OAA Technical Memorandum NESS 96

SATELLITE DATA SET FOR SOLAR INCOMING RADIATION STUDIES

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NESS 71 Nimbus-5 Sounder Data Processing System, Part II: Results. W. L. Smith, H. M. Woolf, C. M. Hayden, and W. C. Shen. July 1975, 102 pp. (COM-75-11334/AS)

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NESS 73 Operational Processing of Solar Proton Monitor Data. Stanley R. Brown, September 1975. (Revision of NOAA TM NESS 49), 15 pp. (COM-73-11941)

NESS 74 Monthly Winter Snowline Variation in the Northern Hemisphere from Satellite Records, 1966-75. Donald R. Wiesnet and Michael Matson, November 1975, 21 pp. (PB-248437)

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J. Dan Tarpley, Stanley R. Schneider,
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ABSTRACT. The National Environmental Satellite Service (NESS) collected and processed Geostationary Operational Environmental Satellite (GOES) data in the summer of 1977 as part of a joint experiment with the Great Plains Agricultural Council (GPC) to determine if incoming solar radiation could be inferred from satellite data. The satellite data collection effort entailed the calculation of cloud amount, cloud brightness, mean target brightness, precipitable water, and surface pressure for 50-km areas over the Great Plains. Sixty-three days of satellite data were collected. A coincident set of pyranometer data was obtained by the GPC.

1. THE JOINT NESS/GPC SOLAR INSOLATION EXPERIMENT

The NESS has undertaken a joint experiment with the GPC to determine if incoming solar radiation at the surface can be inferred using satellite data. The study is divided into two parts, a data-gathering effort and an analysis effort. This report discusses the recording and processing of the satellite measurements for the data collection part of the experiment.

Insolation (incoming solar radiation) is defined as the rate at which direct and scattered solar radiation is incident upon a unit horizontal surface and is measured in units of energy/area•second. Insolation at the Earth's surface in the visible region of the solar spectrum is one of the most important meteorological variables determining growth rate of crops. The ultimate use for satellite-inferred insolation is measurement of the spatial distribution of radiation for large-scale estimates of potential evapotranspiration and photosynthesis.

Insolation is also the quantity of interest in estimating the solar energy available at specific locations. For example, detailed insolation data are needed for finding optimum sites for solar power plants.

The NESS/GPC experiment entailed the collection of coincident satellite, conventional meteorological, and pyranometer data over the Great Plains during the summer of 1977. The conventional meteorological data and the satellite measurements were those expected to contain the most information relating to surface insolation. Scene brightness, cloud brightness, and cloud amount were computed from satellite data. Surface pressure and precipitable water were obtained from the National Meteorological Center (NMC), and ground truth measurements of insolation were made with the GPC pyranometer network.

2. DESCRIPTION OF THE SATELLITE AND SENSOR

Two geostationary meteorological satellites operated by NESS, the Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite (SMS-2/GOES-2), view the Earth's disk through Visible and Infrared Spin-Scan Radiometer (VISSR) instruments. A description of this dual geostationary satellite system can be found in Technical Memorandum NESS 64 (Bristor 1975). The satellites, GOES-2 and SMS-2, were fixed over the equator at 75°W and 135°W, respectively, at an altitude of about 37,500 km.

The VISSR instrument provides concurrent observations in the infrared (IR) spectrum (10.5 to 12.6 μm) and in the visible (VIS) spectrum (0.55 to 0.75 μm). The IR data are expressed as eight-bit count values that can be converted to equivalent blackbody temperatures. The VIS data are expressed as six-bit count values measuring relative brightness. Information is also appended to the data that allows the values to be located with respect to the Earth's surface.

3. THE VISSR DATA BASE (VDB)

The digital VISSR data, at reduced resolution from the eastern and western satellites, are being processed into an experimental VDB. Data may be obtained from each satellite at 30-minute intervals. About 18 minutes are required for the VISSR to produce the digital image or "picture" of the full disk. The western satellite's data are normally acquired at 15 minutes and 45 minutes after the hour, while the eastern satellite's data are acquired on the hour and half hour. Data from the full Earth's disk are currently reduced to areas extending from 50°N-50°S latitude and approximately 50° longitude east and west of the satellite subpoints. These stored arrays of digital data will be referred to as "pictures."

The VDB is formed by processing data ingested in real time from the SMS/GOES satellites onto computer disks. Data at full resolution are received at Suitland, Maryland, via two 7-m dish antennas. The data then pass through interfacing electronics to the VISSR ingest computers (sectorizers), where the resolution of the VIS channel is reduced from 1 km to 4 km. The resolution of the IR channel at this stage is still 4x8 km. The data are then passed to NOAA's IBM S360/195 computer via a direct-memory interface unit and software known as the real-time monitor. The software that actually builds the VDB takes data from a staging disk formed by the real-time monitor, reduces both the VIS and IR channels to 8-km resolution, and places the data on computer disks. When data are placed in the VDB in this manner, they can normally be accessed for use about 3 minutes after the end of the picture or about 22 minutes after the start of the picture. Some data in the VDB are placed there via magnetic tape and would be available for use about one hour after picture start time. It should also be noted that the VDB also contains selected, 4-km VIS pictures.

The VDB physically resides on four disk packs that comprise a portion of the NOAA IBM S360/195 computer facility at Suitland. The data are maintained for 24 hours. After 24 hours, a selected portion of the data is archived on

magnetic tape for the Environmental Data Service (EDS); the remaining data are overwritten on disk with current data. The characteristics of the experimental VDB are summarized in table 1.

Table 1.--The experimental VISSR Data Base (VDB)

Satellite	Subpoint	Acquisition times	Data coverage	Data residence time
East (GOES-2)	75°W	On the hour and selected half-hour pictures	50°N-50°W; 25°W-125°W	24 hr
West (SMS-2)	125°W	15 minutes after the hour and selected 45-minutes after-the-hour pictures	50°N-50°S; 85°W-175°E	24 hr

Sensor Data Characteristics:

Data type	Spectral interval	Units	Convertible to	Nominal subpoint spatial resolution
IR	10.5-12.6 μm	8-bit count values	Equivalent blackbody radiative temperatures	8 km
VIS	0.55-0.75 μm	6-bit count values	Albedo	8 km

Other Characteristics:

- Earth location and calibration information are appended.
- Resides on four disk packs in the NOAA IBM S360/195 computer system.
- Currently, some 95 of the possible 144 pictures are processed.
- The processing system, format, and data coverages are experimental and, thus, are subject to interruption at any time by operational priorities and requirements.
- 0930Z, 1000Z, 1600Z, 2130Z, 2200Z IR and 1600Z VIS are archived for EDS.
- 1015Z, 1045Z, 1515Z, 1545Z, 2145Z IR and 2145Z VIS are archived for EDS.

4. DESCRIPTION OF THE STUDY AREA

The region selected for the insolation test is bounded by the 29°N and 49° N parallels of latitude and the 95°W and 105°W meridians. This geographic block with dimensions of 10° longitude by 20° latitude covers an area of about 1,560,000 square km. The area (figure 1) includes the bulk of the Great Plains and is comprised of all or parts of 13 states: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Montana, Wyoming, Colorado, and New Mexico.

According to the U.S. Geological Survey (USGS 1970), the region is comprised of over 75 percent farmland with wheat, sorghum, and barley being the predominant crops. Mean annual precipitation ranges from 30 cm in the western

Figure 1.--Area covered by surface insolation experiment.

Dakotas up to 100 cm in eastern Oklahoma and Texas. Daily temperatures for the June, July, and August test period average about 26°C with daily maximums averaging 5°C higher. The area is classified by the USGS as "marginal" regarding drought potential; that is, it is vulnerable to droughts of long duration.

Elevation above sea level in the test area rises continuously from about 300 m in the east to 1,600 m in the west. Land-surface forms vary from the broad, flat Red River of the north plain along the Minnesota-North Dakota border to the domed Black Hills of South Dakota where elevations peak at over 2,100 m.

Most of the test area is displayed in figure 2, a 1-km resolution image transmitted by GOES-1 on September 30, 1976, at 1800Z (local noon). A number of surface landmarks in the test area are annotated including three large reservoirs formed by dams on the Missouri River: Oahe in South Dakota, Garrison in North Dakota, and Ft. Peck in Montana. Owing to the thick cover of ponderosa pine forests, the Black Hills of South Dakota show up as the darkest (least reflective) feature on the image. Southeast of the Black Hills are the barren, weathered rock formations of the Badlands, the lightest (most reflective) surface feature on the image. Barely visible in western Nebraska is Lake McConaughy, formed by a dam on the North Platte River constructed several miles upstream from its confluence with the South Platte. Numerous small reservoirs can also be seen dotting the Oklahoma-Texas region. The largest of these, Lake Texoma, is the product of a Red River dam on the Texas-Oklahoma border. The forested ranges of the Rocky Mountains are clearly visible on the left-hand side of the image.

5. SATELLITE AND CONVENTIONAL METEOROLOGICAL DATA COLLECTION

Visible solar radiation incident on the Earth is either reflected to space, absorbed in the atmosphere, or absorbed by the Earth's surface. Surface insolation, the quantity of interest, is a function of incident solar radiation and the amounts of energy reflected to space and absorbed in the atmosphere.

The visible solar radiation flux incident at the top of the atmosphere is precisely known; it is a function of solar zenith angle and Sun-Earth distance. It is depleted in a clear atmosphere by absorption and scattering, resulting in an attenuated direct beam and a significant flux of diffuse radiation. The major absorbers are water vapor and aerosols. Radiation is scattered by atmospheric molecules (Rayleigh scattering) and aerosols (Mie scattering). In the presence of clouds, there is a very large increase in scattering and some increase in absorption, and, of course, less incoming radiation at the surface.

It is not known what quantities measurable from satellites and/or obtainable from NMC are the best predictors of surface insolation. The quantities obtained for this experiment were surface pressure and precipitable water from NMC and mean target brightness, cloud amount, and cloud brightness from satellite observations.

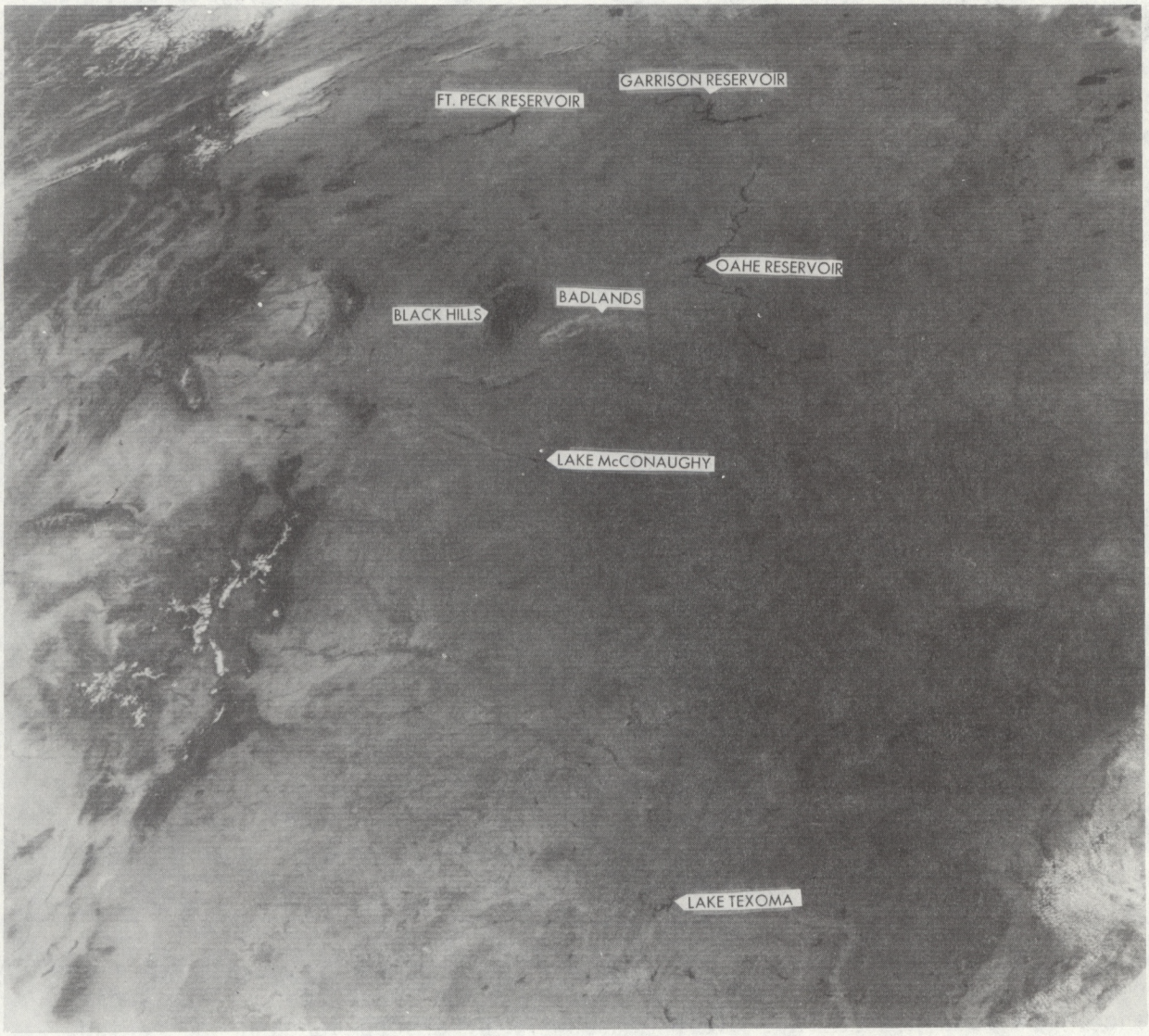


Figure 2.--One-km GOES-1/VISSR image taken over the test area on September 30, 1977.

Surface pressure is a measure of the total air mass traversed by the radiation and should be correlated with the depletion caused by molecular scattering. Precipitable water (the total water in an atmospheric column) provides information on absorption and scattering by water vapor.

The three satellite-derived quantities describe cloud conditions and total scattered radiation from the targets. The mean target brightness measures the reflected radiation due to all causes; the cloud amount and brightness yield information on the radiation component absorbed and scattered by clouds.

For the experiment, the Great Plains was divided into targets that were approximately 50 km on a side, made up of 7x6 arrays of pixels. The targets were centered at the intersections of 1/2°-interval latitude and longitude lines beginning at the study area boundaries. Thus, the Great Plains was divided into 861 targets in a 21x41 array. Data were collected for each target.

5.1. Determination of Target Clear Radiances

To determine cloud characteristics, it was necessary to know when each pixel was cloud free. The approach used here was to compute an expected clear-radiance count value for each target on the basis of solar zenith angle and the azimuth angle between the Sun and satellite. Regression techniques with coefficients derived from a set of clear observations were used to estimate clear radiances.

5.1.1. Data Collection

To compute clear-radiance regression coefficients, a set of more than a hundred observations per target was collected and stored. Clear radiances were calculated on a 2° grid, and values of 1/2° target intervals were achieved by interpolating between grid points. The 2° grid provided clear radiances at high enough resolution to account for most topography- and vegetation-caused variations in the Great Plains surface albedo and, at the same time, saved handling large amounts of data required by full 1/2° resolution.

During 27 days in May 1977, data were accessed at each 2° grid point from as many visible pictures as were available for each day. The data were in arrays of 9x9 pixels centered on the grid points; the arrays were approximately 100 km on a side. These clear-radiance data arrays were larger than the insolation targets to give a more representative value when the clear radiances were interpolated at 1/2° intervals. Quantities computed and stored for each 2° grid point were the target array mean and standard deviation and the solar azimuth and zenith angles.

5.1.2. Determination of Regression Coefficients

Processing of the data to obtain regression coefficients required the elimination of cloud-contaminated observations and fitting a regression

equation to the remaining clear cases. Figure 3 illustrates the steps in the procedure. An automatic cloud detection and elimination procedure was used because of the large volume of data.

The data were processed by target. A pass was made through the data discarding samples with solar zenith angles greater than 85° or with target standard deviation greater than 1.3 counts. Samples taken at large solar zenith angles were more likely to be anomalous, probably because of cloud shadows. Standard deviation was used as an indicator of clouds in the target; the standard deviation test threw out about 90 percent of the cloud-contaminated cases.

The data remaining after the initial sort were fitted to a regression equation of the form,

$$CR = a + b \cos \chi + c \sin \chi \cos \phi + d \sin \chi \cos^2 \phi \ ,$$

where CR is the visible clear radiance from the target, χ is the local solar zenith angle, and ϕ is the azimuth angle between Sun and satellite. The angles are shown in figure 4. The second term on the right of the equation accounts for changing incident flux; the last two terms account for changes in apparent target brightness caused by shadowing at the surface.

The sort on standard deviation produced a data set sufficiently cloud free that a reasonable clear-radiance prediction equation was obtained from it. Residuals from the "first-guess," clear-radiance equation were used to identify remaining cloud-contaminated data. This was a cyclic procedure (figure 3) that, after two cycles, yielded a cloud-free data set and accurate regression coefficients.

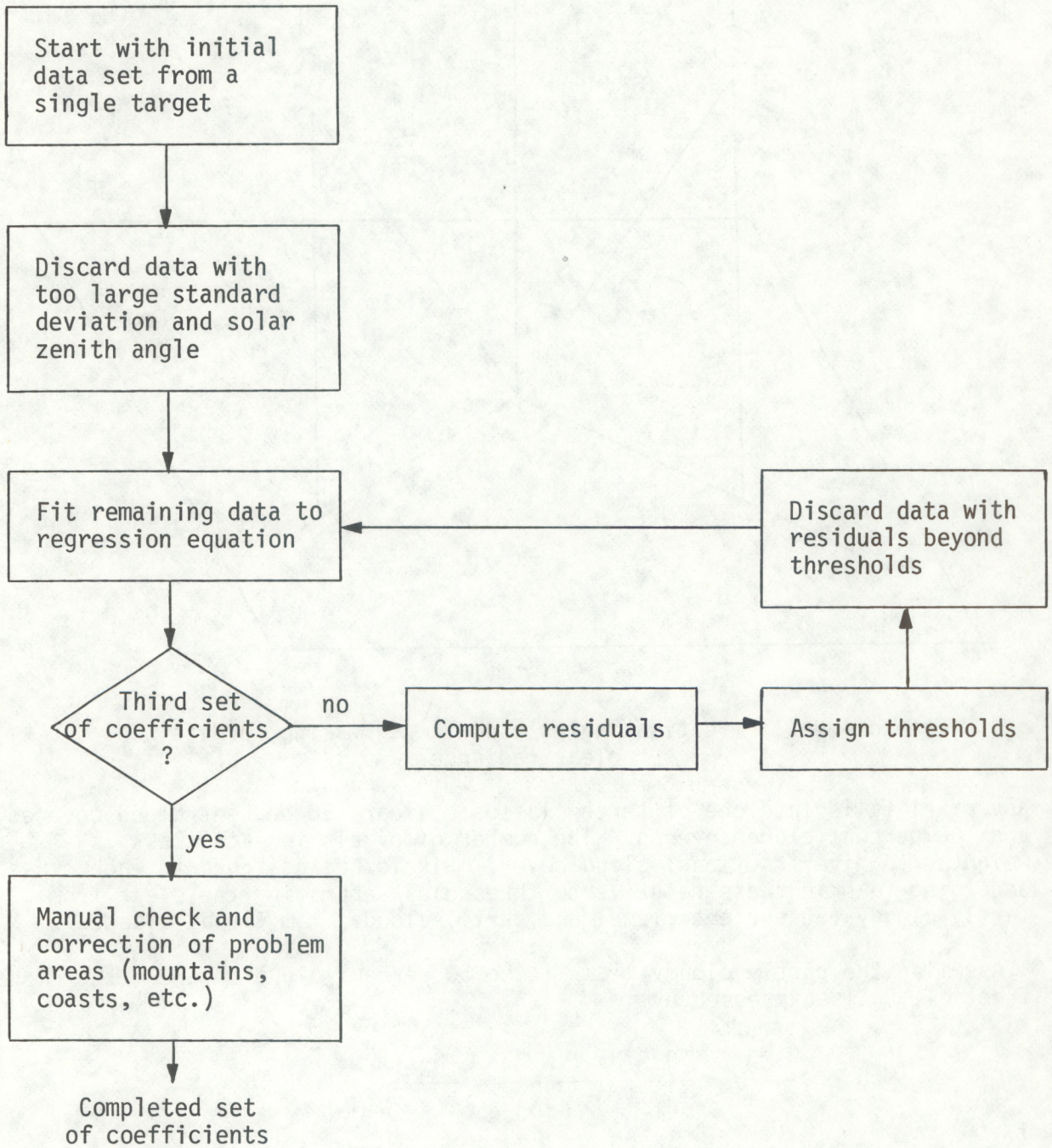
The residuals, defined as the difference between the measured and predicted radiances, were compared against thresholds; residuals exceeding these thresholds were discarded from the data set. The thresholds were tightened between the first and second passes through the data to eliminate data contaminated by small amounts of cloudiness.

The standard error of the estimate for the final regression equation ranged from 0.5 to 0.9 counts for most Great Plains' targets, an accuracy considered sufficient for assigning clear/cloudy thresholds. Targets containing features with markedly contrasting brightness could not be accurately fitted to the regression equation. Such targets included those containing mountain ranges, coastal areas, and large lakes. In all these cases, the regression coefficients determined for targets with a uniform surface as bright as the brightest feature in the nearest nonuniform target were used to predict clear radiance for the nonuniform target. This procedure insured that no clear surface was mistaken for cloudiness in the nonuniform targets. The regression coefficients used for each 2° grid point are given in appendix A.

5.2. Cloud Amount

Cloud amount in each target was computed using a two-threshold method (Shenk and Salomonson 1972). The approximation basic to this method is that

Figure 3.--Procedure for obtaining clear-radiance coefficients for a specific target.



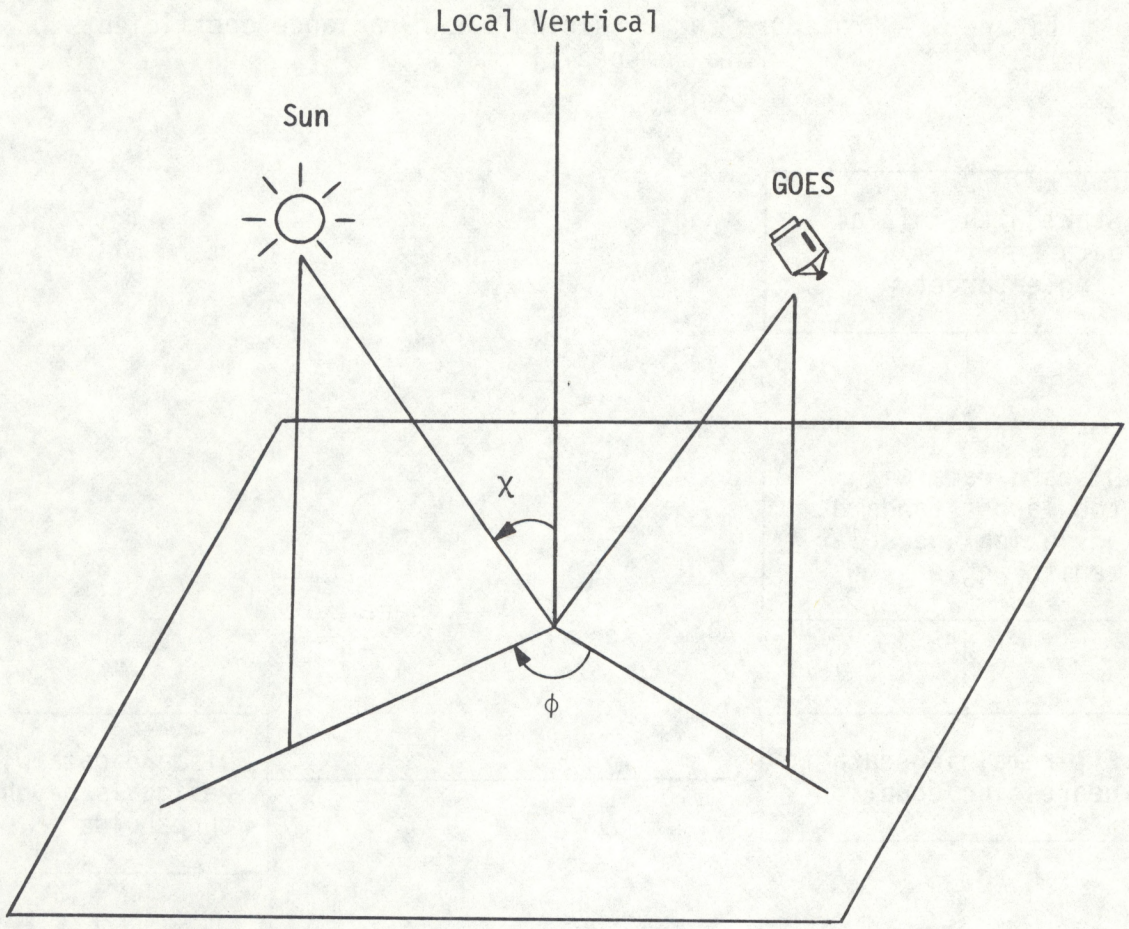


Figure 4.--Illumination angles used in regressing for visible clear radiance.

any pixel falls into one of three classes: clear, 50 percent cloud covered, and 100 percent cloud covered. The number of pixels in each class is weighted to give fractional cloud cover. Pixels are assigned to each class according to brightness relative to thresholds separating the clear from partly-cloudy (50 percent cloud) and partly-cloudy from cloudy classes.

Assuming the partly cloudy class to be 50 percent cloud covered, the cloud fraction, C, is expressed by

$$C = \frac{0.5\ N_2 + N_3}{N_1 + N_2 + N_3} = \frac{N_2 + 2N_3}{2N} \quad ,$$

where N is the total number of pixels in the target area and N_1, N_2, and N_3 are the numbers of pixels in the clear, partly-cloudy, and cloudy classes, respectively.

A clear/partly-cloudy threshold, T_1, was obtained by adding three counts to the clear radiance predicted by regression. A pixel was called clear if its

count value was $\leq T_1$. A partly-cloudy/cloudy threshold, T_2, was taken to be the clear radiance plus five counts. The partly-cloudy pixels were those with values $> T_1$ and $\leq T_2$. The cloudy pixels were those $> T_2$.

The accuracy of the cloud fraction algorithm is unknown. The thresholds used were set to yield relatively good estimates with bright waterdrop clouds. (Thin cirrus clouds in the target lead to underestimates of cloud amount.) For inferring insolation, it is probably sufficient to have a quantity that is a sensitive indicator of cloud cover; it is not necessary that it be absolutely accurate.

5.3. Computation of Cloud Brightness

The amount of solar radiation absorbed and reflected by clouds is a function of cloud thickness. The brightness of clouds when observed from a satellite is a good indicator of their thickness, so mean cloud brightness was included in the insolation data set. Mean cloud brightness was computed by averaging the count values of all pixels in a target that were brighter than the partly-cloudy/cloudy threshold. If there were no pixels brighter than the threshold, then the brightness was set to zero.

5.4. Mean Target Brightness

The third satellite-derived quantity computed for each target was the mean brightness. This quantity is simply the mean count value of all pixels in each 7x6 pixel array (target).

5.5. Precipitable Water and Surface Pressure

Two readily available meteorological quantities that affect the amount of solar radiation reaching the surface are atmospheric pressure and moisture. These quantities were accessed from the NMC 00Z data file in the form of surface pressure (mb) and precipitable water (mm/cm^2). These files are updated twice daily; the 00Z file contains information most nearly time-coincident with the satellite measurements. The data are kept in the NESS/NMC computing facility on a 65x65 mapped data array. Accessing routines retrieve pressure and precipitable water for each target using the values at the nearest NMC grid point which, in the Great Plains region, may be as far as 2° latitude and longitude from the target.

5.6. Calculation of Solar Zenith and Azimuth Angles

Hourly values of local solar zenith and azimuth angles used to compute expected clear radiances (figure 4) were saved for each target for possible use in analyzing the data. Computation of azimuth and zenith angles requires the latitude and longitude of the target, solar declination, and time of observation. Latitude and longitude can be exactly specified. The solar declination changes slowly, especially during the summer, so the value used was the declination of 1200 GMT on the day of the observation.

The beginning time for each picture from the east satellite is on the hour and half hour. The instrument scans the Great Plains between five and ten minutes after initiation of the picture; however, the exact measurement time

for each target is unknown. The beginning time was used for computation of the solar position angles. The resulting errors were in the neighborhood of one degree.

6. RESULTS OF SUMMER 1977 COLLECTION EFFORT

The GOES-1, 8-km VDB was used between June 1 and August 15 to extract information from about 10 pictures daily (1400, 1500, 1600, 1700, 1800, 2000, 2100, 2130, 2200, and 2300Z). The 1900Z time slot was reserved for production of 1-km sectors over the Western United States and, thus, was not available to the VDB.

Sixty-three days of usable data were obtained during the 75-day test; the 12 "bad" days are accounted for in table 2. The 63 days of usable data translated into 630 possible time slots or pictures available for the study. The 630 time slots resulted in 485 usable pictures, 35 unusable pictures, and 110 missing pictures. Unusable pictures account for only 6.77 percent of the total pictures received. Unusable pictures included those caused by excess line dropout, mislocation, and bad data. Of the 35 unusable pictures, 15 were received during a one-week satellite transition period (August 7-14, 1977); data on most of the unusable pictures were not properly geographically registered.

Table 2.--Breakdown of lost days of data

Reasons	Date	Number of days lost
User program error-cloud subroutine	June 1-6	6
User program error-line limits	June 10-11	2
Unavailability of NMC data base	June 8	1
Output disk file not mounted by operator*	July 2	1
Unintelligible output	July 8	1
Data lost in transfer from disk to tape	July 27	1
Total		12

*Output file switched to an on-line disk starting on this date.

As can be seen in table 3, the total number of usable pictures was 485. Of these, 80 pictures contained some line dropout. The 485 usable pictures, when averaged over 63 days, yielded 7.65 pictures per day. A histogram showing the daily number of usable pictures over the entire period is given in figure 5.

Throughout the test period, one designated target was monitored twice daily to check the accuracy of scene brightness values derived from the clear-radiance regression. The target, located in east-central Kansas at 38°N, 97°W, is fairly representative of the test area. Comparisons of the measured versus the predicted responses at 1600Z and 2100Z are shown respectively in

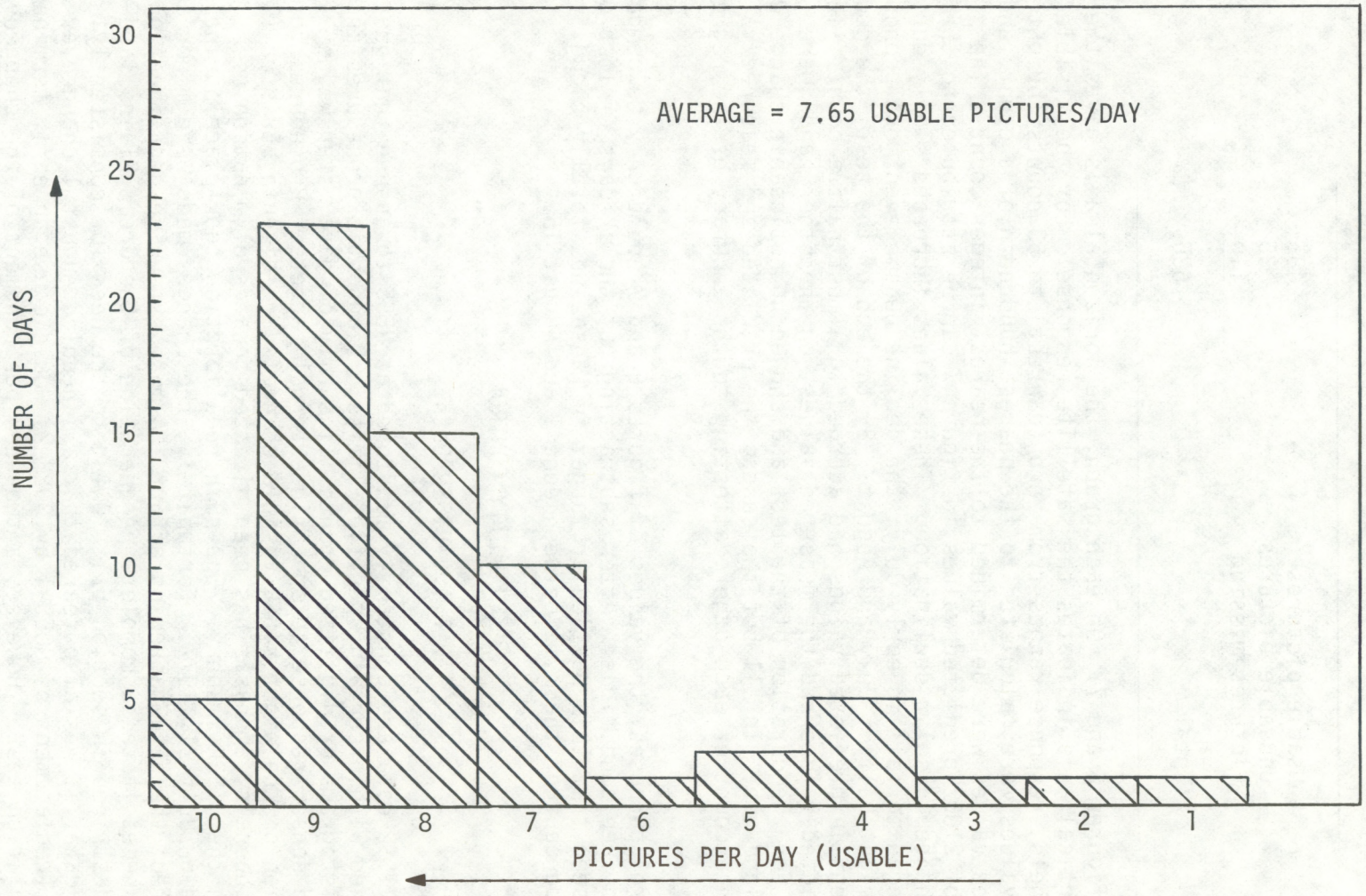


Figure 5.--Histogram showing the daily number of pictures successfully utilized during the test period.

Table 3.--Breakdown of possible time slots

Usable pictures	485
Unusable pictures	35
Pictures missing	110
Total	630

graphs on figures 6 and 7. On each graph, the horizontal axis gives the date and the vertical axis indicates the satellite response. For the visible VISSR channels, response ranges from zero (darkest) to 63 counts (brightest). Predicted values were calculated to the nearest hundredth of a count, and the measured values were determined to the nearest integer count. The variation of 2100Z predicted values in figure 7 can be attributed to the seasonal change in solar declination. These values increased slowly during June but began to fall in early July; the decline became even more pronounced during the last half of July and August. By the end of the test, the downward movement in predicted values had accrued to almost half a count. The 1600Z predicted values and the measured values, on the other hand, were consistent for the duration of the test and showed no noticeable change with season or land use. In all but two cases, the predicted and measured values were within a count of each other, attesting to the accuracy of the regression model.

For control purposes, the values of figures 6 and 7 could only be compared under cloud-free conditions. After subtracting out the 12 days of lost data, it can be seen that this particular target in Kansas was totally cloud free almost 50 percent of the time between June 1 and August 15.

7. QUALITY CONTROL

7.1. VISSR Data

The raw VISSR data are constantly monitored at NESS to assure that quality is maintained within certain specified limits. Diagnostic procedures include checking histograms of digitized counts, linearity of data, step wedge values, and sensor response to specific external targets. Procedures for normalization of the eight VISSR visible channels are given by Bristor (1975). For these channels, emphasis has been directed towards elimination of striping in the VISSR imagery. One such recalibration took place during the test period on July 21, 1977. Fortunately, the changes made were minor and did not affect the data-gathering effort. A more extensive recalibration might have necessitated a complete regeneration of the Great Plains land-use data base described in section 5.1. Owing to the need for consistently calibrated data, it was also feared that a scheduled August 1 changeover of satellites (replacement of GOES-1 by GOES-2) would cause an early termination of the insolation test. However, a two-week postponement of the changeover was granted to allow the insolation test to run to completion.

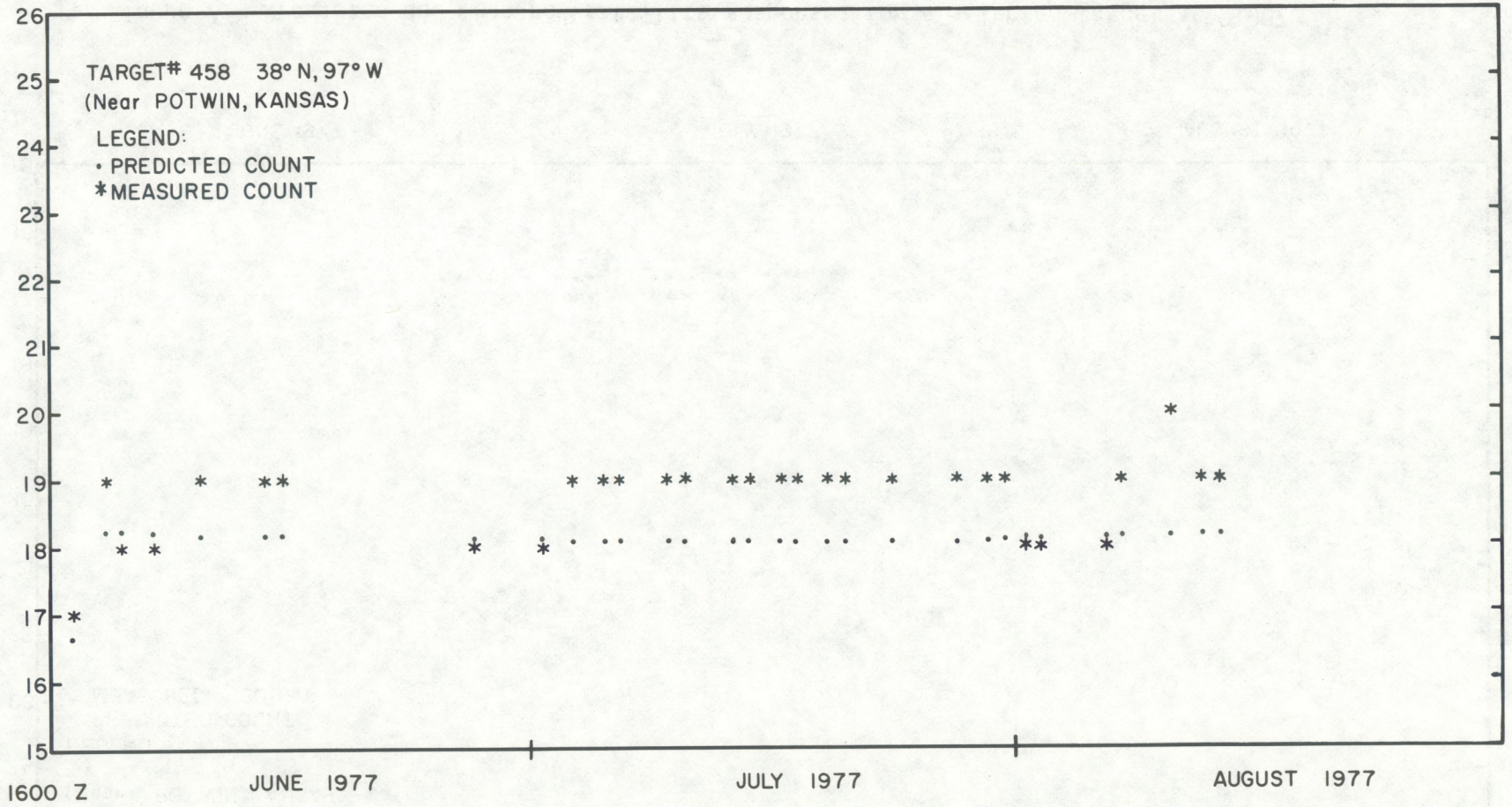


Figure 6.--Predicted and measured satellite responses for a selected target at 1600Z.

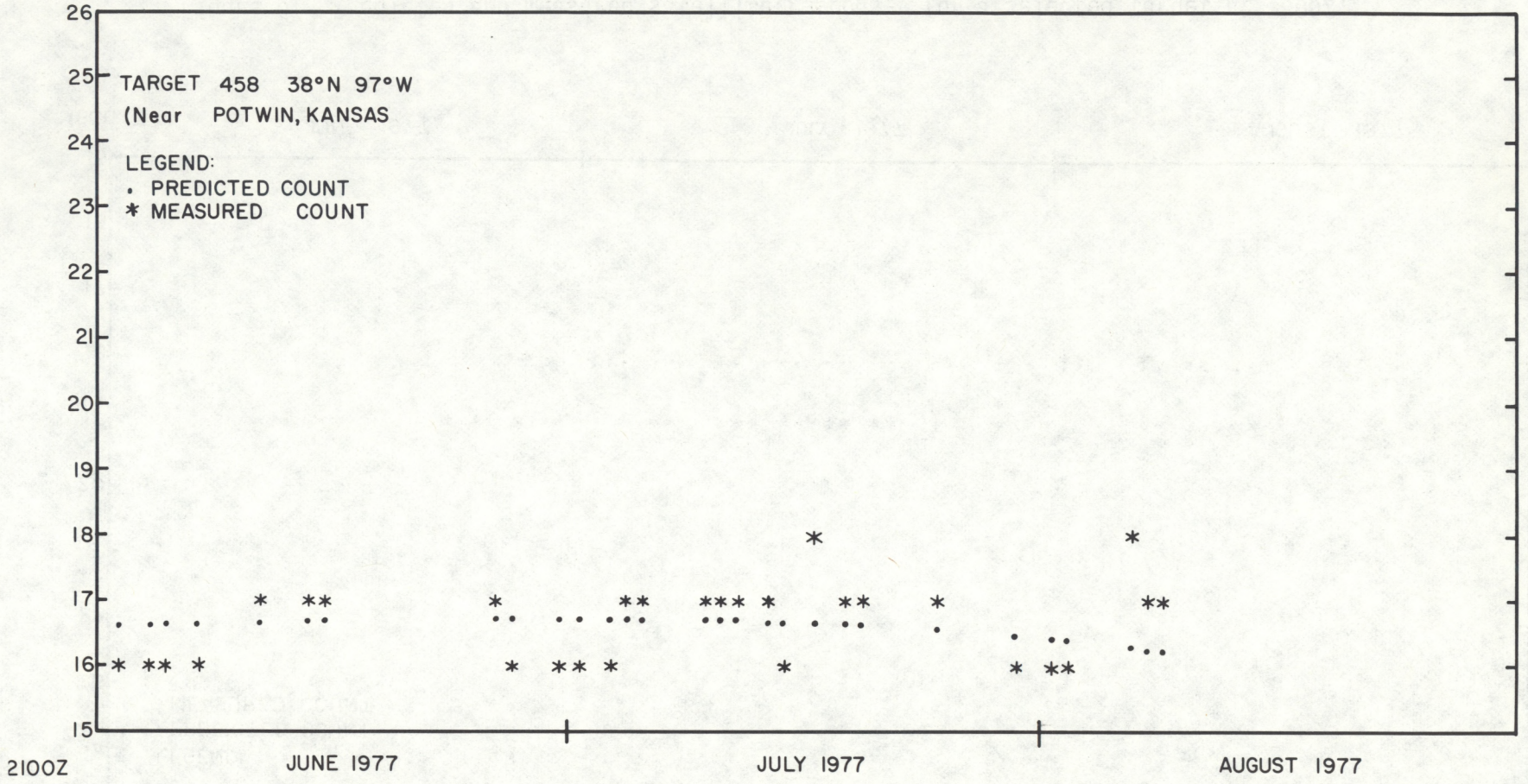


Figure 7.--Predicted and measured satellite responses for a selected target at 2100Z.

7.2. Test Data

The collected data were printed out daily so that values could be checked and geographic registration verified. Line dropout and invalid data were noted using both automatic and manual techniques. Brightness values, not in the valid 0-to-63 range, were tagged with a "-1" and their location was recorded in a log book.

Earth location was checked through the use of alphanumeric printouts giving a representation of each picture accessed from the VDB. Such a printout (reduced in scale) is displayed in figure 8. The printout is composed of alphanumeric characters, each character representing a pixel of 8-km resolution. Look-up tables were devised to assign the alphanumeric characters to the visible count values in such a way as to give a representation of surface features and clouds. The 10 characters used (WXO&=+-,. and blank) are arranged so that W's correspond to the lowest (darkest) values and blanks correspond to the highest (brightest) values. Thus, bodies of water are represented by a field of W's in the printout and clouds appear as blank. The look-up tables were varied with time of day to accommodate hourly changes in tone and contrast. Separate tables were used for the following time periods: 1400 and 2300Z, 1500 and 2200Z, 1600 and 2100Z, and 1700 through 2000Z.

The printout in figure 8 depicts the Great Plains at 1600Z on April 25, 1977. It contains 286 scan lines and is bounded by the 49°N parallel on top and the 24°N parallel on bottom. The GOES compatible grid was overlaid on the data through the use of an optical instrument, the Bausch and Lomb Zoom Transfer Scope. Particularly noticeable surface features on the printout are the Gulf Coast, Ft. Peck Reservoir in Montana, Garrison Reservoir in North Dakota, the Black Hills and Oahe Reservoir in South Dakota, Lake McConaughy in Nebraska, and Lake Texoma on the Texas-Oklahoma border. The most prominent landmark on the printout, the Black Hills, covers over 50 pixels; the smallest discernible, Lake McConaughy, covers only three. The range of count values for cloud-free targets is only six. The darkest feature, the Black Hills, is represented by an "&", which, at 1600Z, yields a count value of 17. The lightest land feature, the Badlands, is just to the southeast of the Black Hills and is represented by a swath of periods, ".", which corresponds to a count value of 23.

Any land feature can be used to verify the registration of the pictures on the VDB by comparing its location on the printout to its known geographic location. When all land features are obscured by cloud cover, a 4-km resolution GOES-1 image (figure 9) corresponding to the printout can be used for earth-location purposes. As can be seen in figure 9, there are scattered clouds just south of the Texas Panhandle and in the Oklahoma-Kansas region. These same clouds can be discerned as blank areas on the computer printout in figure 8. Similarly, mountain snowpacks and orographic clouds in Wyoming and Colorado can be seen in both image and printout.

8. DATA TAPE FORMAT

The data collection program was run once daily accessing all pictures on the VDB between 1400 and 2300Z as well as the NMC data files. The output

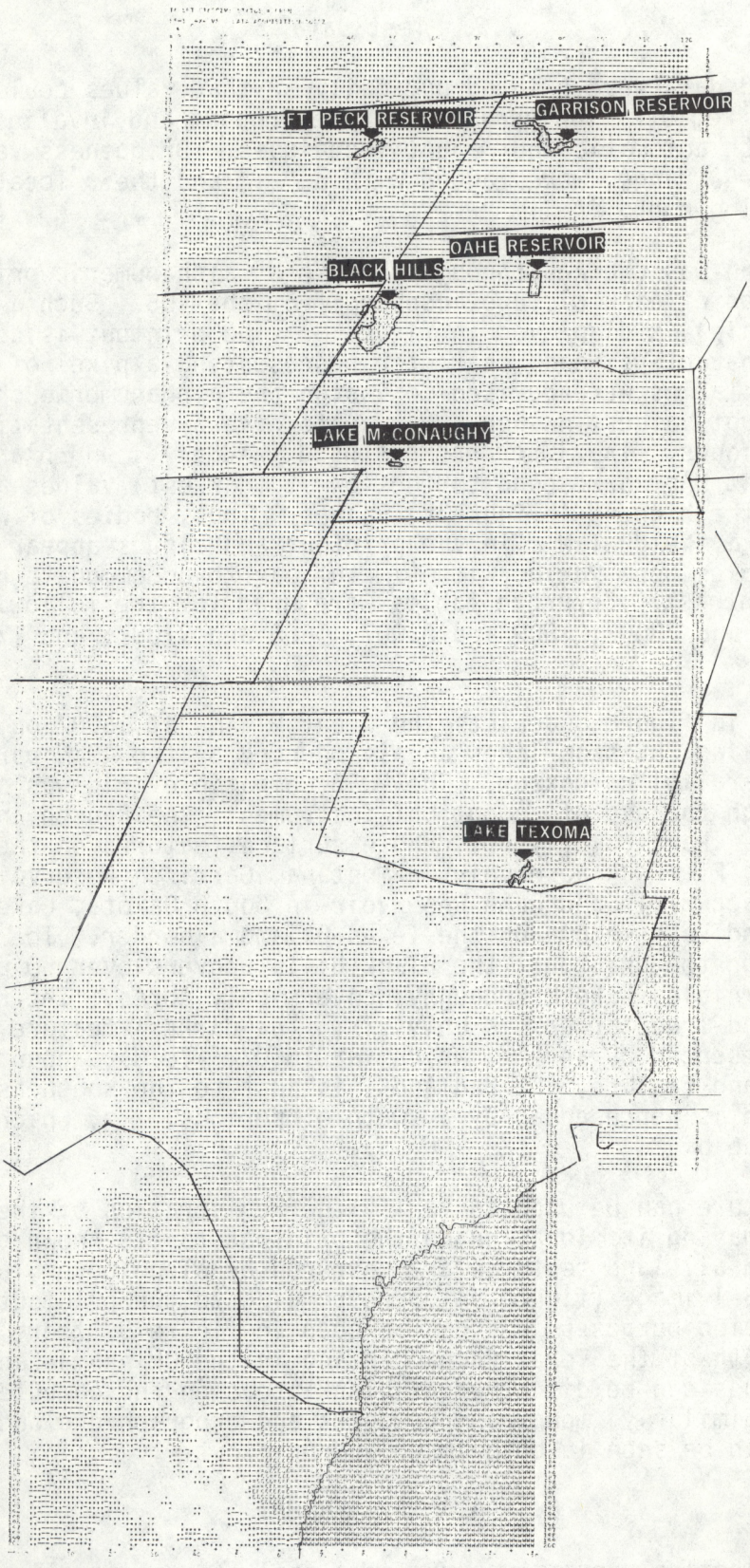


Figure 8.--Computer printout of a 1600Z VISSR image on April 25, 1977. Each character represents an 8-km pixel.

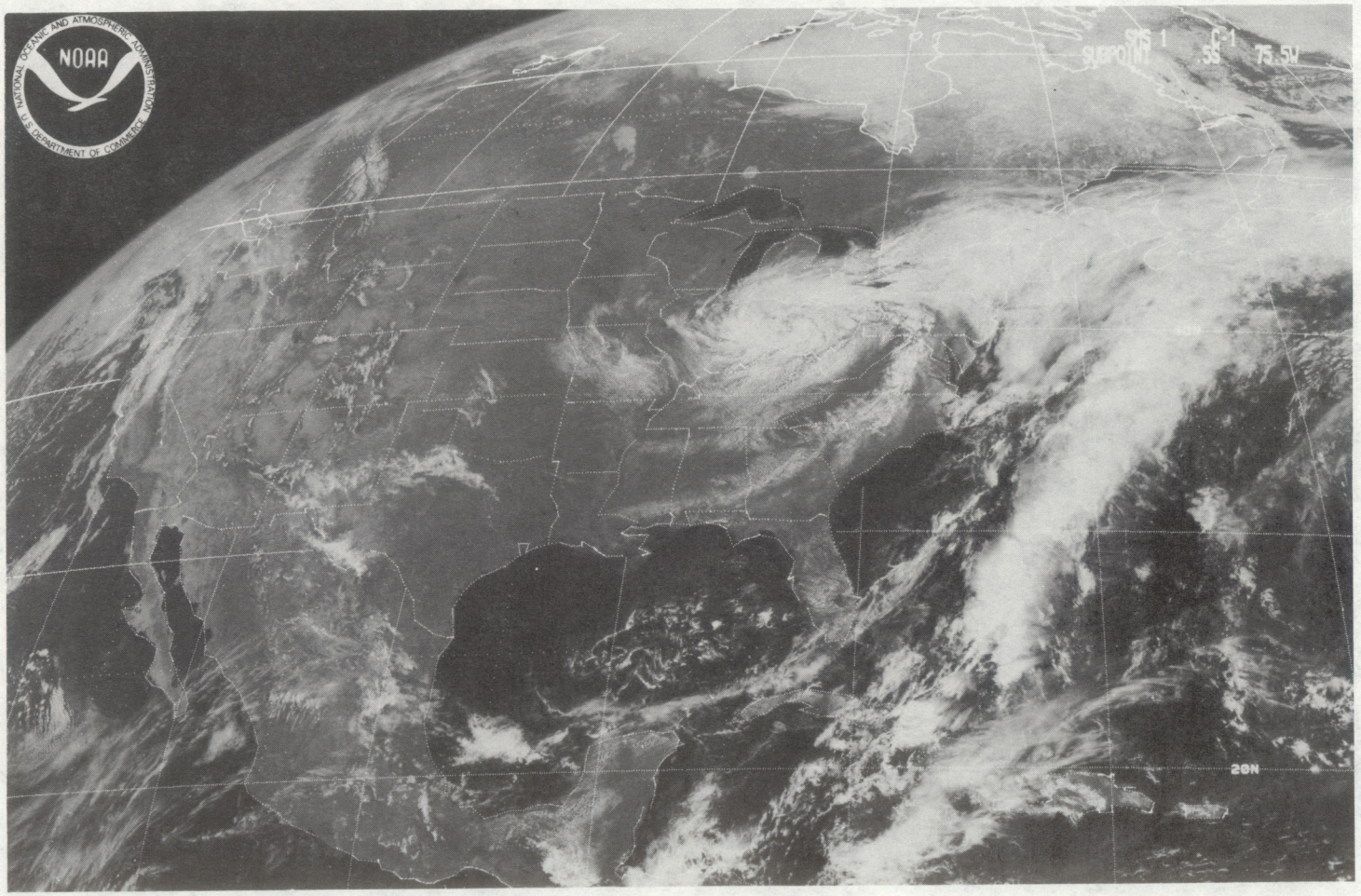


Figure 9.--A 4-km resolution VISSR image used for data registration.

data were written onto a disk pack for temporary storage and transferred each week to a nine-track, 1600 bpi magnetic tape. At the conclusion of the test, the tape contained 485 usable pictures collected over a 63-day period; all unusable pictures were deleted. Appendix B gives the date and time of each block of test data resident on the tape.

The tape consists of one file with 2,551 record blocks. Each block consists of two records:

1. Header record, 42-byte title, with a 21A2 format

    a. quantity measured
    b. date of data and/or time of picture

2. Data record, 1,722 bytes, with an INTEGER*2 format

    a. 861 targets in 2-byte words
    b. Targets are ordered starting at the northwest corner of the study area and progress from west to east and north to south, respectively.

There are seven types of data records on the tape.

1. surface pressure--millibars
2. precipitable water--millimeters
3. mean target brightness--counts
4. cloud amount--percent
5. cloud brightness--counts
6. solar zenith angle--radians times 1,000
7. solar azimuth angle--radians times 1,000

Data record types 1 and 2 (surface pressure and precipitable water) appear only at the beginning of each day; data record types 3 and 7 are present for each picture. Examples of each record type are given in appendix C.

Copies of the tape are available at a nominal price to cover cost of the tape and reproduction.

9. PYRANOMETER DATA

Much of the value of the satellite data set is due to the coincident ground-truth measurements made with the GPC pyranometer network. The network consists of about 40 pyranometers well distributed over the Great Plains. The sensors measured hourly integrated radiation with the hour beginning and ending on the half hour. The instruments were calibrated to a single standard; calibrations were made in early August near the end of the observing period.

The pyranometers ran from June 1, 1977, through August 31, 1977. The data were collected, quality checked, and stored on magnetic tape at the Blackland Research Center at Temple, Texas.

10. SUMMARY

The purpose of the summer 1977 effort was to collect a coincident set of pyranometer, satellite, and conventional meteorological data for the study of satellite-inferred insolation. This report details the collection of the satellite and meteorological parts of the data and provides a set of regression coefficients for use in determining clear radiance. The relationships between pyranometer and satellite data are being studied by NESS and GPC investigators. The authors urge interested persons or organizations to compare these data and examine the merits of satellite data for the measurement of insolation.

The satellite and conventional meteorological data sets can be obtained from

Mr. J. Emmett Bragg
Environmental Products Group, S132
NESS, World Weather Building
5200 Auth Road
Camp Springs, Maryland 20233

Information on the pyranometer data set is available from

Dr. J.T. Ritchie
USDA-ARS Blackland Research Center
P.O. Box 748
Temple, Texas 76501

ACKNOWLEDGMENTS

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U.S. Geological Survey, 1970: The national atlas of the United States of America. U.S. Department of Interior, Washington, D.C., 417 pp.

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APPENDIX A. REGRESSION COEFFICIENTS FOR PREDICTING CLEAR RADIANCE

LAT	LONG	a	b	c	d
49	105	9.57	11.49	1.25	4.78
49	103	9.54	10.78	1.22	4.56
49	101	9.95	9.38	.38	4.98
49	99	8.93	9.80	.76	4.43
49	97	9.68	8.66	1.81	2.50
49	95	9.68	8.66	1.81	2.50
47	105	8.26	12.40	1.93	4.86
47	103	8.91	10.76	1.18	4.98
47	101	9.19	9.96	.80	4.47
47	99	8.31	10.45	1.76	3.84
47	97	8.58	8.79	1.21	3.84
47	95	8.25	9.58	1.39	2.83
45	105	8.03	11.18	1.57	5.20
45	103	9.07	10.89	1.52	4.32
45	101	9.33	9.80	2.02	3.93
45	99	8.57	9.81	1.40	4.07
45	97	8.07	10.29	.40	4.12
45	95	7.35	10.85	1.44	2.06
43	105	8.29	12.82	.03	6.11
43	103	7.77	11.87	1.19	4.80
43	101	8.34	11.56	1.38	4.57
43	99	8.66	9.78	.94	4.07
43	97	7.91	10.43	.11	4.81
43	95	7.12	9.89	1.02	3.35
41	105	7.71	12.31	.88	5.45
41	103	7.71	12.31	.88	5.45
41	101	7.60	12.69	1.07	5.42
41	99	8.33	12.18	.73	4.73
41	97	7.56	11.55	1.56	3.67
41	95	7.88	10.42	1.75	3.66
39	105	6.91	14.39	.92	5.42
39	103	6.91	14.39	.92	5.42
39	101	7.67	12.22	.59	4.84
39	99	8.45	10.45	.04	5.34
39	97	8.05	10.36	.78	3.80
39	95	9.42	8.43	1.27	2.85
37	105	5.86	14.63	1.10	7.71
37	103	5.86	14.63	1.10	7.71
37	101	7.61	14.05	.82	4.68
37	99	7.69	11.38	.73	4.86
37	97	8.87	9.08	.79	3.38
37	95	7.95	10.08	.71	4.13
35	105	4.94	15.43	2.58	4.72
35	103	5.62	15.35	2.11	5.20
35	101	6.48	13.02	.68	5.52
35	99	7.72	10.68	.95	4.58
35	97	7.33	10.56	1.04	4.47

LAT	LONG	a	b	c	d
35	95	7.38	9.98	0.39	5.30
33	105	4.88	15.73	2.12	6.82
33	103	4.88	15.73	2.12	6.82
33	101	5.84	13.12	.92	6.66
33	99	7.00	11.45	.65	5.13
33	97	8.23	9.95	1.05	3.96
33	95	7.53	9.41	1.33	4.69
31	105	3.02	18.71	3.80	6.81
31	103	4.48	19.25	2.45	5.94
31	101	5.58	12.83	1.18	5.56
31	99	5.26	12.72	.82	6.22
31	97	7.39	10.59	.56	4.80
31	95	7.57	11.37	2.40	-2.72
29	105	2.38	19.30	4.39	5.98
29	103	3.93	16.88	1.54	7.63
29	101	5.01	13.95	1.43	5.25
29	99	6.06	11.38	1.30	4.84
29	97	6.20	11.00	1.97	4.44
29	95	7.57	11.37	2.40	-2.72

APPENDIX B. DATE AND TIME OF PICTURES

	Date	Time (Z)	Total number of pictures
1	6-07-77	1600 1800 2000 2100 2130 2200 2300	7
2	6-09-77	1400 1500 1600 1700 2000 2100 2130 2200 2300	9
3	6-12-77	1500 1600 1700 1800 2000 2100 2130 2200 2300	9
4	6-13-77	1600 1700 1800 2000 2100 2130 2200 2300	8
5	6-14-77	1400 1600 1700 1800 2000 2100 2130 2200 2300	9
6	6-15-77	1500 1600 1700 1800 2000 2100 2130 2200 2300	9
7	6-16-77	1400 1600 1700 1800 2000 2100 2130 2200	8
8	6-17-77	1400 1500 1600 1700 2000 2100 2130 2200 2300	9
9	6-18-77	1500 1600 1700 1800 2000 2100 2130 2200	8
10	6-19-77	1400 1500 1600 1800 2000 2100 2130 2200 2300	9
11	6-20-77	1500 1600 1700 1800 2000 2100 2130 2200 2300	9
12	6-21-77	1400 1500 1600 1700 1800 2000 2100 2130 2200 2300	10
13	6-22-77	1400 1500 1600 2000 2100 2130 2200 2300	8
14	6-23-77	1600 1700 2000 2100 2130 2200 2300	7
15	6-24-77	1600 1700 1800 2000 2100 2130 2200 2300	8

	Date	Time (Z)	Total number of pictures
16	6-25-77	1400 1500 1600 1700 1800 2000 2100 2130 2200 2300	10
17	6-26-77	1400 1500 1600 1700 1800 2000 2100 2130 2200 2300	10
18	6-27-77	1500 1600 1700 1800 2000 2100 2130 2200	8
19	6-28-77	1400 1500 1600 1700 1800 2000 2130 2200 2300	9
20	6-29-77	1400 1500 1600 1700 1800 2130 2200 2300	8
21	6-30-77	1600 1700 2000 2100 2130 2200 2300	7
22	7-01-77	1400 1500 1600 1800 2100 2130 2200 2300	8
23	7-03-77	1400 1500 1600 1700 1800 2000 2100 2200 2300	9
24	7-04-77	1400 1500 1700 2000 2100 2200 2300	7
25	7-05-77	1500 1600 1700 1800 2000 2100 2130 2200 2300	9
26	7-06-77	1500 1600 2000	3
27	7-07-77	1500 1700 1800 2100 2130	5
28	7-09-77	1500 1600 1700 2000 2100 2200 2300	7
29	7-10-77	1400 1500 1600 1700 2000 2100 2130 2200 2300	9
30	7-11-77	1600 1700 1800 2000 2100 2130 2200 2300	8
31	7-12-77	1400 1600 1700 2000 2100 2130 2200	7
32	7-13-77	1500 1600 1800 2000 2100 2130 2200 2300	8

	Date	Time (Z)	Total number of pictures
33	7-14-77	1400 1500 1600 1700 1800 2000 2100 2300	8
34	7-15-77	1600 1800 2000 2100 2130 2200 2300	7
35	7-16-77	1400 1500 1600 1700 1800 2000 2100 2200 2300	9
36	7-17-77	1400 1500 1600 1700 2000 2100 2130 2200 2300	9
37	7-18-77	1600 1700 1800 2000 2100 2130 2200	7
38	7-19-77	1600 1700 1800 2100 2130 2200 2300	7
39	7-20-77	1400 1500 1600 1700 1800 2000 2100 2130 2300	9
40	7-21-77	1500 1600 1700 1800 2000 2100 2130 2200 2300	9
41	7-22-77	1500 1600 1700 1800 2100 2130 2200 2300	8
42	7-23-77	1500 1600 1700 1800 2000 2100 2130 2200 2300	9
43	7-24-77	1400 1500 1600 1700 1800 2000 2100 2130 2200 2300	10
44	7-25-77	1500 1600 1700 1800 2000 2100 2130 2200 2300	9
45	7-26-77	1400 1500 1600 1800 2000 2100 2130 2200 2300	9
46	7-28-77	1400 1500 1600 2300	4
47	7-29-77	1400 1500 1600 1700 2000 2100 2130 2200 2300	9
48	7-30-77	1400 1500 1600 1800 2000 2100 2130 2200 2300	9

	Date	Time (Z)	Total number of pictures
49	7-31-77	1400 1500 1600 1700	4
50	8-01-77	1400 1500 1600 1700 1800 2100 2130 2300	8
51	8-02-77	1400 1500 1600 1800 2100 2130 2200 2300	8
52	8-03-77	1500 1600 1800 2100 2130 2200 2300	7
53	8-04-77	1400 1500 1600 1700	4
54	8-05-77	1400 1500 1600 1700 1800 2000 2100 2130 2200 2300	10
55	8-06-77	1400 1500 1600 1700 1800 2000 2100 2130 2200	9
56	8-07-77	1400 1600 1700 1800 2000 2100 2130 2200 2300	9
57	8-08-77	1400 1600 1700 1800 2000 2100 2130 2200 2300	9
58	8-09-77	2100 2200	2
59	8-10-77	1400 1600 1700 2100 2130 2200	6
60	8-11-77	1400 1600 2100 2130 2200	5
61	8-12-77	1400 1600 1800 2300	4
62	8-13-77	1400 1600 1700 1800 2100 2130 2200 2300	8
63	8-14-77	1500	1

APPENDIX C. EXAMPLES OF EACH DATA TYPE

DATE OF THIS DATA IS 8/ 6/77

SURFACE PRESSURES FOR 8/ 7/77 00Z

922	922	922	922	922	944	944	944	944	944	944	944	944	944	944	976	976	976	976	976
922	922	922	922	922	922	944	944	944	944	944	944	944	944	944	976	976	976	976	976
922	922	922	922	922	922	944	944	944	944	944	944	944	944	944	944	976	962	962	962
922	922	922	922	922	922	922	944	944	944	944	944	944	944	944	944	944	962	962	962
922	922	922	922	922	922	922	922	944	944	944	944	944	944	944	944	944	962	962	962
922	922	922	922	922	922	915	915	944	944	944	944	944	944	944	944	944	962	962	962
922	922	915	915	915	915	915	915	915	944	944	944	944	944	944	944	944	962	962	962
915	915	915	915	915	915	915	915	915	944	944	944	944	944	944	944	944	944	962	962
915	915	915	915	915	915	915	915	915	915	944	944	944	944	944	944	944	944	962	962
850	915	915	915	915	915	915	915	915	915	944	944	944	944	944	944	949	949	949	978
850	915	915	915	915	915	915	915	915	915	944	949	949	949	949	949	949	949	949	978
850	850	915	915	915	915	915	915	899	899	899	949	949	949	949	949	949	949	949	978
850	850	850	915	915	899	899	899	899	899	899	899	949	949	949	949	949	949	949	949
850	850	796	899	899	899	899	899	899	899	899	899	949	949	949	949	949	949	949	949
796	796	796	796	899	899	899	899	899	899	899	899	899	949	949	949	949	949	949	949
796	796	796	796	899	899	899	899	899	899	899	899	899	949	949	949	949	957	957	957
796	796	796	796	796	899	899	899	899	899	899	899	899	899	957	957	957	957	957	957
796	796	796	796	796	796	899	899	899	899	911	911	911	911	957	957	957	957	957	957
796	796	796	796	796	796	899	911	911	911	911	911	911	911	957	957	957	957	957	957
796	796	796	796	857	857	857	911	911	911	911	911	911	911	911	957	957	957	957	957
796	857	857	857	857	857	857	911	911	911	911	911	911	911	911	957	957	957	957	957
857	857	857	857	857	857	857	857	911	911	911	911	911	911	911	911	957	957	973	973
857	857	857	857	857	857	857	857	911	911	911	911	911	911	911	911	942	973	973	973
760	857	857	857	857	857	857	857	857	911	911	942	942	942	942	942	942	973	973	973
760	857	857	857	857	857	857	857	896	942	942	942	942	942	942	942	942	973	973	973
760	760	857	857	857	896	896	896	896	896	942	942	942	942	942	942	942	973	973	973
760	760	896	896	896	896	896	896	896	896	942	942	942	942	942	942	942	942	973	973
821	821	821	896	896	896	896	896	896	896	942	942	942	942	942	942	942	973	973	993
821	821	821	896	896	896	896	896	896	896	896	942	942	942	942	981	981	981	993	993
821	821	821	821	896	896	896	896	896	896	896	942	981	981	981	981	981	981	993	993
821	821	821	821	896	896	896	896	896	946	946	946	981	981	981	981	981	981	993	993
821	821	821	821	821	896	946	946	946	946	946	946	981	981	981	981	981	981	993	993
821	821	821	896	896	946	946	946	946	946	946	946	946	981	981	981	981	981	981	993
896	896	896	896	896	896	946	946	946	946	946	946	946	981	981	981	981	981	981	1012
896	896	896	896	896	896	946	946	946	946	946	946	946	981	981	981	993	993	993	1012
896	896	896	896	896	896	896	946	946	946	946	946	970	970	993	993	993	993	993	993
896	896	896	896	896	896	896	946	946	970	970	970	970	970	993	993	993	993	993	993
841	896	896	896	896	896	906	906	970	970	970	970	970	970	970	993	993	993	993	993
841	896	896	906	906	906	906	906	970	970	970	970	970	970	970	993	993	993	993	993
841	844	906	906	906	906	906	906	906	970	970	970	970	970	970	993	993	993	993	1017	1017
844	844	906	906	906	906	906	906	906	970	970	970	970	970	970	991	1017	1017	1017	1017	1017

Data record type 1: surface pressure in millibars.

PRECIPITABLE WATER FOR 81 7/27 002

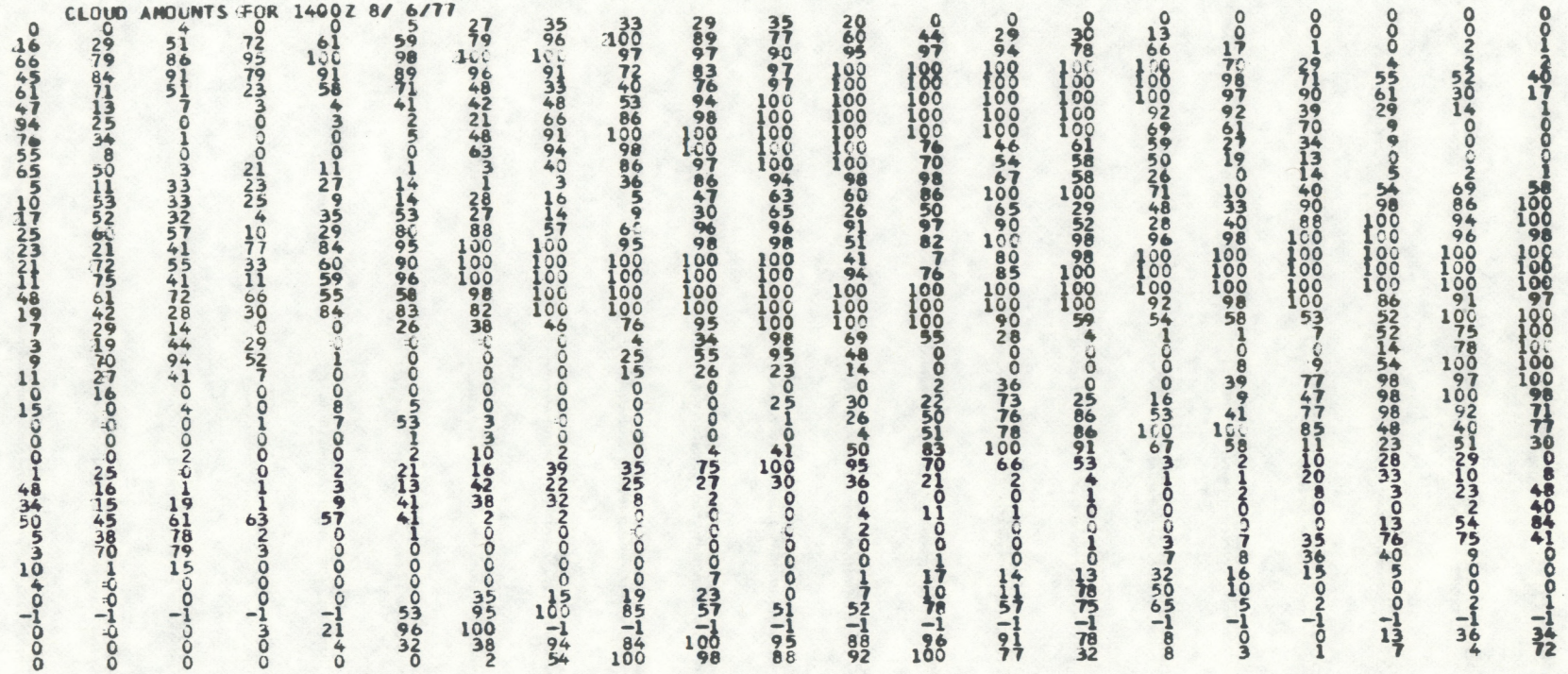
19	19	19	19	19	21	21	21	21	21	21	21	21	21	21	21	20	20	20	20	20
19	19	19	19	19	19	21	21	21	21	21	21	21	21	21	21	20	20	20	20	20
19	19	19	19	19	19	21	21	21	21	21	21	21	21	21	21	21	20	20	20	20
19	19	19	19	19	19	19	21	21	21	21	21	21	21	28	28	28	25	25	25	25
19	19	19	19	19	19	19	19	21	28	28	28	28	28	28	28	28	25	25	25	25
19	19	19	19	19	19	26	26	28	28	28	28	28	28	28	28	28	28	25	25	25
19	19	26	26	26	26	26	26	26	28	28	28	28	28	28	28	28	28	25	25	25
26	26	26	26	26	26	26	26	26	26	28	28	28	28	28	28	28	28	28	25	25
26	26	26	26	26	26	26	26	26	26	26	28	28	28	28	28	28	28	28	25	25
19	26	26	26	26	26	26	26	26	26	26	26	28	28	28	28	34	34	34	33	33
19	19	26	26	26	26	26	26	26	26	26	28	28	34	34	34	34	34	34	34	33
19	19	19	26	26	28	28	28	28	28	28	28	28	28	34	34	34	34	34	34	34
19	19	15	28	28	28	28	28	28	28	28	28	28	28	28	34	34	34	34	34	34
15	15	15	15	28	28	28	28	28	28	28	28	28	28	28	28	34	34	34	34	34
15	15	15	15	28	28	28	28	28	28	28	28	28	28	28	28	34	34	34	34	34
15	15	15	15	15	28	28	28	28	28	28	28	28	28	28	28	40	40	40	40	40
15	15	15	15	15	15	28	28	28	28	28	31	31	31	31	31	40	40	40	40	40
15	15	15	15	15	15	28	31	31	31	31	31	31	31	31	31	40	40	40	40	40
15	15	15	15	20	20	20	31	31	31	31	31	31	31	31	31	31	40	40	40	40
15	20	20	20	20	20	20	31	31	31	31	31	31	31	31	31	31	40	40	40	40
20	20	20	20	20	20	20	20	31	31	31	31	31	31	31	31	31	40	40	40	40
20	20	20	20	20	20	20	20	31	31	31	31	31	31	31	31	34	45	45	45	45
9	20	20	20	20	20	20	20	20	31	31	34	34	34	34	34	34	45	45	45	45
9	20	20	20	20	20	20	20	21	34	34	34	34	34	34	34	34	45	45	45	45
9	9	20	20	20	21	21	21	21	21	34	34	34	34	34	34	34	45	45	45	45
9	9	21	21	21	21	21	21	21	21	34	34	34	34	34	34	34	34	45	45	47
12	12	12	21	21	21	21	21	21	21	34	34	34	34	34	34	34	34	45	45	47
12	12	12	21	21	21	21	21	21	21	21	34	34	34	34	34	38	38	47	47	47
12	12	12	12	21	21	21	21	21	21	21	34	38	38	38	38	38	38	38	47	47
12	12	12	12	21	21	21	21	21	25	25	25	38	38	38	38	38	38	38	47	47
12	12	12	12	12	21	25	25	25	25	25	25	38	38	38	38	38	38	38	47	47
12	12	12	21	21	25	25	25	25	25	25	25	25	38	38	38	38	38	38	38	47
21	21	21	21	21	21	25	25	25	25	25	25	25	25	38	38	38	38	38	38	47
21	21	21	21	21	21	25	25	25	25	25	25	25	25	38	38	38	38	38	38	47
21	21	21	21	21	21	21	25	25	25	25	25	25	30	38	38	38	38	38	38	38
21	21	21	21	21	21	21	25	25	30	30	30	30	30	38	38	38	38	38	38	38
24	21	21	21	21	21	27	27	30	30	30	30	30	30	30	38	38	38	38	38	38
24	21	21	27	27	27	27	27	30	30	30	30	30	30	30	38	38	38	38	38	38
24	27	27	27	27	27	27	27	27	30	30	30	30	30	30	38	38	38	38	45	45
27	27	27	27	27	27	27	27	27	30	30	30	30	30	30	39	45	45	45	45	45

Data record type 2: precipitable water in millimeters.

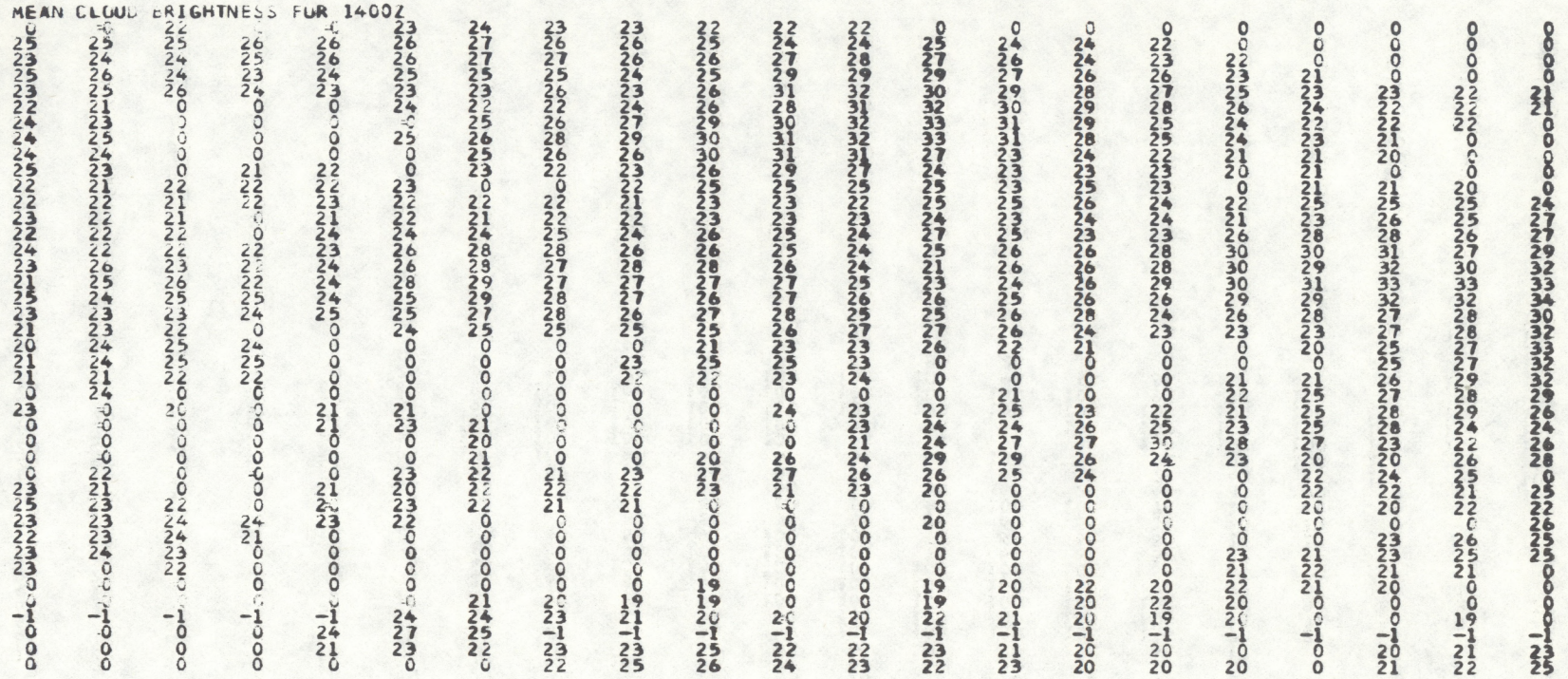
MEAN VISIBLE BRIGHTNESS FOR 1400Z

16	17	17	17	17	17	19	19	19	18	19	18	16	16	16	17	17	16	15	15	14
18	19	21	23	22	22	25	26	26	24	22	21	20	19	18	17	17	16	16	15	14
22	23	23	25	26	26	27	27	25	26	26	27	27	26	22	21	18	17	16	16	15
21	25	24	22	23	24	25	24	22	24	28	29	29	27	26	26	21	18	17	16	15
21	23	21	18	20	21	20	19	19	24	30	32	30	29	28	27	25	21	20	19	18
19	18	17	17	17	20	19	20	20	26	28	31	32	30	29	28	26	23	19	19	17
24	18	16	16	17	17	19	23	26	29	30	32	33	31	29	24	23	19	18	18	16
23	19	16	16	16	17	21	27	29	30	31	32	33	31	28	22	20	21	17	17	16
20	17	16	16	16	16	21	25	26	30	31	31	24	19	21	20	17	18	17	16	16
22	20	16	18	17	16	17	19	22	26	29	27	22	20	20	20	17	17	16	16	16
16	17	18	18	18	18	17	17	19	24	24	25	24	21	21	18	16	17	16	16	15
17	20	18	17	17	18	18	18	17	20	21	20	24	25	26	22	17	19	21	21	20
17	20	19	17	18	20	18	18	17	19	21	18	20	20	18	20	18	23	25	24	27
18	20	20	17	19	23	23	22	21	25	25	23	26	24	19	18	20	26	28	26	27
17	18	19	21	22	26	28	28	26	26	25	20	23	26	26	27	30	30	31	26	28
16	23	20	18	21	25	28	27	28	28	26	19	17	24	24	28	30	29	32	30	32
15	22	20	16	21	27	29	27	27	27	27	24	21	23	26	29	30	31	33	33	33
20	20	23	22	20	21	29	28	27	26	27	26	26	25	26	26	29	29	32	32	34
16	19	18	18	24	23	25	28	26	27	28	25	25	26	28	24	26	28	26	27	29
15	17	16	15	15	17	19	20	23	25	26	27	27	25	21	20	20	19	21	28	32
13	16	20	18	15	15	15	15	16	18	22	21	17	15	15	15	15	15	20	24	33
14	21	25	20	15	15	15	15	18	21	24	19	15	15	14	15	14	15	16	24	32
14	17	18	16	15	14	15	14	16	17	17	16	14	14	15	14	16	16	21	29	32
13	17	16	15	16	15	15	15	14	14	15	15	15	15	15	15	17	22	27	28	29
14	13	15	15	16	16	15	15	15	15	18	18	17	17	15	17	16	20	28	29	26
12	13	14	15	15	20	16	16	15	15	15	16	17	20	22	25	19	23	27	27	21
12	15	15	15	16	16	15	15	15	15	16	16	16	20	24	25	28	25	19	18	23
13	14	15	15	15	15	16	16	16	16	20	20	26	29	24	30	21	25	17	21	19
14	17	15	16	16	17	17	18	18	24	27	25	23	21	20	16	16	16	18	18	14
19	17	16	16	16	16	18	17	17	17	18	18	17	16	16	15	16	17	18	16	15
19	16	17	16	16	19	18	18	16	16	15	16	16	16	16	15	16	16	15	17	18
19	19	21	21	20	18	15	15	15	15	15	16	17	16	15	15	15	14	14	15	19
15	18	22	16	15	15	15	15	15	15	15	16	15	15	15	15	15	15	16	21	23
15	21	22	16	15	16	15	15	15	15	15	15	15	15	14	15	16	18	21	23	19
16	15	17	15	15	15	15	15	15	15	15	15	15	15	15	16	16	18	18	15	13
16	15	17	16	16	16	16	15	15	15	15	15	15	16	16	17	17	15	15	14	13
16	16	16	17	16	17	18	17	16	16	16	16	16	16	19	19	17	17	16	13	12
-1	-1	-1	-1	-1	20	23	23	20	18	18	18	20	18	19	18	19	16	15	14	12
15	14	15	15	17	26	25	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
15	15	14	15	16	18	18	22	22	25	22	21	22	21	19	15	14	14	15	17	17
15	15	14	15	15	15	14	19	25	26	23	22	22	21	17	15	14	14	15	14	22

Data record type 3: target brightness in counts.



Data record type 4: cloud amount in percent.



Data record type 5: cloud brightness in counts.

ZENITH ANGLES TIMES 1000(FOR 1400Z

1193	1188	1182	1176	1171	1165	1159	1153	1148	1142	1136	1131	1125	1119	1113	1108	1102	1096	1091	1085	1079
1194	1188	1182	1176	1171	1165	1159	1153	1147	1142	1136	1130	1124	1119	1113	1107	1101	1096	1090	1084	1078
1194	1188	1182	1177	1171	1165	1159	1153	1147	1141	1136	1130	1124	1118	1112	1106	1101	1095	1089	1083	1077
1194	1188	1183	1177	1171	1165	1159	1153	1147	1141	1135	1129	1124	1118	1112	1106	1100	1094	1088	1082	1077
1195	1189	1183	1177	1171	1165	1159	1153	1147	1141	1135	1129	1123	1117	1111	1105	1099	1094	1088	1082	1076
1195	1189	1183	1177	1171	1165	1159	1153	1147	1141	1135	1129	1123	1117	1111	1105	1099	1093	1087	1081	1075
1195	1189	1183	1177	1171	1165	1159	1153	1147	1141	1135	1129	1123	1117	1111	1105	1098	1092	1086	1080	1074
1196	1190	1184	1178	1171	1165	1159	1153	1147	1141	1135	1129	1122	1116	1110	1104	1098	1092	1086	1080	1074
1196	1190	1184	1178	1172	1165	1159	1153	1147	1141	1135	1128	1122	1116	1110	1104	1098	1091	1085	1079	1073
1197	1191	1184	1178	1172	1166	1159	1153	1147	1141	1135	1128	1122	1116	1110	1103	1097	1091	1085	1079	1072
1197	1191	1185	1179	1172	1166	1160	1153	1147	1141	1135	1128	1122	1116	1109	1103	1097	1091	1084	1078	1072
1198	1192	1185	1179	1173	1166	1160	1154	1147	1141	1135	1128	1122	1116	1109	1103	1097	1090	1084	1078	1071
1198	1192	1186	1179	1173	1167	1160	1154	1147	1141	1135	1128	1122	1116	1109	1103	1096	1090	1084	1077	1071
1199	1193	1186	1180	1173	1167	1161	1154	1148	1141	1135	1128	1122	1115	1109	1103	1096	1090	1083	1077	1070
1200	1193	1187	1180	1174	1167	1161	1154	1148	1141	1135	1128	1122	1115	1109	1102	1096	1090	1083	1077	1070
1200	1194	1187	1181	1174	1168	1161	1155	1148	1142	1135	1129	1122	1115	1109	1102	1096	1089	1083	1076	1070
1201	1194	1188	1181	1175	1168	1162	1155	1148	1142	1135	1129	1122	1116	1109	1102	1096	1089	1083	1076	1069
1202	1195	1189	1182	1175	1169	1162	1155	1149	1142	1136	1129	1122	1116	1109	1102	1096	1089	1082	1076	1069
1203	1196	1189	1183	1176	1169	1163	1156	1149	1142	1136	1129	1122	1116	1109	1102	1096	1089	1082	1076	1069
1203	1197	1190	1183	1176	1170	1163	1156	1150	1143	1136	1129	1123	1116	1109	1102	1096	1089	1082	1076	1069
1204	1197	1191	1184	1177	1170	1164	1157	1150	1143	1136	1130	1123	1116	1109	1103	1096	1089	1082	1075	1069
1205	1198	1191	1185	1178	1171	1164	1157	1150	1144	1137	1130	1123	1116	1110	1103	1096	1089	1082	1075	1069
1206	1199	1192	1185	1178	1172	1165	1158	1151	1144	1137	1130	1124	1117	1110	1103	1096	1089	1082	1075	1069
1207	1200	1193	1186	1179	1172	1165	1158	1152	1145	1138	1131	1124	1117	1110	1103	1096	1089	1082	1075	1069
1208	1201	1194	1187	1180	1173	1166	1159	1152	1145	1138	1131	1124	1117	1110	1103	1096	1089	1082	1076	1069
1209	1202	1195	1188	1181	1174	1167	1160	1153	1146	1139	1132	1125	1118	1111	1104	1097	1090	1083	1076	1069
1210	1203	1196	1189	1182	1174	1167	1160	1153	1146	1139	1132	1125	1118	1111	1104	1097	1090	1083	1076	1069
1211	1204	1196	1189	1182	1175	1168	1161	1154	1147	1140	1133	1126	1119	1112	1104	1097	1090	1083	1076	1069
1212	1205	1197	1190	1183	1176	1169	1162	1155	1148	1141	1133	1126	1119	1112	1105	1098	1091	1083	1076	1069
1213	1206	1198	1191	1184	1177	1170	1163	1156	1148	1141	1134	1127	1120	1112	1105	1098	1091	1084	1077	1069
1214	1207	1199	1192	1185	1178	1171	1163	1156	1149	1142	1135	1127	1120	1113	1106	1099	1091	1084	1077	1070
1215	1208	1201	1193	1186	1179	1172	1164	1157	1150	1143	1135	1128	1121	1114	1106	1099	1092	1085	1077	1070
1216	1209	1202	1194	1187	1180	1172	1165	1158	1151	1143	1136	1129	1121	1114	1107	1100	1092	1085	1078	1070
1217	1210	1203	1195	1188	1181	1173	1166	1159	1151	1144	1137	1130	1122	1115	1107	1100	1093	1085	1078	1071
1218	1211	1204	1196	1189	1182	1174	1167	1160	1152	1145	1138	1130	1123	1116	1108	1101	1093	1086	1079	1071
1220	1212	1205	1198	1190	1183	1175	1168	1161	1153	1146	1138	1131	1124	1116	1109	1101	1094	1087	1079	1072
1221	1214	1206	1199	1191	1184	1177	1169	1162	1154	1147	1139	1132	1124	1117	1110	1102	1095	1087	1080	1072
1222	1215	1207	1200	1192	1185	1178	1170	1163	1155	1148	1140	1133	1125	1118	1110	1103	1095	1088	1080	1073
1224	1216	1209	1201	1194	1186	1179	1171	1164	1156	1149	1141	1134	1126	1119	1111	1104	1096	1089	1081	1073
1225	1217	1210	1202	1195	1187	1180	1172	1165	1157	1150	1142	1135	1127	1119	1112	1104	1097	1089	1082	1074
1226	1219	1211	1204	1196	1189	1181	1173	1166	1158	1151	1143	1136	1128	1120	1113	1105	1098	1090	1082	1075

Data record type 6: solar zenith angle (radians times 1,000).

AZIMUTH ANGLES TIMES 10000 FOR 1400Z

1544	1550	1557	1563	1570	1576	1583	1590	1596	1603	1610	1616	1623	1630	1636	1643	1650	1657	1664	1671	1678
1540	1547	1553	1560	1566	1573	1579	1586	1592	1599	1606	1612	1619	1626	1632	1639	1646	1652	1659	1666	1673
1537	1543	1549	1556	1562	1569	1575	1582	1588	1595	1601	1608	1615	1621	1628	1635	1641	1648	1655	1661	1668
1533	1540	1546	1552	1559	1565	1572	1578	1584	1591	1597	1604	1610	1617	1624	1630	1637	1643	1650	1657	1664
1530	1536	1542	1549	1555	1561	1568	1574	1581	1587	1593	1600	1606	1613	1619	1626	1632	1639	1646	1652	1659
1526	1533	1539	1545	1551	1558	1564	1570	1577	1583	1589	1596	1602	1609	1615	1621	1628	1634	1641	1648	1654
1523	1529	1535	1541	1548	1554	1560	1566	1573	1579	1585	1592	1598	1604	1611	1617	1624	1630	1636	1643	1649
1519	1526	1532	1538	1544	1550	1556	1563	1569	1575	1581	1587	1594	1600	1606	1613	1619	1625	1632	1638	1645
1516	1522	1528	1534	1540	1546	1553	1559	1565	1571	1577	1583	1590	1596	1602	1608	1615	1621	1627	1634	1640
1513	1519	1525	1531	1537	1543	1549	1555	1561	1567	1573	1579	1585	1592	1598	1604	1610	1616	1623	1629	1635
1509	1515	1521	1527	1533	1539	1545	1551	1557	1563	1569	1575	1581	1587	1593	1600	1606	1612	1618	1624	1631
1506	1512	1518	1523	1529	1535	1541	1547	1553	1559	1565	1571	1577	1583	1589	1595	1601	1607	1613	1620	1626
1502	1508	1514	1520	1526	1531	1537	1543	1549	1555	1561	1567	1573	1579	1585	1591	1597	1603	1609	1615	1621
1499	1505	1510	1516	1522	1528	1534	1539	1545	1551	1557	1563	1569	1574	1580	1586	1592	1598	1604	1610	1616
1496	1501	1507	1513	1518	1524	1530	1535	1541	1547	1553	1559	1564	1570	1576	1582	1588	1594	1600	1606	1612
1492	1498	1503	1509	1515	1520	1526	1532	1537	1543	1549	1554	1560	1566	1572	1578	1583	1589	1595	1601	1607
1489	1494	1500	1505	1511	1517	1522	1528	1533	1539	1545	1550	1556	1562	1567	1573	1579	1585	1590	1596	1602
1486	1491	1496	1502	1507	1513	1518	1524	1529	1535	1541	1546	1552	1557	1563	1569	1574	1580	1586	1592	1597
1482	1488	1493	1498	1504	1509	1515	1520	1526	1531	1537	1542	1548	1553	1559	1564	1570	1575	1581	1587	1592
1479	1484	1489	1495	1500	1506	1511	1516	1522	1527	1533	1538	1543	1549	1554	1560	1565	1571	1577	1582	1588
1475	1481	1486	1491	1497	1502	1507	1512	1518	1523	1528	1534	1539	1545	1550	1555	1561	1566	1572	1577	1583
1472	1477	1483	1488	1493	1498	1503	1509	1514	1519	1524	1530	1535	1540	1546	1551	1556	1562	1567	1573	1578
1469	1474	1479	1484	1489	1494	1500	1505	1510	1515	1520	1526	1531	1536	1541	1547	1552	1557	1563	1568	1573
1466	1471	1476	1481	1486	1491	1496	1501	1506	1511	1516	1522	1527	1532	1537	1542	1547	1553	1558	1563	1569
1462	1467	1472	1477	1482	1487	1492	1497	1502	1507	1512	1517	1523	1528	1533	1538	1543	1548	1553	1559	1564
1459	1464	1469	1474	1479	1484	1488	1493	1498	1503	1508	1513	1518	1523	1528	1533	1539	1544	1549	1554	1559
1456	1461	1465	1470	1475	1480	1485	1490	1495	1499	1504	1509	1514	1519	1524	1529	1534	1539	1544	1549	1554
1452	1457	1462	1467	1471	1476	1481	1486	1491	1495	1500	1505	1510	1515	1520	1525	1530	1535	1539	1544	1549
1449	1454	1459	1463	1468	1473	1477	1482	1487	1492	1496	1501	1506	1511	1515	1520	1525	1530	1535	1540	1545
1446	1451	1455	1460	1464	1469	1474	1478	1483	1488	1492	1497	1502	1506	1511	1516	1521	1525	1530	1535	1540
1443	1447	1452	1456	1461	1465	1470	1475	1479	1484	1488	1493	1498	1502	1507	1512	1516	1521	1526	1530	1535
1439	1444	1448	1453	1457	1462	1466	1471	1475	1480	1484	1489	1493	1498	1503	1507	1512	1516	1521	1526	1530
1436	1441	1445	1449	1454	1458	1463	1467	1472	1476	1480	1485	1489	1494	1498	1503	1507	1512	1516	1521	1526
1433	1437	1442	1446	1450	1455	1459	1463	1468	1472	1477	1481	1485	1490	1494	1498	1503	1507	1512	1516	1521
1430	1434	1438	1443	1447	1451	1455	1460	1464	1468	1473	1477	1481	1485	1490	1494	1499	1503	1507	1512	1516
1427	1431	1435	1439	1443	1448	1452	1456	1460	1464	1469	1473	1477	1481	1486	1490	1494	1498	1503	1507	1511
1424	1428	1432	1436	1440	1444	1448	1452	1456	1461	1465	1469	1473	1477	1481	1486	1490	1494	1498	1502	1507
1420	1424	1428	1433	1437	1441	1445	1449	1453	1457	1461	1465	1469	1473	1477	1481	1485	1489	1494	1498	1502
1417	1421	1425	1429	1433	1437	1441	1445	1449	1453	1457	1461	1465	1469	1473	1477	1481	1485	1489	1493	1497
1414	1418	1422	1426	1430	1434	1437	1441	1445	1449	1453	1457	1461	1465	1469	1473	1477	1480	1484	1488	1492
1411	1415	1419	1423	1426	1430	1434	1438	1442	1445	1449	1453	1457	1461	1464	1468	1472	1476	1480	1484	1488

Data record type 7: solar azimuth angle (radians times 1,000).

(Continued from inside front cover)

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