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FINAL TECHNICAL REPORT

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A Laboratory Investigation of the Variability of Cloud Reflected Radiance Fields

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During the term of support by NASA of this research program, we have successfully developed a new approach to determining the radiative properties of complex cloud fields. This innovative research began as a unique, untried concept and has matured into a verified, useful technique. The accomplishments of this research are highlighted below. Following the highlights are brief explanations of each accomplishment.

Accomplishments:

- Design and construction of a laboratory apparatus (CFOS) to simulate the interaction of cloud fields with visible radiation.
- Verification of CFOS by comparing experimental results from it with calculations performed with a Monte Carlo radiative transfer model.
- Development of a software library to process, reduce and display CFOS data for use in research studies.
- Utilization of CFOS to study the reflected radiance patterns from simulated cloud fields.

1.0 Design and construction of a laboratory apparatus (CFOS) to simulate the interaction of cloud fields with visible radiation.

The CFOS apparatus is designed to measure the simulated reflection of shortwave radiation by optically thick clouds. The CFOS basically consists of a light source, a target cloud field, an array of radiation detectors and a data display/collection system. Fig. 1 shows a schematic of the CFOS which is housed in a 10 m X 10 m dark room at the Department of Atmospheric Science at Colorado State University. Each of the components which comprise the CFOS has been selected or designed to simulate as closely as possible the actual interaction of visible solar radiation with real clouds and to perform measurements on the simulation analogous to the real world case. Each aspect of the CFOS is described below along the rationale used in selecting various options in the components design.

A. <u>The Source</u>

In simulating the interaction between the visible solar irradiance and clouds it is desirable to duplicate as closely as possible three characteristics of the natural source. First, the source should possess, to the extent possible, a visible spectrum of a 5700 K blackbody radiator. Second, the beam irradiance should be uniform across the area of the cloud field, and third, the beam should be parallel. Because the cost of constructing a solar simulator approaching the above description would have been prohibitive, efforts were focused on achieving the latter two characteristics for the following reasons. First, theoretically, the spectral distribution of the incident radiation is important only in relation to the microphysical properties of the cloud; i.e. scattering

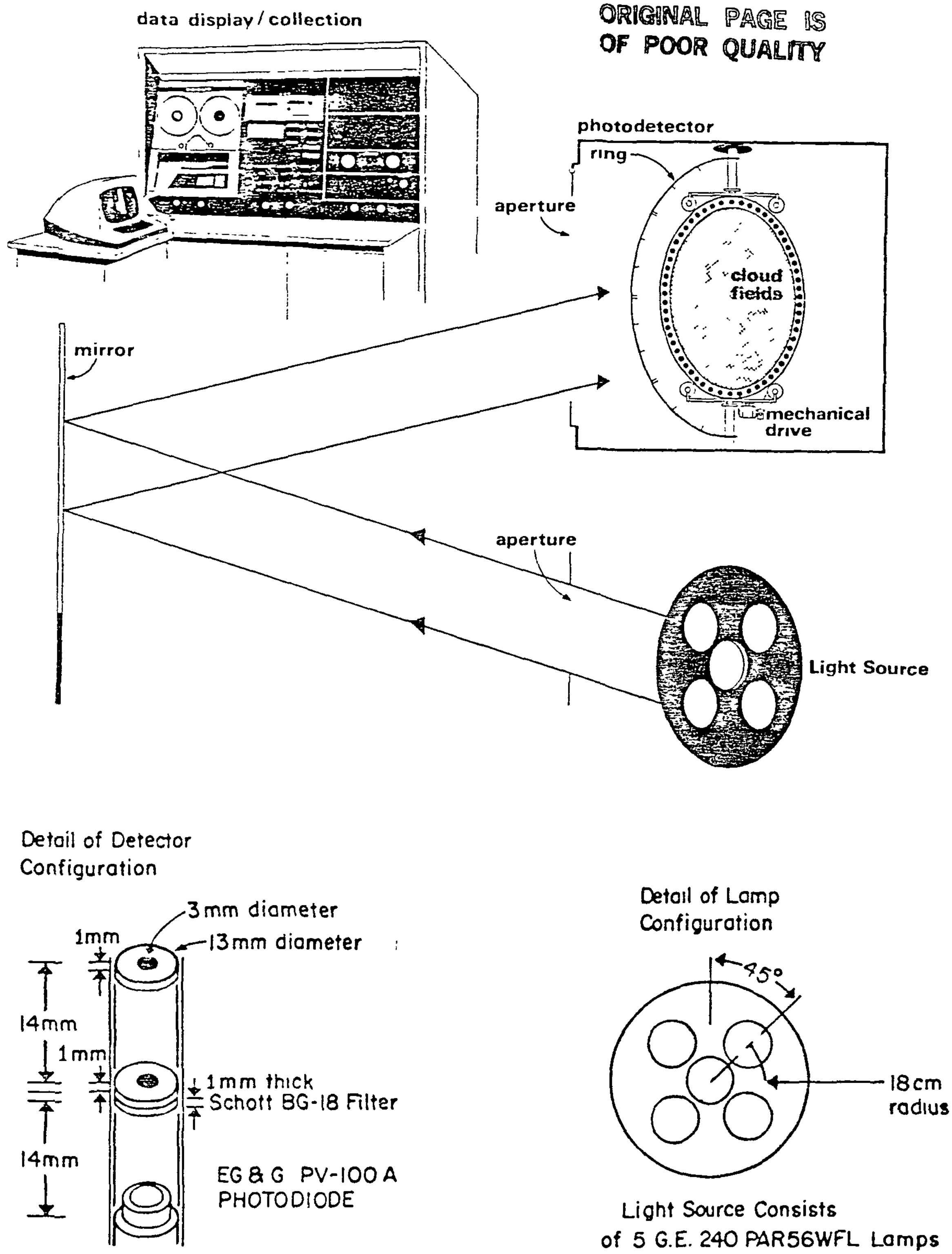


Figure 1. A schematic drawing of the Cloud Field Optical Simulator (CFOS) designed to simulate the interaction of visible solar radiation with optically thick clouds.

properties at a wavelength λ are determined only as a function of the ratio λ/r, and where r is the radius of the droplet. Since simulated clouds used in the CFOS are not composed of droplets (much less the specific droplet distributions measured in real clouds) and in view of the considerations given above, achieving the proper spectral response was given a lower priority and emphasis was given to designing a source which fulfilled the remaining criteria. Maintaining the proper spatial characteristics of the beam, as specified in the second and third criteria listed above, assures that the effects of cloud geometry are accurately taken into account. Doing so, even at the expense of achieving less than optimum spectral characteristics, is consistent with recent findings concerning the importance of cloud geometry. To these ends it was found that an array of low voltage display lamps provided illumination with the best spatial uniformity over the target cloud field. The low voltage design of the lamps allows small filament assemblies to be precisely placed at the focal points of accurately molded reflectors. The result is a smooth illumination curve which decreases slowly (7% in the first 4°) as a function of the angle from the beam axis of each lamp. Use of an array of overlapping beams, each aimed at a different section of the cloud field, results in an irradiance uniform to within ±3% of the mean value in the plane of the cloud field. The source was placed behind a circular aperture 0.5 m in diameter to shield the cloud field from stray light and to constrain the beam to within 3° of its axis, thus assuring nearly parallel light. The beam is reflected by a large plane mirror in order to allow enough distance (20 m) for the nearly parallel beam to diverge to a cross section sufficient to illuminate the entire target area (~3 m^2). Although the source output is reasonably constant in time, it is monitored by a wide field-of-view detector near the cloud field so that the effects due to even small variations may be accounted for in the analysis.

B. <u>The cloud field assembly</u>

The target cloud field assembly consists of the simulated clouds and the hardware necessary to support and orient the clouds with respect to the incoming radiation and the detectors. The assembly is contained in a separate 4 m X 4 m X 4 m black box in the laboratory room. The types of materials used to construct the simulated clouds are discussed in Sections 3a-c. As shown in Fig. 1, the target cloud field is mounted in a circular area ~2 m in diameter. The incoming radiation enters through a large aperture in one face of the box. The target cloud field is oriented in a vertical plane and has two rotational degrees of freedom. The first of these allows rotation about the vertical axis of the cloud field and simulates changing solar zenith angle. The second rotation is about a horizontal axis through the center of and perpendicular to the plane of the cloud field which allows simulation of a change in solar azimuth angle. Each of these rotations is driven by a separate motor and may be controlled at the data display station. The rotations are monitored to the nearest degree through the use of optical encoders and associated logic circuitry. Any sun-cloud geometry of interest may be easily simulated in the CFOS as a result of this design.

C. Sensor array

In order to examine the relationship between the summative and component properties of radiation reflected from the simulated clouds it is necessary to sample the radiation field from a number of angular viewing coordinates. The placement of the CFOS sensors with respect to the cloud field may be seen in Fig. 1. Fifteen sensors are mounted on a semi-circular ring whose ends are attached to the cloud field apparatus at points above and below the cloud field on its vertical diameter which serves as an axis of rotation for the ring. The sensors are spaced at increments of 10° of arc along the ring, beginning at the center of the ring and proceeding toward its ends. This sensor configuration permits a density of angular sampling of the reflected radiation which is more than adequate to establish the relationships between the desired quantities.

Each sensor consists of a high-quality silicon photodiode with a built-in high-gain operational amplifier circuit. The diodes are mounted in small cylindrical enclosures each of which contains a spectral filter and two circular diaphragms. The diaphragms limit the field of view of each photodiode to 7.5° half-angle. The relative spectral responses of the detectors with and without the optical filters are shown in Fig. 2. The filtered spectral response corresponds closely to that of the human eye. Thus, features visually observed should be evident also in the measurements. The field of view of the detectors is such that the center detector resolves a circular area 0.5 m in diameter when viewing the cloud field at the nadir. By using the relationships between the optical and geometric properties of simulated and real clouds (see Sections 3a-c) it is possible to associate the CFOS sensor configuration with that of a real world sensor 100 km above the earth's surface with a nadir ground resolution of 25 km.

D. Data display/collection station

One of the advantages of a laboratory investigation of the radiative properties of clouds lies in the ability to observe an unchanging cloud field from a variety of angular coordinates. This feature is fully appreciated by observing the changes in the various detector voltages as the "sun-cloud-sensor" geometry changes. The output of each sensor including the source monitor may be read from digital voltmeters at the data display/collection station. An array of light-emitting diode bar graph displays indicates the voltage outputs of all 15 diodes simultaneously, giving an instantaneous sample of the radiance patterns. The simulated solar zenith and azimuth angles and the angle of rotation of the detector ring are controlled from and monitored at the display station.

In order to examine the structure of the radiance patterns and to detect changes in the field or image as the clouds' geometric properties are changed it is necessary to assemble all measurements into a single representation of the reflected radiance pattern. This is accomplished in two stages by the CFOS. First, the data are recorded using an Apple II microcomputer as a smart data collection device. Various parameters such as sampling rates and the numbers of measurements included in average readings may be programmed into the data collection process. Second, the data from the floppy diskette in the Apple II are transferred

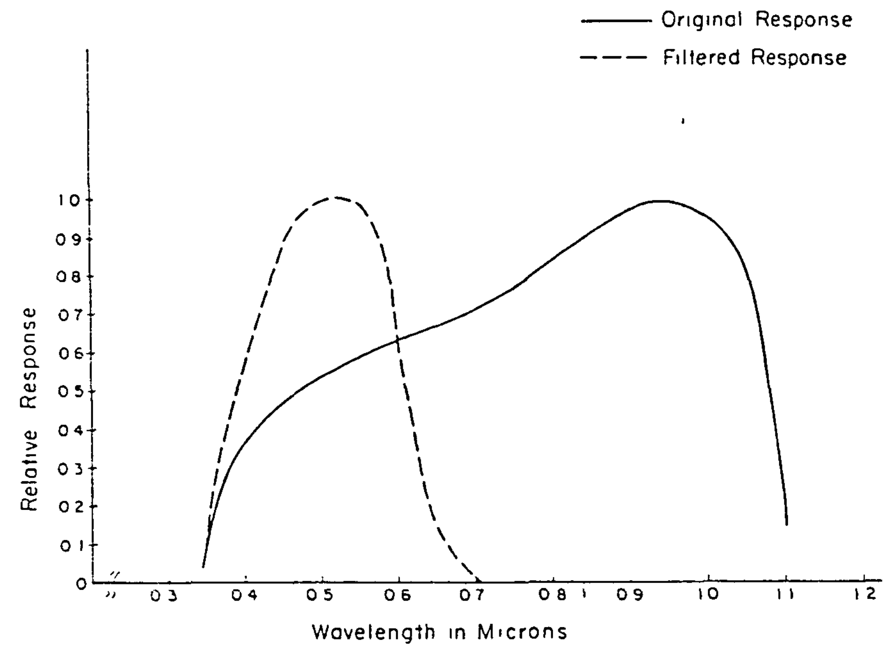


Figure 2. The relative spectral responses of the detectors used in the CFOS with and without optical filters.

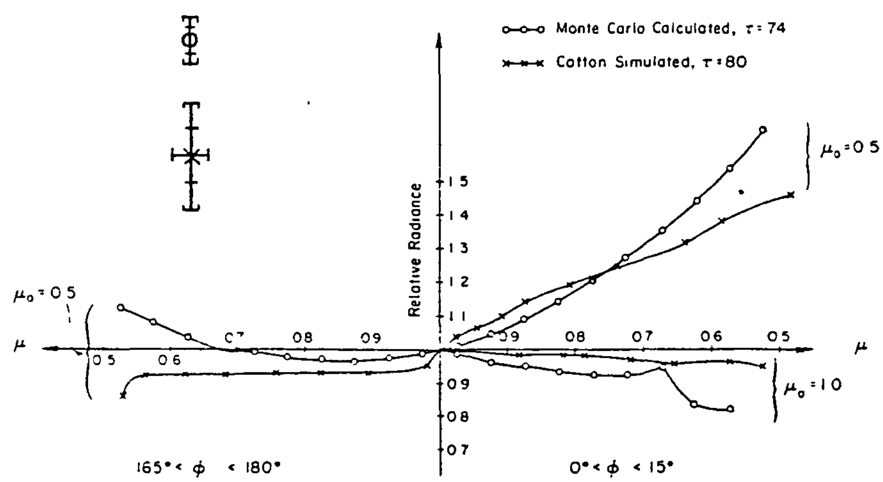


Figure 3. A comparison of the relative radiances reflected into the principal plane by cotton-simulated clouds (measured by the CFOS) to those calculated using a Monte Carlo model for water clouds. Comparisons are shown for solar zenith angles of 60° and 0°. (Only one of the symmetric branches is shown in the 0° case). Note that the uncertainty in observed and modeled relative radiances are a function of the observation zenith angle. The error brackets shown are maximum values typical at $\mu = 0.55$. Uncertainties near $\mu = 1.0$ are about half these maximum values and are indicated by the error bars.

to an Apple III microcomputer where they are processed. The processing is relatively simple; measurements are rotated into a nadir-relative azimuth angle coordinate system, voltages are divided by relative sensitivities, effects caused by variations in the source are removed, the reflected radiances are integrated over the lower hemisphere to obtain a flux density, and various graphical displays are generated. The total time of the processing of the data is ~15 min. Thus, experiments may be repeated for slight perturbations in the cloud field geometry and changes in the radiance field may be appreciated within a short time. Also, data and displays from the radiance patterns may be saved on diskette files for later viewing and comparison.

The CFOS apparatus described above should provide insight into the composition of wide field of view satellite measurements and images. It offers an interactive setting in which cloudy scenes may be created, observed visually, and whose relative radiance fields may be measured quantitatively. The next section describes the verification of the CFOS and in doing so furthers the appreciation of the similitude between the CFOS and the real world.

2.0 Verification of CFOS by comparing experimental results from it with calculations performed with a Monte Carlo radiative transfer model.

The previous sections have described a laboratory device designed to measure the simulated radiative properties of clouds of a realistic shape. In the sections which follow the properties of the simulated clouds and the relationship of their scattering properties to those of simulated water clouds are discussed. The verification of the CFOS is based not on analogies between the microphysical properties of real and simulated clouds, but rather on comparisons of observable radiative properties.

A. Selection of suitable materials for cloud simulation

The validity of measurements obtained from the CFOS depends, almost entirely, on the measurable radiative properties of the simulated clouds. Several materials were examined in a search for one which adequately simulates the visible reflective properties of optically thick clouds. The criteria which were examined in the selection process were first, the behavior of the radiances reflected into the principal plane by a horizontally semi-infinite cloud, and second, the visual appearance of the simulated clouds and cloud fields. Based on these criteria, two materials emerged as superior to all others tested; they are surgical quality sterilized cotton and decorative billet (DB) styrofoam which is marketed by Dow Chemical under product code #81568.

It should be emphasized that the manner in which light interacts on the microphysical scale with the materials selected may differ considerably from the classical picture of independent Mie scattering in a spherical polydispersion. For example, the surgical cotton used in the experiments consists of long fibers of mainly cellulose from 10 to 25 μm in diameter. The mean index of refraction of cellulose is 1.55 in the mid-visible. The DB styrofoam is a polystyrene extrusion. It contains no pigments or other suspensions and has a mean cell dimension of 1.9 mm. The index of refraction of polystyrene is 1.59-1.60 in the visible.

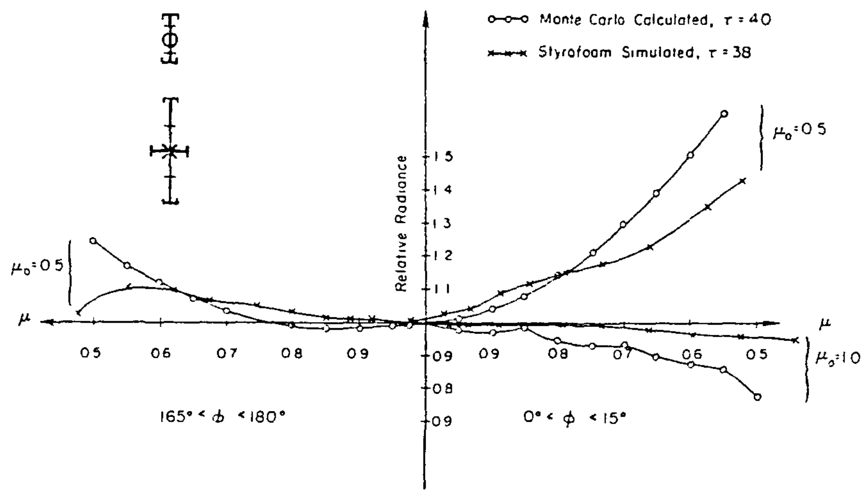


Figure 4. As in Fig. 3, but for styrofoam-simulated clouds.

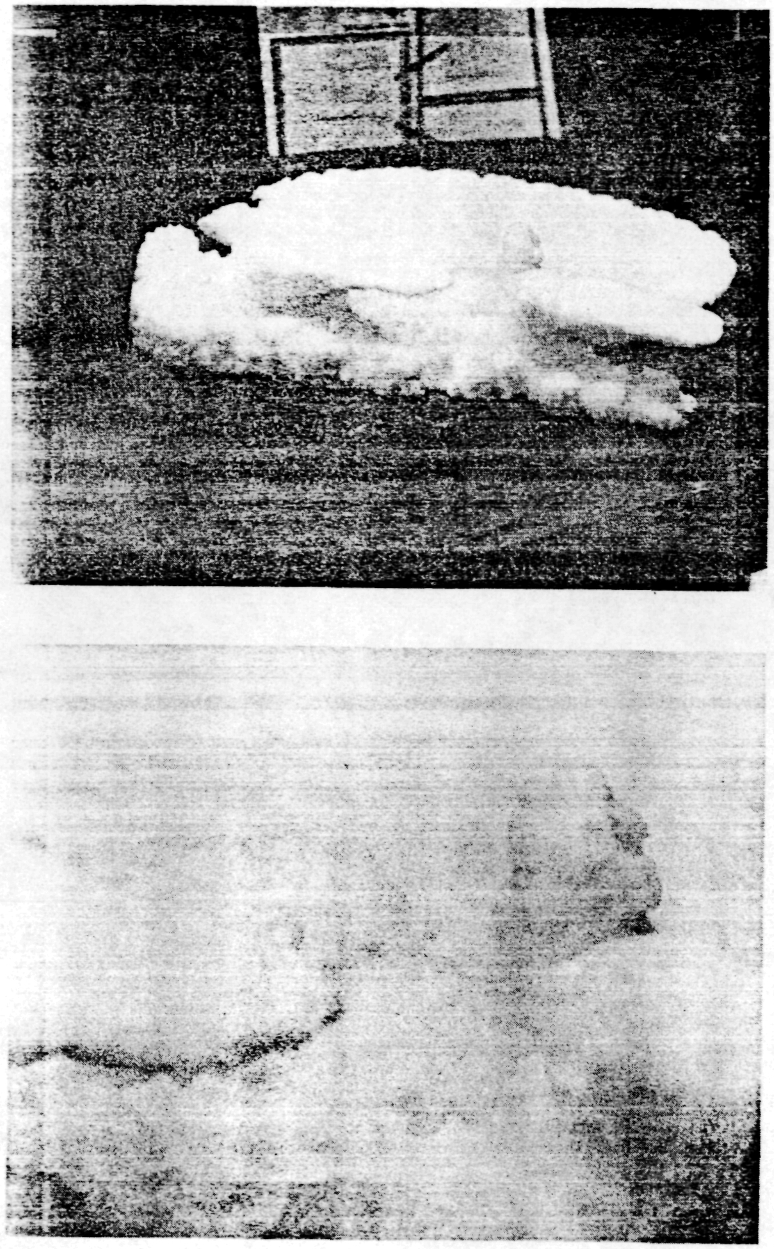


Figure 5. Photographs of a styrofoam-simulated cloud system. The bottom photograph is an enlargement of the first showing the detail of the area between the simulated cumulonimbus clouds.

Polystyrene is a transparent plastic. The white appearance of styrofoam results from multiple reflections of the incident light from the many facets which surround the individual cells. Thus, it would be difficult to draw an analogy between the local scattering process in water clouds and the multiple reflection process in styrofoam. Moreover, recent studies have shown that cloud shape may dominate microphysical scattering as the most important factor affecting the radiance pattern. Also, it is doubtful that any material which closely duplicates the scattering process in water clouds would possess an extinction coefficient great enough to permit simulation of optically thick clouds in a laboratory setting. The goal of the CFOS experiment is to determine if it is possible to simulate the observable properties of optically thick clouds of a realistic shape and not necessarily to duplicate the exact scattering process on the microphysical scale. Thus the determination of which materials are best qualified as simulation materials is based on comparison of observable optical properties of the simulation materials with those predicted by radiative transfer models of real water clouds. Such comparisons have been made for "horizontally infinite" and cubic finite cloud shapes.

Figures 3 and 4 show comparisons between the radiances reflected into the principal plane by horizontally infinite cotton and styrofoam simulated clouds compared with theoretical curves derived from a Monte Carlo radiative transfer calculation. The model was run for a C.1 (Deirmendjian, 1969) droplet distribution with an absorption for a wavelength of 0.7 μm and for solar zenith angles with cosines of $\mu_o = 1.0$ and $\mu_o = 0.5$. The radiances have been normalized to the value at the zenith and are displayed as a function of the cosine of the zenith angle (μ) and the relative azimuth angle ϕ into which they are reflected. Scattering into the forward direction ($0^\circ \leq \phi \leq 15^\circ$) is depicted in the right halves of the figures and backscatter ($165^\circ \leq \phi \leq 180^\circ$) is indicated in the left halves. The materials are almost equivalent in satisfying the first criterion. The styrofoam-simulated clouds display a slightly more realistic behavior in the backscatter direction.

Both materials do well in simulating the visual appearance of real clouds. Fig. 5 shows photographs of styrofoam-simulated clouds of a realistic shape. If we add a third criterion, the ease of working with the materials, styrofoam is preferable for the following reasons. First, styrofoam is rigid and will maintain a constant ratio of geometric to optical depth, and the shape of simulated clouds will be retained regardless of orientation. Second, the simulated styrofoam clouds are easily placed and maneuvered in a cloud field and may be categorized and stored for use in other cloud scenes. Finally styrofoam clouds are easily made into regular shapes i.e., cubes, cylinders, spheres, etc., so that their radiation properties may be compared with theory.

B. The optical depth of simulated clouds

In order to relate the reflective properties of simulated clouds to real water clouds it is necessary to have an accurate estimate of the optical depth of the simulated clouds. One means of doing so is based on the bulk radiative properties of a 'horizontally-infinite' sheet of the cloud material at 0° zenith. Specifically, theory predicts that the ratio of the spectral reflectance R_λ to the spectral transmittance T_λ of a semi-infinite cloud over a non-reflecting surface is nearly a linear function of optical depth (see, e.g., Coakley and Chylek, 1975; Stephens, 1978). Fig. 6 shows a plot of the ratio of R/T generated from the parameterization of Stephens (1978) for water clouds in the visible portion of the spectrum. The solid curve shown in the figure is the result of a linear regression of the form $R/T = \tau(\ln\tau + 8.307)/153.149$, which is nearly linear for $10 < \tau < 200$. Also shown is the ratio (R_λ/T_λ) calculated using an Eddington model for various microphysical distributions and a few results of the R_λ/T_λ ratio from Monte Carlo calculations. The nearly linear dependence between R/T and τ, the visible optical depth, is apparent.

An equivalent visible optical depth (τ_e) may be assigned to the CFOS cloud material by measurement of the ratio of R/T for a sheet of the material with a large ratio of horizontal to vertical dimension. Once τ_e is established for a large slab of styrofoam several clouds may be "sculptured" from the slab while maintaining in each the vertical dimension of the original slab. The procedure requires an additional stop in the case of cotton since the vertical structure of the original "slab" (surgical cotton is available in 12" X 60" sheets) cannot be maintained while forming clouds of a realistic shape. However, it was found that the mass of the material in a vertical column of unit cross section is also related to the ratio of the R/T in a nearly linear manner (see Fig. 7). Thus, for a cloud simulated from surgical cotton on approximate visible optical depth may be assigned by weighing the cloud and measuring its cross-sectional area to determine the area mass density, then using the R/T line as a transfer function to obtain τ_e.

C. Retrieval of basic finite cloud features

A crucial test of the CFOS is the ability to measure the reflected radiances of finite clouds. Figs. 8 and 9 show comparisons between radiances reflected into the principal plane by finite clouds as measured on the CFOS and the same quantities predicted by the theoretical Monte Carlo model described in McKee and Cox (1976). The radiances in each case have been normalized by the radiance measured or calculated at the zenith. The CFOS profiles have been retrieved from measurements over a field of simulated (styrofoam) cubic clouds cut from a slab of material whose R/T ratio corresponded to an equivalent vertical optical depth $\tau_e = 76$. The simulation clouds were placed at the centers of adjacent squares of sides 5w, where w is the dimension of the finite cubic cloud. This arrangement resulted in a true fractional cloud cover $f = 0.04$. The cloud rows were aligned along two mutually perpendicular axes, one of which formed the line of intersection of the principal plane with the surface. Figs. 8 and 9 show measured retrievals. The first (applicable only for observation of the cloud field in the direction of the cloud rows) assumes that as the observation zenith angle (θ) increases, the solid angle of the observed cloud field relative to the underlying surface increases by a factor of $1 + \tan\theta$, resulting in a modified fractional cloud cover f' given by

$$f' = \begin{cases} f(1+\tan\theta), & \theta < \theta_{max} \\ f_{max} = f(1+\tan\theta_{max}), & \theta > \theta_{max} \end{cases}$$

In the above, F_{max} is the fractional cloud cover derived as the tops and sides of the cubic clouds maximally obscure the inter-cloud spacing. Note, in the present case, for observations taken in the principal plane

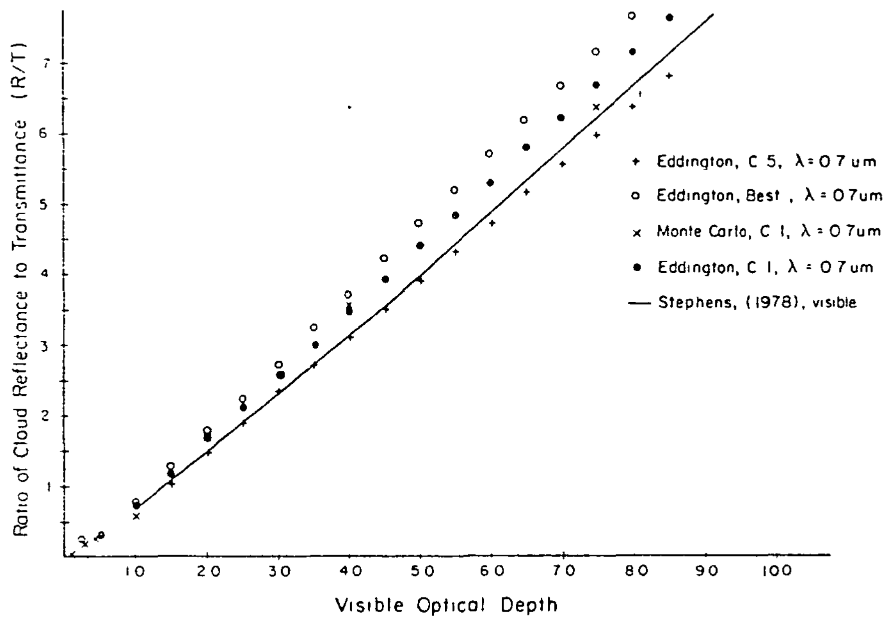


Figure 6. The ratio of reflectance to transmittance for horizontally infinite clouds plotted as a function of optical depth in the visible region of the spectrum for a solar zenith angle of 0°. Values of the ratio from the Eddington and Monte Carlo models are valid at 0.7 μm, values from Stephens (1978) are representative in the visible (λ ≤ 0.75 μm).

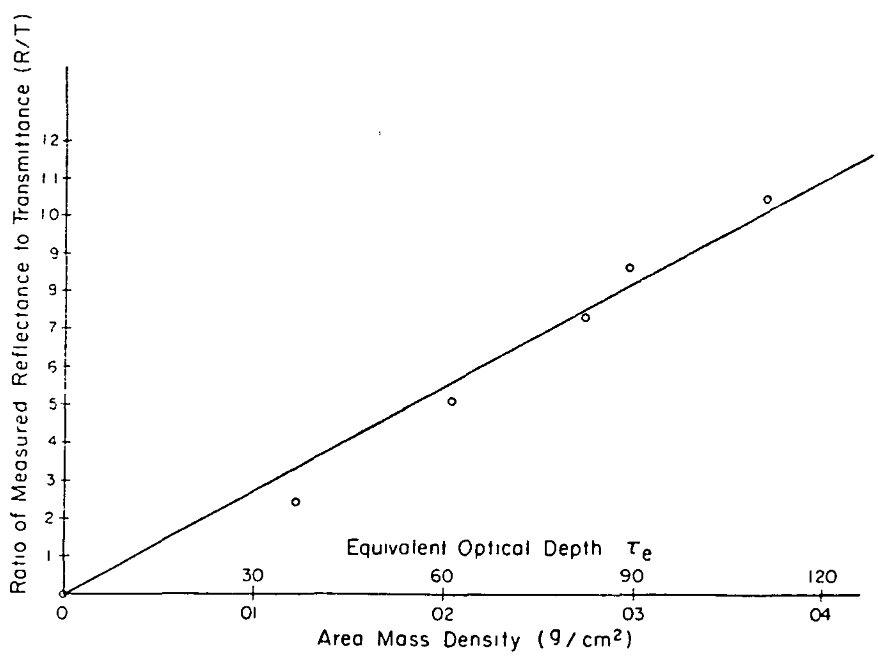


Figure 7. The ratio of reflectance to transmittance for cotton simulated "horizontally infinite" clouds plotted as a function of the area mass density of the material which is used as a transfer function to obtain the equivalent optical depth of simulated clouds.

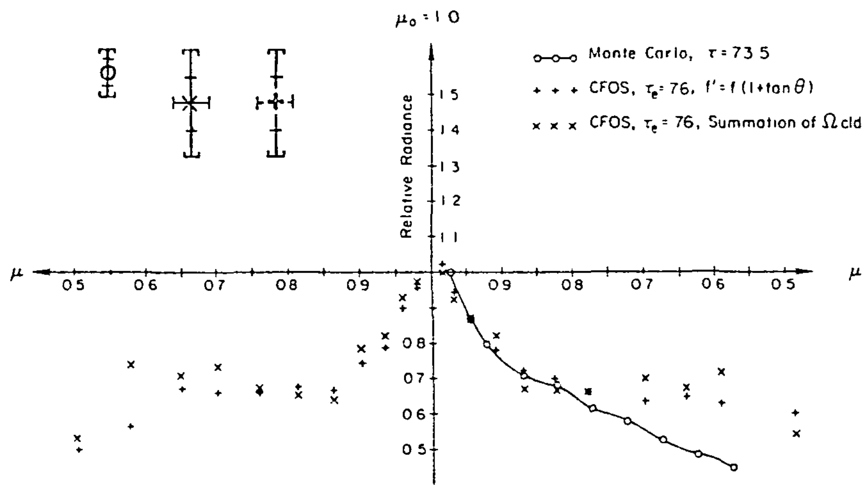


Figure 8. A comparison between calculated and simulated radiances reflected from finite cubic clouds into the principal plane for a solar zenith angle of $0°$ using styrofoam as the cloud simulation material. (Only one of the symmetric btanches is shown for the modeled results.) Note that the uncertainty in observed and modeled relative radiances are a function of the observation zenith angle. The error brackets shown are maximum values typical at $\mu = 0.55$. Uncertainties near $\mu = 1.0$ are about half these maximum values and are indicated by the error bars.

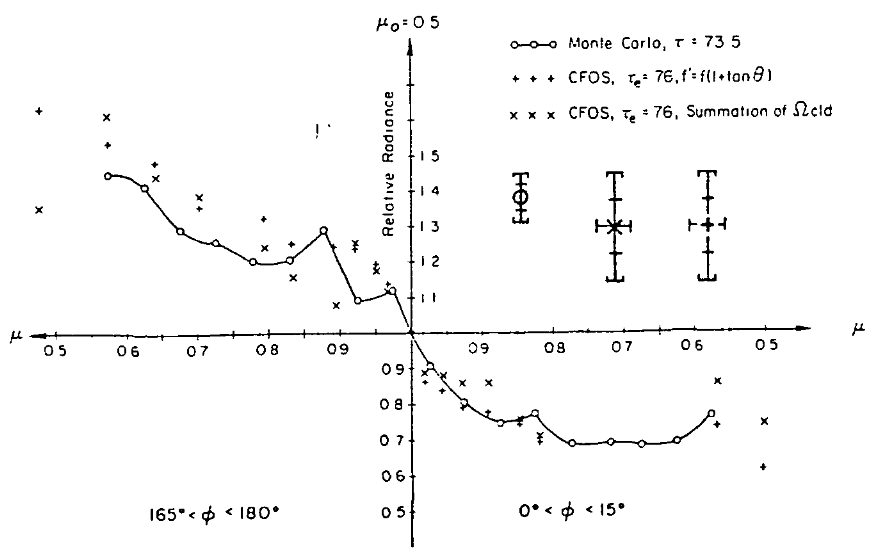


Figure 9. As in Fig. 8, but for a solar zenith angle of $60°$.

(parallel to the row directions), $f_{max} = 0.20$ and $\theta_{max} = 76°$, which is larger than the zenith angle of any of the observations depicted below, so that the first line in the equation above applies. The second treatment utilized the exact geometry of the cloud field and the CFOS detectors, counted the clouds in the field of view, and calculated the total solid angle subtended by the clouds and their shadows. In this interpretaiton the radiance measurement (N) is given as

$$N = N_{cld} \cdot \Omega_{cld} + N_{cir} \cdot \Omega_{cir} + 0 \cdot \Omega_{sdw},$$

where the subscripts cld, clr, and sdw represent cloud, clear and shadow, respectively, and Ω is the fractional solid angle subtended by each target component. It was assumed that there was no radiance contribution from the shadow regions. The clear measurements were made of the surface on which the clouds were mounted in the absence of the clouds. The albedo of the surface was 0.02. The second treatment resulted in a "noisier" curve because a single cloud was either considered completely within or exterior to the field of view. Nevertheless, smoothed versions of the curves are in good agreement. The apparent disagreement between the curves for the 0° solar zenith case at large observation zenith angles is principally from two factors. First, the styrofoam material is least faithful in its reproduction of the reflected radiance of real clouds at the larger observation angles as evidenced in the comparisons for horizontally infinite clouds in Fig. 4. Second, in the Monte Carlo model, for a 0° solar zenith angle, there is no radiation incident on the vertical side walls of the cubic clouds. However, in the laboratory, the incident radiation is not parallel in the strictest sense. Thus, over the extended cloud field, some incident radiation falls on the vertical walls of some of the simulated clouds. This results in relatively brighter side walls in the simulated case which contribute greatly to the radiance field at larger observation zeniths.

It should be noted that the retrieval of the finite cloud reflected radiances described above represents a rigorous test of the CFOS concept. The low surface albedo (0.02) combined with the extremely small fractional cloud cover (0.04) resulted in reflected radiances at the lowest bound of the domain for which the CFOS was designed. Larger clouds, smaller cloud spacing and more realistic simulated surfaces will all tend to increase the radiance signal. In addition, the above experiment represents the retrieval radiances reflected from only part of the scene. Measurements of total scene radiances are of a more stable nature.

3.0 Development of a software library to process, reduce and display CFOS data for use in research studies.

Introduction

This manual was written in order to provide a transfer of established methodology used in the operation of the Cloud Field Optical Simulator (CFOS) to interested users of the device. Throughout this document it is assumed that the reader is familiar with the basic design and purpose of the CFOS. If this is not the case the reader is referred to a publication Davis, Cox and McKee (1983), which will provide sufficient backround information and which may be found in Appendix A. This manual is divided into two parts. Part one is a description of the methodology of data collection. In part one the reader will find a discussion of alignment of the CFOS, calibration of the sensors, and the normal procedure which has been developed to collect meaningful data. Part two is a discussion of data processing. The main thrust of part two focuses on how to proceed from the raw data to an array of bi-directional reflectance data. This, of course, is not the only product for which the CFOS was designed but the basic methods are demonstrated in obtaining this type of data. Part two necessarily discusses some of the application software which has been written for the CFOS although additional software exists for particular tasks. All the software is listed in Appendix B along with a brief statement of its purpose. Finally, it must be noted that all of procedures associated with the CFOS have been in a constant state of flux. CFOS itself has always been in part the object of the ongoing research effort. Thus, especially in using the applications software, some user familiarity with the code must be established. CFOS is not now, nor in all probability will ever become a black-box laboratory device.

I. PART I

A. Laboratory procedures

Part I is divided into two sections. Section one presents suggestions, advice and procedures to ensure that the basic laboratory device is aligned for data collection. Certain care must be taken before any data is collected especially if there has been a significant down period or if it is discovered that the device has been moved or altered as may happen for instance if items not related to CFOS have been moved in or out of the basement annex. Section two discusses the calibration and method of data collection which has been found to provide the best results to date. It should be stressed at the outset that calibration should be considered part of the data collection process since it has been found that the calibration coefficients are not constants. In all of part one it is assumed that the reader has been briefed on the proper way to power up the laboratory and on the functions of the various controls accessed at the data display station.

B. Section 1

1. Source alignment

The source may need to be realigned periodically because of the reasons mentioned above. The source alignment consists of adjustment of the relative position and orientation of the light source itself and the mirror and establishing the zero degree position of the cloud field ring all of which are interdependent. An iterative procedure has been developed which seems to work reasonably well; however, it is somewhat time consuming. One begins by ensuring that the normal to the cloud field ring is pointing in the approximate direction of the light source. Then by adjusting the position of the array of lamps so that its lateral positioning behind the aperture appears symmetric when viewed by an observer standing on either side of the cloud field ring. In other words, if you can see all the lamps except for part of one of the lower lamps when standing on one side of the cloud field ring, then if you move to the other side of the ring you should be able to see all of the lamps except for a similar portion of the other lower lamp. The position and orientation of the mirror may also need adjustment in order to accomplish this. It may take a few to several adjustments obtain the desired symmetric alignment.

Next, the true zero zenith angle must be set. To do so it is first necessary to establish the center of the cloud field with respect to the direction of the incoming beam. An aluminium bar has been constructed for this purpose. It is fitted with cylindrical feet on each end which may be inserted into the holes in the cloud field ring. A small hole has been drilled in the middle of the bar through which the source light may pass to form a small image of the lamp source on the cloud field backround. The image marks the center of the cloud field with respect to the incoming beam. Next, an alignment photodiode which is mounted in a circular magnetic support is placed on the cloudfield backround at the center point. The photodiode is connected to an operational amplifier circuit and thus requires a supply votage of +/- 15 volts. The output of the device may be read using a digital voltmeter. By examining the output of the device for changes in the simulated solar zenith angle about the initial orientation, one may establish the center of the response pattern. This point marks the true zero of the solar zenith angle regardless of the reading on the data display panel meter. The zero readout may be reset once the optical zero is established. It should be pointed out that near the zero of the solar zenith angle there will be little change in the output of the device due to the nature of the cosine response. Thus one would be well advised to look for symmetric points at larger angles about the zero in solar zenith.

After the optical zero zenith angle is established the next step in the general alignment procedure is to check the spatial homogeneity of the incident irradiance field. The magnetically held diode may be used to check the homogeneity of the incident radiance field. By moving the device about to different positions on the cloud field and comparing the output voltage at the various points homogeneity may be established. If the incident pattern is not homogeneous then the orientations of the individual lamps must be must be adjusted relative to each other. This may be a time consuming process depending on how non-homogeneous the field is and on how large the region is where homogeneity is desired. It is convenient to employ a second digital voltmeter to monitor the output of the test diode. The second dvm should be placed near the lamp source so that it can be read at the source. Then while adjusting the individual lamps with the test diode placed in a region of particularly high or low irradiance the effect of the re-aiming of the individual lamp may be monitored. The dvm located near the interior of the CFOS is convenient to monitor changes in the test diode output as the diode is moved about on the cloud field. Two items should be noted while checking the homogeneity of the incident beam. First, the test diode circuit outputs a dark current voltage which must be subtracted from the readings before establishing the relative magnitude of the incident irradiance. Second, the reorientation of the individual lamps changes to some extent the optical zero zenith angle. If in the process of smoothing the incident light one upsets the optical zero the preceding step should be repeated.

The next item in this section concerns the cleanliness of the glass surfaces in the CFOS. The large mirror will need cleaning from time to

time and the frequency of the cleaning will be obvious. Also, the photodiode glass covers and the glass optical filters housed within each collimating can should be cleaned periodically, especially after significant down time. When this is done the individual diodes invariably become misaligned and uncalibrated. Recalibration will be covered in section 2 of part 1. To re-align each diode a simple flashlight device has been construced which may be mounted over the exterior of each diode can and which projects a small spot of light toward the center of the cloud field backround. The device is powered by any 4.5 volt d.c. source. It is helpful to mount a white piece of paper or cardboard at the center of the cloud backround and to turn off the main lights since the projected spot of light is rather dim. The center of the cloud field may be established on the white reflector as explained above using the large aluminium bar. In this manner each diode's field of view may be centered at the center of the cloud field after the glass surfaces have been cleaned.
The final item to be discussed in this section concerns the alignment of the detector arc. This is one of the simplest of the procedures. The optical zero of the detector ring is established at the position where the shadow of the detector ring falls on the center of the cloud field. Actually, there are five shadows since there are five lamps, but it is fairly obvious where one should place the detector arc zero point. The readout may be reset to zero at this point if desired but this is not necessary if the offset is programmed into the software.

C. Section 2

This section presents a discussion of procedures used more on a daily basis or even more often to ensure quality data. These methods pertain to the actual process of collecting the data and maintaining calibration. It is easiest to begin with the data collection device--the Apple II plus computer and the data logging program. After turning the computer on, with the disk labeled "cfos prodos" inserted, the logging program is initiated by typing "run calib." This program will prompt the user to insert a properly formatted data disk and to select the number of data scans to be included in each measurement. In an actual data collection session 30 data scans have usually been used. However, for merely observing the diode outputs a smaller number is more convenient. The program then displays the output of each of the diodes and the relevant angle settings. Nothing else will happen until the user presses a "control p" which initiates a write to the disk at the end of the current scanning sequence. Data may be taken in this manner for as many different geometries as desired. When it is desired to end the recording session the user must press the "escape" key which will terminate the file. This is the basic way used to collect the data. Small adjustments to the basic process and specific cautions will be found below as they pertain to collection of bi-directional reflectance data, calibration etc.

1. Calibration

In all the applications for which CFOS was constructed only the relative sensitivities need be determined. Even so, it has been found that constant checks must be made on the diode relative sensitivities since they may change significantly even with the temperature excursions induced by the heating system in the basement annex. Thus what follows may seem like overkill, but it has been found that only by continually updating the sensitivities can one expect to obtain results valid to within a few percent.

Each diode circuit has a very high amplification factor which causes a significant dark current signal. It is mainly this compontent of the signal which is temperature sensitive. In order to "predict" the magnitude of the dark current signal, (which is impossible to monitor in an experiment with light incident on the diodes), a separate diode circuit identical to the others has been masked off so that no light may enter the diode can. Note that it is important to ensure that the back of the collimator can is also masked off since it has been observed that sufficient light may enter the can from the backside and cause erroneous results. The purpose of this diode is to put out only a dark current signal which will respond to temperature changes and which may be used to infer the behavior of the dark current signals in the remaining diodes. Simple linear regression has been found to provide predictions of the required dark current signals which are highly correlated to the actual measured valued. (Correlation coefficients greater than 0.99 are not uncommon.) The regression relations should be re-calculated periodically using the following procedure.

It is desirable to collect the regression data over a period of time when the temperature extremes in the CFOS laboratory are similar to those encountered during the data collection session. Thus it may be desirable to collect the data over the weekend before a series of measurements will be made or if the outside ambient temperature has changed drastically to collect a new set overnight. By modifying the data logging program slightly the system may be placed in a continuous logging mode and serveral hundred scans may be recorded from which the regression data may be generated.

The modification consists of inserting the line,

"1516 GOSUB 600"

Depending on the amount of time the program is left to record data, a very large may be generated. The software which processes this data is described in Part II. During the time these data are being collected it is necessary that the curtains on CFOS remain closed and is would be preferable if the main overhead lighting remain off.

Once the regression data have been collected the relative sensitivities may be determined. These numbers also change and must be continually updated. In fact, below in the description of a typical data collection session note that a calibration update is performed before each scene measurement. To obtain the relative calibration coefficients an isotropic reflector is used. It has been found that ordinary polyurethane foam provides a surface which is nearly istropic out to observation angles of nearly 60 degrees when illuminated at normal incidence. It is convenient to use magnets to mount the foam on the cloud field backround since it must be mounted and removed frequently. With the foam in place the reflected signal from all the lamps is too large for the highly sensitive detectors. In order to circumvent this problem a separate power supply has been connected only to the center lamp of the light source. A circuit breaker is provided to ensure that the output of this power supply may be isolated at all times from the AC supply which normally operates the source.

Thus using only the center lamp one may collect data and record it on a disk file which may be analyzed to obtain the relative sensitivities. It is advisable to set the detector arc angle at about 10 to 15 degrees in order to displace the shadow it casts as far as possible from the center of the foam. The software to produce the diode sensitivities is descibed in Part II.

2. A typical data collection session

To begin a typical data collection session it is assumed that the regression data have been collected and that the relative sensitivities are known fairly well. What is described here is a procedure which when followed will produce data with standard deviations of a few percent of their respective mean values.

Although dark current data have already been collected best results will be obtained if this information is updated prior to each experiment. To do so the CFOS curtains are closed and a data file is written with all lights off. This file need consist of only 10 to 20 records each containing 30 or so scans. While this data is being collected the lights should remain off and none of the motor controls should be activated since the motors and switches may introduce noise into the diode signals. End the file with the usual escape sequence.
Next leaving the main AC power off the center lamp of the source array is activated by powering up the separate DC supply. The circuit breaker switch at the lamp source must also be turned on. Open the curtains and mount the calibration foam so that it is as much in the center of the cloud field support as possible. Offset the detector arc angle to about 15 degrees so that the shadow will not be in the field of the detectors. Write a file of about 10 scans to establish current calibration coefficients. End the file with the escape sequence.

Now the system is ready for data collection. Turn off the center lamp supply and open the circuit breaker. Turn on the main lamp switch. It is best to let the source lamps heat up as their output will fall considerably in the first 5 minutes or so. Variation in source strength is accounted for in the data reduction software but a constant source is best. Remove the foam calibration reflector and mount the cloud field target. It is easiest if the cloud field is premounted on a separate backround so that it may be rapidly mounted and removed. Normally bi-directional reflectance data is collected by scanning the detector arc through plus and minus 60 degrees with the cloud field set at the desired zenith angle. It is best to confine the total target to within about 9 inches of the center in order to avoid errors intoduced by changes in the solid angle subtended by cloud elements as the detectors are rotated. So beginning with the detector arc offset at 60 degrees from the center, on a new data file, record a data scan. Then proceed every 10 degrees in detector arc across the reflectance field. The data record which is being averaged while the arc is moved should be not be recorded since moving the arc will introduce noise into the data. Only the next record during which no arc movement has occurred should be recorded. After some practice it is possible to move the arc while the computer is writing to disk in which case the next record may be used. If, after the "control p" sequence has been entered, it is desired to inhibit the write to disk, press any key on the Apple II keyboard and the current record will not be written to disk. This happens occasionally if doors are opened or in some cases people may need to walk across the path of the incident beam. These records should be discarded. It often happens that moving the arc will cause some change in the zenith angle setting in which case the zenith angle should be adjusted to the desired value. When all the data have been collected for a particular scene the file should be ended with the escape sequence. For best results the same scene should be repeated as many as four times to assure the quality of the data. (This should yield results with standard deviations of less than 2% of the mean values.) Each time the experiment is repeated the dark current and sensitivities should be redone as explained above.

At the end of the session the curtains should be closed, the computer turned off and the lamps should be turned off. However, the power to the main control panel should be left on. It has been found that the stability of the entire system is highest if the amplifier circuits are constantly powered up. The data disk should be removed and saved for processing, which is the subject of Part II below.

II. PART II

In part two the software which has been developed for the processing of bi-direcional reflectance data is described. Additional software exists and is listed in Appendix B. Only a mention of the particular use of this latter software will be given since it is unlikely that a new user will have need for these routines without some modification. As mentioned in the introduction, it is assumed that the user will become familiar with the software. Many will require some user interaction. All of the programs which are discussed below are found on the Davong system hard disk under volume prefix /area1 or .H1 or on the CFOS software backup diskette included with this manual.

We begin by assuming the user has completed a session in the CFOS laboratory and has written a data disk containing a file for establishing the dark current regression coefficients, one for updating the coefficients, a file containing relative calibration data and one or more files containing data for analysis of bi-directional reflectance data. All of the files written by the Apple II in the CFOS laboratory have a file name of the type D.mmddyy.hhmm, where mm is the two digit designator of the month, dd designates the day of the month yy the year, hh the hour on a 24 hour clock and mm the minute when the file was written. For example, the last dark current regression data recorded is listed on the first page of the Appendix B as D.082484.1348.

The first task is to run the regression program which will establish the initial regression coefficients between the masked diode and the remaining detectors. Run the program called "CFOSREG". It will prompt you for the name of the file containing the regression data. It expects to find the file on device .d2. After the file name is input the reqression coefficients will be calculated and written to a file on the Davong system hard disk called "/area1/cfos.cal/coeff". As the data is processed the values of the slope, intercept and regression coefficients will be written to the screen. If the file contains a large amount of data the processing may take several minutes to a half hour. Once the regression coefficients have been calculated it is a good idea to transfer the raw data file to the hard disk for temporary storage in case the file containing the coefficients is lost as has been done with the file d.082484.1348.

The program above is utilized only occasionally after a new regression is needed for whatever reason. More often the file "/area1/cfos.cal/coeff" will already exist on the hard disk and these coefficients will need to be updated. This is the task of the program called "/area1/cfos.cal/cfosdark" using the data collected just prior to the relative sensitivity measurement described in Part I. This program also prompts for the name of the data input file which it expects to find on device .d2. The program uses the regression coefficients in "/area1/cfos.cal/coeff" and simply updates the offset coefficients which it then writes to a file called "/area1/cfos.cal/adjust". This procedure is normally repeated for each new bi-directional reflectance data set prior to running the relative calibration program described next.

Now the program "/area1/cfos.cal/cfossens" is run to process the relative sensitivity measurements. The user is asked for the name of the data file which it expects to find on device .d2 after which the contents of "/area1/cfos.cal/cfoscoeff" and "/area1/cfos.cal/adjust" are used along with the current data file to establish sensitivities relative to diode #8. These values are written to a file "/area1/cfos.cal/sensiv".

The preliminaries out of the way it is now possible to process meaningful bi-directional reflectance data. This is the task of the program "/area1/cfos.bdr/cfosbdr" which expects to find the raw data in the subdirectory "/area1/cfos.back/". If several bi-directional reflectance files have been collected it is convenient to use the filer to transfer these files to the hard disk prior to the data processing session. The present routine uses the data in the files "/area1/cfos.cal/coeff", "/area1/cfos.cal/adjust", and "/area1/cfos.cal/sensiv" along with the present raw data to establish the normalized bi-directional data set. Normally the regime of detector arc angles is limited to +/- 60 degrees in these data. The program terminates by writing to a file in the subdirectory "/area1/cfos.bdr/" concatenated with the current raw data file name. The bi-directional field, the number of detector arc angle scans, the normalizing flux density and the minimum and maximum of the field are also written to the file for later use.

This completes the main processing for bi-directional reflectance data. However, now that the field has been established it is fairly common to continue the process further to obtain a denser interpolated field which may be plotted or used for error analysis, for example. So continuing along the data processing chain of events one may run the program "/area1/cfos.interp/cfosinterp" which performs a weighted interpolation on the normalized bi-directional reflectance data. The weighting is based on the inverse of the angular distance between the point at which the interpolation is desired and a neighborhood around this point which may be changed to include all of the normalized data points or just a surrounding few. The running time is highly dependent on the number of points used in the interpolation. The program prompts for the number of nadir and azimuthal points at which interpolated results are desired as well as the input data file name. This latter file name should be the concatenated portion of the normalized data which was written by "/area1/cfos.bdr/cfosbdr" to the subdirectory "/area1/cfos.bdr/". This is of course just the "d.mmddyy.hhmm" designator of the original raw data. The product of this program is an interpolated field which is written to a file under the subdirectory

"/area1/cfos.plot/" concatenated with the "d.mmddyy.hhmm" designator of the original data.

One final product of this line of processing is a polar plot of the bi-directional reflectance data. Such a plot is the product of a program "/area1/cfos.plot/cfosplot". This program utilizes the HP 7470A plotter to produce the drawing. The input data set is the product of the previous interpolation program and is requested by the program. Another use of the interpolated field is variance estimation. It is desirable from time to time to analyze the variance in the bi-directional reflectance data for the same scene measured several times or the variance among sets of data for slightly different scenes. This type of analysis is the object of the program "/area1/cfosste" which prompts for first the number of interpolated data fields and then the name of each one. Again, it is assumed that the interpolated fields are to be found in under the subdirectory "/area1/cfos.plot/" with concatenations of the raw data file names to be input by the user. The program presently assumes that 144 interpolated data points are available for each scene in a 12 by 12 array over the azimuth and nadir regime. The poduct is the standard error at each grid point and an average standard error for all grid points. This program was used to establish the basic precision of the bi-directional reflectance analysis which has been outlined in this manual.

This completes the description of the software needed to obtain bi-directional reflectance information. There are several other programs listed in Appendix B. What follows is a very brief description of the remaining software.

"/area1/cfos.cal/cfoscal" was the predecessor to the current sensitivity procedure. It assumed the dark current coefficients were constants and were entered in DATA statements within the program.

"/area1/cfos/cldareadist" is a simple algorithm which implements a cloud field statistical model given by Planck.

"/area1/cfos/clddist1" is a simple algorithm which implements the cloud field distribution program by Hozumi.

"/area1/cfos/cfosmovie" was used to provide a "movie" type graphical display of bi-directional reflectance fields. The input files to this program were previously generated fotofiles and are assumed to exist on device .h1.

"/area1/cfos/cfosfin" was used to produce graphical displays on the monitor and a pricipal plane graph on the silentype of bi-directional reflectance patterns for finite cloud fields.

"/area1/cfos/cfosback" was originally used experimentally to adjust for the backround reflectance pattern but was not found to be useful.

"/area1/cfos/cfosoff" was used to analyze the effect of displacing a single cloud or a small field clouds from the center of the CFOS cloud field support.

"/area1/plot.pack/myplot", "/area1/plot.pack/myplot1", and "/area1/plot.pack/hp.text" were prototype plotting routines from which the cfos plotting routines were patterned.

"/area1/plot.pack/rectterp" and "/area1/plot.pack/recplot" are routines analagous to their cfosinterp and cfos.plot counterparts(described above) and were used originally to interpolate and plot the radiance patterns exiting modeled and measured finite cubic clouds.

References

Coakley, J. A., and P. Chy'lek, 1975: The two stream approximation in radiative transfer: Including the angle of the incident radiation. J. Atmos. Sci., 32, 409-418.

Davis, J. M., S. K. Cox, and T. B. McKee, 1983: Design and verification of a cloud field optical simulator. J. Appl. Meteor., 22, 947-958.

Deirmendjian, D., 1969: Electromagnetic Scattering on Spherical Poly-dispersions. Elsevier, 290 pp.

Stephens, G. L., 1978: Radiation profiles in extended water clouds. II: Parameterization schemes. J. Atmos. Sci., 35, 2123-2132.

List of Figure Legends

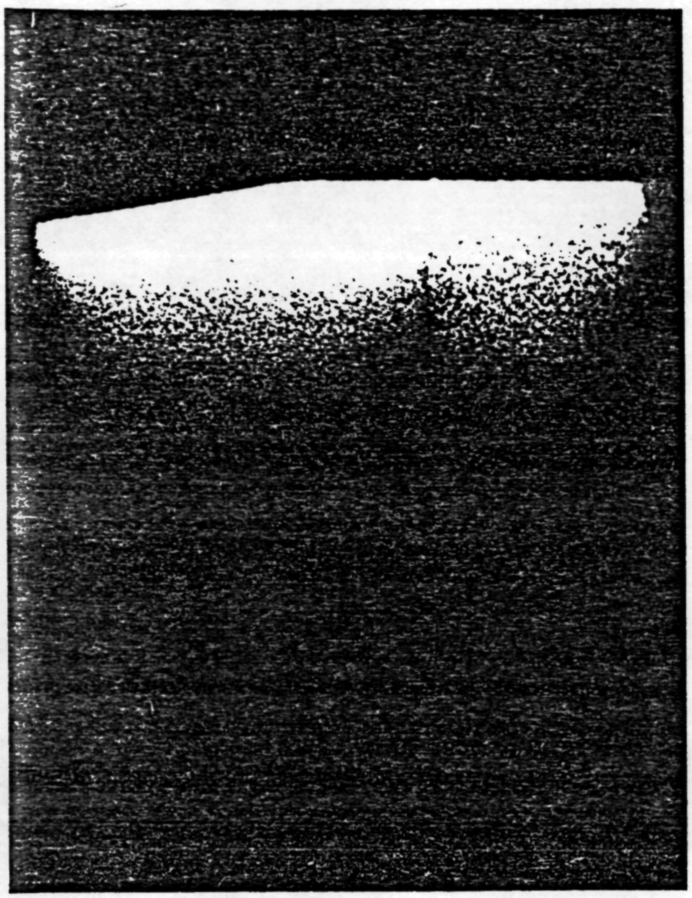


Figure 1

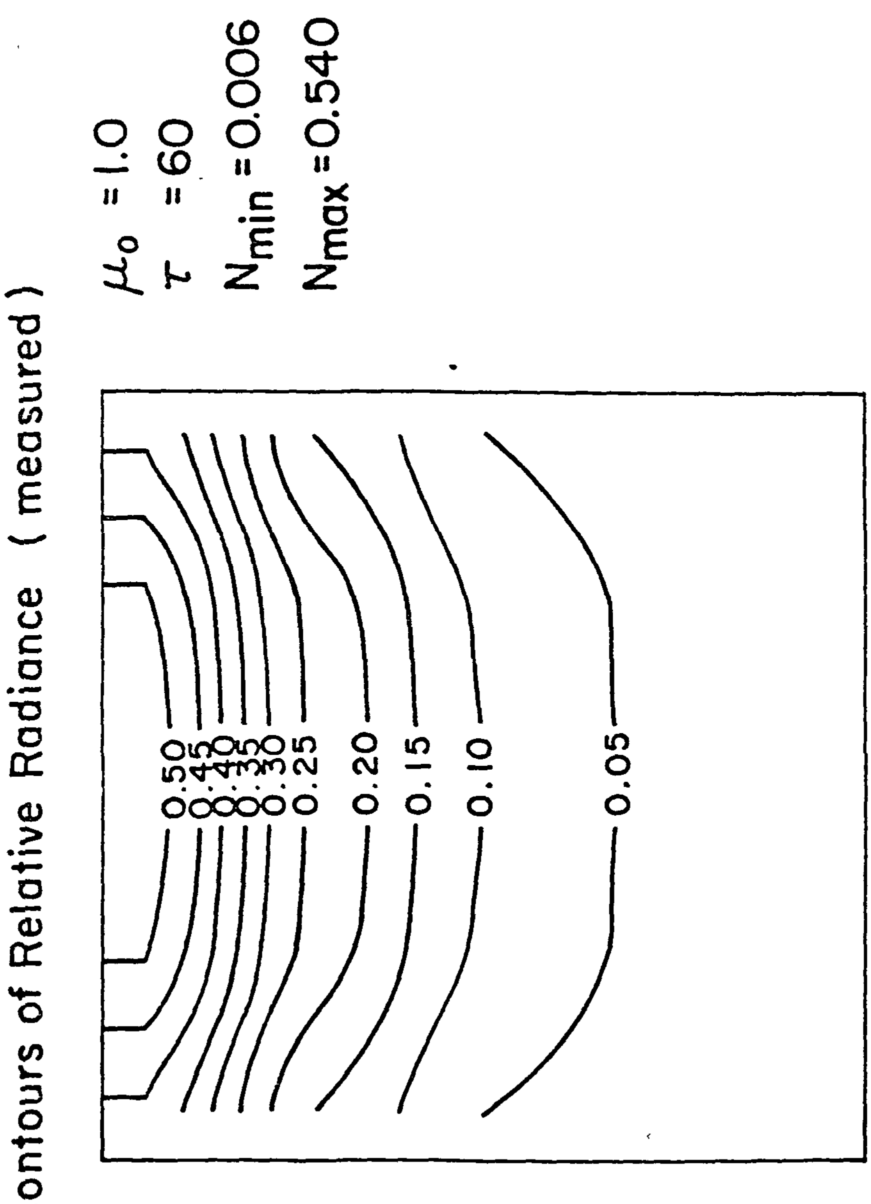
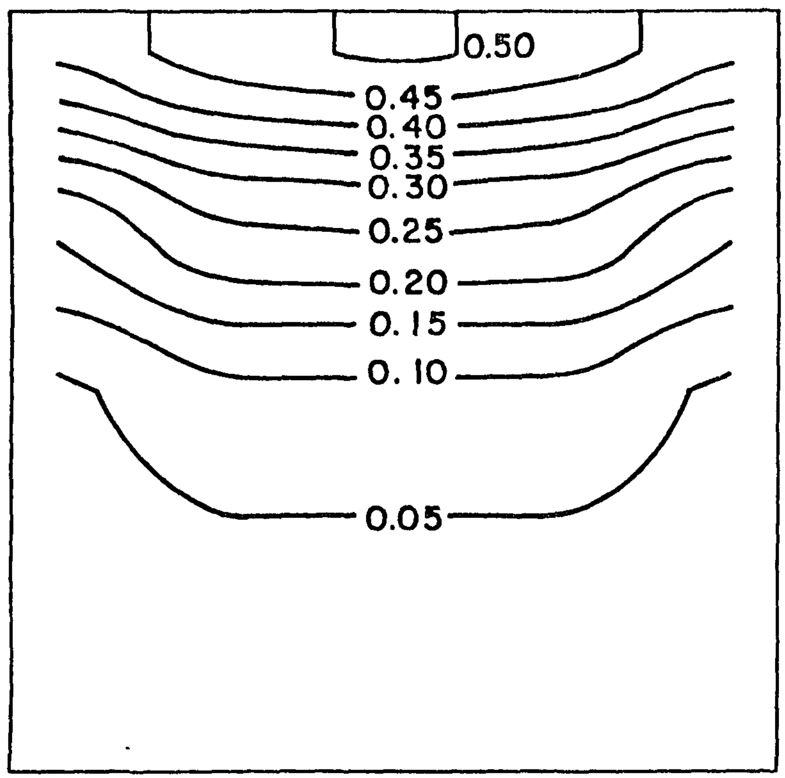

Contours of Relative Radiance (measured)
μ_o = 1.0
τ = 60
N_{min} = 0.006
N_{max} = 0.540
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05

Figure 2

Contours of Relative Radiance (calculated)



$\mu_0 = 1.0$
$\tau = 60$

$N_{min} = 0.020$
$N_{max} = 0.520$

Figure 3

5.0 Publications and Reports

McKee, T. B., J. M. Davis, and S. K. Cox. Design and Verification of a Cloud Field Optical Simulator. Published in Preprint of the Fourth Conference on Atmospheric Radiation, Toronto, Ontario, Canada, June 16-18, 1981.

Davis, J. M., S. K. Cox, and T. B. McKee, 1983: Design and verification of a cloud field optical simulator. J. Appl. Meteor., 22, 947-958.

Davis, J. M., S. K. Cox, and T. B. McKee. The role of finite clouds in scenes scharacterized by forward scattering bi-directional reflectances. International Radiation Symposium '84, August 21-29, 1984.

Davis, J. M. and S. K. Cox, 1986: Additional confirmation of the validity of laboratory simulation of cloud radiances. Accepted for publication in J. Climate and Appl. Meteor., February, 1986.

6.0. Statement on Inventions

There were no patentable inventions made during the performance of this work.

APPENDIX

Data Reduction and Analysis

Programs for the Cloud Field Optical Simulator

```
10    REM PROGRAM CFOS
20    PRINT"          CFOS CALIBRATION PROGRAM"
30    DIM A$(15)
40    DIM VALUE(500,20)
57    DIM DC(19)
70    DIM SLOP(15),OFFS(15),SENS(15)
75    DATA -633.57,66,195,-357,-240,-52,-59,21,-1,-84, -221,-192,-182,307
80    DATA 1.3758,0.811,0.839,0.694,1.486,1.049,1.149,0.78,.85,0.89,1.05,1.13,1
                                       .215,1.041,0.597
100    FOR K=1 TO 15
110      READ OFFS(K)
120      NEXT K
130    FOR K=1 TO 15
140      READ SLOP(K)
155      NEXT K
190    DTRD=3.14159/180.
250    OPEN#1 AS INPUT,".D2/D.091784.1247"
251    T$="TEST.DARK"
260    B$=""
280    INPUT#1,1;B$
370    NS=VAL(B$)
380    PRINT NS
400    FOR K=1 TO NS
410      B$=""
420      INPUT#1,K+1;B$
430      POS1=1
435      FOR J=1 TO 20
440        SPACE=POS1
450        POS2=INSTR(B$," ",SPACE)
460        NOC=POS2-POS1
470        VALUE(K,J)=VAL(MID$(B$,POS1,NOC))
480        POS1=POS2+1
490        PRINT VALUE(K,J)
500        NEXT J
510      NEXT K
520    FOR K=1 TO NS
530      FOR J=1 TO 15
540        SENS(J)=SENS(J)+(VAL(K,J)*SLOP(J)+OFFS(J))/NS
550        NEXT J
560      NEXT K
570    FOR K=1 TO 15
580      SENS(J)=SENS(J)/SENS(8)
590      NEXT K
600    OPEN#4 AS OUTPUT,".SILENTYPE"
610    OUTPUT#4
620    FOR K=1 TO 15
630      PRINT SENS(K)
640      NEXT K
650    END
```

```
10    REM PROGRAM CFOS
20    PRINT"         CFOS DARK CURRENT UPDATE PROGRAM"
30    DIM A$(15),VALUE(100,20)
40    DIM SLOP(15),OFFS(15)
50    PRINT"INPUT FILE NAME OF DARK CURRENT UPDATE RUN"
60    INPUT D$
250    OPEN#1 AS INPUT,"/AREA1/CFOS.CAL/COEFF"
260    FOR J=1 TO 15
270      READ#1,J;SLOP(J),OFFS(J)
280      NEXT J
290    OPEN#2 AS INPUT,".D2/"+D$
300    B$=""
310    INPUT#2,1;NS
320    NS=NS-2
380    PRINT NS
400    FOR K=1 TO NS
410      B$=""
420      INPUT#2,K+1;B$
430      POS1=1
435      FOR J=1 TO 20
440        SPACE=POS1
450        POS2=INSTR(B$," ",SPACE)
460        NOC=POS2-POS1
470        VALUE(K,J)=VAL(MID$(B$,POS1,NOC))
480        POS1=POS2+1
490        PRINT VALUE(K,J)
500        NEXT J
510      NEXT K
520    FOR J=1 TO 15
530      DIFF=0
540      FOR K=1 TO NS
550        DIFF=DIFF+(VALUE(K,16)*SLOP(J)+OFFS(J)-VALUE(K,J))/NS
560        NEXT K
570      OFFS(J)=OFFS(J)-DIFF
575      PRINT DIFF
580      NEXT J
600    OPEN#5 AS OUTPUT,"/AREA1/CFOS.CAL/ADJUST"
610    FOR J=1 TO 15
620      WRITE#5,J;OFFS(J)
630      NEXT J
640    CLOSE
650    END
```

```
10    REM PROGRAM CFOS
20    PRINT"          CFOS DARK CURRECT OFFSET PROGRAM"
30    DIM A$(15)
40    DIM VALUE(650,20)
50    DIM SLOP(15),OFFS(15)
100    PRINT"INPUT THE NAME OF THE DATA INPUT FILE"
110    INPUT D$
120    DTRD=3.14159/180.
150    OPEN#1 AS INPUT,"/.D2/"+D$
160    B$=""
180    INPUT#1,1;B$
190    DTRD=3.14159/180.
270    NS=VAL(B$)
280    PRINT NS
300    FOR K=1 TO NS
310      B$=""
320      INPUT#1,K+1;B$
330      POS1=1
335      FOR J=1 TO 20
340        SPACE=POS1
350        POS2=INSTR(B$," ",SPACE)
360        NOC=POS2-POS1
370        VALUE(K,J)=VAL(MID$(B$,POS1,NOC))
380        POS1=POS2+1
390        PRINT VALUE(K,J)
400        NEXT J
410      NEXT K
415    FOR J=1 TO 15
420      N=0
430      SX=0
440      SY=0
450      SXX=0
460      SYY=0
470      SXY=0
480      FOR K=1 TO NS
490        N=N+1
500        X=VALUE(K,16)
510        Y=VALUE(K,J)
520        SXY=SXY+X*Y
530        SX=SX+X
540        SY=SY+Y
550        SXX=SXX+X*X
560        SYY=SYY+Y*Y
570        NEXT K
580      BETA1=(N*SXY-SX*SY)/(N*SXX-SX*SX)
610      BETA0=SY/N-BETA1*SX/N
620      PRINT BETA1,BETA0
630      R=(N*SXY-SX*SY)/SQR((N*SXX-SX*SX)*(N*SYY-SY*SY))
640      PRINT R
650      SLOP(J)=BETA1
660      OFFS(J)=BETA0
670      NEXT J
680    OPEN#3 AS OUTPUT,"/AREA1/CFOS.CAL/COEFF"
690    FOR J=1 TO 15
700      WRITE#3,J;SLOP(J),OFFS(J)
710      NEXT J
720    CLOSE
730    END
```

```
10   REM PROGRAM CFOS
20   PRINT"          CFOS CALIBRATON PROGRAM"
30   DIM A$(15),VALUE(100,20)
40   DIM SLOP(15),OFFS(15),COFFS(15),SENS(15)
50   PRINT"INPUT FILE NAME OF DARK CURRENT CALIBRATON RUN"
60   INPUT D$
150   OPEN#1 AS INPUT,"/AREA1/CFOS.CAL/COEFF"
160   FOR J=1 TO 15
170     READ#1,J;SLOP(J),OFFS(J)
180     NEXT J
200   OPEN#2 AS INPUT,"/AREA1/CFOS.CAL/ADJUST"
210   FOR J=1 TO 15
220     READ#2,J;COFFS(J)
230     NEXT J
240   PRINT" CURRENT DARK CURRENT OFFSET UPDATE VALUES"
250   FOR J=1 TO 15
260     PRINT COFFS(J)
270     NEXT J
280   CLOSE#2
290   OPEN#2 AS INPUT,".D2/"+D$
300   B$=""
310   INPUT#2,1;NS
320   NS=NS-2
380   PRINT NS
400   FOR K=1 TO NS
410     B$=""
420     INPUT#2,K+1;B$
430     POS1=1
435     FOR J=1 TO 20
440       SPACE=POS1
450       POS2=INSTR(B$," ",SPACE)
460       NOC=POS2-POS1
470       VALUE(K,J)=VAL(MID$(B$,POS1,NOC))
480       POS1=POS2+1
490       PRINT VALUE(K,J)
500       NEXT J
510     NEXT K
520   FOR J=1 TO 15
530     SENS(J)=0.
540     FOR K=1 TO NS
550       SENS(J)=SENS(J)+(VALUE(K,J)-VALUE(K,16)*SLOP(J)-COFFS(J))/NS
560       NEXT K
570     PRINT SENS(J)
575     NEXT J
580   FOR J=1 TO 7
590     SENS(J)=SENS(J)/SENS(8)
600     SENS(J+8)=SENS(J+8)/SENS(8)
610     NEXT J
620   SENS(8)=1
625   OPEN#5 AS OUTPUT,"/AREA1/CFOS.CAL/SENSIV"
630   FOR J=1 TO 15
640     WRITE#5,J;SENS(J)
650     NEXT J
660   CLOSE
670   OPEN#1 AS OUTPUT,".SILENTYPE"
680   FOR J=1 TO 15
690     PRINT#1SENS(J)
700     NEXT J
710   CLOSE
720   END
```

```
10    PRINT"ENTER THE TOTAL CLOUD COVER"
20    INPUT ST
30    PRINT"ENTER THE CHI PARAMETER"
40    INPUT CHI
50    PRINT"ENTER THE DIAMETER LIMITS D1 AND D2"
60    INPUT D1,D2
70    PRINT"ENTER THE EXPONENT ALPHA"
80    INPUT ALPHA
100    D1A=D1*ALPHA
110    D2A=D2*ALPHA
120    A=-(ST/(2*CHI)*(EXP(-D2A)*(D2A^2+2*D2A+2)-EXP(-D1A)*(D1A^2+2*D1A+2)))
130    PRINT D1,D2,A
140    END
```

```
10    REM CLOUD DISTRIBUTION PROGRAM A LA HOZUMI
20    DIM D(50),N(50),A(50),V(50)
25    OPEN#1 AS OUTPUT,".PRINTER"
110    FOR M=5 TO 95 STEP 10
120      A=124*EXP(-4.7*M*.01)
130      B=4.5*EXP(-3.5*M*.01)
135      ASUM=0
140      FOR I=1 TO 20
150        D1=I*0.50-0.50
160        D2=I*0.50
170        N(I)=A/B*(EXP(-B*D1)-EXP(-B*D2))*40
175        DB1=D1*B
176        DB2=D2*B
180        A(I)=3.14159*A/(4*B^3)*(EXP(-DB1)*(DB1*DB1+2*DB1+2)-EXP(-DB2)*(DB2
           B2+2*DB2+2))/100
190        ASUM=ASUM+A(I)
280        PRINT#1M,D1,D2,N(I),A(I)
290        NEXT I
295      PRINT#1ASUM:PRINT#1:PRINT#1
300      NEXT M
310    END
```

```
1500    OPEN#2,".GRAFIX"
1510    INVOKE".D1/BGRAF.INV"
1520    PERFORM INITGRAFIX
1530    PERFORM GRAFIXMODE(%1,%1)
1540    PERFORM FILLPORT
1550    PERFORM GLOAD.".H1/FOAM.60DEGGRAF"
1560    PERFORM GRAFIXON
1570    PERFORM GRAFIXMODE(%1,%2)
1580    PERFORM GLOAD.".H1/FOAM.30DEGGRAF"
1590    PERFORM GRAFIXON
1600    PERFORM GRAFIXMODE(%1,%1)
1605    PERFORM INITGRAFIX
1610    PERFORM GLOAD.".H1/FOAM.0DEGGRAF"
1620    PERFORM GRAFIXON
1625    FOR K=1 TO 1000:PERFORM GRAFIXON:NEXT K
1630    PERFORM GRAFIXMODE(%1,%2)
1640    PERFORM GLOAD.".H1/FOAM.60DEGPLOT"
1650    PERFORM GRAFIXON
1660    PERFORM GRAFIXMODE(%1,%2)
1670    PERFORM GLOAD.".H1/FOAM.30DEGPLOT"
1680    PERFORM GRAFIXON
1690    PERFORM GRAFIXMODE(%1,%1)
1700    PERFORM GLOAD.".H1/FOAM.0DEGPLOT"
1710    PERFORM GRAFIXON
1720    FOR K=1 TO 1000:PERFORM GRAFIXON:NEXT K
1730    GOTO 1540
1740    END
```

```
10    REM PROGRAM CFOS
20    PRINT"              CFOS DATA REDUCTION PROGRAM"
30    PRINT:PRINT:PRINT"        THE DIODE SENSITIVITIES USED IN THIS PROGRAM ARE"
40    DIM DIANG(15),SENS(15),DC(19),NADANG(500),RAZANG(500),VOLT(500)
50    DIM DIO(19),ANG(3),NR(36),NRN(36),MEAS(500,2)
55    DIM A$(15)
60    DATA 20,30,40,50,60,70,80,90,100,110,120,130,140,150,160
70    DATA 1.,1.06,.88,.94,.84,.95,1.18,.79,.94,1.03,.86,.98,.98,1.06,1.04
75    DATA 1098,125,477,852,427,573,314,338,193,652,185,503,73,220,287,25,3

80    FOR I=1 TO 15
90     READ DIANG(I)
100      NEXT I
110    FOR I=1 TO 15
120      READ SENS(I)
130      NEXT I
140    PRINT"         DIODE NUMBER      DIODE ANGLE       DIODE SENSITIVITY"
143    NP=8
150    FOR I=1 TO 15
160      PRINT USING 170;I,DIANG(I),SENS(I)
170      IMAGE 10X,2#,14X,3#,16X,1#.2#
180      NEXT I
190    DTRD=3.14159/180.
200    REM DEFINE ARCOS FUNCTION
210    DEF FN ACOS(X)=ATN(SQR(1-X*X)/X)
220    L=0
225    AVZEN=0
250    OPEN#1 AS INPUT,".D2/BACKZ60"
251    T$="FOAM"
255    FOR LL=1 TO 2
260      B$=""
270      FOR I=1 TO 15
280        GET#1;A$(I)
290        IF A$(I)=CHR$(13) THEN 280
300        IF A$(I)=CHR$(10) THEN 340
310        IF A$(I)=CHR$(32) THEN 340
320        NEXT I
340      FOR K=1 TO I
350        B$=B$+A$(K)
360        NEXT K
370      NS=VAL(B$)
380      PRINT NS
400      FOR K=1 TO NS
410        B$=""
420        FOR J=1 TO 18
430          B$=""
440          FOR I=1 TO 15
450            GET#1;A$(I)
460            IF A$(I)=CHR$(13) THEN 450
470            IF A$(I)=CHR$(32) THEN 500
480            IF A$(I)=CHR$(10) THEN 500
490            NEXT I
500          FOR M=1 TO I
510            B$=B$+A$(M)
520            NEXT M
530          DIO(J)=VAL(B$)
535          DIO(J)=(DIO(J)-DC(J))/1000.
540          IF K=1 THEN REF=DIO(18)
545          NEXT J
550        FOR J=1 TO 3
560          B$=""
```

```
580            GET#1:A$(I)
590            IF A$(I)=CHR$(13) THEN 580
600            IF A$(I)=CHR$(32) THEN 630
610            IF A$(I)=CHR$(10) THEN 630
620            NEXT I
630          FOR M=1 TO I
640            B$=B$+A$(M)
650            NEXT M
660          ANG(J)=VAL(B$)
665          NEXT J
670        FOR I=1 TO 15
680          ALPHA=ANG(2)-ANG(1)
690          X=SIN(DIANG(I)*DTRD)*COS(ALPHA*DTRD)
695          NAD= FN ACOS(X)
700          L=L+1
705          NADANG(L)=NAD
710          COMP=(DIANG(I)-90)*DTRD
720          DEN=(SIN(NADANG(L))*SIN(ALPHA*DTRD))
730          IF DEN=0. THEN 750
740          X=(COS(COMP)-COS(NADANG(L))*COS(ALPHA*DTRD))/DEN
750          IF DEN=0. THEN X=.00001
760          IF DIANG(I)<90. THEN X=-X
770          IF NADANG(L)>.000001 THEN 775:ELSE X=1.0
775          IF X>1. THEN X=1.
776          IF X<-1. THEN X=-1.
780          RAZANG(L)= FN ACOS(X)
790          IF ALPHA<0. THEN RAZANG(L)=RAZANG(L)+180*DTRD
800          IF RAZANG(L)<0. THEN RAZANG(L)=360.*DTRD+RAZANG(L)
811          MEAS(L,LL)=DIO(I)/SENS(I)*REF/DIO(18)
812          VOLT(L)=MEAS(L,2)-MEAS(L,1)
815          PRINT L,NADANG(L)/DTRD,RAZANG(L)/DTRD,VOLT(L)
820          NEXT I
830        PRINT:PRINT
835        AVZEN=AVZEN+ANG(1)/NS
840        NEXT K
841      CLOSE#1
842      IF LL=2 THEN 850
843      OPEN#1 AS INPUT,".D2/FIN60.Z60CUBE"
844      L=0:AVZEN=0.
845      NEXT LL
850    NMEAS=L
860    GOSUB 1200
900    REM SUBROUTINE INTERP
910    DELTA=30*DTRD
920    SUMF=0.:SUMW=0.
930    FOR I=1 TO NMEAS
940      Z=NADANG(I):A=RAZANG(I)
950      IF ABS(Z-ZINT)>DELTA THEN 1040
960      IF ABS(A-AINT)>DELTA THEN 1040
970      THETA=COS(Z)*COS(ZINT)+SIN(Z)*SIN(ZINT)*COS(A-AINT)
980      IF THETA>0. THEN 1000:ELSE 1000
990      THETA= FN ACOS(THETA)
1000      GOSUB 1100
1010      SUMW=SUMW+W
1020      SUMF=SUMF+W*VOLT(I)
1040      NEXT I
1100    REM SUBROUTINE WEIGHT
1120    WGHT=1.E+06
1130    IF THETA<.0001 THEN 1140:ELSE 1150
1140    W=WGHT:RETURN
1150    WGHT=DELTA/THETA
1160    W=WGHT:RETURN
1200    REM SUBROUTINE MAX---------MIN
1210    MAX=0
1220    MIN=100
```

```
1237     IF NADANG(I) 60*DTRD THEN 1260
1240     IF VOLT(I) MAX THEN MAX=VOLT(I)
1250     IF VOLT(I) MIN THEN MIN=VOLT(I)
1260     NEXT I
1265   PRINT MIN,MAX
1300   REM SUBROUTINE INTEGRATE RADIANCES
1310   SUM=0.:TOTNUM=0
1315   FOR J=1 TO 36
1320     NR(J)=0:NRN(J)=0
1325     NEXT J
1330   NINC=90*DTRD/36.
1335   FOR I=1 TO NMEAS
1340     J=INT(NADANG(I)/NINC)+1
1345     NR(J)=NR(J)+VOLT(I)
1350     NRN(J)=NRN(J)+1
1355     NEXT I
1360   FOR I=1 TO 36
1365     IF NRN(I)=0 THEN 1395
1370     ANG=(2*I-1)/2*NINC
1375     SUM=SUM+NR(I)/NRN(I)*COS(ANG)*SIN(ANG)*NINC
1380     TOTNUM=TOTNUM+NRN(I)
1390     NINC=90.*DTRD/36.:GOTO 1400
1395     NINC=NINC+NINC
1400     NEXT I
1410   FLUXUP=3.14159*2*SUM
1420   PRINT FLUXUP
1430   STOP
1435   OPEN#5 AS OUTPUT,".SILENTYPE"
1436   OUTPUT#5
1437   FOR K=8 TO 375 STEP 15
1438     VOLT(K)=(MEAS(K,2)-MEAS(K,1)*(1-F*(1+TAN(NADANG(K)))))/F/(1+TAN(NADAN
         G(K)))
1439     PRINT MEAS(K,1),MEAS(K,2),VOLT(K),NADANG(K)/DTRD,(1-COS(NADANG(K)))
1440     NEXT K
1441   PRINT:PRINT
1445   END
1500   OPEN#2,".GRAFIX"
1510   INVOKE".D1/BGRAF.INV"
1520   PERFORM INITGRAFIX
1530   PERFORM GRAFIXMODE(%1,%1)
1540   PERFORM FILLPORT
1550   RAD=60
1560   GOSUB 1880
1570   PERFORM PENCOLOR(%15)
1580   NPOINTS=72
1590   PERFORM GRAFIXON
1600   FOR K=1 TO 3
1610     X1=K*30*DTRD
1620     R=RAD*SIN(X1)
1630     PERFORM MOVETO(%(R*140/192*2+140),%96)
1640     FOR I=1 TO 365 STEP 5
1650       X=R*COS(I*DTRD)*140/192+70:X=2*X
1660       Y=R*SIN(I*DTRD)*192/140+96
1670       PERFORM LINETO(%X,%Y)
1680       NEXT I
1690     NEXT K
1700   ANGINC=30*DTRD
1710   PERFORM MOVETO(%140,%96)
1720   FOR I=1 TO 12
1730     ANG=ANGINC*I
1740     X=RAD*COS(ANG)*140/192+70:X=2*X
1750     Y=RAD*SIN(ANG)*192/140+96
1760     PERFORM LINETO(%X,%Y)
1770     PERFORM MOVETO(%140,%96)
1780     NEXT I
```

```
1790    PERFORM MOVETO(%230,%98)
1795    PRINT#2;"180"
1800    PERFORM MOVETO(%10,%188)
1802    PRINT#2 USING 1804;AVZEN
1804    IMAGE "Z=",##.
1806    PERFORM MOVETO(%180,%188)
1808    PRINT#2 USING 1810;FLUXUP
1810    IMAGE "F=",#.##
1812    PERFORM MOVETO(%10,%8)
1814    PRINT#2 USING 1816;MIN
1816    IMAGE "MIN=",#.#
1818    PERFORM MOVETO(%180,%8)
1820    PRINT#2 USING 1822;MAX
1822    IMAGE "MAX=",#.#
1825    PERFORM MOVETO(%126,%188)
1830    PRINT#2;"90"
1840    PERFORM MOVETO(%30,%98)
1850    PRINT#2;"0"
1860    PERFORM MOVETO(%120,%8)
1870    PRINT#2;"270"
1875    GOTO 3000
1880    PERFORM GRAFIXON
1885    PERFORM INITGRAFIX
1890    PERFORM XFROPTION(%0)
1895    COLINC=(MAX-MIN)/10.
1900    FOR K=1 TO NMEAS
1905      IF NADANG(K)>60*DTRD THEN 2025
1910      R=-RAD*SIN(NADANG(K))
1920      X=R*COS(RAZANG(K))*140/192+70:X=X*2
1925      XS=3*COS(NADANG(K))+1:XS=XS*2
1930      Y=R*SIN(RAZANG(K))*192/140+96
1935      YS=6*COS(NADANG(K))+3
1940      IF COLINC=0. THEN COLOR=10:ELSE COLOR=(VOLT(K)-MIN)/COLINC
1950      COLOR=INT(COLOR)
1960      PERFORM FILLCOLOR(%COLOR)
1970      R=X+XS
1980      L=X-XS
1990      T=Y+YS
2000      B=Y-YS
2010      PERFORM VIEWPORT(%L,%R,%B,%T)
2020      PERFORM FILLPORT
2025      NEXT K
2030    PERFORM INITGRAFIX
2040    RETURN
2050    END
3000    REM SUBROUTINE PRINCIPAL PLANE RADIANCE GRAPH
3010    REM FIND THE MAX AND MIN VOLT IN THE PRINCIPAL PLANE
3020    MAX=0.:MIN=100.
3030    FOR I=8 TO(NS-1)*15+8 STEP 15
3040      IF VOLT(I)>MAX THEN MAX=VOLT(I)
3050      IF VOLT(I)<MIN THEN MIN=VOLT(I)
3060      NEXT I
3070    PRINT MAX,MIN
3100    REM SET XSCALE AND XINC
3110    XRANGE=NADANG(8)+NADANG((NS-1)*15+8)
3120    XRANGE=XRANGE/DTRD
3130    XRANGE=INT((XRANGE/2+10)/10)
3140    XINC=40
3150    REM SET YSCALE AND YINC
3155    MID=INT((NS+1)/2)
3160    FOR I=8 TO(NS-1)*15+8 STEP 15
3170      IF NADANG(I)<8*DTRD THEN NORM=VOLT(I)
3180      NEXT I
3185    J=0
3190    FOR I=8 TO(NS-1)*15+8 STEP 15
```

```
3210      NR(J)=VOLT(I)/NORM
3220      NEXT I
3230    MAX=MAX/NORM:MIN=MIN/NORM
3240    REM SET YRANGE AND YINC
3250    YINC=15
3260    YRANGE=MAX-MIN
3265    PERFORM GRAFIXMODE(%2,%2)
3270    PERFORM GRAFIXON
3275    PERFORM FILLPORT
3280    PERFORM MOVETO(%280,%30)
3290    PERFORM MOVEREL(%-3,%3)
3310    PERFORM MOVETO(%280,%30)
3320    PERFORM MOVEREL(%0,%-10)
3330    ANG=0
3340    PRINT#2ANG
3350    FOR K=-1 TO 1 STEP 2
3360      FOR I=1 TO XRANGE
3370        XR=280+K*I*40:YR=30
3380        PERFORM MOVETO(%XR-1,%YR+3)
3400        PRINT#2;"I"
3410        PERFORM MOVETO(%XR,%YR)
3420        PERFORM MOVEREL(%-3,%-10)
3430        ANG=I*10
3440        PRINT#2:ANG
3450        NEXT I
3470      NEXT K
3490    LL=280-XRANGE*40
3500    LR=280+XRANGE*40
3510    PERFORM MOVETO(%LL,%30)
3520    PERFORM LINETO(%LR,%30)
3530    PERFORM MOVETO(%280,%30)
3540    FOR J=1 TO 3
3550      XR=280:YR=30+J*50
3560      PERFORM MOVETO(%XR-3,%YR+2)
3570      PRINT#2;"-"
3575      PERFORM MOVETO(%XR,%YR)
3580      PERFORM MOVEREL(%10,%0)
3590      PRINT#2;J
3600      NEXT J
3610    PERFORM MOVETO(%XR,%YR)
3620    PERFORM LINETO(%280,%30)
3622    PERFORM MOVETO(%280,%30)
3625    J=0:L=0
3630    FOR I=8 TO(NS-1)*15+8 STEP 15
3635      IF VOLT(I)=0 THEN 3710
3640      K=1
3645      J=J+1
3650      IF RAZANG(I)>5*DTRD THEN K=-1
3660      X=280+K*NADANG(I)/DTRD*4
3670      Y=NR(J)*50+30
3675      PRINT NR(J),NADANG(I)/DTRD,RAZANG(I)/DTRD,X,Y
3680      X=INT(X)
3690      Y=INT(Y)
3695      IF ABS(X-509)<3 THEN 3710
3700      IF L=0 THEN PERFORM MOVETO(%X,%Y):ELSE PERFORM LINETO(%X,%Y)
3701      L=L+1
3705      PERFORM DOTAT(%X,%Y)
3710      NEXT I
3720    PERFORM MOVETO(%100,%180)
3730    PRINT#2 USING 3740;T$
3740    IMAGE "RELATIVE RADIANCES                    IN THE PRINCIPAL PLANE FOR ",1
        0A
3750    PERFORM MOVETO(%40,%170)
3760    PRINT#2 USING 3770;AVZEN
3770    IMAGE "SOLAR ZENITH ANGLE= ",##.,"DEG"
```

```
3790  PRINT#2"ANTI-SOLAR SIDE"
3800  PERFORM MOVETO(%400,%10)
3810  PRINT#2"SOLAR SIDE"
3820  PERFORM MOVETO(%240,%10)
3830  PRINT#2"NADIR ANGLE"
3840  END
11438  VOLT(K)=(MEAS(K,2)-MEAS(K,1)*(1-F*(1+TAN(NADANG(K)))))/(F*(1+TAN(NADAN
       G(K))))
```

```
10    REM PROGRAM CFOS
20    PRINT"          CFOS CALIBRATION PROGRAM"
40    DIM DIANG(50)
45    DIM DARK(500)
50    DIM DIO(40),ANG(3),NR(36),NRN(36)
55    DIM A$(15)
56    DIM VALUE(500,20)
57    DIM DC(19)
58    DIM SENS(10,16)
60    DATA 20,30,40,50,60,70,80,90,100,110,120,130,140,150,160
70    DATA 1.00,.91,1.07,.98,.99,.96,1.2,1.09,1.03,1.23,.89,1.02,1.10,.88,.96
75    DIM BDR(50)
190    DTRD=3.14159/180.
200    REM DEFINE ARCOS FUNCTION
210    DEF FN ACOS(X)=ATN(SQR(1-X*X)/X)
220    L=0
225    AVZEN=0
250    OPEN#1 AS INPUT,"/AREA1/CFOS.BACK/D.071684.1244"
251    T$="TEST.DARK"
260    B$=""
280    INPUT#1,1;B$
370    NS=VAL(B$)
375    NS=NS-2
380    PRINT NS
400    FOR K=1 TO NS
410      B$=""
420      INPUT#1,K+1;B$
430      POS1=1
435      FOR J=1 TO 20
440        SPACE=POS1
450        POS2=INSTR(B$," ",SPACE)
460        NOC=POS2-POS1
470        VALUE(K,J)=VAL(MID$(B$,POS1,NOC))
480        POS1=POS2+1
490        PRINT VALUE(K,J)
500        NEXT J
510      NEXT K
520    REF=VALUE(1,17)
530    NS2=NS/2
540    FOR J=1 TO NS
550      VALUE(J,8)=VALUE(J,8)*REF/VALUE(J,17)
560      DARK(J)=VALUE(J,9)*0.761652+163.5
580      NEXT J
600    F=.01
610    FOR J=1 TO NS
620      DIANG(J)=VALUE(J,19)
630      IF DIANG(J)<0. THEN DIANG(J)=360.-DIANG(J)
640      PRINT DIANG(J)
650      NEXT J
660    FOR J=1 TO NS
670      DIANG(J)=((DIANG(J)+VALUE(J,18))-360)*DTRD
680      DIANG(J)=ABS(DIANG(J))
685      SINE=ABS(SIN(DIANG(J)))
686      COSE=ABS(COS(DIANG(J)))
690      DIO(J)=(VALUE(J,8)-DARK(J))
700      NEXT J
701    DIO(7)=(DIO(8)+DIO(6))/2.
710    FOR J=1 TO NS
720      PRINT DIO(J)/DIO(7),DIANG(J)/DTRD
730      NEXT J
740    SUM=0.
```

```
[illegible] FOR K=1 TO NS
755    SINE=ABS(SIN(DIANG(K)))
756    COSE=ABS(COS(DIANG(K)))
760    SUM=SUM+DIO(K)*COSE*SINE*10*DTRD*1*3.14159
780    NEXT K
790  SOLANG=(1.0-COS(DIANG(1)))*2.0*3.14159
795  OPEN#2 AS OUTPUT,".SILENTYPE"
796  OUTPUT#2
800  FOR K=1 TO NS
810    BDR(K)=DIO(K)*3.14159/SUM
820    PRINT BDR(K),COS(DIANG(K))
830    NEXT K
840  END
850  NMEAS=L
900  FOR K=1 TO 5
910    FOR J=1 TO 18
920      DC(J)=DC(J)+VALUE(K,J)/5
930      NEXT J
940    NEXT K
950  FOR K=1 TO 19
960    PRINT DC(K)
970    NEXT K
1000  FOR K=6 TO NS
1010    J=(K-5)-15*INT((K-5)/15)
1020    IF J=0 THEN J=16
1030    I=INT((K-6)/15)+1
1040    REF=VALUE(5+I,1)
1042    SENS(I,J)=(VALUE(K,J)-DC(J))/REF*VALUE(I+5,18)/VALUE(K,18)
1050    PRINT I,J,K,VALUE(K,J),SENS(I,J)
1060    NEXT K
1100  END
1200  FOR I=1 TO 4:FOR J=2 TO 16:SENS(I,J)=SENS(I,J)/SENS(I,1):NEXT J:NEXT I
1210  FOR I=1 TO 5:FOR J=1 TO 16:PRINT SENS(I,J):NEXT J:NEXT I
1300  OPEN#3 AS OUTPUT,".SILENTYPE"
1310  OUTPUT#3
1320  FOR J=1 TO 16
1330    PRINT SENS(1,J),SENS(2,J),SENS(3,J),SENS(4,J),SENS(5,J)
1340    NEXT J
```

```
10    REM PROGRAM CFOS
20    PRINT"          CFOS CALIBRATION PROGRAM"
40    DIM DIANG(50)
45    DIM DARK(500)
50    DIM DIO(40),ANG(3),NR(36),NRN(36)
55    DIM A$(15)
56    DIM VALUE(500,20)
57    DIM DC(19)
58    DIM SENS(10,16)
60    DATA 20,30,40,50,60,70,80,90,100,110,120,130,140,150,160
70    DATA 1.00,.91,1.07,.98,.99,.96,1.2,1.09,1.03,1.23,.89,1.02,1.10,.88,.96
75    DIM BDR(50)
190    DTRD=3.14159/180.
200    REM DEFINE ARCOS FUNCTION
210    DEF FN ACOS(X)=ATN(SQR(1-X*X)/X)
220    L=0
225    AVZEN=0
250    OPEN#1 AS INPUT,"/AREA1/CFOS.OFF/D.071984.0826"
251    T$="TEST.DARK"
260    B$=""
280    INPUT#1,1;B$
370    NS=VAL(B$)
375    NS=NS-2
380    PRINT NS
400    FOR K=1 TO NS
410      B$=""
420      INPUT#1,K+1;B$
430      POS1=1
435      FOR J=1 TO 20
440        SPACE=POS1
450        POS2=INSTR(B$," ",SPACE)
460        NOC=POS2-POS1
470        VALUE(K,J)=VAL(MID$(B$,POS1,NOC))
480        POS1=POS2+1
490        PRINT VALUE(K,J)
500        NEXT J
510      NEXT K
520    REF=VALUE(1,17)
530    NS2=NS/2
540    FOR J=1 TO NS
550      VALUE(J,8)=VALUE(J,8)*REF/VALUE(J,17)
560      DARK(J)=VALUE(J,9)*0.871844+47.374
580      NEXT J
600    F=.01
610    FOR J=1 TO NS
620      DIANG(J)=VALUE(J,19)
630      IF DIANG(J)<0. THEN DIANG(J)=360.-DIANG(J)
640      PRINT DIANG(J)
650      NEXT J
660    FOR J=1 TO NS
670      DIANG(J)=((DIANG(J)+VALUE(J,18))-360)*DTRD
680      DIANG(J)=ABS(DIANG(J))
685      SINE=ABS(SIN(DIANG(J)))
686      COSE=ABS(COS(DIANG(J)))
690      DIO(J)=(VALUE(J,8)-DARK(J))
700      NEXT J
701    DIO(7)=(DIO(6)+DIO(8))/2.
710    FOR J=1 TO NS
720      PRINT DIO(J)/DIO(7),DIANG(J)/DTRD
730      NEXT J
740    SUM=0.
```

```
755    SINE=ABS(SIN(DIANG(K)))
756    COSE=ABS(COS(DIANG(K)))
760    SUM=SUM+DIO(K)*COSE*SINE*10*DTRD*1*3.14159
780    NEXT K
790   SOLANG=(1.0-COS(DIANG(1)))*2.0*3.14159
795   OPEN#2 AS OUTPUT,".SILENTYPE"
796   OUTPUT#2
800   FOR K=1 TO NS
810     BDR(K)=DIO(K)*3.14159/SUM
820     PRINT BDR(K),COS(DIANG(K))
830     NEXT K
840   END
850   NMEAS=L
900   FOR K=1 TO 5
910     FOR J=1 TO 18
920       DC(J)=DC(J)+VALUE(K,J)/5
930       NEXT J
940     NEXT K
950   FOR K=1 TO 19
960     PRINT DC(K)
970     NEXT K
1000   FOR K=6 TO NS
1010     J=(K-5)-15*INT((K-5)/15)
1020     IF J=0 THEN J=16
1030     I=INT((K-6)/15)+1
1040     REF=VALUE(5+I,1)
1042     SENS(I,J)=(VALUE(K,J)-DC(J))/REF*VALUE(I+5,18)/VALUE(K,18)
1050     PRINT I,J,K,VALUE(K,J),SENS(I,J)
1060     NEXT K
1100   END
1200   FOR I=1 TO 4:FOR J=2 TO 16:SENS(I,J)=SENS(I,J)/SENS(I,1):NEXT J:NEXT I
1210   FOR I=1 TO 5:FOR J=1 TO 16:PRINT SENS(I,J):NEXT J:NEXT I
1300   OPEN#3 AS OUTPUT,".SILENTYPE"
1310   OUTPUT#3
1320   FOR J=1 TO 16
1330     PRINT SENS(1,J),SENS(2,J),SENS(3,J),SENS(4,J),SENS(5,J)
1340     NEXT J
```

```
10    REM PROGRAM CFOS
20    PRINT"          CFOS BI-DIRECTIONAL REFLECTANCE PROGRAM    "
40    DIM DIANG(15),SENS(15),COFFS(15),NR(50),NRN(50)
45    DIM DARK(20,15),DIO(20,17),BDR(20,15),OFFS(15),SLOP(15)
50    DIM ANG(20,3),NAD(20,15),AZI(20,15)
60    DATA 20,30,40,50,60,70,80,90,100,110,120,130,140,150,160
80    FOR I=1 TO 15
90      READ DIANG(I)
100       NEXT I
110    OPEN#1 AS INPUT,"/AREA1/CFOS.CAL/COEFF"
120    OPEN#2 AS INPUT,"/AREA1/CFOS.CAL/ADJUST"
130    OPEN#3 AS INPUT,"/AREA1/CFOS.CAL/SENSIV"
140    FOR J=1 TO 15
150      READ#1,J;SLOP(J),OFFS(J)
160      READ#2,J;COFFS(J)
170      READ#3,J:SENS(J)
180      OFFS(J)=COFFS(J)
190      NEXT J
200    CLOSE
205    DTRD=3.14159/180.
210    REM DEFINE ARCOS FUNCTION
215    DEF FN ACOS(X)=ATN(SQR(1-X*X)/X)
220    PRINT" INPUT DATA FILE NAME "
225    INPUT D$
250    OPEN#1 AS INPUT,"/AREA1/CFOS.BACK/"+D$
260    B$=""
280    INPUT#1,1;B$
370    NS=VAL(B$)
375    NS=NS-2
380    PRINT NS
400    FOR K=1 TO NS
410      B$=""
420      INPUT#1,K+1;B$
430      POS1=1
435      FOR J=1 TO 17
440        SPACE=POS1
445        POS2=INSTR(B$," ",SPACE)
450        NOC=POS2-POS1
455        DIO(K,J)=VAL(MID$(B$,POS1,NOC))
460        POS1=POS2+1
465        PRINT DIO(K,J)
470        NEXT J
475      FOR J=18 TO 20
480        SPACE=POS1
485        POS2=INSTR(B$," ",SPACE)
490        NOC=POS2-POS1
495        ANG(K,J-17)=VAL(MID$(B$,POS1,NOC))
500        POS1=POS2+1
505        PRINT ANG(K,J-17)
510        NEXT J
515      NEXT K
520    REF=DIO(1,17)
530    NS2=NS/2
540    FOR J=1 TO NS
545      FOR K=1 TO 15
550        DARK(J,K)=DIO(J,16)*SLOP(K)+OFFS(K)
560        DIO(J,K)=(DIO(J,K)-DARK(J,K))/SENS(K)
570        DIO(J,K)=DIO(J,K)*REF/DIO(J,17)
590        NEXT K
600      NEXT J
610    FOR J=1 TO NS
```

```
635   ANG(J,2)=-ANG(J,2)
640   PRINT ANG(J,2)
650   FOR K=1 TO 15
680     ALPHA=ANG(J,2)-ANG(J,1)
690     X=SIN(DIANG(K)*DTRD)*COS(ALPHA*DTRD)
700     NAD(J,K)= FN ACOS(X)
710     COMP=(DIANG(K)-90)*DTRD
720     DEN=(SIN(NAD(J,K))*SIN(ALPHA*DTRD))
730     IF DEN=0. THEN 750
740     X=(COS(COMP)-COS(NAD(J,K))*COS(ALPHA*DTRD))/DEN
750     IF DEN=0. THEN X=0.00001
760     IF DIANG(K)<90. THEN X=-X
770     IF NAD(J,K)>0.00001 THEN 775:ELSE X=1.0
775     IF X>1. THEN X=1.
776     IF X<-1. THEN X=-1.0
780     AZI(J,K)= FN ACOS(X)
790     IF ALPHA<0.0 THEN AZI(J,K)=AZI(J,K)+180.0*DTRD
800     IF AZI(J,K)<0. THEN AZI(J,K)=360.0*DTRD+AZI(J,K)
810     PRINT J,K,NAD(J,K)/DTRD,AZI(J,K)/DTRD,DIO(J,K)
820     NEXT K
830   NEXT J
840  SUM=0
850  TOTNUM=0
860  FOR J=1 TO 36
870    NR(J)=0
880    NRN(J)=0
900    NEXT J
910  NINC=90*DTRD/36.
920  FOR J=1 TO 13
930    FOR K=1 TO 15
940      I=INT(NAD(J,K)/NINC)+1
950      NR(I)=NR(I)+DIO(J,K)
960      NRN(I)=NRN(I)+1
970      NEXT K
980    NEXT J
1000  FOR I=1 TO 36
1010    IF NRN(I)=0 THEN 1070
1020    ANG=(2*I-1)/2*NINC
1030    SUM=SUM+NR(I)/NRN(I)*COS(ANG)*SIN(ANG)*NINC
1040    TOTNUM=TOTNUM+NRN(I)
1050    NINC=90.*DTRD/36.
1060    GOTO 1090
1070    NINC=NINC+NINC
1090    NEXT I
1100  FLUXUP=3.14159*SUM*2.
1110  PRINT"UPWARD FLUX DENSITY";FLUXUP
1120  MAX=0
1130  MIN=90
1140  FOR J=1 TO 13
1150    FOR K=1 TO 15
1160      IF NAD(J,K)>MAX THEN MAX=NAD(J,K)
1170      IF NAD(J,K)<MIN THEN MIN=NAD(J,K)
1180      NEXT K
1190    NEXT J
1200  PRINT MIN,MAX
1210  SOLANG=2.0*3.14159*(1.-COS(MAX))
1220  FRACSA=SOLANG/(2.*3.14159)
1230  PRINT SOLANG,FRACSA
1300  FOR J=1 TO 13
1310    FOR K=1 TO 15
1320      BDR(J,K)=DIO(J,K)*3.14159/FLUXUP
1330      PRINT J,K,NAD(J,K)/DTRD,AZI(J,K)/DTRD,BDR(J,K)
1340      NEXT K
1350    NEXT J
1360  MAX=0
```

```
1375   I=1
1380   FOR J=1 TO 13
1390     FOR K=1 TO 15
1400       IF BDR(J,K)>MAX THEN MAX=BDR(J,K)
1410       IF BDR(J,K)<MIN THEN MIN=BDR(J,K)
1420       NEXT K
1430     NEXT J
1440   PRINT MIN,MAX
1460   OPEN#3 AS OUTPUT,"/AREA1/CFOS.BDR/"+D$
1470   WRITE#3,1;NS,FLUXUP,MIN,MAX
1475   I=1
1480   FOR J=1 TO NS
1490     FOR K=1 TO 15
1500       I=I+1
1510       WRITE#3,I;J,K,NAD(J,K),AZI(J,K),BDR(J,K)
1520       NEXT K
1530     NEXT J
1540   CLOSE
1550   END
```

```
1   HOME
5   X0=0.0:Y0=0.0:X1=6:Y1=4
10   DIM V(11),SCALEX(21),SCALEY(21),XNUM(21),YNUM(21)
15   DIM XG(200),YG(200),BDN(6,12),BDA(2,12),BD(30),NA(14)
80   FOR I=1 TO 10
90     P1X=1500:P1Y=1500
95     X0=0.0:Y0=0.0:X1=6:Y1=4
100     XMIN=0:YMIN=0.:XMAX=180:YMAX=3.0
110     NDIVX=12:NDIVY=5:NP=14:DIRUN=1.0:DIRISE=0.
115     DTRD=3.14159/180
120     SAW=.1*2.54:SAH=.13*2.54
125     GOSUB 500
150     END
200     REM INITIALIZE PLOTER
201     OPEN#9,".RS232"
202     PRINT#9;CHR$(27):".I32;;17:":PRINT#9;CHR$(27);".N;19;";"IN;"
203     P1X$=CONV$(P1X):P2X$=CONV$(P2X):P1Y$=CONV$(P1Y):P2Y$=CONV$(P2Y):
204     P2X=P1X+(X1-X0)*1010:P2Y=P1Y+(Y1-Y0)*1010
205     IF X0=X1 THEN P1X=500:P2X=10000:P1Y=600:P2Y=7500
206     P1X$=CONV$(P1X):P2X$=CONV$(P2X):P1Y$=CONV$(P1Y):P2Y$=CONV$(P2Y)
207     PFIELD$=P1X$+","+P1Y$+","+P2X$+","+P2Y$
208     PRINT#9;"IP";PFIELD$;";"
210     REM SUBROUTINE TO SCALE AXISES
211     REM X0,X1,Y0,Y1 DEFINE STARTING AND ENDING POINTS IN INCHES
212     REM XMIN,XMAX,YMIN,YMAX ARE THE MAX AND MIN VALUE ON AXISES
213     REM SCALEX,SCALEY=SCALED DATA FOR TIC MARKS
214     REM NDIVX,NDIVY=NUMBER OF DIVISIONS ON AXISES
215     DELTAX=(X1-X0)/NDIVX
216     DELTAY=(Y1-Y0)/NDIVY
217     SCALEX(1)=X0:SCALEY(1)=Y0
218     FOR ISUB=1 TO NDIVY:SCALEY(ISUB+1)=SCALEY(ISUB)+DELTAY:NEXT
219     FOR ISUB=1 TO NDIVX:SCALEX(ISUB+1)=SCALEX(ISUB)+DELTAX:NEXT
220     SC$=CONV$(X0)+","+CONV$(X1)+","+CONV$(Y0)+","+CONV$(Y1)
221     PRINT#9;"SC";SC$;";":RETURN
225     REM SUBROUTINE TO SET SYMBOL MODE
226     SYM1$=CONV$(W)+","+CONV$(H)
227     PRINT#9;"SI";SYM1$;"SM";SYM$;";"
228     RETURN
230     REM THIS SUBROUTINE PLOTS SYMBOL SYM$ AT LOCATION X,Y
231     REM PD=0 FOR PEN UP; PD=1 FOR PEN DOWN; LINET=LINE TYPE(0-4)
232     REM LINEL= LENGTH (PERCENT OF DIST. BETWEEN P1 AND P2)
233     IF PD=0 THEN PRINT#9;"PU;";:ELSE PRINT#9;"PD;";
234     IF PD=0 GOTO 239
235     IF LINEL=0 THEN LINEL=4
236     LT$=CONV$(LINET)+","+CONV$(LINEL)
237     PRINT#9;"LT";LT$;";"
239     SYM2$=CONV$(X)+","+CONV$(Y):SYMB$=SYM$
240     PRINT#9;"PA";SYM2$;";"
241     RETURN
245     REM PLOT AXIS
246     PRINT#9;"PU;"
247     X0$=CONV$(X0):Y0$=CONV$(Y0):X1$=CONV$(X1):Y1$=CONV$(Y1)
248     PRINT#9;"PA";X0$;",";Y0$;";";"PD;PA";X1$;",";Y0$;";";"PU;"
249     PRINT#9;"PA";X0$;",";Y0$;";";"PD;PA";X0$;",";Y1$;";";"PU;"
250     PRINT#9;"TL1.0,0.0;PA";X0$;","Y0$;";"
251     FOR ISUB=1 TO NDIVX+1:SCALE$=CONV$(SCALEX(ISUB))
252       PRINT#9;"PA";SCALE$;",";Y0$;";XT;":FOR I=1 TO 100:NEXT I:NEXT ISUB
253     PRINT#9;"TL1.0,0.0;PA";X0$;","Y0$;";"
254     FOR ISUB=1 TO NDIVY+1:SCALE$=CONV$(SCALEY(ISUB))
255       PRINT#9;"PA";X0$;",";SCALE$;";YT;":FOR I=1 TO 100:NEXT I:NEXT ISUB
256     RETURN
```

```
261     REM LOCATION IS THE LOWER LEFT HAND CORNER
262     REM DIRUN,DIRISE: SET DIRECTION . 1,0 FOR HORIZONTAL
263     REM SAW,SAH SET WIDTH AND HEIGHT IN CM.
264     IF SAW=0 THEN SAW=0.1:SAH=0.15
266     AXX$=CONV$(AXX):AYY$=CONV$(AYY):AXNUM$=CONV$(AXNUM)
267     PRINT#9;"SI";CONV$(SAW);",";CONV$(SAH);";"
268     PRINT#9;"PA";AXX$;",";AYY$;";LB";AXNUM$;CHR$(3)
269     RETURN
270     REM SUBROUTINE TO PLOT TEXT  TXT$ AT LOCATION TXX,TYY
271     REM LOCATION IS THE LOWER LEFT HAND CORNER
272     REM DIRUN,DIRISE; SET DIRECTION . 1,0 FOR HORIZONTAL
273     REM SAW,SAH SET WIDTH AND HEIGHT IN CM.
274     IF SAW=0 THEN SAW=0.1:SAH=0.15
276     TXX$=CONV$(TXX):TYY$=CONV$(TYY)
277     PRINT#9;"SI";CONV$(SAW);",";CONV$(SAH);";"
278     PRINT#9;"DI";CONV$(DIRUN);",";CONV$(DIRISE);";":FOR M=1 TO 999:NEXT M
279     PRINT#9;"PA";TXX$;",";TYY$;";LB";TXT$;CHR$(3)
280     RETURN
281     REM SUBROUTINE TO CENTER DIGITS ON X AXIS
282     NUMDIGIT=LEN(CONV$(AXNUM))
283     AXX=AXX-(NUMDIGIT*SAW)/2/2.54
284     RETURN
285     REM SUBROUTINE TO CENTER DIGITS ON Y AXIS
286     AYY=AYY-SAH/2/2.54:RETURN
287     REM PLOT A CURVE OF NP POINTS IN XG,YG
288     XP=(XG(1)-XNUM(5))*DX:YP=(YG(1)-YNUM(1))*DY
289     SYM2$=CONV$(XP)+","+CONV$(YP)
290     PRINT#9;"PU;PA";SYM2$;";PD;"
291     FOR IPLOT=2 TO NP
292       XP=(XG(IPLOT)-XNUM(5))*DX:FOR D=1 TO 200:NEXT D
293       YP=(YG(IPLOT)-YNUM(1))*DY
294       SYM2$=CONV$(XP)+","+CONV$(YP)
295       PRINT#9;"PA";SYM2$;";":NEXT IPLOT
296     PRINT#9;"PU;"
297     RETURN
299     RETURN
300     REM SUBROUTINE TO GET ERRORS ON HP
301     PRINT#9;CHR$(27);".E;"
302     PRINT#9;"OE;":INPUT#9;ERROR$:PRINT ERROR$
303     RETURN
500     GOSUB 200
510     GOSUB 245
520     FOR I=1 TO 11
525       XNUM(I)=(I-1)*0.10
530       NEXT I
535     FOR I=2 TO 10
540       XNUM(I+10)=1.1-I*.1
545       NEXT I
550     FOR I=1 TO 6
560       YNUM(I)=(I-1)*.50
570       NEXT I
575     SAW=.10*2.54:SAH=.10*2.54
580     AXX=SCALEX(2)
590     AYY=-.15*2.54
600     FOR I=1 TO NDIVX-1
610       AXNUM=XNUM(I+5)
620       GOSUB 281
625       FOR J=1 TO 100:NEXT J
630       GOSUB 260
640       AXX=SCALEX(I+2)
650       NEXT I
660     DX=(X1-X0)/(XNUM(NDIVX+1)-XNUM(1))
665     DXH=DX
680     TXT$="COSINE OF THE OBSERVATION ZENITH"
690     NUMLET=LEN(TXT$)
```

```
710    TYY=-.3*2.54
720    GOSUB 270
725    DY=(Y1-Y0)/(YNUM(NDIVY+1)-YNUM(1))
726    AXX=-.2*2.54:AYY=0
730    FOR I=1 TO NDIVY+1
740      AXNUM=YNUM(I)
750      GOSUB 285
760      FOR J=1 TO 200:NEXT J
770      GOSUB 260
775      FOR J=1 TO 200:NEXT J
780      AYY=SCALEY(I+1)
790      NEXT I
800    TXT$="NORMALIZED RADIANCE"
810    TXX=-0.35*2.54
820    DIRUN=0.
830    DIRISE=1
840    NUMLET=LEN(TXT$)
850    TYY=Y1/2.-NUMLET*SAW/2/2.54
855    FOR J=1 TO 800:NEXT J
860    GOSUB 270
870    FOR I=1 TO NDIVX+1
880      XNUM(I)=(I-1)*0.1
890      NEXT I
900    FOR K=1 TO NP
910      PRINT K
920      INPUT BD(K)
930      NEXT K
940    FOR K=1 TO NP
950      REM PRINT K:INPUT XG(K)
960      YG(K)=BD(K)
970      PRINT XG(K),YG(K)
980      NEXT K
985    DX=5.
990    GOSUB 287
1000    SYM$="X"
1005    W=.2:H=.2
1010    FOR K=1 TO NP
1020      X=(XG(K)-XNUM(5))*DX
1030      Y=(YG(K)-YNUM(1))*DY
1040      FOR J=1 TO 400:NEXT J
1045      GOSUB 225
1050      GOSUB 230
1060      NEXT K
1070    END
1100    TXT$="OCEAN BDR IN THE PRINCIPAL PLANE"
1105    DIRUN=1.0:DIRISE=0:SYM$="":GOSUB 225
1120    TXX=1.25
1130    TYY=5
1140    GOSUB 270
1145    END
1150    TXX=1.5
1160    TYY=4.5
1170    SAW=.075*2.54:SAH=0.075*2.54
1180    TXT$="O - COSINE OF THE SOLAR ZENITH = 0."
1190    GOSUB 270
1195    END
1200    TYY=4.25
1210    TXT$="X - COSINE OF THE SOLAR ZENITH = 0.5"
1220    GOSUB 270
1225    END
1230    TYY=4.0
1240    TXT$="O - 0.2 CLOUD COVER"
1250    GOSUB 270
1260    END
```

```
1    HOME
5    X0=0.0:Y0=0.0:X1=6:Y1=4
10    DIM V(11),SCALEX(21),SCALEY(21),XNUM(21),YNUM(21)
15    DIM XG(200),YG(200),BDN(6,12),BDA(2,12),BD(30),NA(14)
80    FOR I=1 TO 10
90      P1X=1500:P1Y=1500
95      X0=0.0:Y0=0.0:X1=6:Y1=4
100      XMIN=0:YMIN=0.:XMAX=180:YMAX=3.0
110      NDIVX=12:NYDIV=5:NP=24:DIRUN=1.0:DIRISE=0.
115      DTRD=3.14159/180
120      SAW=.1*2.54:SAH=.13*2.54
125      GOSUB 500
150      END
200      REM INITIALIZE PLOTER
201      OPEN#9,".RS232"
202      PRINT#9;CHR$(27);".I32;;17:":PRINT#9;CHR$(27);".N;19;";"IN;"
203      P1X$=CONV$(P1X):P2X$=CONV$(P2X):P1Y$=CONV$(P1Y):P2Y$=CONV$(P2Y):
204      P2X=P1X+(X1-X0)*1010:P2Y=P1Y+(Y1-Y0)*1010
205      IF X0=X1 THEN P1X=500:P2X=10000:P1Y=600:P2Y=7500
206      P1X$=CONV$(P1X):P2X$=CONV$(P2X):P1Y$=CONV$(P1Y):P2Y$=CONV$(P2Y)
207      PFIELD$=P1X$+","+P1Y$+","+P2X$+","+P2Y$
208      PRINT#9;"IP";PFIELD$;";"
210      REM SUBROUTINE TO SCALE AXISES
211      REM X0,X1,Y0,Y1 DEFINE STARTING AND ENDING POINTS IN INCHES
212      REM XMIN.XMAX,YMIN.YMAX ARE THE MAX AND MIN VALUE ON AXISES
213      REM SCALEX.SCALEY=SCALED DATA FOR TIC MARKS
214      REM NDIVX.NDIVY=NUMBER OF DIVISIONS ON AXISES
215      DELTAX=(X1-X0)/NDIVX
216      DELTAY=(Y1-Y0)/NDIVY
217      SCALEX(1)=X0:SCALEY(1)=Y0
218      FOR ISUB=1 TO NDIVY:SCALEY(ISUB+1)=SCALEY(ISUB)+DELTAY:NEXT
219      FOR ISUB=1 TO NDIVX:SCALEX(ISUB+1)=SCALEX(ISUB)+DELTAX:NEXT
220      SC$=CONV$(X0)+","+CONV$(X1)+","+CONV$(Y0)+","+CONV$(Y1)
221      PRINT#9;"SC";SC$;";":RETURN
225      REM SUBROUTINE TO SET SYMBOL MODE
226      SYM1$=CONV$(W)+","+CONV$(H)
227      PRINT#9;"SI";SYM1$;"SM";SYM$;";"
228      RETURN
230      REM THIS SUBROUTINE PLOTS SYMBOL SYM$ AT LOCATION X,Y
231      REM PD=0 FOR PEN UP; PD=1 FOR PEN DOWN; LINET=LINE TYPE(0-4)
232      REM LINEL= LENGTH (PERCENT OF DIST. BETWEEN P1 AND P2)
233      IF PD=0 THEN PRINT#9;"PU;";:ELSE PRINT#9;"PD;";
234      IF PD=0 GOTO 239
235      IF LINEL=0 THEN LINEL=4
236      LT$=CONV$(LINET)+","+CONV$(LINEL)
237      PRINT#9;"LT";LT$;";"
239      SYM2$=CONV$(X)+","+CONV$(Y):SYMB$=SYM$
240      PRINT#9;"PA";SYM2$;";"
241      RETURN
245      REM PLOT AXIS
246      PRINT#9;"PU;"
247      X0$=CONV$(X0):Y0$=CONV$(Y0):X1$=CONV$(X1):Y1$=CONV$(Y1)
248      PRINT#9;"PA";X0$;",";Y0$;";";"PD;PA";X1$;",";Y0$;";";"PU;"
249      PRINT#9;"PA";X0$;",";Y0$;";";"PD;PA";X0$;",";Y1$;";";"PU;"
250      PRINT#9;"TL1.0,0.0;PA";X0$;","Y0$;";"
251      FOR ISUB=1 TO NDIVX+1:SCALE$=CONV$(SCALEX(ISUB))
252        PRINT#9;"PA";SCALE$;",";Y0$;";XT;":FOR I=1 TO 100:NEXT I:NEXT ISUB
253      PRINT#9;"TL1.0,0.0;PA";X0$;","Y0$;";"
254      FOR ISUB=1 TO NDIVY+1:SCALE$=CONV$(SCALEY(ISUB))
255        PRINT#9;"PA";X0$;",";SCALE$;";YT;":FOR I=1 TO 100:NEXT I:NEXT ISUB
256      RETURN
```

```
261     REM LOCATION IS THE LOWER LEFT HAND CORNER
262     REM DIRUN,DIRISE; SET DIRECTION . 1,0 FOR HORIZONTAL
263     REM SAW.SAH SET WIDTH AND HEIGHT IN CM.
264     IF SAW=0 THEN SAW=0.1:SAH=0.15
266     AXX$=CONV$(AXX):AYY$=CONV$(AYY):AXNUM$=CONV$(AXNUM)
267     PRINT#9;"SI";CONV$(SAW);",";CONV$(SAH);";"
268     PRINT#9;"PA";AXX$;",";AYY$;";LB";AXNUM$;CHR$(3)
269     RETURN
270     REM SUBROUTINE TO PLOT TEXT  TXT$ AT LOCATION TXX,TYY
271     REM LOCATION IS THE LOWER LEFT HAND CORNER
272     REM DIRUN,DIRISE; SET DIRECTION . 1,0 FOR HORIZONTAL
273     REM SAW,SAH SET WIDTH AND HEIGHT IN CM.
274     IF SAW=0 THEN SAW=0.1:SAH=0.15
276     TXX$=CONV$(TXX):TYY$=CONV$(TYY)
277     PRINT#9;"SI";CONV$(SAW);",";CONV$(SAH);";"
278     PRINT#9;"DI";CONV$(DIRUN);",";CONV$(DIRISE);";":FOR M=1 TO 999:NEXT M
279     PRINT#9;"PA";TXX$;",";TYY$;";LB";TXT$;CHR$(3)
280     RETURN
281     REM SUBROUTINE TO CENTER DIGITS ON X AXIS
282     NUMDIGIT=LEN(CONV$(AXNUM))
283     AXX=AXX-(NUMDIGIT*SAW)/2/2.54
284     RETURN
285     REM SUBROUTINE TO CENTER DIGITS ON Y AXIS
286     AYY=AYY-SAH/2/2.54:RETURN
287     REM PLOT A CURVE OF NP POINTS IN XG,YG
288     XP=(XG(1)-XNUM(5))*DX:YP=(YG(1)-YNUM(1))*DY
289     SYM2$=CONV$(XP)+","+CONV$(YP)
290     PRINT#9;"PU;PA";SYM2$;";PD;"
291     FOR IPLOT=2 TO NP
292       XP=(XG(IPLOT)-XNUM(5))*DX:FOR D=1 TO 200:NEXT D
293       YP=(YG(IPLOT)-YNUM(1))*DY
294       SYM2$=CONV$(XP)+","+CONV$(YP)
295       PRINT#9;"PA";SYM2$;";":NEXT IPLOT
296     PRINT#9;"PU;"
297     RETURN
299     RETURN
300     REM SUBROUTINE TO GET ERRORS ON HP
301     PRINT#9;CHR$(27);".E;"
302     PRINT#9;"OE;":INPUT#9;ERROR$:PRINT ERROR$
303     RETURN
500     GOSUB 200
510     GOSUB 245
520     FOR I=1 TO 11
525       XNUM(I)=(I-1)*0.10
530       NEXT I
535     FOR I=2 TO 10
540       XNUM(I+10)=1.1-I*.1
545       NEXT I
550     FOR I=1 TO 6
560       YNUM(I)=(I-1)*.50
570       NEXT I
575     SAW=.10*2.54:SAH=.10*2.54
580     AXX=SCALEX(2)
590     AYY=-.15*2.54
600     FOR I=1 TO NDIVX-1
610       AXNUM=XNUM(I+5)
620       GOSUB 281
625       FOR J=1 TO 100:NEXT J
630       GOSUB 260
640       AXX=SCALEX(I+2)
650       NEXT I
660     DX=(X1-X0)/(XNUM(NDIVX+1)-XNUM(1))
680     TXT$="COSINE OF THE OBSERVATION ZENITH"
690     NUMLET=LEN(TXT$)
700     TXX=X1/2.-NUMLET*SAW/2/2.54-0.30
```

```
720     GOSUB 270
725     DY=(Y1-Y0)/(YNUM(NDIVY+1)-YNUM(1))
726     AXX=-.2*2.54:AYY=0
730     FOR I=1 TO NDIVY+1
740       AXNUM=YNUM(I)
750       GOSUB 285
760       FOR J=1 TO 200:NEXT J
770       GOSUB 260
775       FOR J=1 TO 200:NEXT J
780       AYY=SCALEY(I+1)
790       NEXT I
800     TXT$="NORMALIZED RADIANCE"
810     TXX=-0.35*2.54
820     DIRUN=0.
830     DIRISE=1
840     NUMLET=LEN(TXT$)
850     TYY=Y1/2.-NUMLET*SAW/2/2.54
855     FOR J=1 TO 800:NEXT J
860     GOSUB 270
870     FOR I=1 TO NDIVX+1
880       XNUM(I)=(I-1)*0.1
890       NEXT I
900     FOR K=1 TO NP
910       PRINT K
920       REM INPUT BD(K)
930       NEXT K
940     FOR K=1 TO NP
950       XG(K)=1.+COS((-57.5+5*K)*DTRD)
960       YG(K)=BD(K)
970       PRINT XG(K),YG(K)
980       NEXT K
985     DX=DX*NDIVX/NP
990     GOSUB 287
1000     SYM$="X"
1005     W=.2:H=.2
1010     FOR K=1 TO NP
1020       X=(XG(K)-XNUM(5))*DX
1030       Y=(YG(K)-YNUM(1))*DY
1040       FOR J=1 TO 400:NEXT J
1045       GOSUB 225
1050       GOSUB 230
1060       NEXT K
1070     END
1100     TXT$="CFOS  BDR IN THE PRINCIPAL PLANE"
1105     DIRUN=1.0:DIRISE=0:SYM$="":GOSUB 225
1120     TXX=1.25
1130     TYY=5
1140     GOSUB 270
1145     END
1150     TXX=1.5
1160     TYY=4.5
1170     SAW=.075*2.54:SAH=0.075*2.54
1180     TXT$=" COSINE OF SOLAR ZEN = 1.0"
1190     GOSUB 270
1195     END
1200     TYY=4.25
1210     TXT$="X - CLEAR SURFACE"
1220     GOSUB 270
1230     TYY=4.0
1240     TXT$="O - 0.2 CLOUD COVER"
1250     END
```

```
10    REM PROGRAM CFOS
20    PRINT"          CFOS BI-DIRECTIONAL REFLECTANCE PLOT PROGRAM"
45    DIM RAD(10,10),RDN(30,30)
50    DIM NXP(10,10),NYP(10,10),NXD(30),NYD(30)
60    DATA 2.5,7.5,12.5,17.5,22.5,27.5,32.5,37.5,42.5,47.5,52.5,57.5
70    DATA 15,45,75,105,135,165,195,225,255,285,315,345
75    PI=3.14159:POVR2=PI/2
80    PRINT"ENTER THE NUMBER OF X DATA POINTS AVAILABLE"
85    INPUT NPX
90    PRINT"ENTER THE NUMBER OF Y DATA POINTS AVAILABLE"
95    INPUT NPY
100    FOR J=1 TO 30
110      FOR K=1 TO 30
120        RDN(J,K)=0.
150        NEXT K
160      NEXT J
165    PRINT"ENTER THE NUMBER OF  X  INTERPOLTION POINTS"
167    INPUT NX
170    FOR J=1 TO NX-1
190      NXD(J)=60/NX*J
200      NEXT J
216    PRINT"ENTER THE NUMBER OF     Y     INTERPOLATION POINTS"
217    INPUT NY
220    FOR J=1 TO NY-1
230      NYD(J)=60/NY*J
240      NEXT J
250    PRINT"ENTER THE RADIANCE DATA  AS X POS   Y POS    RAD(X,Y)"
260    FOR J=1 TO NPX
270      FOR K=1 TO NPY
280        INPUT NXP(J,K),NYP(J,K),RAD(J,K)
290        NEXT K
300      NEXT J
400    GOSUB 1000
500    REM SUBROUTINE TO CALCULATE WEIGHT
510    DELTA=60/12
520    IF THETA>DELTA GOTO 570
530    WGHT=1.0E+06
540    IF THETA<0.001 THEN RETURN
550    WGHT=DELTA/THETA
560    RETURN
570    WGHT=0.
580    IF(THETA-DELTA)>=DELTA THEN RETURN
590    WGHT=2.0-THETA/DELTA
600    RETURN
700    REM SUBROUTINE TO INTERPOLATE IN BDR ARRAY
710    SUMF=0.
720    SUMW=0.
730    FOR M=1 TO NPX
740      FOR N=1 TO NPY
750        XI=NXP(M,N)
760        YI=NYP(M,N)
770        THETA=SQR((XI-XPRM)^2+(YI-YPRM)^2)
800        GOSUB 500
810        W=WGHT
820        SUMW=SUMW+W
830        SUMF=SUMF+W*RAD(M,N)
840        NEXT N
850      NEXT M
860    INTERP=0.
870    IF SUMW =0. THEN RETURN
880    INTERP=SUMF/SUMW
```

```
1000  REM CALCULATE RAD VALUES AT REGULAR ARRAY POINTS
1010  FOR J=1 TO NX-1
1020    FOR K=1 TO NY-1
1030      XPRM=NXD(J)
1040      YPRM=NYD(K)
1320      GOSUB 700
1330      RDN(J,K)=INTERP
1340      PRINT RDN(J,K)
1350      NEXT K
1360    NEXT J
1400  OPEN#4 AS OUTPUT,"/AREA1/CFOS.PLOT/"+"STYRO"
1410  MIN=99999
1420  MAX=0
1430  FOR J=1 TO NX-1
1440    FOR K=1 TO NY-1
1450      IF RDN(J,K)<MIN THEN MIN=RDN(J,K)
1460      IF RDN(J,K)>MAX THEN MAX=RDN(J,K)
1470      NEXT K
1480    NEXT J
1485  PRINT"MIN AND MAX OF INTERPOLATED FIELD ",MIN,MAX
1490  WRITE#4,1;NX-1,NY-1,MIN,MAX
1495  I=1
1500  FOR J=1 TO NX-1
1510    FOR K=1 TO NY-1
1520      I=I+1
1530      WRITE#4,I;NXD(J),NYD(K),RDN(J,K)
1535      PRINT NXD(J),NYD(K),RDN(J,K)
1540      NEXT K
1550    NEXT J
1560  CLOSE
1570  END
```

```
20   DIM X(30),Y(30),XG(360),YG(360),RDN(30,30),ZLEV(20)
40   DIM R(6),XNUM(12),YNUM(12),NXD(30),NYD(30)
50   DTRD=3.14159/180.
60   DIM YM(30),Z(30,30)
70   DATA 0,30,60,90,120,150,180,210,240,270,300,330
80   FOR I=1 TO 12
100     NEXT I
110   NLEV=10
115   NINCR=.05
120   GOSUB 1000
130   GOSUB 1600
200   REM INITIALIZE PLOTER
201   OPEN#9,".RS232"
202   PRINT#9;CHR$(27);".I32;;17:":PRINT#9;CHR$(27);".N;19;";"IN;"
203   P1X$=CONV$(P1X):P2X$=CONV$(P2X):P1Y$=CONV$(P1Y):P2Y$=CONV$(P2Y):
204   P2X=P1X+(X1-X0)*1010:P2Y=P1Y+(Y1-Y0)*1010
205   IF X0=X1 THEN P1X=500:P2X=10000:P1Y=600:P2Y=7500
206   P1X$=CONV$(P1X):P2X$=CONV$(P2X):P1Y$=CONV$(P1Y):P2Y$=CONV$(P2Y)
207   PFIELD$=P1X$+","+P1Y$+","+P2X$+","+P2Y$
208   PRINT#9;"IP";PFIELD$;";"
209   GOSUB 220:RETURN
210   REM SUBROUTINE TO SCALE AXISES
211   REM XO,X1,YO,Y1 DEFINE STARTING AND ENDING POINTS IN INCHES
212   REM XMIN,XMAX,YMIN,YMAX ARE THE MAX AND MIN VALUE ON AXISES
213   REM SCALEX,SCALEY=SCALED DATA FOR TIC MARKS
214   REM NDIVX,NDIVY=NUMBER OF DIVISIONS ON AXISES
215   DELTAX=(X1-X0)/NDIVX
216   DELTAY=(Y1-Y0)/NDIVY
217   SCALEX(1)=X0:SCALEY(1)=Y0
218   FOR ISUB=1 TO NDIVY:SCALEY(ISUB+1)=SCALEY(ISUB)+DELTAY:NEXT
219   FOR ISUB=1 TO NDIVX:SCALEX(ISUB+1)=SCALEX(ISUB)+DELTAX:NEXT
220   SC$=CONV$(X0)+","+CONV$(X1)+","+CONV$(Y0)+","+CONV$(Y1)
221   PRINT#9;"SC";SC$;";":RETURN
225   REM SUBROUTINE TO SET SYMBOL MODE
226   SYM1$=CONV$(W)+","+CONV$(H)
227   PRINT#9;"SI";SYM1$;"SM";SYM$;";"
228   RETURN
230   REM THIS SUBROUTINE PLOTS SYMBOL SYM$ AT LOCATION X,Y
231   REM PD=0 FOR PEN UP; PD=1 FOR PEN DOWN; LINET=LINE TYPE(0-4)
232   REM LINEL= LENGTH (PERCENT OF DIST. BETWEEN P1 AND P2)
233   IF PD=0 THEN PRINT#9;"PU;";:ELSE PRINT#9;"PD;";
234   IF PD=0 GOTO 239
235   IF LINEL=0 THEN LINEL=4
236   LT$=CONV$(LINET)+","+CONV$(LINEL)
237   PRINT#9;"LT";LT$;";"
239   SYM2$=CONV$(X)+","+CONV$(Y):SYMB$=SYM$
240   PRINT#9;"PA";SYM2$;";"
241   RETURN
245   REM PLOT AXIS
246   PRINT#9;"PU;"
247   X0$=CONV$(X0):Y0$=CONV$(Y0):X1$=CONV$(X1):Y1$=CONV$(Y1)
248   PRINT#9;"PA";X0$;",";Y0$;";";"PD;PA";X1$;",";Y0$;";";"PU;"
249   PRINT#9;"PA";X0$;",";Y0$;";";"PD;PA";X0$;",";Y1$;";";"PU;"
250   PRINT#9;"TL1.0,0.0;PA";X0$;","Y0$;";"
251   FOR ISUB=1 TO NDIVX+1:SCALE$=CONV$(SCALEX(ISUB))
252     PRINT#9;"PA";SCALE$;",";Y0$;";XT;":NEXT
253   PRINT#9;"TL1.0,0.0;PA";X0$;","Y0$;";"
254   FOR ISUB=1 TO NDIVY+1:SCALE$=CONV$(SCALEY(ISUB))
255     PRINT#9;"PA";X0$;",";SCALE$;";YT;":NEXT
256   RETURN
260   REM SUBROUTINE TO PLOT NUMBER AXNUM AT LOCATION AXX,AYY
```

```
262  REM DIRUN,DIRISE: SET DIRECTION . 1,0 FOR HORIZONTAL
263  REM SAW,SAH SET WIDTH AND HEIGHT IN CM.
264  IF SAW=0 THEN SAW=0.1:SAH=0.15
266  AXX$=CONV$(AXX):AYY$=CONV$(AYY):AXNUM$=CONV$(AXNUM)
267  PRINT#9;"SI";CONV$(SAW);",";CONV$(SAH);";"
268  PRINT#9;"PA";AXX$;",";AYY$;";LB";AXNUM$;CHR$(3)
269  RETURN
270  REM SUBROUTINE TO PLOT TEXT  TXT$ AT LOCATION TXX,TYY
271  REM LOCATION IS THE LOWER LEFT HAND CORNER
272  REM DIRUN,DIRISE: SET DIRECTION . 1,0 FOR HORIZONTAL
273  REM SAW,SAH SET WIDTH AND HEIGHT IN CM.
274  IF SAW=0 THEN SAW=0.1:SAH=0.15
275  PRINT#9;"PU;"
276  TXX$=CONV$(TXX):TYY$=CONV$(TYY)
277  PRINT#9;"SI";CONV$(SAW);",";CONV$(SAH);";"
278  PRINT#9;"DI";CONV$(DIRUN);",";CONV$(DIRISE);";"
279  PRINT#9;"PA";TXX$;",";TYY$;";LB";TXT$;CHR$(3)
280  RETURN
281  REM SUBROUTINE TO CENTER DIGITS ON X AXIS
282  NUMDIGIT=LEN(CONV$(AXNUM))
283  AXX=AXX-(NUMDIGIT*SAW)/2/2.54
284  RETURN
285  REM SUBROUTINE TO CENTER DIGITS ON Y AXIS
286  AYY=AYY-SAH/2/2.54:RETURN
287  REM PLOT A CURVE OF NP POINTS IN XG,YG
288  XP=XG(0):YP=YG(0)
289  SYM2$=CONV$(XP)+","+CONV$(YP)
290  PRINT#9;"PU;PA";SYM2$;";PD;"
291  FOR IPLOT=1 TO NP
292    XP=XG(IPLOT)
293    YP=YG(IPLOT)
294    SYM2$=CONV$(XP)+","+CONV$(YP)
295    PRINT#9;"PA";SYM2$;";PD;":NEXT IPLOT
296  PRINT#9;"PU;"
297  RETURN
299  RETURN
300  REM SUBROUTINE TO GET ERRORS ON HP
301  PRINT#9;CHR$(27);".E;"
302  PRINT#9;"OE;":INPUT#9;ERROR$:PRINT ERROR$
303  RETURN
400  REM SUBROUTINE TO PUT AZIMUTH TIC MARKS
410  TXT$="_"
420  SAW=0.1:SAH=0.1
430  DIRUN=CSIN
435  IF ABS(DIRUN)<0.01 THEN DIRUN=0.
440  DIRISE=SINE
445  IF ABS(DIRISE)<0.01 THEN DIRISE=0
450  TXX=XG(K):TYY=YG(K)
460  GOSUB 270
470  RETURN
1000  REM INITIALIZE PLOTTER
1010  P1X=1500
1020  P1Y=1250
1030  X0=0
1040  Y0=0
1050  X1=6
1060  Y1=6
1070  SAW=0.1*2.54
1080  SAH=0.13*2.54
1090  CX=3.0
1100  CY=3.0
1110  XMIN=0.0
1120  XMAX=6.0
1130  YMIN=0.00
1140  YMAX=6.
```

```
1160  W=1
1170  H=1
1180  GOSUB 225
1200  REM PLOT BOUNDARY
1205  XNUM(1)=0:YNUM(1)=0
1206  DX=1:DY=1:NP=5
1210  XG(1)=-2+CX:YG(1)=-2+CY
1220  XG(2)=+2+CX:YG(2)=YG(1)
1230  XG(3)=XG(2):YG(3)=+2+CY
1240  XG(4)=XG(1):YG(4)=YG(3)
1250  XG(5)=XG(1):YG(5)=YG(1)
1255  PRINT#9;"PU"
1260  FOR K=1 TO NP
1270    XP=XG(K):YP=YG(K)
1280    SYM2$=CONV$(XP)+","+CONV$(YP)
1290    PRINT#9;"PA";SYM2$;";PD;PA;"
1295    NEXT K
1390  SAW=.25:SAH=.25
1400  TXT$=" TAU = 60.0"
1410  TXX=2.25:TYY=CY-2.25
1415  DIRUN=1.0:DIRISE=0.0
1420  GOSUB 270
1425  TXT$=" TAU =  0.0"
1430  TXX=2.25:TYY=CY+2.25
1440  GOSUB 270
1510  FOR P=1 TO 100:NEXT P
1530  RETURN
1600  REM INPUT INTERPOLATED BDN FIELD
1610  PRINT"INPUT FILE NAME OF INTERPOLATED DATA"
1620  INPUT D$
1630  OPEN#2,"/AREA1/CFOS.PLOT/"+D$
1640  I=1
1650  READ#2,1;NX,NY,MIN,MAX
1655  PRINT NX,NY,MIN,MAX
1660  FOR J=1 TO NX
1670    FOR K=1 TO NY
1680      I=I+1
1690      READ#2,I;NXD(J),NYD(K),RDN(J,K)
1700      PRINT J,K,NXD(J),NYD(K),RDN(J,K)
1710      NEXT K
1720    NEXT J
1730  REM SET UP CONTOUR ARRAYS
1800  ZMIN=MIN
1810  ZMAX=MAX
1820  FOR J=1 TO NX
1830    FOR K=1 TO NY
1840      Z(J,K)=RDN(J,K)
1850      NEXT K
1860    NEXT J
1870  NXP=NX:NXP1=NX-1
1880  NYP=NY:NYP1=NY-1
1910  FOR N=1 TO NLEV
1920    ZLEV(N)=INT(ZMIN*100)/100+N*NINCR
1925    NEXT N
1930  GOSUB 4900
4900  IDUB=0
4910  DELTAT=4/NYP1
4920  DELTAR=4/NXP1
5000  FOR I=1 TO NYP1
5001    T0=(I-1)*DELTAT
5002    T1=T0+DELTAT
5003    FOR J=1 TO NXP1
5004      R0=(J-1)*DELTAR
5005      R1=R0+DELTAR
5006      H1=Z(J,I)
```

```
5008   H3=Z(J+1,I+1)
5009   H4=Z(J,I+1)
5010   REM IF I = NYP1 THEN H3=Z(J+1,1)
5011   REM IF I = NYP1 THEN H4=Z(J,1)
5012   FOR K=1 TO NLEV
5013     ZLEV=ZLEV(K)
5014     IF H1>=ZLEV GOTO 5023
5015     IF H2>=ZLEV GOTO 5019
5016     IF H3>=ZLEV GOTO 5020
5017     IF H4>ZLEV GOTO 5030
5018     GOTO 5100
5019     IF H3<ZLEV GOTO 5021:ELSE GOTO 5022
5020     IF H4<ZLEV GOTO 5031:ELSE GOTO 5032
5021     IF H4<ZLEV GOTO 5033:ELSE GOTO 5034
5022     IF H4<ZLEV GOTO 5035:ELSE GOTO 5036
5023     IF H2>=ZLEV GOTO 5026
5024     IF H3>=ZLEV GOTO 5027
5025     IF H4<ZLEV GOTO 5036:ELSE GOTO 5035
5026     IF H3<ZLEV GOTO 5028:ELSE GOTO 5029
5027     IF H4<ZLEV GOTO 5037:ELSE GOTO 5033
5028     IF H4<ZLEV GOTO 5032:ELSE GOTO 5031
5029     IF H4>=ZLEV GOTO 5090
5030     TA=T0+(H1-ZLEV)/(H1-H4)*DELTAT:TB=T1:RA=R0:RB=R0+(H4-ZLEV)/(H4-H3
         )*DELTAR:GOTO 5080
5031     TA=T0+(H2-ZLEV)/(H2-H3)*DELTAT:TB=T1:RA=R1:RB=R0+(H4-ZLEV)/(H4-H3
         )*DELTAR:GOTO 5080
5032     TA=T0+(H1-ZLEV)/(H1-H4)*DELTAT:TB=T0+(H2-ZLEV)/(H2-H3)*DELTAT:RA=
         R0:RB=R1:GOTO 5080
5033     TA=T0:TB=T0+(H2-ZLEV)/(H2-H3)*DELTAT:RA=R0+(H1-ZLEV)/(H1-H2)*DELT
         AR:RB=R1:IDUB=0:GOTO 5080
5034     IDUB=1:GOTO 5030
5035     TA=T0:TB=T1:RA=R0+(H1-ZLEV)/(H1-H2)*DELTAR:RB=R0+(H4-ZLEV)/(H4-H3
         )*DELTAR:GOTO 5080
5036     TA=T0:TB=T0+(H1-ZLEV)/(H1-H4)*DELTAT:RA=R0+(H1-ZLEV)/(H1-H2)*DELT
         AR:RB=R0:IDUB=0:GOTO 5080
5037     IDUB=-1:GOTO 5031
5080     XA=RA+1:XB=RB+1:YA=TA+1:YB=TB+1
5082     XA$=CONV$(XA):XB$=CONV$(XB):YA$=CONV$(YA):YB$=CONV$(YB)
5083     PRINT#9;"PU";XA$;",";YA$;";PD";XB$;",";YB$;";PU;"
5085     IF IDUB=-1 THEN 5036
5086     IF IDUB=1 THEN 5033
5090     NEXT K
5100   NEXT J
5200  NEXT I
5250 END
5300 FOR J=1 TO NXP1
5310   FOR K=1 TO NYP1
5320     IF Z(J,K)=ZMIN THEN JMIN=J:KMIN=K
5330     IF Z(J,K)=ZMAX THEN JMAX=J:KMAX=K
5340     NEXT K
5350   NEXT J
5360 PRINT JMIN,KMIN,JMAX,KMAX
5365 DIRUN=1:DIRISE=0
5370 RMIN=(JMIN-1)*DELTAR
5380 RMAX=(JMAX-1)*DELTAR
5390 TMIN=(KMIN-1)*DELTAT
5400 TMAX=(KMAX-1)*DELTAT
5410 XMIN=RMIN+1
5420 XMAX=RMAX+1
5430 YMIN=TMIN+1
5440 YMAX=TMAX+1
5450 TXX=XMIN:TYY=YMIN:TXT$="L"
5460 GOSUB 270
5470 TXX=XMAX:TYY=YMAX:TXT$="H"
5480 GOSUB 270
```

```
5500  TXX=0.30
5510  TYY=-.50
5520  TXT$="L = "+CONV$(ZMIN)+"     H = "+CONV$(ZMAX)+"   INTERVAL = "+CONV$(ZL
      EV(2)-ZLEV(1))
5530  GOSUB 270
5540  END
```

```
20   DIM NA(30),AZ(30),XG(360),YG(360),BDN(30,30),ZLEV(20)
40   DIM R(6),XNUM(12),YNUM(12)
50   DTRD=3.14159/180.
60   DIM AZM(30),Z(30,30)
70   DATA 0,30,60,90,120,150,180,210,240,270,300,330
80   FOR I=1 TO 12
90     READ AZM(I)
100     NEXT I
110   NLEV=10
115   NINCR=.50
120   GOSUB 1000
130   GOSUB 1600
200   REM INITIALIZE PLOTER
201   OPEN#9,".RS232"
202   PRINT#9;CHR$(27);".I32;;17:":PRINT#9;CHR$(27);".N;19:";"IN;"
203   P1X$=CONV$(P1X):P2X$=CONV$(P2X):P1Y$=CONV$(P1Y):P2Y$=CONV$(P2Y):
204   P2X=P1X+(X1-X0)*1010:P2Y=P1Y+(Y1-Y0)*1010
205   IF X0=X1 THEN P1X=500:P2X=10000:P1Y=600:P2Y=7500
206   P1X$=CONV$(P1X):P2X$=CONV$(P2X):P1Y$=CONV$(P1Y):P2Y$=CONV$(P2Y)
207   PFIELD$=P1X$+","+P1Y$+","+P2X$+","+P2Y$
208   PRINT#9;"IP";PFIELD$;";"
209   GOSUB 220:RETURN
210   REM SUBROUTINE TO SCALE AXISES
211   REM X0,X1,Y0,Y1 DEFINE STARTING AND ENDING POINTS IN INCHES
212   REM XMIN,XMAX,YMIN,YMAX ARE THE MAX AND MIN VALUE ON AXISES
213   REM SCALEX,SCALEY=SCALED DATA FOR TIC MARKS
214   REM NDIVX,NDIVY=NUMBER OF DIVISIONS ON AXISES
215   DELTAX=(X1-X0)/NDIVX
216   DELTAY=(Y1-Y0)/NDIVY
217   SCALEX(1)=X0:SCALEY(1)=Y0
218   FOR ISUB=1 TO NDIVY:SCALEY(ISUB+1)=SCALEY(ISUB)+DELTAY:NEXT
219   FOR ISUB=1 TO NDIVX:SCALEX(ISUB+1)=SCALEX(ISUB)+DELTAX:NEXT
220   SC$=CONV$(X0)+","+CONV$(X1)+","+CONV$(Y0)+","+CONV$(Y1)
221   PRINT#9;"SC";SC$;";":RETURN
225   REM SUBROUTINE TO SET SYMBOL MODE
226   SYM1$=CONV$(W)+","+CONV$(H)
227   PRINT#9;"SI";SYM1$;"SM";SYM$;";"
228   RETURN
230   REM THIS SUBROUTINE PLOTS SYMBOL SYM$ AT LOCATION X,Y
231   REM PD=0 FOR PEN UP; PD=1 FOR PEN DOWN; LINET=LINE TYPE(0-4)
232   REM LINEL= LENGTH (PERCENT OF DIST. BETWEEN P1 AND P2)
233   IF PD=0 THEN PRINT#9;"PU;";:ELSE PRINT#9;"PD;";
234   IF PD=0 GOTO 239
235   IF LINEL=0 THEN LINEL=4
236   LT$=CONV$(LINET)+","+CONV$(LINEL)
237   PRINT#9;"LT";LT$;";"
239   SYM2$=CONV$(X)+","+CONV$(Y):SYMB$=SYM$
240   PRINT#9;"PA";SYM2$;";"
241   RETURN
245   REM PLOT AXIS
246   PRINT#9;"PU;"
247   X0$=CONV$(X0):Y0$=CONV$(Y0):X1$=CONV$(X1):Y1$=CONV$(Y1)
248   PRINT#9;"PA";X0$;",";Y0$;";";"PD;PA";X1$;",";Y0$;";";"PU;"
249   PRINT#9;"PA";X0$;",";Y0$;";";"PD;PA";X0$;",";Y1$;";";"PU;"
250   PRINT#9;"TL1.0,0.0;PA";X0$;","Y0$;";"
251   FOR ISUB=1 TO NDIVX+1:SCALE$=CONV$(SCALEX(ISUB))
252     PRINT#9;"PA";SCALE$;",";Y0$;";XT;":NEXT
253   PRINT#9;"TL1.0,0.0;PA";X0$;","Y0$;";"
254   FOR ISUB=1 TO NDIVY+1:SCALE$=CONV$(SCALEY(ISUB))
255     PRINT#9;"PA";X0$;",";SCALE$;";YT;":NEXT
256   RETURN
```

```
260  REM SUBROUTINE TO PLOT NUMBER AXNUM AT LOCATION AXX,AYY
261  REM LOCATION IS THE LOWER LEFT HAND CORNER
262  REM DIRUN,DIRISE; SET DIRECTION . 1,0 FOR HORIZONTAL
263  REM SAW,SAH SET WIDTH AND HEIGHT IN CM.
264  IF SAW=0 THEN SAW=0.1:SAH=0.15
266  AXX$=CONV$(AXX):AYY$=CONV$(AYY):AXNUM$=CONV$(AXNUM)
267  PRINT#9;"SI";CONV$(SAW);",";CONV$(SAH);";"
268  PRINT#9;"PA";AXX$;",";AYY$;";LB";AXNUM$;CHR$(3)
269  RETURN
270  REM SUBROUTINE TO PLOT TEXT  TXT$ AT LOCATION TXX,TYY
271  REM LOCATION IS THE LOWER LEFT HAND CORNER
272  REM DIRUN,DIRISE; SET DIRECTION . 1,0 FOR HORIZONTAL
273  REM SAW,SAH SET WIDTH AND HEIGHT IN CM.
274  IF SAW=0 THEN SAW=0.1:SAH=0.15
275  PRINT#9;"PU;"
276  TXX$=CONV$(TXX):TYY$=CONV$(TYY)
277  PRINT#9;"SI";CONV$(SAW);",";CONV$(SAH);";"
278  PRINT#9;"DI";CONV$(DIRUN);",";CONV$(DIRISE);";"
279  PRINT#9;"PA";TXX$;",";TYY$;";LB";TXT$;CHR$(3)
280  RETURN
281  REM SUBROUTINE TO CENTER DIGITS ON X AXIS
282  NUMDIGIT=LEN(CONV$(AXNUM))
283  AXX=AXX-(NUMDIGIT*SAW)/2/2.54
284  RETURN
285  REM SUBROUTINE TO CENTER DIGITS ON Y AXIS
286  AYY=AYY-SAH/2/2.54:RETURN
287  REM PLOT A CURVE OF NP POINTS IN XG,YG
288  XP=XG(0):YP=YG(0)
289  SYM2$=CONV$(XP)+","+CONV$(YP)
290  PRINT#9;"PU;PA";SYM2$;";PD;"
291  FOR IPLOT=1 TO NP
292    XP=XG(IPLOT)
293    YP=YG(IPLOT)
294    SYM2$=CONV$(XP)+","+CONV$(YP)
295    PRINT#9;"PA";SYM2$;";PD;":NEXT IPLOT
296  PRINT#9;"PU;"
297  RETURN
299  RETURN
300  REM SUBROUTINE TO GET ERRORS ON HP
301  PRINT#9;CHR$(27);".E;"
302  PRINT#9;"OE;":INPUT#9;ERROR$:PRINT ERROR$
303  RETURN
400  REM SUBROUTINE TO PUT AZIMUTH TIC MARKS
410  TXT$="_"
420  SAW=0.1:SAH=0.1
430  DIRUN=CSIN
435  IF ABS(DIRUN)<0.01 THEN DIRUN=0.
440  DIRISE=SINE
445  IF ABS(DIRISE)<0.01 THEN DIRISE=0
450  TXX=XG(K):TYY=YG(K)
460  GOSUB 270
470  RETURN
1000  REM INITIALIZE PLOTTER
1010  P1X=1500
1020  P1Y=1250
1030  X0=0
1040  Y0=0
1050  X1=6
1060  Y1=6
1070  SAW=0.1*2.54
1080  SAH=0.13*2.54
1090  CX=3.0
1100  CY=3.0
1110  XMIN=0.0
1120  XMAX=6.0
1130  YMIN=0.00
```

```
1150  GOSUB 200
1160  W=1
1170  H=1
1180  GOSUB 225
1200  REM PLOT BOUNDARY
1205  XNUM(1)=0:YNUM(1)=0
1206  DX=1:DY=1:NP=360
1210  FOR I=1 TO 6
1220    R(I)=I*0.45
1230    FOR K=0 TO 360 STEP 5
1235      CSIN=COS(K*DTRD):SINE=SIN(K*DTRD)
1240      XG(K)=R(I)*CSIN+CX
1250      YG(K)=R(I)*SINE+CY
1265      SYM2$=CONV$(XP)+","+CONV$(YP)
1270      XP=XG(K):YP=YG(K)
1280      SYM2$=CONV$(XP)+","+CONV$(YP)
1290      PRINT#9;"PU;PA";SYM2$;";PD;"
1300      FOR P=1 TO 12
1310        IF K=AZM(P) THEN GOSUB 400
1315        NEXT P
1330      NEXT K
1340    NEXT I
1350  I=6
1360  FOR K=0 TO 330 STEP 30
1390    SAW=.25:SAH=.25
1400    TXT$=" "+CONV$(K)
1410    DIRUN=COS(K*DTRD)
1415    IF ABS(DIRUN)<0.01 THEN DIRUN=0.
1420    DIRISE=SIN(K*DTRD)
1425    IF ABS(DIRISE)<0.01 THEN DIRISE=0.
1430    TXX=R(6)*COS(K*DTRD)+CX
1440    TYY=R(6)*SIN(K*DTRD)+CY
1450    IF K<=90 THEN 1500
1455    IF K>=270 THEN 1500
1460    DIRISE=-DIRISE
1470    DIRUN=-DIRUN
1480    TXX=TXX+3*SAW*COS(K*DTRD)
1490    TYY=TYY+3*SAH*SIN(K*DTRD)
1500    PRINT K,TXX,TYY,DIRUN,DIRISE:GOSUB 270
1510    FOR P=1 TO 100:NEXT P
1520    NEXT K
1530  RETURN
1600  REM INPUT INTERPOLATED BDN FIELD
1610  PRINT"INPUT FILE NAME OF INTERPOLATED DATA"
1620  INPUT D$
1630  OPEN#2,"/AREA1/CFOS.PLOT/"+D$
1640  I=1
1650  READ#2,1;NNAD,NAZM,FLUXUP,MIN,MAX
1655  PRINT NNAD,NAZM,FLUXUP,MIN,MAX
1660  FOR J=1 TO NNAD
1670    FOR K=1 TO NAZM
1680      I=I+1
1690      READ#2,I;NA(J),AZ(K),BDN(J,K)
1700      PRINT J,K,NA(J),AZ(K),BDN(J,K)
1710      NEXT K
1720    NEXT J
1730  REM SET UP CONTOUR ARRAYS
1800  ZMIN=MIN
1810  ZMAX=MAX
1820  FOR J=1 TO NNAD
1830    FOR K=1 TO NAZM
1840      Z(J,K)=BDN(J,K)
1850      NEXT K
1860    NEXT J
1870  NRAD=NNAD:NRM1=NRAD-1
```

```
1910  FOR N=1 TO NLEV
1920    ZLEV(N)=INT(ZMIN*10)/10+N*NINCR
1925    NEXT N
1930  GOSUB 4900
4900  IDUB=0
4910  DELTAT=3.14159/(NTM1)*2
4920  DELTAR=R(6)/(NRM1)
5000  FOR I=1 TO NTM1
5001    TO=(I-1)*DELTAT
5002    T1=TO+DELTAT
5003    FOR J=1 TO NRM1
5004      RO=(J-1)*DELTAR
5005      R1=RO+DELTAR
5006      H1=Z(J,I)
5007      H2=Z(J+1,I)
5008      H3=Z(J+1,I+1)
5009      H4=Z(J,I+1)
5010      IF I=NTM1 THEN H3=Z(J+1,1)
5011      IF I=NTM1 THEN H4=Z(J,1)
5012      FOR K=1 TO NLEV
5013        ZLEV=ZLEV(K)
5014        IF H1>=ZLEV GOTO 5023
5015        IF H2>=ZLEV GOTO 5019
5016        IF H3>=ZLEV GOTO 5020
5017        IF H4>ZLEV GOTO 5030
5018        GOTO 5100
5019        IF H3<ZLEV GOTO 5021:ELSE GOTO 5022
5020        IF H4<ZLEV GOTO 5031:ELSE GOTO 5032
5021        IF H4<ZLEV GOTO 5033:ELSE GOTO 5034
5022        IF H4<ZLEV GOTO 5035:ELSE GOTO 5036
5023        IF H2>=ZLEV GOTO 5026
5024        IF H3>=ZLEV GOTO 5027
5025        IF H4<ZLEV GOTO 5036:ELSE GOTO 5035
5026        IF H3<ZLEV GOTO 5028:ELSE GOTO 5029
5027        IF H4<ZLEV GOTO 5037:ELSE GOTO 5033
5028        IF H4<ZLEV GOTO 5032:ELSE GOTO 5031
5029        IF H4>=ZLEV GOTO 5090
5030        TA=TO+(H1-ZLEV)/(H1-H4)*DELTAT:TB=T1:RA=RO:RB=RO+(H4-ZLEV)/(H4-H3
            )*DELTAR:GOTO 5080
5031        TA=TO+(H2-ZLEV)/(H2-H3)*DELTAT:TB=T1:RA=R1:RB=RO+(H4-ZLEV)/(H4-H3
            )*DELTAR:GOTO 5080
5032        TA=TO+(H1-ZLEV)/(H1-H4)*DELTAT:TB=TO+(H2-ZLEV)/(H2-H3)*DELTAT:RA=
            RO:RB=R1:GOTO 5080
5033        TA=TO:TB=TO+(H2-ZLEV)/(H2-H3)*DELTAT:RA=RO+(H1-ZLEV)/(H1-H2)*DELT
            AR:RB=R1:IDUB=0:GOTO 5080
5034        IDUB=1:GOTO 5030
5035        TA=TO:TB=T1:RA=RO+(H1-ZLEV)/(H1-H2)*DELTAR:RB=RO+(H4-ZLEV)/(H4-H3
            )*DELTAR:GOTO 5080
5036        TA=TO:TB=TO+(H1-ZLEV)/(H1-H4)*DELTAT:RA=RO+(H1-ZLEV)/(H1-H2)*DELT
            AR:RB=RO:IDUB=0:GOTO 5080
5037        IDUB=-1:GOTO 5031
5080        XA=RA*COS(TA)+CX:XB=RB*COS(TB)+CX:YA=RA*SIN(TA)+CY:YB=RB*SIN(TB)+
            CY
5082        XA$=CONV$(XA):XB$=CONV$(XB):YA$=CONV$(YA):YB$=CONV$(YB)
5083        PRINT#9;"PU";XA$;",";YA$;";PD";XB$;",";YB$;";PU;"
5085        IF IDUB=-1 THEN 5036
5086        IF IDUB=1 THEN 5033
5090        NEXT K
5100      NEXT J
5200    NEXT I
5250  END
5300  FOR J=1 TO NNAD
5310    FOR K=1 TO NAZM
5320      IF Z(J,K)=ZMIN THEN JMIN=J:KMIN=K
5330      IF Z(J,K)=ZMAX THEN JMAX=J:KMAX=K
```

```
5350     NEXT J
5360    PRINT JMIN,KMIN,JMAX,KMAX
5365    DIRUN=1:DIRISE=0
5370    RMIN=(JMIN-1)*DELTAR
5380    RMAX=(JMAX-1)*DELTAR
5390    TMIN=(KMIN-1)*DELTAT
5400    TMAX=(KMAX-1)*DELTAT
5410    XMIN=RMIN*COS(TMIN)+CX
5420    XMAX=RMAX*COS(TMAX)+CX
5430    YMIN=RMIN*SIN(TMIN)+CY
5440    YMAX=RMAX*SIN(TMAX)+CY
5450    TXX=XMIN:TYY=YMIN:TXT$="L"
5460    GOSUB 270
5470    TXX=XMAX:TYY=YMAX:TXT$="H"
5480    GOSUB 270
5490    END
5500    TXX=0.30
5510    TYY=-.50
5520    TXT$="L = "+CONV$(ZMIN)+"     H = "+CONV$(ZMAX)+"  INTERVAL = "+CONV$(ZL
        EV(2)-ZLEV(1))
5530    GOSUB 270
5540    END
```

```
10    REM PROGRAM CFOS
20    PRINT"          CFOS BI-DIRECTIONAL REFLECTANCE INTERP. PROGRAM"
45    DIM BDR(13,15),BDN(30,30),NAN(30),AZIN(30)
50    DIM NAD(13,15),AZI(13,15)
60    DATA 2.5,7.5,12.5,17.5,22.5,27.5,32.5,37.5,42.5,47.5,52.5,57.5
70    DATA 15,45,75,105,135,165,195,225,255,285,315,345
75    PI=3.14159:POVR2=PI/2
100    FOR J=1 TO 30
110      FOR K=1 TO 30
120        BDN(J,K)=0.
150        NEXT K
160      NEXT J
165    PRINT"ENTER THE NUMBER OF NAD INTERPOLTION POINTS"
167    INPUT NNAD
170    FOR J=1 TO NNAD
190      NAN(J)=PI/3/NNAD*(J-1)
200      NEXT J
205    DTRD=3.14159/180.
210    DEF FN ACOS(X)=ATN(SQR(1-X*X)/X)
215    DEF FN ACOS(X)=ATN(SQR(1-X*X)/X)
216    PRINT"ENTER THE NUMBER OF AZIMUTHAL INTERPOLATION POINTS"
217    INPUT NAZM
220    FOR J=1 TO NAZM
230      AZIN(J)=2*PI/NAZM*(J-1)
240      NEXT J
250    PRINT" INPUT DATA FILE NAME "
260    INPUT D$
270    OPEN#3 AS INPUT,"/AREA1/CFOS.BDR/"+D$
280    READ#3,1;NS,FLUXUP,MIN,MAX
290    I=1
300    FOR J=1 TO NS
310      FOR K=1 TO 15
320        I=I+1
330        READ#3,I;J,K,NAD(J,K),AZI(J,K),BDR(J,K)
340        PRINT J,K,NAD(J,K),AZI(J,K),BDR(J,K)
350        NEXT K
360      NEXT J
370    PRINT" UPWARD FLUX DENSITY EQUALS ",FLUXUP
380    PRINT" MIN AND MAX VALUES OF BDR FUNCTION ",MIN,MAX
400    GOSUB 1000
500    REM SUBROUTINE TO CALCULATE WEIGHT
510    DELTA=PI/6.
520    IF THETA>DELTA GOTO 570
530    WGHT=1.0E+06
540    IF THETA<0.001 THEN RETURN
550    WGHT=DELTA/THETA
560    RETURN
570    WGHT=0.
580    IF(THETA-DELTA)>=DELTA THEN RETURN
590    WGHT=2.0-THETA/DELTA
600    RETURN
700    REM SUBROUTINE TO INTERPOLATE IN BDR ARRAY
710    SUMF=0.
720    SUMW=0.
730    FOR M=JMIN TO JMAX
740      FOR N=KMIN TO KMAX
750        ZI=NAD(M,N)
760        AI=AZI(M,N)
770        THETA=COS(ZI)*COS(ZPRM)+SIN(ZI)*SIN(ZPRM)*COS(AI-APRM)
780        IF THETA<0. GOTO 840
790        THETA= FN ACOS(THETA)
```

```
800        GOSUB 500
810        W=WGHT
820        SUMW=SUMW+W
830        SUMF=SUMF+W*BDR(M,N)
840        NEXT N
850      NEXT M
860    INTERP=0.
870    IF SUMW<=0. THEN RETURN
880    INTERP=SUMF/SUMW
900    RETURN
1000    REM CALCULATE BDR VALUES AT REGULAR ARRAY POINTS
1010    FOR J=1 TO NNAD
1020      FOR K=1 TO NAZM
1030        ZPRM=NAN(J)
1040        APRM=AZIN(K)
1050        REM FIND JMIN,JMAX,KMIN,KMAX TO LIMIT REGION OF INTERPOLATION
1060        SIND=SIN(ZPRM)*SIN(PI-APRM)
1070        COSD=SQR(1-SIND*SIND)*SGN(COS(APRM))
1075        COSA=COS(ZPRM)/COSD
1080        IF COSA>=1.0 THEN COSA=1.0
1085        IF COSA<=-1.0 THEN COSA=-1.0
1090        A= FN ACOS(COSA)
1100        D=ATN(SIND/COSD*SGN(COS(APRM)))+POVR2
1120        AINC=INT(A/PI*18)+7
1130        DINC=INT(D/PI*18)-1
1150        JMIN=AINC-1
1160        JMAX=AINC+1
1170        KMIN=DINC-1
1180        KMAX=DINC+1
1190        IF JMIN>=1 THEN 1230
1200        JMIN=JMIN+1
1210        GOTO 1190
1230        IF JMAX<=13 THEN 1260
1240        JMAX=JMAX-1
1250        GOTO 1230
1260        IF KMIN>=1 THEN 1290
1270        KMIN=KMIN+1
1280        GOTO 1260
1290        IF KMAX<=15 THEN 1320
1300        KMAX=KMAX-1
1310        GOTO 1290
1320        GOSUB 700
1330        BDN(J,K)=INTERP
1340        PRINT BDN(J,K),JMIN,JMAX,KMIN,KMAX
1350        NEXT K
1360      NEXT J
1400    OPEN#4 AS OUTPUT,"/AREA1/CFOS.PLOT/"+D$
1410    MIN=99999
1420    MAX=0
1430    FOR J=1 TO NNAD
1440      FOR K=1 TO NAZM
1450        IF BDN(J,K)<MIN THEN MIN=BDN(J,K)
1460        IF BDN(J,K)>MAX THEN MAX=BDN(J,K)
1470        NEXT K
1480      NEXT J
1485    PRINT"MIN AND MAX OF INTERPOLATED FIELD ",MIN,MAX
1490    WRITE#4,1;NNAD,NAZM,FLUXUP,MIN,MAX
1495    I=1
1500    FOR J=1 TO NNAD
1510      FOR K=1 TO NAZM
1520        I=I+1
1530        WRITE#4,I;NAN(J),AZIN(K),BDN(J,K)
1535        PRINT NAN(J),AZIN(K),BDN(J,K)
1540        NEXT K
1550      NEXT J
```

```
1570  END
```



```
10    REM CFOS BI-DIRECTIONAL REFLECTANCE STANDARD ERROR PROGRAM
20    DIM N(30,12,12),NAN(12),AZIM(12)
30    DIM NBAR(12,12),NSTD(12,12),SSN(12,12),SNS(12,12)
40    DIM D$(30)
100    PRINT"INPUT THE NUMBER OF INTERPOLATED DATA FILES TO USE"
110    INPUT NUM
130    FOR I=1 TO NUM
140      PRINT"INPUT THE DATASET NAME FOR FILE NUMBER",I
150      INPUT D$(I)
155      D$(I)="/AREA1/CFOS.PLOT/"+D$(I)
160      NEXT I
200    FOR I=1 TO NUM
210      OPEN#2 AS INPUT,D$(I)
220      KOUNT=1
230      FOR J=1 TO 12
240        FOR K=1 TO 12
250          KOUNT=KOUNT+1
255          READ#2,1;NNAD,NAZM,FLUXUP,MIN,MAX
260          READ#2,KOUNT;NAN(J),AZIM(K),N(I,J,K)
270          NEXT K
280        NEXT J
290      CLOSE#2
300      NEXT I
310    FOR J=1 TO 12
320      FOR K=1 TO 12
330        SSN(J,K)=0
340        SNS(J,K)=0
350        NBAR(J,K)=0
360        NSTD(J,K)=0
370        NEXT K
380      NEXT J
400    FOR J=1 TO 12
410      FOR K=1 TO 12
420        FOR I=1 TO NUM
430          SSN(J,K)=SSN(J,K)+N(I,J,K)*N(I,J,K)
440          SNS(J,K)=SNS(J,K)+N(I,J,K)
450          NBAR(J,K)=NBAR(J,K)+N(I,J,K)/NUM
460          NEXT I
470        SNS(J,K)=SNS(J,K)*SNS(J,K)
480        NSTD(J,K)=SQR((SSN(J,K)-SNS(J,K)/NUM)/(NUM-1))
490        NSTD(J,K)=NSTD(J,K)/NBAR(J,K)
500        PRINT J,K,NSTD(J,K)*100
510        NEXT K
520      NEXT J
530    AVGERR=0
540    FOR J=1 TO 12
550      FOR K=1 TO 12
560        AVGERR=AVGERR+NSTD(J,K)*100/144
570        NEXT K
580      NEXT J
590    PRINT"OVERALL STANDARD ERROR FOR BDR",AVGERR
600    END
```