COSMIC NOISE AND THE ATMOSPHERE

By

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Abstract

The paper will describe the program of observation of variations in received cosmic noise at 18 megacycles pursued at the Sampson Station of the Observatory of Rensselaer Polytechnic Institute. The variations are primarily due to ionospheric effects in response to solar flares. Auroras and other geomagnetic effects are also detected. Of particular interest are indications of tropospheric effects which also are under study. These effects and their relation to the cosmic records will be described.

Meteorology was once considered to be part of the science of astronomy. Up to three quarters of a century ago in the United States most academic study of meteorology took place at the astronomical observatories associated with the universities. This is still true in many parts of the world. Perhaps the basis of this intertwining of the two sciences was originally that the students of each were looking upward. But it is something more than this; the common root of the words "meteorology" and "meteorites" tells a story in this connection.

As astronomy turned more and more from a science concerned with visual measurements of position toward astrophysics, the physical interpretation of spectroscopic and photometric observations, and as meteorology turned from the interpretation of observations made at single stations toward synoptic observations from networks of stations (a development probably dependent in large measure on the extension of the telegraph lines), the two sciences became separated.

As basic sciences however, it is our view at Rensselaer that meteorology and astronomy belong together again. Since the times of which we have just been speaking, meteorology has become more and more concerned with physical interpretation, and astronomy, particularly in recent years, has become more and more concerned with the envelope of the earth as a particular sample of the material in the rest of the universe. With appropriate scaling factors and suitable variations of the external conditions such as temperature or radiation density, oceanography, meteorology, the upper atmosphere, stellar

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atmospheres, and the interstellar gas are all physically related. An overall study of these situations which are at first sight so different can be very fruitful in understanding the fundamental physics of large scale gaseous and liquid masses, and the differences between the situations should be highly instructive.

The status of these sciences at Rensselaer is that both are presently pursued primarily in the Department of Physics. Research and teaching in astronomy have been introduced. It is our intention that meteorology, or as we sometimes refer to it, atmospheric science, will come along rapidly.

One of our principal astronomical projects has been concerned with the interaction of the sun and the earth's atmosphere. The sun, as you know, is to a first approximation a blackbody sphere at a temperature of 6,000 degrees centigrade. It might be thought of as a distant hot lamp. There are however, many variations of the solar output. We are particularly concerned with those bursts of energy from the lower atmosphere of the sun called solar flares.

During a solar flare, radiation of very short wavelength in the far ultraviolet or X-ray region is emitted copiously. This radiation has the effect of ionizing the atoms in our upper atmosphere, so a solar flare produces temporarily an extra layer of ionization. It is this extra layer which appears to affect short wave communication and the earth's magnetic field.

Radio frequency radiation from outer space is raining down on us from all directions. If a radio telescope were pointed straight up to the zenith, it would "see" a daily variation of intensity as, in the course of the earth's rotation, the sky background, the Milky Way, swept through the beam of the telescope. But if the transparency of the ionosphere were variable, the received intensity would fluctuate in response to the changes in transparency.

The ionosphere is only partially transparent to wavelengths of 15 meters and longer. When there is a heavy amount of ionization, the transparency goes down. Therefore, when one observes the incoming radiation at a wavelength very close to 15 meters, the amount getting through is an indication of the amount of ionization, which in turn has been affected by solar flares.

This is what is observed with Rensselaer's equipment. Sudden drops of incoming radiation are known as sudden cosmic noise absorptions (SCNA) which are indicative of the occurrences of solar flares. The accompanying photograph of one of our records (Fig. 1) shows what happens.

In this figure a typical week's record of 18-megacycle cosmic noise is shown. We notice a daily rise and fall as the hot and the cool sides of the sky go past the antenna beam. The major deviations on the record which may be seen coming at the same time every day are calibration marks. However, on July 30 at 15 hours a considerable drop of the signal is seen, with a slow recovery in about an hour. This is a sudden cosmic noise absorption associated with a solar flare.

Part way through the SCNA there is a superposed burst, which in this case must be of solar origin. The time delay of 20 minutes or so between the start of the SCNA and the arrival of the burst at 18 megacycles is consistent with theoretical expectations of the order in which radiations of various frequencies escape through the solar corona. The 18-megacycle radiation escapes from near the top of the corona and the time delay can be explained by assuming the propagation of a disturbance upward from the solar surface (where the solar flare is observed) at a speed of several thousand kilometers per second. At this speed, particles associated with the disturbance would arrive at the earth's distance after a lag of about 24 hours.

Often but not always a flare is followed about 24 hours or more later by a marked display of the aurora borealis. This display is presumably caused by the charged particles, emitted by the sun at the same time that the flare occurs, bombarding the upper atmosphere. These particles produce extra ionization, but at much higher levels where oxygen and nitrogen are excited to glow and to emit the characteristic colors of the aurora. The changing patterns of the aurora are caused by the changing paths of the charged particles as they are influenced by the earth's magnetic field, which they influence in turn. We have noticed that when an aurora is overhead at night, the cosmic noise is often decreased. (See for example the record of 4 October 1959 in Fig. 8).

In addition to the solar events described, we have observed a number of irregularities on the 18-megacycle records which are correlated with tropospheric events. The purpose of this paper is to bring some of these relationships to attention. In order to show the type of relationships of which we are speaking, we compare Fig. 2 and Fig. 3, two weeks of records during which there is little if any solar activity. During the first of these weeks, Fig. 2, the weather was quiet. There was no disturbed atmospheric electrical field and only a few traces of precipitation in the form of very light snow flurries. By and large the 18-megacycle record is also smooth.

During the week shown in Fig. 3, the solar activity was as quiet as the one in Fig. 2. Meteorologically however, this week is characterized by considerable fluctuation of the atmospheric electrical field, associated with considerable precipitation, including a thunderstorm in the early hours of November 28. The 18-megacycle record is considerably disturbed in correlation with these events. The lines which are sketched in above the 18 megacycle curve schematically represent the atmospheric electricity disturbances. The fluctuations are generally greater than a hundred volts per meter. The arrows below the 18-megacycle trace represent the duration of precipitation. It is noted that the largest fluctuations in the atmospheric electricity record occur almost simultaneously with large fluctuations in the 18-megacycle record. The 18-megacycle disturbances are usually upward from the base level of the curve which means an increase in radiated noise into the antenna. Accompanying precipitation, however, is often characterized by decreases in the incoming cosmic noise as if the air mass above the antenna absorbed some of the incoming radiation. Note particularly for example the thunderstorm in the early hours of November

28. The 18-megacycle record fluctuates both ways with periods of increased 18-megacycle noise alternating with periods of short duration, 5 to 10 minutes, during which the 18-megacycle radiation received is considerably below normal. It is of interest to note that the 18-megacycle record at McMath-Hulbert Observatory in Michigan shows a similar irregularity between 0330 and 0700 UT on this day.

Observations of this sort of coincidence have led us to investigate these and other relationships between the received 18-megacycle cosmic noise and meteorological parameters.

The variations of the 18-megacycle record which are correlated with atmospheric electricity fluctuations are of two forms. The first is characterized by the record of the second half of November 24 (Fig. 3). On this day the atmospheric electrical field first fluctuated both positive and negative and then remained at a high positive field. During this time, for a period of eight hours or more, the 18-megacycle record was characterized by a series of bursts. These give the appearance of what would be found during a solar noise storm, which might have been assumed in the absence of the atmospheric electricity record.

Another type of 18-megacycle variation shown in Fig. 4 consists typically of a sharp increase in signal followed by absorption in phase with a sharp reversal of the atmospheric electric field. In the example shown the field became slightly negative and then rapidly reversed to positive. During this reversal the received 18-megacycle noise increased, as if there were emission of 18-megacycle noise during the reversal process. Following this the field became sharply negative, going off scale. During the interval of high negative field the received 18-megacycle noise was less than normal, as if a highly ionized region above the antenna were absorbing the 18-megacycle radiation in analogous fashion to what takes place in the ionosphere.

The lower trace in Fig. 4 shows the atmospheric electricity record at Schenectady some thirty miles west of our site. While the scale factor is different, we notice that the record has the same characteristics as the one taken at Grafton, namely a negative off-scale reading, a reversal to positive and then negative again, and also the final positive field and then recovery to normal fair weather field. It is interesting that the variations in Schenectady take place thirty to forty minutes prior to those observed in Grafton. This time lag is relatively common, showing that the electric field fluctuations travel with the weather, or that the charge cell associated with the fluctuations travels with the typical wind speed. There are, however, also some situations in which the electric field variations are virtually simulatneous at Schenectady and at Grafton.

Fig. 5 shows an example of one type of effect on the 18-megacycle record which accompanies the onset of precipitation, in this case hail occurring in the midst of a somewhat longer duration rainstorm. In the few minutes prior to the start of the hail the atmospheric electrical field went through a sharp reversal, somewhat as in the previous situation and the received 18-megacycle noise increased by something like 5 decibels. In this particular example the atmospherics at 27 kilocycles also increased as shown in the second trace and the reflected light from the northern sky shows a characteristic decrease, then increase, indicating the passage of cloud cell of some thickness. There is also, at the start of the hail, a fluctuation of a few hundredths of a millibar in the atmospheric pressure of the ground, as recorded on a microbarovariograph(1), an instrument which measures short period departures in pressure from the mean atmospheric pressure. This fluctuation is presumably an indication of the vertical drafts associated with the cloud cell.

While the particular event illustrated here shows the simultaneous variation of a number of parameters, it is often true that the start of precipitation will be accompanied by a sudden shift in level of the 18-megacycle trace, either up or down, without the accompanying disturbances on the other records. In such cases the shift in the 18-megacycle trace is rather smaller than what is shown here, amounting to only a decibel or so. Fig. 6 shows the trace for October 9, 1959, a day when the cosmic noise level decreased generally with the onset of precipitation, and for another day, December 7, 1959, when the general level increased with the beginning of precipitation.

In the case shown in Fig. 7 for October 5, 1959, there was no recorded precipitation at the observatory site, but there was at the Albany Weather Bureau and in Schenectady at the same time, beginning at 2100. The reflected light curve shows a sudden decrease then an increase in sky brightness at about 2115 indicating the passage of a thick cloud cell but it probably did not pass directly overhead. The effect on the 18-megacycle record is to produce what we sometimes refer to as a "false SCNA." This cosmic noise absorption has similar characteristics to the ionospherically produced SCNA's with a rapid drop and a slow recovery. Comparison with other records shows that there was no generally observed cosmic noise absorption at this time, and there was no conspicuous solar flare on the sun. Fig. 8 shows the similarity between the false SCNA of October 5 and two real SCNA's on November 29th and 30th. The irregularity of the trace between 0000 and 1200 on October 4th is due to an aurora.

Considering the two types of precipitation events which have been described, 248 days of precipitation at Schenectady, Albany, or the Sampson Station were examined for the presence of the 18-megacycle effects. Of this group 146 days showed one or another of the 18-megacycle effects, 62 days showed no effects, and on 40 days it was uncertain from the record as to whether precipitation effects were present or not. This would appear to indicate that, in general, precipitation is accompanied by localized absorption or emission of 18-megacycle radiation.

As might be expected, the effects are exaggerated during thunderstormes. On June 6, 1959 shown in Fig. 9, although interrupted by a calibration, the 18-megacycle noise background built up and subsequently decayed during the passage of a thunderstorm. The character of the record is here very reminiscent of what might be observed during a solar noise storm, with a number of

(1) On loan from the Lamont Geological Observatory, Palisades, New York.

bursts of radiation. It should be mentioned that the bursts shown are of large band-width and duration, otherwise they would be discriminated against with this equipment.

Looking at the July 11th record in this figure, we see again the build up of 18-megacycle noise at the approach of a thunderstorm. As the record trace built up to the maximum the effect of the thunderstorm was to knock out the power lines for the next few hours at the end of which the record had returned to its normal level but with a considerable amount of noise.

On the next day we see a noisy record all day long. There were no local storms reported on this day, but there was considerable tunderstorm activity throughout the states of Pennsylvania and New York and all of New England.

The disturbance of July 12 was repeated again for the next several days with diminishing intensity. A peculiar aspect of this situation is that the disturbance reaches maximum intensity in the vicinity of local noon and does not show at all during the nighttime. This event also shows on similar records taken at High Altitude Observatory in Colorado, and at McMath-Hulbert Observatory in Michigan, and was at first supposed to be a solar noise storm. However, none of the accompanying solar effects were observed, and a noise storm at this frequency of several days duration would be a very unusual event. The interval involved was a period during which high thunderstorm activity moved over much of the continent.

Out of 42 thunderstorms events from July 1957 to November 1959, 33 showed such effects well and 8 showed them rather more weakly. One storm showed an atypical effect, which can be explained by a coincident SCNA and solar flare. There were no storms which showed no effect.

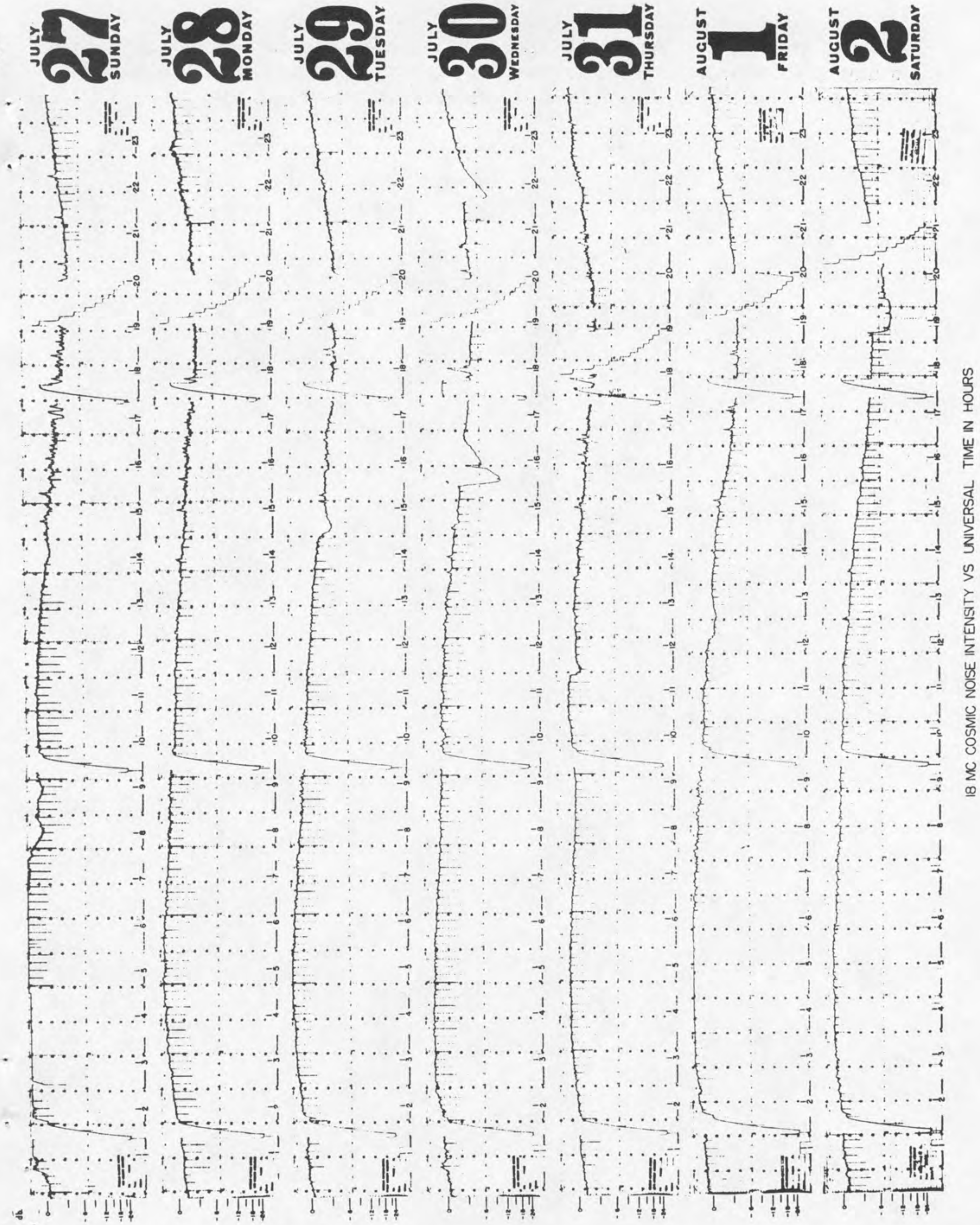
An unusual event on April 5th 1959 is shown in Fig. 10. Here a sharp micro oscillation in atmospheric pressure (less than 1 millibar) occurred coincident with the time of a radio burst at 18-megacycles. The radio burst was also recorded on 18-megacycles at observatories in Michigan and in Colorado and on 55-megacycles in the Netherlands. A class 1+ solar flare was in progress at the time having started some 26 minutes before the pressure pulse.

This sudden lowering of the pressure coincident with the radio burst suggests the possibility of sudden high level warming as a result of the solar event. But it is difficult to see how the reaction could take place so quickly. A check with some other stations in various parts of the world where similar pressure recorders are located revealed that most of them were not operating on April 5th. However, the microbarovariograph at Lamont Geological Observatory in Palisades, New York showed no distinctive pressure pulse at this time.

In conclusion, observations of this sort are just one example of the interplay between astronomy and atmospheric science. Clearly there are other completely different areas where the two sciences overlap. With respect to the particular events described, it is possible that such observations may prove useful in studying the physical characteristics of the troposphere, keeping in mind that we are still searching for a direct solar-weather relation.

Fig. 1

1958



18 MC COSMIC NOISE INTENSITY VS UNIVERSAL TIME IN HOURS

Fig. 2

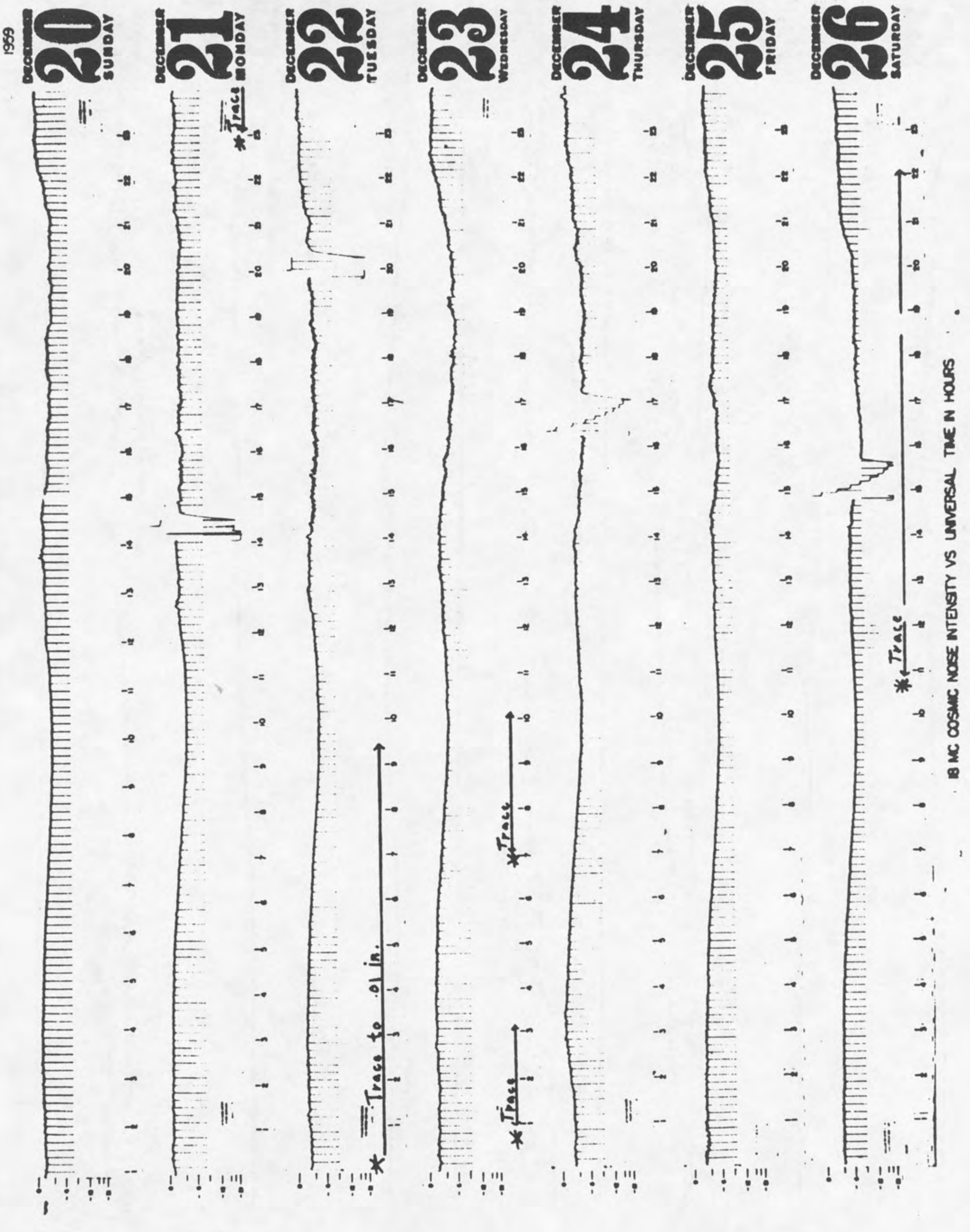

1959
DECEMBER 20 SUNDAY
DECEMBER 21 MONDAY
DECEMBER 22 TUESDAY
DECEMBER 23 WEDNESDAY
DECEMBER 24 THURSDAY
DECEMBER 25 FRIDAY
DECEMBER 26 SATURDAY
* Trace
* Trace to .01 in.
* Trace
* Trace
* Trace
18 MC COSMIC NOISE INTENSITY VS UNIVERSAL TIME IN HOURS

Fig. 3

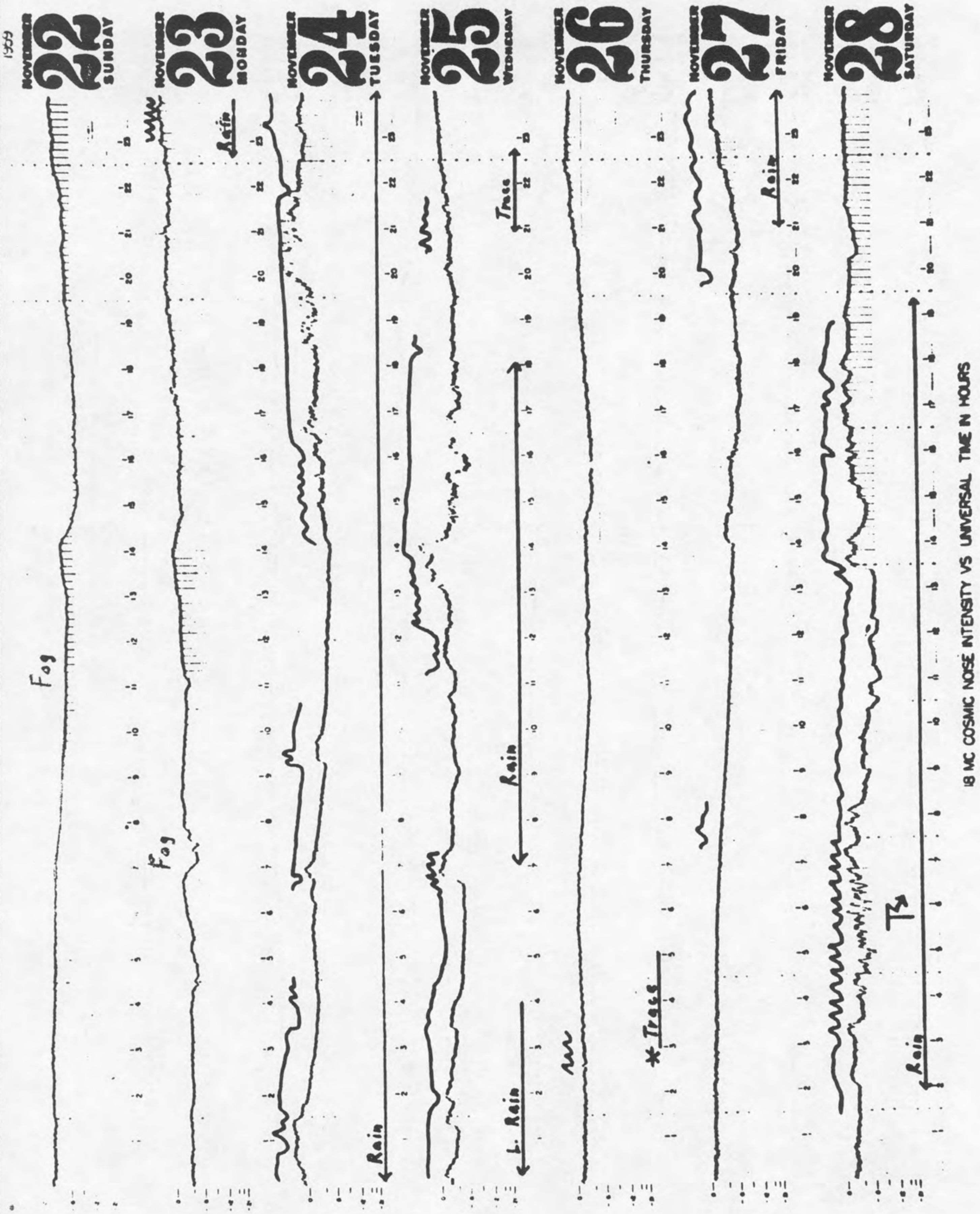

1959
NOVEMBER 22 SUNDAY
NOVEMBER 23 MONDAY
NOVEMBER 24 TUESDAY
NOVEMBER 25 WEDNESDAY
NOVEMBER 26 THURSDAY
NOVEMBER 27 FRIDAY
NOVEMBER 28 SATURDAY
Fog
Fog
Rain
Rain
Rain
Trace
Rain
L. Rain
* Trace
Rain
Ts
Rain
18 MC COSMIC NOISE INTENSITY VS UNIVERSAL TIME IN HOURS

Fig. 4

COSMIC NOISE ABSORPTION

ATMOSPHERIC ELECTRICITY

NOV. 2, 1959

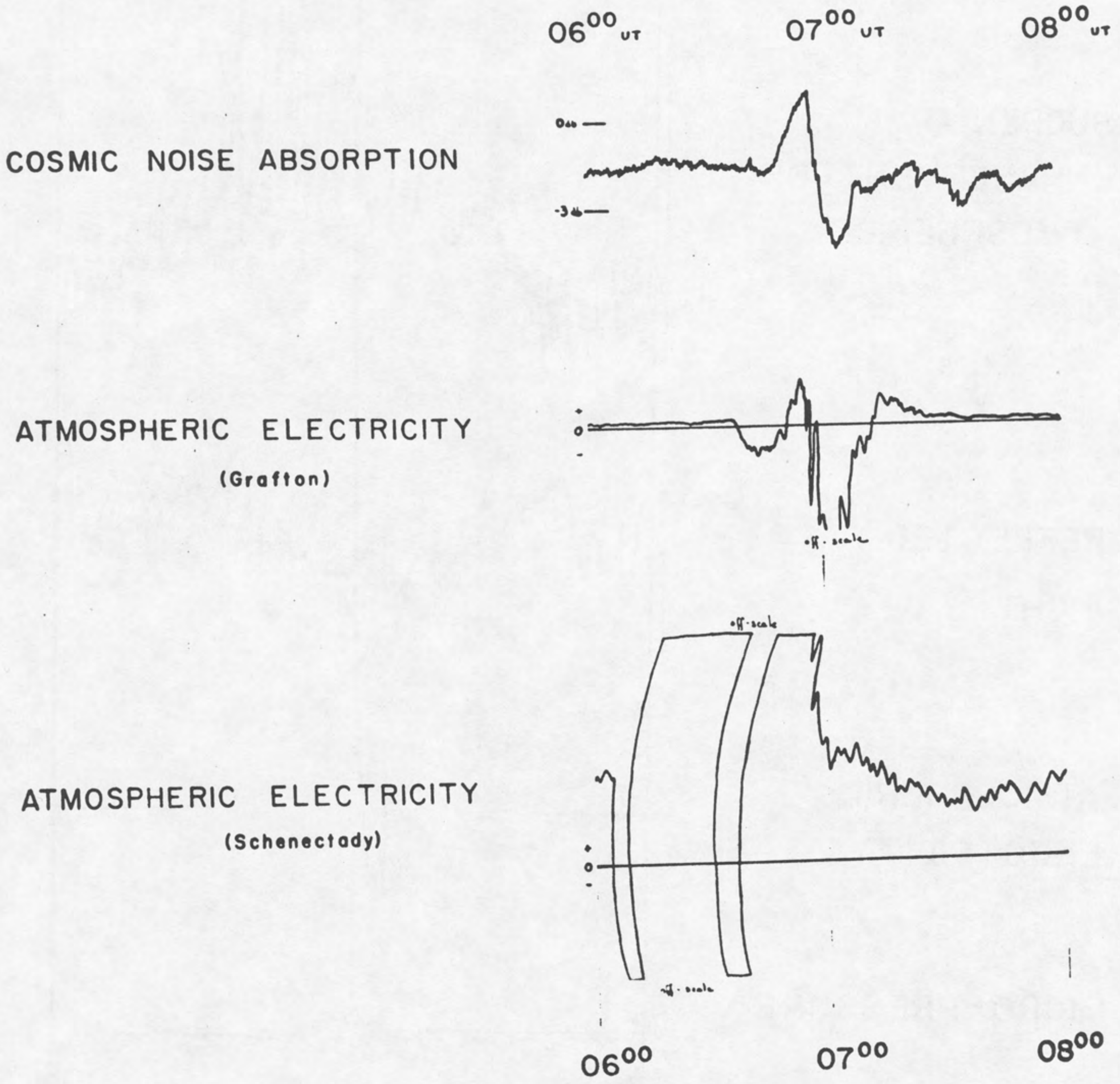
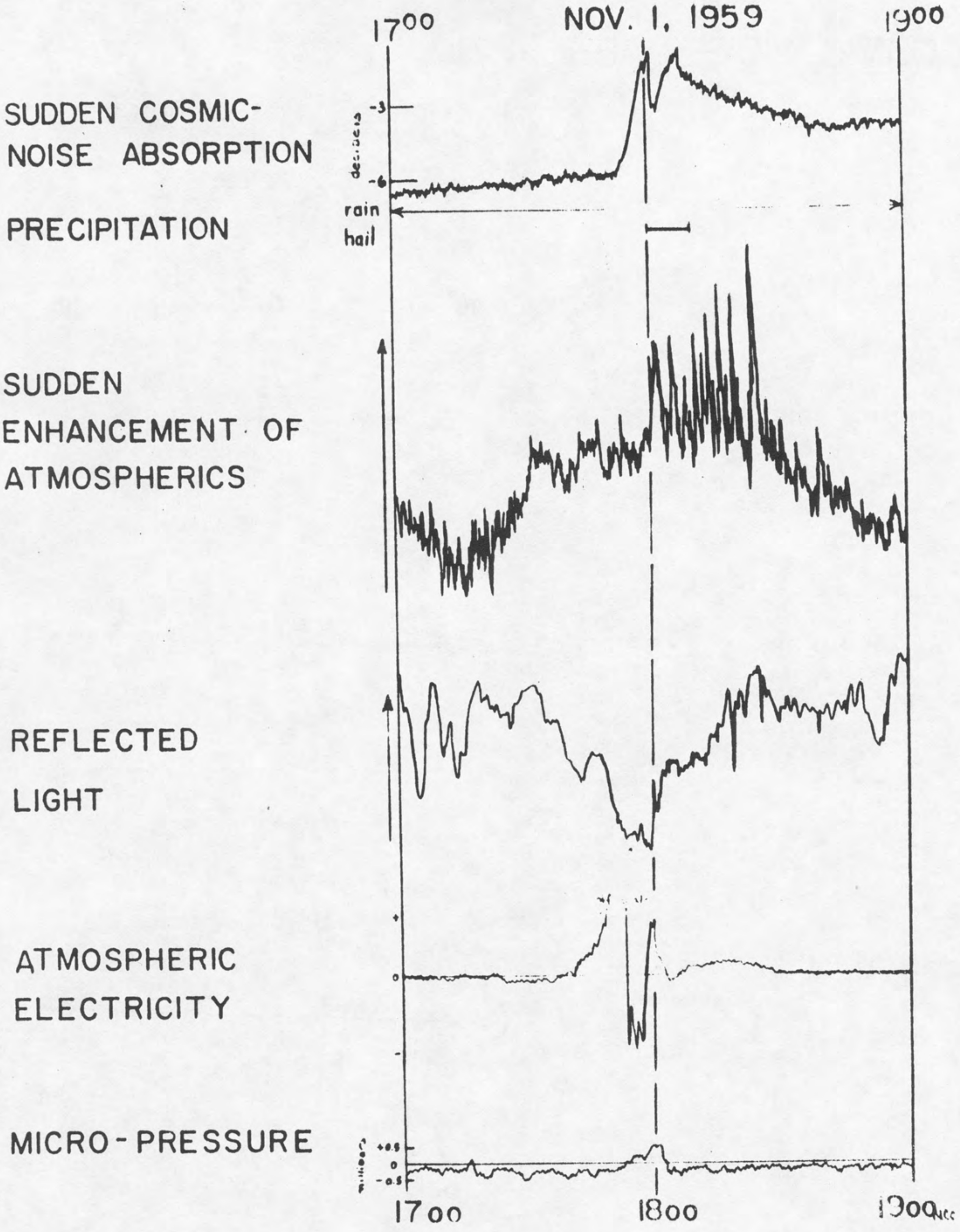
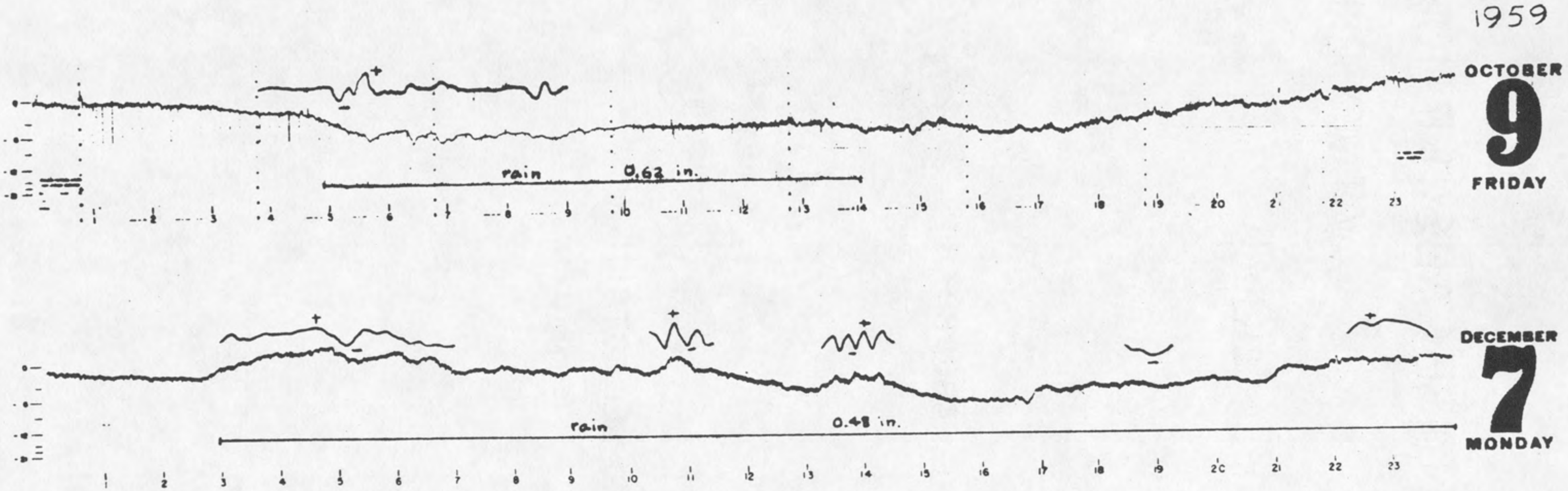


Fig. 5


NOV. 1, 1959
17⁰⁰
19⁰⁰
SUDDEN COSMIC-NOISE ABSORPTION
decibels
-3
-6
PRECIPITATION
rain
hail
SUDDEN ENHANCEMENT OF ATMOSPHERICS
REFLECTED LIGHT
ATMOSPHERIC ELECTRICITY
+
0
-
MICRO-PRESSURE
millibars
+0.5
0
-0.5
1700
1800
1900

Change in level due to onset of precipitation and electrical activity

Fig. 6



18 MC COSMIC NOISE INTENSITY VS UNIVERSAL TIME IN HOURS

Fig. 7

COSMIC NOISE ABSORPTION
ATMOSPHERIC ELECTRICITY
REFLECTED LIGHT

OCT. 5, 1959

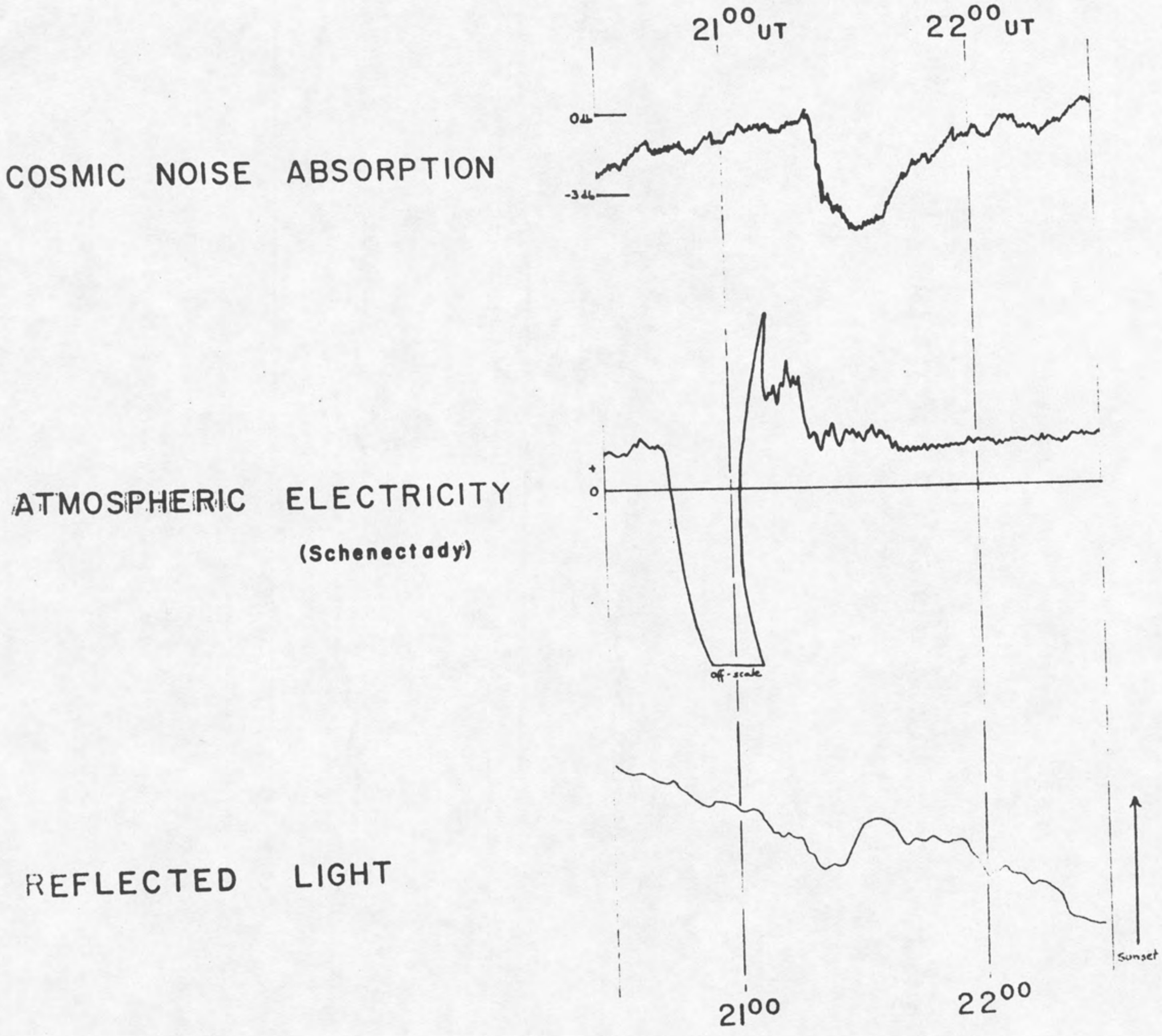
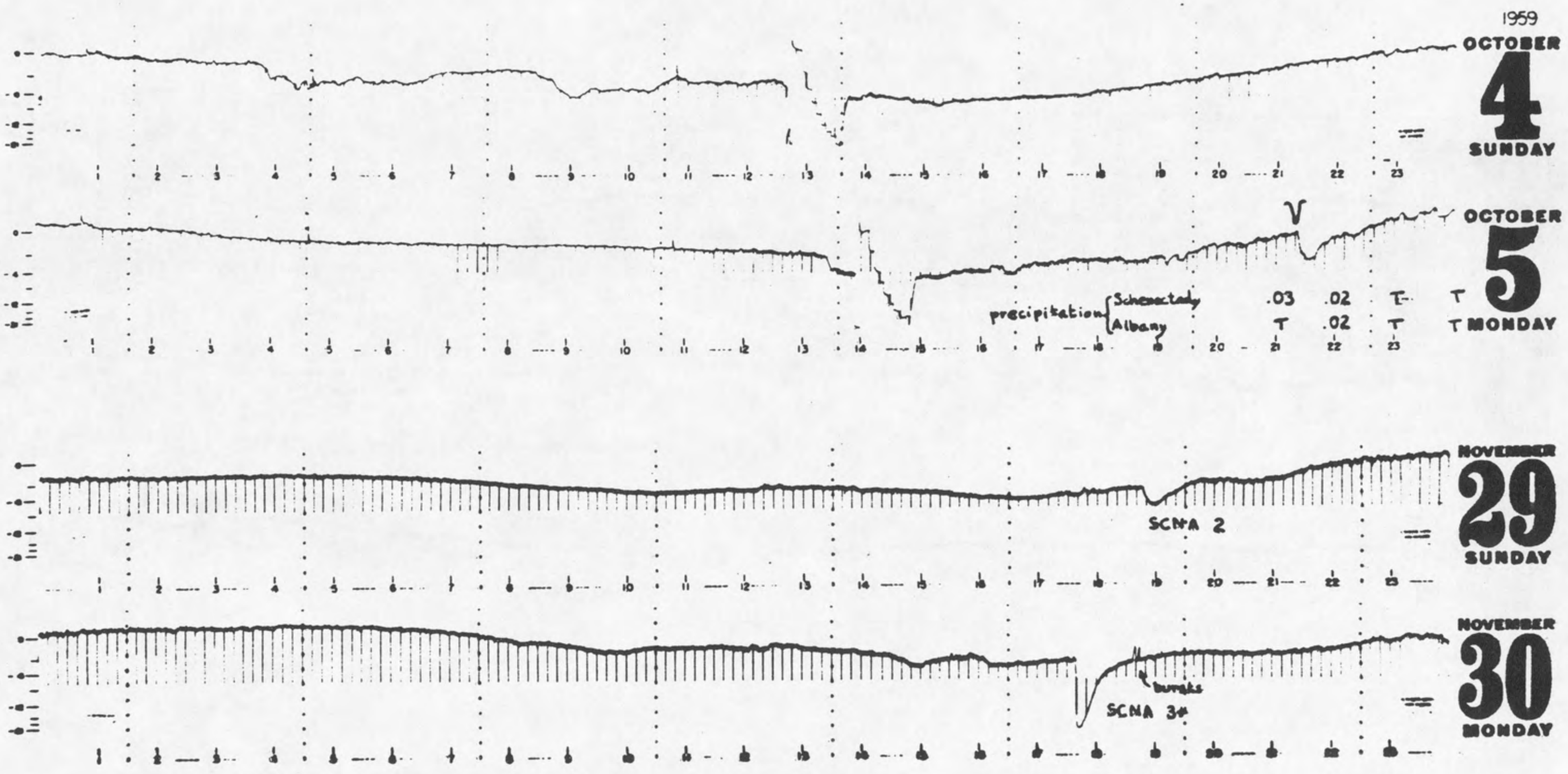


Fig. 8

False SCNA (due to precipitation) and True SCNA



18 MC COSMIC NOISE INTENSITY VS UNIVERSAL TIME IN HOURS

Fig. 9

Effects of thunderstorms

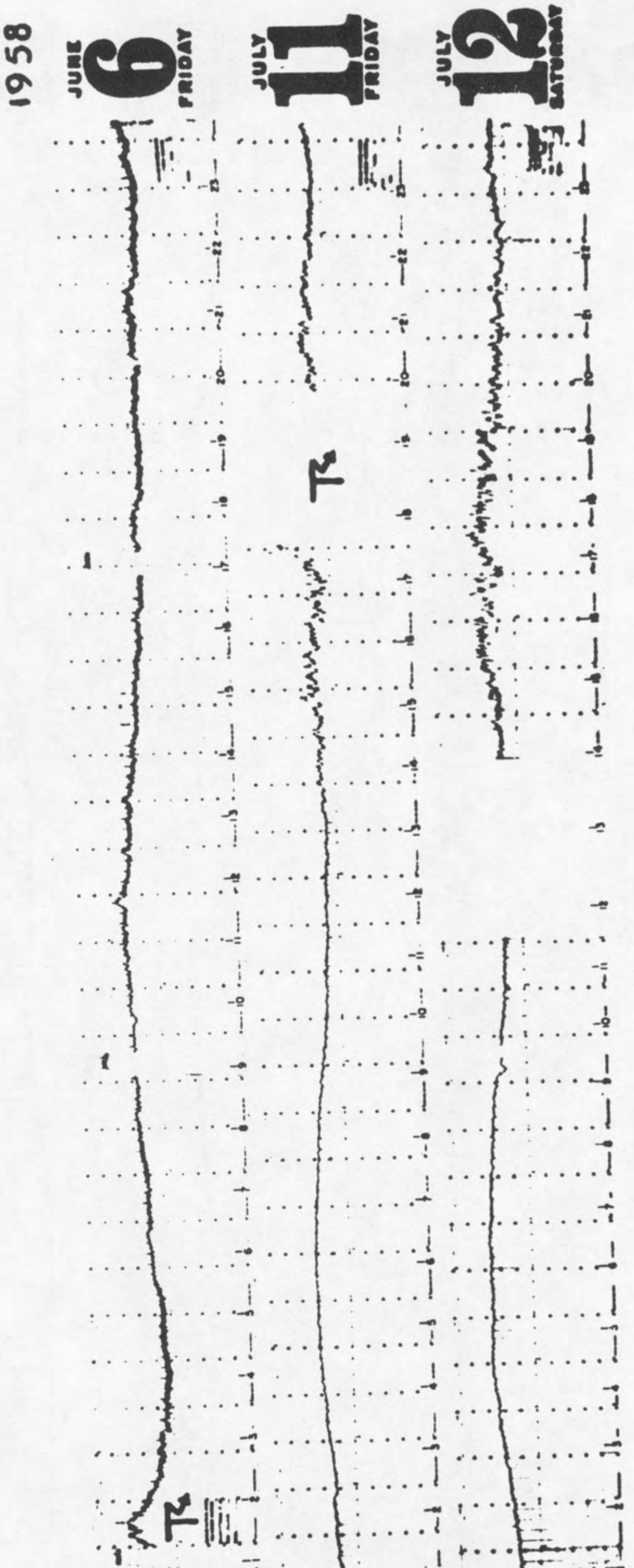


Fig. 10

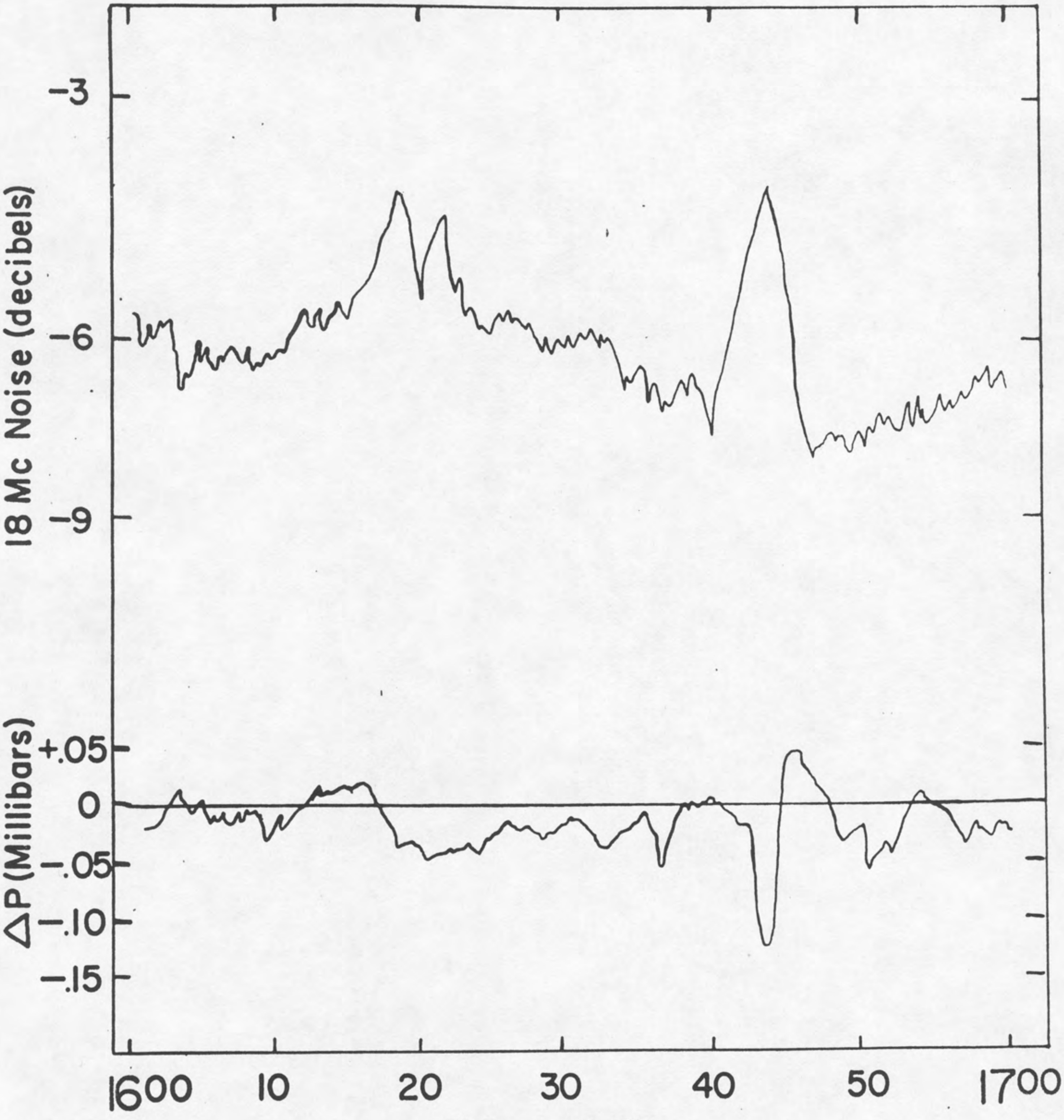


Fig. 10. Comparison of 18 megacycle cosmic-noise and microbarovariograph traces between 1600 and 1700 U. T. on April 5, 1959. Note sharp drop then rise in pressure at time of solar radio burst 1640 to 1647.