Lenox Institute Press
Newtonville, NY, USA; Auburndale, MA, USA

Evolutionary Progress in Science, Technology, Engineering, Arts and Mathematics (STEAM) Series

SCIENTIFIC STUDIES OF GLOBAL WARMING, CLIMATE CHANGE, GLACIER MELTING AND SALMON PROTECTION

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Wong, Josephine O., Wang, Nai-Yi, Wang, Lawrence K. and Wang, Mu-Hao Sung (2019). Scientific studies of global warming, climate change, glacier melting and salmon protection. In: "*Evolutionary Progress in Science, Technology, Engineering, Arts, and Mathematics (STEAM)"*, Wang, Lawrence K. and Tsao, Hung-ping (editors). Volume 1, Number 9, September 2019; 110 pages. Lenox Institute Press, Newtonville, NY, 12128-0405, USA. No. STEAM-VOL1-NUM9-SEP2019; ISBN 978-0-9890870-3-2. US Department of Commerce, National Technical Information Service, 5301 Shawnee Road, Alexandria, VA 22312, USA.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
15-09-2019	TECHNICAL PROGRESS REPORT	JAN 2017-SEP 2019

4. TITLE AND SUBTITLE

SCIENTIFIC STUDIES OF GLOBAL WARMING, CLIMATE CHANGE, GLACIER MELTING AND SALMON PROTECTION

5a. CONTRACT NUMBER NA

5b. GRANT NUMBER NA

5c. PROGRAM ELEMENT NUMBER NA

6. AUTHOR(S)

Josephine O. Wong, Nai-Yi Wang, Lawrence K. Wang and Mu-Hao Sung Wang

5d. PROJECT NUMBER STEAM-VOL1-NUM9-SEP2019

5e. TASK NUMBER NA

5f. WORK UNIT NUMBER NA

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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2. STATE UNIVERSITY OF NEW YORK AT BUFFALO, NY; NaiYiWang@comcast.net
3. LENOX INSTITUTE PRESS, PO Box 405, Newtonville, NY 12128-0405, USA
LENOX INSTITUTE, 160 Pine Street, Suite 19, Auburndale, MA 02466, USA

8. PERFORMING ORGANIZATION REPORT NUMBER
STEAM-VOL1-NUM9-SEP2019

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Wang, Lawrence K. and Tsao, Hung-ping (editors). "*Evolutionary Progress in Science, Technology, Engineering, Arts, and Mathematics (STEAM)*", Volume 1, Number 9, September 2019; Lenox Institute Press, PO Box 405, Newtonville, NY, 12128-0405, USA

10. SPONSOR/MONITOR'S ACRONYM(S)
LENOX

11. SPONSOR/MONITOR'S REPORT NUMBER
STEAM-VOL1-NUM9-SEP2019

12. DISTRIBUTION / AVAILABILITY STATEMENT

NO RESTRICTION

13. SUPPLEMENTARY NOTES

REGISTRATION ISBN 978-0-9890870-3-2; 110 pages including 1 Table, 21 Figures

14. ABSTRACT Scientific studies of global warming, climate change, glaciers melting and salmon protection conducted by international researchers are reviewed, presented and discussed. The topics covered in this book chapter include: technical terminologies, climate change, global warming, main contributors to greenhouse gases, global warming potential and its limitations, absorption of heat by carbon dioxide, rising temperature trend in the environment, land temperature rise, ocean temperature and its water level rise, glacier melting, glacier protection, tidewater glaciers, Glacier Bay National Park and Reserve, Mendenhall Glacier, Mendenhall Lake, salmon protection, salmon life cycle, fire frequency, carbon dioxide stabilization, actions for environmental protection, and Macaulay Salmon Hatchery, Alaska, USA.

15. SUBJECT TERMS global warming, climate change, glacier melting, salmon protection, Glacier Bay National Park and Reserve, Mendenhall Glacier, salmon life cycle, Macaulay Salmon Hatchery

16. SECURITY CLASSIFICATION OF: UNCLASSIFIED UNLIMITED (UU)			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	UU	110	Wang, Lawrence K.
UU	UU	UU			**19b TELEPHONE NUMBER** *(include area code)* (518) 250-0012

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Keywords: global warming, climate change, glacier melting, salmon protection, Glacier Bay National Park and Reserve, Mendenhall Glacier, salmon life cycle, Macaulay Salmon Hatchery

ACRONYM AND NOMENCLATURE

BC	Black carbon
CCS	Carbon capture and sequestration
CFC	Chlorofluorocarbon
CH_4	Methane
CO_2	Carbon dioxide
GHG	Greenhouse gas
GWP	Global warming
HBFC	Hydrobromofluorocarbon
HC	Hydrocarbon
HCFCs	Halogenated fluorocarbons
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
N_2O	Nitrous oxide
O_3	Ozone
PFCs	Perfluorinated carbons
PM	Particulate matter
USGS	US Geological Survey
WMO	World Meteorological Organization

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1. INTRODUCTION OF TECHNICAL TERMINOLOGIES

It is well known that the earth has gone through multiple ice ages in periods of dramatic cooling and dramatic warming. Among the many ice ages the earth has undergone, we are currently going through a warming trend. Questions we would ask are, 'Why is the earth warming?', 'How does the source warm the earth?', and 'What are the implications on glaciers and animals?' There are much more questions than answers (1-37). First of all, some important technical terminologies in the covered areas are introduced prior to technical discussions (26-28). Selected technical terminologies are presented in below and the Glossary section of this chapter:

1.1. Environment and Ecosystem Protection

Environment is an envelope or complex physical, chemical, and biotic factors (as climate, air, soil, light, temperature, living things, etc.) that act upon an ecological community (a collection of living things) and ultimately determine its form and survival.

Ecosystem is a natural unit or entity including living and non-living parts that interact to produce a stable system through cyclic exchange of materials.

Protection of our environment and ecosystem is important to our human survival.

1.2 Weather, Climate, Climate Change, and Air Pollution Control

Weather is the specific condition of the atmosphere at a particular place and time. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Climate in a narrow sense is usually defined as the "average weather", or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. A simple way of remembering the difference is that climate is what you expect (e.g. cold winters) and 'weather' is what you get (e.g. a blizzard).

Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. The classical period is 3 decades, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The average weather (usually taken over a 30-year time period) for a particular region and time period. Climate is not the same as weather, but rather, it is the average pattern of weather for a particular region. Weather describes the short-term state of the atmosphere. Climatic elements include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather.

Climate change means the changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other features of the climate system. Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer. It is believed that air pollutants, known as greenhouse gases, cause the climate change. One of the objectives of this study is to determine (a) the effect of climate change, and (b) whether or not proper air pollution control may prevent the climate change.

1.3 Greenhouse Gases, Greenhouse Effect, Global Warming, Global Warming Potential

A greenhouse gas (GHG) is any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated fluorocarbons (HCFCs), ozone (O_3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs), water vapor and sulfur hexafluoride. Gases absorb heat in the atmosphere near the Earth's surface, preventing it from escaping into space. If the atmospheric concentrations of these gases rise, the average temperature of the lower atmosphere will gradually increase, a phenomenon known as the greenhouse effect.

Specifically greenhouse effect is produced as greenhouse gases allow incoming solar radiation to pass through the Earth's atmosphere, but prevent most of the outgoing infrared radiation from the surface and lower atmosphere from escaping into outer space. This process occurs naturally and has kept the Earth's temperature about 60 degrees Fahrenheit warmer than it would otherwise be. Current life on Earth could not be sustained without the natural greenhouse effect. The greenhouse effect trap and build-up heat in the atmosphere (troposphere) near the Earth’s surface. Some of the heat flowing back toward space from the Earth's surface is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the Earth’s surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase.

Global warming is known due to the recent and ongoing global average increase in temperature near the Earths surface. It is the observed increase in average temperature near the Earth’s surface and in the lowest layer of the atmosphere. In common usage, “global warming” often refers to the warming that has occurred as a result of increased emissions of greenhouse gases from human activities. Global warming is a type of climate change; it can also lead to other changes in climate conditions, such as changes in precipitation patterns.

Global warming potential (GWP) is a measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), compared to carbon dioxide. GWP is a number that refers to the amount of global warming caused by a substance. The GWP is also the ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide (CO_2). Thus, the GWP of CO_2 is 1.0. Chlorofluorocarbon (CFC)-12 has a GWP of 8,500; CFC-11 has a GWP of 5,000; hydrochlorofluorocarbons and hydrofluorocarbons have GWPs ranging from 93 to 12,100; and water has a GWP of 0.

1.4 Glacier Protection

Briefly speaking, glacier is an extended mass of ice formed from snow falling and accumulating over the years and moving very slowly, either descending from high mountains, as in valley glaciers, or moving outward from centers of accumulation, as in continental glaciers. According to the USGS (US Geological Survey), a glacier is a large, perennial accumulation of crystalline ice, snow, rock, sediment, and often liquid water that originates on land and moves down slope under the influence of its own weight and gravity. Typically, glaciers exist and may even form in areas where:

1. mean annual temperatures are close to the freezing point
2. winter precipitation produces significant accumulations of snow
3. temperatures throughout the rest of the year do not result in the complete loss of the previous winter’s snow accumulation

Over multiple decades this continuing accumulation of snow results in the presence of a large enough mass of snow for the metamorphism from snow to glacier ice process to begin. Glaciers are classified by their size (i.e. ice sheet, ice cap, valley glacier, cirque glacier), location, and thermal regime (i.e., polar vs. temperate). Glaciers are sensitive indicators of changing climate. Prevention of global warming may protect the existing glaciers.

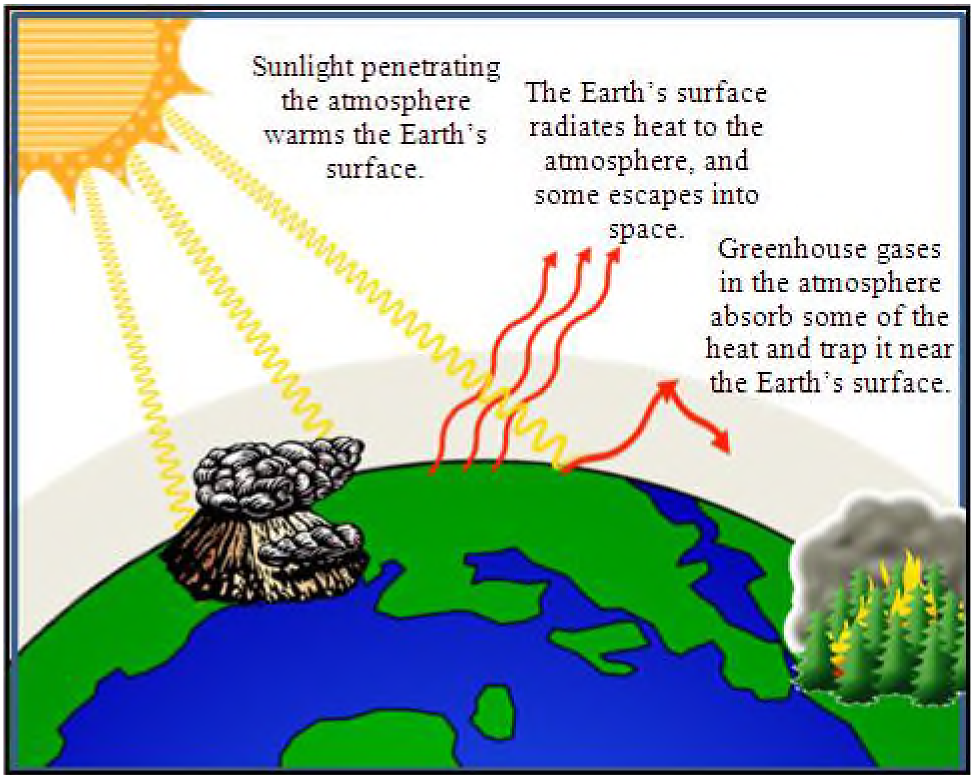
1.5. Salmon Protection

Salmon is the common name for several species of ray-finned fish in the family Salmonidae. Salmon are native to tributaries of the North Atlantic and Pacific Ocean. Many species of salmon have been introduced into non-native environments such as the Great Lakes of North America and Patagonia in South America. Salmon are intensively farmed in many parts of the world.

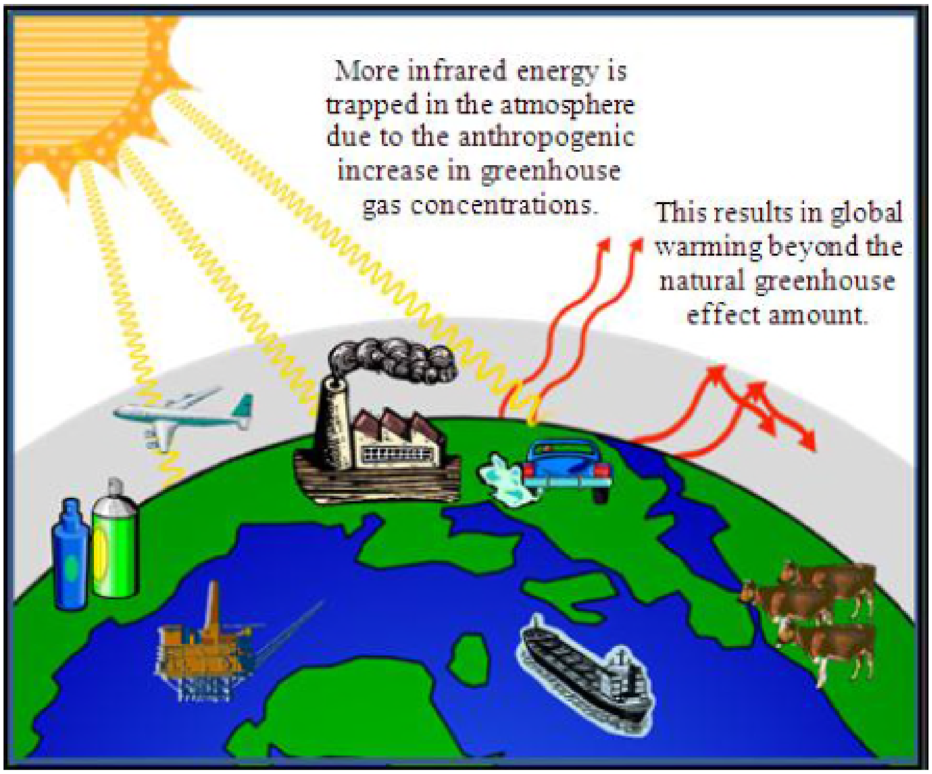
Typically, salmon are anadromous: they hatch in fresh water, migrate to the ocean, then return to fresh water to reproduce. However, populations of several species are restricted to fresh water through their lives. Folklore has it that the fish return to the exact spot where they hatched to spawn. Tracking studies have shown this to be mostly true. A portion of a returning salmon run may stray and spawn in different freshwater systems; the percent of straying depends on the species of salmon. Homing behavior has been shown to depend on olfactory memory. (38-40). Salmon is a precious natural resource that needs to be protected.

2. GENERAL INTRODUCTION

Michael Robert (2) proposes Figure 1 and Figure 2 for illustrating the effects of greenhouse gases on global warming before human activities and after human activities, respectively. As shown in the two figures, the main reason for the earth's warming is due to the greenhouse effect. Before human activity, natural activities such as volcanic activity and natural forest fires would emit greenhouse gases in the atmosphere. As greenhouse gases absorbed heat and solar radiation, the concentrations of gases get trapped near the earth's surface and sustain life. (2) A microcosm of this balance can be seen in the relationship between humans and trees. Humans take in oxygen and release carbon dioxide (CO_2), while trees take in carbon dioxide and release oxygen, thereby creating a balance in nature. However, due to increased human activity (from electricity, transportation, industry, and population increase (3), large amounts of CO_2 and other greenhouse gases have been released in to the atmosphere. Also as trees get cut down and deforested, there are less resources using up the CO_2, causing levels to rise beyond natural levels. So, what happens to the high levels of greenhouse gases? The excess CO_2 and other greenhouse gases trap the extra radiation near the earth's surface, causing global temperatures to rise, or global warming. (2)



[insert Figure 1. The Natural Greenhouse Effect Before Human Activity (2, Permission to use)]

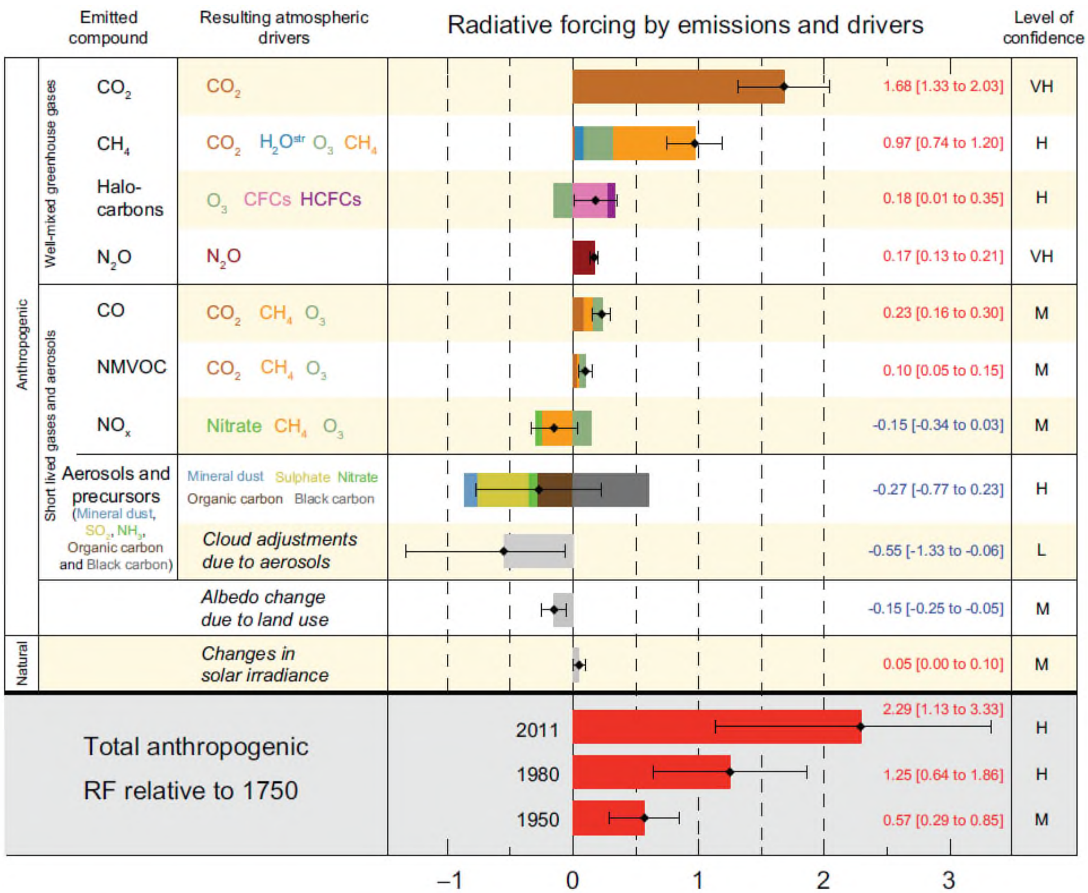


[insert Figure 2. The Greenhouse Effect After Human Activity (2, Permission to use)]

3. MAIN CONTRIBUTORS TO GREENHOUSE GASES

The definitions of greenhouse gases and other technical terms have been introduced in Section 1. The main contributor to the greenhouse effect is carbon dioxide. Following carbon dioxide is methane Gas (CH_4) and nitrous oxide (N_2O,), and the halocarbons as the leading greenhouse gases. Figure 3 below shows the major climate changing agents of greenhouse gases and their radiative forcing ($W\ m^{-2}$), showing their emission ability to retain heat, and their great amounts on the earth's surface (4). As seen in Figure 3, carbon dioxide has the greatest amount where it absorbs heat at a radiative forcing above 1.5 W m^{-2} of increased and retained solar radiation at the earth's surface. Although the halocarbons, methane, and nitrous oxide, have a greater warming potential than carbon dioxide, the larger quantity of carbon dioxide has a greater impact. (28). Ozone depends on the location. In the troposphere where people live, is a greenhouse gas where it absorbs heat; however, ozone in the stratosphere, actually absorbs UV radiation and holds back the radiation from hitting the earth's surface, thereby keeping the earth cooler. Water does not affect the warming of the earth too much since the concentration levels are fairly constant. Land use goes both ways where dark forested areas or black carbon on snow or from diesel engines in the troposphere would absorb heat, whereas planting lighter colored plants or arid regions where light reflects back to space would actually cool the earth. Aerosols' effects are uncertain; the concentration of aerosols can be monitored based on the brightness of clouds, the higher the concentration of aerosols are, the brighter the clouds are. The reason is the aerosols feed the water droplets that contribute to the clouds, and the more water droplets there are, the more the droplets reflect light more. Aerosols in the stratosphere from volcanic activity block the radiation to help cool the earth. There is still much to investigate and discover about aerosols. (2,4)

Figure 3 shows the total weighted average of all the climate changing agents; there is a total of 2.29 W m^{-2} increase in the amount of solar energy absorbed at the surface of the earth. (2, 4) Because carbon dioxide shows the greatest quantity and has the greatest impact, carbon dioxide will be the main focus and should often be a reference point to compare to other greenhouse gases. Values in Figure 3 are global average radiative forcing (RF*), partitioned according to the emitted compounds or processes that result in a combination of drivers. The best estimates of the net radiative forcing are shown as black diamonds with corresponding uncertainty intervals; the numerical values are provided on the right of the figure, together with the confidence level in the net forcing (VH – very high, H – high, M – medium, L – low, VL – very low). Albedo forcing due to black carbon on snow and ice is included in the black carbon aerosol bar. Small forcings due to contrails (0.05 W m^{-2}, including contrail induced cirrus), and HFCs, PFCs and SF_6 (total 0.03 W m^{-2}) are not shown. Concentration-based RFs for gases can be obtained by summing the like-colored bars. Volcanic forcing is not included as its episodic natural makes is difficult to compare to other forcing mechanisms. Total anthropogenic radiative forcing is provided for three different years relative to 1750. The strength of drivers in Figure 3 is quantified as Radiative Forcing (RF) in units watts per square meter (W m^{-2}) as in previous IPCC assessments. RF is the change in energy flux caused by a driver, and is calculated at the tropopause or at the top of the atmosphere. In the traditional RF concept employed in previous IPCC reports all surface and tropospheric conditions are kept fixed. In calculations of RF for well-mixed greenhouse gases and aerosols in this report, physical variables, except for the ocean and sea ice, are allowed to respond to perturbations with rapid adjustments. The resulting forcing is called Effective Radiative Forcing (ERF) in the underlying report. This change reflects the scientific progress from previous assessments and results in a better indication of the eventual temperature response for these drivers. For all drivers other than well-mixed greenhouse gases and aerosols, rapid adjustments are less well characterized and assumed to be small, and thus the traditional RF is used. (4)



Radiative Forcing relative to 1750 W m^{-2} (4)

[insert Figure 3. Radiative forcing estimates in 2011 relative to 1750 and aggregated uncertainties for the main drivers of climate change.]

4. GLOBAL WARMING POTENTIAL AND ITS LIMITATIONS

In the earlier sections of this chapter, Global Warming Potential (GWP) is a measurement of how well heat is absorbed by greenhouse gases. The IPCC defines Global Warming Potential (GWP) as, “the ratio of the time integrated radiative forcing from a pulse emission of 1 kg of a substance, relative to that of 1 kg of carbon dioxide, over a fixed horizon period. GWP is a relative index used to compare the climate impact of an emitted greenhouse gas, relative to an equal amount of Carbon Dioxide." (10) Also, the IPCC examines the GWP for 1 gram of carbon dioxide at a 20-, 100-, and 500- year time horizon in comparison to other greenhouse gases. (9) The six major greenhouse gases are determined by the Kyoto Protocol. The Kyoto Protocol is an international treaty that sets obligations on industrialized countries to lower the emissions of greenhouse gases. The GWP values can be seen in Table 1; the table shows the six major greenhouse gases from the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), HFCs, PFCs, and sulfur hexafluoride (SF_6). The Intergovernmental Panel on Climate Change (IPCC) includes many greenhouse gases in their consensus and a list of HFCs and PFCs. The HFC and PFC chosen in Table 1 are for the greatest GWP values within the consensus list. The lifetime among the six gases range from 12 to 10,000 years. The value closest to the median is sulphur hexafluoride, with a lifetime of 3,200 years. At a time horizon of 500 years, while carbon dioxide releases 1 gram, sulphur hexafluoride releases 11,200 grams of carbon dioxide (11,200 times more!) for the same time horizon. A stronger greenhouse gas can easily leak and create a major impact.

Six Greenhouse Gases listed designated by the Kyoto Protocol	Lifetime (years)	Global Warming Potential for the Given Time Horizon		
		20-year	100-year	500-year
Carbon Dioxide, CO_2	~150	1	1	1
Methane, CH_4	12	72	25	7.6
Nitrous Oxide, N_2O	114	289	298	153
HFC-23	270	12,000	14,800	12,200
PFC-116	10,000	8,630	12,200	18,200
Sulphur Hexafluoride, SF_6	3,200	5,210	7,390	11,200

[insert Table 1. IPCC Global Warming Potential Consensus (2, 8, 9)]

The global warming potential have limitations where radiative properties are uncertain and nonlinear (CO_2, CH_4, N_2O); the actual resident life of greenhouse gases and how long it actually stays in the atmosphere vary and some are unknown (CO_2, ozone precursors, diesel PM, and PM); if the resident lifetimes are short lived in the atmosphere, the GWP is not useful; there is not only direct radiative forcings, but also indirect radiative forcings with uncertainties (i.e. Ozone precursors are not only a gas, but they also form ozone). (2) While the graphs and data interpretations are accepted, people have challenged methodologies and how data is used and interpreted, however, in this case, the US Environmental Protection Agency (USEPA), United Nations (UN), and the Intergovernmental Panel Data Analysis reports and technical books (3-6, 8-11, 16-17, 19-25) are widely accepted. Comparing global warming potentials to carbon dioxide, greenhouse gases are better understood when examining why carbon dioxide absorbs heat on a molecular level.

5. HEAT ABSORPTION BY CARBON DIOXIDE

Carbon dioxide's ability to absorb heat is characterized by the molecular structure, the wavelength, and radiative properties. Visible light from the sun is able to pass the Carbon dioxide molecules without its energy being absorbed since the frequency of visible light does induce a dipole moment on the atmospheric CO_2 molecules. Carbon dioxide does however absorb infrared radiation (heat from the Earth's surface) and also re-emits that energy at the same wavelength as what was absorbed (also as heat). (6) As for its molecular structure, "Carbon dioxide doesn't have a molecular dipole in its ground state. However, some CO_2 vibrations produce a structure with a molecular dipole. Because of this, CO_2 strongly absorbs infrared radiation." (7)

On the electromagnetic spectrum, Infrared lies in the range of 700 nm to 1 mm (1,000,000 nm). Carbon dioxide has absorption wave-numbers of 667 cm^{-1} and 2349 cm^{-1} (11). When converted to wavelengths, equal ~15,000 nm and ~4257 nm respectively, and are well within the Infrared range. Coincidently 15,000 nm also corresponds to the maximum intensity of the Planck function. (6)

The energy of a molecule can change due to a change in the energy state of the electrons of which it is composed. Thus, the molecule also has electronic energy. The energy levels are quantized and take discrete values only. Absorption and emission of radiation takes place when the atoms or molecules undergo transitions from one energy state to another. In general, these transitions are governed by selection rules. Atoms exhibit line spectra associated with electronic energy levels.

The dipole moment is determined by the magnitude of the charge difference and the distance between the two centers of charge. If there is a match in frequency of the radiation and the natural vibration of the molecule, absorption occurs and this alters the amplitude of the molecular vibration. This also occurs when the rotation of asymmetric molecules around their centers results in a dipole moment change, which permits interaction with the radiation field. Dipole moment is a vector quantity and depends on the orientation of the molecule and the photon electric vector. (12)

In accordance with Kirchhoff's Laws: the following are noted:

(a) Materials that are strong absorbers at a given wavelength are also strong emitters at that wavelength; similarly weak absorbers are weak emitters

(b) Emission, reflection, and transmission account for all the incident radiation for media in thermodynamic equilibrium (6)

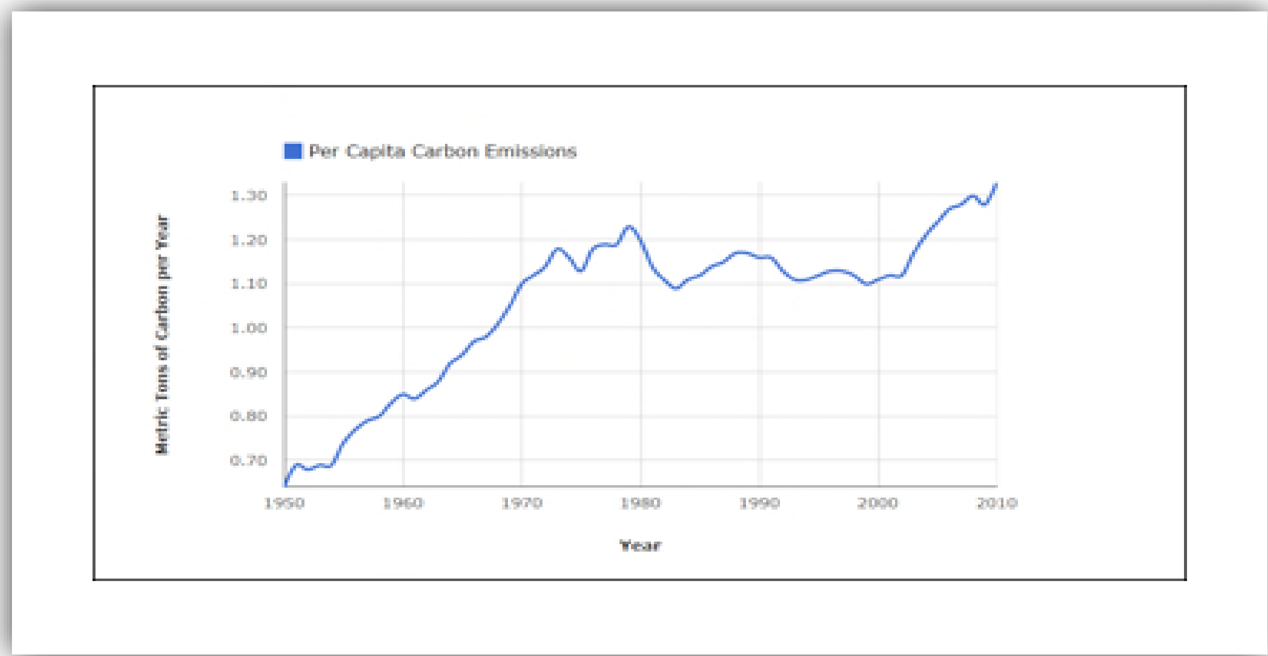
6 RISING TEMPERATURE TREND IN THE ENVIRONMENT

6.1 Atmosphere Temperature Increase

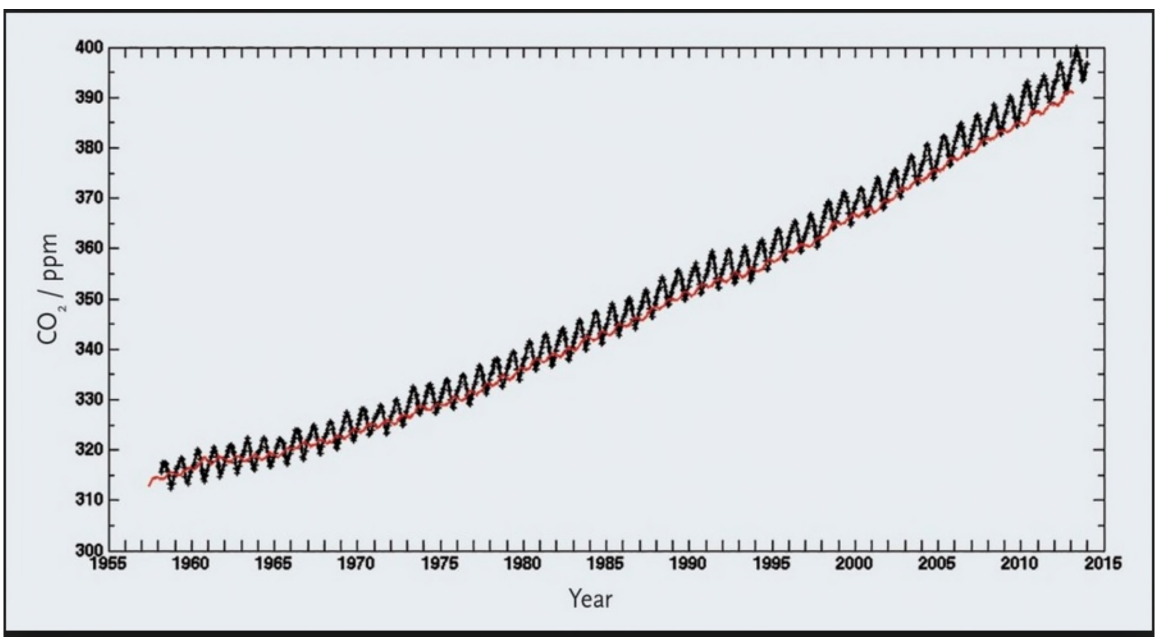
As a result of increased human activity, more greenhouse gases are warming the earth, resulting in an increased temperature trend around the world. The following graphs suggest the increase in emissions have led to the increase in CO_2 in the atmosphere, thereby increasing the temperature of the earth's surface on land. Figure 4 shows the global per capita carbon emission estimates versus years. It appears that the global per capita carbon emission increases significantly after year 2000 (15).

6.2 Land and Ocean Temperature Increase

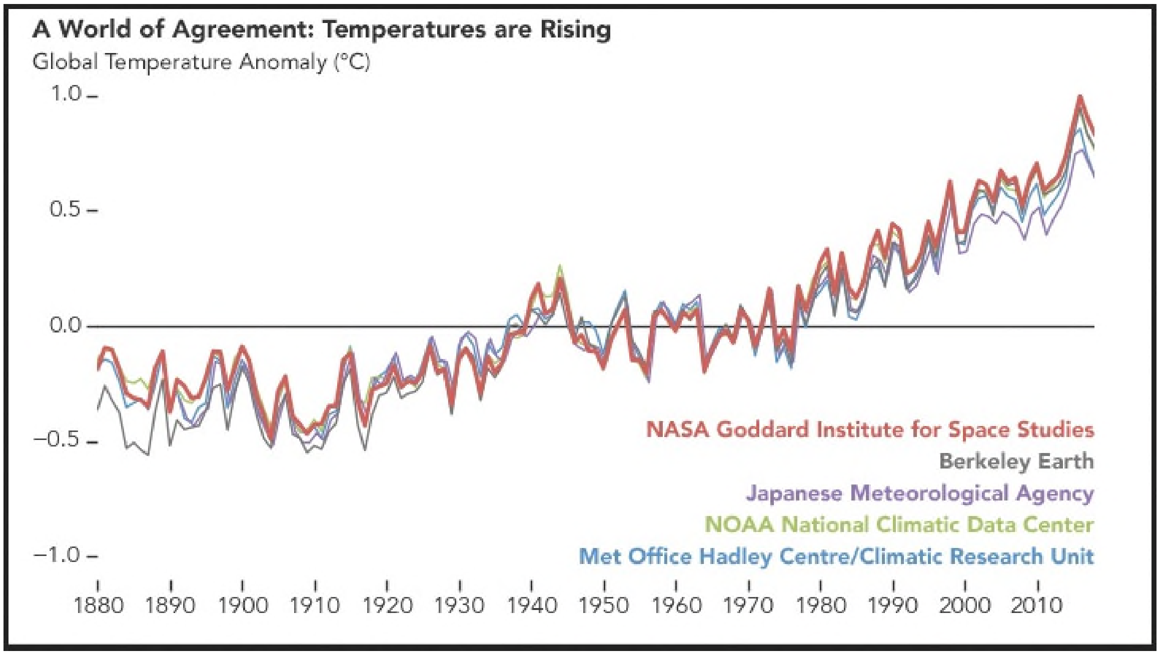
As land temperatures rise, we find ocean temperatures rise as well. “The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85 [0.65 to 1.06] °C3, over the period 1880 to 2012, when multiple independently produced datasets exist. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 [0.72 to 0.85] °C, based on the single longest dataset available. There are two methods: The first calculates the difference using a best fit linear trend of all points between 1880 and 2012. The second calculates the difference between averages for the two periods 1850–1900 and 2003–2012. (4) Figure 5 shows an increase of carbon dioxide in the atmosphere from 1958 to 2012 (4), while Figure 6 shows the annual temperature anomalies from land ocean in the period of 1880-2012 (16). Based on the presented figures, an increase of global carbon emissions shown in Figure 4, leads to an increase of carbon dioxide in the atmosphere shown in Figure 5, and finally results in a temperature increase on land and ocean shown in Figure 6.



[insert Figure 4. Global per capita carbon emission estimates versus years (15)]



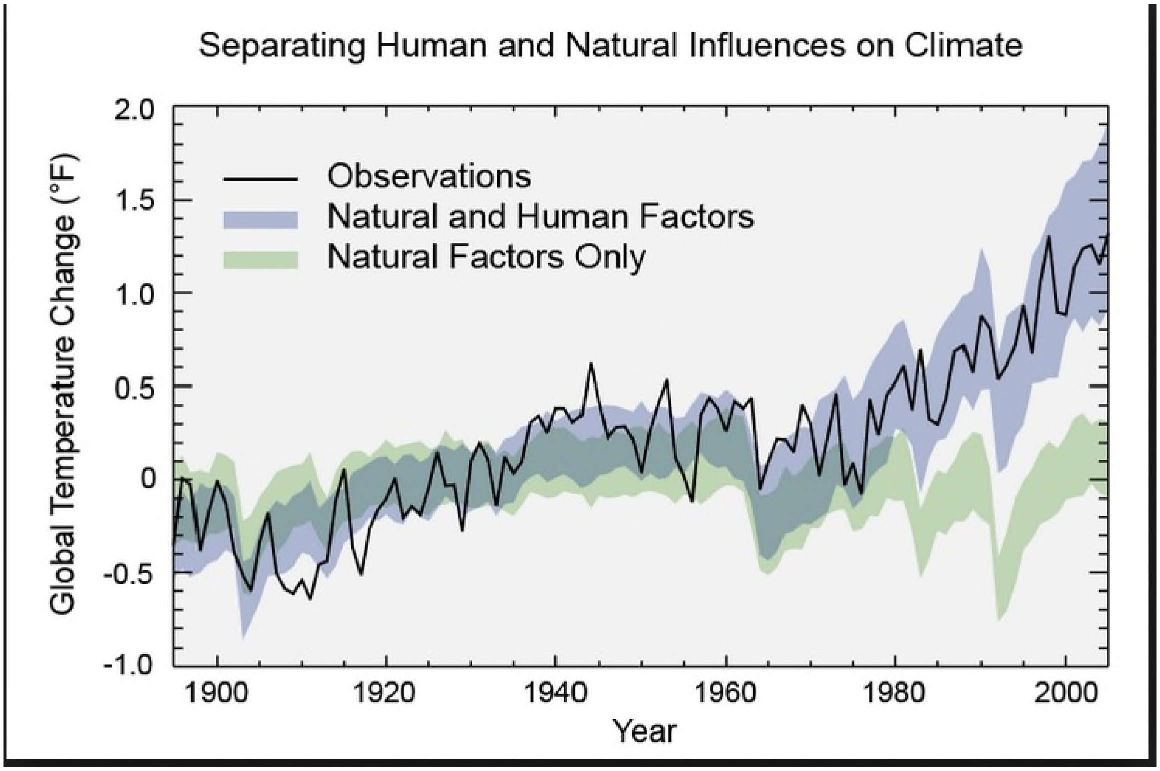
[insert Figure 5. Increase of carbon dioxide in the atmosphere (4)]



[insert Figure 6. Land and ocean temperature increase: Annual temperature anomalies from land and ocean 1880-2012. (16)]

6.3 Rising Temperatures of Land, Air, Sea, and Ice

Figure 7 summarizes the temperatures of land, air, and sea, with a dramatic increase beginning in 1980. Similarly, 1920 to 1940 also experienced an upward trend; however, from 1940 approaching 1980, the temperatures slightly decreased. The reason the temperatures dropped is due to the industrial revolution's emissions, where manufacturers and factories sent a layer of soot in the atmosphere. The layer of soot became a barrier and blocked solar radiation from hitting the earth's surface, causing a cooling effect. However, when the Clean Air Act of 1970 was enforced, the layer of soot moved out of the atmosphere and so began the true and actual warming trend. (2, 18, 19).

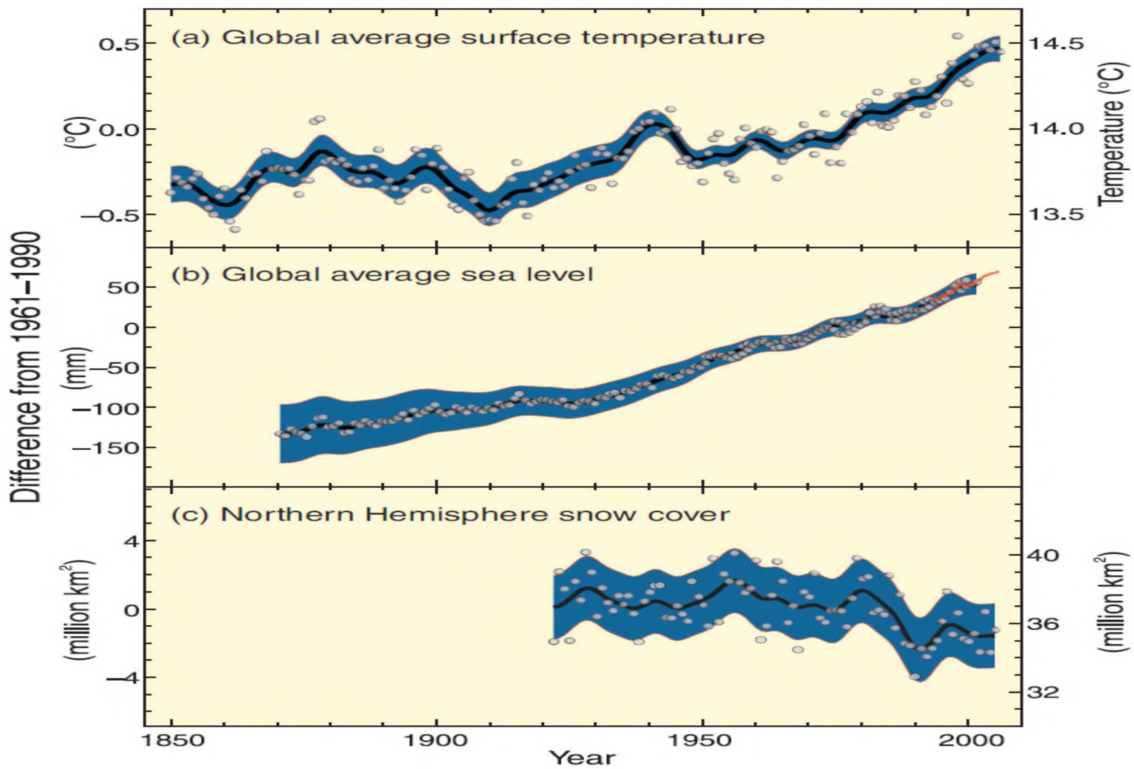


[insert Figure 7. Observed globally averaged combined land and ocean surface temperature anomaly 1895-2012]

7. EFFECT OF GLOBAL WARMING AND CLIMATE CHANGE ON SEA LEVELS RISE.

As global average surface temperatures rise, and global average sea levels increase, the snow cover and ice will decrease and melt. Figure 8 reports the changes of temperature, sea level and Northern Hemisphere snow cover. Specifically observed changes in Figure 8(a) shows global average surface temperature versus years. Figure 8(b) shows global average sea level from tide gauge (blue) and satellite (red) data versus years. Figure 8(c) shows

Northern Hemisphere snow cover for March-April versus years. All differences are relative to corresponding averages for the period 1961-2000. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties shown in the figures.



[insert Figure 8. Changes in Temperature, Sea Level, and Northern Hemisphere Snow Cover]

8. EFFECT OF GLOBAL WARMING AND CLIMATE CHANGE ON GLACIERS.

Similar to the decrease of snow cover in Figure 8, glaciers are melting too. Many glaciers have already disappeared, while existing glaciers are retreating. Some are retreating faster than predicted rates; according to a climate-based computer model, glaciers will vanish by 2030. (22)

8.1 Mendenhall Glacier

A few figures are presented here for the purpose of illustration. Figure 9 shows a closer winter view of Mendenhall Glacier (also Sitaantaagu) , which is about 13.6 miles (21.9 km) long located in Mendenhall Valley, about 12 miles (19 km) from downtown Juneau, Alaska, USA. The glacier has retreated 1.75 miles (2.82 km) since 1929, when Mendenhall Lake was created, and over 2.5 miles (4.0 km) since 1500. The end of the glacier currently has a negative glacier mass balance and will continue to retreat due to that fact that the annual temperatures are currently increasing, and the outlook is for this trend to continue due to global warming.. It is noted that the white Mendenhall Glacier face has now almost totally pulled out of beautiful Mendenhall Lake in July 2019, shown in Figure 10.

Without global warming, a normal glacier is stable and its mass is sustainable. This is because in cold weather, the entire glacier is frozen, but in warm weather, moist air will be carried up to the head of the glacier's ice field, where colder ambient temperatures at the mountain top will cause it to precipitate as snow. The increased amount of snow will feed the ice field, enough to offset the melting at the glacier's terminus in warm weather. However, with global warming, this sustainable phenomenon will fade away if temperatures continue to climb, since the head of the glacier will no longer have cold enough ambient temperatures to cause snow to precipitate.

Although there are many negative effects of the recession of the Mendenhall Glacier and glaciers in general, there are also a few positive outcomes. With the retreat of a glacier, such as Mendenhall Glacier, a lake such as Mendenhall Lake (Figure 10) has formed. The lake is a result of the run-off from the glacier and is increasing in size as the glacier continues to retreat. The lake began to form and has continued to grow becoming a unique ecosystem or a nursery for a variety of aquatic animals and plants, including several type of salmon, Dolly Varden char, and cutthroat trout.

[insert Figure 9. Closer View of Mendenhall Glacier and Frozen Mendenhall Lake in Winter (https://en.wikipedia.org/wiki/Mendenhall_Glacier#External_links)]

[insert Figure 10. Closer View of Mendenhall Glacier and Mendenhall Lake in July 2019 (credit: Lawrence K. Wang and Mu-Hao Sung Wang)]

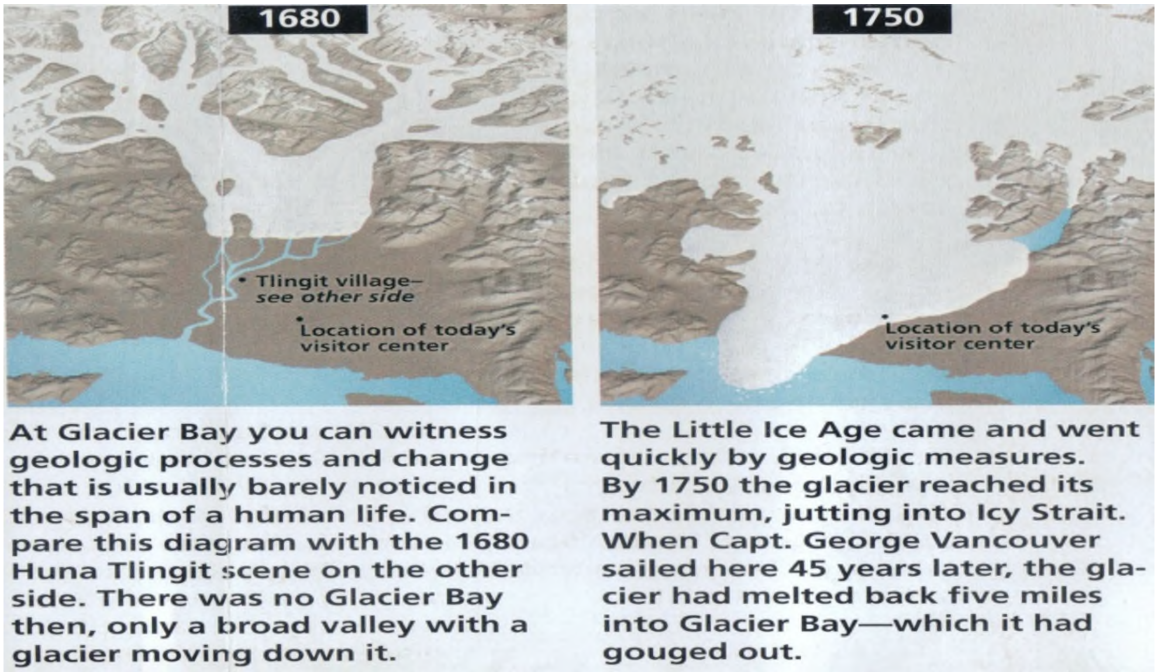
8.2 Glacier Bay National Park and Reserve

Glacier Bay National Park and Preserve is located in Southeast Alaska west of Juneau, USA . The park and preserve cover a total of 3,223,384 acres (5,037 sq mi; 13,045 km^2), with 2,770,000 acres (4,328 sq mi; 11,210 km^2) being designated as a wilderness area. Ecosystems in the park are wet tundra, Alpine tundra, coastal forest, and glaciers and icefields. Sport hunting and trapping are also allowed in the preserve. Wildlife in Glacier Bay includes both brown and black bear species, timber wolf, coyote, moose, black-tailed deer, red fox, porcupine, marmot, dall sheep, beaver, lynx, two species of otter, mink, wolverine, and mountain goat. Birds that nest in this park include the bald eagle, golden eagle, five species of woodpecker, two species of hummingbird, raven, four species of falcon, six species of hawk, osprey, and ten species of owl. Marine mammal species that swim offshore are the sea otter, harbor seal, Steller sea lion, Pacific white-sided dolphin, orca, minke whale, and humpback whale.

To hunt and trap, you must have all required licenses and permits and follow all other state regulations. The National Park Service and the State of Alaska cooperatively manage the wildlife resources of the preserve.

The Park is named for its abundant tidewater and terrestrial glaciers, numbering 1,045 in total. There are seven tidewater glaciers in the park: Margerie Glacier, Grand Pacific Glacier, McBride Glacier, Lamplugh Glacier, Johns Hopkins Glacier, Gilman Glacier, and LaPerouse Glacier. In general, tidewater and terrestrial glaciers in the Park have been thinning and slowly receding over the last several decades, although some glaciers continue to advance, including Johns Hopkins Glacier and glaciers in Lituya Bay.

The rapid advance and subsequent retreat of the glaciers in the Glacier Bay National Park and Preserve area during several substages from 1680 to the present time are recorded and illustrated by Figure 11a and Figure 11b.



[insert Figure 11a. Rapid Advance of Glacier at Glacier Bay form 1680 to 1750 (Credit: State of Alaska, USA)]

[insert Figure 11b. Subsequent Retreat of Glacier at Glacier Bay from 1880 to Today (Credit: State of Alaska, USA)]

There are no roads leading to the park and it is most easily reached by air travel or sea travel. Despite the lack of roads, the Glacier Bay National Park and Preserve has received an average of about 470,000 recreational visitors annually from 2007 to 2016, with 520,171 visitors in 2016. Most of the visitors arrive via cruise ships from 1890 to the present time, shown in Figure 12. The number of ships that may arrive each day is limited by regulation. Other travelers come on white-water rafting trips. Figure 13 presents a closer view of one of great glaciers of Glacier Bay National Park and Preserve. Scientists work with the park rangers in the park and preserve hoping to learn how glacial activity relates to climate change (Figure 14).

Scientists who observe Earth's climate change have documented warming temperatures around the world (31-32). Of the more than 100,000 glaciers in Alaska, USA, 95% are currently thinning, stagnating, or retreating, and Glacier Bay's glaciers follow this trend. The combination of wind, tidal fluctuation, and moderate maritime temperatures keep the Glacier Bay's sea water from freezing over. Much of the Glacier Bay water is over 1,000 feet deep. (32).

Tidewater glaciers shown in Figure 13 are being eaten away on both ends as global warming worsens, suggesting faster sea level rise and ice melt that can alter ocean ecosystems (31). Until now, scientists had limited understanding of what happens under the water at the point where land-based glaciers meet the sea water. Using a combination of radar, sonar and time-lapse photography, a team of scientists including Nina Pullano has now provided the first detailed measurements of the underwater changes over time. Their scientific findings suggest that the theories and principles currently used to gauge tidewater glacier changes are significantly underestimating glaciers' ice loss because the overall trend of glacier retreat around the world is caused by both warming air and warming oceans (31).

[insert Figure 12. Most of Visitors Arrive Glacier Bay Via Cruise Ships from 1890s to the Present Time (July 2019; Golden Princess cruise ship; USA)]

[insert Figure 13. Tidewater Glacier of Glacier Bay National Park and Preserve, Alaska, USA (Credit: LK Wang, MHS Wang)]

[insert Figure 14. Scientists Who Investigated the Glacier Bay National Park and Preserve, Alaska, USA, in July 2019] (Note: Dr. Lawrence K. Wang 王抗曝 Dr. Mu-Hao Sung Wang 宋慕浩 Mrs. Sandra Ma Wang 馬曉蘭 and Dr. Nai-Yi Wang 王乃彝 from left to right)

9. EFFECT OF GLOBAL WARMING AND CLIMATE CHANGE ON SALMON AND ECOSYSTEM.

9.1 Effect on Ecosystem

When temperatures increase and glaciers retreat, forests are more susceptible to fires and

may be more frequent (33). And as glaciers recede and ice melts in the Arctic, polar bears can lose their natural habitats, starve from malnutrition, and drown (30) if their food source, such as salmon is depleted. Animals listed as endangered due to climate change, include the Mediterranean monk seal, sea turtles, and more. Another example of the ecosystem becoming unstable is seen by a visiting manatee found in the Hudson River, New York, USA. The problem is manatees usually reside in Florida's warm waters. Evidently, the water temperatures were comfortable enough that the manatee continued up to New York without turning back to Florida. (24) Figure 15 shows that fire frequency may increase as glaciers retreat at Glacier Bay National Park and Reserve. Figure 16 shows how bears rely on salmon as their food source.

[insert Figure 15. Global warming and climate change increase forest fire frequency (Credit: LK Wang and MHS Wang)]

[insert Figure 16. Salmon is a major food source for bears (credit: LK Wang ad MHS Wang)]

9.2 Effect on Salmon

A warming climate will alter both freshwater and marine communities, affecting resources for both fishers and endangered fish species. For Pacific salmon, climate has diverse affects. Changes in stream temperature and flow alter fish survival, swimming performance, and metabolic rates, which in turn determine energetic costs and growth. (34-36)

Climate also affects salmon's habitat abundance, diversity, and access. The physical environment affects all species, most notably for salmon, both prey and predators. In response to higher temperatures, predators will likely consume more prey. Furthermore, warm–water invasive predators such as bass will grow more prevalent.

A review of the scientific literature of climate impacts on salmon reveals the many pathways these influences can take. (34-36)

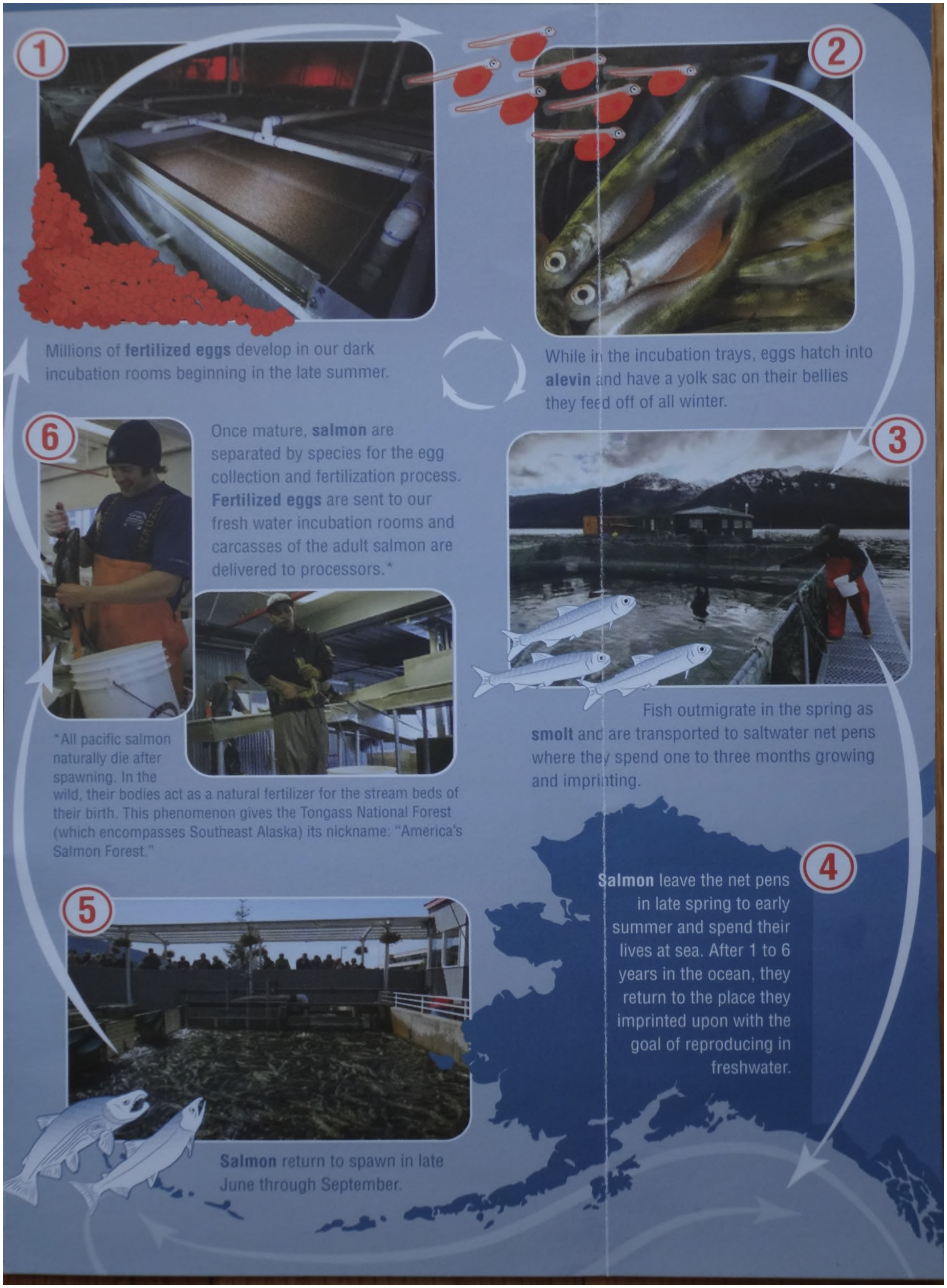
In the Ecosystems Analysis Program of Northwest Fisheries Science Center (NWFSC), the scientists' goal is to quantify climate influences on salmon in freshwater and marine environments over all life stages. The NWFSC supports the conservation and management of living marine resources and their habitats in the Northeast Pacific Ocean. Their research assists resource managers in making sound decisions that build sustainable fisheries, recover endangered and threatened species, sustain healthy ecosystems, and reduce risks to human health. (34)

Frequently NWFSC research requires developing novel statistical tools. Their scientists then incorporate these relationships into models that can be used to assess extinction risk. Their comprehensive, multi–lateral approach has the following specific objectives: (a) Identify relationships between the environment and population responses such as migration timing and rates of survival. Using these relationships, develop life–cycle models that can help predict the response of endangered salmon populations to climate change (35); (b) Monitor the state of the science in annual syntheses of the global literature on climate effects on salmon (35); (c) Provide scientific support for resource management actions to protect endangered species (36); and (d) Collaborate with other groups on the Pacific coast, the nation, and the world to enhance our resilience to climate variability and climate change.

To combat the loss of Pacific salmon, Macaulay Salmon Hatchery was established in Juneau, AK, USA. Figures 17 and 18 partially introduce the hatchery facility. In the wild, salmon have to beat all the odds to leave a home stream as juveniles to begin their life journey at seas or oceans. Only a very small fraction ranging from 5 to 10 % of salmon eggs survive from fertilization to outmigration into the big ocean environment. At Macaulay Salmon Hatchery, 80-90 % success rate from egg to juvenile stage has been consistently achieved due to their research. Once salmon juveniles leave the hatchery, they face very dangerous life at ocean as wild salmon. Figures 17a-17b show the hatchery that rear and release salmon into the wild to enhance the opportunities for additional research, commercial use, personal use, sport, and subsistence fishing. Douglas Island Pink & Chum Inc. (DIPCI) owns the hatchery with a mission to sustain and enhance the valuable salmon resources, since salmon, as well as many other animals have been directly or indirectly affected by the climate changes. Salmon does need protection (37). The hatchery's salmon management effort is presented in its process diagram, Figure 18. In Step 1 of Figure 18, millions of fertilized eggs develop in dark incubation rooms beginning in the late summer. In Step 2, while in the incubation trays, eggs hatch into alevin and have a yolk sac on their bellies they feed off of all winter. In Step 3, fish outmigrate in the spring as smolt and are transported to saltwater net pens where they spend one to three months growing and imprinting. In Step 4, salmon leave the net pens in late spring to early summer and spend their lives at sea. After 1 to 6 years in the ocean, they return to the place they imprinted upon with the goal of reproducing in freshwater. In Step 5, salmon return to spawn in late June through September. All pacific salmon naturally die after spawning in the wild, and their dead bodies act as a natural fertilizer for the stream beds of their birth. This phenomenon gives the Tongass National Forest in the Southeast of Alaska, its nickname of " America's Salmon Forest". The specific salmon released by Macaulay Salmon Hatchery are imprinted in their brains knowing where their home is, and they will swim to the hatchery's entrance ladders (Figure 17a), gradually jumping up to the hatchery internal facility (Figure 17b; and Figure 18 Step 5). In Step 6 inside the internal facility, mature salmon are separated by species for the separate egg collection and sperm collection. By mixing the eggs with the sperms, the salmon eggs are fertilized. Fertilized eggs are sent to the hatchery's fresh water incubation rooms and carcasses of the adult salmon are delivered to processors. After Step 6 is over, Step 1 is repeated again.

[insert Figure 17a. Salmon ladders of Macaulay Salmon Hatchery of Douglas Island Pink & Chum, Inc. , Juneau, AK, USA. (Credit: LK Wang and MHS Wang)]

[insert Figure 17b. Internal facility of Macaulay Salmon Hatchery, Douglas Island Pink & Chum, Inc. , Juneau, AK, USA. (Credit: LK Wang and MHS Wang)]



[insert Figure 18. Salmon life cycle managed by Macaulay Salmon Hatchery, AK, USA (Credit: Macaulay Salmon Hatchery)]

9.3 Carbon Dioxide Stabilization in the Environment

As atmospheric temperatures increase and land temperatures increase, ocean temperatures increase, causing snow and glaciers to melt, and sea levels to rise. Surely, there will be negative effects as a result of changing the earth's composition. In order to stay away from the most severe consequences, the concentration levels of CO_2 in the atmosphere must be stabilized.

Currently, the concentration of carbon dioxide is 430 parts per million (ppm) CO_2, whereas the concentration of CO_2 before the industrial revolution was only 280 ppm. Concentrations of CO_2 have caused the world to warm by more than half a degree Celsius and will warm by another half a degree over the next few decades, because of the inertia in the climate system. "Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach double pre-industrial levels by 2050 - that is 550 ppm CO_2 - and would continue growing thereafter.

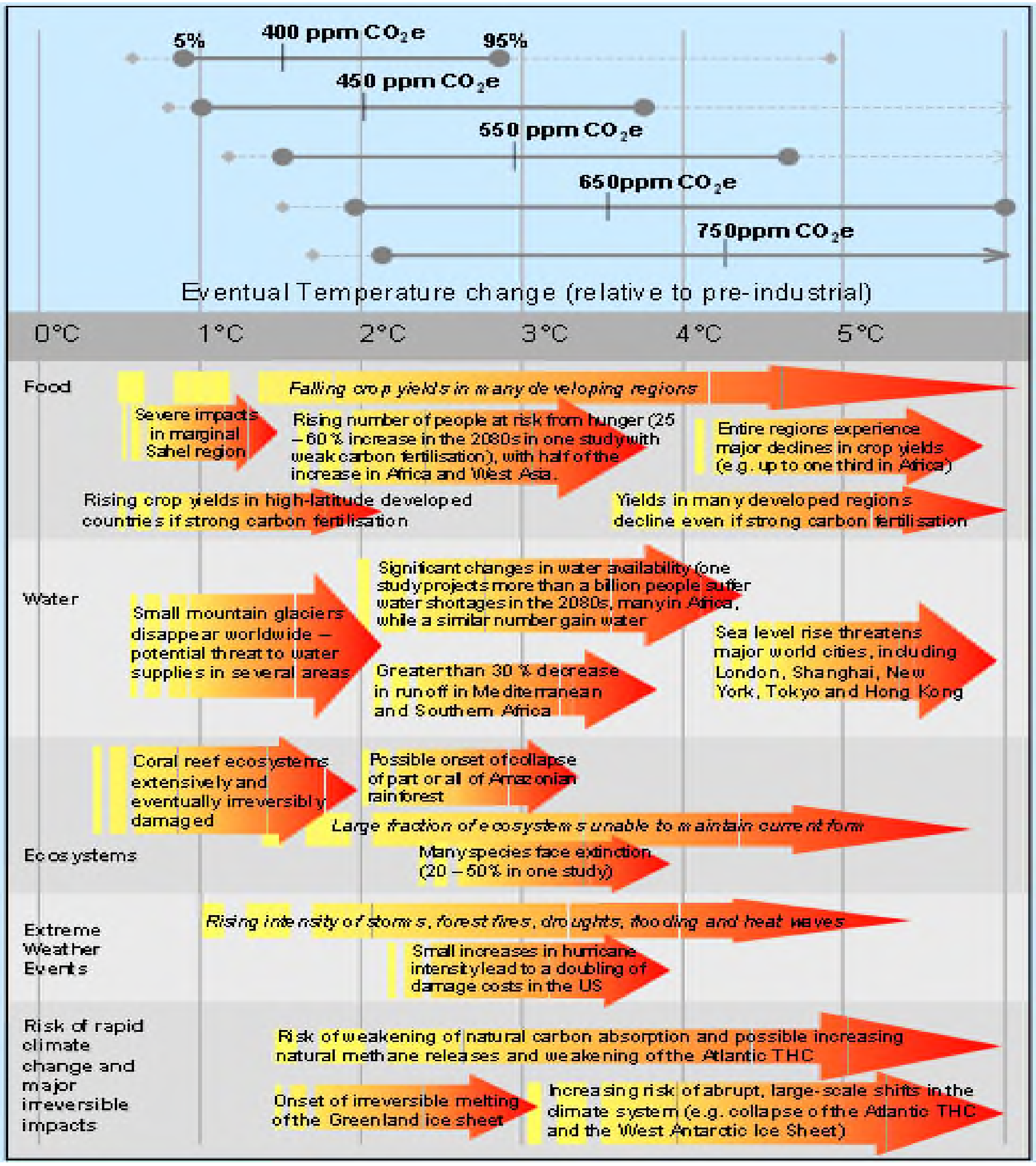
But the annual flow of emissions is accelerating, as fast-growing economies invest in high-carbon infrastructure and as demand for energy and transport increases around the world. The level of 550 ppm CO_2 could be reached as early as 2035. At this level there is at least a 77 % chance (and perhaps up to a 99% chance, depending on the climate model used) of a global average temperature rise exceeding 2 °C. (25)

Figure 19 uses CO_2 as the reference greenhouse gas; as mentioned, the current CO_2 concentration is referred to as CO_2e, CO_2 equivalent, where e is the value of all greenhouse gases times their warming potential. In Figure

19, the total product of CO_2e represents the total emissions in the atmosphere in terms of CO_2, and is ultimately compared to the desired stability values. The eventual temperature change, relative to pre-industrial figure shows an increase in temperature change per incremental increase in CO_2. For example, for the CO_2 concentration of 430 ppm, the eventual temperature increase would be about 2 degrees.

Scientifically Figure 19 illustrates the types of impacts that could be experienced as the world comes into equilibrium with more greenhouse gases. The top pane l shows the range of temperatures projected at stabilization levels between 400 ppm and 750 ppm CO_2e at equilibrium. The solid horizontal lines indicate the 5 - 95% range based on climate sensitivity estimates from the IPCC 2001 and a recent Hadley Centre ensemble study 3. The vertical line indicates the mean of the 50^{th} percentile point. The dashed lines show the 5 - 95% range based on eleven recent studies 4. The bottom panel illustrates the range of impacts expected at different levels of warming. The relationship between global average temperature changes and regional climate changes is very uncertain, especially with regard to changes in precipitation. This Figure 19 shows potential changes based on current scientific literature. (25)

In summation, as temperatures increase, Figure 19 demonstrates the consequences of hunger, droughts, and extinction. Crops will yield less during harvest especially in developing countries, water will become scarce as glaciers disappear, and as the ocean waters get warmer, animals will lose their habitats, leading to negative effects of the ecosystem and extinction.



[insert Figure 19. Stabilization levels and probability ranges for temperature increases]

Obviously, the greatest negative impacts are costly. It is clear we need to take action sooner rather than later. The longer we debate about what to do, the more costly it will be. A particular study tried to stabilize the concentration of greenhouse gases in the atmosphere targeting the year 2040; if we start in 2010, we can decrease emissions at a rate of 3.2% per year, but if we wait 10 years later in 2020, and allow emissions to increase during that time, it would require decreasing emissions at a rate of 8.2% per year to arrive to the same goal in the year 2040. (2)

10. APPLICATIONS TO TAKE ACTION

To avoid the consequences, solutions begin with us. We can start by (2):

- Carpooling
- Get a vehicle with better gas mileage
- Use compact florescent lights
- Make your home more energy efficient by replacing appliances
- Turn off your powerstrip when you are done, it conserves 25%
- Be a better consumer by buying recycled things, and recycle simple things like the disposable coffee sleeve from your coffee shop
- Get off junkmail
- Stop buying bottled water and use a water filter

11. SUMMARY

What is certain? It is certain that:

- The increasing amount of human activity is changing the composition of the atmosphere with overwhelming supporting data.
- Carbon dioxide, methane, and nitrous oxide are increasing dramatically as a result of human activities.

- Greenhouse gases absorb heat and emit heat; since they get trapped in the atmosphere, the heat gets trapped in the atmosphere and warms the earth.
- "The lifetime of major greenhouse gases from human activities can remain in the atmosphere for decades to centuries.
- Average global temperatures have risen over 1 degree Fahrenheit, and up to 4 degrees Fahrenheit in some regions, over the last century."

What is uncertain? It is uncertain that:

- "forecasting exact impacts to health, agriculture, water resources, forests, wildlife and coastal areas in regional basis is difficult.
- There is also uncertainty in quantifying the exact magnitude and extent of adverse effects, projecting magnitude of sea level rise, and
- quantifying the indirect effects of aerosol particles the Earth's energy balance (i.e. Cloud formation and its radiative properties, precipitation efficiencies).

Adaptation/mitigation for the effects of climate change is necessary because evidence shows it is too late for complete prevention. The responsible thing to do is to start preparing now.

Climate change has become a contentious political issue, which is unfortunate if only because it distracts society and our policy makers from necessary discussions and decisions about how to respond to the impacts of climate change on our communities.

Over a full century passed since the beginning of climate science; Climate science is older than the atom bomb, the discovery of penicillin, trans-Atlantic jet flights, digital computers, and moon rockets. Since 1827, our understanding and certainty of the earth warming is a proven result of human activities.

But, as always, we must try and separate the science we know from the policy we must create. Perhaps the solution to climate change will be something environmentalists hate. If that's our best bet, so be it. But whatever bet we make on our future in terms of climate action, it must truly be our best and our most informed. Pretending climate science hasn't been saying much the same thing for a long, long time now is nothing more than wishful thinking.

GLOSSARY

Aerosol **(a)** A small droplet or particle suspended in the atmosphere, typically containing sulfur. Aerosols are emitted naturally (e.g., in volcanic eruptions) and as the result of human activities (e.g., by burning fossil fuels). There is no connection between particulate aerosols and pressurized products also called aerosols. (b) A product that relies on a pressurized gas to propel substances out of a container. Consumer aerosol products in the United States have not used ozone-depleting substances (ODS) since the late 1970s because of voluntary switching followed by federal regulation. The Clean Air Act and the US Environmental Protection Agency (USEPA) regulations further restricted the use of ODS for non-consumer products. All consumer products, and most other aerosol products, now use propellants that do not deplete the ozone layer, such as hydrocarbons and compressed gases. (c) Aerosols are fine solid or liquid particles, caused by people or occurring naturally, that are suspended in the atmosphere. Aerosols can cause cooling by scattering incoming radiation or by affecting cloud cover. Aerosols can also cause warming by absorbing radiation. (d) Small particles or liquid droplets in the atmosphere that can absorb or reflect sunlight depending on their composition.

Anthropogenic Made by people or resulting from human activities. Usually used in the context of emissions that are produced as a result of human activities.

Atmosphere The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium, radiatively active greenhouse gases such as carbon dioxide (0.035% volume mixing ratio), and ozone. In addition the atmosphere contains water vapor, whose amount is highly variable but typically 1% volume mixing ratio. The atmosphere also contains clouds and aerosols. The atmosphere can be divided into a number of layers according to its mixing or chemical characteristics, generally determined by temperature. The layer nearest the Earth is the troposphere, which reaches up to an altitude of about 8 km (about 5 miles) in the polar regions and up to 17 km (nearly 11 miles) above the equator. The stratosphere reaches to an altitude of about 50 km (31 miles) and lies above the troposphere. The mesosphere extends up to 80-90 km and is above the stratosphere, and finally, the thermosphere, or ionosphere, gradually diminishes and forms a fuzzy border with outer space. There is very little mixing of gases between layers.

Black carbon Soot produced from coal burning, diesel engines, cooking fires, wildfires, and other combustion sources. These particles absorb solar energy and have a warming influence on the climate.

Black carbon aerosol Black carbon (BC) is the most strongly light-absorbing component of particulate matter (PM), and is formed by the incomplete combustion of fossil fuels, biofuels, and biomass. It is emitted directly into the atmosphere in the form of fine particles (PM2.5).

Carbon capture and sequestration (CCS) Carbon capture and sequestration (CCS) is a set of technologies that can greatly reduce carbon dioxide emissions from new and existing coal- and gas-fired power plants, industrial processes, and other stationary sources of carbon dioxide. It is a three-step process that includes capture of carbon dioxide from power plants or industrial sources; transport of the captured and compressed carbon dioxide (usually in pipelines); and underground injection and geologic sequestration, or permanent storage, of that carbon dioxide in rock formations that contain tiny openings or pores that trap and hold the carbon dioxide.

Carbon capture and storage The process of capturing carbon dioxide and injecting it into geologic formations underground for long-term storage. “Carbon capture and storage” is same as “carbon capture and sequestration”.

Carbon cycle (a) All parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of carbon interconnected by pathways of exchange. The reservoirs are the atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest pool of carbon near the surface of the Earth, but most of that pool is not involved with rapid exchange with the atmosphere. (b) Circulation of carbon atoms through the Earth systems as a result of photosynthetic conversion of carbon dioxide into complex organic compounds by plants, which are consumed by other organisms, and return of the carbon to the atmosphere as carbon dioxide as a result of respiration, decay of organisms, and combustion of fossil fuels.

Carbon dioxide A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. It is the principal human-caused greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1.

Carbon dioxide equivalent A metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalents ($MMTCO_2Eq$)." The carbon dioxide equivalent for a gas is derived by multiplying the tons of the gas by the associated global warming potential . $MMTCO_2Eq$ = (million metric tons of a gas) * (GWP of the gas)

Carbon dioxide fertilization The enhancement of the growth of plants as a result of increased atmospheric CO_2 concentration. Depending on their mechanism of photosynthesis, certain types of plants are more sensitive to changes in atmospheric CO_2 concentration.

Carbon footprint The total amount of greenhouse gases that are emitted into the atmosphere each year by a person, family, building, organization, or company. A persons carbon footprint includes greenhouse gas emissions from fuel that an individual burns directly, such as by heating a home or riding in a car. It also includes greenhouse gases that come from producing the goods or services that the individual uses, including emissions from power plants that make electricity, factories that make products, and landfills where trash gets sent.

Carbon sequestration (a) Storage of carbon through natural or technological processes in biomass or in deep geological formations. (b) Terrestrial, or biologic, carbon sequestration is the process by which trees and plants absorb carbon dioxide, release the oxygen, and store the carbon. Geologic sequestration is one step in the process of carbon capture and sequestration (CCS), and involves injecting carbon dioxide deep underground where it stays almost permanently.

Carbon tetrachloride (CCl_4) A compound consisting of one carbon atom and four chlorine atoms. Carbon tetrachloride was widely used as a raw material in many industrial uses, including the production of chlorofluorocarbons and as a solvent. Solvent use ended when it was discovered to be carcinogenic. It is also used as a catalyst to deliver chlorine ions to certain processes. Its ozone depletion potential is 1.2.

Chlorofluorocarbon (CFC) A compound consisting of chlorine, fluorine, and carbon. Chlorofluorocarbons (CFCs) are very stable in the troposphere. They move to the stratosphere and are broken down by strong ultraviolet light, where they release chlorine atoms that then deplete the ozone layer. CFCs were commonly used as refrigerants, solvents, and foam blowing agents. The most common CFCs were CFC-11, CFC-12, CFC-113, CFC-114, and CFC-115. CFCs have been phased out in the United States, with a few exceptions. CFCs are the gases covered under the 1987 Montreal Protocol and used for refrigeration, air conditioning, packaging, insulation, solvents, or aerosol propellants. Since they are not destroyed in the lower atmosphere, CFCs drift into the upper atmosphere where, given suitable conditions, they break down ozone. These gases are being replaced by other compounds: hydrochlorofluorocarbons, an interim replacement for CFCs that are also covered under the Montreal Protocol, and hydrofluorocarbons, which are covered under the Kyoto Protocol. All these substances are also greenhouse gases.

Class I Ozone-Depleting Substance One of several groups of chemicals with an ozone-depletion potential of 0.2 or higher. Class I ozone-depleting substances listed in the Clean Air Act include chlorofluorocarbons, halons, carbon tetrachloride, methyl chloroform hydrobromofluorocarbons, and methyl bromide.

Class II Ozone-Depleting Substance A chemical with an ozone-depletion potential of less than 0.2. Currently, all hydrochlorofluorocarbons are Class II ozone-depleting substances.

Climate (a) Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. The classical period is 3 decades, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. (b) The average weather (usually taken over a 30-year time period) for a particular region and time period. Climate is not the same as weather, but rather, it is the average pattern of weather for a particular region. Weather describes the short-term state of the atmosphere. Climatic elements include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather.

Climate change (a) Changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other features of the climate system. (b) Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer.

Deforestation The change of forested lands to non-forest uses. This is often cited as one of the major causes of the enhanced greenhouse effect for two reasons: (a) trees that are burned or decompose release carbon dioxide; and (b) trees that are cut no longer remove carbon dioxide from the atmosphere.

Desertification Land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Further, the UNCCD (The United Nations Convention to Combat Desertification) defines land degradation as a reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (a) soil erosion caused by wind and/or water; (b) deterioration of the physical, chemical and biological or economic properties of soil; (c) long-term loss of natural vegetation, such as conversion of forest to non-forest.

Ecosystem (a) All the living things in a particular area as well as components of the physical environment with which they interact, such as air, soil, water, and sunlight. (b) Any natural unit or entity including living and non-living parts that interact to produce a stable system through cyclic exchange of materials. (c) The complex of a community of organisms and the community's environment functioning as an ecological unit.

Emissions The release of a substance (usually a gas when referring to the subject of climate change) into the atmosphere.

Enhanced greenhouse effect The concept that the natural greenhouse effect has been enhanced by increased atmospheric concentrations of greenhouse gases (such as CO_2 and methane) emitted as a result of human activities. These added greenhouse gases cause the earth to warm.

Environment The complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism (a living thing) or an ecological community (a collection of living things) and ultimately determine its form and survival. The circumstances, objects, and conditions that surround each of us.

Fluorinated gases Powerful synthetic greenhouse gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons) and are often used in coolants, foaming agents, fire extinguishers, solvents, pesticides, and aerosol propellants. These gases are emitted in small quantities compared to carbon dioxide (CO_2), methane (CH_4), or nitrous oxide (N_2O), but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases (High GWP gases).

Fluorocarbons Carbon-fluorine compounds that often contain other elements such as hydrogen, chlorine, or bromine. Common fluorocarbons include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

Forcing Factors that affect the Earth's climate. For example, natural factors such as volcanoes and human factors such as the emission of heat-trapping gases and particles through fossil fuel combustion.

Fossil fuel **(a)** A general term for a fuel that is formed in the Earth from plant or animal remains, including coal, oil, natural gas, oil shales, and tar sands. (b) A general term for organic materials formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils by exposure to heat and pressure in the earth's crust over hundreds of millions of years.

Glacier **(a)** A very large body of ice moving slowly down a slope or valley or spreading outward on a land surface. (b) A multi-year surplus accumulation of snowfall in excess of snowmelt on land and resulting in a mass of ice at least 0.1 km^2 in area that shows some evidence of movement in response to gravity. A glacier may terminate on land or in water. Glacier ice is the largest reservoir of fresh water on Earth, and second only to the oceans as the largest reservoir of total water. Glaciers are found on every continent except Australia.

Global average temperature An estimate of Earths mean surface air temperature averaged over the entire planet.

Global change Changes in the global environment that may alter the capacity of the Earth to sustain life. Global change encompasses climate change, but it also includes other critical drivers of environmental change that may interact with climate change, such as land use change, the alteration of the water cycle, changes in biogeochemical cycles, and biodiversity loss.

Global Climate Models (GCM) Mathematical models that simulate the physics, chemistry, and biology that influence the climate system.

Global warming (a) The recent and ongoing global average increase in temperature near the Earths surface. (b) The observed increase in average temperature near the Earth's surface and in the lowest layer of the atmosphere. In common usage, "global warming" often refers to the warming that has occurred as a result of increased emissions of greenhouse gases from human activities. Global warming is a type of climate change; it can also lead to other changes in climate conditions, such as changes in precipitation patterns.

Global warming potential (GWP) (a) A measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), compared to carbon dioxide. (b) A number that refers to the amount of global warming caused by a substance. The GWP is the ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide (CO_2). Thus, the GWP of CO_2 is 1.0. Chlorofluorocarbon (CFC)-12 has a GWP of 8,500; CFC-11 has a GWP of 5,000; hydrochlorofluorocarbons and hydrofluorocarbons have GWPs ranging from 93 to 12,100; and water has a GWP of 0.

Greenhouse effect (a) The effect produced as greenhouse gases allow incoming solar radiation to pass through the Earth's atmosphere, but prevent most of the outgoing infrared radiation from the surface and lower atmosphere from escaping into outer space. This process occurs naturally and has kept the Earth's temperature about 60 degrees Fahrenheit warmer than it would otherwise be. Current life on Earth could not be sustained without the natural greenhouse effect. (b) Trapping and build-up of heat in the atmosphere (troposphere) near the Earth's surface. Some of the heat flowing back toward space from the Earth's surface is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the Earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase.

Greenhouse gas (GHG) (a) Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated fluorocarbons (HCFCs), ozone (O_3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs), water vapor and sulfur hexafluoride. (b) Gases that absorb heat in the atmosphere near the Earth's surface, preventing it from escaping into space. If the atmospheric concentrations of these gases rise, the average temperature of the lower atmosphere will gradually increase, a phenomenon known as the greenhouse effect.

Habitat The place or environment where a plant or animal naturally or normally lives and grows.

Hydrobromofluorocarbon (HBFC) An ozone-depleting substance consisting of hydrogen, bromine, fluorine, and carbon.

Hydrocarbon (HC) A compound consisting of carbon and hydrogen. Hydrocarbons include methane, ethane, propane, cyclopropane, butane, and cyclopentane. Although they are flammable, hydrocarbons (HCs) may offer advantages as substitutes to ozone-depleting substances because they have zero ozone depletion potential, low toxicity, and with the exception of methane, have low global warming potentials. Fossil fuels are made up of hydrocarbons.

Hydrochlorofluorocarbon (HCFC) A compound consisting of hydrogen, chlorine, fluorine, and carbon. Hydrochlorofluorocarbons (HCFCs) are one class of chemicals that was used to replace the chlorofluorocarbons (CFCs). They contain chlorine and thus deplete stratospheric ozone, but to a much lesser extent than CFCs. HCFCs have ozone depletion potentials (ODPs) ranging from 0.01 to 0.1. In conclusion, although ozone depleting substances, they are less potent at destroying stratospheric ozone than chlorofluorocarbons (CFCs). They have been introduced as temporary replacements for CFCs and are also greenhouse gases. Production of HCFCs is being phased out.

Hydrofluorocarbon (HFC) A compound consisting of hydrogen, fluorine, and carbon. Hydrofluorocarbons (HFCs) are a class of replacements for chlorofluorocarbons. Because they do not contain chlorine or bromine, they do not deplete the ozone layer. All HFCs have an ozone depletion potential of 0. Some HFCs have high global warming potentials. In conclusion, they were introduced as alternatives to ozone depleting substances in serving many industrial, commercial, and personal needs. HFCs are emitted as by-products of industrial processes and are also used in manufacturing. They do not significantly deplete the stratospheric ozone layer, but they are powerful greenhouse gases with global warming potentials ranging from 140 (HFC-152a) to 11,700 (HFC-23).

Hydrofluoroolefin (HFO) A compound consisting of hydrogen, fluorine, and carbon. Hydrofluoroolefins (HFOs) are alternatives to ozone-depleting substances that typically have very low global warming potentials.

Hydrologic cycle The process of evaporation, vertical and horizontal transport of vapor, condensation, precipitation, and the flow of water from continents to oceans. It is a major factor in determining climate through its influence on surface vegetation, the clouds, snow and ice, and soil moisture. The hydrologic cycle is responsible for 25 to 30 percent of the mid-latitudes' heat transport from the equatorial to polar regions.

Hydrosphere The component of the climate system comprising liquid surface and subterranean water, such as: oceans, seas, rivers, fresh water lakes, underground water etc.

Ice core A cylindrical section of ice removed from a glacier or an ice sheet in order to study climate patterns of the past. By performing chemical analyses on the air trapped in the ice, scientists can estimate the percentage of carbon dioxide and other trace gases in the atmosphere at a given time. Analysis of the ice itself can give some indication of historic temperatures.

Indicator An observation or calculation that allows scientists, analysts, decision makers, and others to track environmental trends, understand key factors that influence the environment, and identify effects on ecosystems and society.

Indirect emissions Indirect emissions from a building, home or business are those emissions of greenhouse gases that occur as a result of the generation of electricity used in that building. These emissions are called "indirect" because the actual emissions occur at the power plant which generates the electricity, not at the building using the electricity.

Industrial revolution A period of rapid industrial growth with far-reaching social and economic consequences, beginning in England during the second half of the 18th century and spreading to Europe and later to other countries including the United States. The industrial revolution marks the beginning of a strong increase in combustion of fossil fuels and related emissions of carbon dioxide.

Infrared radiation Infrared radiation consists of light whose wavelength is longer than the red color in the visible part of the spectrum, but shorter than microwave radiation. Infrared radiation can be perceived as heat. The Earths surface, the atmosphere, and clouds all emit infrared radiation, which is also known as terrestrial or long-wave radiation. In contrast, solar radiation is mainly short-wave radiation because of the temperature of the Sun.

Intergovernmental panel on climate change (IPCC) The IPCC was established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change. The IPCC draws upon hundreds of the world's expert scientists as authors and thousands as expert reviewers. Leading experts on climate change and environmental, social, and economic sciences from some 60 nations have helped the IPCC to prepare periodic assessments of the scientific underpinnings for understanding global climate change and its consequences. With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world's governments on the state of the science of the climate change issue. For example, the IPCC organized the development of internationally accepted methods for conducting national greenhouse gas emission inventories.

Kyoto Protocol An international treaty that sets obligations and industrialized countries to lower their emissions of greenhouse gases.

Mesosphere Earth's atmosphere is divided into five main layers: the exosphere, the thermosphere, the mesosphere, the stratosphere and the troposphere. Stratosphere is the region of the atmosphere above the troposphere. Mesosphere is the region of the atmosphere above the stratosphere, but below thermosphere.

Methane (CH_4) (a) Colorless, odorless, flammable hydrocarbon (CH_4) that is a product of decomposition of organic matter and of the carbonization of coal. Methane is one of the greenhouse gas chemical compounds. (b) A hydrocarbon that is a greenhouse gas with a global warming potential most recently estimated at 25 times that of carbon dioxide (CO_2). Methane is produced through anaerobic (without oxygen) decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion.

Natural gas Underground deposits of gases consisting of 50 to 90 percent methane (CH_4) and small amounts of heavier gaseous hydrocarbon compounds such as propane (C_3H_8) and butane (C_4H_{10}).

Natural variability Variations in the mean state and other statistics (such as standard deviations or statistics of extremes) of the climate on all time and space scales beyond that of individual weather events. Natural variations in climate over time are caused by internal processes of the climate system, such as El **Niño** , as well as changes in external influences, such as volcanic activity and variations in the output of the sun.

Nitrogen cycle The natural circulation of nitrogen among the atmosphere, plants, animals, and microorganisms that live in soil and water. Nitrogen takes on a variety of chemical forms throughout the nitrogen cycle, including nitrous oxide (N_2O) and nitrogen oxides (NOx).

Nitrogen oxides (NOx) Gases consisting of one molecule of nitrogen and varying numbers of oxygen molecules. Nitrogen oxides are produced in the emissions of vehicle exhausts and from power stations. In the atmosphere, nitrogen oxides can contribute to formation of photochemical ozone (smog), can impair visibility, and have health consequences; they are thus considered pollutants.

Nitrous oxide (N_2O) A powerful greenhouse gas with a global warming potential of 298 times that of carbon dioxide (CO_2). Major sources of nitrous oxide include soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning. The GWP is from the IPCC's Fourth Assessment Report (AR4). Natural emissions of N_2O are mainly from bacteria breaking down nitrogen in soils and the oceans. Nitrous oxide is mainly removed from the atmosphere through destruction in the stratosphere by ultraviolet radiation and associated chemical reactions, but it can also be consumed by certain types of bacteria in soils.

Non-methane volatile organic compounds (NMVOCs) Organic compounds, other than methane, that participate in atmospheric photochemical reactions.

Nutrients Chemicals (such as nitrogen and phosphorus) that plants and animals need to live and grow. At high concentrations, particularly in water, nutrients can become pollutants.

Ocean acidification (a) Increased concentrations of carbon dioxide in sea water causing a measurable increase in acidity (i.e., a reduction in ocean pH). This may lead to reduced calcification rates of calcifying organisms such as corals, mollusks, algae and crustaceans. (b) The process by which ocean waters have become more acidic due to the absorption of human-produced carbon dioxide, which interacts with ocean water to form carbonic acid and lower the ocean's pH. Acidity reduces the capacity of key plankton species and shelled animals to form and maintain shells.

Ozone Ozone is the triatomic form of oxygen (O_3). It is a gaseous atmospheric constituent. In the troposphere, it is created by photochemical reactions involving gases resulting both from natural sources and from human activities (photochemical smog). In high concentrations, tropospheric ozone can be harmful to a wide range of living organisms. Ozone is a bluish gas that is harmful to breathe. Tropospheric ozone acts as a greenhouse gas. Nearly 90% of the Earth's ozone is in the stratosphere and is referred to as the ozone layer. In the stratosphere, ozone is created by the interaction between solar ultraviolet radiation and molecular oxygen (O_2). Stratospheric ozone plays a decisive role in the stratospheric radiative balance. Since ozone absorbs a band of ultraviolet radiation called UVB that is particularly harmful to living organisms, the ozone layer prevents most UVB from reaching the ground. Depletion of stratospheric ozone, due to chemical reactions that may be enhanced by climate change, results in an increased ground-level flux of ultraviolet (UV-) B radiation.

Ozone "Hole" A large area of the stratosphere with extremely low amounts of ozone.

Ozone depleting substance (ODS) A family of man-made compounds that includes, but are not limited to, chlorofluorocarbons (CFCs), bromofluorocarbons (halons), methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs). These compounds have been shown to deplete stratospheric ozone, and therefore are typically referred to as ODSs.

Ozone layer depletion Chemical destruction of ozone molecules in the ozone layer. Depletion of this ozone layer by ozone-depleting substances will lead to higher UVB levels (a band of ultraviolet radiation), which in turn will cause increased skin cancers and cataracts and potential damage to some marine organisms, plants, and plastics.

Particulate matter (PM) Very small pieces of solid or liquid matter such as particles of soot, dust, fumes, mists or aerosols. The physical characteristics of particles, and how they combine with other particles, are part of the feedback mechanisms of the atmosphere.

Photosynthesis The process by which plants take CO_2 from the air (or bicarbonate in water) to build carbohydrates, releasing O_2 in the process. There are several pathways of photosynthesis with different responses to atmospheric CO_2 concentrations.

Phytoplankton Microscopic plants that live in salt and fresh water environments.

Precession The wobble over thousands of years of the tilt of the Earths axis with respect to the plane of the solar system.

Precipitation Rain, hail, mist, sleet, snow or any other moisture that falls to the Earth.

Radiation Energy transfer in the form of electromagnetic waves or particles that release energy when absorbed by an object.

Radiative forcing **(a)** A change in the balance between incoming solar radiation and outgoing infrared radiation. (b) A measure of the influence of a particular factor (e.g. greenhouse gas (GHG), aerosol, or land use change) on the net change in the Earths energy balance.

Salmon It is the common name for several species of ray-finned fish in the family Salmonidae. Salmon are native to tributaries of the North Atlantic and Pacific Ocean. Many species of salmon have been introduced into non-native environments such as the Great Lakes of North America and Patagonia in South America. Salmon are intensively farmed in many parts of the world. Typically, salmon are anadromous: they hatch in fresh water, migrate to the ocean, then return to fresh water to reproduce. However, populations of several species are restricted to fresh water through their lives. Folklore has it that the fish return to the exact spot where they hatched to spawn. Tracking studies have shown this to be mostly true. A portion of a returning salmon run may stray and spawn in different freshwater systems; the percent of straying depends on the species of salmon. Homing behavior has been shown to depend on olfactory memory.

Soil Complex mixture of inorganic minerals (i.e., mostly clay, silt, and sand), decaying organic matter, water, air and living organisms.

Soil carbon A major component of the terrestrial biosphere pool in the carbon cycle. The amount of carbon in the soil is a function of the historical vegetative cover and productivity, which in turn is dependent in part upon climatic variables. The amount of carbon in the soil is a function of the historical vegetative cover and productivity which in turn is dependent in part upon climatic variables..

Solar energy Also called solar radiation. Energy from the Sun. Also referred to as short-wave radiation. Of importance to the climate system, solar radiation includes ultraviolet radiation, visible radiation, and infrared radiation. It also includes indirect forms of energy such as wind falling or flowing water's hydropower, ocean thermal gradients, and biomass, which are produced when direct solar energy interact with the earth

Solar radiation Radiation emitted by the Sun. It is also referred to as short-wave radiation. Solar radiation has a distinctive range of wavelengths (spectrum) determined by the temperature of the Sun. Of importance to the climate system, solar radiation includes ultraviolet radiation, visible radiation, and infrared radiation.

Source Any process or activity that releases a greenhouse gas, an aerosol, or a precursor of greenhouse gas into the atmosphere.

Stratosphere The region of the atmosphere above the troposphere, and between the troposphere and mesosphere. The stratosphere extends from about 8-50 km (6-31 miles) in altitude. Specifically it has a lower boundary of approximately 8 km at the poles to 15 km at the equator and an upper boundary of approximately 50 km. Depending upon latitude and season, the temperature in the lower stratosphere can increase, be isothermal, or even decrease with altitude, but the temperature in the upper stratosphere generally increases with height due to absorption of solar radiation by ozone. So the stratosphere gets warmer at higher altitudes. In fact, this warming is caused by ozone absorbing ultraviolet radiation. Warm air remains in the upper stratosphere, and cool air remains lower, so there is much less vertical mixing in this region than in the troposphere. Commercial airlines fly in the lower stratosphere.

Terrestrial radiation The total infrared radiation emitted by the Earth and its atmosphere in the temperature range of approximately 200 to 300 Kelvin. Terrestrial radiation provides a major part of the potential energy changes necessary to drive the atmospheric wind system and is responsible for maintaining the surface air temperature within limits of livability.

Troposphere **(a)** The region of the atmosphere closest to the Earth. The troposphere extends from the surface up to about 10 km (6 miles) in altitude, although this height varies with latitude. Almost all weather takes place in the troposphere. Mt. Everest, the highest mountain on Earth, is only 8.8 km (5.5 miles) high. Temperatures decrease with altitude in the troposphere. As warm air rises, it cools, falling back to Earth. This process, known as convection, means there are huge air movements that mix the troposphere very efficiently. (b) The lowest part of the atmosphere from the surface to about 10 km in altitude in mid-latitudes (ranging from 9 km in high latitudes to 16 km in the tropics on average) where clouds and "weather" phenomena occur. In the troposphere temperatures generally decrease with height. All weather processes take place in the troposphere. Ozone that is formed in the troposphere plays a significant role in both the greenhouse gas effect and urban smog. The troposphere contains about 95 percent of the mass of air in the Earth’s atmosphere.

Weather Weather is the specific condition of the atmosphere at a particular place and time. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Climate in a narrow sense is usually defined as the "average weather", or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. A simple way of remembering the difference is that climate is what you expect (e.g. cold winters) and 'weather' is what you get (e.g. a blizzard).

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LIST OF TABLE

Six Greenhouse Gases listed designated by the Kyoto Protocol	Lifetime (years)	Global Warming Potential for the Given Time Horizon		
		20-year	100-year	500-year
Carbon Dioxide, CO_2	~150	1	1	1
Methane, CH_4	12	72	25	7.6
Nitrous Oxide, N_2O	114	289	298	153
HFC-23	270	12,000	14,800	12,200
PFC-116	10,000	8,630	12,200	18,200
Sulphur Hexafluoride, SF_6	3,200	5,210	7,390	11,200

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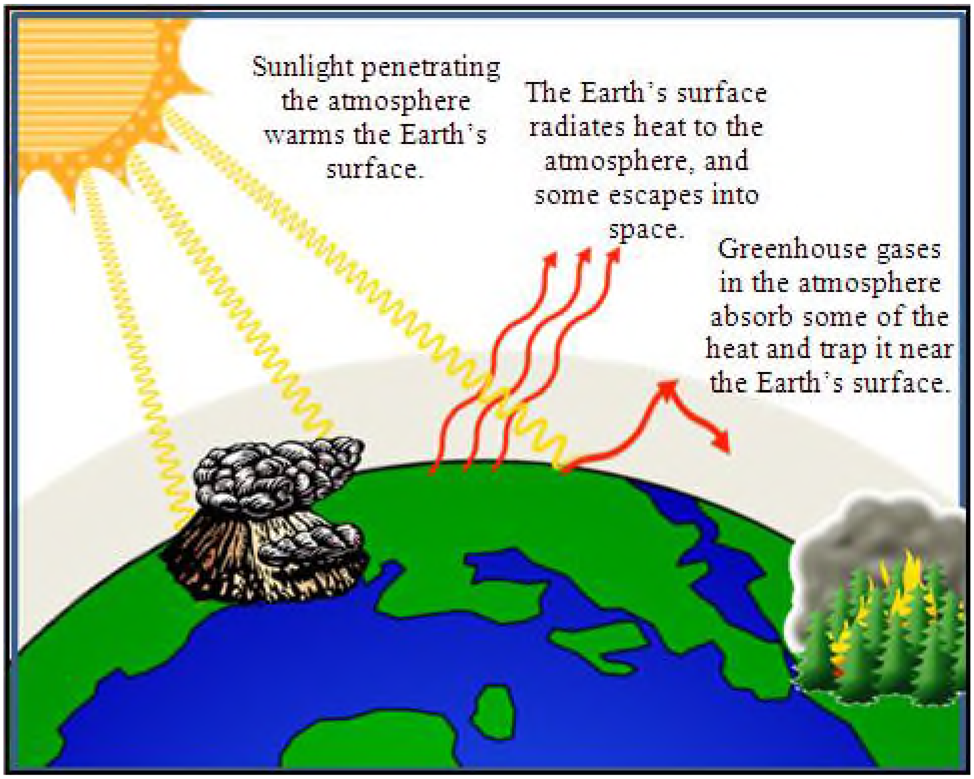

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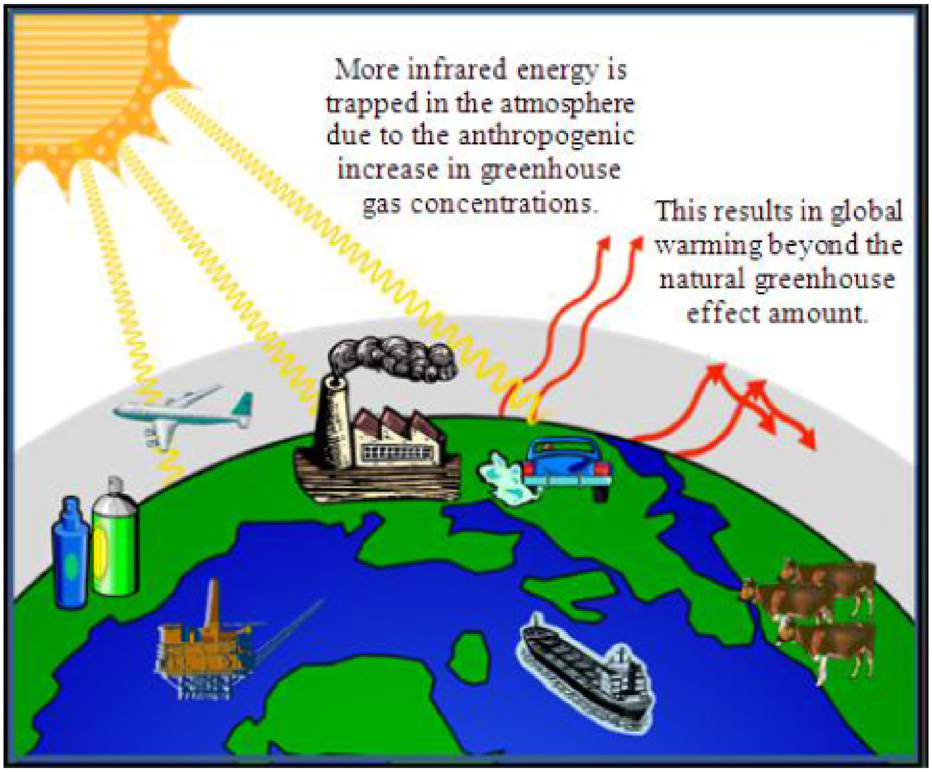
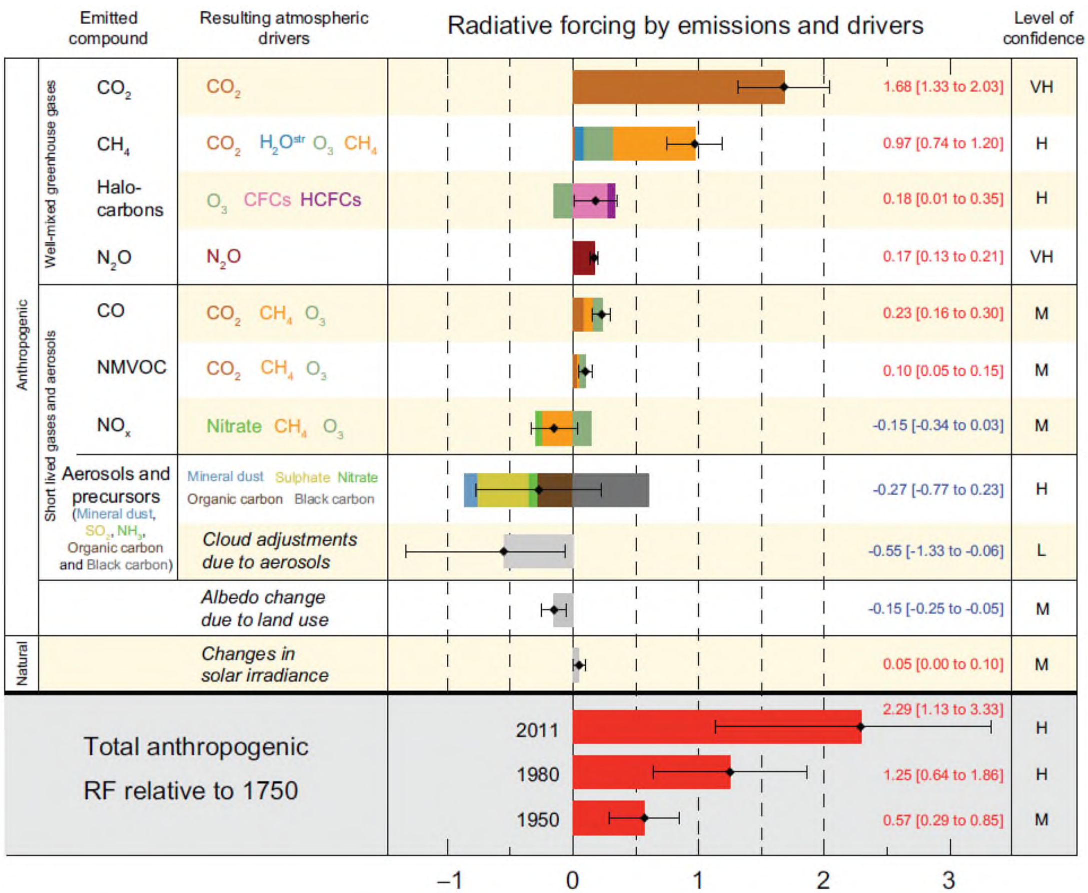


Figure 6. The Greenhouse Effect After Human Activity (2, Permission to use)



Radiative Forcing relative to 1750 W m^{-2} (4)

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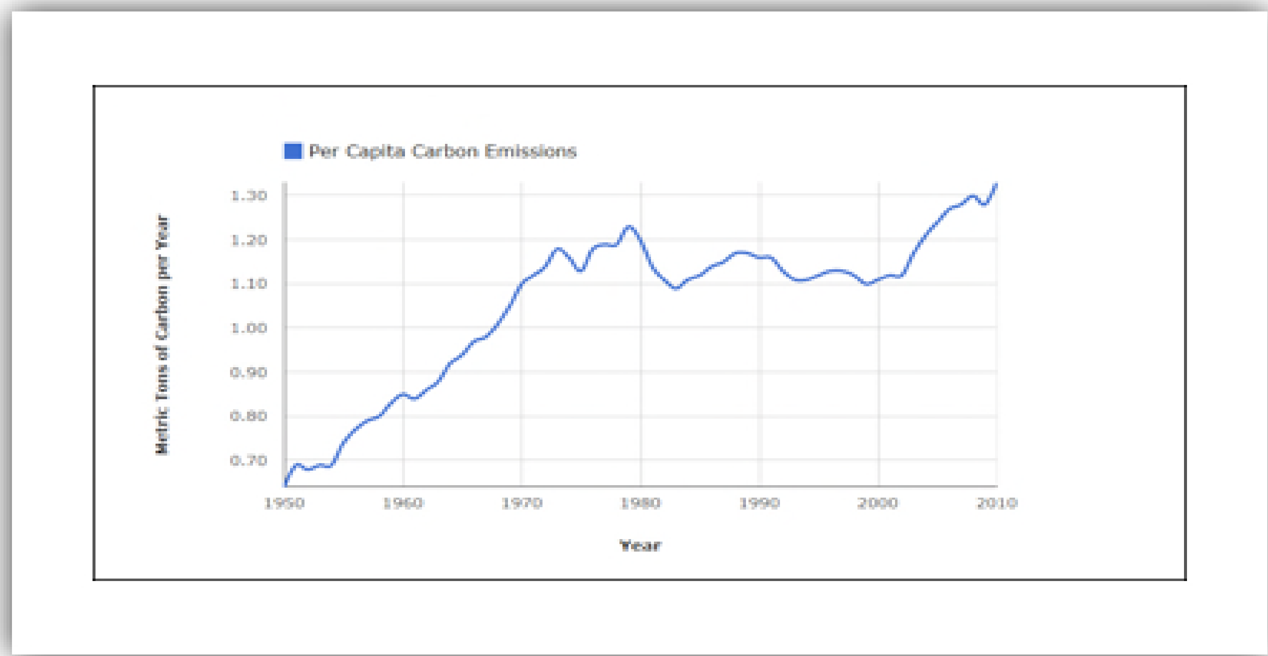

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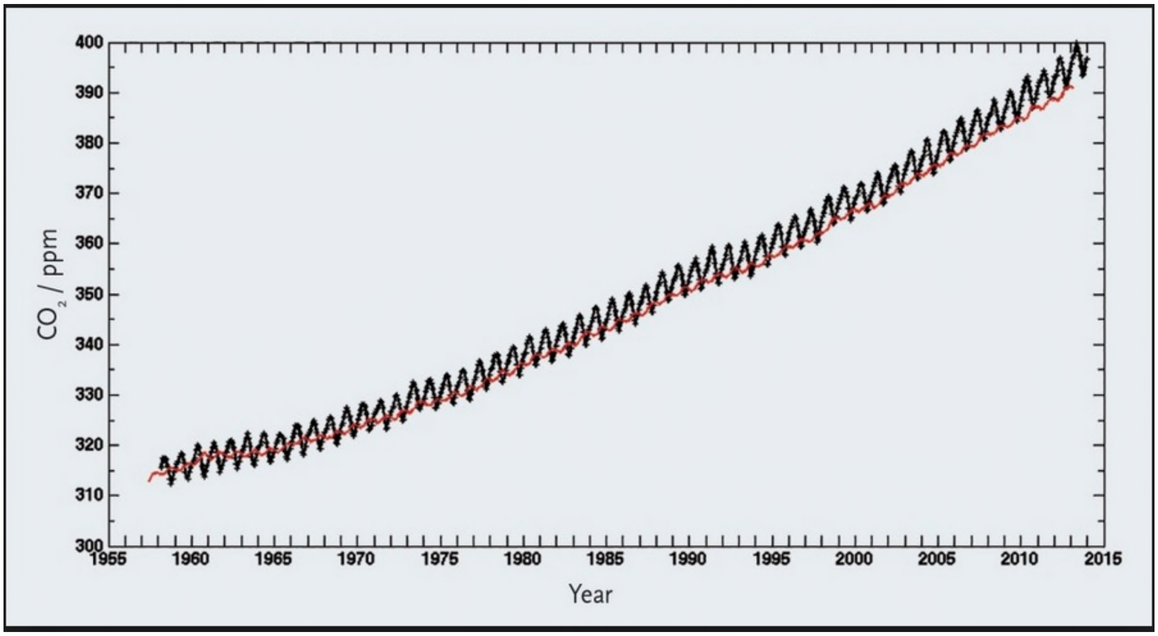

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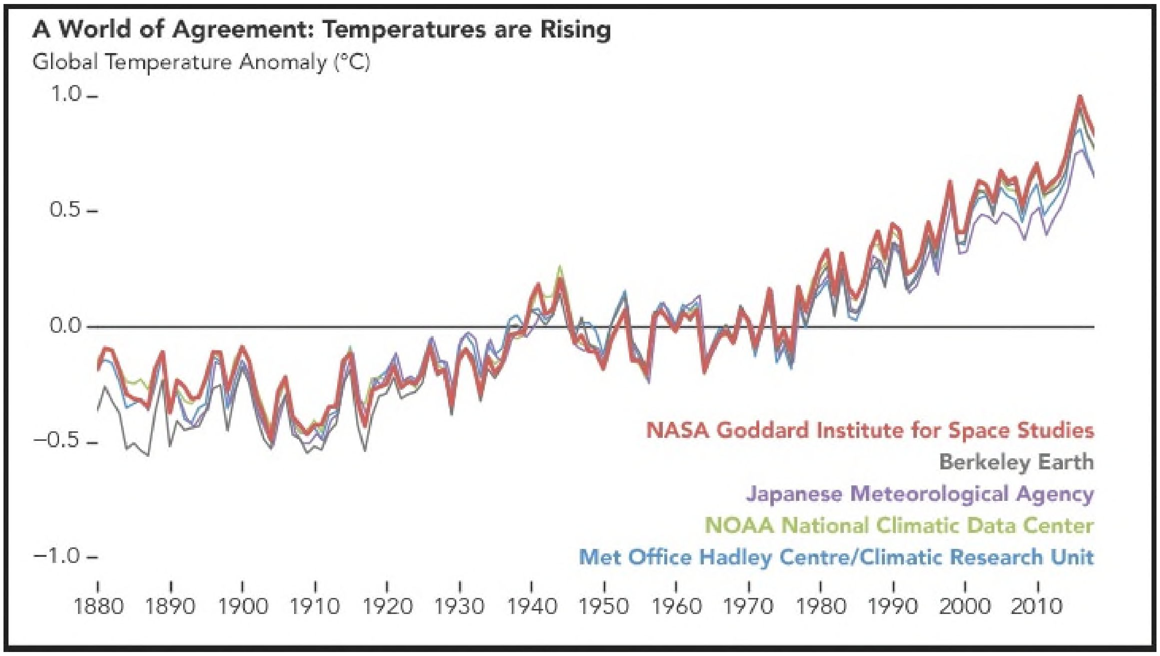

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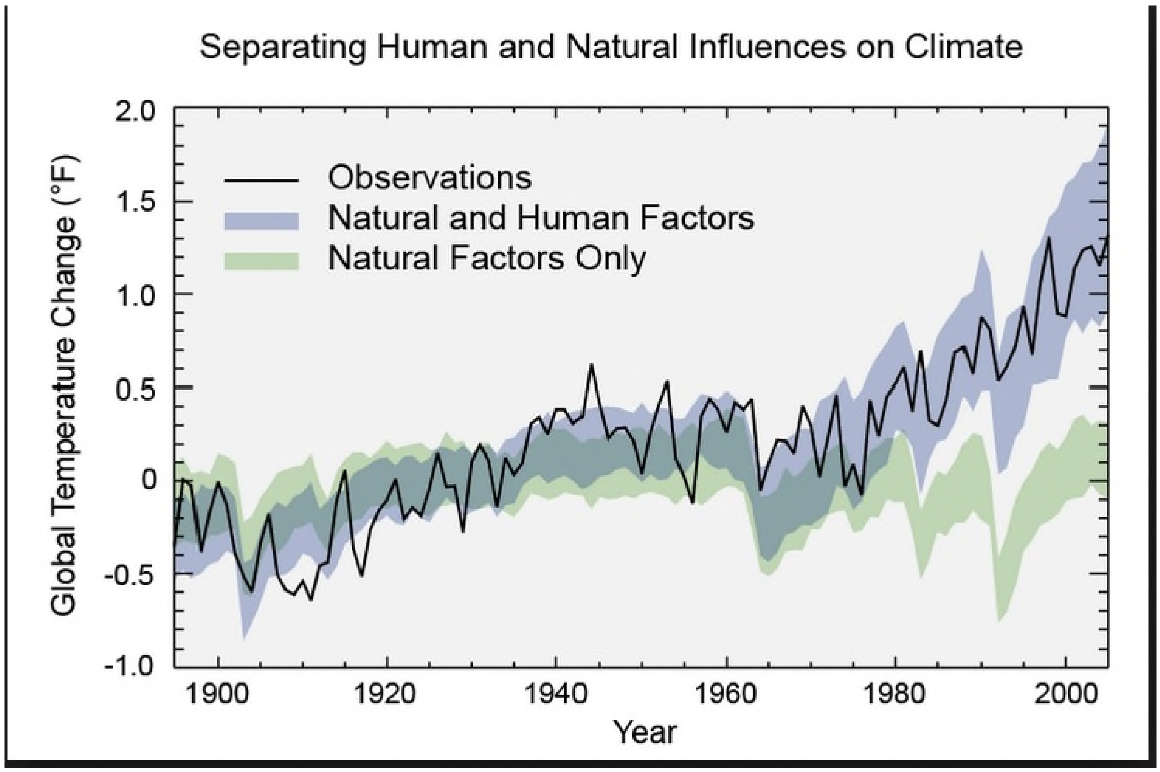

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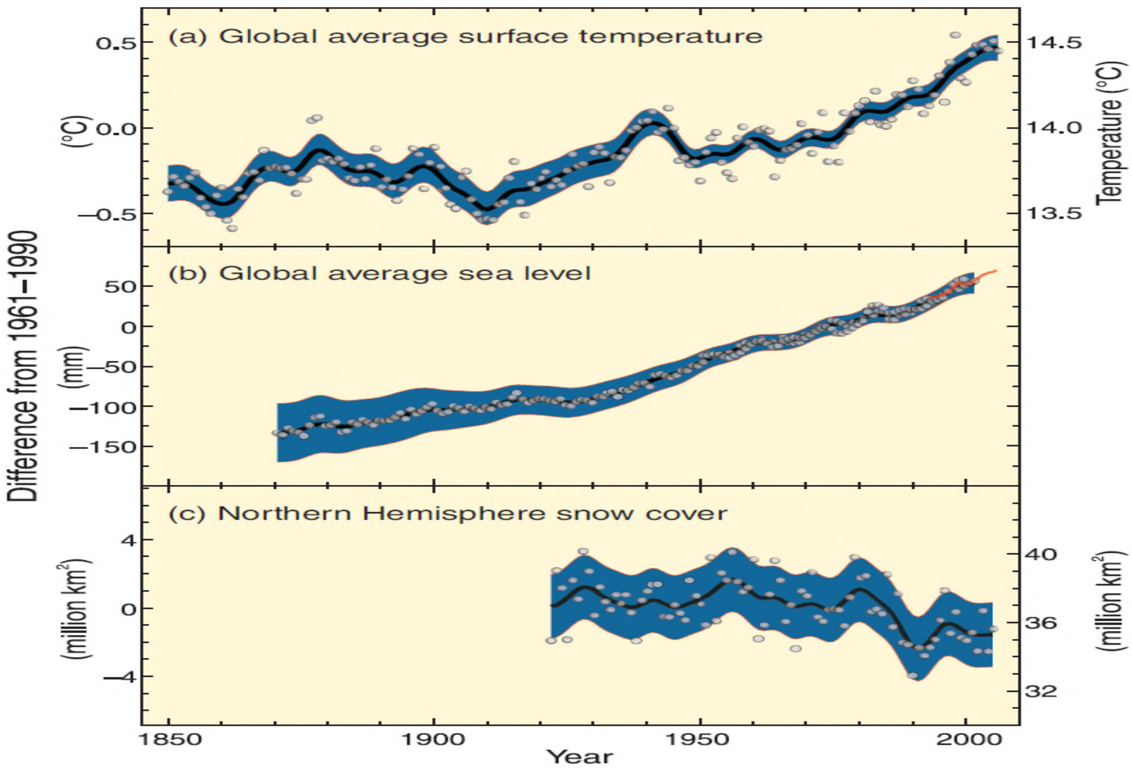

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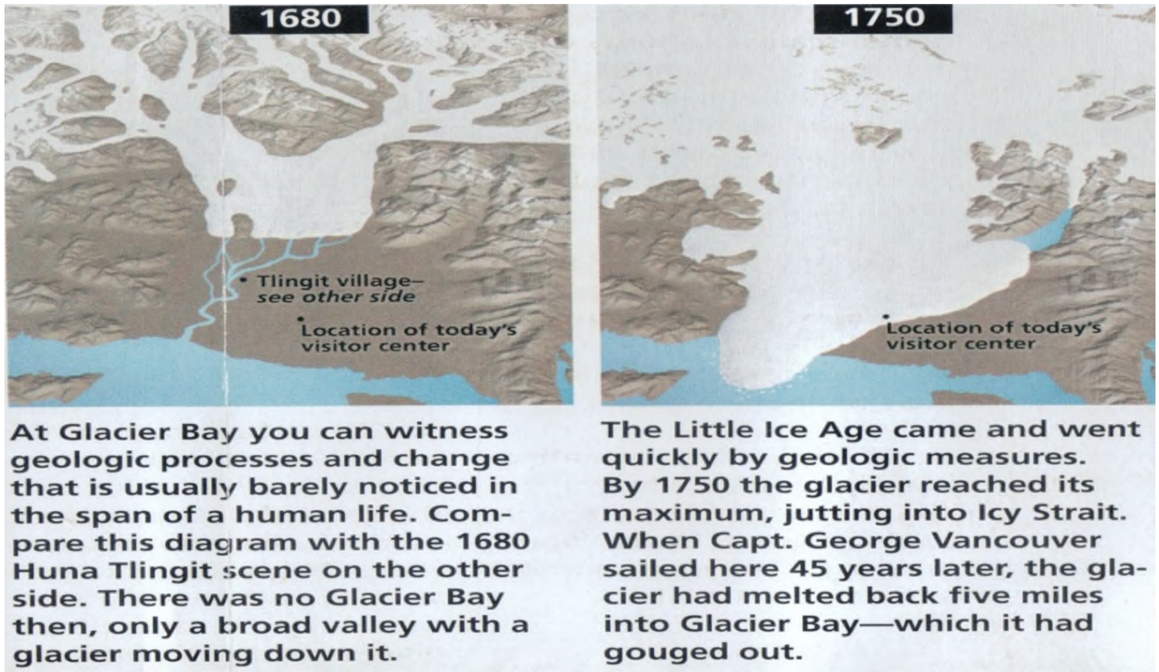

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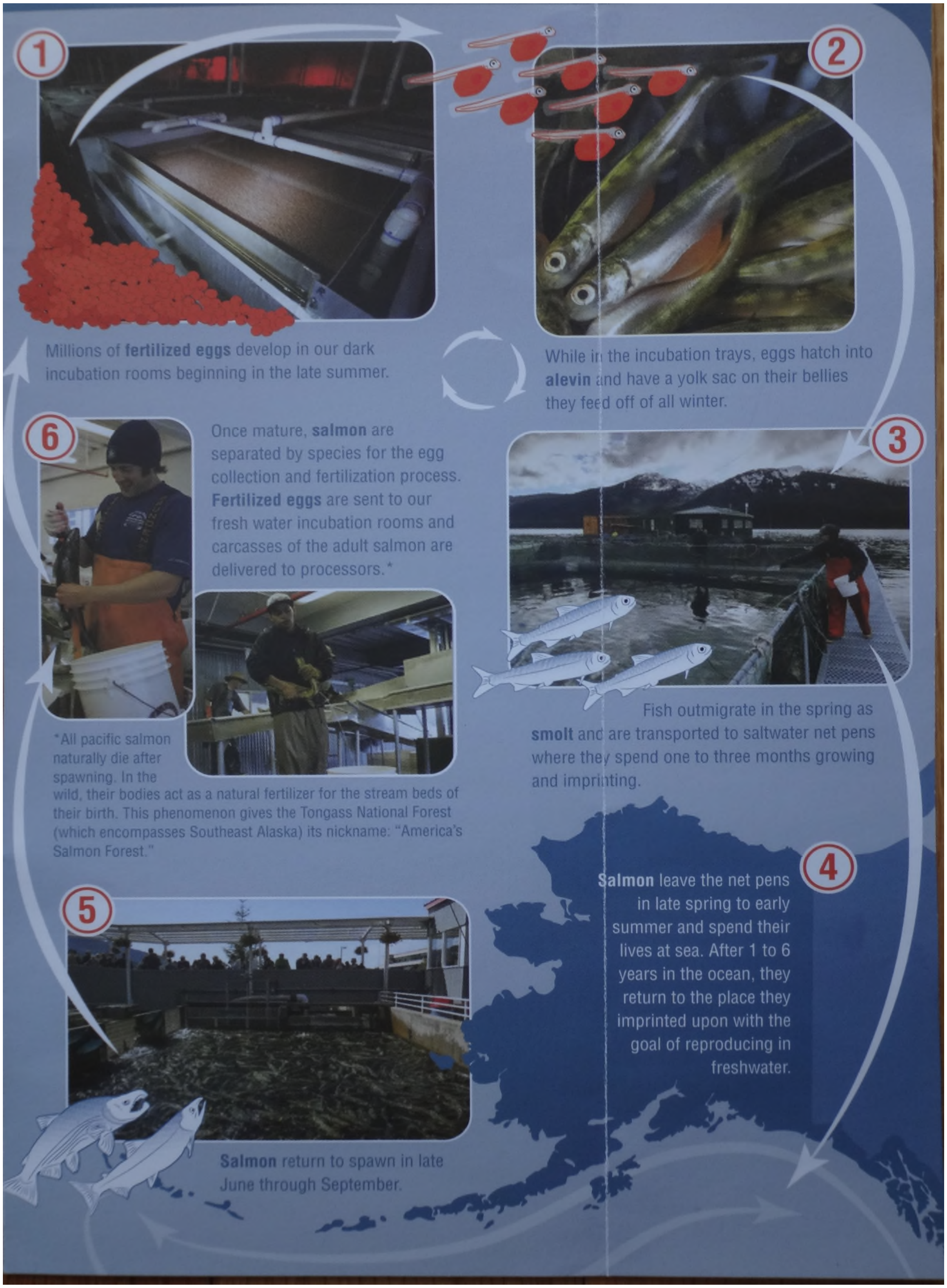

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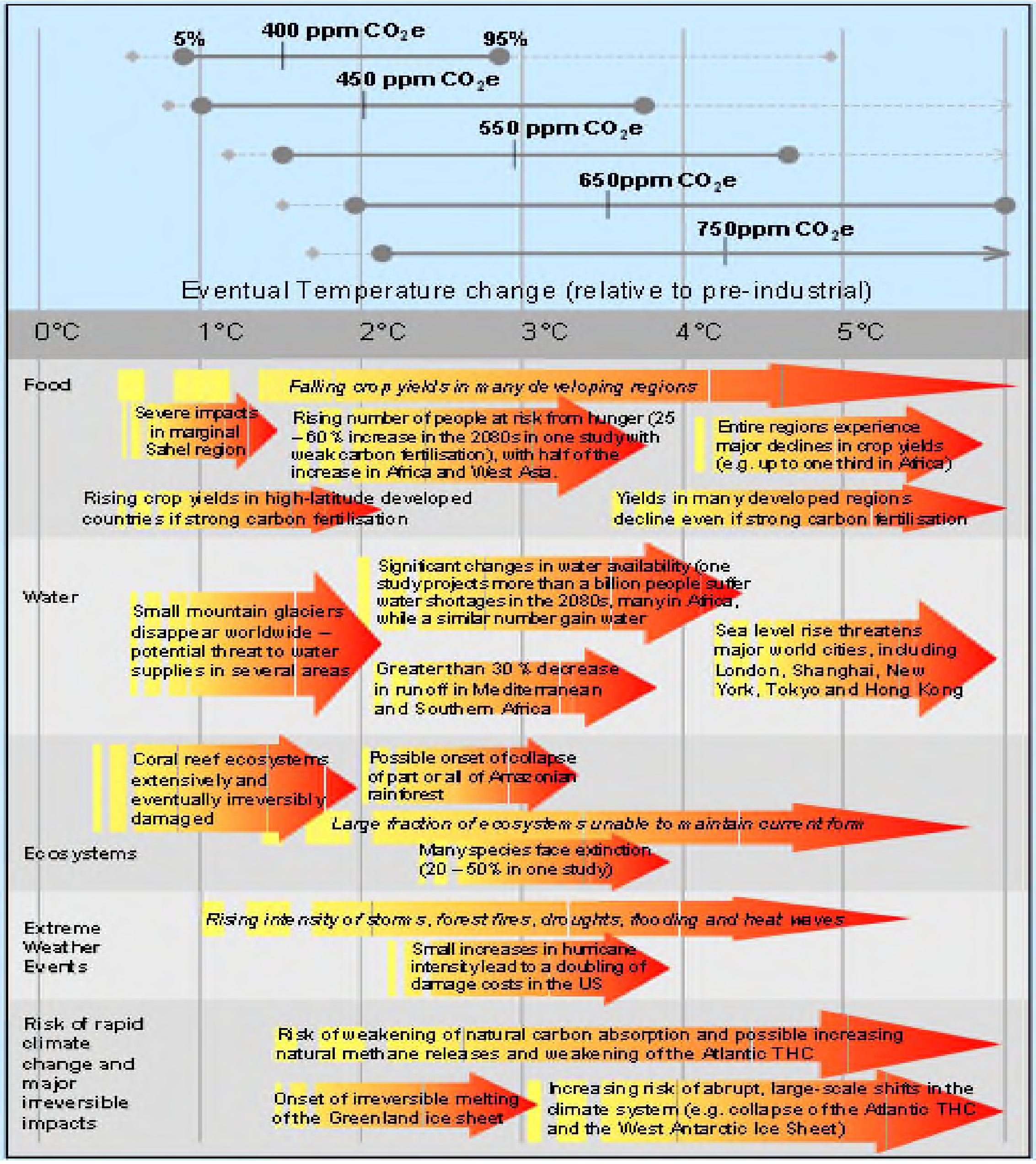

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EDITORS PAGE

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1. Dr. Lawrence K. Wang (王抗曝)

Lawrence K. Wang has over 30+ years of professional experience in facility design, environmental sustainability, natural resources, STEAM education, global pollution control, construction, plant operation, and management. He has expertise in water supply, air pollution control, solid waste disposal, drinking water treatment, waste treatment, and hazardous waste management. He was the Director/Acting President of the Lenox Institute of Water Technology, Engineering Director of Krofta Engineering Corporation and Zorex Corporation, and a Professor of RPI/SIT/UIUC, in the USA. He was also a Senior Advisor of the United Nations Industrial and Development Organization (UNIDO) in Austria. Dr. Wang is the author of over 700 technical papers and 45+ books, and is credited with 24 US patents and 5 foreign patents. He earned his two HS diplomas from the High School of National Taiwan Normal University, and the State University of New York. He also earned his BS degree from National Cheng-Kung University, Taiwan, ROC, his two MS degrees from the University of Missouri and the University of Rhode Island, USA, and his PhD degree from Rutgers University, USA. Currently he is the Chief Series Editor of the Handbook of Environmental Engineering series (Springer); Chief Series Editor of the Advances in Industrial and Hazardous Wastes Treatment series, (CRC Press, Taylor & Francis); co-author of the Water and Wastewater Engineering series (John Wiley & Sons); and Co-Series Editor of the Handbook of Environment and Waste Management series (World Scientific). Dr. Wang is active in professional activities of AWWA, WEF, NEWWA, NEWEA, AIChE, ACS, OCEESA, etc.

2. Dr. Hung-ping Tsao (曹恆平)

Hung-ping Tsao has been a mathematician, a university professor, and an assistant actuary, serving private firms and universities in the United States and Taiwan for 30+ years. He used to be an Associate Member of the Society of Actuaries and a Member of the American Mathematical Society. His research have been in the areas of college mathematics, actuarial mathematics, management mathematics, classic number theory and Sudoku puzzle solving. In particular, bikini and open top problems are presented to share some intuitive insights and some type of optimization problems can be solved more efficiently and categorically by using the idea of the boundary being the marginal change of a well-rounded region with respect to its inradius; theory of interest, life contingency functions and pension funding are presented in more simplified and generalized fashions; the new way of the simplex method using cross-multiplication substantially simplified the process of finding the solutions of optimization problems; the generalization of triangular arrays of numbers from the natural sequence based to arithmetically progressive sequences based opens up the dimension of explorations; the introduction of step-by-step attempts to solve Sudoku puzzles makes everybody's life so much easier and other STEAM project development. Dr. Tsao is the author of 3 books and over 30 academic publications. He earned his high school diploma from the High School of National Taiwan Normal University, his BS and MS degrees from National Taiwan Normal University, Taipei, Taiwan, his second MS degree from the UWM in USA, and a PhD degree from the University of Illinois , USA.

Editors of the eBOOK Series of the *"EVOLUTIONARY PROGRESS IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"*

Dr. Lawrence K. Wang (王抗曝) -- left

Dr. Hung-ping Tsao (曹恆平) -- right

E-BOOK SERIES AND CHAPTER INTRODUCTON

Introduction to the eBOOK Series of the *"EVOLUTIONARY PROGRESS IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"* and This Chapter *"HUMANITARIAN ENGINEERING EDUCATION OF THE LENOX INSTITUTE OF WATER TECHNOLOGY AND ITS NEW NEW POTABLE WATER FLOTATION PROCESSES"*

The acronym STEM stands for "science, technology, engineering and mathematics" . In accordance with the National Science Teachers Association (NSTA), "A common definition of STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy".

The problem of this country has been pointed out by the US Department of Education that "All young people should be prepared to think deeply and to think well so that they have the chance to become the innovators, educators, researchers, and leaders who can solve the most pressing challenges facing our nation and our world, both today and tomorrow. But, right now, not enough of our youth have access to quality STEM learning opportunities and too few students see these disciplines as springboards for their careers." STEM learning and applications are very popular topics at present, and STEM related careers are in great demand. According to the US Department of Education reports that the number of STEM jobs in the United States will grow by 14% from 2010 to 2020, which is much faster than the national average of 5-8 % across all job sectors. Computer programming and IT jobs top the list of the hardest to fill jobs. Despite this, the most popular college majors are business, law, etc., not STEM related. For this reason, the US government has just extended a provision allowing foreign students that are earning degrees in STEM fields a seven month visa extension, now allowing them to stay for up to three years of “on the job training”. So, at present STEM is a legal term.

The expanded acronym STEAM now stands for “science, technology, engineering, arts and mathematics”. As one can see, STEAM (adds “arts”) is simply a variation of STEM. The word of “arts” means application, creation, ingenuity, and integration, for enhancing STEM inside, or exploring of STEM outside. It may also mean that the word of “arts” connects all of the humanities through an idea that a person is looking for a solution to a very specific problem which comes out of the original inquiry process. STEAM is an academic term in the field of education. The University of San Diego and Concordia University offer a college degree with a STEAM focus. Basically STEAM is a framework for teaching or R&D, which is customizable and functional, thence the “fun” in functional. As a typical example, if STEM represents a normal cell phone communication tower looking like a steel truss or concrete column, STEAM will be an artificial green tree with all devices hided, but still with all cell phone communication functions. This ebook series presents the recent evolutionary progress in STEAM with many innovative chapters contributed by academic and professional experts.

This ebook chapter, *"Scientific Studies of Global Warming, Climate Change, Glacier Melting and Salmon Protection"*, is written by a group of scientists, Josephine O. Wong, Ni-Yi Wang, Lawrence K. Wang and Mu-Hao Sung Wang. The importance and controversy of global warming, climate change, glacier, salmon, etc. are without saying. The authors present the scientific studies and their findings for the readers to judge. This chapter covers the wide fields of meteorology, chemistry, ecology, biology, geology, engineering, technology, mathematics, and arts, and is a typical STEAM project.