CLIMATE CHANGE SCIENCE

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C3ER BRAC University

Since 2011

BRAC University
66 Mohakhali
Dhaka 1212
Bangladesh
+880-2-9844051-4

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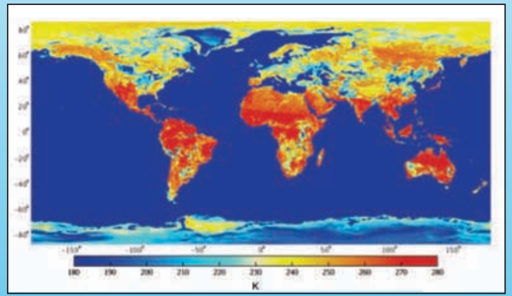
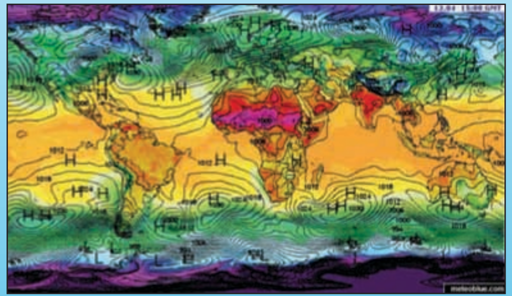
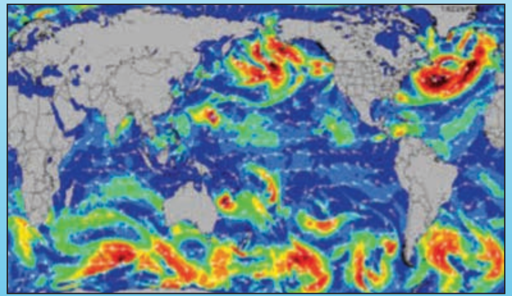
WEATHER

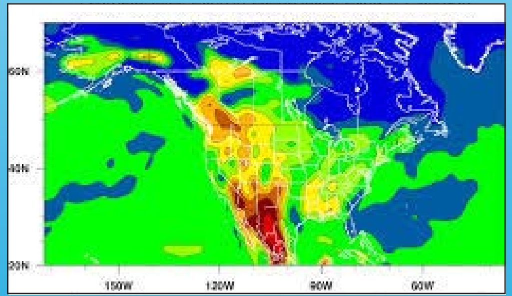
- The term “weather” refers to the temporary conditions of the atmosphere, the layer of air that surrounds the Earth. For example: if it is raining, hot, or windy.
- Weather is not really predictable beyond a week or two into the future.
- Weather doesn't just stay in one place. It moves, and changes from hour to hour or day to day.

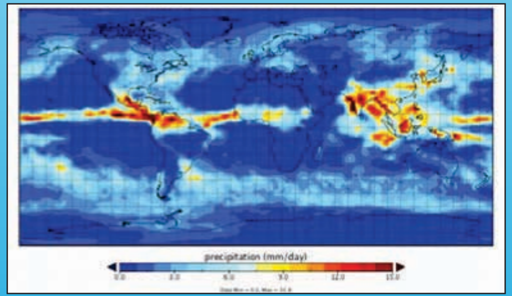
- There are six main components, or parts, of weather. They are temperature, atmospheric pressure, wind, humidity, precipitation, and cloudiness. Together, these components describe the weather at any given time.

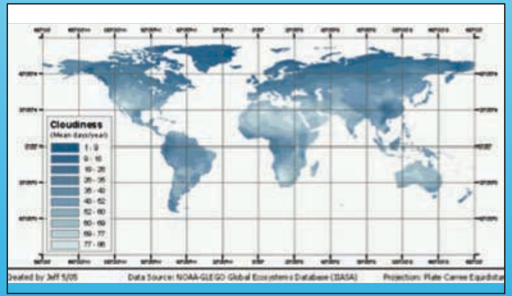

H-Polarized Brightness Temperature


Atmospheric Pressure Map


world wind map


Mean Relative Humidity [Surface] (%)

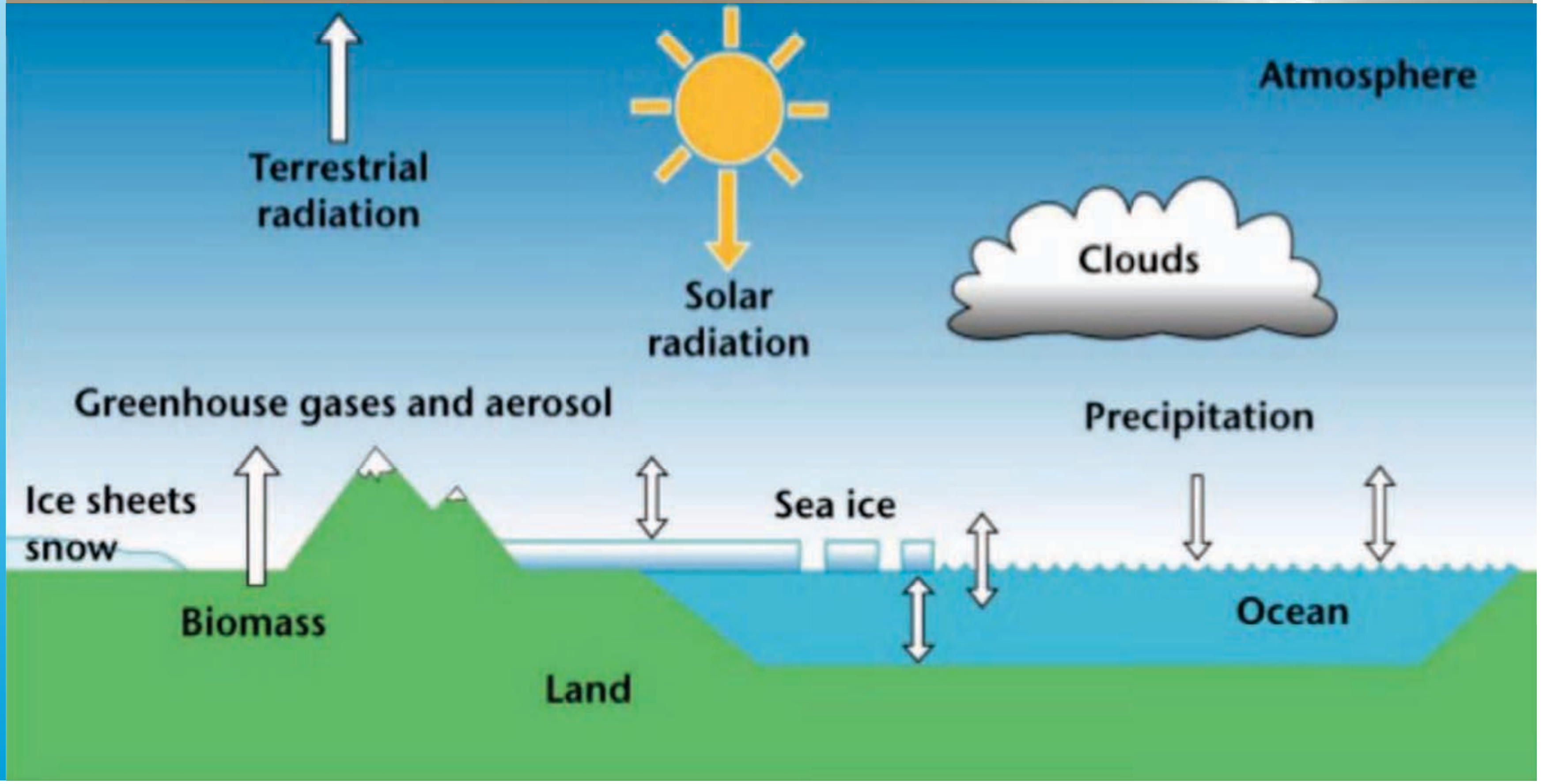

Global Precipitation July 2010


Global Cloudiness

courtesy: https://www.google.com/

CLIMATE

- In short, climate is the description of the long-term pattern of weather in a particular area.
- Some scientists define climate as the average weather for a particular region and time period, usually taken over 30-years. It's really an average pattern of weather for a particular region.

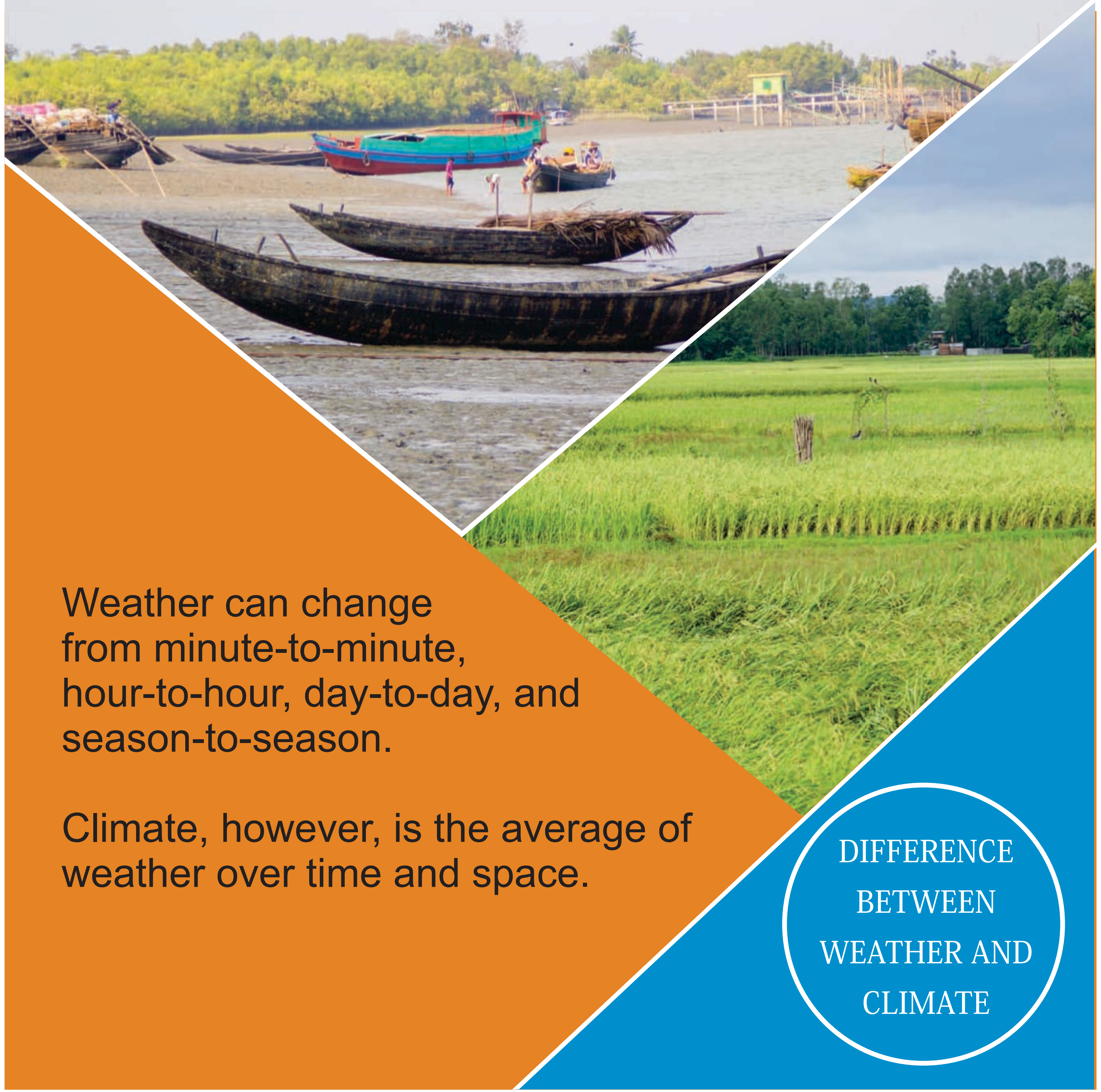


DIFFERENCE BETWEEN WEATHER AND CLIMATE

- When scientists talk about climate, they're looking at averages of precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather that occur over a long period in a particular place.

- For example, after looking at rain gauge data, lake and reservoir levels, and satellite data, scientists can tell if during a summer, an area was drier than average. If it continues to be drier than normal over the course of many summers, than it would likely indicate a change in the climate.

- Several factors determine the climate of a region. Such as: 1. Latitude 2. Altitude 3. Distance from the sea 4. Prevailing wind 5. Rainfall 6. Location of Mountain 7. Forest 8. Slope of land and 9. Soil characteristics.



Weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season.

Climate, however, is the average of weather over time and space.

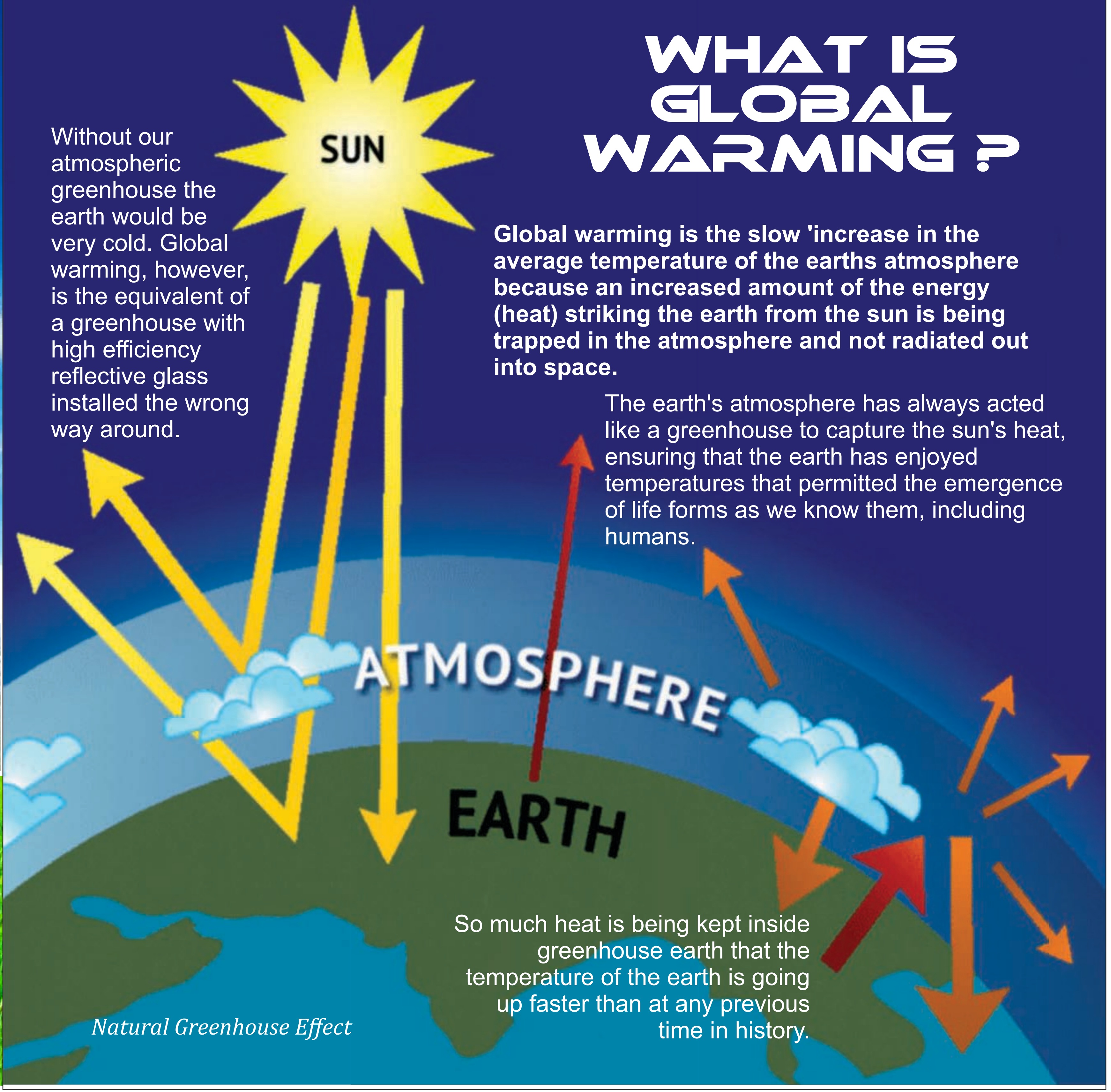
An easy way to remember the difference is that climate is what you expect, like a very hot summer, and weather is what you get, like a hot day with pop-up thunderstorms.

WHAT IS GLOBAL WARMING ?

Global warming is the slow 'increase in the average temperature of the earths atmosphere because an increased amount of the energy (heat) striking the earth from the sun is being trapped in the atmosphere and not radiated out into space.

The earth's atmosphere has always acted like a greenhouse to capture the sun's heat, ensuring that the earth has enjoyed temperatures that permitted the emergence of life forms as we know them, including humans.

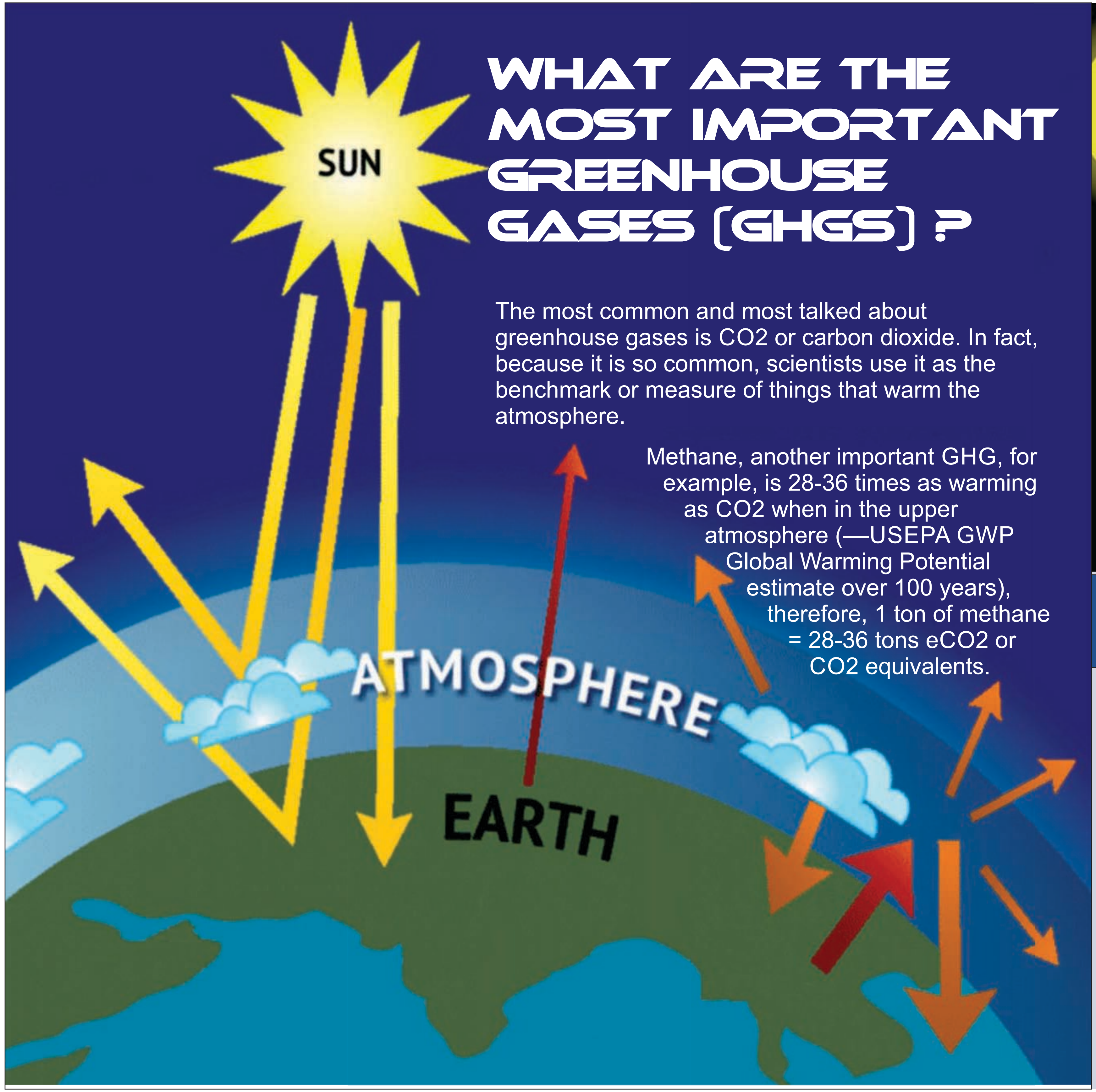
Without our atmospheric greenhouse the earth would be very cold. Global warming, however, is the equivalent of a greenhouse with high efficiency reflective glass installed the wrong way around.



So much heat is being kept inside greenhouse earth that the temperature of the earth is going up faster than at any previous time in history.

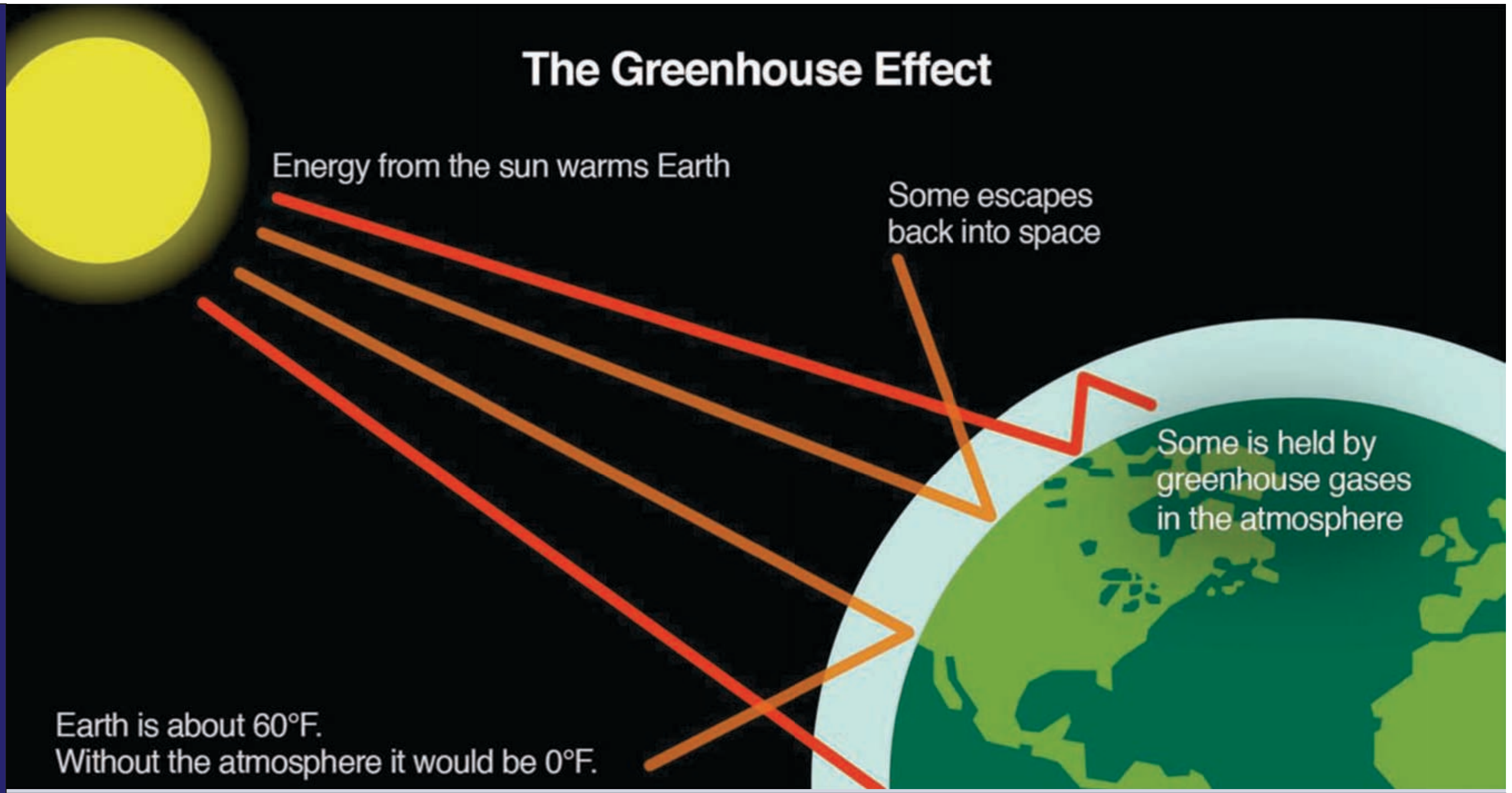
Natural Greenhouse Effect

WHAT ARE THE MOST IMPORTANT GREENHOUSE GASES (GHGS)?



The most common and most talked about greenhouse gases is CO2 or carbon dioxide. In fact, because it is so common, scientists use it as the benchmark or measure of things that warm the atmosphere.

Methane, another important GHG, for example, is 28-36 times as warming as CO2 when in the upper atmosphere (—USEPA GWP Global Warming Potential estimate over 100 years), therefore, 1 ton of methane = 28-36 tons eCO2 or CO2 equivalents.



Greenhouse Gas	Global Warming Potential (FWP) (over 100 years)	% of Total Anthropogenic GHG Emissions (2010)
Carbon dioxide (Co_2)	1	76%
Methane (Ch_4)	25	16%
Nitrous oxide (N_2O)	298	6%
Hydrofluorocarbons (HFC_S	124-14,800	< 2%
Peofluorocarbons (PFC_S)	7,390=12.200	< 2%
Sulphur hexafluaride (SF_O)	22,800	< 2%
Nitrogen trifluoride (Nf_3)	17,200	< 2%

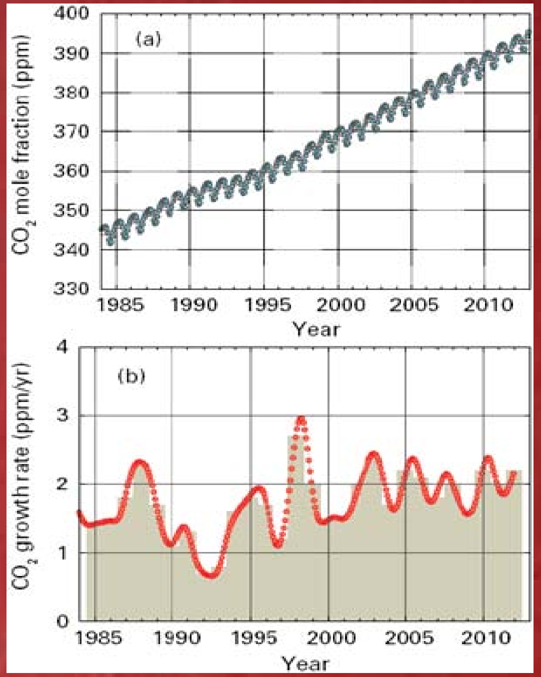
Overview of Greenhouse Gases Regulated under the Kyoto Protocol.

Source: Reproduced from IPCC 2007 and UNEP 2012

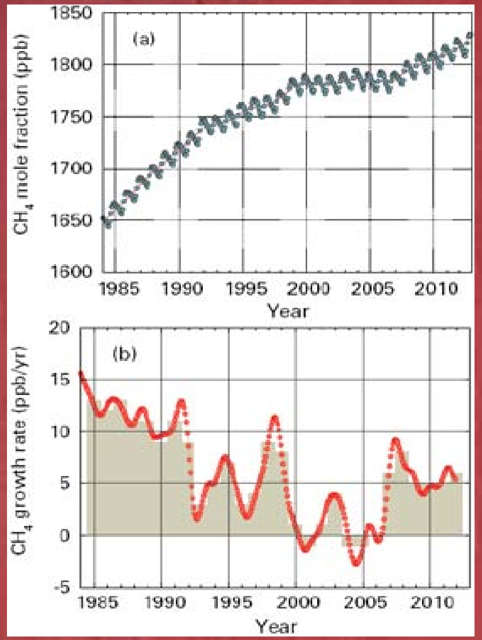
The most commonly discussed GHGs are:

Carbon dioxide (Co2)

Co2 or carbon dioxide is produced any time something is burned. It is the most common GHG, constituting by some measures almost 55% of total long-term GHGs. It is used as a marker by the United States Environmental Protection Agency, for example, because of its ubiquity. Carbon dioxide is assigned a GWP or Global Warming Potential of 1. The figure (right) indicates that Since 1750 CO2 concentration in the atmosphere has increased by 40%.



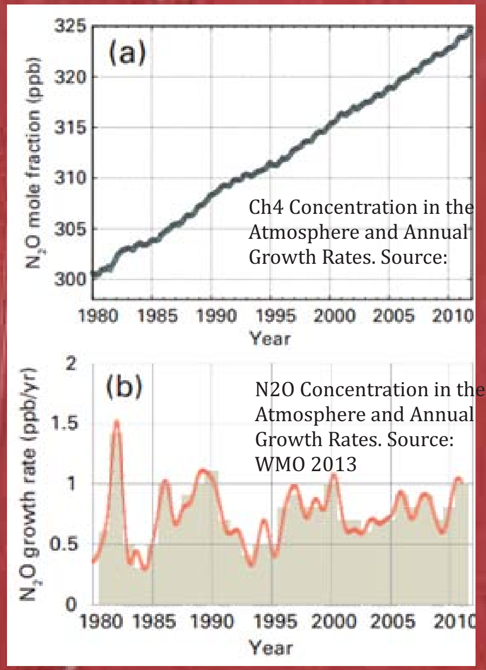
Co2 Concentration in the Atmosphere and Annual Growth Rates. Source: WMO 2013



Ch4 Concentration in the Atmosphere and Annual Growth Rates. Source: WMO 2013

Methane (CH4)

Methane or CH4 is produced in many combustion processes and also by anaerobic decomposition, for example, in flooded rice paddies, pig and cow stomachs, and pig manure ponds. Methane breaks down in approximately 10 years, but is a precursor of ozone, itself an important GHG. CH4 has a GWP of 28-36. According to Figure (left) since 1750 CH4 concentration in the atmosphere has increased by 150%.



N2O Concentration in the Atmosphere and Annual Growth Rates. Source: WMO 2013

Nitrous Oxide (NOx)

Nitrous oxide in parean (laughing gas), NO/N2O or simply NOx is a byproduct of fertilizer production and use, other industrial processes and the combustion of certain materials. Nitrous oxide lasts a very long time in the atmosphere, but at the 100 year point of comparison to CO2, its GWP is 265-298. Figure (left) shows that since 1750 N2O concentration in the atmosphere has increased by 20%.

Ch4 Concentration in the Atmosphere and Annual Growth Rates. Source: WMO 2013

Fluorinated gases

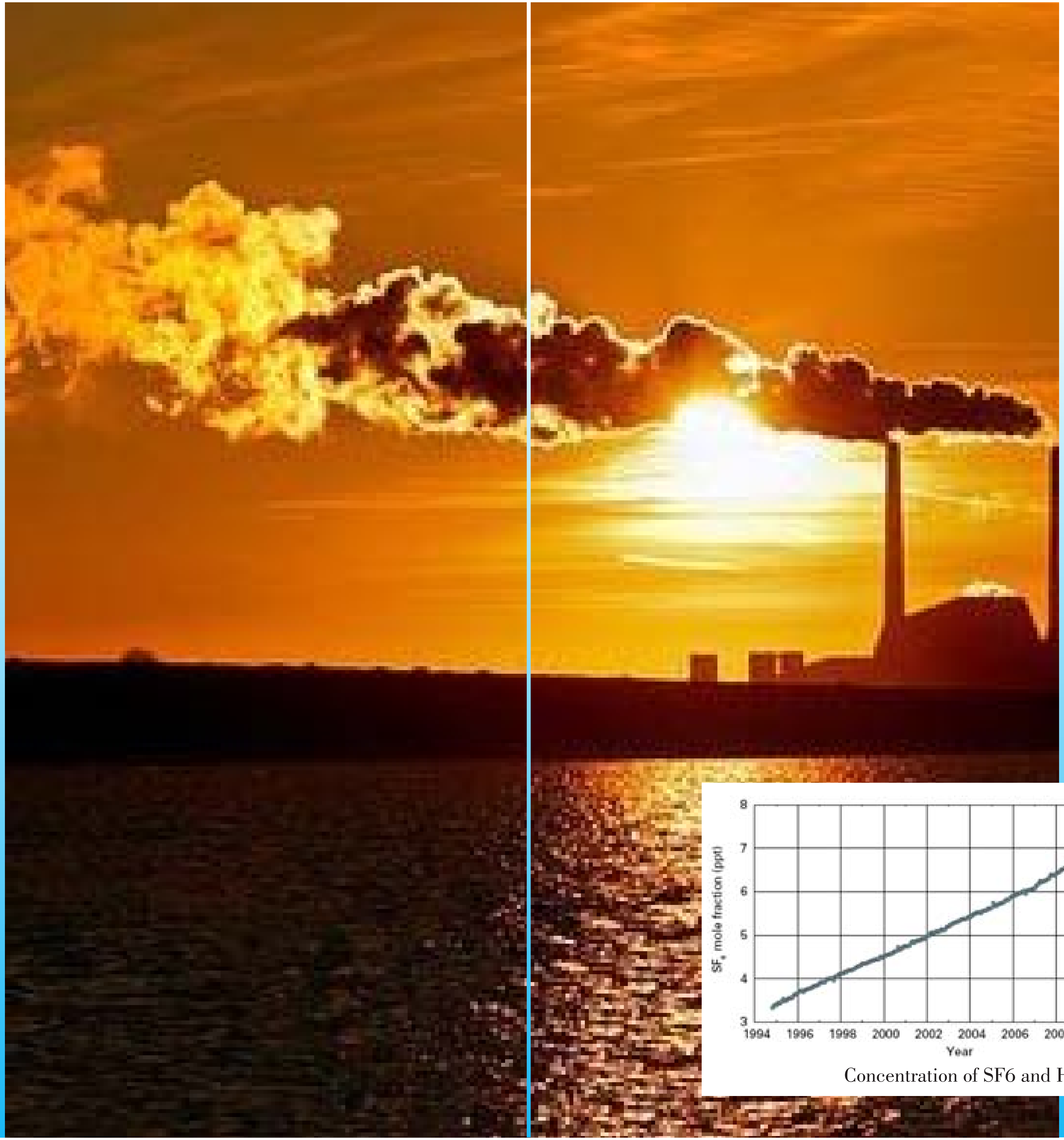
Fluorinated gases were created as replacements for ozone depleting refrigerants, but have proved to be both extremely long lasting and extremely warming GHGs. They have no natural sources, but are entirely man-made. At the 100 year point of comparison, their GWPs range from 1,800 to 8,000 and some variants top 10,000. Three main groups of fluorinated gases are: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6).

Hydrofluorocarbons (HFCs)

Hydrofluorocarbons or 'HFCs' have been increasingly used in the last decade or so as an alternative to ozone damaging CFCs in refrigeration systems. Unfortunately, though they provide an effective alternative to CFCs, they can also be powerful greenhouse gases with long atmospheric lifetimes.

The three main HFCs are HFC-23, HFC-134a and HFC152a, with HFC-134a being the most widely used refrigerant. Since 1990, when it was almost undetectable, concentrations of HFC-134a have risen massively.

HFC-134a has an atmospheric lifetime of about 14 years and its abundance is expected to continue to rise in line with its increasing use as a refrigerant around the world.

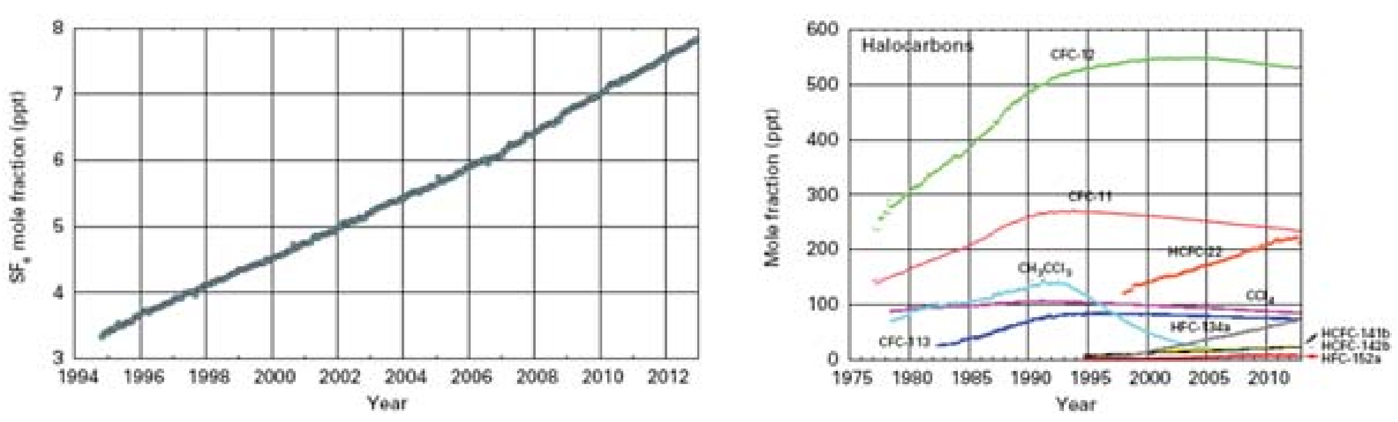


Perfluorocarbons (PFCs)

Perfluorocarbons are compounds produced as a by-product of various industrial processes associated with aluminum production and the manufacturing of semiconductors. Like HFCs, PFCs generally have long atmospheric lifetimes and high Global Warming Potentials of approximately 6,500 and 9,200.5.

Sulphur hexafluoride (SF6)

Sulphur hexafluoride or SF6 is used for specialized medical procedures, but primarily in what are called dielectric materials, especially dielectric liquids. These are used as insulators in high voltage applications such as transformers and grid switching gear. SF6 will last thousands of years in the upper atmosphere and has a GWP of 22,800. Figure (Bottom) represents that the concentration of SF6 and Halocarbons in the atmosphere.



Concentration of SF6 and Halocarbons in the Atmosphere. Source: WMO 2013

Water Vapor (H_2O)

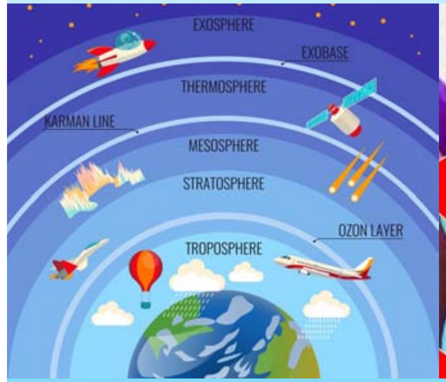
Although water vapor has not received the scrutiny of other GHGs, it is the primary contributor to the greenhouse effect. Natural processes, such as evaporation from oceans and rivers, and transpiration from plants, contribute 90 percent and 10 percent of the water vapor in our atmosphere, respectively.

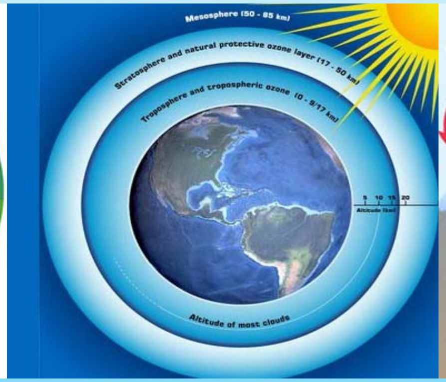
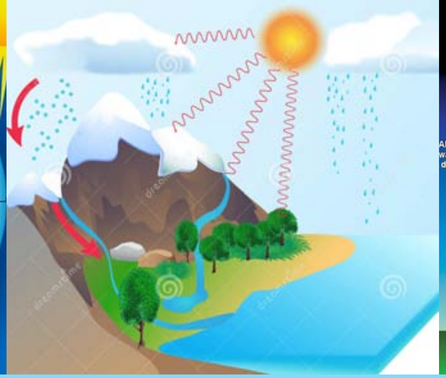
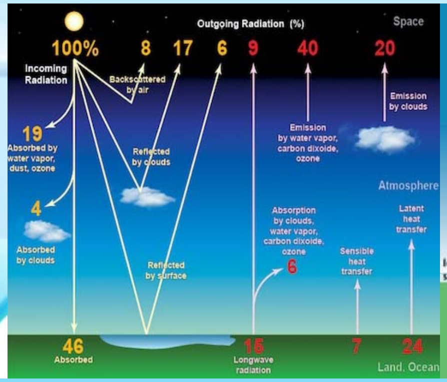
The primary human related source of water vapor comes from fuel combustion in motor vehicles; however, this is not believed to contribute a significant amount (less than one percent) to atmospheric concentrations of water vapor. IPCC has not determined a GWP for water vapor.

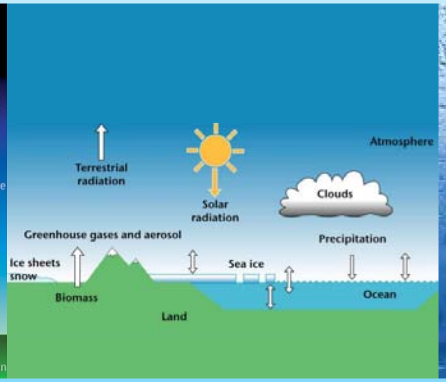
In addition to the six major GHGs discussed above (excluding water vapor), many other compounds have the potential to contribute to the greenhouse effect. Some of these substances were previously identified as stratospheric ozone (O_3) depletors; therefore, their gradual phase out is currently in effect. The following is a listing of these compounds:

Chlorofluorocarbons (CFCs)

CFCs are used as refrigerants, cleaning solvents, and aerosols spray propellants. CFCs were also part of the U.S. Environmental Protection Agency's (EPA's) Final Rule (57 FR 3374) for the phase out of O_3 depleting substances. Currently, CFCs have been replaced by HFCs in cooling systems and a variety of alternatives for cleaning solvents. Nevertheless, CFCs remain suspended in the atmosphere contributing to the greenhouse effect. CFCs are potent GHGs with GWPs ranging from 4,000 for CFC 11 to 14,000 for CFC 13.





Hydrochlorofluorocarbons (HCFCs)

HCFCs are solvents, similar in use and chemical composition to CFCs. The main uses of HCFCs are for refrigerant products and air conditioning systems. As part of the Montreal Protocol, all developed countries that adhere to the Montreal Protocol are subject to a consumption cap and gradual phase out of HCFCs. The United States is scheduled to achieve a 100 percent reduction to the cap by 2030. The GWPs of HCFCs range from 93 for HCFC-123 to 2,000 for HCFC-142b.

Trichloroethane

Trichloroethane or methyl chloroform is a solvent and degreasing agent commonly used by manufacturers. The GWP of methyl chloroform is 110 times that of CO_2.

GREEN HOUSE EFFECT

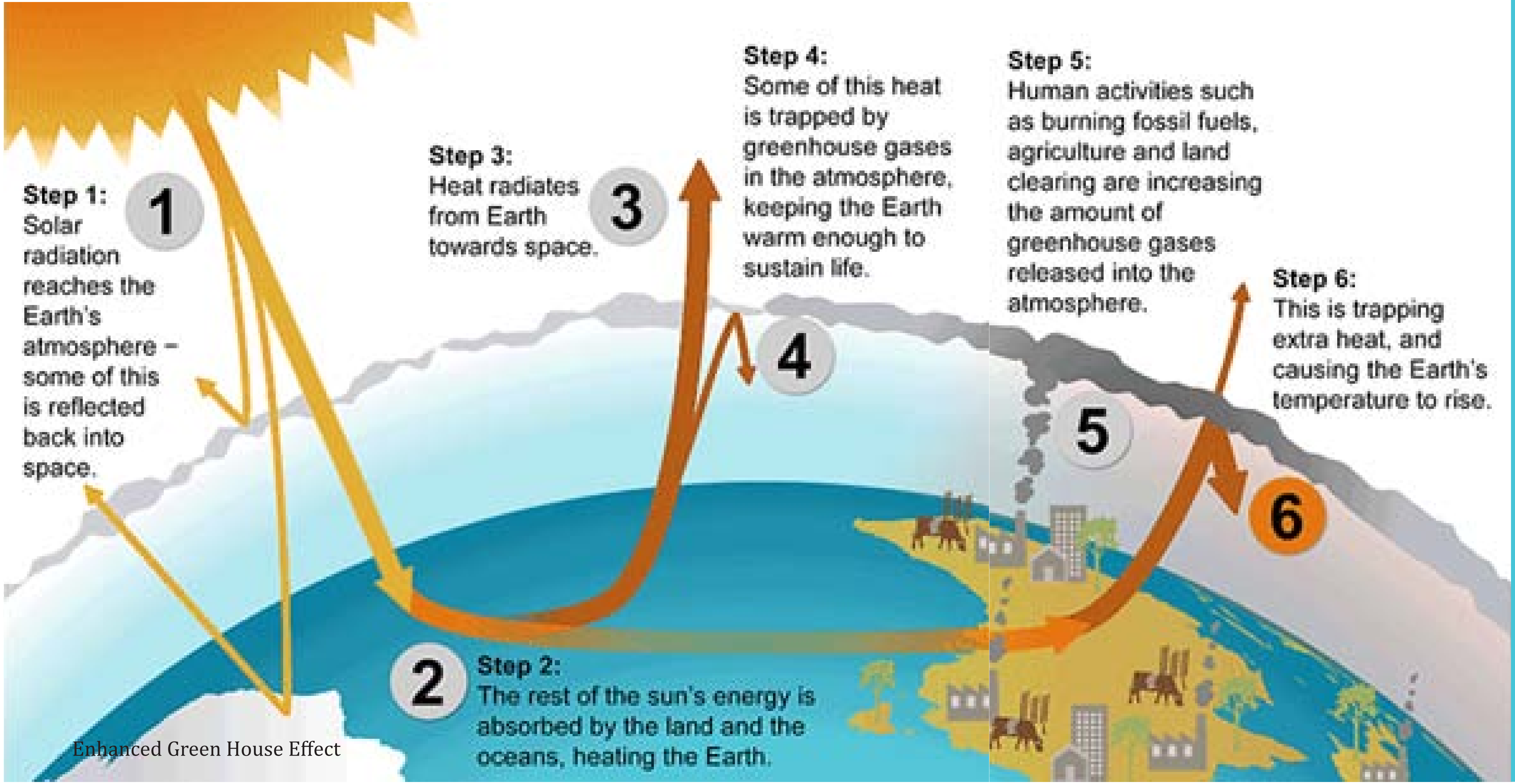
The greenhouse effect is a natural process that warms the Earth's surface. When the Sun's energy reaches the Earth's atmosphere, some of it is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases.

Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons (CFCs).

The absorbed energy warms the atmosphere and the surface of the Earth. This process maintains the Earth's temperature at around 33 degrees Celsius warmer than it would otherwise be, allowing life on Earth to exist.

ENHANCED GREENHOUSE EFFECT

The problem we now face is that human activities – particularly burning fossil fuels (coal, oil and natural gas), agriculture and land clearing – are increasing the concentrations of greenhouse gases. This is the enhanced greenhouse effect, which is contributing to warming of the Earth.



Enhanced Green House Effect

Step 1: Solar radiation reaches the Earth's atmosphere - some of this is reflected back into space.

Step 2: The rest of the sun's energy is absorbed by the land and the oceans, heating the Earth.

Step 3: Heat radiates from Earth towards space.

Step 4: Some of this heat is trapped by greenhouse gases in the atmosphere, keeping the Earth warm enough to sustain life.

Step 5: Human activities such as burning fossil fuels, agriculture and land clearing are increasing the amount of greenhouse gases released into the atmosphere.

Step 6: This is trapping extra heat, and causing the Earth's temperature to rise.

WHAT IS CLIMATE CHANGE

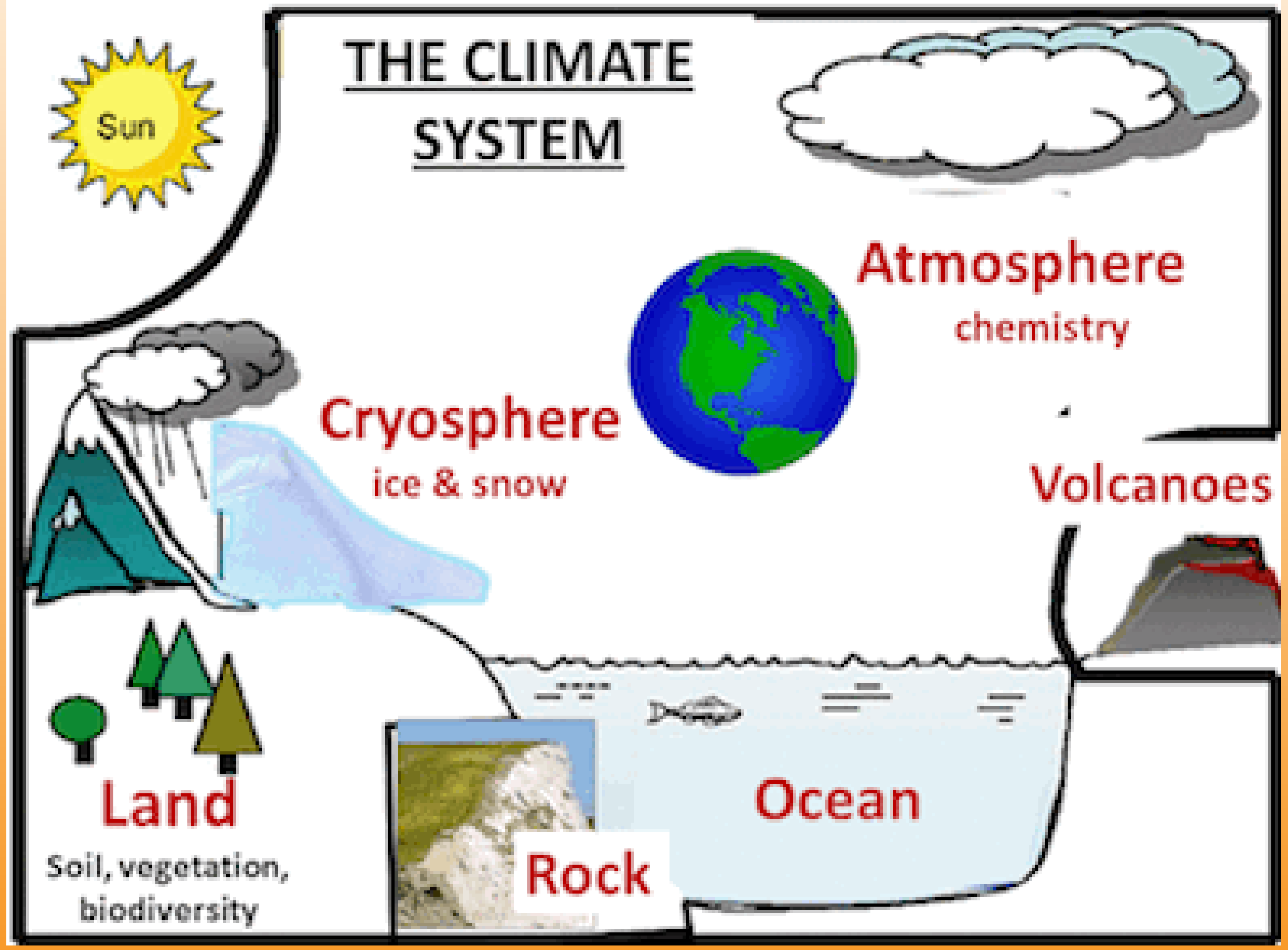
Climate change refers to significant, long-term changes in the global climate.

The global climate (Figure 1) is the connected system of sun, earth and oceans, wind, rain and snow, forests, deserts and savannas, and everything people do, too. The climate of a place, say New York, can be described as its rainfall, changing temperatures during the year and so on.

But the global climate is more than the "average" of the climates of specific places.

A description of the global climate includes how, for example, the rising temperature of the Pacific feeds typhoons which blow harder, drop more rain and cause more damage, but also shifts global ocean currents that melt Antarctica ice which slowly makes sea level rise until New York will be under water.

It is this systemic connectedness that makes global climate change so important and so complicated.



Source: US Environmental Protection Agency

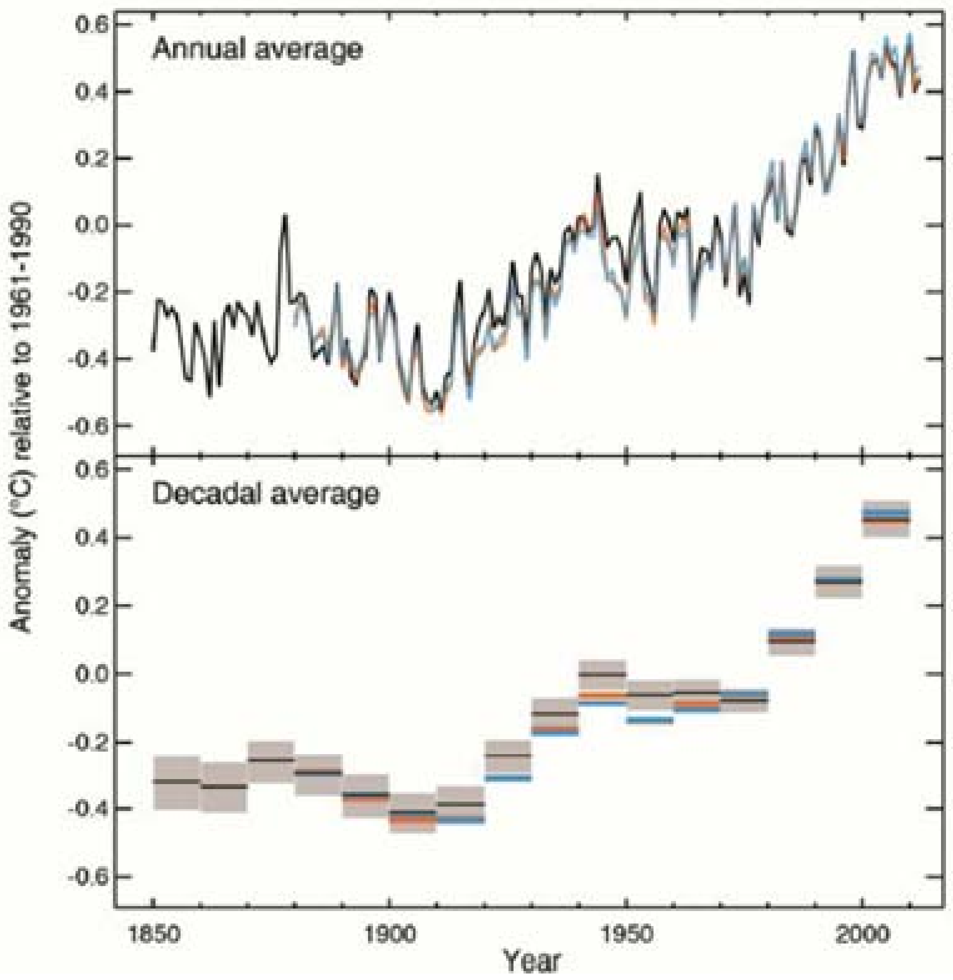
THE EVIDENCE FOR RAPID CLIMATE CHANGE IS COMPELLING

Global Temperature Rise

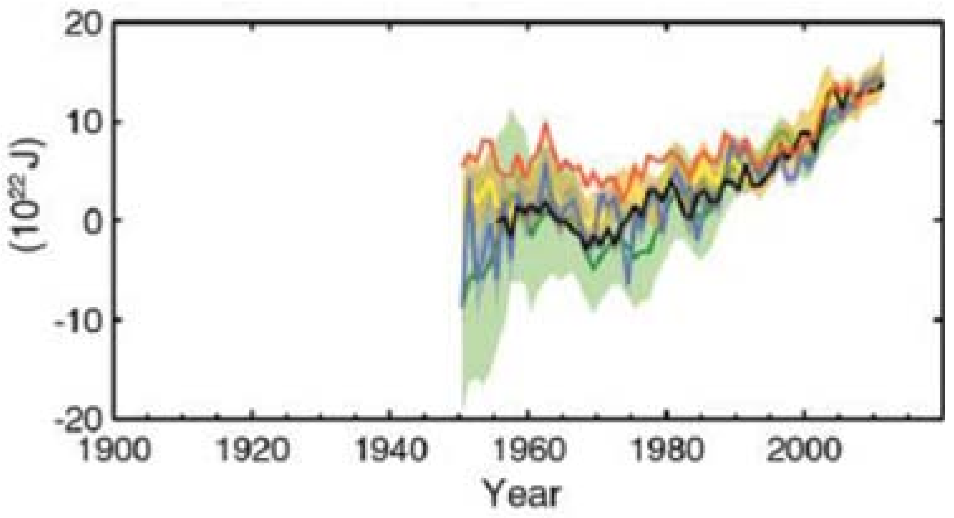
The planet's average surface temperature has risen about 1.62 degrees Fahrenheit (0.9 degrees Celsius) since the late 19th century, a change driven largely by increased carbon dioxide and other human-made emissions into the atmosphere. Most of the warming occurred in the past 35 years, with the five warmest years on record taking place since 2010. Not only was 2016 the warmest year on record, but eight of the 12 months that make up the year — from January through September, with the exception of June — were the warmest on record for those respective months.

Warming Oceans

The oceans have absorbed much of this increased heat, with the top 700 meters (about 2,300 feet) of ocean showing warming of 0.302 degrees Fahrenheit since 1969. Figure More than 60% of the net energy increase in the climate system is stored in the upper ocean (period 1971-2010).



Globally averaged land and ocean surface temperature.
Source: IPCC 2013, p4



Change in global average upper ocean heat content.
Source: IPCC, 2013, p8

Shrinking ice sheets

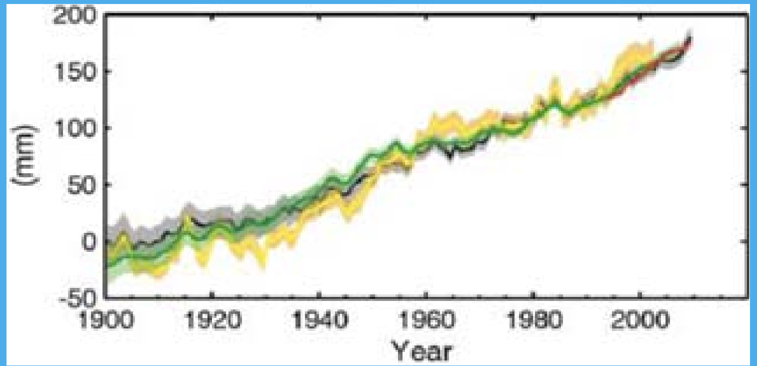
The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost an average of 281 billion tons of ice per year between 1993 and 2016, while Antarctica lost about 119 billion tons during the same time period. The rate of Antarctica ice mass loss has tripled in the last decade.

Glacial retreat

Glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes, Rockies, Alaska and Africa.

Decreased snow cover

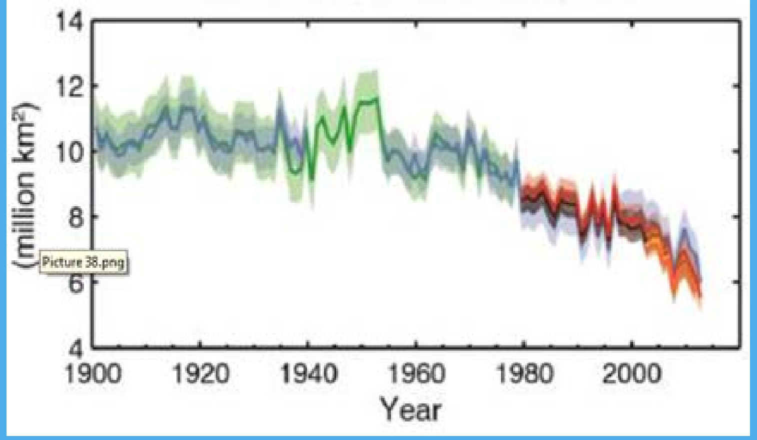
Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades and that the snow is melting earlier.



Global Average sea level change. Source: IPCC, 2013. P8

Sea level rise

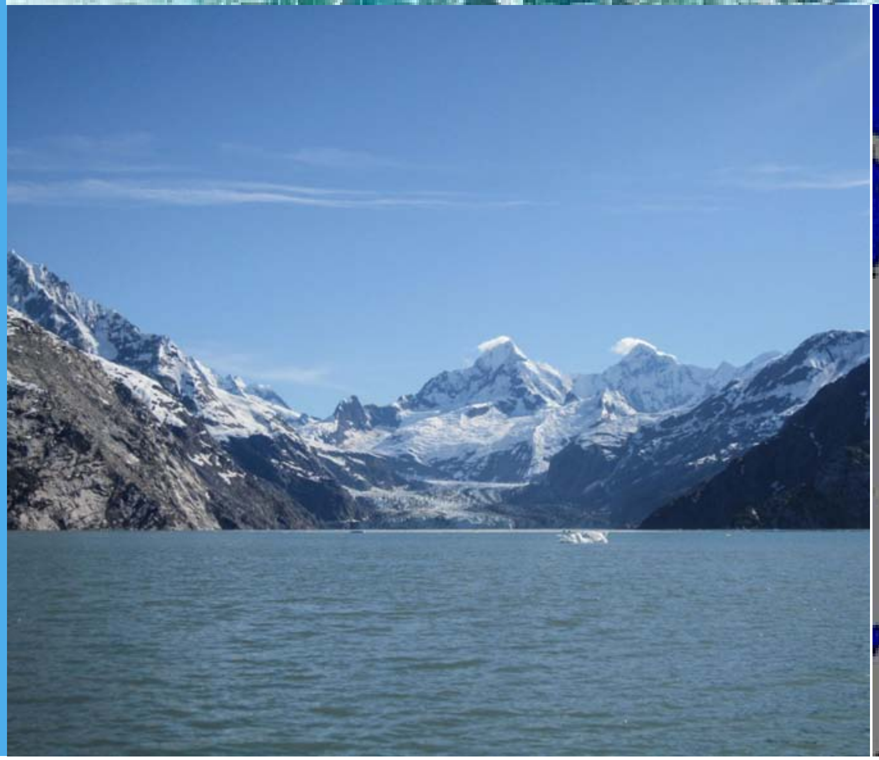
Global sea level rose about 8 inches in the last century. The rate in the last two decades, however, is nearly double that of the last century. Figure 13 shows that over the period 1901 to 2010, global mean sea level rose by 0.19m.

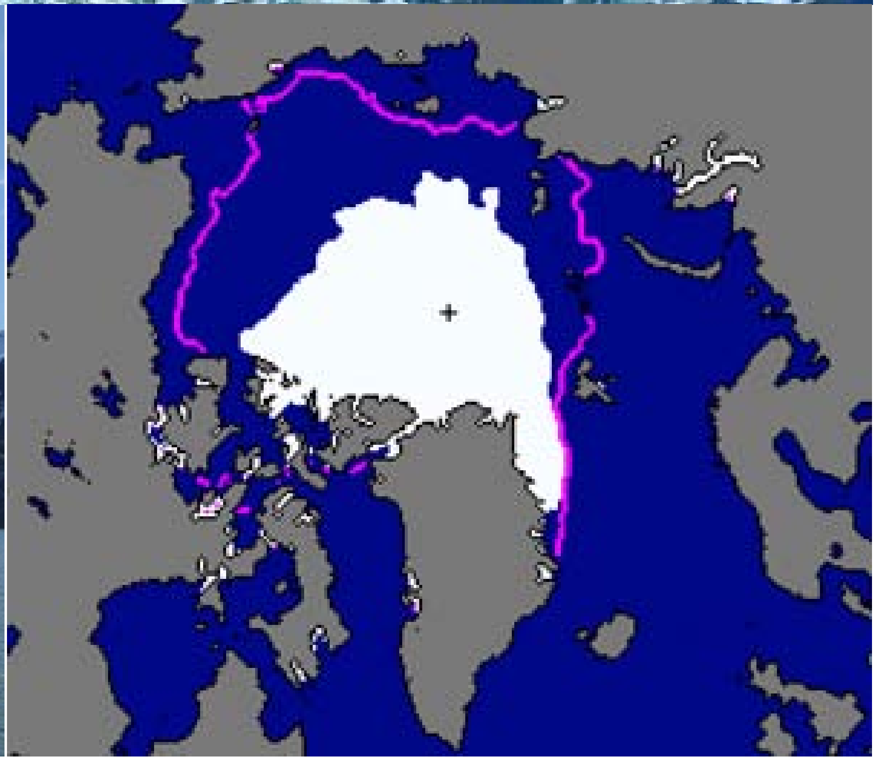


Arctic summer sea ice extent. Source: IPCC, p8

Declining Arctic sea ice

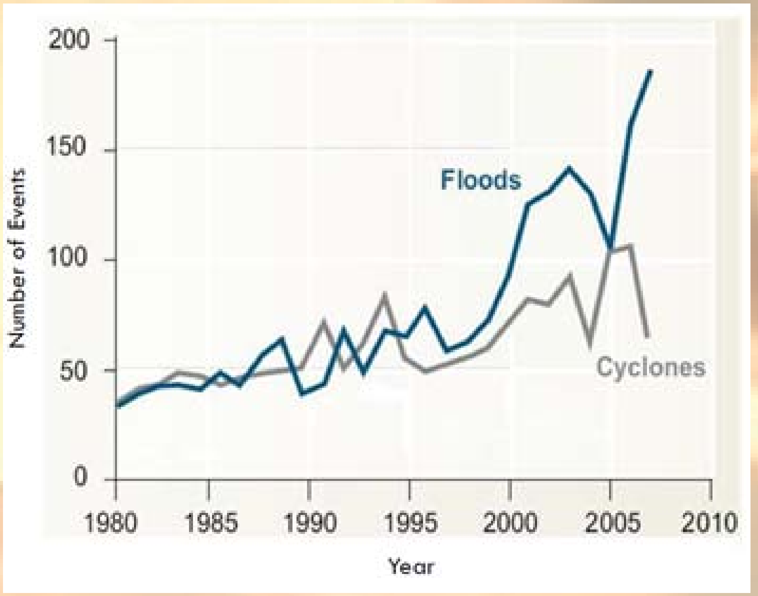
Both the extent and thickness of Arctic sea ice has declined rapidly over the last several decades. Figure 14 shows the observed decrease in arctic sea ice extent (1900-2010)





Extreme events

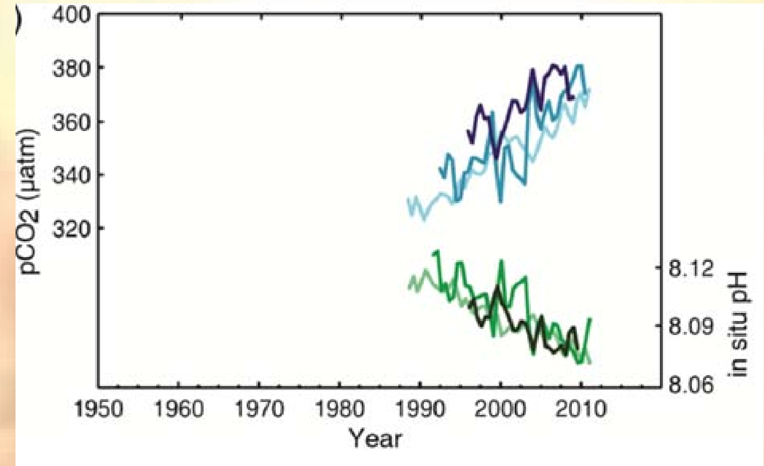
As the world has warmed, that warming has triggered many other changes to the Earth's climate. Changes in extreme weather and climate events, such as heat waves and droughts, are the primary way that most people experience climate change. Human-induced climate change has already increased the number and strength of some of these extreme events. Over the last 50 years, much of the U.S. has seen increases in prolonged periods of excessively high temperatures, heavy downpours, and in some regions, severe floods and droughts.



Climate Change and extreme weather events.
Source: UNEP 2009, p12.

Ocean acidification

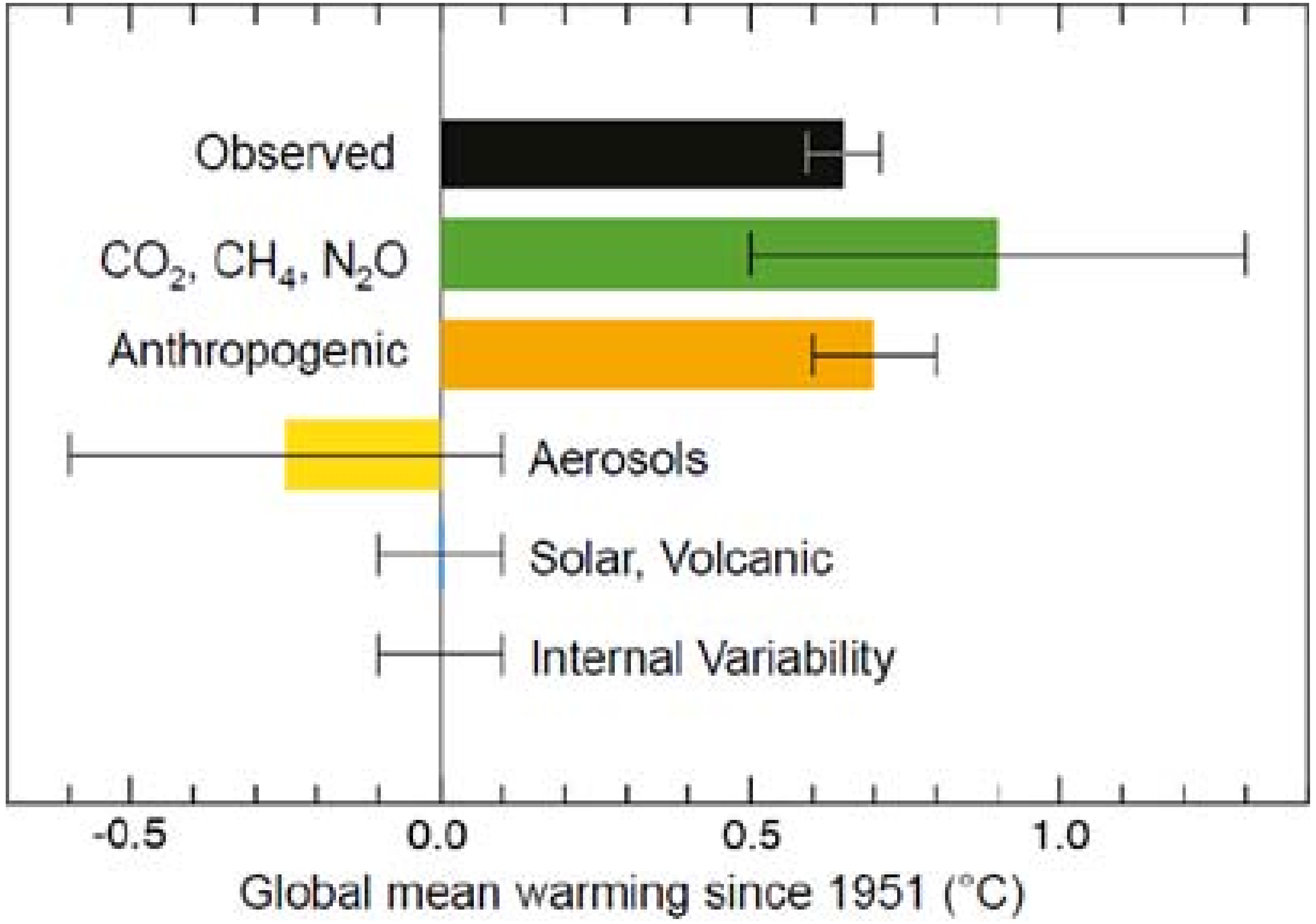
Since the beginning of the Industrial Revolution, the acidity of surface ocean waters has increased by about 30 percent. This increase is the result of humans emitting more carbon dioxide into the atmosphere and hence more being absorbed into the oceans. The amount of carbon dioxide absorbed by the upper layer of the oceans is increasing by about 2 billion tons per year.



Surface Ocean CO2 and pH. Source: IPCC, 2013, p10

HUMAN INFLUENCE ON THE CLIMATE SYSTEM

It is extremely likely that more than 50% of the warming since 1951 is due to the increase in greenhouse gases and other anthropogenic forcing's together.



Global Mean Warming since 1951

PROJECTED TRENDS AND IMPACTS OF CLIMATE CHANGE

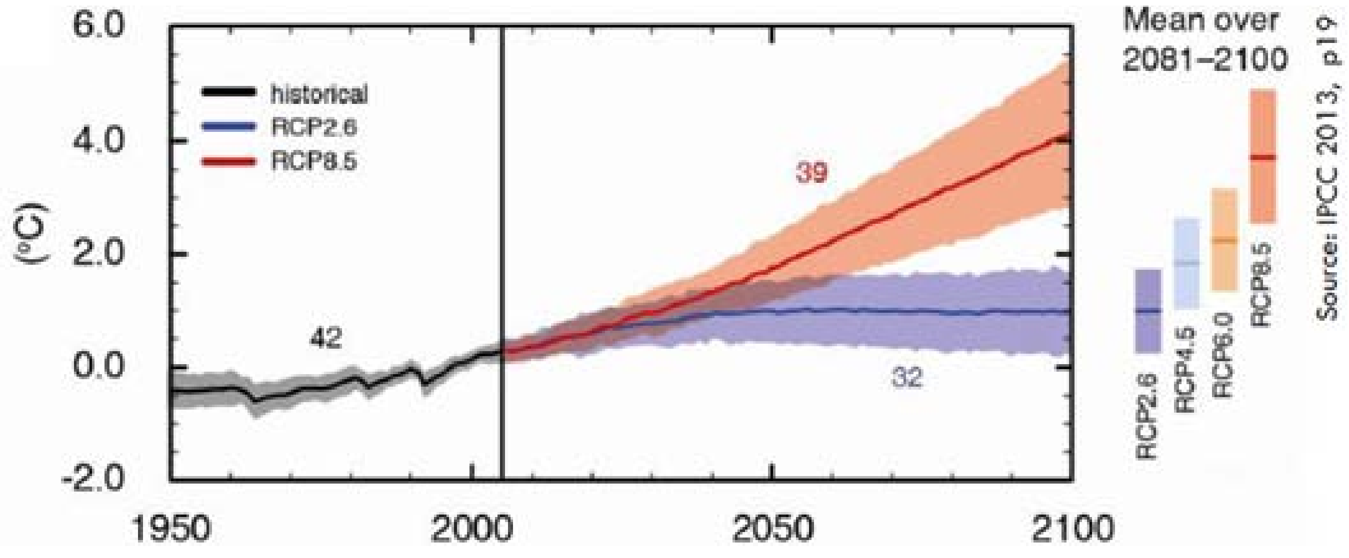
Set of four new scenarios defined by the scientific community for the Fifth IPCC Assessment Report.

Four RCPs include:

- One mitigation scenario leading to a very low forcing level (RCP2.6),
- Two stabilization scenarios (RCP4.5 and RCP6), and
- One scenario with very high greenhouse gas emissions (RCP8.5).
- RCPs represent a range of 21st century climate policies.

PROJECTED CHANGE IN AVERAGE SURFACE TEMPERATURE

Global surface temperature change for the end of the 21st century is likely to reach 4°C if no action is taken.

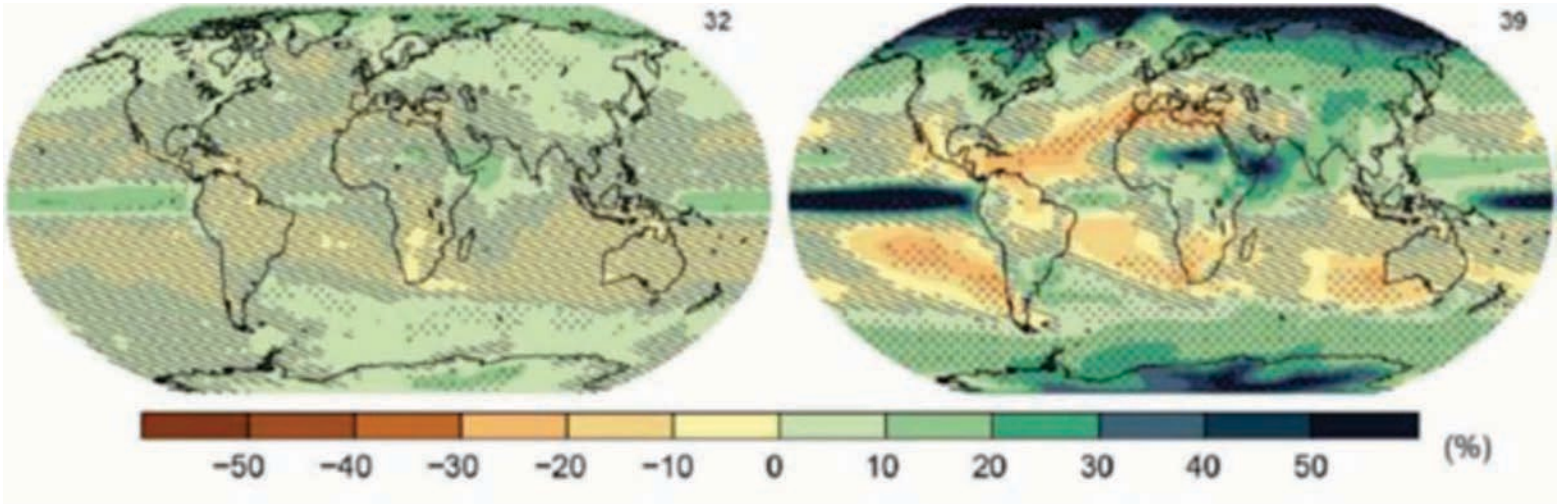


Global average surface average temperature change. Source

Projected Change in Average Precipitation

Time Period: 1986-2005 to 2081-2100

Scenario RCP 2.6 | Scenario RCP 8.5

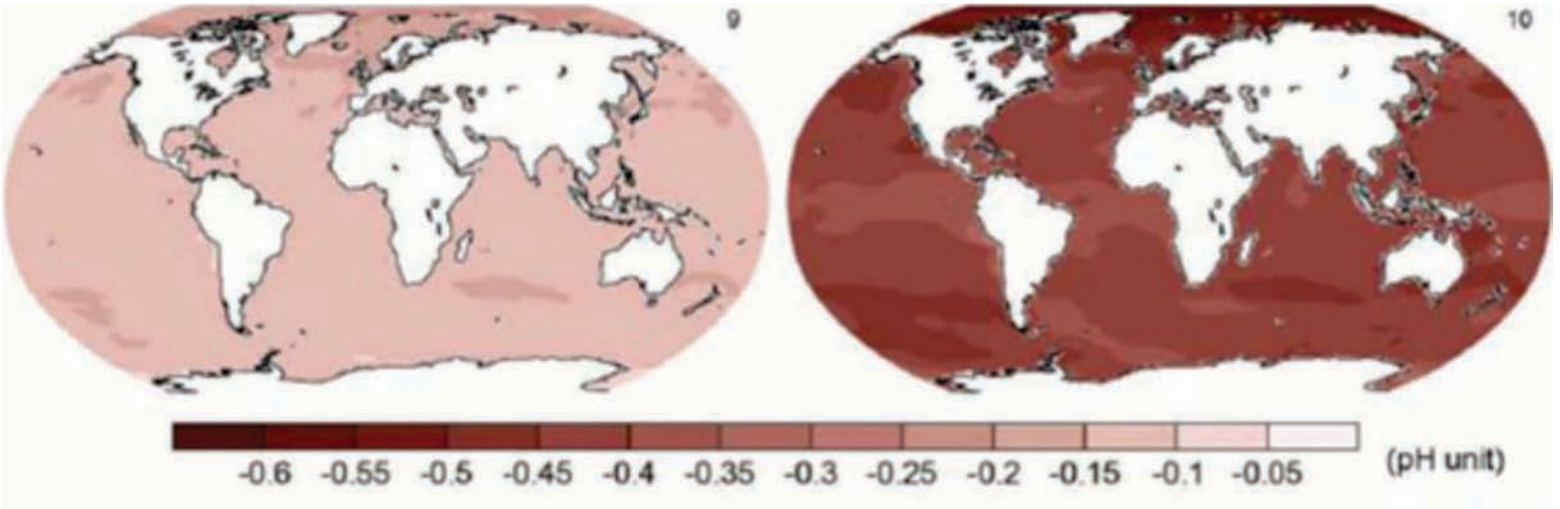


Projected Change in average precipitation. Source: IPCC 2013, p20

Projected Change in Ocean Surface pH

Time Period: 1986-2005 to 2081-2100

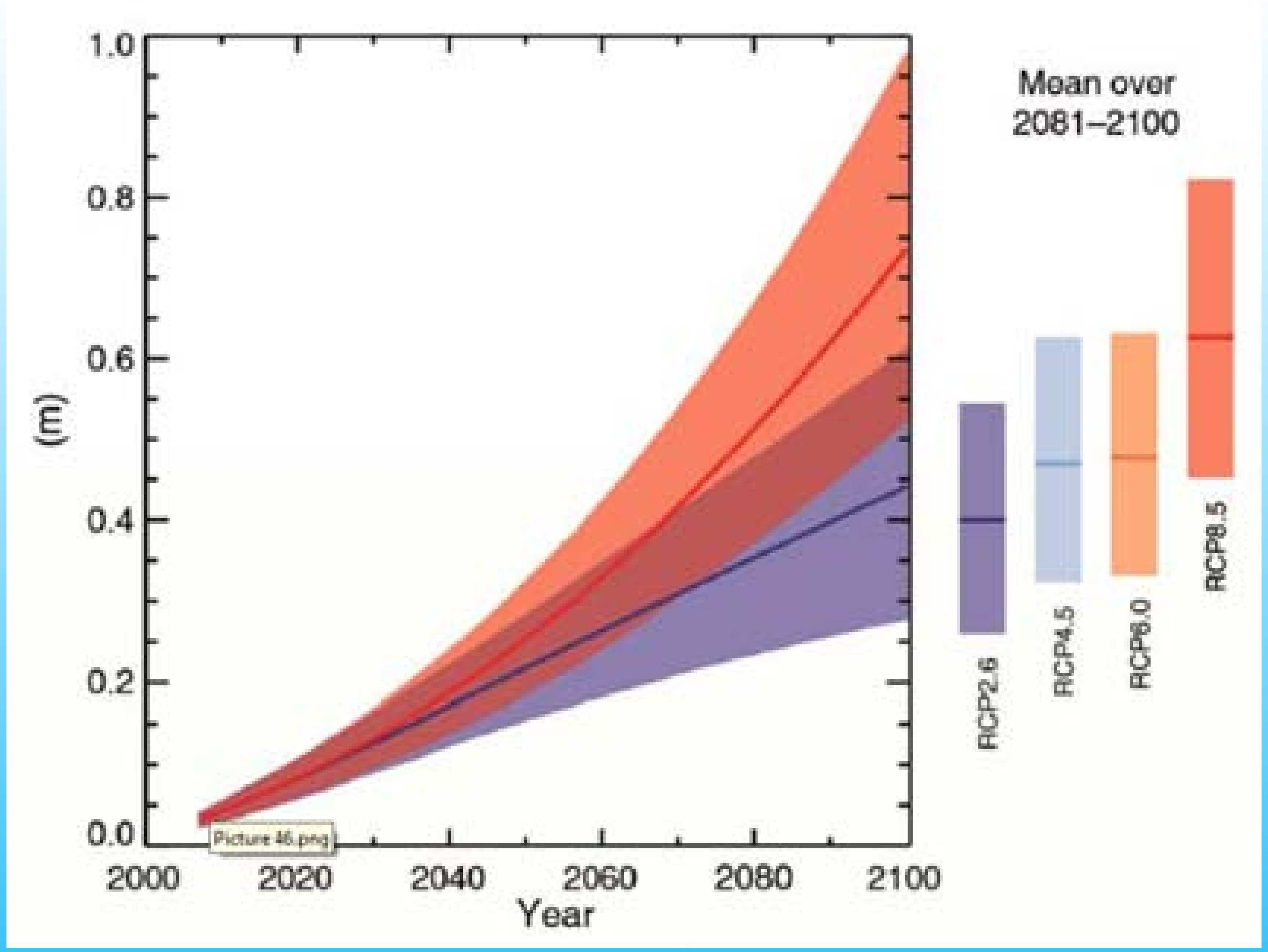
Scenario RCP 2.6 | Scenario RCP 8.5



Projected Change in Ocean Surface pH. Source: IPCC. p20

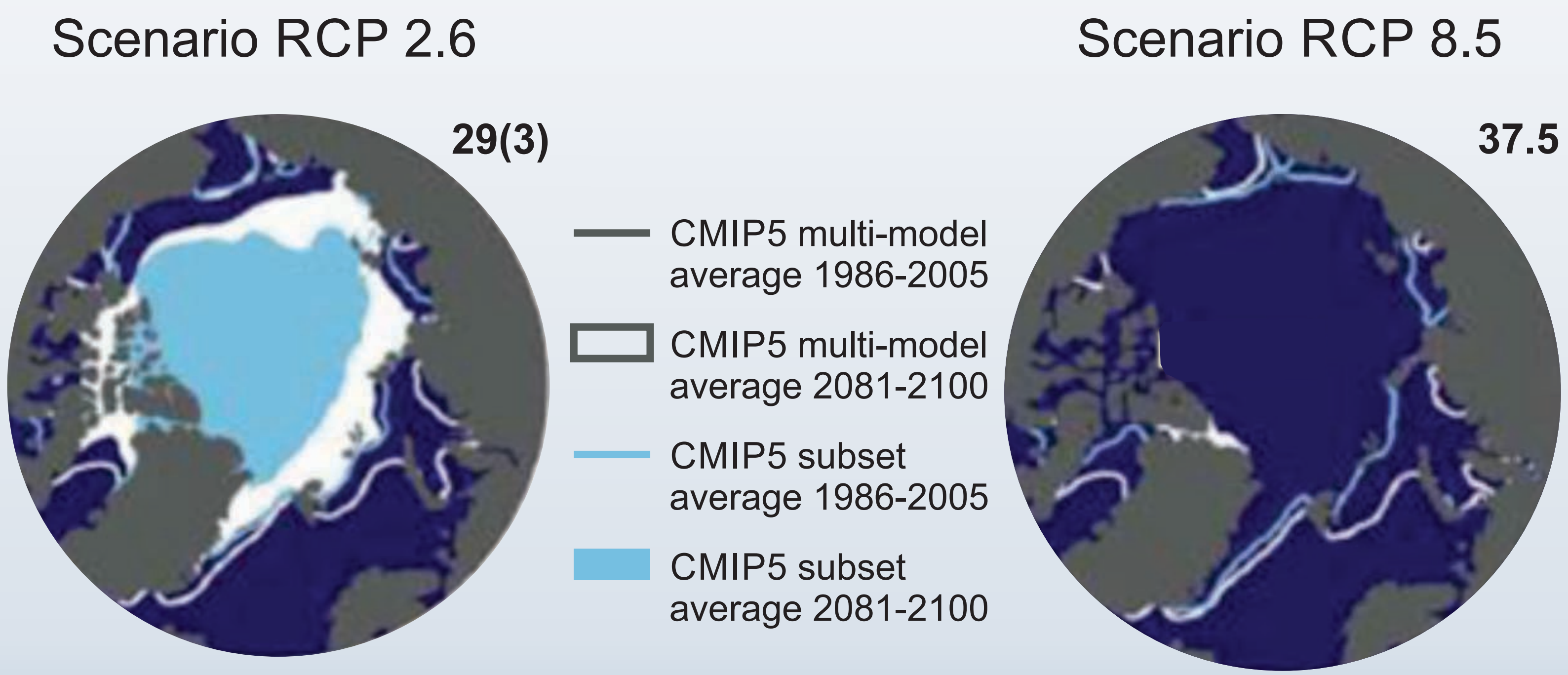
Projected Sea Level Rise

Global mean sea level will continue to rise during the 21st century.



Projected Northern Hemisphere September Sea Ice Extent

Average 2081-2100



Projected Northern Hemisphere September Sea Ice Extent.

Source: IPCC 2013, p20

History of climate change science

The history of climate change science is shown in the following Table 1.

Table 1: History of Climate Change Science

Year	Activity
1824	Argument raised that the temperature of the Earth can be augmented by the interposition of the atmosphere
1861	Indication that CO_2 and H_2O can cause changes in the climate
1895	First proposal of the idea of a man-made greenhouse effect
1938	Proof that doubling of atmospheric CO_2 concentration resulted in an increase in the mean global temperature of 2°C
1950s	Start of interdisciplinary field of carbon cycle science
1958	The high-accuracy measurements of atmospheric CO_2 concentration
1970s	Other greenhouse gases widely recognized
1979	The first World Climate Conference in Geneva
1988	Establishment of Intergovernmental Panel on Climate Change (IPCC)
1990	The first IPCC report

Source: BBC Website