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SCINTILLATION OF UHF SATCOM SIGNALS, OCCURRENCE AT GUAM FROM MI--ETC(U)
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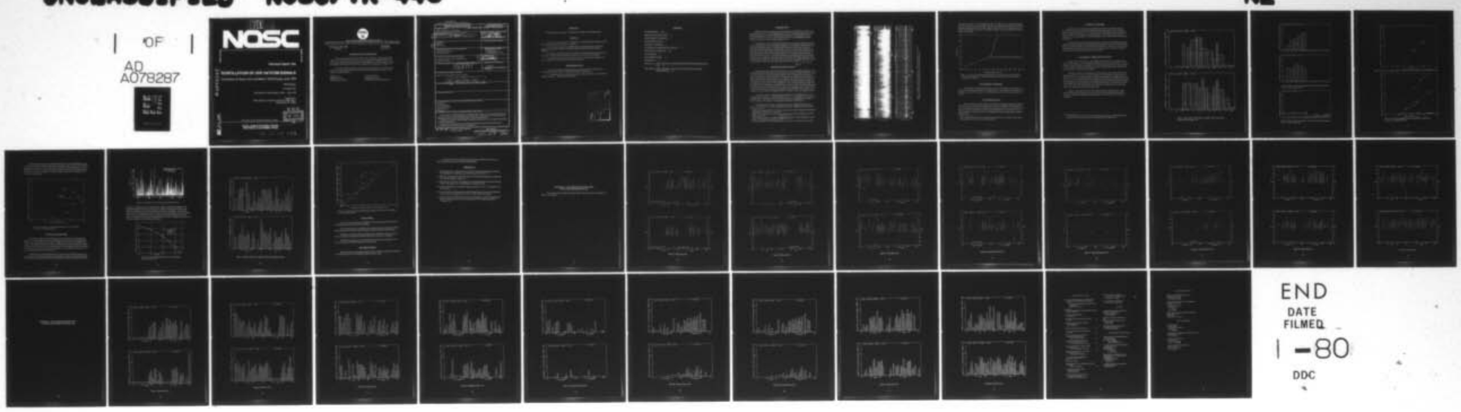

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Technical Report 446

SCINTILLATION OF UHF SATCOM SIGNALS

Occurrence at Guam from mid-March 1978 through June 1979

MR Paulson

15 August 1979

Final Report for Period March 1978 — June 1979

Prepared for
Naval Electronic Systems Command (PME 106-1)
Washington DC 20360

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ADMINISTRATIVE INFORMATION

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The satellite signal amplitude measurements used in this report were made by personnel at the naval communications area master station (NAVCAMS) on Guam under the direction of CWO D Thomas.

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JH Richter, Head
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The occurrence of significant scintillation at Guam has greatly increased over that observed during the 1976 solar activity minimum. The seasonal variation in scintillation shows a broad maximum, increasing in March and decreasing in October, with little scintillation during November through February.

Scintillation frequently can cause uhf satellite communications outages of 6 - 8 hours a night, with occasional outages of 10 hours or more.

Although only seasonal variation and solar activity dependence have been shown, there may be other, unidentified factors that affect the occurrence of scintillation.

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OBJECTIVE

Obtain longer term statistics on equatorial scintillation of uhf satellite signals.

RESULTS

1. The occurrence of significant scintillation at Guam has greatly increased over that observed during the 1976 solar activity minimum.

2. The seasonal variation in scintillation shows a broad maximum, increasing in March and decreasing in October, with little scintillation during November through February.

3. Although only seasonal variation and solar activity dependence have been shown, there may be other, unidentified factors that affect the occurrence of scintillation.

4. Scintillation frequently can cause uhf satellite communications outages of 6–8 hours a night, with occasional outages of 10 hours or more.

RECOMMENDATIONS

1. Use space diversity reception at Guam. It has been shown to be effective in overcoming the adverse effects of scintillation fading on the down link.

2. In planning for future systems, give serious consideration to the use of somewhat higher frequencies – probably L-band or higher.

CONTENTS

INTRODUCTION

NOSC has been investigating equatorial scintillation and its effects on satellite communications since 1970. The experimental parts of these investigations began with amplitude measurements on TACSAT I signals for about a month at a time around the fall equinox in 1970, 1971, and 1972 (ref 1) and on the Pacific ocean MARISAT/Gapfiller satellite in 1976 from 1 July through November (ref 2).

Although much was learned about scintillation from those early amplitude measurements, it was apparent that longer term measurements were needed for a better understanding of its seasonal and solar-cycle variations and of how much of the time it might be expected to disrupt uhf satellite communications. Personnel at the naval communications area master station (NAVCAMS) at Guam have undertaken the task of monitoring the uhf broadcast signals from both the Pacific and Indian ocean Gapfiller satellites (at elevation angles of about 50° and 10°, respectively, from Guam) to provide information on the long-term aspects of scintillation. Their initial data from mid-March through mid-August 1978 were discussed in NOSC TR 328 (ref 3). The present report is an update of TR 328 and will include its data as well as subsequent data taken through June 1979.

ORIGINS OF SCINTILLATION

Irregularities in ionospheric electron density cause corresponding irregularities in the ionospheric refractive index, and these in turn cause scintillation of radio waves from a satellite. As the radio waves pass through the ionosphere they are diffracted or refracted by regions in which these irregularities occur. The irregular wave front emerges from the ionosphere and propagates to the ground, where a standing wave pattern is set up. This pattern has regions where the signal strength is stronger than the undisturbed signal and regions of weak signal or no signal at all. As the irregularities in the ionosphere drift and change with the zonal winds, the standing wave pattern moves across the ground, causing the intensity of a signal received on an antenna to fluctuate. Signal enhancements of up to 10 dB and fades of more than 30 dB occur regularly at frequencies around 250 MHz. The two upper charts in figure 1 show examples of scintillation at about 257 MHz for the two Gapfiller satellites.

The electron density irregularities that cause this type of scintillation occur in the F-region of the ionosphere at about 200–400 km (ref 4). No acceptable theory has been yet formulated that would explain the mechanism that generates irregularities in ionospheric electron density. The subject is currently under discussion in the literature.

The bottom chart in figure 1 shows another type of scintillation that occurs at times. It is thought to be caused by irregularities at E-region heights (about 100–120 km),

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1. NOSC Technical Report NELC TR 1875, Effects of Equatorial Scintillation Fading on SATCOM Signals, by MR Paulson and RUF Hopkins, 8 May 1973
2. NOSC TR 113, Spatial Diversity Characteristics of Equatorial Scintillation, by MR Paulson and RUF Hopkins, 2 May 1977
3. NOSC TR 328, Occurrence of Scintillation of Uhf SATCOM Signals at Guam from Mid-March to Mid-August 1978, by MR Paulson, 7 September 1978
4. Equatorial Scintillation, by JR Koster; Planet Space Sci, vol 20 no 12, December 1972, p 1999–2014

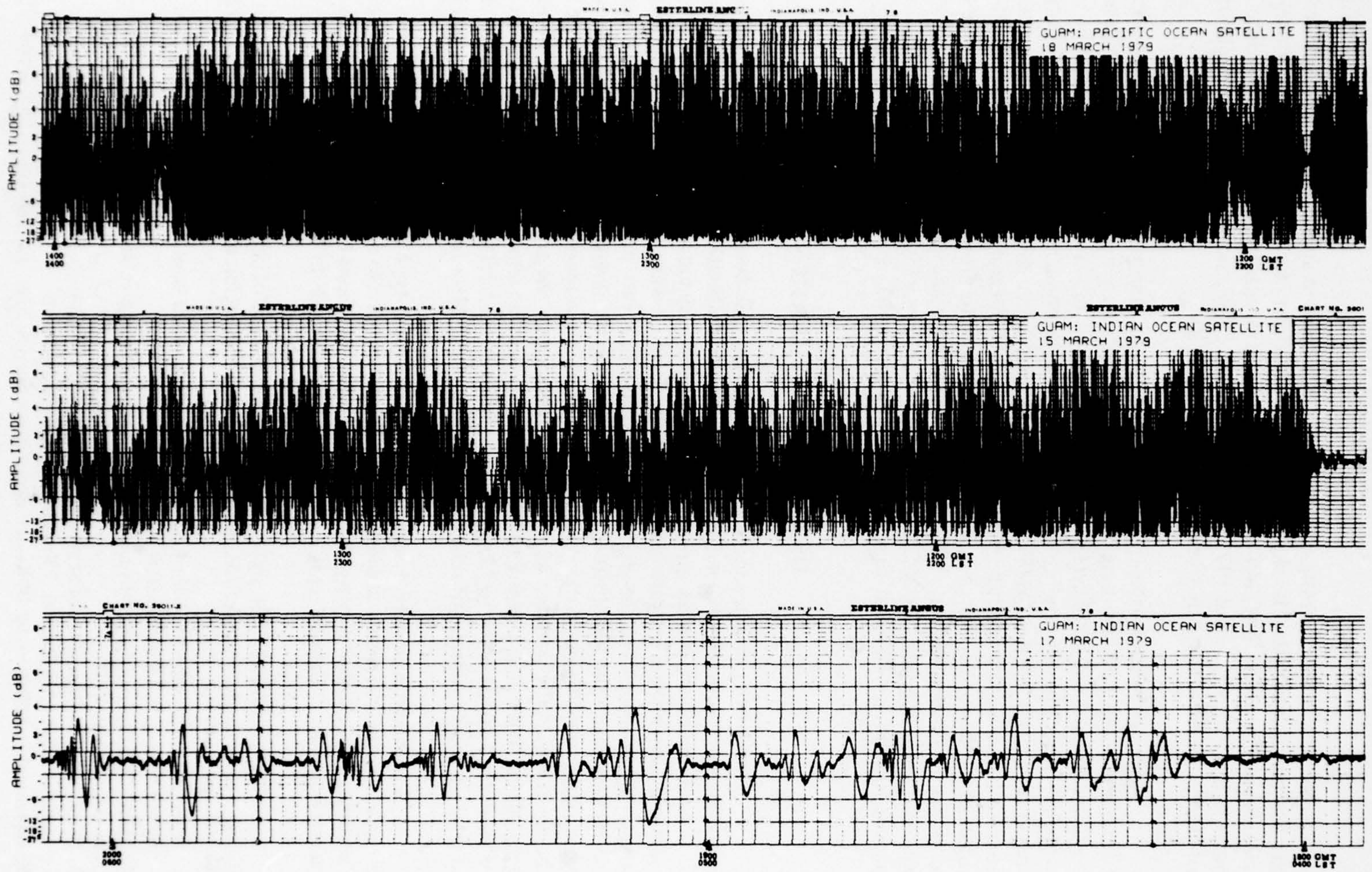

Figure 1. Examples of amplitude scintillation for the Pacific and Indian ocean satellites. Scintillation shown in the bottom graph may have been caused by sporadic E.

referred to as sporadic E. These irregularities have very little effect on vertical radio signals. They affect signals only from satellites at low elevation angles, which provide relatively long propagation paths through the E-region. Figure 2, taken from ref 5, is a graph of electron density versus height, measured by a rocketborne sounder. It shows a sporadic E condition and its vertical extent.

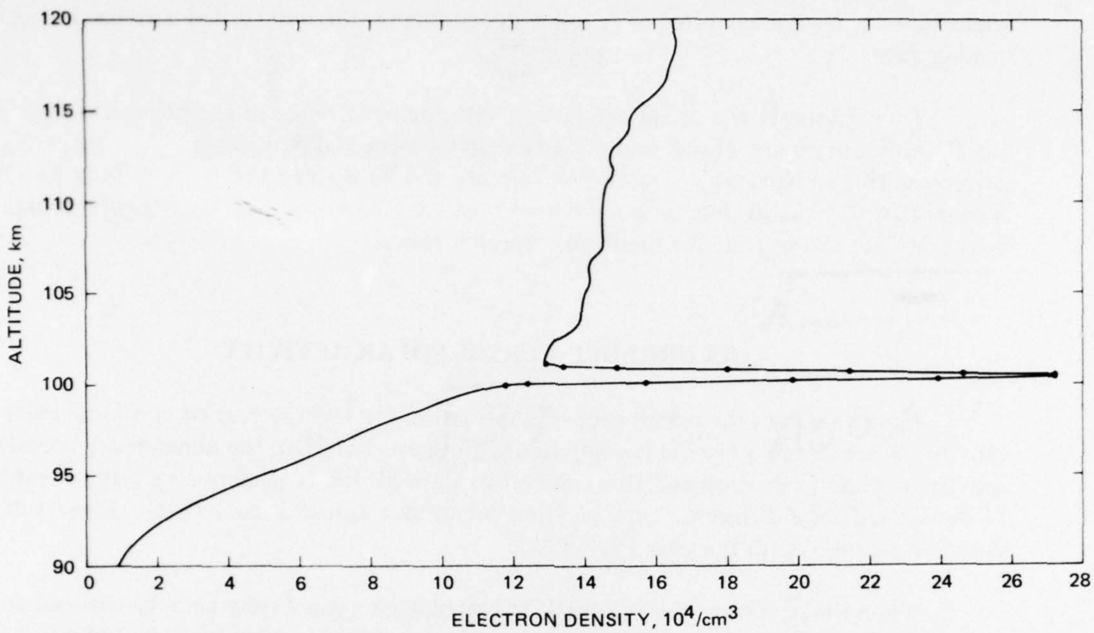

Figure 2. Electron density profile from Nike Apache 14.514, launch time 1505 UT (1005 EST) at Wallops Island, 10 August 1973. Altitudes are indicated at intervals of 0.1 km between 99.9 km and 101.1 km. (From ref 5)

MEASUREMENT TECHNIQUE

The amplitude of the broadcast signals for each of the satellites was recorded 24 hours a day on strip-chart recorders, at 3 inches per hour. During periods of scintillation the recorders were run at 12 inches per hour. Calibration curves were run on each system once a week.

DATA PRESENTATION

Plots of starting and ending times of scintillations with fades greater than 6 dB, read from the charts for each of the two satellites for each day from March 1978 through June 1979, are included as appendix A. Plots of the total numbers of hours each day that scintillation occurred are included as appendix B. In both appendixes, days on which no data were available are marked with a star. No scintillation occurred on days shown as entirely blank (no star).

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5. Electron Temperature Measurements in Mid-Latitude Sporadic E Layers, by SR Schutz and LC Smith; J Geophys Res, vol 81 no 19, 1 July 1976, p 3214-3220

SEASONAL VARIATION

Figure 3 shows the daily hours of scintillation summed on a monthly basis and presented as a percent of time that scintillation occurred each month in 1978. Figure 4 shows the same type of data for 1979. In months where appreciable data were missing, the various portions of the month were summed separately. The actual monthly occurrence might have been somewhat higher or lower depending on the unrecorded activity during the missing days.

These plots show a broad maximum, with the occurrence of scintillation increasing rapidly in February and March and decreasing in October and November. Very little scintillation occurred in November, December, January and February. For both 1978 and 1979 it appears that the (broad) maximum occurrence of scintillation was in April for the Indian ocean satellite and in June for the Pacific ocean satellite.

OCCURRENCE VERSUS SOLAR ACTIVITY

Figure 5 shows the occurrence of scintillation for 1976, a year of minimum solar activity. When figure 5 (1976) is compared with figure 3 (1978), the dependence on solar activity is evident. Paulson and Hopkins (ref 2) showed this dependence by using a common 11-day period for 4 different years, plotting occurrence against solar activity. The result is shown in figure 6, with the year 1978 added.

When the occurrence of scintillation was plotted against solar activity without considering the time of year, seasonal variations appeared to be masking the solar activity dependence (ref 3). To test this possibility, the data were averaged on a monthly basis for the various years when scintillation data were available. The data were not all taken at the same location, however, some having been taken at Kwajalein and reported by Nichols (ref 6) and some at Palau and Guam. Also, because of equipment problems or a limited time interval for the tests, many of the data samples were not for the complete month. In most cases there were only three data samples for each month.

Figure 7 shows data for the months of May, September, and December. These months show good linear dependence of the occurrence of scintillation on solar activity. Activity for May is much higher than for September, and there is very little activity in December.

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6. Lincoln Laboratory Technical Note 1974-19, Uhf Fading from a Synchronous Satellite Observed at Kwajalein October 1970 through June 1972, by BE Nichols, MIT, 22 March 1974

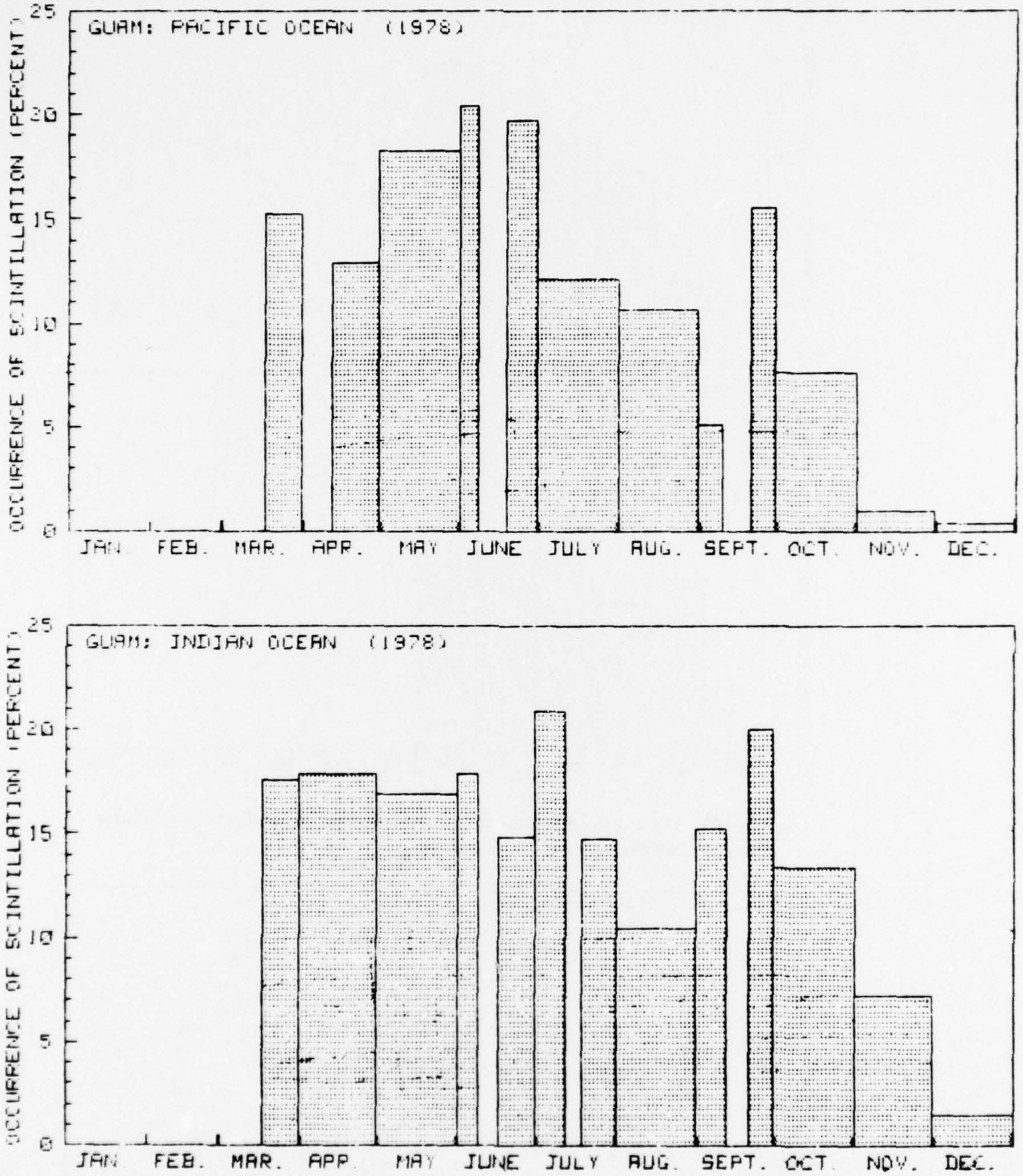

Figure 3. Percent of time that scintillation occurred for each of the satellites, shown as monthly averages, 1978.

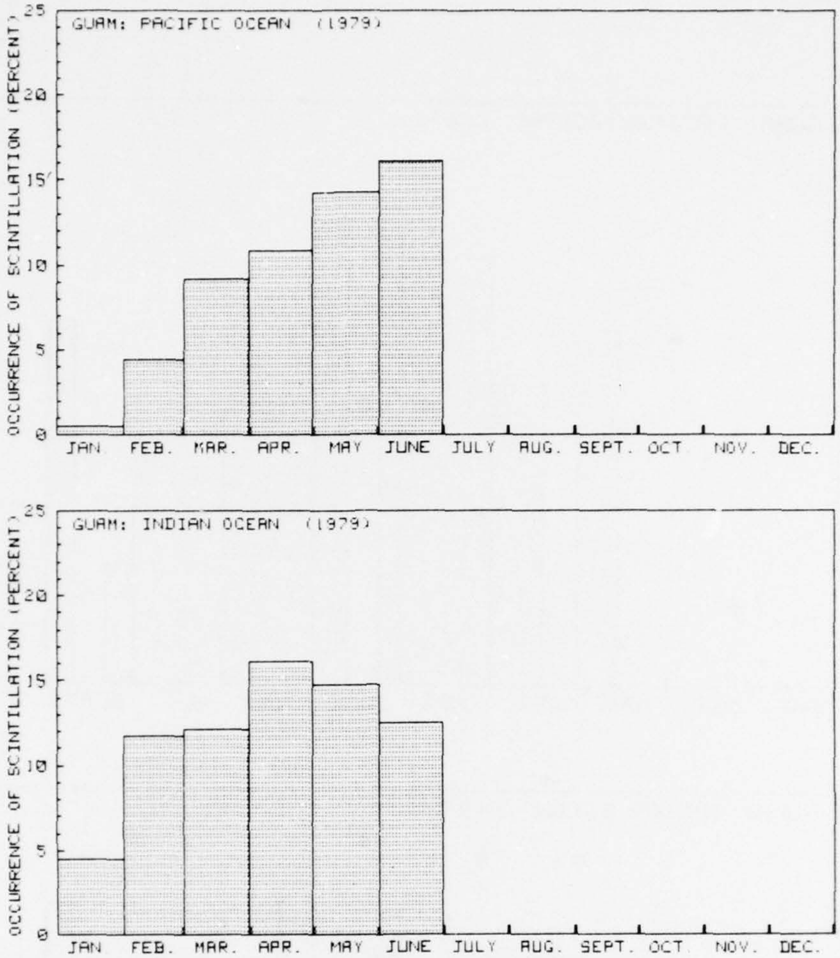

Figure 4. Percent of time that scintillation occurred for each of the satellities, shown as monthly averages, 1979.

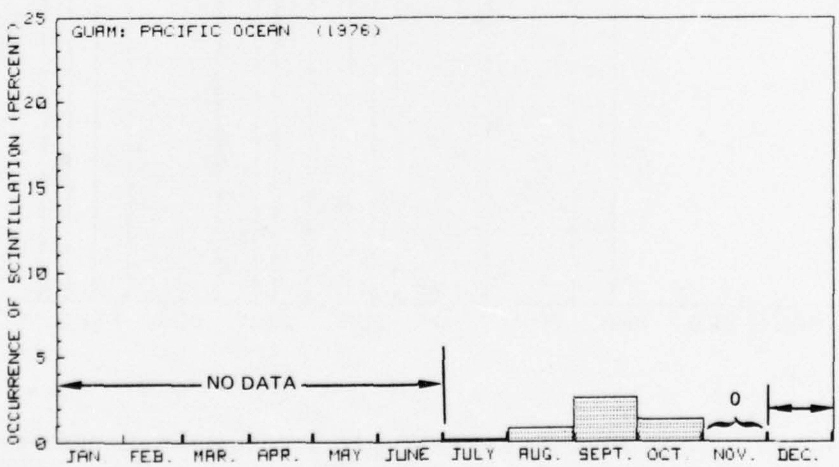

Figure 5. Percent of time that scintillation occurred for the Pacific ocean satellite, shown as monthly averages, 1976.

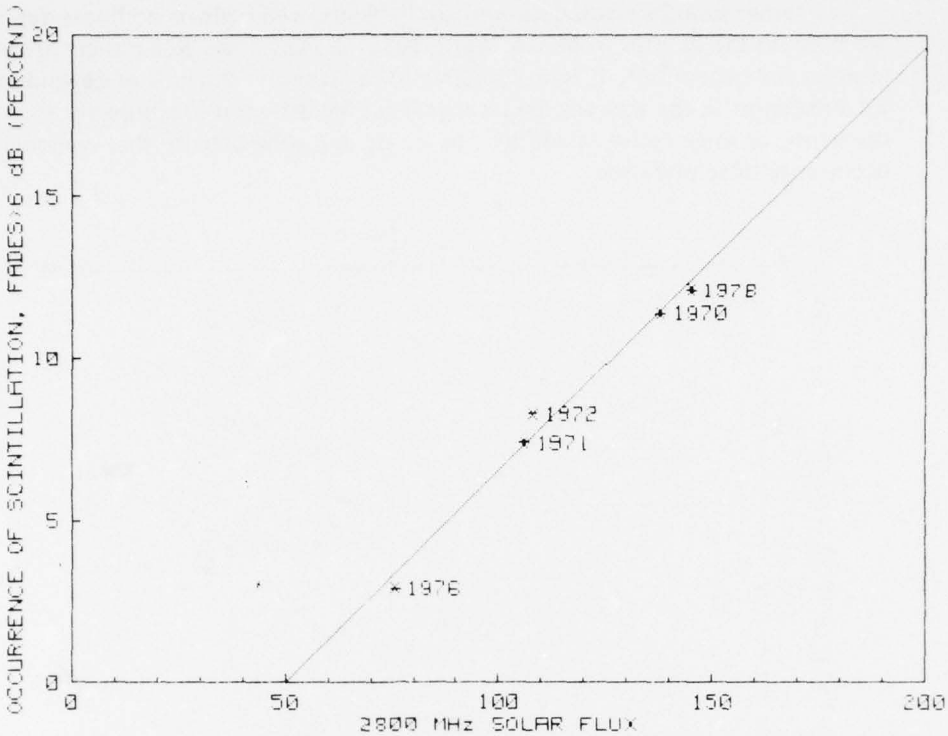

Figure 6. Occurrence of scintillation during a common 11-day period compared to the 2800 MHz solar flux.

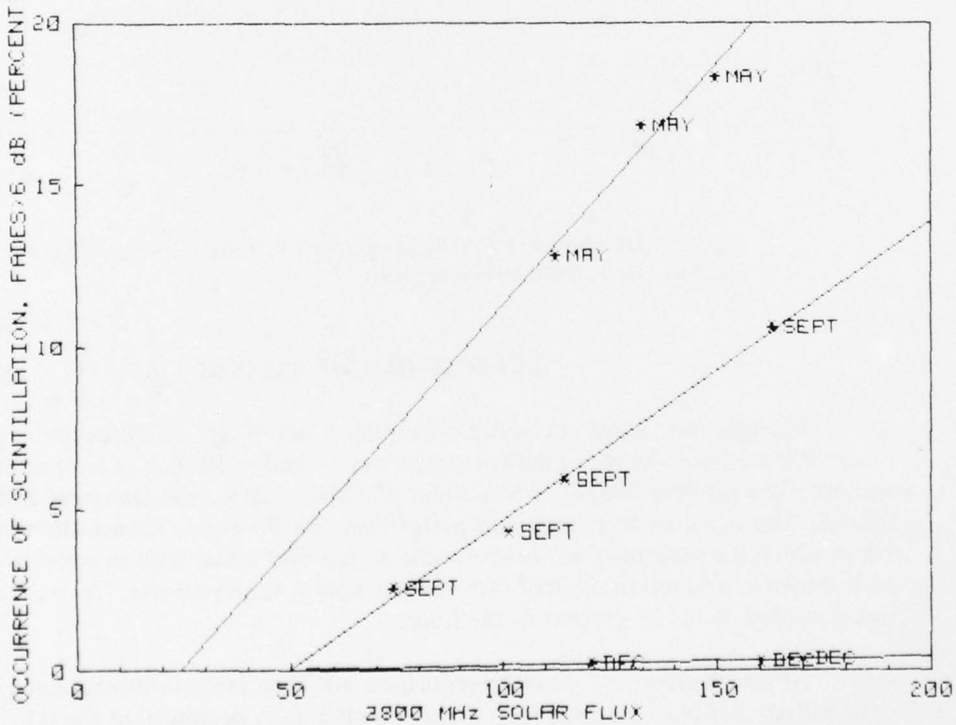

Figure 7. Occurrence of scintillation during May, September, and December compared to the 2800 MHz solar flux.

Other months when data were available showed little or no linear dependence: figure 8 shows the months of March, April, June, and October. Since there are only three data samples for each month, it is not possible to say whether the lack of dependence is caused by differences in the way the data were taken, the different locations for the various measurements, or some factor in addition to season and solar activity that contributed to the occurrence of scintillation.

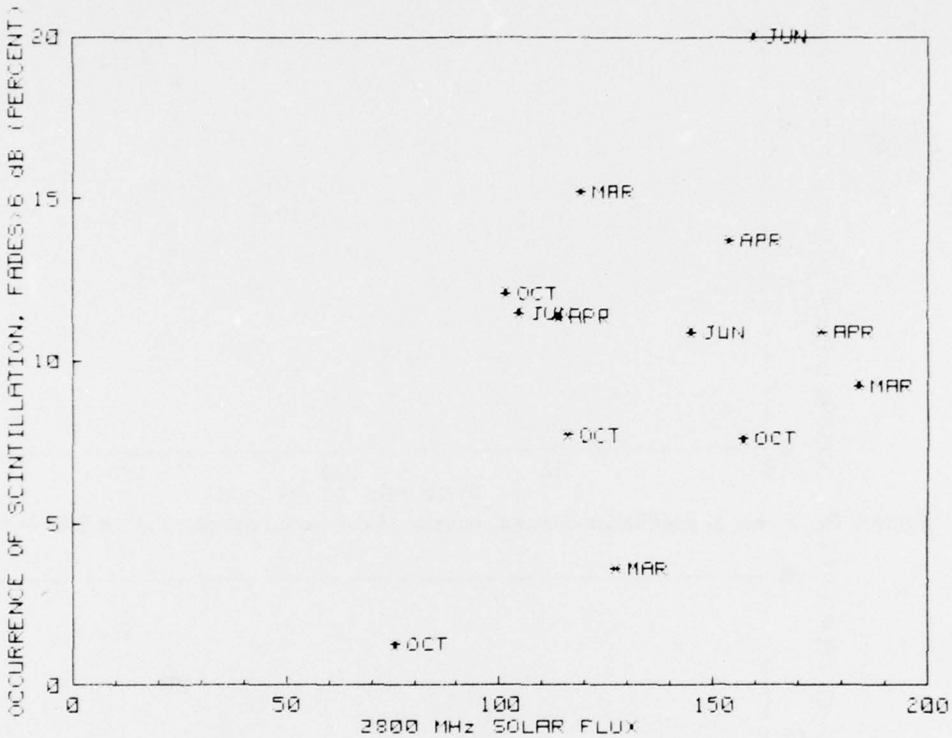

Figure 8. Occurrence of scintillation during March, April, June, and October compared to the 2800 MHz solar flux.

EFFECTS ON UHF SATCOM

Scintillation fading can have a disruptive effect on uhf satellite communications. Figure 9 is a 1-hour sample of data error rates measured in 1976, a year of minimum solar activity. The satellite frequency was about 257 MHz and the data rate was 2400 bits per second. The signal-to-noise ratio was better than 30 dB. This is shown differently in figure 10, in which the percent of a 1-hour sample period over which a given error rate was exceeded is shown as a function of error rate. In this figure, as an example, the error rate of 10^{-2} was exceeded about 27 percent of the hour.

Although error rate measurements have not been made in subsequent years, when solar activity has been getting progressively much higher, personnel at the satellite terminal in Guam have kept a daily record of uhf communications outages that appear to have been

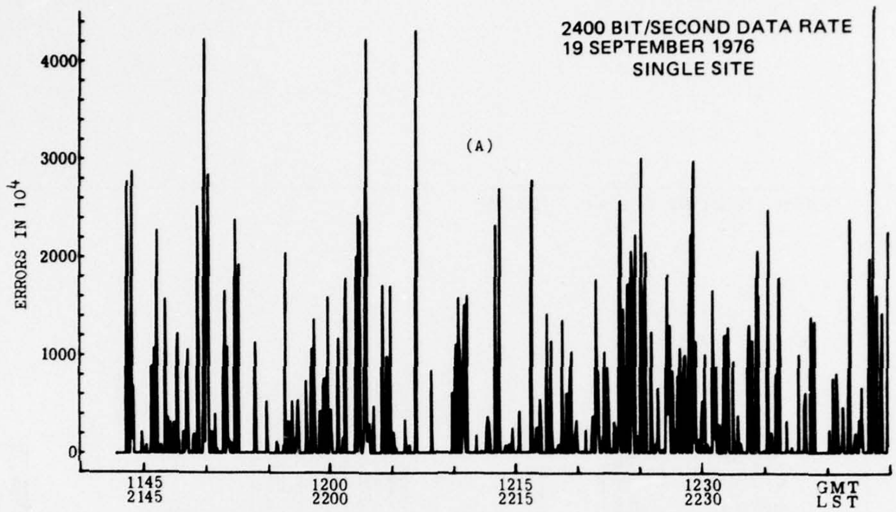

Figure 9. An example of error rates measured for a single receiver site.

caused by scintillation, for each of the satellites. Figure 11 plots these outages for the months of April and May 1978. In figure 12 the reported outages for the Indian ocean satellite are plotted as a function of the daily occurrence of scintillation. A correlation between the two showed a value of 0.84. A one-to-one correspondence between communications outage and scintillation would be manifested by all points falling on the line in figure 12. Since most of the points are somewhat above the line, scintillation with fades less than 6 dB possibly could be causing some outages.

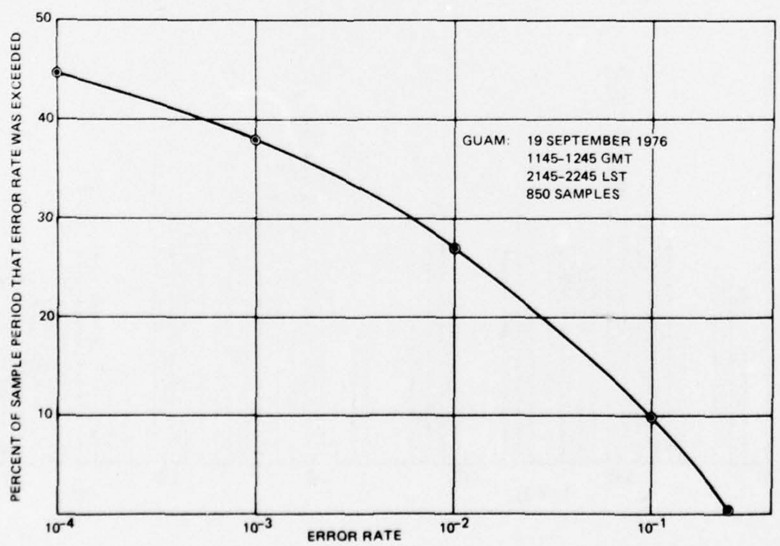

Figure 10. Percent of sample period that error rate was exceeded, as a function of error rate.

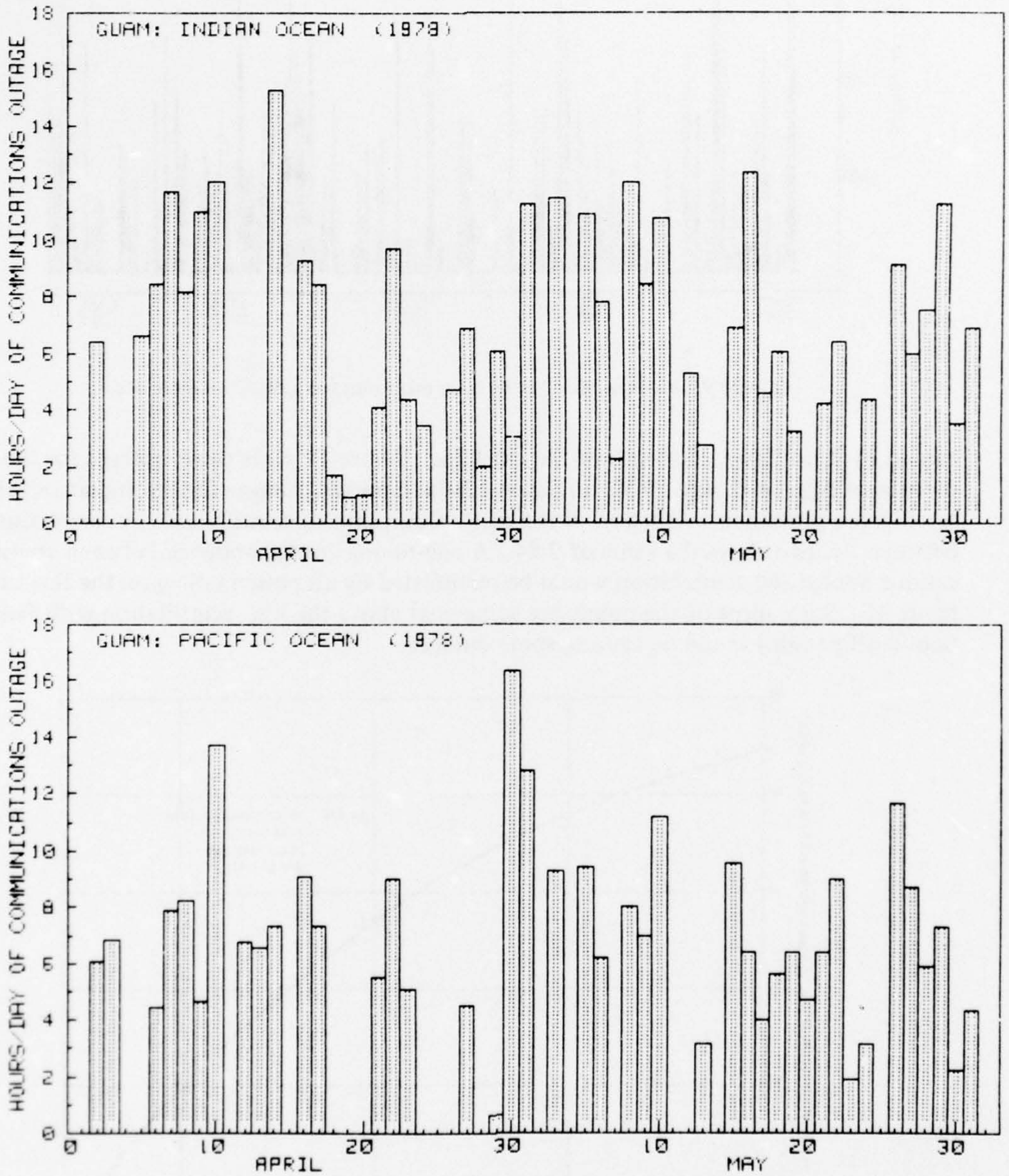

Figure 11. Reported daily hours of operation loss due to scintillation at Guam.

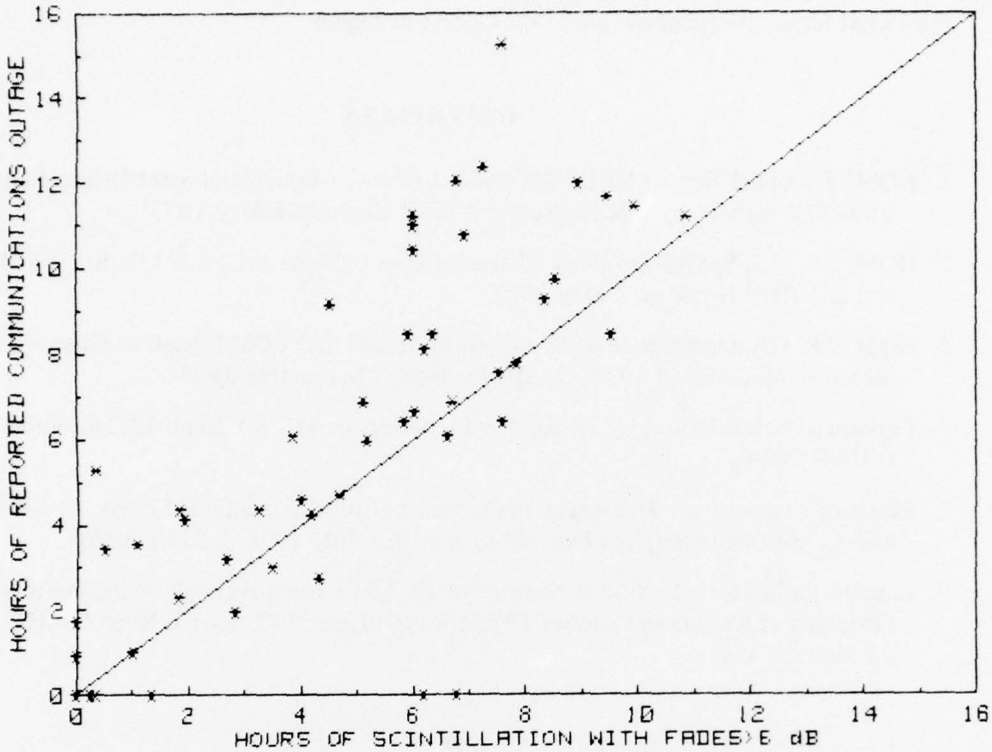

Figure 12. Comparison of reported communications outage with the occurrence of scintillation for the Indian ocean satellite.

CONCLUSIONS

The occurrence of significant scintillation at Guam has greatly increased over that observed during the 1976 solar activity minimum.

The seasonal variation in scintillation shows a broad maximum, increasing in March and decreasing in October, with little scintillation during November through February.

Although only seasonal variation and solar activity dependence have been shown, there may be other, unidentified, factors that affect the occurrence of scintillation.

Scintillation frequently can cause uhf satellite communications outages of 6 to 8 hours a night, with occasional outages of 10 hours or more.

RECOMMENDATIONS

Space diversity reception should be used at Guam. It has been shown to be effective in overcoming the effects of scintillation fading on the down link.

Any planning for future systems should give serious consideration to the use of somewhat higher frequencies; probably L-band or higher.

REFERENCES

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2. NOSC TR 113, Spatial Diversity Characteristics of Equatorial Scintillation, by MR Paulson and RUF Hopkins, 2 May 1977

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5. Electron Temperature Measurements in Mid-Latitude Sporadic E Layers, by SR Schutz and LC Smith; J Geophys Res, vol 81 no 19, 1 July 1976, p 3214–3220

6. Lincoln Laboratory Technical Note 1974-19, Uhf Fading from a Synchronous Satellite Observed at Kwajalein October 1970 through June 1972, by BE Nichols, MIT, 22 March 1974

APPENDIX A: DAILY HOURS OF SCINTILLATION WITH FADES GREATER THAN 6 dB

Time periods when scintillation fading exceeded 6 dB are shown for the Pacific and Indian ocean satellites.

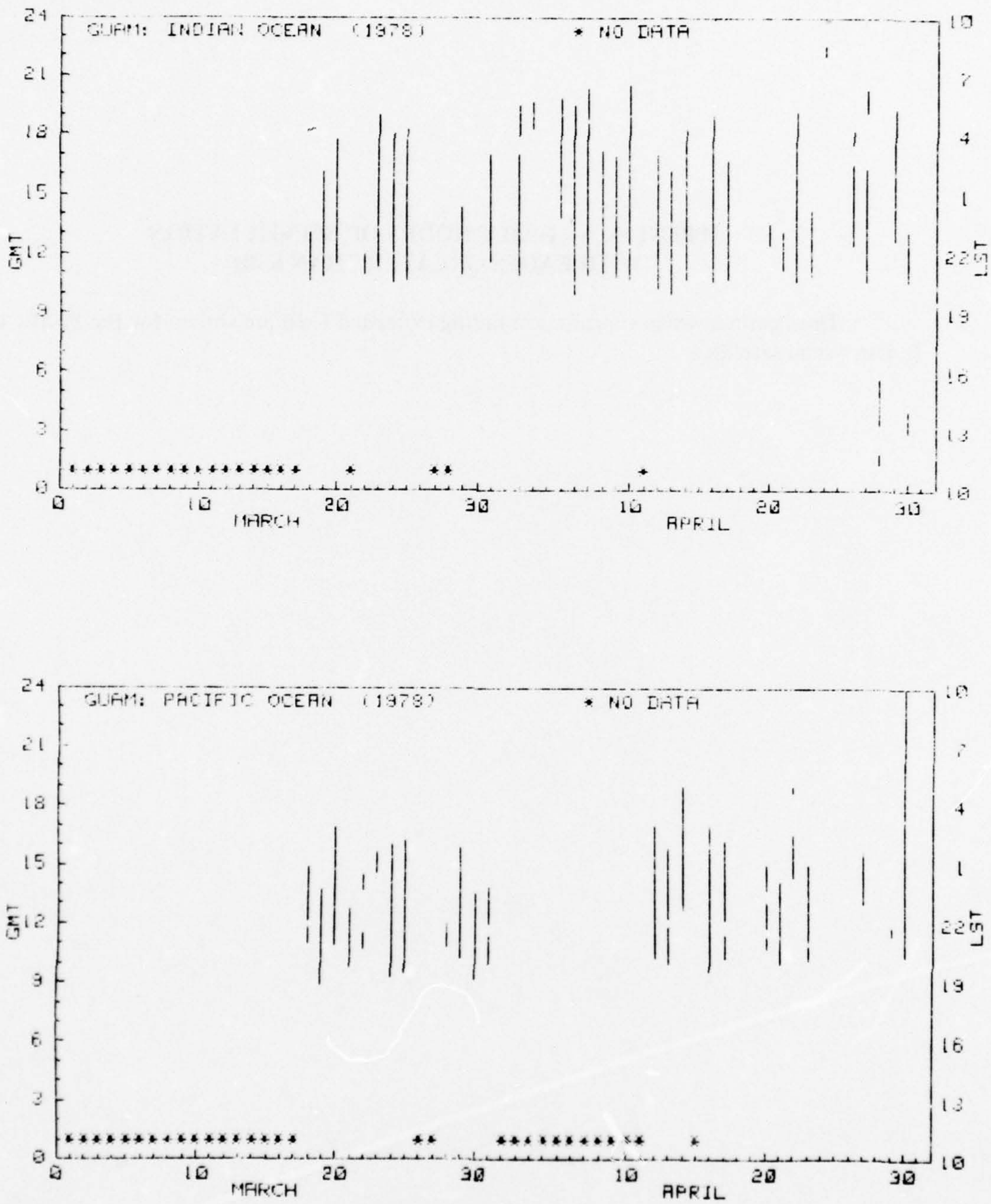
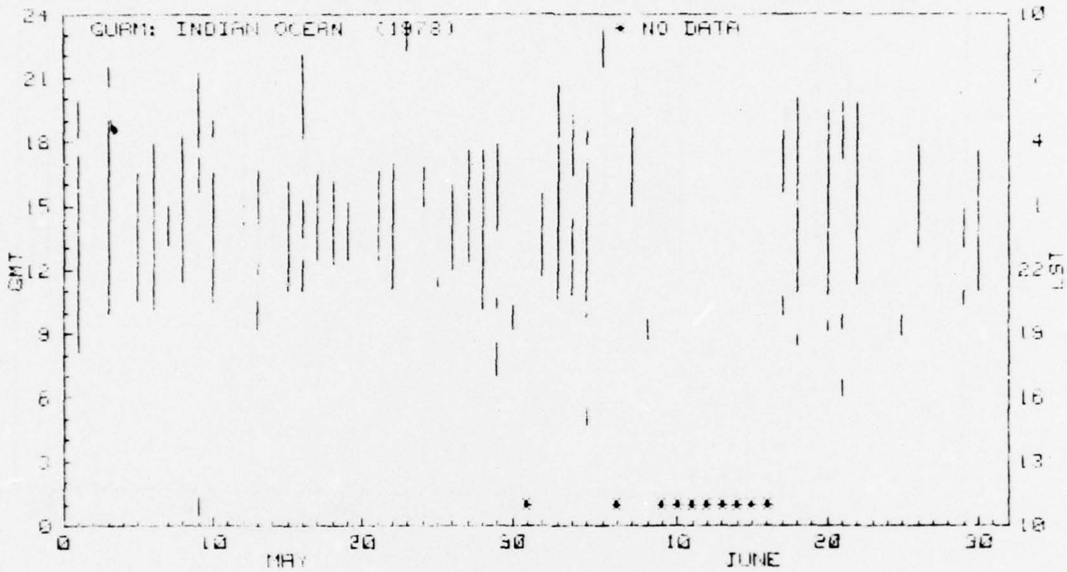


Figure A1. March-April 1978.



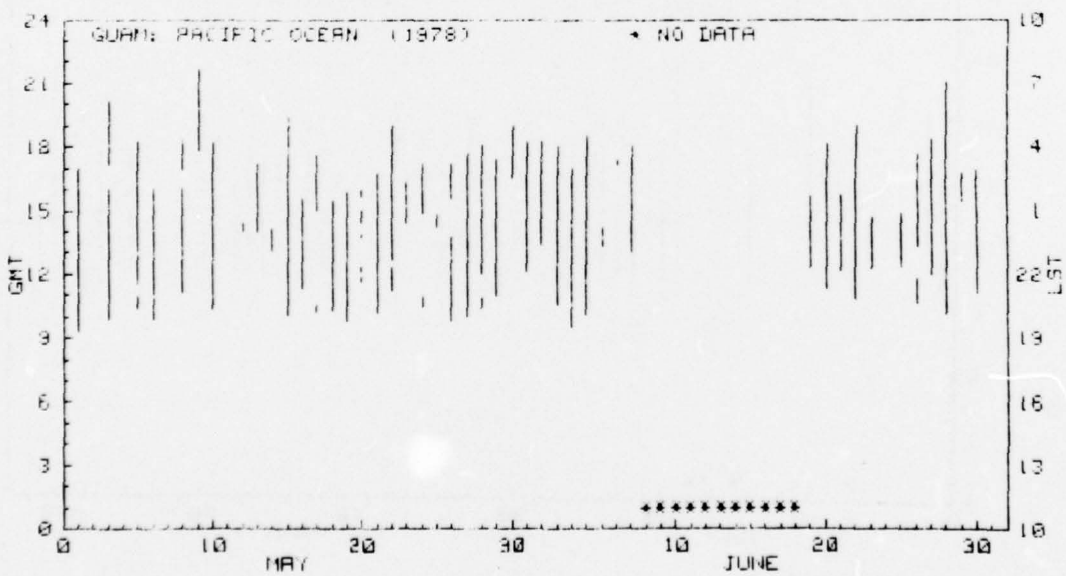
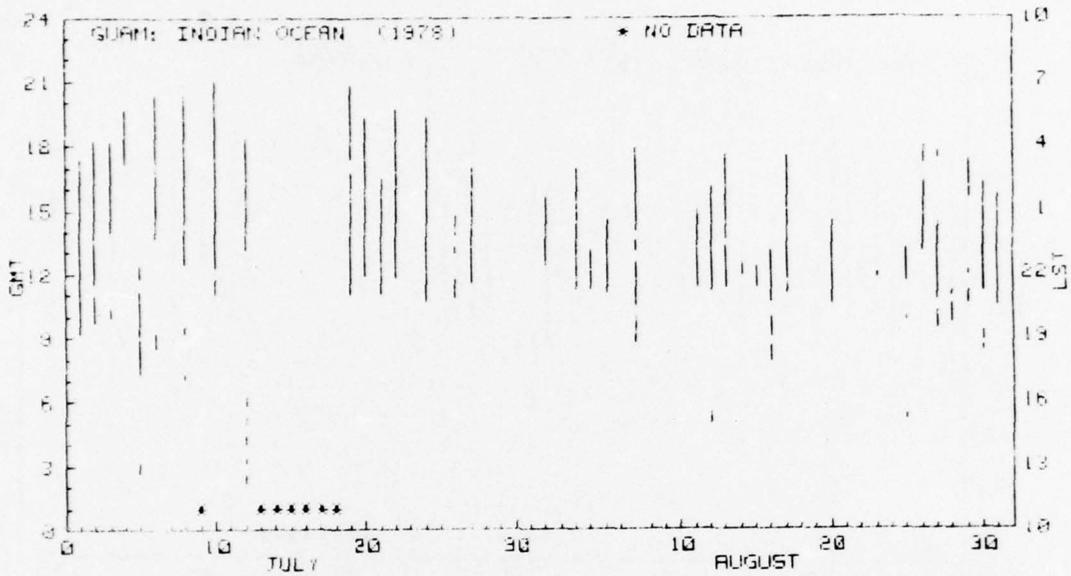


Figure A2. May-June 1978.



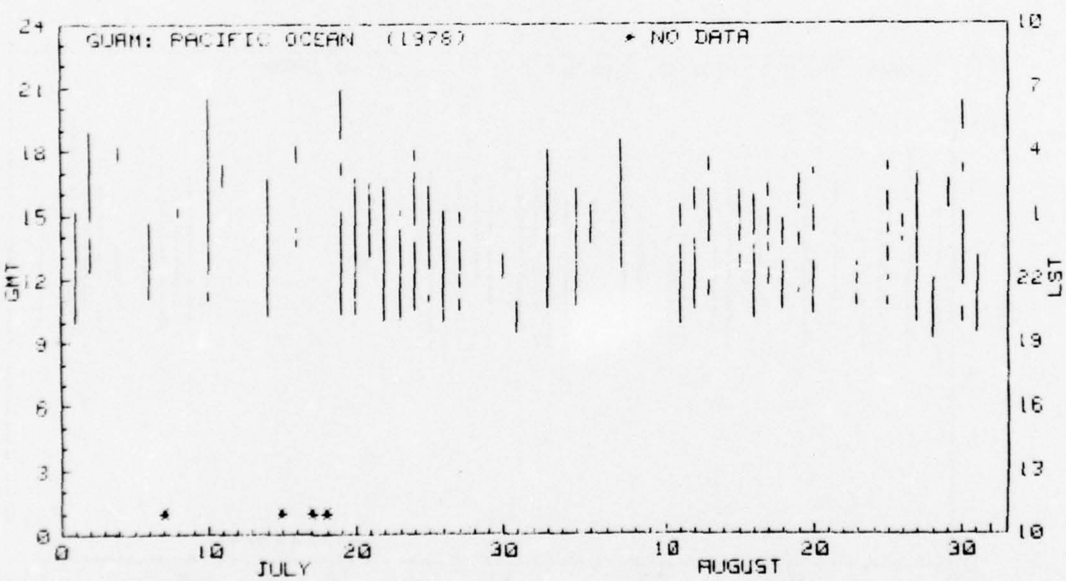
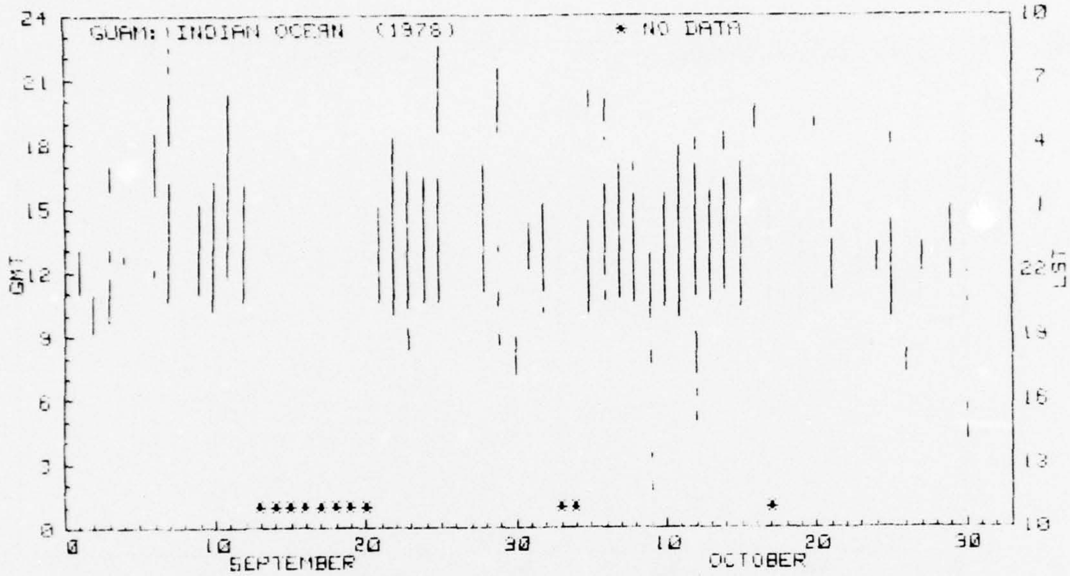


Figure A3. July-August 1978.



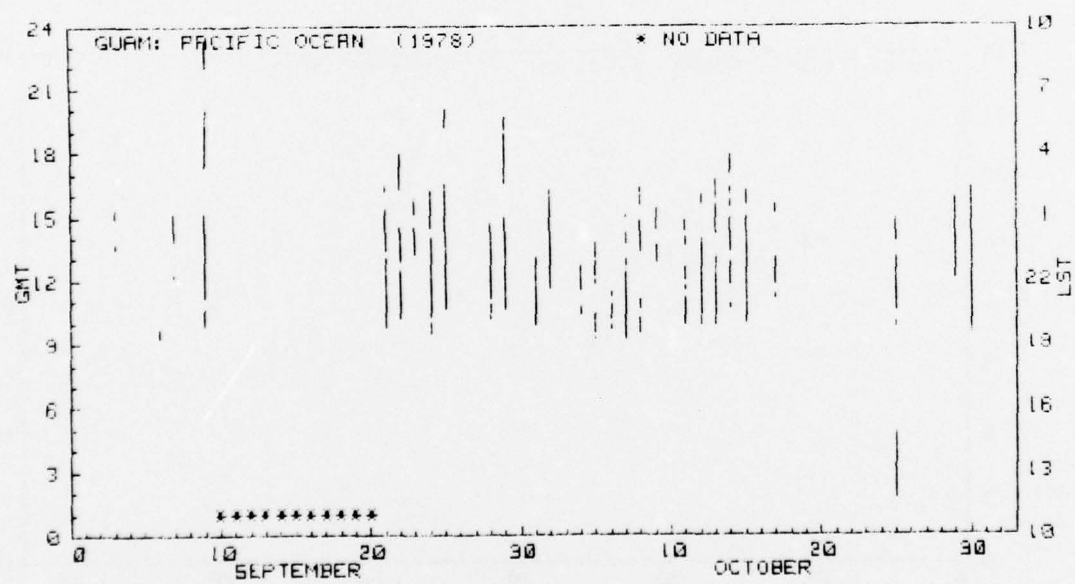
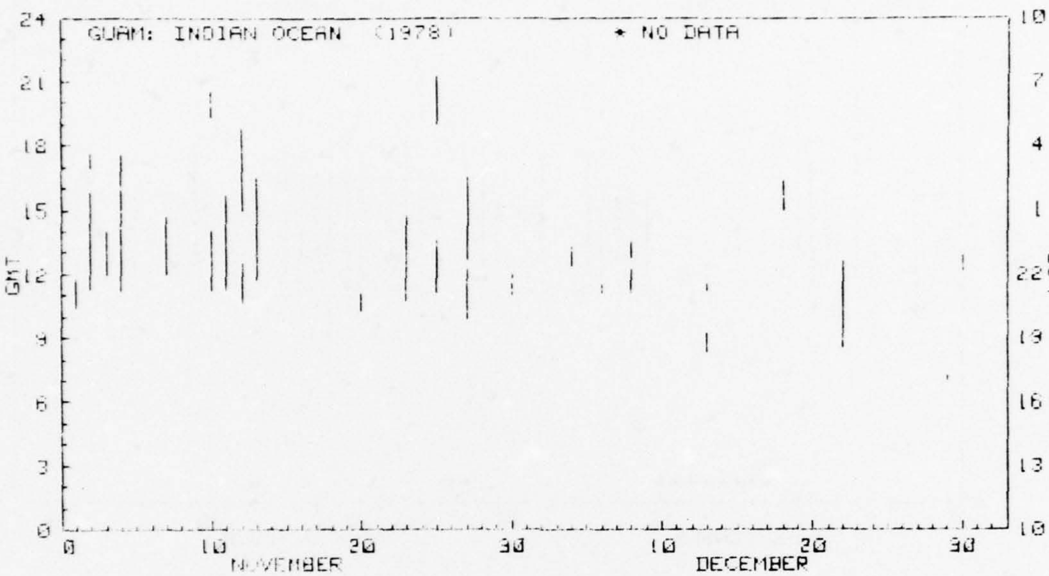


Figure A4. September–October 1978.



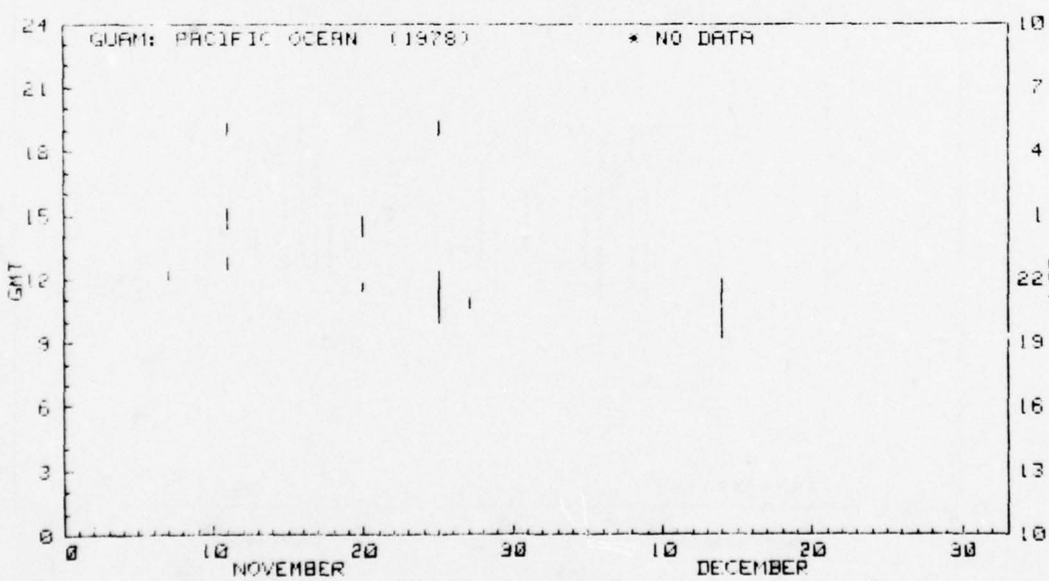
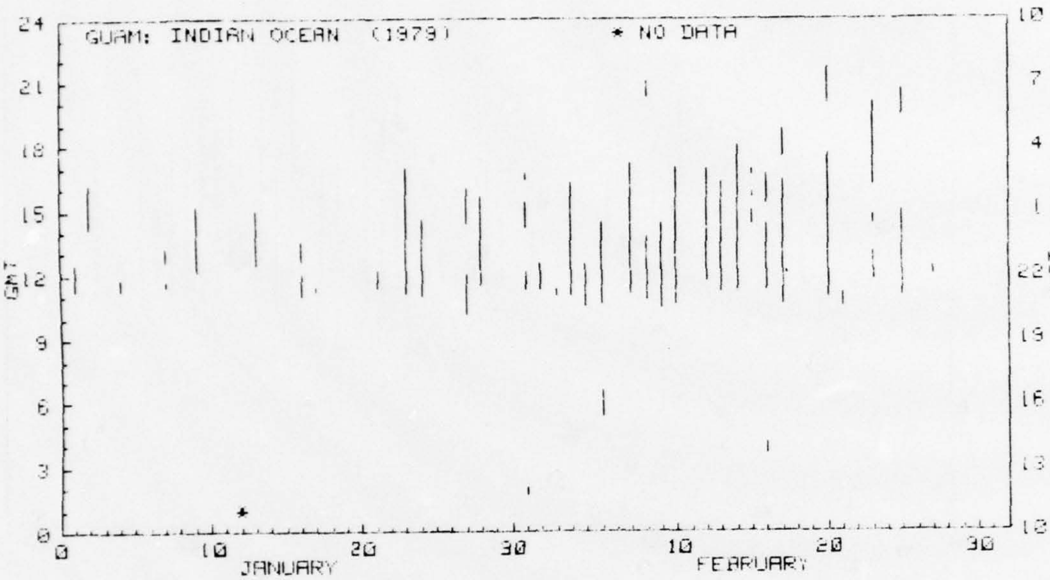


Figure A5. November-December 1978.



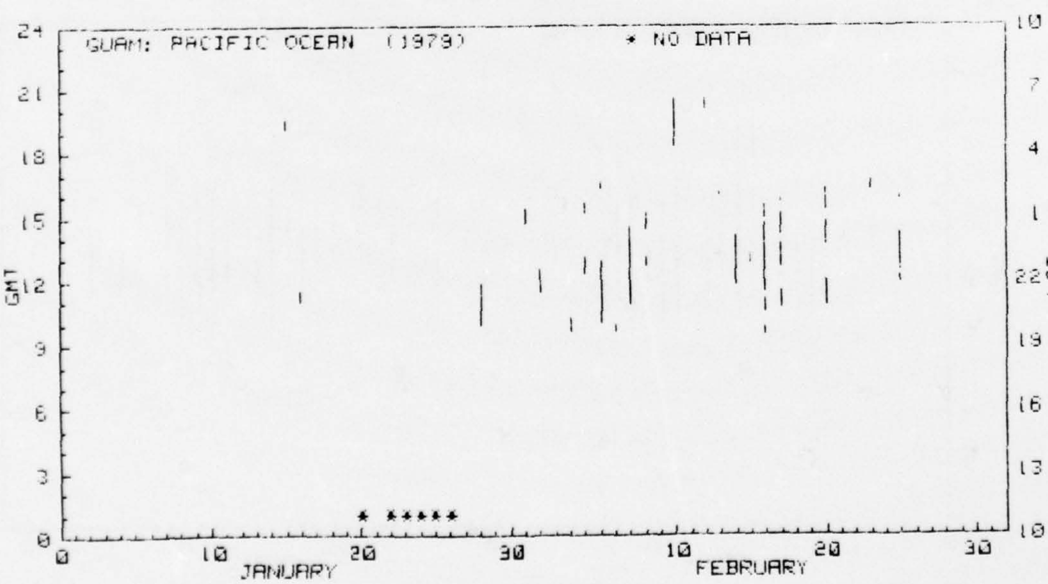
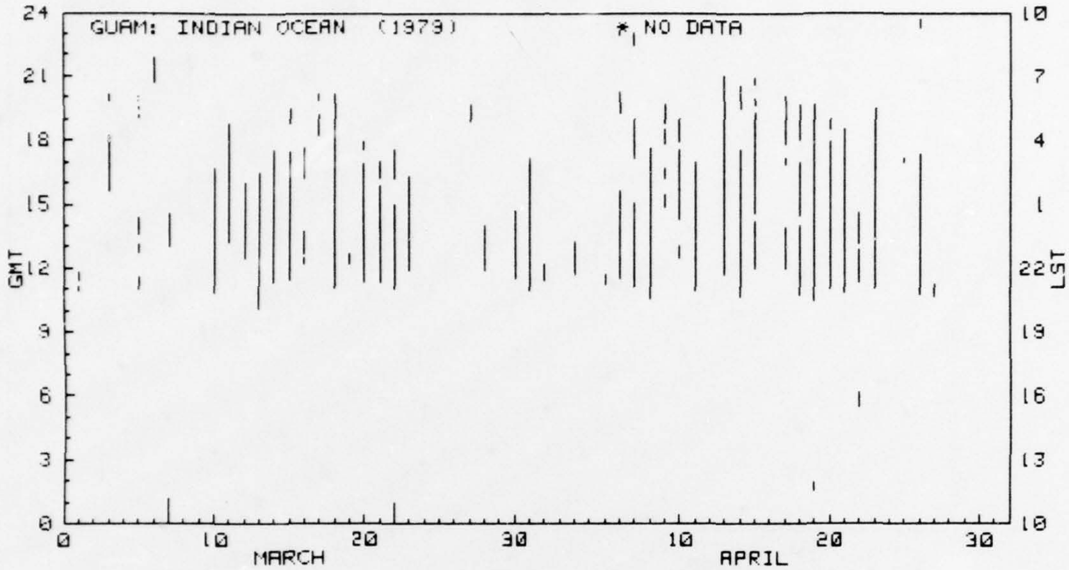


Figure A6. January-February 1979.



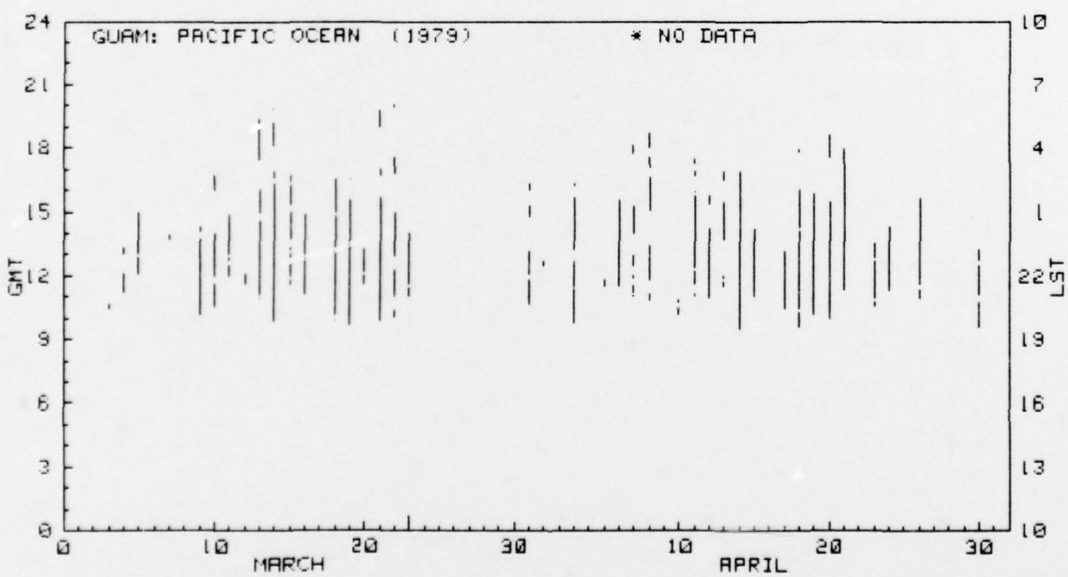
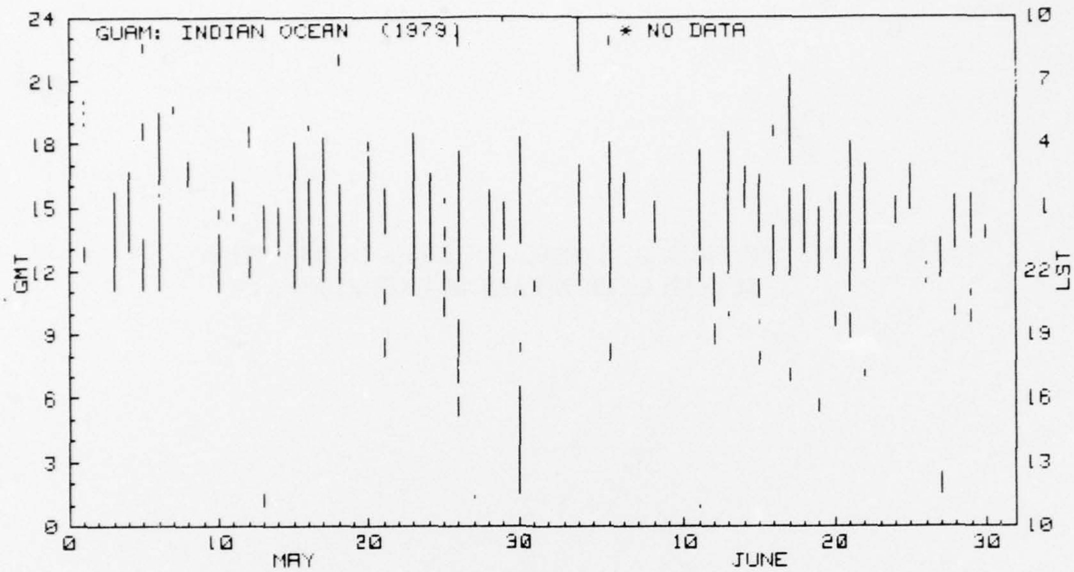


Figure A7. March-April 1979.



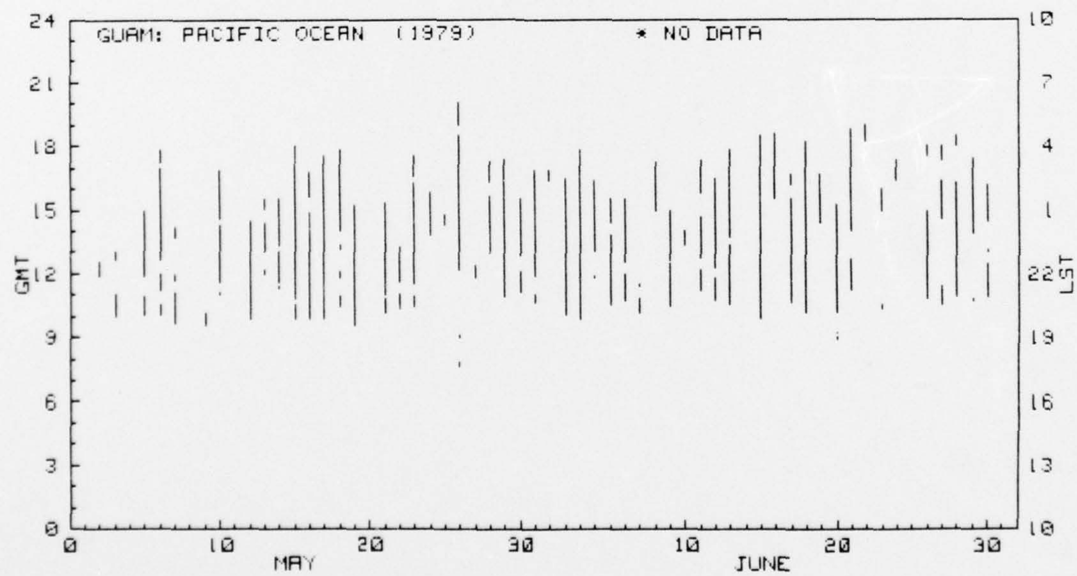
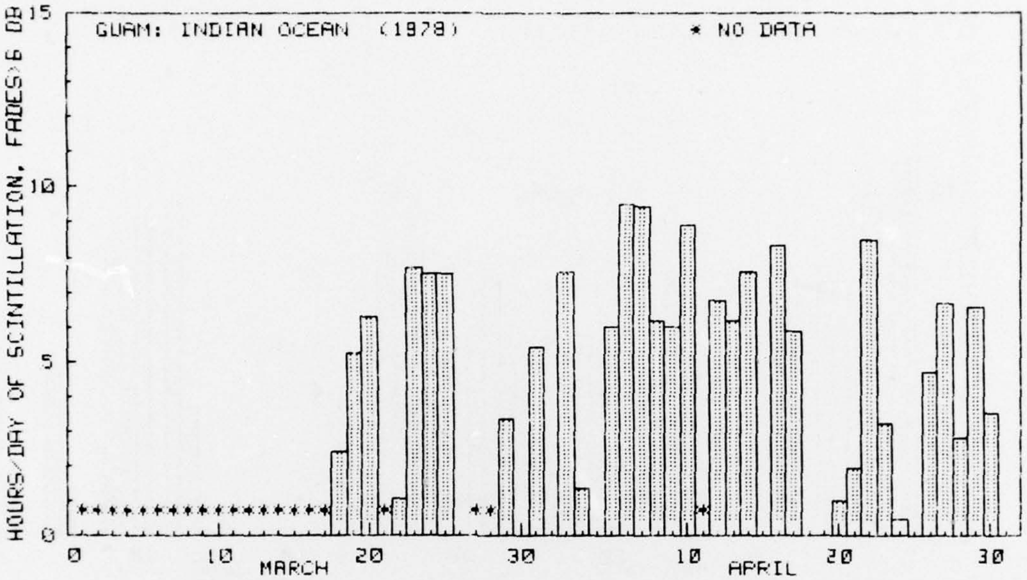


Figure A8. May-June 1979.

APPENDIX B: TOTAL HOURS EACH DAY THAT SCINTILLATION FADING EXCEEDED 6 dB



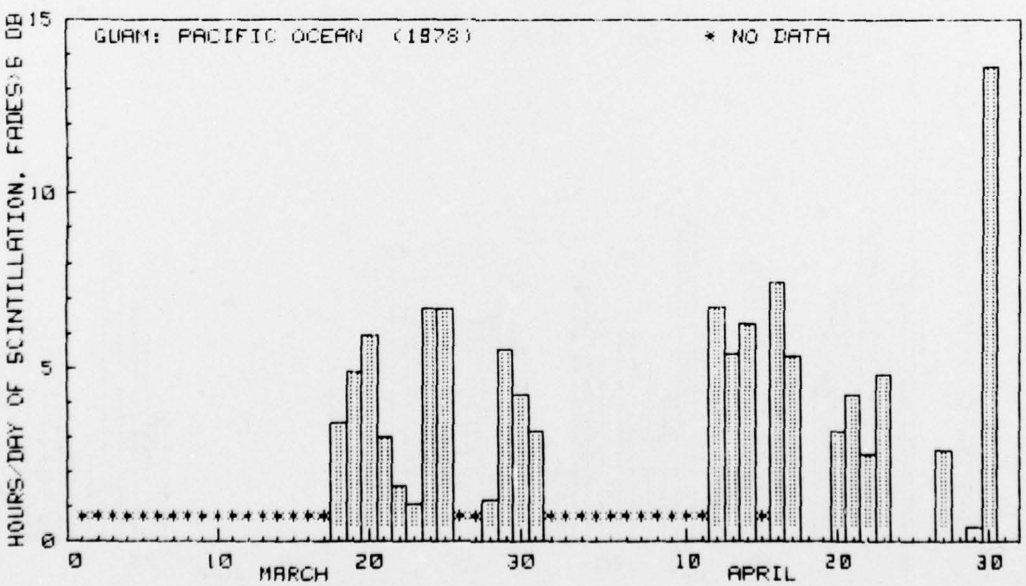
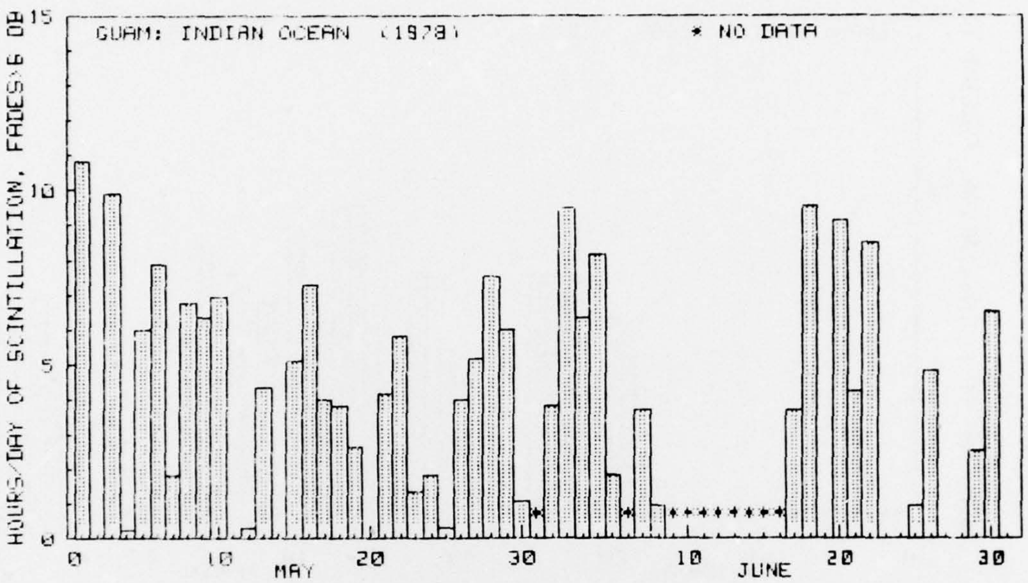
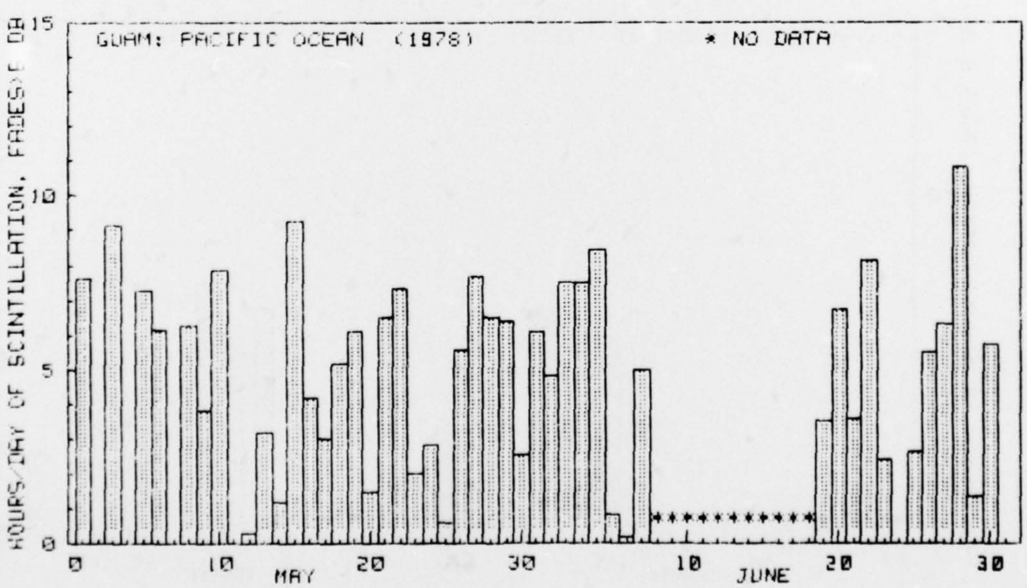


Figure B1. March-April 1978.





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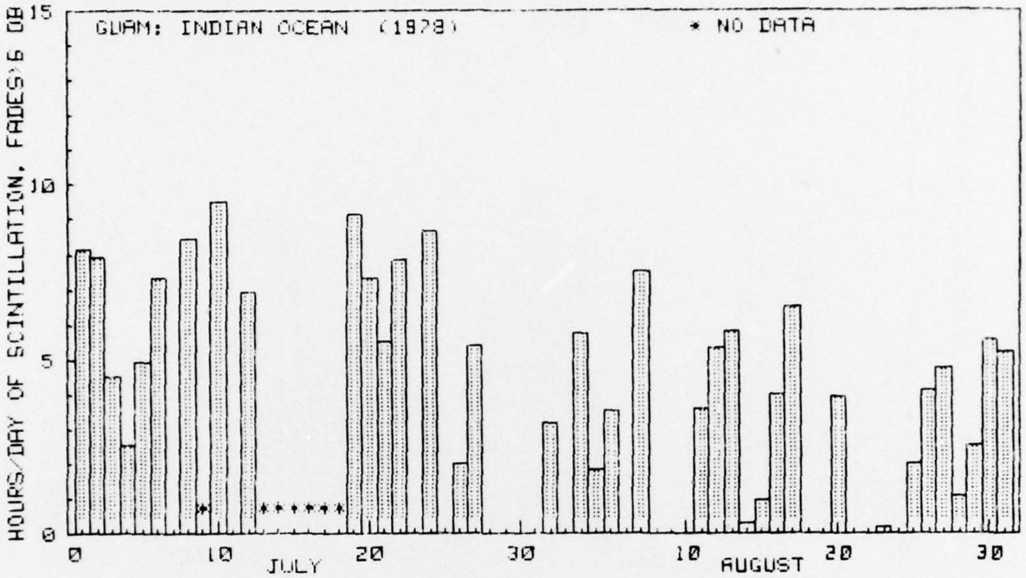


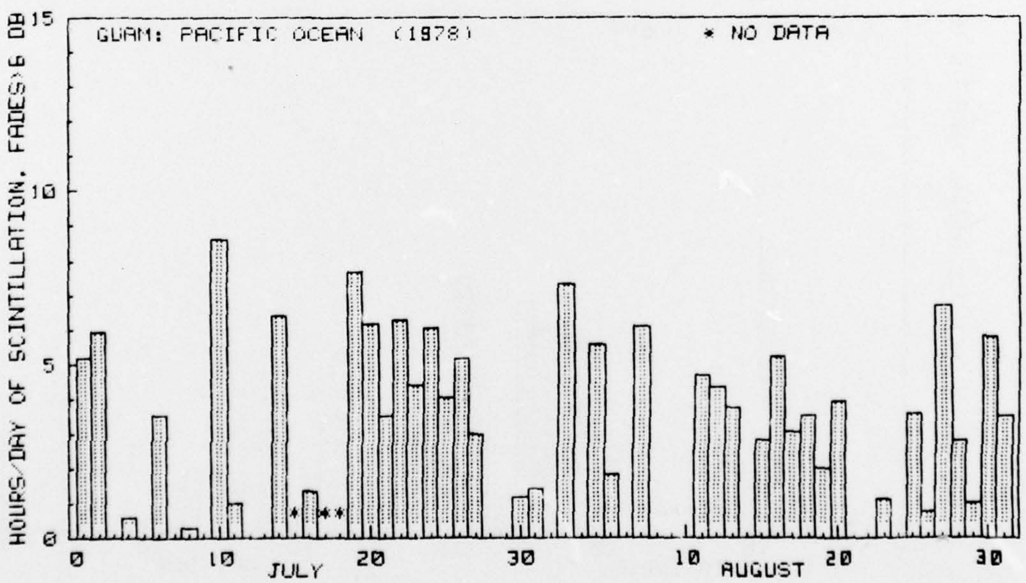
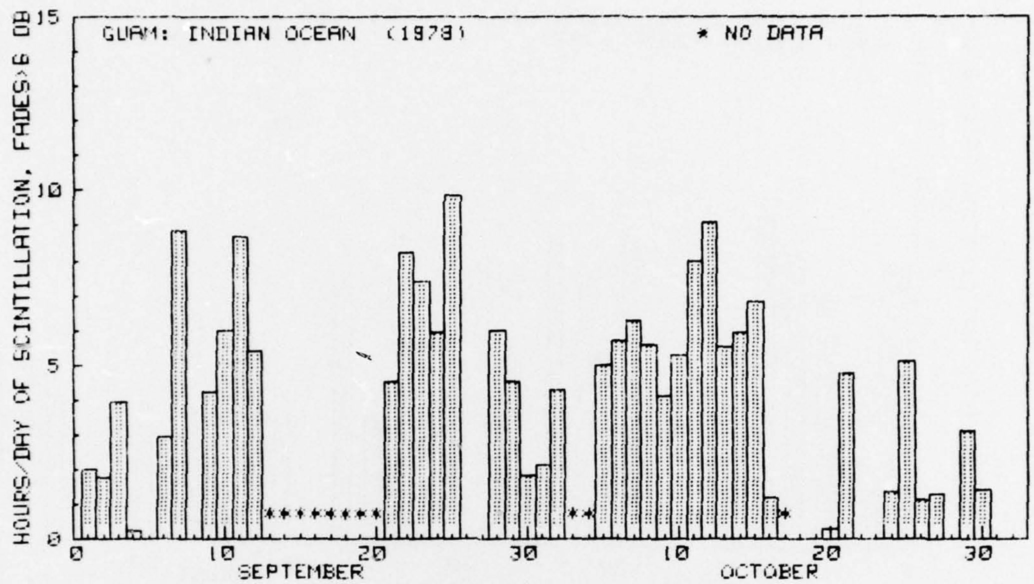


Figure B3. July-August 1978.



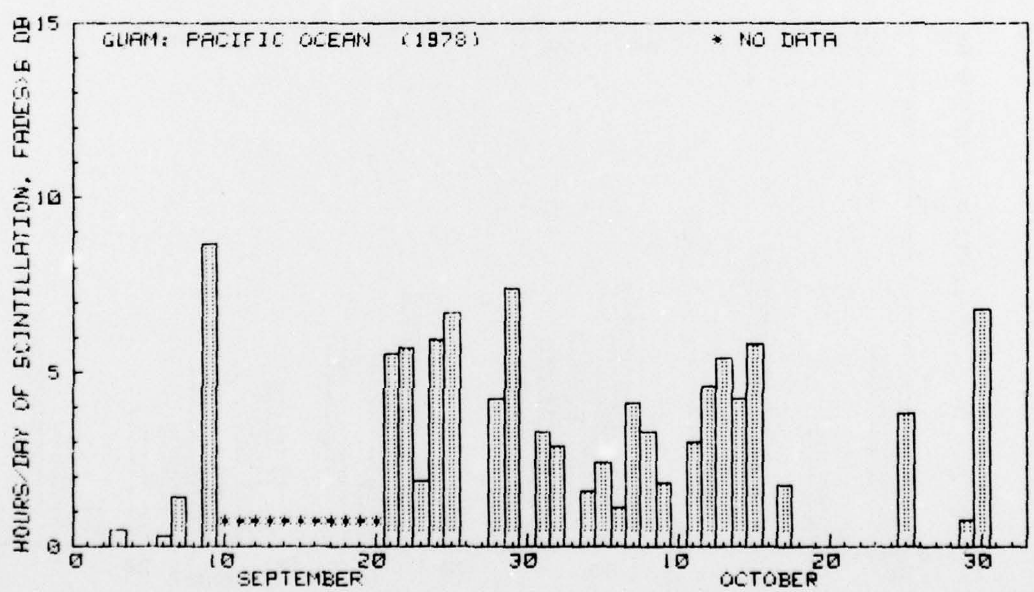
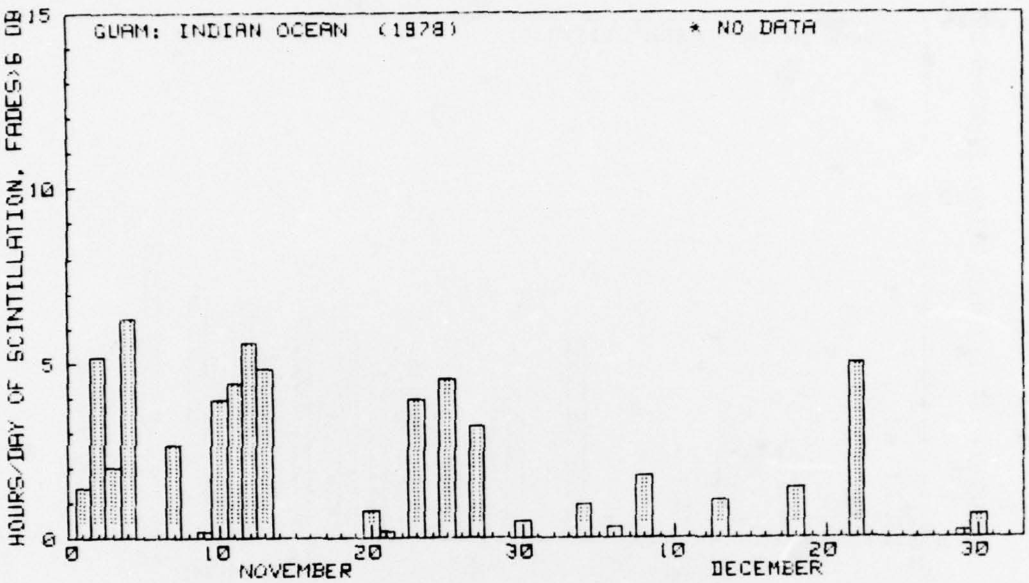


Figure B4. September-October 1978.



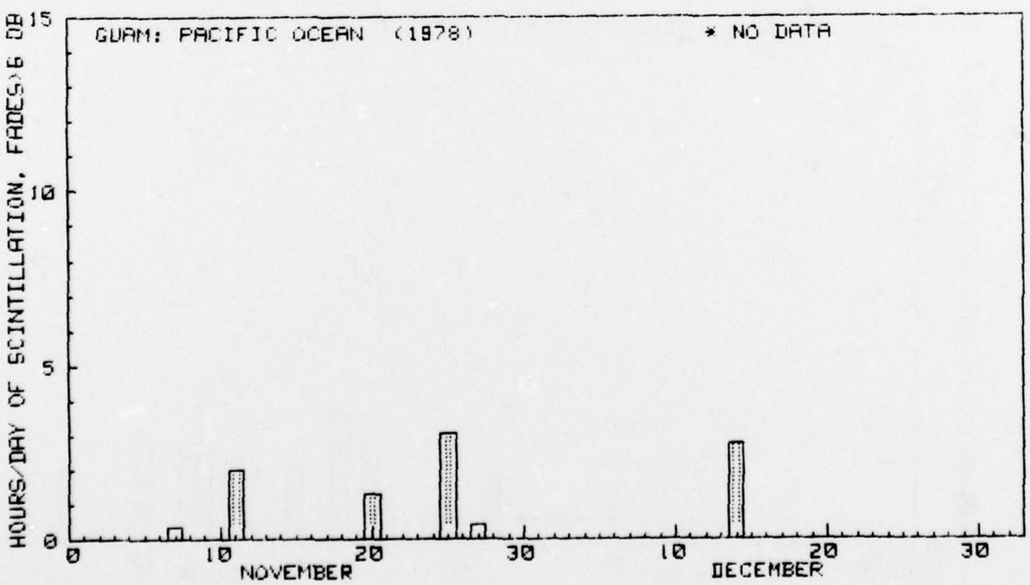
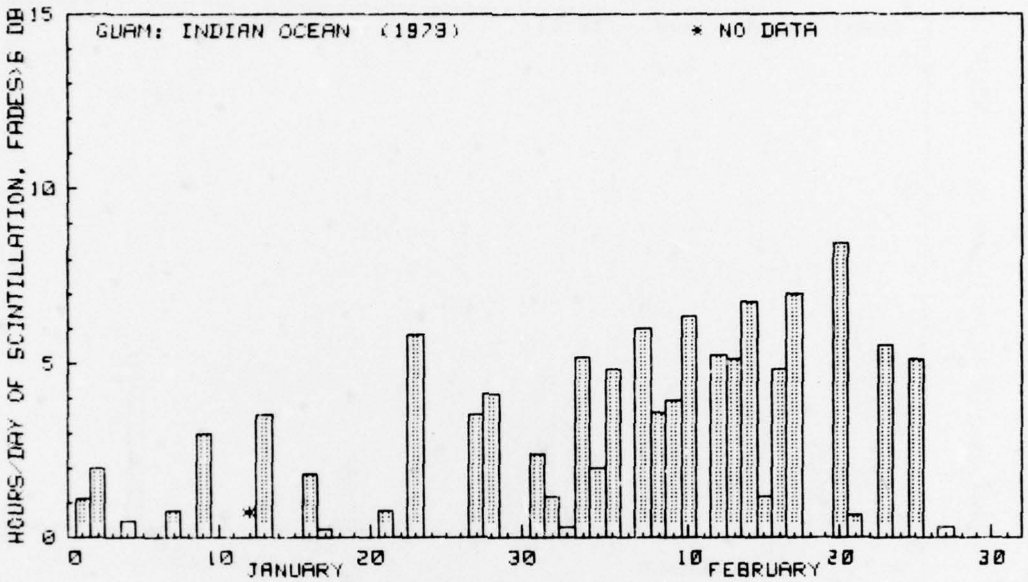


Figure B5. November-December 1978.



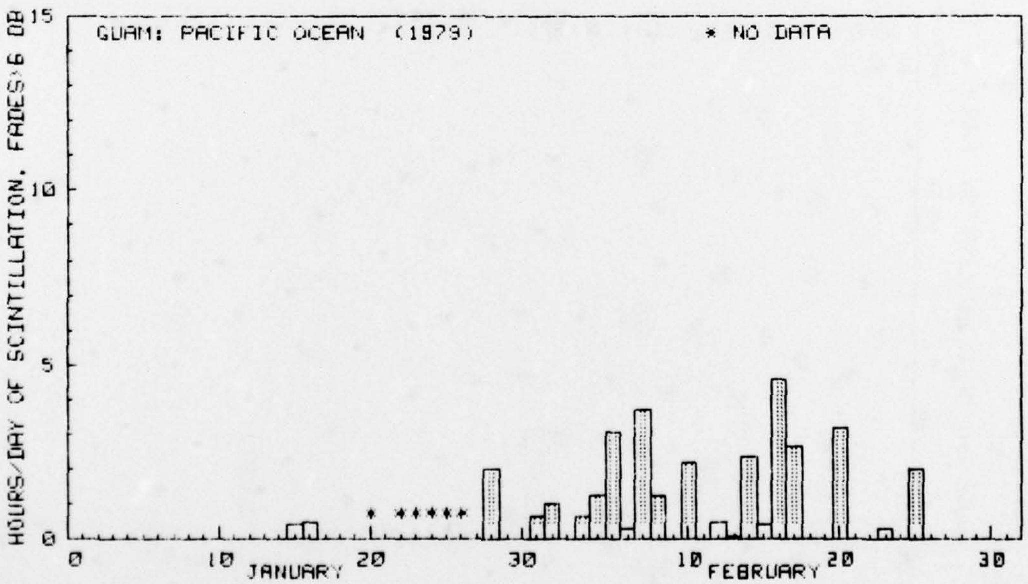


Figure B6. January-February 1979.

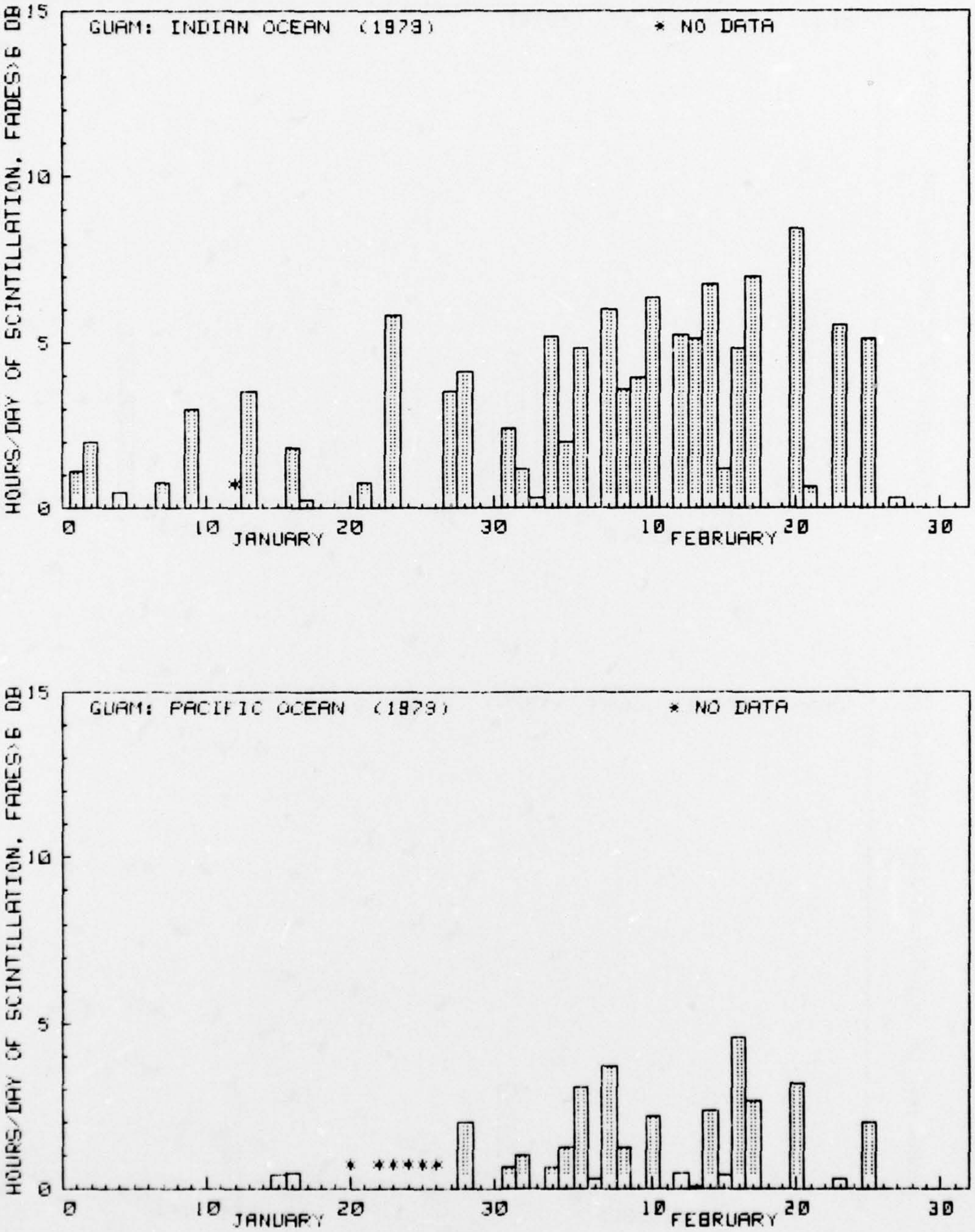
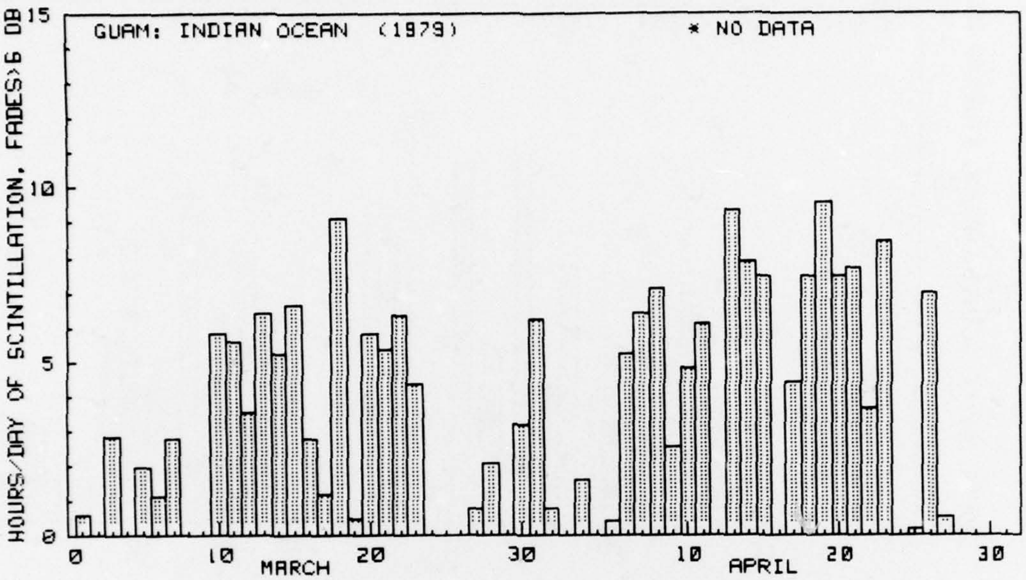


Figure B6. January-February 1979.



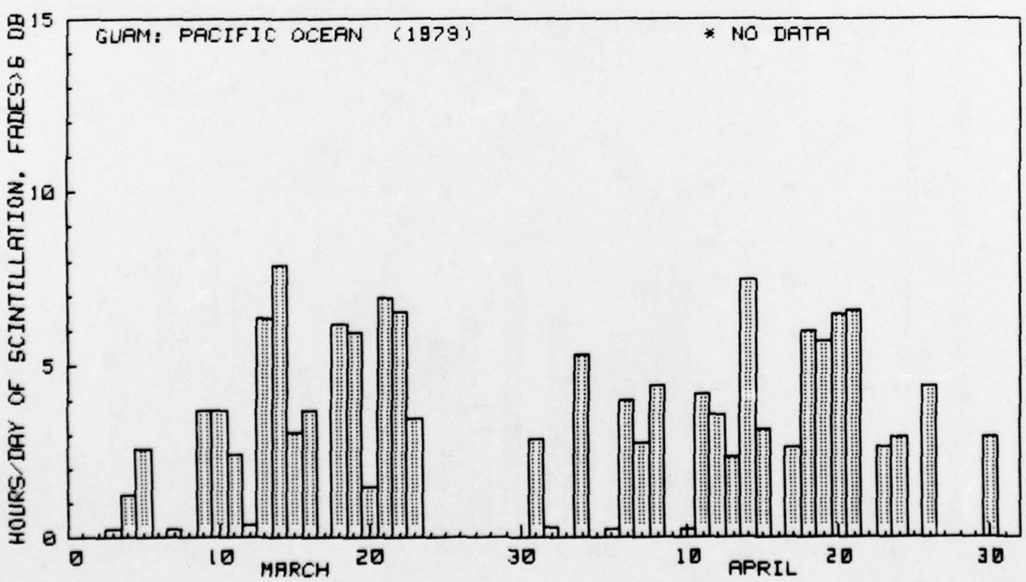
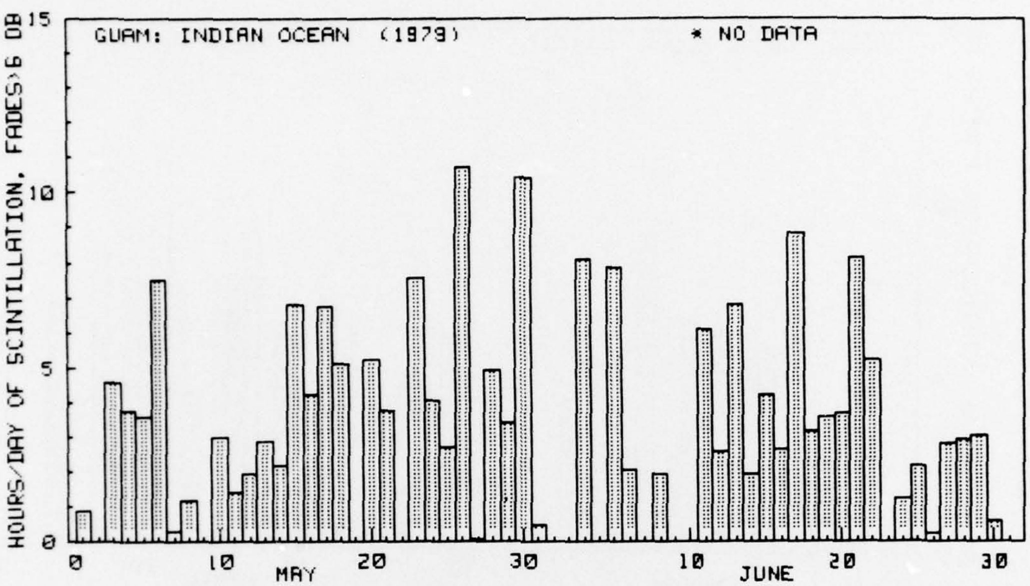


Figure B7. March-April 1979.



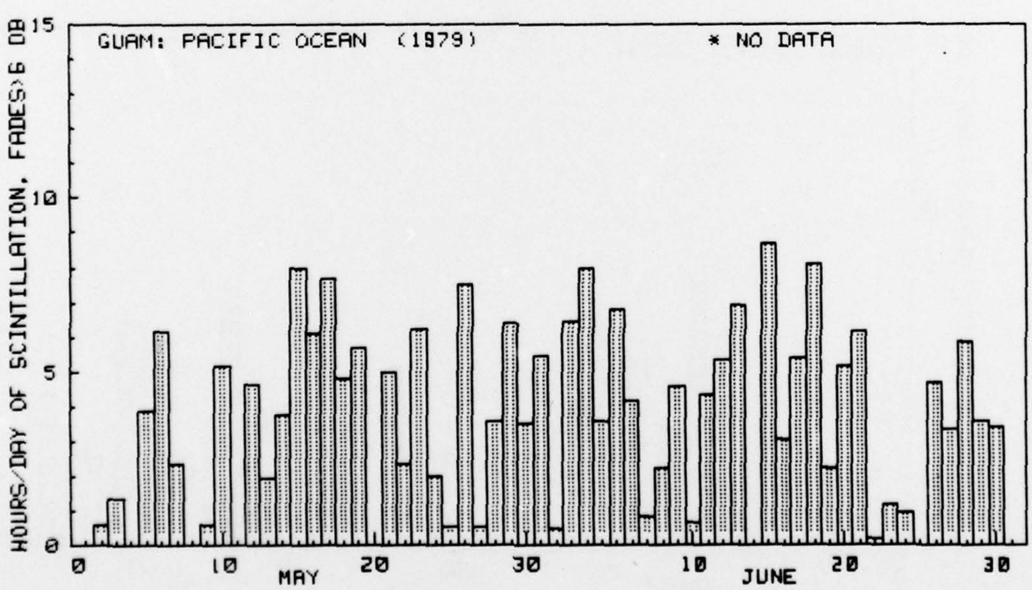


Figure B8. May-June 1979.

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