18CEO406T - GLOBAL WARMING AND CLIMATE CHANGE

UNIT – 1 [S7 to S9]

S7: Atmospheric stability continuation, Pollutant dispersion

Pollutant Dispersion

The stream of polluted air downwind of a smoke stack is called a smoke plume. If the plume is buoyant, or if there is a large effluent velocity out of the top of the smoke stack, the center of the plume can rise above the initial emission height. This is called plume rise. The word "plume" in air pollution work means a long, slender, nearly-horizontal region of polluted air. However, the word "plume" in atmospheric bound-ary-layer (ABL) studies refers to the relatively wide, nearly vertical updraft portion of buoyant air that is convectively overturning. Because smoke plumes emitted into the boundary layer can be dispersed by convective plumes, one must take great care to not confuse the two usages of the word "plume".

Dispersion is the name given to the spread and movement of pollutants. Pollution dispersion de-pends on

- wind speed and direction,
- plume rise, and
- atmospheric turbulence.

Pollutants disperse with time by mixing with the surrounding cleaner air, resulting in an increasingly dilute mixture within a spreading smoke plume.

Wind and turbulence are characteristics of the ambient atmosphere, as were described in earlier chapters. While emissions out of the top of the stack often have strong internal turbulence, this quickly decays, leaving the ambient atmosphere to do the majority of the dispersing.

The amount of a pollutant in the air can be given as a fraction or ratio, q. This is the amount (moles) of pollution divided by the total amount (moles) of all constituents in the air. For air quality, the ratios are typically reported in parts per million (ppm). For example, 10 ppm means

10 parts of pollutant are contained within 106 parts of air. For smaller amounts, parts per billion (ppb) are used.

For a standard atmosphere at sea level, where temperature is 15°C and pressure is 101.325 kPa, the equation above reduces to

$$q(\text{ppmv}) = \frac{b}{M_s} \cdot c(\mu\text{g/m}^3)$$

where $b = 0.02363$ (ppmv) / (μg m^{-3}).

For example, nitrogen dioxide (NO_2) has a molecular weight of $M_s = 46.01$ g/mole (see Table 1-2 in Chapter 1). If concentration $c = 100$ μg m^{-3} for this pollutant, then the equation above gives a volume fraction of $q = (0.02363/46.01) \cdot (100) = 0.051$ ppmv.

Table 19-1. Air quality concentration standards for the USA (US), Canada (CAN), and The European Union (EU) for some of the commonly-regulated chemicals, as of Sep 2017. Concentrations represent averages over the time periods listed. For Canada, the CAAQS are changing over years 2015 -> 2020. Older Canadian National Ambient Air Quality Objectives (acceptable levels) are in grey.

Avg. Time	US	CAN	EU
Sulfur Dioxide (SO_2)			
1 yr		->5 ppb	
1 day			125 μg m^{-3}
3 h	1300 μg m^{-3} or 0.5 ppm		
1 h	75 ppb	->70 ppb	350 μg m^{-3}
Nitrogen Dioxide (NO_2)			
1 yr	100 μg m^{-3} or 53 ppb	53 ppb	40 μg m^{-3}
1 h	100 ppb	213 ppb	200 μg m^{-3}
Carbon Monoxide (CO)			
8 h	10,000 μg m^{-3} or 9 ppm	13 ppm	10,000 μg m^{-3}
1 h	40,000 μg m^{-3} or 35 ppm	31 ppm	
Ozone (O_3)			
8 h	0.070 ppm	63 -> 62 ppb	120 μg m^{-3}
Particulates, diameter < 10 μm (PM_{10})			
1 yr		70 μg m^{-3}	40 μg m^{-3}
1 day	150 μg m^{-3}	120 μg m^{-3}	50 μg m^{-3}
Fine Particulates, diam. < 2.5 μm ($PM_{2.5}$)			
1 yr	12 μg m^{-3}	10->8.8 μg m^{-3}	25 μg m^{-3}
1 day	35 μg m^{-3}	28->27 μg m^{-3}	
Lead (Pb)			
1 yr			0.5 μg m^{-3}
3 mo	0.15 μg m^{-3}		
Benzene (C_6H_6)			
1 yr			5 μg m^{-3}
Arsenic (As)			
1 yr			6 ng m^{-3}

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S8; Introduction to greenhouse gases and global warming, Photo chemical smog

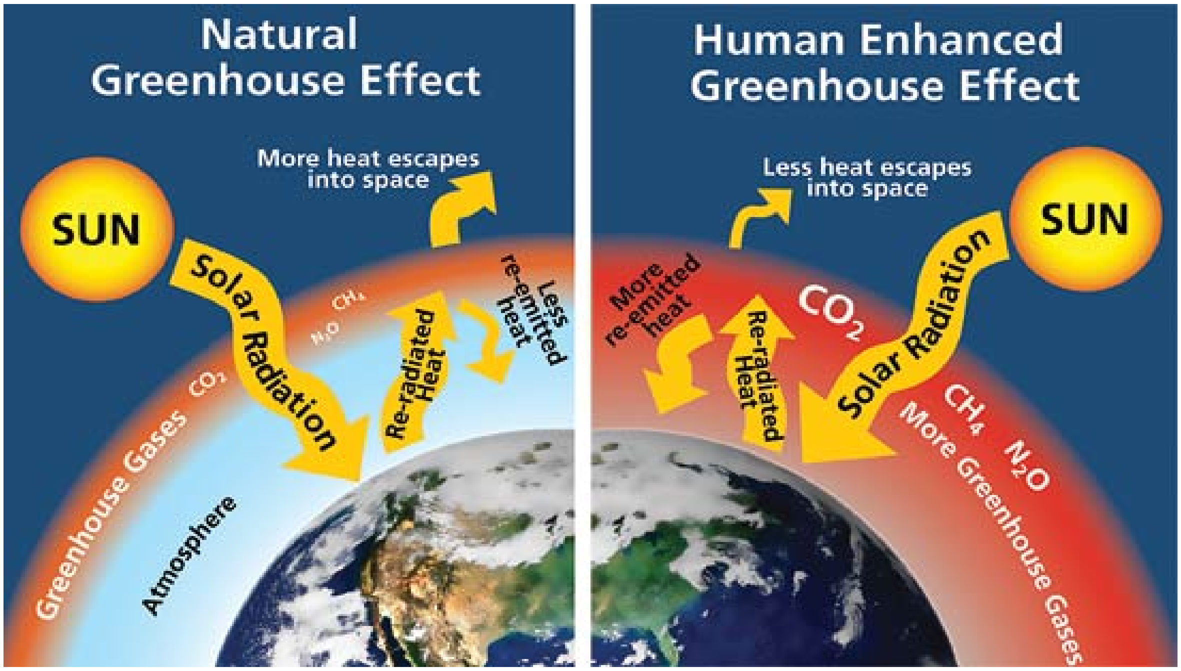
GREEN HOUSE GASES

Allowing short wave solar radiation into earth's surface and retaining the long wave infrared radiation reflected by the earth's surface by greenhouse gases in the atmosphere is termed as greenhouse effect.

Greenhouse gases include any gas in the atmosphere that is capable, as a result of its particular molecular structure, of absorbing infrared radiation or heat. They are called greenhouse gases because they behave like glass in a greenhouse gas, allowing sunlight to pass through but trapping the heat formed and preventing it from escaping, thereby causing a rise in temperature.

Greenhouse gases cause the **greenhouse** effect on planets. The primary **greenhouse gases** in Earth's atmosphere are

1. CO_2 Carbon dioxide
2. CH_4 Methane
3. N_2O Nitrous Oxide
4. SF_6 Sulphur hexafluoride
5. PFCs Perfluorocarbones
6. HFCs Hydrofluorocarbons



Energy from the sun drives the earth's weather and climate, and heats the earth's surface.

In turn, the earth radiates energy back into space.

Some atmospheric gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat (like the glass panels of a greenhouse).

These gases are therefore known as greenhouse gases. The greenhouse effect is the rise in temperature on Earth as certain gases in the atmosphere trap energy.

Sources of Green house gases:

- **Carbon dioxide**, which is emitted whenever coal, oil, natural gas and other carbon-rich fossil fuels are burned. Although carbon dioxide is not the most powerful greenhouse gas, it is the largest contributor to climate change because it is so common. In order to reduce carbon dioxide emissions, we need to reduce the amount of fuel we use in our cars, homes, and lives.

- **Methane** is caused by the decomposition of plant matter, and is released from landfills, swamps, rice paddies. Cattle also release methane. Although methane emissions are lower than carbon dioxide emissions, it is considered a major greenhouse gas because each methane molecule has 25 times the global warming potential of a carbon dioxide molecule.
- **Nitrous oxide** is released from bacteria in soil. Modern agricultural practices — tilling and soil cultivation, livestock waste management, and the use of nitrogen-rich fertilizers — contribute significantly to nitrous oxide emissions. A single nitrous oxide molecule has 298 times the global warming potential of a carbon dioxide molecule.
- Additional greenhouse gases include **hydrofluorocarbons** (1,430-14,800 time the global warming potential of carbon dioxide), **sulfur hexafluoride** (22,800 times the global warming potential of carbon dioxide), and water vapor.

Causes of Greenhouse Effect

The major causes of the greenhouse effect are:

Burning of Fossil Fuels

Fossil fuels are an important part of our lives. They are widely used in transportation and to produce electricity. Burning of fossil fuels releases carbon dioxide. With the increase in population, the utilization of fossil fuels had increased. This has led to an increase in the release of greenhouse gases in the atmosphere.

Deforestation

Plants and trees take in carbon dioxide and release oxygen. Due to the cutting of trees, there is an inconsiderable increase in the greenhouse gases which increases the earth's temperature.

Farming

Nitrous oxide used in fertilizers is one of the contributors to greenhouse effect in the atmosphere.

Industrial Waste and Landfills

The industries and factories produce harmful gases which are released in the atmosphere.

Landfills also release carbon dioxide and methane that adds to the greenhouse gases.

Effects of Greenhouse Effect

The main effects of increased greenhouse gases are:

Global Warming

It is the phenomenon of a gradual increase in the average temperature of the Earth’s atmosphere. The main cause for this environmental issue is the increased volumes of greenhouse gases such as carbon dioxide and methane released by the burning of fossil fuels, emissions from the vehicles, industries and other human activities.

Depletion of Ozone Layer

Ozone Layer protects the earth from harmful ultraviolet rays from the sun. It is found in the upper regions of the stratosphere. The depletion of the ozone layer results in the entry of the harmful UV rays to the earth’s surface that might lead to skin cancer and can also change the climate drastically.

The major cause of this phenomenon is the accumulation of natural greenhouse gases including chlorofluorocarbons, carbon dioxide, methane, etc.

Runaway Greenhouse Effect

This phenomenon occurs when the planet absorbs more radiations than it can radiate back. Thus, the heat lost from the earth's surface is less and the temperature of the planet keeps rising. Scientists believe that this phenomenon took place on the surface of Venus billions of years ago.

This phenomenon is believed to have occurred in the following manner:

- A runaway greenhouse effect arises when the temperature of a planet rises to a level of the boiling point of water. As a result, all the water from the oceans converts into water vapour, which traps more heat coming from the sun and further increases the planet's temperature. This eventually accelerates the greenhouse effect. This is also called the "positive feedback loop".
- There is another scenario giving way to the runaway greenhouse effect. Suppose the temperature rise due to the above causes reaches such a high level that the chemical reactions begin to occur. These chemical reactions drive carbon dioxide from the rocks into the atmosphere. This would heat the surface of the planet which would further accelerate the transfer of carbon dioxide from the rocks to the atmosphere, giving rise to the runaway greenhouse effect.

In simple words, increasing greenhouse effect gives rise to a runaway greenhouse effect which would increase the temperature of the earth to such an extent that no life will exist in the near future.

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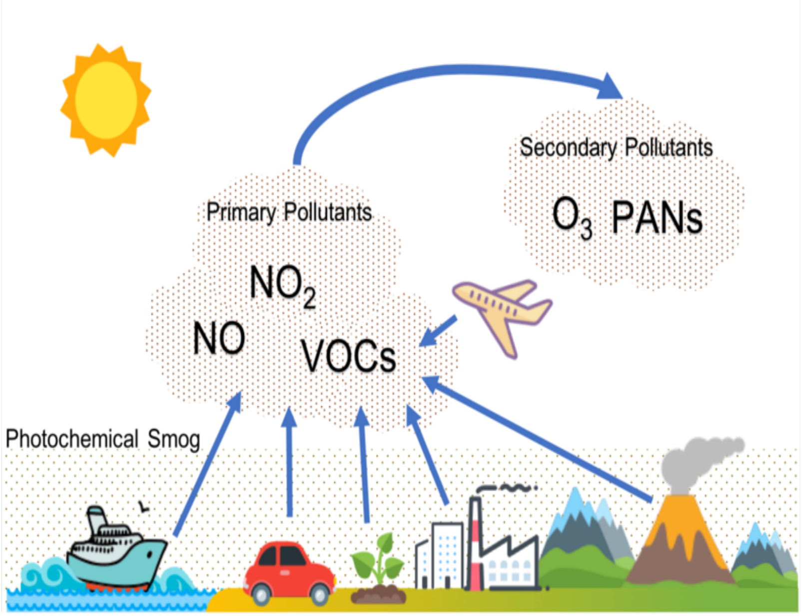
Photochemical smog:

Photochemical smog is a mixture of pollutants that are formed when nitrogen oxides and volatile organic compounds (VOCs) react to sunlight, creating a brown haze above cities. It tends to occur more often in summer, during more sunlight.



Photochenical smog is a major contributor to air pollution. The word "smog" was originally coined as a mixture of "**smoke" and "fog".** This type of air pollution is formed through the reaction of solar radiation with airborne pollutants like nitrogen oxides and volatile organic Compounds.

These compounds, which are called primary pollutants, are often introduced into the atmosphere through automobile emissions and industrial processes. Products like ozone, aldehydes, and peroxyacetyl nitrates are called secondary pollutants. The misture of these primary and secondary pollutant forms photochemical smog. Both primary and secondary pollutants in photochemical smog are highly reactive.

Photochemical smog, which is also known as **"Los Angeles smog,"** occurs most prominently in urban areas that have large numbers of automobiles. It requires neither smoke nor fog. This type of smog has its origin in the nitrogen oxides and hydrocarbon vapours emitted by automobiles and other sources, which then undergo photochemical reactions in the lower atmosphere. The highly toxic gas ozone arises from the reaction of nitrogen oxides with hydrocarbon vapours in the presence of sunlight, and some nitrogen dioxide is produced from the reaction of nitrogen oxide with sunlight.

Effect of smog:

- causes a light brownish coloration of the atmosphere,
- reduced visibility,
- plant damage,
- irritation of the eyes, and respiratory distress.
- Surface-level ozone concentrations are considered unhealthy if they exceed 70 parts per billion for eight hours or longer; such conditions are fairly common in urban areas prone to photochemical smog.

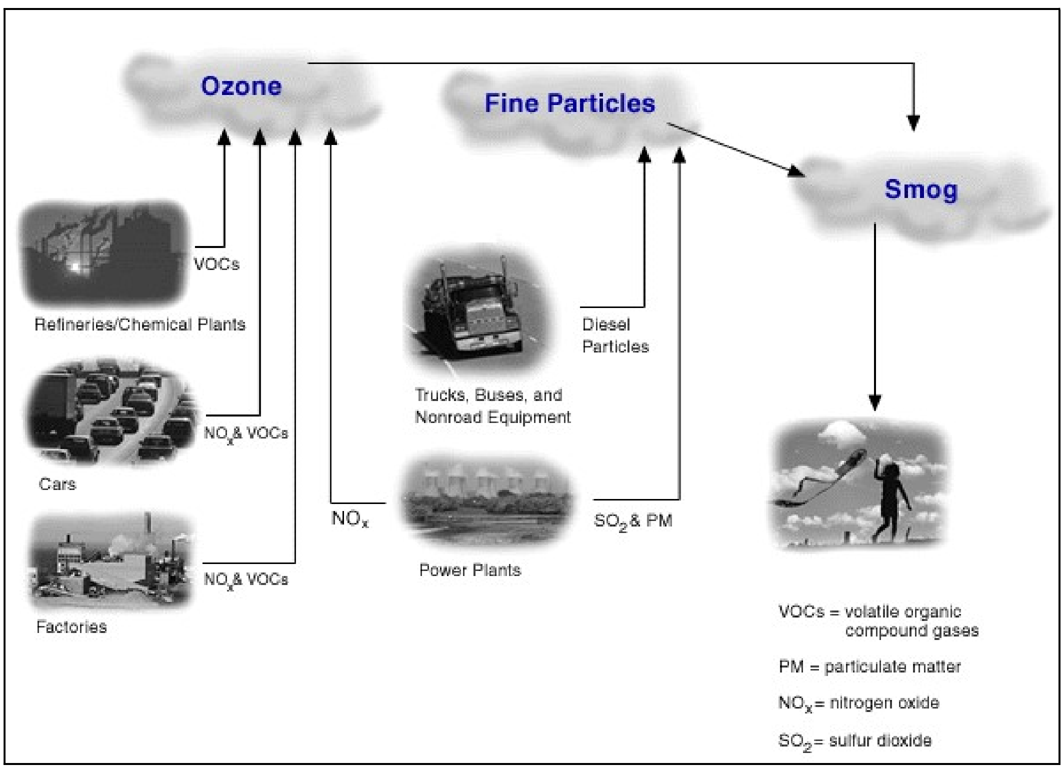


Fig: sources of Smog

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S~~8~~ ; OZONE DEPLETION and El Nino and their impact

OZONE DEPLETION

Ozone layer depletion, is simply the wearing out (reduction) of the amount of ozone in the **stratosphere**. Ozone depletion occurs when destruction of the stratospheric ozone is more than the production of the molecule. The scientists have observed reduction in stratospheric ozone since early 1970s. It is found to be more prominent in Polar Regions.

There are two regions in which the ozone layer has depleted.

In the mid-latitude, for example, over Australia, ozone layer is thinned. This has led to an increase in the UV radiation reaching the earth. It is estimated that about 5-9% thickness of the ozone layer has decreased, increasing the risk of humans to over-exposure to UV radiation owing to outdoor lifestyle.

Since 1928, Chlorofluorocarbons have been produced, originally as nonflammable refrigerants for use in refrigerators, and eventually for use in fire extinguishers, dry cleaning agents, pesticides, degreasers, adhesives, and as propellants for aerosol products.

As these CFCs have been released into the atmosphere, the level of ozone in the stratosphere has decreased.

CFCs have an estimated lifespan of **more than 100 years**

Cause of ozone depletion:

Natural causes of depletion of ozone layer: Ozone layer has been found to be affected by certain natural phenomena such as Sun-spots and stratospheric winds. But this has been found to cause not more than 1-2% depletion of the ozone layer and the effects are also thought to be only temporary. It is also believed that the major volcanic eruptions (mainly El Chichon in 1983 and and Mt. Pinatubo in 1991) has also contributed towards ozone depletion.

Man-made causes of depletion of ozone layer: The main cause for the depletion of ozone is determined as excessive release of chlorine and bromine from man-made compounds such as chlorofluorocarbons (CFCs). CFCs (chlorofluorocarbons), halons, CH_3CCl_3 (Methyl chloroform), CCl_4(Carbon tetrachloride), HCFCs (hydro-chlorofluorocarbons), hydrobromofluorocarbons and methyl bromide are found to have direct impact on the depletion of the ozone layer. These are categorized as ozone-depleting substances (ODS). Chlorofluorocarbons are released into the atmosphere due to:

- Cleaning Agents
- Coolants in refrigerators
- Packing material
- Air conditioning
- Aerosol spray cans etc.

The problem with the Ozone-Depleting Substances (ODS) is that they are not washed back in the form of rain on the earth and in-fact remain in the atmosphere for quite a long time. With so much stability, they are transported into the stratosphere. The emission of ODS account for roughly 90% of total depletion of ozone layer in stratosphere. These gases are carried to the stratosphere layer of atmosphere where ultraviolet radiations from the sun break them to release chlorine (from CFCs) and bromine (from methyl bromide and halons). The chlorine and bromine free radicals react with ozone molecule and destroy their molecular structure, thus depleting the ozone layer. One chlorine atom can break more than 1, 00,000 molecules of ozone. Bromine atom is believed to be 40 times more destructive than chlorine molecules. The chlorine becomes actively involved in the process of destruction of ozone. The net result is that two molecules of ozone are replaced by three of molecular oxygen, leaving the chlorine free to repeat the process:

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + O \rightarrow Cl + O_2$$

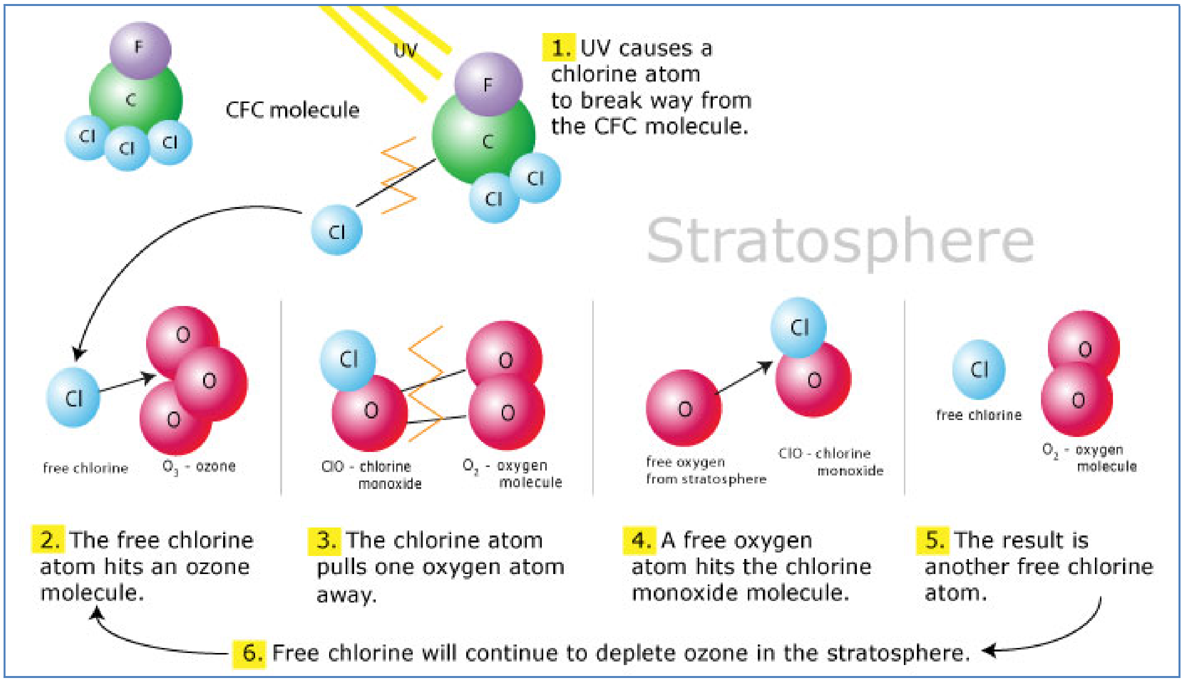

Fig: Ozone depletion by CFCs

Main Ozone Depleting Substances (OCD)

- **Chlorofluorocarbons:** Account for more than 80% of ozone depletion. Used in freezers, air cooling component, dry-cleaning agents, hospital sterilants.
- **Methyl Chloroform:** Used for vapour degreasing, some aerosols, cold cleaning, adhesives and chemical processing.
- **Hydro chlorofluoro carbons:** Substitutes for CFC's but still play a vital role in ozone depletion.
- **Halons**
- **Carbon Tetrachloride:** Mainly used in fire extinguishers

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El Nino and their impact

El Niño and La Niña events are a natural part of the global climate system. They occur when the Pacific Ocean and the atmosphere above it change from their neutral ('normal') state for several seasons.

El Niño events are associated with a warming of the central and eastern tropical Pacific, while La Niña events are the reverse, with a sustained cooling of these same areas.

Impacts of global warming

1) **Rising Seas**--- inundation of fresh water marshlands (the everglades), low-lying cities, and islands with seawater.
2) **Changes in rainfall patterns** --- droughts and fires in some areas, flooding in other areas. See the section above on the recent droughts, for example!
3) **Increased likelihood of extreme events**--- such as flooding, hurricanes, etc.
4) **Melting of the ice caps** --- loss of habitat near the poles. Polar bears are now thought to be greatly endangered by the shortening of their feeding season due to dwindling ice packs.
5) **Melting glaciers** - significant melting of old glaciers is already observed.
6) **Widespread vanishing of animal populations** --- following widespread habitat loss.
7) **Spread of disease** --- migration of diseases such as malaria to new, now warmer, regions.
8) **Bleaching of Coral Reefs due to warming seas and acidification due to carbonic acid formation** --- *One third* of coral reefs now appear to have been severely damaged by warming seas.
9) **Loss of Plankton due to warming seas** --- The enormous (900 mile long) Aleution island ecosystems of orcas (killer whales), sea lions, sea otters, sea urchins, kelp beds, and fish populations, appears to have collapsed due to loss of plankton, leading to loss of sea lions, leading orcas to eat too many sea otters, leading to urchin explosions, leading to loss of kelp beds and their associated fish populations.

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