FINAL REPORT

NASA Grant NGR 05-002-185

"Infrared Sky Noise Survey"

to

California Institute of Technology

Pasadena, California

Principal Investigator

J.A. Westphal

(NASA-CR-139693) INFRARED SKY NOISE SURVEY Final Report (California Inst. of Tech.) 46 p HC $5.50 CSCL 04A
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G3/13 47909

"O foolhardy astronomers, O exquisite and subtle calculators, who practice astronomy in huts and taverns, at the fireplace, in books and writings, but not in the heavens themselves. For very many do not ever know the stars. And yet they would go to the stars."

-- Tycho De Brahe

Introduction

This document is the final report on the 10 micron "Infrared Sky Noise Survey", NASA Grant NGR 05-002-185 which ran from 1 June 1970 until 30 June 1974. During this period a sky noise measuring telescope, detector and associated electronics and recording equipment was developed and deployed for periods up to 18 months at various potential or existing infrared observing sites in the U.S., Mexico and Chile.

This project started in response to a clear need for objective uniform IR site survey data expressed in a meeting of most of the world's active IR observers, organized by NASA at the Jet Propulsion Laboratory in Pasadena, California during July 1969.

It was hoped that such a survey would be generally useful for planning of IR observations at existing facilities, and for selecting sites for any new instruments that might be built.

The instrument which was developed at CIT during the first part of this grant is described in an appended final report on a concurrent grant financing a study of the physics of sky noise and will not be further described here. However, a copy of a general description of the survey, attached as the next section of this report, was sent to all prospective sites and ultimately eight sites were activated by NASA through individual grants, to operate for approximately one year.

The results of this data collection activity are described and shown in the appended "Preliminary Report of the Ten Micron Infrared Sky Noise Survey" broadly distributed in November 1972.

10 Micron Sky Noise Survey

The purpose of the Infrared Sky Noise Survey (ISNS) is to measure the sky noise in the 8-14 micron atmospheric window at several potentially good observatory sites over a one-year period. This information, gathered with a uniform set of equipment and reduced in a uniform way, will be useful as a guide for infrared observers and an aid in selection of sites for future infrared oriented telescope facilities.

A special noise monitor has been designed at CIT for this purpose and 10 sets of equipment have been constructed. Each consists of a 16-inch f-4 off-axis paraboloid with $\approx \frac{1}{2}$ mm blur circle which is wobbled at 15 H_z so as to compare two 4-arcmin diameter spots separated by 10 arcmin in azimuth. The monitor is mounted so as to look roughly north (south in the Southern Hemisphere) at 45° altitude, so that it can operate unattended 24 hours/day without danger of solar illumination.

The radiation is sensed with a liquid helium-cooled copper doped germanium detector. A synchronous amplifier and associated electronics are mounted on the detector dewar and the power supplies and mirror driver electronics are mounted near the bottom of the fiberglass tube of the monitor. A small 6' x 9' house has been furnished at those sites where it is appropriate.

Each monitor is automatically internally calibrated with a black-body at six-hour intervals and records its output on a small strip chart recorder which runs unattended for 30 days. The liquid nitrogen jacket of the helium dewar must be filled every day and the liquid helium flask must be filled every other day.

The monitor does not require attention beyond the maintenance of coolant and changing of the strip charts. The building furnished has an automatic window feature which closes a sliding window if either the wind velocity or the relative humidity exceeds set limits. Unfortunately, such a system is not foolproof so a certain amount of attention is necessary during unusual weather conditions.

A further part of the site survey requires accumulation of precipitable water measurements daily with a small IR filter spectral hygrometer. These instruments, based on a design from Fred Gillett, operate quickly with minimal difficulty from a small tripod using the sun as a source. Each site has been furnished with one of these meters.

All data,accumulated at each site, are being returned to CIT for reduction by a uniform technique. If it is desired to retain copies of the data at the site, they are made before the originals are sent to CIT. (Because of the mechanics of the data digitization, it is essential that the original strip charts be sent to CIT).

At the end of the survey CIT will prepare a summary of the results from all of the sites which will be furnished to all the participants, as well as be available to any other interested parties.

The physics of IR sky noise is poorly understood. It is hoped that, as well as comparing sites, it will be possible to use this large mass of data to further study the details of the mechanisms responsible for "sky noise".

Noise monitors are presently being operated at eight sites: Palomar, Kitt Peak, Mt. Lemmon-Summit, McDonald, White Mt. Summit in California; Mauna Kea in Hawaii; Tololo in Chile; and San Pedro Martir, Baja California in Mexico.

The output of the sky noise monitor at Mt. Lemmon-Bigelow has been compared for several days with the noise levels monitored by Frank Low's 10 - micron sky survey equipment, located within 100 feet of the noise monitor. A very strong correlation was found, with the noise monitor capable of measuring sky noise to somewhat lower levels. We feel this test indicated that the noise measured by the noise monitor, over a 10 arc min separation, is closely related to that measured with much less separation by the sky survey system which has, of course, been optimized to cancel out the sky noise. Thus, it seems very likely that the statistics developed from the noise survey will be reflected during normal 10 micron photometry with larger telescopes, and that the results of the survey will indeed be a valuable criterion for the selection of superior IR sites.

DATA REDUCTION

The data are being reduced for evaluation utilizing digitization equipment originally built for the 2.2μ sky survey. Each record is digitized at 15 minute intervals in a manner which distinguishes normal sky noise, outage due to natural causes such as bad weather, and outage due to unavoidable causes purely associated with the site monitoring. The data are processed by a computer which analyzes separately the data from four time periods in each day.

A further tabulation on a monthly basis is also being made. The final date will be presented in the form of histograms which delineate per month and per quarter-day the fraction of time each site had noise within one of 12 bins of noise levels or were inoperable.

An intensive process of security is maintained to keep the data processing unbiased. After each tape has been examined for operational problems, it is given to a secretary who replaces all identifying remarks by a number. This number is then maintained as the only record of the tape through the processing.

Final Report

NASA Grant NGR 05-002-184

"Infrared Sky Noise Study"

to

California Institute of Technology
Pasadena, California

Principal Investigators
J.A. Westphal
Gerry Neugebauer
Robert B. Leighton

Prepared by J.A. Westphal

Introduction

In 1969 NASA began to consider funding a large ground-based IR telescope. The geographic location is of prime importance in such a project, since IR observations are particularly sensitive to the amount and variation of water vapor in the earth's atmosphere and, in certain cases, to the presence of "sky noise". It was clear that a comparison of these parameters at various potential observatory sites was very desirable.

Early in 1970, we proposed that CIT organize and supervise a survey of several sites. We were very concerned as to how to measure the sky noise in some uniform, unbiased way since very little was really understood about its nature. Therefore, we also proposed a study of sky noise itself to be made concurrently with the preparations for the multiple site survey. This proposal was funded by NASA beginning 1 June 1970. This document is the final report of the work conducted under Grant NGR 05-002-184 which ultimately expired 31 May 1972.

Development of a Sky Noise Instrument

From the earliest days of modern 10 micron IR observations, investigators have been plagued with slow variations in the difference in flux between the two sky positions sampled by the optical modulator or "chopper". These variations, with periods longer than about one second, were labeled "sky noise", although it is now known that much of this noise was due to the modulation scheme and should be properly called "modulation noise". As IR technology improved much of the problem of sky noise disappeared, primarily by using very small focal plane displacements of "throws" and by careful attention to the design of the modulator. However, when large throws were needed, as in the case of planetary measurements, sky noise again became a serious problem.

Sky noise is most serious when an attempt is made to conduct 10μ sky surveys with large focal plane apertures, even when the most effective modulators are used. In this case the very large throughput of the system makes it extremely susceptible to small variations in sky emission. An example of this problem can be seen in Figure 1, which shows the variation in sky noise as a 10μ detector on the 62-inch f-1 telescope used for the CIT 2μ Sky Survey is moved from 11 mm outside the stellar focus to 24 mm inside that focus. If the sources of the sky noise are far from the telescope and if they have steep spatial flux gradients, then one would expect to be able to "focus" on these sources. The fact that the noise is a maximum at the stellar focus indicates that the noise sources are far away. This is a very convincing experiment, since any "modulation noise" should be independent of the focal position.

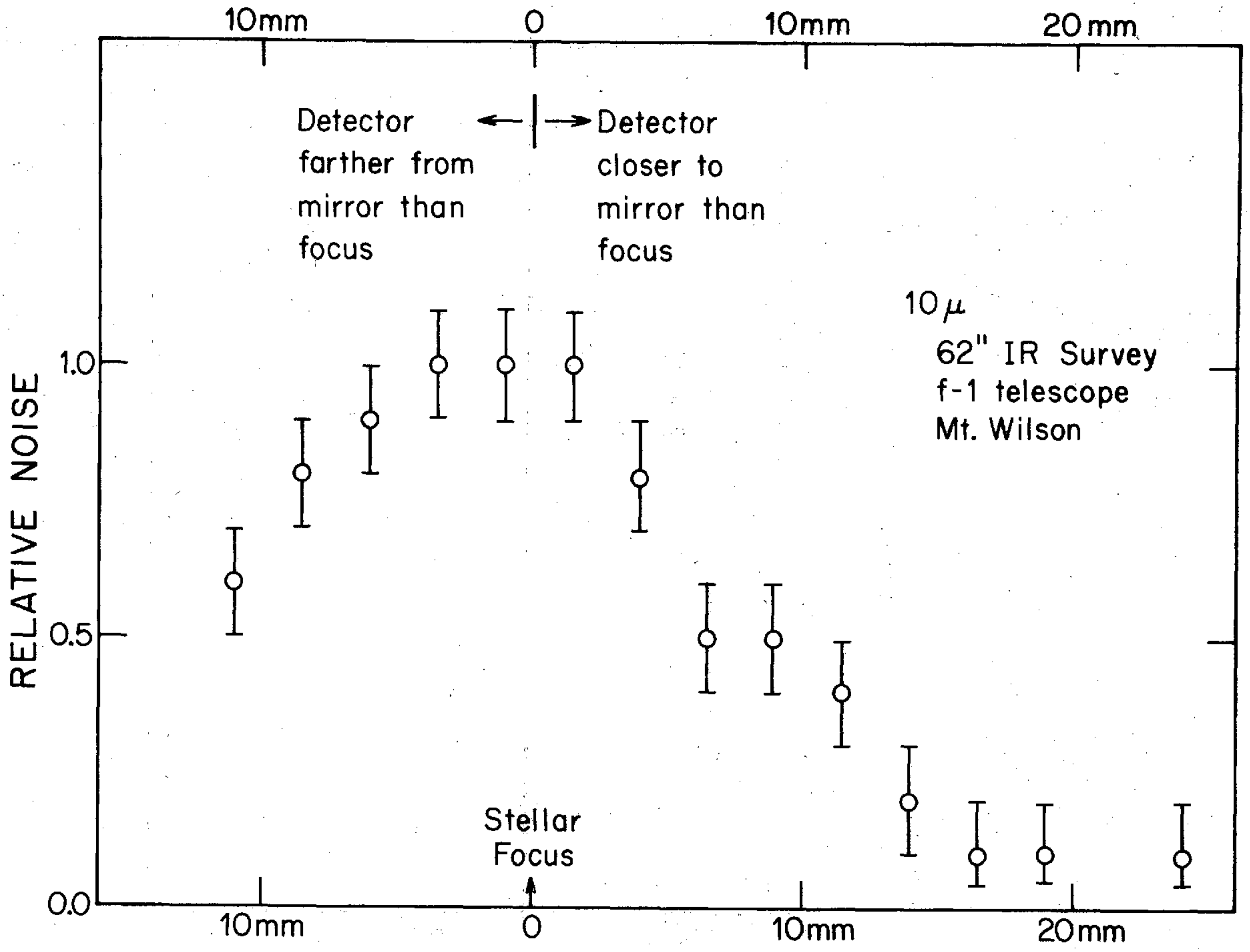
10mm
0
10mm
20 mm
Detector farther from mirror than focus
Detector closer to mirror than focus
10 μ
62" IR Survey
f-1 telescope
Mt. Wilson
RELATIVE NOISE
1.0
0.5
0.0
Stellar Focus
10mm
0
10mm
20mm

FIGURE 1

At the time of our proposal, the "lore" of sky noise was summarized as follows:

"1. The sky noise seems generally to be most severe in the 8-14 atmospheric window, although it is often seen at 5μ and in the $16-25\mu$ region.

2. The noise is often, but not always, correlated with the quality of the visible "seeing": when the seeing is very bad the sky noise is usually severe, but when the seeing is quite good the sky noise may be either moderate or low. Examples of strong anti-correlation are also know.

3. Clouds, particularly high cirrus, almost always produce high noise levels. Some observers feel that the major source of sky noise is "invisible cirrus"; however, our own experience strongly suggests that other sources are also present.

4. Sudden shifts in wind direction or increase in velocity usually cause increases in sky noise; however, wind velocity is not obviously correlated.

5. Measurements of the microthermal structure of the lower 30 meters of the atmosphere indicate temperature variations large enough to produce the flux levels commonly seen in sky noise; however, the correlation between these temperature fluctuations and the sky noise, based on very limited data, is not clear.

6. Limited studies, conducted during an attempt to conduct a 10μ sky survey at Mt. Wilson, show that it is possible to "focus" the telescope on the noise sources. If one places the detector at the infinity focus of the telescope, notes the sky noise amplitude, and then moves the detector toward the mirror, the sky noise output drops drastically. Conversely, if one moves the detector away from the mirror the sky noise first increases then as one moves farther away it gradually decreases again.

7. The amplitudes of the various frequencies in the sky noise seem to vary in a roughly 1/f fashion down to very low frequencies (1 hr.). Both clouds and *microthermal variations* have a similar frequency spectrum. Unfortunately, this property of sky noise makes conventional signal averaging (integration) very ineffective as a technique for improving the signal-to-noise ratio of an observation. *Although some clever techniques have recently been developed to* alleviate this problem, it is important to find superior sites and better techniques, particularly for observations of extended objects.

8. At some sites, on occasion, the sky noise is smaller than the detector noise. In our personal experience this has been observed at Cerro Tololo where during all three nights of 10μ and 20μ observing during a 1968 run the sky noise was less than cell noise. The significance of a three-night sample is probably very low, but encouraging."

It was with this background that we started to study sky noise and to develop hardware and techniques to measure and compare sky noise at several sites.

It was extremely important that we devise a device that would maximize its output for sky noise and minimize its output for modulation, detector and other noise sources. Experience, particularly with the 62" f-1 sky survey telescope, had indicated that an ideal modulator would be one that rocked or "wobbled" the primary mirror. However, the 62" required a fixed tripod above the wobbling primary to support the detector dewar, and we were concerned that this tripod/dewar assembly might be a source of excess noise. We felt that an off-axis paraboloid would be an ideal telescope since nothing would be in the optical path except the primary mirror itself. We were able to obtain a 16-inch f-4 metal off-axis paraboloid with about a 1 mm blue circle for a reasonable cost and a prototype instrument was built.

This telescope consisted of a 2 mm liquid helium cooled Ge:Hg detector with a 8-14μ cooled bandpass filter and a f-4 cold radiation baffle looking down at the 16-inch off-axis primary which was wobbled at 15 hz. The 15 hz Ac detector output signal was amplified, synchronously detected and smoothed with a 1-second time constant. By displaying this output on a strip chart recorder, we could then study the variations in the difference in flux between two 2mm diameter spots in the focal plane of the telescope. Figure 2 shows such a recording for several hours looking at an elevation angle of about 45° in a northerly direction. The distance between the sampled spots in the focal plane was about 6 mm. Large variations in the sky noise on this record are representative of the changes seen at Palomar when the sky is visually clear. Of particular interest are the long period variations seen around 0400 and the sharp increase and change in character of the noise just after midnight.

If the output of the telescope is rectified and averaged for about 400 seconds, it is possible to record only the envelope of the variations and produce much more compact records for long periods of time. This was done for the routine survey instruments and Figure 3 shows some results from two of these instruments. The small differences are doubtless due to the telescopes pointing in slightly different direction. At this point it seemed important to compare the output of the sky noise telescope with the output of a more conventional IR telescope with a modern modulation system and a state-of-the-art detector.

With the assistance of Dr. Frank Low, we were able to arrange to set up the telescope about 50 feet west of the 28-inch 10μ sky survey telescope on Mt. Lemmon, Arizona. After a period of several clear days, during which both systems were working properly,

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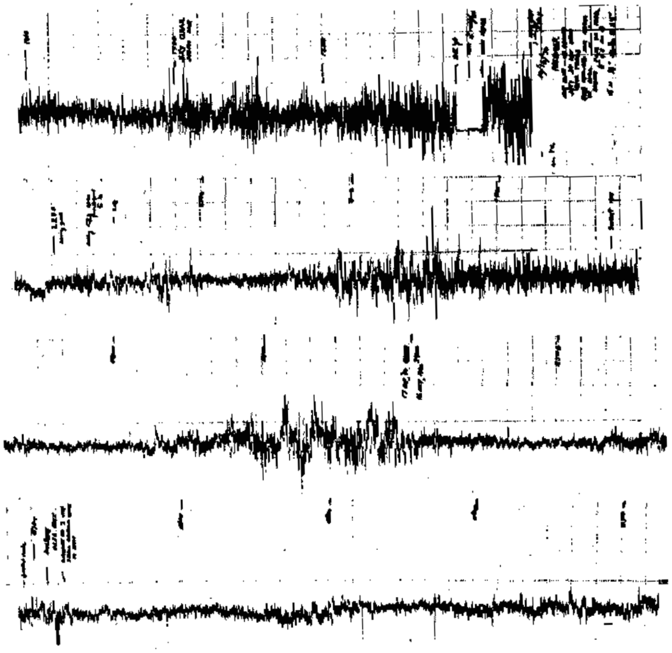

FIGURE 2

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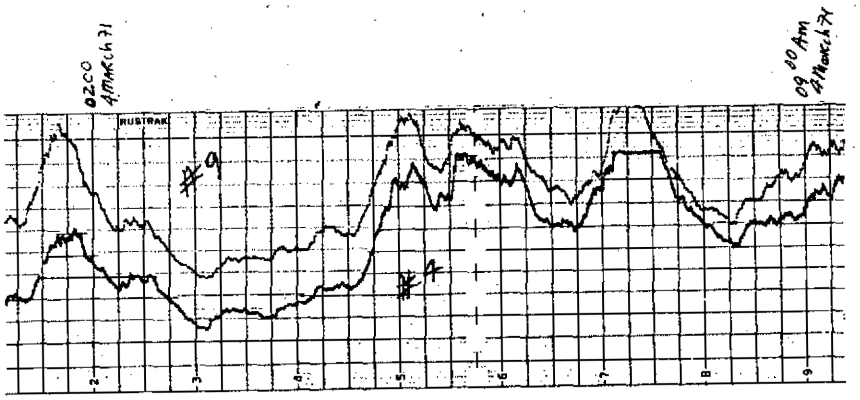


FIGURE 3

we compared the outputs and found a very good correlation, indicating that both systems were measuring real variations in sky emission. As would be expected, the sky noise telescope was somewhat more sensitive for measuring sky noise since the 10μ survey system was designed to minimize its sensitivity to sky brightness fluctuations.

At this point we felt that we had developed a viable system, sensitive to sky noise and capable of operating almost unattended at several possible IR sites.

A more complete description of these instruments and the details of the sky noise survey will be presented in the final report of the grant which supported that activity. The rest of this report will discuss our investigation of the nature of sky noise.

The Nature of Sky Emission and the Fluctuations

The basic source of sky noise is the flux emitted by the various solid and gaseous components of the atmosphere. If this flux was precisely constant over the time required to make a measurement of some astronomical source then it could be simply subtracted from the measured value of object plus sky and would not cause a great difficulty in most cases.

However, even if the long time mean value of the sky emission was constant there would still be variations due to "photon noise", that is, noise due to the random arrival of individual photons. Only very recently have other noise sources in some detectors been suppressed to the point that they are "photon noise limited". Most of the background flux seen by IR detectors in conventional telescopes comes from the optical surfaces and support structure and only a small part from the sky. However, efforts are now underway to design IR telescopes which may be sufficiently "clean" so that the photon noise from the sky would be important. The absolute average sky flux will then be an important factor in the selection of an IR site.

It is, however, the variation spatially and temporally of the sky flux that causes the "sky noise" we have studied.

Gaseous Sources of Sky Noise

Fortunately the "permanent" constituants of the atmosphere, oxygen, nitrogen and the rare gases do not absorb or emit IR radiation in the 1-30 micron region. Only the trace molecules are significant emitters. Of these the most important, particularly at good IR observing sites, are water vapor and carbon dioxide. These gases are responsible for deep absorption bands throughout the mid-IR and define the "windows" through which observations are made.

By far the most variable in both time and space is water vapor, which may change by orders of magnitude on short time scales even at high elevation sites. Because water vapor is so important, the sky noise survey also measured, at least once a day, the amount of precipitable water at each site. The results of these measurements can be seen in the "Preliminary Report on the IR Sky Noise Survey" available from NASA or CIT.

The water vapor emits IR radiation not only in the well known deep absorption bands but also in a broad continuum far removed from the deep bands. Even if one observes far from these deep bands, substantial flux is still seen from the atmospheric water vapor. If the amount of water vapor present varies, then one sees "sky noise" due to this source. Using reasonable values for the emissivity of the water vapor and the scale of the spatial variations, it is easy to calculate that all of the sky flux variations seen at the telescope could be due to this effect. As we shall see, this is also true of a number of other sources and the surprise is that the sky noise level is generally as low as we observe.

The wings of the CO_2 absorption bands and many weak CO_2 lines are scattered through the normal IR "windows". These lines and wings act just as water vapor does if there are variations in the quantity of CO_2 moving past the telescope. However, the CO_2 concentrations, particularly at sites that have little local vegetation, are probably quite uniform so this may not be a major source of noise.

If the moving air in the optical path has local variations in temperature, then even uniform concentrations of CO_2 or water vapor give rise to sky noise since the flux emission is a strong function of temperature. Such temperature variations have been well established by microthermal studies and usually are on the order of a few degrees Celsius near the ground with "blob" sizes from a few cm up to very large sizes. Again simple calculations based on these numbers yield noise flux values large enough to explain the observations.

Aerosol Sources of Sky Noise

Aerosols are present in the air over most IR sites and can be a major source of sky emission particularly at the lower sites or near cities, mining and smelting activities, dirt roads, etc. Most aerosols are black body emitters in the 1-30μ region and usually are non-uniformly distributed. Aerosols are therefore strong sources of sky noise due both to non-uniformity and to their presence in blobs of warm and cool air moving across the optical path. Clouds are of course aerosol particles of either liquid or solid water and cause very severe sky noise problems. Any cloud visible to the eye is extremely noisy. Often preceding the visible clouds, particularly cirrus clouds, the sky noise instrument will indicate rapidly increasing noise levels suggesting presence of very thin cirrus. Simple calculations again indicate that aerosols can cause all the sky noise normally observed.

Experiments to Further Define Sky Noise

Several experiments were undertaken to further understand the detailed nature of sky noise.

1. Measurement of high speed humidity and temperature changes. In connection with the installation of the new 60-inch telescope, a survey of two sites on Palomar was conducted during 1967. Two 30-meter towers were erected and four high speed thermistor sensors were installed on each tower at 6 m, 10 m, 20 m, and 30 m. The variations in air temperature in the period range from 0.25 to 100 seconds at each station on each tower were recorded for several months. The relative humidity and windspeed/direction were also recorded. Comparison of this data with the sky noise values often indicated correlations, but it was clear that much sky noise originated higher than 30 meters. An attempt was made to measure the microthermal and humidity variations at heights up to 300 m on a tethered balloon, but it was unsuccessful due to logistic problems. Short runs of data, however, indicated that the microthermal amplitudes decreased vertically with scale height of perhaps 25 or 30 m.

2. Variation of sky noise with "stroke". In conventional IR photometry, one normally chops between two sky positions just far enough apart to allow total separation of the source

from the sky. For small objects, stars, satellites, etc., it is common to use strokes of about 5 arc sec. or 10 arc sec. depending on the size of the telescope and the quality of the seeing. However, for planets and other extended sources it is very desirable to use a stroke somewhat larger than the diameter of the source. This leads to strokes of up to 1 arc min. for planets and 30 arc min. for the moon. It seemed important to know how the sky noise varies as a function of the stroke under various conditions, since an optimum stroke might possibly exist for a given problem.

Figure 4 shows how the sky noise varied for strokes between 3 arc min. and 35 arc min. using the sky noise telescope. This data was derived by operating two identical telescopes, looking along almost the same path for several days, one with a fixed 8 arc min. stroke, the other with each of four different strokes. Data was collected for at least one day under clear conditions with each stroke value. The data were then normalized against the fixed stroke values.

The bar on the 8 arc min. point represents the reproductability of the two instruments and the bars at other stroke values show the range of observed values. The data is consistent with a linear variation of noise with stroke and extrapolates nicely to the values recorded at small strokes with conventional photometers. This means that one should use the smallest possible stroke for IR photometry.

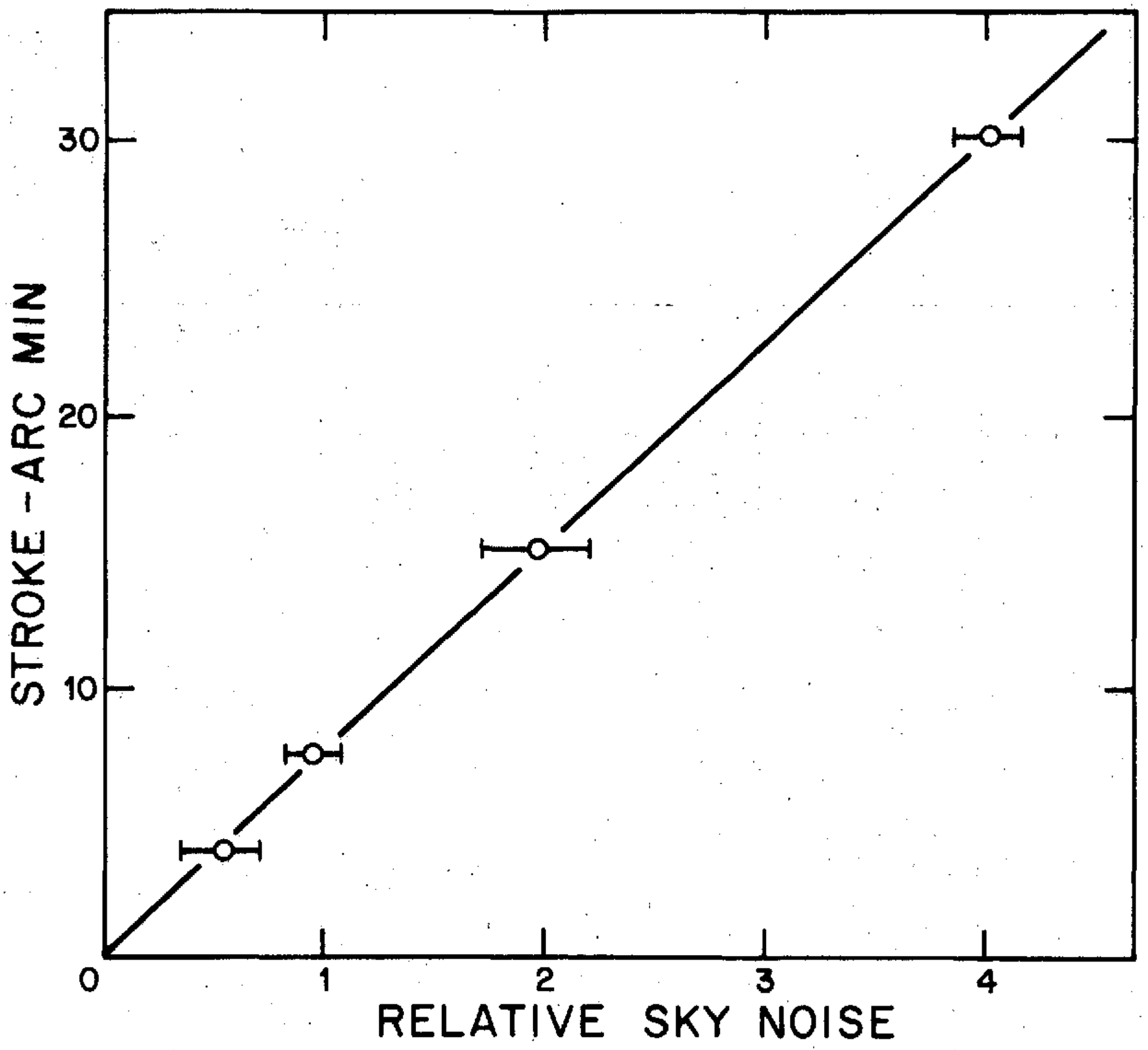


FIGURE 4

3. Attempts to correlate meteorology with sky noise.

As quoted earlier the sky noise "lore" suggested that local meterological conditions affect the sky noise in complex ways. To learn more about this, we conducted a series of experiments with the sky noise telescope at Palomar. For several long periods we took IR time lapse movies of the sky in the region near our measuring beam. These movies were made by exposing 16 mm Kodak High Speed IR Film 2481 through the recommended filter, one frame each 4 seconds during daylight hours. We had hoped to see very faint cirrus clouds by this technique. Unfortuantely the exacting exposure requirements were such that it was only rarely that we saw cirrus not visible to the eye. In every such case the sky noise had increased markedly before the cirrus was visible. An interesting effect was seen, however, in those cases where the cirrus was dissipating instead of forming, in these cases the sky noise was low in the clear spaces between the clouds.

We believe this means that "invisible" cirrus does exist and is commonly present when cirrus clouds are forming, but that it is absent when they are dissipating.

This photographic work also lead us to understand another serious source of sky noise. Very often in recent years the "smog" from the Los Angeles Basin blows over Palomar Mountain. When this happens, the IR movies show the advancing aerosols before they are visually obvious and explain many of the observed sudden increases in sky noise when the sky looks clear. These aerosols plus the nitrogen oxides, water vapor and carbon dioxide also contained in smog, are a major source of sky noise at Palomar. Undoubtedly the copper smelter aerosols and gases which often invade the Kitt Peak, Mt. Hopkins and Mt. Lemmon observatory sites, the volcanic polutants sometimes present at Mauna Kea and the smoke from agricultural burning sometimes seen at White Mountain, California are also sources of severe sky noise.

Many hours were spent just watching the behavior of the sky noise output in attempts to find unknown correlations. Many times, particularly at night, large changes in sky noise were observed without obvious cause. Often when the sky noise became very high on moonless nights, observations at dawn found the sky covered with thin cirrus even though a careful visual search had found no clouds while it was dark. We feel that a simplified model of the sky noise telescope could become a very useful permanent observatory cloud sensor to aid all kinds of photometric observations. We are now developing such a monitor with other funds.

Summary

We believe the following conclusions are justified by the large mass of data from the Sky Noise Survey and the special experiments to understand sky noise conducted under this grant.

1. Sky noise really exists, i.e. both spatial and temporal variations in the local sky emission flux field are commonly present even at the best known IR observing sites.

2. Sky noise has approximately 1/f properties both temporally and spatially with a wide range of frequencies.

3. There are many sources of sky noise, the most common are:

   (a) blobs of hot or cold air of finite emissivity blowing across the optical path.

   (b) blobs of increased or decreased water vapor, carbon dioxide or aerosol content blowing by, even at constant temperature.

   (c) any visible clouds.

   (d) "invisible" cirrus when the cirrus cover is forming.

4. The spatial distribution of the sky noise sources are such that the observed noise values are linear function of chopping stroke, therefore the minimum stroke is the best.

5. IR sky noise measurements are a very effective way to detect cloudiness at an observatory and can be used to monitor the photometric

quality of the sky for both IR and visible photometry.

6. It is unlikely that sky noise levels can be significantly decreased by any technique except choice of site. The most desirable site would have at least these properties:

(a) high and dry (to decrease total water vapor)
(b) isolated (to decrease man-made aerosols)
(c) away from both polar and tropical regions (to decrease cloud cover)
(d) barren (to decrease locally generated water vapor and carbon dioxide variations)
(e) good visual seeing (an indication that the microthermal activity is low)

Of these (e) is clearly the most important particularly for photometry of small sources where the focal plane aperture size and therefore the stroke are defined by the seeing blur circle.

7. The study of sky noise is especially frustrating, since one is trying to measure a non-stationary phenomenon.

Acknowledgment

This study would not have proceeded without the invaluable assistance of E.O. Lorenz. We also thank Dr. Frank Low for his cooperation and the mountain staff at Palomar for their support.

APPENDIX II

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF SL

November 7, 1972

MEMORANDUM

TO: Distribution

FROM: SL/Program Chief, Planetary Astronomy

SUBJECT: Preliminary report of the ten micron infrared sky noise survey

I am pleased to forward to you two copies of the subject report. The report is self-explanatory. To keep the reduction of results as unbiased as possible, the staff at Cal. Tech. worked with the data using numbers rather than locations for the sites. The code used is not known by the Cal. Tech. staff at the time of writing this letter.

The code is as follows:

Site number	Location
1	Mt. Palomar
2	Mt. Lemmon
4	Cerro Tololo, Chile
5	Kitt Peak
6	McDonald Obs.
7	Mauna Kea, Hawaii
8	San Pedro Martir, Baja California, Mexico
11	White Mountain, Calif.

As stated in the report, the sites in Baja California and Cerro Tololo were started late. Measurements at Cerro Tololo were halted in October 1971 when problems were encountered with the liquid helium procurement. The observations made at White Mountain were sporatic due to cost and logistic difficulties in maintaining an observer at the site. Although some stations were on the air prior to July 1971, it was decided to use the time period July 1, 1971 to June 30, 1972 as the survey year as most stations were operable throughout that time period.

PRELIMINARY REPORT OF THE TEN MICRON INFRARED SKY NOISE SURVEY

by

J.A. Westphal

California Institute of Technology

1 November 1972

INTRODUCTION

During 1971 and early 1972, a survey of the level of 10 micron "sky noise" at several sites in the U.S., Mexico and Chile, was conducted with identical equipment furnished by CIT. The data from these sites have now been reduced in a preliminary form and will be presented in this report.

Two sites chose to discontinue operations during long rainy seasons. These time intervals were considered "off-scale" and are included in the data. The site at the summit of White Mountain, California, was operated on a part-time basis as weather and logistics allowed; the data from this site is therefore non-representative in some unknown way. The sites in Baja, California and Tololo, Chile, were started late and the Tololo site operated only a short time before the liquid helium procurement problems caused discontinuance of measurements.

PROCEDURE

In an attempt to keep the data reduction as objective as possible, we have endeavored to reduce and process the data in "blind" form.

To do this we have used the following procedure:

1. As the data from each site were received at CIT, they were inspected by either J. A. Westphal or E.O. Lorenz, the project engineer, to make sure the equipment was operating properly and that the notes on the charts, indicating time, helium condition, etc., would be clear to the digitizing personnel.

2. The charts were subsequently given to a secretary in the IR Physics office, who removed all identifying names, notes, etc., and placed a site code number on each chart. Only this one individual had access to the "code" which identified site number with site name. At the end of the survey, this code sheet was turned over to W. E. Brunk. A Xerox copy of the beginning of each roll was made to insure that rolls could be identified after coding if necessary. As a final step, after this report was written, E. O. Lorenz cross-checked the original charts with the graphs included in this report to insure that all the accounting was correct.

3. All data digitizing, processing and reduction were done by Physics personnel by site number. Only the raw digitization was done before the end of the survey (30 June 1972). No reduction or comparison of sites was done before 15 July 1972.

4. This report will display the reduced noise data only by site number. It is anticipated that a cover letter to this report by W. E. Brunk will contain the site code information. This report will be distributed by Dr. Brunk from NASA Headquarters.

WATER VAPOR

As an addition to the noise survey, each site was requested to measure the precipitable water around local noon using a portable filter-type water vapor meter modeled after a design by Fred Gillett. This particular model uses the ratio of the atmospheric transmissions in the 1.65μ and 1.87μ region utilizing the sun as an extra-terrestrial source. These data were reduced at the end of the survey, correcting for actual air mass at the time of each observation. In the copies of this data in this report, a few very low water numbers are plotted. These are data from very large air masses and are undoubtedly incorrect. Off-scale data are shown as "X" along the top.

Two sets of water vapor data are shown from White Mountain in California. That set with only a few points was derived from measurements with the water meter furnished with the survey. That set with a large number of points is derived from a "Low" type water meter used at the site and cross-checked by D. Cudaback with the survey meter. There is no reason to expect that these values are not comparable with other sites.

REDUCTION OF IR NOISE DATA

The reduction of the noise data consisted of digitizing each original chart at 15-minute intervals. Chart zero and calibration measurements were also digitized. The digitized data were then stored until the survey was completed. At that time, all the data were reduced, in mass, to produce the various displays of this report. The data were normalized between sites by use of a calibration value derived from the flux from a 500°K blackbody which was automatically measured, through each survey machine, each 6 hours.

DATA

The following tables and graphs summarize the data in various ways:

Figure 1 shows the percentage of the possible time that was covered at each site; note that two sites had very low coverage and conclusions about the average noise conditions at these sites must be very tentative.

Figure 2 shows, for each site in three daily time intervals, the percentage of the operating time in which the noise was less than 1.0×10^{-7} watts/cm^2/ster which corresponds to 20% of full scale of the site with the most sensitive system.

Figure 3 shows the percentage of the time for which the values of the noise levels were greater than 5.0×10^{-7} watts/cm^2/ster.

Tables 1-16 show the monthly values of the sky noise at each site in each time-bin along with the monthly coverage and summary data.

Graphs 1-12 show the raw data calibrated to a uniform amplitude scale. Values greater than full scale on the most sensitive monitor are shown as full scale. Time intervals when the monitor was not running are shown as gaps in the data.

It is our intention to further process the data so as to present it in other convenient forms and to describe the details of the equipment and procedures, in a final report in the near future.

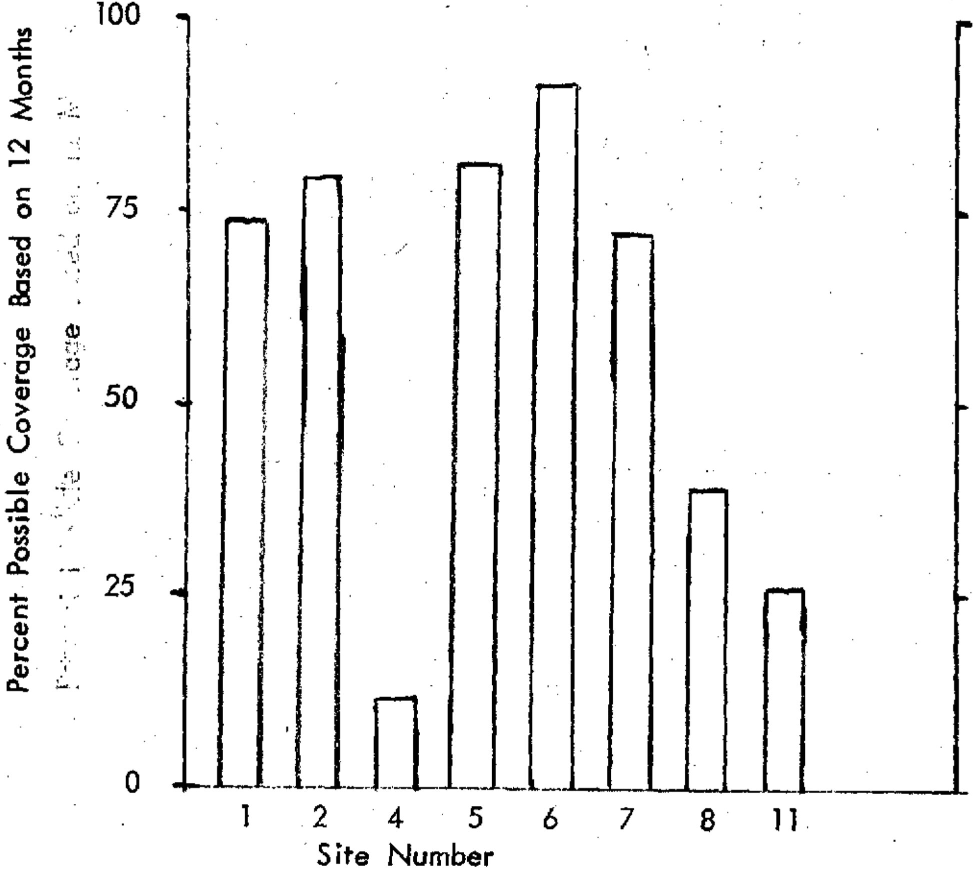
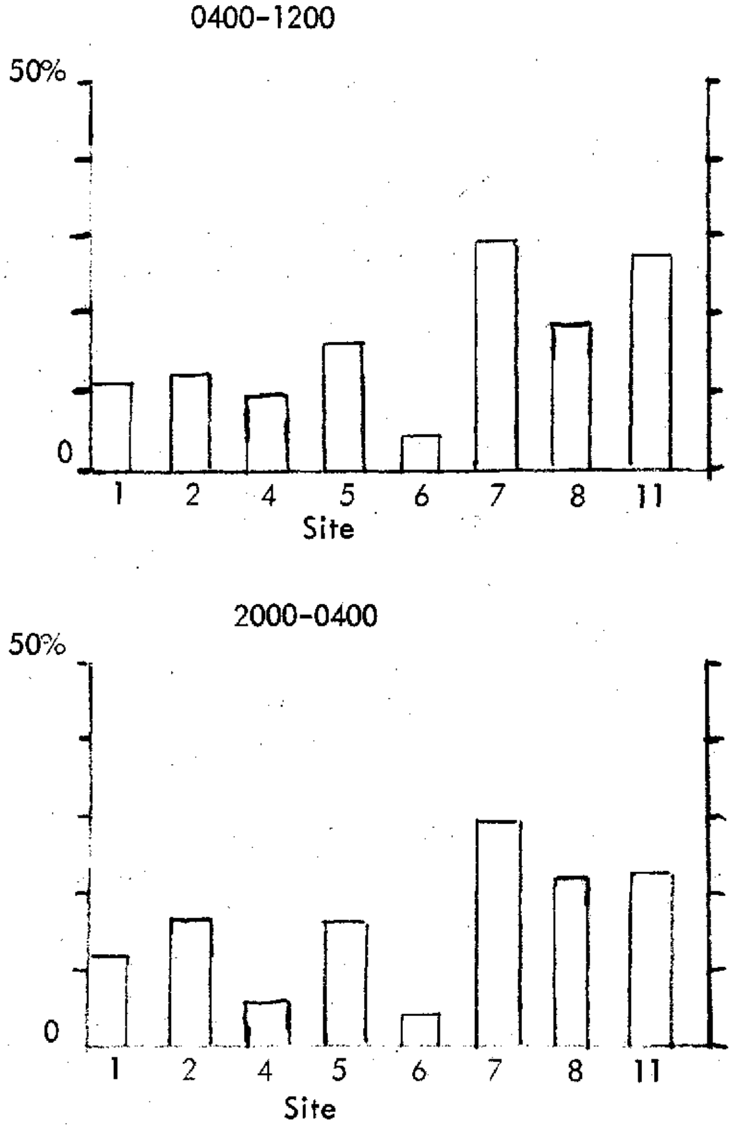

Percent Possible Coverage Based on 12 Months
100
75
50
25
0
1
2
4
5
6
7
8
11
Site Number

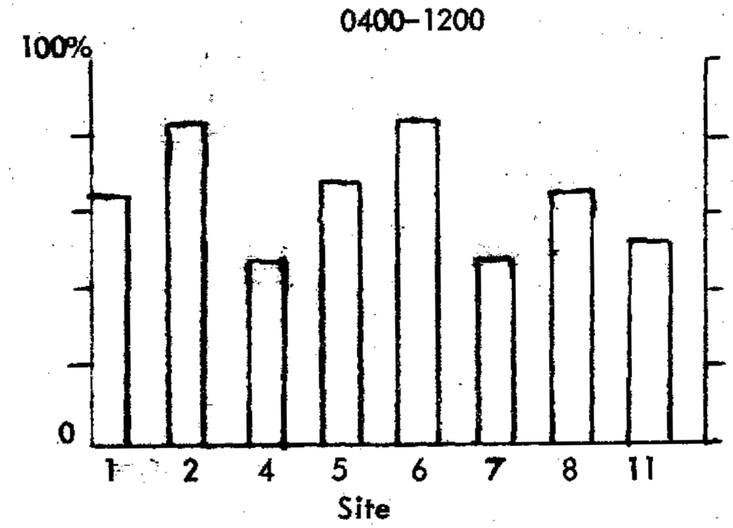
Figure 1

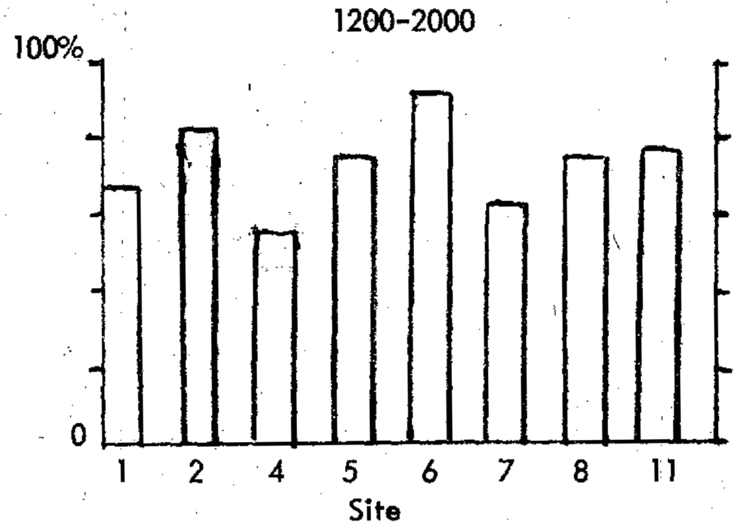


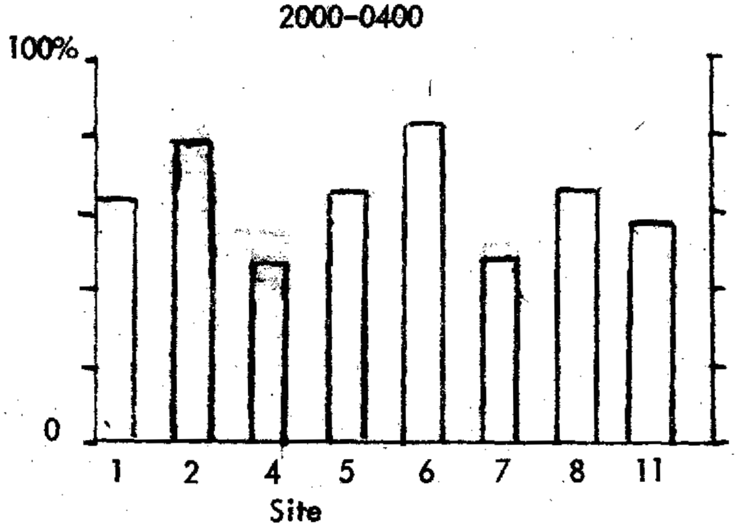
PERCENTAGE OF TIME DATA VALUES ARE LESS THAN 10^{-7} w/cm^2/ster.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

Figure 2







PERCENTAGE OF TIME DATA VALUES
ARE GREATER THAN 5 X 10^{-7} $w/cm^2/ster$

Figure 3

TABLE 1

SITE 01

HOURS 400-1200

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.025	0.299	0.677
AUG	71	0.015	0.069	0.916
SEP	71	0.051	0.154	0.795
OCT	71	0.004	0.367	0.629
NOV	71	0.055	0.309	0.636
DEC	71	0.224	0.370	0.406
JAN	72	0.333	0.223	0.444
FEB	72	0.192	0.289	0.518
MAR	72	0.228	0.399	0.373
APR	72	0.094	0.289	0.617
MAY	72	0.011	0.204	0.785
JUN	72	0.0	0.0	1.000

SITE 01

HOURS 1200-2000

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.002	0.044	0.954
AUG	71	0.0	0.005	0.995
SEP	71	0.011	0.071	0.918
OCT	71	0.007	0.189	0.803
NOV	71	0.027	0.288	0.685
DEC	71	0.143	0.451	0.407
JAN	72	0.245	0.332	0.423
FEB	72	0.044	0.191	0.765
MAR	72	0.020	0.378	0.602
APR	72	0.007	0.173	0.820
MAY	72	0.010	0.055	0.935
JUN	72	0.0	0.0	1.000

SITE 01

HOURS 2000-400

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.084	0.200	0.715
AUG	71	0.018	0.076	0.906
SEP	71	0.090	0.185	0.725
OCT	71	0.015	0.395	0.590
NOV	71	0.075	0.303	0.622
DEC	71	0.301	0.367	0.332
JAN	72	0.319	0.229	0.452
FEB	72	0.175	0.238	0.587
MAR	72	0.199	0.517	0.283
APR	72	0.055	0.323	0.621
MAY	72	0.046	0.287	0.667
JUN	72	0.0	0.0	1.000

TABLE 2

SITE 1

PERCENT COVERAGE

July	0.719
Aug	0.904
Sept	0.862
Oct.	0.932
Nov	0.765
Dec	0.590
Jan	0.864
Feb	0.858
Mar	0.730
Apr	0.815
May	0.815
Jun	0.083

OVERALL COVERAGE = 0.745

Fractional Time <u>Below</u> 10^{7} w/cm^{2}/ster.

HOURS	VALUE
0400-1200	.104
1200-2000	.044
2000-0400	.116
0000-2400	.087

Fractional Time <u>Above</u> 5 x 10^{-7} w/cm^{2}/ster.

HOURS	VALUE
0400-1200	.637
1200-2000	.771
2000-0400	.614
0000-2400	.677

TABLE 3

SITE 02

HOURS 400-1200

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.000	0.000	1.000
AUG	71	0.000	0.000	1.000
SEP	71	0.000	0.000	1.000
OCT	71	0.083	0.083	0.833
NOV	71	0.155	0.128	0.718
DEC	71	0.000	0.269	0.731
JAN	72	0.250	0.097	0.653
FEB	72	0.220	0.098	0.681
MAR	72	0.352	0.166	0.481
APR	72	0.212	0.055	0.733
MAY	72	0.229	0.134	0.637
JUN	72	0.000	0.000	1.000

SITE 02

HOURS 1200-2000

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.000	0.000	1.000
AUG	71	0.000	0.000	1.000
SEP	71	0.000	0.000	1.000
OCT	71	0.000	0.000	1.000
NOV	71	0.179	0.174	0.647
DEC	71	0.238	0.333	0.428
JAN	72	0.237	0.126	0.636
FEB	72	0.102	0.181	0.716
MAR	72	0.151	0.316	0.532
APR	72	0.181	0.148	0.671
MAY	72	0.098	0.273	0.629
JUN	72	0.000	0.000	1.000

SITE 02

HOURS 2000-400

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.000	0.000	1.000
AUG	71	0.000	0.000	1.000
SEP	71	0.000	0.000	1.000
OCT	71	0.000	0.000	1.000
NOV	71	0.223	0.116	0.661
DEC	71	0.021	0.319	0.659
JAN	72	0.241	0.061	0.698
FEB	72	0.328	0.057	0.615
MAR	72	0.342	0.190	0.467
APR	72	0.325	0.031	0.643
MAY	72	0.344	0.019	0.637
JUN	72	0.000	0.000	1.000

TABLE 4

SITE 2

PERCENT COVERAGE

Jul	1.000
Aug	1.000
Sep	1.000
Oct	0.108
Nov	1.000
Dec	0.046
Jan	0.696
Feb	0.914
Mar	0.882
Apr	0.853
May	1.000
June	1.000

OVERALL COVERAGE = 0.792

Fractional Time Below 10^{-7}w/cm^2/ster.

HOURS	VALUE
0400-1200	.124
1200-2000	.084
2000-0400	.161
0000-2400	.123

Fractional Time Above 5 x 10^{-7}w/cm^2/ster.

HOURS	VALUE
0400-1200	.813
1200-2000	.804
2000-0400	.796
0000-2400	.804

SITE 4

TABLE 6

PERCENT COVERAGE	
Aug	0.540
Sep	0.744
Oct	0.155

OVERALL COVERAGE = 0.120

Fractional Time Below 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.085
1200-2000	.003
2000-0400	.051
0000-2400	.047

Fractional Time Above 5 x 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.458
1200-2000	.537
2000-0400	.463
0000-2400	.486

TABLE 5

SITE 04

HOURS 400-1200

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
AUG	71	0.177	0.562	0.260
SEP	71	0.031	0.433	0.537
OCT	71	0.000	0.158	0.842

SITE 04

HOURS 1200-2000

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
AUG	71	0.010	0.644	0.345
SEP	71	0.000	0.354	0.646
OCT	71	0.000	0.432	0.568

SITE 04

HOURS 2000-400

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
AUG	71	0.116	0.593	0.290
SEP	71	0.007	0.475	0.518
OCT	71	0.000	0.120	0.880

TABLE 7

SITE 05

HOURS 400-1200

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.0	0.055	0.945
AUG	71	0.0	0.0	1.000
SEP	71	0.013	0.004	0.983
OCT	71	0.144	0.146	0.711
NOV	71	0.127	0.082	0.791
DEC	71	0.020	0.034	0.946
JAN	72	0.492	0.205	0.303
FEB	72	0.284	0.246	0.470
MAR	72	0.195	0.450	0.355
APR	72	0.334	0.224	0.443
MAY	72	0.151	0.390	0.459
JUN	72	0.292	0.045	0.663

SITE 05

HOURS 1200-2000

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.0	0.0	1.000
AUG	71	0.0	0.0	1.000
SEP	71	0.002	0.003	0.995
OCT	71	0.080	0.228	0.692
NOV	71	0.077	0.185	0.738
DEC	71	0.048	0.048	0.904
JAN	72	0.273	0.296	0.431
FEB	72	0.088	0.260	0.652
MAR	72	0.057	0.322	0.621
APR	72	0.122	0.361	0.517
MAY	72	0.026	0.408	0.565
JUN	72	0.211	0.038	0.750

SITE 05

HOURS 2000-400

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.0	0.048	0.952
AUG	71	0.0	0.0	1.000
SEP	71	0.004	0.006	0.989
OCT	71	0.099	0.288	0.613
NOV	71	0.181	0.105	0.714
DEC	71	0.050	0.043	0.906
JAN	72	0.529	0.238	0.233
FEB	72	0.279	0.285	0.436
MAR	72	0.171	0.468	0.361
APR	72	0.416	0.253	0.331
MAY	72	0.153	0.405	0.442
JUN	72	0.234	0.037	0.728

TABLE 8

Site 5

PERCENT COVERAGE

Jul	0.268
Aug	1.000
Sept	1.000
Oct	0.971
Nov	0.879
Dec	0.876
Jan	0.580
Feb	0.704
Mar	0.903
Apr	0.842
May	0.957
Jun	0.764

OVERALL COVERAGE = 0.812

Fractional Time Below 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.155
1200-2000	.075
2000-0400	.165
0000-2400	.131

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

Fractional Time Above 5 x 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.690
1200-2000	.746
2000-0400	.657
0000-2400	.698

TABLE 9

SITE 06

HOURS 400-1200

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.002	0.0	0.998
AUG	71	0.110	0.021	0.869
SEP	71	0.020	0.047	0.933
OCT	71	0.059	0.166	0.774
NOV	71	0.022	0.215	0.763
DEC	71	0.039	0.198	0.763
JAN	72	0.051	0.288	0.661
FEB	72	0.099	0.272	0.628
MAR	72	0.003	0.342	0.655
APR	72	0.057	0.104	0.839
MAY	72	0.038	0.126	0.836
JUN	72	0.0	0.004	0.996

SITE 06

HOURS 1200-2000

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.0	0.0	1.000
AUG	71	0.026	0.096	0.878
SEP	71	0.006	0.061	0.933
OCT	71	0.015	0.074	0.910
NOV	71	0.0	0.100	0.900
DEC	71	0.012	0.112	0.875
JAN	72	0.032	0.265	0.703
FEB	72	0.007	0.155	0.838
MAR	72	0.001	0.077	0.921
APR	72	0.0	0.053	0.947
MAY	72	0.032	0.029	0.939
JUN	72	0.002	0.002	0.995

SITE 06

HOURS 2000-400

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.0	0.006	0.994
AUG	71	0.145	0.008	0.847
SEP	71	0.020	0.025	0.956
OCT	71	0.004	0.182	0.814
NOV	71	0.008	0.273	0.720
DEC	71	0.036	0.252	0.713
JAN	72	0.088	0.218	0.694
FEB	72	0.091	0.304	0.604
MAR	72	0.004	0.336	0.660
APR	72	0.034	0.095	0.872
MAY	72	0.049	0.064	0.887
JUN	72	0.002	0.003	0.994

TABLE 10

Site 6

PERCENT COVERAGE

Jul	1.000
Aug	0.846
Sep	0.696
Oct	0.850
Nov	0.913
Dec	0.952
Jan	0.992
Feb	0.923
Mar	0.926
Apr	0.918
May	0.964
June	1.000

OVERALL COVERAGE = 0.915

Fractional Time Below 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.041
1200-2000	.010
2000-0400	.039
0000-2400	.030

Fractional Time Above 5 x 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.813
1200-2000	.909
2000-0400	.817
0000-2400	.846

TABLE 11

SITE C7

HOURS 400-1200

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.358	0.351	0.291
AUG	71	0.343	0.399	0.258
SEP	71	0.290	0.323	0.387
OCT	71	0.379	0.259	0.362
NOV	71	0.000	0.000	1.000
DEC	71	0.429	0.268	0.303
JAN	72	0.231	0.232	0.537
FEB	72	0.143	0.078	0.779
MAR	72	0.519	0.078	0.403
APR	72	0.253	0.185	0.562
MAY	72	0.296	0.159	0.545
JUN	72	0.167	0.157	0.676

SITE 07

HOURS 1200-2000

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.134	0.413	0.453
AUG	71	0.153	0.333	0.514
SEP	71	0.120	0.254	0.627
OCT	71	0.091	0.331	0.578
NOV	71	1.000	0.000	-.000
DEC	71	0.281	0.304	0.415
JAN	72	0.111	0.274	0.615
FEB	72	0.073	0.066	0.861
MAR	72	0.410	0.230	0.360
APR	72	0.124	0.171	0.705
MAY	72	0.184	0.141	0.676
JUN	72	0.052	0.106	0.842

SITE C7

HOURS 2000-400

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.370	0.427	0.203
AUG	71	0.357	0.377	0.266
SEP	71	0.320	0.320	0.360
OCT	71	0.254	0.306	0.440
NOV	71	0.833	0.167	-.000
DEC	71	0.337	0.277	0.386
JAN	72	0.175	0.309	0.516
FEB	72	0.108	0.075	0.817
MAR	72	0.540	0.151	0.309
APR	72	0.242	0.186	0.572
MAY	72	0.360	0.087	0.553
JUN	72	0.243	0.165	0.592

TABLE 12

Site 7

PERCENT COVERAGE

Jul	0.899
Aug	0.735
Sept	0.818
Oct	0.690
Nov	0.008
Dec	0.859
Jan	0.804
Feb	1.000
Mar	0.599
Apr	0.831
May	0.945
June	0.471

OVERALL COVERAGE = 0.722

Fractional Time <u>Below</u> 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.295
1200-2000	.153
2000-0400	.288
0000-2400	.244

Fractional Time <u>Above</u> 5×10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.484
1200-2000	.618
2000-0400	.477
0000-2400	.527

TABLE 13

SITE 08

HOURS 400-1200

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
SEP	71	0.0	0.313	0.688
OCT	71	0.253	0.200	0.547
NOV	71	0.050	0.100	0.850
DEC	71	0.023	0.012	0.965
JAN	72	0.121	0.071	0.809
FEB	72	0.495	0.167	0.338
MAR	72	0.094	0.039	0.867
APR	72	0.218	0.118	0.663
MAY	72	0.382	0.299	0.320
JUN	72	0.131	0.438	0.430

SITE 08

HOURS 1200-2000

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
SEP	71	0.070	0.163	0.767
OCT	71	0.120	0.408	0.472
NOV	71	0.164	0.027	0.808
DEC	71	0.083	0.021	0.896
JAN	72	0.090	0.085	0.826
FEB	72	0.267	0.452	0.282
MAR	72	0.057	0.052	0.891
APR	72	0.117	0.189	0.694
MAY	72	0.097	0.353	0.549
JUN	72	0.042	0.373	0.585

SITE 08

HOURS 2000-400

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
SEP	71	0.046	0.508	0.446
OCT	71	0.187	0.193	0.620
NOV	71	0.208	0.181	0.611
DEC	71	0.058	0.024	0.918
JAN	72	0.060	0.073	0.867
FEB	72	0.429	0.132	0.439
MAR	72	0.113	0.020	0.868
APR	72	0.378	0.060	0.562
MAY	72	0.483	0.164	0.353
JUN	72	0.246	0.528	0.226

TABLE 14

SITE 8

PERCENT COVERAGE

Sept	0.056
Oct	0.187
Nov	0.167
Dec	0.414
Jan	0.529
Feb	0.568
Mar	0.606
Apr	0.539
May	0.850
Jun	0.653

OVERALL COVERAGE = 0.381

Fractional Time Below 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.186
1200-2000	.098
2000-0400	.221
0000-2400	.168

Fractional Time Above 5 x 10^{-7} w/cm^2/ster.

HOURS	VALUE
0400-1200	.669
1200-2000	.722
2000-0400	.651
0000-2400	.681

TABLE 15

SITE 11

HOURS 400-1200

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.084	0.305	0.611
SEP	71	0.240	0.280	0.480
OCT	71	0.490	0.142	0.368
NOV	71	0.066	0.158	0.776
JAN	72	1.000	0.0	0.0
MAR	72	0.396	0.130	0.474
APR	72	0.082	0.195	0.723
MAY	72	0.365	0.161	0.474
JUN	72	0.327	0.276	0.397

SITE 11

HOURS 1200-2000

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.0	0.052	0.948
SEP	71	0.0	0.0	1.000
OCT	71	0.336	0.302	0.362
NOV	71	0.108	0.432	0.459
JAN	72	1.000	0.0	0.0
MAR	72	0.141	0.310	0.549
APR	72	0.058	0.164	0.778
MAY	72	0.044	0.190	0.766
JUN	72	0.015	0.131	0.854

SITE 11

HOURS 2000-400

MONTH	YEAR	NOISE<.10	.10<NOISE<.50	.50<NOISE
JUL	71	0.021	0.288	0.691
SEP	71	0.500	0.500	0.0
OCT	71	0.619	0.119	0.262
NOV	71	0.317	0.150	0.533
JAN	72	1.000	0.0	0.0
MAR	72	0.407	0.102	0.491
APR	72	0.064	0.125	0.812
MAY	72	0.259	0.131	0.609
JUN	72	0.210	0.293	0.497

Fractional Time <u>Below</u> $10^{-7} w/cm^2/ster.$

HOURS	VALUE
0400–1200	.276
1200–2000	.069
2000–0400	.234
0000–2400	.193

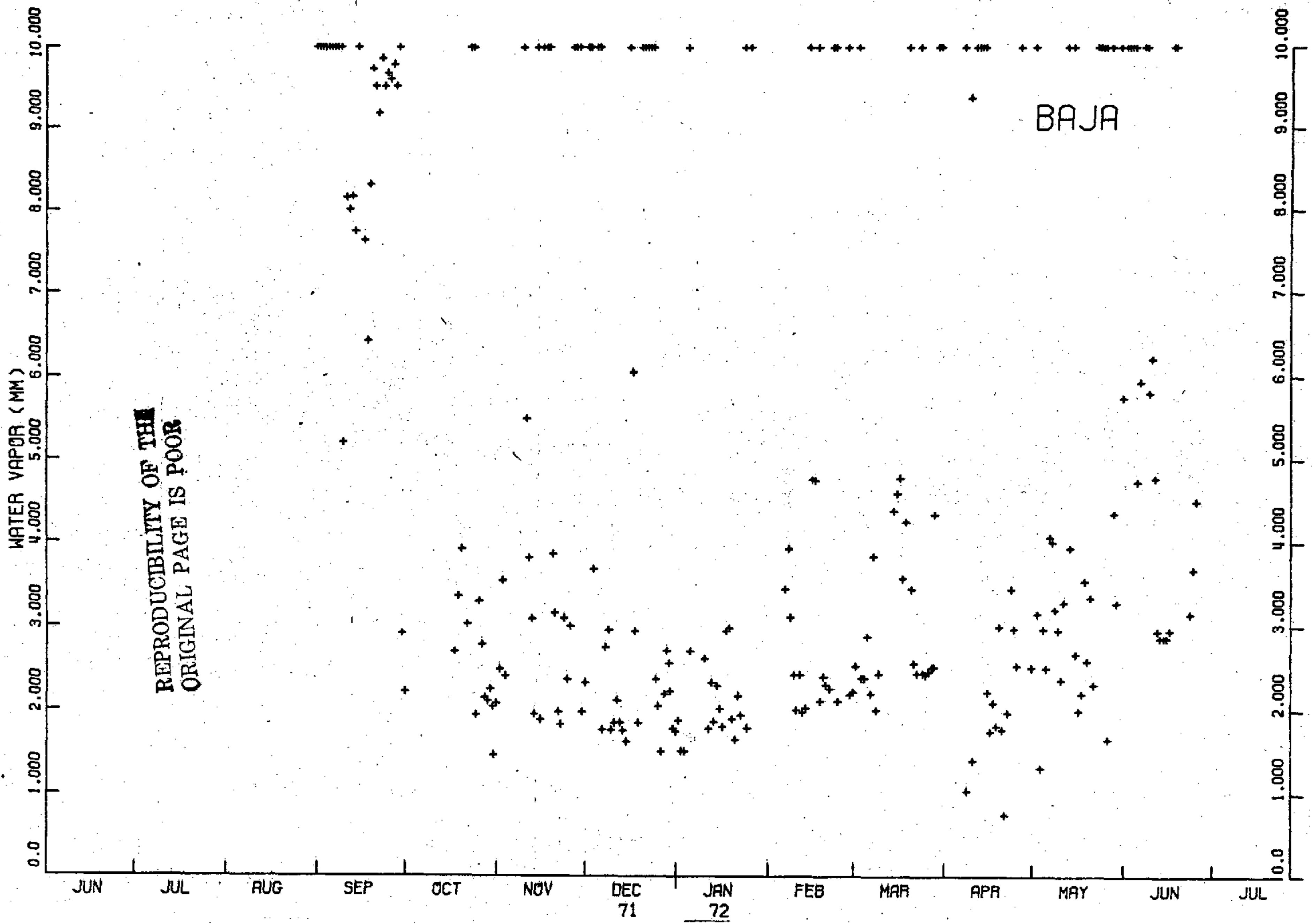
PERCENT COVERAGE

July	0.710
Sept	0.011
Oct	0.338
Nov	0.070
Jan	0.021
Mar	0.250
Apr	0.382
May	0.638
June	0.601

OVERALL COVERAGE = 0.252

Fractional Time <u>Above</u> $5 \times 10^{-7} w/cm^2/ster.$

HOURS	VALUE
0400–1200	.507
1200–2000	.766
2000–0400	.571
0000–2400	.616


BAJA
WATER VAPOR (MM)
0.0
1.000
2.000
3.000
4.000
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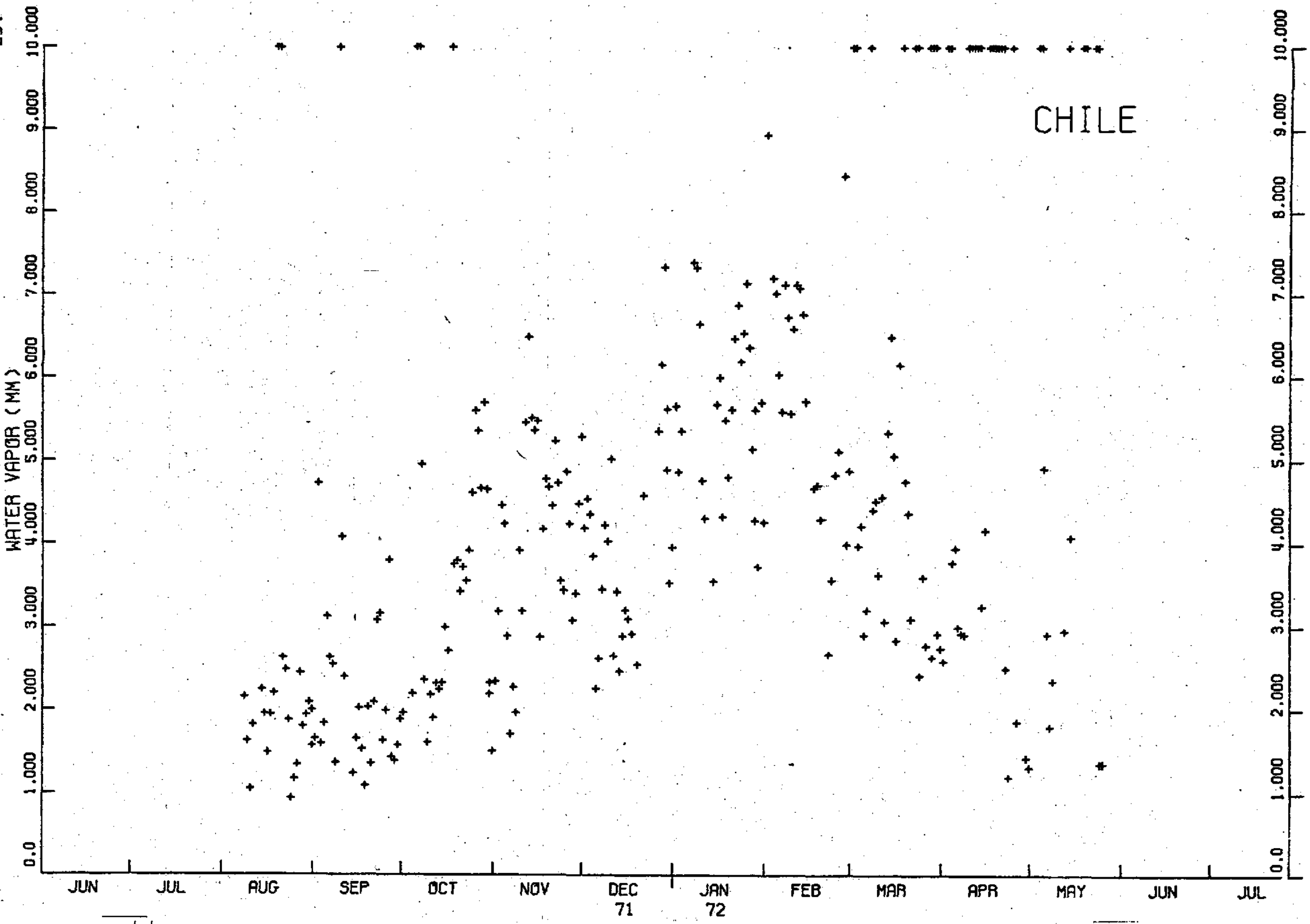
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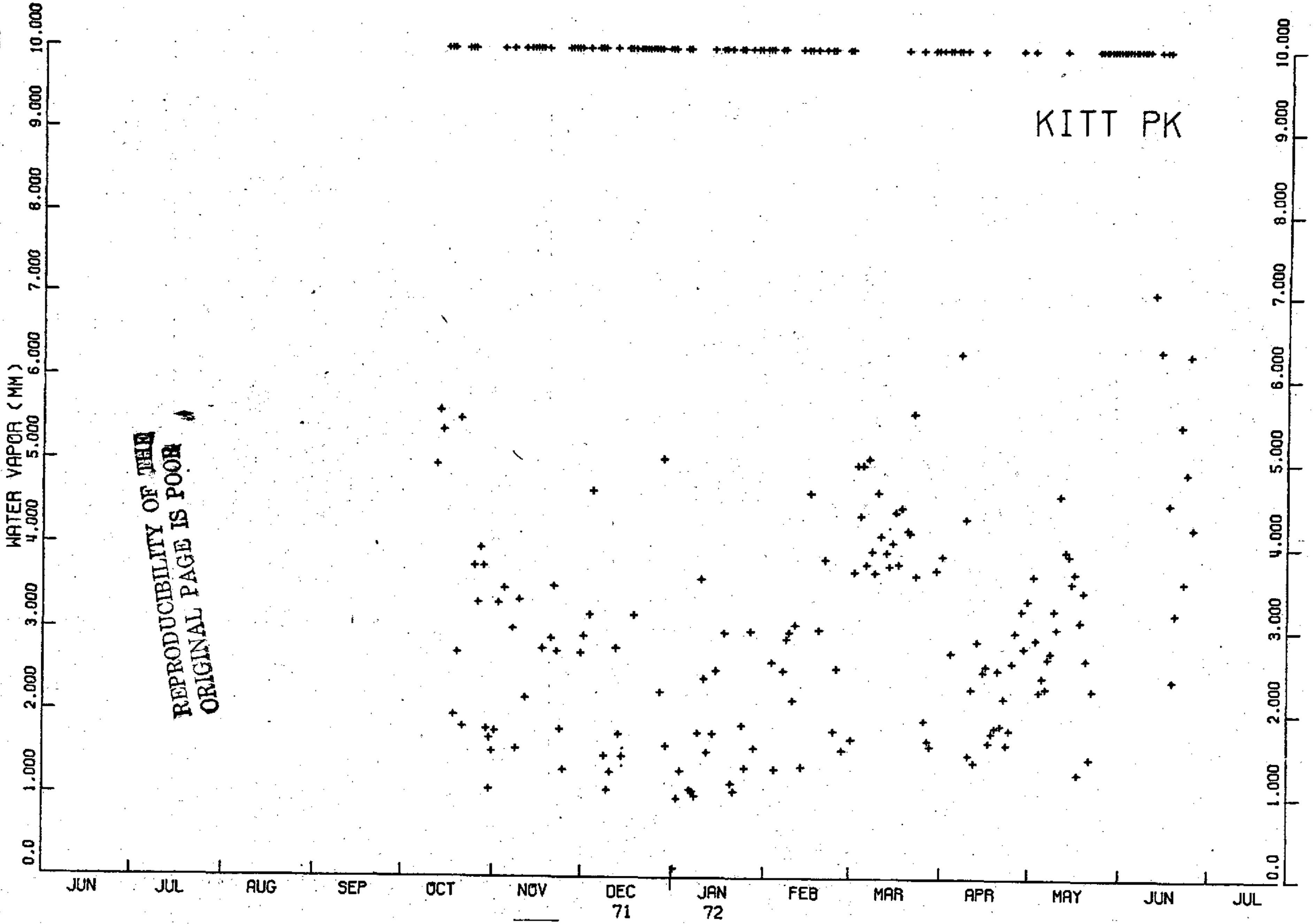
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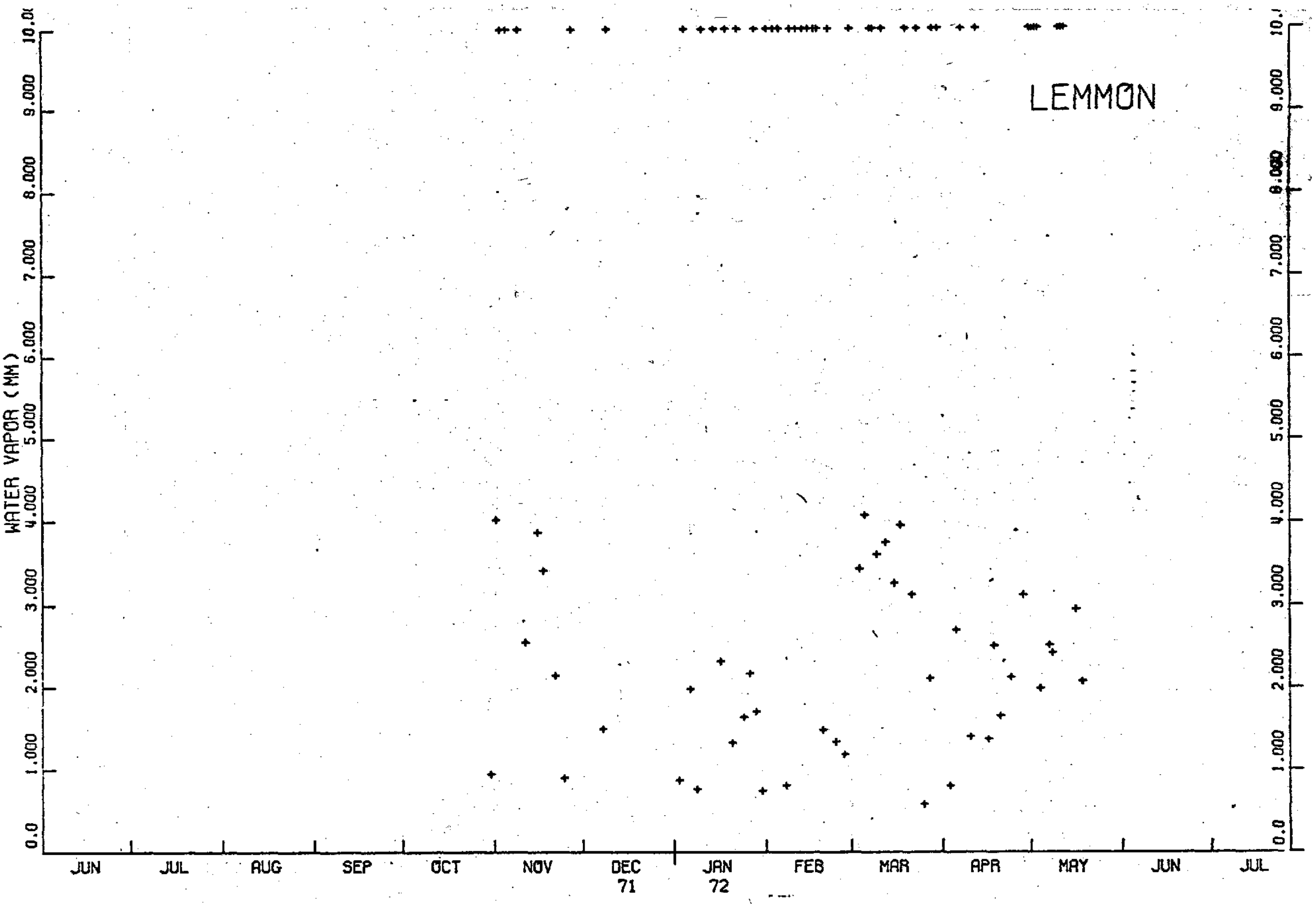
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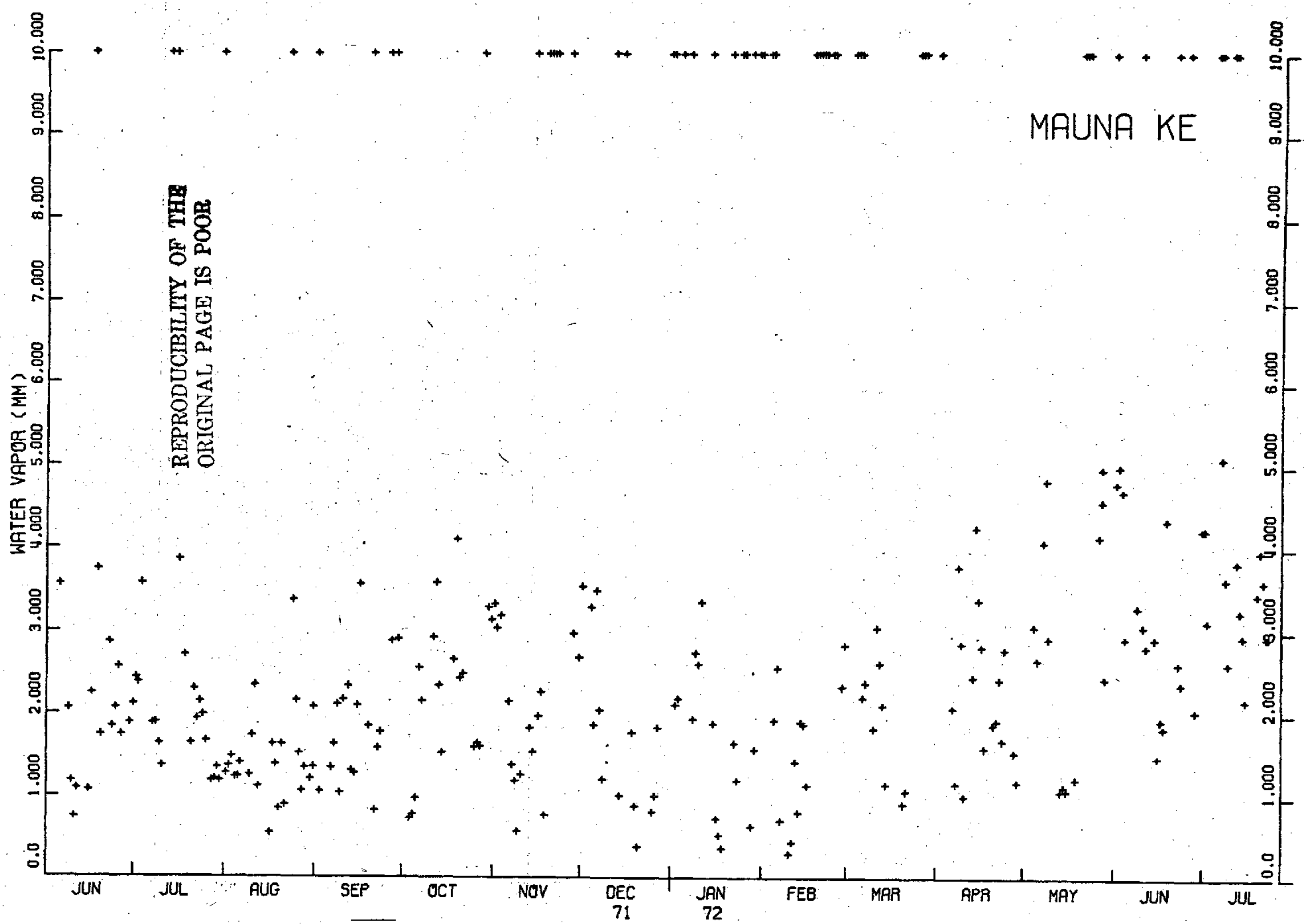
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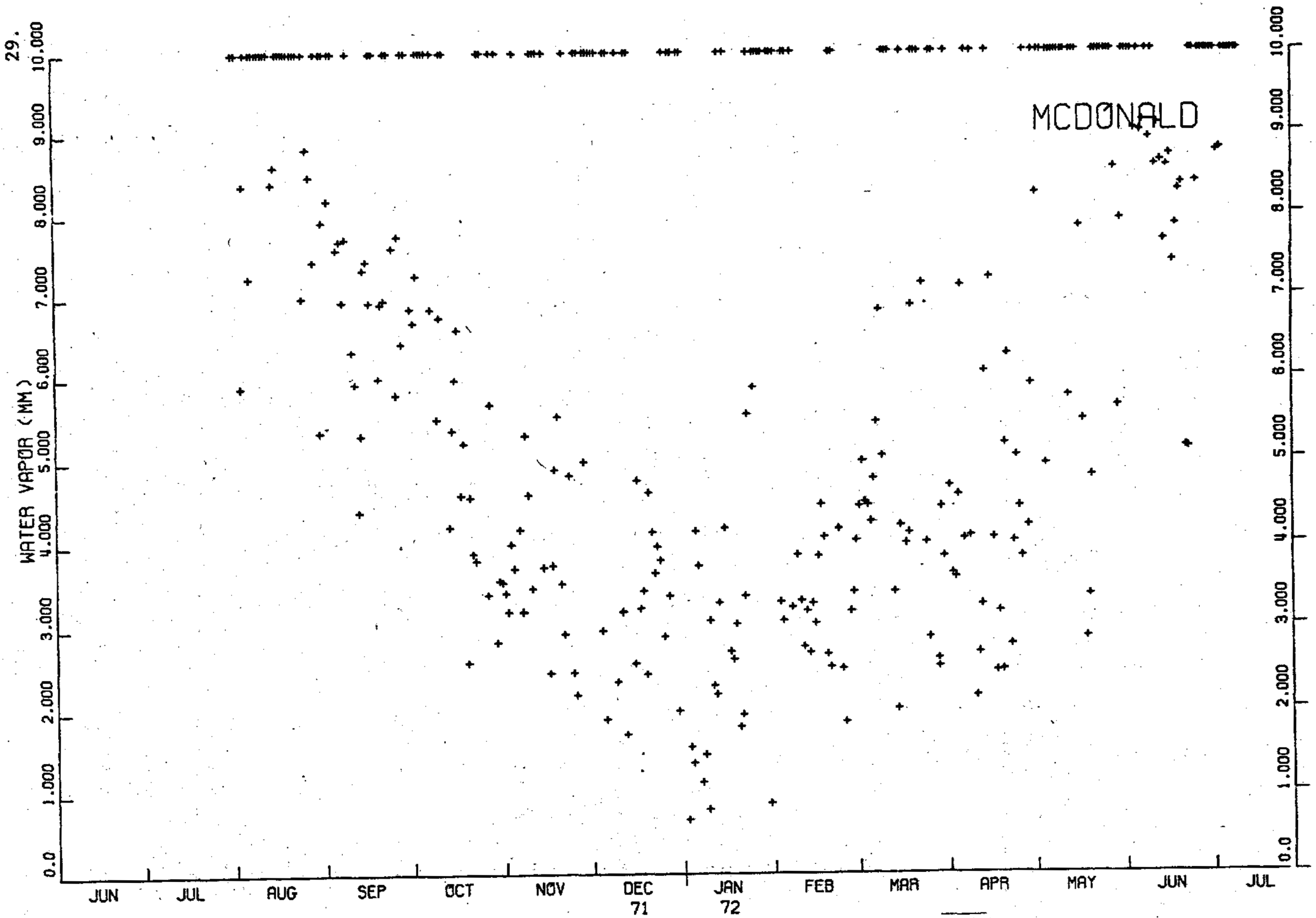
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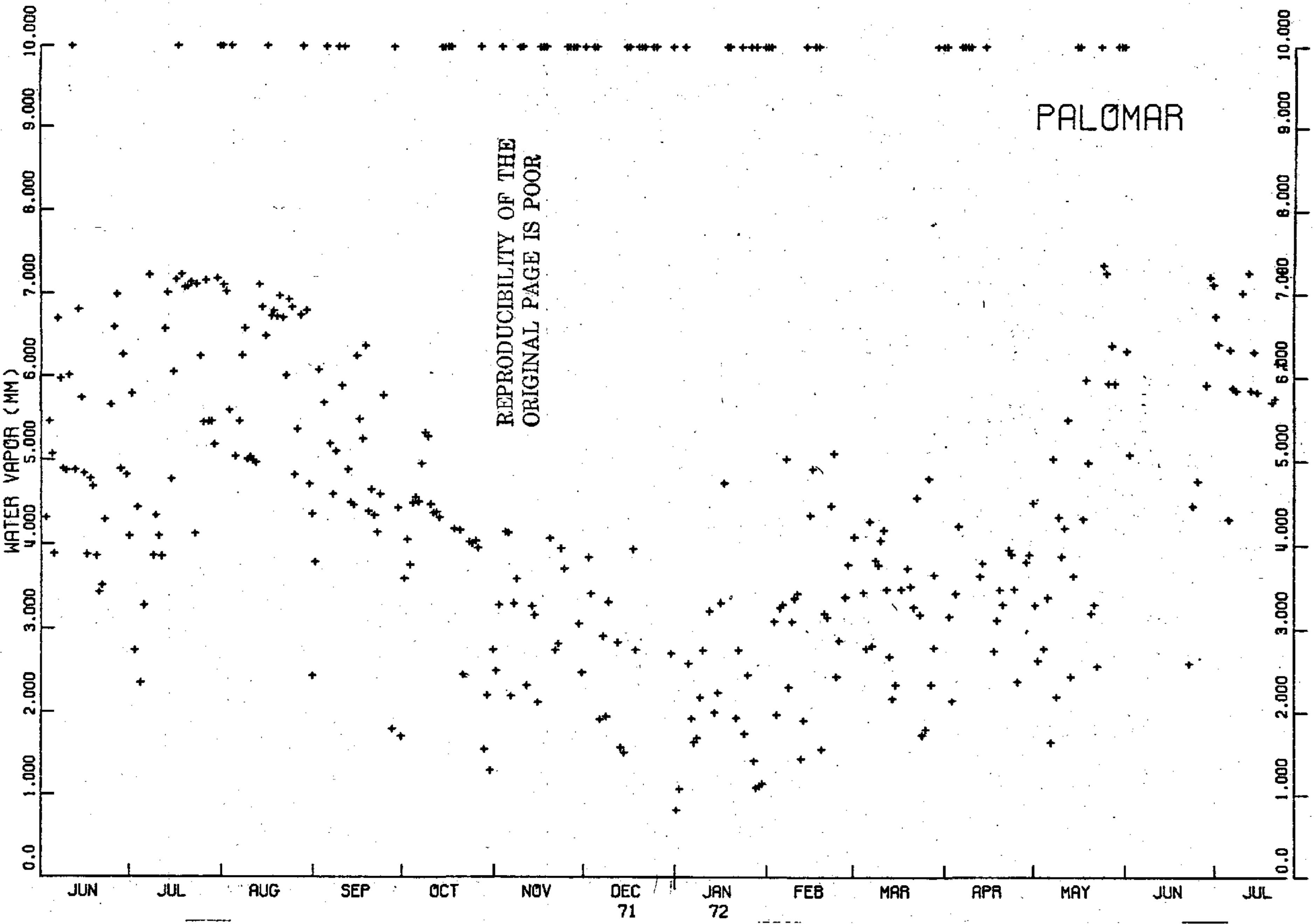
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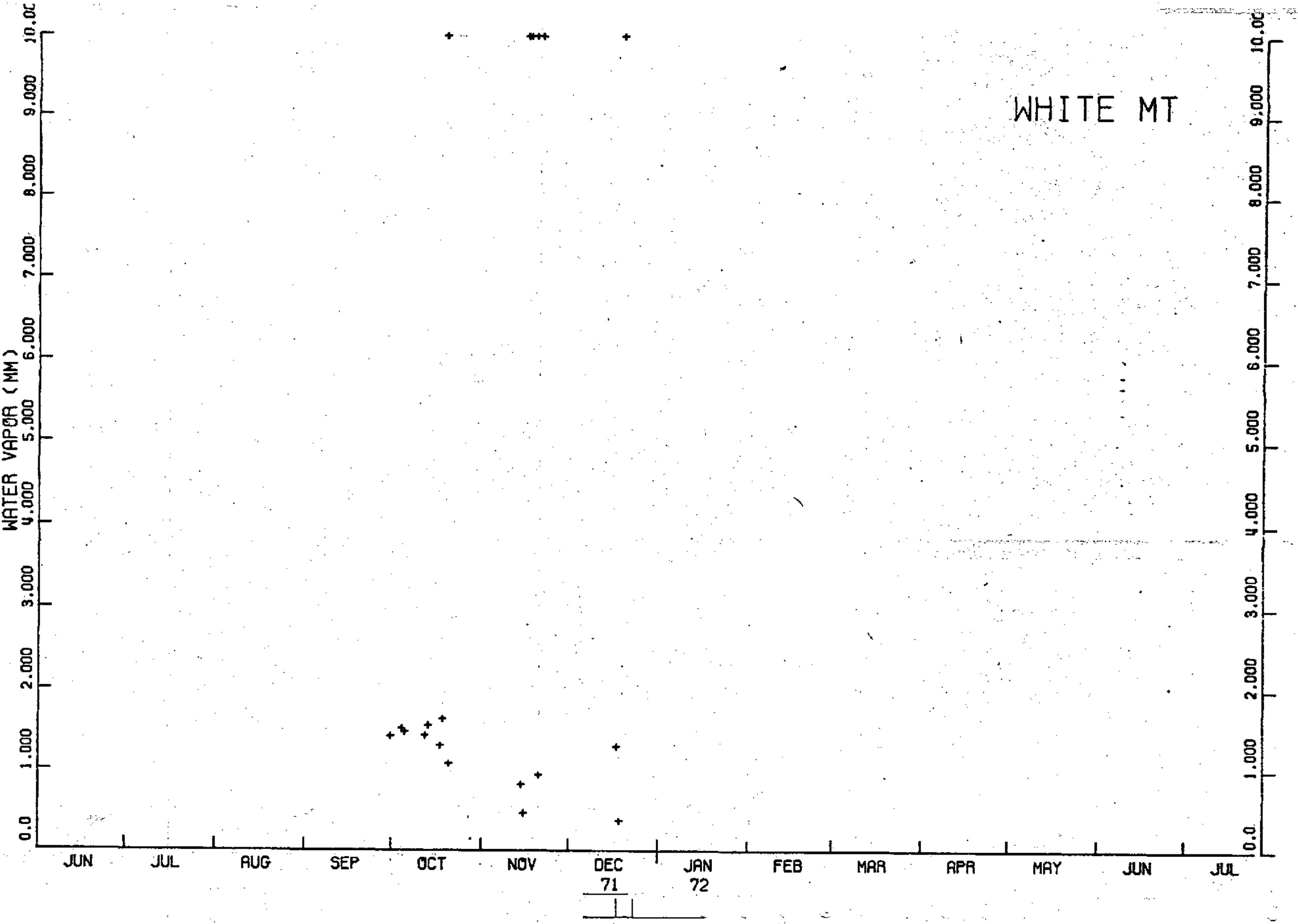
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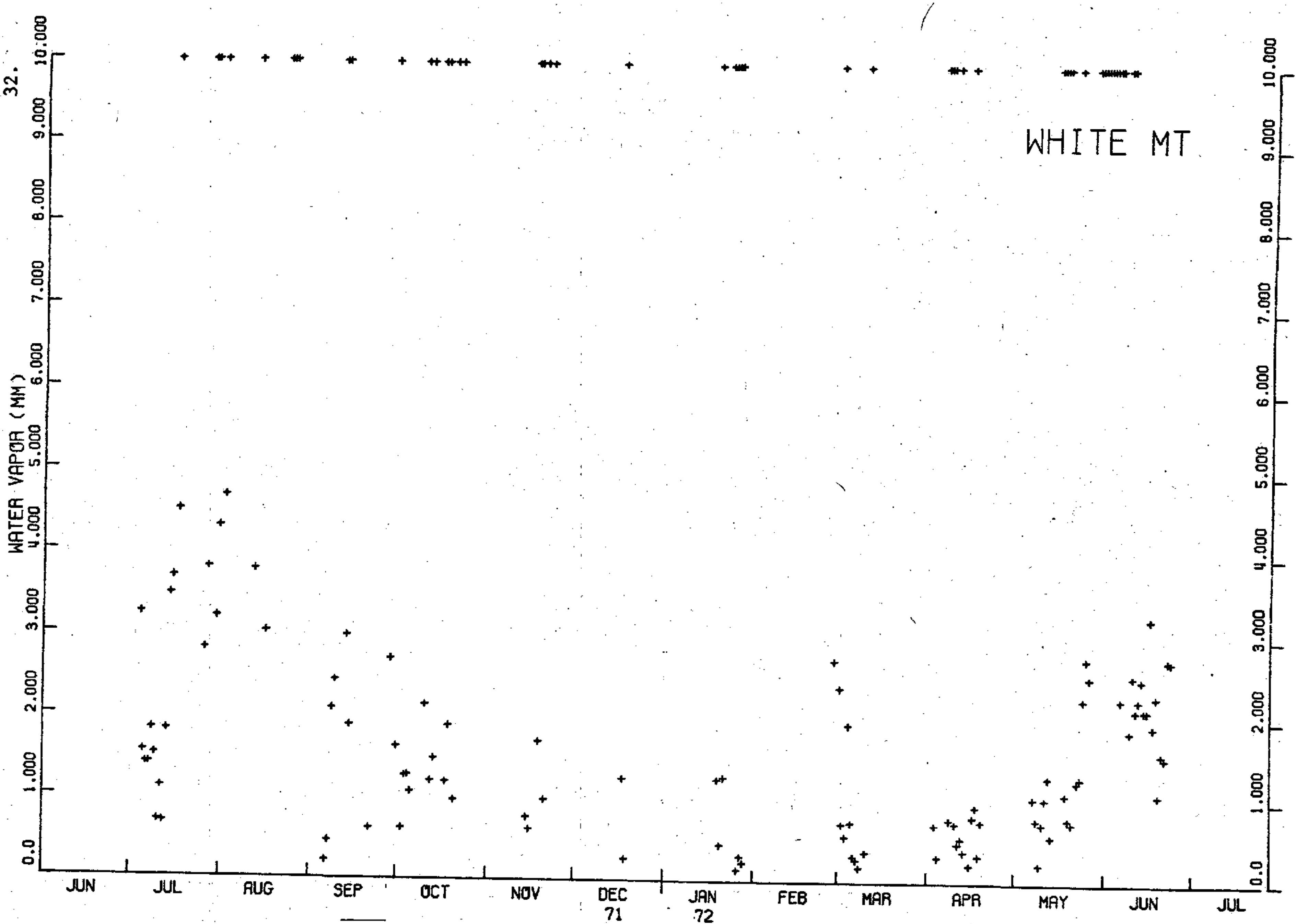
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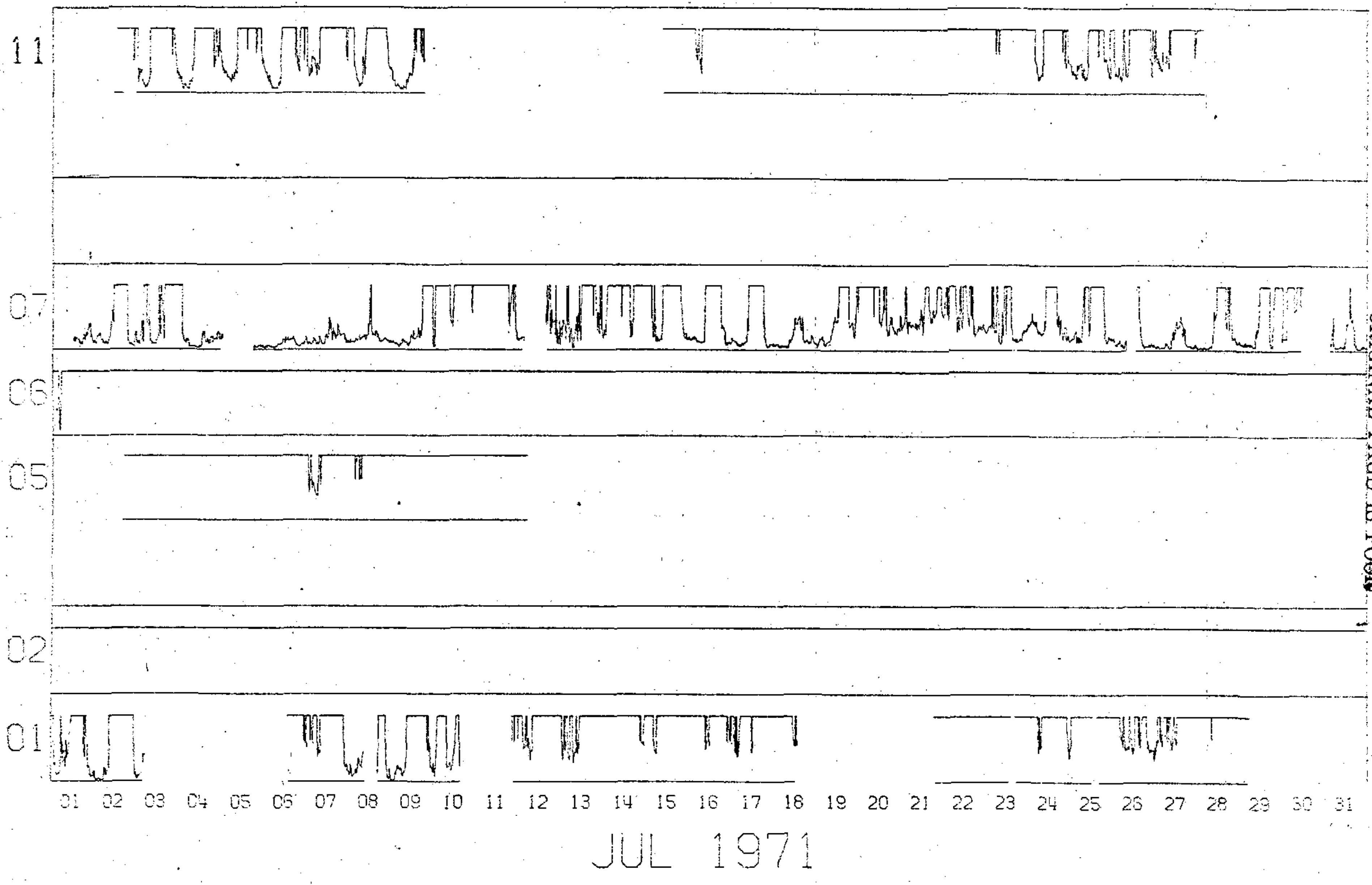
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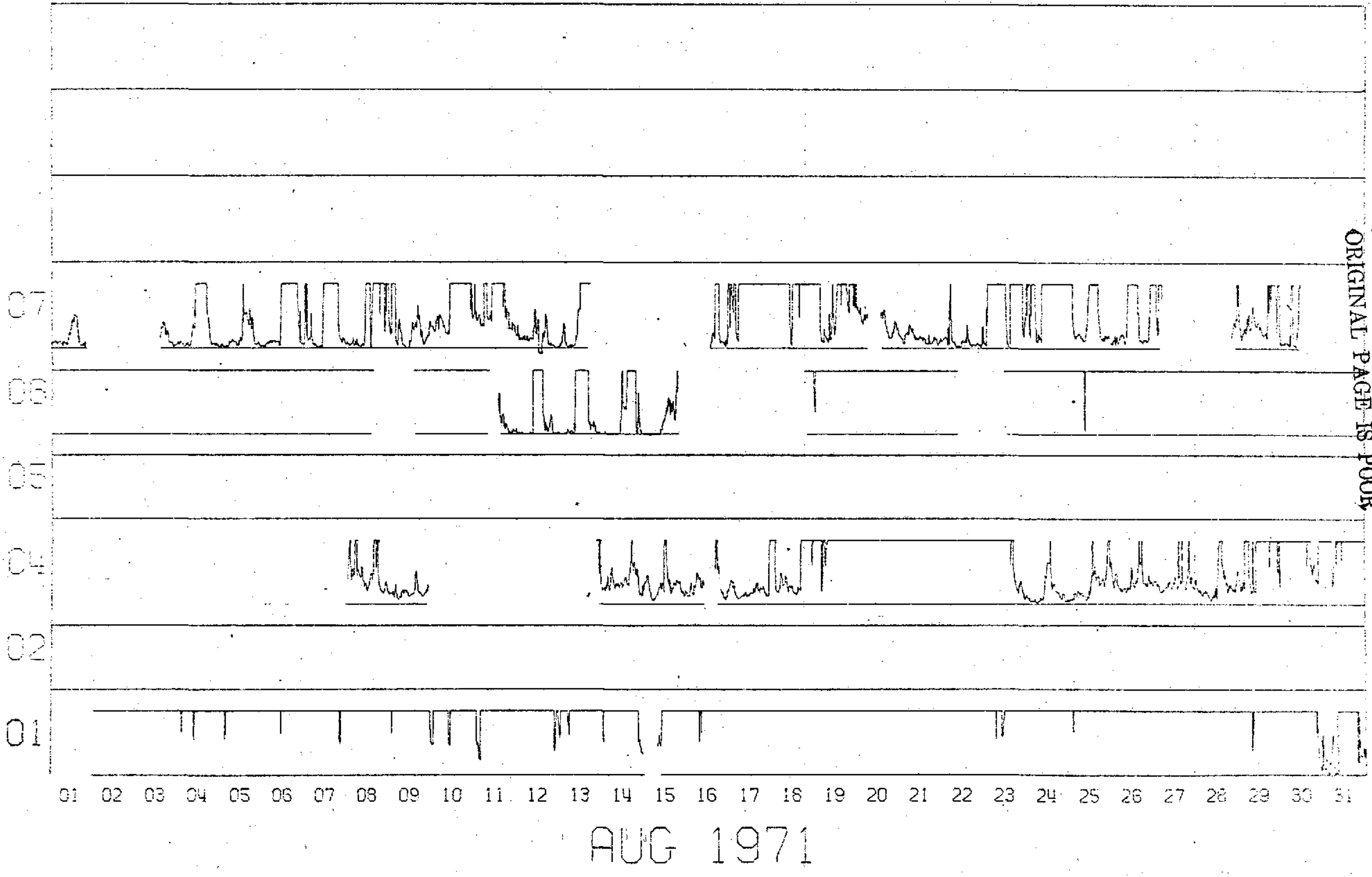

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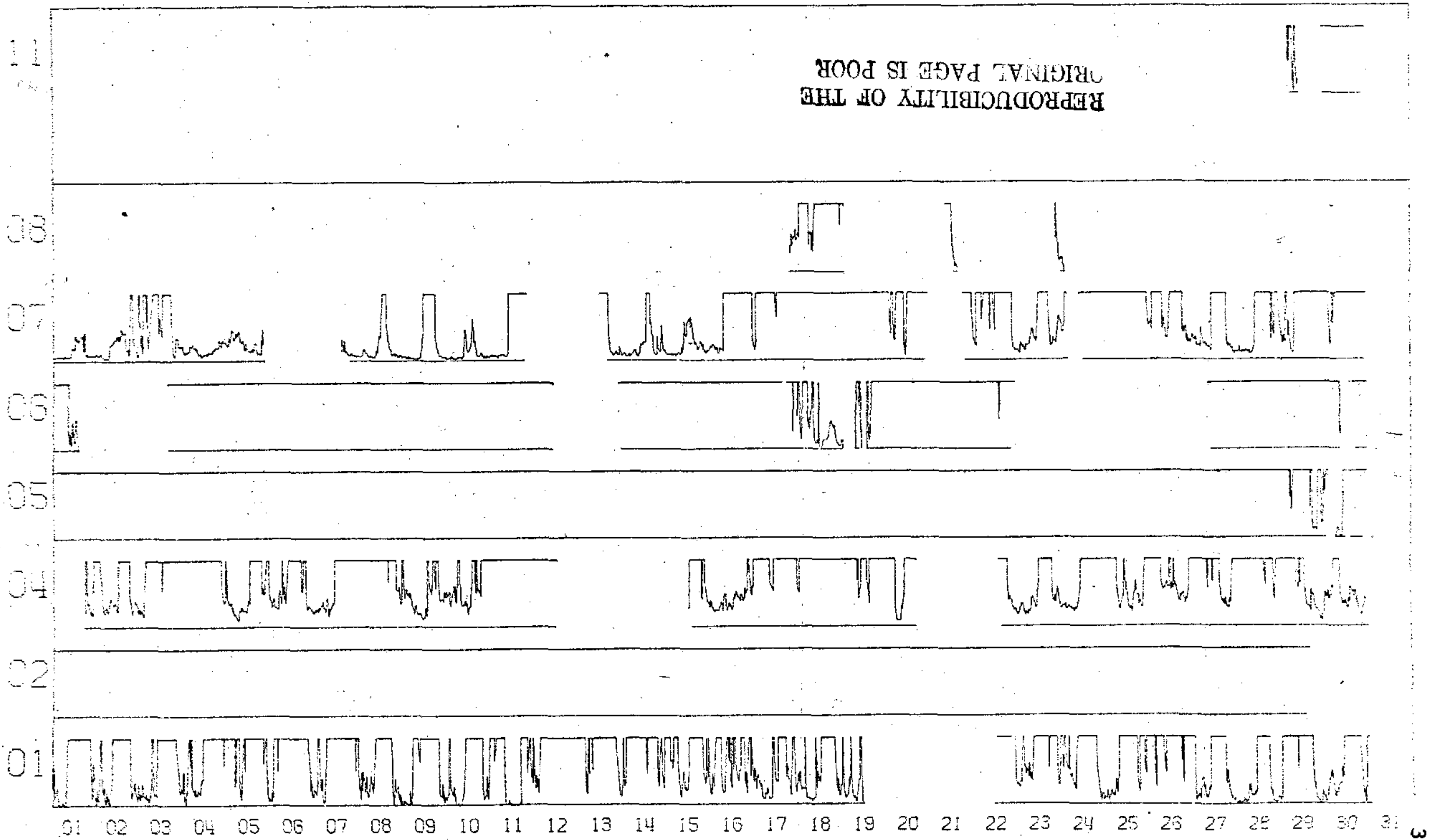
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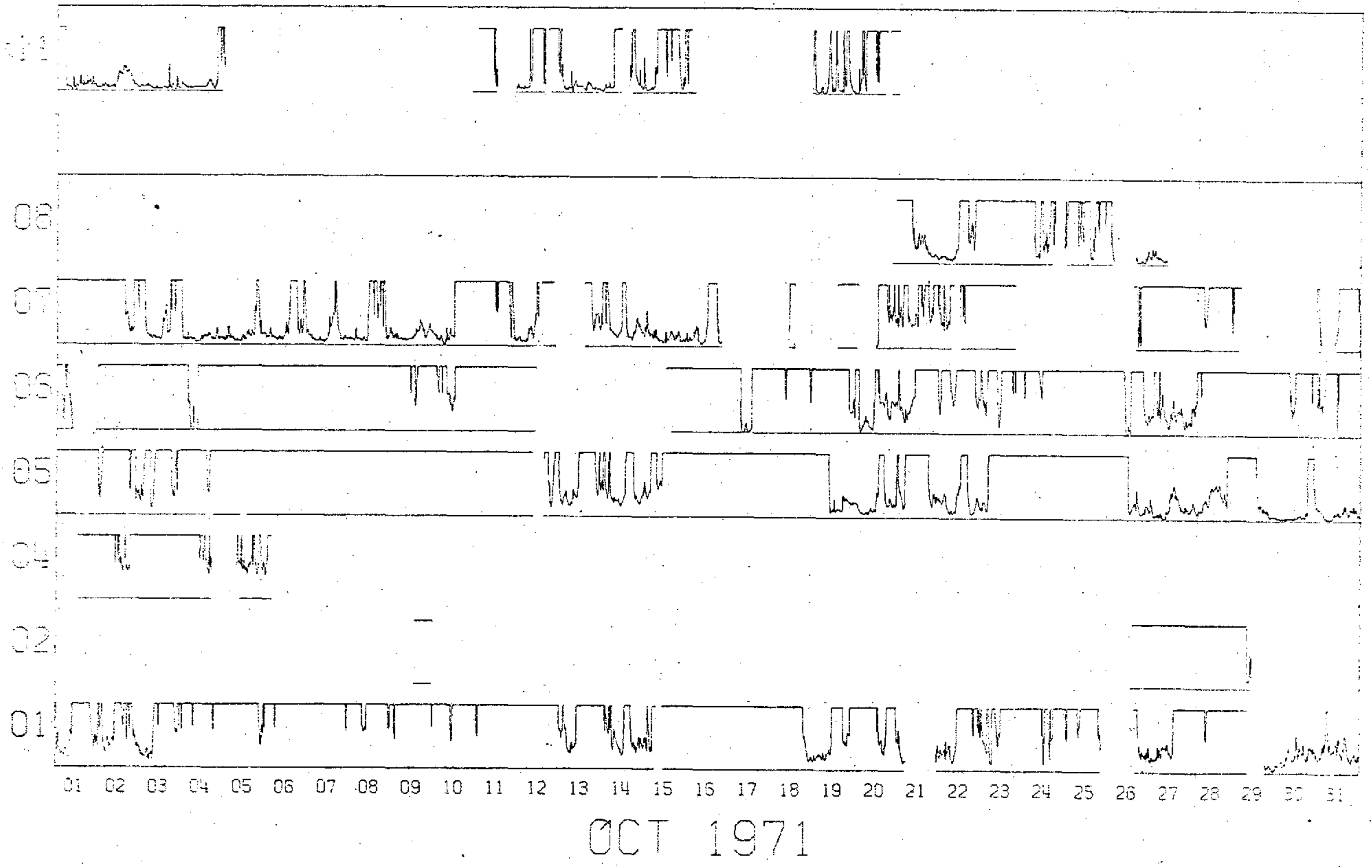
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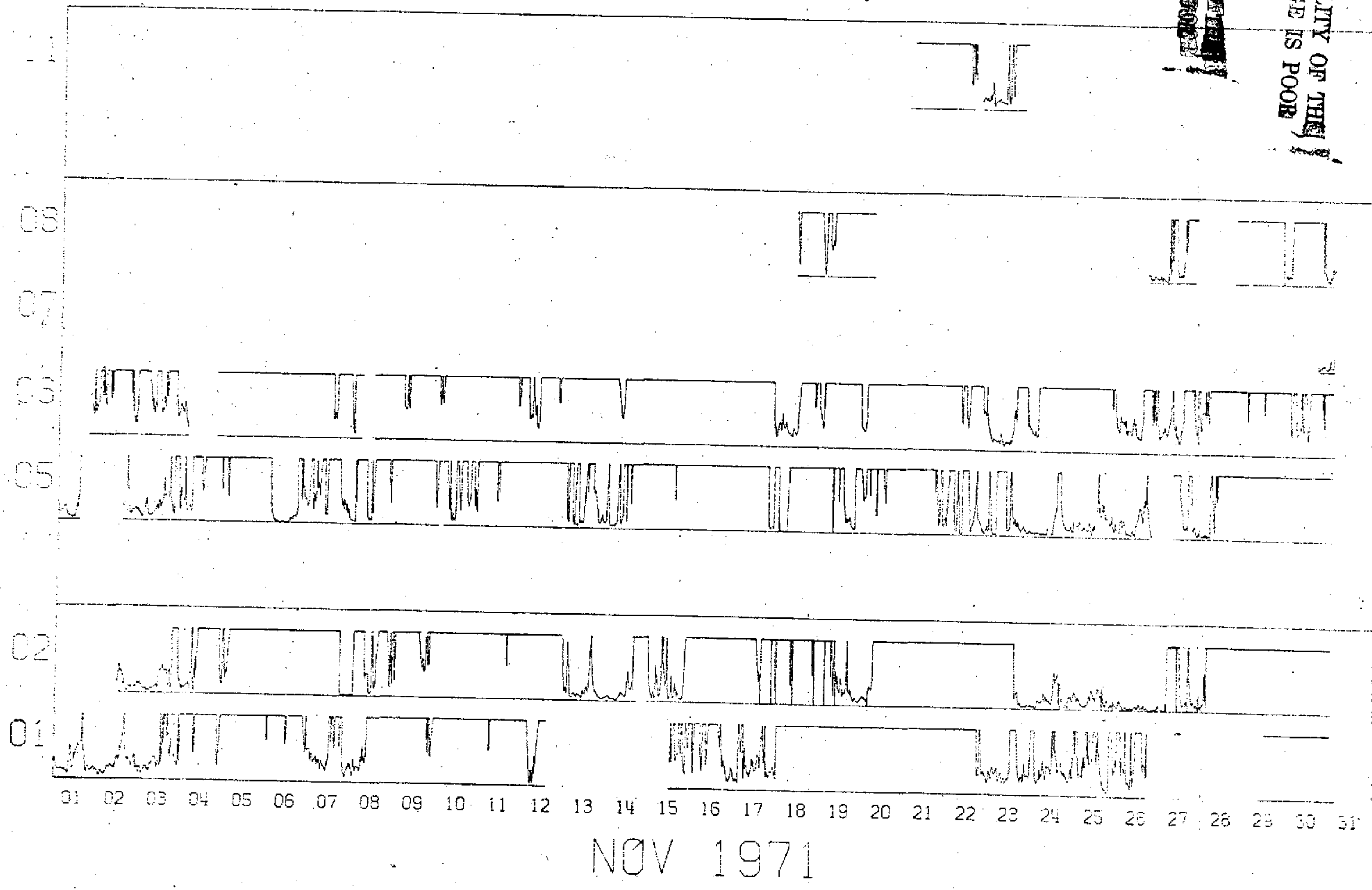
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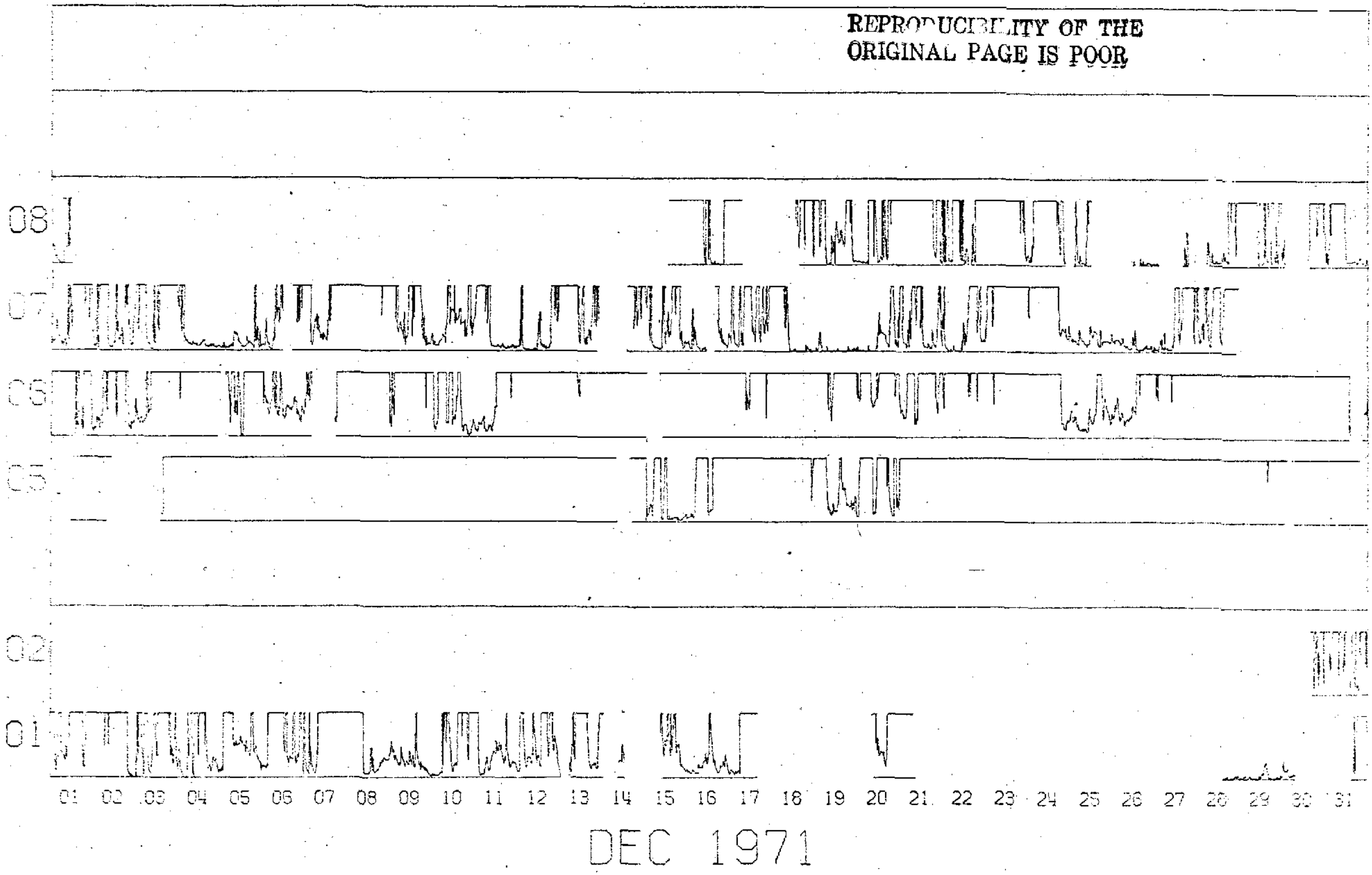
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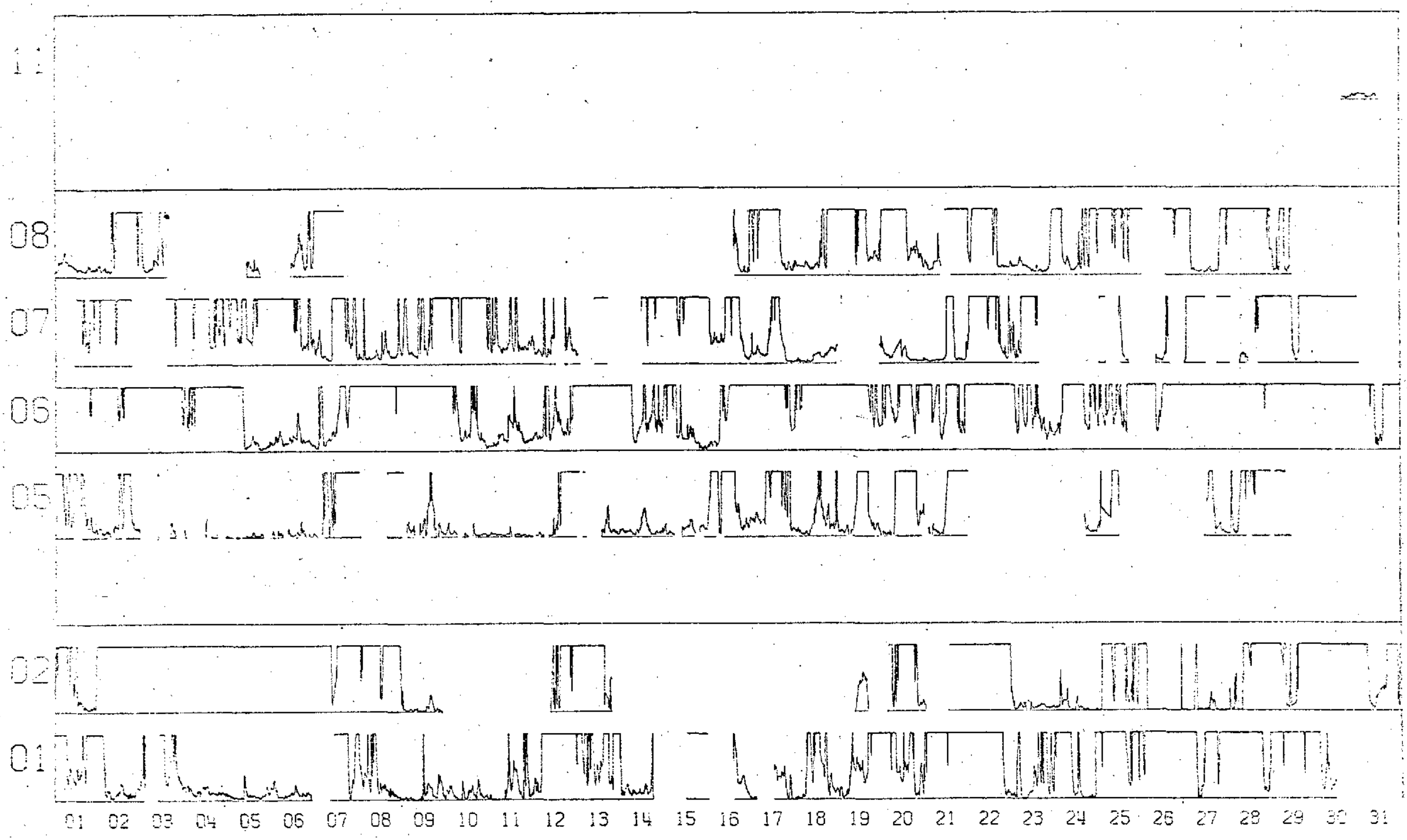
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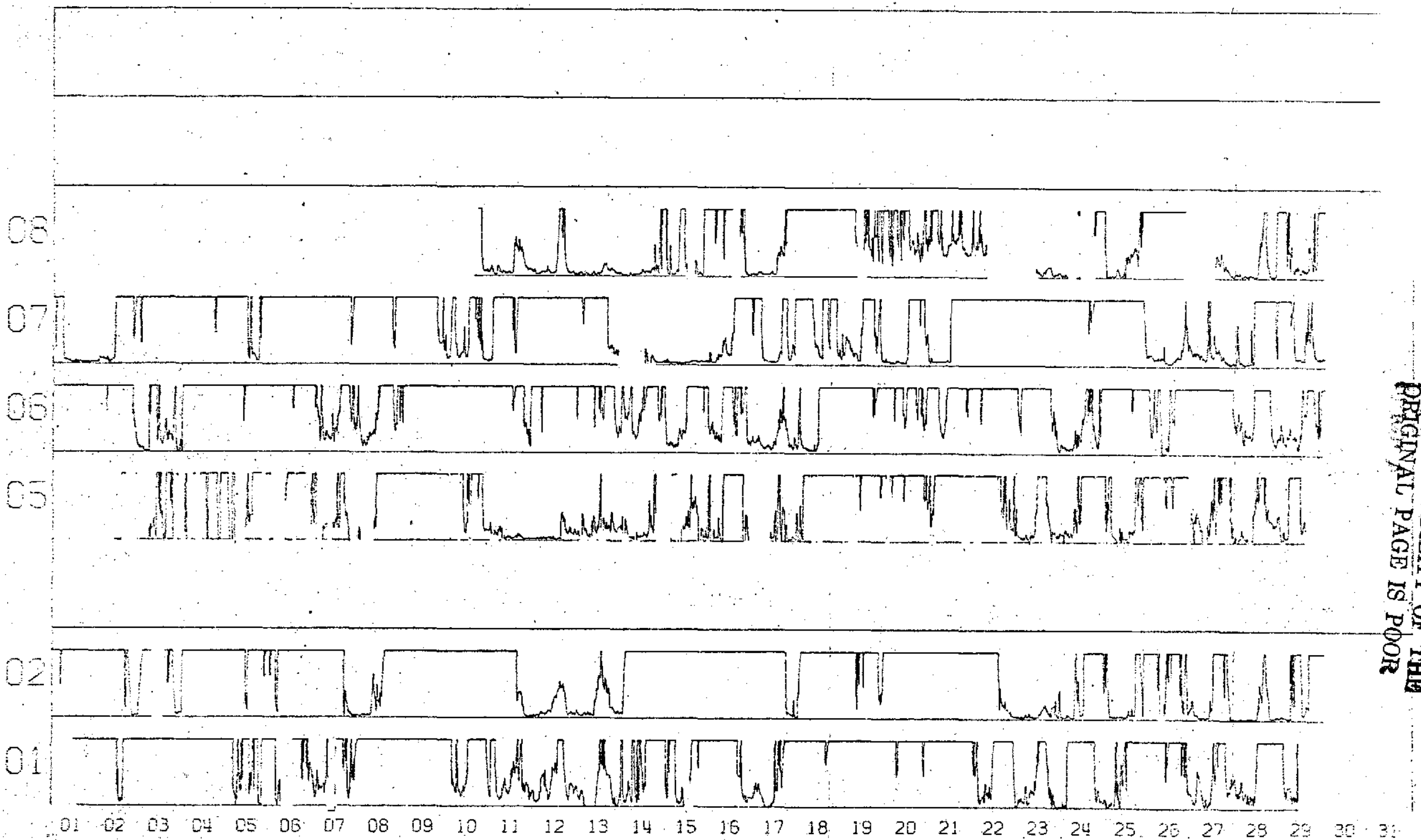
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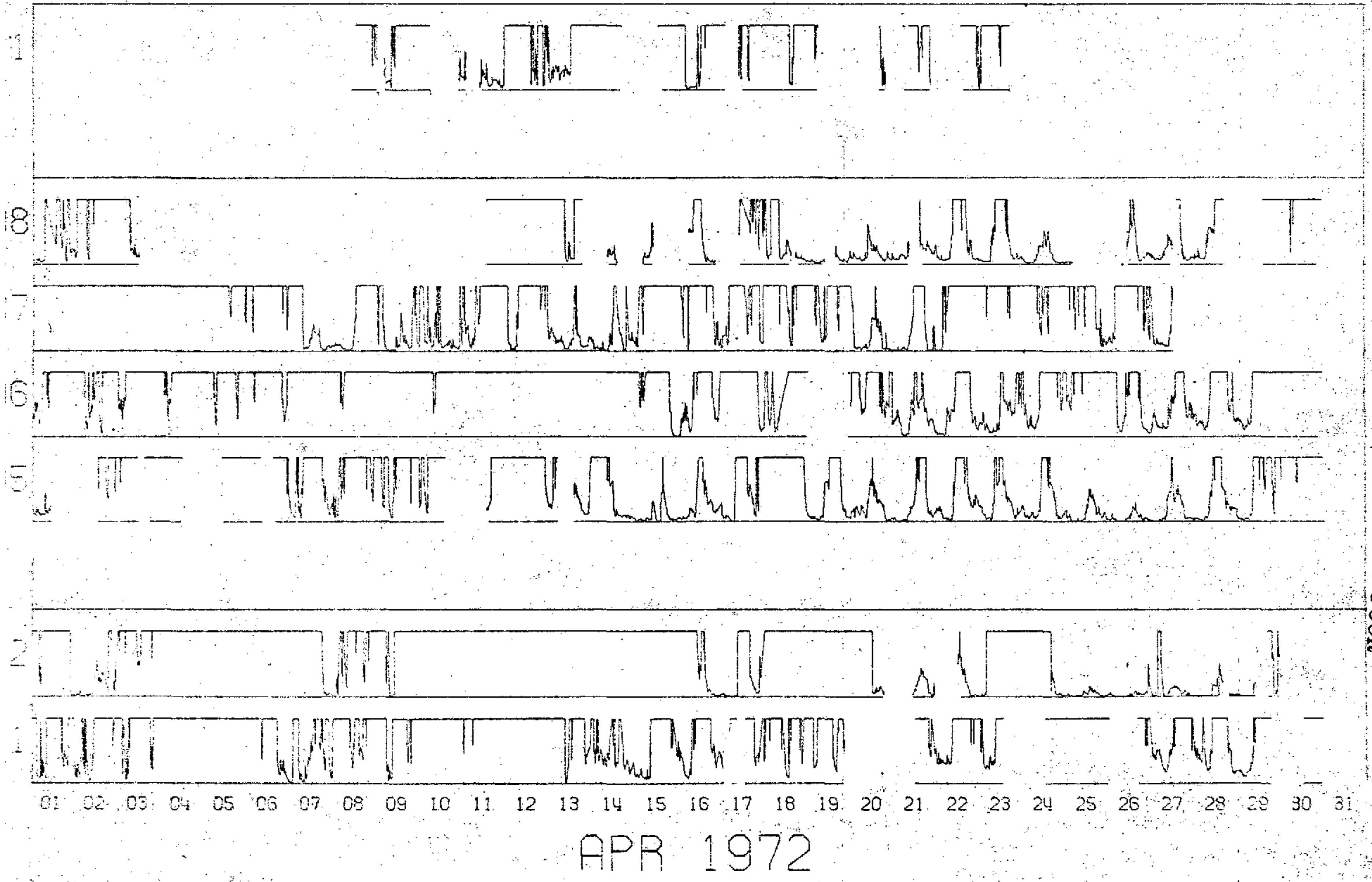
MAR 1972



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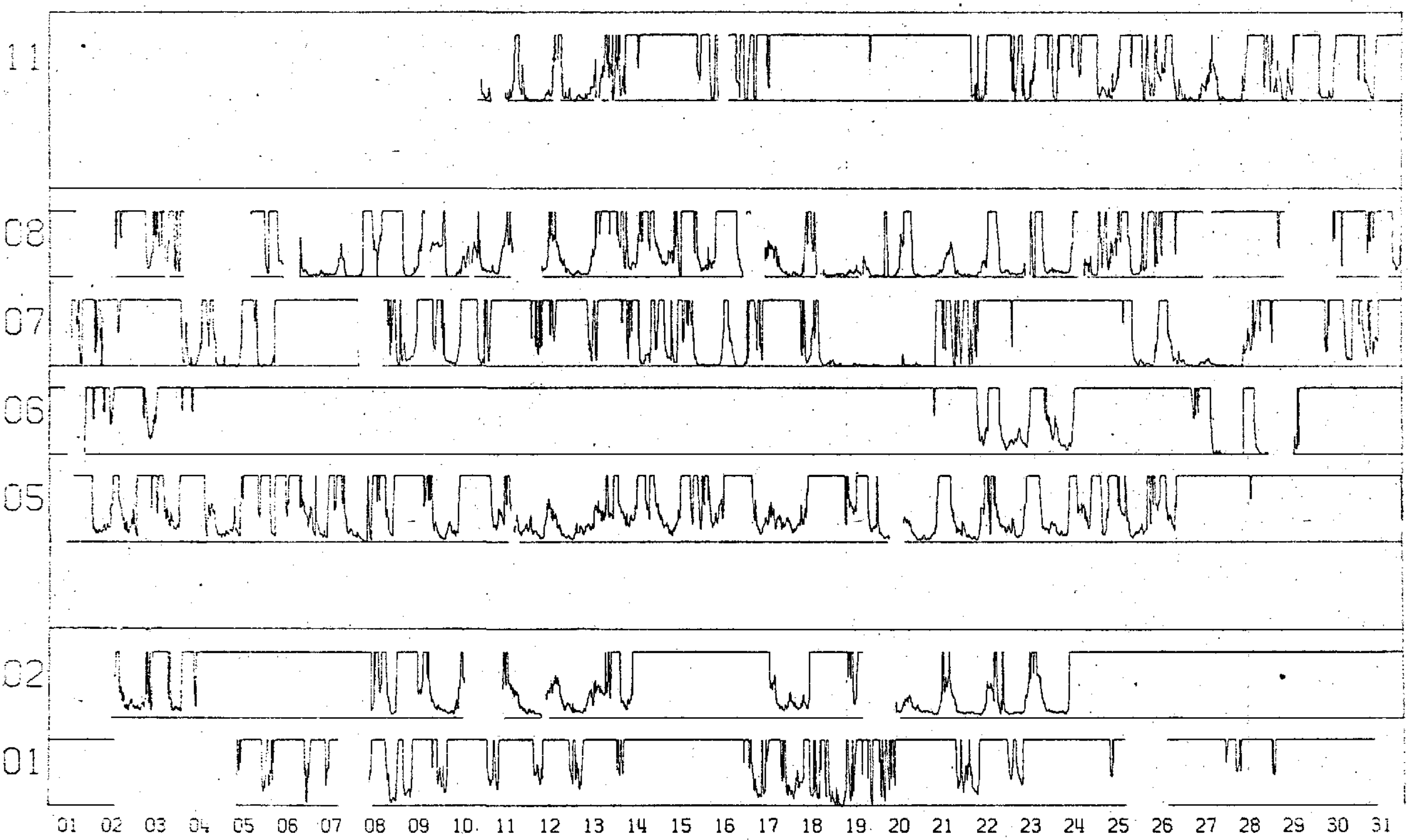
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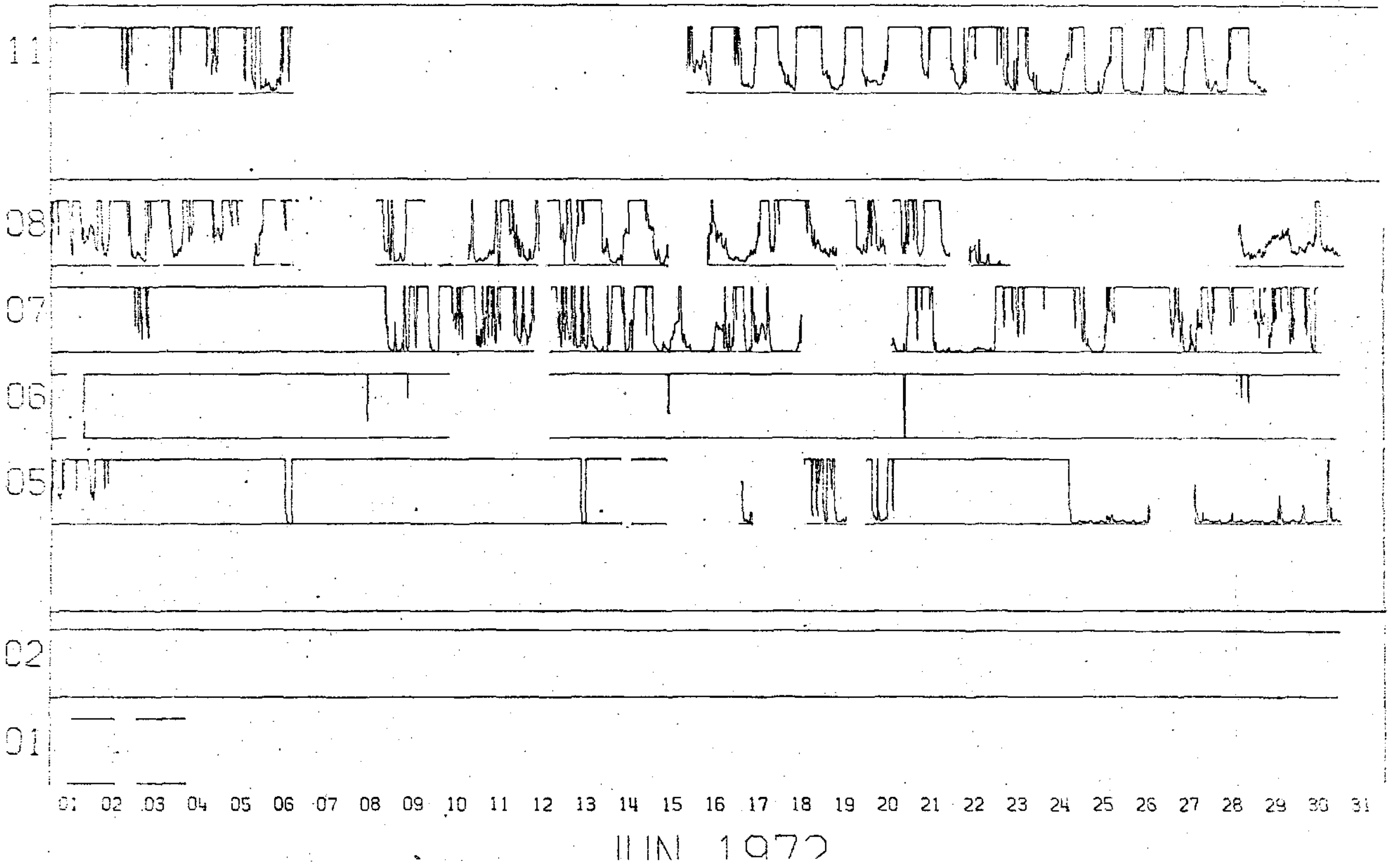

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