ANNUAL REPORT* OF THE KODAIKANAL OBSERVATORY FOR THE YEAR 1959

Introduction

The intensive programme of observations carried out during the International Geophysical Year were continued during the period under review, the year of the International Geophysical Cooperation. These included visual and photographic observations of the solar photosphere, chromosphere and of prominences, as well as the 24-hour recording of the ionospheric characteristics and of the geomagnetic elements. While there has been a decline in the solar activity, there have been no days on which sunspots were not visible. Evidence of the high activity of the sun is found in the number of solar flares observed visually with the spectrohelioscope during the year, of which one was of intensity 3, the several ionospheric fadeouts recorded by the C-3 Recorder and the incidence of magnetic storms, the number of such occasions almost equalling that found during the previous year which covered the sunspot maximum.

A very important feature of the year has been the installation of much new equipment for solar observations. The new equipment thus made available to the researchers at Kodaikanal include a Solar Telescope that can yield solar images of 13″ and 7″ diameter on the slit of a spectrograph of 18-metres focal length, a 20-cm. aperture Lyot Coronagraph and a Lyot Monochromatic Heliograph for direct photography of the sun in hydrogen alpha line.

Observing conditions

Observing conditions throughout the year were slightly below average. Owing to a very wet summer and intense rainfall during the south-west monsoon period, the total number of hours during which solar observations could be carried out was much less than in previous years. The total annual rainfall recorded was 1881 mm. a value much in excess of the fifty year average of 1689 mm. The total number of hours of bright sunshine was 2068 which is about four per cent below normal.

Solar Research

Special investigations have been made on the intensity distribution across sunspots in integrated light, the variation of prominence heights with latitude, the distribution in longitude of sunspots and the distribution of calcium flocculi on the sun's disk. The routine programme of daily observations of sunspots, prominences and flocculi with the aid of the photoheliograph, spectroheliograph and spectrohelioscope has been continued. Direct solar photographs could be taken only on two hundred and sixty days compared to two hundred and seventy eight days in the previous year. H-alpha disk

*This report deals chiefly with the astronomical and allied geophysical work of the Kodaikanal Observatory. The meteorological data will be published in the India Weather Review, the seismological data in the Seismological Bulletin and the administrative details in the Administration Report of the India Meteorological Department.

K disc and K limb spectroheliograms were secured on two hundred and forty four, two hundred and thirty five and two hundred and twenty four days respectively. The total number of exposures of each kind was as follows:

1. Direct photographs	395
2. H-alpha spectroheliograms of flare regions	52
3. H-alpha spectroheliograms of entire disc	762
4. K232 spectroheliograms	646
5 K. Prominences	621

Observations with the spectrohelioscope were made on two hundred and fifty two days covering a total duration of four hundred and thirty one hours. Seventeen solar flares were observed at the spectrohelioscope, one of these of intensity 3, twelve of intensity 2 and four of intensity 1.

The average definition of the sun's image was 3 on a scale of 5. The following table gives the number of days, monthwise, of the seeing conditions recorded in the photoheliograph dome while a direct photograph of the sun was being taken.

Months	Number of days				
	Seeing 1	Seeing 2	Seeing 3	Seeing 4	Seeing 5
January	..	1	20	7	..
February	..	2	17	6	..
March	..	3	18	10	..
April	1	..	22	1	..
May	..	2	22	1	..
June	..	..	10	..	..
July	..	1	12	..	..
August	..	1	17	..	..
September	..	4	15	3	..
October	..	3	13	1	..
November	..	..	17	1	..
December	..	3	19	..	..

Sunspot Activity

Compared with 1958, there was a decline in sunspot activity during 1959. The mean latitude of all the observed spot groups in the northern and southern hemispheres was 15.4° and 13.3° respectively as against 18.1° and 16.2° respectively for the previous year. Details of sunspot observations are given in the following table:

Months		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
No. of new spot groups	N	37	25	28	27	24	14	30	27	18	10	21	27	288
	S	24	10	15	13	10	9	7	11	14	17	5	8	143
Mean daily number of spot groups		13·1	8·2	10·5	9·2	7.8	8·3	8·1	8·8	8·2	6·2	6.2	6.5	8.4
Kodaikanal daily relative sunspot number		252.0	138.1	184.0	187.0	176.0	159.3	146.0	195.1	149.1	105.8	109.5	112.7	159.5

Prominences

Prominence activity continued to be high during 1959. The mean daily areas and numbers of prominences at the limb derived from photographs taken at Kodaikanal are as follows:

	Area (in Sq. minutes)					Numbers				
1959	N	S	E	W	Total	N	S	E	W	Total
January-June .	3.33	1.85	2.29	2.89	5.18	6.11	3.93	4.92	5.12	10.04
July-December .	1.74	2.13	1.85	2.02	3.87	3.35	3.37	3.27	3.45	6.72
Whole year (Weighted mean).	2.71	1.96	2.12	2.55	4.67	5.04	3.71	4.28	4.47	8.75

Compared with 1958 there has been a decrease in activity both in areas and numbers, the decrease in area being 20.8% and that in numbers 6.5%.

The distribution of areas in 5° ranges of latitude shows two peaks of activity in the northern hemisphere in the zones 25°-30° and 75°-80° while in the southern hemisphere there is a broad peak of activity in the latitude belt 15°-35°. The activity in the southern hemisphere, judged by areas and numbers, continued to be less than in the northern hemisphere.

The mean daily areas and numbers of hydrogen dark-markings on the disc as obtained from Kodaikanal records are as follows:

	Area (in millionths of the sun's visible hemisphere—uncorrected for foreshortening).					Numbers				
1959	N	S	E	W	Total	N	S	E	W	Total
January-June .	2555	2148	2065	2638	4703	16.21	13.35	13.70	15.86	29.56
July-December .	3038	2069	2482	2625	5107	17.42	13.36	14.97	15.81	30.78
Whole year (Weighted mean).	2747	2110	2231	2626	4857	16.69	13.34	14.21	15.82	30.03

Compared to the previous year there was no significant variation in the mean daily areas. The distribution of areas in 5° ranges of latitude showed a maximum in the zone 25°-30° in the northern hemisphere and a broad peak of activity in the southern hemisphere extending from latitude 15°-25°. The markings also showed less activity in the southern than in the northern hemisphere. The western preponderance of areas and numbers observed last year continued.

Intensity distribution in integrated light across sunspots

The intensity distribution across sunspots in integrated light was measured with the aid of a thermocouple by Kutty Krishnan Nayar. These measures were made on drift curves across a 15″ diameter solar image obtained with the aid of an enlarging lens, and a theromocouple placed behind an aperture admitting 165 square seconds of arc of the sun's disc. Thirty two spots of umbral area falling between forty and four hundred millionths of the sun's visible hemisphere were scanned and the central intensities recorded. The corrected central intensity of a spot is found to vary with the umbral area. The trend is for bigger spots to appear darker, though no exact correlation could be found between umbral area and central intensity. The central intensity corrected for scattering was also found to be independant of the position of the spot on the disk.

Prominence Heights.—Gopalakrishnan has studied Kodaikanal data on heights on the quiescent prominences obtained with the K-spectroheliograph during the period 1915-1954. A study of latitude variation of these regions indicates that the mean height of prominences is maximum in the equatorial region decreasing gradually to 45° latitude, after which it falls off more rapidly.

Distribution of sunspots in longitude.—Ramanathan and Jayanthan have studied the distribution of sunspots in longitude over six sunspot cycles with the aid of Greenwich sunspot data. The distribution of sunspot areas in longitude for the northern and southern hemispheres was considered separately and the analysis shows that the distribution of sunspot activity in longitude in both hemispheres is similar, when integrated over a complete cycle. The active centres on the sun's disc move occasionally in longitude currently with movement in latitude, but this motion is neither uniform nor does it always conform to the same direction.

Distribution of calcium flocculi.—Kuriyan, using Kodaikanal spectroheliograms for the period 1911-1934 has searched for an east-west asymmetry in the distribution of calcium flocculi on the sun's disc. The results obtained indicate a predominant excess of flocculi on the western half of the sun during the maxima of the cycles. Investigation is being extended for another two sunspot cycles.

The exchange of spectroheliograms with foreign observatories was continued. For the period July 1958—June 1959, 76 H-alpha disc and 78 K-disc spectroheliograms from the Meudon Observatory and 92 H-alpha disc., 95 K-disc and 113 K-limb spectroheliograms from the Mt. Wilson Observatory were received. 144 H-alpha disc and 52 K-disc spectroheliograms for certain specified days for the period 1955-1959 were sent to Meudon Observatory, on request. Copies of daily spectroheliograms (disc in H-alpha and K and limb in K) were supplied in fortnightly batches to the Fraunhofer Institute,

Germany for the preparation of daily solar maps. Four photoheliograms together with the relevant zero plates for certain days in 1958-59 were supplied to the Astronomer Royal, Royal Greenwich Observatory, England. Quarterly statements relating to solar flares were sent, as in previous years, to the Meudon Observatory and to the Royal Greenwich Observatory. Central meridian passage of important sunspots and forecasts of expected magnetic and ionospheric disturbances were supplied to a number of interested institutions in India.

Research in Ionospheric Physics and Geomagnetism.—Special investigations have been made in the study of scattering of electromagnetic waves by the ionospheric F region and its relation to geomagnetic phenomena, the movements in the F region during solar eclipses and the influence of ionospheric storminess and solar activity on geomagnetic distortion anomalies in the equatorial F-2 region. The C-3 Ionosphere Recorder functioned on all days of the year for twentyfour hours each day and only about two hundred and fifty hours were lost, due to either power failures or equipment malfunctioning. The daily programme was confined to records every fifteen minutes and on about two hundred occasions mostly at pre-dawn hours in the year the records were taken at much shorter intervals, for the study of the rapid changes in the ionospheric parameters. Short-wave field intensity values were recorded during day-light hours on all days of the year. During this period short-wave radio fade-outs (of Dellinger type) were recorded on one hundred and forty three occasions of which the fade-outs recorded on March 16 and July 14 lasted over an exceptionally long duration of about one hundred and twenty minutes.

Continuous photographic recording of H, Z and D elements with La Cour and Watson Magnetographs and visible recording of H and Z with Askania Magnetic Field Balances functioned round-the-clock all days of the year. Absolute values of H, D and Z were determined every week with a set of QHM (Nos. 254, 255 and 256) and BMZ instruments. Absolute measurments of H with a Kew Magnetometer and of inclination with a Schulze Earth Inductor were also made once every month. Scale value determinations of these magnetographs were done twice every month. During the year twentyone crochets and twenty seven magnetic storms were detected on Kodaikanal magnetograms. Twenty two of these twenty seven storms were of the sudden commencement type with ranges in H. F. between 168 and 785 gammas. The remaining five storms were classified as severe since the H.F. ranges of these exceeded 400 gammas. Periodical statements of observational data concerning solar flares, relative sunspot numbers, ionospheric parameters and sudden ionospheric disturbances were sent to a number of interested institutions in India. Photographs of a few geomagnetic crochets and microfilm copies of some magnetic storms and magnetograms obtained during 1958 were supplied on request to the Research Department, All India Radio, the Geophysical Institute, Alaska, the Ionospheric Observatory at Ibadan and the Czechoslovenska Academic, Prague.

The Observatory continued to supply monthly median values of foF_2 and $(M3000)F_2$ to the Radio Research Committee of India and the Central Radio Propagation Laboratory, U.S.A. Quarterly statements of monthly median values of all ionospheric parameters were sent to both the Radio Research Station, Slough and C.R.P.L. at Boulder. Quarterly magnetic storm data were sent to Prof. John A. Simpson of the University of Chicago.

Scattering of radio waves by the F layer.—Bhargava and Jayarajan have carried through a study of equatorial F scatter during night hours using Kodaikanal data over a period of 4 years from 1955 to 1959. They find that intense geomagnetic activity prevailing at increasing level of solar activity appears to inhibit the occurrence of equatorial Spread F.

Movements in the F region during solar eclipses.—Bhargava and R. V. Subrahmanyan have investigated F layer ionospheric data collected at Kodaikanal during the partial solar eclipses of June 20, 1955 and December 14, 1955. In order to study the effects of the eclipses at several true heights, the distribution of electron densities for several levels between 250 and 400 km. has been obtained from the h'-f curves. It is seen that the electron densities are affected differently during eclipses depending on the season and the time of occurrence of the eclipses. Furthermore, the large vertical ionic drifts caused at low latitude stations by electrodynamic forces are considerably modified during the eclipses. Using Kodaikanal geomagnetic data of H variation obtained simultaneously with ionospheric records they suggest that the modifications introduced in the 'normal' movements, during the eclipses are associated with the drop in 'effective' conductivity in the dynamo region and the consequent annihilation of equatorial 'electrojet' at the time of eclipse.

Influence of ionospheric storminess and solar activity on geomagnetic distortion anomalies in the equatorial F2 region

Bhargava and R. V. Subrahmanyam in their study of ionospheric F-2 layer data obtained at Kodaikanal for over half a solar cycle, find that the abnormal increase in the electron densities, immediately following sunrise, as well as the diurnal asymmetry undergo systematic changes during stormy conditions. In order to examine if these changes are accounted for by additional electromagnetic movements during disturbed conditions, the magnitudes of movement terms of the continuity equation at three heights for both quiet and disturbed days have been computed. The changes in the pattern of diurnal variation of NmF2 with increasing solar activity and a possible mechanism for these changes can be explained in terms of (1) a slight phase shift in the electrodynamic tide, (2) residual storm currents, (3) change in the mode of production, and (4) change in the 'effective' conductivity. From an analysis of published F2 layer data of a number of stations with magnetic dip $\pm 40^{\circ}$, it has been seen that the ratios of morning to afternoon peak densities yield a fair measure of equatorial geomagnetic distortion anomaly. A remarkable similarity has been found between the variation with dip of the horizontal force of the Earth's field and the ratios of the morning to afternoon electron peaks in the F2 layer.

Miscellaneous Observations
(Ozone, Meteorology, Cosmic Ray, Seismology and Earth-shine)

Meteorological observations with all the visual and self-recording instruments were carried out as usual. Cosmic ray records with the Kolhörster apparatus were taken throughout the year. The Milne-shaw Seismograph recorded 56 earthquakes. Regular observations of atmospheric ozone were made with a Dobson Spectrophotometer on 190 days and Umkehr observations were taken on 29 days during the year. Earth-shine observations were recorded on 21 days.

Instrumental development

With the completion of the solar tower and tunnel during the year, the solar telescope with associated 18-metre spectrograph was installed by the end of the year. A coelostat having two fused quartz mirrors of aperture 60 cms. at the top of the tower 30' in height sends light vertically down to a third fused quartz mirror of indentical size. The light is then deviated horizontally on to a 38 cm. aperture achromat of 36 metres focal length. When a smaller image is found necessary, a 20 cm. aperture lens of focal length 18-metres can be introduced in place of the 38 cm. object glass. In the focal-plane of the telescope objective lies the slit of the 18-metre spectrograph function ing in a Littrow arrangement. A 20 cm. Hilger lens of focal length 18-metres forms the objective in the spectrograph. The primary dispersing unit is a 203 mm. Bausch & Lomb grating with 600 lines per millimetre blazed in the fourth order green. Provision is made for the grating to be moved out of position in order to allow the light to fall on 7 prisms, should this be considered necessary. The spectrograph is housed in steel tubing of 76 cms. diameter. The two ends of this steel housing containing the slit and photographic plate and the dispersing unit can be rotated to facilitate different settings of the slit in position angle.

The 20 cm. Lyot Coronagraph and 15 cm. Monochromatic Heliograph operating in the H-alpha line have been erected on an equatorial table attached to the former Madras refractor mounting. A single lens reflex camera at the focal plane end of the Heliograph permits the photography of features on the solar disc in H-alpha light. This twin-arrangement telescopes is housed in a 25' diameter dome erected during the year.

The entire effort of the instrument shop was devoted for the construction of the Lyot Heliograph and the 18-metre spectrograph as well as the erection of the solar telescope, coronagraph and the heliograph.

Construction and testing of two new receivers to work on 100 Mc. and 200 Mc. for radio-astronomical observations and a third receiver on a wavelength of 60 mc. for radio-star scintillation work were completed. An interferometer to work on a wavelenght of 3 m. was designed and constructed.

Voltage and frequency fluctuations in the A. C. Power supply have been a problem for several years and in order to remedy this, 3 A.C. Generators have been acquired capable of having a load of 75 K.W. These generators will be used as a standby power supply at times of power failure or when the regular mains operations of electronic equipment is hampered by undesirable fluctuations.

Library

2723 periodicals were received during the year under review. 72 books were purchased during the year. In addition to the journals subscribed to and the books purchased, exchange publications were received from 204 Observatories and research institutions.

Building & Grounds

The dome, tower and underground tunnel for housing the solar telescope and spectrograph were completed during the year. Construction work was also completed on the dome and building that accommodates the coronagraph and the heliograph. Also, the construction of the buildings for a new laboratory was commenced during the period under review. The other buildings and domes of the observatory were kept in good repair.

International Geophysical Year

Intensive solar, geomagnetic and ionospheric observations and visual watch for aurorae undertaken during the I.G.Y. 1957-58 were continued during 1959, the year of International Geophysical Cooperation. The solar data were sent periodically to the World Data Centres. Complete magnetic and ionospheric data with f-plots for Regular World Days and Special World Intervals were under preparation for transmission to the respective World Data Centres. Daily messages relating to solar and geomagnetic observations at Kodaikanal in the I.G.Y. code and in plain language were sent to New Delhi for inclusion in the I.G.Y. broadcasts.

Publications

Bandhopadhyay, Kalyan Kumar . .	Relative intensity distribution on Mars in red light during the 1954 opposition. Kodaikanal Observatory Bulletin No. CLIV (1959).
Bhargava, B. N. and Gopala Rao, U. V.	Ionospheric disturbances associated with magnetic storms at Kodaikanal. Indian Journal of Meteorology and Geophysics Vol. 10 (1959).
Das, A. K.	The solar cycle and the associated behaviours of sunspots and prominences. Kodaikanal Observatory Bulletin No. CLII. (1959).
Gopala Rao, U. V.	See Bhargava, B. N.
Jayanthan, R.	The Flare of 1957 September 17.—The Observatory, Vol. 79 (1959).
Narayana J. V.	Magnetic field of the planet Venus. Kodaikanal Observatory Bulletin No. CLIII. (1959).
——	Observations of Mars during 1954 Opposition. Kodaikanal Observatory Bulletin No. CLIV (1959).
—— and Viswanathan, N. . .	Observations of Mars at Kodaikanal during the 1956 opposition—Kodaikanal Observatory Bulletin No. CLIV (1959).
Sankaranarayanan, S.	Centre-limb variation of solar exitation temperature as derived from TiI lines.—Kodaikanal Observatory Bulletin No. CXLIX (1959).
Venugopal, V. R..	Variation of the F-2 layer ionization with solar activity at Kodaikanal on magnetically disturbed and quiet days.—Kodaikanal Observatory Bulletin No. CLI (1959).
Viswanathan, N.	See Narayana, J. V.

Kodaikanal Observatory Bulletin No. 150 containing the summary of results of solar, magetic and ionospheric observations for the first half of 1957 was published during the year. In additions to the above, quarterly synopses of results of solar, magnetic, ionospheric and ozone observations made at Kodaikanal appeared in the Indian Journal of Meteorology and Geophysics. The Monthly Notices of the Royal Astronomical Society published a report of the work done at Kodaikanal Observatory during 1958 as well as on the prominence activity during the same year.

Visitors

Dr. V. Ambartsumian, Director of the Burakan Observatory, Armenia, U.S.S.R. visited the observatory in January and delivered a talk on "Systems of Galaxies".

M. K. VAINU BAPPU
Director.

KODAIKANAL OBSERVATORY,
December, 1960.

GIPN—SV 2 D.D.G. Kodi./60—24-4-61—400