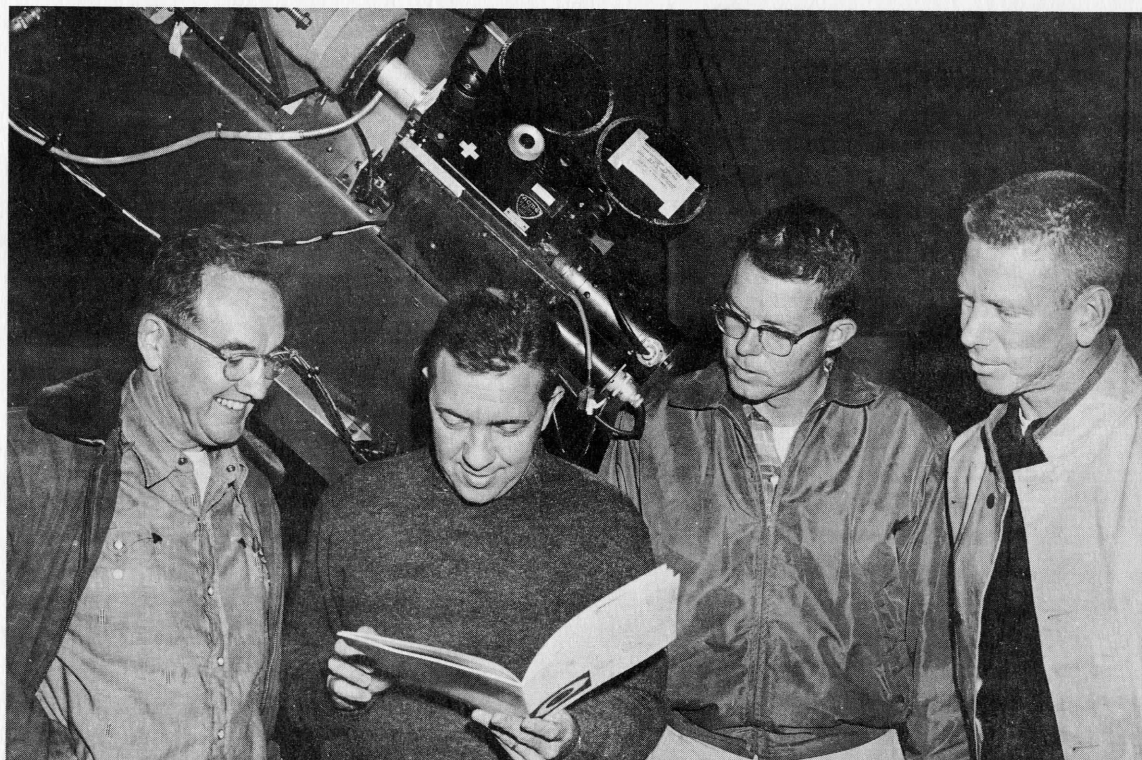


THE
DIRECTOR'S REPORT

1 July through 31 December 1959



*Research Visitor at Climax**

High Altitude Observatory
of the
University of Colorado
Boulder and Climax, Colorado

The High Altitude Observatory is an independent non-profit research and educational institution closely associated with the University of Colorado. Its major research objectives are study of the sun and the sun's effects on the earth.

*Cover: Dr. James A. Van Allen of the State University of Iowa conducted the HAO's annual Trustees research review in October including a visit to the Climax observing station (see page 9). Here (left to right) Roberts, Van Allen, and observers Watson and James are standing in the small dome at Climax. Behind them is the flare patrol camera, mounted on the lower end of the 10-foot equatorial.

SUMMARY

After many years, HAO is at last assured of a Boulder research center that is all under a single roof. This will vastly simplify the coordination of HAO's research and administration, which is far more difficult in our present disjointed physical plant. Many generous contributors made the new center possible. The building is under way and should be ready for occupancy late in the summer.

A stratospheric view of the earth's atmosphere and of astronomical phenomena offers many advantages. The air is cleaner, steadier and thinner at stratospheric altitudes, which means that astronomical telescopes operated there do not suffer the "heat shimmer" and light absorption that prevails at ground observatories. Moreover, the very electrical, chemical and physical processes of the stratosphere itself are sometimes easier to study when you are in their midst. Also a stratospheric observing platform offers an intermediate step into space that is safer, cheaper, and highly advantageous for many types of experiments. As a consequence, we foresee that stratospheric observatories are a future certainty.

Such stratospheric laboratories become a feasible prospect when one considers modern developments in balloon technology and in aircraft design. HAO made its first steps towards use of a stratospheric observatory in August, with a manned flight in an open gondola to

38,000 feet altitude, with a photographic sky photometer and coronagraph aboard.

Astro-geophysics continues to grow at HAO and the University. Support for additional fellowships at pre-doctoral and post-doctoral levels from The Ford Foundation will make possible a greater development of this aspect of our program.

A research area of outstanding future importance, underway at HAO this year, is the one conducted by Haurwitz. It deals with the dynamics of an atmospheric gas under idealized conditions involving various heat inputs, viscosities, and other factors. It opens an aspect of our research new to us here, as does the work of Julian on certain problems of the water resources of the Upper Colorado River basin. Both emphasize the expanding interests of HAO in meteorology and the atmospheric sciences.

I. HIGHLIGHTS

New Research Center Building Under Construction

A new research center for HAO's Boulder operations was on its way towards completion at the end of the year. It is a great thrill to all of us in HAO to be able to watch the new research center taking shape on the hill beside the Sommers-Bausch Observatory. The plans call for us to move next August. We have been scattered about on and off the University campus at Boulder for nearly a decade, now. It will give an enormous boost to our work for us to be in the new laboratory building.

The center will bring the Boulder portions of our research, teaching, and administrative activities under a single roof. The Sommers-Bausch Observatory, which has as a major function to provide an observing and demonstration facility for solar and stellar research, is directly adjacent. This will permit a far more effective use of the excellent 10 1/2-inch telescope.

The realization of this long-standing HAO dream was made possible by the generosity of a large number of contributors. The principal of these was the Max C. Fleischmann Foundation of Nevada, whose original gift stimulated a great deal of additional help, and whose subsequent generous contributions made possible the achievement of the whole objective. Major gifts were also made by the S. S. Kresge Foundation, Boettcher Foundation, Adolph Coors Company, James Foundation of New York, and the El Pomar Foundation.

The Regents of the University also provided substantial funds towards the new building, which will house the activities of the graduate Department of Astro-Geophysics, taught primarily by members of the HAO staff.

Additional contributors who assisted in this project were: Preston R. Bassett, Ward and Pauline Darley, Farr Farms Foundation, Harry Hoeffler, The Great Western Sugar Company, Martin Low, Alan McClure, McDermott Foundation, Nordberg Foundation, Lawrence Phipps Foundation, Charles S. Sterne, Texas Instruments Foundation, Associated Alumni of University of Colorado, Associated Students of University of Colorado, Van Hummell-Howard Foundation, Captain Mary P. Converse, T.J. Countis, Victor E. Favier, Walter and Helen Forbush, Louise Ireland Frey, Frances C. O'Melia, Lloyd V. Shields, Gurdon F. Smith and two anonymous donors.

The new laboratory building has a choice site on the University campus, east of 24th Street, on the hill directly north of the new University of Colorado Law School. The building will be owned and operated by the University and will serve HAO, the World Data Center, and the department of astro-geophysics for many years to come.

We expect to dedicate the new building in October 1960, and hope that as many as possible of our friends will make the trip to see us then, and to share our appreciation of the new center.

Stratospheric Balloon Flight

Last August 7th, in the grey light just before dawn, deep in the sheltering hollow of the Strato-Bowl, near Rapid City in South Dakota, Robert Cooper of HAO and Commander Malcolm Ross of the U.S. Navy checked through the final preparations for the launching of an open-basket balloon flight to the stratosphere. On previous days weather and wind had consistently delayed the flight. But this time all went well. The huge 72-foot balloon was inflated with helium, the medical research teams connected their recording equipment to the suits of the fliers, and the pair of scientists climbed aboard for the abrupt take-off. The following are Cooper's own words of description of the take off and subsequent flight.

"The preparations for the flight had started at 10 P.M. the previous evening and take-off was at 5:39 A.M. from the Strato-Bowl outside Rapid City, South Dakota. Commander Malcolm Ross was the pilot and my job was to operate the "flying coronagraph," which records the sky brightness near the sun.

"The open gondola in which we flew was attached to a truck bed by four ropes and when the order to cut us loose was given, we felt four distinct shocks, the last of which was the one which sent us soaring into the blue. Our ascent rate was around 1,000 feet per minute, initially, in order to be sure we cleared the rim of the Strato-Bowl as rapidly as possible. This ascent rate was to be continued until we reached 10,000 feet where we were to level off and perform all our equipment checks, but that was impossible.

"As soon as we were high enough to see all around us, we could see thunder-heads forming in our vicinity and had to maintain our fast rate of ascent, in order to fly over them and not get caught inside. At 38,000 feet we barely scraped over the top of the biggest cumulo-nimbus anvil and were

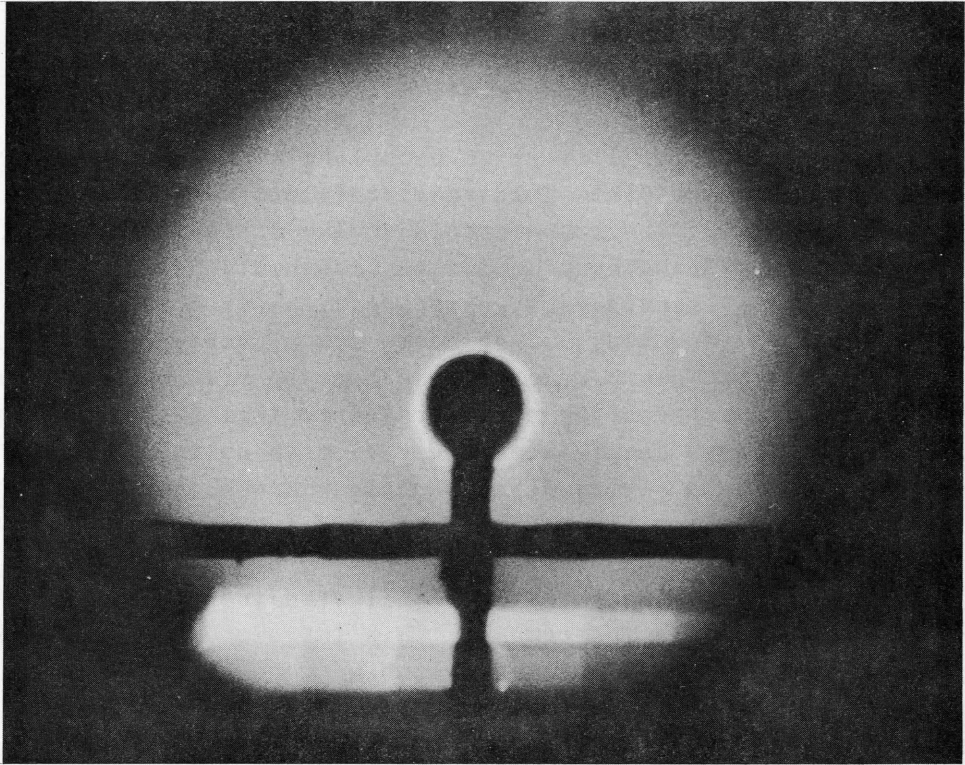


FIGURE 1

The sky at 38,000 ft. altitude, photographed by Cooper from HAO-ONR balloon flight. The aureole of light from the sky near the sun is the smooth bright area above the horizontal dark bar. The sun is eclipsed by the dark disk in the center of the frame while the bright ring of light immediately surrounding the disk is caused by light diffracted by the occulting disk. The support for the occulting disk is seen as a vertical, dark bar. At the bottom of the frame appear two step wedges which act as standards against which to compare the sky brightness. Preliminary measurements show that the sky brightness at 38,000 ft. is about 0.8×10^{-6} times the brightness of the solar disk. This is about five times the brightness the sky would have were the earth's atmosphere completely free of contaminating dust.

then in the clear. The observations were started at about 8 A.M. and by 10 A.M. we had completed seven photographs at floating altitude.

"Observations of this type are rather difficult at this altitude because of the extreme cold, bulky clothing, and all the umbilical cords with which one is attached. First, of course, is the pressurized oxygen connections without which one cannot live very long. Then there are microphone and headset connections. They became useless because of the -67°C . temperatures. Connections for telemetry of medical data including electrocardiograms, respiration and various body temperatures made me feel like a clumsy fly in a spider's web.

"The most annoying thing of all was my own breath which condensed into tiny ice crystals and floated into the light beam falling into the instrument. This introduced some erroneous apparent sky brightness, which we were fortunately able later to correct, but which was highly undesirable.

"After a slow descent to about 10,000 feet we prepared for landing "somewhere in Iowa." At the rate we had been traveling in the jet stream, we had out-run all our ground tracking vehicles and had only an R5D Aircraft circling us. Our microphones had frozen at high altitude and were useless so we were out of communication with even the R5D.

"Our first pass at a landing was made at a rate of about 300 feet per minute toward an open field. A breeze of about 15 m.p.h. drifted us toward some farm buildings and pig pens. We decided not to land there. Out went 100 lbs of ballast and up we went to 4,000 feet. The gas in the balloon had by now been heated and was giving us more lift than we wanted. Despite repeated valvings of gas we still kept slowly rising.

"Our cold weather clothing for high altitude became extremely uncomfortable at lower altitudes over Iowa on an August afternoon. To add insult to injury, our insulated gallon water jug was frozen solid and we couldn't get any water.

"Eventually we were able to bring down the gondola in a cornfield near Milford, Iowa, over 400 miles from our takeoff point, after about nine hours of flight. We landed with a tremendous thump when the balloon was cut loose about seven

or eight feet above the ground. Then the cargo chute blossomed out despite our efforts to spill it, and it spilled us.

"The gondola protected us from injury, but we were shaken up some. Upon emerging from the gondola we found a crowd gathering already. Nobody, men nor women, would move away when we announced that we would have to change our clothes. So we were forced to carry out what was probably the first strip-tease in an Iowa cornfield.

"A helicopter picked us up and flew us to the Milford Airport where we were met by Winzen Research Company's small tracking plane and transported to Minneapolis."

The flight was the first of several projected by HAO for the purpose of studying the distribution of atmospheric light-scattering particles. These particles are found at all altitudes in the atmosphere, in varying numbers and sizes. Some of the atmospheric particles are highly effective in forming ice nuclei; others induce precipitation under suitable conditions, but do not seem to be effective at forming ice crystals; still others appear to be ineffective at either. The relative abundance of these is important in meteorological processes.

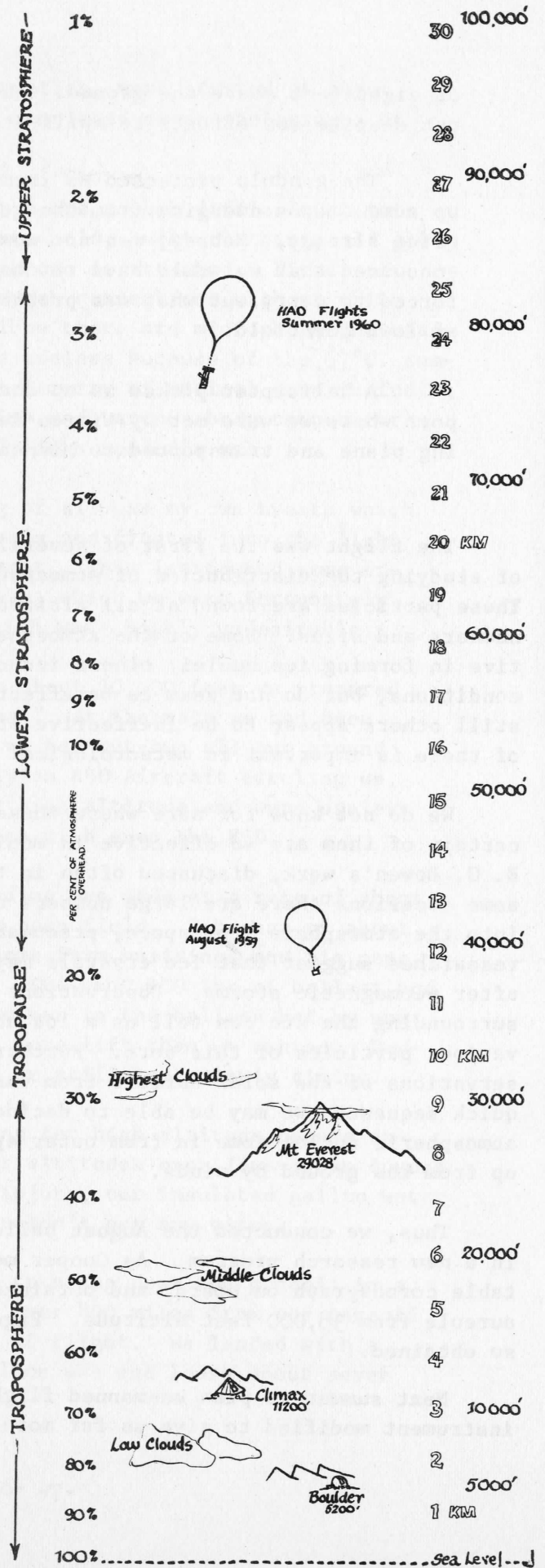
We do not know for sure where these particles come from, nor why certain of them are so effective in modifying cloud physical processes. E. G. Bowen's work, discussed often in these pages, suggests that on some occasions there are large numbers of ice-forming nuclei drifting into the atmosphere from space, presumably from meteoric dust. Other researches suggest that ice crystals may form in high atmospheric levels after geomagnetic storms. Observations of the bright aureole of light surrounding the sun can tell us a lot about the sizes and abundances of various particles of this sort. Further, if we can make successive observations of the solar aureole from various altitudes, in reasonably quick sequence, we may be able to decide how many light-scattering atmospheric nuclei come in from outer space, instead of being carried up from the ground by winds.

Thus, we conducted the August balloon flight as a pilot experiment in a new research program. As Cooper mentioned, he used a small portable coronagraph on board, and obtained seven photographs of the solar aureole from 38,000 feet altitude. Figure 1 shows one of the pictures so obtained.

Next summer we plan un-manned flights to 90,000 feet, with the same instrument modified to give us far more detailed results. If these

FIGURE 2

Drawing by Eddy showing regions of the earth's atmosphere, the altitude of the September balloon flight by Cooper and Dr. Malcolm Ross of the Office of Naval Research. It shows also the height of the unmanned HAO flights planned for the summer of 1960.



balloon flights are successful, and the results do suggest a cosmic origin for a substantial part of the atmospheric dust in the high stratosphere, then we shall attempt still more complex flights in very high-altitude aircraft. From these we will hope also to collect nuclei samples, and also to study the effect of latitude on the distribution of particles. In particular, we will then try to find out whether there are specially strong effects near the auroral zones at the time of magnetic storms. If this result should be positive, we will have made great progress in pursuit of an explanation of the solar-weather effect reported in earlier issues of these reports (1).

Ford Foundation Grant for Astro-Geophysics

A most gratifying recent event was the award, in September, of a grant of \$117,000 by the Ford Foundation in support of Astro-Geophysics. This award vastly strengthens the joint HAO-University effort by supplementing the available funds for graduate students in astro-geophysics. It makes it possible for us to admit a larger number of students, and to provide a more vigorous and effective program.

The Ford grant will support (1) graduate student fellowships and loans, (2) post-doctoral fellowships, and (3) senior scientist visiting appointments. All of these objectives lie at the heart of the joint HAO-University program.

The Ford Foundation grant also serves admirably to supplement the fellowship program of the HAO Institute for Solar-Terrestrial Research. We plan to formulate a program of graduate student aid based on the Ford Foundation "formula" for fellowships and loans. I plan to describe this program in my next report.

II. ANNUAL TRUSTEE'S RESEARCH REVIEW

This year's research review was conducted by Dr. James A. Van Allen, of State University of Iowa, the discoverer of the Van Allen radiation belts. Van Allen spent the week of September 14th to 18th at HAO, systematically reviewing the entire research program of the HAO with the scientific staff. These annual reviews have proved of high interest to staff and visitors alike.

(1) Director's Report, January-June 1959, page 3.

To us, they afford an opportunity to present the broad outlines of different areas of our work and to receive the general suggestions and criticisms of the reviewer, which we encourage him to give us with all possible directness. At the end of the week the reviewer meets at dinner with the staff and the Trustees of HAO. After the dinner, the reviewer closets himself with the trustees and gives suggestions and recommendations to them for improving the quality, scope, or administration of the Observatory's program.

This year, the schedule included the following items:

- a. Discussion of prominence, chromosphere, and flare physics, led by Zirin and Newkirk
- b. Discussion of coronal research, led by Billings
- c. Discussion of ionospheric effects of solar emissions, led by Warwick
- d. Discussion of geomagnetism, aurora and airglow research, led by Matsushita
- e. Discussion of solar radio noise studies, led by Warwick
- f. Discussion of solar-weather research and atmospheric physics, led by Roberts
- g. Visit to Climax and a review of the observing program, conducted by Roberts
- h. Review of the program of the astro-geophysics department, led by Warwick
- i. Colloquium talk by Chapman on "The Sudden Commencement of Geomagnetic Storms"
- j. Tour of the Solar Activity and Data Centers, led by Trotter, Carlen and Hansen
- k. Colloquium talk by Van Allen on "Some Results from Artificial Satellite Research"
- l. Reception for the graduate students and Van Allen

- m. Discussion of research on dynamical meteorology, led by Haurwitz
- n. Tour of radio astronomy site, conducted by Warwick
- o. Dinner with staff and trustees for Van Allen
- p. Review session with Van Allen and trustees.

It was a full program and a stimulating one for us at HAO. Reviewing it from this perspective, it seems that we must have badly worn out our visitor! Perhaps in future years we should scale down the program to cover only selected aspects of our work.

III. PROGRESS IN INSTITUTE FOR SOLAR-TERRESTRIAL RESEARCH

The end of the first four years of the privately-sponsored research program of the Institute for Solar-Terrestrial Research came in December. However, funds received under the program have not yet been fully expended, and we expect to continue this work in 1960 under the initial funds, supplemented by those pledged by new sponsors. We also plan in 1960 to seek sponsors for an additional four-year schedule of research.

A. Solar-Weather Studies

My last report gave a full account of the promising course this research has taken. We now plan three additional steps: (1) an international seminar in April 1960 to assess where we stand in the problem of suspected solar effects on weather and their implications for improvement in long-range weather forecasting and other aspects of the atmospheric sciences; (2) an analysis of the weather patterns of additional winters (1959-60 and several winters from the last sunspot maximum around 1948, even though the older weather data are not nearly so satisfactory as present); and (3) a re-analysis of the weather maps of one or more of the recent winters by a completely independent research group (we will invite the Department of Transport of Canada to undertake this effort). If these additional studies confirm our earlier work, this result alone will amply justify the entire four-year program of the Institute, and will show us that our research gamble has yielded a far more handsome pay-off than we dared hope.

Macdonald began detailed analyses of development of large storm systems over the western hemisphere at the 500 mb level (about 18,000 feet) for 1946-49. He was particularly interested, in this analysis, to determine

whether there is a shift of energy from the large wave-length systems to the smaller wave-length systems, or vice versa.

Macdonald also began some detailed studies of interconnections between atmospheric circulation at meteorological levels and influences in the ionosphere. He found that when major troughs, signifying large storm systems, passed across selected stations, there appeared to be changes of the density of the electrons in the F_2 region of the ionosphere. This is particularly surprising because the F_2 is the highest level of the ionosphere, some 200 miles up, and it implies coupling of weather phenomena at relatively low levels in the atmosphere to the electrical conditions in the highest levels of the ionosphere.

"Mountain waves" over Colorado also occupied a substantial portion of Macdonald's time during the period. He did this work jointly with Mr. Henry Harrison of United Air Lines. Mountain waves are disturbances in the horizontal wind flow. Such waves are particularly prevalent in the vicinity of the Great Divide in Colorado, and are important because they sometimes produce severe turbulence in aircraft. Mr. Harrison and Macdonald found that mountain waves are particularly prevalent and strong when the wind flow is from the northwest as it crosses the north-south mountain range in the eastern part of the Colorado Rockies. Some speculations are being developed regarding the reasons for this type of behavior.

B. Astro-Geophysics Fellowships

The Institute for Solar-Terrestrial Research has vastly benefitted the graduate student research program of the HAO and the Department of Astro-Geophysics. It has done so by giving a start in graduate study to approximately nine of our graduate students. Though this support was not initially conceived as a major goal of the program, it has turned out to be of extraordinary significance in HAO's overall progress.

C. High Resolution Coronagraph and Spectrograph at Climax

Bids have been received for most of the optical work on HAO's new high resolution coronagraph and spectrograph for Climax. The construction is now under way at the Perkin-Elmer Corporation. Their excellent background for such work will assure us of satisfactory optical components, some of which are difficult to produce.

Most of the mechanical and electronic work will be done in our own shops under the guidance of Lee and Lacey. We still hope to have the instrument well along towards completion by the end of 1960.

IV. DEPARTMENT OF ASTRO-GEOPHYSICS

The department was, as before, directed by Warwick during this period.

Courses in the graduate department of astro-geophysics for the fall semester were as follows:

Modern Astrophysics--Newkirk
Experimental Techniques in Astrophysics--Billings, assisted by
Mr. G. Schnable and Dr. E. W. Dennison, Sacramento Peak
Statics and Thermodynamics of the Atmosphere--Haurwitz
Geomagnetism--Matsushita
Gas-Dynamic Phenomena--Dr. R. N. Thomas, N.B.S.
Reading and Research in Astrophysics--Staff
Doctoral Thesis--Athay

James C. Axtell received his Ph.D. degree from the University of Colorado at the August commencement. He was awarded his degree from the department of physics because his course work, examinations and thesis were rather far along towards completion before the department of astro-geophysics came into being. However, the thesis research was supported and directed by HAO, and in particular by Newkirk. The thesis was based on work with the K-coronameter. Axtell began his graduate research program with support from Radio Corporation of America, and later it was supported by the Institute for Solar-Terrestrial Research.

V. OTHER RESEARCH PROGRAMS OF HAO

A. Staff

1. New Staff

Two scientists who have had close ties with HAO for years have begun sabbatical years at HAO. They are Dr. Walter Steiger of the University of Hawaii and Dr. Malcolm Correll of DePauw University. Steiger directs the solar flare patrol station at Makapuu Point on Oahu. He has also conducted surveys and pilot solar observations from the summit of Haleakala Mountain on Maui, where it is likely that a future solar coronagraph and atmospheric sciences research site may be located.

Correll has been a summer visitor at HAO for several years, and a collaborator with Roberts and others in studies of solar atmospheric magnetic fields as deduced from prominence motions. He heads the department of physics at DePauw in Greencastle, Indiana.

Dr. Hans U. Dütsch of the Light-Climatic Observatory at Arosa, Switzerland, has joined HAO for a year to carry on his studies of ozone distributions in the stratosphere. He is closely associated with Haurwitz in this work. His visit was sponsored by the IGY program.

Dr. Hermann U. Schmidt joined HAO, also for a year, from the Max Planck Institute in Munich, where he has been associated with Schlüter and Biermann in studies of hydromagnetic phenomena. He is engaged in studies of prominence and corona matter, and has been working closely with Zirin.

Mr. Geoffrey A. M. King joined HAO as a one year visitor to work principally with the NBS staff on problems of the ionosphere. His visit was also sponsored by the IGY program.

Other new staff members included Mrs. Martha L. Arnett, Miss Mary C. Britton, Mrs. Esther K. Arinaga, and Mrs. Elizabeth A. Winter, who joined the secretarial staff. Mrs. Diane R. Gordon joined the Data Center staff. New research staff members included Mr. William L. Wright, who rejoins us after some years of absence, and Miss Nancy H. Potter, Mrs. Delight M. Dowell, and Miss Barbara A. Robertson.

2. Terminations

The period was not only one characterized by a large number of new appointments, but a correspondingly large number of people left HAO. We were particularly sad to have Mrs. Karen Sullivan and Mrs. Claire Simmons leave the secretarial staff after their many years of wonderful service to HAO. Dr. André Boischot concluded his year's stay, working with Warwick on the radio noise program. Mr. G. William Curtis left Climax and his very fine performance as Observer-in-Charge to come to Boulder as a graduate student in the department of astro-geophysics. Others who left HAO service included Miss Marsha Montgomery, Miss Penny Kimmell, and Mrs. Margaret Warwick from the secretarial staff, and Mrs. Marcia Carlen and Mrs. Karen Lowman from the research staff.

3. General

Miss Betty Prescott became Mrs. Betty Prescott Tanner during the summer, but will continue her work with Trotter on the solar activity program.

Chapman spent four months with us, from July to the end of October. In early November he went for some months to visit at the University of Michigan, where he and Dr. Lawrence Aller have been collaborating on some research on the corona. Chapman goes to Alaska again in the late winter and spring, and will be back in Boulder again in May.

The extended visit of Mr. S. Akasofu, a graduate student of Chapman at the University of Alaska, was the occasion for some stimulating discussions about the effects of hydromagnetic waves produced when solar corpuscular clouds impinge on the earth's outer atmosphere and its imbedded magnetic fields. Akasofu is highly critical of several recent hypotheses that purport to give substantial heating effects in the ionosphere from these waves.

Mr. George Schnable from the Sacramento Peak Observatory spent four weeks with us in October. During the period he consulted with the staff on optical design problems and also gave Billings's class in "Instrumental Techniques" the benefit of his remarkable knowledge of optics.

Schnable's visit was followed by a two-month visit by Dr. Edwin W. Dennison, also from Sacramento Peak. Dennison, whose strong interests are in photoelectric photometry, taught the "Instrumental Techniques" course while he was here and consulted with the staff on photometric problems.

These two visits were of great benefit to both staff and students and we hope to have many more such extended visits from the Sacramento Peak staff.

B. Research in Progress

This section contains, once again, brief summaries of certain selected areas of HAO's research activities.

1. Active Solar Region Analysis

In earlier reports I have indicated how analysis of the widths of spectrum lines of the solar corona and prominences give us information regarding the temperatures and other physical conditions of the artificial eclipse features of the sun. In this half-year Billings spent a good deal of his time studying the broadening of coronal spectral lines in active solar regions.

These regions are characterized, when seen in the light of single lines of the sun's coronal spectrum, by definite concentrations of intensity above active sunspot groups. They also exhibit numerous structural features, such as filaments, loops, and other forms, some of which greatly resemble solar prominences. However, the corona is not characterized by the violent motions that are so representative of prominences. Moreover, the lines of the coronal spectrum are very broad, unlike prominence lines, and this characteristic broadening undoubtedly testifies to the extremely high temperatures of the coronal regions, as distinguished from the prominences associated with them. (2)

Until the development of the rapid scanning techniques possible with the present Climax coronagraph, it was difficult to study the variations of the width of coronal lines across various regions of coronal intensification. The Climax observers have now succeeded in obtaining a large number of excellent spectra, using fine grain film, covering a large number of heights above typical active regions. From these Billings made detailed analyses of the variations of line width through these regions. The results show that the line breadth varies only slowly through coronal regions, and that sometimes there are regions of slightly narrower lines, implying lower temperatures, even near the centers of active regions.

Billings also studied the variations of line width with increasing height above active regions. In some instances the width, and thus temperature, rises as one goes from the surface of the sun to greater heights. It then passes through a maximum and begins to descend again with still greater heights. This descent of temperature, at greater heights, implies a fall-off in temperature about six times as great as that deduced by Chapman for the case where thermal conduction is considered as the only process of heat transfer through these heights. Billings speculates that the temperature drop means that some of the energy of the corona is dissipated by radiation of X rays. When these studies are carried further, he hopes to be able to make at least some rough calculations of the expected amount of X-ray energy dissipated in this fashion.

Another important aspect of active regions of the sun is the shape and strength of the magnetic fields in the corona and chromosphere above the solar surface. It is extremely difficult to observe magnetic fields directly at these heights, and it has never yet been done. The "Zeeman effect," which widens spectrum lines and affects the polarization in the line wings, would be extremely small

(2) Director's Quarterly Report, 1956-4, page 8.
Director's Quarterly Report, 1955-4, page 3.

for the expected values of the magnetic fields in the corona. Thus, it is dubious that prominence or coronal spectra, which have large innate breadths, can reveal the magnetic field.

However, Billings made an effort to deduce the magnetic field structure indirectly, by assuming that the magnetic field is responsible for supporting the coronal material in an active region and preventing its lateral spread, as sea water seeks its own level on the earth. By developing a theory for the known effects of gravity and the assumed effects of magnetic field in a support of the coronal gas, Billings made some rough calculations of magnetic field configurations. These have given what seem to be plausible magnetic field configurations. He hopes that it will be possible to map certain specific regions by this method, and then to compare the so-deduced magnetic field configurations with those derived from the motion of solar prominences in the same regions. One should expect the prominences to move in a direction parallel to the magnetic fields, as was pointed out in studies by Roberts and Correll, reported in these pages some time ago. (3)

As a final portion of the study of the spectrum of active regions, Billings began analysis of the line profiles by a new method, suitable for machine computation that allows him to detect not only the widths of the coronal lines, but also to determine very small Doppler shifts of coronal lines indicative of the velocity along the line of sight as small as a fraction of a mile per second. These studies show that there seems to be some evidence for a periodic structure, above an active region, in the width of the lines. Billings believes this may represent hydromagnetic waves (waves involving magnetic as well as hydrodynamic properties of ionized gas clouds) which can transport energy through the coronal atmosphere. The results of these studies suggest that the hydromagnetic waves move out in the coronal atmosphere at speeds of the order of some hundreds of thousands of miles per hour. From this one can deduce that a magnetic field of the order of one gauss is adequate to explain the observed shapes of coronal regions, and the observed characteristics of the hydromagnetic waves moving through the corona.

2. Solar Effects in the Ionosphere

Observations of radio stars continue with the HAO radio interferometer north of Boulder. This instrument operates at wavelengths in the tens-of-meters wavelengths and sweeps through a large range of radio spectrum (15 to 33 mc/s). Observations with the instrument

(3) Director's Quarterly Report, Second and Third Quarters 1957, page 19.

show most interesting scintillation effects in the appearance of radio star signals at certain times. Studies of the scintillation and radio signal absorption from distant radio stars continue, and will be reported in subsequent issues of the Director's Report.

3. Radio Noise and the K-Corona

Observations of the solar corona at Climax, using the K-coronameter led Newkirk to the derivation of an idealized model of the distribution of electrons in the corona. This model is based on the variation of brightness of the K-corona in a typical active region of the sun. This brightness variation, of course, represents the variation in the density of electrons in the corona (the electrons being the component that gives rise to the light of the K-corona).

Using the model of the K-corona, Newkirk calculated, using the University of Colorado's Bendix G15 computer, exact paths taken by various wavelengths of radio waves traversing the solar atmosphere. It was possible for Newkirk, using this computer, to study the path changes of radio waves through the model electron corona region, as the sun rotates carrying the active region along with it. The agreement between the calculated radiation at various positions on the disk and actually observed radiation is sufficiently good that Newkirk now believes the radio noise (the so called "slowly varying component") originates in thermal emission from coronal regions of enhanced density in which the electron density is relatively high (around 10^{10} electrons per cubic centimeter). This is an important conclusion because it shows that more complicated explanations do not need to be derived.

4. Studies of Geomagnetism

Matsushita undertook extensive studies of geomagnetic variations during IGY, using the special network of rapid-recording geomagnetic stations in the continental United States. He discussed, particularly, the behavior of the "sudden commencement" magnetic storms, paying attention to the details of the shapes of the variations of the magnetic field elements at the very start of the magnetic storms.

From this study Matsushita concluded that there must be two layers in the "electrojets" ("jet streams" of ionized gas at ionospheric levels) in equatorial latitudes. And he concluded that there must be a reversal of direction between the two layers of these equatorial electrojets. By such reasoning he feels that he can explain the characteristics of the variations of the sudden commencement curves.



FIGURE 3

The joint HAO program with the NBS to investigate magnetic storms led in September to a conference on magnetic prediction. Discussing the numerous factors that must be considered in making a prediction are, left to right, Roberts, Matsushita, Miss Virginia Lincoln (NBS), Trotter, Chapman, Dr. Constance C. Warwick (NBS), Dr. Barbara Bell, (Harvard), Miss Marion Wood (NBS), and Mr. Martin Nason (NBS). (NBS Official Photo)

5. Atmospheric Dynamics

For many investigations in geophysics and astrophysics, it would be most desirable to have a better understanding of the origin, maintenance, and final state of circulation of winds induced by thermal effects in the earth's atmosphere. In fact, such investigations are of general interest for gaseous spherical shells surrounding any planetary or stellar body. Haurwitz has recently studied such circulations using simplified theoretical models with which it is possible to assess the influence of various factors such as localized heatings, friction, injection of higher temperature gases, etc. Haurwitz's analyses have been carried out in an analytical form, which permits them to be exactly handled by relatively modest computing techniques, instead of requiring the massive techniques of numerical integration.

Haurwitz's work has dealt with various initial conditions, such as differing rates of heating, amounts of friction, etc. He has studied the attained velocities of the gas systems after various times. He has also considered the effect of Coriolis force on large scale systems, with and without frictional effects, and has worked out various idealized solutions. These studies have extremely great value in assessing how, in a complicated atmospheric system, the kinetic energy of various components of motion comes about from various initial temperature circumstances. Basic studies like this are essential if we are ever to understand fully the mechanisms of the large-scale circulation, including jet-streams, polar vortices, and other features of planetary wind systems.

6. Solar Activity Observing

As in previous periods, solar activity observing has made up a substantial part of the HAO's activities. Trotter continued the weekly and quarterly reporting of this solar activity, including data from HAO and Sacramento Peak Observatory and from other stations in the U.S. and abroad.

7. HAO Radio Spectrograph

HAO's radio spectrograph, built by Warwick, Lee and their associates, made its first detailed observations over a frequency range of 15 to 33 mc/s late in July. It has been operating continuously ever since. The instrument operates as a "phase switching, swept frequency interferometer." It has excellent sensitivity and permits detection of radio stars even close down to the horizon as they become absorbed by the Ionosphere (4).

(4) Director's Quarterly Report, Third and Fourth Quarters 1958, page 3.

The instrument has also been used extensively for observations of solar radiation. Large numbers of radio bursts have been detected. Practically every day's records show bursts that sweep in a matter of seconds from high to low frequency, suggesting extremely high-velocity clouds of gas traveling out through the solar atmosphere with a substantial fraction of the velocity of light (Type III bursts, as first described by Paul Wild of Australia). Large numbers of very intense outbursts of Type II have also occurred, sweeping at a far slower rate.

The instrument has also given extremely interesting results on radio frequency outbursts known as "continuum events" (or Type IV bursts). For these the spectrum is a broad band of frequencies sometimes covering our entire spectrum range, and going well beyond it, as shown by other radio spectrographs. These continuum events are particularly interesting in that they show a very high correlation with the occurrence of magnetic storms, subsequently, at the earth, and with the arrival of particles radiated from the sun with velocities comparable to those of cosmic rays. First results of this instrument have already been submitted to the technical journals. Striking examples of intense solar emissions detected by this instrument occurred in late August and again in November.

8. Colorado Streamflow Project

HAO took its first venture, during this period, into detailed studies of rainfall and streamflow data. We have particularly concerned ourselves with the flow of the upper Colorado River. The studies were supported by the State of Colorado, and during this period were carried on principally by Macdonald and Julian. Their goals were to study, first, the statistical properties of streamflow data available from historical records. The first goal was to determine whether the past records suggest distribution that departs significantly from random distributions in the level of flow from one year to the next. Secondly, Julian attempted to determine, from the statistical point of view, the physical processes involved in the hydrologic cycle--that is, to delineate the cause-effect relations between precipitation, snow-melt, and run-off--on both the minor tributaries and the major branches of the Colorado River.

The statistical techniques used, called "power spectrum analysis," are the most modern and powerful techniques for investigation of periodicities or cyclical characteristics in rainfall data. They will, therefore, enable us to renew the old question of the study of periodicities in meteorological quantities, and also will enable

us to discover whether there are variations significantly related to solar activity in the streamflow data for this particular river basin.

9. Studies of Cosmic Noise Absorption

Records of cosmic noise absorption have been obtained at 18 mc since the start of IGY, on equipment developed at HAO and operated at Boulder, Hawaii, Sacramento Peak, and Michigan. The records from this program are now being studied in detail by Steiger, who is programming the data for analysis on the IBM-650 computer at NBS. The observations are being handled in such a way that the cosmic noise power is derived at times when there is no absorption in the ionosphere and in such a way that diurnal, seasonal, and sunspot cycle variations can be accurately measured in the records. From this we hope that the nature of the absorption and the radiations responsible for the absorptions will become better understood.

10. Ozone Studies

During this period Dutsch has intercompared different methods for determining the distribution of ozone in the earth's atmosphere. Ozone, though a relatively rare constituent of the atmosphere, is extremely important because of its role in absorbing solar ultraviolet radiations, and because its presence identifies parcels of air in their motion, and also identifies areas where various kinds of processes of absorption are going on. A great amount of value is being derived, nowadays, from the study of the migration of regions of high ozone concentration, from variations in the rate of formation of ozone, and from a study of the relations between ozone concentrations at different heights and features of the large-scale atmospheric circulation. Ozone anomalies are often strikingly associated with large weather anomalies.

One result of studies of data for Arosa, Switzerland, for the winter of 1956-57 is of particular interest. It shows that the amount of ozone seems to vary throughout the night, with a maximum occurring about one and a half hours before midnight, and a continuous decrease for the rest of the night. Various efforts to interpret this variation are now under way.

11. High Resolution Flare Patrol

In December the high resolution flare patrol for installation at Climax was completed, under the general supervision of Warwick.

The patrol utilizes both 35 mm and 70 mm continuous film strip cameras. The instrument is designed to photograph the entire disk of the sun, and to alternate photographs of the disk with photographs of the entire circumference of the artificially eclipsed solar limb. Thus, both the motion of the prominences and of disk features can be simultaneously detected.

The instrument was not, at the end of the year, actually installed at Climax. Moreover, a number of features still require substantial development before the full potentiality of the new patrol can be achieved. We expect, however, to have excellent high resolution flare patrol and limb patrol observations in full operation during 1960.

12. Chromospheric Spicule Studies

Results of the spicule studies, which are being interpreted by Athay, will be reported in a future issue.

13. Eclipse Program

The Canary Island Eclipse Expedition was a very discouraging event. Groups from the HAO and the Sacramento Peak Observatory carried out an extremely well coordinated operation to the island of Fuerteventura in the Canary Islands. The location was extremely difficult to occupy, because of its isolation, the lack of adequate harbor, and the complete absence of cargo-handling facilities, but the landing was made successfully and the equipment installed in excellent operating condition on the site. Figure 4 shows a drawing sent by a resident of the island, Sr. Peres, who happens also to be mayor of a nearby town. It shows the equipment being landed from the skiff to the shore by hand.

Advance preparations of the site were carried out by Low and Laybourn who went to the Islands in August. They found the observing conditions, at the hour of the day corresponding to the eclipse, to be excellent. After the main party arrived, some six weeks before the eclipse, conditions were still very good, and we had highest expectations for clear weather at the time of the eclipse. With excellent cooperation from the local population and with diligent work under rather difficult conditions by the eclipse expedition, everything was in full readiness and in completely satisfactory operating condition at the time of the eclipse.

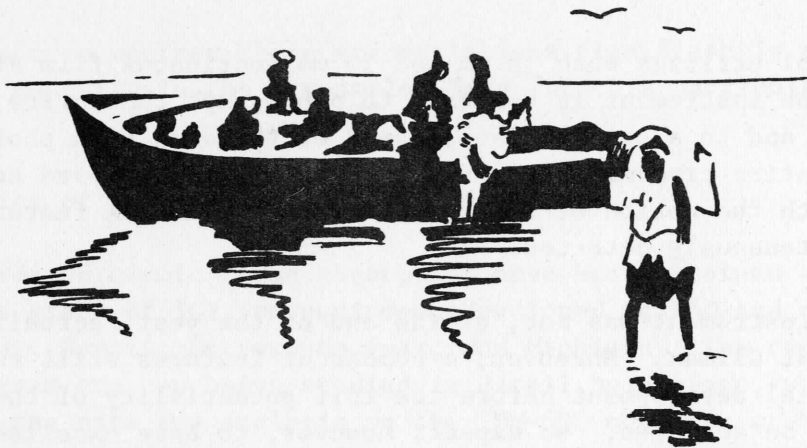


FIGURE 4

The HAO eclipse expedition to Fuerteventura in the Canary Islands in October could not have set up the instruments without the assistance of the local people. There were no dock facilities on the island, so all equipment was unloaded from small boats through the surf. Sr. Peres, mayor of the local community, sent us this sketch of the unloading operation.

It came as a shocking anti-climax when eclipse day broke with overcast skies which continued through totality. It did not help the morale of the party that shortly after the completion of the eclipse the sky cleared. There was nothing to be done except pack up the equipment and head home.

We have not yet determined whether we will make an effort to carry the equipment to the European eclipse in February 1961, which crosses Italy, Yugoslavia, Bulgaria, and the U.S.S.R.

14. Solar Data Center

The solar data center continued collection of data under the International Geophysical Cooperation-1959. International cooperation has maintained at a level very near that of the IGY.

A principal activity during the period was preparation of publications of IGY solar data, under the general direction of Hansen,

who is working closely with Dr. M. A. Ellison, who will edit the solar section of the IGY Annals.

15. High Altitude Balloon Studies of Solar Aureole

See HIGHLIGHTS, page 3

16. Alfred P. Sloan Research Fellowship Program

Zirin's work under the Sloan Research Fellowship continues to yield extremely valuable results. I plan to describe this in our next report. Zirin has undertaken further studies of the processes in solar prominences, leading to the conclusion that prominence spectra fall, in general, into two rather specific regimes of temperature, one at high values, and one at low values.

Zirin has also undertaken, in collaboration with Dr. John W. Firor of the Carnegie Institution of Washington, some studies of the infrared spectrum of the solar corona using television image tubes. These tubes offer very great advantages over photography, in that exposures of a few minutes duration suffice to reveal the spectrum lines whereas photography requires a substantial fraction of an hour.

17. Chromosphere Monograph

The monograph on problems of the solar chromosphere was completed by Athay and by Richard N. Thomas of NBS. The manuscript has now been submitted to the publisher, and it is expected that publication will occur late in 1960.

VI. RELATED PROGRESS AT OTHER INSTITUTIONS

A. Balloon Observations of the Solar Disk

The magnificent results of high altitude balloon observations of the granular structure of the solar face, obtained some time ago by Dr. M. Schwarzschild of Princeton University were substantially surpassed in an effort undertaken in late summer by the same group. A spectacular series of balloon flights produced an outstanding set of new solar photographs, including major sunspots and regions of quiet solar surface. The observations confirmed the polygonal shapes of the solar granules, but gave far better resolution of shapes and brightness fluctuations than anyone has ever before obtained.

The balloon technique developed by Schwarzschild and colleagues may go down as a major milestone in the development of solar astronomy, for it clearly demonstrated the feasibility of the use of balloons to get around serious difficulties that plague land-based telescopes. Air turbulence produced by irregular ground heating ruins high resolution telescope observations from the ground by producing displacements and distortions of the solar image. At 80,000 feet above sea level the distortions appear to be absent.

Results from this series of flights will occupy several years of analysis. Meanwhile, Schwarzschild has given the balloon telescope pointing and operation control to HAO for use in its coming series of atmospheric aureole studies, to be conducted in the summer of 1960.

B. Solar Radio Noise Studies

Spectacular advances have recently come about in our understanding of radio noise emission of the sun at wavelengths from a few centimeters to a meter or so. Superb work has been done by J. F. Denisse and his highly active group of colleagues at the Meudon Observatory in France. They have pooled the various known observational facts and evolved an increasingly self-consistent and highly important picture of the physics of active solar regions responsible for strong radio noise emission.

Perhaps the most intriguing new aspect of knowledge about the solar radio noise emission is the "Type IV radio noise burst" first recognized by Dr. André Boisshot in 1952, well before his stay here at HAO in 1958-59. These bursts of radio noise have a broad spectrum of radio frequencies in the range of tens of centimeters. They appear to result from radio emanations from a large cloud of high speed electrons ejected from the sun during certain strong solar flares (but by no means from all large flares).

Denisse and associates have tried to draw together a consistent story of the sequence of solar events responsible for the observed radio effects, as a guide to further research efforts (5). Denisse suggests that the starting process is a shock wave that moves upwards in the sun's atmosphere with a speed of about 1000 miles per second. This wave front, in his picture, then becomes turbulent, and begins accelerating electrons and protons to very high speeds as the wave moves outwards and diminishes in its associated magnetic field. These solar particles, indeed, achieve low energy cosmic ray speeds.

(5) This material was presented at Lake Arrowhead in California, at HAO and at the American Geophysical Union meeting, all during April 1960.

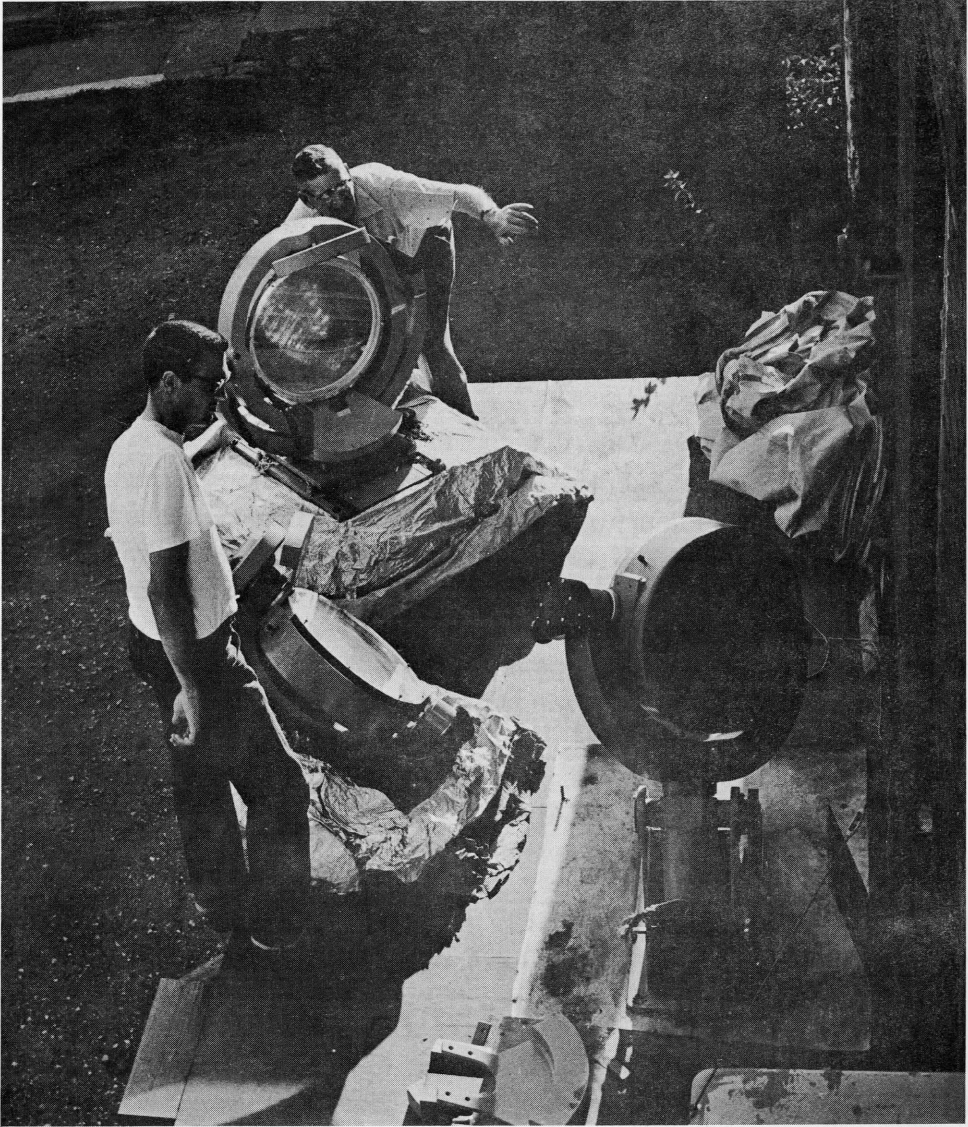


FIGURE 5

Gene Laybourn (right) and Ted Pretti (left) adjusting the big mirrors designed to carry sunlight into the spectrograph used at the October eclipse expedition to the Canary Islands. Here the mirrors are mounted outside the HAO shop facilities in Boulder where the equipment was designed, assembled and tested. Although clouds made the Canary expedition unsuccessful, the same equipment may be taken to the next eclipse whose path will be over Italy, Yugoslavia, Bulgaria, and the U.S.S.R. in February 1961. (see page 23). (Photo by Christiane Gallet).

As the field gets smaller, over a period of some minutes, it loses control of the fast particles, and they stream out into space, so that some of them fall into the polar cap of the earth. This causes, Denisse postulates, the now well-observed polar cap radio fadeouts that come an hour or so after certain solar flares.

Back at the sun some of the electrons remain trapped in the magnetic fields behind the shock wave, and these electrons as they spiral about the field generate the so-called synchrotron (or cyclotron) radiation that makes up the continuous spectrum of radio emission of the Type IV burst, which lasts some minutes.

After a half-hour or so, Denisse speculates, the electrons are reflected back towards the sun and become trapped in magnetic "bottles" in a fashion analogous to the terrestrial Van Allen belts. He maintains that the trapped electrons may remain trapped in significantly heightened numbers for several days, producing solar hot spots as they are absorbed in the corona or chromosphere, and possibly producing some of the sun's X-ray and ultraviolet output.

He further speculates that the continuation of the shock wave into space, when it reaches earth in a day or two, produces the well-known "sudden commencement magnetic storms" that almost uniformly follow Type IV radio noise events.

The picture is a most provocative one. It also underlines the extraordinary power of the tools of radio astronomy when they are applied to solar and atmospheric research. Much will have to be done to test these new ideas, but they certainly show the way to several specific optical and radio observational studies that will test their validity. The Type IV radio bursts will surely write one of the most important chapters in the modern history of solar physics and of solar-terrestrial research.

C. More on Meteoric Influences on Weather

Another milestone has been passed in research on the reality of cosmic influences on terrestrial weather. During the period, Glenn W. Brier (6) of the U.S. Weather Bureau conducted careful statistical studies designed to test the assertion by E. G. Bowen of Australia, previously detailed in these reports (7), to the effect that the same calendar dates exhibit, in many different years, abnormally great or abnormally small

(6) Paper subsequently presented at American Geophysical Union meeting in Washington, D. C., April 1960.

(7) For example, Director's Quarterly Report, Third and Fourth Quarters 1958, page 29; 1956-4, page 13; 1956-1 page 15.

amounts of rainfall. For example, 22 January, over a long period of years, appeared to Bowen to exhibit great world-wide rainfall, and to his colleague, E. K. Bigg, abnormally frequent and dense cirrus cloud cover over Australia.

Brier assembled data from three independent sets of rainfall data, as follows: (1) world rainfall figures from several hundred stations for 1880 to 1950; (2) average daily precipitation amounts from about 150 U.S. stations for the period 1952-1957; and (3) average daily precipitation for the same U.S. stations for 1958.

From this body of material, treated by sophisticated statistical tests, using electronic computers, Brier found that there was indeed strong evidence that all three sets of data were associated, and that they exhibited significantly high and low precipitation on the same calendar dates in different years. Moreover, the timing of the peaks around given calendar dates was so sharp that the associations fell off to nearly the randomly expected values by ± 2 days from the peak dates. This sharpness very strongly suggests that the associations with the weather anomalies is not the result of some obscure climatological tendency of a meteorological event to occur within a period of a week or two of some seasonal date, as some people have suggested.

The only plausible explanation of these effects appears to be one originally made by Bowen, namely that the rainfall peaks are produced by some kind of world-wide natural "cloud-seeding effect" associated with peaks of meteoric or cometary debris lying in stable orbits in space, where they are intersected by the earth in its annual flight about the sun, and on the same calendar dates year after year. However, a detailed description of the way the dust enters the relevant parts of the atmosphere, and how it produces the apparent weather effects remains for future research work.

It is also highly interesting that another result bearing on this same question has recently reached us from Russian sources (8). These research workers find that a twenty year series of Soviet weather station data reveals periods of abnormally widespread precipitation that occur on the calendar dates specified by Bowen, as well as on certain other dates. They confirm, moreover, Bowen's earlier assertions that the increased rainfall dates tend to lag known meteor showers by about 30 days (± 2 days).

The final word is not yet said on this meteor-weather effect. My own feeling, expressed previously in these pages, is that we will find

(8) Dmitriev, A. A. and A. V. Chili, "On Meteor Showers and Precipitation," (Translated by P. A. Kazakov) Trudy Morskogo Gidrofizicheskogo Instituta, 12, 181-190.

DISAPPEARING FILAMENT

1 SEP 1959

FILAMENT DISAPPEARS
CLASS 2 FLARE APPEARS IN SAME AREA



1803



1833



1902



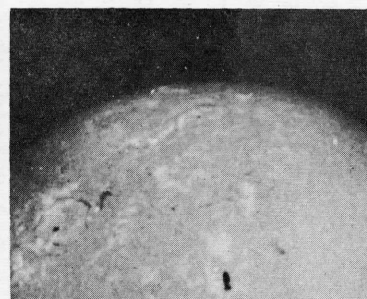
1907



1910



1915



1927



1958

FIGURE 6

This remarkable series of photographs in the light of Hydrogen gas, taken at the Sacramento Peak Observatory on 1 September 1959, shows the rapid and sudden disappearance of a dark filament from the surface of the sun. The filament at upper left apparently blows up over the brief period of an hour or so and is replaced with a Class 2 flare in the same region, visible in the last frame. The physical processes of such events are under intensive study here and at Sacramento Peak.

that the mechanism responsible for Bowen's results, whatever it proves to be, is intimately tied to the mechanism of the suspected solar-weather connections found in our own work.

VII. RECENT VISITORS TO HAO

1 July - August	Sherman C. Lowell, Adelphi College, Garden City, Long Island, New York
1 July - September	Syun-ichi Askasofu, Geophysical Institute, College, Alaska
1 - 31 July	E. K. Smith, National Bureau of Standards, Ionospheric Research Section, Boulder, Colorado
6 - 18 July	Takeo Hatanaka, University of Tokyo, Tokyo, Japan
10 July	A. M. Khan, Meteorological Service of Pakistan
16 July	Nancy Roman, National Aeronautics and Space Administration, Washington, D. C.
21 July - 21 August	M. Hasegawa, Kyoto University, Kyoto, Japan
1 - 31 August	Marcel Nicolet, Institute of Royal Meteorology, Belgium
1 August - September	Charles C. Bates, Office of Naval Operations, Washington, D. C.
1 August - 31 August 11 December	Max H. Woodbury, New York University, New York
6 August	Edward N. Lorenz, Massachusetts Institute of Technology, Cambridge, Massachusetts
8 - 12 August	Louis Berkofsky, AFCRC, Boston, Massachusetts
10 August	Reimer Lüst, Max Planck Institute, Munich, Germany
10 - 14 August	Robert Leighton, California Institute of Technology, Pasadena, California
19 - 21 August	Edwin J. Chernosky, AFCRC, Geophysics Research Directorate, Bedford, Massachusetts

22 August Hans Panofsky, Department of Meteorology,
 Pennsylvania State University, University
 Park, Pennsylvania

13 - 19 September James A. Van Allen, State University of Iowa,
 Iowa City, Iowa

17 September Earl G. Droessler, National Science Foundation,
 Washington, D. C.

17 September Frank S. Johnson, Lockheed, Sunnyvale, California

20 - 23 September J. Paul Wild, CSIRO, Sydney, Australia

24 - 28 September Guido Münch, Mount Wilson Observatory, Pasadena,
 California

25 - 28 September David D. Woodbridge, Army Ballistic Missile Agency,
 Huntsville, Alabama

8 October Su-Shu Huang, University of California, Berkeley,
 California

9 - 12 October E. Schatzman, Institute d'Astrophysique, Paris,
 France

19 - 26 October Julius Bartels, University of Göttingen, Germany

28 - 30 October H. W. Wells, Department of Terrestrial Magnetism,
 Carnegie Institution of Washington, Washington,
 14 December D. C.

2 - 4 November Diran Deirmendjian, Rand Corporation, Santa Monica,
 California

2 - 6 November John W. Evans, Sacramento Peak Observatory,
 Sunspot, New Mexico

3 November N. R. Noonkester, U. S. Navy Electronics Laboratory,
 San Diego, California

20 November Luna Leopold, U. S. Geodetic Survey, Washington, D. C.

30 November John B. Zirker, Sacramento Peak Observatory,
 Sunspot, New Mexico

1 - 2 December	John Waddell, Sacramento Peak Observatory, Sunspot, New Mexico
10 December	John R. Winckler, University of Minnesota, Minneapolis, Minnesota
28 December	J. A. Peoples, University of Kansas, Lawrence, Kansas
31 December	Harlow Shapley, Harvard College Observatory, Cambridge, Massachusetts

VIII. PUBLICATIONS FROM HAO DURING PERIOD

Tandberg-Hanssen, E.: "Physical Conditions in Limb Flares and Active Prominences. III. The Difference between the Surge and Loop Prominences of December 19, 1956," *Astrophysical Journal*, 130, 202-214, 1959.

Billings, Donald E.: "Velocity Fields in a Coronal Region with a Possible Hydromagnetic Interpretation," *Astrophysical Journal*, 130, 215-220, 1959.

Schwartz, Sanford B. and Harold Zirin: "Collisional Ionization Cross-Section for Fe XIV in the Solar Corona and the Coronal Electron Temperature," *Astrophysical Journal*, 130, 384-392, 1959.

Matsushita, S.: "Geomagnetic and Ionospheric Phenomena Associated with Nuclear Explosions," *Nature*, 184, pp. B.A. 33-B.A.34, 1959.

Malville, John M.: "Antarctic Auroral Observations, Ellsworth Station, 1957," *Journal of Geophysical Research*, 64, 1389-1393, 1959.

Johnson, H. R. and F. Rohrlich: "Negative Atomic Ions," *Journal of Chemical Physics*, 30, 6, 1608-1613, 1959.

Warwick, Constance S. and R. T. Hansen: "Geomagnetic Activity Following Large Solar Flares," *Journal of Atmospheric and Terrestrial Physics*, 14, 287-295, 1959.

Johnson, H. R. and F. Rohrlich: "Atomic Electron Affinities," *Nature*, 183, pp. 244-245, 1959.

IX. DATA REPORTS AND SPECIAL PUBLICATIONS FROM HAO

A. World Data Center Publications:

IGY Solar Activity Report Series No. 8, January to March 1959,
"Intermediate Reports of Surges and Active Prominence Regions."

B. Solar Activity Reports:

Trotter, Dorothy E. and Walter Orr Roberts, Solar Activity Summary
IV, Report No. HAO-45, 12 October through 2 January 1959.

Trotter, Dorothy E., Donald E. Billings, Betty Tanner, and Barbara
F. Dolder, Preliminary Report of Solar Activity, Nos. 409
through 435, 1959.

Walter Orr Roberts

Walter Orr Roberts
High Altitude Observatory
Boulder, Colorado
25 June 1960

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