Climate Change and Depletion of the Ozone Layer

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Introduction

Climate change and thinning of the ozone layer are common environmental issues that world community faces today. Both these are mainly due to man made activities which bring significant threats to the living beings on the planet.

Ozone-climate interaction is complex, and impacts of one issue induce consequences on the other. Both ozone depleting substances (ODSs), many of which are also greenhouse gases (GHGs) and other gases, affect incoming and outgoing radiation, thus enhancing global warming. Until recent times these two global issues were treated separately and international agreements on control measures have also been adapted separately. For example, the Vienna Convention for the protection of the ozone layer and Montreal Protocol on substances that deplete the ozone layer, are global initiatives to bring back the stratospheric ozone layer to its original condition. The United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol have been adapted internationally to reduce greenhouse gas emission to the atmosphere. These are international responses to ozone depletion and climate change, as global control measures. However, now scientists have revealed that ozone depletion and climate change have significant interactions, affecting the entire globe, and hence they cannot be treated in isolation. Either ODSs or GHGs emitted from man made sources enter the same atmosphere that lies around the earth surface as a thin layer. Both these issues lead to significant changes in the atmospheric chemistry and disrupt its normal functions.

Now policy makers on environmental issues take greater interest in tackling this problem, considering both issues together and not separately. However, since some of the powerful countries have not signed the Kyoto Protocol, still there remains a barrier for collective global action.

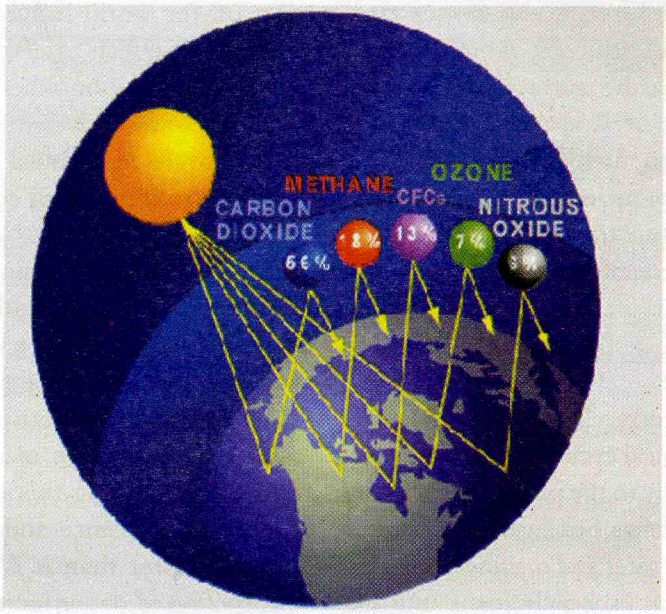

Figure 1: Greenhouse gases trap IR radiation and tend to warm the earth surface
Adapted from *www.koshland-science-museum.org*

Climate change

Climate Change has been identified as a serious problem that the world community faces today. Responding to these climate issues has become a significant challenge especially in developing countries. High concentrations of GHGs in the atmosphere, mainly due to man made activities, produce global warming which considerably affect climate change. The observed changes today and the anticipated changes in the future in climate will affect both human and natural ecosystems in many ways. Thunder storms, floods, drought and severe and frequent cyclones are ongoing consequences which bring great climatic variability. Floods and drought due to variations in rainfall are already serious issues for nations whose economy is primarily based on agriculture.

Developing countries are more vulnerable to climate change than developed nations mainly due to their inability to take appropriate actions. GHG emissions from developing countries are negligible as compared to

developed countries whose energy consumption is high. Poor nations whose economy is mainly based on agriculture have to face difficulties due to irregularities in the hydrological cycle caused by global warming and climate change.

Greenhouse effect

Earth surface absorbs radiation emanating from the sun and causes terrestrial warming. Much of the radiation is reemitted by the heated earth surface to the atmosphere, especially long wave radiation (Infra Red-IR), which are trapped by greenhouse gases present in the atmosphere leading to enhanced warming. This phenomenon is known as the greenhouse effect .The most abundant greenhouse gases, in order of their relative abundance are carbon dioxide, methane, nitrous oxide, ozone and CFCs. Increased levels of Greenhouse Gases from anthropogenic (man made) sources, which lead to temperature rise near the earth's surface, is known as Global Warming. Emissions of Carbon Dioxide (CO_2) have been increasing due to fuel burning and forest clearing. Industrialized nations are mainly responsible for such emissions contributing to greenhouse effect. Methane (CH_4) is mainly generated from wetlands due to anaerobic activities.

Effects of climate change

Global warming brings adverse climatic consequences such as thunder storms, tropical cyclones and hurricanes causing destructions especially to the people living in low lying coastal areas and river deltas. Sea level rise as a result of thermal expansion of sea water and melting of glaciers is also likely to be significant, especially for islands like Sri Lanka. Melting of polar ice caps leads to a significant increase of water in oceans. Coastal inhabitants are highly vulnerable to sea level rise which may also bring big threats to the global biodiversity. Mean global temperature has increased by 0.3-0.6 ^{0}C over the past 100 years and corresponding sea level rise was between 10 to 20cm.

Some of the direct health impacts of climate change are cardiovascular diseases and respiratory diseases while indirect effects include algal toxicity, cholera, vector born diseases such as malaria, dengue, malnutrition, asthma etc. The forest acts as a possible sink for carbon dioxide (CO_2) which facilitates maintaining the natural balance of the atmosphere. Forest cover seems to be a natural defense to ensure survival of life on earth. Intake of CO_2 by green tissues during photosynthesis known as carbon fixing, regulates the CO_2 concentration in the atmosphere. An increased level of deforestation (removing forest cover) due to over exploitation results in elevated CO_2 levels in the atmosphere leading to disruption of the natural balance. The ultimate result would be inadequate forest cover for absorbing CO_2, thus enhancing global warming and climate change. Deforestation is happening at an alarming rate, especially in tropical countries due to their development activities both in Industry and Agriculture.

Emissions are not confined to particular nations which are responsible for it, and dispersion occurs through the atmosphere over different nations, since the global atmosphere has no boundaries, and emissions from any part of the world influence the whole earth, bringing undesirable effects to all countries. This is known as trans-boundary pollution where the developing nations may also have to face adverse consequences of it. Thick dense forest cover in tropical areas tends to absorb GHG emitted from northern countries.

Depletion of the ozone layer

Ozone is being constantly produced and destroyed by chemical reactions that take place in the atmosphere. For over 600 million years there has been a balance between this natural production and destruction process. Anthropogenic (man made) substances released to the atmosphere during this century has started to disrupt this natural balance and make the ozone destruction process faster than it is being created. This leads to destruction of ozone increasingly and bringing the ozone level down.

This enhanced ozone depletion happens as a result of Ozone Depleting Substances emitted into the atmosphere. These products are mainly man made and released through human activities. Substances used in the industrial and agricultural sectors such as Chlorofluorocarbon (CFC), Halons, Carbon tetrachloride (CTC) and Methyl Bromide (MeBr) are mainly responsible for ozone depletion.

These chemically inert and very stable substances slowly reach the upper atmosphere and high energy Ultra Violet (UV) radiation emanating from the sun breaks them apart in to their atomic constituents. Chlorine and Bromine

atoms released in this way act as catalysts for chemical reactions that lead to acceleration of the ozone destruction process. Each atom can destroy thousands of ozone molecules due to its catalytic property, before being removed from the atmosphere.

important as primary producers in aquatic food webs. Reduced plankton levels leads to diminished fish stock in the oceanic environment through a chain reaction. An elevated level of UV reaches the earth surface threatening microbial life on earth. For example Cyanobacteria which

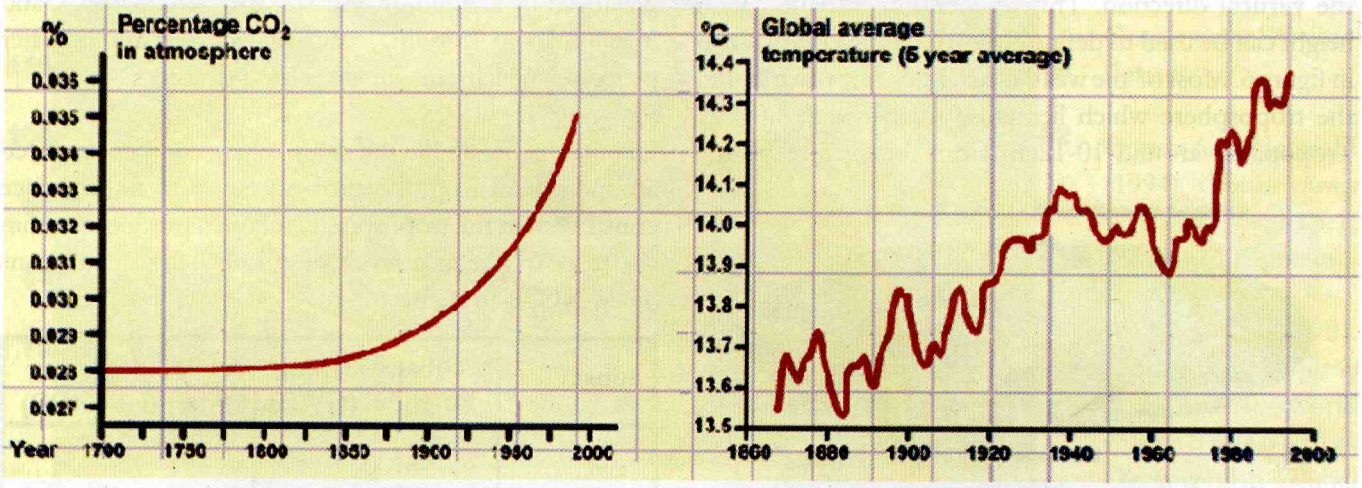

Figure 2: Graphs of rise in global atmospheric CO_2 concentration and global average temperatures. Adapted from *www.bbc.co.uk/.../weatherhumansrev*

Accumulation of Chlorine and Bromine atoms in the upper atmosphere make the ozone destruction process faster which leads to the ozone level being brought down. The severe depletion of ozone was first observed in the 1980s in the Antarctic, which came to be known as the "ozone hole" caused by destructive reactions of halogens. Ozone layer depletion is being monitored and observations indicate that there is destruction of ozone every where, and even over the tropics the ozone layer is very thin.

The Stratospheric Ozone layer acts as a protective shield for UV radiation which comes from the sun. It absorbs UV radiation and hence reduces the amount reaching the earth surface. UV rays which are considered to be harmful for life on earth, has significant potential to produce skin cancers, cataracts and immune suppression in human beings. Many studies have shown that there is a strong relationship between skin cancers and UV-B exposure. Higher UV levels have a significant impact on the human immune system thus suppressing immunity. Increased levels of UV reaching the earth surface leads to increase ground level ozone concentrations which bring toxic effects to the life on earth. Increased UV levels due to decreased ozone level have significant impacts on plants thus inhibiting their growth. It may also affect photosynthesis in planktons which are vitally play an important role in fixing atmospheric Nitrogen in legumes is highly sensitive to UV rays.

Thinning of the ozone layer brings significant impacts on climate change both directly and indirectly.

Link between climate change and ozone layer depletion

Identification of the interaction between Ozone depletion and climate change has critical importance since it affects the atmosphere around us. The atmosphere is an open system, being subjected to both matter and energy inputs and out puts. Within the troposphere, absorption of terrestrial radiation by atmospheric gases cause the earth surface to grow warmer and this phenomenon is called Greenhouse Effect. Most of the Ozone Depleting Substances are potential GHGs. For example, Halons which are very effective firefighting substances and CFC used as a refrigerant and in many other industries are strong ozone depleting substances, while they are also greenhouse gases with a high global warming potential.

Atmospheric composition mainly depends on the energy it absorbs. UV radiation absorbed by the stratospheric ozone determines the chemical and physical structure of the stratosphere. Energy absorbed by ozone in the

region around 25-30 km from the surface of the earth creates the temperature inversion (increase of temperature with altitude - see Fig. 5) which creates stratosphere. This non uniform energy absorption creates an atmospheric temperature profile which is zigzag in the vertical direction. This temperature variation with height can be used to define atmospheric layers as shown in figure 6. Most of the weather activities take place within the troposphere which lies close to the earth surface. Tropopause around 10-12km from the surface of the earth acts as a barrier for vertical motion and limits or determines the cloud height. If the ozone layer is destroyed tropopause will move up almost up to the mesopause which is around 80km high, and thus the cloud height can be as high as 80km. Therefore, rain produced by a cloud of that size can be enormous, and it will lead to flooding, land slides and various other processes which are climate related disasters.

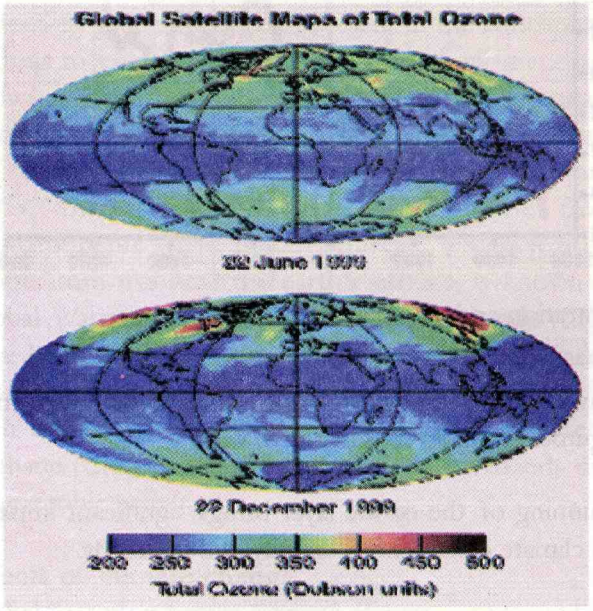

Figure 3: Distribution of ozone over the earth surface. Courtesy of NASA

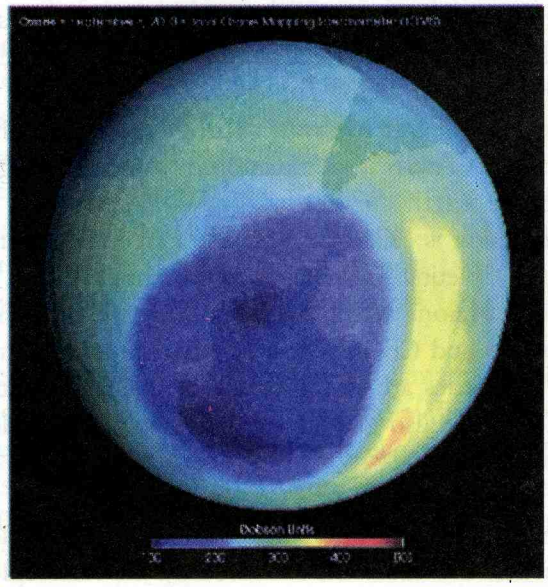

Figure 4: Ozone Hole over Antarctica as observed by NASA, September 2000.

Ozone is generated in the stratosphere and concentrated around 30 km from the earth surface. Ozone is a trace constituent in the troposphere. It is also produced within the troposphere as a result of photochemical reactions when NO_2 is present.

Substance	Global warming Potential (GWP)	Ozone depleting Potential (ODP)
CFC	8100	1
HCFC	1500	0.055
Halon	6500	10.00

Table 1: GWP and ODP of a few selected manmade chemicals.

UV radiation absorbed by the stratosphere has a direct influence on the chemical composition of the troposphere. Ozone layer depletion allows more high energy solar radiation to reach the earth surface thus warming the lower atmosphere and cooling of the stratosphere. This leads to greater temperature gradient in the vertical direction, which in turn produces enhanced vertical motion and severe weather conditions. Enhanced energy and associated temperature increase of the earth will change the weather and climatic pattern of the globe at an enhanced rate.

Cooling effect of the stratosphere due to loss of ozone leads to the forming of Polar Stratospheric Clouds (PSCs) in polar regions during winter season. These polar stratospheric clouds act as a medium for many chemical reactions. Halogens such as Chlorine and Bromine get dissolved here and are converted to more reactive forms. When spring comes these active halogens cause the ozone destruction process to become faster through a series of reactions. Massive ozone holes in polar regions during spring are made in this way.

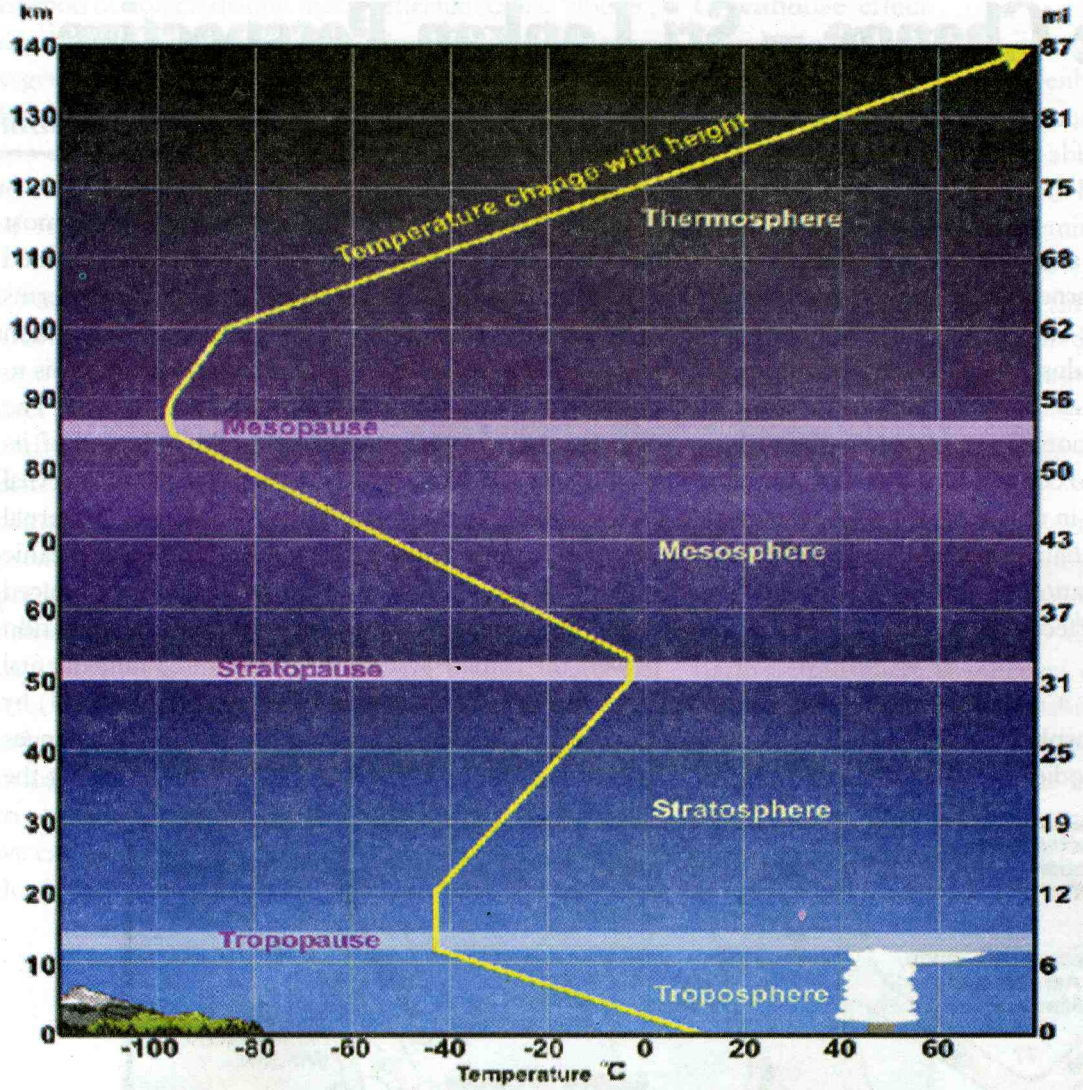

Figure 5: Atmospheric temperature profile. Figure illustrates the temperature variation with height.

Ozone depletion and climate change affects chemical and physical processes of the atmosphere separately as well as through their interactions. Climate change will influence the chemistry, dynamic and radiation process of the whole atmosphere. Changes in atmospheric circulation patterns due to thinning of ozone layer and increased energy at the earth surface bring harmful climatic effects causing health, economic, social and environmental problems to human beings.

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He is also the winner of United States Environmental Protection Agency Ozone Layer Protection Award for 2008.

Reference:

Garnier.C, et al (2003), Impact of climate change on tropispheric ozone,*Ozone-climatic interactions,*Luxembourg.

Fergusson.A, (2001), *Ozone depletion and climate change understanding the linkage*(1-8), Minister of Public Works and Government Services, Canada.

Qureshi,A.andHobbie,D. (1994), *Climate change in Asia*, chap:1, Manila, Phillippines.

WMO, (1998). *Scientific assessment of ozone depletion*, World Meteorological Organization Global Ozone Research and Monitoring Project - Report No. 44

www.esrl.noaa.gov/csd/assessments/1998/