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Effects of Ozone on Vegetation

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Air-pollutant ozone and its effect on agricultural productivity in India are discussed. Surface ozone concentrations in the Indian region, as obtained from chemical transport model HANK and AOT40 are presented. Estimates of losses in agricultural productivity from exposure to ozone are based on several different experiments in Europe and America. Possible adaptation measures are also discussed.

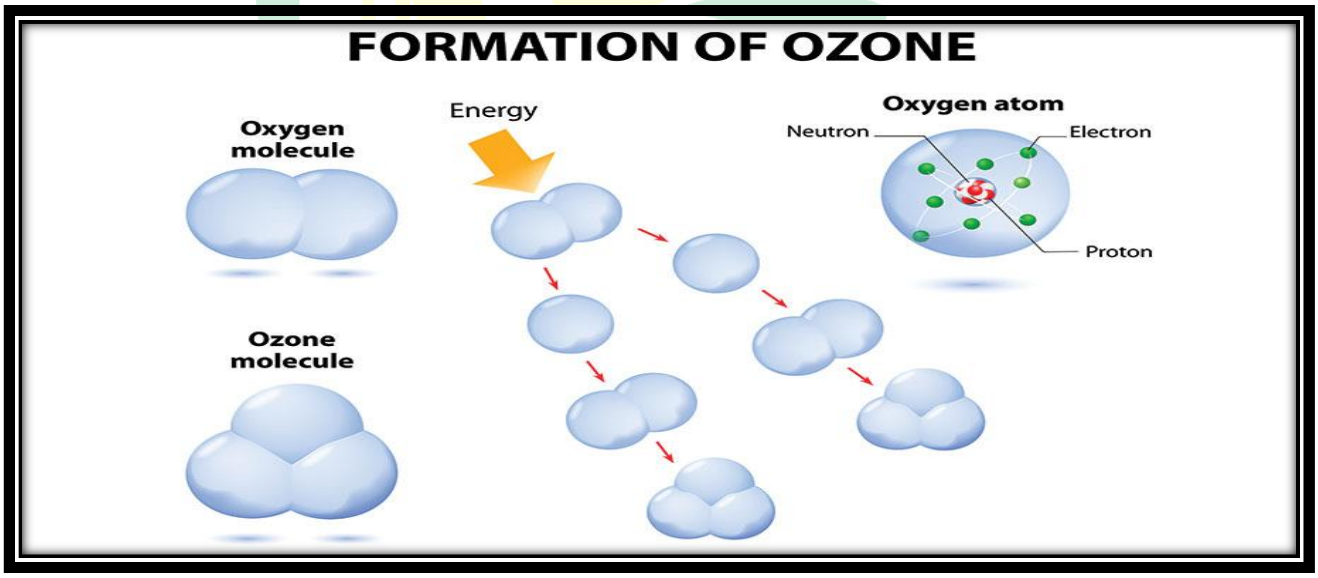
Introduction

Air pollutants like ozone (O_3), carbon monoxide (CO), oxides of nitrogen (NO_x), ammonia (NH_3), and carbon dioxide (CO_2) not only affect the global climate and air quality but also the agricultural productivity directly (Fig. 1).

Tropospheric ozone is an oxidant that damages agriculture, ecosystems, and materials. Ozone creates reactive molecules that destroy rubisco, an enzyme crucial for photosynthesis. O_3 effects on vegetation occur during the growing season, when stomatal gas exchange is active. It is also known to make leaves age faster. The preliminary data, suggests that yields will be cut by up to 10%.

Rising carbon-dioxide levels had previously led researchers to make rosy predictions about crop yields in coming decades — the gas promotes growth by increasing rates of photosynthesis, among other effects. But much of the work has been based on greenhouse trials and has ignored the impact of ozone concentrations near the ground. Urban air pollutants are expected to push up levels of near-surface O_3 by at least 25% by the middle of this century, but rises in China and in India could be two to three times as great. After deposition to land, NH_3 increases nitrogen eutrophication of oligotrophic habitants. Subsequent nitrification of NH_3 leads to acidification of soils and watercourses. Concentrations of air pollutants, including surface O_3 have historically increased in both polluted and remote regions and now frequently exceed regulatory standards. Global background surface O_3 concentrations have roughly doubled since pre industrial times, primarily because of increases in anthropogenic emissions of nitrogen oxides (NO_x), carbon monoxide (CO), and methane (CH_4), and are projected to continue to increase.

Temporal and spatial critical load exceedances of air pollutants need to be developed for viable economic and environmentally friendly policy activities. Every exceedance of critical loads of one of these air-pollutants may cause potential harmful effects to ecosystems in long-term.



Temporal and Spatial Variation of Ozone in the Indian Region

Few point measurements of surface ozone in India that are available, are not sufficient to make any assessment of its impact on agricultural productivity. However, all the available measurements of surface O_3 concentrations show increasing trends in the ambient air at most places during last few years. This is apparently due to increasing emissions of precursor gases from fossil fuel combustion and some agricultural practices. In view of the above cited limitations an effort has been made to develop a gridded distribution of the chemical species over the Indian region using a three-dimensional, episodic, nested, regional, chemistry, transport model HANK (Hess et al., 2000). Using this model, O_3 concentrations in the entire Indian region with an hourly temporal variation are obtained for 120 days.

The computed results from the model show substantial temporal and spatial variation in the tropospheric O_3 concentrations in different parts of the Indian regions, due to different meteorological conditions and topography. Daytime monthly average ozone concentrations varying between 25 ppbv and 100 ppbv are shown as contour plots in Fig.2. Maximum value of the concentration occurs in March. In general concentrations increase from February to March and then start decreasing from April to May.

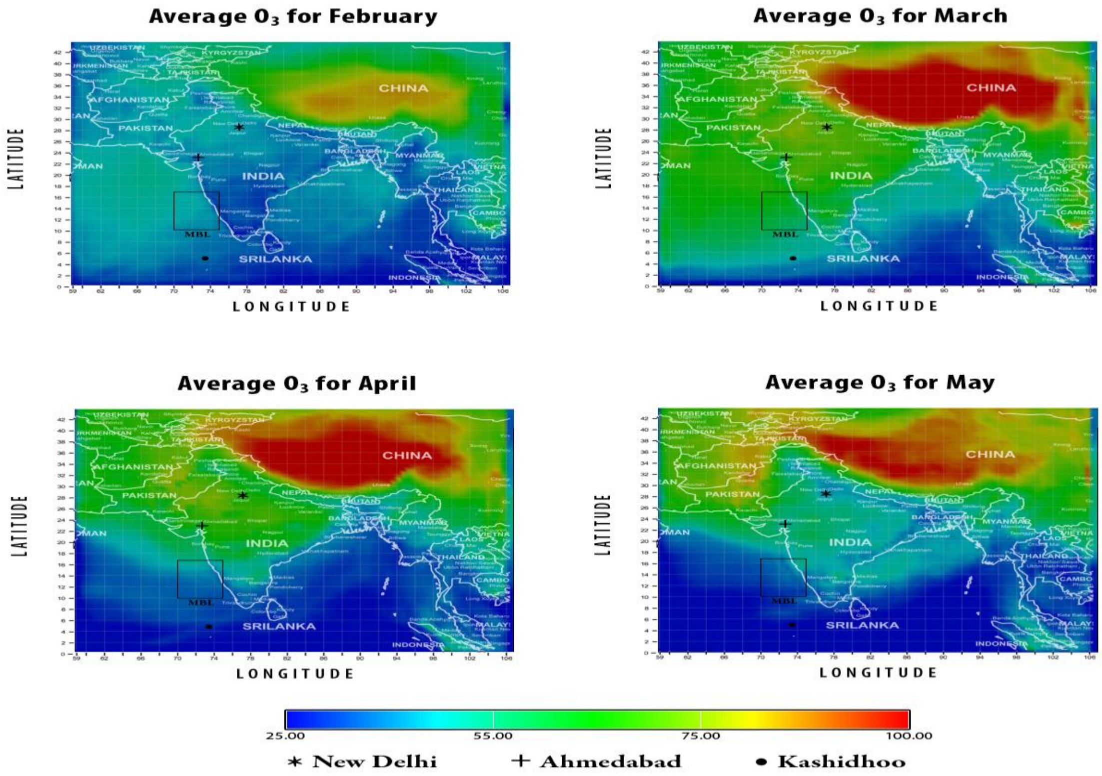
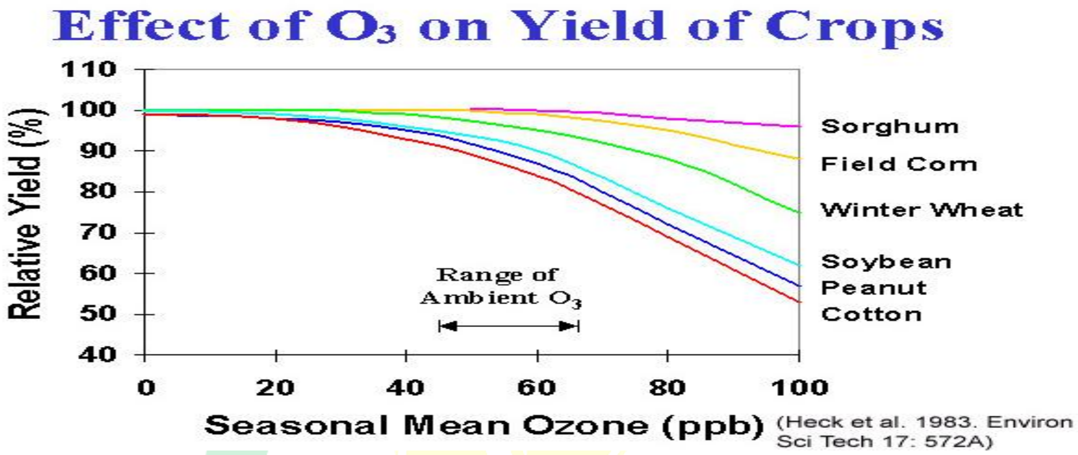
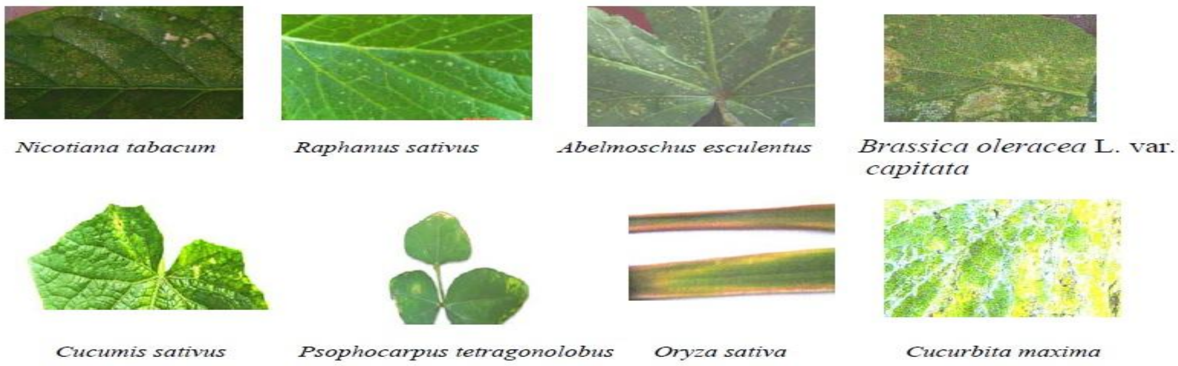


Figure 2: Average daytime monthly ozone concentration in the Indian region

Effects of Ozone

Ozone enters the plant leaves through its gas exchange pores.It dissolves in water within the plant and reacts with chemicals causing a variety of problems.Some cell membranes become leaky.Photosynthesis slows down. Slow plant growth.Ozone induced compounds interfere with cell energy production in mitochondria.Decrease in the number of flowers and fruits. Impair with Water Use Efficiency (WUE).Make plants more susceptible to pests, diseases and drought.Leaves get tiny light – tanirregular spots less than 1mm in diameter (flecking) , small darkly pigmented areas approx. 2-4 mm dia. (stippling) , bronzing and reddening.Reduces soil fertility.





Yellowing of leaves after exposure to ozone

Reddening in leaves after exposure to ozone

Mitigation and Adaptation Measures

Although rising levels of air-pollutants are increasingly being recognized as a potential threat to productivity losses especially in agriculture, in most places including the Indian region, institutional and policy responses have been limited to *adhoc* mitigation measures only for emission of precursor gases from some key sectors. However, since implementation of even the most sincere and effective mitigation measures may leave behind some residual pollutants both from current level of activities and due to growth in economic activities, it would be necessary to simultaneously look for appropriate coping mechanisms to enhance the adaptive capacity, and thereby reducing the vulnerability of natural and human systems. The policy challenge therefore lies on one hand in identifying activities to reduce air pollution in a cost-effective way through legislation, scientific and technical options, economic instruments, information and awareness, and appropriate institutions and on the other in identifying appropriate adaptation options for avoiding and/or minimizing adverse impacts and costs.

Adaptation Strategies

Adaptation options can be classified into the following categories:

1. Technological developments (e.g., new crop varieties, water management innovations etc.) These options will take time.
2. Changing the cropping calendar to take advantage of the wet period and to avoid extreme weather events during the growing season.
3. Government program and insurance (e.g., agricultural subsidies, private insurance).
4. Farm production practices (e.g., crop diversification, irrigation).
5. Farm financial management (e.g., crop shares, income stabilization programs).

Conclusion

There is general consensus that surface O_3, which is on rise in ambient air, have adverse effects on the agriculture productivity. This is particularly important for developing countries like India where ensuring food security to a large population of more than a billion is a major task. Climate researchers are urgently working on ways to help farmers plan ahead. One approach is to combine climate simulations with software that models crop yields, to predict agricultural boom or bust. Further studies are needed to understand the integrated effects of air pollutants like NH_3, CO_2, and O_3 on the agricultural productivity. There is a need to reduce emissions of precursor gases to reduce the O_3 formation in the troposphere. In addition, appropriate adaptation programs/ policies should also be devised to help the vulnerable communities cope with the adversities of impacts of elevated surface O_3.

There are a few technological measures that can help protect the agricultural crops. These include developing chemicals that will minimize the ozone effects; and developing genetic seeds, which are tolerant to current air pollutant levels. These approaches are time consuming and may cause other undesirable consequences. In the long run, the best approach is to limit the amount of pollutants released in the atmosphere. Education is possibly the most effective approach to reduce the air pollution. We seek cost effective and technically feasible emission reduction policies.

A data base of air pollutant concentrations across the region along with the climatic conditions and field experiments with crops exposed to different levels of the pollutants are needed to study the impacts and suggest the adaptation and mitigation measures.