that the average rate was 1.7 millimeters (1/16 inch) per year between 1901 and 2010 for a total sea level rise of 0.19 meters (7.5 inches). Between 1993 and 2010, the rate was very likely 3.2 millimeters per year (1/8 inch); similar rates likely occurred between 1930 and 1950.

Causes

Water expands in volume as it gets warmer. According to the report, this expansion and glacier melting have been the dominant contributors to 20th century global sea level rise. Observations since 1971 indicate that thermal expansion and glaciers (excluding the glaciers in Antarctica) explain 75% of the observed rise.

Projections

According to the report, it is very likely that the rate of global sea level rise during the 21st century will exceed the rate observed from 1971 to 2010 due to increased ocean warming and the shrinkage of glaciers and ice sheets. For the period 2081–2100, compared to 1986–2005, global average sea level rise is likely to be 0.26–0.54 meters (10.25 to 21.25 inches) for the lowest emission scenario to 0.53–0.97 meters (21 to 38 inches) for the highest emission scenario.

The report's authors considered the evidence for higher projections but concluded that there is currently insufficient evidence to evaluate the probability of specific levels above the likely range. Based on the current understanding, only the collapse of sea-based sectors of the Antarctic Ice Sheet could cause global average sea level to rise substantially above the likely range during the 21st century. This potential additional rise cannot be precisely quantified but there is medium confidence that it would not exceed several tenths of a meter of sea level rise during the 21st century.

According to the report, it is virtually certain that global mean sea level rise will continue beyond 2100, with sea level rise due to thermal expansion to continue for many centuries. Longer term sea level rise depends on future emissions.

The report believes that it is very likely sea level change will vary regionally in the 21st century and beyond, with some places experiencing significant deviations of local and regional sea level change from the global mean change. Shifting surface winds, the expansion of warming ocean water, and the addition of melting ice can alter ocean currents, leading to changes in sea level that vary from place to place. Over a period of a decade or more, the rates of regional sea level change as a result of climate variability can differ from the global average rate by more than 100%.

CHANGES IN PRECIPITATION

Historic Data

The report notes that confidence in precipitation change averaged globally over land areas is low before 1950 and only medium afterwards because of insufficient data, particularly in the earlier part of the instrumental record. It is likely that the number of heavy precipitation events over land has increased in more places than it has decreased since the mid-20th century, and there is medium confidence that anthropogenic forcing has contributed to this increase.

According to the report, it is unclear whether more land areas have been affected by drought since the mid-20th century. This uncertainty is due to the limited quantity and quality of direct observations, among other things.

Projections

According to the report, it is virtually certain that future precipitation change will vary regionally, increasing in some regions and decreasing in some others. For the near- and long-term, the report confirms a clear tendency for increases in heavy precipitation events that was projected in the last IPCC assessment, but there are substantial variations across regions. The report projects that extreme precipitation events over most mid-latitude land masses (which include Connecticut) will very likely become more intense and more frequent by the end of this century, as global mean surface temperature increases.

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