

THE  
DIRECTOR'S QUARTERLY REPORT

*Third and Fourth Quarters 1958*

*1 July through 31 December 1958*



Splicing Flare Films\*

*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: Over the 18 years of its operations HAO has collected a large file of films of solar activity which are kept immediately available for research uses. Copies of the original 35 mm negatives of solar prominence and coronal sequences from Climax and Sacramento Peak and a variety of other solar films are stored in the HAO film library. Mrs. Barbara F. Dolder is shown here coding and splicing a flare patrol film made at Climax. (Photo by Christiane Gallet.)

## SUMMARY

The true significance of the International Geophysical Year, now ended, will become apparent only with the passage of years. However, notable advances are already evident. They range from the discovery by satellite research of the spectacular van Allen radiation bands to detection of relatively low altitude atmospheric X rays accompanying auroras found by high flying balloon observations. Solar activity measurements will contribute to many of the research programs to come. Thus we look with satisfaction to the completeness of coverage achieved at HAO and elsewhere during the past 18 months of the IGY.

The new HAO radio interferometer has made major contributions to our work this half-year. With it we have found interesting effects of scintillation of radio stars and of possible absorptions of radio star emission by high level auroral zone ionization. We have also deduced some new facts about satellite spin from the records made during the first few days of the radio telescope's operation, just after the surprise firing of the Soviet Sputnik I satellite.

Studies of coronal active regions received special attention during the second half of 1958. New theoretical evidence has been developed to support our view that normal active region coronal temperatures range upwards from two million degrees. We have also found it possible

to make more detailed maps of the distribution of coronal spectrum line breadth in active regions--a substantial observational advance.

At long last we have been able, with the help of National Science Foundation funds, to start work on the major coronagraph and spectrograph planned as the principal telescope for the 26-foot equatorial at Climax. When finished this will materially step up the observational power of our Climax station.

The October 12th eclipse was clouded out on the island of Puka-Puka in the South Pacific. With the rain disappeared all of our hopes for a new and powerful attack on the chromosphere along the lines started at Khartoum in 1952. We plan, however, to try again in October 1959.

The enormous solar radio noise increase that I observed from the Crimea in August, and described in my last report, turned out to be a truly major event. When I reached home, I found that it had not only saturated the HAO radio telescope, but had produced a striking low-energy cosmic ray effect observed by various groups. These events are described in more detail in Section V.

As on several past occasions, my report combines the description of our work over two quarters of a year.

## I. HIGHLIGHTS

### A. IGY Ends

The International Geophysical Year, greatest cooperative scientific experiment of history, is now over. One of the greatest and most unexpected discoveries of IGY was made by Dr. James A. van Allen and his colleagues at the State University of Iowa. From satellites and moon-rockets they found evidence for previously undetected belts of intensive radiation at 1000 miles and higher above the earth. The radiation belts produced thousands of times more intense X rays within the rockets than anyone had anticipated would be the case from cosmic ray researches. Moreover, the new radiation belts seem to be solar in origin, and strongest over the earth's equator. They dipped to lower altitudes in the auroral zone, causing some scientists to suggest that the aurora is, in fact, the result of the "leakage" of this radiation to the earth. This is now known as the "leaky bucket theory."

At the Moscow meetings of the international IGY Committee, which I attended in July and August, the Soviets proposed a full-fledged continuation of the IGY into 1959 and later years. We from America, on the other hand, felt that certain areas of cooperative international observation should be continued, but that we could not afford to direct so large a fraction of our research effort to observations in geophysics until stronger theoretical and analytical efforts had been made with IGY data. A compromise plan was worked out to continue certain key observing and data-reporting schemes in 1959 under a cooperative program now called the "International Geophysical Cooperation-1959." For the solar field this means that substantial observing and data routines will continue as a service to the geophysical disciplines. We hope, however, to tailor these in such a way that they aid rather than interfere with our regular research programs.

### B. Possible High Level Auroral Absorption

One of the highlights of HAO's work this half-year has a close connection with the auroral zone, and thus perhaps with the van Allen radiation belts mentioned above. Moreover, it comes from the new Air Force supported radio telescope program of Warwick, Lee and their colleagues. This has been re-directed from satellite studies to its original aim of measuring radio stars at wavelengths of about 18 and 38 mc/s.

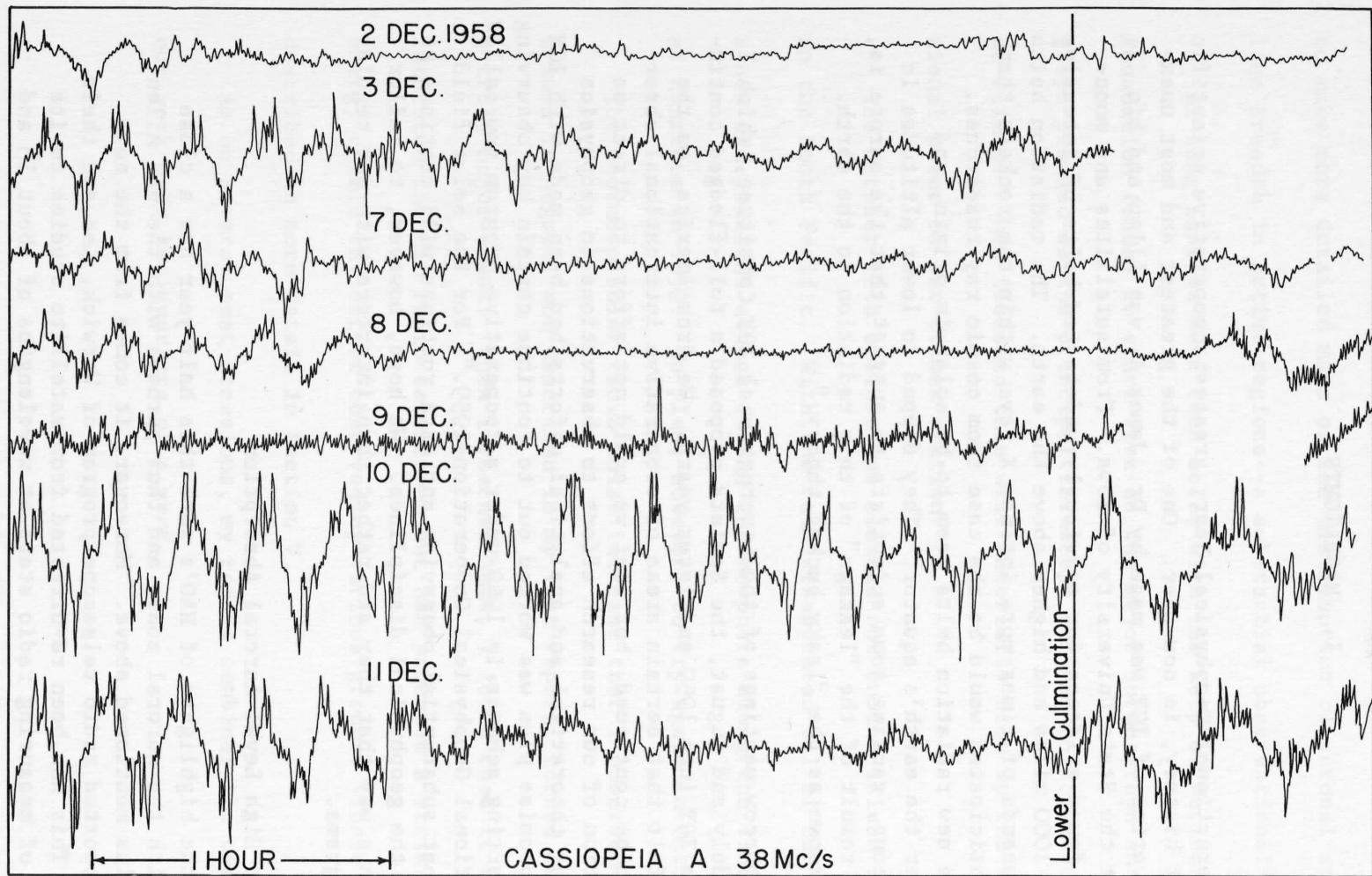


FIGURE 1

38 Mc/s interferometer records from the radio star Cassiopeia A, showing disappearance of signals on some nights, like December 8th (line 4) about two hours *before* the radio star reaches the point nearest the horizon (lower culmination). We suspect that the disappearance may occur when the radio signals from the star pass tangentially through the auroral zone and are subjected to increased absorption.

The result, still very speculative, deals with the 38 mc/s. radio signals of the radio source known as "Cassiopeia A," one of the strongest radio signals in the sky. The radio noise of this object comes, probably, from continuing radio oscillations set up by a cataclysmic prehistoric explosion of a relatively modest star into a supernova. The explosion probably occurred more than 100 thousand years ago. Even today one can find at this spot a faint, irregular cloud of gas that exhibits internal motions with speeds as high as a thousand miles per second.

Warwick and Boischot made records of this radio star in December as it skimmed low over the northern sky during the night. For these measures they pointed our large two-reflector radio telescope towards the north and tracked the star as it passed "lower culmination," the point nearest the horizon in its 24-hour circular orbit around the north pole star. When they started the observations, they expected to find the star weakening to a minimum near lower culmination as the beam of radio noise passed through a longer path of air, and thus of partially absorbing ionospheric gases.

What they found instead is shown in Figure 1. The time of closest approach to the horizon is marked by the vertical line at the right. Each horizontal graph represents a different night in December. The star signals produced in the telescope (rigged as an interferometer), a rising and falling oscillation clearly shown, for example, at the left of the second line for December 3. Clearly evident is the fact that some nights, like December 10, showed oscillations through lower culmination, though others, like December 8, showed no signal at all at minimum. But most striking, the disappearance often occurred about two hours before lower culmination, as shown on December 8.

Searching for an explanation of this has been a fascinating task. One possibility was evident at once to Warwick and Boischot. When its signals start fading out two hours before lower culmination, the Cygnus source lies some 20° west of the north direction. If you trace the line of sight to the Cygnus source at this time, you find it passes just about along the line of tangency to the average position of the auroral zone.

Consequently, the obvious possibility arises that the density of ionized gases in the auroral zone is high enough to absorb or scatter the signals when they traverse it tangentially, thus passing through a large total volume of auroral ionization. This idea is particularly

intriguing because the source is fairly high in the sky at this time, and therefore the point of tangency at the distance of the auroral zone is about 450 miles up. This is more than twice the heights to which we normally consider processes of the ionosphere, and thus of radio wave reflection, to be important.

If the interpretation, now highly conjectural, is confirmed by future work, we will have in this method an important new means of probing the physical conditions of high layers of the atmosphere in the significant zone of auroral activity. We are plagued in this work by spurious radio static from the power lines leading to our site; in fact a good part of the time our records of Cassiopeia A have been totally blanked near lower culmination by this interference. We hope to bury the power lines as soon as possible to avert this trouble and to make it possible for us to continue these unexpected new leads.

### C. Higher Temperatures for the Solar Corona

For several years, now, we have carried on a program of study on the physical processes involved in emission of the various spectrum lines of the solar corona. This work, supported principally by the U.S. Navy Office of Naval Research, has been supervised by Billings and Zirin. As one of its important phases, it has involved the Ph.D. thesis work of Schwartz under the general guidance of Zirin. One aspect of this study has now come to a culmination point with results on the formation of the high-ionization spectrum lines of the corona that are most interesting.

The coronal spectrum lines are unusual in origin. They are radiated from atoms of gas in the solar atmosphere that have undergone severe stripping of their outer electrons in the powerful ionization conditions that exist there. This causes a displacement of the normally emitted spectrum lines towards the far ultraviolet, where they are inaccessible to observation because of the opacity of the earth's atmosphere. The lines that are radiated in the visible are, on the other hand, hard to identify with the atomic properties of the radiating gases. Hence coronal line identification was long a major unsolved solar problem.

A few years ago our ONR-sponsored program made a significant contribution to coronal physics by helping to settle the identification of the relatively rare "yellow coronal line" of wavelength 5694A, whose origin was long regarded as a top-priority mystery. We found entirely



new and independent evidence that the line came from Calcium XV (calcium atom with 14 electrons stripped away). This identification could not lightly be made because it tagged the line as the highest ionization spectrum line known to man. Subsequent theoretical developments, however, have fully confirmed the identification (1).

To strip large numbers of electrons from the vaporized metal atoms of the corona involves extremely high temperatures of from 500,000° to 4,000,000° (Absolute). Just how high these temperatures are, and just how they are produced in the vicinity of the much cooler (6,000° Absolute) solar surface has long been a basic problem of solar physics. Schwartz and Zirin attacked the first of these two questions.

When the coronal lines were first examined in detail many years ago, they were found to be fuzzy and broad, rather than sharp and narrow like most lines of the atmospheric solar spectrum. Usually the widths were interpreted as evidences of large amounts of internal large scale motion in the gas clouds of the corona, resulting in smearing of the lines by the Doppler effect. However, we felt at HAO that the lines were primarily broadened by the high temperatures of the gases, which caused the individual atoms to radiate over a broader range of spectrum due to the high speeds corresponding to these temperatures. The temperatures we derived in this way ranged from about 2,000,000° upwards.

Theories of the ionization of the corona, on the other hand, suggested that for iron atoms to lose 9 electrons (Fe X) to 13 electrons (Fe XIV), as observed in the coronal line spectrum, the temperatures should be only about 500,000° to 1,000,000° (Absolute). At 2,000,000° (Absolute), these theories stated, Fe X could scarcely continue to radiate, since atoms in this condition would immediately be stripped to higher levels. We were thus confronted with a conflict of evidences.

Schwartz's thesis demonstrates that the ionization theory previously used was probably incorrect, and that the higher temperatures of about 2,000,000° are right to produce the observed ionizing effects. The way to this result was a laborious one, involving substantial use

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(1) Director's Quarterly Report, 1955-4, page 4; Director's Quarterly Report, 1956-4, page 8.

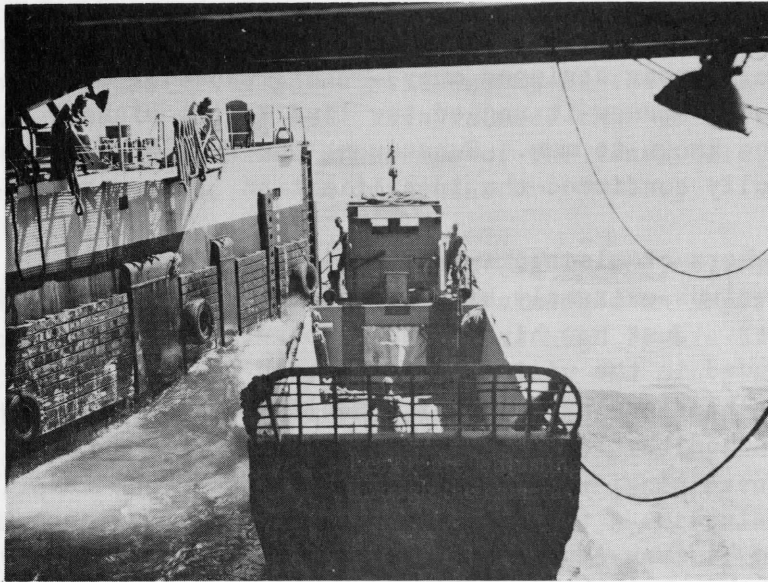
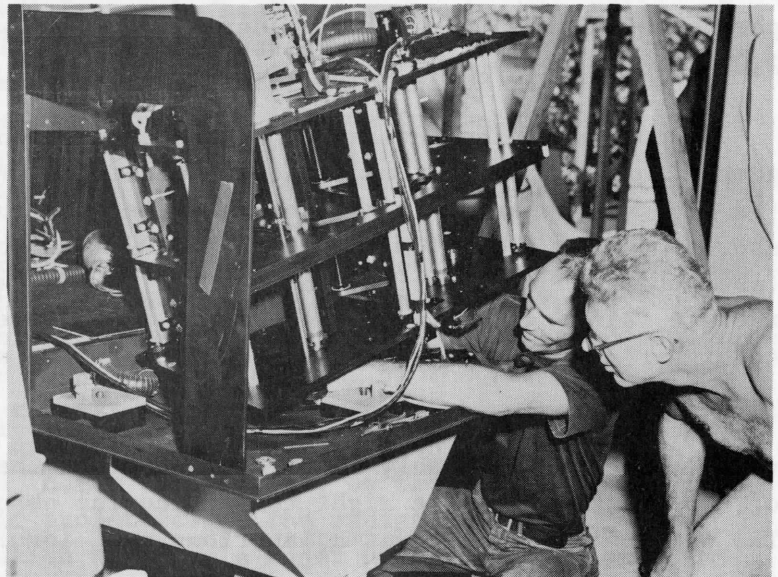


FIGURE 2

The eclipse expedition reached Danger Island on the Point Defiance, a Navy LSD (landing ship dock). A small landing vessel is shown afloat in the stern of the ship.

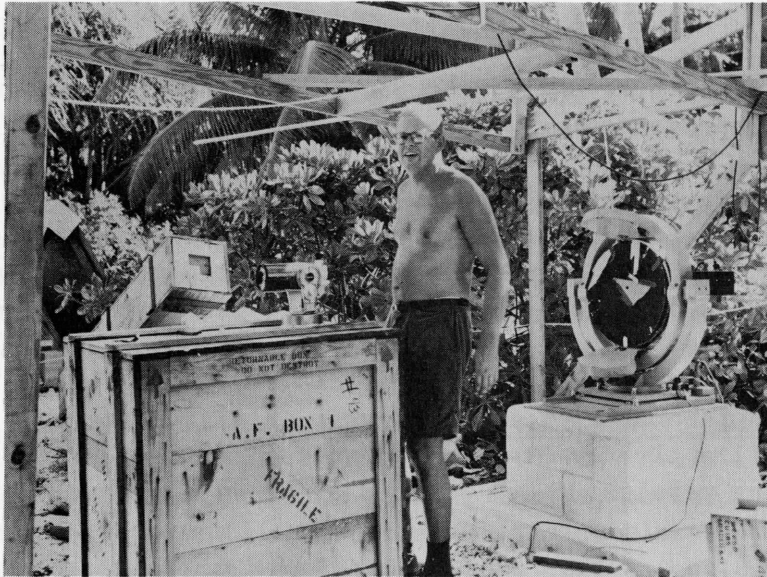


Mr. Lee Lacey (HAO) and Dr. John W. Evans (Sacramento Peak) are adjusting one of the mechanisms that moved the film through the cameras.

ECLIPSE  
EXPEDITION



Our group camped ashore with a group of Navy men who assisted with construction, cooking and other essential chores. The quonset served as laboratory and living quarters for our people.



Mr. Richard B. Dunn (Sacramento Peak) is using the Questar telescope to check the "seeing" conditions over the lagoon. The objective mirror at the right reflected the solar image to the spectrograph.

*Photographs from the Naval Research Laboratory.*

of an IBM-704 calculating machine, for which we are deeply indebted to the Martin Company and IBM. Moreover, a great deal of labor went into setting up the equations for solution of the problem. The formulation of the underlying theory itself, before calculation, was also rather complex and will undoubtedly be the subject of considerable scientific controversy before it is independently confirmed or rebutted. The result will justify this attention, however, since it is of fundamental importance in atomic theory dealing with collisions of gas atoms at high temperatures.

We are happy with the result because it removes the discrepancy, mentioned above, between temperatures calculated from spectrum line profiles and temperatures calculated from the relative intensities of different spectrum lines. Moreover, work to date suggests additional observations that can be made with the coronagraph to confirm the theory, since it predicts the intensity that we should observe for certain other coronal spectrum lines we have not regularly observed, but will now seek to measure. If it stands the test of time this study of coronal ionization theory may rank as one of the most important contributions from the HAO to date.

#### D. The Eclipse

The eclipse expedition to Puka Puka was a heartbreaking failure. After weeks of hot, difficult struggle, the Sacramento Peak Observatory and the High Altitude Observatory crew finally whipped the eclipse equipment into shape.

However, luck and the South Sea gods that govern weather in the Danger Islands were not with us. A thunderstorm blanketed the islands during the crucial minutes of October 12th, and there was nothing to do but pack up and return home.

The Naval Research Laboratory eclipse rockets, rising above the weather, performed brilliantly for Drs. Chubb and Friedman, however, and gave most intriguing results. (See Related Progress at Other Institutions, Part VI.)

## II. PROGRESS ON NEW HAO RESEARCH BUILDING

Wonderful support has been given us towards our new and critically needed research center in Boulder. The deadline of December 1958 on one of the previous pledges was extended, and additional contributions have been coming to us in a most gratifying way. We extend our sincere thanks to all who have so helped us.

The Max C. Fleischmann Foundation of Nevada has now agreed to match all funds contributed between December 1st, 1958 and June 1, 1959. The total of all pledges (as of February 28, 1959) therefore brings us up to \$218,600 of the needed \$250,000. An added \$15,700, matched with an equal amount from the Fleischmann Foundation, will thus complete the financing.

Final building plans are in preparation, and I hope by the next report of this series to be able to notify our friends of completion of the fund and of the ground-breaking. Needless to say, help over this last hurdle also will be greatly appreciated!

## III. PROGRESS IN THE INSTITUTE FOR SOLAR-TERRESTRIAL RESEARCH

### A. Conference on Long-Range Forecasting

A principal activity under our Institute program this half-year was the Conference on Long-Range Forecasting held on September 24, 25 and 26 at Dercum's Ski Tip Ranch near Dillon, Colorado. The conference was co-sponsored by the Munitalp Foundation, and was patterned on the informal organization worked out by Dr. Vincent J. Schaefer, research director of the Foundation. Macdonald carried out HAO's part in the conference planning.

Its plan, developed at the First Annual Adirondack Conference a year earlier, was to bring about a dozen-and-a-half working research meteorologists together for a three-day period to confront each other and their scientific problems in the completely informal atmosphere of a mountain lodge, where their home offices couldn't reach them, and where there were no distractions to a contemplative and relaxed discussion of the way to progress in long-range weather forecasting.

Four areas of discussion were confronted in the three days:

- (1) Evidence for the causes of weather changes in various time scales,

and the theories which have been proposed to explain them, Roberts, discussion leader; (2) Review of the potential methods which might be used to make long-range predictions, Dr. Eberhard Wahl, discussion leader; (3) The possible uses of long range forecasts, their practical and potential uses, Mr. Robert D. Elliott, discussion leader; (4) Future fields of research, including those not now being followed, Mr. Jerome Namias, discussion leader.

The participants were as follows:

Mr. Glen W. Brier United States Weather Bureau	Mr. Jerome Namias United States Weather Bureau
Mr. Robert D. Elliott North American Weather Consultants	Dr. Walter Orr Roberts High Altitude Observatory
Mr. Raymond E. Falconer Munitalp Foundation	Dr. Eberhard W. Wahl Air Force Cambridge Research Cntr.
Mr. D. C. House United States Weather Bureau	Dr. Hurd C. Willett Massachusetts Institute of Tech.
Dr. Irving P. Krick Irving P. Krick Associates, Inc.	Dr. Max A. Woodbury New York University
Mr. Norman J. Macdonald High Altitude Observatory	Dr. Vincent J. Schaefer Munitalp Foundation
Mr. Keith Veigas Travelers Weather Service	Dr. Charles Smiley Brown University
Mr. Walter Garstka - Observer Bureau of Reclamation	Dr. Edward J. Cahill Standard Oil of California
J. H. Brazell, Esq. - Observer East African Meteorological Dept. East Africa High Commission	

The conference was so organized that the discussions were conducted informally, with no transcript of the proceedings intended. Informal evaluation, suggestion and free speculation were encouraged in all possible ways. Tangible results were to be expected, however, not in

the form of reports or resolutions, but in the form of influences that might affect the later research planning of the individual participants, all of whom are engaged actively in work related to the central goals of improving weather forecasting at a time-scale of a week and longer.

From the standpoint of the research interests of HAO, Macdonald and I came home convinced that one of the most important areas requiring continued and vigorous search for causal processes is that of "trigger mechanisms" which might make available large amounts of energy through the action of relatively very small amounts of energy. Certainly any breakthrough in this field could have important implications in long-range forecasting. Although there is no certainty of its coming from solar-weather research, nevertheless some kind of scientific breakthrough is seemingly required if significant advances in long-range forecasting are to be achieved.

## B. Solar-Weather Studies

Macdonald continued his efforts to extend our research on the tendency for trough systems to develop to larger size when they are preceded by geomagnetic storms two to four days before their first appearance in the Aleutian area. He ran into snags, however, trying to use for lower levels the same kind of trough index as we used in our first studies at the 300 mb (about 30,000 feet). Nevertheless, we plan to continue the effort, so that we can study additional years from the older data, which were restricted to lower levels. We would like very much to use observations from the 1947-49 solar maximum for comparison, but fear that the map analysis done in these years may not be sufficiently accurate for our purpose, even at the lower 500 mb (18,000 feet) level.

The undisputed solar control of ionospheric layers of the earth's atmosphere, above 50 miles altitude, suggests that if there are solar-weather influences, there will also be discernible relationships between ionospheric levels and the surface weather. As a consequence, we have started some exploratory searches for relations between surface weather phenomena and ionospheric levels similar to what has been reported in the past by Father Gherzi, Conrad Mook, S. J. Bauer and others. Our first checks of the data are, at the least, not discouraging to the hypothesis of a real connection. We hope that the research staff of the Central Radio Propagation Laboratory of the National Bureau of Standards here in Boulder will join in this effort, giving us the bene-

fit of their extensive experience with the physical conditions of the ionosphere. HAO's work on this is being done principally by Macdonald, with advice from Matsushita, Tandberg-Hanssen and Roberts.

#### C. Astro-Geophysics Fellowships

Several students in our graduate department of astro-geophysics are continuing their graduate study in solar-terrestrial research with support from the Institute.

### IV. DEPARTMENT OF ASTRO-GEOPHYSICS

The fall semester saw the beginning of the second academic year of the new graduate program in astro-geophysics of the University, staffed principally by members of the HAO research group. The roster of graduate students enrolled in the department for the first semester is as follows:

Mohammad K. Alam	Hollis R. Johnson
Paul C. Arnold	Jorma J. Riihimaa
Rakesh K. Bhatnagar	William R. Simmons
John A. Eddy	Jerry L. Weinberg
Lewis L. House	Oran R. White

The work of directing the progress of the department is of greatest importance to the future of the HAO and to the realization of its educational goals. Consequently, I asked the Trustees to designate a new position in the HAO structure, Assistant Director for Astro-Geophysics, to be filled by a member of the HAO staff who devotes substantial effort to planning, working and dreaming about the optimum program for the department. I hope ultimately that this position can be officially sanctioned by the University, and that the person filling it will be able to serve in a recognized capacity on the academic faculty. The first appointment, made this fall for one year, was to Warwick.

### V. OTHER RESEARCH PROGRAMS OF HAO

#### A. Staff

Chapman spent part of the half-year with us, returning to Boulder after the international meetings in Europe, and staying until about February 1, 1959, when he went to Sacramento Peak. He will return again next summer, after another stay in Alaska at the Geophysical



Institute.

Zirin spent about five months in Europe, a good part of which was in Munich as a guest investigator at the Max Planck Institute. He also made a rather leisurely tour in his own car to the Crimea in USSR after the IAU meetings in Moscow. His stay in Europe and his work back here are under his two-year appointment as an Alfred P. Sloan Research Fellow.

Jefferies returned to Sacramento Peak Observatory in July after spending a year as a guest worker at the HAO. He made an important contribution to the staff and we look forward to continued collaboration with him during the remainder of his stay in the United States. He plans to return to Australia this coming summer.

Dr. Joseph C. Cain of the Geophysical Institute at the University of Alaska continued his visit as a guest worker during the period.

Durbin terminated his appointment at Climax somewhat unexpectedly because of health problems of his youngest son. His place was taken by Mr. Roland Manning who moved to Climax in October.

Dr. André Boischot joined HAO to collaborate with Warwick in the radio astronomy program. He has worked with Dr. Denisse and others at the Meudon Observatory near Paris, and is a colleague of our research associates, Jean Claude Pecker and Gérard Wlérick.

Mrs. Jean Corbett joined the staff as secretary to Low. Miss Florence Sigismund became telephone operator; Mrs. Stephanie McAlister took over in the library when Mrs. Alexandra Platts left us in September.

Mrs. Karen Lowman joined HAO as a research assistant. Mrs. Sandra Carlen joined the staff to work in the Data Center, and Mrs. Margaret Warwick replaced Mrs. Phyllis Guffy on the secretarial staff.

## B. Research in Progress

Seven HAO staff members attended the International Astronomical Union meetings in Moscow, and during this time the eclipse expedition was loaded and shipped off for Puka Puka. As a consequence, the month of August saw many of the staff away. In September, however, things settled back to the normal busy course of affairs. The principal advances

are singled out below.

## 1. Active Solar Region Analysis

The study of active regions at the solar limb continues to occupy a major part of our attention. Several pieces of work were carried to completion, and submitted for publication.

One, by Tandberg-Hanssen, Curtis and Watson, reports an interesting new observation made on the solar disk in the great flare (importance rating of 3+, which is the highest given). For this flare we succeeded in getting spectra of the flare region with the infrared spectrum lines of helium at 10,830 Å. These revealed that the helium spectrum line appeared, at different times and places, both as an emission line and as an absorption line. This is, so far as we know, only the second time the line has been seen as an emission feature, though one should expect it to appear in this fashion. The spectra were of sufficient quality to allow us to make studies of the line widths. If we could photograph such a feature at the solar edge the results would be of greatly enhanced scientific value; the prospect is not favorable, however, since flares are rare enough to make it difficult, without further insisting that they be at the solar limb.

Tandberg-Hanssen also undertook a detailed study of the limb spectra of upwelling prominence surges and downflowing active region loops that appeared on 19 December 1956 at two distinct regions of the solar limb. The loop prominence, characterized by very strong coronal emission, was studied earlier by Zirin and others, but the new analysis sought to study the differences in temperature conditions between the two prominence types, and within different parts of each of the prominence types. Again the analysis involved study of the detailed shape of the spectrum lines, which are broadened by several causes, including temperature and motions. The looped prominences were intimately connected with the corona, and appeared just below regions of strong yellow coronal line emission. The spectrum lines broadened as the traces were made higher in the region. The surges, on the other hand, started out as intrinsically very bright jets, and faded rapidly as they moved higher in the corona. Moreover, the spectrum lines narrowed at greater heights. It is clear from this that the conditions of temperature and line-broadening are complex. In addition the study showed that even

within the prominences of the same type the conditions producing line emission are very different, although not as differentiated as between the two active region types. It is highly probable, thus, that prominences generally contain several domains of very different physical conditions, each radiating its own characteristic radiation, and that no simple homogeneous active-region prominence model will ever be possible.

Billings has taken an independent mode of approach to problems of the physics of the active regions, working from coronal spectra alone. He has been seeking, in typical active regions, to find how the line breadths of the corona lines change with height in a given active center. The corona lines are from gas in so tenuous a condition that even in the strongest concentrations the gases are essentially transparent. This greatly simplifies the interpretation of the physical conditions in which the lines originate, though it restricts the problem only to those regions and to those conditions where the lines can be seen. Billings and Cooper have found, to our great interest, some rather definite evidence for changes of line breadths with heights; it seems, moreover, reasonable to interpret these changes as temperature differences.

In one region studied, the green coronal line broadened to widths indicative of temperatures of three million degrees (K) in the general vicinity where the yellow coronal line became strong, suggesting that here was a transition to a considerably hotter region.

In a more quiet, but still active, region Billings found indications of a periodic fluctuation of coronal line width, suggestive of a hydromagnetic wave in the coronal plasma. He analysed the data, assuming that the wave was indeed a hydromagnetic wave, a reasonable assumption because the corona is very probably an ionized gas threaded by a magnetic field. He concluded that if the basic assumption of a hydromagnetic wave can be supported, such an analysis might lead to the derivation of highly valuable information about the nature of the magnetic field threading the gas. Such data would be extremely valuable for studying the origin of radio noise, solar corpuscular emissions and the possible origin of low energy solar cosmic rays.

In the same active region Billings also found evidence for a large scale circulatory or swirling motion in the corona with a velocity of about 1 km/s. In this motion the material on the equatorwards of the 30° solar latitude point was moving towards the earth, and that north of this latitude was moving more slowly in the opposite direction. These results are all now being readied for publication.

## 2. Solar Effects in the Ionosphere

Under HIGHLIGHTS I have already described interesting new evidence of a possible high level absorption of radio noise that should perhaps be classed as ionospheric, though the preliminary evidence gathered by Warwick and Boischof suggests it may occur well above the usual ionospheric heights in the auroral zone.

Another new result from the program of Warwick and Boischof involves the nature of the tracings of the power of the 18 mc/s and 38 mc/s radio signal of the Cassiopeia A radio star. This power, measured both on the individual antennas of our radio telescope, and when the antennas were connected together as an interferometer, generally exhibits a short-period sharply peaked fluctuation. The graphs show an irregular fluctuation with sharp peaks of power that average several times greater than the overall average of the power. Moreover, the peaks are always intensifications of power, rather than random fluctuations around the average and are often correlated at the two very different frequencies. Our results resemble ionospheric "ridges" found by Wild of Australia, but these phenomena have not been found by the English workers.

Warwick and Boischof have speculated that perhaps these peaks are produced by drifting irregularities of the ionosphere that are lens-shaped and so concentrate power on the telescope at irregular but closely-spaced intervals. If the interpretation is correct, the regions producing such an effect must be relatively large compared to these radio signal wavelengths, and must involve substantial changes of ion densities. There is, moreover, hope of gaining considerable quantitative information from the character of the records.

We completed the cosmic noise recorder for use at the University of Hawaii, and installed it at their Makapuu Point station after the weather-scarred eclipse expedition (see HIGHLIGHTS) returned from

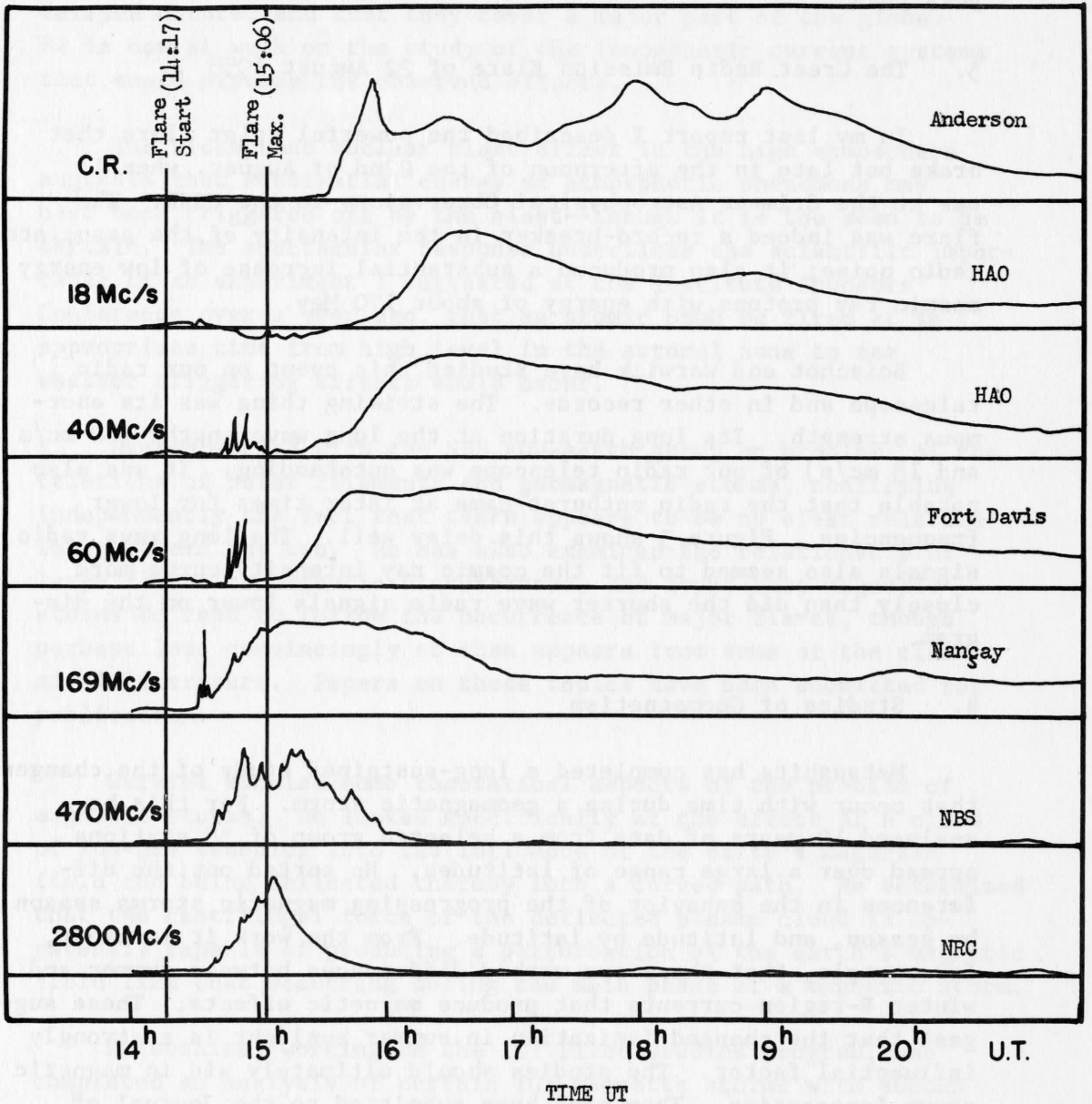


FIGURE 3

Cosmic rays and radio noise after the great flare of 22 August 1958. This is the flare that occurred while I was watching the radio telescope recordings at the Crimean Observatory in the USSR. Note how the longer wave radio outbursts, in the upper graphs, approximate more closely the cosmic ray record. The bottom record is at the frequency of the Crimean recorder pictures in Fig. 2 of my last report, where the needles have climbed almost to the peak. The first optical evidence of the flare occurred at about 14:17 UT shown by the vertical line near the left. The radio noise bursts about 14:30 UT in the records seem to represent an early phenomenon that is probably of different physical cause from the broad maximum that set in about 15:30 UT in the longer wave records. (See page 20.)

Puka Puka.

### 3. The Great Radio Emission Flare of 22 August 1958

In my last report I described the powerful solar flare that broke out late in the afternoon of the 22nd of August, when I was at the Crimean Astrophysical Observatory in the USSR. The flare was indeed a record-breaker in the intensity of the associated radio noise; it also produced a substantial increase of low energy cosmic ray protons with energy of about 170 Mev.

Boischot and Warwick have studied this event on our radio telescope and in other records. The striking thing was its enormous strength. Its long duration at the long wavelengths (40 mc/s and 18 mc/s) of our radio telescope was outstanding. It was also notable that the radio outburst came at later times for lower frequencies. Figure 3 shows this delay well. The long wave radio signals also seemed to fit the cosmic ray intensity curve more closely than did the shorter wave radio signals lower on the diagram.

### 4. Studies of Geomagnetism

Matsushita has completed a long-sustained study of the changes that occur with time during a geomagnetic storm. For this he analysed 10 years of data from a selected group of 38 stations spread over a large range of latitudes. He sorted out the differences in the behavior of the progressing magnetic storms season by season, and latitude by latitude. From the work it is clear, for example, that there are marked differences between summer and winter E-region currents that produce magnetic effects. These suggest that the changed ionization in summer sunlight is a strongly influential factor. The studies should ultimately aid in magnetic storm forecasting. They have been submitted to the Journal of Geophysical Research for publication.

An H-bomb blast in August, released at a high level over Johnston Island, produced spectacular geomagnetic and auroral effects at very low latitudes. It also caused a powerful radio communications blackout. Never before had such effects been produced by man's activity. Matsushita has examined widespread geomagnetic records, including the central U.S. network, and concludes that

there are important effects both of an instantaneous and a more delayed nature, and that they cover a major part of the globe. He is now at work on the study of the ionospheric current systems that would produce the observed effects.

The widespread nuclear blast effect in the high atmosphere suggests that substantial energy of atmospheric phenomena may have been triggered off by the blast--though it is too soon to be certain. The spectacular response underlines the scientific importance of an experiment I suggested at the Institute Sponsors' Conference over a year ago, that an atomic bomb be fired at an appropriate time from high level in the auroral zone to see whether triggering effects would occur.

Hansen worked with the NBS sun-earth group on problems of the relations of solar filaments and geomagnetic storms, confirming independently the fact that there appears to be no clear relationship between the two. He has also examined the relationship of large flares to magnetic disturbances, and found that magnetic storms do tend to follow the occurrence of major flares, though perhaps less convincingly so than appears from some of the classical literature. Papers on these topics have been submitted for publication.

Warwick tackled some theoretical aspects of the problem of magnetic storms. He looked specifically at the effect of a cloud of ion-gas sweeping into the influence of the earth's magnetic field and being deflected thereby into a curved path. He determined that the centrifugal force of the deflected plasma cloud is apparently capable of producing a perturbation of the earth's magnetic field like that occurring during the main phase of a magnetic storm.

Matsushita, working on the IGY Pilot Studies program, has completed an analysis of certain IGY magnetic storms with sudden commencement. He found that the U.S. network of magnetic stations reveals detailed magnetic deflection differences that can be interpreted as effects of an E-region wind crossing the eastern portion of the network. These results will be prepared for publication soon.

## 5. Solar Activity Observing

An intensive IGY solar observational program was kept in full swing during the half-year. The cooperative coverage obtained by HAO and the Sacramento Peak Observatory has been most gratifying.

## 6. Temperatures and Motions in the Corona

See HIGHLIGHTS, and also (1) Active Solar Region Analysis, above.

## 7. Chromospheric Spicule Studies

Athay's program of spicule study has been carried on principally by the Climax observers Curtis and Watson, who have been attempting to obtain improved spicule observations of the K-line of Ca+ and the spectrum line of helium in the infrared spectrum at 10,830 A.

## 8. IGY Pilot Studies

See (5) Studies in Geomagnetism, above.

Billings is continuing work on the problem of the observation of the spectrum of solar flares and the determination of the transparency of flare gases.

## 9. Eclipse Research

See HIGHLIGHTS for the sad story of the rain-bedraggled eclipse expedition. We did obtain some cosmic noise absorption records for the eclipse, and the NBS and NRL programs not dependent on weather were successful.

We are now turning our eyes resolutely towards the Canary Islands on the French Sahara where the next eclipse occurs on 2 October 1959, under highly favorable weather prospects.

## 10. Solar Activity Guide Book



## 11. Solar Data Center

Data centralization continues smoothly in the solar activity discipline, with regular reports funnelling in from all over the world. The Data Center has issued several additional volumes reporting preliminary results on surges, limb prominences, and other solar data. Work is under way on preparation of plans for post-IGY publication of a comprehensive volume on solar activity in the IGY Annals.

Hansen and Billings completed, during the period, a study of the absolute calibration of the Climax and Sacramento Peak coronal intensity scales, (2) which serves as a background for a comparison of world coronal scales now being done by Hansen under Data Center auspices.

## 12. K-Coronameter Observations

Newkirk has taken the approximately 50 days of good measures of the K-corona obtained at Climax (3) and used them for the development of an improved model of the sun's slowly-varying radio corona. For this he has taken the optical data to define the electron distribution of an active region, and then he has traced the radio wave refraction through this model corona. He has traced this for the 21 cm radio radiation. The work is in progress and is being calculated on the new Bendix G-15 computer of the University of Colorado, which is provided free for this analysis. It is proving extremely advantageous for the problem.

## 13. High Altitude Balloon Studies of Solar Aureole

The unfortunate failure of the Project Stratolab balloon flight of the ONR and Dr. John Strong for photography of Mars has led to indefinite postponement of our balloon flight, which was scheduled to follow Dr. Strong's. The balloon split abruptly and crashed to the ground minutes before launching; fortunately release had not

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(2) HAO Solar Research Memorandum No. 120, 28 November 1958.

(3) Director's Quarterly Report, 1958 I-II, pages 23-25.

occurred, and no one was injured. However, careful studies of the cause of failure and plans to avert any similar events are under way. We hope to re-schedule our flight for sometime in the first half of 1959.

#### 14. Chromosphere Monograph

Athay is intensively engaged in work on a comprehensive summary book on the solar chromosphere prepared jointly with R. N. Thomas of NBS. Most of the book is in second draft stage, but the progress of advancing research is so fast that it is proving difficult to solidify the text.

With graduate student, Hollis Johnson, Athay is working also on problems of the intensities of helium lines in the chromosphere. This fundamental work on the chromosphere may develop into a thesis project for Johnson by the fall of 1959.

#### 15. Alfred P. Sloan Research Fellowship Program

Zirin began work under his two-year Alfred P. Sloan Research Fellowship. This award, announced earlier in the year, will leave him entirely free to concentrate full effort on problems of the basic physics of the corona. His program began with a stay at the Max Planck Institute in Munich, where he spent the last four months of the year. He returned to Boulder in January after travel to solar research centers in the USSR, Czechoslovakia, Switzerland and France.

While there he worked with R. Lü<sup>st</sup> and Guido Mün<sup>ch</sup>. With Lü<sup>st</sup> he cooperated on problems of the condensation of prominences from the corona under the influence of magnetic compression. In particular they examined the time-scales of cooling and heating processes including thermal conduction and radiation. They concluded that prominences can cool rapidly only after first being abruptly heated and compressed to substantially higher than normal density.

With Mün<sup>ch</sup> he worked on the problems of the "galactic corona," which Spitzer of Princeton has postulated surrounds the entire

Milky Way star system.

## 16. Satellite Spin

Warwick has carried on further work on satellite spin. (4) In earlier reports we have pointed out how it is possible to measure with great accuracy the spin rate of Sputnik I in morning passes. From the decay of the spin rate he was able to compute the air density.

Warwick has now found some intriguing results from the lower-altitude evening passes of Sputnik I. Initially he did not analyse these evening passes because the records showed far more complex flutter of signal strength corresponding to the stronger atmospheric forces resulting from its lower altitude of about 175 miles, compared with the 300 miles or so of the morning passes.

Warwick has now succeeded in using the accurately determined spin rates of the morning passes to help unravel the more complex results of the evening passes. From this he is finding it possible to determine that the spin axis of the satellite is wobbling rapidly in the evening passes, presumably from additional precessional forces resulting from the asymmetrical distribution of the satellite's mass and the increased drag of air. With further work he hopes to determine accurately the local density of the air producing the effect, and thence improved information on the variation of density with height at these levels. The results will be pushed vigorously in coming months.

## 17. Large Coronagraph for Climax

Newkirk has been working hard on designs for the large coronagraph and spectrograph to be installed at Climax on the 26-foot equatorial. In December the National Science Foundation granted the Observatory \$80,000 for construction of the spectro-

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(4) See also: Director's Quarterly, 1958 I-II, pages 10 and 12; 1957 IV, pages 3-6; 1957 II-III, pages 5-8.

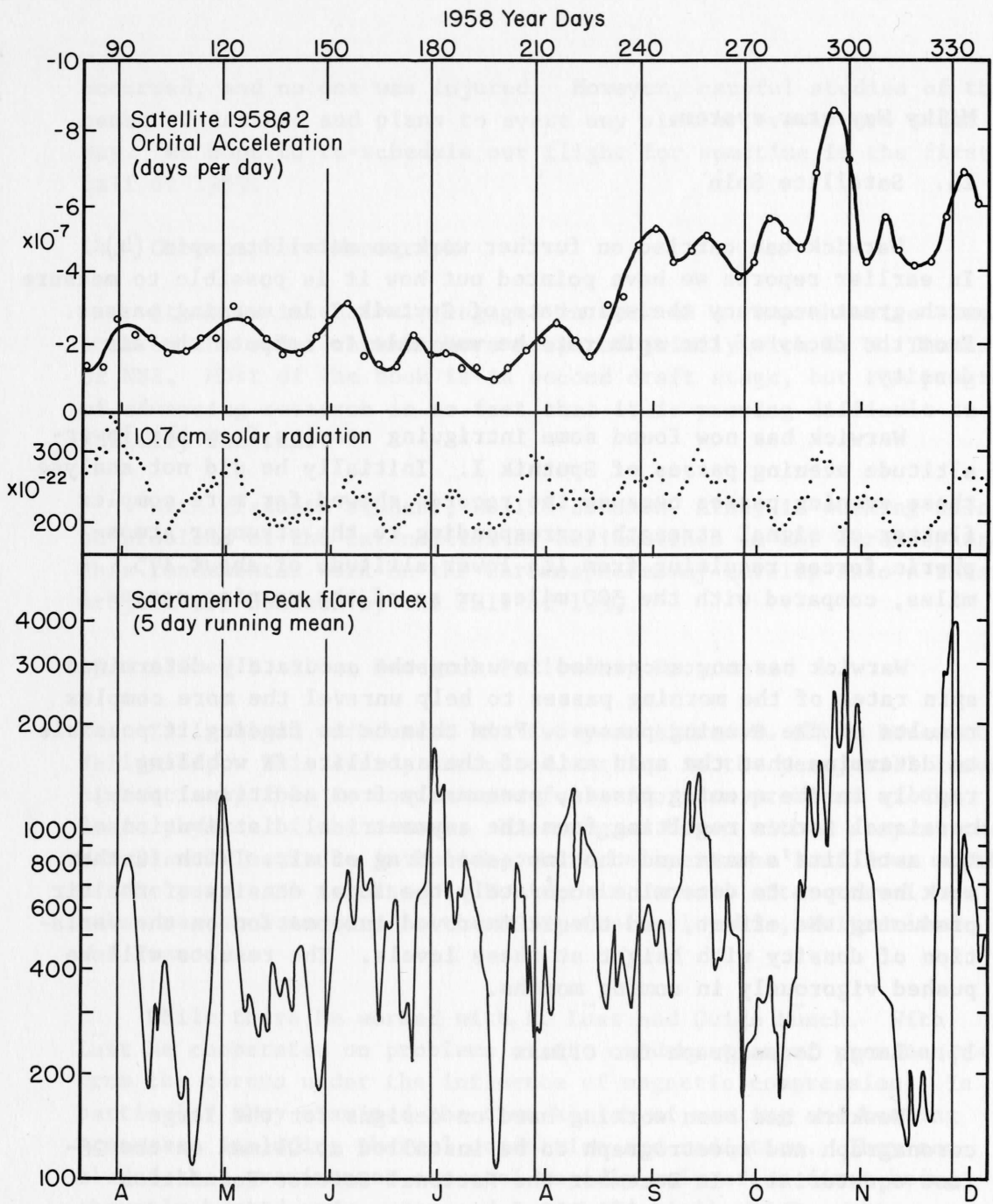


FIGURE 4

The changes of satellite period shown in the top graph appear to be intimately related to solar activity as measured (middle) by 10.7 cm solar radio noise and (bottom) by the level of solar flare activity. The 10.7 cm radio noise is probably generated by solar activity in the lowest reaches of the corona or the upper reaches of the chromosphere. The correspondence illustrates vividly the importance of developing more satisfactory theories of coronal and chromospheric emission, since the nature of the effects of this solar radiation on the earth will not be fully understood until such theories are worked out. (Upper two graphs from L. Jacchia, Smithsonian Institution.)

graph. Private funds will make possible the construction of the coronagraph. We hope to have work well under way in 1959 and to use the instrument in 1960. Our Research Associate, J. H. Rush, will be in charge of the detailed designs, and we plan to do a major part of the work in our own shops under the guidance of Lacey and Lee.

## VI. RELATED PROGRESS AT OTHER INSTITUTIONS

This section contains a few highlights of our rapidly advancing knowledge in solar physics and in cosmic-terrestrial relationships.

### A. Solar Effect on Satellite Drag

Perhaps the most surprising result of solar-terrestrial research to come from the satellite program is that exhibited in Figure 4. This graph was prepared by Dr. Luigi G. Jacchia of the Astrophysical Observatory of the Smithsonian Institution.

The upper figure represents the orbital deceleration of satellite 1958  $\beta 2$  (Vanguard I). It is evident that the deceleration causing the satellite to fall into a lower orbit does not remain a constant force, but varies somewhat irregularly, with one or two peaks of decelerating drag every month. Most astonishing, however, is the apparent relation between the drag and the activity of the sun as represented by its 10.7 cm radio noise emission. This emission is radiated from the low layers of the solar atmosphere, and is closely correlated with the total area of chromospheric plages, complex sunspots, and the stronger maxima of the corona. For comparison we have plotted on the same time-scale, but below the Smithsonian results, the five-day average flare index from Sacramento Peak.

So far as I know, no explanation of the effect has been worked out. However, it seems likely that the effect is related to the changes of the density of ionization of the atmosphere traversed by the satellite at perigee. It might, however, represent a total air density effect, through changes in air temperature. Quantitative calculations ought to lead to a fairly conclusive answer. But the result is particularly interesting, because it appears at face value to imply a closer atmospheric control by the sun than ionospheric researches have revealed.

## B. Rocket Research at the Eclipse

Even though our own eclipse expedition to Puka Puka was a failure because of a thunderstorm during totality, our shipmates from the Naval Research Laboratory were not so unfortunate. Their expedition was based on the expedition ship, standing some miles off Puka Puka towards the central line of the totality. Their program, directed by Drs. Talbot Chubb and Herbert Friedman was a gratifying success. And though they did not depend for success on clear weather, they were able to get a glimpse of the eclipse through light clouds.

Their program consisted of a series of rocket firings of X-ray and ultraviolet detectors designed to determine the nature of the radiations coming from the eclipsed sun.

As totality came and passed on they fired five rockets which telemetered back the history of the progress of the radiational output of the sun. At totality the Lyman alpha radiation of the sun dropped to a negligible fraction of the normal uneclipsed value, while the X rays of 15 to 50 A wavelength continued to radiate a substantial fraction of the uneclipsed sun value, clinching their coronal origin. We await the detailed reduction of the measures with eagerness.

As an extra bonus, and by extraordinary good luck the sixth rocket, which did not fire during the eclipse series, was launched the day after, and by chance during the progress of a substantial solar flare. From it came measures of substantially increased X rays at wavelengths shorter than 8 A, a range and energy which Friedman and Chubb have considered to be responsible for at least a substantial part of D-region ionospheric radio fadeouts. Moreover, their flight, which reached altitude shortly after the rise of the flare to maximum, failed to detect any increase of Lyman alpha, which some of our staff have felt is the more likely cause of the D-region fadeouts.

The great success of these experiemnts took some of the sting out of the misfortune of our own efforts.

## C. Solar-Weather Research

Another bit of evidence on the cosmic dust hypothesis for rain-

producing atmospheric nuclei was published by E. G. Bowen.(5) He shows that when atmospheric ice nuclei counts from the north and south hemispheres are compared, they reveal peaks at about the same dates. Small differences of one to three days appear, and are not explained. The general agreement in dates, however, strengthens the suspicion that these are indeed from outside the earth.

A new paper by Conrad P. Mook (6) of the Diamond Ordnance Fuze Laboratories examines the course of several east coast hurricanes, and finds an apparent alteration in the F-region ionospheric reflections when the eye of the hurricane passes near the Washington ionospheric station. This result implies, if it can be confirmed in a larger data sample, that there is a real coupling between large surface storms and the highest layers of the ionosphere, a matter of great theoretical importance. It does not, however, until further developed, give any idea whether the effect is propagated from the ionosphere downwards or from the hurricane upwards. It may be, as Mook suggests, that both phenomena have a common origin at the jet stream level of the atmosphere.

F. Link (7), of Czechoslovakia, has attempted to look at the longer term connections of weather and solar activity, going back into pre-Galilean times in solar activity through records of the frequency of comet discoveries, which appear to be solar activity linked. From the balance of evidence he claims support for the notion that European climate exhibits slowly changing character of about 400 year period.

A new Japanese study by Arai (8) throws light on the hypothesis we have developed here regarding changes in the westerly wind systems over North America after magnetic storms. Arai analysed the character of the "planetary waves" of the large scale north hemisphere circumpolar winds. He found a negative correlation of the first and a positive correlation with the second harmonic of long waves of the 500 mb circulation with solar activity (day to day changes of sunspot numbers).

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(5) Australian Journal of Physics, vol. 11, page 452, 1958.

(6) Journal of Geophysical Research, vol. 63, page 569, 1958.

(7) Die Sterne, vol. 34, page 129, 1958.

(8) Y. Arai, Journal of Meteorological Studies of Japan, Series II, Vol. 36, No. 2, page 6, 1958.

This result suggests, thus, a tendency towards meridional flow with larger sunspot number. The results were apparently significant both in long term year to year trends and in short term day to day trends. The result, however promising, requires further checking, and in particular, it would be interesting to do a similar analysis with geomagnetic character rather than sunspot numbers for the "solar" measurement.

A new but somewhat difficult to follow paper on solar-weather connections appeared recently in the publication of the American Geophysical Union.(9) The paper gave results of a study of temperature distributions over the U.S. and Europe on days following various levels of solar activity. The paper suggested that in the western U.S. there develops a marked minimum of temperatures about eight days after solar activity peaks. Visser suggests that a blocking effect develops after intensified solar activity both over western Europe and over the U.S. He points out that blocks develop with apparently significantly increased probability at such times, but that they do not invariably occur. The paper, like our own work, involved a small time-sample. However, the result coincides with almost all similar solar-weather studies in indicating that the effect of increased solar activity is ultimately exhibited as increased north-south air exchange, with correspondingly increased temperature mixing.

We have just examined in detail an interesting report from M.I.T. by W. D. Sellers (10) issued in 1957. In this report Sellers examines a most interesting case in January 1953, when a large stratospheric heating and the development of a large cyclone began over Canada. These events were major in scope, and were entirely missed in the conventional forecasting methods. A pronounced magnetic storm of January 4th preceded the development of marked temperature rises at various levels from 10 to 20 miles altitude. The rise was largest at the top level, and was followed by major meteorological changes. The authors, with commendable caution, point out that the geomagnetic storm

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(9) Visser, Transactions of the American Geophysical Union, vol 39, page 835, 1958.

(10) Scientific Report No. 2, Contract AF 19(604)-1566, June 1957, page 96ff.



may have been accidentally related to the development, but they also mention that it is possible that the increased geomagnetic activity enters the picture as a trigger mechanism for the release of atmospheric energy, though it is probably not the heat source itself.

#### D. Some Russian Worries about Long-Range Forecasting

The Russians have as large a stake in the development of long-range forecasting as we. And they are acutely aware of its significance. Moreover, they seem to be no more successful than we in developing reliable methods. A paper by N. A. Belinsky (11) recently received takes a hard look at some of the problems. Belinsky concludes: (1) that the strength of cyclonic circulation increases at times of high solar activity, and (2) that more attention must be given to processes involving the release of latent heat of vaporization and condensation. He then makes an astute observation about solar-weather research, as follows: "In examining works devoted to explaining the dependence on solar activity of phenomena observed in the troposphere, a methodologically unjustified tendency was noted in many of these works, i.e. there was a tendency to establish a direct dependency of the course of this or that element in the atmospheric regions on solar activity." We would agree heartily with Belinsky that the effect of solar activity on weather, if real, is highly complex. It is almost certainly an indirect one involving trigger mechanisms of some sort.

One of his colleagues (12), reviewing the advance of long range meteorological forecasting during the various five-year plans since 1930, hails the development of high speed calculators (their BES<sub>m</sub> and M-2) and looks to these for improved research based on numerical-dynamical approaches similar to those in use here. He then speaks apologetically for their progress as follows: "In spite of the painstaking work of Pargava himself, as well as by the staff of scientific workers .... quality of long range weather forecasting remains, unfortunately, low and for the last ten years it has not notably improved ..... It is difficult to point out the true causes of our failures and to chart the

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(11) Excerpts from N. A. Belinsky, Utilization of Certain Characteristics of Atmospheric Processes for Long Range Forecasting, Leningrad, 1957.

(12) I. G. Pchelko, Works of Central Institute of Forecasts No. 55, Moscow, 1957.

correct road towards solution of the problem of long range weather forecasting. One thing is clear--that this problem is unusually complex and probably we have, at some times, strongly overestimated our possibilities.....In the light of the decisions of the 20th Congress of the CDSU, we shall fight persistently for the technical equipment for our work and for general heightening of the quality of scientific research."

#### VII. RECENT VISITORS TO HAO

June-August	Dr. Bernhard Haurwitz, New York University, New York, New York.
June-August	Dr. Jerome Spar, New York University, New York, New York.
25 June-15 August	Dr. Pearl Lichtenstein, Rensselaer Polytechnic Institute, Troy, New York.
3 July-15 August	Dr. Richard Schotland, New York University, New York, New York.
6-14 July	Dr. Herbert Riehl, University of Chicago, Chicago, Illinois.
3-10 July	Dr. Herman Newstein, New York University, New York, New York.
7-28 July	Mr. Raymond E. Falconer, Munital Foundation, New York, New York.
9-10 July	Dr. Helen Dodson-Prince, McMath-Hulbert Obser- vatory, Pontiac, Michigan.
9 July	Dr. Seth B. Nicholson, Mount Wilson Observatory, Pasadena, California.
9 July, 19-20 Nov.	Dr. John W. Evans, Sacramento Peak Observatory, Sunspot, New Mexico.
11 July	Dr. <del>Mr.</del> A. Keith Pierce, National Astronomical Observatory, Phoenix, Arizona
12 July	Mr. Harry Ramsey, Sacramento Peak Observatory, Sunspot, New Mexico.

14-18 August Dr. Masahisa Sugiura, University of Alaska,  
College, Alaska.

7-15 August Mr. James McQuigg, University of Missouri,  
Columbia, Missouri.

8 August Mr. Conrad P. Mook, Diamond Ordnance Fuze  
Laboratories, Washington, D.C.

9 September Dr. David W. Woodbridge, Redstone Arsenal,  
Huntsville, Alabama.

11 September Mr. Malcolm Rigby, American Meteorological  
Society, Washington, D.C.

30 September Mr. S. Bauer, Army Signal Corps, Fort Monmouth,  
New Jersey.

30 September Dr. George Swenson, University of Illinois,  
Urbana, Illinois.

30 September Mr. Glenn W. Brier, United States Weather Bureau,  
Washington, D.C.

30 September Dr. R. G. Giovanelli, CSIRO, Australia.

30 September Dr. Henry Smith, Sacramento Peak Observatory,  
Sunspot, New Mexico.

3-7 November Dr. Jesse L. Greenstein, California Institute  
of Technology, Pasadena, California.

19-20 November Dr. J. Zirker, Sacramento Peak Observatory,  
Sunspot, New Mexico.

8 December Dr. and Mrs. H. von Klüber, Cambridge, England.

#### VIII. PUBLICATIONS FROM HAO DURING THE REPORT PERIOD

Roberts, Walter Orr: "Solar-Terrestrial Relationships," Geophysics and  
the IGY, Geophysical Monograph No. 2, AGU, Washington, D.C., July,  
1958.

Athay, R. Grant: "The Solar Ultraviolet Spectrum of He II," Astro-  
physical Journal, 128, 447, 1958.

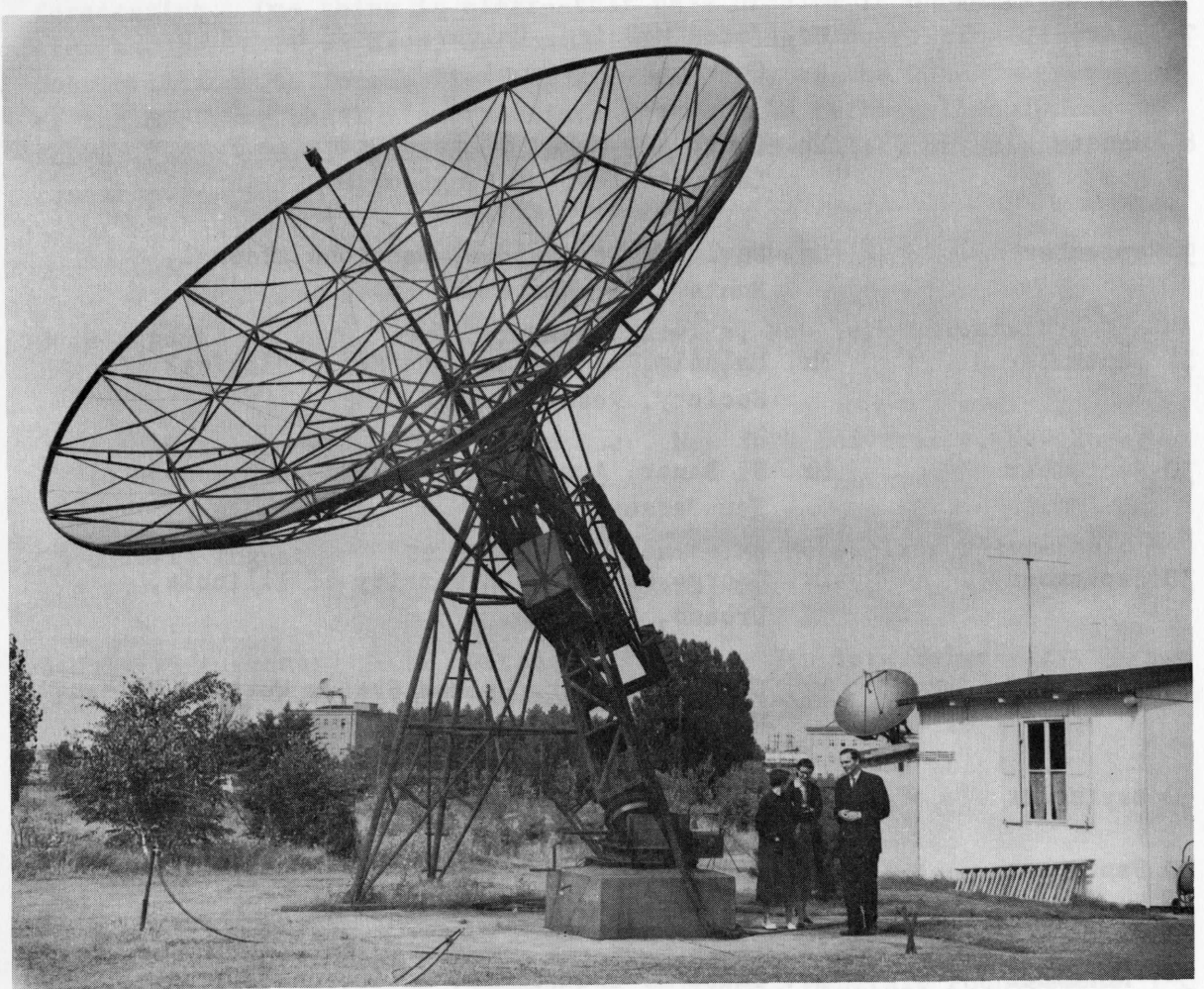


FIGURE 5

Mrs. Warwick and Mrs. Zirin are shown talking with Dr. Otto Hachenberg, Director of the Heinrich Hertz Institute in the eastern sector of Berlin. The Warwicks and Zirins stopped for a visit there on their auto journey from Paris to Moscow for the International Astronomical Union meetings in August.

The Institute carries on research on solar-terrestrial relationships through studies of solar radio emissions and their ionospheric effects. In the foreground is an 8 meter radio telescope used for measuring 20 centimeter solar radio emission and in the right background a 2.5 meter dish for observing solar emission at 3.2 centimeters.

- Zirin, Harold: "The Calculation of Opacities for Stellar Interiors," *Astrophysical Journal*, 128, 342, 1958.
- Pottasch, Stuart R.: "Part VI: Conditions at the Ionization and Shock Fronts in Collisions of Gas Clouds. Bright Rims in Diffuse Nebulae," *Reviews of Modern Physics*, 30, 1053, 1958.
- Chapman, S.: "Atmospheric Chemistry and Chemical Aeronomy," *Letters to the Editor, Meteorological Magazine*, 87, 275, 1958.
- Chapman, S.: "Fredrik Carl Mülertz Störmer 1874-1957," *Biographical Memoirs of Fellows of the Royal Society*, 4, 257, 1958.
- Matsushita, S.: "Some Studies of the Upper Atmosphere in the Auroral Zone," *Annales De Geophysique*, 14, 483, 1958.
- Zirin, Harold, Keith Watson and G. William Curtis: "Spectra of Quiescent and Loop Prominences," *Publications of the Astronomical Society of the Pacific*, 70, 406, 1958.
- Chapman, S. and K. Davies: "On the Approximate Daytime Constancy of the Absorption of Radio Waves in the Lower Ionosphere," *Journal of Atmospheric and Terrestrial Physics*, 13, 86, 1958.
- Roach, F. E., E. Tandberg-Hanssen and L. R. Megill: "The Characteristic Size of Airglow Cells," *Journal of Atmospheric and Terrestrial Physics*, 13, 113, 1958.
- Roach, F. E., E. Tandberg-Hanssen and L. R. Megill: "Movements of Airglow Cells," *Journal of Atmospheric and Terrestrial Physics*, 13, 122, 1958.
- Pottasch, Stuart R.: "The Nova Outburst," a thesis from the High Altitude Observatory and the Department of Astro-Geophysics, University of Colorado; 22 May 1958.

#### IX. DATA REPORTS AND SPECIAL PUBLICATIONS FROM HAO

We have not previously listed the data reports and special publications of permanent interest from HAO during the period, but will list these from now on. This list includes all such reports issued in 1958.

A. World Data Center Publications:

IGY Solar Activity Report Series No. 3, January-March 1958,  
"Intermediate Reports of Surges and Active Prominence Regions."

IGY Solar Activity Report Series No. 4, September 1956-January 1958,  
"Observations of the Solar Electron Corona," by G. Newkirk, G.  
G. W. Curtis and K. Watson.

IGY Solar Activity Report Series No. 5, April-June 1958,  
"Intermediate Reports of Surges and Active Prominence Regions."

IGY Solar Activity Report Series No. 6, July-September 1958,  
"Intermediate Reports of Surges and Active Prominence Regions."

B. Solar Activity Reports:

Trotter, Dorothy E. and Walter Orr Roberts, Solar Activity Summary  
I, Report No. HAO-42, 13 January-through 4 April 1958.

Trotter, Dorothy E. and Walter Orr Roberts, Solar Activity Summary  
II, Report No. HAO-43, 5 April through 25 June 1958.

C. Reports from the Institute for Solar-Terrestrial Research:

Spar, Jerome, "Meteorological Models for the Study of Atmospheric  
Responses to Anomalous Solar Emissions," Technical Report No. 5,  
Institute for Solar-Terrestrial Research, October 1958.

Macdonald, Norman J. and Walter Orr Roberts, "The Relationship of  
300 mb Circulation Change to Geomagnetic Disturbances from 1952 to  
1958," Technical Report No. 6, Institute for Solar-Terrestrial  
Research, November 1958.

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