Optical, Radio and Temperature Observations at the 10 July 1972 and 30 June 1973 Total Solar Eclipses

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Abstract

Shadow bands were detected with a multichannel photo-electric system at the 10 July 1972 eclipse. The bands were strongest in blue, weaker in red and weakest in green-yellow light. A second system showed that the light intensity fluctuation frequency consisted of a continuous frequency of approximately 6 hertz with an approximate 22 hertz frequency appearing from 50 seconds to 10 seconds before totality. A monitor at 3.85 megahertz showed that radio frequency noise began to increase approximately 22 minutes before totality and increased by at least a factor of five peaking about 4 minutes after the end of totality. An electronic thermometer showed a 10° Fahrenheit drop in temperature, the minimum occuring approximately 5 minutes after the end of totality. For the 30 June 1973 eclipse more extensive electronic detection equipment was developed. Detectors for radio frequency noise at 146.94, 50.4 and 7.5 megahertz and 550 kilohertz were used. A voltage-to-frequency converter system showed that the light level decreased from approximately 11 foot-candles shortly after sunrise to an undetectable level during totality. Ionosphere height measurements were analyzed at frequencies ranging from 0.5 to 20 megahertz showing a decrease in height during totality for frequencies ranging from 3.5 to 5.5 megahertz. Possible correlations of shadow band activity, radio frequency noise and ionosphere heights are being studied further.

Introduction

A number of interesting phenomena occur before, during and after the total phase of a solar eclipse. Many of these phenomena have not been analyzed thoroughly primarily due to the very short time period during which they occur. This paper reports observations of such phenomena at two recent eclipses.

For a few minutes preceding and following the total phase of a solar eclipse, faint light and dark bands move across the surface of the earth. Continuing observations of these shadow bands begun at the 1966 eclipse in Rio Grande do Sul, Brazil (1), and further refined at the 1970 eclipse in Greenville, North Carolina (2), a team of 14 persons set up equipment for visual, photographic and photoelectric detection of shadow bands at the 10 July 1972 eclipse at Malignant Cove, Nova Scotia. In addition, rf noise (at 3.85 mHz) and air temperature were recorded. Further continuation of our eclipse observations was accomplished at the recent eclipse, 30 June 1973, one team (M.H., D.W., G.B.) observed in Surinam, South America, and the other from aboard ship off the coast of Mauritania, Africa. The Surinam work involved measurements of the variations of intensity of rf noise at four different frequencies, plus recording of air temperature and light level.

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Ionospheric height measurements using a range of frequencies of 0.5 to 20 mHz were made by a collaborating group in Surinam and the analysis of these data is presented.

Equipment

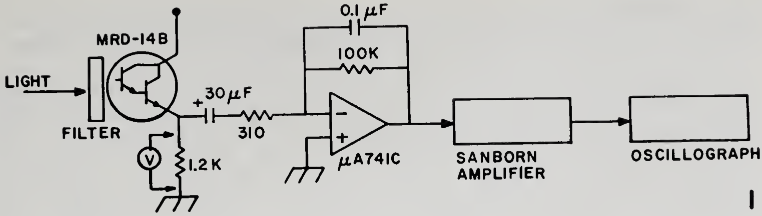
Five systems were used at the 10 July 1972 eclipse. System No. 1 was designed to determine the optical wavelength nature of the shadow bands. The photodetector for channel A was a CdS cell with no optical filter. Motorola MRD-14B Photo Darlington transistors were used on the other six channels with optical filters as follows: Channel B, blue wide-band; Channel C, red wide-band; Channel D, green wide-band; Channel E, blue-green narrow-band (5270 Å); Channel F, green-yellow narrow-band (5870 Å); Channel G, red narrow-band (6870 Å). The electronics for a single channel is shown in Figure 1. A voltmeter across the load resistor monitored the output of the transistor. The a-c coupling between the transistor and the μA741C amplifier made it unnecessary to continually adjust for variation of total light intensity, a difficulty experienced at the 7 March 1970 eclipse (2). The capacitor feedback loop in the pre-amplifier eliminates high frequency noise generated by the detector. The outputs of the seven channels were recorded on a Brush high speed multi-channel strip chart recorder.

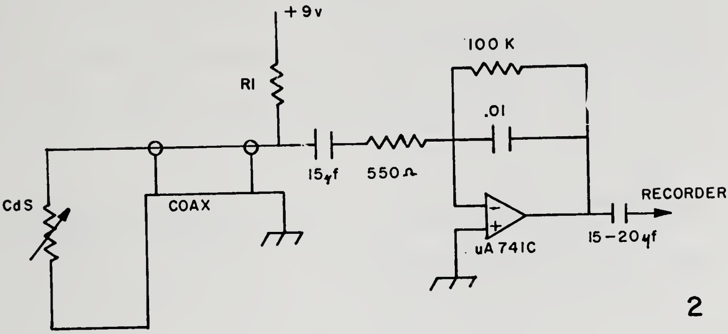
System No. 2 was designed to determine the light intensity fluctuation frequency composition of the shadow bands. One CdS photocell was connected to a set of eight electronic filters, each tuned to a separate frequency of light fluctuation. The filters resonated at the following frequencies with adjacent filters overlapping at 0.707 of the maximum voltage: 2, 4, 6, 8.2, 11, 15, 22 and 28.2 Hz for Channels A through H, respectively. The CdS photo resistive cell is connected to a step attenuating load resistor. The detector signal is capacitively coupled to a 40 Hz low-pass filter with the output directly fed into the eight separate band-pass filters. Each of the signals is amplified and displayed on a 100 μA meter. The set of eight meters (with a large dial watch for timing purposes) was continuously photographed with a Super 8 movie camera.

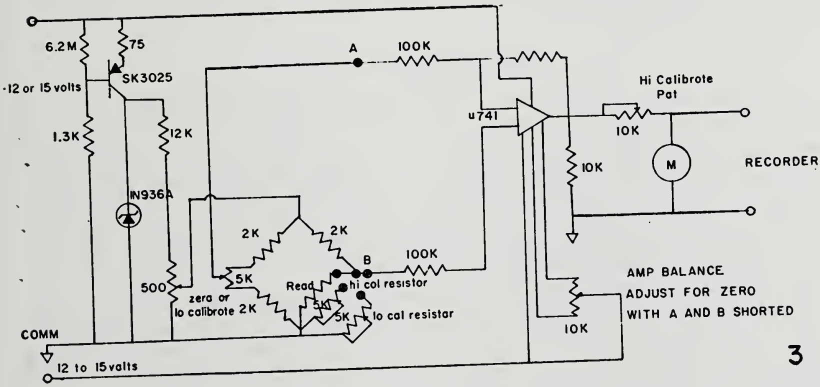
System No. 3 consisted of two CdS photocells spaced 30 cm apart and placed in a plane perpendicular to the sun's rays and in a vertical plane. The photocells were connected to a Brush two-channel high speed strip chart recorder. The velocity of the shadow bands could be obtained by measuring the time difference of correlating points of the two recordings.

System No. 4 was a Heathkit HR-10B amateur radio receiver and a strip chart recorder. This system monitored rf noise at 3.85 mHz. This frequency was selected due to a lack of amateur radio "traffic" at this frequency. Experiencing a great amount of rf interference in our equipment at the 7 March 1970 eclipse suggested this experiment.

System No. 5 was an electronic thermometer connected to a strip chart recorder for monitoring the air temperature, before, during and after totality.







FIGURES 1-3. *Photoelectric system used for detecting optical wavelength characteristics of shadow bands (System No. 1). One channel of a seven channel system is illustrated. 2) Photoelectric system for shadow band velocity, band width and band separation measurement. 3) Electronic thermometer used for measuring air temperature at the 30 June 1973 eclipse.*

Seven systems (Nos. 6 through 12) were used at the 30 June 1973 eclipse. System No. 6 consisting of two detectors, each using the electronics shown in Figure 2, was connected to a dual channel Astro-Med Model 202 strip chart recorder. This experiment, which was an advancement over System No. 3, was used to try to measure the velocity, the band width and the band separation of shadow bands.

System No. 7 was an electronic thermometer for air temperature measurement. The output of this circuit is independent of power fluctuations. The circuit, see Figure 3, is a balanced bridge using a military thermal resistor (Read). The output of the bridge and calibration circuits is fed into a balanced operational amplifier for amplification to levels suitable for meter and recorder outputs.

Systems Nos. 8, 9, 10 and 11 were designed to monitor rf noise at frequencies of 146.94 mHz (using a highly directional antenna aimed at the sun), 50.4 mHz, 7.5 mHz and 550 kHz (all three using non-directional antennas). The receivers were, respectively, a Motorola crystal controlled HA-734 receiver through a diode pump into a Heathkit Model IR-18M chart recorder, a Lafayette Model HA-750 receiver into an AIWA Model TP-707P cassette recorder and a Military Command radio receiver Model BC-453B into an AIWA Model TP-707P cassette recorder.

System No. 12, used for measuring the light level before, during and after totality, consisted of a voltage-to-frequency converter, resulting in frequencies in the audio range recorded onto a cassette tape.

In addition to using the above mentioned equipment designed and operated by our team, Mr. A. A. Sandel, Director of the Meteorological Service of Surinam, put us in contact with a group in Paramaribo who daily monitor ionospheric heights using 0.5 to 20 mHz frequencies. Photographic recordings before, during and after totality were brought back for analysis.

Results and Discussion

Strip chart recordings of the shadow bands, using System No. 1, are shown in Figure 4. Comparison of the recordings at four different time periods before totality shows the over-all change in intensity of shadow bands with time and the great complexity of the bands. Analysis of the complete recording from 600 sec before totality (-600 sec) to 35 sec before totality (-35 sec) reveals the following: Channel A (unfiltered CdS cell) showed the most activity, while Channel B (blue wide-band) was next most active and Channel C (red wide-band) was third in activity. Channel D (green wide-band) showed relatively little activity. Channel E (blue-green, 5270 Å) showed more activity than Channel G (red, 6870 Å). Channel F (green-yellow, 5870 Å) showed almost no activity. These approximate relative intensity values are shown in Figure 5. Since the shadow bands occur at approximately the same time as the flash spectrum, one might expect a direct correlation between the two which possibly is evident in Figure 5.

The recordings of System No. 1 were also analyzed for light intensity fluctuation frequencies. At all colors there was a predominate frequency of about 6 Hz for large amplitude components. These components were present all the time the equipment was on (beginning 600 sec before totality). The high frequency components were low in amplitude and in the range of 15 to 25 Hz from 600 to 150 sec prior to totality. The high frequency components increased in frequency to as high as 50 Hz at 120 sec prior to totality in the red region. At 75 sec prior to totality the lower most dominant frequency was still 6 Hz and the higher frequency components were in the 13 to 16 Hz range. Activity on all the channels with wide band filters (and the unfiltered channel) began to decrease at about 130 sec before totality with very little activity remaining at approximately 20 sec before totality. This decrease just before totality corresponds well with previous results (2).

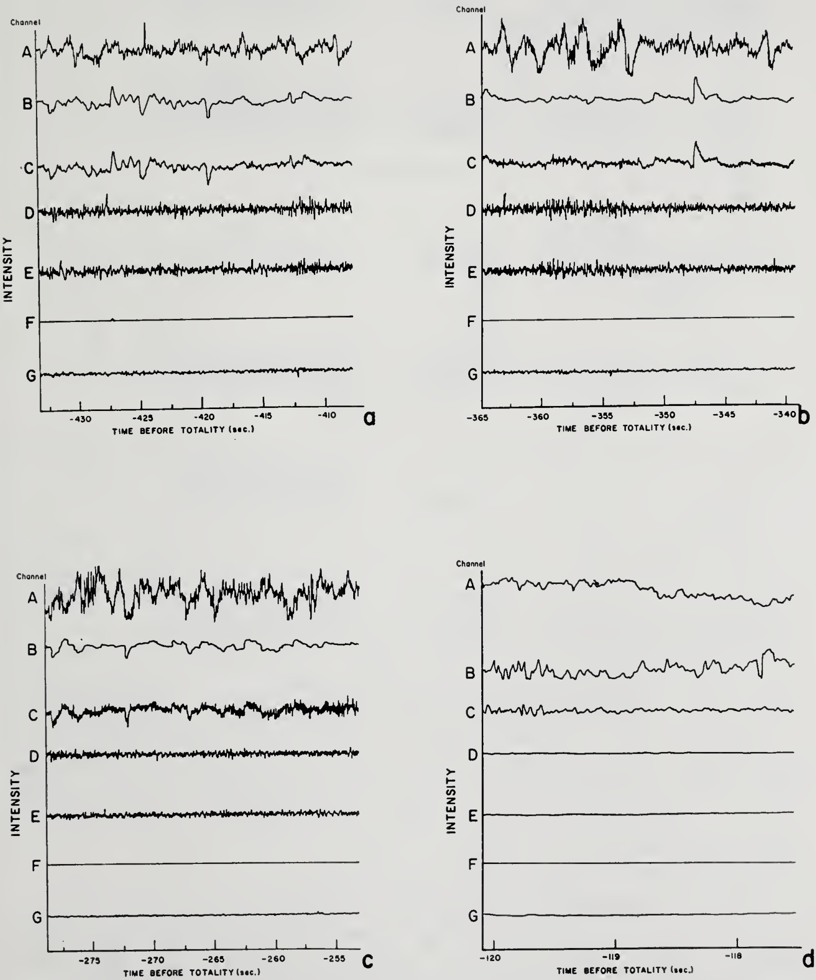


FIGURE 4. *Strip chart recordings of shadow bands (System No. 1) at four different time periods (a, b, c, d) ranging from 430 sec to 118 sec before totality. (Solar eclipse, 10 July 1972, Nova Scotia).*

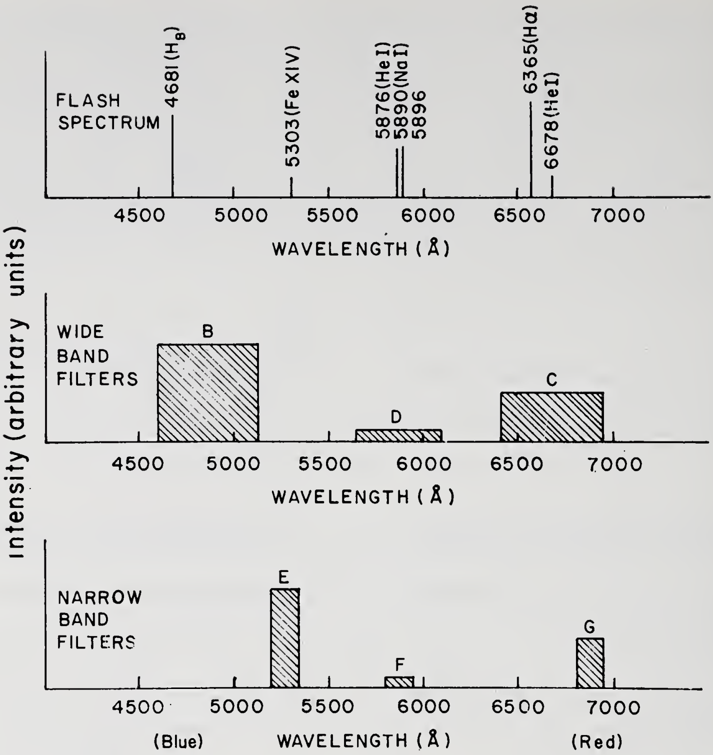


FIGURE 5. *Shadow band light fluctuation intensity* vs. *optical frequency as obtained with System No. 1. Channel letter is noted above each bar. (Solar eclipse, 10 July 1972, Nova Scotia).*

The Super 8 movie of System No. 2 was visually analyzed and the readings of six times (at 20-sec intervals prior to totality) are shown in Figure 6. Frequencies of 2 to 8 Hz remained fairly constant throughout the total time the movie was taken. This corresponds with the results of System No. 1. At about 22 Hz the intensity was very low at first but then increased considerably about 50 sec before totality and remained strong to about 10 sec before totality. This component at about 22 Hz may correspond to the usual visual shadow band phenomenon. For example, at the 7 March 1970 eclipse in Greenville, N.C., one group measured the velocity of the bands, as they moved across a shadow band screen, to be approximately 2 m/sec and estimated the spacing of the bands (center to center distance) to be 10 cm which gives a frequency of about 20 Hz.

The two channels of System No. 3 recorded shadow bands with features that correlate well with the results of Systems Nos. 1 and 2. However, there are no obvious correlations between the two recordings themselves and thus no velocity measurements were possible.

The strip chart recording at 3.85 mHz (System No. 4) shows that rf noise began to increase about 22 min before totality and increased by an estimated factor of five times normal background peaking approximately 4 min after the end of totality.

Air temperature readings were taken every 5 min from the original strip chart recording (System No. 5) and replotted as shown in Figure 7. This shows a 10° F drop in temperature during the eclipse. The minimum temperature occurred approximately 5 min after the end of totality. The odd shape of the curve after totality was likely due to a varying cloud cover.

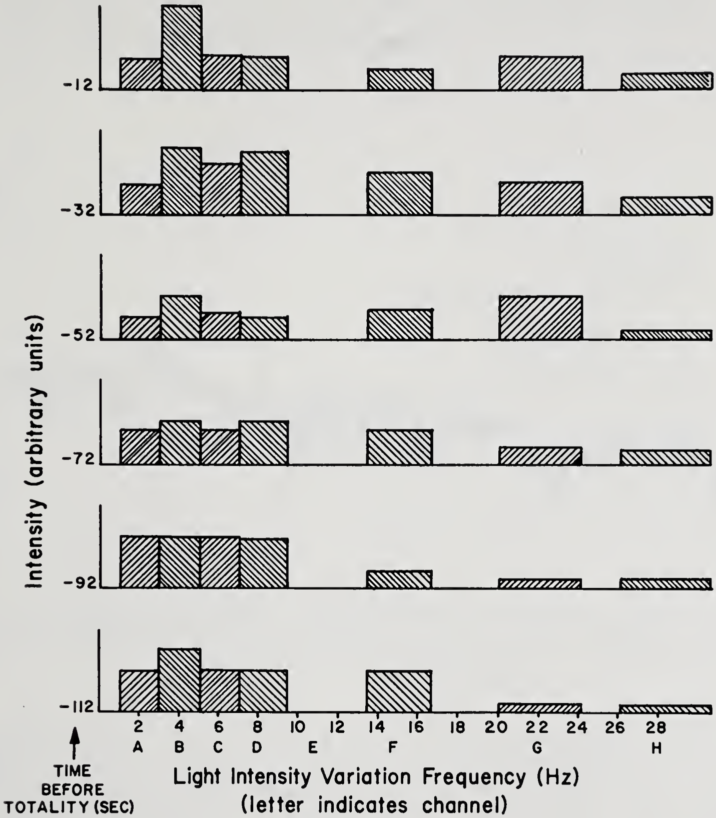
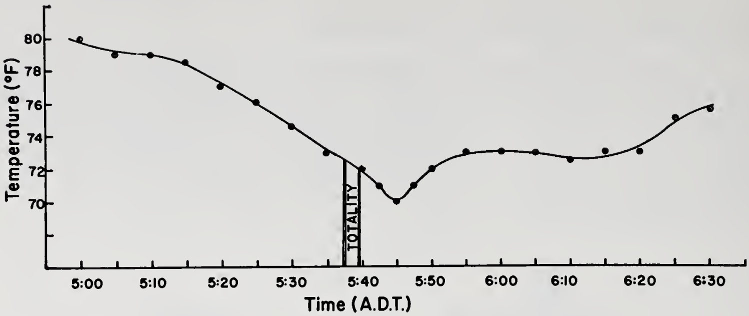


FIGURE 6. *Shadow band intensity of light variation* vs. *frequency of light intensity variation at different times prior to totality, System No. 2. (Solar eclipse, 10 July 1972 Nova Scotia).*

The shadow band velocity experiment, System No. 6, consisting of two detectors and a dual channel strip chart recorder, gave no indication of shadow band activity.

System No. 7, used to measure air temperature, indicated only a slight interruption in the usual rate of increase of temperature after sunrise.



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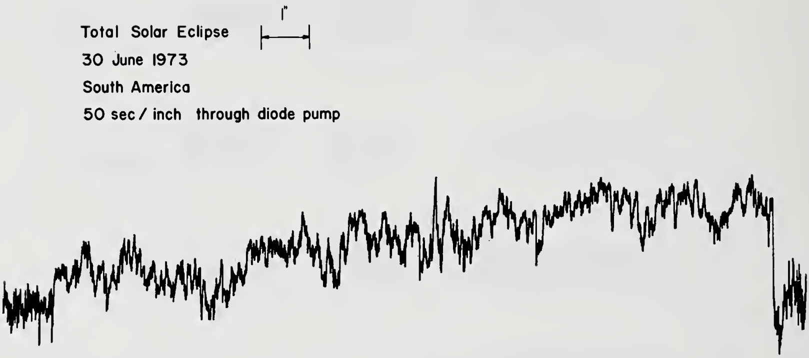

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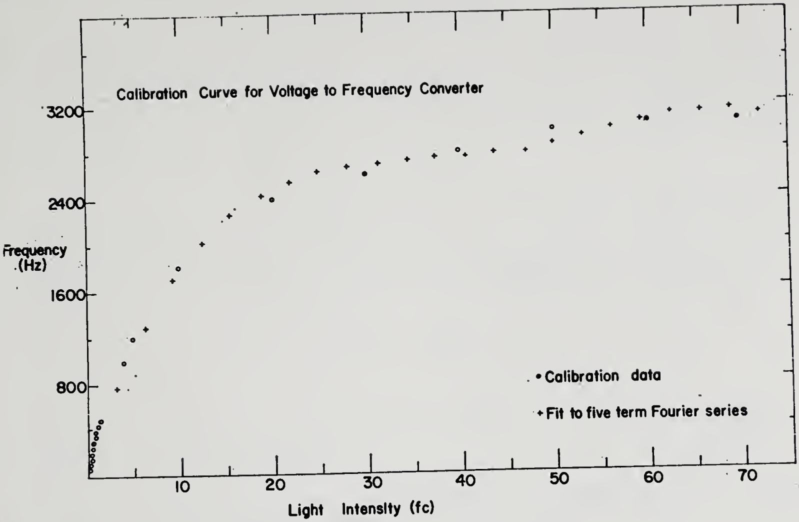
FIGURES 7 and 8. *Air temperature* vs. *time during the solar eclipse, 10 July 1972, in Nova Scotia. Temperature readings taken from a continuous strip chart recording of an electronic thermometer.* 8) *Recording of rf noise before, during and after totality at 7.5 mHz. (Solar eclipse, 30 June 1973, Surinam).*

The rf noise experiments, Systems Nos. 8, 9, 10, 11 gave indications of changes of rf noise intensity before, during and after totality. There is some indication that rf at 146.94 mHz (antenna directed toward the sun) decreased during totality while the rf detected by the non-directional antennas (at 50.4 mHz, 7.5 mHz, and 550 kHz) increased. Due to problems of interference from the portable electric generator the data are marginal. Figure 8 shows a recording of rf noise before, during and after totality at 7.5 mHz. As can be seen there is an increase and then a decrease in the rf energy.

System No. 12 was calibrated by simultaneously shining a variable light source onto the detector of the system and onto a photometer. A range of light levels gave a range of audio frequencies which was compared audibly with a calibrated audio signal generator. The resulting calibration curve is shown in Figure 9. The cassette tape recording made at the eclipse was then played and the audio frequency was compared with the audio signal generator at specific times. This was done three times, indicated as black, green and red data. The resulting graph of light level is shown in Figure 10 which shows that the light level decreases from approximately 11 foot-candles shortly after sunrise to an undetectable level during totality with the expected increase after totality.



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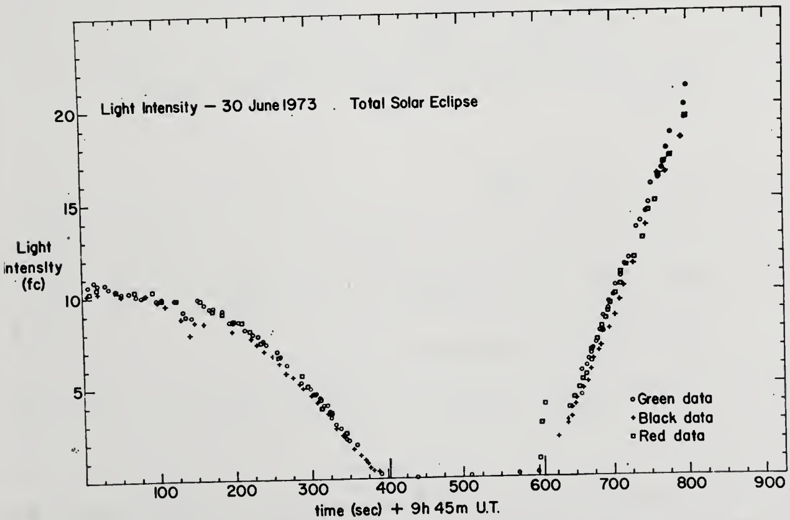

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FIGURES 9 and 10. *Audio frequency* vs. *light intensity for the voltage-to-frequency converter determined by an audio signal generator and photometer system.* 10) *Light intensity* vs. *time for the 30 June 1973 solar eclipse in Surinam, South America.*

The photographic recordings of the ionospheric heights before, during and after totality were analyzed by measuring the heights for every half mHz over a time span of 28 min (Fig. 11). Generally the ionospheric height that reflects certain frequencies is different than the ionospheric height that reflects other frequencies. A decrease in the ionospheric heights for frequencies ranging from 3.5 to 5.5 mHz at the time of totality is quite apparent while there is little change from 6.0 to 7.5 mHz.

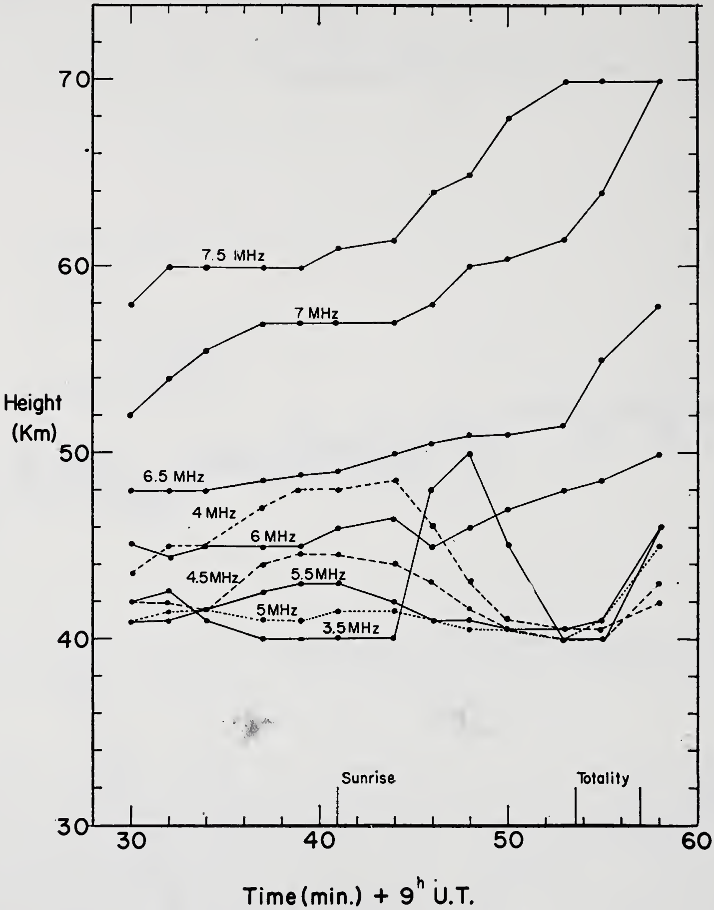

FIGURE 11. *Ionospheric height* vs. *time for rf frequencies ranging from 3.5 mHz to 7.5 mHz. (Solar eclipse, 30 June 1973, Surinam).*

Conclusions

The conclusions from this eclipse work are: 1) shadow bands are strongest in blue and weakest in green-yellow light; 2) the light intensity fluctuation frequency is fairly steady at about 6 Hz with a frequency of approximately 22 Hz occurring very near totality; 3) comparison of four eclipse observations shows that haze greatly reduces shadow band visibility; 4) radio frequency noise increases using non-directional antennae and perhaps decreases using antennae directed toward the sun; 5) ionospheric heights vary little using frequencies from 6.0 to 7.5 mHz but from 3.5 to 5.5 mHz the eclipse lowers the heights considerably. Correlations of shadow band activity, radio frequency noise and ionospheric heights may be found as further study is made.

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