Highlights of the
IPCC 5th Assessment Report: The Physical Science Basis of Climate Change (WGI)
Summary for Policymakers
&
Implications for the US Fish and Wildlife Service

US Fish & Wildlife Service
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Introduction

- The **Intergovernmental Panel on Climate Change** (**IPCC**) was first established in 1988 by the World Meteorological Organization and United Nations Environment Programme. Its mission is to provide comprehensive scientific assessments of the most recent scientific, technical and socio-economic information relevant to the understanding of climate change, its potential environmental and socio-economic consequences, and possible options for adapting to or mitigating its effects.

- The IPCC is organized into three Working Groups and a Task Force. Working Group I deals with "The Physical Science Basis of Climate Change", Working Group II with "Climate Change Impacts, Adaptation and Vulnerability", and Working Group III with "Mitigation of Climate Change". Approximately every six years the IPCC issues an overall assessment report (AR) consisting of reports from Working Groups I, II, and III.

- At the end of September 2013, the IPCC issued the Working Group I (WGI) report of its 5th Assessment Report (AR5). This document highlights the findings of the WGI report – as described in its "Summary for Policymakers." This document also discusses implications of these findings for US Fish and Wildlife Service planning and resources management.

- We note that the degree of certainty in key findings in the WGI report is based on the author teams' evaluations of underlying scientific understanding and is expressed as a qualitative level of confidence (from *very low* to *very high*) and, when possible, probabilistically with a quantified likelihood (from *exceptionally unlikely* to *virtually certain*). These terms are defined in the appendix to this document.

Key Findings

Observed Changes in the Climate System

- Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.

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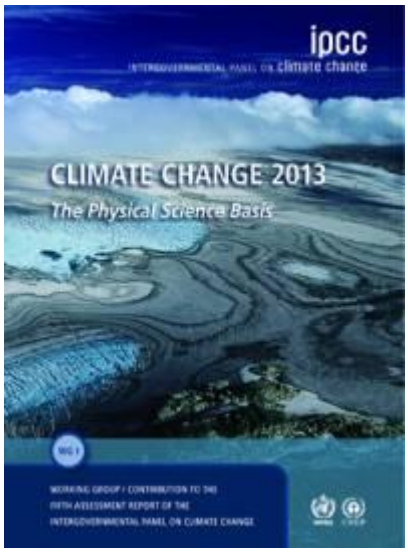
Understanding the Climate System and its Recent Changes

Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing (balance of incoming and outgoing energy), observed warming, and understanding of the climate system.

Future Global and Regional Climate Change

Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

Please refer to the Summary for Policymakers for more details and the location of supporting information within the body of the WGI report. http://www.climatechange2013.org/report/



Atmosphere

What changes have already been observed?

- 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 likely the warmest 30-year period of the last 1400 years (*medium confidence*).

- The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 1.5 [1.2 to 1.9] ^{o}F or 0.85 [0.65 to 1.06] °C, over the period 1880–2012, when multiple independently produced datasets exist.

- In addition to robust multi-decadal warming, global mean surface temperature exhibits substantial decadal and inter-annual variability. Due to natural variability, trends based on short records are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends.

- *Confidence* in precipitation change averaged over global land areas since 1901 is *low* prior to 1951 and *medium* afterwards. Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901 (*medium confidence* before and *high confidence* after 1951).

- Changes in many extreme weather and climate events have been observed since about 1950.
    - It is *very likely* that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale.
    - The frequency or intensity of heavy precipitation events has *likely* increased in North America and Europe.

Implications for USFWS

- Increasing temperatures over the 20th century have already affected the distribution and phenology of many plant and animal species in North America. Distribution shifts have most frequently been poleward and higher in elevation (Chen et al. 2011) although this may not always be the case (Crimmins et al. 2011). Phenological changes have been associated with flowering in plants (Cleland et al. 2007), migration in a variety of animal species (Hurlbert and Liang 2012), and even entire communities (Ovaskainen et al. 2013). Changes in distribution and phenology are of concern to Service Refuge managers, T&E biologists, migratory bird specialists, and fish biologists as these changes are likely to affect species and habitat management (e.g., Caplat et al. 2013; Price and Root 2005).

- Air temperature increases have already led to rising stream and river temperatures (Kaushal et al. 2010), with concomitant effects on the flora and fauna of those water bodies (Isaak et al. 2010).

- The global average temperature increase reported in the WG I report does not necessarily reflect hemispheric (e.g., Northern Hemisphere), continental (e.g., North America) or regional (e.g., Alaska) temperature changes that have occurred. For example, it is generally agreed that temperature increases in Alaska have been greater than the global average (http://www.nesdis.noaa.gov/technical_reports/NOAA_NESDIS_Tech_Report_142-7-Climate_of_Alaska.pdf). Service biologists and planners should consult regional and local publications for appropriate temperature increase data for their region. Such publications would

include the climate analyses performed by NOAA for the draft National Climate Assessment (http://www.nesdis.noaa.gov/technical_reports/142_Climate_Scenarios.html).

- Due to natural variability, temperature trends based on a short period of records – such as the last 15 years -- are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends. Thus, short-term trends should not be used to support arguments that global warming is accelerating or slowing down. Conclusions regarding the rate of global warming should be based on records spanning at least a 20-30 year period, preferably longer (see, for example: http://www.pbmc.coppe.ufrj.br/pt/noticias/381-has-global-warming-stopped).

- The general precipitation increase over the Northern Hemisphere reported in the WG I report does not necessarily reflect continental (e.g., North America) or regional (e.g., Desert Southwest) precipitation changes. Service biologists and planners should consult regional publications for appropriate precipitation data for their region. Such publications would include the climate analyses performed by NOAA for the draft National Climate Assessment (http://www.nesdis.noaa.gov/technical_reports/142_Climate_Scenarios.html).

- The likely increase in the frequency or intensity of heavy precipitation in North America has possibly contributed to more and larger flooding events in some areas. The National Climate Assessment discusses observed changes in flooding events throughout the United States (Draft National Climate Assessment, Chapter 3; Draft National Climate Assessment, Chapter 2).

What Changes are Projected to Occur Globally and Regionally?

- Global surface temperature change for the end of the 21st century is *likely* to exceed 2.5°F (1.5°C) relative to 1850 to 1900 for all Representative Concentration Pathway (RCP)[2] scenarios except RCP2.6. GST change is likely to exceed 3.6°F (2°C) for RCP6.0 and RCP8.5, and *more likely than not* to exceed 3.6°F (2°C) for RCP4.5.

- The global mean surface temperature change for the period 2016–2035 relative to 1986–2005 will *likely* be in the range of 0.5°F to 1.3°F (0.3°C to 0.7°C) (*medium confidence*). This assessment is based on multiple lines of evidence and assumes there will be no major volcanic eruptions or secular changes (i.e., long-term non-periodic variation) in total solar irradiance.

- Warming will continue to exhibit inter-annual-to-decadal variability and will not be regionally uniform.

- It is *virtually certain* that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase.
    - It is *very likely* that heat waves will occur with a higher frequency and duration.
    - Occasional cold winter extremes will continue to occur

[2] Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5). The pathways are used for climate modeling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 (+2.6, +4.5, +6.0, and +8.5 W/m2, respectively). Thus, RCP2.6 represents the lowest greenhouse gas concentrations and least warming, while RCP8.5 represents the greatest greenhouse gas concentrations and the most warming.

- Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions.

- Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will *very likely* become more intense and more frequent by the end of this century, as global mean surface temperature increases.

- There is *high confidence* that the El Niño-Southern Oscillation (ENSO) will remain the dominant mode of inter-annual variability in the tropical Pacific, with global effects in the 21st century. Due to the increase in moisture availability, ENSO-related precipitation variability on regional scales will *likely* intensify.

Implications for USFWS

- Temperature increases will continue contributing to changes in distribution and phenology in many North American species (Lawler et al. 2009). Managers and planners will need to factor in these changes to management activities as well as refuge and landscape plans under development. (see, for example: Shafer et al. 2011).

- Warming air temperatures will also affect stream temperatures (Wu et al. 2012), affecting the flora and fauna therein.

- Warming trends will vary regionally. Service biologists and planners should consult regional publications for appropriate temperature projections for their region. Such publications would include the climate analyses performed by NOAA for the draft National Climate Assessment (http://www.nesdis.noaa.gov/technical_reports/142_Climate_Scenarios.html).

- A temperature increase of 3.6°F (2°C) has been put forward by many reputable climate scientists as the threshold for "dangerous climate change." As Hansen et al. (2013) have stated: "Emissions of ~1000 GtC, sometimes associated with 2°C global warming, would likely spur "slow" feedbacks and thus ultimately cause warming of 5.4-7.2°F (3-4°C) with disastrous consequences. Rapid emissions reduction is required to restore Earth's energy balance and avoid ocean heat uptake that would practically guarantee irreversible effects." (Hansen et al. 2013)

- An increase in heat waves could contribute to increased stress to wildlife populations and their habitats, especially in conjunction with drought (e.g., Albright et al. 2010)

- Changes in precipitation will vary regionally and will affect runoff and flooding, especially combined with increasing temperatures that will affect runoff (Das et al. 2011; (Wu et al. 2012). Service aquatic biologists will be particularly concerned with these changes. Biologists should consult the draft National Climate Assessment (NCA) for regional assessments of increases or decreases in precipitation and their effects (e.g. Draft National Climate Assessment, Chapter 3; Draft National Climate Assessment, Chapter 2). The draft NCA states:
    - Annual precipitation and runoff increases are observed now in the Midwest and Northeast regions and are projected to continue or develop in the northern states; decreases are observed and projected in southern states.
    - Floods are projected to intensify in most regions of the U.S., even in areas where average annual precipitation is projected to decline, but especially in areas that are expected to become wetter, such as the Midwest and the Northeast.

Oceans

What changes have already been observed?

- Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (*high confidence*).

- It is *virtually certain* that the upper ocean (0-2,300 feet; 0-700 meters) warmed from 1971 to 2010, and it *likely* warmed between the 1870s and 1971.

- Ocean acidification is quantified by decreases in pH.[3] The pH of ocean surface water has decreased by 0.1 pH units since the beginning of the industrial era (*high confidence*), corresponding to a 26% increase in hydrogen ion concentration.

Implications for USFWS

- Ocean warming has contributed to sea level rise through thermal expansion of the warmer water (see section on sea level rise.) Sea level rise is already affecting coastal Refuges, particularly on the eastern and Gulf coasts, and Refuge managers will need to consider sea-level rise in planning and management.

- Ocean warming has contributed to ecological changes in marine systems (Helmuth et al. 2013). Marine fishes and invertebrates respond to ocean warming through distribution shifts, generally to higher latitudes and deeper waters (Pinsky et al. 2013). These shifts can also affect other trophic levels in marine systems, such as the distribution and abundance of seabirds (Sydeman et al. 2012). Service seabird specialists should consider these effects in their management of seabirds, especially breeding colonies. Marine mammals may also be affected (Moore and Huntington 2008).

- Ocean acidification is affecting a diversity of marine organisms (Fabry et al. 2008). Research has already found that corals, coccolithophore algae, coralline algae, foraminifera, shellfish and pteropods experience reduced calcification or enhanced dissolution when exposed to elevated carbon dioxide (CO2) (Guinotte and Fabry 2008). Possible negative effects on coral reefs and shellfish populations should be monitored. Seabirds that feed on calciferous prey and migratory shorebirds that feed on shellfish could also be affected.

What Changes are Projected to Occur Globally and Regionally?

- The global ocean will continue to warm during the 21st century. Heat will penetrate from the surface to the deep ocean and affect ocean circulation.

[3] pH is a measure of the hydrogen ion concentration of a solution. Solutions with a high concentration of hydrogen ions have a low pH (and are more acidic) and solutions with a low concentrations of hydrogen ions have a high pH (and are more basic).

- It is *very likely* that the Atlantic Meridional Overturning Circulation (AMOC)[4] will weaken over the 21st century. It is *very unlikely* that the AMOC will undergo an abrupt transition or collapse in the 21st century for the scenarios considered.

- Further uptake of carbon by the ocean will increase ocean acidification.

Implications for USFWS

- Ocean warming will continue to contribute to sea level rise. Coastal Refuge managers will need to consider sea-level rise in planning and management. (see section on sea level rise.)

- Ocean warming will continue contributing to ecological changes in marine systems (e.g., corals (Frieler et al. 2013); fisheries (Hollowed et al. 2013)). Coral reef, seabird and marine mammal specialists will need to be aware of these changes, as they may affect population numbers and distribution.

- Ocean acidification and other biogeochemical responses will continue to affect a diversity of marine organisms (Mora et al. 2013; Wittmann and Portner 2013; Kroeker et al. 2013). Coral reefs and shellfish populations should be monitored. Seabirds that feed on calciferous prey and migratory shorebirds that feed on shellfish could also be affected.

[4] The Atlantic MOC (AMOC) consists of a near-surface, warm northward flow, compensated by a colder southward return flow at depth. Heat loss to the atmosphere at high latitudes in the North Atlantic makes the northward-flowing surface waters denser, causing them to sink to considerable depths. These waters constitute the deep return flow of the overturning circulation.

Ice Sheets (Cryosphere)

What changes have already been observed?

- Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent (*high confidence*).

- The annual mean Arctic sea ice extent decreased over the period 1979–2012 with a rate that was *very likely* in the range 3.5 to 4.1% per decade, and *very likely* in the range 9.4 to 13.6% per decade for the summer sea ice minimum (perennial sea ice). The average decrease in decadal mean extent of Arctic sea ice has been most rapid in summer (*high confidence*); the spatial extent has decreased in every season, and in every successive decade since 1979 (*high confidence*). There is *medium confidence* from reconstructions that over the past three decades, Arctic summer sea ice retreat was unprecedented and sea surface temperatures were anomalously high in at least the last 1,450 years.

- There is *high confidence* that permafrost temperatures have increased in most regions since the early 1980s. Observed warming was up to 5.4 ^{o}F (3 °C) in parts of Northern Alaska (early 1980s to mid-2000s) and up to 3.6 ^{o}F (2 °C) in parts of the Russian European North (1971–2010). In the latter region, a considerable reduction in permafrost thickness and areal extent has been observed over the period 1975–2005.

- There is *very high confidence* that the extent of Northern Hemisphere snow cover has decreased since the mid-20th century. Northern Hemisphere snow cover extent decreased 1.6 [0.8 to 2.4] % per decade for March and April, and 11.7 [8.8 to 14.6] % per decade for June, over the 1967–2012 period.

- Multiple lines of evidence support very substantial Arctic warming since the mid-20th century.

Implications for USFWS

- There has been an increasing loss of sea-ice habitat for sea ice-dependent species (e.g., polar bear, walrus and ice seals: Grebmeier et al. 2006; Kovacs et al. 2011) with some population-level effects observed (e.g., polar bears in western Hudson Bay, southern Beaufort Sea: Stirling 2002; Regehr et al. 2007). Summer sea ice losses have been greater than winter losses. Marine mammal biologists are already considering these effects in their management and research efforts.

- Summer sea ice loss is altering marine ecosystems and leading to greater ship access, offshore development opportunity, and increased community vulnerability to coastal erosion. These all could have effects on marine mammals and seabirds and should be considered by Service biologists. Coastal erosion could affect coastal Alaskan Refuges. (http://www.doi.gov/news/upload/ArcticReport-03April2013PMsm.pdf)

- Melting of Alaska permafrost causes multiple vulnerabilities through drier landscapes (especially in discontinuous permafrost zones), more wildfire, increased cost of maintaining infrastructure, and the release of greenhouse gases (GHGs) (National Climate Assessment, Chapter 22). Both wetland drying and the increased frequency of warm dry summers and associated thunderstorms have led to more large fires in the last ten years than in any decade since record-keeping began in the 1940s. Alaskan Refuge managers need to be aware of these impacts and monitor/manage as appropriate. In addition, drying

wetlands across extensive areas could seriously affect waterfowl populations and waterfowl biologists will need to monitor this closely. (Jorgenson et al. 2013)

- Rapid glacier melt in Alaska has implications for hydropower production, ocean circulation patterns, major U.S. fisheries, and global sea level rise (National Climate Assessment, Chapter 22). Fisheries biologists need to be cognizant of the effects that rapid glacier melting has on streamflow and stream temperatures.

- Earlier snowmelt has been occurring in many locations, with concomitant changes in spring runoff and stream hydrographs (Lundquist et al. 2009). These changes have implication for fish and other aquatic species and should be monitored by fisheries biologists.

What Changes are Projected to Occur Globally and Regionally?

- It is very likely that the Arctic sea ice cover will continue to shrink and thin and that Northern Hemisphere spring snow cover will decrease during the 21st century as global mean surface temperature rises (*medium confidence*). Global glacier volume will further decrease (*medium confidence*).

- Based on an assessment of the subset of models that most closely reproduce the climatological mean state and 1979–2012 trend of the Arctic sea ice extent, a nearly ice-free Arctic Ocean in September before mid-century is *likely* for RCP8.5 (*medium confidence*). A projection of when the Arctic might become nearly ice-free in September in the 21st century cannot be made with confidence for the other scenarios.

Implications for USFWS

- Sea-ice loss will continue to be a major resource issue for the Service in the coming decades. Summer sea ice may be lost entirely, and winter ice is likely to continue its decline, albeit more slowly than summer ice decline. This will have major consequences for Arctic marine and terrestrial ecosystems, marine mammals, seabirds, and aquatic species (e.g., Moore and Huntington 2008; Doney et al. 2012).

- Melting of Alaska permafrost will continue. Future permafrost thaw will likely increase lake area in areas of continuous permafrost and decrease lake area in the discontinuous permafrost zone (Avis et al. 2011). Of particular significance will be drying that leads to wetland habitat loss and increased incidence of wildfire (e.g., Corcoran et al. 2009; Flannigan et al. 2009). Refuge managers and waterfowl biologists will need to monitor these changes closely.

- Rapid glacier melt in Alaska and other areas will continue. Fisheries biologists need to be cognizant of the effects that rapid glacier melting has on streamflow and stream temperatures (e.g., Moore et al. 2009)

- Earlier snowmelt will continue to affect spring runoff and stream hydrographs (e.g., Rausher et al. 2008; Pederson et al. 2011). These changes have implication for fish and other aquatic species (e.g., Jones et al. 2013) and should be monitored by fisheries biologists.

Sea Level

What changes have already been observed?

- The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (*high confidence*). Over the period 1901-2010, global mean sea level rose by 7.5 inches (0.19 m).

- It is *very likely* that the mean rate of global averaged sea level rise was .07 inch/yr. [.06-.08 inch/yr.] or 1.7 [1.5 to 1.9] mm/yr between 1901 and 2010, .08 inch/yr. [.07-.09 inch/yr.] or 2.0 [1.7 to 2.3] mm/yr between 1971 and 2010, and .13 inch/yr. [.11-.14 inch/yr.] or 3.2 [2.8 to 3.6] mm/yr between 1993 and 2010.

- Since the early 1970s, glacier mass loss and ocean thermal expansion from warming together explain about 75% of the observed global mean sea level rise (*high confidence*). Over the period 1993–2010, global mean sea level rise is, with *high confidence*, consistent with the sum of the observed contributions from ocean thermal expansion due to warming, from changes in glaciers, Greenland ice sheet, Antarctic ice sheet, and land water storage.

Implications for USFWS

- Sea-level rise is ongoing (http://www.epa.gov/climatechange/science/indicators/oceans/sea-level.html; http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml). In concert with other factors such as subsidence and eutrophication, this sea-level rise has destroyed coastal marsh habitats through drowning and altered water chemistry, particularly along the Gulf and Atlantic coasts (e.g., Couvillion et al. 2011 for coastal Louisiana). These actions pose challenges to many coastal Refuges as well as T&E and migratory bird biologists.

- Increasing sea levels have likely contributed to increased storm surges (Strauss et al. 2012), coastal erosion (Zhang et al. 2004), and saltwater intrusion into aquifers and estuaries. These pose additional challenges to Refuge, endangered species, and migratory bird biologists.

What Changes are Projected to Occur Globally and Regionally?

- Global mean sea level will continue to rise during the 21st century. Under all RCP scenarios the rate of sea level rise will very likely exceed that observed during 1971-2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets.

Implications for USFWS

- Service managers and biologists will continue to be challenged by rising sea levels, and concomitant effects on storms surges, coastal erosion, and saltwater incursion into aquifers and estuaries.

- For high emissions IPCC now projects a global rise by 20.5-38.6 inches (52-98 centimeters) by the year 2100; with lower emissions, a rise of 11-24 in. (28-61 cm) is projected. There will be regional differences in the actual amount of sea level rise.

- NOAA published sea level rise scenarios for use in the most recent National Climate Assessment (NOAA 2012):
    - The lowest sea level change scenario (8 inch rise)
    - The intermediate-low scenario (1.6 feet)
    - The intermediate-high scenario (3.9 feet)
    - The highest sea level change scenario (6.6 foot rise)

- A number of reports have modeled effects of possible sea-level rise on coastal habitats, including numerous studies using the Sea Level Affecting Marshes Model (SLAMM) (e.g., Manomet Center for Conservation Sciences and the National Wildlife Federation 2012).

- Storm surges will increase in frequency and intensity along the Atlantic coast (Tebaldi et al. 2012; Lin et al. 2012; Grinsted et al. 2013), affecting coastal Refuges and trust species occurring there on a more regular and intense basis.

Carbon and Other Biogeochemical Cycles

What changes have already been observed?

- The atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have increased to levels unprecedented 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 net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification.

- The atmospheric concentrations of the greenhouse gases carbon dioxide, methane, and nitrous oxide have all increased since 1750 due to human activity. In 2011 the concentrations of these greenhouse gases were 391 ppm, 1803 ppb, 324 ppb and exceeded the pre-industrial levels by about 40%, 150%, and 20%, respectively.

Implications for USFWS

- These figures stress the need to reduce greenhouse gas concentrations in the atmosphere in order to minimize temperature increases and other climate changes such that adaptation actions can be successful. Without mitigation of greenhouse gas concentrations in the atmosphere, most adaptation efforts are likely to be unsuccessful in the long term.

- The Service can do its part through emissions reductions and biological carbon sequestration. Refuges should continue research on carbon cycling and continue finding ways to use biological carbon sequestration as a tool for habitat restoration/creation.

What Changes are Projected to Occur Globally and Regionally?

- Climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere (*high confidence*).

Implications for USFWS

- The Service will need to continue its efforts to reduce emissions and sequester carbon into the foreseeable future.

Understanding the Climate System and its Recent Changes

Evaluation of Climate Models

- Climate models have improved since the Fourth Assessment Report (AR4). Models reproduce observed continental-scale surface temperature patterns and trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions (*very high confidence*).

Drivers of Climate Change

- Total radiative forcing (balance of incoming and outgoing energy) is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750.

Quantification of Climate System Responses

- Observational and model studies of temperature change, climate feedbacks and changes in the Earth's energy budget together provide confidence in the magnitude of global warming in response to past and future forcing.

Detection and Attribution of Climate Change

- Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. This evidence for human influence has grown since IPCC's AR4. It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.

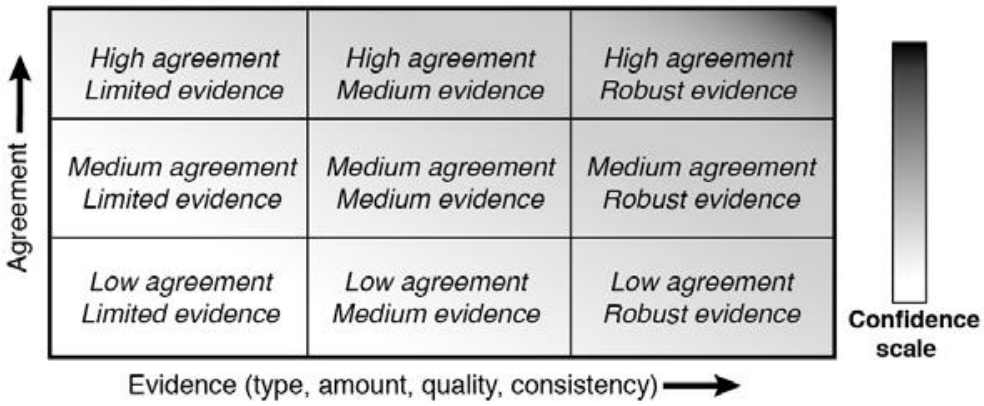
Climate Stabilization, Climate Change Commitment, and Irreversibility

- Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2.

Appendix

In the AR5, each key finding is based on an author team's evaluation of associated evidence and agreement. The confidence metric provides a qualitative synthesis of an author team's judgment about the validity of a finding, as determined through evaluation of evidence and agreement. If uncertainties can be quantified probabilistically, an author team characterizes a finding using the calibrated likelihood language or a more precise presentation of probability. Unless otherwise indicated, high or very high confidence is associated with findings for which an author team has assigned a likelihood term. The following terms have been used to indicate the assessed likelihood:

Term*	**Likelihood of the outcome**
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

* Additional terms (*extremely likely:* 95–100% probability, *more likely than not:* >50–100% probability, and *extremely unlikely:* 0–5% probability) may also be used when appropriate.

The following summary terms are used to describe the available evidence: limited, medium, or robust; and for the degree of agreement: low, medium, or high. A level of confidence is expressed using five qualifiers very low, low, medium, high, and very high. The figure below depicts summary statements for evidence and agreement and their relationship to confidence. There is flexibility in this relationship; for a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence.