Table 9. Mean total ozone values and deviations of 5-year averages from long period means (Ahmedabad/Mount Abu)

| Year | Mean | SD | Deviation from 1960–84 mean |
|---|---|---|---|
| | D.U. | | |
| 1960–64 | 258.6 | — | −7.2 |
| 1965–69 | 256.2 | — | −9.6 |
| 1970–74 | 259.4 | — | −6.4 |
| 1975–79 | 270.2 | — | +4.4 |
| 1980–84 | 284.4 | — | +18.6 |
| 1960–84 | 265.8 | 13.7 | — |
| 1960–74 | 258.1 | 12.6 | — |
| 1975–84 | 277.3 | 16.6 | — |
| Total ozone | mean (1975–84)−mean (1960–74) = 19.2 DU. | | |

This difference is statistically significant even at 1% level.

the years 1960–84, the mean for 1982 being taken at about the same value for 1983, after seeing the trend for 1981 and 1983.

While generally a decreasing trend has been noted at the other stations discussed before, the Ahmedabad/Mount Abu series has shown marked rise in the year 1976 to 1984.

## Concluding remarks

In the above paragraphs the monthly and annual data of Kodaikanal, New Delhi and Varanasi have been analysed using two approaches, i) the listing of monthly means of total ozone which lie outside the long-term mean ± 2 SD, covering a period of 24–28 years, and ii) a study of the five-yearly averages of the monthly means compared with the long-term means using $t$ test of significance and also a study of linear trend in the series where feasible.

The result of the first approach is that there are generally only a few values lying outside the range given by long-term mean ± 2 SD. Interestingly the monthly series formed by combining Ahmedabad and Mount Abu for different periods shows a similar feature.

In the second method of using five-yearly means, Kodaikanal and New Delhi show few significant deviations. Varanasi, however, shows a larger number of significant deviations. For Ahmedabad–Mount Abu, the difference between (1960–74) and (1975–84) means, is found to be significant even at the 1% level. Another feature noted is the very significant rise in the years 1976 to 1984 giving a mean for the total ozone amount for 1980–84 of 284.4 DU higher by 18.6 DU over the long-term mean. The linear trend study of Kodaikanal data shows how small the CCs and regression coefficients are in most of the months. For New Delhi, the linear trend of the annual series shows no significance statistically.

A comparison of Kodaikanal mean data 1960–88 analysed here and the corresponding means given by Newell and Selkirk[1] shows close agreement differing in many months by only one or two units.

The above results broadly support the view that Indian data considered for this analysis are consistent, though there seems to be a need for closer examination of the data of Varanasi and Ahmedabad/Mount Abu.

1. Newell, R. I. and Selkirk, H. B., *Q. J. R. Meteorol. Soc.*, 1988, **114**, 595–617.

# BOOK REVIEWS

**The Holes in the Ozone Scare.** Rogelio A. Maduro and Ralph Schauerhammer, 21st Century Science Associates, Washington, DC, USA, 1992, 356 pp.

Just 20 years ago there was very little public awareness of the existence of ozone in the upper atmosphere and still less of the important role that it plays in filtering out the harmful ultra-radiation from the sun. Now, of course, every educated person has heard about the hole in the ozone layer in the Antarctic, resulting from (it is widely believed) the release into the atmosphere of man-made chlorofluorocarbons (CFCs). Governments have acted with unusual speed in reaching international agreement to protect the ozone shield by banning the manufacture of CFCs. How has all this come about?

According to Maduro and Schauerhammer in their provocative book, the present ozone scare is nothing more than an enormous hoax perpetrated by a few of the world's leading chemical manufacturers who stand to make vastly increased profits by selling expensive patented replacements for CFCs. Once they had realized this possibility, the manufacturers overcame their initial opposition to the scientists who were advocating a CFC ban and used all their influence to stir up public opinion in favour of the ban. But, say Maduro and Schauerhammer, the ban is completely unnecessary and will do far more harm than good; in their view the so-called hole is a natural phenomenon and there are no grounds for trying to scare the public into believing that the continued use of CFCs would lead to disaster.

Before examining these various claims in more detail, it may be useful to recall a few of the salient facts about atmospheric ozone. This triatomic form of oxygen ($O_3$) is formed mainly in the upper stratosphere (above 30 km) by the action of ultra-violet light on oxygen ($O_2$). The ozone itself strongly absorbs ultra-violet of wavelengths around 300 nm and in doing so is broken up into a molecule of oxygen and an atom of oxygen. Ozone is also destroyed by a variety of chemical processes in the stratosphere, principally involving chlorine and nitrogen. The amount of ozone in the stratosphere at any one time represents the equilibrium between these various processes. If all the ozone were concentrated at the earth's surface, it would form a layer approximately 0.3 cm thick; in fact, some 90 per cent of the ozone occurs between 12 and 45 km altitude. The ozone amount in the vertical column above any given place depends greatly on the latitude and season, there being a fairly regular annual cycle with a maximum in the spring and a minimum in the autumn; at Tromsø in Norway, typical of the northern polar region, the average amount in February is almost double that in November. The amplitude of the annual cycle is somewhat smaller in the southern polar region while in the tropics it is smaller still. In addition to the annual cycle, there are also very large changes from day to day and also quite significant changes from year to year in the annual mean values. Because of these large variations and the difficulties in making very accurate measurements of the ozone amount, it is by no means easy to detect with any degree of certainty any small trend in the global amount of ozone over a period of a decade or two.

When ozone measurements were started at Halley Bay (75°S) in 1957 (during the International Geophysical Year), it was found that, as expected, the amount of ozone was low in the Antarctic autumn but failed to rise during the spring; only in November did it rise suddenly to reach the values which had been expected by comparison with corresponding latitude and season in the northern hemisphere. The famous pioneer of research in atmospheric ozone, G. M. B. Dobson, considered that this *anomaly* (as he called it) was related to the very low temperatures in the Antarctic stratosphere being maintained by the intense vortex of strong westerly winds blowing round the Antarctic continent which does not break down until November. In 1985 J. Farman reported that there had been a dramatic change in the annual ozone cycle at Halley Bay in that in spring the amount actually *decreased*, with values some 20 per cent less than in previous years. It is this phenomenon, which still occurs each year to a greater or lesser extent, which has come to be known by the rather misleading name of hole in the ozone layer.

So much for some of the relevant features of atmospheric ozone. What do Maduro and Schauerhammer have to say? After stressing the undisputed merits of CFCs as refrigerants (they are cheap, stable, chemically inert and non-toxic), they outline the Rowland and Molina theory, according to which CFCs no longer remain inert when they reach the stratosphere. This they can do precisely because their chemical stability in the lower atmosphere ensures that their lifetime is long enough to enable them to be transported gradually to the stratosphere by convection and mixing. In the thin stratospheric air the CFCs are broken down by ultra-violet radiation to release chlorine which attacks the ozone. The authors do not find this theory very convincing. They point out that the maximum possible amount of chlorine released by CFCs is insignificant compared with the amounts entering the atmosphere from other sources, notably by evaporation from seawater and emissions from volcanoes. They consider that although much of the chlorine from these other sources is quickly removed from the atmosphere, for example by rain, significant amounts can still penetrate into the stratosphere. They claim that scientists measuring chlorine in the stratosphere deliberately try to make the public believe that all the chlorine in Antarctica comes from CFCs.

The next chapter describes what the authors call the 'ozone wars', which began in the early 1970s with a succession of claims that a variety of human activities could result in ozone depletion. In the debates about the development of supersonic transport aircraft (SSTs), for example, it was argued that the water vapour in the SST exhausts would wipe out the ozone layer. This would allow more ultra-violet radiation to reach the ground, allegedly causing a massive increase in skin cancer. This scare was seized upon by the news media, funding for the American SST was killed and the ozone depletion theory was born. Other claims were that nitrogen oxides from the testing of nuclear devices or from the use of nitrogen fertilizers would damage the ozone layer. The gases emitted by the solid-fuel rockets of the Space Shuttle were also implicated. It was not until 1973 that Rowland and Molina called attention to the possibility of ozone depletion by CFCs. On the basis of this theory it was variously predicted in 1975 that by 1990 the ozone layer would be depleted by anything between 10 and 18 per cent. Although these predictions proved to be wrong, some of the scientists who made them are now 'in top posts with command over scientific journals and associations and, ultimately, public opinion. In this intensely political situation, the doomsday scientific establishment thus decides who is published in the literature and who receives grants···. Scientists who have had the courage to oppose the doomsday theories in public have had their papers rejected for publication, their grant money discontinued, and in some cases, have even lost their research and teaching positions.' In a book which 'aims to provide the scientific evidence that will enable the reader to make his own informed judgement' one would have expected to find some evidence to justify such bald statements.

Chapter 3 discusses the validity of claims that ozone depletion has been observed on a global basis—for example, the American Ozone Trends Panel reported in 1988 a decrease in global ozone of 0.2 per cent per annum since 1969. Maduro and Schauerhammer ask why begin in 1969, which happened to be a peak year for ozone? They claim that if the Panel had picked on the 17 years from 1962 to 1979 they would have found an *increase* in the ozone amount! They also stress the inaccuracies in measuring ozone amounts and cast doubts on the way in which earlier ozone observations have been re-analysed. Furthermore, they question the statistical significance of the reported trends, bearing in mind the large natural variability in ozone amounts, including an 11-year cycle related to sunspot activity. They also underline the uncertainties in predictions of future trends based on different models; some have predicted an 18 per cent reduction in the next 100 years while others say that it will be more like 5 per cent. Finally they quote a statement by one of the leading ozone depletion protagonists to the effect that scientists, although ethically bound to tell the truth, the whole truth and nothing but the truth, sometimes have to 'offer up scary scenarios, make simplified dramatic statements, and make little mention of any doubts' in order to get media coverage and capture public imagination.

In the next chapter, the authors discuss what 'really' happens to CFCs released into the atmosphere. They claim that the Rowland/Molina theory rests on the assumption that the only significant sink for CFCs is in the stratosphere through photodissociation by the ultra-violet radiation. This assumption is in their view incorrect. There are several other possible sinks, such as the action of microbes in the soil and of lipoproteins in plants, not to mention absorption into the oceans. They also argue that as CFCs are only affected by ultra-violet radiation of very short wavelengths which do not penetrate into the lower stratosphere (having been absorbed at higher altitudes by $O_2$ and $O_3$), they can only be destroyed if and when they reach the upper stratosphere. But, say Maduro and Schauerhammer, measurements show that the concentrations of CFCs decrease rapidly after they enter the bottom layer of the stratosphere; they barely reach altitudes where photodissociation can occur. The diagram which they reproduce to support this statement is however not in itself convincing; they claim that it shows clearly that CFCs do not rise above 40 km but in fact the concentration curves stop at about 32 km, at which height some of the CFCs are still present in significant amounts.

Chapter 5 contains the authors' views on the 'hole' observed by Farman and others above the Antarctic continent. They write that it was the announcement of this discovery in 1985 which revived dramatically the CFC ozone issue which had been relatively dormant since the banning of the use of CFCs in aerosol in the United States in 1978. Although this particular form of ozone depletion had not been predicted by the Rowland/Molina theory, it immediately became 'the proof that the depletion theorists had been looking for'. But Maduro and Schauerhammer do not recognize any difference between what Farman reported and what Dobson had described nearly 30 years earlier. For them there is no need to look for new explanations, such as the effects of chlorine released from CFCs, to account for the so-called Antarctic ozone hole since it was well-known decades before man-made CFCs could possibly have had any impact. In support of their view, they refer to a paper by Rigaud and Leroy in 1990 in which a re-examination of the IGY ozone records at Dumont d'Urville (67°S) revealed ozone levels in the spring of 1958 even lower than those reported by Farman. They believe that the intensity of the regular annual depletion in the Antarctic stratosphere varies from year to year; it is ephemeral, 'depending perhaps on variations in stratospheric temperatures, water vapour or chlorine from volcanic eruptions'.

The main reason for public anxiety about the hole in the ozone layer is of course the predicted increase in harmful ultra-violet radiation reaching the earth's surface and the resulting increased incidence of skin cancer. This is the subject of chapter 6. The ultra-violet spectrum extends approximately from 400 to 40 nm. The shortest waveband, known as ultra-violet C (286 to 40 nm) is almost completely filtered out by $O_2$ molecules in the upper stratosphere, with the creation of ozone in the process. The ozone also filters out ultra-violet all the way from the C band to the end of the B band (320 to 286 nm). In this way, practically all the C and B radiation is absorbed in the stratosphere. Any remaining ultra-violet B which reaches the ground is biologically active; for example it causes sunburn and skin cancer, especially in fair-skinned people. A five per cent reduction in ozone would allow roughly 10 per cent more B radiation to penetrate to the ground with a corresponding increase in cancer. Maduro and Schauerhammer stress that there is no evidence that ultra-violet B causes the malignant form of skin cancer (melanoma); the much commoner benign cancer which it produces responds readily to treatment and, although it can be disfiguring, it rarely kills its victims. The big increase in melanoma in the United States in recent years has 'absolutely nothing' to do with CFCs and ozone depletion; it can be explained by better reporting and by changes in lifestyle. The amount of ultra-violet reaching the ground increases rapidly with a decrease in latitude; a 10 per cent increase would result from only a 100 km displacement towards the equator. Why, our authors, ask, are people so scared about possible ozone depletion? If, as some authorities claim, the global ozone has already decreased by 3 per cent since 1969, there should have been an increase of 6 per cent in the ultra-violet reaching the ground. From the scientific literature the authors were unable to find any evidence of such an increase—rather the reverse. They go so far as to claim that the data 'that could answer the question are being suppressed'.

The remaining chapters of the book can be summarized very quickly. Chapter 7 discusses the consequences of the Montreal Protocol of September 1987, which set the first global controls on the use of CFCs, and of subsequent agreements to strengthen some of its provisions. The authors believe that the prospects of finding suitable replacements for CFCs as refrigerants are not good. The ban on CFCs will therefore result in 'a collapse of food storage capacity worldwide', leading to the deaths of between 20 and 40 million individuals every year. CFC replacements will in any case be 10 to 30 times more expensive and all existing refrigerators will have to be scrapped and replaced. The global costs will amount to more than 500 billion dollars per year by the year 2000.' The only people to profit will be the manufacturers who have been advocating the CFC ban. The Montreal Protocol also calls for the banning of several other chemicals alleged to harm the ozone layer, as for example halons, which are the best available chemicals for use in fire extinguishers and for which there is no known suitable substitute. According to the authors, 'thousands of people will die every year in fires because of the ban on halons—murdered by the environmentalists, as effectively as if they had put a gun to their heads and pulled the trigger'.

In chapters 9 and 10 the authors examine in more detail the role of the big corporations in pushing the ban on CFCs. Along with the big foundations, they provided financial support for environmental organizations and encouraged them to stir up public opinion in favour of the ban. Without their support 'there would have been no Montreal Protocol'. As for the leaders of the environmental movements, the majority are motivated by their firm belief 'people are the problem' and that depopulation is therefore the only way to save the planet. The top ozone depletion propagandists not only know that the CFC ban will kill people, 'they *want* it to'. For their part, the authors believe that the underlying disease causing biological and ecological disaster is poverty. This can be overcome by economic development, for example by embarking on giant projects to improve the world's transport systems, water supplies and power systems. There are no 'limits to growth'. There are in fact too few people in the world. The authors' dream is that when these great projects here on Earth are underway we can renew our efforts at space exploration and colonization. Eventually we shall transform Mars 'from a dead desert into a beautiful garden, fit for billions of human beings'.

For scientists who harbour any doubts about the wisdom of politicians in banning CFCs (in their desire to at least appear to be 'green'), this is a very disappointing book. If the authors had restricted themselves to an impartial and objective examination of the evidence, they might have succeeded in strengthening some of these doubts. As it is, the gross overstatement of their case, the virulence of their accusations—not to mention their numerous mistakes—can only be counter-productive for any thinking person. They accuse the 'ozone priesthood' of making fraudulent claims and of using scare tactics to alarm the public in order to gain support (and there may well be an element of truth in this), but they themselves are even more guilty of the same crimes. In the simplest terms, there has been a substantially greater depletion of ozone in Antarctica in each of the past ten years than in previous years, and the most convincing explanation to date is that CFCs are the main culprit. If this is confirmed, there is good reason to believe that the amount of stratospheric ozone will in due course be depleted in other parts of the world—there is some evidence that this has already begun. Even without the risks of increased incidence of skin cancer (perhaps the weakest part of the arguments of the 'ozone priesthood'), there would be a good case for replacing CFCs by some other less harmful chemicals. Politicians may have been somewhat precipitate in banning CFCs so quickly, but they are unlikely to be persuaded to change their minds by the biased misrepresentations of Maduro and Schauerhammer.

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**Ozone Depletion—Implications for the Tropics.** Mohammad Ilyas, ed. University of Science, Penang, Malaysia and United Nations Environment Programme, Nairobi, Kenya. 1991. pp. 374. Hardbound.

This monograph contains selected papers presented at the International Conference on Tropical Ozone and Atmospheric Change held at Penang, Malaysia, during February 20–23, 1990. The conference was the first such meeting which dealt comprehensively with all aspects of the ozone depletion problem with special reference to the tropics. This conference also provided the first professional forum at which the UNEP ozone layer review reports were presented.

Many of the papers have undergone revision by the authors after presentation at the conference, incorporating later findings or results or the conclusions as modified by the conference deliberations. As such, the usefulness of this monograph is considerably enhanced.

The volume is divided into six parts. Part 1 entitled 'Protection of ozone layer: Overview' contains seven papers of which three are devoted to overviews on different aspects of ozone depletion by independent scientists and four are UNEP Ozone layer overviews. The first paper on 'Chlorofluorocarbons and ozone depletion' is by F. S. Rowland, who was the first to point out the adverse effects of chlorofluorocarbons (CFCs) on atmospheric ozone. It contains a masterly analysis of the role played by man-made CFCs in depleting atmospheric ozone. The pioneering investigations made by himself and his group in the US from 1974 are summarized. The crucial role of the chlorine atoms contained in CFCs in destroying ozone by a kind of catalytic chain reaction is stressed and the predictions made in 1974 about an eventual loss of 7 to 13% of global ozone, resulting from continued emissions of CFCs into the atmosphere, are discussed. For a test of their 1974 calculations, balloon-borne measurements of CFC concentrations were made in 1975 in the US by NASA and NCAR groups up to altitudes of 35 km. The close agreement between the theoretically predicted vertical distributions and the experimentally determined ones is remarkable. A slight but significant decrease in total ozone over the high and middle-latitudes observed in recent years, and the phenomenon of the 'Antarctic ozone hole' is then discussed. The flights made by ER-2 aircraft into the Antarctic polar vortex at heights of 18 to 19 km to measure concentrations of chlorine oxide (ClO) and ozone ($O_3$) revealed spectacular results. The sudden decrease in ozone mixing ratio while traversing certain latitudinal belts is accompanied by an equally sudden increase in the ClO mixing ratios, thus establishing conclusive evidence that ClO is the primary agent responsible for the ozone loss in Antarctica. In conclusion Rowland observes—'My recommendation made first in 1974 has now been adopted globally—all uses of CFCs should be eliminated'.

The second overview is by J. C. Farman, who was the first to report ozone depletion over Antarctica in 1985. It deals primarily with the formation of the 'Antarctic ozone hole' and its link with chlorine and ClO. The sequence of atmospheric processes leading to the 'hole' are: transport of ozone and photodecomposition products of halocarbons deep down into the polar stratosphere, the isolation of polar air as the winter vortex develops, condensation at very low temperatures of nitric acid hydrates forming polar stratospheric clouds, conversion of stable chlorine compounds to less stable forms on the surfaces of nitric compounds in these same particles, the release of ClO and $Cl_2$ radicals when sunlight returns and finally the extremely rapid ozone reduction. Vertical soundings of ozone concentration made at Halley Bay, Antarctica before and after the development of the 'ozone hole' during 1987 are presented, showing that at the ozone