GLOBAL CLIMATIC CHANGES

Due to what reasons?

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The Climate system

- *The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things.*

- *The atmospheric component of the climate system most obviously characterizes climate; climate is often defined as 'average weather'.*

- *Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years).*

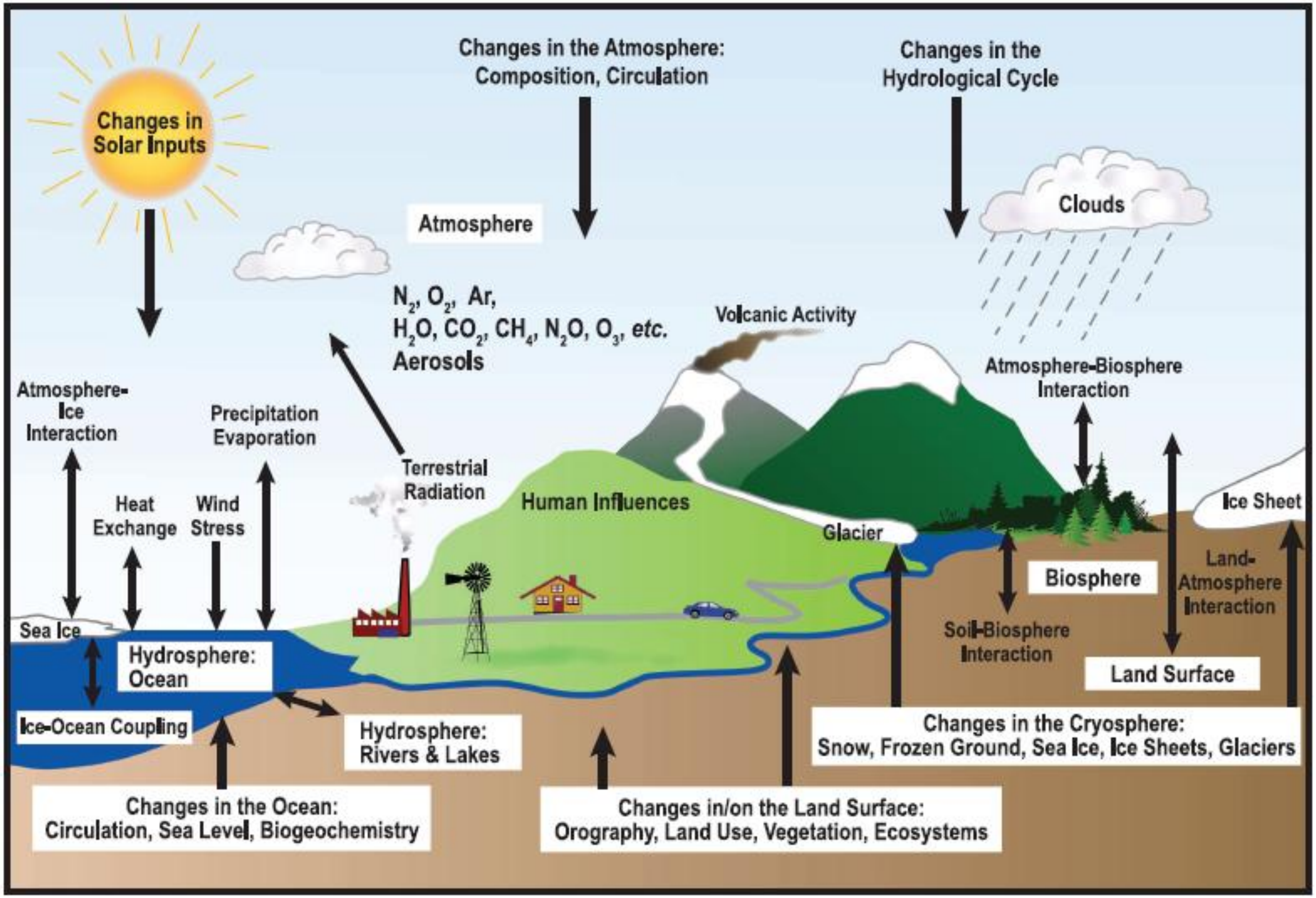
- *The climate system evolves in time under the influence of its own internal dynamics and due to changes in external factors that affect climate (called 'forcings')*

Components of climate system

- *It can be useful to think of climate as dealing with the background conditions for weather. More precisely, climate can be viewed as concerning the status of the entire Earth system, including the atmosphere, land, oceans, snow, ice and living things (see Figure 1) that serve as the global background conditions that determine weather patterns.*

- *While many factors continue to influence climate, scientists have determined that human activities have become a dominant force, and are responsible for most of the warming observed over the past 50 years.*

- *Human-caused climate change has resulted primarily from changes in the amounts of greenhouse gases in the atmosphere, but also from changes in small particles (aerosols), as well as from changes in land use, for example.*



Schematic view of the components of the climate system, their processes and interactions.

Climate Forcings

- *External forcings include natural phenomena such as volcanic eruptions and solar variations, as well as human-induced changes in atmospheric composition. Solar radiation powers the climate system.*

- *There are three fundamental ways to change the radiation balance of the Earth:*

1) by changing the incoming solar radiation (e.g., by changes in Earth's orbit or in the Sun itself);

2) by changing the fraction of solar radiation that is reflected (called 'albedo'; e.g., by changes in cloud cover, atmospheric particles or vegetation); and

3) by altering the long wave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations).

- *Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms.*

Climate forcings contd…

- *The amount of energy reaching the top of Earth's atmosphere each second on a surface area of one square metre facing the Sun during daytime is about 1,370 Watts, and the amount of energy per square metre per second averaged over the entire planet is one-quarter of this*

- *About 30% of the sunlight that reaches the top of the atmosphere is reflected back to space.*

- *Roughly two-thirds of this reflectivity is due to clouds and small particles in the atmosphere known as 'aerosols'.*

- *Light-coloured areas of Earth's surface mainly snow, ice and deserts reflect the remaining one-third of the sunlight.*

- *The most dramatic change in aerosol-produced reflectivity comes when major volcanic eruptions eject material very high into the atmosphere.*

Climate forcing

- *A climate forcing is a perturbation of the Earth's energy balance that tends to alter the Earth's temperature.*

- *For example, if the brightness of the sun increases 2% that is a positive forcing of about 4.5 W/m^2 (watts per square meter), because it results in an increase of that amount in the energy absorbed by the Earth.*

- *Such a forcing would upset the normal balance that exists between the amount of solar energy absorbed by the Earth and the amount of heat radiation emitted to space by the Earth.*

- *So the Earth responds to this forcing by warming up until its thermal radiation to space equals the energy absorbed from the sun.*

Climate forcing contd..

- *Doubling the amount of carbon dioxide (CO^2) in the atmosphere causes a global climate forcing similar in magnitude to that for a 2% increase of solar irradiance.*

- *The CO^2 forcing works by making the atmosphere more opaque to infrared radiation, the wavelengths of the Earth's heat radiation. As a result of this increased opacity the heat radiation to space arises from greater heights in the atmosphere.*

- *Because the temperature falls off with height in the lower atmosphere, energy radiated to space with doubled CO^2 is reduced by an amount that is readily calculated from radiation physics to be approximately 4 W/m^2.*

- *So the planet's energy imbalance is about the same as for a 2% increase of solar irradiance. In either case, the Earth responds by warming up enough to restore energy balance.*

Energy balance

- *The energy that is not reflected back to space is absorbed by the Earth's surface and atmosphere. This amount is approximately 240 Watts per square metre (W/m^2).*

- *To balance the incoming energy, the Earth itself must radiate, on average, the same amount of energy back to space. The Earth does this by emitting outgoing long wave radiation. Everything on Earth emits longwave radiation continuously.*

- *That is the heat energy one feels radiating out from a fire; the warmer an object, the more heat energy it radiates.*

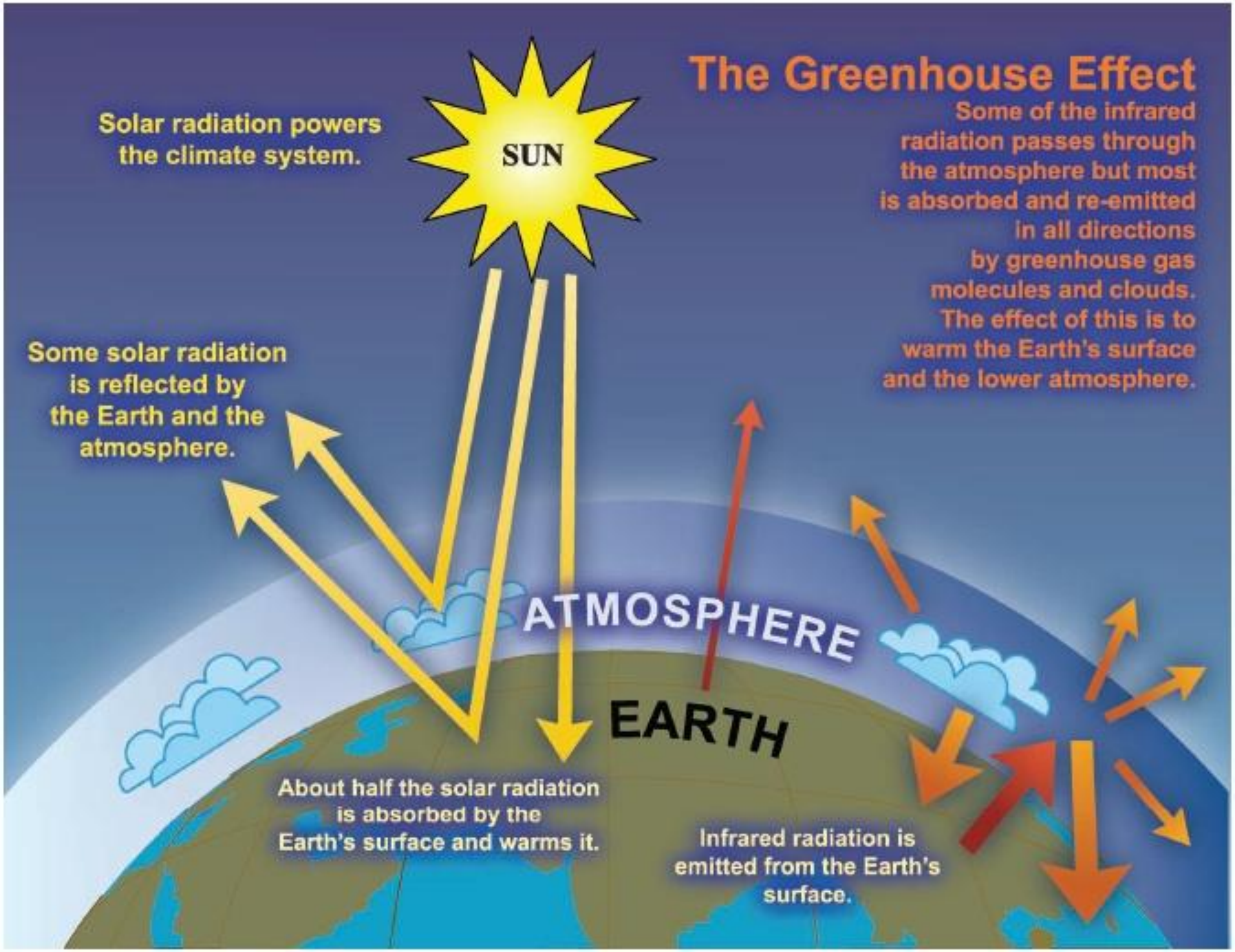
- *To emit 240 W/m^2 , a surface would have to have a temperature of around –19°C. This is much colder than the conditions that actually exist at the Earth's surface (the global mean surface temperature is about 14°C).*

- *Instead, the necessary –19°C is found at an altitude about 5 km above the surface.*

What is the Greenhouse Effect?

- *The Sun powers Earth's climate, radiating energy at very short wavelengths, predominately in the visible or near-visible (e.g., ultraviolet) part of the spectrum.*
- *Roughly one-third of the solar energy that reaches the top of Earth's atmosphere is reflected directly back to space. The remaining two-thirds is absorbed by the surface and, to a lesser extent, by the atmosphere.*
- *To balance the absorbed incoming energy, the Earth must, on average, radiate the same amount of energy back to space.*
- *Because the Earth is much colder than the Sun, it radiates at much longer wavelengths, primarily in the infrared part of the spectrum (see Figure 1). Much of this thermal radiation emitted by the land and ocean is absorbed by the atmosphere, including clouds, and reradiated back to Earth.*

  This is called the greenhouse effect.


The Greenhouse Effect
SUN
Solar radiation powers the climate system.
Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.
Some solar radiation is reflected by the Earth and the atmosphere.
ATMOSPHERE
EARTH
About half the solar radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

Greenhouse Effect contd..

- *The glass walls in a greenhouse reduce airflow and increase the temperature of the air inside. Analogously, but through a different physical process, the Earth's greenhouse effect warms the surface of the planet.*

- *Without the natural greenhouse effect, the average temperature at Earth's surface would be below the freezing point of water. Thus, Earth's natural greenhouse effect makes life as we know it possible.*

- *However, human activities, primarily the burning of fossil fuels and clearing of forests, have greatly intensified the natural greenhouse effect, causing global warming.*

- *The two most abundant gases in the atmosphere, nitrogen (comprising 78% of the dry atmosphere) and oxygen (comprising 21%), exert almost no greenhouse effect.*

Green house gases

– *The reason the Earth's surface is this warm is the presence of greenhouse gases, which act as a partial blanket for the long wave radiation coming from the surface.*

– *This blanketing is known as the natural greenhouse effect. The most important greenhouse gases are water vapour and carbon dioxide.*

Green house gases contd..

- *Human activities intensify the blanketing effect through the release of greenhouse gases.*

- *For instance, the amount of carbon dioxide in the atmosphere has increased by about 35% in the industrial era, and this increase is known to be due to human activities, primarily the combustion of fossil fuels and removal of forests.*

- *Thus, humankind has dramatically altered the chemical composition of the global atmosphere with substantial implications for climate.*

Feedback mechanisms in climate change

- *Since pre-industrial times, the atmospheric concentration of carbon dioxide has increased by 31 % Over the same period, atmospheric methane has risen by 151 %, mostly from agricultural activities like growing rice and raising cattle.*

- *As the concentration of these gases grows, more heat is trapped by the atmosphere and less escapes back into space. This increase in trapped heat changes the climate, causing altered weather patterns that can bring unusually intense precipitation or dry spells and more severe storms.*

Examples of observed climatic changes

- *Increase in global average surface temperature of about 1°F in the 20th century*
- *Decrease of snow cover and sea ice extent and the retreat of mountain glaciers in the latter half of the 20th century*
- *Rise in global average sea level and the increase in ocean water temperatures*
- *Likely increase in average precipitation over the middle and high latitudes of the Northern Hemisphere, and over tropical land areas*
- *Increase in the frequency of extreme precipitation events in some regions of the world*

How much warmer is the Earth likely to become?

Earth's average surface temperature will increase between (1.4°- 5.8°C) between 1990 and 2100 if no major efforts are undertaken to reduce the emissions of greenhouse gases (the "business-as-usual" scenario). This is significantly higher than that predicted in 1995 (1.0°- 3.5°C)

Scientists predict that even if we stopped emitting heat-trapping gases immediately, the climate would not stabilize for many decades because the gases we have already released into the atmosphere will stay there for years or even centuries.

So while the warming may be lower or increase at a slower rate than predicted if we reduce emissions significantly, global temperatures cannot quickly return to today's averages. And the faster and more the Earth warms, the greater the chances are for some irreversible climate changes.

Would a temperature rise of a couple degrees really change the global climate?

- *An increase of a few degrees won't simply make for pleasantly warmer temperatures around the globe. Even a modest rise of (1.1°-1.7°C) could have dramatic effects.*
- *In the last 10,000 years, the Earth's average temperature hasn't varied by more than (1.0°C).*
- *Temperatures only 5°- 9°F cooler than those today prevailed at the end of the last Ice Age, in which the Northeast United States was covered by more than 3,000 feet of ice.*

Drastic Consequences of Global warming

Scientists predict that continued global warming on the order of 2.5°-10.4°F over the next 100 years is likely to result in:

A rise in sea level between (9 - 88 cm), leading to more coastal erosion, flooding during storms, and permanent inundation

Severe stress on many forests, wetlands, alpine regions, and other natural ecosystems

Greater threats to human health as mosquitoes and other disease-carrying insects and rodents spread diseases over larger geographical regions

Disruption of agriculture in some parts of the world due to increased temperature, water stress, and sea-level rise in low-lying areas such as Bangladesh or the Mississippi River delta.

Greenhouse Effect contd..

- *The greenhouse effect comes from molecules that are more complex and much less common.*
- *Water vapour is the most important greenhouse gas, and carbon dioxide (CO2) is the second-most important one.*
- *Methane, nitrous oxide, ozone and several other gases present in the atmosphere in small amounts also contribute to the greenhouse effect.*
- *In the humid equatorial regions, where there is so much water vapour in the air that the greenhouse effect is very large, adding a small additional amount of CO2 or water vapour has only a small direct impact on downward infrared radiation.*

Greenhouse Effect contd..

- *However, in the cold, dry polar regions, the effect of a small increase in CO_2 or water vapour is much greater. The same is true for the cold, dry upper atmosphere where a small increase in water vapour has a greater influence on the greenhouse effect than the same change in water vapour would have near the surface.*

- *Several components of the climate system, notably the oceans and living things, affect atmospheric concentrations of greenhouse gases.*

- *A prime example of this is plants taking CO_2 out of the atmosphere and converting it (and water) into carbohydrates via photosynthesis. In the industrial era, human activities have added greenhouse gases to the atmosphere, primarily through the burning of fossil fuels and clearing of forests.*

Greenhouse Effect contd..

- *Adding more of a greenhouse gas, such as CO_2, to the atmosphere intensifies the greenhouse effect, thus warming Earth's climate. The amount of warming depends on various feedback mechanisms.*

- *For example, as the atmosphere warms due to rising levels of greenhouse gases, its concentration of water vapour increases, further intensifying the greenhouse effect. This in turn causes more warming, which causes an additional increase in water vapour, in a self-reinforcing cycle. This water vapour feedback may be strong enough to approximately double the increase in the greenhouse effect due to the added CO_2 alone.*

- *Additional important feedback mechanisms involve clouds. Clouds are effective at absorbing infrared radiation and therefore exert a large greenhouse effect, thus warming the Earth. Clouds are also effective at reflecting away incoming solar radiation, thus cooling the Earth.*

How do Human Activities Contribute to Climate Change and How do They Compare with Natural Influences?

Greenhouse Gases

- *Human activities result in emissions of four principal greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the halocarbons (a group of gases containing fluorine, chlorine and bromine).*

- *These gases accumulate in the atmosphere, causing concentrations to increase with time. Significant increases in all of these gases have occurred in the industrial era. All of these increases are attributable to human activities.*

- *Carbon dioxide has increased from fossil fuel use in transportation, building heating and cooling and the manufacture of cement and other goods. Deforestation releases CO_2 and reduces its uptake by plants. Carbon dioxide is also released in natural processes such as the decay of plant matter.*

Human Contributions for Climatic change

- *Methane has increased as a result of human activities related to agriculture, natural gas distribution and landfills. Methane is also released from natural processes that occur, for example, in wetlands. Methane concentrations are not currently increasing in the atmosphere because growth rates decreased over the last two decades.*

- *Nitrous oxide is also emitted by human activities such as fertilizer use and fossil fuel burning. Natural processes in soils and the oceans also release N2O.*

- *The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 319 ppb in 2005. The growth rate has been approximately constant since 1980. More than a third of all nitrous oxide emissions are anthropogenic and are primarily due to agriculture*

Human Contributions contd..

- *Carbon dioxide is the most important anthropogenic greenhouse gas (see Figure SPM-2). The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm3 in 2005.*

- *The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores.*

- *The annual carbon dioxide concentration growth-rate was larger during the last 10 years (1995 – 2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year) although there is year-to-year variability in growth rates.*

Human Contributions contd..

- *Halocarbon gas concentrations have increased primarily due to human activities. Natural processes are also a small source. Principal halocarbons include the chlorofluorocarbons (e.g., CFC-11 and CFC-12), which were used extensively as refrigeration agents and in other industrial processes before their presence in the atmosphere was found to cause stratospheric ozone depletion.*

- *Ozone is a greenhouse gas that is continually produced and destroyed in the atmosphere by chemical reactions. Halocarbons released by human activities destroy ozone in the stratosphere and have caused the ozone hole over Antarctica*

Human Contributions contd..

- *Water vapour is the most abundant and important greenhouse gas in the atmosphere. However, human activities have only a small direct influence on the amount of atmospheric water vapour.*

- *Indirectly, humans have the potential to affect water vapour substantially by changing climate. For example, a warmer atmosphere contains more water vapour.*

- *Human activities also influence water vapour through CH_4 emissions, because CH_4 undergoes chemical destruction in the stratosphere, producing a small amount of water vapour.*

Human Contributions contd..

- *The global atmospheric concentration of methane has increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s, and is 1774 ppb in 2005.*
- *The atmospheric concentration of methane in 2005 exceeds by far the natural range of the last 650,000 years (320 to 790 ppb) as determined from ice cores.*
- *Growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. It is very likely6 that the observed increase in methane concentration is due to anthropogenic activities, predominantly agriculture and fossil fuel use*

DIRECT OBSERVATIONS OF RECENT CLIMATE CHANGE

- *Eleven of the last twelve years (1995 -2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850).*
- *The average atmospheric water vapour content has increased since at least the 1980s over land and ocean as well as in the upper troposphere.*
- *Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system.*
- *Such warming causes seawater to expand, contributing to sea level rise*

OBSERVATIONS OF RECENT CLIMATE CHANGE

- *Mountain glaciers and snow cover have declined on average in both hemispheres. Widespread decreases in glaciers and ice caps have contributed to sea level rise*

- *New data now show that losses from the ice sheets of Greenland and Antarctica have very likely contributed to sea level rise over 1993 to 2003. Flow speed has increased for some Greenland and Antarctic outlet glaciers, which drain ice from the interior of the ice sheets.*

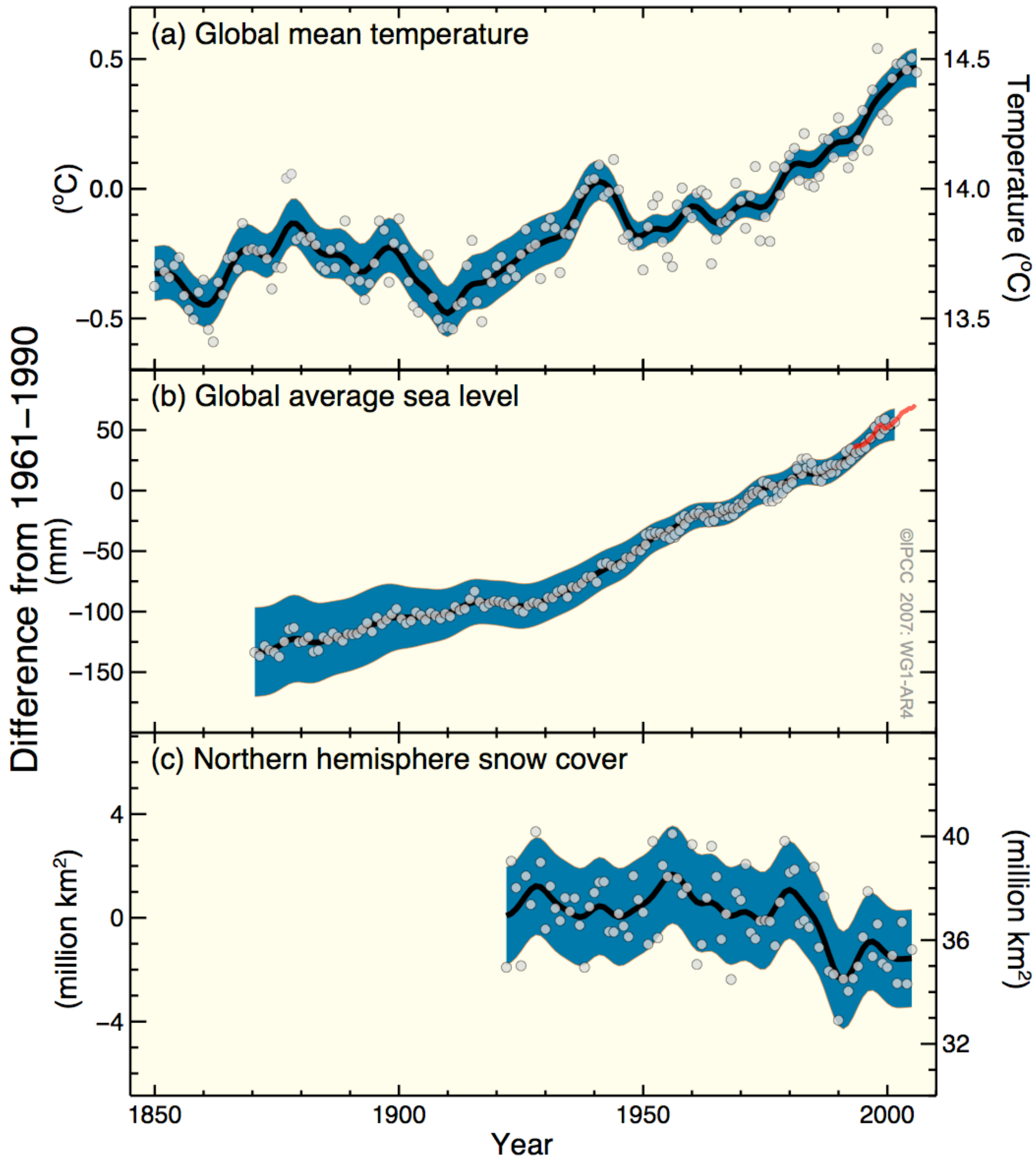
- *Global average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003. The rate was faster over 1993 to 2003, about 3.1 mm per year.*

- *Average Arctic temperatures increased at almost twice the global average rate in the past 100 years.*

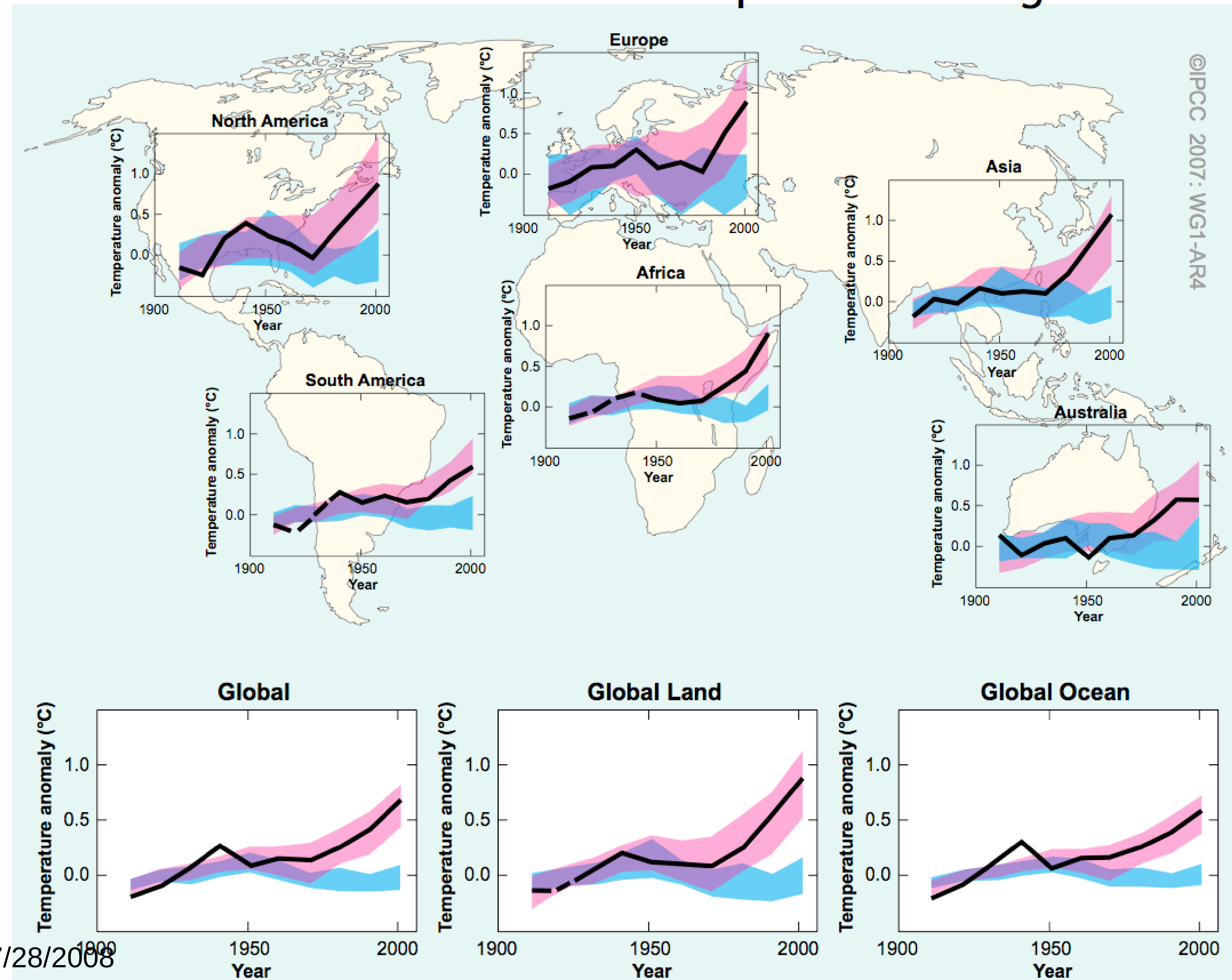
OBSERVATIONS OF RECENT CLIMATE CHANGE

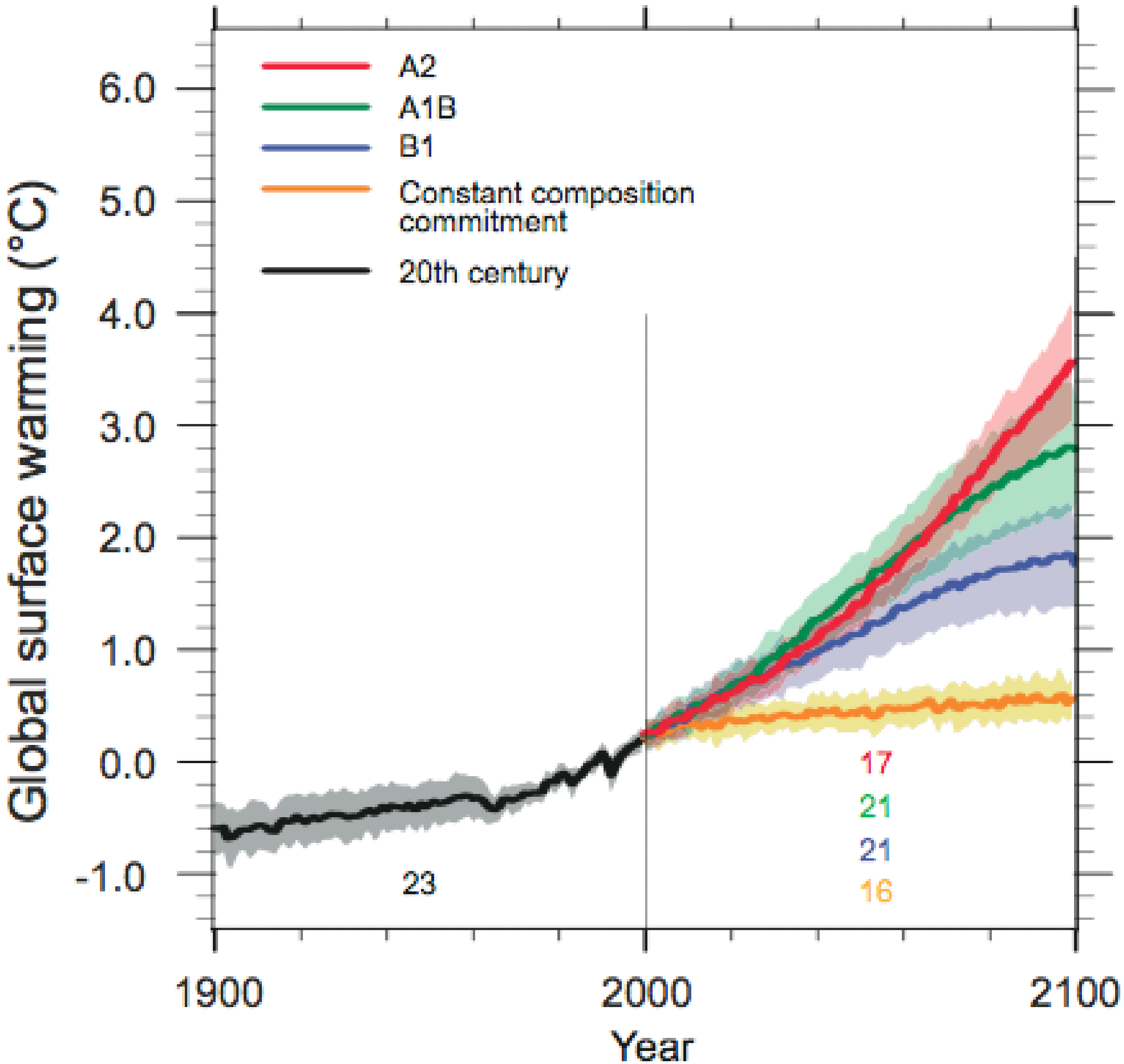
- *Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by 2.7 % per decade, with larger decreases in summer of 7.4 % per decade.*
- *Temperatures at the top of the permafrost layer have generally increased since the 1980s in the Arctic (by up to 3°C). The maximum area covered by seasonally frozen ground has decreased by about 7% in the Northern Hemisphere since 1900, with a decrease in spring of up to 15%.*
- *The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapour. Widespread changes in extreme temperatures have been observed over the last 50 years.*
- *Cold days, cold nights and frost have become less frequent, while hot days, hot nights, and heat waves have become more frequent.*

Changes in Temperature , Sea Level and Northern Hemisphere Snow Cover



Global and Continental Temperature Change




A2
A1B
B1
Constant composition commitment
20th century
Global surface warming (°C)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
23
17
21
21
16
1900
2000
2100
Year