NOAA Technical Report NESDIS 20

An Atlas of High Altitude Aircraft Measured Radiance of White Sands, New Mexico, in the 450–1050 nm Band

Washington, D.C.
April 1985

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

NOAA TECHNICAL REPORTS

National Environmental Satellite, Data, and Information Service

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An Atlas of High Altitude Aircraft Measured Radiance of White Sands, New Mexico, in the 450–1050 nm Band

Gilbert R. Smith
Robert H. Levin
John S. Knoll

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U. S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Anthony J. Calio, Deputy Administrator

National Environmental Satellite, Data, and Information Service
John H. McElroy, Assistant Administrator

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Abstract

The National Oceanic and Atmospheric Administration (NOAA) activity at White Sands New Mexico was directed at providing visible wavelength calibration of earth oriented satellite instruments. The best method of calibrating a satellite sensor is to make a simultaneous measurement with a calibrated instrument from a high altitude aircraft. Independent of the calibration, and as an interim product of data analysis, the aircraft instrument data is scientifically useful and is herein presented as an atlas of White Sands surface radiance.

Introduction

White Sands, New Mexico, was chosen as a target because of the brightness and diffuse nature of its surface and a high probability of a clear sky. The White Sands, as observed from both aircraft and satellite, is not uniform in area brightness. The flats area is lower in brightness than the dunes and is spotted with darker patches. The dunes area is composed of several different types (shapes) of dunes and the brightness varies respectively. In addition, uniformity of the dunes area is a function of sun shadowing. Analysis of images from the GOES VISSR instrument within an 8 x 8 kilometer region of the brighter, north central dunes shows a coefficient of variation of brightness of 8.3 percent with a spread of 30 percent.

The NOAA activity at White Sands was intended to provide a data base of calibrated radiance of the Sands, as seen from space, for typical satellite look angles. To achieve this objective, a calibrated spectrometer[1] was flown aboard a NASA Lear jet at 11.28 km above the ground. Aircraft data was taken in coincidence with the GOES VISSR in a time period centered about solar noon and in coincidence with the polar orbiting NOAA AVHRR in a time period centered about the early afternoon satellite overpass. The common target area for all data was the bright spot centered in the northern dunes field at approximately 32.9°N 106.2°W.

Surface truth measurements were made during each data gathering time period. These measurements consisted of sand surface soil moisture[2], solar spectra in the visible wavelengths, balloon launches for vertical atmoshperic sounding, surface meteorological data and the visual observations by both the NOAA aircraft crew and ground base crew.

The data illustrated in the figures of this report are clear sky radiance measured at the altitude of the aircraft with no corrections made for the atmosphere above the aircraft. Observed variance in the brightness of the sands is primarily a function of the solar illumination angle.

White Sands Field Missions

The NOAA White Sands field missions were made possible through a Memorandum of Understanding (MOU) between the NASA Lewis Research Center for the use of the Lear jet and the NASA White Sands Test Facility (WSTF) at the White Sands Missile Range (WSMR). All NOAA and NASA Lewis activity was directed to the WSMR through the NASA WSTF.

Each NOAA White Sands field mission consisted of two field groups. One was the aircraft group and the other was the ground site crew that operated the instrumentation located on the Sands. The ground site crew was based at Las Cruces, New Mexico.

The aircraft group was located in El Paso, Texas, and was responsible for the operation and calibration of the aircraft instrument and was a part of the flight crew. The aircraft instrumentation was mounted aboard the Model 25 Lear jet of the NASA Lewis Research Center, Cleveland, Ohio, and was flown over the Sands on clear days at an altitude of 11.28 km (37,000 feet), above the ground.

Flight Instrumentation

The December 1980, June 1981, and September 1981 flight series instrumentation[1] used a scanning grating spectrometer mounted for downward viewing, through a quartz window, in the aircraft instrument bay. The instrument was a 1/4 meter focal length Ebert spectrometer with a spectral resolving power of 100, using a silicon detector at the exit slit. The grating was scanned every 5.6 seconds through the wavelength range of 480 to 960 nm. At 11.28 km altitude (above the surface), the 1/4 meter spectrometer had a one square kilometer surface footprint.

The August 1982 flight series instrumentation[1] used a downward viewing spectrometer mounted in a cradle allowing a variable elevation and azimuth view vector.The system was designed so that the centerline of the instrument entrance optics always passed through the physical center of the quartz window on the aircraft pod for any azimuth or elevation position. The instrument was a 1/8 meter focal length, rapid scan Ebert double monochromator with a spectral resolving power of 100 using a silicon detector at the exit slit. The grating scanned every 5.08 seconds through the wavelength range of 450 to 1050 nm. The instrument foreoptics was designed to produce a one square kilometer footprint on the Earth from an altitude of 11.28 km.

The aircraft data recording system[1] produced a digital cassette tape of instrument output for each day of flight. Instrument parameters, aircraft flight parameters, and in-flight calibration data are stored on the cassette tape. Instrument output was also recorded on an analog chart recorder. At NESDIS, the cassette tapes were transferred to magnetic discs for archival and data analysis.

Aircraft Instrument Laboratory Calibration

The standard for laboratory radiance calibration was a 76.2 cm diameter white integrating sphere source[3]. The interior sphere surface is coated with a $BaSO_4$ base paint, acceptable for producing a uniformly diffuse white reflectance surface. The sphere is illuminated by 12 interior mounted quartz halogen lamps, powered by a constant current source. The useful wavelength range of the sphere is 350 to 2000 nm. The National Bureau of Standards (NBS) traceability of the sphere radiance is maintained through annual calibration. The sphere source is used to adjust the dynamic range and monitor the output stability of the aircraft instrument. Calibration data is recorded just prior to, and immediately following an aircraft flight series. The aircraft instrument was calibrated in wavelength in the laboratory before and after each flight series using the emission lines of gaseous discharge lamps.

Aircraft Instrument Flight Calibration

In-flight relative radiance measurements were accomplished with an on-board calibration source. The 1980-1981 instrumentation used a flat, diffuse white plate, illuminated by a quartz halogen lamp, which was mechanically inserted in the field of view of the instrument. The 1982 instrument used a 2" diameter sphere source, illuminated by an internal quartz halogen lamp. The sphere source was mechanically inserted into the field of view. This provided data concerning instrument gain stability while in flight. A mechanical beam block was also inserted in the instrument field of view to provide a zero reference. While the aircraft was on the ground, radiance measurements were made using an "external" (to the aircraft) calibration source similar to, but larger than the on board source. Data from the external source included the effect of transmission through the aircraft pod quartz window.

Flight Data

Each graph of radiance versus wavelength, figures 1 through 18, represents the results of a single wavelength scan of approximately 5 seconds duration. These scans were taken over the dunes area, under clear sky conditions. Thirty (30) scans were taken during each aricraft flight leg and 8 to 10 legs were flown each day. As a result, there is an abundance of data. Surface radiance is found by multiplying the the integrating sphere radiance by the ratio of instrument output when viewing the surface divided by instrument output when viewing the sphere. The data of figures 1 through 12, of August 1982, was taker with the 1/8 meter Ebert double monochromator in the view vector of the satellite indicated. The solar illumination level changes very little around solar noon (1900Z) as indicated by comparing the plots of Figure 10 and 12. In the 2100 to 2200Z time frame of early afternoon, however, the solar illumination is changing rapidly as evidenced by comparing Figures 1 and 3.

The data of Figures 13 through 19 were recorded with the 1/4 meter Ebert spectrometer. This is the near solstice and equinox data of September 1981, June 1981 and December 1980.

Figure 19 compares 1/4 meter spectrometer June, September and December data. The variation shown is a result of the seasonal solar illumination angle. The data for these three plots is from the dunes area taken near solar noon in the east VISSR view vector.

Numerous spectra were taken before and after solar noon, and before and after the afternoon spacecraft overpass. These spectra will not be shown in this report for the sake of brevity, however, investigators who may have use for such data may obtain copies by contacting the authors.

Ground Parameter Measurements

For each day of aircraft flights, an attempt was made to measure atmospheric absorption spectra, using the sun as a source from sunrise to solar noon, in the wavelength range of 400-800 nm, from a site located at the border of the dunes and flats. The instrument used was a scanning grating 1/8 meter double monochromator, mounted in an elevation-azimuth yoke, which was servo-controlled to track the sun using a solar quadrant detector. The system was computer program controlled and data was recorded both digitally on tape and on a chart recorder. With the exception of three days in September 1981 and four days in August 1982, operational equipment problems and White Sands Missile Range (WSMR) ground restrictions prevented the gathering of useable absorption spectra at the ground site on the Sands.

The WSMR Atmospheric Sciences Laboratory (ASL) supplied both RAOB ascent data for the time period coincident with the aircraft overflights and White Sands surface meteorological observations for the daylight hours of the aircraft flight days. The WSMR Data Sciences Division supplied NOAA with a 9-track tape which included the ASL observations and similar routine measurements taken at the WSMR Headquarters area and at Holloman Air Force Base (HAFB).

The NOAA ground site crew made surface meteorological observations at the time of aircraft flight. They also recorded the sun illumination vector conditions and the conditions of observation from the satellite-aircraft view vector. In addition, the aircraft crew made downward visibility observations. This data set establishes the visible conditions of measurement.

Surface sand (gypsum) soil moisture content[2] was measured each day of aircraft overflight. During the field missions of 1980 and 1981, samples were taken from 17 selected locations, all within a 5-mile radius, in the NASA Northrup Strip-Space Harbor area. Four of these locations were in the dunes and thirteen were on the flats. In August 1982, samples were only taken from the dunes.

Ground parameter measurement data is available and may be obtained by contacting the authors. The quality and usefulness of these measurements are a separate issue and are not discussed in this article.

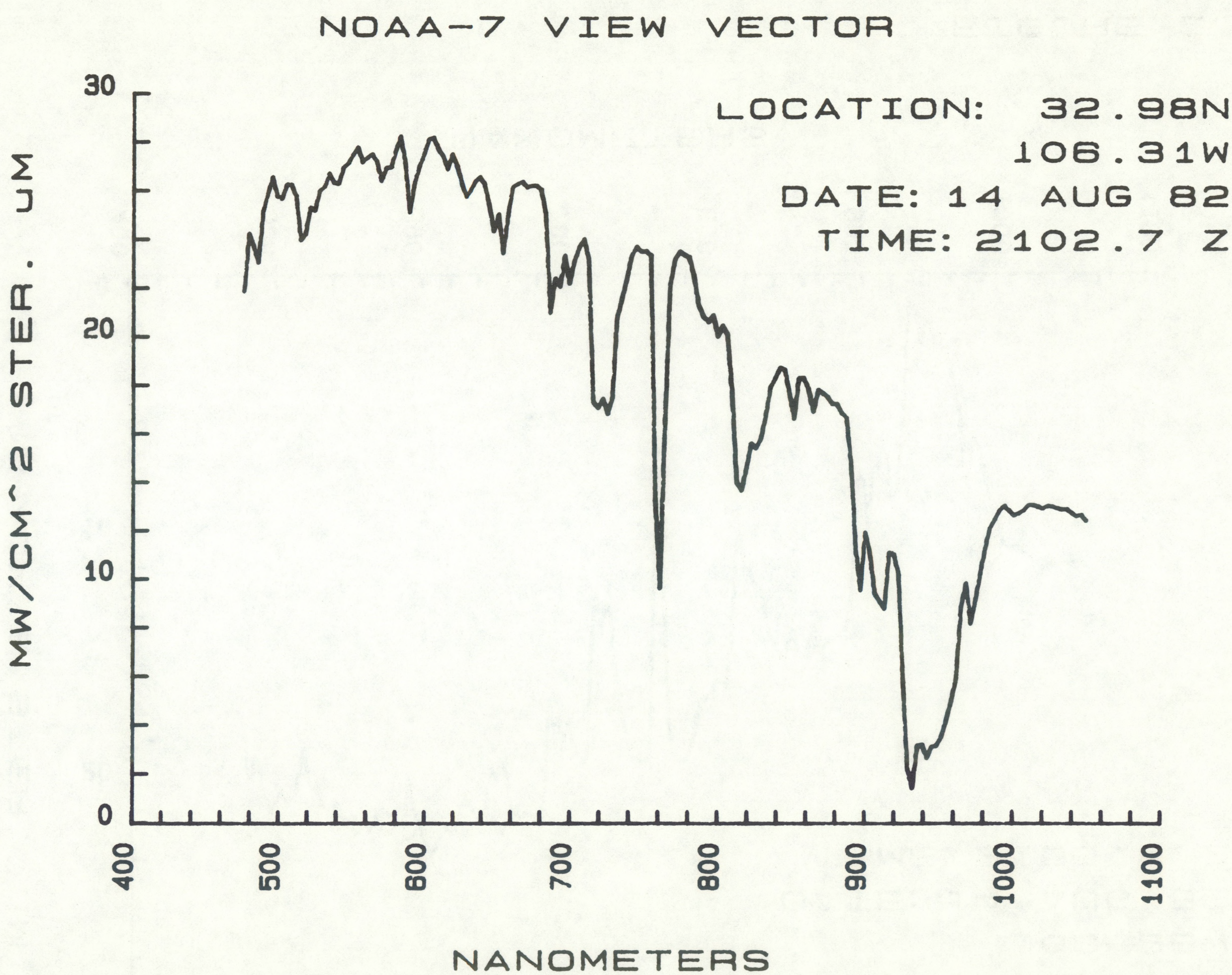
Acknowledgments

The authors which to acknowledge the cooperation of the NASA Lewis Aircraft Operations Group, directed by Mr. Byron Batthauer, and the Lear jet pilots and crew; the NASA White Sands Test Facility (WSTF) Northrup Site Space Harbor, directed by Mr. Alexander Paczynski; the White Sands Missile Range (WSMR) Atmospehric Sciences Laboratory staff and Mr. Leo Gardea of WSMR scheduling.

We wish to thank our colleagues in the NESDIS SEL Experimental Applications Branch, Peter Abel, Lee Johnson, Frank Mignardi and Ken Hayes for their contributions to the instrument electronic design, assembly, testing, calibration, data gathering in the field and data analysis; and Robert Koyanagi, Calvin Jones, Edward King, Paige Bridges and John Bray, for their contribution to instrument mechanical design, assembly, and aircraft integration.

References

1. Smith, G.R., et al., NOAA Technical Report, NESDIS No. 9, June 1984.
2. Smith, G.R., NOAA Technical Memorandum, NESDIS No. 7, September 1984.
3. Hovis, W.A., J.S. Knoll, Applied Optics, Volume 22, page 4009,December 1983.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106.31W
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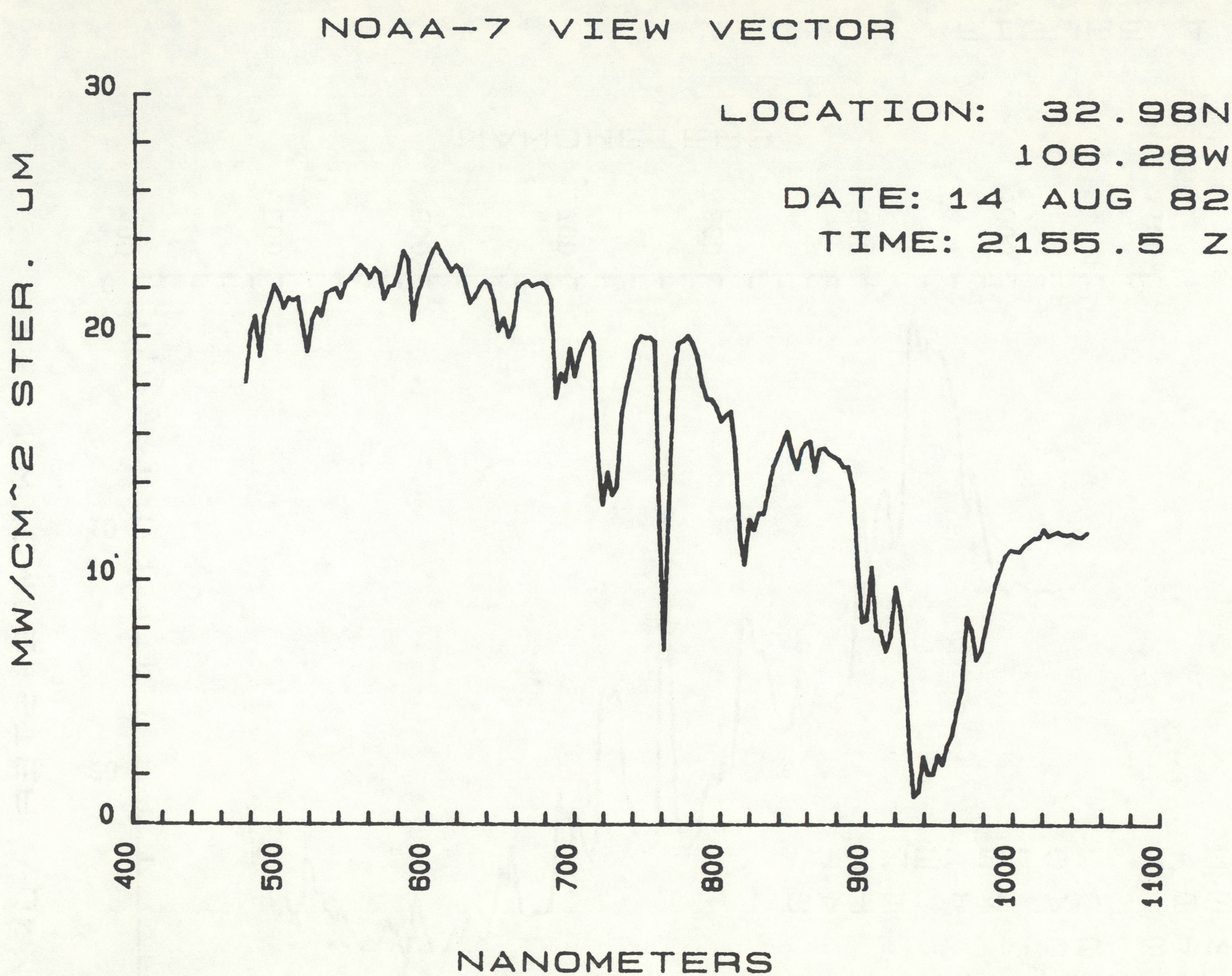
MW/CM^2 STER. uM
0
10
20
30
400
500
600
700
800
900
1000
1100
NANOMETERS

FIGURE 1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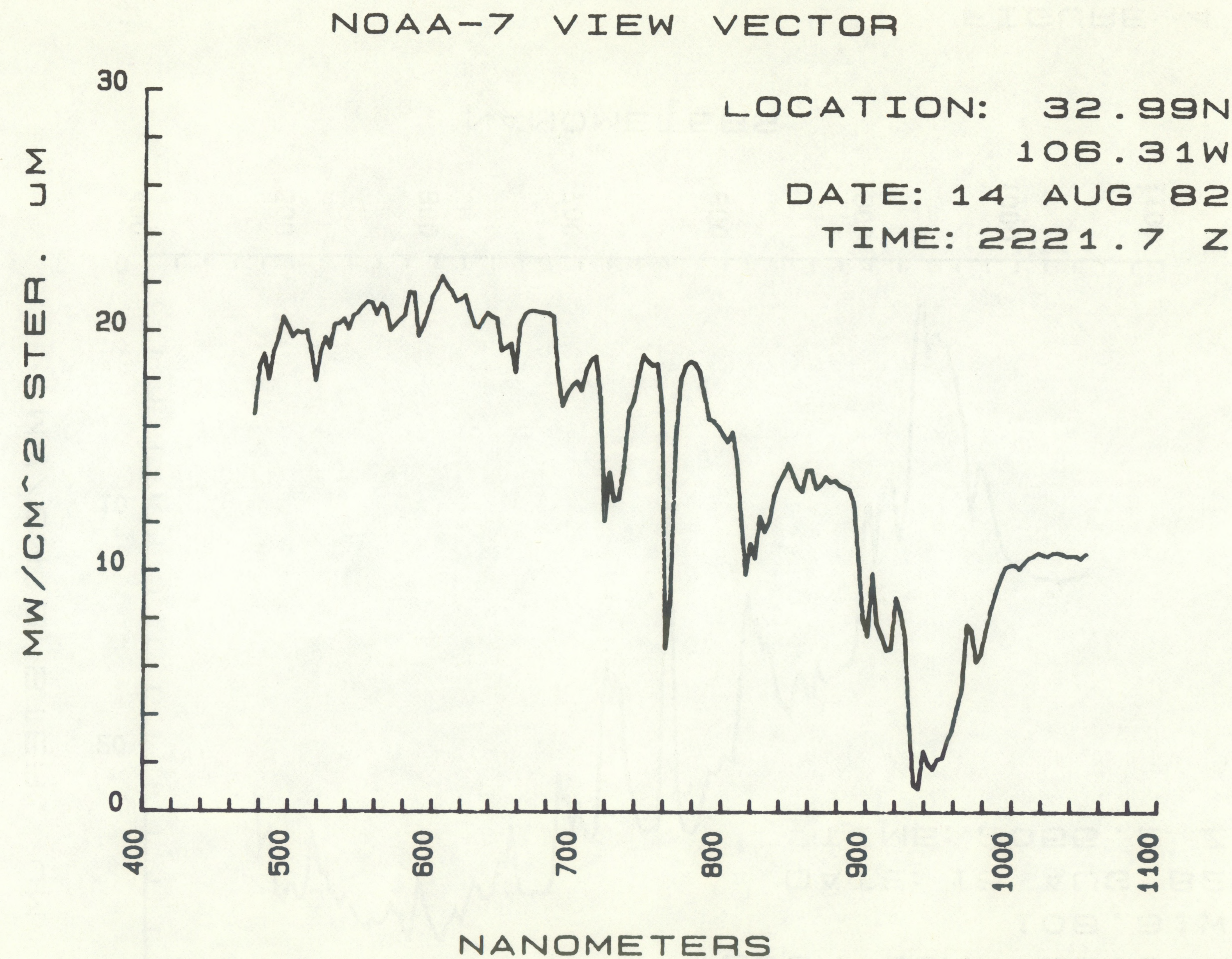
900
1000
1100
NANOMETERS

FIGURE 2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TIME: 2221.7 Z
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20
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400
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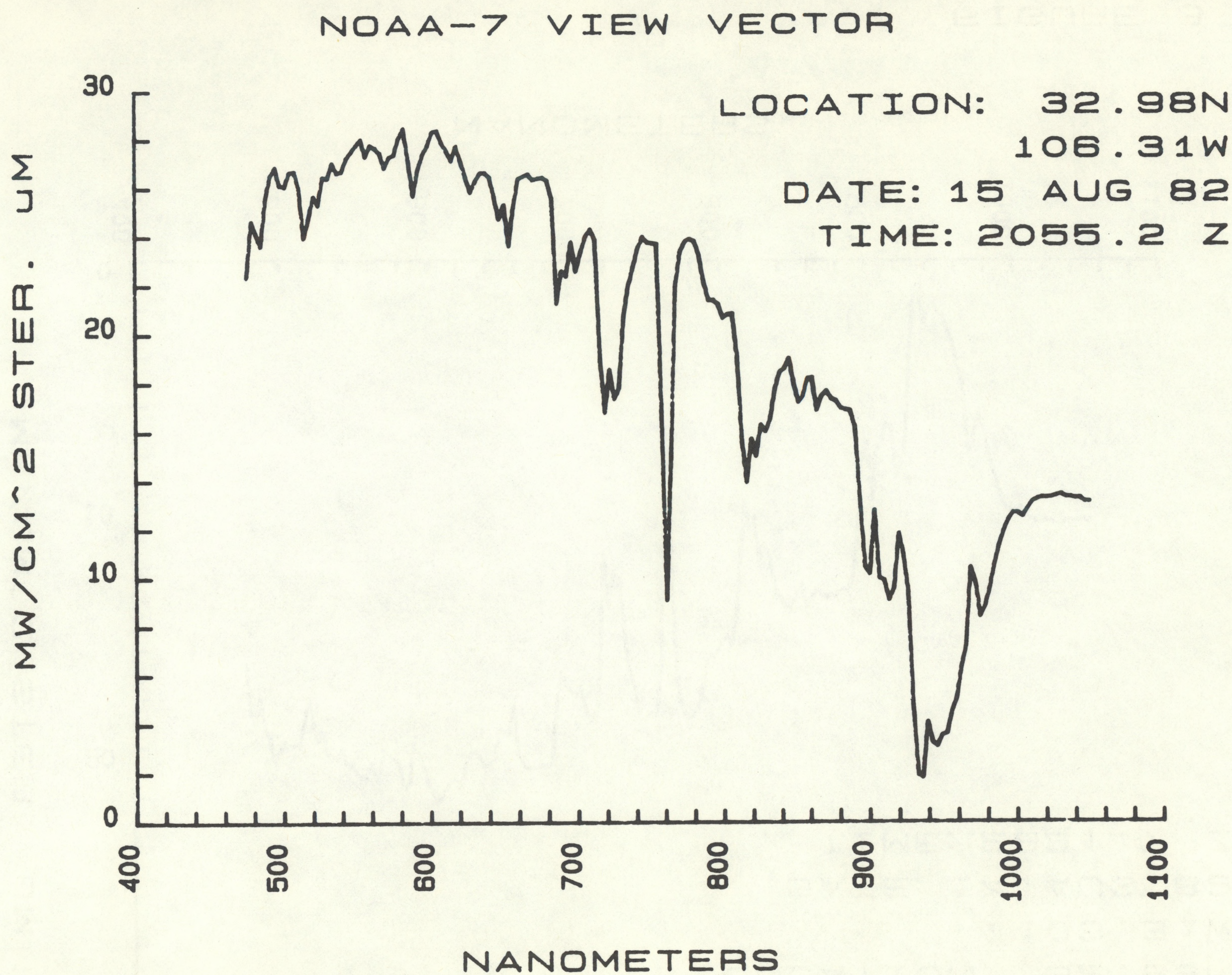
600
700
800
900
1000
1100
NANOMETERS

FIGURE 3



NOAA-7 VIEW VECTOR
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106.31W
DATE: 15 AUG 82
TIME: 2055.2 Z
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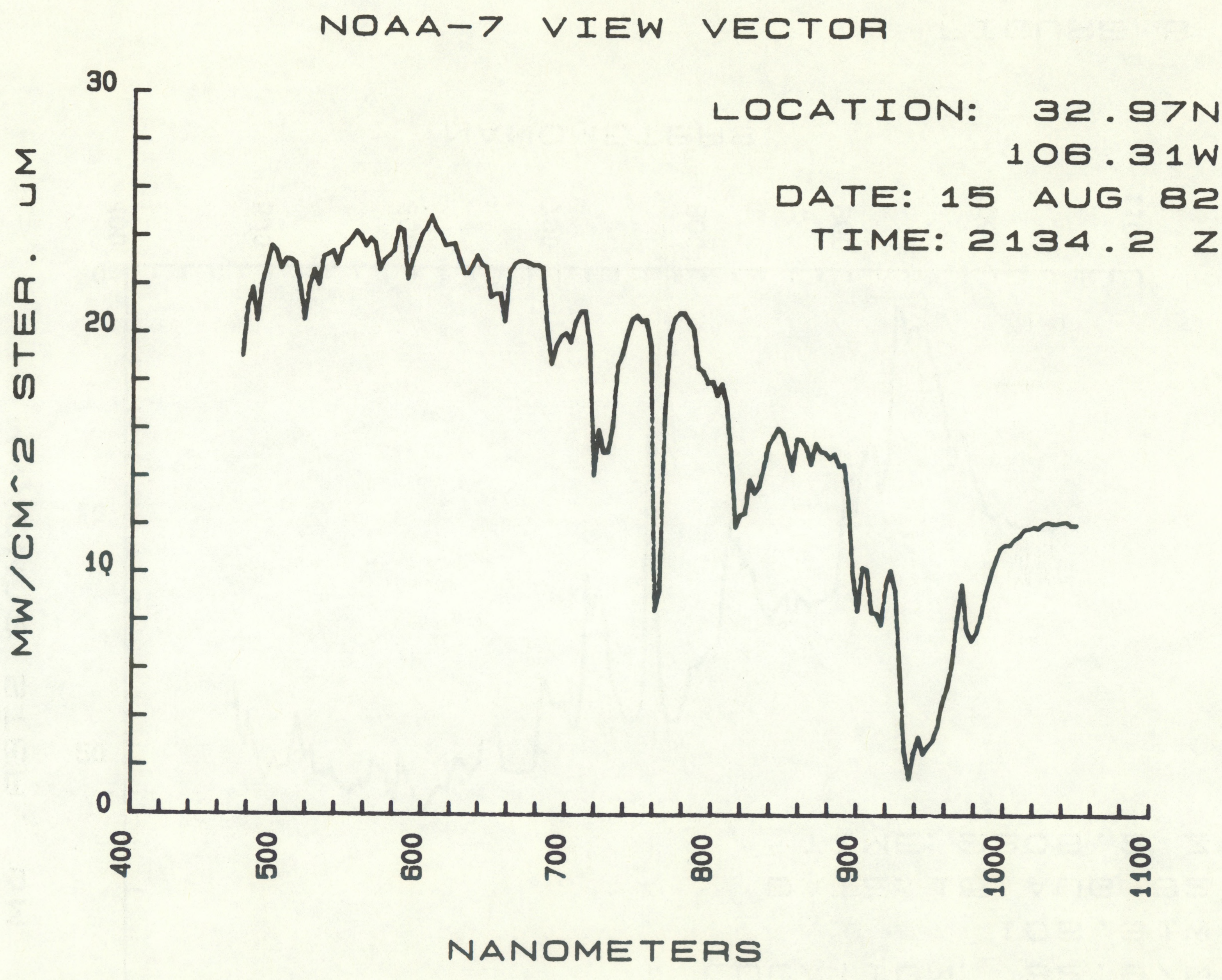
20
10
0
400
500
600
700
800
900
1000
1100
NANOMETERS

FIGURE 4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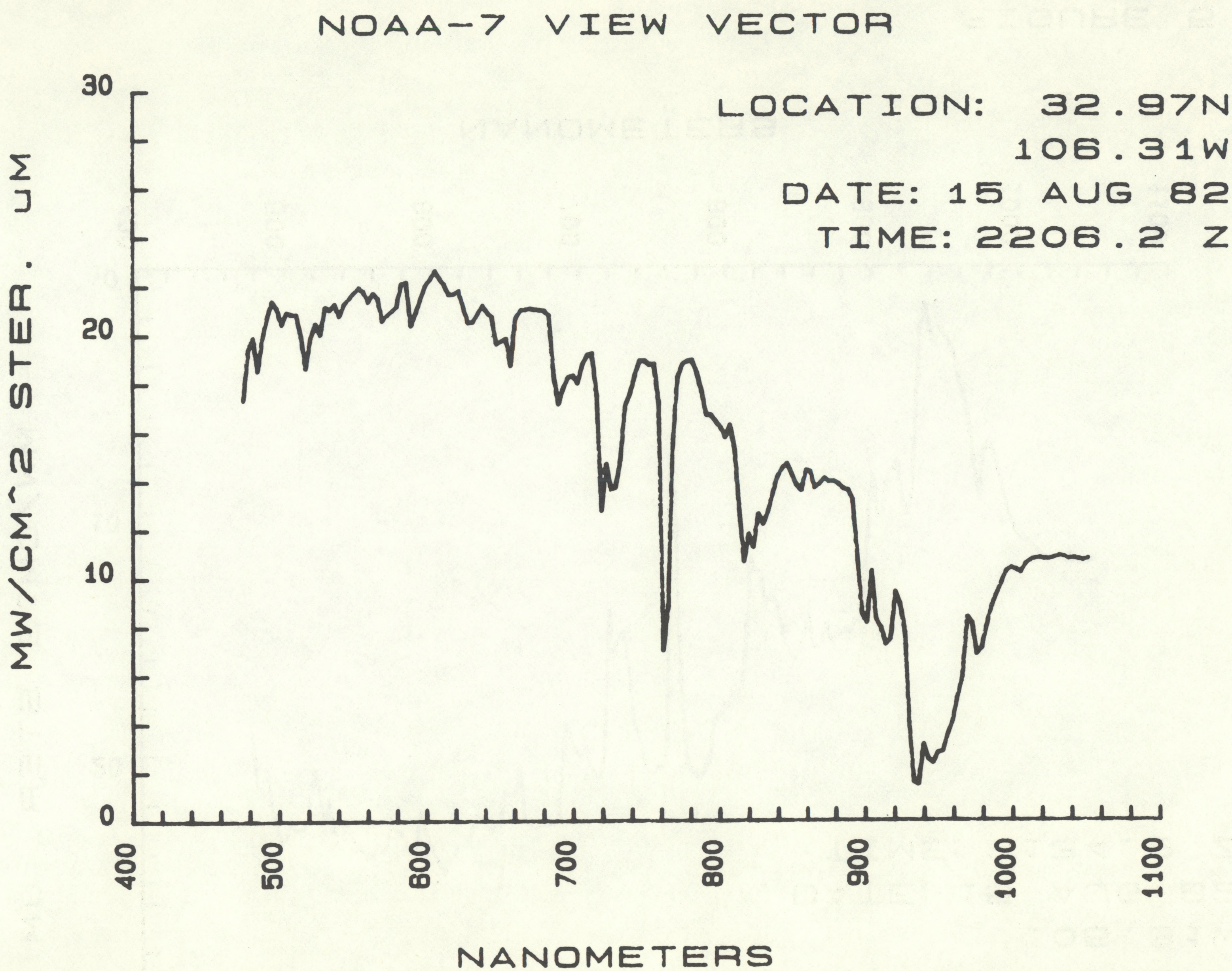
1100
NANOMETERS

FIGURE 5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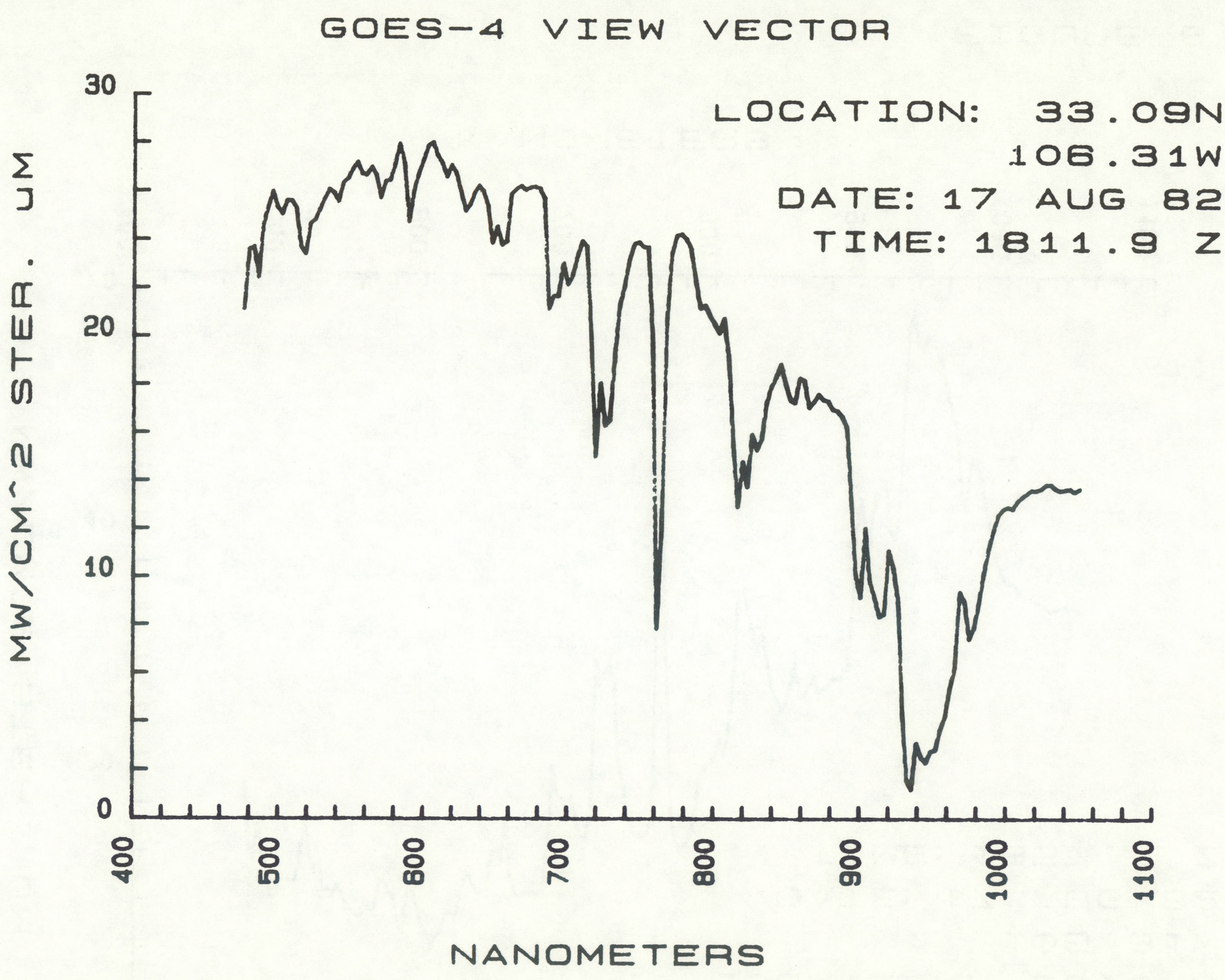
1000
1100
NANOMETERS

FIGURE 6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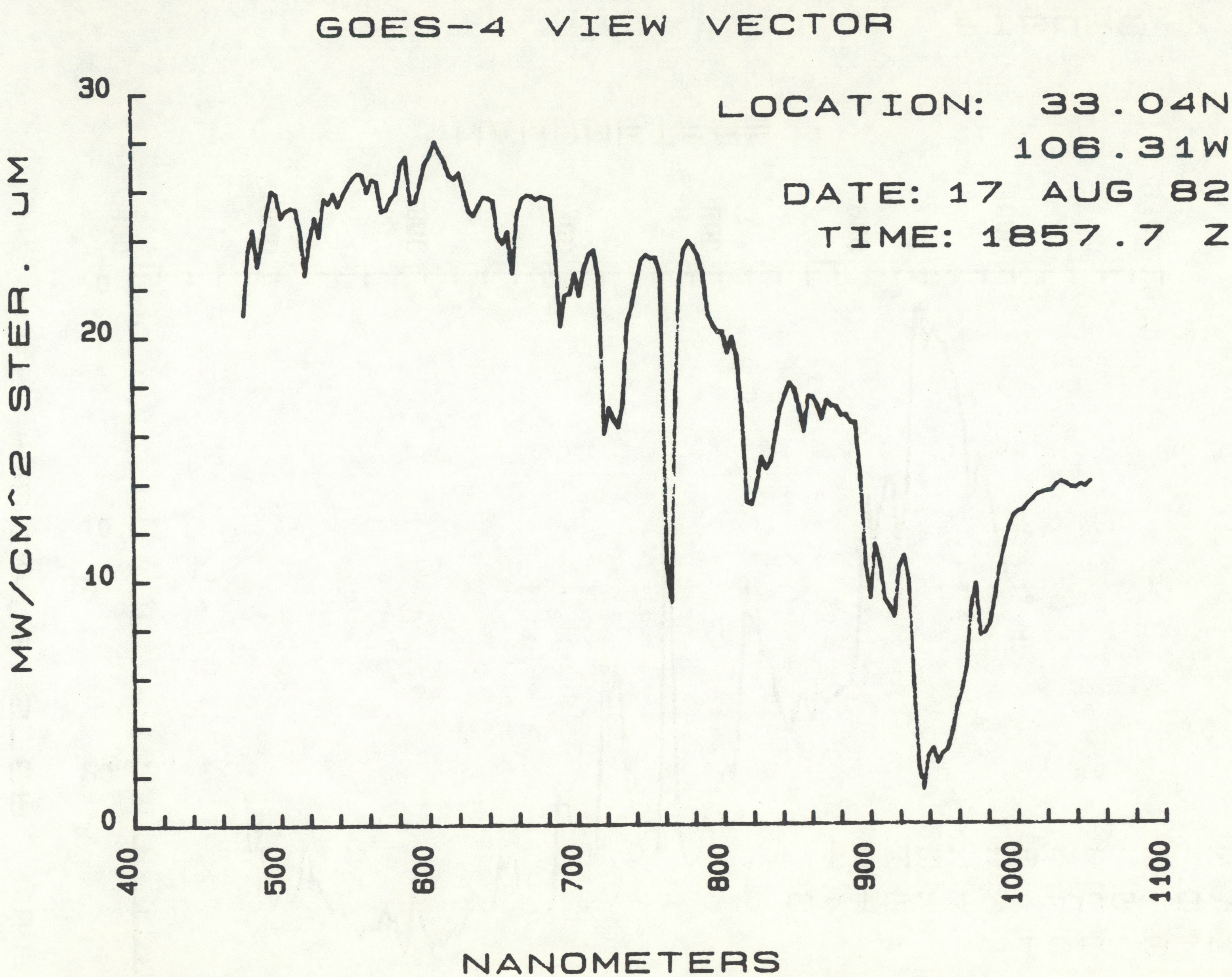
1000
1100
NANOMETERS

FIGURE 7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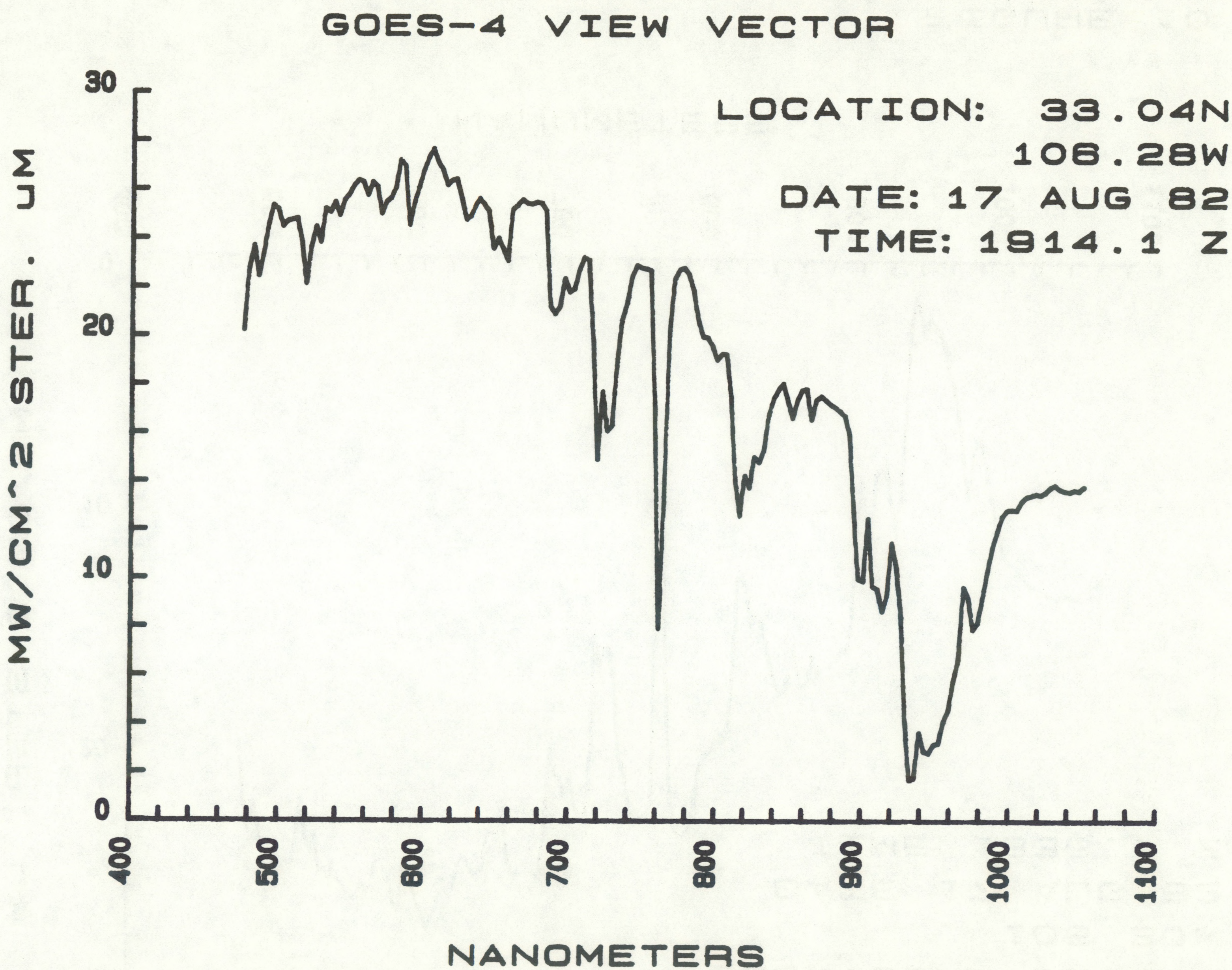
NANOMETERS

FIGURE 8



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TIME: 1914.1 Z
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900
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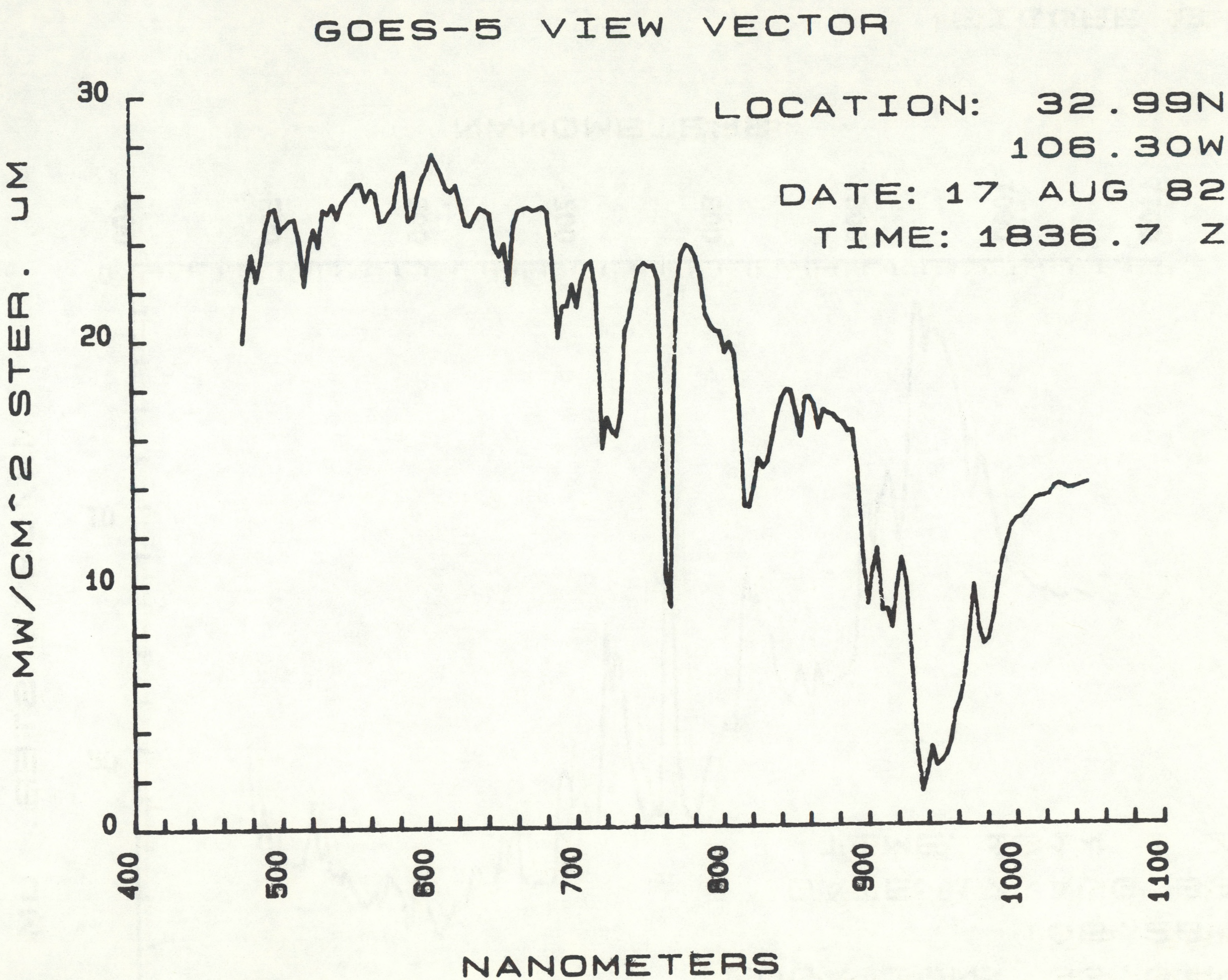
1100
NANOMETERS

FIGURE 9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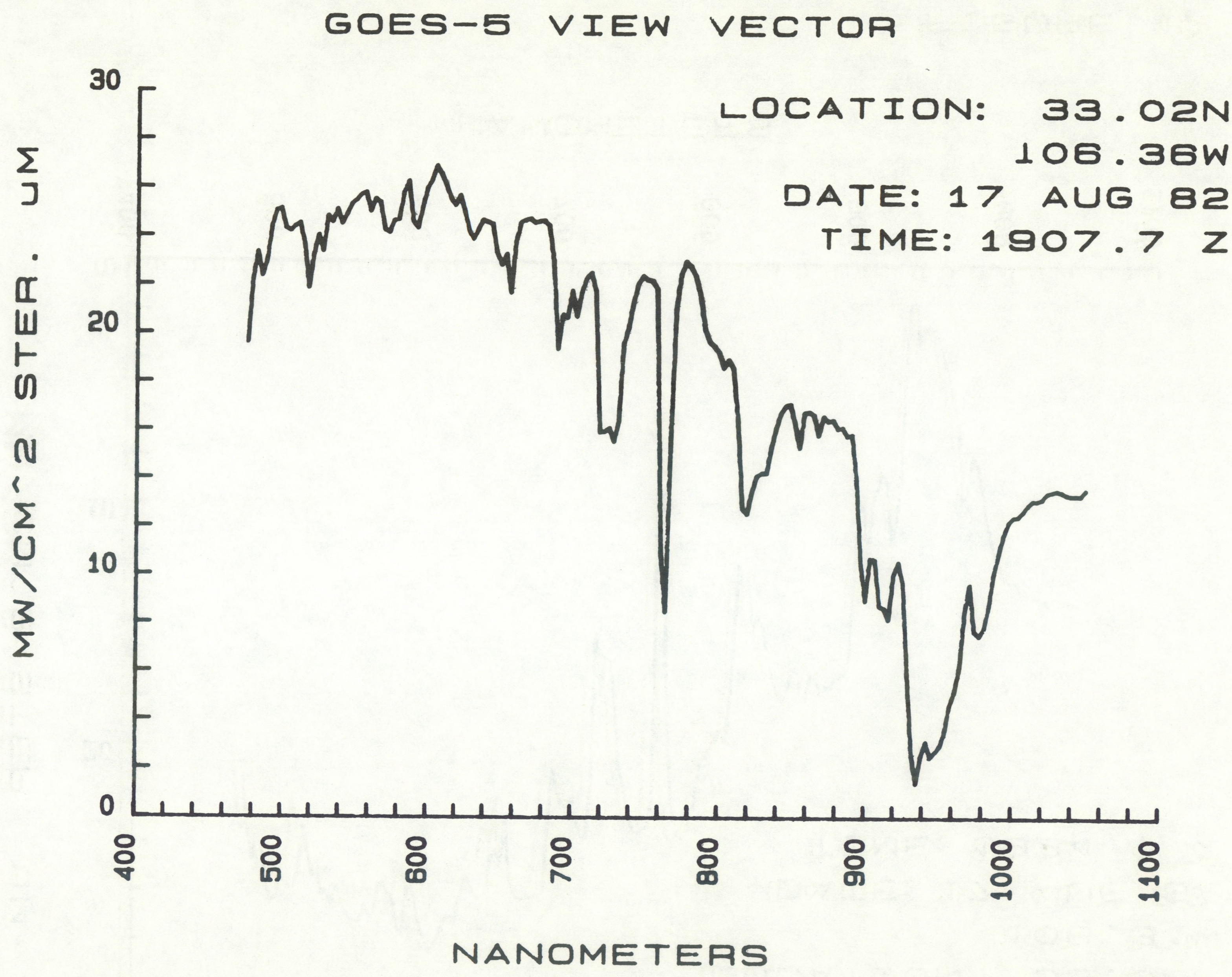
1100
NANOMETERS

FIGURE 10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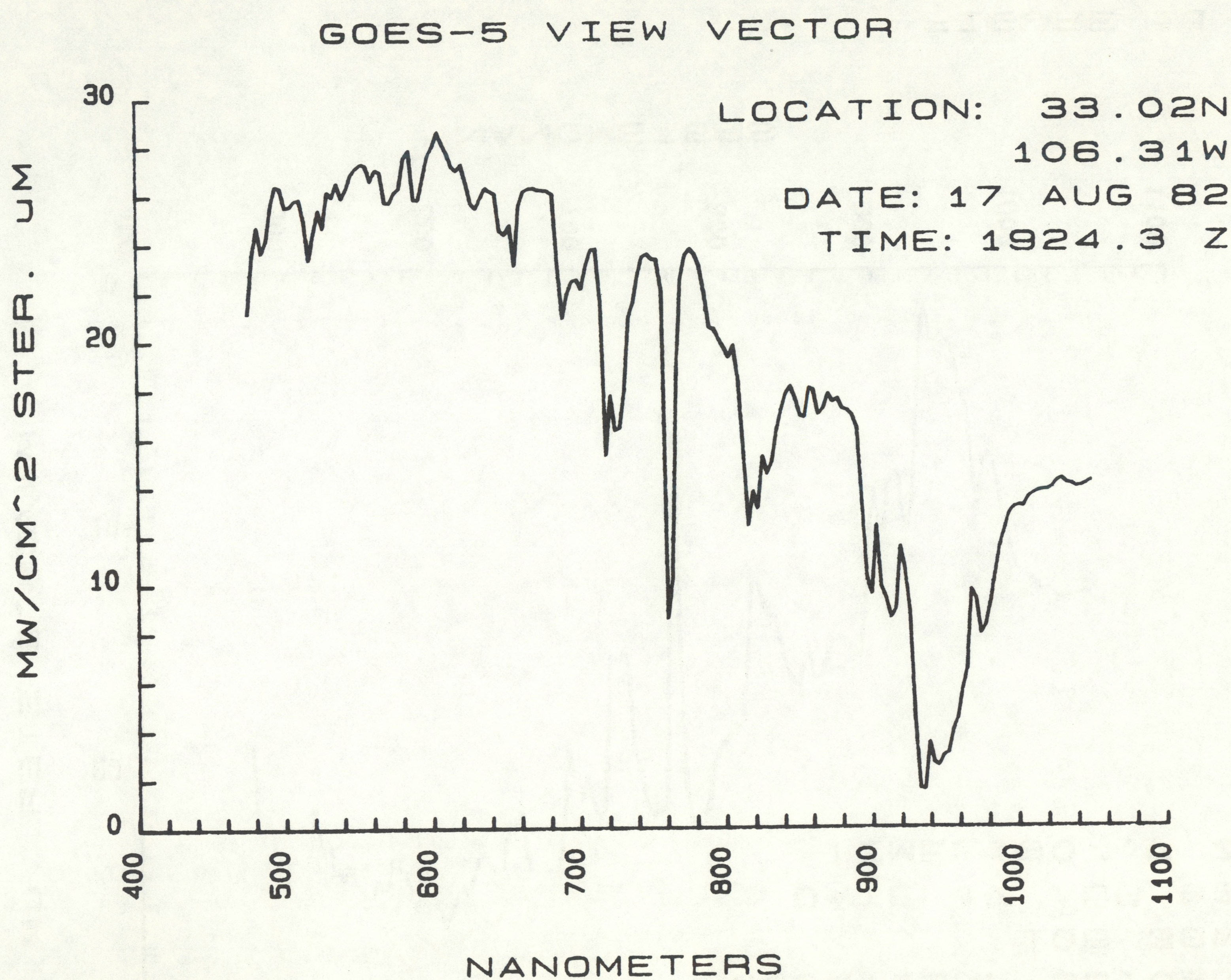
NANOMETERS

FIGURE 11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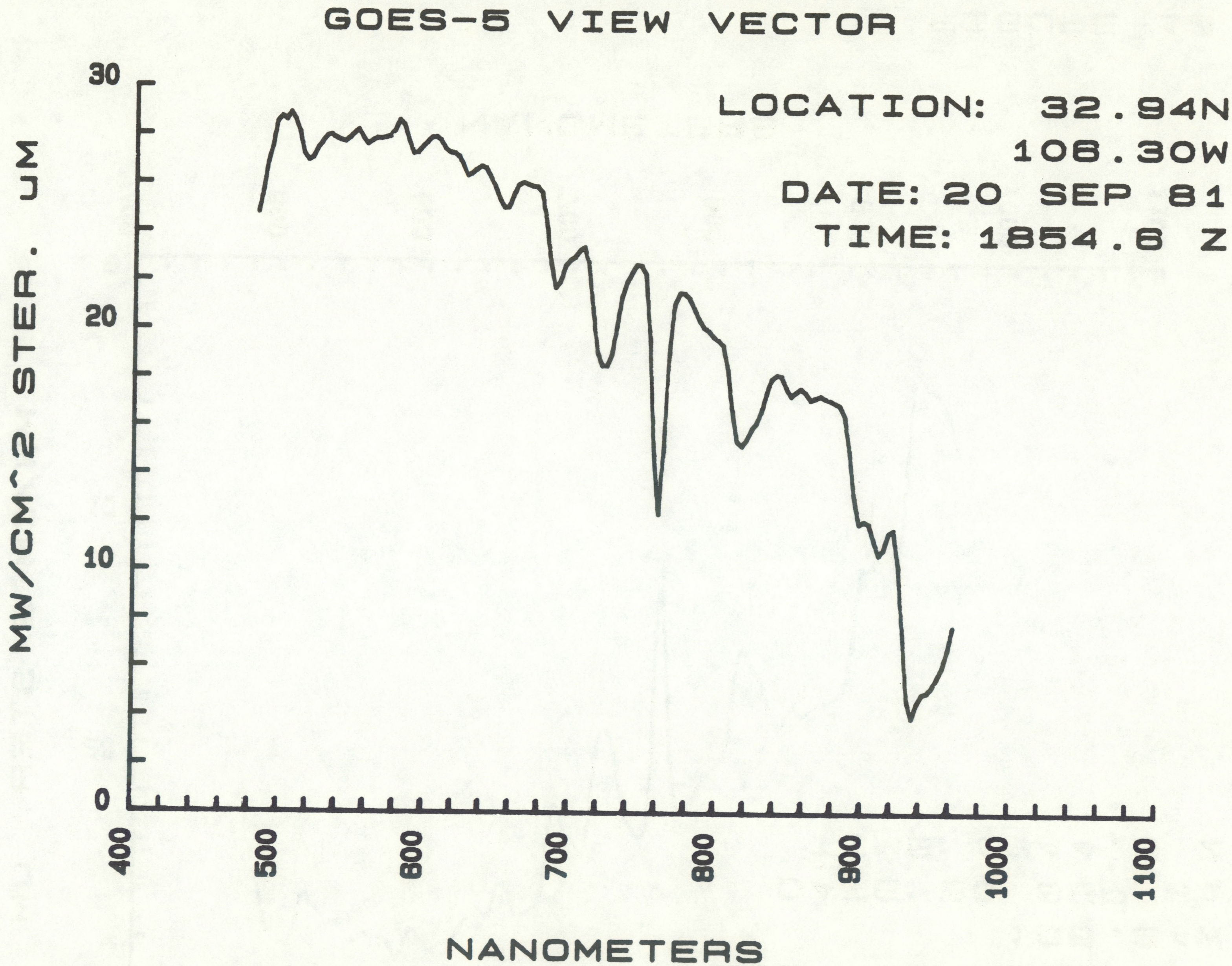
1100
NANOMETERS

FIGURE 12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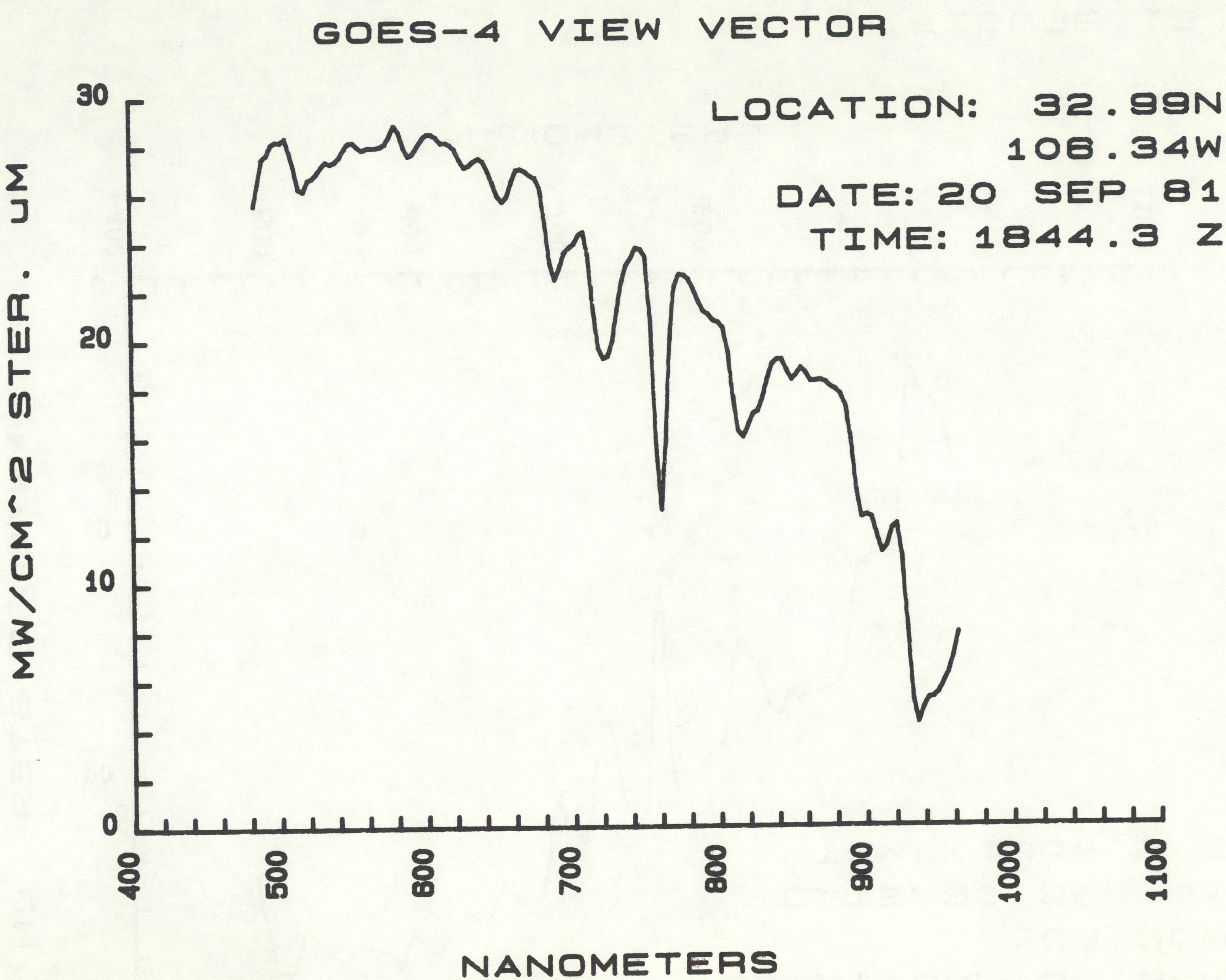
NANOMETERS

FIGURE 13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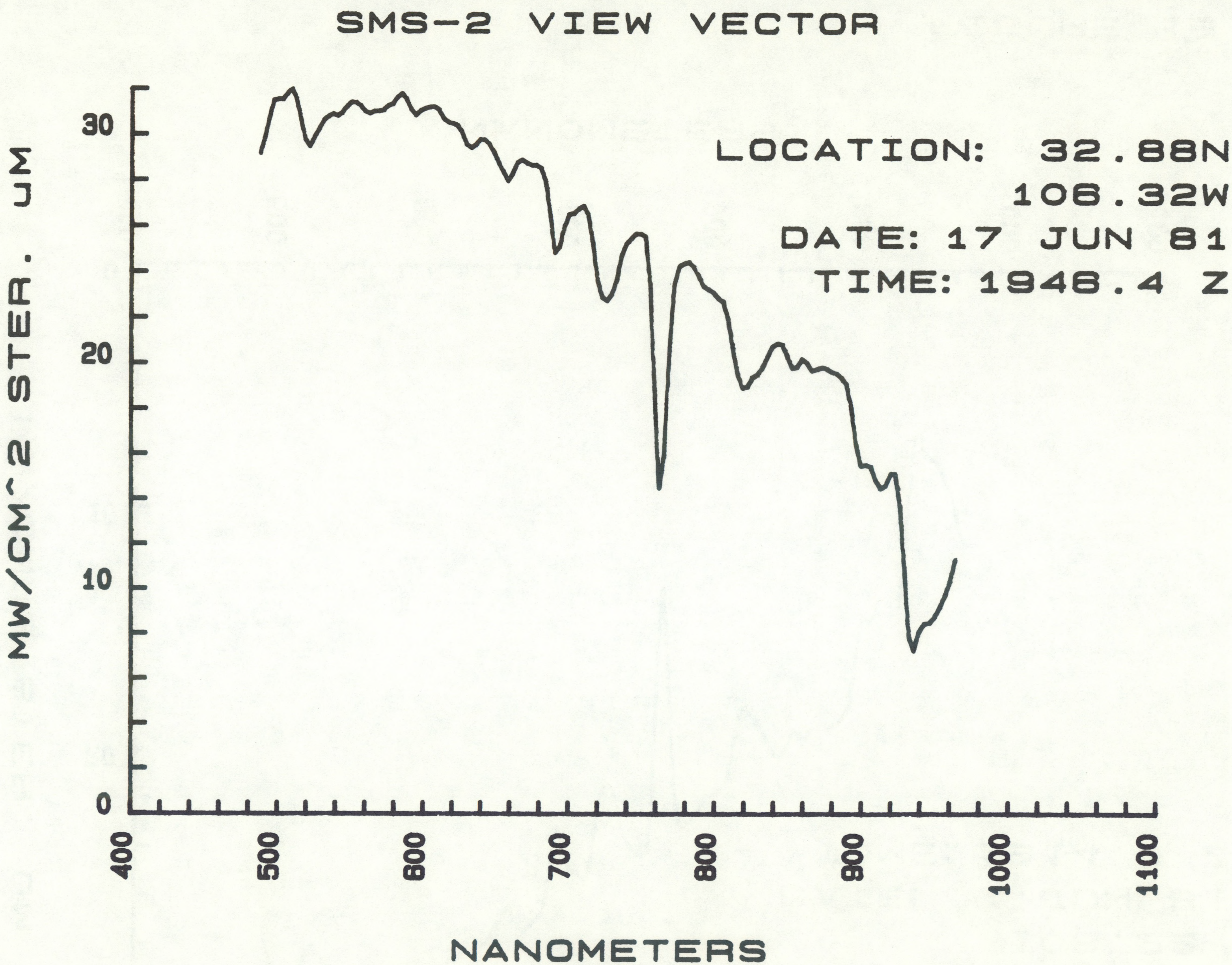
1100
NANOMETERS

FIGURE 14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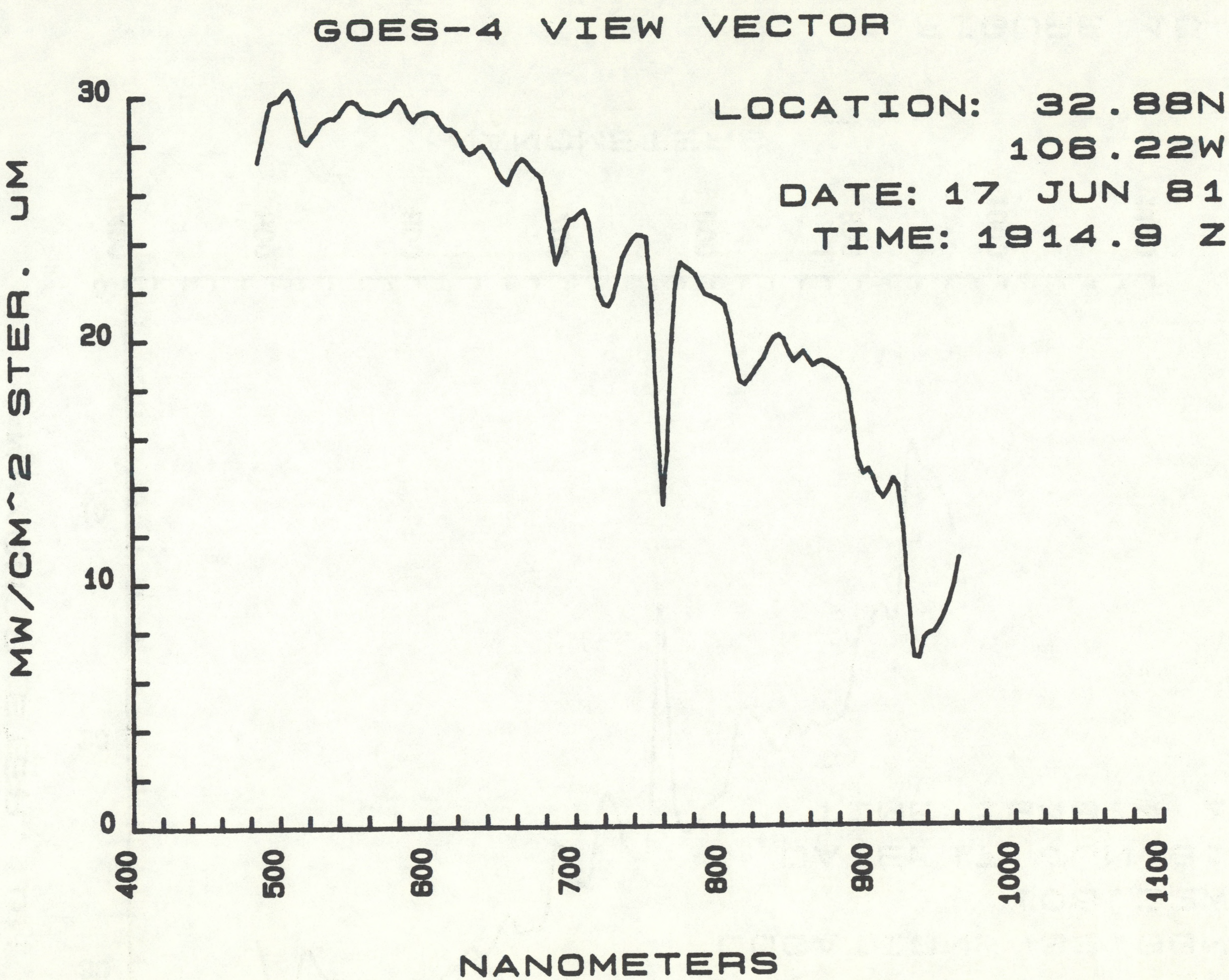
NANOMETERS

FIGURE 15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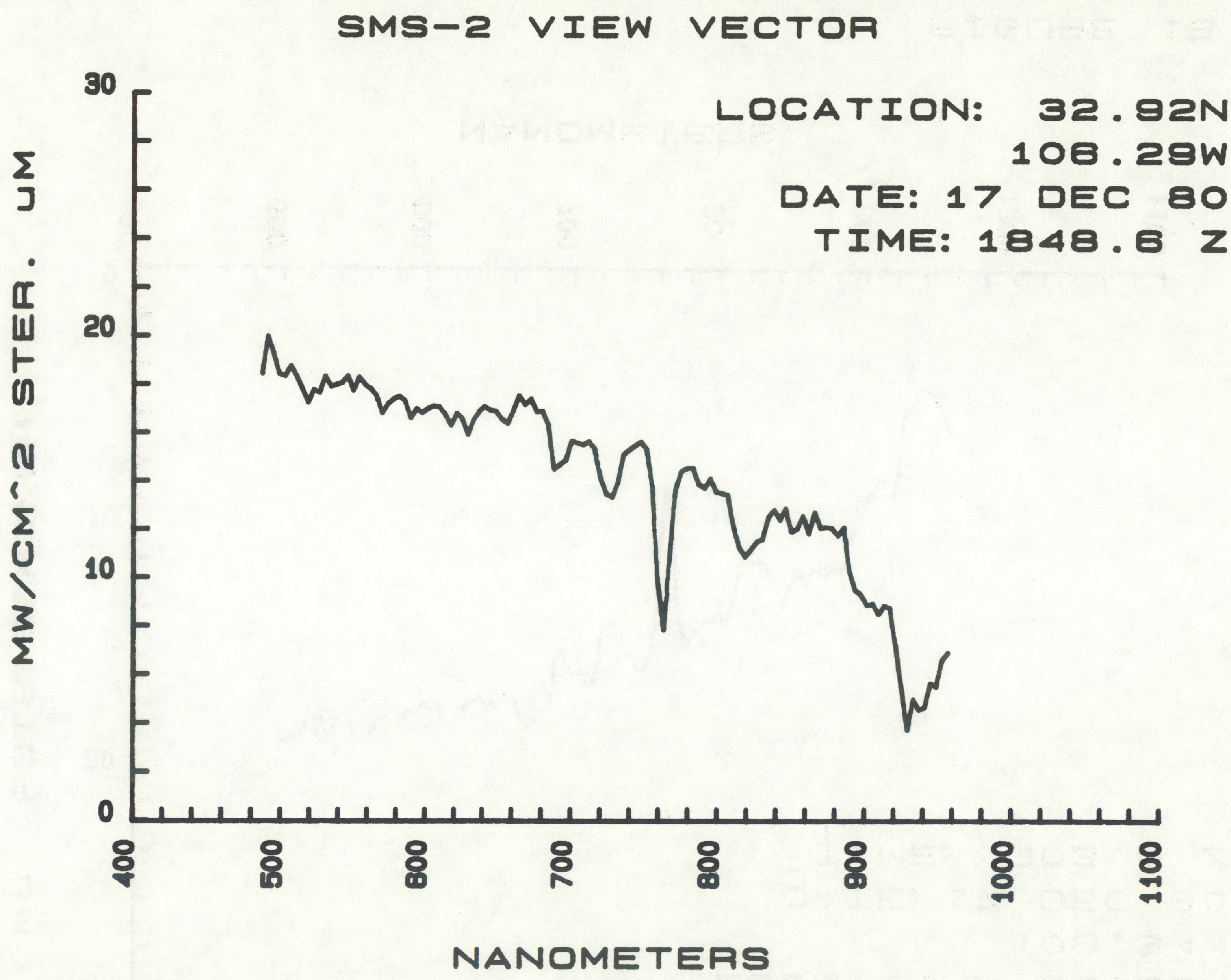
NANOMETERS

FIGURE 16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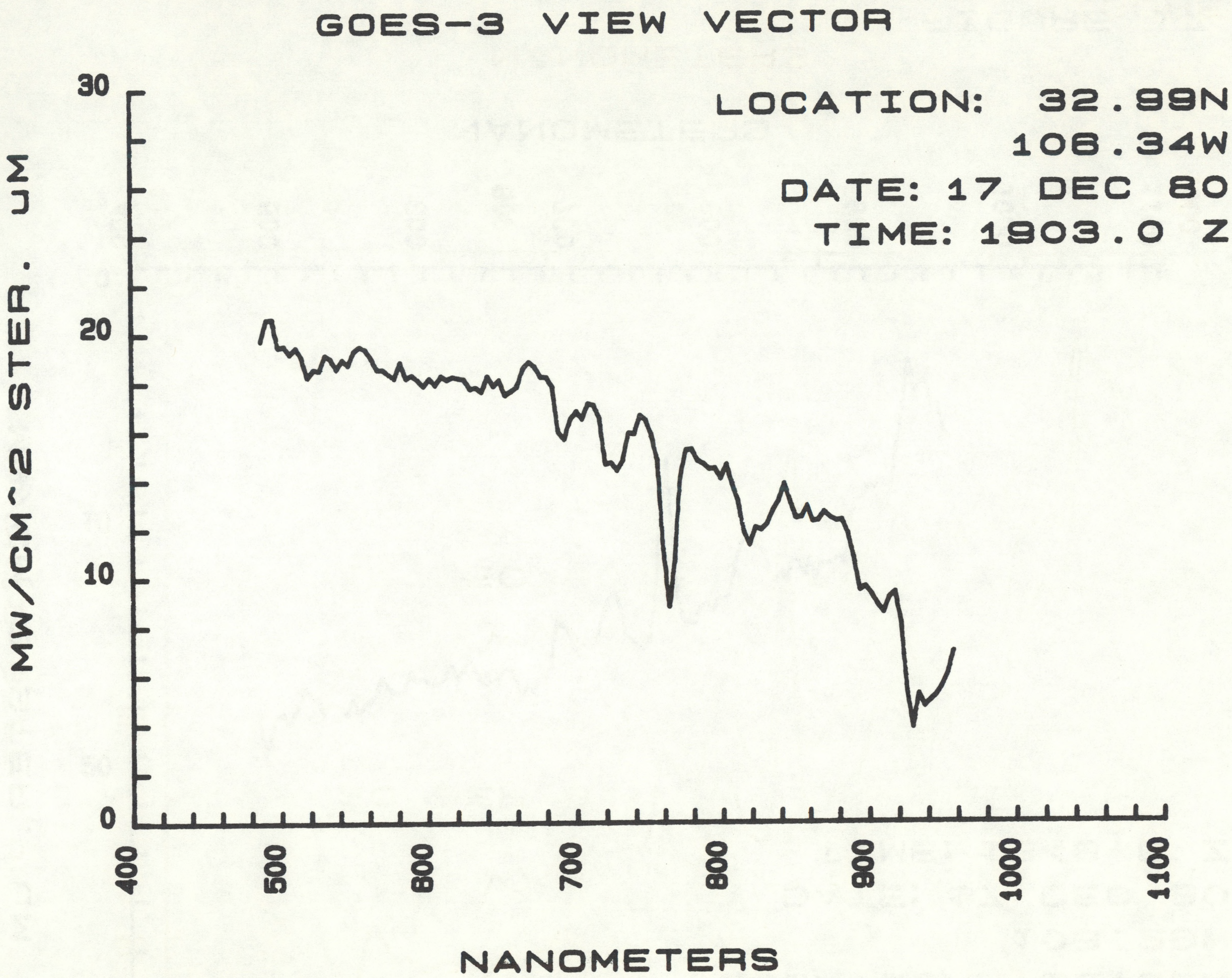
NANOMETERS

FIGURE 17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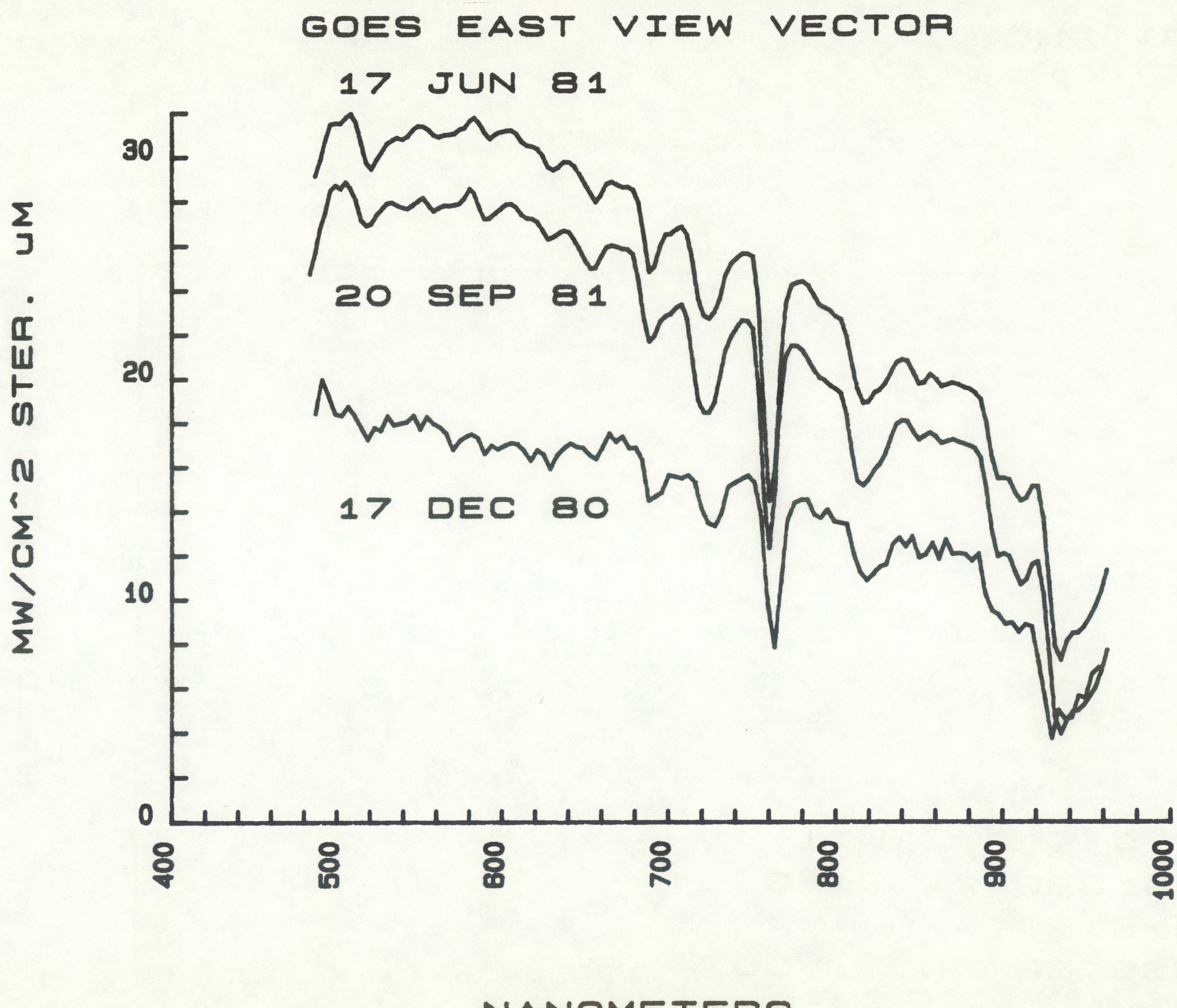
NANOMETERS

FIGURE 18



GOES EAST VIEW VECTOR
17 JUN 81
20 SEP 81
17 DEC 80
MW/CM^2 STER. uM
0
10
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30
400
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600
700
800
900
1000
NANOMETERS

FIGURE 19

(Continued from inside cover)

NESDIS 6 Spatial and Temporal Distribution of Northern Hemisphere Snow Cover. Burt J. Morse (NESDIS) and Chester F. Ropelewski, October 1983. (PB84 118348)

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NESDIS 8 Monitoring of Long Waves in the Eastern Equatorial Pacific 1981-83 Using Satellite Multi-Channel Sea Surface Temperature Charts. Richard Legeckis and William Pichel, April 1984. (PB84 190487)

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NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

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