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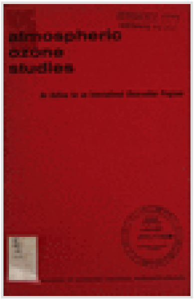

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ATMOSPHERIC OZONE STUDIES

An Outline for an *International Observation Program*

A Report by the Panel on Ozone
to the Committee on
Atmospheric Sciences
National Academy of Sciences
National Research Council

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Dr. Frederick Seitz, President
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D. C.

Dear Dr. Seitz:

As its contribution to consideration of the expanding opportunities new technology affords to an understanding of the global atmosphere as a single physical system, the Academy's Committee on Atmospheric Sciences has reviewed areas of atmospheric research in which a worldwide approach appears to be timely.

Early last year, a special panel was convened under the chairmanship of Professor Julius London to review the observational and research needs for the study of ozone in the atmosphere. Determinations of the physical properties, the physical-chemical interactions, and the distribution of ozone in the atmosphere constitute fundamental problems of intrinsic scientific interest. Moreover, the role of ozone in the radiative-thermal budget and in the dynamics of the general circulation of the upper stratosphere and mesosphere is an important one.

A study of how to extend current observations of ozone from balloons and rockets and a program to develop laser techniques for use from satellite platforms are among the recommendations of the Panel to advance our knowledge concerning this atmospheric constituent and its role in the global circulation.

Our committee invites the attention of the scientific community and of governmental agencies to these and the other recommendations contained in this report. Because 1965 has been designated as International Cooperation Year—dedicated to an assessment of the further steps that can be taken toward enhancing international cooperation—we take particular pleasure in calling attention to these opportunities for international cooperation.

Sincerely yours,

Thomas F. Malone

Thomas F. Malone
Chairman

PREFACE

This report presents a summary of the views of the Panel on Ozone, expressed both in meetings and by correspondence. The suggestions and opinions discussed by participants in the International Planning Conference on Atmospheric Ozone, September 7 and 8, 1964, Santa Fe, New Mexico, were given full and appropriate attention by the Panel. Because this conference contributed significantly to many of the ideas contained in this report, the participants are listed in the Appendix.

The interest and support of the activities of the Panel on Ozone by the Atmospheric Sciences Section, National Science Foundation and the U.S. Weather Bureau, under Task Order No. 9 of NSF-C310, is gratefully acknowledged.

The Panel hopes that this report may contribute in some useful measure to efforts now under way nationally and internationally to enhance international cooperation in the atmospheric sciences.

JULIUS LONDON
Chairman
Panel on Ozone

October 1965

INTRODUCTION

Research in the atmospheric sciences during the past 15 years has uncovered a host of important and intriguing problems involving the structure and dynamics of the stratosphere and mesosphere. The breakdown of the winter polar vortex in the stratosphere and the large reversed seasonal temperature variation in high latitudes at the mesopause are but two cases in point. Research efforts directed toward treating these problems require knowledge of the fundamental physical processes affecting the energetics and motions of this part of the atmosphere (15-80 km). In this region ozone is significantly involved, both directly and indirectly, in such processes.

In the lower stratosphere the ozone mixing ratio is a quasi-conservative property of the air and can be used in diagnostic studies to trace various scales of atmospheric motion. At higher levels, because of its strong absorption of solar ultraviolet radiation, ozone plays a dominant part in the radiative-thermal budget and thus helps to develop some of the characteristics of the general circulation of the upper stratosphere and mesosphere. A broad program to increase our knowledge of the physical properties and distribution of atmospheric ozone is thus of utmost importance if we are to attempt to deal with and solve some of the fundamental problems of this region of the atmosphere.

ATMOSPHERIC OZONE

Ozone is formed in the atmosphere primarily by photochemical processes. Molecular oxygen is dissociated into two atoms through absorption of solar ultraviolet radiation. Subsequent collisions involving atomic and molecular oxygen form ozone. It is then destroyed either by photodissociation or in collision with atomic oxygen to reform molecular oxygen. Destruction also takes place when ozone is brought into contact with the earth's surface. In addition to these, there are many other reactions that may be pertinent in defining the details of ozone distribution.

Since both the production and the destruction of ozone depend largely on the availability of atomic oxygen particles and of the relevant ultraviolet radiation, the half-restoration period, describing the speed with which the ozone concentration approaches its equilibrium amount, varies with both height and mean solar zenith angle. The half-restoration period is about 1 hr at 50 km at all latitudes and during all seasons. This increases at 35 km to approximately 5 days (60° latitude - summer) and 100 days (60° latitude - winter). At 20 km, the half-restoration period at all latitudes is of the order of years, which for most meteorological purposes is forever. Thus, ozone is nearly in photochemical equilibrium at 50 km and is a reasonably conservative property of the air at all levels below 20-25 km, except very close to the ground. Thus the ozone distribution below 25 km is largely determined by photochemical production in the stratosphere and atmospheric motions in the upper troposphere and lower stratosphere.

Above 50 km, the daylight restoration period for ozone increases gradually with height. This period is about 1 day for continuous sunshine at 75 km. At night, however, as soon as photodissociation of ozone stops, the ozone concentration increases sharply and, at these heights (upper mesosphere), the concentration may reach a maximum of as much as 10^{11} molecules/cc just before local sunrise. At sunrise and immediately after, ozone is quickly dissociated (whereas there is not yet enough atomic oxygen for rapid production) so that its concentration may be far below its equilibrium value. It then increases slowly toward sunset.

Ozone is one of the active radiating gases in the atmosphere. It has both infrared and ultraviolet absorption spectra that contribute significantly to the radiation budget of the stratosphere and mesosphere. The major radiative importance of ozone comes, of course, from its strong ultraviolet absorption in the spectral interval 2200 Å to 3200 Å (Hartly bands), which, for instance, produces the temperature maximum at the stratopause.

Observations of total ozone have been made at an increasing number of places since 1925. The present network for total-ozone measurements includes 80-90 stations, of which about 90 per cent are in the Northern Hemisphere. As a result of these observations the climatological distribution of total ozone is becoming known. It is found that, in general, total ozone increases with latitude (the largest latitudinal gradient being generally located in middle latitudes). In addition to this well-known latitudinal variation, there is a pronounced longitudinal variation in total ozone, such that there are marked ozone ridges associated with troughs in the mean contour field in the upper troposphere and lower stratosphere. The geographic variation with respect to both latitude and longitude is found to be greatest during the spring and least during the fall. Also, this variation seems to be much more marked in the Northern Hemisphere than in the Southern Hemisphere.

Data concerning the vertical distribution are not as complete as those for total-ozone distribution. Available observations indicate, however, that ozone exists in relatively small concentrations throughout the troposphere (average value near 5×10^{10} molecules/cc). Seasonal and latitudinal variations are most pronounced in the lower stratosphere, where the concentration increases markedly with height. The surface of maximum ozone concentration in the vertical slopes downward with increasing latitude from 26 km in the equatorial region to about 18 km in the Arctic and Antarctic regions. Highest concentrations in the stratosphere are found at high latitudes in the late winter and spring and are of the order 5×10^{12} molecules/cc, which is a factor of 2 larger than the peak values observed near the equator throughout the year.

Above the level of maximum concentration the ozone amount decreases, and during the daytime is probably of the order of 10^9 molecules/cc at 75 km. Theory predicts, and the <u>single</u> existing nighttime observation indicates, that during the night there is a secondary ozone maximum in the mesosphere. Daytime observations indicate that above 40 km the ozone values approach the equilibrium distribution.

At present, very few observations of the vertical ozone distribution are being made on a routine basis. One exception is the excellent North American network of 11 stations established to take observations throughout the period of the International Years of the Quiet Sun.

It has been known for some time that both the total amount and vertical distribution of ozone also vary with synoptic patterns. High total amounts and increased ozone concentrations in the upper troposphere and lower stratosphere are closely associated with deep tropospheric low-pressure systems.

Thus, the distribution and energetics of ozone are basic parameters in studies of the dynamics of the upper atmosphere and its interrelationship with the troposphere. The following discussion presents an outline of the research problems in atmospheric ozone likely to be of importance in this context during the next 10 years; the type of observations needed; and some preliminary suggestions for time and space networks for these observations.

RESEARCH PROBLEMS

The primary focal point for extended observations and research in atmospheric ozone, requiring worldwide cooperation and planning, involves the study of its formation in the stratosphere, its transport downward into the troposphere, and its ultimate destruction at the earth's surface. Most research efforts deal, in one form or another, with this basic problem. Two additional related problems that require careful consideration are: (1) the radiative processes (including photochemistry) in the stratosphere and mesosphere, involving interactions with the dynamics of this region of the atmosphere, and, (2) the physical processes involving possible upper-atmosphere reactions to anomalous solar radiation.

At this time we cannot see any operational use for observations of ozone. Although there are clearly established associations between ozone and large-scale flow patterns in the atmosphere, there are no present indications that ozone information will become a prediction tool for synoptic-scale atmospheric motions. It may be that future research will uncover some significant modes of mechanical energy transfer downward from the stratosphere and/or that our active needs will involve some forecasting skill at higher levels. In either case, at some future time we shall have to re-examine our estimate of the operational importance of ozone observations.

It is convenient to discuss the various research problems under two interrelated headings—one dealing primarily with analysis of ozone observations and the other with the role of ozone in the energetics of the stratosphere and mesosphere. As we shall see in the ensuing discussions, some of these problems require a program of widespread cooperation, whereas other problems (more limited in scope but perhaps of no less importance) can be studied quite satisfactorily by small groups of competent research scientists.

ANALYSIS OF OZONE OBSERVATIONS

Broad problems. As described above, the existing climatological picture of ozone distribution is sketchy and must be improved. The present need is to increase the density of the worldwide network of routine total-ozone observations in both hemispheres. Because of the indicated geographic patterns in total amounts, it is also of great importance to get widespread coverage by observations of the vertical ozone distribution.

The global network of observations, however, is necessary primarily as an aid in the study of the properties of the general circulation of the upper troposphere and lower stratosphere, and the horizontal and vertical transport processes that are part of this general circulation. The knowledge of the differences between photochemical and observed ozone distributions should be used in any evaluation of transport mechanisms in the stratosphere. For this purpose it would be extremely desirable to include these ozone observations in a broad program that would involve measurements of other stratospheric trace substances (dust, water vapor, radioactive isotopes, and particulates, for example) so that a pattern of the upper-atmosphere circulation can be derived that is consistent with the production and distribution of these trace substances. Such atmospheric circulation models must also, of course, provide for balanced momentum and heat budgets of the stratosphere. Thus, knowledge of ozone production and distribution can be used to test the validity of various proposed dynamical models of the lower stratosphere and upper troposphere.

A global ozone study would also aid in the analysis of the differences in the circulation patterns of the Northern and Southern Hemispheres, and in particular the exchange processes that take place between them. For this reason, a worldwide network must include a significant number of observational stations in the equatorial and oceanic areas.

The ozone mixing ratio below about 25 km is a conservative atmospheric property and can, therefore, be followed as a passive tracer to give insight into the mechanics of the tropospheric-stratospheric exchange process. Since the seat of ozone production lies in the stratosphere, and particularly in low latitudes, a dense network of ozone observations could shed light on the manner in which air is exchanged through the tropopause region and ozone is brought into the upper troposphere. Study of its subsequent destruction at the earth's surface is then a necessary part of the understanding of the ozone budget in the atmosphere.

Although it is nearly in photochemical equilibrium at the stratopause (50 km), the ozone distribution departs somewhat from equilibrium values in the upper mesosphere. As a result, short-period changes in the ozone distribution are influenced by motions in this region. Ozone observations taken at various latitudes and during different seasons in the mesosphere are needed to help in understanding the effects of photochemistry and atmospheric motions in changing the ozone distribution at these levels. In addition, since there are large diurnal variations of the photochemical distribution in this region, observations should be taken during both the day and night.

In recent years a 26-month equatorial oscillation in the stratospheric wind and temperature has been found, with indications that a similar oscillation exists in total ozone. This is not surprising since the maximum ozone density occurs at levels close to the observed stratospheric oscillations. It is thus pertinent to extend the investigation of ozone changes in equatorial regions and to develop a sufficiently long series of observations of the vertical ozone distribution at these latitudes to aid in the study of this stratospheric oscillation.

Problems of limited scope. The foregoing discussion concerns some of the basic studies that require a worldwide observational program. In addition, however, there is need for planning with respect to more modest research problems whose investigation is pertinent to some of the details of the behavior of the upper troposphere and stratosphere. Additional studies might be made that would involve three-dimensional analysis of the ozone distribution as related to particular synoptic patterns.

It would be highly useful to have intensified ozone-observational programs (both in space and time) designed to aid in the study of specific stratospheric phenomena. Such programs, for instance, would be extremely valuable in diagnostic studies of the onset and development of the "explosive warming" that sometimes occurs during the winter and spring in the stratosphere. It is known that the more pronounced of these warmings are associated with large increases of total ozone, but as yet there have been insufficient observations of the vertical distribution to delineate clearly the level(s) at which this increase is most important. Detailed observations of the time variations of the ozone distribution during the occurrence of these warming situations would aid in the analysis of the vertical motion pattern associated with this phenomenon.

Another example of a detailed synoptic program could involve the study of local ozone variations as related to the jet stream.

Limited studies might also deal with the problem of tropospheric ozone. Although it is quite clear that the primary mechanism for ozone production is absorption of solar radiation in the stratosphere and mesosphere, it has been indicated that there may be effective local processes of ozone production and destruction associated with lightning discharges, clouds, and dust layers in the troposphere and lower stratosphere. Definitive studies of these relevant problems might well be planned. In addition, studies of the exchange mechanism near the earth's surface and the problems of ozone destruction at the lower boundary are pertinent to an understanding of the entire ozone budget. Such studies should be made over different types of surfaces and, where possible, should be made in connection with existing micrometeorological sites (tower installations, for example).

OZONE AND THE ENERGETICS OF THE UPPER ATMOSPHERE

With regard to the role of ozone in the energetics of the upper atmosphere, the two important problems that require continued investigation are (1) the photochemical production and maintenance of the ozone distribution, and (2) the incorporation of ozone radiative heating and cooling into dynamical models of the circulations of the stratosphere and mesosphere.

Knowledge of the solar spectrum in the relevant region of the ultraviolet is of primary importance for both of these problems. This involves accurate observations of the absolute intensities, including time variations (both short-period and secular changes) in the spectral interval 1200Å to 3500Å.

In addition, improved laboratory data for the pertinent photochemical parameters are needed. These data, for instance, include reaction rates, and their temperature dependence, for the various kinetic reactions that enter into the photochemical equations for ozone. New information must be acquired concerning the concentrations of additional trace substances in the upper atmosphere (H, OH, NO, etc.) because of their part in the photochemistry of ozone and the energy balance in this region.

It should be emphasized that, although water vapor can play a significant role in the energetics and dynamics of the stratosphere, its distribution in the upper troposphere and stratosphere is known with even less certainty than that of ozone. It is particularly important, therefore, that continued efforts be made to develop instrumentation for reliable measurements of the stratospheric water-vapor concentration.

Improved observations of the solar spectrum and of the photochemical parameters, as discussed above, will make it possible to extend the theory of ozone variations in the upper atmosphere. The physical processes can then be outlined and tested to study upper-atmosphere responses to possible variations in solar radiation.

METHODS OF OBSERVATION

At the present time, observations are made of the total amount of ozone (in a vertical column) and of the vertical distribution. The standard instrument used to measure total ozone is the Dobson spectrophotometer. In addition, the Dobson spectrophotometer can be used for observations of the vertical ozone distribution (Umkehr method) and at present it is the only instrument that can routinely give information about ozone in the region 30-45 km. It is suggested that use of the Dobson instrument be extended in a global network, but that considerable effort be made to increase its reliability and sensitivity, make it an automatic recording instrument, and reduce its size and price. In connection with the performance of the Dobson spectrophotometer, it is important that considerable effort be made to check the solar spectrum in the region 2950-3400 Å for accurate calibration of the instrument. For long-period operation of the instrument, both relative intensities and possible time variations of the relevant solar spectrum must be known.

There are many methods of observing the vertical ozone distribution. The most suitable present methods for routine measurements below 35 km seem to be balloonborne chemiluminescent or electrochemical systems. These methods are still in the developmental stage and it is imperative that the instruments be standardized and made more reliable. The response time seems to be quite adequate for foreseeable future needs. With further improvement of both the chemiluminescent and electrochemical sondes, it is essential that the unit cost be reduced so that the necessary routine network of vertical ozone sondes can become economically feasible.

Umkehr observations can be of some value for ozone observations below 35 km despite the lack of adequate resolution, since the Dobson spectrophotometer is used as the standard in the global network. Thus, some information of the vertical ozone distribution can be provided in regions in which there are no ozonesonde programs. This could, for instance, be of considerable help in the study of the 26-month stratosphere oscillation.

In the region of 35-80 km, only Umkehr measurements (for the lower part) and occasional rocket measurements, using spectroscopic techniques (for the upper part) have been successful. Many additional methods have been proposed, such as twilight observations using echo-type satellites, satellite observations of backscattered radiation, and dropsondes from meteorological rockets, making use of an adaptation of one of the balloonborne methods discussed above. These latter techniques could be important as a way of getting nighttime observations, particularly in the mesosphere where large diurnal variations of the ozone concentration are indicated. In this connection, it should also be pointed out that twilight observations of the ozone distribution in the mesosphere would present some difficulty in interpretation because of the probable rapid ozone variation during sunrise and sunset in this region.

The most likely techniques for continuous ozone measurements would probably involve satellite observations, particularly since a large part of the significant ozone distribution is found above tropospheric cloud systems. Laser applications seem the most promising for this purpose, because of their high-intensity and low-dispersion characteristics. Some suitable lasers for use in the Chappius ozone-absorption band are already avaiiable and more are being developed.

MAJOR CONSIDERATION FOR AN INTERNATIONAL OBSERVATIONAL PROGRAM

For study of the various research problems outlined above, it is necessary to plan for an extended network of observations so that pertinent and useful data can be obtained.

The long record of total ozone observations should be continued and the number of stations taking these observations should be increased. In this regard, particular attention should be given to increasing the observational network over equatorial regions, ocean areas, and all areas in the Southern Hemisphere. For observations over ocean areas it is suggested that use be made of some of the existing weather ships, which are in a particularly favorable position to make routine ozone observations.

For purposes of continuity and because of the relative ease of operation, it is suggested that the Dobson spectrophotometer, improved as recommended, be used as the standard total-ozone measuring instrument. Where filter-type instruments are currently in use, and a changeover is not feasible, it is suggested that careful calibration checks be made to insure standardization of the results.

The greatest effort in extending the ozone network must be directed toward the development of routine observations of the vertical ozone distribution. For the region below 30 km, the two balloonborne ozone sonde techniques discussed above, give the most promise and should be further improved. In order to portray the ozone climatology and to investigate the atmospheric transport processes, it is suggested that, at minimum, a vertical-distribution network be established for taking observations once a week; with a skeleton network taking observations more frequently. This minimum network should ultimately consist of stations located along each of three different latitude circles—one near the equator, one in the subtropics (about 30° latitude), and the third at about 50° N latitude. Particularly in the subtropics and high latitudes, at least 12 reasonably well-distributed stations are required at each of the indicated latitudes. The network should also include some observations in polar regions.

In addition, it is suggested that the networks be designed to include three meridional nets, near 80° W, 0°, and 140° E. This network must be so designed that the effect of standing and transient eddies on the horizontal and vertical transport of ozone can be evaluated. Where special efforts are required (e.g., for studies of specific synoptic problems) closer networks should be operated for limited periods of time. Although the largest ozone variations are found in subpolar latitudes, it is important that most observations of the vertical ozone distribution be made in equatorial latitudes, the principal region of ozone production. Observations of ozone variation in this region would contribute to studies of the 26-month oscillation of wind and temperature found in the equatorial stratosphere.

In all observations of the vertical ozone distribution it is desirable to have simultaneous observations of the total amount. In a limited manner, weather-observing aircraft equipped with standard ozone-measuring devices should augment the ozone network, particularly on a synoptic scale. In order to study possible mechanisms of tropospheric ozone production and destruction, it would be desirable to take these latter observations in connection with measurements of other parameters (atmospheric electricity, for example). Also, it would be of value to have some observations of the vertical distribution taken over weather ships, along with the general program for total ozone.

At present, the only routine observations of the ozone distribution above 30 km are being carried out by Umkehr measurements using the Dobson spectrophotometer. These observations can give useful information on ozone variations up to 50 km, the lowest level at which variable solar radiation might affect the photochemistry of ozone. Until new improved methods are devised and made operational, such observations should be continued. Simultaneously, in order to derive an improved pattern of the ozone distribution in the upper stratosphere and mesosphere, and to check on the theory of the photochemistry of ozone, it is urged that a program of rocket observations to at least 80 km altitude be planned to take a set of observations at low latitudes and, during each of the four seasons, at middle and high latitudes in each hemisphere. For these purposes it would be best to coordinate this program with a system such as the "Potential Meteorological Rocket Network" proposed by COSPAR, and discussed in Publication 1079* of the National Academy of Sciences—National Research Council.

* A Review of Space Research, Publication 1079, National Academy of Sciences—National Research Council, 1962, Chapter 8, pp. 8-2, 8-3, 8-4, 8-8.

Because of the large diurnal variation of ozone indicated at the top of the mesosphere, it is particularly important that some mesospheric observations be obtained during the night. Current methods under development involve the use of rocketborne light sources and fast-response dropsondes equipped with some modification of the chemiluminescent technique. Efforts should be continued, however, toward the development of a continuous observation system; the most promising method for such ozone observations seems to be use of laser techniques from satellite platforms.

The problem of the vertical, geographic, and seasonal variation of ozone is completely interrelated with problems of the structure and circulation of the stratosphere and mesosphere. A realistic program of ozone observations and research has been outlined above that should materially assist in our understanding of the behavior of this region of the atmosphere, of increasing scientific concern and growing operational interest.

SUMMARY OF CONCLUSIONS

THE PROBLEMS

The primary focal point for extended observations and research in atmospheric ozone, requiring worldwide cooperation and planning, involves the study of its formation in the stratosphere, transport downward to the troposphere, and ultimate destruction at the earth's surface. Also requiring careful consideration are studies of the physical processes (including photochemistry) in the stratosphere and mesosphere involving interactions with the dynamics of this region of the atmosphere, and those involving possible upper-atmosphere reactions to anomalous solar radiation.

The types of observations needed in support of studies of these research problems, along with some preliminary suggestions for time and space networks for these observations, are presented in the following two sections.

TYPES OF OBSERVATIONS

(1) The most suitable present methods for routine measurements below 35 km seem to be balloonborne chemiluminescent or electrochemical systems. These methods are still in the developmental stage, and it is important that the instruments be standardized and made more reliable. With further improvement of both the chemiluminescent and electrochemical sondes, it is essential that the unit cost be reduced so that the necessary routine network of vertical ozone sondes can be economically feasible.

(2) The most likely techniques for continuous ozone measurements, particularly above 30 km, would probably involve satellite observations. However, until satellite ozone observations can be made routinely, it is necessary that a program of rocket ozone observations (optical and/or dropsondes) be carefully planned.

(3) In order to extend the network of total ozone observations and to complement the network of vertical ozone observations, it is suggested that use of the Dobson spectrophotometer be extended in a global network of observations of total ozone and of the vertical ozone distribution (Umkehr method). With regard to the Dobson instrument, efforts should be made to increase its reliability and sensitivity, make it an automatic recording instrument, and reduce its size and price.

(4) It is of primary importance to monitor the solar spectrum in the relevant region of the ultraviolet. This involves accurate satellite observations of the absolute intensities including time variations in the spectral interval 1200Å to 3500Å.

OBSERVATION NETWORKS

(1) The greatest effort in extending the ozone network must be directed toward the development of routine observations of the vertical ozone distribution. For the region below 35 km the two balloon-borne ozone sonde techniques, mentioned above, give the most promise. In order to investigate atmospheric transport processes in the upper troposphere and lower stratosphere, it is suggested that, at minimum, a vertical-distribution network be established for taking observations once a week, with a skeleton network taking observations more frequently. This minimum network should ultimately consist of stations located along each of three different latitude circles—one near the equator, one in the subtropics (about 30° latitude), and the third at about 50° N latitude. At least 12 reasonably well-distributed stations are required at the selected latitudes, particularly in the subtropics and high latitudes. The network should also include some observations in polar regions.

In addition, it is suggested that the network include three meridional sections, near 80° W, 0°, and 140° E. This network must be so designed that the effect of standing and transient eddies on the horizontal and vertical transport of ozone can be evaluated.

(2) It is urged that a program of rocket observations, to at least 80 km, be planned to take observations during each of the four seasons at low, middle, and high latitudes in each hemisphere. For these purposes it would be highly desirable to coordinate this program with a system such as the "Potential Meteorological Rocket Network" proposed by COSPAR and discussed in Publication 1079 of the National Academy of Sciences—National Research Council.

Because of the large indicated diurnal variation of ozone at the top of the mesosphere, it is particularly important that some mesospheric observations be obtained during the night. Efforts should be continued, however, toward the development of a continuous observation system; the most promising method for such ozone observations seems to be use of laser techniques involving satellite platforms.

(3) The long record of total ozone observations should be continued and the number of stations taking these observations should be increased. In this regard, particular attention should be given to increasing the observational network over equatorial regions, ocean areas and all areas in the Southern Hemisphere. For observations over ocean areas, it is suggested that use be made of some of the existing weather ships, which are in particularly favorable positions to make routine observations.

APPENDIX

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INTERNATIONAL PLANNING CONFERENCE ON ATMOSPHERIC OZONE

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September 7-8, 1964

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