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STOP GLOBAL WARMING
Approach to Mitigation and Adaptation

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STOP GLOBAL WARMING

Approach to Mitigation and Adaptation 2015

環境省
Ministry of the Environment

Chapter 1 Global Warming — The Changes we face

Global warming is unequivocal. According to the 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change(IPCC), human activities are extremely likely to have been the dominant cause of the observed warming. We are facing unprecedented change of climate due to global warming. Extreme weather events such as extreme high temperatures and intense tropical cyclones occur worldwide, and they inflict unprecedented damage on people's lives and properties and then living creatures are exposed to risk of extinction.

contents

*IPCC: Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by WMO and UNEP. IPCC published the Fifth Assessment Report (AR5) in the period from 2013 to 2014.

Frequently occurring extreme weather events around the world

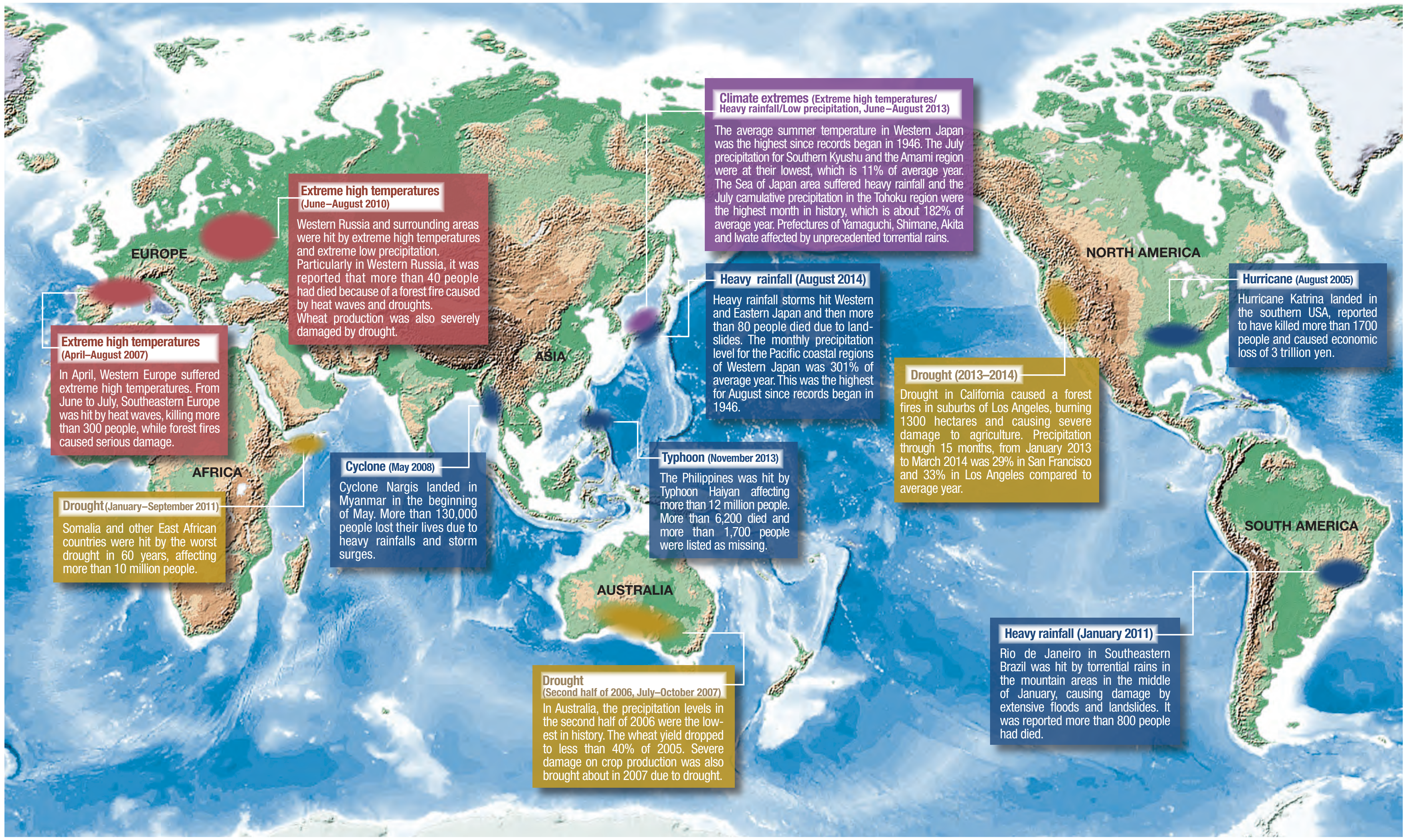
In recent years, extreme weather events are observed globally. Extreme weather events such as intense typhoons, hurricanes, torrential rains, droughts and heat waves have caused disasters in many areas, causing significant number of life losses and profound damage to crops. Such incidents are reported almost every year.

In November 2013, Typhoon Haiyan has hit the Philippines and it has killed more than 6,200 people.

In the case of Japan, in August 2014 at Miiri Area in Hiroshima City, record-breaking maximum hourly precipitation of 101mm, which is the highest in history, caused a huge damage.

According to IPCC's Fifth Assessment Report (AR5), it is virtually certain that as global mean temperature increases, there will be more frequent hot temperature extremes, and it is very likely that there will be more frequent extreme precipitation in the tropics and mid-latitude regions.

Example of worldwide extreme weather events



Climate extremes | Heavy rainfall/Floods | Extreme high temperatures | Drought

(Created based on Source 1)

Continuous ice sheet and glacier melting

The world's glaciers are shrinking due to global warming. Particularly Greenland with 10% of the world's glaciers, is showing accelerated melting. The "Shizuku" satellite (Global Change Observation Mission - Water (GCOM-W)), launched by JAXA (Japan Aerospace Exploration Agency), on July 12, 2012, collected data and it showed that the entire surface of ice sheet in Greenland was melting. In addition, glaciers in the European Alps or mountain regions in Bolivia in South America have also been melting, causing influences on tourism such as skiing and for the energy supply such as hydro power generation.
Melting glaciers are also a factor of rising sea levels. Global averaged sea level increased about 60mm between 1993 and 2010, and almost half of this increase is considered due to melting glaciers.

Melting of the entire area of ice sheets surface in Greenland —Captured by "Shizuku"

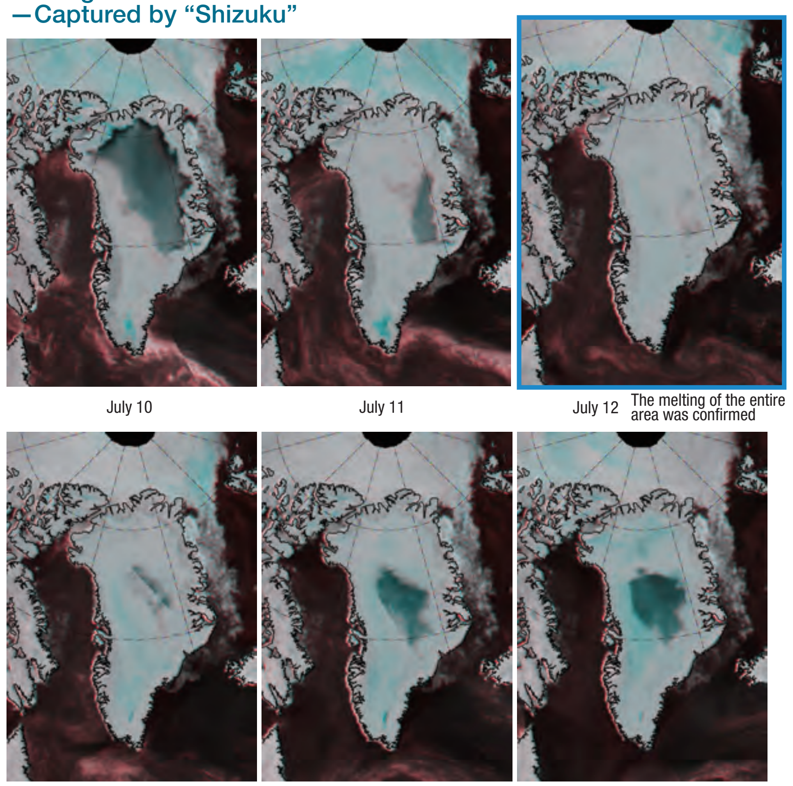
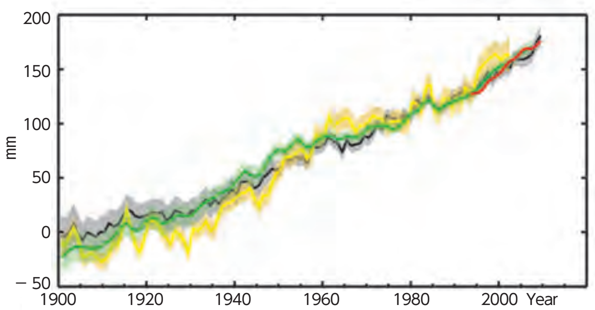


Photo provided by JAXA
(From Source 2)

Rise in sea levels

The mean rate of global averaged sea level rise was 1.7 mm per year between 1901 and 2010, 2.0mm per year between 1971 and 2010, and 3.2mm per year between 1993 and 2010 (18 years), it has risen rapidly to around 3.2mm per year. The biggest reason for this increase is thermal expansion in the oceans, but a decrease in glaciers and the ice sheets in Greenland and Antarctica are considered to be other reasons. These are all caused by global warming.

Global averaged sea level change



Black/Yellow/Green: Measured by tide gauges
Red: Measured by altimeters installed in satellites
Colored shading: uncertainty in evaluation results
(IPCC AR5 WGI Fig.SPM.3(d))

Rate of sea level rise by factors (1993–2010)

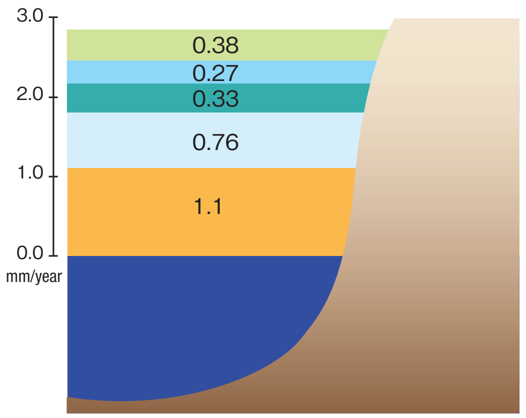


Chart with contributing factors for the global averaged sea level rise. The sum of these factors could explain a large proportion of the observed global averaged sea level rise.

Thermal expansion
Decrease in glacier and ice cap
Decrease in Greenland ice sheet
Decrease of Ant-arctic ice sheet
Decrease of land water storage
(Created from Source 3)

Ecosystem disruption / Expansion of Infection risk

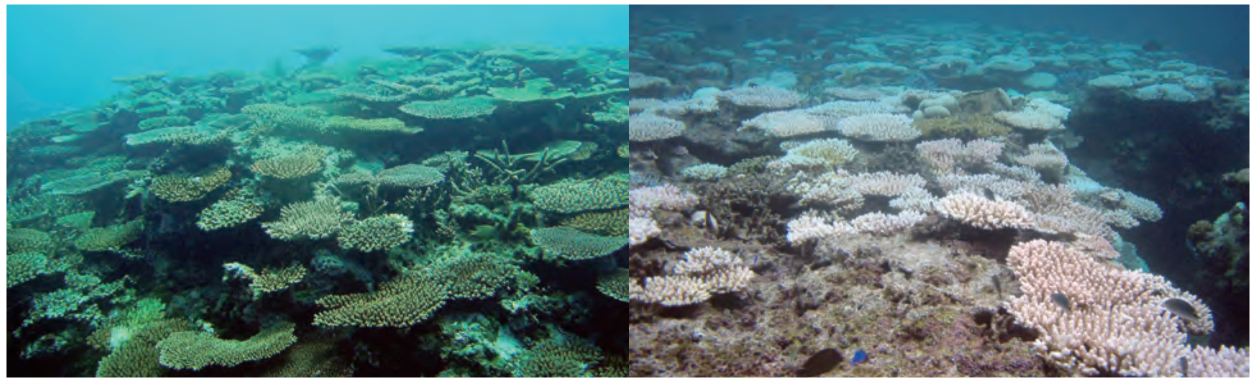
Increase of surface and ocean temperatures caused by global warming are affecting organisms living at land, sea, and freshwater areas and the overall ecosystem. Around the world, deforestation is occurring, animal habitats are changing and populations are being reduced.

Coral bleaching

It is reported that one-third of warm-water corals are in danger of extinction. Since the 1980s, coral bleaching has become more apparent and it is considered that global warming largely influences the phenomenon.
Coral bleaching occurs because the coral loses algae, called zooxanthella. When this occurs, coral's white skeleton becomes visible and appears "white." The reasons of coral bleaching are water temperature changes, strong sunlight, ultraviolet light and lower salinity. Particularly water temperature changes significantly affect coral. If the temperature is 30°C or higher for a prolonged period, the zooxanthella algae is damaged, causing coral bleaching, and if the high temperature continues for a longer period, the coral dies. In addition, increased levels of CO_2, a major factor of global warming, also affect badly to the coral. If the CO_2 concentration level in the atmosphere increases, more CO_2 is absorbed by seawater and it leads to ocean acidification. It interrupts coral's calcification process. Global warming is a major threat to coral.

Coral bleaching

before after



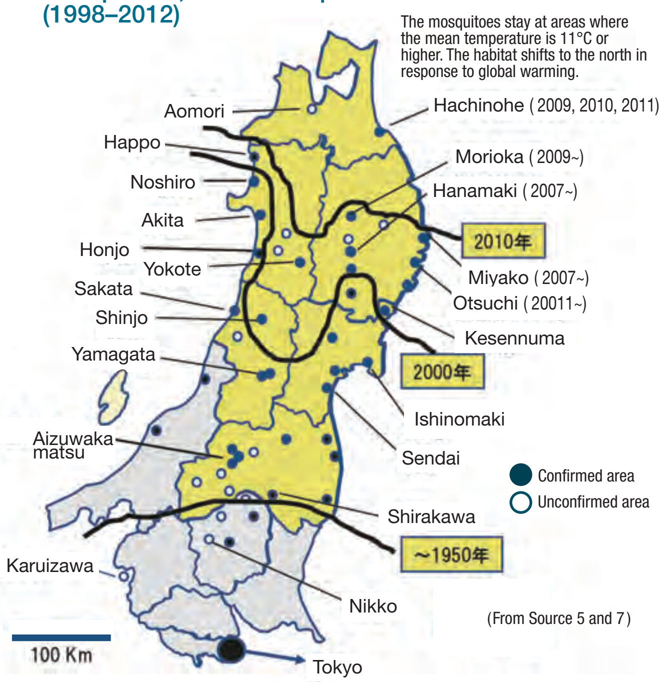
(From Source 4, 5 and 6)

Aedes albopictus transmit dengue fever—Moving up to the north

In August 2014, dengue fever was found in Japan for the first time in 70 years. The number of infections has been increasing and reaching a total of 160 people according to a report by the Ministry of Health, Labour and Welfare published at the end of October.
Mosquitoes, aedes albopictus, transmit dengue fever and chikungunya fever. They inhabit in areas where the annual mean temperature is 11°C or higher. The northern limit of this kind of mosquito habitat in 1950s was the northern side of Tochigi prefecture. Since then, the habitat has gradually moving further north due to global warming. For the first time in Aomori Prefecture, its mosquito habitat was confirmed by a survey in 2010. It is projected that the habitat will extend to the northern tip of Honshu by 2035 and extend to Hokkaido by 2100.

Mosquitoe, aedes albopictus
Photo provided by National Institute of Infectious Diseases

Mosquitoes, aedes albopictus distribution extension (1998–2012)



(From Source 5 and 7)

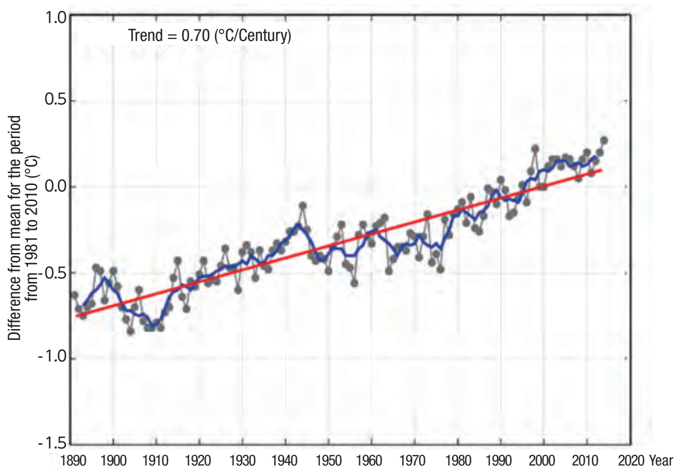
Chapter 2 New evidence of Climate Change

The IPCC Fifth Assessment Report (AR5) was developed in about four years by more than 800 scientists in the world who reviewed researches on global warming. The evidence collected during AR5's development indicated a more serious situation. It's time to face the facts on global warming and take action.

Global mean temperature is increasing

The global mean combined land and sea surface temperature has increased by 0.85°C, over the period 1880 to 2012. Each of the last three decades has been warmer than any preceding decade since 1850.
The rate of increase of global mean surface temperature in the 21st century has been 0.03°C per decade, remaining on the same level. This stagnant condition of global warming is called a hiatus. Researchers around the world are investigating this phenomenon and have discovered that the circulation of atmosphere and ocean in the Pacific Ocean have been in a distinctive state for over the past ten years due to the influence of a "natural fluctuation." As the surface layer of the Pacific is cool and warm seawater tends to be confined to the western Pacific, global mean surface temperature has not been increasing. This natural fluctuation is a decadal internal variability and it has been indicated that global warming is not stagnant on the Earth as a whole.
In 2014, the deviation of global mean surface temperature (the base line value for the 30 years between 1981 and 2010 has been subtracted from the mean temperature) was +0.27°C. This was the hottest year since record keeping began in 1981.

Global mean temperature is increasing(1891–2014)



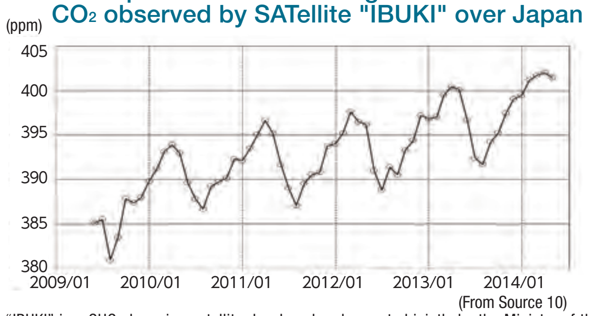
(From Source 8,9)

Carbon dioxide concentration has increased 40% since the pre-industrial era

Carbon dioxide (CO_2) is a typical greenhouse gases (GHG) contributing to global warming. The atmospheric concentration of the gas has been rapidly increasing since 1750, when the Industrial Revolution began. Humans have been extracting energy by burning fossil fuel such as petroleum and coal to achieve economic growth. This has resulted in the atmospheric CO_2 concentration increases of 40% compared to 1750.

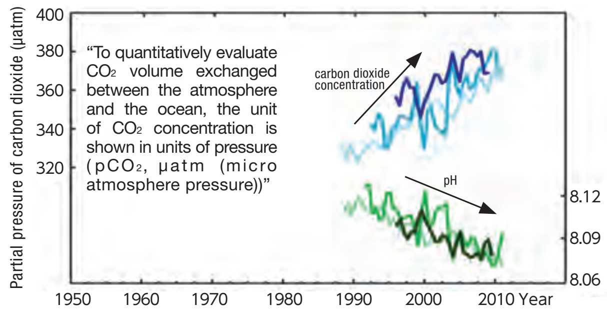
As the atmospheric CO_2 increases, more CO_2 is absorbed into the ocean, causing ocean acidification. The figure on the right (below) shows secular changes of CO_2 concentrations on the ocean surface and the pH of ocean surface water. It is apparent that as CO_2 concentrations increase, the pH of ocean levels decrease, meaning ocean acidification is advancing.

Atmospheric column-averaged concentrations of CO_2 observed by SATellite "IBUKI" over Japan



(From Source 10)
"IBUKI" is a GHG observing satellite developed and operated jointly by the Ministry of the Environment (MOE), the National Institute for Environmental Studies (NIES), and the Japan Aerospace Exploration Agency (JAXA)

Carbon dioxide and pH at sea surface level

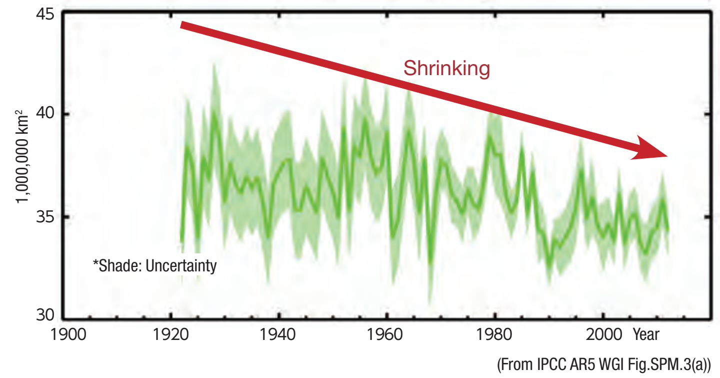


(From IPCC AR5 WGI Fig.SPM.4(a))

Decreasing snow and ice in the Northern Hemisphere

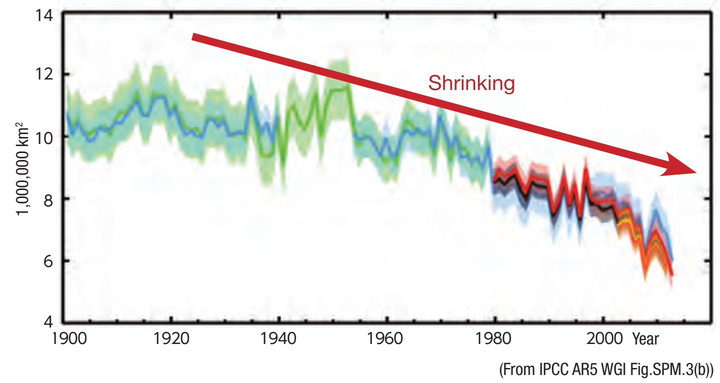
Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide. There is very high confidence that the extent of Northern Hemisphere snow cover has decreased since the mid-20th century. The figure on the right (above) shows the extent of Northern Hemisphere March-April (spring) average snow cover, indicating a shrinking trend.
The extent of Arctic sea ice has been shrinking significantly since the second half of 1970s. The figure on the right (below) indicates the extent of Arctic July-August-September (summer) average sea ice. It is very likely in the range of 0.73 to 1.07 million km² (approximately 9 to 13 times as large as Hokkaido) per decade for the summer sea ice minimum (perennial sea ice).It is considered that the area is rapidly shrinking.

Northern Hemisphere spring snow cover



(From IPCC AR5 WGI Fig.SPM.3(a))

Arctic sea ice extent

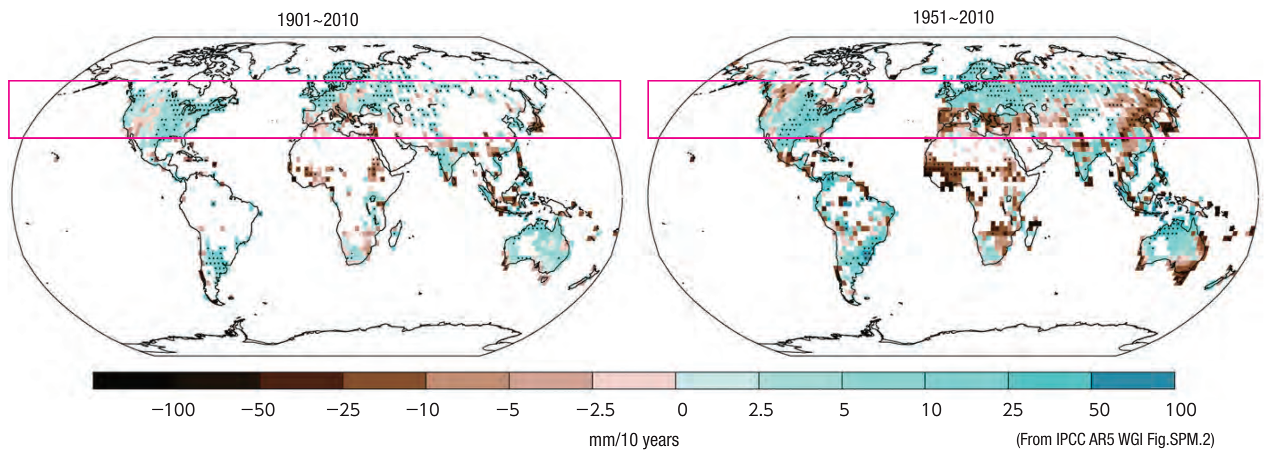


(From IPCC AR5 WGI Fig.SPM.3(b))

Increasing precipitation in mid-latitudes of the Northern Hemisphere

Looking at the observed change in annual global precipitation (1901–2010), since 1951 through current, precipitation has been increased over mid-latitude land areas of the Northern Hemisphere. And the frequency of heavy precipitation events tends to increase in North America and Europe. In contrast, precipitation amount tends to decrease in West Africa and Southeastern Australia.

Observed change in annual precipitation over land



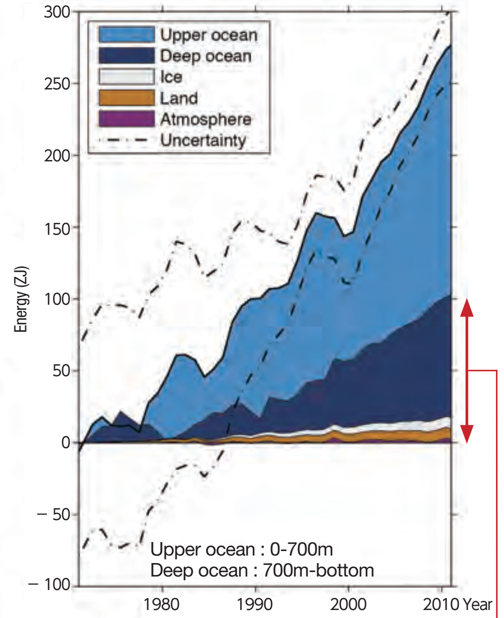
(From IPCC AR5 WGI Fig.SPM.2)

Warming of the upper and deep ocean temperatures

Ocean warming dominates the energy change that causes climate change, accounting for more than 90% of the increase from 1971 to 2010. (See figure on the right.) In particular, more than 60% of the net energy increase in the climate system is stored in the upper ocean (0–700m). The upper 75m warmed by 0.11°C per decade during 1971 to 2010.

In contrast, the layer deeper than 700m accumulates about 30% of the increased energy amount. New findings indicate that seawater temperature increases have likely taken place even in the deep ocean more than 3000m, due to global warming.

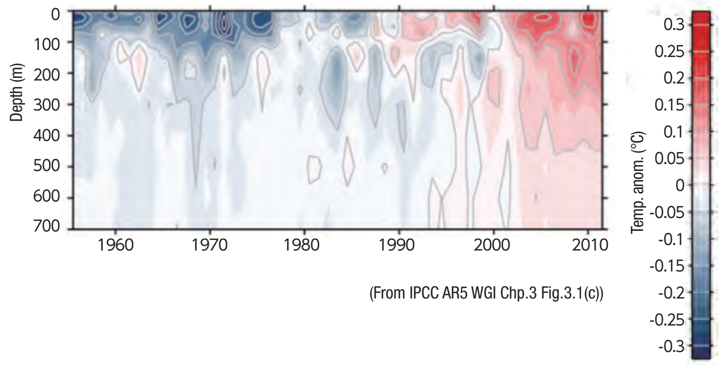
Energy accumulation within the Earth's Climate System



The deep ocean stores 100 ZJ (1 ZJ = 10^{21}J) energy. This is equivalent to all the electricity generated in Japan approximately over 30,000 years (2012).

(From IPCC AR5 WGI Chp.3 Box3.1 Fig.1)

Globally averaged temperature anomaly (time vs. depth, colours and grey contours in degrees Celsius) relative to the 1971–2010 mean



(From IPCC AR5 WGI Chp.3 Fig.3.1(c))

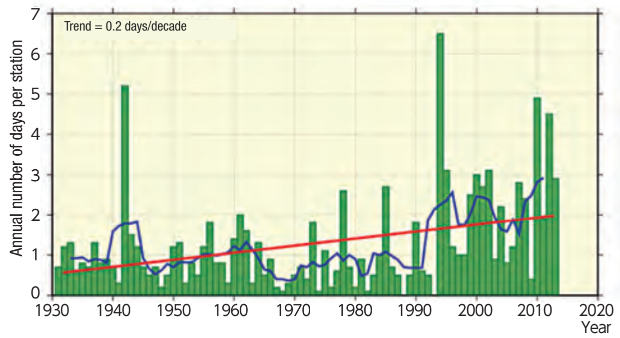
Extreme events are increasing

As global warming progresses, changes in climate extremes appear more. Since 1951, there have been fewer cold days and more hot days worldwide. Many areas of Europe, Asia and Australia have more days with high temperatures and heat waves.

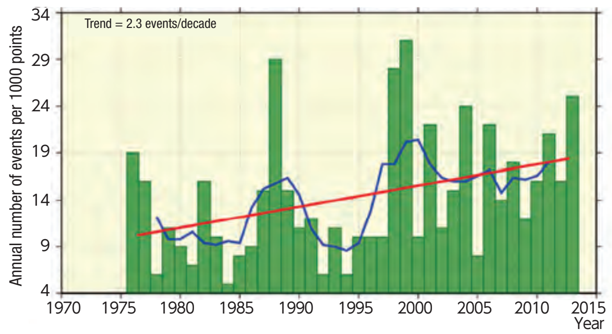
In Japan, the number of days with maximum temperatures (Tmax) of ≥35°C has been increasing at a pace of around 0.2 days per decade during the period from 1931 to 2013. (See the figure on the left below.)

The number of days with extreme heavy rainfall has also been increased. The figure on the right (below) shows the annual number of events with extreme precipitation exceeding 80mm per hour at AMeDAS locations from 1976 to 2013. The number of events with extreme precipitation has been increasing at a pace of about 2.3 events per decade during the period.

Number of days with maximum temperatures ≥ 35°C/year



Number of events with extreme precipitation ≥ 80mm/hour



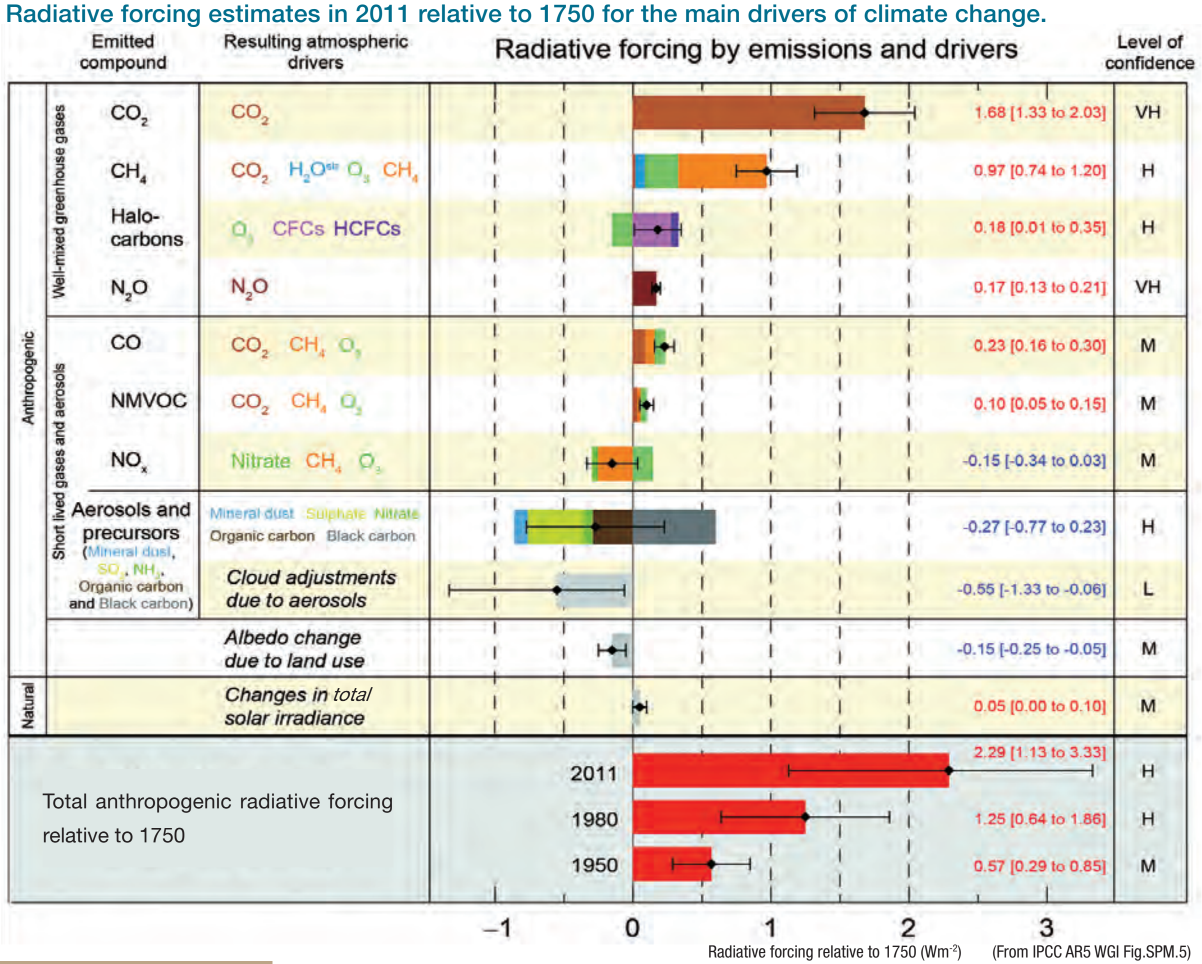
(From Source 11)

Human activities are contributing to global warming

One of the factors that changes the climate system is the GHG concentration such as CO_2 and methane, but the aerosol concentration such as mineral dust and SO_2 or change in the surface properties also affect the climate system. Changes in concentration levels of such gasses and materials accelerate (positive radiative forcing) or limit (negative radiative forcing) global warming. These concentration changes caused by these factors are shown by using a value called radiative forcing (RF)."

Human activities have been deeply related to changes in the climate system since the pre-industrial era, and it is known that the largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2.

Radiative forcing estimates in 2011 relative to 1750 for the main drivers of climate change.



(From IPCC AR5 WGI Fig.SPM.5)

column

Could melting of permafrost increase warming?

Permafrost is permanently frozen ground, mainly found in the high latitudes of the Arctic. The soil contains old organic carbon deposits and it is thought that there exists at least twice as much as the amount of carbon currently present in the atmosphere as carbon dioxide (CO_2). If permafrost melting continues due to global warming, the carbon contained in the soil will be released into the atmosphere as methane (CH_4) and CO_2 (i.e. GHG), and it would lead to increasing temperatures. Furthermore, more methane and CO_2 would be released from the permafrost, creating positive feedback, which is anticipated to amplify global warming.

According to a recent study, it has recorded significant CH_4 emissions from the Arctic Siberian shelf and from Siberian lakes. It is not obvious if this has been caused by local global warming or for other reasons.

(From IPCC AR5 WGI FAQ6.1)

Permafrost Photo:Takesi Ise

Chapter 3

Observed Impacts and Potential Impacts
——*What kind of risks do we face?*

How much will global temperatures and sea levels increase if global warming continues? Recent studies have revealed that global warming has impacted on human society and ecosystem in various ways. We must carry out appropriate solutions now, otherwise our living could be exposed to dangerous conditions several decades or 100 years after. It is important for us to more precisely understand projection data to comprehend how global warming affects our future.

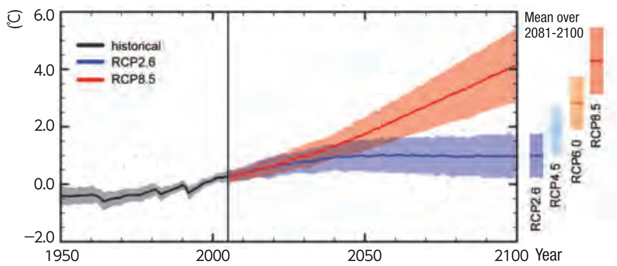
What will the earth be like at the end of the 21st century? (Future projections)

The global mean temperature will increase 4.8°C at maximum

Increase of global mean surface temperatures for 2081–2100 relative to 1986–2005 is projected to likely be at least 0.3°C and to a maximum 4.8°C. Inland temperatures will increase faster than ocean areas. The Arctic region will warm more rapidly than the global mean, and mean warming over land will be larger than over the ocean.
The difference between 0.3°C and 4.8°C of projected temperature is due to differences in "scenarios"*. Each scenario provides a different solution for global warming. For example, RCP8.5, which assumes no further global warming measures such as CO_2 reduction in addition to current level (the most severe global warming), projects a temperature increase of 2.6°C to 4.8°C. On the other hand, RCP2.6, which assumes implementation of as many as possible aggressive solutions (the least severe global warming), projects a temperature increase of 0.3°C to 1.7°C.

* For details on these scenarios, see Chapter 4 (Page 18).

Change in global annual mean surface temperature relative to 1986–2005



(IPCC AR5 WGI Fig. SPM.7 (a))

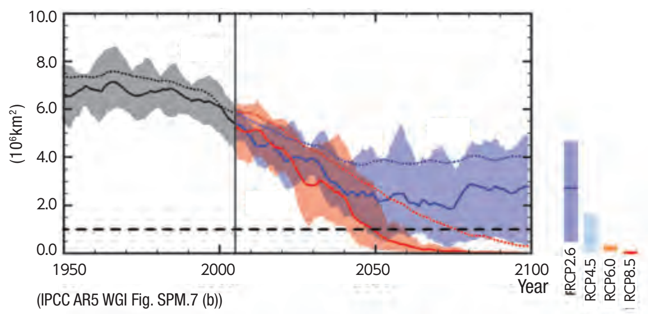
Rise in sea levels

Sea level rise is also change that we cannot ignore. Global mean sea level rise for 2081–2100 relative to 1986–2005 will likely be in the ranges of 0.26 to 0.55m for RCP2.6 (the least severe global warming), and 0.45 to 0.82m for RCP8.5 (the most severe global warming). Confidence in projections of global mean sea level rise has increased since the AR4 due to improved modelling on contributions from land ice.

Shrinking sea ice in Arctic seas

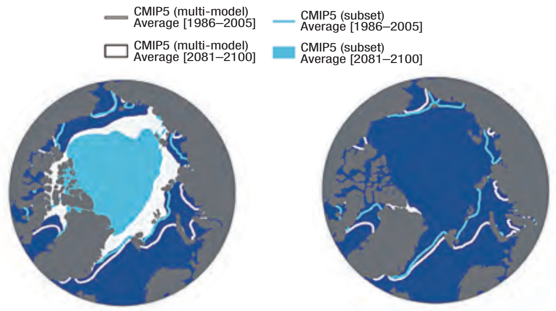
It is very likely that the Arctic sea ice cover will continue to shrink and thin and that Northern Hemisphere spring snow cover will decrease during the 21st century. It is projected that sea ice areas will shrink 43% in September (from current levels) at the end of 21st century for RCP2.6 (the least severe global warming). However for RCP8.5 (the most severe global warming), where sea ice in the north polar region is likely to disappear almost completely in summer (September) by the middle of the 21st century.
The Impacts of global warming will affect not only Arctic sea ice but also the area of the Northern Hemisphere. In particular, it is very likely that Northern Hemisphere spring snow cover will decrease during the 21st century.

Northern Hemisphere September sea ice extent



(IPCC AR5 WGI Fig. SPM.7 (b))

Northern Hemisphere September sea ice extent (average 2081–2100)

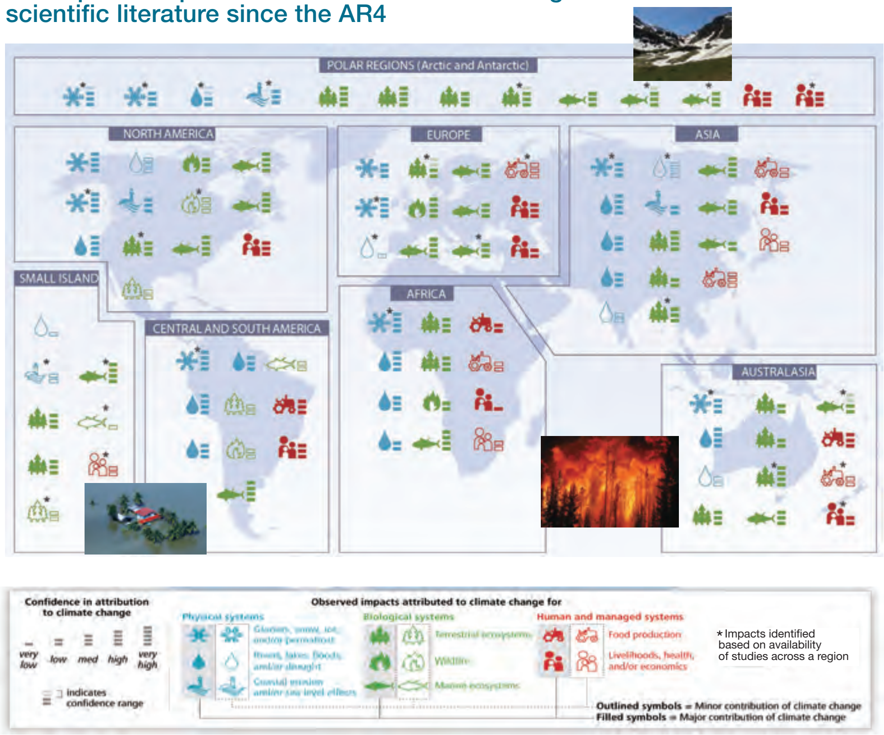


(IPCC AR5 WGI Fig.SPM.8 (c))

Various observed impacts worldwide

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. As in the figure on the right, we can see widespread impacts on physical systems such as glaciers, sea levels, floods and droughts, impacts on biological systems such as terrestrial ecosystems, wildfire, marine ecosystems, and impacts on human and managed systems such as lives, health, and/or economics. More specifically according to the IPCC AR5, "Evidence of climate-change impacts is strongest and most comprehensive for natural systems." If global warming continues to advance, severity and confidence of these impacts will become higher, meaning that there will be a greater chance of climate change risk.

Widespread impacts attributed to climate change based on the available scientific literature since the AR4



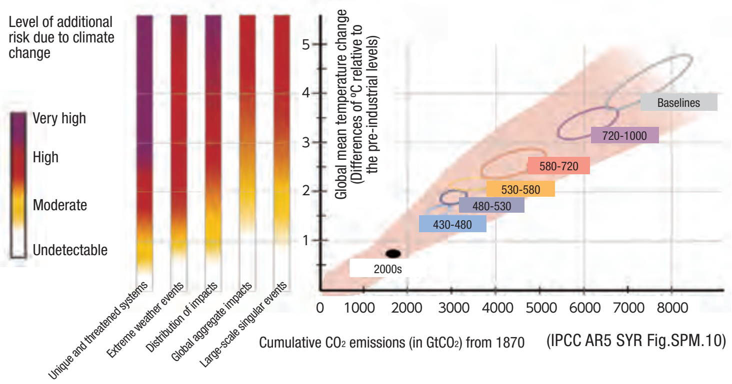
The symbols represent the impact types. Filled symbols indicate the significance of the impacts of climate change. The barometers next to the symbols indicate confidence; the higher the scale, the higher the confidence.

(IPCC AR5 SYR Fig.SPM.4)

Increasing risks with CO_2 emissions increase (Future projection)

The 8 key risks brought by climate change that follow span sectors and regions. (1) Sea level rise, storm surge in coastal areas (2) Inland floods in urban areas, (3) Extreme weather events leading to stop function of infrastructure networks and critical services (4) Mortality and morbidity due to extreme heat (5) Food insecurity and the breakdown of food systems (6) Insufficient water resources and reduced agricultural productions (7) Loss of marine and coastal ecosystems (8) Loss of terrestrial and inland water ecosystems services.

The relationship between risks from climate change, temperature change and cumulative CO_2 emissions



(IPCC AR5 SYR Fig.SPM.10)

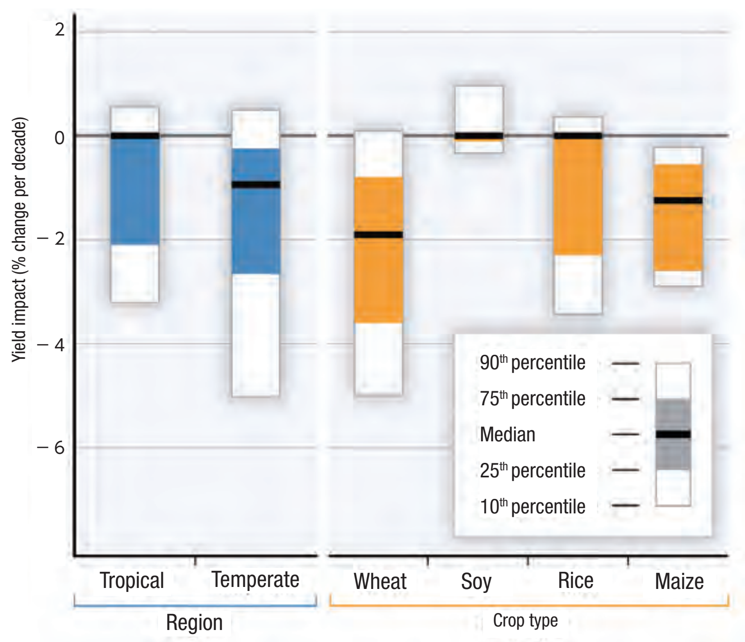
The graph on the left (below) shows a correlation of temperature increases and related risks. The graph on the right shows a correlation of temperature increases and cumulative CO_2 emissions brought about by human activity since the pre-industrial era.
The graph warns us that temperature increases will bring five integrative reasons for concern (RFCs) in the future–"Impacts on some unique and threatened systems, including ecosystems and cultures," "Extreme weather events," "Regional impacts such as those on agricultural crops and water scarcity," "Global impacts such as those on the world economy or biodiversity," "Large-scale singular events such as the loss of ice sheet."
If the temperature increases 1°C, the risk of extreme weather events (e.g., typhoons, heat waves) will also increase. 2°C, the ecosystems with less adaptability (e.g., coral reefs) will be exposed to very high risk. If it increases 3°C or more, global biodiversity will be reduced, ecosystem services will be lost and the human society will also be greatly affected. To mitigate these risks, it is essential to limit CO_2 emissions over the future.

Reduction of crop yields (Observed impacts)

Climate change is also closely related to food production. The figure on the right is a summary of estimated impacts of observed climate changes on yields over 1960–2013 for four major crops in temperate and tropical regions.

Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts. The smaller number of studies showing positive impacts relate mainly to high-latitude regions, though it is not yet clear whether the balance of impacts has been negative or positive in these regions.

Impacts on yields for four major crops in tropical and temperate regions



Increasing risks in marine ecosystem (Future projection)

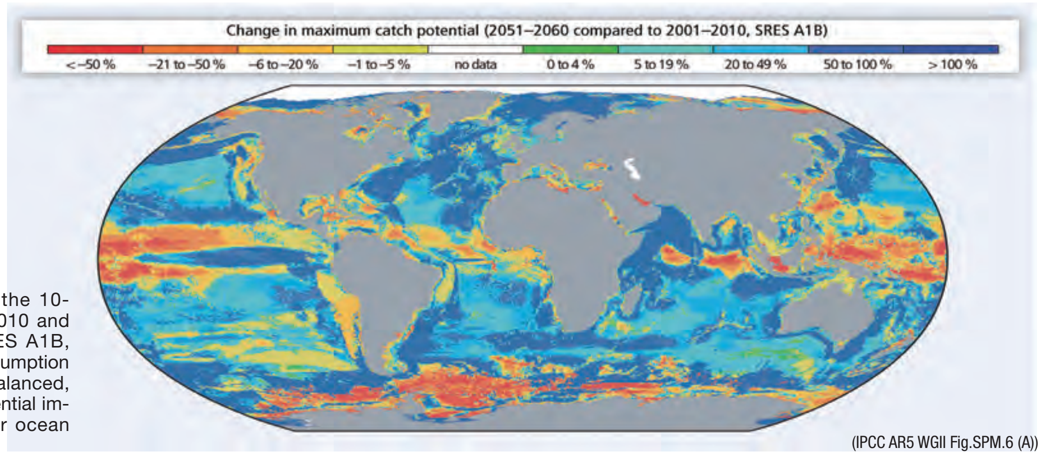
Global marine-species redistribution and marine-biodiversity reduction in sensitive regions will challenge the sustained provision of fisheries productivity and other ecosystem services.

The figure below shows projected global redistribution of maximum catch potential of ~1000 exploited fish and invertebrate species. Projections compare the 10-year averages 2001–2010 and 2051–2060, without analysis of potential impacts of overfishing or ocean acidification. It is predicted that the catch potential will decrease greatly as the red gets darker. On average, it is projected that the total allowable catch increases in the mid to high latitude areas but decreases in tropical areas.

Rapid global warming impacts the ecosystem as species move to higher latitude areas or to deeper water in search of cold water. If global warming continues, these species, from which we receive benefits via fisheries, may disappear.

Ocean acidification poses substantial risks to marine ecosystems, especially polar ecosystems and coral reefs, associated with impacts on the physiology, behavior, and population dynamics of individual species from phytoplankton to animals.

Projected global redistribution of maximum catch potential of ~1000 exploited fish and invertebrate species



Projections compare the 10-year averages 2001–2010 and 2051–2060 using SRES A1B, scenario of energy consumption and technology well-balanced, without analysis of potential impacts of overfishing or ocean acidification.

(IPCC AR5 WGII Fig.SPM.6 (A))

Coastal areas/small islands threatened by storm surges or coastal erosion (Future projection)

Sea level rise caused by global warming significantly affects those living in coastal areas, lowlands or small islands. They are more vulnerable to storm surges and floods caused by typhoons and coastal flooding and erosion.

The figure below shows the estimated increase in height (m) that flood protection structures would need to be raised in the 2081–2100 period to preserve the same frequency of exceedances that was experienced for the 1986–2005 period, relative sea level rise projections under an Representative Concentration Pathway 4.5 (RCP4.5) scenario.

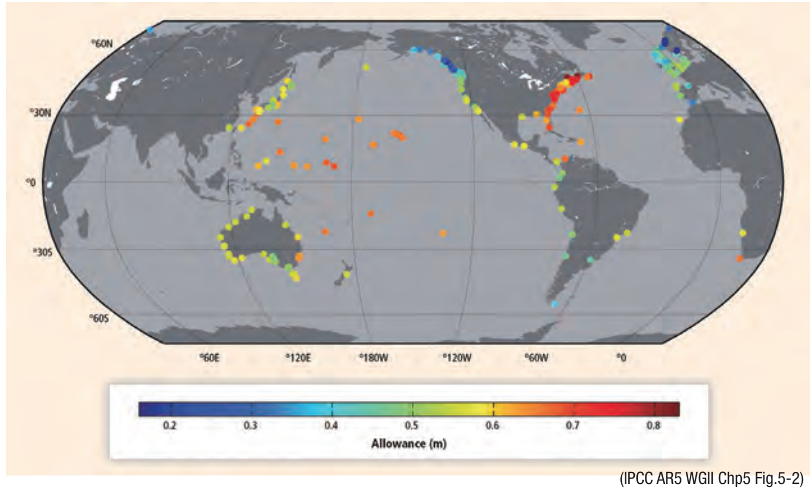
This means that in some East Coast areas of the USA, flood protection structures must be raised more than 70cm. In Japan, some coastal areas need to raise flood protection structures 50–70cm.

Tuvalu—Flooding in lowland areas is part of everyday life

Photo:Tomoko Kana

It is estimated that annual riverine flood losses in the USA could increase from approximately US$2 billion now to US$7 to US$19 billion annually by 2100. The IPCC AR5 warns that the promotion of urbanization without the flood management operation facility could lead to further increase of the impact of flood, due to global warming.

The estimated increase in height that flood protection structures would need to be raised in the future (allowance height)



(IPCC AR5 WGII Chp5 Fig.5-2)

Water problems are bipolar : Drought and Flood (Future projection)

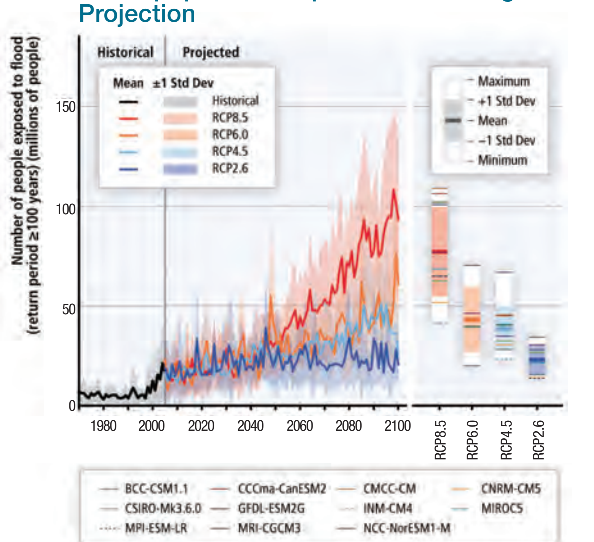
Freshwaters (not seawater) are essential not only for drinking, but also for agriculture and industry. It is projected that progress of global warming will increase the fleshwaters-related risk significantly.

One of these risks is water scarcity. In the RCP8.5 scenario, which projects the most rapid global warming, current dry areas are likely to suffer more frequent droughts by the end of the 21st century and dry subtropical areas will have less renewable surface water and groundwater resources. It is indicated that this water scarcity will cause severe competition over water resources across industry sectors such as energy and agriculture, which may develop into conflict.

In contrast, water resources are projected to increase at high latitudes. Heavy rainfalls increase sediment and pollutants, and floods increase disruption of treatment facilities.Climate change is projected to reduce the quality of raw water and pose risks to the quality of drinking water even with conventional treatment, facilities during floods.

The figure on the right shows how the numbers of people exposed to large-scale floods (occurring once in every 100 years during the 20th century) are projected to increase until 2100. The RCP8.5 scenario projects that about 100 million people per annum will suffer from such large-scale floods around 2100.

World population exposed to flooding–Projection



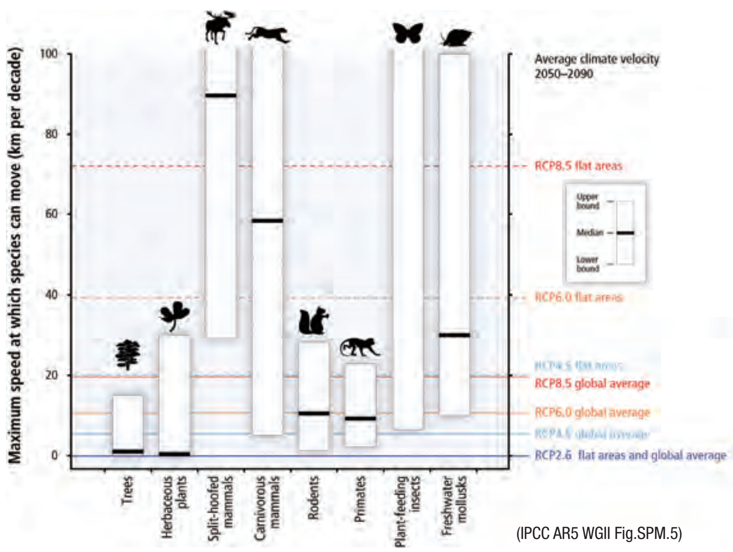
(IPCC AR5 WGII TS Fig.6 (C))

At the end of the 21st century, 100 million people will be exposed annually to very severe floods (occurring once in 100 years during the 20th century) if global warming continues to advance rapidly (RCP8.5 scenario).

Ecosystem—facing a crisis (Future projection)

A large fraction of both terrestrial and freshwater species faces increased extinction risk under projected climate change during and beyond the 21st century, especially as climate change interacts with other stressors, such as habitat modification, over-exploitation, pollution, and invasive species. Extinction risk is increased under all RCP scenarios, with risk increasing with both magnitude and rate of climate change. Many species will be unable to track suitable climates under mid- and high-range rates of climate change (i.e., RCP4.5, 6.0, and 8.5) during the 21st century.
The figure on the right shows if animals and plants are able to respond to changes to habitat due to climate change. The left vertical axis indicates the maximum speed at which the species can move across landscapes; the right vertical axis indicates the speed at which temperatures are projected to move across landscapes.

Maximum speed at which species can move compared with the speed at which temperatures are projected to move

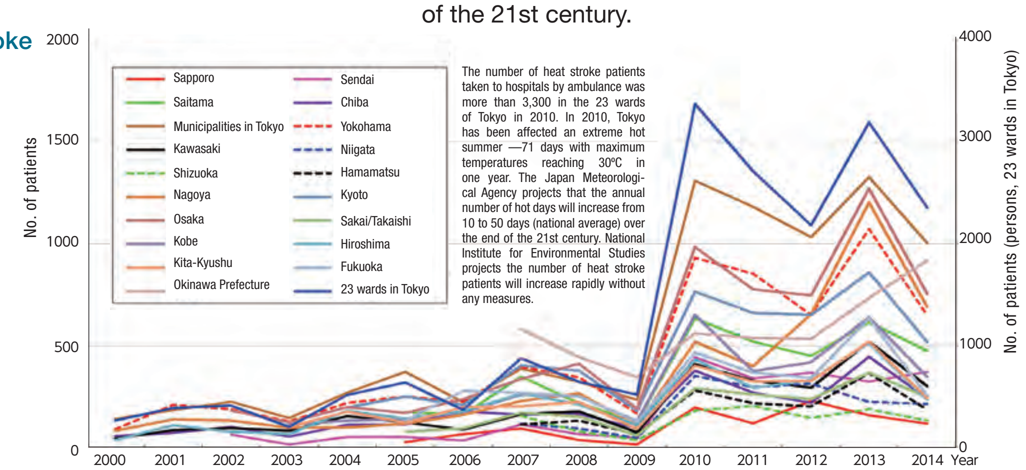


(IPCC AR5 WGII Fig.SPM.5)

Threat to human health (Future projection)

It is projected that climate change such as global warming will have significant impacts not only on animals and plants but also on people's health. The risk of injury, disease, and death due to harsh heatwaves and wildfires, as well as malnutrition caused by reduction of food production, will be heightened particularly in low-income developing countries.
In Japan, a number of heat stroke patients shows increasing trends in recent years due to high temperature during summer season (Figure below); it is projected that this number will increase in future. According to the CO_2 emission scenario (where the annual mean temperature in 2100 is increased approximately 2.1–3.8ºC relative to the pre-industrial level), the risk of dying from heat stress will be about 1.8–2.2 times higher in the 2050's than in the 1981–2000 period and about 2.1–3.7 times more in the 2090's.
Even in the RCP2.6 scenario that projects the least severe global warming, it is projected that the number of excess deaths due to heat stress will more than double in all prefectures regardless of age group.
The economic damage caused by death from heat stroke will also significantly increase. According to the RCP8.5 scenario for the most severe global warming, it is estimated that the damage will increase as much as 147.9–521.8 billion yen per year in Japan by the end of the 21st century.

Number of heat stroke patients in cities—Yearly change (2000–2014)

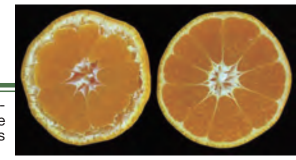


(From Source 5, 11,15 and 16)

Increasing deforestation and forest degradation (Loss of carbon sink)

Forests are important carbon sinks. Increasing deforestation and forest degradation emit carbon which is stored in the forest, which promotes global warming. During the period from 2000 to 2010, about 52 million hectares of forests were lost and forest areas shrunk to about just over 4 billion hectares.
Brazil, Indonesia and Australia have lost particularly large forest areas. A major factor of deforestation is the equivalent of tropical forest land into farmland. This has been a result of the expansion of crops and agricultural products that are being exported, such as palm oil, gum trees and coffee. There are, however, other background factors relevant to deforestation in addition to the direct factors of land equivalent and development. Those factors include the expansion of market economy, poverty and population growth, and they are intricately intertwined.
CO_2 emissions caused by deforestation factors described above are estimated to be 20% of the global emissions. This is the second biggest ratio following CO_2 emissions caused by burning fossil fuels. In response, the international community is promoting "REDD+" to reduce the emission of greenhouse gases (GHG) by controlling deforestation and forest degradation in developing countries. The basic concept of the scheme is as follows: Firstly, a scenario (reference level) that can project future GHG emissions caused by deforestation is defined based on mainly at historical data on GHG emissions in the target countries. If the implementing country can reduce the amount of GHG emissions below a reference level by implementing solutions such as reforestation and afforestation, the country can obtain credits corresponding to reduced emissions.
REDD+ is also expected to bring additional benefits such as recovering biodiversity by restoring forest functions and providing a better livelihood for local people by utilizing forest resources. (From Source 17 and 18)

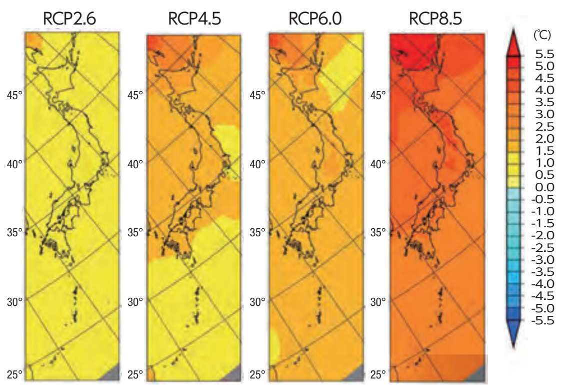
Projected climate change and Impact assessment in Japan



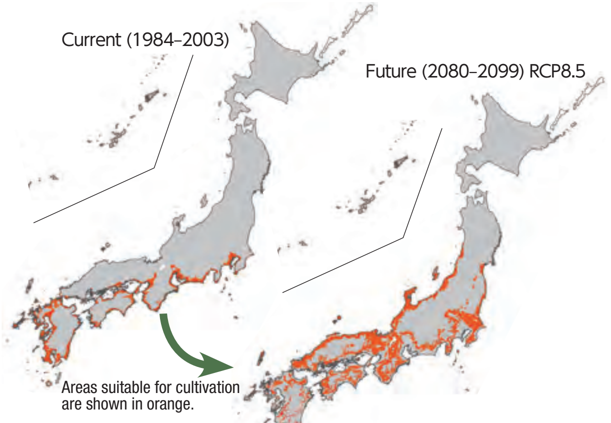
Citrus unshiu: Quality is damaged due to high temperatures and heavy rainfall

How will temperatures and precipitation in Japan change in future? Based on IPCC RCP scenarios projections on future climate change and its impacts on economy, society and ecosystem are published.
According to the results, it is projected that annual mean temperatures (2080–2100) will increases 0.5ºC–1.7ºC based on the RCP2.6 model of the least global warming, and 3.4ºC–5.4ºC based on the RCP8.5 model of the most severe global warming relative to current level (1984–2004). Temperature in Japan is projected to increase all around; particularly, the temperature in northern Japan is projected to increase largely.
Every scenario projects no obvious change in annual rainfall, but many scenarios project there will be more heavy rainfall. In contrast, most scenarios project less snowfall annually, and amounts of snowfall will be much less on the Japan Sea side of East Japan.
Based on the climate change projections, impact assessments have been conducted on many fields such as agriculture, and ecosystem. For example, all scenarios project that land suitable for cultivating citrus unshiu, which is the most produced fruit in Japan, will move to the northward and from coastal areas to inland areas. It is projected that the area suitable for growing the citrus will increase. However, RCP8.5 projects that current areas (i.e., Kii Peninsula, Shikoku and Kyushu) will be reduced. Climate change may affect our lives. (From Source 19, 20 and 21)

Annual mean temperature —Distribution of changes (2080–2100)



Areas suitable for growing citrus unshiu—Changes



Chapter 4

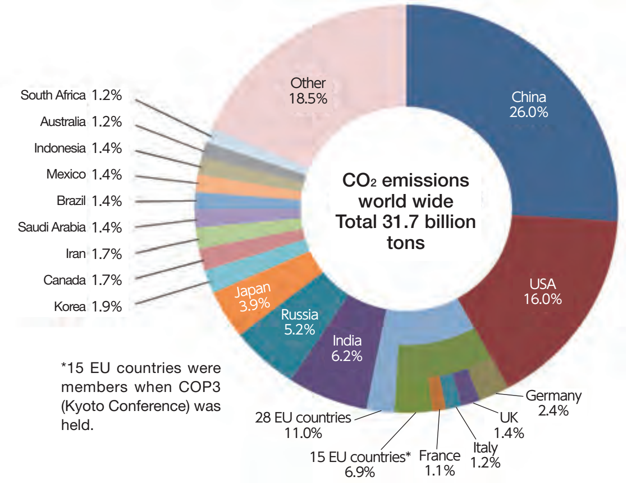
Recent CO_2 Emissions and Adaptation to Risks

It is unequivocal that anthropogenic CO_2 emissions have influenced on global warming. To protect human society and ecosystems from a crisis, all countries in the world must immediately implement effective CO_2 emission reduction efforts by cooperating together. On the other hand, we also have to quickly adapt to the impacts of climate changes that are occurring worldwide.

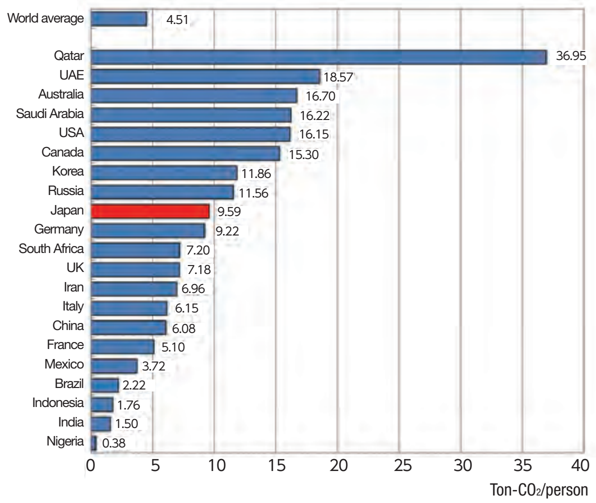
CO_2 emissions by countries

The data (2012) for CO_2 emissions by country shows China at the top, emitting more than a quarter of the world CO_2 emissions (31.7 billion tons), followed by USA. Japan ranked at fifth. Qatar, which produces a lot of oil and natural gas, is first for CO_2 emissions per person, followed by the UAE (second) and Saudi Arabia (fourth), which are also large oil producers. China, the largest CO_2 emitting country, is ranked lower than Japan.

CO_2 emissions from energy sources by countries in 2012



CO_2 emissions from energy sources per capita by country in 2012

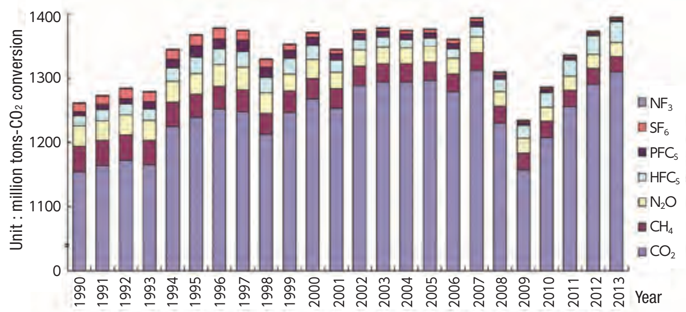


(From Source 22)

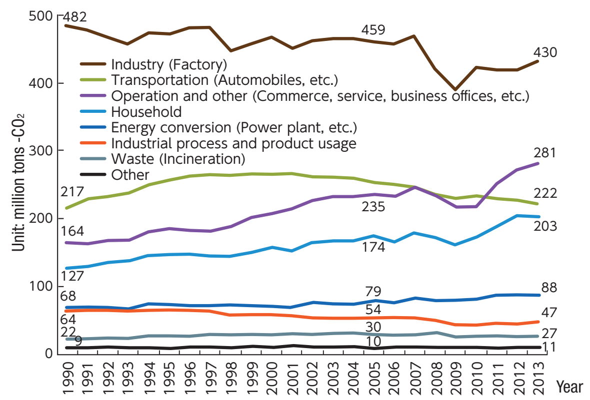
CO_2 emissions in Japan

Total volume of greenhouse gas (GHG) emissions (preliminary figures) in 2013 was 1.395 billion tons (CO_2 equivalent), an increase of 1.6% from the previous year and 1.3% from 2005. Emissions by sector shows that emissions from the "industry" sector (e.g., factories), which has the biggest emission decreased 6.3% from 2005, but "operation and other (e.g.,offices)" and "household" sectors significantly increased by 19.5% and 16.3% respectively.

The trend of GHG emissions in Japan



The trend of CO_2 emissions by sectors (after electricity/heat distribution)



(From Source 23)

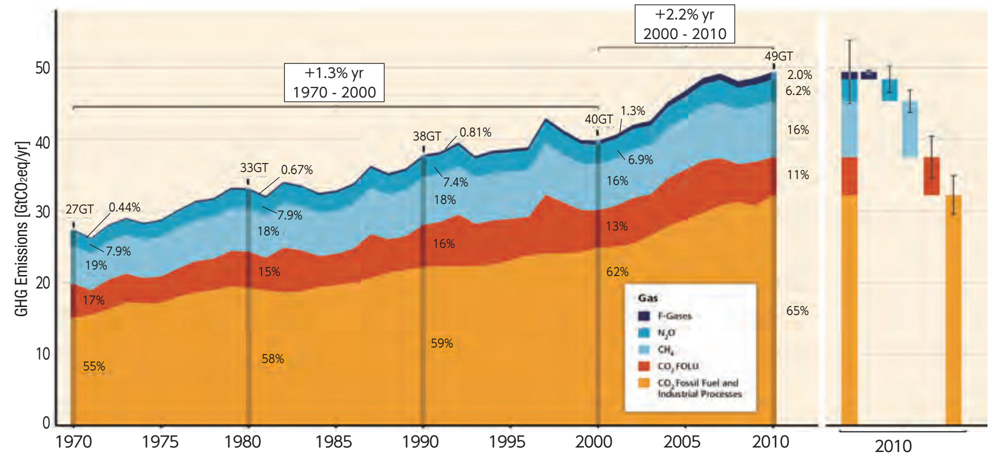
Increasing emissions past 10 years

Global anthropogenic GHG emissions have continued to increase during 1970–2010. Annual GHG emissions have grown on average by 2.2% per year from 2000 to 2010 compared to 1.3% per year from 1970 to 2000 (Figure).

The anthropogenic GHG of which emissions have significantly increased has been the CO_2 generated by burning fossil fuels or from industrial processes. Among anthropogenic GHG emissions, CO_2 emissions from fossil fuel combustion and industrial processes contributed about 78% of the total GHG emissions increase during 1970–2010.

Half of cumulative anthropogenic CO_2 emissions during 1750–2010 have emitted in the past 40 years. Furthermore, if we look at the cumulative CO_2 emissions from fossil fuel combustion, cement production and flaring during 1750–2010, the amount had tripled over the past 40 years.

Trend of anthropogenic GHG emissions 1970–2010



(IPCC AR5 WGIII Fig.SPM.1)

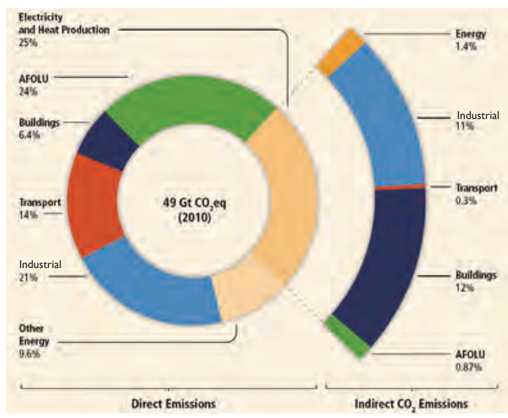
Biggest driver of CO_2 emissions increase

Why are CO_2 emissions from fossil fuels increasing? This is due mainly to economic growth and population increases. The impact of economic and population growth in 2000-2010 became bigger compared to the previous 30 years. CO_2 emission has a pronounced tendency to increase as GDP per person grows.

In 2010, 35% of GHG emissions were released in the energy supply sector, following by 24% in AFOLU, 21% in industrial sector, 14% in transport sector and 6.4% in building sector. However, including indirect emissions electricity and heat allocated by sector, industrial sectors accounts for more than 30% and building sector is close to 20%, their ratios increase in total emission.

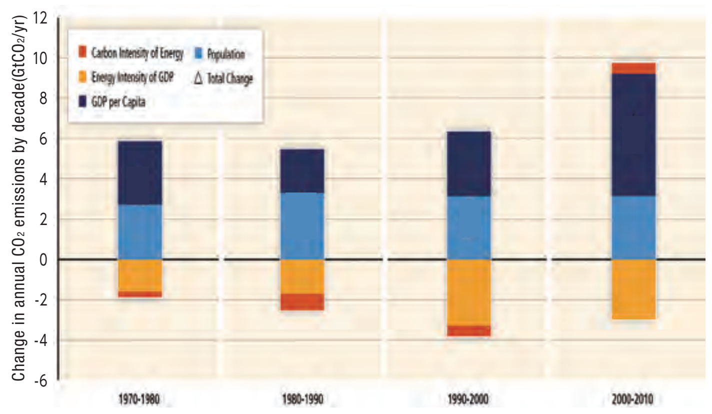
Since the growth in these sectors is attributed to economic growth, it is important to decrease emissions in these sectors.

GHG emissions by economic sectors (2010)



(IPCC AR5 WGIII Fig. SPM.2)

Decomposition of the change in global CO_2 emissions from fossil fuel combustion

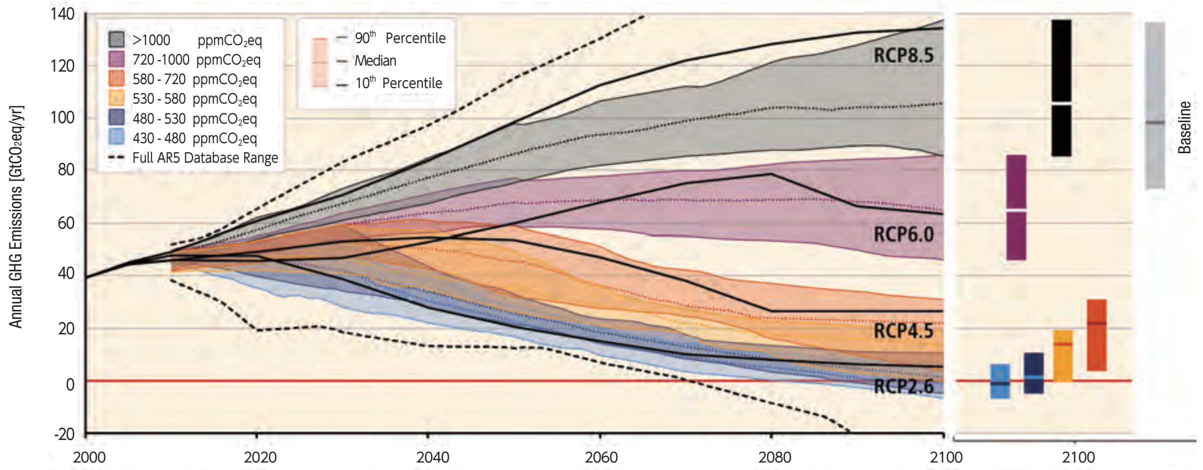


(IPCC AR5 WGIII Fig. SPM.3)

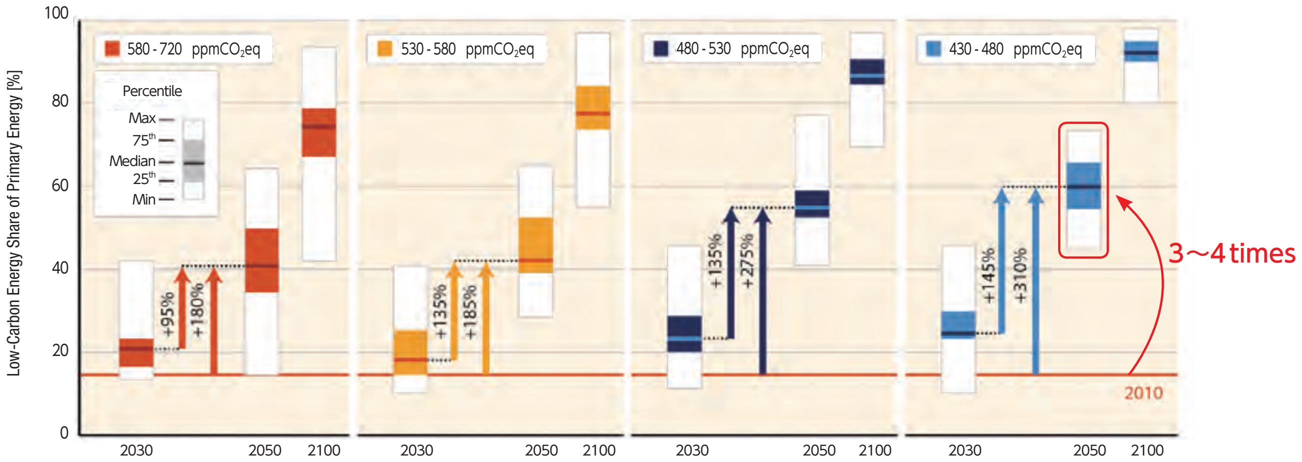
CO_2 emissions projection in 2100 — 4 mitigation pathways

The IPCC Fifth Assessment Report (AR5) reviews multiple scenarios for changes in GHG emissions and projects atmospheric concentrations and temperature increases in 2100.
There are two types of scenarios–"Baseline Scenarios" assumes no additional efforts (mitigation measures) to constrain emission of anthropogenic GHGs, and the "Mitigation Scenario" which involves additional efforts. Also one of the mitigation scenarios defines "overshoot" in which the concentration exceeds a certain threshold before 2100.
RCP2.6 leading to GHG concentrations in 2100 of range for the 430 ppm to 480 ppm CO_2-eq is the only scenario that is likely to stay below 2°C over the 21st century relative to pre-industrial levels.
RCP4.5 for the 580 ppm to 720 ppm CO_2-eq is more unlikely than likely or unlikely to stay below 2°C over the 21st century relative to pre-industrial levels.
RCP6.0 for the 720 ppm to 1000 ppm CO_2-eq, and RCP8.5 for over 1000 ppm are unlikely to stay below 2°C over the 21st century relative to pre-industrial levels.
RCP2.6 is characterized by 40% to 70% global anthropogenic GHG emissions reductions by 2050 compared to 2010, and emissions levels near zero or below in 2100. And it is also characterized by changing land usage (such as afforestation and deforestation control), more rapid improvements in energy efficiency.
Compared to 2010, it will become tripling to nearly a quadrupling of the share of renewable energy such as PV solar power and wind energy, and zero- and low carbon energy supply such as fossil energy with carbon dioxide capture and storage (CCS) and bioenergy with CCS (BECCS) by 2050. If we won't introduce key technologies as soon as possible, mitigation costs can increase substantially in addition to the achievement of RCP2.6 will get harder.

GHG emission pathways 2000-2100: All AR5 Scenarios



Associated upscaling of low-carbon energy supply



Comparing 2010's low-carbon energy share and 2050's low-carbon energy share of primary energy, the low-carbon energy share at the 430-480ppm CO_2-eq will increase significantly by 3 to 4 times.

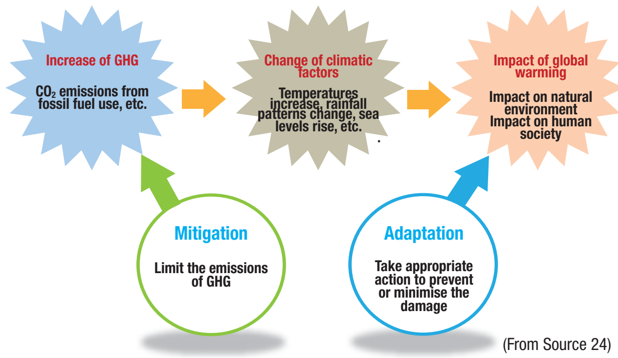
(IPCC AR5 SYR Fig. SPM.11)

Adaptation to global warming already occurs

First step to adaptation

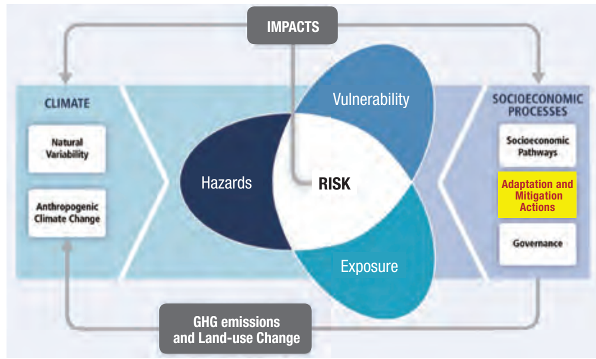
There are two types of global warming measures, which are "Mitigation" and "Adaptation". (See figure on the left below). Mitigation is to reduce GHG emissions and this is the top priority measure. And if we cannot avoid its impact even after mitigation, we should take the adaptation measure to control the nature and our society against its impact.
The IPCC AR5 states how to reduce and manage the impact or risk from climate change by launching mitigation and adaptation measures.
The figure on the right below illustrates the core concepts of the risk of climate-related impacts. This risk results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems, which are closely related to the changes in both the climate system and socioeconomic processes including adaptation and mitigation.
The risks of global warming that are becoming apparent in recent years vary among countries or areas, therefore, there is no particular adaptation measures that are effective to everywhere in the world. We have to implement appropriate adaptation measures such as building a legal or social system suitable for the particular area. Instead of looking only at the negative side of global warming, we need to apply the positive aspects of global warming to our everyday lives. For example, we can grow tropical fruits taking advantage of higher temperatures in summer to explore new markets. "Living better in the era of global warming"–This is what we are required to do.

Two global warming measures: Mitigation and Adaptation



(From Source 24)

Climate-related Risks—Core Concepts



(IPCC AR5 WGII Fig. SPM.1)

Adaptation strategies and plans in the world

Countries across the world have been establishing adaptation strategies and plans. For example, Climate Change Act came into force in UK in 2008. It defines the National Adaptation Program (NAP) under the Climate Change Adaptation Action Framework in 2013 and reviews the Program every 5 years. Australia, on the other hand, is projected more forest fires due to an increase of heat waves, and is planning an adaptation plan focusing on early warning systems, flameproof building design, fuel management, etc.

Leading-edge adaptation strategies and plans in the world

Country	Name	Area	Implementation status
UK	- Adapting to climate change in UK -A framework for Action (2008) - National Adaptation Program (NAP, 2013)	- 7 fields (Environment creation, Infrastructure, Health, Resilient community, Agriculture/forestry, Natural environment, etc.)	- Action framework describes the principles and flow required to establish programs. - Adaptation program lists concrete solutions for each area for each of the 31 goals. They correlate to 100 risks extracted from the Impact Assessment.
USA	- Progress Report of the Interagency Climate Change Adaptation Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy (2010) - Strategic Sustainability Performance Plans (41 organizations including departments and agencies, 2013)	- Task force progress report is cross-sectorial. (WG: 9 fields (Adaptive science, Adaptive plan, Water resource adaptation, Insurance, International, Communication and publicity, Urban, Health, Plant/fish/wildlife)	- Task Force Progress Report describes the principles and policy objectives. It does not define them as a strategy or plan. - Adaptation plan for each department and agency is announced by each department and agency based on a presidential order.
The Netherlands	- National Programme for Spatial Adaptation to Climate Change (ARK, 2007) - Delta Program (2011)	- 8 fields (Water, Nature, Agriculture, Energy, Transportation, Buildings/Infrastructure, Public health, Recreation) (National Spatial Planning Program is cross-sectorial	- National Programme for Spatial Adaptation to Climate Change sets out the cross-sectorial concept. - Delta Program includes specific measures such as flood solutions or fresh water supply. It is announced every year.
Australia	- National Climate Change Adaptation Framework (2007) - Government Policies (2010)	- Adaptation framework: 8 fields such as Water resources, Biodiversity, Human health, Natural disaster management) - Government Policies: 6 fields such as Coastal areas management, Infrastructure, Natural disaster prevention	- Adaptation Framework mainly describes cross-sectorial concepts and action guidelines for research lasting 5 to 7 years. - Government Policies describes the government view for adaptation and the areas of higher priority in the 5 to 10 year period.

(From Source 25)

Adaptation efforts worldwide

Based on the prediction of climate change in the future, countries all over the world identify the fields that will have got particularly big impacts or have high priority for implementing adaptation measures. They also estimate the damages from climate change and costs of these adaptation measures. These adaptation measures differ depending on the country and region, such as constructing levees to protect the land from storm surges caused by sea level rise, and taking measures against the heat-induced damage to agricultural products. This section describes the advanced approaches taken by countries all over the world.

UK

UK launched an adaptation program in 2012, and is taking adaptation measures such as for flood risk management, water resources, freshwater ecology, as the high-priority areas. In the improvement project at the Thames Estuary, the Thames Barrier which expands 18km has been installed to protect the low lands from flooding. The gates are closed about 10 times a year during storm surges to prevent flooding. (From Source 25)

On the river mouth, the Thames Barrier is designed to protect inland areas from storm surges until 2030 even if sea level increases 8mm per year. Photo : Koichiro Aitani

The Netherlands

There are concerns that flood risks from the Rhine river will increase due to torrential rains and it is projected that the Rhine river will have a 10% or more increased flow in 2050 than today. "Room for the River", the national flood risk management plan in Netherlands, was established to improve the safety level of flood control by securing an approximately 7,000 hectare flood control basin. In Rotterdam, a city at the mouth of the Rhine, the Maeslantkering (movable storm surge barrier) was built to protect the city from storm surges from the North Sea. (From Source 26)

The Maeslantkering (movable storm surge barrier) in Rotterdam at the mouth of the Rhine. It protects the city from storm surges from the North Sea. Photo provided by het Keringhuis

Tuvalu

Mangroves grow in the brackish environment where the sea and river meet, and function as a levee to protect coastal areas from storm surges or tsunami. In the mangrove forest, both fresh and salt water creatures as well as aquatic and land creatures are creating a rich biodiversity. Therefore, in Tuvalu, which is a country now facing problems of flooding caused by sea level rise due to global warming, an activity of planting mangroves is underway on Funafala Island (Funafuti Atoll). (From Source 27)

Mangroves are planted as a natural levee to protect the land from storm surges in Tuvalu.

© Shuuichi Endou / NPO Tuvalu Overview

Australia

In 2006, Australia was hit by the worst drought in the past 100 years. As a result, wheat production dropped to about a 40% level from the previous year. Also in 2007, there was another drought, and the Australian agriculture suffered heavy damage. The government announced plans to relocate wheat farm lands to northern areas with more rain by implementing supporting measures such as providing subsidies to wheat growers. (From Source 28)

Australia announced plans to relocate wheat farm land extending from the southeast to the southwest to the north.

Photo : Shinji Kazama

Adaptation efforts in Japan

Japan is also implementing adaptation strategy. Since climate change impacts vary among regions, local governments play a very important role in planning and implementing the adaptation measures. Some prefectures including Nagano, Saitama, Tokyo, and Mie have already launched advanced adaptation efforts. Nagano has clearly defined the adaptation measures in the "Environment and Energy Plan in Nagano–Third Prefectural Plan against Climate Change in Nagano" (2013), and launched various projects such as the "Climate Change Monitoring System" and the "Shinshu Climate Change Adaptation Platform." This section describes the adaptation measures planned by Wakayama and Yamagata.

"Heat-resistant" chickens

At food production sites, various adaptation measures have been launched while analyzing situation of damage.

One of these measures is the development of "heat-resistant" egg-producing hens conducted by Wakayama Livestock Experiment Station Poultry Research Center. Covered with feathers, birds do not have sweat glands and have a very low tolerance for summer heat. As summer becomes hotter every year due to global warming, the hens have been laying fewer eggs, the quality of those eggs has deteriorated, and more hens have been dying because of the heat. These are serious problems for poultry farmers, and an immediate solution is required.

The Poultry Research Center has been experimenting by feeding chickens special feeds that contain antioxidants such as Japanese pepper seed (one of the specialty products from Wakayama). Researchers learned that they can improve egg production while keeping the decrease in the egg laying rate, daily egg production and egg quality to a minimum under the stress of summer heat. They are planning to develop this feeding technology and promote it to other poultry farmers so that they can produce local branded eggs and can implement a recycling-oriented society.

(From Source 29 and 30)

Antioxidant materials using special products from Wakayama are added to feed for hens: (1) "Plum BX70" (Desalinated and concentrated plum vinegar produced in the process of making Japanese pickled plum); (2) "Ricetrienol" (Fat extracted from rice bran); and (3) "Japanese pepper seed" are under consideration.

Growing temperate citrus in cold Tohoku

Yamagata prefecture , which is one of the largest agricultural production area in Japan, established "Vision for Research and Development of Agriculture, Forestry and Fisheries Corresponding to Global Warming" in 2010 (revised in March 2015), and is conducting strategic R&D getting ahead of global warming.

One of these projects is to grow temperate crops. In Yamagata, many fruit trees such as cherry and apple are grown thanks to cool weather, but several decades later it is projected that they can grow citrus trees, which are usually grown in warmer places. The Yamagata Shonai Production Area Research Center performed an experimental study of growing outdoors of 8 Japanese citrus varieties such as sudachi, yuzu, and citrus unshiu. As a result, it was determined that five kinds of citrus including sudachi and citrus unshiu can overwinter fairly well if they were covered with non-woven fabrics during the winter. The sudachi in particular produces good-quality fruits that can be commercialized without any difficulty. The trunk of a tree is growing well, so Yamagata is moving forward with further research on appropriate tree growing methods.

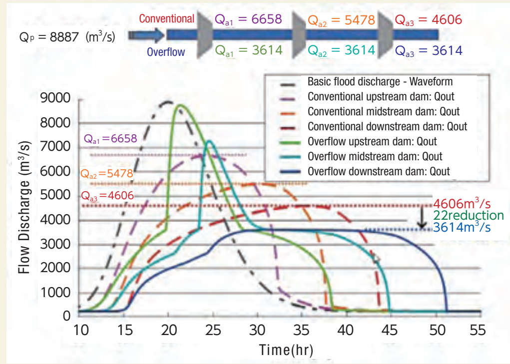
(From Source 29 and 31)

Since the temperature in winter drops to around -7°C, the whole tree is covered by a non-woven fabric to overwinter.

column

New technologies for disaster-prevention (adaptation to river-related disaster)

Kyushu is annually hit by torrential rains in the summer and fall, so there is an urgent need to launch adaptation measures for flooding disaster. Responding to this urgency, a research group from Kyushu University has developed a new water control technology, the "cascade method," by constructing a "flood mitigation dam." This dam consists of a series of small-scale flood mitigation dams (flood control basins in the river channel). Simulations demonstrated that flood control capability, which is critical to control river flow, is enhanced by allowing overflows from the emergency spillways with the upstream dams in the mountain areas (cascade method) (See figure on the right). This flood mitigation dam can control disasters related to flooding and landslides, changing due to rainfall intensity growth and rainfall amount increase. The research group is going to start a concrete survey on the Chikugo River, and expect good results. (From Source 5)



Flood control capacity by cascade method

Compared to conventional dams, the cascade method can reduce maximum flow discharge from downstream dams by 22%.

Chapter 5 Efforts in Japan
——The way to realize a low carbon society

It is crucial that the international community cooperate to mitigate climate change. Under "Proactive Diplomatic Strategy for Countering Global Warming," Japan will contribute to climate change mitigation by reinforcing its international partnerships and reaching out worldwide to promote innovative environmental technologies. Domestically, Japan will reform its industrial and energy structure and the life style of its nation to establish a low carbon society.

Mid-term and long-term global warming measures

Global warming measures need to be carried out based on scientific knowledge through joint efforts with the international community. Japan has set a goal of reducing greenhouse gas (GHG) emissions by 50% at the global level and 80% in the developed world by 2050.
To reach this goal, Japan, under "Actions for Cool Earth (ACE): Proactive Diplomatic Strategy for Countering Global Warming" announced in November 2013, has been taking various efforts. Japan will contribute to global GHG reduction by leading the development of innovative technologies and promoting effective low carbon technologies and systems worldwide.

(From Source 32, 33 ,34)

Trend of International society

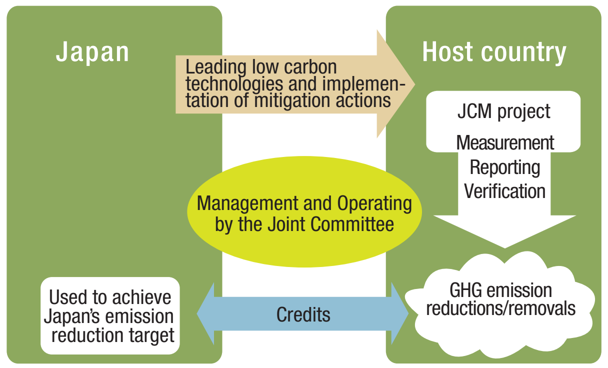
International negotiations and support to developing countries

Based on the Cancun Agreements adopted at the Conference of the Parties to the UNFCCC (COP16) held in 2010, developed countries/developing countries have taken up emissions reduction targets/actions under the Convention.
Further, negotiations are progressing towards an agreement on a post 2020 international framework applicable to all parties to be adopted at COP21 to be held in Paris at the end of 2015. All parties are invited to communicate their Intended Nationally Determined Contributions well in advance of COP21 (and by the first quarter of 2015 for those Parties ready to do so). The EU has already announced its 2030 target to reduce GHG emissions by at least 40% from 1990 levels. The USA has already announced that it will reduce GHG emissions by 26-28% by 2025 from 2005 levels. Japan will submit a new reduction target as early as possible.
Because the ratio of GHG emissions for developing countries has been increasing every year, it is crucial to promote the activities for those countries to reduce GHG. For this reason, Japan is providing advanced environmental technologies, experience, and know-how, in addition to promoting financial assistance. Japan announced a maximum $1.5 billion contribution to the "Green Climate Fund" established in COP16, to support global warming measures by developing countries.

(From Source 32, 35, 36)

Joint Crediting Mechanism (JCM)

The JCM is established to facilitate diffusion of leading low carbon technologies through which Government of Japan acquires the credit to be used to achieve its emission reduction target and contribute to global actions for GHG emission reductions. Government of Japan has signed bilateral documents for the JCM with 12 countries, namely Mongolia, Bangladesh, Ethiopia, Kenya, Maldives, Vietnam, Laos, Indonesia, Costa Rica, Palau, Cambodia and Mexico (As of February 2015).
22 projects are selected under the financing programme for JCM Model Projects by the Ministry of the Environment (MOE) in 8 countries including, for example, Indonesia and Vietnam (As of February 2015). First JCM project, "Energy saving for air-conditioning and process cooling at textile factory" by Ebara Refrigeration Equipment & Systems, has been registered by the Joint Committee between Indonesia and Japan in October 2014.



(From Source 37)

Act on Promotion of Global Warming Measures

The "Act on Promotion of Global Warming Measures" was enacted in October 1998 in response to the Kyoto Protocol. The Act has since been revised several times and the March 2013 revision added nitrogen trifluoride to the GHG list and provided that the national government shall establish the Global warming measure plan. The key points of the revised Act as follows.

(From Source 38, 39, 40, 41)

Global warming measure plan (Article 8)
- Establish the Global warming measure plan that define such specific matters as GHG emissions control / removal goals and measures that businesses and individuals should devise

Action plans of the state, prefecture and municipality (Articles 20-1 through 20-4)
- Prepare plans in which the state and local governments proactively conduct reduction efforts
- Promotes detailed solutions and coordination with other regional projects

Establishing emission control policies (Article 21)
- Controls for emissions from business activities (e.g., implementation of high-efficient equipment, air-conditioning control, efficient use of office equipment, etc.) (Article 20-5)
- Emission controls for everyday life (e.g., promotion of "Visualize CO_2" for products, promotion of the "3Rs") (Article 20-6)
(Announcement of policies needed to correctly and effectively exercise these two obligations)

Calculation, report, and publication of GHG emissions (Articles 21-2 through 21-11)
- Mandates that businesses of a certain scale or bigger must calculates their GHG emissions and report the amounts to the government; the government is responsible for collecting and publishing the data
- Reporting by each business type and franchise chain
- Including encouragement of the use of credits through the CDM, etc.

Centers for Climate Change Actions (Nationwide, prefectural/designated cities, etc.) (Article 24, Article 25)
- National center: the Japan Network for Climate Change Action has been specified.
- Regional centers: 47 prefectures and eight cities (Aomori, Akita, Kumagaya, Kawasaki, Hamamatsu, Nagano, Kumamoto and Kawaguchi) have been specified (As of October 1st, 2014)

Transaction system of Kyoto mechanism (Registry) (Article 29 through Article 41)
- Rules of transaction and protection for Kyoto mechanism credits
- Procedures for using "A/R CDM"

Miscellaneous regulations
- Promotion of commodities that emit less GHG (Article 42-2)

Promotion of implementation of low carbon technologies
—Listing leading-edge low carbon technologies

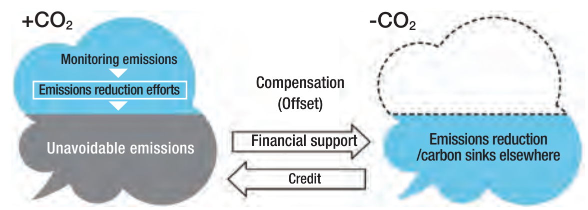
MOE established policies to control the emission of GHG and thus promoting the solutions. MOE announced the "L2-Tech/Japan Initiative" in March 2014, listed leading-edge low carbon technologies, and promoted the development and popularization of those technologies. MOE listed those technologies according to the area where they have been applied–Industry/operation (common to all industries), industry (manufacturing facilities specific to an industry, etc.), transportation, homes, energy conversion, and industrial waste processing/recycling, and organized the data such as explanation of the facilities and equipment, explanation of index, and L2-Tech criteria (the highest efficiency value that has been achieved). Those technologies cover permanent magnet synchronous motors, high-efficiency turbo freezing machines, heat insulating materials, fuel cells, etc. For technology development and popularization, MOE will update and expand the list and data by surveying the needs by which factories and businesses canreduce CO_2 emissions or reduce costs if they apply low-carbon technologies. MOE will also launch a project to subsidize and promote operations improvement of the investment in leading-edge technologies that can efficiently reduce CO_2 emissions from, for example, office buildings.

(From Source 34, 42, 43)


Permanent magnet synchronous motor

Carbon Offset System— Linking local communities, private sector and consumers

The Carbon Offset is a concept for entities and individuals to offset their GHG emissions. After recognizing their emissions and making efforts to reduce these emissions, entities and individuals can offset these emissions with the emission reductions or carbon sinks elsewhere. MOE has established carbon offset since 2008.



Many credits have been issued every year from introducing renewable energy or managing forest by tree thinning, etc. Entities can purchase these credits and add to their products. When the consumers select to purchase these products, it subsequently results in providing finance to the credit generators, and promotes further use of renewable energy, forest improvement, etc.
In 2013, the "J-Credit System" was launched, making it easier for credit generators and credit users to generate or acquire credits. It is also projected that the system will contribute to simulate agriculture and forestry.

(From Source 44, 45, 46, 47)

“Fun to Share”: Climate change mitigation campaign

Ideas to prevent global warming are newly creating every day. The important thing is to share those ideas with everyone and start doing whatever we can do.
MOE launched a Climate change mitigation campaign called “Fun to Share” in March 2014. “Fun to Share” is a slogan for everyone to share ideas and technologies to build a low carbon society by doing various things while enjoying their daily lives without trying too hard to reach the goal.
MOE is introducing ideas, technologies and approaches, conducted by companies, organizations, local communities and others for realization of a low carbon society via the official website, SNS (e.g., Facebook), TV, newspapers and events. If you think “this is a good approach” or “I want to try,” share these ideas with others to get the message out to the rest of the world.
MOE develops efforts to realize a low carbon society through the following actions:
“Cool Biz”: An initiative to suggest a lifestyle COOLBIZ focuses on comfortable living in the case of setting the thermostat up to 28°C. In addition to cloth, it involves the promotion of using curtains and blinds, changing work hours, replacing older air-conditioning units with newer energy-saving models, and “Cool Share” which means sharing a cool place with others.

“Fun to Share Match” held by “Shimizu S-Pulse” (a professional soccer team). Supporters and sponsors are jointly promoting environmental protection.
© S-pulse

The “Fun to Share Lounge” opened as an information dissemination center where efforts to establish a low carbon society by corporations, etc. are gathered, such as unique technologies and approaches for a low carbon society.

“Warm Biz”: An initiative to suggest a lifestyle WARMBIZ focuses on comfortable living in the case of setting the thermostat down to 20°C. In addition to new conception concerning such as warmer clothing, meals, bathing, and exercising, “Warm Share” is promoted, which means sharing warmth with family members, neighbors and others in town.
ECO transportation—“smart move”— is a suggestion for smart move a new lifestyle for ecological action such as commuting, going to school, shopping, and traveling. Not just for reducing CO_2 emissions, but for achieving a healthier, more comfortable, and more convenient lifestyle, more use of public transportation, bicycles, walking, how to use cars, car-sharing and community bicycles are being promoted.
ECO Driver—the manner for the future— encourages ECO DRIVER. everyone to become an “ECO Driver” who has the excellent driving manners. By driving carefully without suddenly braking or accelerating, not only CO_2 emissions can be reduced but expense can be saved through improving fuel efficiency while we can prevent accidents.
(From Source 48, 49)

Eco-home diagnosis programme

CO_2 emissions from residential sector share 15% of the total GHG emissions in Japan. We are required to reduce CO_2 emissions largely. Since FY2014, MOE implemented the “Eco-home diagnosis programme” that proposes ways to reduce CO_2 emission, “visualizing” CO_2 emitted from homes and utility expenses.Thus, MOE actively supports homeowners who try to reduce CO_2 emissions.
The“Eco-home Appraiser,” who has passed a certification examination (authorized by MOE) and has been registered at a diagnostics institution, diagnosis the level of energy efficiency by use of “Eco-home Diagnosis Software.” Some corporations also offer their own proprietary eco diagnostics for homes.

Eco-home diagnosis—Diagnostics Screen

The diagnosis (1) checks the status of energy consumption and whether a home is using more energy than others, (2) breaks down CO_2 emissions (“Visualizing CO_2”) to identify problem areas (e.g., hot-water or heating systems) that are using too much energy, and (3) gives advice on how to reduce CO_2 emissions and energy costs by implementing measures for cars, hot water-supply systems, water-saving systems, air-conditioners, refrigerators, and lighting apparatus.
In the projects set up to improve infrastructure from 2011 to 2013, about 30,000 diagnostics were conducted. According to FY2012 survey, 70% or more of those who received diagnosis evaluated to high ratings.
(From Source 42, 50, 51)

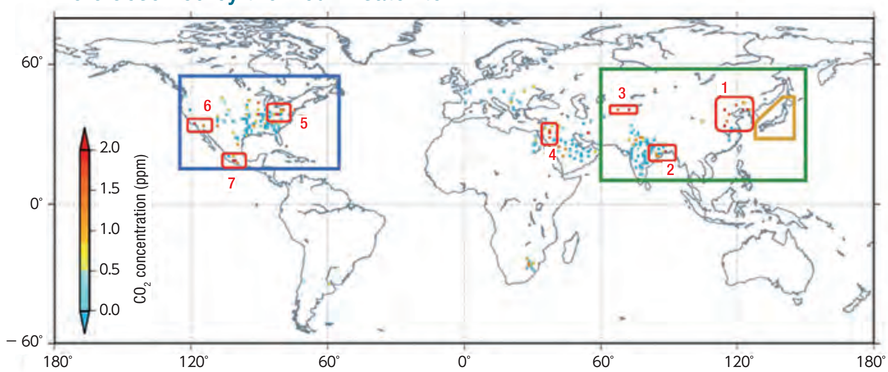
GOSAT (©JAXA)

Japan’s contributions in scientific fields

Monitoring GHG from space

GOSAT (Greenhouse gasses Observing SATellite) (“Ibuki”) was launched on January 23, 2009 to monitor GHG (mainly, CO_2 and methane) from space and the satellite is monitoring continuously.
In the past, the number of terrestrial observation points for GHG has been around 200, but thanks to GOSAT the number has increased to about 13,000, more detailed and precise observation are available now. GOSAT provides the information of CO_2 and methane (including the geographical distribution, seasonal and interannual variations), therefore it contributes to deepen our scientific understanding about global warming and climate change, and it is useful for estimation of future climate change and planning measures to reduce GHG emissions.
There are plans to launch GOSAT-2 (successor of GOSAT) in FY2017. GOSAT-2 will estimate the amount of GHG emissions by each major city or emission source, and monitor for air pollution by aerosols.
(From Source 34, 52,53, 54)

Areas where high concentrations of anthropogenic CO_2 were observed by the “Ibuki” satellite.

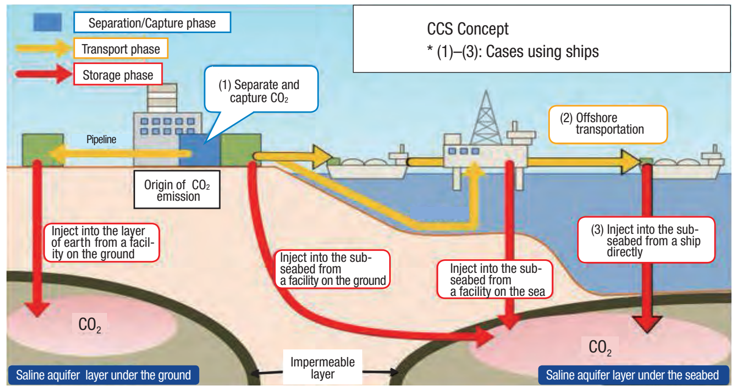


Areas where particularly high concentrations of anthropogenic CO_2 were observed (average from June 2009 to December 2012) are shown in red boxes.

Carbon dioxide Capture and Storage (CCS)

CCS is a technology that separates and captures CO_2 emitted from power plants, by capturing CO_2 with CO_2 absorbent, then transferring and injecting it in the ground. In Japan, CO_2 emissions have continuously increased due to the increase in electricity production by thermal power generation. For this reason, in order to commercialize CCS by around 2020, MOE is implementing the “Project of Promotion of Carbon Negative Society through CCS”. By introducing environmentally friendly CCS adequately and smoothly, it is expected that CO_2 emissions will be significantly reduced.
(From Source 55,56)

CCS concept



The World’s Leading-edge floating offshore wind power

Offshore wind power plant with floating turbine needs advanced technologies to be installed in deep sea areas. Having not much shallow sea areas, Japan has more advantages floating wind turbines rather than bottom-mounted wind turbines. However, there have been only a few demonstration projects on this type of methodology in the world.
In this situation, in 2010, MOE launched the first project in Japan to examine the feasibility of floating offshore wind power. In October 2013, MOE started operating a 2MW demonstration turbine at the commercial scale off the coast of Goto City, Nagasaki Prefecture.
Through the performance like this project, MOE will continue working towards the early, practical utilization of floating offshore wind power.
(From Source 57, 58, 59)

2MW floating offshore wind turbine off Kabashima Island (Goto City, Nagasaki Prefecture)
Photo provided by Goto City

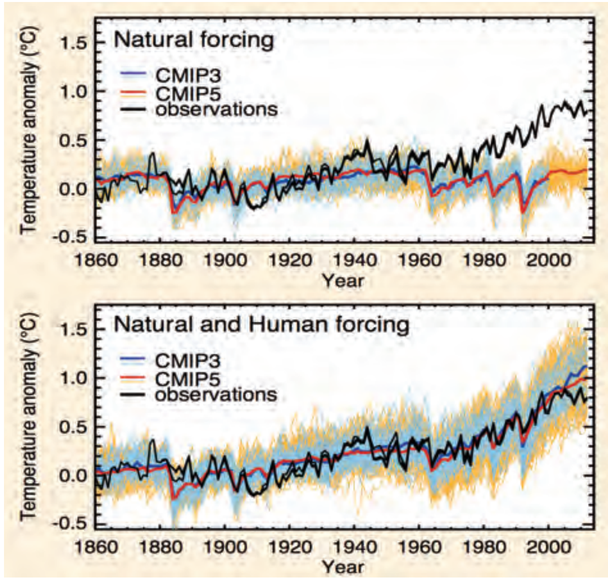
Q&A Really Serious? Global Warming Issues

Q Human-induced Greenhouse Gases are Major Factor of Global Warming?

A There are many factors that make global mean temperatures to change. Natural forcing (external forces to change climate system) such as activated solar activities and volcano eruption has been a major factor of climate change before the era of increases of human activities. However, according to the IPCC Fifth Assessment Report, "It is extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by human activities" In other words, recent climate changes are hard to explain by internal changes in the climate system itself (internal variability) and natural forcing, but by human forcing such as emitting of greenhouse gases (GHG) and atmospheric pollution.

To determine major causes of climate change, observed changes must be reproduced from computer model simulations of internal variability and different patterns of changes by each external forcing. When it simulates, the key for this simulation is the pattern (metaphorically called "fingerprints") in the history of climate change. Simulations driven only by natural forcings (yellow and blue lines in the upper panel) fail to reproduce the increase of temperature in the second half 20th century. Simulations including both natural and human forcings provide a much better representation of the pattern of the increase of temperature (lower panel).

Observed values and simulation results of global and annual-averaged surface temperature change from 1860 to 2010



The upper figure shows two separately simulated climate models, shown as light blue and yellow lines; applied with just natural forcing as driving factors and their ensemble averages, shown as thick blue and red lines. Obviously, change patterns of these lines and the black line (observed values) have not corresponded well since the 1970s. In contrast, the bottom figure of the same models include the natural forcing and human forcing (e.g., GHG and aerosols) as driving factors, corresponds well to the observed values.

(From IPCC AR5 WGI FAQ 10.1)

Q Could Geoengineering Counteract Climate Change?

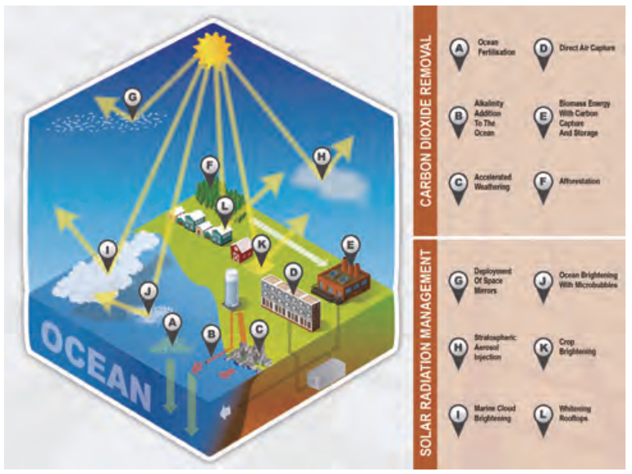
A Geoengineering (also called climate engineering) is defined as a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate impacts of climate change. Two distinct categories of geoengineering methods are usually considered: Solar Radiation Management (SRM) aims to offset warming from anthropogenic GHG by making the planet more reflective, while Carbon Dioxide Removal (CDR) aims at reducing the atmospheric CO_2 concentration.

As shown in the figure on the right, some CDR methods rely on biological processes, such as (A) ocean fertilization (transporting a fraction of the biogenic carbon downward by adding nutrients to the ocean), (E) bioenergy with carbon capture and storage (BECCS), and (F) afforestation. The CO_2 removed from the atmosphere would then be stored in land reservoirs, oceanic reservoirs, or geological reservoirs, where it would have to be stored for at least hundreds of years for CDR to be effective.

Some SRM methods propose to (G) reflectors are placed in space to reflect solar radiation, (H) aerosols are injected in the stratosphere, and (K) more reflective crops are grown. It is said that SRM may be effective in solution of increasing temperatures.

However, currently the level of scientific understanding about geoengineering methods is low, and all proposed methods carry risks and side effects.

Overview of some proposed geoengineering methods



Carbon Dioxide Removal (CDR) methods: (A) ocean fertilization; (B) alkalinity from solid minerals is added to the ocean; (C) the weathering rate of silicate rocks is increased, and the dissolved carbonate minerals are transported to the ocean; (D) atmospheric CO_2 is captured chemically, and stored either underground or in the ocean; (E) biomass is burned at an electric power plant with carbon capture and storage; and (F) afforestation. Solar Radiation Management (SRM) methods: (G) reflectors are placed in space; (H) aerosols are injected in the stratosphere; (I) marine clouds are seeded; (J) microbubbles are produced at the ocean surface (to make it more reflective); (K) more reflective crops are grown; and (L) roofs and other built structures are whitened.

(From IPCC AR5 WGI FAQ 7.3)

Q Is the Ocean Really Warming?

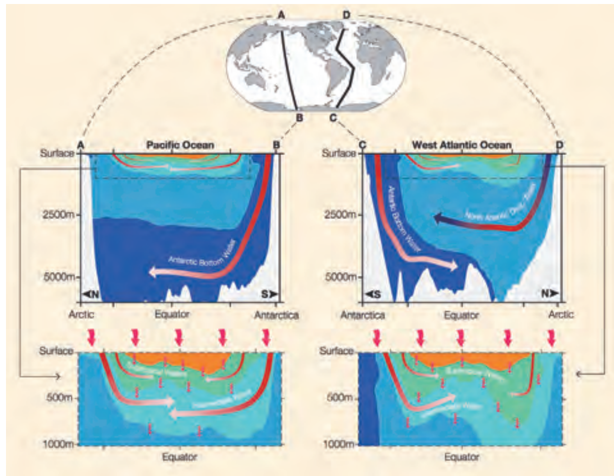
A The Ocean occupies about 70% of the earth's surface, controls the increasing CO_2 concentrations in the atmosphere and mitigate global warming by absorbing heat and CO_2, However, as the ocean is continuously exposed to heat or CO_2, obviously the ocean is warming over different many regions and depth ranges.

It was not until around 1971 that the global mean ocean temperatures in several hundred meters depth could be estimated sufficiently. The international marine observation program, called "Argo," the global monitoring network using temperature/salinity profiling floats was implemented. It covered most of the ocean areas in the world in 2005, and, therefore, accurate global mean sea surface temperatures could be estimated.

Global mean sea surface temperatures have increased over decadal time scales from 1971 to 2010, and the ocean temperatures not only in the sea surface but also in the deep ocean is increasing. The figure on the right shows the pathway in which the ocean absorbs heat. Colder–hence denser–waters from high latitudes such as the northern North Atlantic Ocean and the sea around Antarctica sink from sea surface, and then spread toward the equator under warmer and low-density waters at lower latitudes. As sea surface waters become warmer, accordingly, cold waters in deep ocean also become warmer. As a result, the heat circulation more contributes to the increase of ocean temperatures than the heat directly from sea surface does. Around Antarctica, temperatures of deep waters around the bed of the sea have been observed increasing since around 1992 to 2005.

The ocean has absorbed almost all of the combined heat stored by global warming for 40 years between 1971 and 2010. If GHG concentrations keep increasing in future, the ocean temperatures will keep increasing as well.

Ocean heat uptake pathways



The upper figures show the heat pathways in the deep ocean, and the lower figures represent those in the upper ocean. Cold Antarctic Bottom Water (dark blue) sinks around Antarctica then spreads northward along the ocean floor into the central Pacific and western Atlantic oceans (upper left and right figures: red arrows fading to white, indicating warming of the bottom water). Less cold, hence lighter, North Atlantic Deep Water (lighter blue) sinks in the northern North Atlantic Ocean then spreads south above the Antarctic Bottom Water. Similarly, in the upper ocean, cool Intermediate Waters (cyan) sink in sub-polar regions, before spreading toward the equator under warmer subtropical waters (green), which in turn sink (red arrows fading to white indicate stronger warming of the intermediate and subtropical waters most recently in contact with the surface) and spread toward the equator under tropical waters, the warmest and lightest (orange) in all three oceans (lower left and right figures). Excess heat at the ocean surface also mixes slowly downward (sub-surface wavy red arrows).

(From IPCC AR5 WGI FAQ 3.1)

Q How is Climate Change Affecting Monsoons?

A Monsoons are seasonal winds that are responsible for a large fraction of the annual rainfall in many regions including Asia, Australia, the Americas and Africa. As the climate becomes warmer, monsoonal rainfall is projected to become more intense in the future.

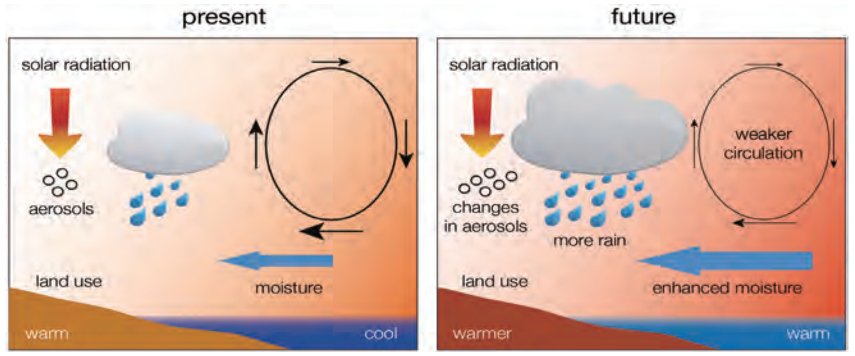
The monsoon is driven by the difference in temperature between land and sea, and makes rainfall by transporting water vapour from the ocean to the land area.

As the temperatures is increasing due to warming, increasing water vapour transport from the ocean into land increases because warmer air contains more water vapour, eventually, potential for heavy rainfalls is increasing.

There are a number of other effects as to how climate change can influence monsoons. If the reflection rate (albedo) of the land surface increases due to land use changes by human activities or atmospheric aerosol loadings increase due to air pollution, the amount of solar radiation absorbed in the atmosphere and the land increases, thus potentially moderating the land-sea temperature difference.

Climate model through the 21st century is projected from 5% to an approximately 15% increase of global monsoon rainfall depending on scenarios. Though total tropical monsoon rainfall increases, some areas will receive less monsoon rainfall, due to weakening tropical wind circulations. Monsoon onset dates are likely to be early or not to change much and the monsoon retreat dates are likely to delay, resulting in lengthening of the monsoon season.

The main ways that human activity influences monsoon rainfall



As the climate warms, increasing water vapour transport from the ocean into land increases because warmer air contains more water vapour. This also increases the potential for heavy rainfalls. Warming-related changes in atmospheric circulation influence the strength and extent of the monsoon. Meanwhile, the increase of reflection rate (albedo) of the land surface due to the change of land use change and atmospheric aerosol loading due to air pollution can affect the amount of solar radiation that is absorbed in the atmosphere and land, potentially moderating the land-sea temperature difference.

(From IPCC AR5 WGI FAQ 14.1)