

THE DIRECTOR'S QUARTERLY REPORT

Fourth Quarter 1957

1 October to 31 December 1957



*Boulder Flare Patrol**

*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: Robert Cooper is shown checking operation of the new flare patrol instrument located outside the Sommers-Bausch Observatory in Boulder. This patrol is run on days when the Climax patrol is clouded in. The camera, seen at the far right, automatically takes a picture of the solar disk in the light of hydrogen every 60 seconds. During a flare the rate is increased to one every 15 seconds. Some member of the staff looks visually through the instrument every five minutes or so and can thus immediately report flares of major importance to the IGY World Warning Center in Fort Belvoir, Virginia. We develop the film at the end of the day and thus have a permanent record of solar activity on deposit at the HAO-operated IGY Solar Data Center. (See page 12.)

SUMMARY

Into the earth's atmosphere radio waves continuously come from space. With the proper radio receivers the steady hissing of cosmic radio noise can be heard day and night--unless it is suddenly interrupted by a flare on the sun. The flare sends out radiations that change the ionization of the earth's upper atmosphere in such a way that the cosmic noise is absorbed. Recently Zirin and Warwick worked out a technique for analyzing records of sudden cosmic noise absorption during flares so as to get a quantitative minute by minute measure of the amount of radiation from the flare. They have now completed a study of six individual flares and thus have taken one more step toward an understanding of the basic physics of these brilliant and significant events on the sun.

During the quarter we continued our study of possible relationships between changes in the earth's atmospheric circulation at 300 millibars and geomagnetic storms. Also we began in a preliminary way to analyze the frequency of hurricane storm tracks hitting the eastern U.S. coast to see if there is any correlation with geomagnetic activity.

Athay made a new and most productive attack on the problem of temperatures of spicules, the small jet-like spikes of gas on the solar surface. He was able to obtain excellent spectra in the light of hydrogen and, simultaneously, to make the only spectra we know of in the light of helium. By analyzing these together he has arrived at the

surprising temperature of 65,000°K for the spicules, which is far hotter than previous estimates. This temperature determination may be a significant factor in explaining the effect of spicules in the heating of the corona.

We are working intensively with the Sun-Earth Relations Group at the National Bureau of Standards on the problem of geomagnetic forecasting. Preparations for the eclipse expedition of October 1958 are continuing at a fairly feverish pace. Hansen has plans under way for calibrating and intercomparing coronal data coming into the Solar Data Center and has begun the preparation of pages of data for publication in the Annals of the IGY.

We are now at last operating a flare patrol instrument in Boulder to supplement those at Climax and Sacramento Peak. The results obtained from the filter in the instrument are disappointing so far and we are experimenting to improve their quality. Eventually we hope to be able to make really good fast-rate patrol observations for comparison with the radio noise observations from the Harvard radio patrol at Fort Davis, Texas and the cosmic noise absorption recorder. Such studies could result in significant advances in our understanding of flares and other types of solar events.

I. HIGHLIGHTS

A. Soviet Satellites

Not long ago the phrase "Soviet satellite" had a different meaning, particularly if you lived within or on the border of one. The new meaning is no less fraught with significance for the western world, nor is it any lesser evidence of Russian aggressiveness. Very possibly the skies will not again be free of man-made artificial moons--flying for peaceful research or for war. And soon they will carry far more complex machines, even to ground-controlled message repeating devices.

The story of the first frantic days of Sputnik I after October 4th sneaked into the last report, though it more properly belonged here. With similar license I will squeeze into this report our gratification that U.S. satellites have entered the Space Age.

HAO's satellite work has still been confined to the Soviet flights because the U.S. satellites did not pass over Boulder at high angles in the sky and also because their radios operated on frequencies not well suited for study in our large radio interferometer. However, we're continuing analysis of the older records, albeit at a less feverish pace, and we have prepared for new observation programs whenever another suitable satellite passes over Boulder.

B. Cosmic Noise Absorption

When a solar flare erupts it sends into space several forms of emissions, one of which produces an instantaneous radio fadeout in the sunlight hemisphere of the earth, providing the flare is large enough. Thus far astronomers have not been able to specify unambiguously just what radiation is emitted and just how it is formed. When we answer this we will have disposed of one of the most important unsolved problems of modern astrophysics.

A small step towards the solution was taken, this quarter, by Warwick and Zirin, using data taken from our IGY-sponsored SCNA meter, an instrument that measures sudden cosmic noise absorptions. In previous reports I have described the instrument in some detail. (1) The technique of cosmic noise absorption study that we have developed depends on picking up, with a radio device that points vertically towards

(1) Director's Quarterly Report 1955-5, page 7 and 1956-1, page 7 and page 11.

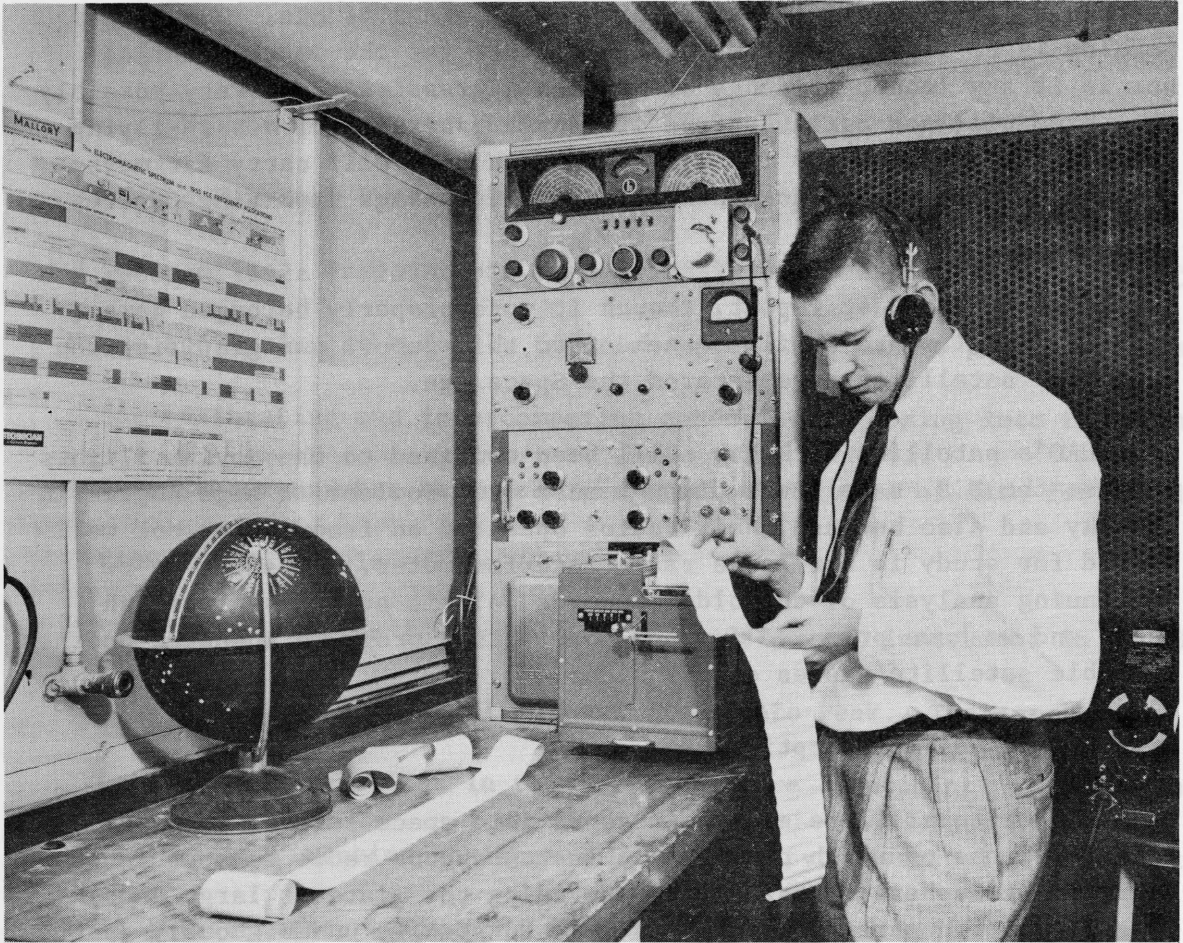


FIGURE 1

Robert Lee is examining records of sudden cosmic noise absorption occurring during a solar flare. Radiation from the flare creates conditions in the high atmosphere that reduce or cut off our earthly reception of radio signals from space. By studying these absorption records we are learning much about the physical conditions of flares. The so-called SCNA recording equipment was designed and constructed by Lee. (See page 3 and Figure 2, page 9)

the sky overhead, the general background of radio signals from distant regions of space. Day and night these make a steady hiss that increases a bit when the densely star-populated regions of the Milky Way pass overhead each 23-plus hours as the earth rotates. It is important to remember that the sun is a sufficiently feeble radio star that the other stars can be heard even in full radio "daylight."

A flare, however, affects the atmosphere at 50-60 miles in such a way that it suddenly absorbs the star background of signals at frequencies near 20 Mc/s, the frequency at which our SCNA meter operates. Thus we have a sudden absorption of this radio noise from cosmic space, which shows up as a quieting of the hiss, which we can then measure accurately.

Warwick and Zirin have now worked out the technique of mathematical analysis for such cosmic absorption records, and have studied in detail the onset and decline of the absorption for over a half-dozen flares detected with the SCNA meter. To do this they have set up the problem for automatic machine calculation. The electronic "Maniac" of Los Alamos has run the data for them, and shown that the method is sound.

What comes out is a quantitative determination of the amount of solar radiation that is emitted, minute by minute, from a given flare to produce a measured absorption. The calculations involve, of course, assumptions about the way the electrical properties of the ionosphere behave--and therefore, when direct rocket or satellite observations of the solar radiation from above the ionosphere become possible, it will enable us to pin down these ionospheric properties with greater precision. In fact, even without rocket observations, it is possible to gain ionospheric information of value from study of the magnitudes of the flare absorption effects. This can be done by studying the "normal quiet sun" variations of absorption as the sun moves to different heights from the horizon.

The flare of 24 June 1957, for which we have excellent photographs and spectrograms, was one so analysed. Warwick and Zirin, studying this flare, made the assumption that its radiational effect came from the Lyman-alpha line of incandescent hydrogen, in the ultraviolet, which most people have assumed to be the radiation responsible for flare effects in the lower ionosphere. They found that its radiation increased to about 800 times the "quiet sun" value. The absorption of cosmic noise at its maximum was about 20% complete, which is a very highly significant value, particularly since it occurred shortly after sunrise when the radiation was weakened by shining obliquely through the earth's atmosphere. The flare observed by photographic means,

however, was rated as a very minor one and far less important than other larger ones whose radiation output, by our calculations, have been only one fiftieth as great, or even less.

We are just beginning to scratch the surface of the possibilities of research by this method. It is gratifying to have a pilot study completed and to know the steps to follow in refining the method. The excellence of the SCNA meter records has been crucial in the success of the work, and for this we are indebted, in large measure, to the skill and judgment of Lee, of our electronics staff, who is shown with the instrument in Figure 1.

II. PROPOSED NEW HAO RESEARCH BUILDING

Another important post-period piece of news is that the Boettcher Foundation has made a most generous starting grant for our building program at Boulder. The Foundation has pledged \$17,500 towards our permanent laboratory, conditional on our finding the balance during 1958. This will assist us enormously. We have applications for help now before several foundations, and sincerely hope that the balance of the necessary \$250,000 can be found soon. Our need for the space grows ever more critical as our Astro-Geophysics Department grows and crowds our increasingly dilapidated temporary quarters on the campus. Advice and help, as ever, are most welcome!

Another building need has come on the heels of this Boulder space need. The observing program at Climax augmented by the work in the large solar laboratory now requires an additional full-time observer, bringing our Climax work force to four full-time people. What's needed here is another family house, in which to locate the William Curtises. Thus the fourth man could move into the Curtises' tight but comfortable quarters--which would be entirely adequate for a couple without children. This winter we have gotten by because Alfred Hobart has been willing to put up with living in a modestly converted garage, formerly used as a cosmic ray experiment shed. And he's lived there without even having running water--a genuine inconvenience in the prevailing winter sub-zero temperatures and five-foot snows. It looks as though \$22,000 is the needed figure, counting the expense of building at Climax. Anybody who knows a way to find this for us can help our whole program immeasurably.

III. PROGRESS IN THE INSTITUTE FOR SOLAR-TERRESTRIAL RESEARCH

A. Solar-Weather Studies

This, like the last period, has been a time when we have made

steady but unspectacular progress. We are still in the middle of the study of past solar records and of upper wind data to test, in an independent sample, the findings of our earlier work. This work suggested that auroras and geomagnetic storms, on a statistically significant number of occasions, precede maximum trough developments over North America by approximately eight days.

We are also looking at the frequencies with which hurricanes strike land in the United States, dividing our data into years with large, medium and small numbers of geomagnetic storms. This study is possible because of the superlative new U.S. Weather Bureau hurricane track data now available for a long period going back into the 19th Century. Results are not yet ready to discuss, however.

B. Two-Day Seminar for Institute Sponsors

On December 2nd and 3rd we held a two-day seminar for our Institute's sponsors and a small number of additional guests. A summary of the discussions has been sent to the sponsors and to the other participants at the meeting. Copies are available on request.

C. Fellowships for Graduate Study in Astro-Geophysics

The fall semester of the University marked the fulfillment of a long-term ambition, with the awarding of three fellowships for study in our new graduate Department of Astro-Geophysics, the objectives of which run parallel to those of the Institute for Solar-Terrestrial Research. Two of these, to Hollis Ralph Johnson, from Garland, Utah, and Mohammad Khurshid Alam, from Karachi, Pakistan, are being supported by Institute funds. The entire list of students who joined the department in the fall term is given in the last Director's Quarterly Report (page 14).

D. Research on Ionospheric Effects from Sputniks

The last report summarizes this work, even though all of it occurred during this quarter. The people principally involved included Warwick, Bretz, Lee, Cooper, Billings and Roberts, though most of the staff pitched in one way or another.

IV. OTHER RESEARCH PROGRAMS OF HAO

A. Staff

David Dodgen, after more than three years of valuable service at

Climax as a member of the observing staff, terminated his appointment and joined the staff of the new national observatory being established by AURA, an association of universities for research in astronomy.

Randy Sherman, who has assisted Lacey in the machine shop of the Observatory for the last two years, also terminated his affiliation with the Observatory for a higher-paying job. At this time Eugene P. Laybourn, who had served for some time on a casual-employee basis, joined the HAO regular staff as a machinist.

Miss Karen Chalonge, daughter of the distinguished French astronomer, Dr. Daniel Chalonge, joined the HAO staff in September on a part-time basis, for the academic year. Her prime interests are in non-science fields, and her employment here makes it possible for her to attend the University graduate school.

Chapman left again in October. He will be travelling extensively in coming months, spending some time in the Department of Aeronautical Engineering at the University of Michigan, and then going to the Geophysical Institute of the University of Alaska in March. He will participate in the meeting of CSAGI (Special Committee for the International Geophysical Year), of which he is president, to be held in Moscow early in August and will stay on for the International Astronomical Union meeting immediately following. A number of other members of the HAO staff will also be going to Moscow for the IAU meeting.

B. Conferences and Meetings Attended

In the long-term perspective, the most important meeting attended this quarter by HAO staff members was probably the one on 22 November 1957, which concerned itself with the formation of a Rocky Mountain Regional Science Council. Low represented HAO and the University. He and the others at the conference took preliminary, but concrete steps to create a formal organization devoted to promoting regional cooperation for the development and utilization of major research facilities in the region, and for the interchange of graduate staff and students--as well as course credits--for work using these regional facilities. As things are visualized, the Council will be advisory only, and will not operate any specific facilities at all. The advisory function can, however, be of vast and highly tangible value to the participating institutions. The Council will embrace research institutions like the Los Alamos Scientific Laboratory, HAO, and the National Bureau of Standards, as well as the affiliated universities and colleges.

Low, as acting chairman of the planning committee, has played a

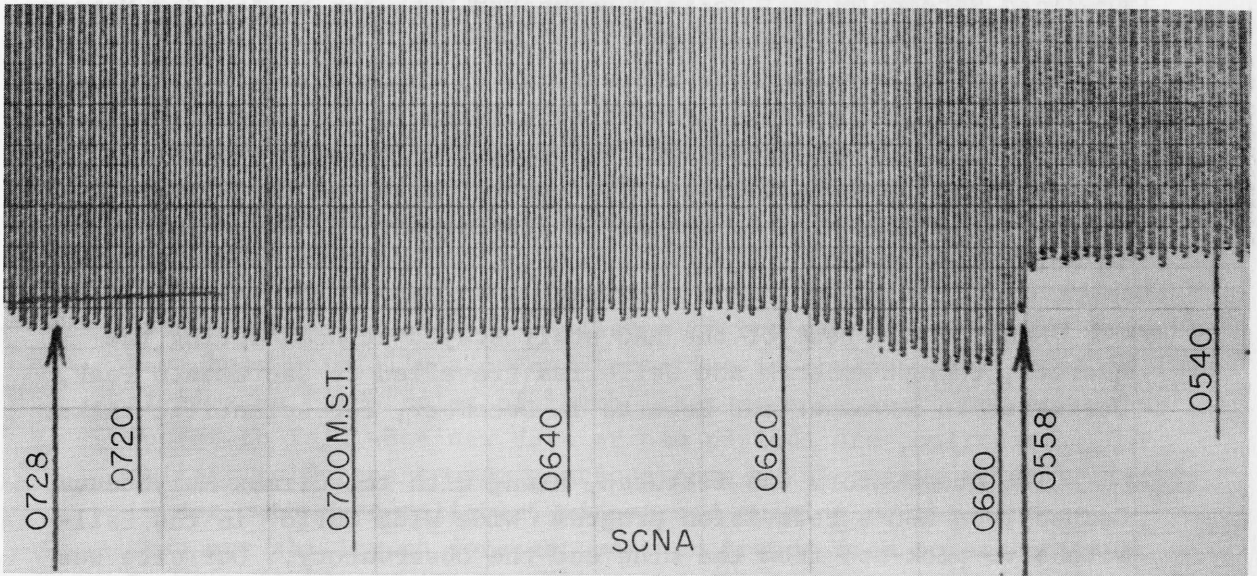
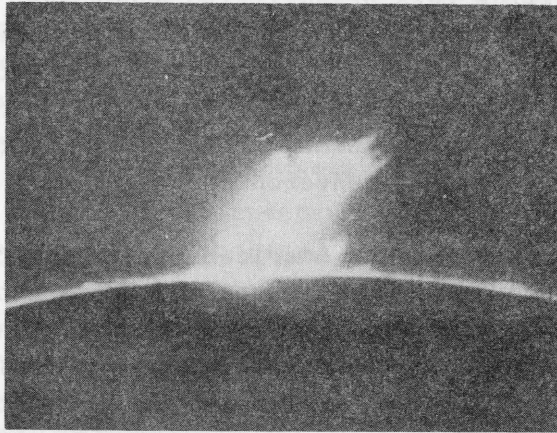


FIGURE 2

These two illustrations show a solar limb flare of June 24, 1956, and the simultaneous record of Sudden Cosmic Noise Absorption. (Time increases from right to left.) This is one of the events analyzed by Warwick and Zirin to determine the minute by minute radiation coming into the earth's atmosphere from the flare. (See page 3)

The upper picture, made at the Sacramento Peak Observatory, shows the flare at 06:05 MST. Spectra of this flare taken at Climax indicate very high temperatures and excitation. Note the abrupt absorption of cosmic noise in the SCNA record at 05:58 MST indicating that radiation during the flare's initial stage increased the ionization in the earth's atmosphere.

key role in getting this organization under way. Richard N. Thomas, of the National Bureau of Standards and an HAO Research Associate, has also been vigorously involved in the formation of this council. I visualize a most useful role for the council in building the research and graduate educational power of the Rocky Mountain area, and HAO welcomes the prospect of research exchanges with other council members.

Macdonald attended the American Meteorological Society Omaha meeting in October, with Mr. Pohrte and Dr. Woodbridge, who consulted from the Colorado School of Mines on the analysis of relations between geomagnetism and weather patterns. Woodbridge, who has now joined the Army Ballistic Missile Agency at Redstone arsenal, presented a summary paper on this work. Macdonald also attended the first American Meteorological Society sponsored Workshop on Applied Meteorology at Hartford, Connecticut, 28-29 October. He combined this with several valuable scientific discussions en route with: (1) Richard A. Craig, Ralph Shapiro and their associates at the Geophysics Research Directorate in Boston; (2) Bernhard Haurwitz and Julius London at New York University; (3) Herbert Riehl at the University of Chicago; (4) U.S. Weather Bureau in Washington; (5) Navy Project AROWA in Norfolk.

Most of the rest of the HAO staff stayed at home during the quarter, though Roberts and Jefferies travelled to Sacramento Peak, Jefferies in November and Roberts in December, for scientific talks.

The Observatory was featured, along with the Climax Molybdenum Company, on NBC's television program "Wide Wide World" in the fall--with live pick-ups from the mine and the Observatory. Our site was overrun with special power cables, lighting racks, viewing and listening monitors, television cameras, and the vast numbers of men needed to put such a program on the air. At the last moment before air time, the clouds moved in and shrouded the peaks, and it began to spit snow. It was not hard, in the outside scenes, to make clear the point that at Climax you fight constantly against wind, cold, and snow as you pursue knowledge of the violently hot solar atmosphere.

C. Research in Progress

During the quarter we settled down from the busy, crowded activities of the summer to a more deliberate pace. Advances occurred in the programs singled out below.

1. Active Solar Region Analysis

Observing efforts have been concentrated on attempting to

catch the full history of a major limb flare photographically with the Climax coronagraph-spectrograph. We have several sets of new partial observations, but as yet still no fully successful data beyond those of 18 December 1956, which are still under analysis. The effort will continue until we succeed in obtaining a full spectroscopic story of the evolution of physical conditions in such a region from selected spectrum lines of the flare and its associated prominences and corona.

2. Solar Effects in the Ionosphere

The work of Zirin and Warwick to interpret cosmic radio noise absorption measures appears under HIGHLIGHTS. This work has shown such promise that we have decided to see if we can build another SCNA detector for operation in Hawaii, and thus gain simultaneous observation of a flare at two substantially different angular heights of the sun above the horizon. We plan to seek the assistance of the Army Ballistic Missile Agency for this project.

3. Solar Effects in Geomagnetism

How can we improve geomagnetic storm forecasting? This question has been a constant challenge to our group--and useful answers have been painfully slow and tentative in coming. For brief periods of time we find "rules of thumb" that seem to work, but then they appear to fail when new data or new periods are confronted. Our ability to forecast geomagnetic storms by observing solar activity is not much more reliable, widespread opinion to the contrary, than our ability to forecast weather trends from solar activity. In both fields it is clear that there are relationships of a statistical nature, but in both it is also amply evident that the forecasts are still on a very unsound theoretical basis.

Two general paths for advancement in geomagnetic forecasting offer themselves, and they can be followed simultaneously: (1) to search in more sophisticated ways for statistical correlations among parameters of solar and geomagnetic activity; (2) to endeavor to develop theoretical knowledge of how magnetic effects ought to come about. Theoretical and empirical approaches should ideally go hand in hand--though it is sometimes necessary in a theoretical approach to a phenomenon as complicated as this one, to work at a level so simplified that applications are impossible or of trivial importance.

We've made a substantial attack on the geomagnetic forecast

problem from the empirical direction recently in a joint NBS-HAO effort involving C. Warwick, Hansen, Tandberg-Hanssen from HAO, and Miss Marian Wood of NBS. Various kinds of solar data for 1940 through 1957, including coronal, prominence, flare and radio noise data, have been tabulated in various ways on IBM punch cards, and large-scale correlation studies have been run on the NBS computer, to relate these indices to geomagnetic indices. The results will be discussed in the next report.

More strictly theoretical approaches are being worked on by Matsushita. They are tied closely to ionospheric studies as well and will be reported later.

4. Solar Activity Observing

To our solar observing program we have finally added a workable flare patrol in Boulder, which supplements Climax and Sacramento Peak on days of poor observing at those stations. (See cover picture.) However, we are disappointed with the quality of the patrol filter we have been using, which we built ourselves. It was planned for easy tuning over a wide wavelength range, but its quality at all wavelengths is not adequate. We plan to continue experiments to improve it.

Considerable pressure is developing for higher resolution and faster-rate flare patrol observations at times of large solar activity. Most stations in the IGY program photograph the sun every two to three minutes with a 15 to 20 mm image on 35 mm film. We hope to aim at two pictures per minute on an image at least doubled in size. The wealth of new solar radio noise observations with spectrum analysers is what justifies such improved optical patrols. Even minor solar events, of magnitude below what we would rate as a flare, or of nature different from flare activity, sometimes have discernible radio effects. Substantial advances in theory may come from careful study of such material. We hope to obtain a better flare filter, and to use it in a faster-rate, larger-scale patrol to make comparisons with the Harvard radio spectrograph patrol at Fort Davis, operated by Dr. Alan Maxwell and colleagues.

Dr. Fred Singer of the University of Maryland has installed a very fast-rate cosmic ray counter at Climax, which can detect rises of a few percent in cosmic rays in a matter of minutes. Fluctuations of such records may also be of interest for comparison with the faster-rate flare patrols.

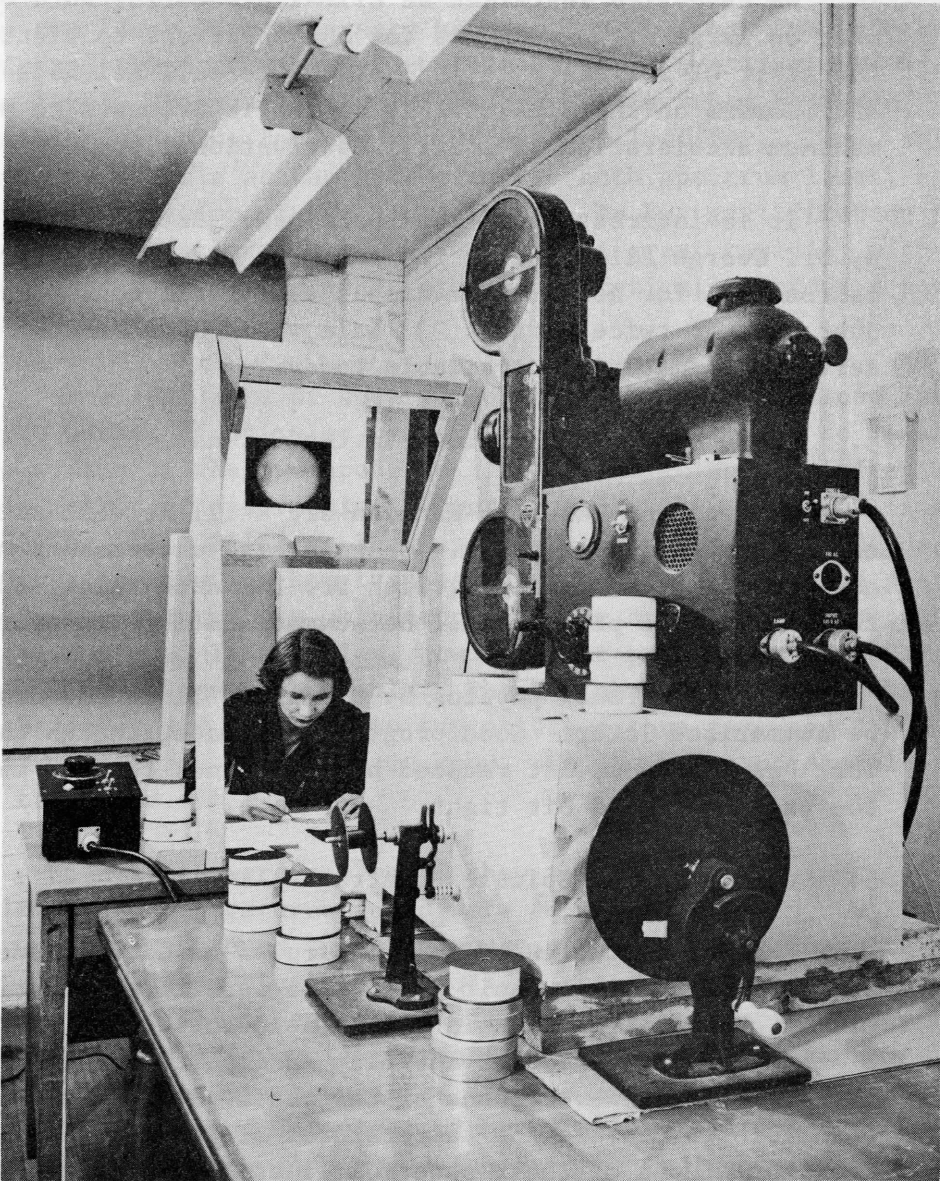


FIGURE 3

Flares recorded on our film by the Boulder and Climax flare patrols are measured by Sylvia Moscové at the HAO Solar Data Center. She determines their area, duration and location on the solar disc. Applying a formula to her measurements, she classifies them as Importance 1, 2, 3 or 3+ and makes a report for the Data Center on a form similar to that used by the 36 other IGY flare patrols in reporting their observations.

The film is moved through the machine shown at the right and the image of the solar disc is projected onto the table where Miss Moscové is working. By pressing a button on the table she can advance the film frame by frame.

We have also installed at Climax a powerful horn of the kind used on large highway trucks for our observers to blast off at the start of a flare. It is designed to call all able-bodied astronomers on the site quickly to the instruments to permit maximum acceleration of special observational programs.

It is interesting to look back over just 25 years to a plea by Dr. George Ellery Hale, famous Mount Wilson Observatory astronomer, for solar observations every half hour--instead of just once or twice a day. (2) Hale would have reveled in the observational materials available today.

5. Temperatures and Motions in the Corona

Chapman and Tandberg-Hanssen are still at work with the coronal diffusion problems. Chapman also undertook some additional collaboration, at Michigan, with Dr. Lawrence Aller, on aspects of this work. The problem will be summarized in a later report.

Work on coronal physics by Billings, Zirin and Schwartz will be summarized later. Good progress was made, though the level of work has been somewhat reduced because funds for the work are at the present time a bit tight.

6. Chromospheric Spicule Spectra

Extensive studies of solar spicules have been made at various observatories, since their properties were first described from Climax observations back in 1943. As described in earlier issues of these reports spicules now play an important role in solar physics. (3) However, none of the research programs to date has been able to measure the temperatures of individual spicules from the widths of their spectrum lines. This is mainly because of their faintness and small size, which make spectroscopic observations extremely difficult.

During the quarter, however, Athay decided to make a direct attack on this problem with the Climax coronagraph-spectrograph. He decided to try to obtain rapid-sequence spectrograms at a succession of small steps of height across individual spicules, and to do this rapidly in the light of two different spectrum

(2) Astrophysical Journal, 73, 1, 1931.

(3) Director's Quarterly Report 1956-2, pages 3-6.

lines--the H-alpha line of hydrogen and the D_3 line of helium. The two lines were necessary because we know that two independent effects, temperature and turbulent motions, are likely to widen the lines. Because helium atoms are heavier than hydrogen, however, the line widening for the two effects will differ. Thus, shots of the same spicule at the same time, in both spectrum lines, should permit separation of the two effects. To our gratification he was successful--in large part because of the great rapidity with which the instrument can be made to scan automatically across a portion of the sun's image.

Excellent sets of spectrum photographs were obtained for a large number of spicules, and from these he was able to measure the widths of the two spectrum lines in large numbers of spicules. This method of determining temperatures by the amount of line widening, is similar to that used for the corona. (4) It depends, however, on knowing how transparent the gases are at the places where the spectra are obtained. For the corona we are sure this is always so. In spicules, however, the problem is more difficult, though we believe manageable. The H-alpha spicule spectrograms, we believe, are superior to any obtained thus far, and the D_3 helium spectra, so far as we know, are the only successful spectra of this kind.

When these were analyzed, they revealed a most intriguing result. The temperatures found were an astonishing $65,000^\circ\text{K}$, and the turbulence was found to be unimportant. This compares with estimates of a temperature of $6,000^\circ\text{K}$ at the surface of the sun and of one to two million degrees in the corona. This spicule temperature determination, which we believe to be the most accurate yet obtained, is at least twice as high as any previous estimates of the temperature of spicules, with the sole exception of the theoretical estimate by Athay and Thomas from indirect means, done some time ago. (5) Thus, we have new evidence bearing on the true nature of spicules, and are considerably closer, we feel, to understanding the role of the spicules in heating the solar corona.

The next step for us is to try to determine the spectrum in higher order lines of the hydrogen spectrum, where the gases are more transparent, and the interpretation of the results slightly more straightforward and unambiguous.

(4) Director's Quarterly Report, 1955-4, Page 3.

(5) R. G. Athay and R. N. Thomas, *Astrophysical Journal*, 123, 299, 1956.

During the quarter Dodgen completed some studies of the mottling visible on H-alpha spectra taken against the solar disk. These features have been studied by Dr. Robert R. McMath and his colleagues at the McMath-Hulbert Observatory. (6) Dodgen and Watson took a considerable number of "runs" of spectra of these features with the Climax coronagraph-spectrograph at small steps across the solar disk, and examined the statistics of formation of the small "cells" of gas showing a different-from-average width of spectrum line, implying cell structure with different physical conditions. Roberts hopes to summarize and assist in the interpretation of these features. Results will be reported later, when the studies are farther along.

7. IGY Program

During the quarter we formulated plans for analysis of IGY data rapidly being accumulated, with a hope of doing some preliminary active region analyses, rapid-run magnetogram analyses, and other short-term studies soon so as to obtain experience that may modify our data-taking before the end of IGY. Funds for this have taken a bit longer to obtain than we anticipated, but we hope to start such studies next quarter.

8. Older Coronal Spectrum Analysis

Work continued on coronal spectra taken, but never fully reduced, in the early days when the Observatory at Climax was a one-man enterprise. In those days I did not have time to measure all of the red coronal lines but concentrated on the green and on the east limb. Measurements of these older plates by Billings and Cooper are now completed. Bretz is at work tabulating and doing some preliminary studies of the data. Support for this was initially provided by the Office of Ordnance Research, and is being continued under the Institute for Solar Terrestrial Research. Results will be summarized later.

9. Eclipse Research

Preparation for the October 1958 eclipse in the South Pacific is going on at a pace that is short of frenzy, but not by much. Nor is it likely to lessen in the months ahead, though most of the equipment is now "farmed out" for construction. Rush, Lee, Lacey and Low have borne the brunt of the pressures, and can testify that the "un-postponability" of an eclipse is a powerful driver! And there are times when we wonder why we ever undertake to go

(6) See Director's Quarterly Report 1956-2, page 16-17.

to eclipses--with all their pressures, and all their chances for complete frustration in clouds. But the results they offer are not available in any other way.

The sailing date has been set for about September 1st, from San Diego, in an LSD--a floating dry-dock ship, which will also accommodate a rocket launching program. Living conditions on the island of Puka Puka, where the expedition will set up its equipment, (latitude 10°S, longitude 165°W) are somewhat uncertain. About 600 natives live on the islands of the atoll. Those who go may be able to live on shipboard if back-and-forth transportation is possible, although tent-living inland may be better than trying to go back and forth, if the sea is at all rough.

Low is writing a popular account of the eclipse plans for Sky and Telescope magazine, and we will probably have copies of it for circulation later. The Air Force Cambridge Research Center supports this work, and the observational program will be a joint HAO-Sacramento Peak enterprise. The travel and logistic support will be provided by the U.S. Navy.

10. Analysis of Sunspot Spectra

11. Solar Activity Guide Book

12. Aurora of Venus

Venus has come into favorable location for aurora studies, and the weather has been excellent. The late delivery of the equipment cost us some valuable observing time, but results have been obtained and these will be described in the next report. This work is ONR-supported.

13. Solar Data Center.

The list of participants in the IGY solar data program is impressive. The map in Figure 4 shows the world distribution of stations contributing to the international effort. (See page 18.)

Hansen, who heads the solar data center, has begun work aimed at inter-comparison of solar coronal data from the eight stations participating in IGY observing and reporting. He has also sent to all stations a set of calibrated density filters to be used for providing a good relative standard station-to-station of the intensity scales in use. Differences of observing technique will

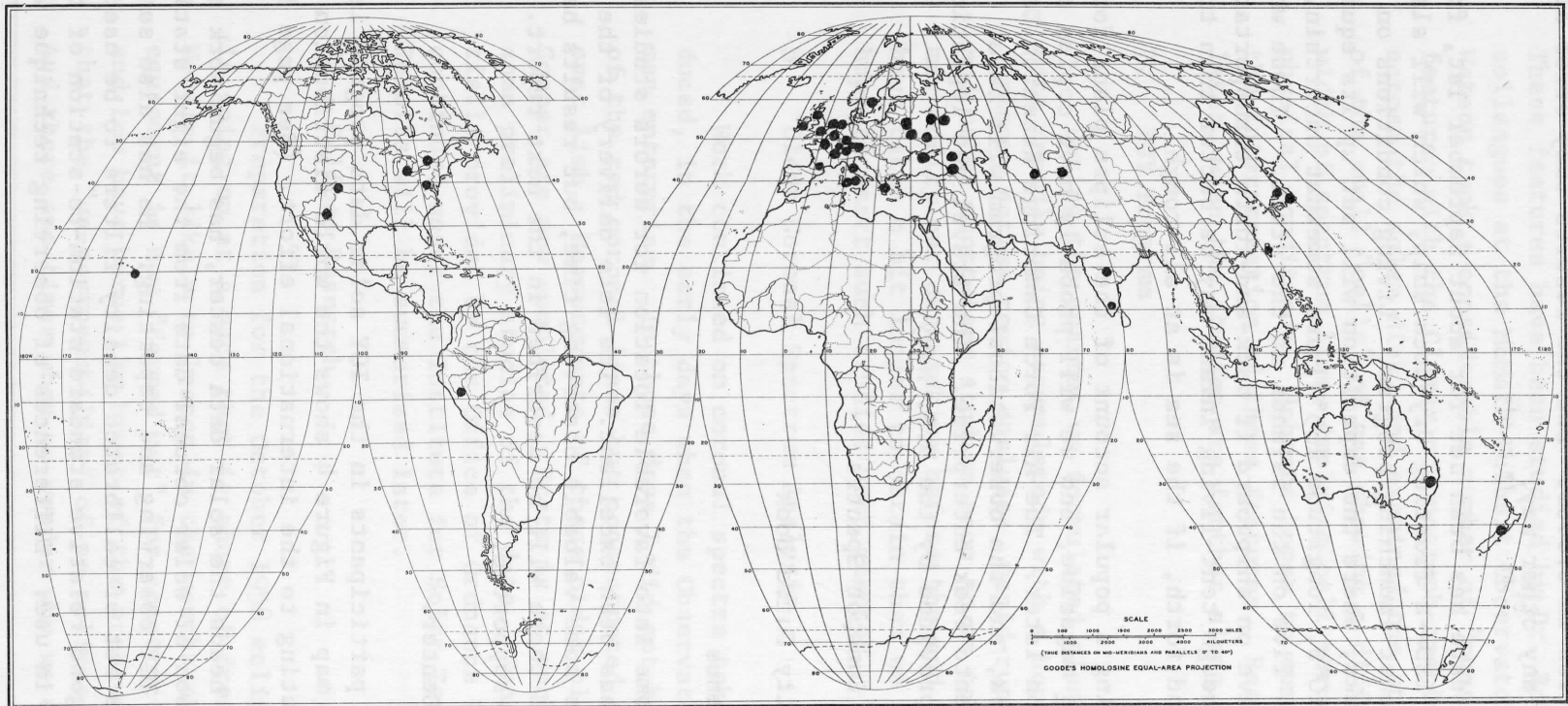


FIGURE 4

On this world map we have plotted all the IGY solar observing stations which send data to the U.S. Solar Data Center at the HAO. We have listed these below.

| | |
|-----------------------------------|--------------------------------|
| Sydney, Australia | Anacapri, Italy (Swedish) |
| Kanzelhohe, Austria* | Saltsjobaden, Sweden |
| Uccle, Belgium | Arosa, Switzerland* |
| Ottawa, Canada | Zurich, Switzerland |
| Ondrejov, Czechoslovakia | Abastumani, USSR |
| Meudon, France | Alma-Ata, USSR* |
| Pic du Midi, France* | Kharkov, USSR |
| Anacapri, Italy (German) | Kiev I, GAO, USSR |
| Freiburg, Germany | Kiev University, USSR |
| Wendelstein, Germany* | Kislovodsk, USSR* |
| Athens, Greece | Moscow NIZMIR, USSR |
| Honolulu, Hawaii | Moscow University, USSR |
| Hyberabad, India | Tashkent, USSR |
| Kodaikanal, India | Voroshilov, USSR |
| Dublin, Ireland | Greenwich, United Kingdom |
| Arcetri, Italy | Edinburgh, United Kingdom |
| Mitaka, Japan | Climax, USA* |
| Norikura, Japan* | McMath-Hulbert, USA |
| Nederhorst, den Berg, Netherlands | Mt. Wilson, USA |
| Utrecht, Netherlands | Naval Research Laboratory, USA |
| Huancayo, Peru | Sacramento Peak, USA* |
| Manila, Phillipines | |

* *Coronal Stations*

still impose difficulties, but this step should, we believe, reduce the scatter of observations by a significant amount.

Preliminary work has started on the preparation of pages for the IGY Annals that will contain the final published reports of solar phenomena for wide distribution to research workers throughout the world. From such reports, produced in every field, most of the final work on IGY-observed phenomena will be made. The data resource will serve science for decades to come, so it is important that the publication be well planned and well executed.

14. K-Corona Observations

Routine observations of the polarized light of the K-corona continue on a regular basis at Climax, weather permitting. We find that snow on the ground reflects enough light into the air to introduce polarization distortions because the reflected light is re-scattered by atmospheric dust and this considerably complicates the reduction.

V. RELATED PROGRESS AT OTHER INSTITUTIONS

A. Basic Solar Research

A recent issue of the *Astronomical Journal* contains an interesting analysis (7) of the fluctuations of sunspot numbers going back through about 17 of the 11 year sunspot cycles, to the year 1755. This paper shows that 88% of the fluctuation of annual average sunspot numbers can be represented by two periodicities of fluctuation: (1) a period of approximately 11 years duration; (2) a period of about 87 years duration. The 11 year period, however, is clearly not a strict one, and fluctuations of the length must be permitted to obtain this degree of fit. This leads to the conclusion that advance prediction at the start of a given cycle of the amplitude of maximum, or time of occurrence of the minimum is nearly hopeless. The author concludes that the hope of reliable prediction must, therefore, rest in improvements in understanding the basic nature of the various factors in solar activity variations.

In the same volume of the journal another paper of great interest appears (8) dealing with sunspot region prominences. The paper proposes

(7) C. W. J. Granger, *Astrophysical Journal*, 126, 152, 1957.

(8) L. Marshall, *Astrophysical Journal*, 126, 177, 1957.

to explain the sudden brightenings or fadings observed in down-streaming sunspot prominences as results of sudden temperature changes that occur as a consequence of changes in the sunspot magnetic fields in which the prominences move. The author states, for example, that if a pair of sunspots in a given spot group suddenly move apart a little bit, this changes the atmospheric magnetic field. In turn, the electrons and protons in the prominence are subjected to an electric field that decreases their velocities as they spiral in the magnetic field. This, in turn, lowers the kinetic temperature of the gas. A sudden change in temperature of this sort may be enough to cause visible emission to appear when previously the temperature was too high for it.

The basic suggestion of searching in such data for evidence on changing atmospheric magnetic fields is an appealing one, though the details of the field changes required to produce the observed phenomena may, because of the complexity of the phenomena, elude us for some time. The paper, however, clearly emphasizes the importance and the potentialities of such work, however difficult it may prove to be.

B. Solar-Weather Research

Rainfall and meteor showers have come into the focus of attention once again, with a new paper by E. G. Bowen. (9) As described in earlier copies of these reports (10), Bowen has suggested that when meteor showers occur with appreciable intensity, they produce a cosmic cloud-seeding effect that shows up statistically as increased world-wide rainfall about 30 days later. Bowen's original paper dealt with rainfall in November-December-January and included approximately 300 rainfall stations and approximately 60 years of data per station, on the average.

Bowen's argument is reinforced by the new data now presented. Not only are the coincidences impressive, but he also shows a relationship between the intensity of the Perseid shower of meteors (the principal one in these months) and the trend of rainfall in the period 1870 to 1950, with both minimizing in 1911, approximately.

The physical significance of Bowen's results is most intriguing. They imply that relatively small increments of meteoric dust produce a definite change, statistically speaking, of the probability of rainfall a long time later (30 days). A big argument against Bowen's interpre-

(9) E. G. Bowen, Australian Journal of Physics, 10, 412, 1957.

(10) Director's Quarterly Report 1956-4, page 13; 1956-1, page 15.

tation of his results has been that meteoric dust introduced at a high level in the atmosphere (above 50 miles) would not settle uniformly over different parts of the world, and so the lag times between meteors and the rainfall effects would not be so sharply defined (30 ± 2 in original study; 31 ± 3 in the present).

Perhaps Bowen's results need attention in terms of some alternate physical picture, but the results seem rather striking. They may also find a common ground with solar-rainfall interconnections. For example, if it is established that the small traces of dust introduced at high levels by meteors do produce a weather change by acting as nuclei for raindrop formation, then perhaps the long-suspected relation between solar corpuscular emission and the size of solar halos will result in an equally sensitive response of weather to a cosmic influence. (This time through the physics of sublimation of water vapor into ice particles rather than through radiation effects, as we have thought before.) In any event, it appears that these lines of research merit considerable pushing in the years ahead.

The study of high-latitude noctilucent clouds at great altitudes (50 miles) after sunset, planned by the Russian IGY teams, will have strong bearing on this research. Perhaps the night-glowing clouds are clouds of meteor dust itself! To be sure, there were great displays of those noctilucent clouds right after the fall of the remarkable Siberian meteorite burst which came down sixteen minutes after midnight (Universal Time) on the morning of June 30, 1908. The cosmic debris devastated an area nearly 60 miles in diameter, near the Stony Tunguska River. So great was the blast that a train on the Trans-Siberian Railroad, some 450 miles away was stopped by its engineer for fear it would be derailed! The succeeding hours and days saw extraordinary displays of noctilucent clouds over large portions of Scandinavia and England, though some authors have argued that the dust was terrestrial dust carried high into the air by the concussion. In any event, it seems unlikely that the coincidence was accidental--though the seventy-odd reliable reports of noctilucent clouds, studied largely by Russian authors, have not yet led to conclusive decisions about their origin.

There appears to be some evidence for solar activity influences on the occurrence of noctilucent clouds and rather conclusive evidence of special meteorological conditions, since the clouds are found just ahead or behind the frontal passage of an anticyclone but never above a high pressure cell or a deep cyclonic low. (11)

(11) N. I. Grisin, Bulletin of the Society of Astronomy and Geodesy, No. 15, Page 3; V. V. Cistiakov and V. G. Teifel, Astronomical Circular 1953, USSR, No. 139, Page 9; 1954, No. 145, Page 15.

VI. RECENT VISITORS TO HAO

- 28 October Dr. Krishman R. Ramanathan, Physical Research
Laboratory, Ahmedabad, India
- 28 October Dr. Albert R. Dawe, Office of Naval Research,
Chicago
- 7 November Dr. Carl Borgmann, University of Vermont and
Ford Foundation
- 13-15 November Mr. and Mrs. Frank M. Bateson, Rarantonga, Cook
Islands
- 16-17 November Mr. Robert D. Elliott, Aerometric Research,
Santa Barbara, California
- 2-3 December Dr. David D. Woodbridge, Army Ballistic Missile
Agency, Huntsville, Alabama

VII. PUBLICATIONS FROM HAO DURING THE REPORT PERIOD

- Chapman, Sydney: "Auroral Observation in India and Pakistan,"
Bulletin of the National Institute of Sciences of India, No. 9,
180, 1957.
- Thomas, Richard N. and R. G. Athay: "On the Uniformity of the Lower
Chromosphere," International Astronomical Union Symposium, No. 4,
Radio Astronomy, 279, 1957.
- Zirin, Harold: "Spectre d'une éruption au bord du disque solaire,"
Comptes Rendus des Séances de l'Académie des Sciences, 244,
2893, 1957.
- Bok, Bart J. and Constance Warwick: "Note on Interstellar Absorption
in the Region West of the Veil Nebula," Astronomical Journal,
62, 323, 1957.

Walter Orr Roberts

Walter Orr Roberts
High Altitude Observatory
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12 April 1958

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