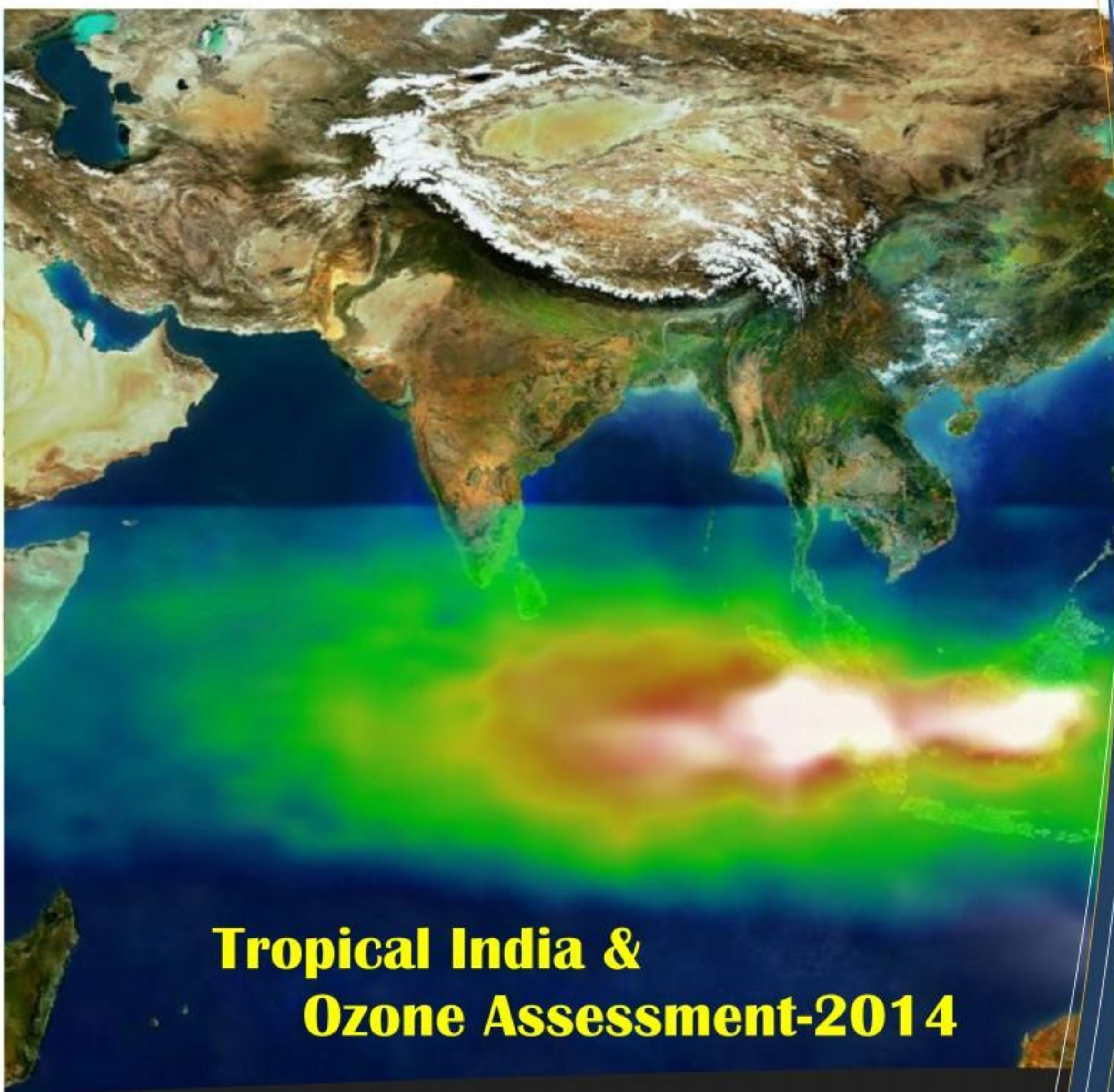
ENVIS-IITM NEWSLETTER

Indian Institute of Tropical Meteorology, Pune

Acid Rain and Atmospheric Pollution

(The project of Ministry of Environment & Forest, Govt. of India)



Tropical India & Ozone Assessment-2014

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"International action on the ozone layer is a major environmental success story" - WMO secretary- General Michel Jarraud

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EDITORIAL

The ENVIS - IITM centre deals with acid rain and atmospheric pollution and it is well known fact that our atmosphere is being polluted to an extreme level by human interference. This alteration in the natural atmosphere is due to emissions of various air pollutants as a consequence of burning of fossil fuels, industrial activity, transportation, power generation, agricultural production, waste disposal and so on. It is important to mention here that the atmospheric Ozone is categorised into two types; we have already discussed in our previous newsletters about ozone which is a pollutant, present in troposphere and in our last issue we focused on good ozone which is present in stratosphere 15-50 km above the earth's surface and its importance, depletion and recovery.

The present issue deals with the outcomes of the UNEP/WMO ***"Scientific Assessment of Ozone Depletion: 2014"*** *report released on 10 September 2014, which is released every four years. This report is significant as it announced the first signs of recovery of the ozone layer. We have tried to cover the current and future changes in the global ozone layer and the challenges which the tropics may face in 21st century during the recovery phase of the ozone layer. We have also tried to highlight the challenges which India might face. We hope our attempt to convey scientific information in simple language will help to create awareness amongst the common public which is the first step towards safeguarding our environment.*

— Dr. Gufran Beig

Scientific Assessment of Ozone Depletion: 2014

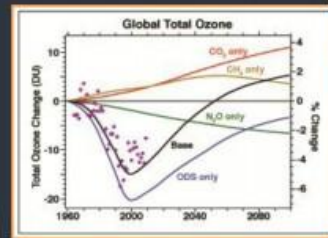
The protective ozone layer that started depleting in the 1980's is on a the path of recovery according to the summary document (Assessment for Decision-Makers) of the report on "Scientific Assessment of Ozone Depletion 2014" published by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). The report was prepared and reviewed by 300 scientists across the world and the above summary was released on 10th September 2014 which indicated that the ozone layer is on the path of recovery to 1980 levels around 2040 in many parts of the world. The discovery, understanding, decisions, actions, and verification under the Montreal Protocol that yielded notable achievements and progress is conveyed to world through this report which is published every 4 year.

CURRENT OZONE LAYER SCENARIO

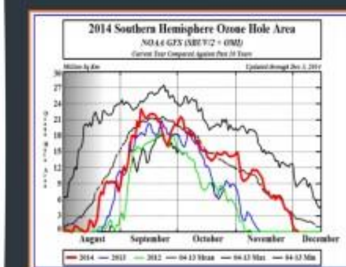
Global ozone levels decreased through the 1980s and early 1990s while stratospheric Ozone Depleting Substances (ODS) abundances were increasing. The implementation of the Montreal Protocol and its Amendments and adjustments stopped this global ozone decline, with ozone levels having approximately stabilized since stratospheric ODS abundances peaked between 1997 and 2000. Now that ODS abundances are declining, global ozone is expected to slowly recover but during this recovery phase, ozone levels will also be affected by the expected anthropogenic increases in abundances of other ozone-relevant gases (carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)) as well as by the natural influences of volcanic eruptions, solar activity, and the natural variability in Earth's climate. Atmospheric lifetimes of most ODS species are long many decades and hence their removal from the atmosphere will occur over a much longer timescale.

Total column ozone declined over most of the globe during the 1980s and early 1990s, by about 2.5% in the global mean, but has remained stable since 2000. There are indications of an increase in global-mean total column ozone over 2000-2012. However, a total column ozone increase that would be attributable to ODS decreases has not yet been observed. Total column ozone averaged over 60°S−60°N and between 2008 and 2012 is lower by about 2% than it was during 1964-1980. Corresponding values for midlatitudes of the Northern and Southern Hemispheres (35°N-60°N and 35°S-60°S) are decreases of 3.5% and 6%, respectively. The larger depletion in the Southern Hemisphere compared to the Northern Hemisphere is linked to the Antarctic ozone hole and there are natural differences in the atmosphere between the Northern and Southern hemispheres, due to influence of the earth's surface topography and slight variation in the earth's orbit and around the Sun. Between 2000 and 2012, column

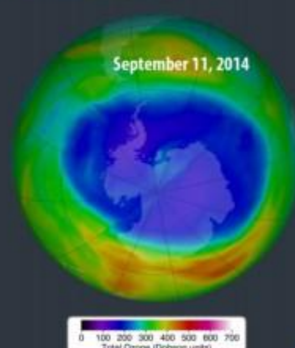
Global Total Ozone



2014 Southern Hemisphere Ozone Hole Area



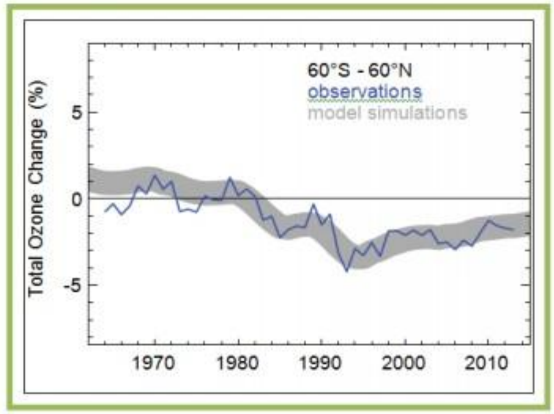
Latest image of ozone depletion over Antarctica



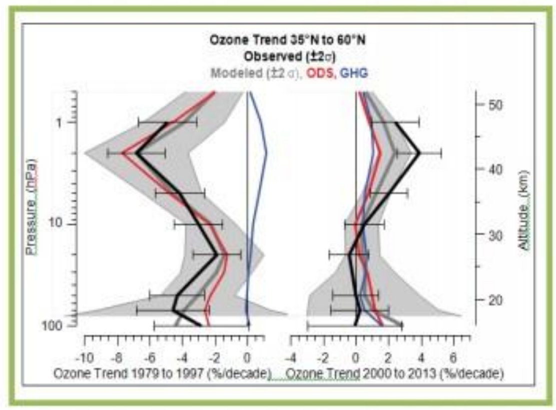
"There are positive indications that the ozone layer is on track to recovery towards the middle of the century. The Montreal Protocol, one of the world's most successful environmental treaties – has protected the stratospheric ozone layer and avoided enhanced UV radiation reaching the earth's surface" - UN under Secretary – General & UNEP Executive Director Achim Steiner

ozone averaged over 60°S-60°N appears to have increased by ~1% based on ground-based and space-based observations.

Upper stratospheric ozone declined during the 1980s and early 1990s, and has clearly increased by about 5% since 2000. From 2000 to 2013 the decline in ODS abundances and the cooling by increased carbon dioxide are both estimated to have made comparable contributions to the observed upper stratospheric ozone increases. A statistically significant increase of 2.5-5% per decade has occurred in the upper stratosphere (35-45 km) over the 2000-2013 period.



Ozone in the tropical lower stratosphere (and tropical column ozone) shows little response to ODSs, because conversion of ODSs into reactive chlorine and bromine is small in this region. Instead, tropical lower stratospheric ozone is more affected by the strength of tropical upwelling of air from troposphere to stratosphere caused by the Brewer-Dobson circulation. Increased tropical upwelling tends to reduce both lower stratospheric ozone and column ozone in the tropics. Such decreases in column ozone would lead to increased ultraviolet (UV) radiation in the tropics, where UV levels are already high.



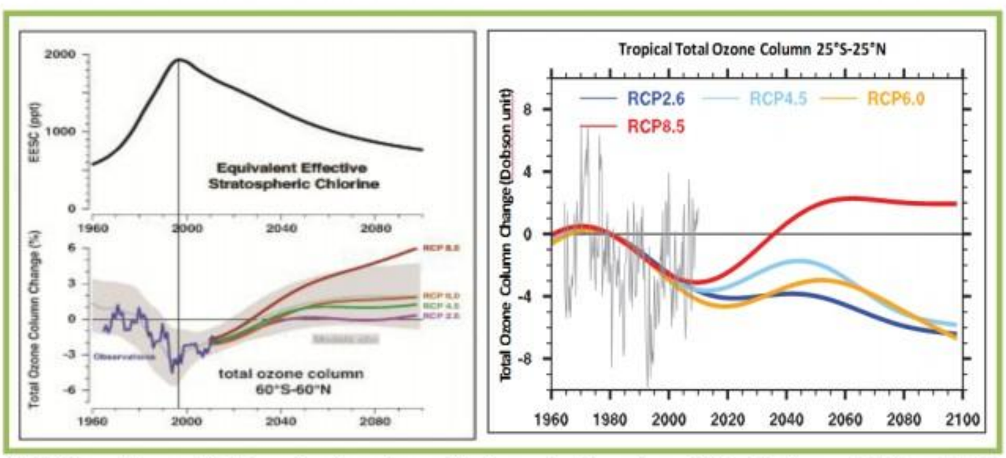
Tropical lower stratospheric ozone decreased by up to 5% near 20 km between the mid-1980s and 2000. Since 2000, both total column and lower stratospheric ozone in the tropics show little change within the large natural variability. The increased upwelling in the tropical lower stratosphere is associated with a strengthening of the shallow branch of the Brewer-Dobson circulation and there is large uncertainty in changes in its deep branch.

Due to successful implementation of the Montreal protocol across the world that mandated phasing out ODS such as chlorofluorocarbons used in refrigerators, air conditioners and solvents, the ozone problem has been tackled upto larger extent and we are in the path of recovery. But now there is also a problem with the new alternatives. Hydroflurocarbons (HFCs) that are widely used (replacing CFCs) these days, do not harm the ozone layer but many of them are potent Green House Gases (GHGs) and have very high global warming potential (GWP). The emissions of many of their substances are growing at a rate of about 7 % per year. Left unabated, they can be expected to contribute very significantly to climate change in the next decades. Replacements of the current mix of High GWPs HFCs with alternative compounds with low GWPs or not-in-kind technologies would limit this potential problem.

FUTURE GLOBAL OZONE LAYER

There are several indications that the ozone layer is beginning to recover from ODS-induced depletion. Tropical ozone has not been strongly affected by ODSs; its future changes will be dominated by GHGs increases. ODSs were the dominant driver of global ozone decline in the late 20th century. As controlled ODS concentrations decline, carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) will strongly influence ozone evolution in the latter part of the 21st century through chemical and climate effects. Six chemistry-climate model simulations show that projected total ozone columns in 2100 differ by up to 20 Dobson Unit (DU) or 7% in the global average, by up to 40 DU or 12% in midlatitudes, and by up to 10 DU or 4% in the tropics between minimum and maximum radiative forcing Representative Concentration Pathway scenarios for future CO_2, N_2O, and CH_4 emissions.

The primary GHGs are CO_2, N_2O, and CH_4 and it was noted their increasing levels warm the troposphere and cool the stratosphere. This stratospheric cooling modifies the rates of some chemical reactions, generally lessening ozone loss rates, and thereby increasing ozone levels. Hence, future ozone levels will increase beyond levels observed prior to 1960 with addition to modifying stratospheric temperatures. Part of the scenario uncertainty in future column ozone is due to differences in emissions of N_2O and CH_4 as they alter the chemistry of the stratosphere by degrading into reactive nitrogen and hydrogen compounds. The reactive nitrogen compounds from the additional N_2O mainly deplete ozone, while the reactive hydrogen compounds from CH_4 increase ozone by mitigating chlorine-driven ozone depletion. N_2O increases will tend to decrease ozone, while increasing CH_4 and CO_2 will tend to increase ozone. Uncertainties in future emissions of these gases lead to large differences in ozone projections at the end of the century.



Future levels of GHGs will modify the stratosphere, but projecting how CO_2, N_2O, and CH_4 will change in the future is very difficult because of changing economics, government policies, and feedback factors in the Earth system. Four possible GHG (CO_2, CH_4, and N_2O) projections have been developed for IPCC. As represented in above figure these four GHG projections are radiative forcing outcomes that correspond to

"Perhaps the single most successful international agreement to date has been the Montreal Protocol" - Kofi Annan, Former Secretary General of the United Nations.

+2.6, +4.5, +6.0, and +8.5 W m-2 of global radiative forcing by the year 2100. The "high" 8.5 W m-2 scenario has steadily increasing CO_2, CH_4, and N_2O over the course of the 21st century. The "low" 2.6 W m-2 forcing scenario has stabilized levels of N_2O and decreasing levels of CO_2 and CH_4 in the 21st century. The 4.5 and 6.0 W m-2 scenarios are intermediate global radiative forcing with increasing levels of CO_2 and varying levels of N_2O and CH_4. The projected future evolution of tropical total column ozone is strongly dependent on future abundances of CO_2, N_2O, and CH_4 and is particularly sensitive to changes in the tropical upwelling and changes in tropospheric ozone. Except for RCP 8.5, which specifies large increases in methane, significant decreases in total column ozone are projected during the 21st century.

The Brewer-Dobson circulation (BDC) is projected to strengthen over the 21st century and thereby affect ozone amounts. A stronger BDC would decrease the abundance of tropical lower stratospheric ozone, increase pole ward transport of ozone and could reduce the atmospheric lifetimes of long lived ODSs and other trace gases. If ODS levels remain high, a large enhancement of stratospheric sulfate aerosol in the next decade, e.g., due to a volcanic eruption of the same size as Mt. Pinatubo, could result in chemical losses of at least 2% in total ozone columns over much of the globe.

Arctic and Antarctic ozone abundances are predicted to increase as a result of the expected reduction of ODSs. A return to values of ozone in high latitudes similar to those of the 1980s is likely during this century, with polar ozone predicted by CCMs to recover about 20 years earlier in the Arctic (2025-2035) than in the Antarctic (2045-2060). Climate change will be an especially important driver for polar ozone change in the second half of the 21st century. Polar ozone levels at the end of the century might be affected by changing concentrations of N_2O and CH_4 through their direct impact on atmospheric chemistry. The atmospheric concentrations of both of these gases are projected to increase in most future scenarios, but these projections are very uncertain.

FUTURE OZONE LAYER IN TROPICS (INDIA SPECIFIC)

Ozone Layer on the Path of Recovery but with a pinch of salt for Tropics

Tropical countries were not significantly affected by the ozone depletion problem in the past and even at present there are no significant changes except the increase in the tropospheric ozone which is mainly due to pollution. Total ozone changes in the tropics are smaller than in any other region and amount is also less as compared to mid and high latitude regions of the world. Many of the tropical countries including India were not much affected by stratospheric ozone depletion problem until now but when other part of the world is going towards better days due to success of Montreal Protocol, they may face 3 major challenges in future as follows:

A) ***Abetting Climate Change is vital for Tropical (Indian) ozone in future:*** Tropical ozone levels are most sensitive to circulation changes driven by greenhouse gases viz. CO_2, N_2O, and CH_4 increases. The N_2O deplete ozone very effectively which will get aggravated in tropics due to Brewer-Dobson circulation phenomenon. As a result of this, significant decreases in column ozone are projected during the 21st Century in the tropics that include India.

B) ***Aerosol Increase may pose challenge for Indian ozone:*** Increase in stratospheric aerosols are major problem in India that is likely to deplete ozone. An increasing trend is reported in stratospheric aerosols in developing countries like India that can negatively impact the ozone layer over the tropics. The increase in aerosols could also be caused by injection of sulfur by geo-engineering that is proposed by one Noble Lauriat to deal with climate change but contested later.

C) ***Air pollution may put challenge:*** Total ozone may increase due to increase in tropospheric ozone. But it will adversely affect us because here Ozone acts as Greenhouse Gas and contributing to climate change and goes to cycle as mentioned in (a). Due to emissions from fossil fuel, bio-fuel, industries and power sectors, tropospheric ozone is increasing as advocated since long by scientists from IITM.

Increasing greenhouse gas emissions and consequent change in the weather system will impact the ozone layer badly if proper control measures are not taken to curb the greenhouse gas emissions.

THE BREWER-DOBSON CIRCULATION (BDC)

On average, air moves upward into the stratosphere from the troposphere predominantly in tropical latitudes, and descends in higher latitudes. This broad pattern of global circulation was first inferred from observations of water vapour and ozone in the stratosphere by Alan Brewer and Gordon Dobson more than a half-century ago. The descent is the primary mechanism that brings down ozone-rich air from the middle and upper stratosphere to the lower stratosphere, strongly affecting latitudinal gradients in total ozone, especially in winter and spring. There are two branches of the BDC, a deep branch that extends to high altitudes in the stratosphere and even to the mesosphere, and a shallow branch that transports air from the tropics pole ward within the lower stratosphere.

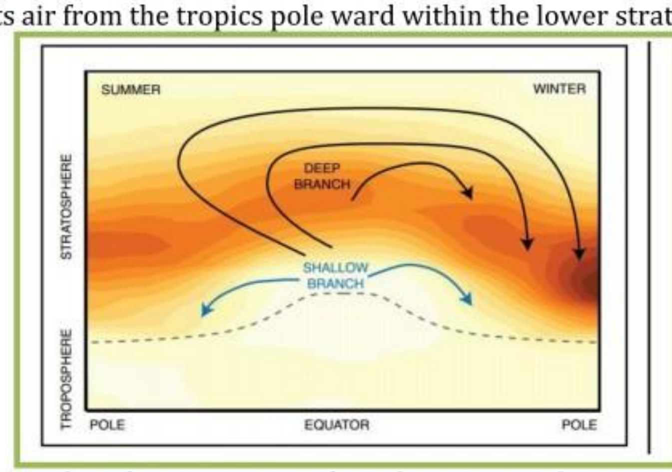


Figure shows the Meridional cross section of Northern Hemisphere winter ozone density (colour shading, with darker shades indicating larger ozone concentrations), and the approximate location of the tropopause (dashed curve).

"The ozone success story should boost our moral to display the same level of urgency and unity to meet challenge of climate change. Human activities will continue to change the composition of the atmosphere"
- Gufran Beig, Project Director, SAFAR/IITM - ENVIS Coordinator / Member, Review Panel of UNEP-WMO report on Scientific Assessment of Ozone Depletion 2014

2014 OZONE HOLE UPDATE

According to scientists from NASA and NOAA, the Antarctic ozone hole reached its annual peak on September 11, 2014 with the size of 24.1 million square kilometres (93 million square miles). Overall, the 2014 ozone hole is smaller than the large holes of the 1998–2006 period, and is comparable to 2010, 2012, and 2013.

DO YOU KNOW?

- *The 2014 level of chlorine containing CFC and bromine containing halons over Antarctic has declined about 9 percent below the record maximum in 2000.*
- *In 1987, ODS contributed about 10 gigatonnes of CO_2 equivalent emissions per years. The Montreal Protocol has reduced these emissions by 90%. This decrease is about 5 times larger than the annual emission reduction target for the first commitment period (2008-12) of the Kyoto Protocol on climate change.*
- *The atmospheric abundance of HFC-23, a potent greenhouse gas, has more than doubled in the past two decades and reached 25 ppt in 2012*
- *HFCs do not harm the O_3 but many of them are potent GHG and gas is roughly 2,100 times as effective as CO_2 at trapping heat. They currently contribute about 0.5 gigatonnes of CO_2 equivalent emission per year. These emissions are growing at a rate of about 7% per years. Left unabated, they can be expected to contribute very significantly to climate change in the next decades.*

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