1. Introduction

It is perhaps especially appropriate that this meeting should be chosen as the occasion for reviewing the current status of the 26-month oscillation, for it was just five years ago this week at the annual meeting of our Society, held that year in Boston, that the discovery of this unique phenomenon was first announced [1]. On that early occasion the following facts concerning the cycle were established. It was shown that the period of the oscillation is 26 months, that it is best developed near the equator, that it progresses downward at a speed of 1 kilometer per month, that it extends upward to at least 30 km and that it dies out upon approaching the tropopause. Its wavelike character was recognized, as was the difficulty of accounting for the generation and appearance of westerly momentum at the equator.

On the other hand, it was not known how rapidly the cycle diminished away from the equator, nor was it known for certain whether it occurred simultaneously at all longitudes and symmetrically in the two hemispheres. The behavior above 30 km, the upper limit of balloon observations at that time, was not known, and it was not known whether at least a weak remnant of the cycle was able to penetrate into the troposphere. Furthermore, nothing was known concerning the behavior of the other basic meteorological variables—the meridional and vertical wind components and the temperature. Did they also sway to the 26-month rhythm? If so, how strongly and in what relationship to the zonal wind oscillation? And finally the answer to the most important question of all was not known: What is the cause of the oscillation?

Today, as we shall see, we have answers to many of these questions. The characteristics of the zonal wind oscillation in the layer between 100 mb and 10 mb (15 and 30 km) are now well established for the entire area between 30N and 30S [2-17]. Small related oscillations of temperature and total amount of ozone have been measured, and the associated fluctuations of the meridional and vertical motions have been deduced from theory. Unmistakable evidence has been gathered that the cycle extends to extratropical regions, though the picture at these latitudes is still somewhat hazy. In September 1964 two years of rocket wind measurements were completed at Ascension Island at 8S. These measurements permit a first glimpse of the oscillation in the layer between 30 km and 50 km. We will see shortly, for the first time, what happens to the oscillation at the higher levels.

The answer to the 64-dollar question still eludes us. We still do not have an acceptable theory concerning the origin of the cycle, though there is no lack of interesting hypotheses concerning its genesis. Finally, the theorists have not been idle. Particularly in the last year or two a number of interesting papers have appeared on the dynamics of the phenomenon, and though by and large these papers have not dealt directly with the central problem of the cause of the cycle, they have brought a clearer understanding of the phenomenon and perhaps insights which will be helpful in tracking down the cause.

This in broad outline is the present status of the problem. It remains now to fill in the details. We will begin by considering the characteristics of the oscillation in the

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1 Paper delivered at 45th annual meeting of the American Meteorological Society, New York, January 1965.
2 Contribution No. 106, Department of Atmospheric Sciences, University of Washington.
tropical stratosphere between 100 mb and 10 mb where our knowledge is reasonably secure. Next we will take a preliminary view of the behavior in the upper stratosphere between 30 and 50 km; then will come a brief summary of the results at extratropical latitudes; and finally we will take a look at some of the theoretical work that has been done and at the all-important question of the origin.

An illuminating view of the zonal wind behavior near the equator is afforded by Fig. 1 (cover photo) which contains a time-height section of the zonal wind speed at Canton Island ($3^\circ$S) during the eleven-year period 1953–1963 [17]. Many of the main characteristics are evident from this figure. The period, as judged from the distance between the axes of easterly and westerly regimes, averages slightly over two years. The downward phase propagation is obvious from the slope of the wind regimes. The easterlies or westerlies appear first at the highest levels and progress downward at a speed of roughly one kilometer per month. It is apparent, too, that the amplitude of the oscillation changes little between 10 mb and 30 mb, where it appears to reach its peak. Below 50 mb the amplitude diminishes rapidly so that only a trace of the oscillation is evident near 100 mb, the level of the equatorial tropopause.

Although the average period during the decade 1950–1960, as judged both by eye inspection and more sophisticated autocorrelation techniques, is 26 months, or a fraction of a month less, it is readily apparent from the Canton Island section that the period is quite irregular varying within the limits of 21 and 30 months. Fig. 2 depicts the variation in period obtained by smoothing slightly the monthly averages, and observing the interval between successive times at which the zonal wind passes through its long-term mean value both on the upswing and downswing portions of the cycle. The diagram shows the rather wide fluctuation in period and brings out a further point of interest: During the period of record, short and long cycles were immediately compensated so that the double cycle always lies in the range 50–52 months.

Information concerning the variation of phase and amplitude with latitude is contained on Fig. 3 [17]. The maximum amplitude occurs at the equator at about the 30-mb level. The amplitude decreases outward more or less symmetrically in the two hemispheres and the profile at a particular height can be shown to have the shape of the Gaussian or probability curve. The phase, which gives the time of maximum westerly component, is approximately uniform with latitude and shows the previously stated variation of 1 month per kilometer in the vertical. Beyond $20^\circ$ lat. the phase is quite uncertain, and there is now some doubt concerning the correctness of this analysis near the margins.

A number of authors [32, 15, 16] have commented on the asymmetrical shape of the zonal wind cycle, as seen, for instance, when the wind speed is plotted against time at a particular level. Such a plot is depicted in Fig. 4 which shows the variation at Balboa, Canal Zone ($8^\circ$N) of the zonal wind component at 50 mb after the annual cycle is removed. Note during most cycles the rapid increase in west wind, the plateau in the...
westerly regime, the slow decline and finally the sharp dip during the easterly regime. From the standpoint of Fourier analysis the asymmetry indicates the presence of harmonics of the 26-month period. Harmonic analysis reveals that the first harmonic or 13-month period is primarily responsible for the observed shape. This may be seen in Fig. 5 which shows the 26- and 13-month components and their sums at 50 mb at Balboa for a combination of seven overlapping cycles.

It is the author's belief that the 13-month harmonic arises from nonlinear interactions between components of the 26-month oscillation and that it therefore offers a valuable tool in probing the dynamics of the cycle. It is well known that nonlinear effects generate new frequencies which are the sums and differences of the fundamental frequencies. If this interpretation is correct, it implies that certain nonlinear effects are large enough to be detected but perhaps not large enough to negate the use of linearization in certain aspects of the analysis—a state of affairs which may prove helpful.

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Fig. 3. Variation of amplitude (m sec$^{-1}$) and phase of the 26-month zonal wind oscillation with height and latitude.

Fig. 4. Monthly-mean zonal wind speed at 50 mb, Balboa, Canal Zone (8N) with annual cycle removed.

Fig. 5. First and second harmonics of 50-mb zonal wind at Balboa and their sum. Fundamental period is 26 months.
Veryard and Ebdon [5] were first to detect the existence of an associated 26-month oscillation in temperatures near the equator. Fig. 6 depicts the main features of the temperature oscillation [17]. The abscissa is latitude and the ordinate height (or pressure). Solid lines are isopleths of constant amplitude and dashed lines represent phase. The largest amplitudes, roughly 2°C, occur at the equator in the middle and upper part of the layer. The amplitude diminishes outward from the equator and reaches a minimum near 15°N. Poleward of this latitude, the amplitude increases again attaining a value of 1°C or more at the higher levels in the subtropics.

The phase of the temperature oscillation, like that of the zonal wind, is delayed at lower levels. The downward phase speed is somewhat slower than that of the wind oscillation. Perhaps the most striking feature of the diagram is the nearly 180 degree phase reversal which occurs near 15°N, the latitude at which the amplitude is smallest. Viewed in meridional profile, the temperature oscillation has the appearance of a standing wave: Warm temperature anomalies near the equator are accompanied by cold anomalies in the subtropics and vice versa.

The relationship between the temperature and wind fluctuations is illustrated in Fig. 7 which shows the variations with time, on a 26-month scale, of the temperature difference between an equatorial station (Canton Island, 3°S) and five subtropical stations (average latitude 27°N) and the zonal wind at Balboa (8°N) which represents well the average fluctuations in the intervening zone [34]. At the higher levels (20 mb and 30 mb) the temperature difference oscillation precedes the wind oscillation by about one quarter cycle. Because of the more rapid downward progression of the wind fluctuation the two cycles come into phase at the lowest level, warm temperatures at the equator and cold temperatures in the subtropics coinciding with westerly winds.

The mode of presentation selected here suggests that the thermal wind relationship is being obeyed, and this inference is borne out by more exact mathematical calculations [30]. Thus the 26-month oscillation maintains approximate equilibrium, even in the vicinity of the equator.
The vertical and meridional wind components are too small to be detected by direct observation, hence it has been necessary to resort to a theoretical approach in attempting to deduce these aspects of the oscillation. In the approach which will be described here [35] the thermodynamic energy and ozone balance equations are solved jointly to obtain the vertical velocity fluctuation. The equation of continuity is then integrated with use of suitable boundary conditions to yield the meridional wind oscillation. The method reveals that the amplitude of the vertical velocity is only of the order of one hundredth of a centimeter per second. Meridional velocities are also very small, achieving maximum speeds of only 2–3 cm sec\(^{-1}\) at 15\(\circ\)N.

The details of the method are summarized in Fig. 8. First an analytic expression for the zonal wind oscillation is specified in agreement with observations. The thermal wind equation is then used to determine an analytic expression for the temperature variation. This expression is next substituted in the thermodynamic energy and ozone balance equations which then contain only two unknowns, the vertical velocity and the ozone anomaly. The solution of the two equations yields an expression for vertical velocity variation which is substituted in the continuity equation to give finally the meridional velocity. Note that the ozone variation appears as an interesting by-product.

The results which are obtained from this method depend considerably on the assumptions employed in formulating the thermodynamic energy and ozone balance equations. A word, therefore, seems in order regarding the various assumptions and simplifications. The equations being discussed have first of all been specialized by Fourier analysis to apply only to the 26-month oscillating components of the various fields. It turns out that the specialized equations are linear partial differential equations identical with those that would be obtained by the perturbation method. Solutions are obtained for an upper layer between 30 mb and 10 mb in which the amplitude is assumed constant with height, and a lower layer between 80 mb and 30 mb in which the amplitude is assumed to increase exponentially with height.
Moreover, simplifying assumptions have had to be made in many of the terms of the equations. Thus the diffusion of heat and ozone has been assumed to obey the Fickian law in the meridional and vertical directions with a lateral eddy diffusion coefficient of the order of 10^{9} c.g.s. units and a vertical coefficient of the order of 10^{3} c.g.s. units. The infrared cooling has been assumed to be Newtonian, that is, proportional to the temperature anomaly with a relaxation time of 20 days. Likewise the photochemical destruction has been assumed proportional to the ozone anomaly with a relaxation time of 2 months in the upper layer and 77 months in the lower. The heating by ozone absorption has been assumed to be proportional to the ozone perturbation and the thermal destruction of ozone to be proportional to the temperature perturbation. Justification for the procedures used in treating the radiation and photochemistry is found in the recent work of Lindzen [37].

I have already mentioned the magnitude of the vertical and meridional motions obtained from the computations based on the foregoing procedures. The overall results of the analysis are perhaps best summarized by the schematic model shown in Fig. 9.

Fig. 9. Schematic model of the 26-month oscillation. E and W refer to locations of cores of easterly and westerly currents, respectively. Regions of warm and cold anomalies are marked appropriately. Arrows give directions of meridional circulations. The blocks and discrete arrows are located at points where the temperature and velocity components are maxima (or minima) in time, but not necessarily in space.
which depicts the motions and temperature anomalies at four phases of the cycle. The diagram at the top depicts the phase at which the west wind maximum appears at 30 km. The easterly current is then dying away near 20 km. Positive temperature anomalies and subsidence occupy the 20–30 km layer at equatorial latitudes; negative anomalies and ascent occur at subtropical latitudes. The westerly regime is characterized by a weak equatorward drift which is strongest near 15° latitude and which reaches its peak somewhat before the occurrence of the maximum westerlies; the easterlies are associated with a poleward drift. Subsequent phases at intervals of one-quarter cycle are shown in succeeding diagrams.

Not shown on the diagrams is the ozone behavior which, as noted earlier, is obtained as a by-product of the computations. The analysis reveals that at the lower levels the temperature anomalies could be used to represent the ozone anomalies, since there is a close correspondence in phase between the two fields at levels below 30 km. Thus at these levels warm temperatures and above normal ozone concentrations occur nearly simultaneously, as do cold temperatures and below normal ozone. The relation between ozone and temperature at the upper levels is less certain and depends critically on the photochemical parameters.

The precise data needed to check these inferences regarding the ozone behavior are not available, inasmuch as long series of ozone data giving accurate measurements of concentrations at specific levels are lacking. However, from measurements of total amount of ozone in vertical columns, and reasonable assumptions concerning the relationship between total and specific amounts, it appears that the ozone is behaving in the prescribed manner. Funk and Garnham [18] were first to note the existence of a biennial fluctuation of total amount from data for Brisbane and Aspendale in Australia. Ramanathan [19] observed that the total amount at Kodaikanal in India also underwent a biennial variation but with the phase opposite to that at the Australian stations. Fig. 10 depicts the antiphase relationship. The two curves at the bottom show smoothed departures of the monthly ozone amounts from their long-term means for Kodaikanal at 10N and Brisbane at 27.5S, as given by Rangarajan [20]. It is apparent that during the four years for which comparisons can be made the variations have been opposite at the two stations, as surmised from the model. At the top of the figure we have depicted the correspondingly smoothed departure of the monthly mean temperature in the layer.

**Fig. 10.** Variation with time of total ozone amounts at Kodaikanal and Brisbane and 50–40 mb average temperature at Canton Island.
50–40 mb from its long-term mean for Canton Island, a typical equatorial station. Note the strong inverse relationship between this curve and the ozone curve for Brisbane.

Thus we see that when equatorial temperatures are warm in the layer about 21 km, the ozone amount is above normal near the equator and below normal in the subtropics where the previous discussion would indicate that temperatures are low. These relationships can be shown to be entirely consistent with the theoretical results summarized in the model in the previous figure [35].

Because of the downward propagation of the 26-month cycle and the suggestion of some authors that it may have its origin in the strongly heated part of the ozone layer near 50 km, the behavior of the oscillation at levels above the usual balloon ceiling is of particular interest. Fortunately two years of rocket soundings have recently been completed at Ascension Island, located at 8S, which permit a preliminary view of the behavior in the region between 30 and 50 km [45]. We will now present, for the first time, the results of this important series of soundings.

Fig. 11 shows plotted at 4 km intervals the zonal wind data from all soundings taken between October 1962 and October 1964. At the 28-km level the 26-month cycle is very much in evidence. Note the east winds at the beginning and end of the 2-year record and the period of westerlies in the middle. At levels above 30 km it is difficult for the eye to detect the presence of the biennial wave. Between 32 km and 40 km the annual cycle is perhaps most conspicuous, while above 40 km a striking 6-month cycle is apparent.

To trace the 26-month cycle upward it is necessary to resort to harmonic analysis. The results of the harmonic analysis, based on the monthly mean wind values represented by the open circles, are shown in Fig. 12. In this figure the vertical scale gives height in kilometers and the horizontal scale gives both amplitude in meters per second and phase in months. The solid curve gives the variation of amplitude with height based in the upper part on the rocket data and in the lower part on routine balloon data. It is apparent that the amplitude increases rapidly upward from the tropopause to 25 km, above which a slow decline sets in. Particularly when one considers the kinetic energy density, this diagram appears to lend little support to a high level origin of the cycle.

The dashed curve depicts the phase variation with height. From this curve the downward speed of propagation is found to decrease from about 2 km per month in the region above 30 km to the commonly given figure of 1 km per month in the region below.
4. Extratropical and tropospheric behavior

Efforts to trace the oscillation into the troposphere and into higher latitudes [21–29] are hampered by the fact that the amplitude becomes much weaker in these regions while the variability (or variance) of the meteorological elements becomes in general much greater. Thus we are faced with the problem of detecting a weak signal amid loud noise. It is possible to do this, of course, provided a sufficiently long series of data exists, and Landsberg [21] has summarized a variety of such long-period measurements—including measurements of surface temperature, precipitation, tree rings, varves and lake levels—which seem to establish beyond reasonable doubt the world-wide existence of the 26-month cycle. The listener interested in examining more closely these pieces of evidence is referred to Landsberg’s paper.

More recently Landsberg et al. [25] have examined surface temperature data at widely separated stations along two meridians from Norway to South Africa and from Canada to Cape Horn and shown from spectral analysis that a significant periodicity, somewhat in excess of two years, is present in the temperature records. Among their more important findings were that (1) the higher-latitude stations were out of phase with those in the tropics and (2) in the Northern Hemisphere, at extratropical stations, the amplitude of the oscillation was largest when the peak occurred during the winter months.

On statistical grounds it appears dangerous to accept uncritically the various results [22, 24–26, 28, 29] of short-period (usually 4–8 years) analyses of temperature and zonal wind data for the extratropical stratosphere which have been appearing in the literature lately. However, the Southern Hemisphere results are so suggestive that it is tempting to construct at least a tentative picture of the extratropical behavior. The next series of figures depicts some of the relationships that have been observed. Fig. 13, from

![Fig. 12. Variation with height of amplitude and phase of biennial cycles at Ascension Island.](image)

![Fig. 13. 12-month running mean 50-mb temperatures.](image)
Angell and Korshover [28], shows the 12-month running average of mean monthly 50-mb temperatures for various stations. In the Southern Hemisphere the existence of a quasi-biennial cycle is clearly evident with the middle and high latitude stations showing an opposite temperature variation to that at Canton Island. McMurdo, the southernmost station, exhibits the largest fluctuation among the extratropical stations. The Northern Hemisphere picture is relatively confused, however, and one is hard-pressed to note some sort of systematic behavior.

A second interesting picture, also due to Angell and Korshover [28], appears in Fig. 14. Here the 12-monthly running means of total ozone amount are compared with temperatures at 50 mb and 100 mb. Note the strong correspondence between the ozone variation at Aspendale, Australia, and the temperatures at Aspendale and Puerto Montt, Chile. On the other hand, note the weak relationships at corresponding stations in the Northern Hemisphere (top panel).

Fig. 15, taken from Sparrow and Unthank [29], shows 12-month running means of total ozone amount at the Australian stations and of zonal winds for various levels at Christchurch, New Zealand (43.5S). The presence of a quasi-biennial cycle is apparent in both sets of data. Moreover, periods of westerly winds appear to coincide with periods of minimum ozone amount.

In summary, it appears that when the total amount of ozone and the 50-mb temperature are above normal in the equatorial zone (These conditions occur when the westerly core is located at about 30 mb.) low ozone amounts, cool temperatures and relatively westerly winds occur in the extratropical latitudes of the Southern Hemisphere. The Northern Hemisphere picture is rather obscure, either because of the masking of the cycle by the greater noise in the data or because of a real difference in the behavior of the two hemispheres. The unravelling of the picture at the higher latitudes is clearly an important and exciting task which will require the careful examination of past data and the patient accumulation of new.
5. Theoretical results

Time does not permit an adequate review of the theoretical results and speculations which have appeared with increasing frequency in recent years. The theoretical contributions have dealt mainly with three topics: (1) the momentum balance, which from the start [1, 3, 4, 11] has been recognized as presenting special difficulties because of the appearance of westerly momentum at the equator, (2) the dispersion characteristics of long-period equatorial waves without reference to their generating mechanism and (3) the cause of the cycle [31, 32].

The momentum balance has been treated recently by Tucker [36] who finds that a cyclic variation in the divergence of the horizontal eddy flux of momentum is primarily responsible for the zonal wind oscillation. However, analysis by Reed [46] of the wind data from tropical stations with the longest records, using power spectrum techniques, fails to give convincing evidence of a 26-month cycle in the eddy flux. The reasons for the discrepancy between Tucker's and Reed's results are not known, but it would seem wisest at this stage to regard the problem of the momentum balance as still unsolved.

The work on wave propagation in the equatorial stratosphere has been done by Lindzen [37] and is important, among other reasons, for demonstrating the importance of radiative and photochemical processes in long-period oscillations and for showing how these effects may be incorporated into treatments of the dynamics of this region. The interested reader is referred to Lindzen's Ph.D. thesis for details of his work. An account of this work is also scheduled for July in the JOURNAL OF THE ATMOSPHERIC SCIENCES.

I have left until last the intriguing and tantalizing question of the origin of the cycle. The theories proposed to date fall into three categories: (1) external theories postulating a direct drive by some extraterrestrial influence, (2) internal theories based on the idea of some natural cycle within the atmosphere analogous, for instance, to the vacillation phenomenon in the rotating model experiments of Hide [47, 48] and Fultz et al. [49], and (3) internal theories hypothesizing a subharmonic response to some shorter-period driving mechanism, in particular the annual heating cycle [33, 35].

Of these various hypotheses, that of an extraterrestrial origin has attracted the greatest notice. Staley [33] has speculated on the possibility of a 26-month fluctuation of the solar ultraviolet radiation. If such a fluctuation exists and is of proper size, it could produce a temperature fluctuation of the observed amplitude. The temperature wave could then be propagated downward by diffusion inducing a corresponding zonal wind fluctuation via the thermal wind equation. In support of his theory Staley pointed to Shapiro and Ward's [38] finding of a slight peak in the spectrum of sunspot number near 25 months. He also noted the possible evidence of a biennial variation in the zonal wind in the equatorial stratosphere of the planet Jupiter [41, 43] which might be of solar origin.

Other writers too have brought forth what they believe to be evidence of a solar origin. Stacey and Westcott [39] have found an alleged quasi-biennial cycle in the equatorial geomagnetic field and Hope [40] has called attention to the work of the Russian author, Kalinin, who found a cycle of slightly greater than two years in seven geomagnetic elements. More recently Westcott [42] has used a beat technique to arrive at a figure of 25.7 months for the sunspot cycle found by Shapiro and Ward; and Newell [44] has shown that there is some evidence to support the view that the sun is a pulsating star with a period of about two years. Newell [34] further has postulated that, whatever
the ultimate origin of the cycle, it is the troposphere which immediately controls the stratospheric behavior.

A difficulty with the solar theories is that in all cases the evidence of a 26-month variation in solar or related parameters is at best borderline. The sunspot hypothesis runs into the added difficulty, noted by several writers, that it requires that a barely perceptible, and perhaps spurious, 26-month sunspot cycle can cause a major oscillation in a region of the atmosphere where the main 11-year cycle has practically no observable effect.

6. Concluding remarks

In summary, the behavior of the 26-month oscillations of temperature and zonal wind is now well established for the tropical stratosphere between 100 mb and 10 mb. Theoretical estimates of the behavior of the meridional and vertical wind components and of the ozone concentration have been made, but further work is required before these can be completely accepted. In the case of the ozone there are some measurements of total amount which appear to support the theoretical results but more measurements are needed, particularly of concentrations at specific levels.

Thanks to the recent rocket soundings from Ascension Island a first glimpse of the wind behavior above 30 km has been obtained. Obviously a longer record and soundings from other localities are needed before we can know adequately the behavior in the layer between 30 and 50 km. The evidence that the oscillation is world-wide seems established beyond doubt. However, the characteristics in extratropical latitudes are fuzzy, at least in the Northern Hemisphere. A coherent picture seems to be emerging for the Southern Hemisphere despite the difficulties of interpretation imposed by the shortness of the record.

Finally the origin of the cycle is still very much a mystery. To further our knowledge of its genesis, two different types of investigations should be pursued: (1) efforts should be made to measure the solar ultraviolet radiation for possible cyclic variations; (2) theoretical studies should be undertaken to determine the response of the equatorial stratosphere to the annual heating cycle under the unusual dynamic conditions that prevail in that region. Not only might a systematic and vigorous search for the cause of the 26-month oscillation provide the answer to an intriguing atmospheric mystery but it might lead as well to unexpected dividends in other areas of meteorological and space research.

Acknowledgments. The author wishes to thank Dr. Richard S. Lindzen for helpful discussions concerning many aspects of the work presented here, and the U. S. Navy Weather Research Facility for its continued support in providing the data used in his own studies of the oscillation. Support by the National Science Foundation under GP-2282 is also gratefully acknowledged.

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new and notes

Symons Gold Medal awarded to Dr. Chapman

The award of the Symons Memorial Gold Medal, highest honor of the Royal Meteorological Society, to Dr. Sydney Chapman was announced at the Annual General Meeting of the RMS on 28 April. Dr. Chapman was honored for his distinguished contributions to meteorology.

Staff member of the High Altitude Observatory, Boulder, Colorado, advisory scientific director of the University of Alaska's Geophysical Institute, and senior research scientist at the Institute of Science and Technology, University of Michigan, Dr. Chapman has received many honors in his long and eminent career. The most recent before the Symons Medal was the Copley Medal of the Royal Society, which was awarded in November 1964 (see: BULLETIN, 45, 12, 776).

On presenting the Copley Medal, Sir Howard Florey, president of the Royal Society, said in part:

"Wherever one turns in geophysics or in the physics of the upper atmosphere one finds that Chapman has made fundamental contributions. For example, his theory of ionospheric layer formation is basic to the subject. He demonstrated that atomic oxygen should be dominant in the high atmosphere, and he has contributed to the theories of the ozone layer and to the problem of the night air glow. The depth and extent of Chapman's researches, which have continued undiminished for more than half a century, have brought both him and British science international renown. Indeed, his worldwide associations became of critical importance in the promulgation of the 1957–58 International Geophysical Year and he was the president of the Special Committee for the International Geophysical Year (CSAGI) from 1953 until 1959."

New officers and members for UCAR

New officers and three trustees-at-large were elected and two new university members admitted in April by the University Corporation for Atmospheric Research (UCAR), the non-profit corporation of universities that manages the National Center for Atmospheric Research (NCAR).

The new officers are: chairman, Dr. A. Richard Kassander, director, Institute for Atmospheric Physics, University of Arizona; vice chairman, Dr. John C. Calhoun, Jr., vice chancellor for programs, Texas A & M University; secretary, Dr. Werner A. Baum, vice president of the University of Miami; and treasurer, Dr. Phil E. Church, chairman of the Department of Atmospheric Sciences, University of Washington. Dr. Alan T. Waterman, Washington, D. C., and William T. Golden, New York, were elected trustees-at-large for terms ending in 1968; Carl L. Mosley, Denver, for a term ending in 1967.

The University of Hawaii and the University of Minnesota became the 20th and 21st members of UCAR. Dr. Horace R. Byers, chairman of the UCAR Board of Trustees, welcomed the new members and said: "The rise in membership in the past twelve months from fourteen to the present twenty-one is a sign of the important part universities are playing in the national and world-wide growth of the atmospheric sciences. It is also heartening evidence of the growing recognition of the useful role UCAR plays."

Dr. Walter Orr Roberts, UCAR director, noted the already existing links between the two new members and NCAR. "NCAR's High Altitude Observatory has set up its K-coronograph for solar research at the University of Hawaii and will shortly send meteorological radar for use in a cooperative U. S.–Japan cloud physics program there. At the University of Minnesota, the late distinguished professor, Dr. Jean Piccard pioneered in the improvement of balloons for scientific use. In addition, Dr. Edward P. Ney and Dr. John R. Winckler are co-chairmen of the advisory panel that reviews the performance of the NCAR Balloon Facility's work in developing balloon techniques and aiding balloon-borne scientific research."

(More new and notes on page 416)